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

LiDAR Surveys and Flood Mapping of Pagsanjan River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños (UPLB)

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND PAGSANJAN RIVER

Enrico C. Paringit, Dr. Eng.,Edwin R. Abucay, Miyah D. Queliste

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (UPLB). UPLB 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 forty-five (45) river basins in the MIMAROPA Region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Pagsanjan River Basin

The Pagsanjan River Basin is a 61,800-hectare watershed located in the province of Laguna. According to the Department of Environment and Natural Resources – River Basin Control Office (DENR-RCBO), it has a drainage area of 325 km^2, and an estimated 520 million cubic meters (MCM) in annual run-off. It covers the Municipalities of Cavinti, Kalayaan, Liliw, Lumban, Luisiana, Magdalena, Majayjay, Nagcarlan, Paete, Pagsanjan, Pila, Santa Cruz, Rizal, and Victoria in Laguna.

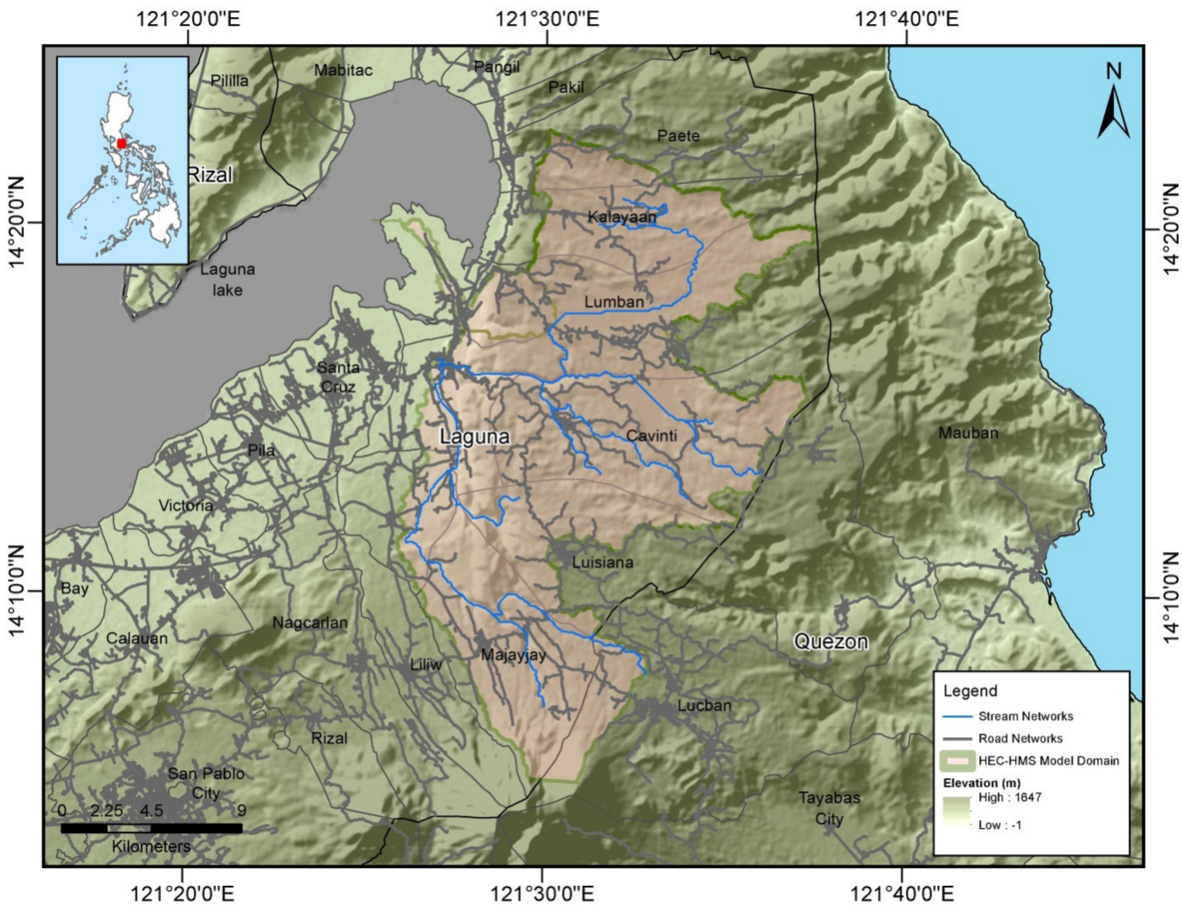

Figure 1. Location map of the Pagsanjan River Basin (in brown)

The Pagsanjan River traverses the Municipalities of Cavinti, Kalayaan, Luisiana, Lumban, Magdalena, Majayjay, Paete, and Pagsanjan. Barangay San Antonio in the Municipality of Kalayaan is the most populated barangay, based on the 2010 National Statistics Office (NSO) Census of Population and Housing. The 2010 census also reports that the total population of people residing along the immediate vicinity of the Pagsanjan River is 88,500, which are distributed among twenty-five (25) barangays situated adjacent to the river. Agriculture and backyard livestock production are the primary sources of income of residents, and the fundamental driver of local economic activity in the Municipality of Pagsanjan.

Based on the Modified Corona Classification of Climate, the prevailing climate types in the MIMAROPA Region (Southwestern Tagalog Region) and the province of Laguna are Types I and III. Climate Type I has pronounced dry and wet seasons. The dry season occurs in the months of November to April; while the wet season takes place for the rest of the year, with a maximum rain period in the months of June to September. Climate Type III, on the other hand, does not have a very pronounced maximum rain period. Its dry season is very brief, lasting only for one to three months – from December to February, or from March to May.

According to the Mines and Geoscience Bureau, the municipalities under the second, third, and fourth districts of Laguna are often affected by floods and rain-induced landslides. In addition to this, a number of municipalities, including Calauan, Cavinti and Lumban, are prone to soil and river bank erosions. Other municipalities, such as, Bay, Biñan, Cabuyao, and Calamba, are susceptible to liquefaction. The field surveys conducted by the PHIL-LiDAR 1 validation team found that there have been several recent flooding events in the area caused by weather disturbances and heavy rains, affecting several barangays in the different municipalities encompassed by the river basin. These events include Typhoon Milenyo in 2006, Typhoons Ondoy and Santi in 2009, Super Typhoon Yolanda in 2013, and Typhoon Glenda in 2014. Typhoon Santi brought about waist-deep flooding in the Municipality of Pagsanjan; and Typhoon Glenda spawned strong winds and torrential rains that induced knee-deep flooding in most parts of the whole province of Laguna. Also, the southwest monsoon in 2012 generated sustained heavy rains that caused inundation in the Municipalities of Santa Cruz and Lumban.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PAGSANJAN 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 Pagsanjan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Oriental Mindoro. These missions were planned for sixteen (16) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Pegasus LiDAR system was used for the flight missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 illustrates the flight plans for the Pagsanjan floodplain.

Table 1. Flight planning parameters for the Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Max. Field of View (θ)	Pulse Rate Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 18H	1100	30	50	200	30	130	5
BLK 18I	1100	30	50	200	30	130	5
BLK 18J	1200	30	50	200	30	130	5
BLK 18K	1100	30	50	200	30	130	5
BLK 18KS	1000	30	50	200	30	130	5
BLK 18RL	1200	30	50	200	30	130	5

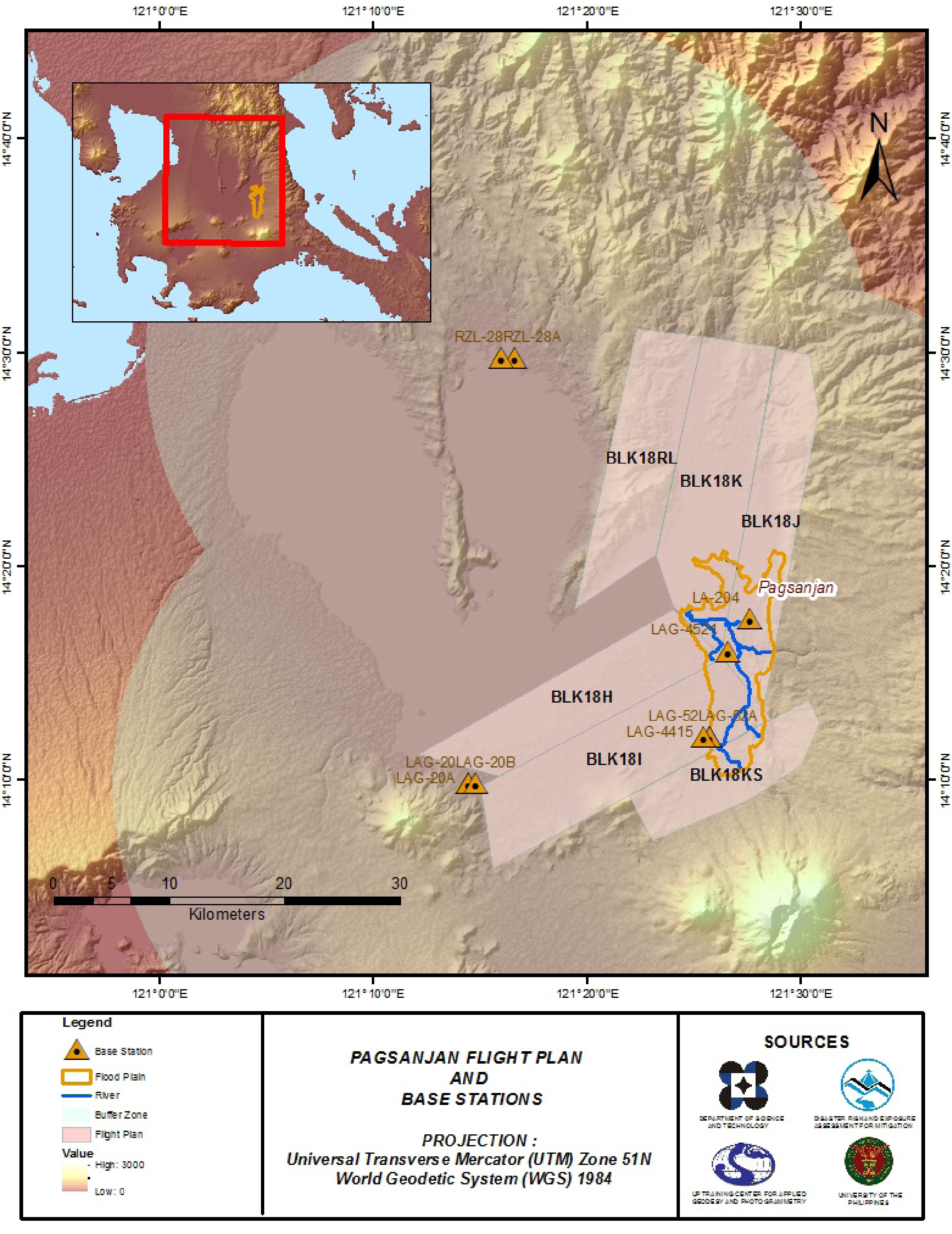


Figure 2. Flight plans and base stations used to cover the Pagsanjan floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover three (3) NAMRIA ground control points: LAG-20, LAG-52, and RZL-28, which are of second (2^{nd}) order accuracy. The field team also re-established ground control points LAG-4415 and LAG-4521, which are of fourth (4^{th}) order accuracy. One (1) NAMRIA benchmark was recovered: LA-204. This benchmark was used as a vertical reference point, and was also established as a ground control point. The project team also established four (4) ground control points: LAG-20A, LAG-20B, LAG-52A, and RZL-28A. The certifications for the NAMRIA reference points are found in Annex 2; while the baseline processing reports for the established ground control points and benchmark are found in Annex 3. These were used as the base stations during flight operations for the entire duration of the survey, held on February 4-9, 2014, on August 15 – September 4, 2015, and on June 11, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. The flight plans and locations of the base stations used during the aerial LiDAR acquisition in the Pagsanjan floodplain are shown in Figure 2. The composition of the full project team is given in Annex 4.

Figure 3 to Figure 5 exhibit the recovered NAMRIA reference points within the area. Table 2 to Table 11 provide the details about the NAMRIA control stations and established points. Table 12 lists all of the ground control points occupied during the acquisition, together with the corresponding dates of utilization.

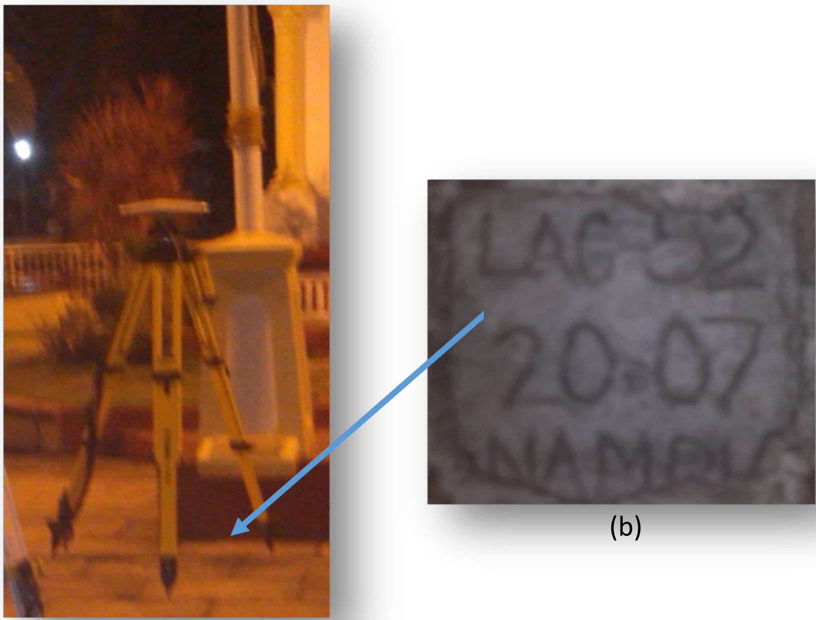
(a)

(b)

Figure 3. (a) GPS set-up over LAG-20 as recovered beside the Umali Hall building in UP Los Baños; and (b) NAMRIA reference point LAG-20, as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point LAG-20, used as a base station for the LiDAR acquisition

Station Name	LAG-20	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	14° 9’ 53.86904” North
	Longitude	121° 14’ 20.35180” East
	Ellipsoidal Height	39.91400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	525799.268 meters
	Northing	1566435.481 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	14°9 ’48.57270” North
	Longitude	121°14’25.28172” East
	Ellipsoidal Height	85.26600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N -PRS 1992)	Easting	309934.22 meters
	Northing	1566588.99 meters



(a) (b)

Figure 4. (a) GPS set-up over LAG-52 as recovered inside the compound of Magdalena Municipal Hall, Laguna; and (b) NAMRIA reference point LAG-52, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point LAG-52, used as a base station for the LiDAR acquisition

Station Name	LAG-52	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 12' 4.64805" North 121° 25' 41.33587" East 66.698 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	546212.761 meters 1570483.553 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 11'59.35842" North 121° 25' 46.26158" East 112.41 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	330382.29 meters 1570462.41 meters

(a) (b)

Figure 5. (a) GPS set-up over LA-204 on the Lumban Bridge, Lumban, Laguna; and (b) NAMRIA reference point LA-204, as recovered by the field team

Table 4. Details of the recovered NAMRIA vertical control point LA-204, used as a base station for the LiDAR acquisition, with re-processed coordinates

Station Name	LA-204	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14°17'36.26369" North 121°27'31.97236" East 11.533 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	333766.797 meters 1580630.698 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°17'30.95486" North 121°27'36.89005" East 57.061 meters

Table 5. Details of the established control point LAG-20A, used as a base station for the LiDAR acquisition, with established coordinates

Station Name	LAG-20A	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14°09’53.79129” North 121°14’20.11156” East 39.898 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	309926.998 meters 1566586.650 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°09’48.49477” North 21°14’25.04144” East 85.250 meters

Table 6. Details of the established control point LAG-20B, used as a base station for the LiDAR acquisition, with established coordinates

Station Name	LAG-20B	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14°09’53.79862” North 121°14’20.20020” East 39.882 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	309929.658 meters 1566586.855 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°09’48.50209” North 121°14’25.13008” East 85.234 meters

Table 7. Details of the established control point LAG-52A, used as a base station for the LiDAR acquisition, with established coordinates

Station Name	LAG-52A	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14°12'04.74360" North 121°25'41.32045" East 66.618 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	330381.851 meters 1570465.349 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°11'59.45397" North 121°25'46.24615" East 112.330 meters

Table 8. Details of the recovered NAMRIA horizontal control point LAG-4415, used as a base station for the LiDAR acquisition, with re-processed coordinates

Station Name	LAG-4415	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 12' 05.16704" North 121° 25' 39.05421" East 66.482 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	330313.993 meters 1570478.818 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 11' 59.87733" North 121° 25' 43.97990" East 112.192 meters

Table 9. Details of the recovered NAMRIA horizontal control point LAG-4521, used a as base station for the LiDAR acquisition, with re-processed coordinates

Station Name	LAG-4521	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 16’ 04.88594” North 121° 26’ 22.83065” East 11.309 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	331675.15 meters 1577836.52 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 15’ 59.58151” North 121° 26’ 27.75062” East 58.861 meters

Table 10. Details of the recovered NAMRIA horizontal point RZL-28, used as a base station for the LiDAR acquisition

Station Name	RZL-28	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 29’ 49.44078” North 121° 16’ 32.56146” East 5.866 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	529720.085 meters 1603180.963 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 29’ 44.06939” North 121° 16’37.46276” East 50.371 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	314172.78 meters 1603302.05.44 meters

Table 11. Details of the established horizontal control point RZL-28A, used as a base station for the LiDAR acquisition, with established coordinates

Station Name	RZL-28A	
Order of Accuracy	2nd	
Relative error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 29' 49.51048" North 121° 16' 32.74896" East 6.047 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	314178.417 meters 1603304.152 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 29' 44.13909" North 121° 16' 37.65027" East 50.552 meters

Table 12. Ground control points used during the LiDAR data acquisition

Date Surveyed	**Flight Number**	**Mission Name**	**Ground Control Points**
04-Feb-14	1067P	1BLK18H035A	LAG-20, LAG-20A
05-Feb-14	1071P	1BLK18I036A	LAG-20, LAG-20B
08-Feb-14	1083P	1BLK18J39A	LAG-52, LAG-52A
09-Feb-14	1087P	1BLK18K40A	LAG-52, LA-204
15-Aug-15	3299P	1BLK18KS227A	LAG-52, LAG-4415
17-Aug-15	3307P	1BLK18JS229B	LAG-52, LAG-4521
04-Sep-2015	3377P	1BLK18JS247A	LAG-52, LA-204
11-Jun-2016	234444P	1BLK18RL163A	RZL-28, RZL-28A

2.3 Flight Missions

A total of eight (8) flight missions were conducted to complete the LiDAR data acquisition in the Pagsanjan floodplain, for a total of twenty-four hours and twenty-seven minutes (24+27) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus system. The flight logs of the missions are provided in Annex 6. Table 13 indicates the total area of actual coverage and the corresponding flying hours per mission; while Table 14 presents the actual parameters used during the LiDAR data acquisition.

Table 13. Flight missions for the LiDAR data acquisition in the Pagsanjan floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
04-Feb-14	1067P	124.52	108.64	10.92	97.72	219	2	55
05-Feb-14	1071P	167.88	190.64	29.91	160.73	311	2	47
08-Feb-14	1083P	121.17	139.59	52.24	87.35	368	3	29
09-Feb-14	1087P	161.41	134.97	12.18	122.79	251	3	5
15-Aug-15	3299P	78.70	84.43	10.87	73.56	N/A	2	35
17-Aug-15	3307P	121.17	93.35	0	93.35	N/A	3	6
04-Sep-2015	3377P	121.17	123.98	8.20	115.78	N/A	3	13
11-Jun-2016	23444P	123.60	179.57	0	179.57	N/A	3	17
TOTAL		1019.62	1055.17	124.32	930.85	1149	24	27

Table 14. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Fre-quen-cy (Hz)	Aver-age Speed (kts)	Average Turn Time (Minutes)
1067P	1100	30	50	200	30	130	5
1071P	1100	30	50	200	30	130	5
1083P	1200	30	50	200	30	130	5
1087P	1100	30	50	200	30	130	5
3299P	1000	30	50	200	30	130	5
3307P	1200	30	50	200	30	130	5
3377P	1200	30	50	200	30	130	5
23444P	1200	30	50	200	30	130	5

2.4 Survey Coverage

The Pagsanjan floodplain is located in the province of Laguna, with majority of the floodplain situated within the Municipality of Pagsanjan. The Municipalities of Magdalena, Pila, Mabitac, Victoria, and Santa Cruz are mostly covered by the survey. The municipalities and cities surveyed, with at least one (1) square kilometer coverage, are enumerated in Table 15. The actual coverage of the LiDAR acquisition for the Pagsanjan floodplain is presented in Figure 6. See Annex 7 for the flight status reports.

Table 15. List of municipalities and cities surveyed during the Pagsanjan floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Laguna	Magdalena	29.61	29.61	99.99%
	Pila	28.77	28.42	98.78%
	Mabitac	60.07	58.93	98.10%
	Victoria	28.37	27.39	96.54%
	Santa Cruz	37.63	36.24	96.32%
	Calauan	79.44	64.58	81.29%
	Famy	33.43	27.07	80.98%
	Pagsanjan	40.77	32.84	80.55%
	Bay	40.80	30.73	75.32%
	Siniloan	26.18	19.44	74.25%
	Pakil	30.02	20.18	67.23%
	Pangil	35.64	23.26	65.27%
	Santa Maria	137.35	86.75	63.16%
	Nagcarlan	81.20	49.02	60.37%
	Liliw	36.20	14.56	40.21%
	Los Baños	50.48	20.20	40.01%
	Luisiana	61.00	20.19	33.10%
	Majayjay	64.40	18.31	28.43%
	Lumban	117.34	29.60	25.23%
	Kalayaan	52.63	5.48	10.42%
	Laguna lake	892.20	87.25	9.78%
	Alaminos	60.56	5.50	9.09%
	Rizal	24.02	1.96	8.17%
	Paete	78.93	5.73	7.26%
	Cavinti	96.78	3.17	3.27%
	Calamba City	130.68	1.55	1.19%
Rizal	Jala-Jala	45.22	25.41	56.19%
	Pililla	62.79	18.12	28.86%
TOTAL		2462.51	791.49	32.14%

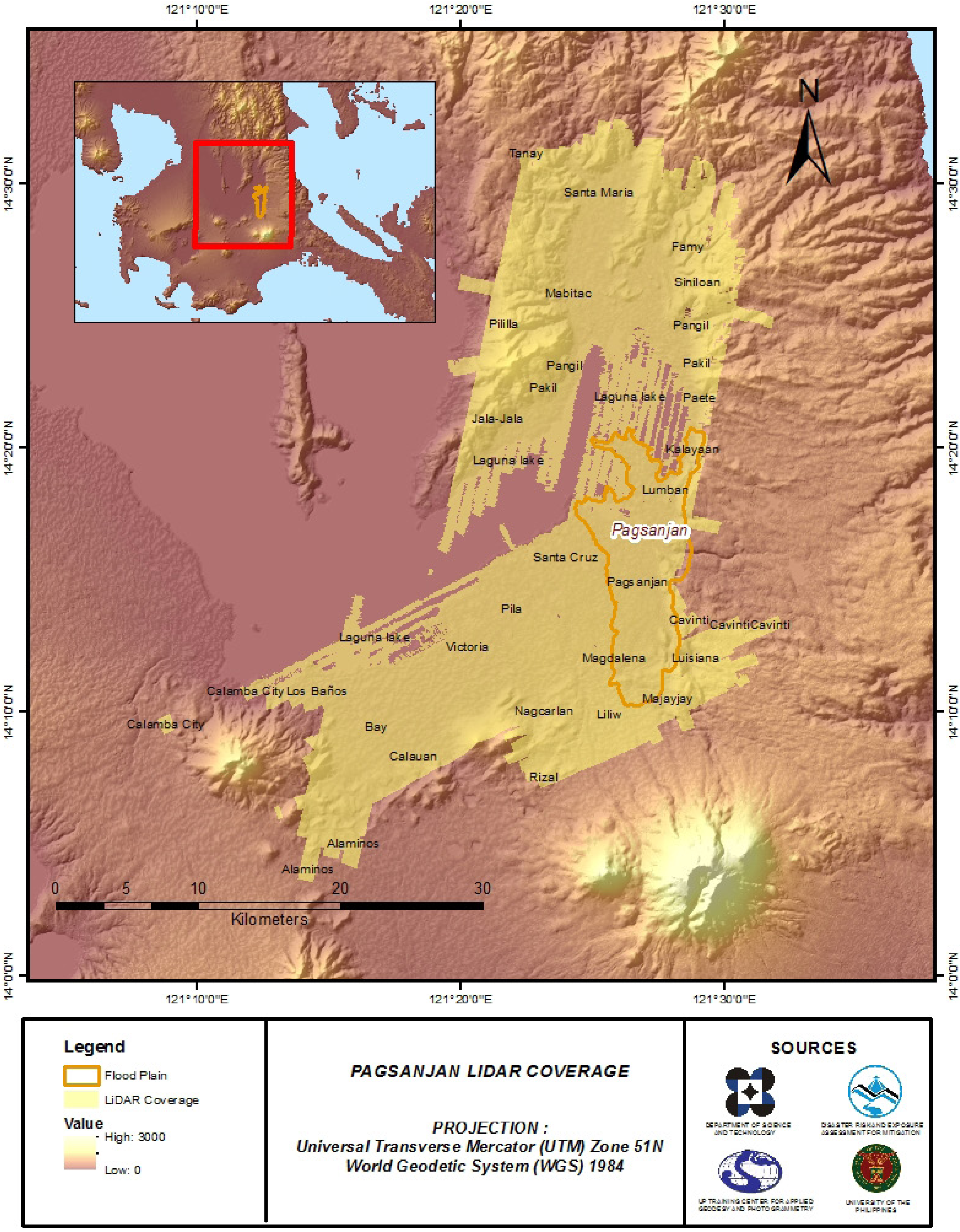


Figure 6. Actual LiDAR survey coverage of the Pagsanjan floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE PAGSANJAN FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

Using the elevation of points gathered from the field, the LiDAR-derived digital models were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry, measured from the field by the Data Validation and Bathymetry Component (DVBC). LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was accomplished through the help of the georectified point clouds, and the metadata containing the time the image was captured.
These processes are summarized in the diagram in Figure 7.

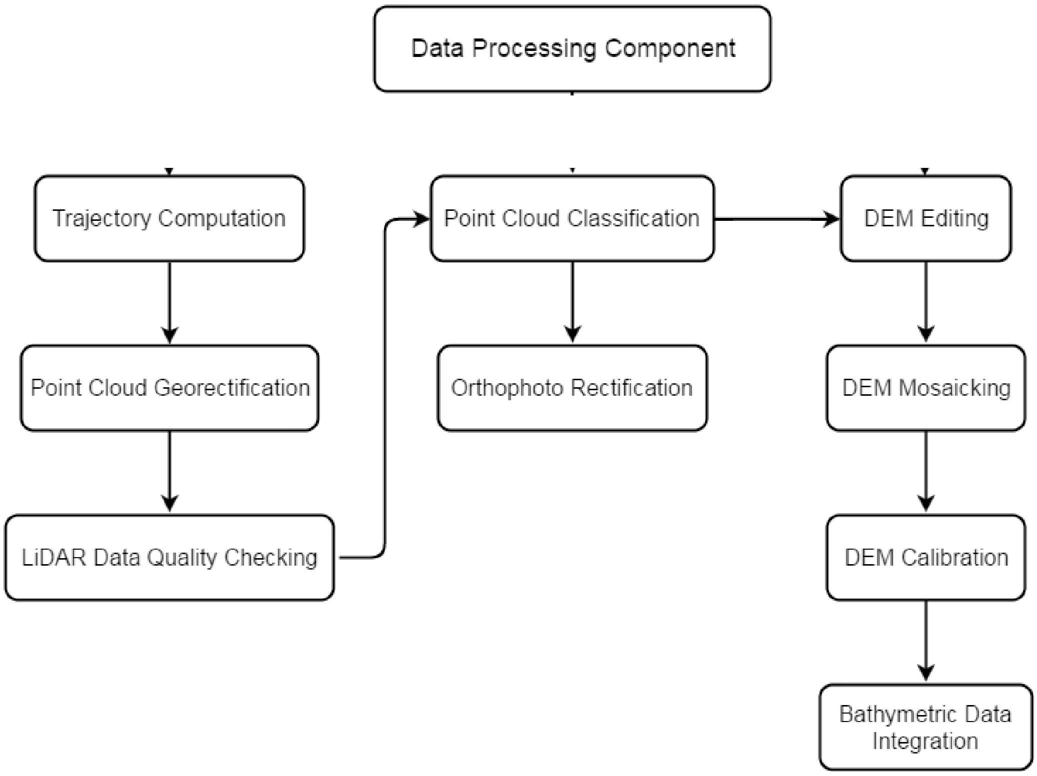


Figure 7. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for the Pagsanjan floodplain can be found in Annex 5. Missions flown over Pagsanjan, Laguna conducted in February 2014, August 2015, and June 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. The DAC transferred a total of 96.97 Gigabytes of Range data, 1.22 Gigabytes of POS data, 354.53 Megabytes of GPS base station data, and 50.29 Gigabytes of raw image data to the data server on February 8, 2014 for the first survey, on September 8, 2015 for the second survey, and on July 12, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Pagsanjan survey was fully transferred on February 26, 2016, as indicated on the data transfer sheets for the Pagsanjan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 23444P, one of the Pagsanjan flights, which are the North, East, and Down position RMSE values, are illustrated in Figure 8. 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 June 11, 2016 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

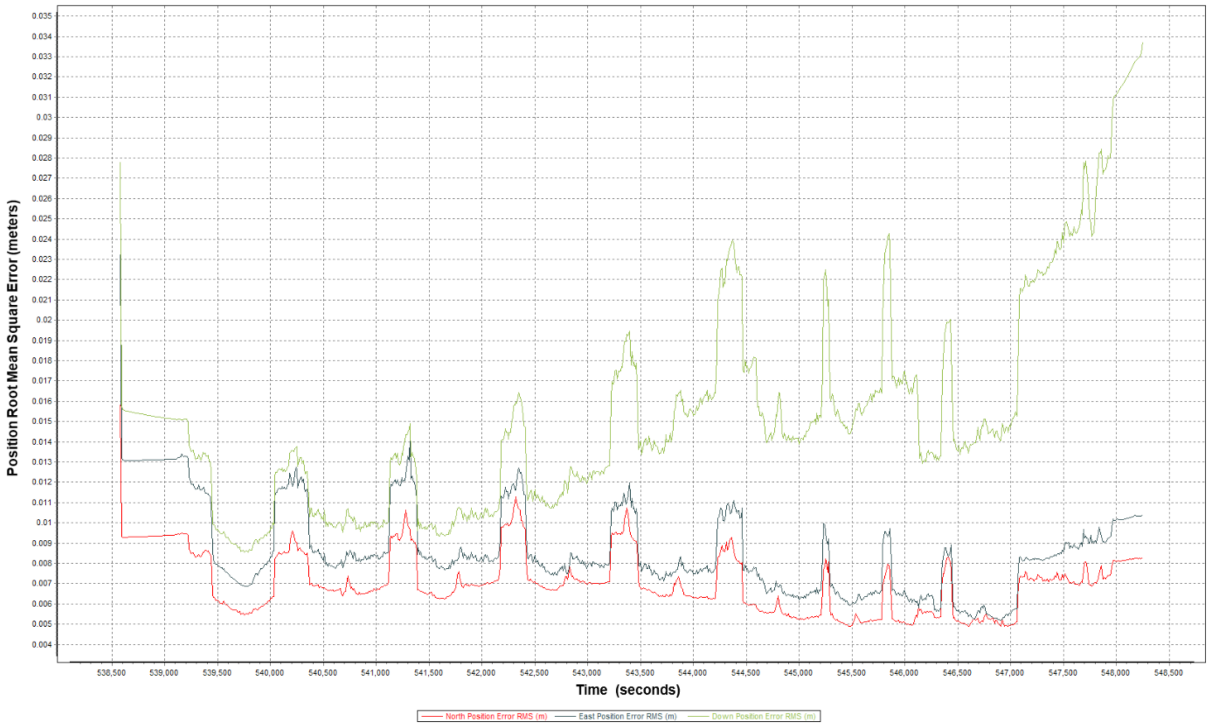


Figure 8. Smoothed Performance Metric Parameters of Pagsanjan Flight 23444P

The time of flight was from 538500 seconds to 548500 seconds, which corresponds to the morning of June 11, 2016. The initial spike reflected on the data represents the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values signifies the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 demonstrates that the North position RMSE peaked at 1.10 centimeters, the East position RMSE peaked at 1.40 centimeters, and the Down position RMSE peaked at 2.80 centimeters, which are within the prescribed accuracies described in the methodology.

Figure 9. Solution Status Parameters of Pagsanjan Flight 23444P

The Solution Status parameters of Flight 23444P, one of the Pagsanjan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are exhibited in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 10. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey, with some peaks to up to 1, attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Pagsanjan flights is depicted in Figure 10.

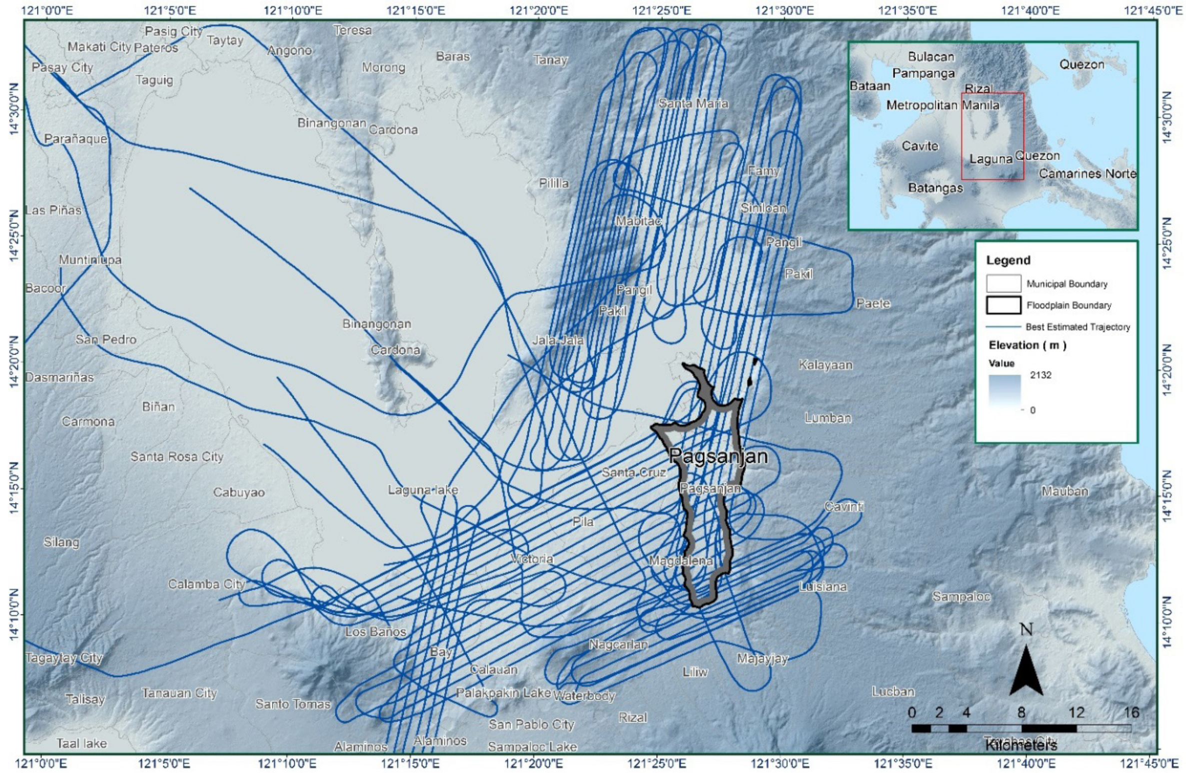


Figure 10. The best estimated trajectory conducted over the Pagsanjan floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains sixty-seven (67) flight lines, with each flight line containing two (2) channels, since the Pegasus system contains two (2) channels. The summary of the self-calibration results for all flights over Pagsanjan floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 16.

Table 16. Self-calibration results for the Pagsanjan flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000192
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000399
GPS Position Z-correction stdev	(<0.01meters)	0.0016

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Pagsanjan floodplain are represented in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

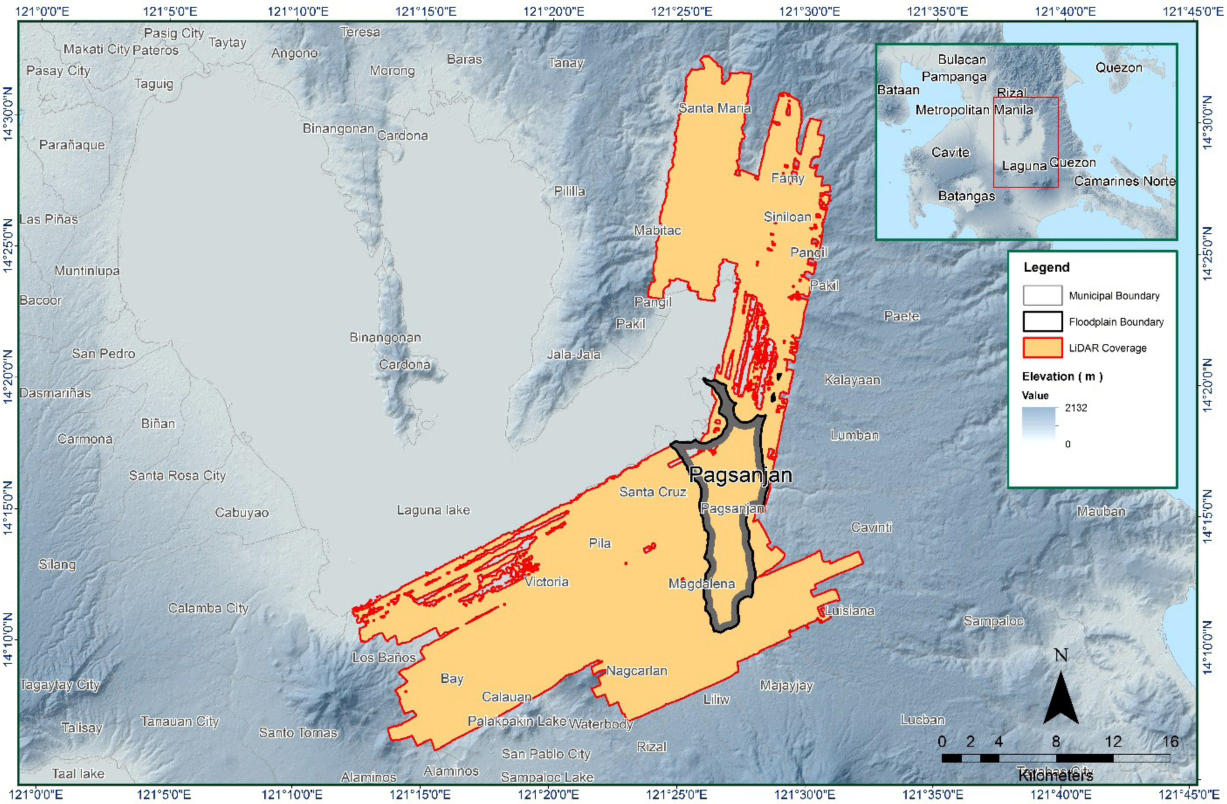


Figure 11. Boundaries of the processed LiDAR data over the Pagsanjan floodplain

The total area covered by the Pagsanjan missions is 795.77 square kilometers, comprised of seven (7) flight acquisitions that were grouped and merged into seven (7) blocks, as outlined in Table 17.

Table 17. List of LiDAR blocks for the Pagsanjan floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
CALABARZON_Blk18J_supplement	3377P	19.86
CALABARZON _Blk18I_supplement	3299P 3377P	89.16
CALABARZON _Blk18K_supplement	3307P	86.37
CALABARZON _reflights_Blk18K	23444P	177.02
Laguna_Blk18J	1083P	133.00
Laguna_Blk18H	1067P	102.25
Cavite_Blk18I	1071P	188.11
	TOTAL	795.77 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 12. Since the Pegasus system employs two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

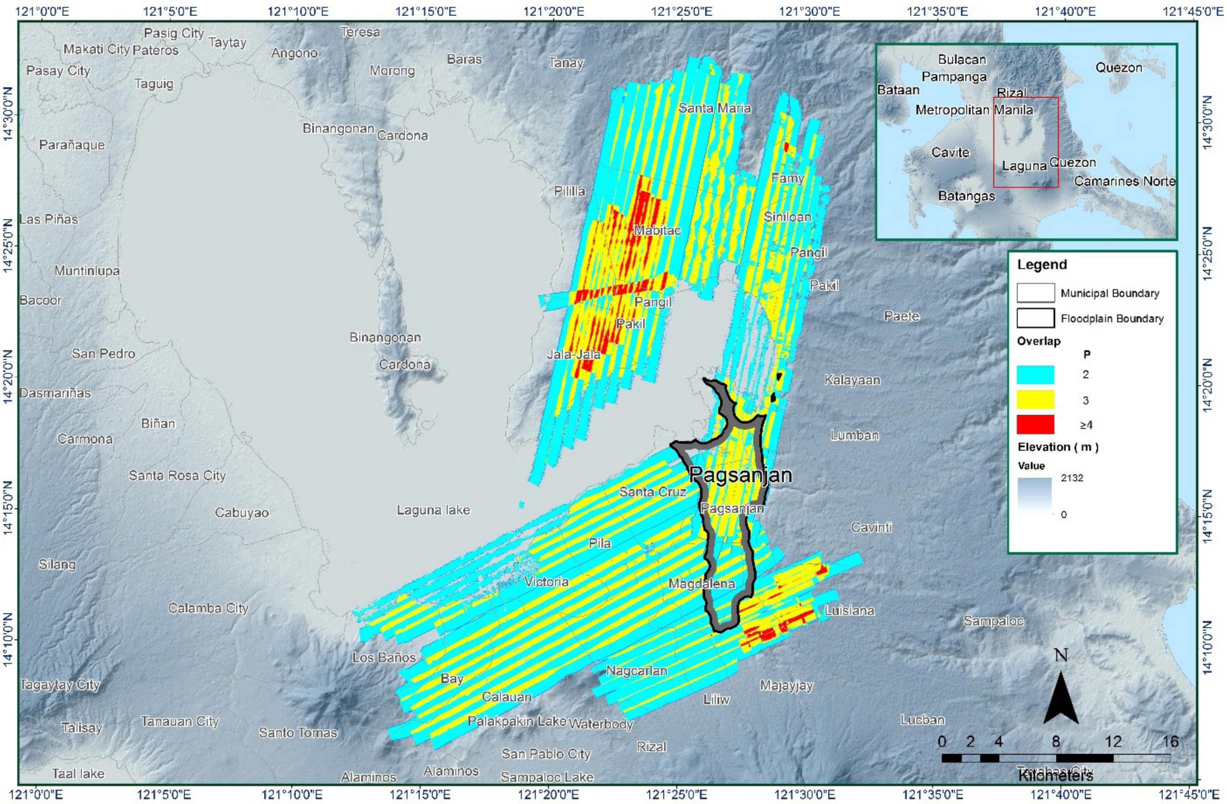


Figure 12. Image of data overlap for the Pagsanjan floodplain

The overlap statistics per block for the Pagsanjan floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 26.06% and 47.16%, 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 displayed in Figure 13. It was determined that all LiDAR data for the Pagsanjan floodplain satisfy the point density requirement, and that the average density for the entire survey area is 2.81 points per square meter.

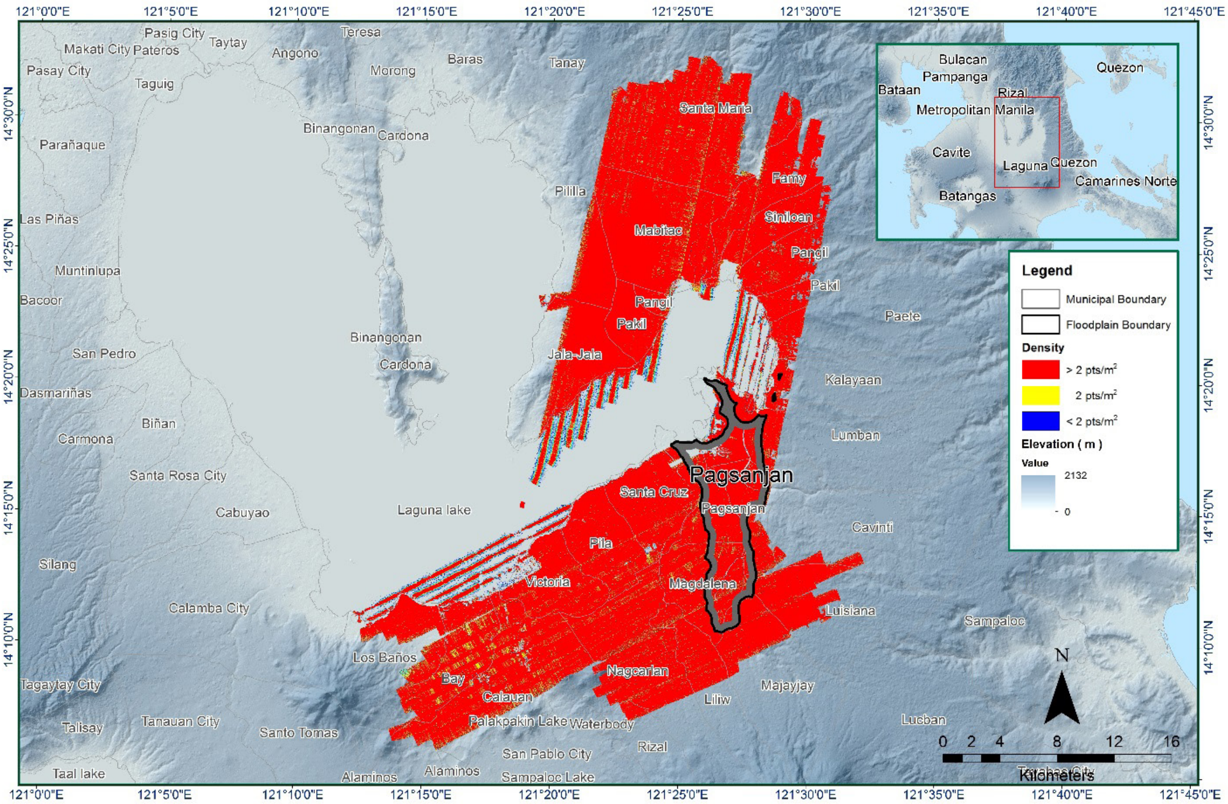


Figure 13. Pulse density map of merged LiDAR data for the Pagsanjan floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red. Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to the elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to the elevations of its adjacent flight line. Areas with bright red or bright blue colors were investigated further using the Quick Terrain (QT) Modeler software.

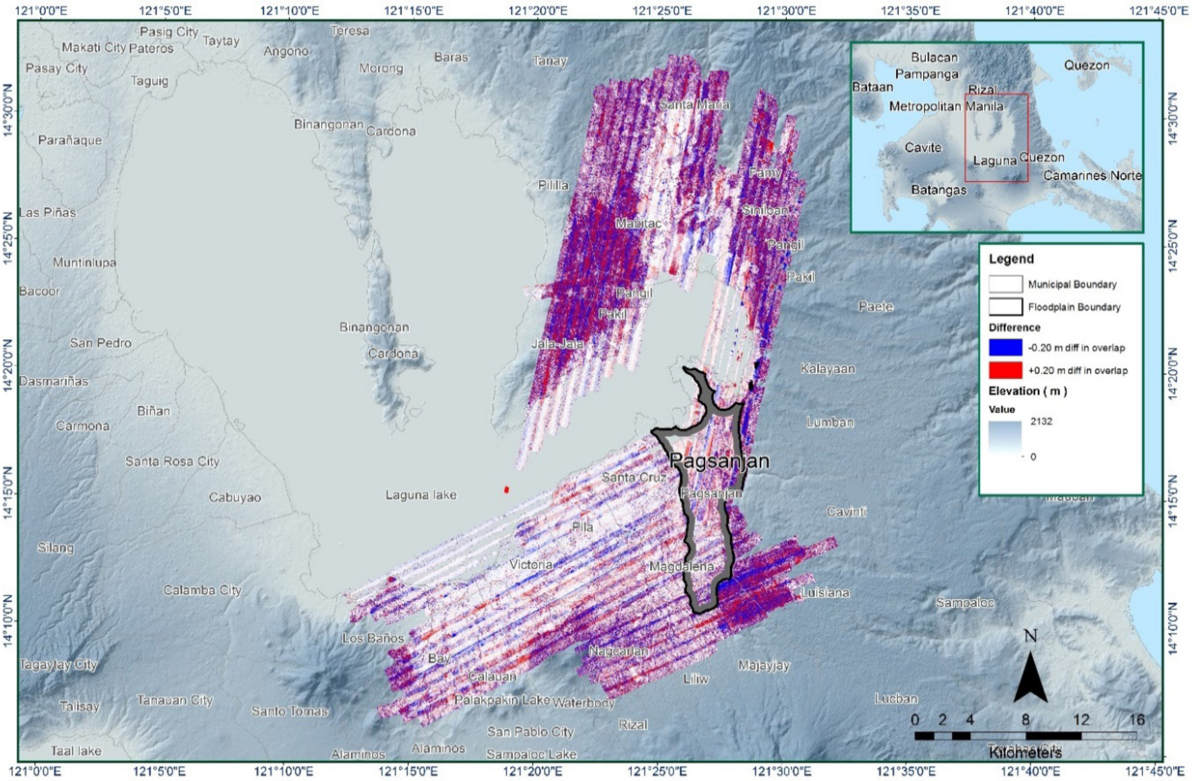


Figure 14. Elevation difference map between flight lines for the Pagsanjan floodplain

A screen capture of the processed LAS data from Pagsanjan Flight 23444P loaded in the QT Modeler is provided in Figure 15. The upper left image shows the elevations of the points from two (2) 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.

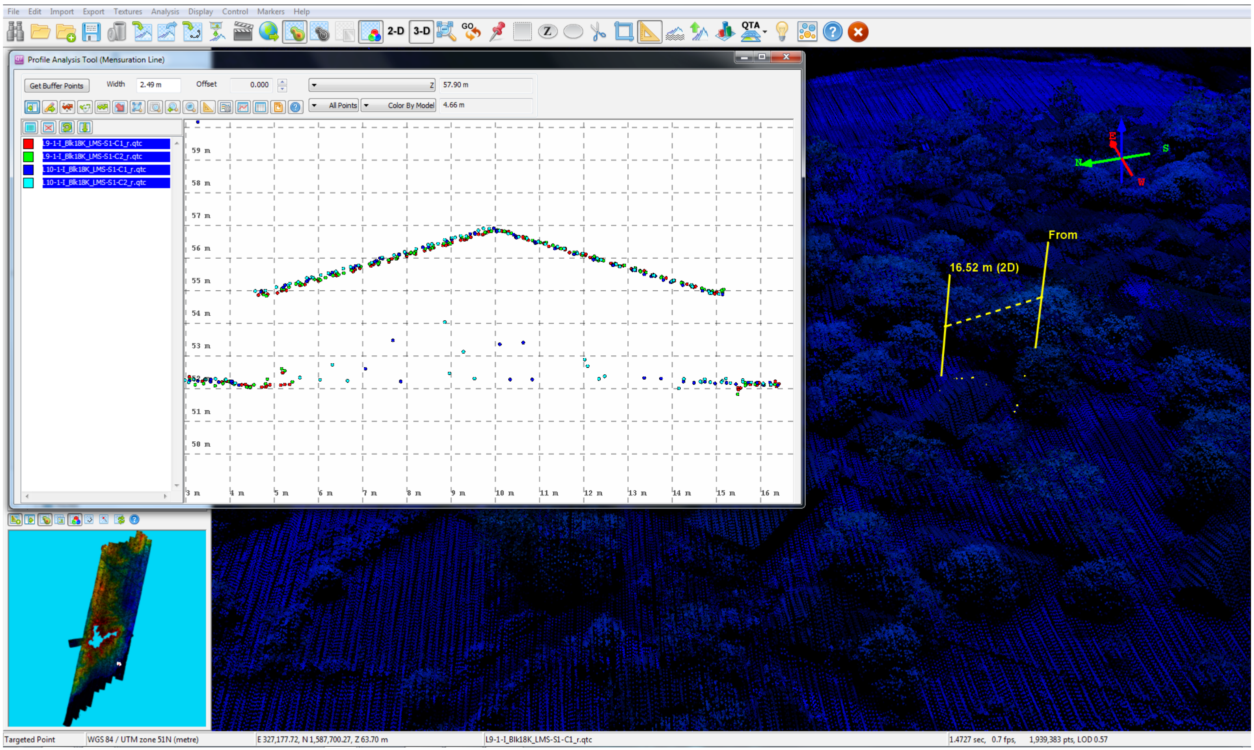


Figure 15. Quality checking for Pagsanjan flight 23444P, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 18. Pagsanjan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	637,353,125
Low Vegetation	500,700,226
Medium Vegetation	636,952,579
High Vegetation	1,115,012,562
Building	74,604,497

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in Pagsanjan floodplain, are presented in Figure 16. A total of 1,433 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 18. The point cloud had a maximum and minimum height of 715.82 meters and 40.37 meters, respectively.

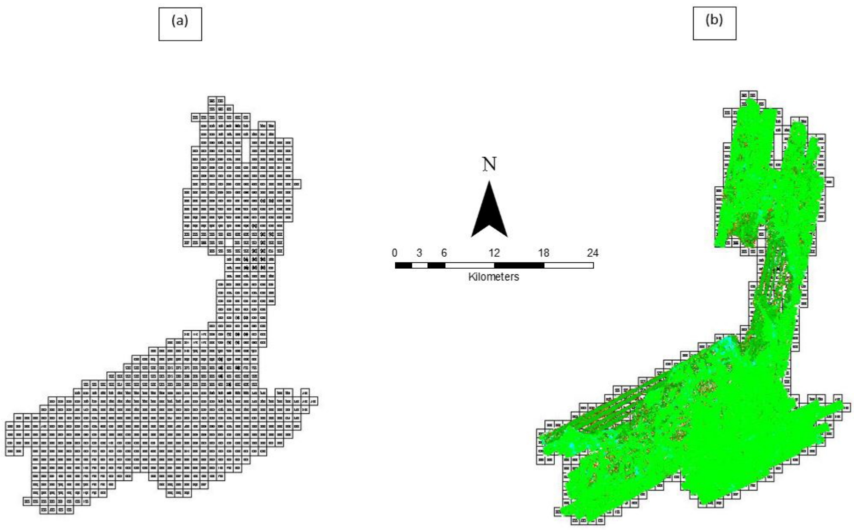


Figure 16. (a) Tiles for Pagsanjan floodplain and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that the residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

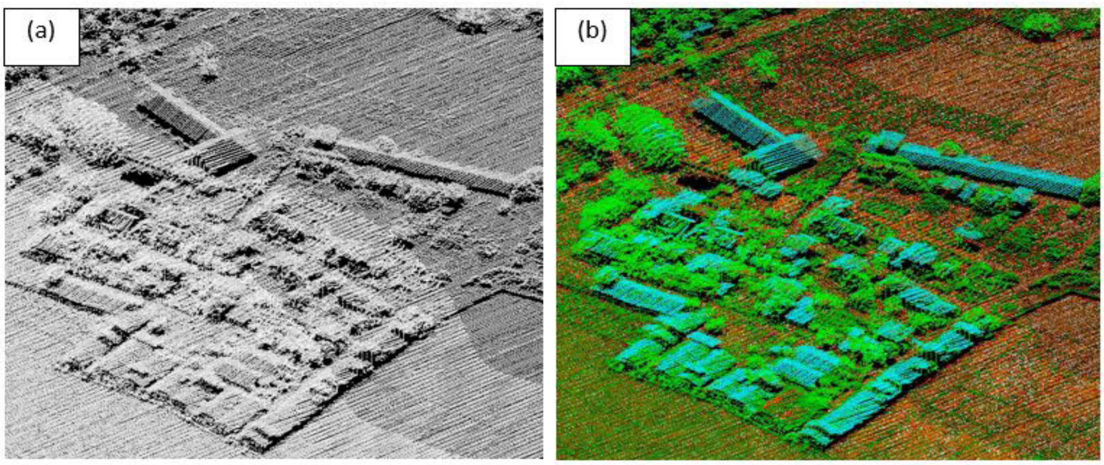


Figure 17. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 18, in top view display. The images convey that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

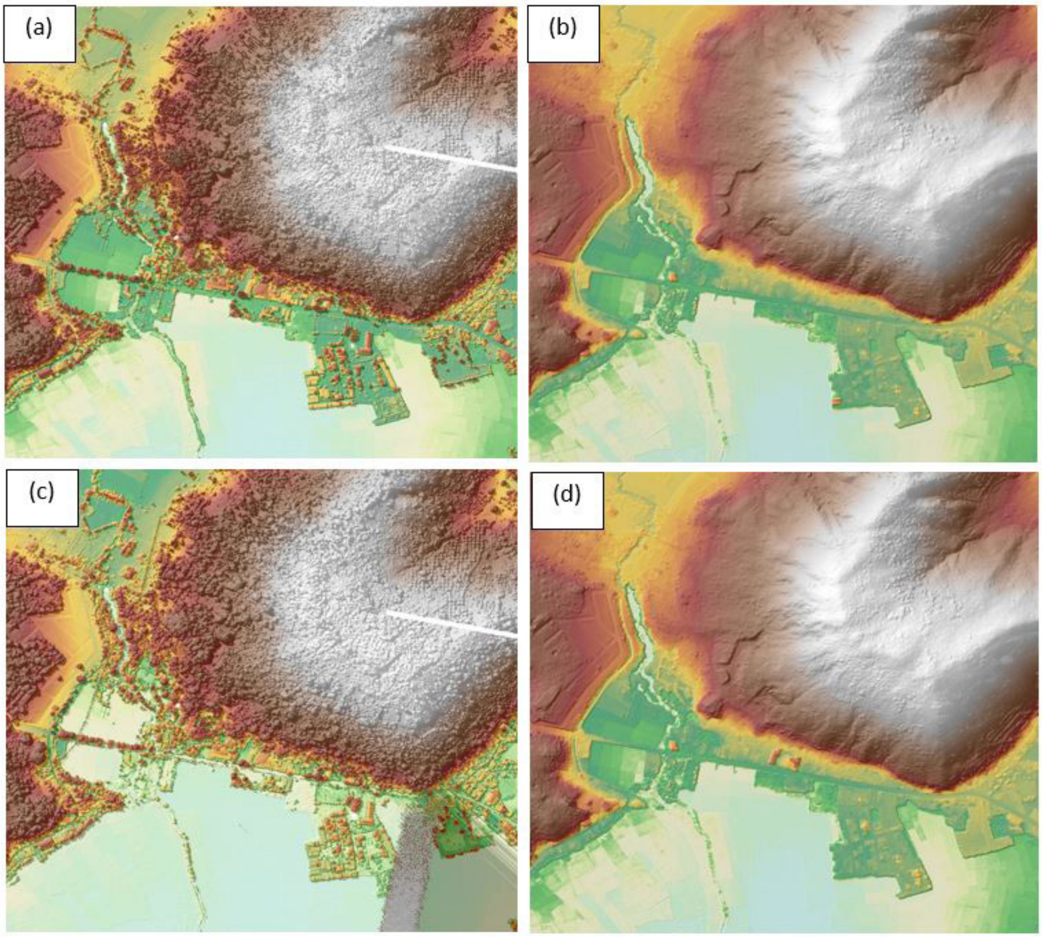


Figure 18. (a) The production of last return DSM and (b) DTM; (c) first return DSM and (d) secondary DTM in some portion of Pagsanjan floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 548 1km by 1km tiles area covered by the Pagsanjan floodplain is presented in Figure 19. 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 Pagsanjan floodplain survey attained a total of 370.61 square kilometers in orthophotographic coverage, comprised of 822 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 20.

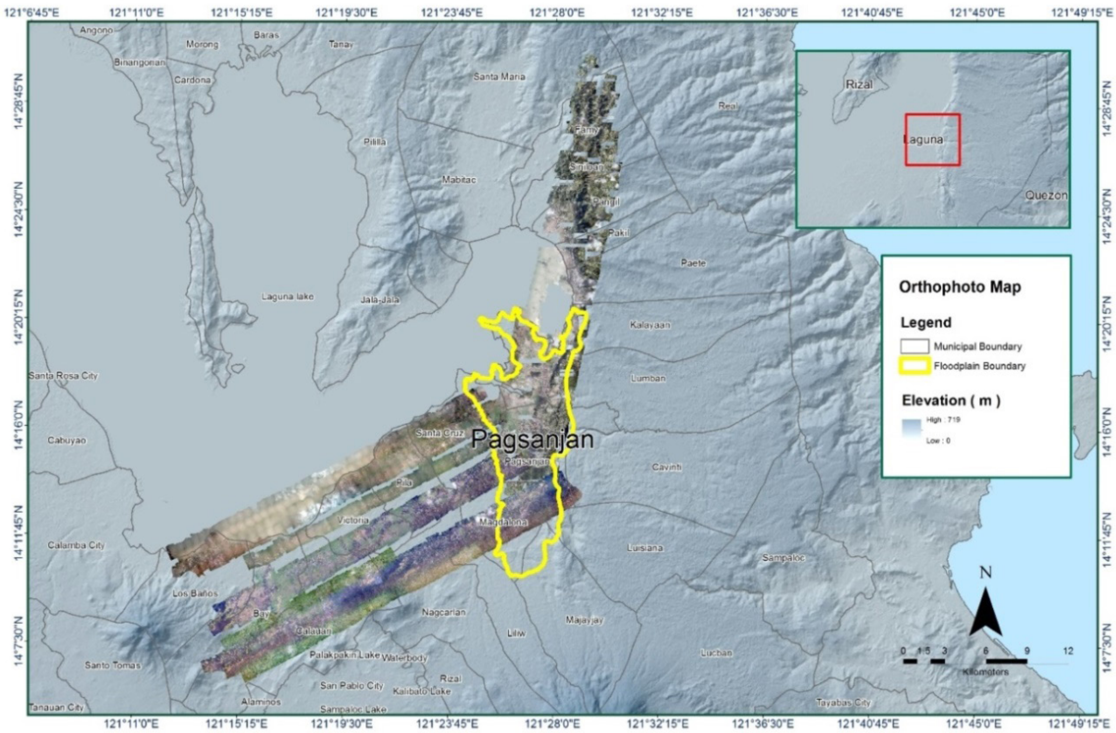


Figure 19. The Pagsanjan floodplain, with available orthophotographs

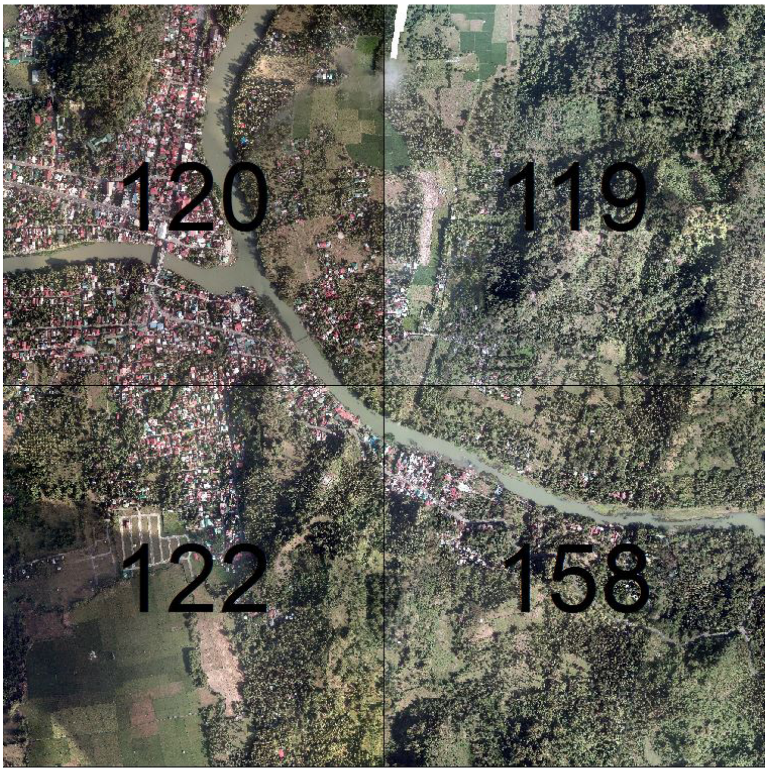


Figure 20. Sample orthophotograph tiles for the Pagsanjan floodplain

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for the Pagsanjan floodplain. These blocks are composed of CALABARZON, CALABARZON_reflights, Laguna, and Cavite blocks, with a total area of 795.77 square kilometers. Table 19 specifies the names and corresponding areas of the blocks, in square kilometers.

Table 19. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
CALABARZON_Blk18J_supplement	19.86
CALABARZON_Blk18I_supplement	89.16
CALABARZON_Blk18K_supplement	86.37
CALABARZON_reflights_Blk18K	177.02
Laguna_Blk18J	133.00
Laguna_Blk18H	102.25
Cavite_Blk18I	188.11
TOTAL	**795.77 sq.km**

Portions of the DTM before and after manual editing are exhibited in Figure 21. The bridge (Figure 21a) was considered to be an obstruction to the flow of water along the river, and had to be removed (Figure 21b) in order to hydrologically correct the river. Another case is a building that was still present in the DTM after classification (Figure 21c), and had to be removed through manual editing (Figure 21d).

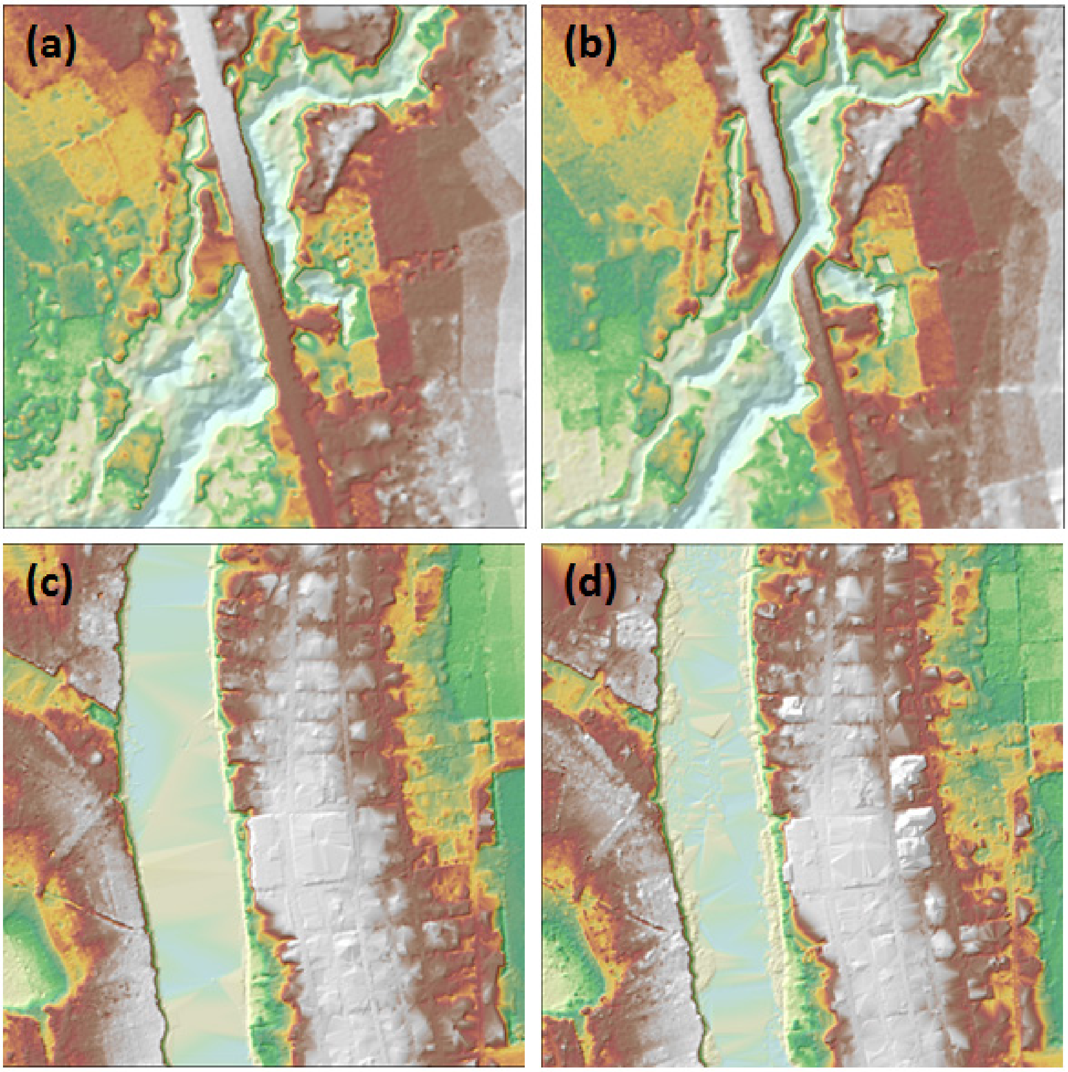


Figure 21. Portions in the DTM of the Pagsanjan floodplain – a bridge (a) before and (b) after manual editing; and a building (c) before and (d) after manual editing

3.9 Mosaicking of Blocks

No assumed reference block was utilized for mosaicking, as the identified reference for shifting was an existing calibrated CALABARZON DEM, which overlaps with the blocks to be mosaicked. Table 20 indicates the shift values applied to each LiDAR block during mosaicking.

The mosaicked LiDAR DTM for the Pagsanjan floodplain is displayed in Figure 22. It can be observed that the Pagsanjan floodplain is 75% covered by LiDAR data.

Table 20. Shift values of each LiDAR block of the Pagsanjan floodplain

Mission Blocks	**Shift Values (meters)**		
	x	**y**	**z**
CALABARZON_Blk18J_supplement	0.99	2.00	-0.18
CALABARZON_Blk18I_supplement	0.00	0.00	-0.74
CALABARZON_Blk18K_supplement	-0.99	-2.00	0.60
CALABARZON_reflights_Blk18K	-0.96	-1.99	0.49
Laguna_Blk18J	0.00	0.00	0.00
Laguna_Blk18H	0.00	0.00	0.30
Cavite_Blk18I	-0.21	-0.08	0.30

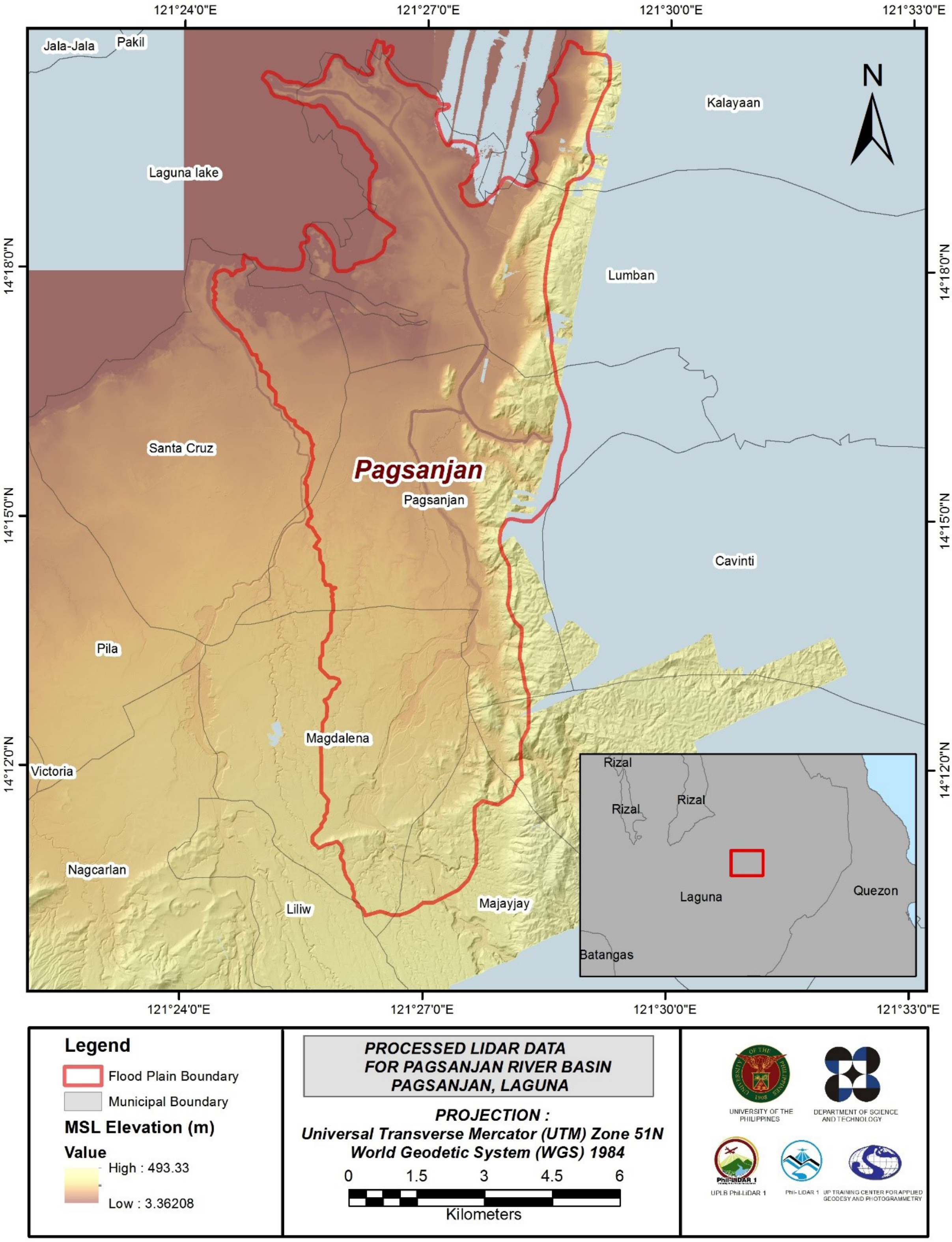


Figure 22. Map of processed LiDAR data for the Pagsanjan floodplain

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 Pagsanjan floodplain. The extent of the validation survey done in Pagsanjan to collect points with which the LiDAR dataset was validated is presented in Figure 23, with the validation survey points highlighted in green. A total of 6,795 survey points were used for the calibration and validation of the Pagsanjan LiDAR data.

Random selection of 80% of the survey points resulted in 5,436 points, which were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflected in Figure 24. Statistical values were computed from the extracted LiDAR values using the selected points, to assess the quality of the data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 2.95 meters, with a standard deviation of 0.10 meters. Calibration of the Pagsanjan LiDAR data was performed by subtracting the height difference value, 2.95 meters, from the Pagsanjan mosaicked LiDAR data. Table 21 specifies the statistical measurements of the compared elevation values between the LiDAR data and the calibration data.

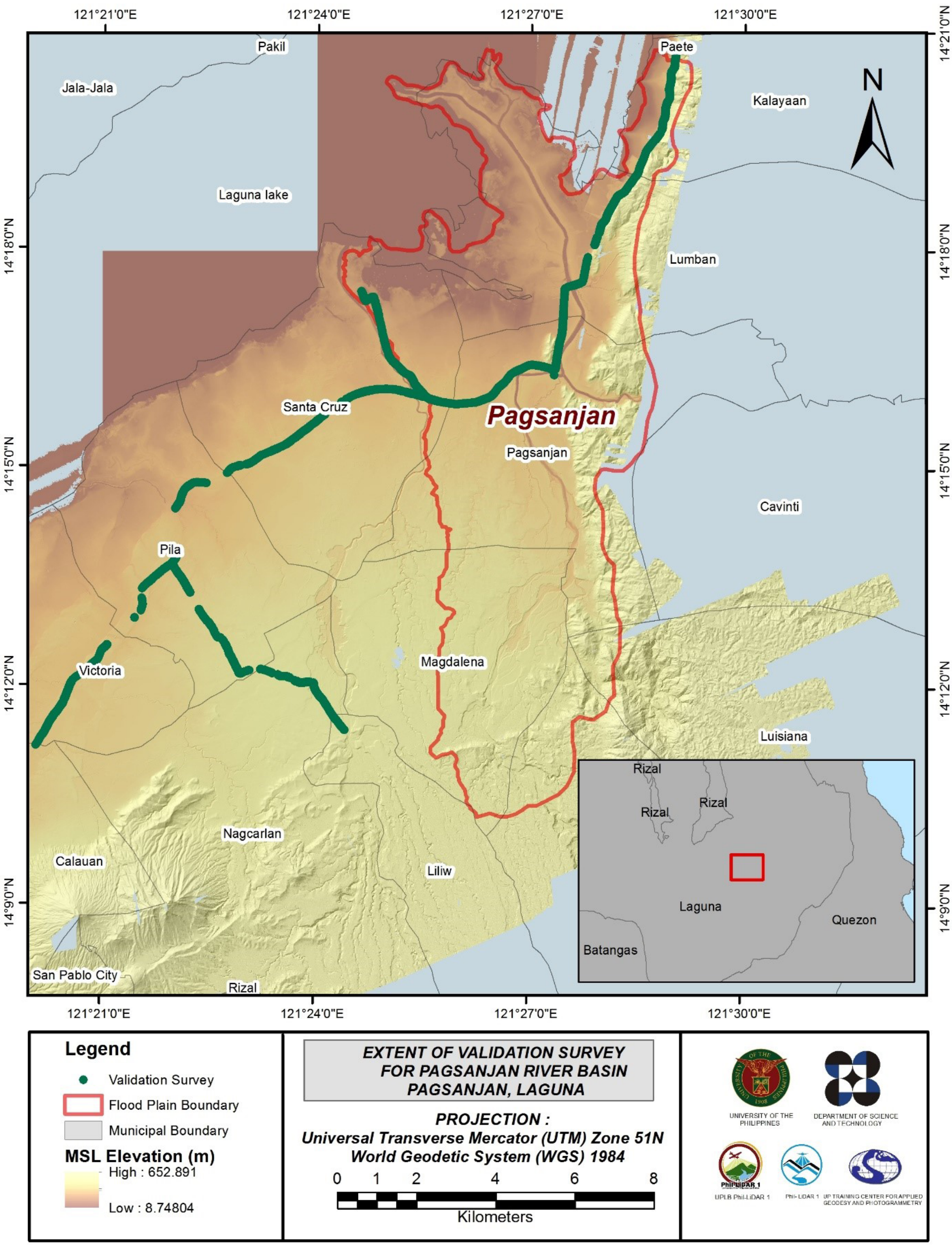


Figure 23. Map of the Pagsanjan floodplain, with the validation survey points in green

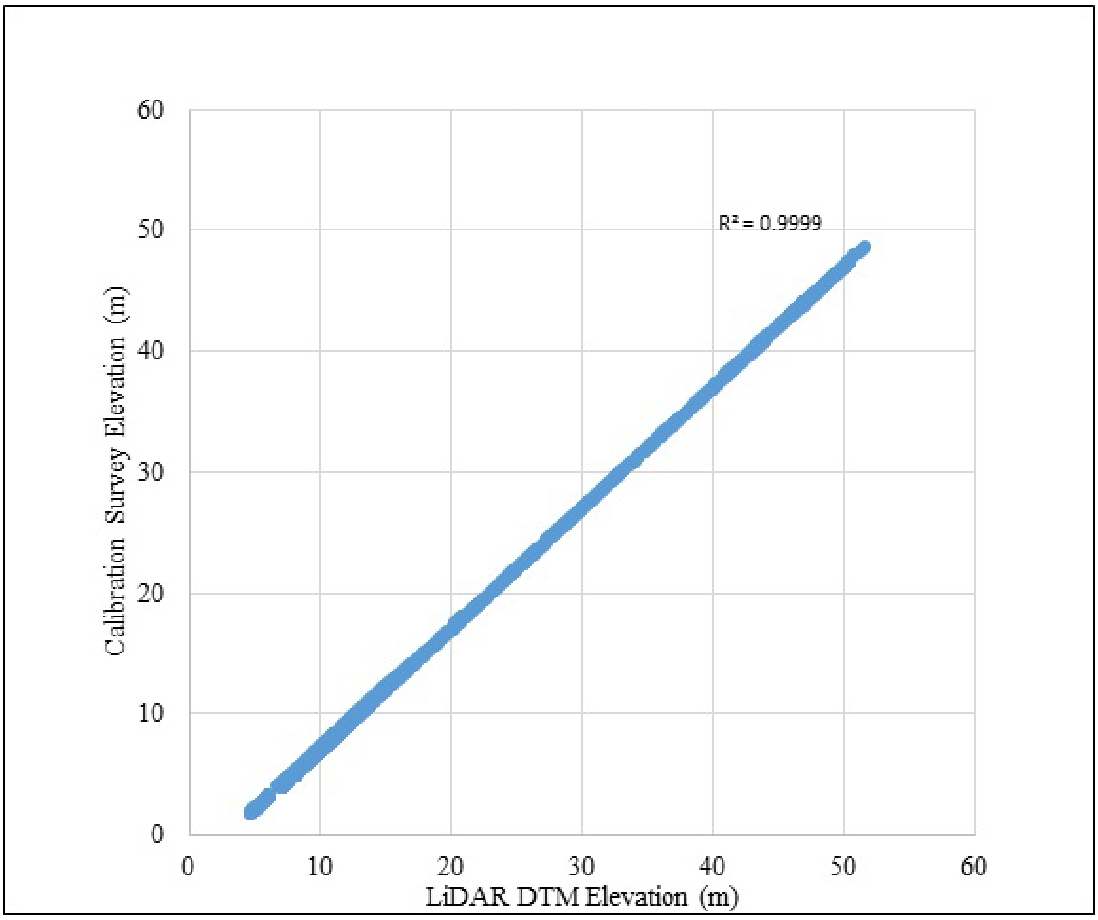


Figure 24. Correlation plot between the calibration survey points and the LiDAR data

Table 21. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.95
Standard Deviation	0.10
Average	-2.95
Minimum	-3.23
Maximum	-2.60

The remaining 20% of the total survey points, resulting in 1,359 points, were used for the validation of calibrated Pagsanjan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is demonstrated in Figure 25. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.10 meters, with a standard deviation of 0.16 meters, as indicated in Table 22.

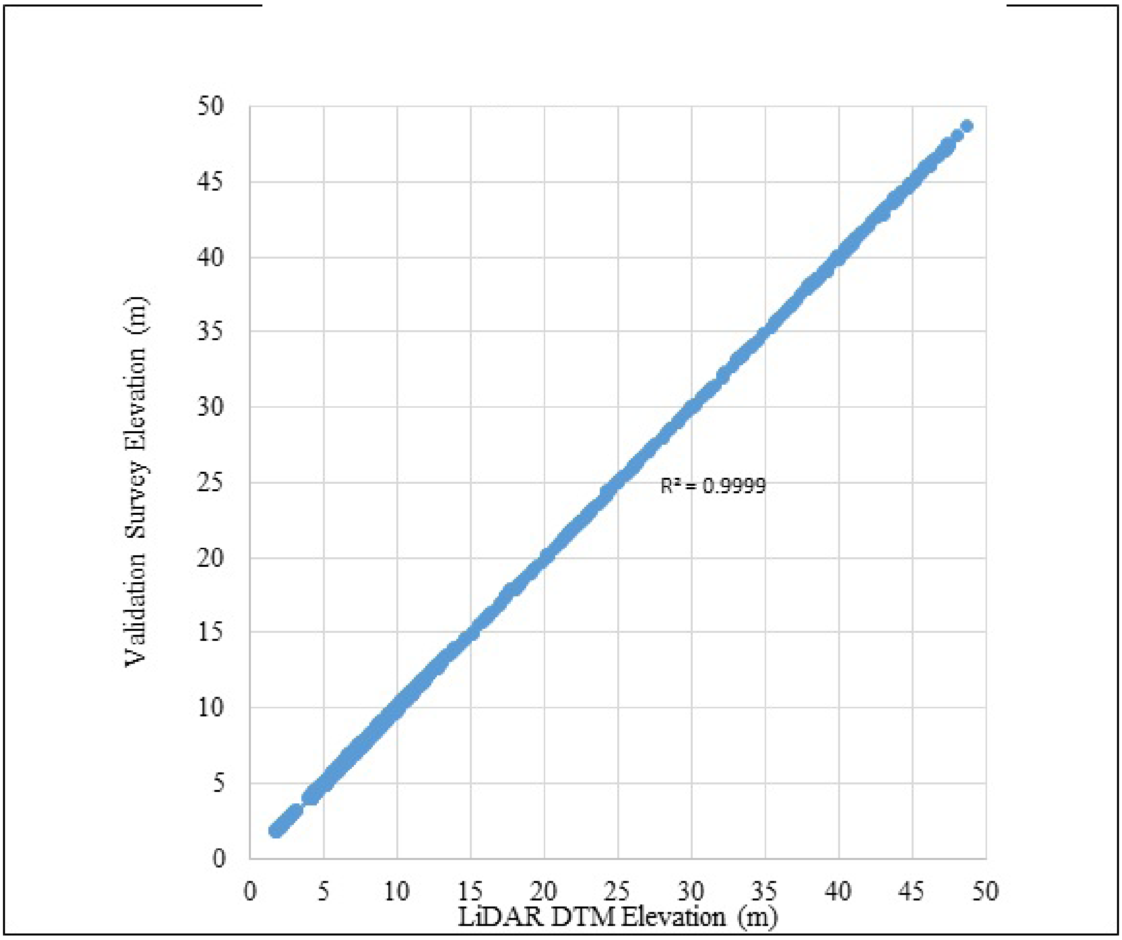


Figure 25. Correlation plot between the validation survey points and the LiDAR data

Table 22. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.10
Standard Deviation	0.16
Average	0.016
Minimum	-0.31
Maximum	0.34

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Pagsanjan, with 3,956 bathymetric survey points. The resulting raster surface produced was obtained through 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 0.48 meters. The extent of the bathymetric survey conducted by the DVBC in Pagsanjan, integrated with the processed LiDAR DEM, is shown in Figure 26.

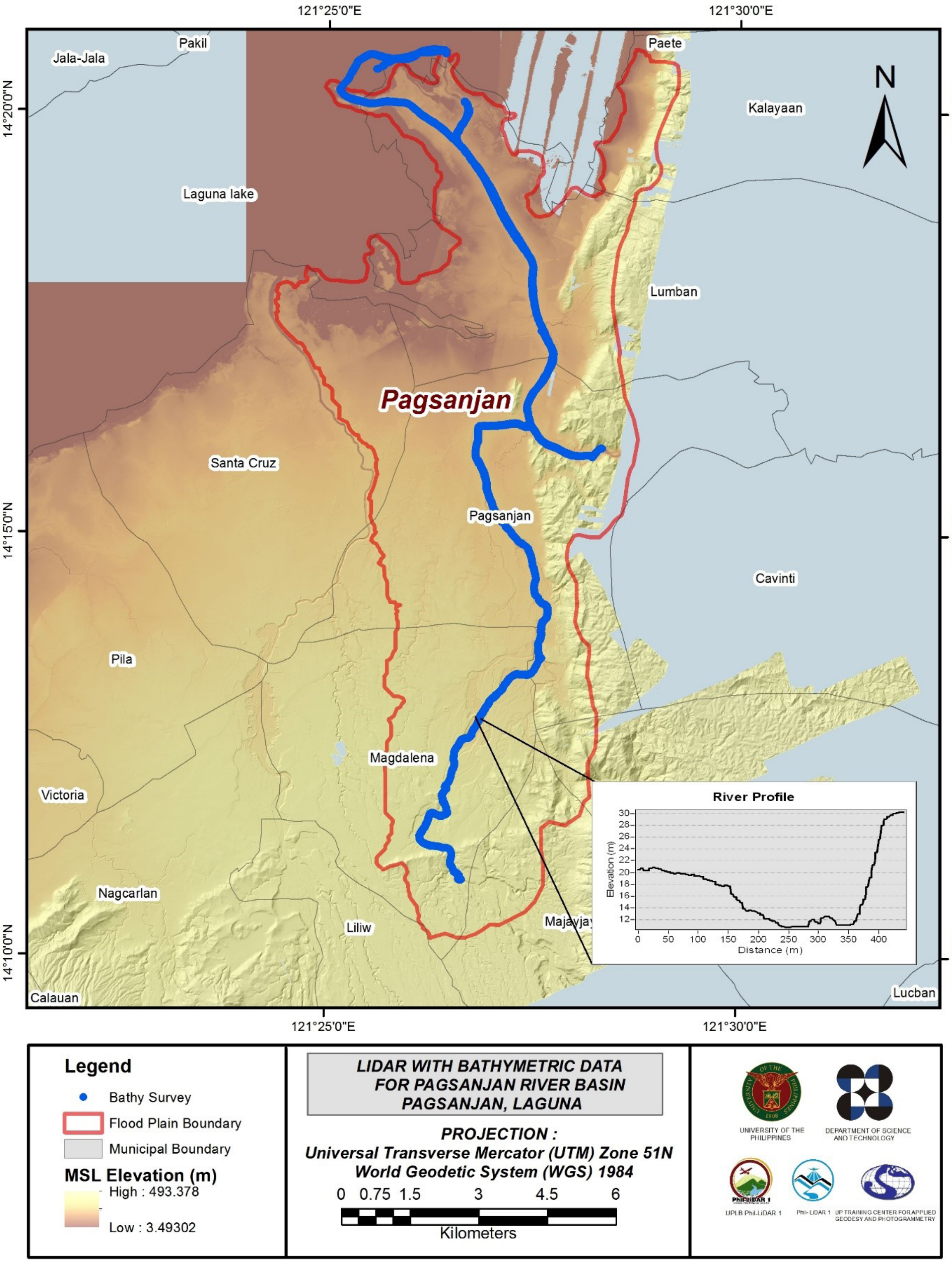


Figure 26. Map of the Pagsanjan floodplain, with bathymetric survey points shown in blue

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

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

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

4.1 Summary of Activities

The DVBC conducted two (2) field surveys in the Pagsanjan River. The first one was conducted on August 26 - 30, 2014, with the following scope of work: (i.) reconnaissance survey to assess the actual situation of the river, and to locate the existing control point monuments; (ii.) courtesy call with the barangays near the Pagsanjan River; (iii.) cross-section and bridge as-built surveys and water level marking of the Majayjay Bridge pier; and (iv.) bathymetric survey from Barangay Burlungan, Magdalena down to the mouth of the river in Barangay Wawa, Lumban, with an estimated length of 25 kilometers. The second fieldwork was conducted on September 2 - 6, 2014, with the following scope of work: (i.) control survey for the establishment of a control point on the approach of the bridge; and (ii.) ground validation data acquisition of about 47 kilometers, along the major roads of Pagsanjan.

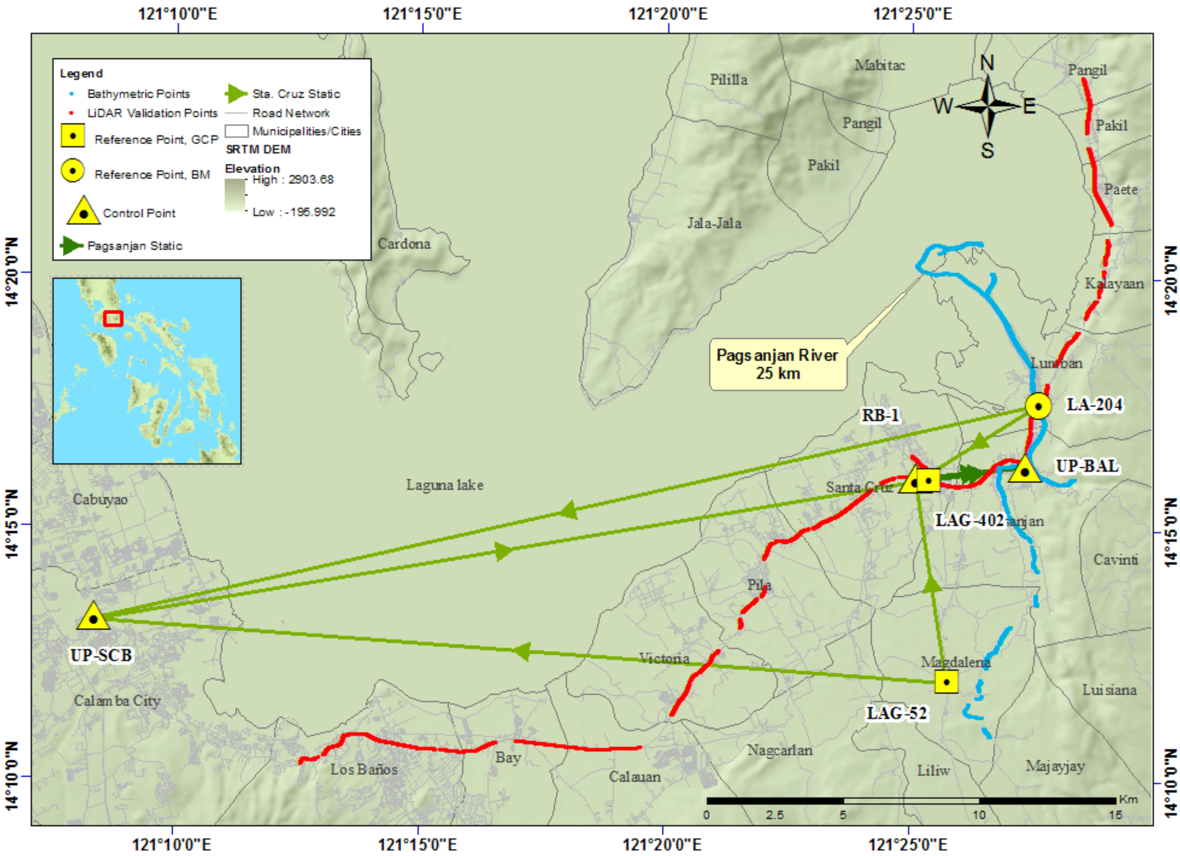


Figure 27. Extent of the bathymetric survey (in blue line) in the Pagsanjan River and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS network was established for a previous PHIL-LiDAR survey for the Sta. Cruz River on September 2, 2014, occupying the following reference points: (i.) LAG-52, a second-order GCP, located in Barangay Poblacion, Municipality of Magdalena, Laguna; and (ii.) LA-204, a first-order BM, located in Barangay Balubad, Municipality of Lumban, Laguna.

The GNSS network used for the Pagsanjan River survey was composed of a single loop established on September 3, 2014, using the control point with fixed values from the previous survey in the Sta. Cruz River, RB-1, located in Barangay Patimbao, Municipality of Sta. Cruz, Laguna.

The summary of control points used is in Table 23, while the established GNSS network is illustrated in Figure 28.

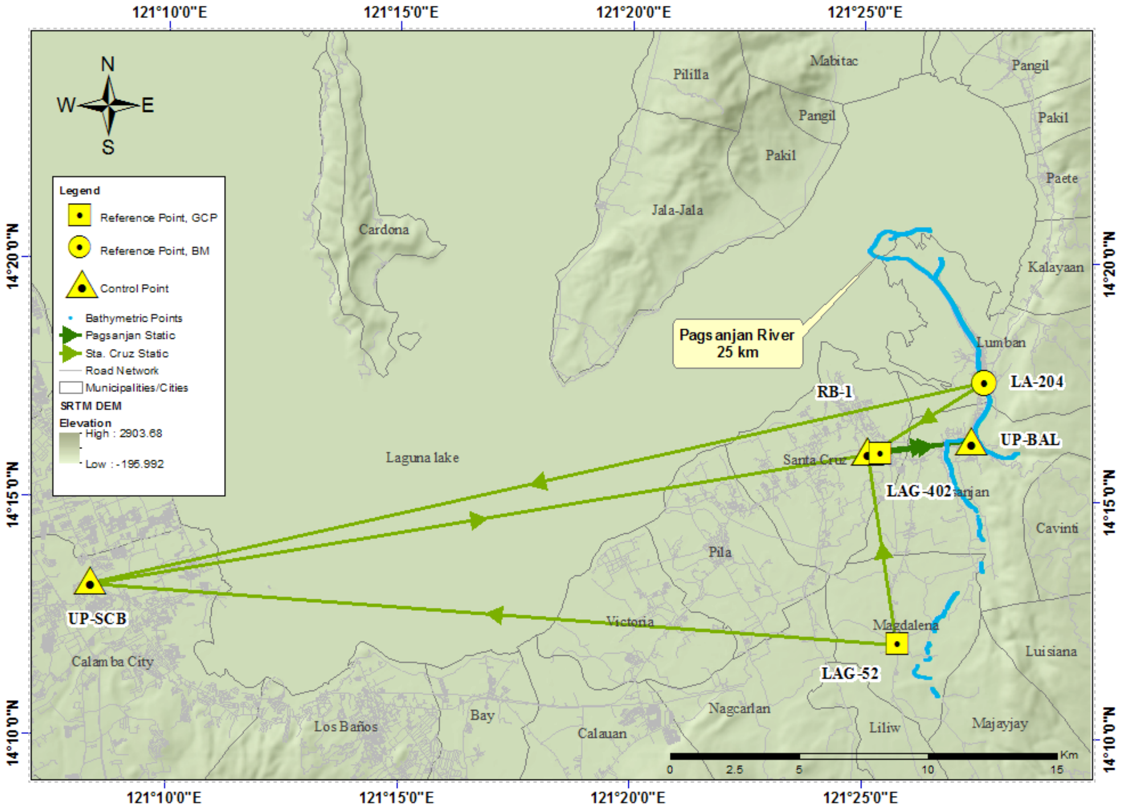


Figure 28. Static network used in the Pagsanjan River Survey

Table 23. References and control points used in the Pagsanjan River survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	BM Ortho (m)	Date Established
First loop September 2, 2014						
LAG-52	2nd Order GCP	14°11'59.35842"	121°25'46.26158"	109.637	63.727	2007
LA-204	1st Order BM	14°17'30.95410"	121°27'36.89050"	54.504	8.564	Sept 2, 2014
RB-1	UP Established	14°16'02.54128"	121°25'05.84019"	59.879	14.109	Sept 2, 2014
UP SCB-1	UP Established	14°13'12.89108"	121°08'21.83033"	65.355	20.595	2007
Second loop September 3, 2014						
RB-1	UP Established	14°16'02.54128"	121°25'05.84019"	59.879	14.109	Sept 2, 2014
UP BAL	UP Established	-	-	-	-	Sept 2, 2014
LAG-402	Used as Marker	-	-	-	-	2007

The GNSS set-ups in the control points occupied and used in the survey are exhibited in Figure 29 to Figure 31.

Figure 29. GNSS base receiver set-up, Trimble® SPS 852 at RB-1, located at the rooftop of Asia Blooms Hotel, Barangay Patimbao, Sta. Cruz, Laguna

Figure 30. Trimble® SPS 882 GPS set-up at LAG 402 on the Pagsawitan Bridge, Pagsawitan, Laguna

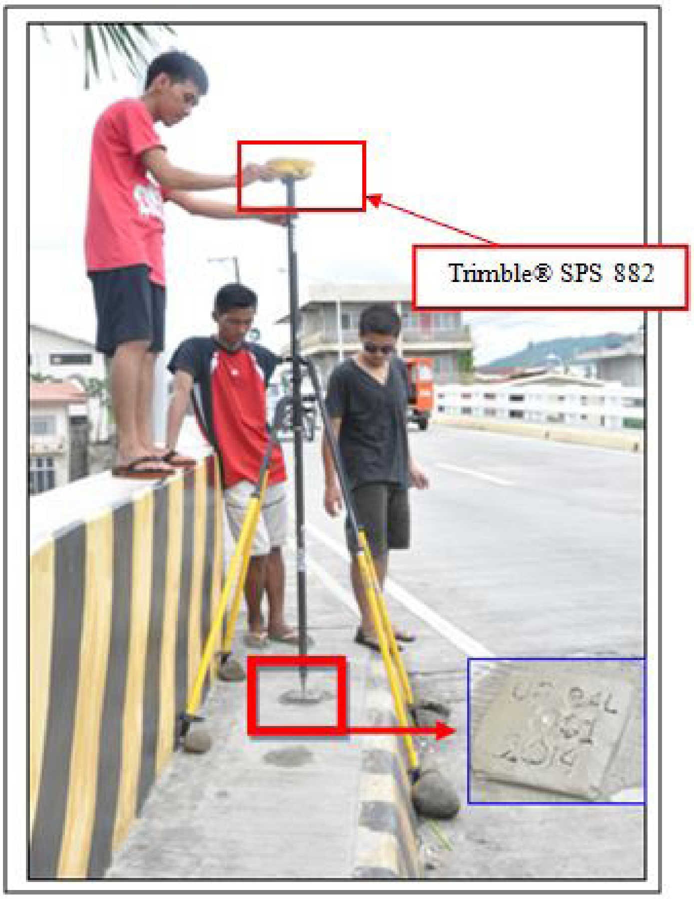


Figure 31. Trimble® SPS 882 GPS set-up at UP-BAL on the Balanac Bridge, Pagsanjan, Laguna

4.3 Baseline Processing

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

Table 24. Baseline Processing Summary Report for the Pagsanjan River survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
RB-1 --- UP-BAL	9-3-14	Fixed	0.005	0.007	83°44'45"	4056.142	-3.964
LAG-402 --- UP-BAL	9-3-14	Fixed	0.006	0.007	81°57'08"	3572.818	-1.319
RB-1 --- LAG-402	9-3-14	Fixed	0.001	0.002	96°44'08"	497.815	-2.641

As shown in Table 24, a total of three (3) baselines were processed, with the coordinate values and elevation value of RB-1, fixed from the previous survey in Sta. Cruz, also held fixed for the Pagsanjan survey. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report presented in Table 25 to Table 28 for complete details.

The three (3) control points – RB-1, UP-BAL, and LAG-402 – were occupied and observed simultaneously to form a GNSS loop. The coordinates and elevation value of RB-1 were held fixed during the processing of the control points, as demonstrated in Table 25. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 25. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
RB-1	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is outlined in Table 26. All fixed control points did not yield values for grid and elevation errors.

Table 26. Adjusted grid coordinates for the control points used in the Pagsanjan floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BAL-1	333404.682	0.001	1578291.652	0.001	9.978	0.002	
LAG-402	329863.907	0.001	1577815.509	0.000	11.448	0.001	
RB-1	329369.956	?	1577877.257	?	14.109	?	ENe

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

a. RB-1

Horizontal Accuracy	=	Fixed
Vertical Accuracy	=	Fixed

b. UP-BAL

Horizontal Accuracy	=	$\sqrt{((0.1)^2 + (0.01)^2}$
	=	$\sqrt{(0.01 + 0.01)}$
	=	$0.14 < 20$ cm
Vertical Accuracy	=	$0.2 < 10$ cm

c. LAG-402

Horizontal Accuracy	=	$\sqrt{((0.1)^2 + (0.0)^2}$
	=	$\sqrt{(0.1 + 0.0)}$
	=	$0.1 < 20$ cm
Vertical Accuracy	=	$0.1 < 10$ cm

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

Table 27. Adjusted geodetic coordinates for control points used in the Pagsanjan River floodplain validation

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Con-straint
BAL-1	N14°16'16.90795"	E121°27'20.35747"	55.917	0.002	
LAG-402	N14°16'00.64134"	E121°25'22.33355"	57.238	0.001	
RB-1	N14°16'02.54129"	E121°25'05.84020"	59.879	?	ENe

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

The computed coordinates of the reference and control points utilized in the Pagsanjan River GNSS Static Survey are indicated in Table 28.

Table 28. Reference and control points used in the Pagsanjan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
First loop September 2, 2014							
LAG-52	2nd Order GCP	14°11'59.35842"	121°25'46.26158"	109.637	1570395.63	330531.105	63.727
UP-SCB	UP Established	14°13'12.89108"	121°08'21.83033"	65.355	1572885.788	299233.666	20.595
RB-1	UP Established	14°16'02.54128"	121°25'05.84019"	59.879	1577877.257	329369.956	14.109
LA-204	1st Order BM	14°17'30.95410"	121°27'36.89050"	54.504	1580563.904	333915.29	8.564
Second loop, September 3, 2014							
RB-1	UP Established	14°16'02.54129"	121°25'05.84020"	59.879	1577877.257	329369.956	14.109
UP-BAL	UP Established	14°16'16.90795"	121°27'20.35747"	55.917	1578291.652	333404.682	9.978
LAG-402	Used as Marker	14°16'00.64134"	121°25'22.33355"	57.238	1577815.509	329863.907	11.448

4.5 Cross-section and Bridge As-Built Survey

The cross-section surveys and bridge as-built features determination were conducted on August 29 - 30, 2014 at the Majayjay Bridge in Barangay Burlungan, Magdalena; and on July 28, 2015 at the Balanac Bridge in Barangay 1, Pagsanjan, and at the Cavinti Bridge in Barangay Pinagsanjan, Pagsanjan. Trimble® SPS 882 in GNSS PPK survey technique was used for the surveys, as depicted in Figure 32 and Figure 33.

Figure 32. Cross-section survey at the Majayjay Bridge in Barangay Burlungan, Magdalena

Figure 33. Cross-section survey at the Balanac Bridge

The length of the cross-sectional line surveyed in the Majayjay Bridge was about 42.9 meters, with thirty (30) points. The length of the cross-sectional line surveyed in the Balanac Bridge was 118.9 meters, with 153 points; and that of the cross-sectional line surveyed in the Cavinti Hanging Bridge was 96.5 meters, with 42 points. All cross-sectional surveys utilized UP-BAL as the GNSS base station. The location maps, cross-section diagrams, and bridge as-built forms are presented in Figure 34 to Figure 40.

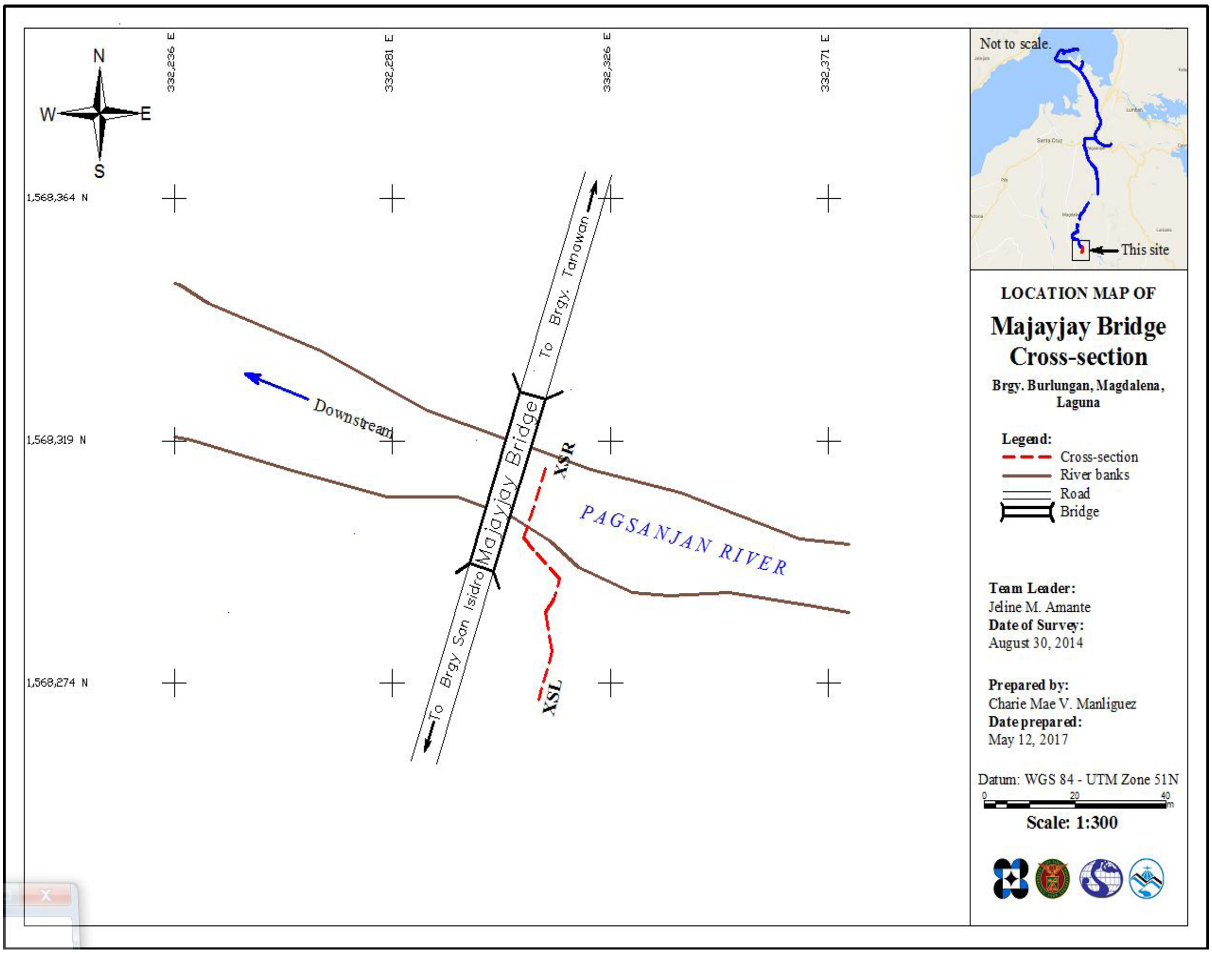


Figure 34. Majayjay Bridge cross-section location map

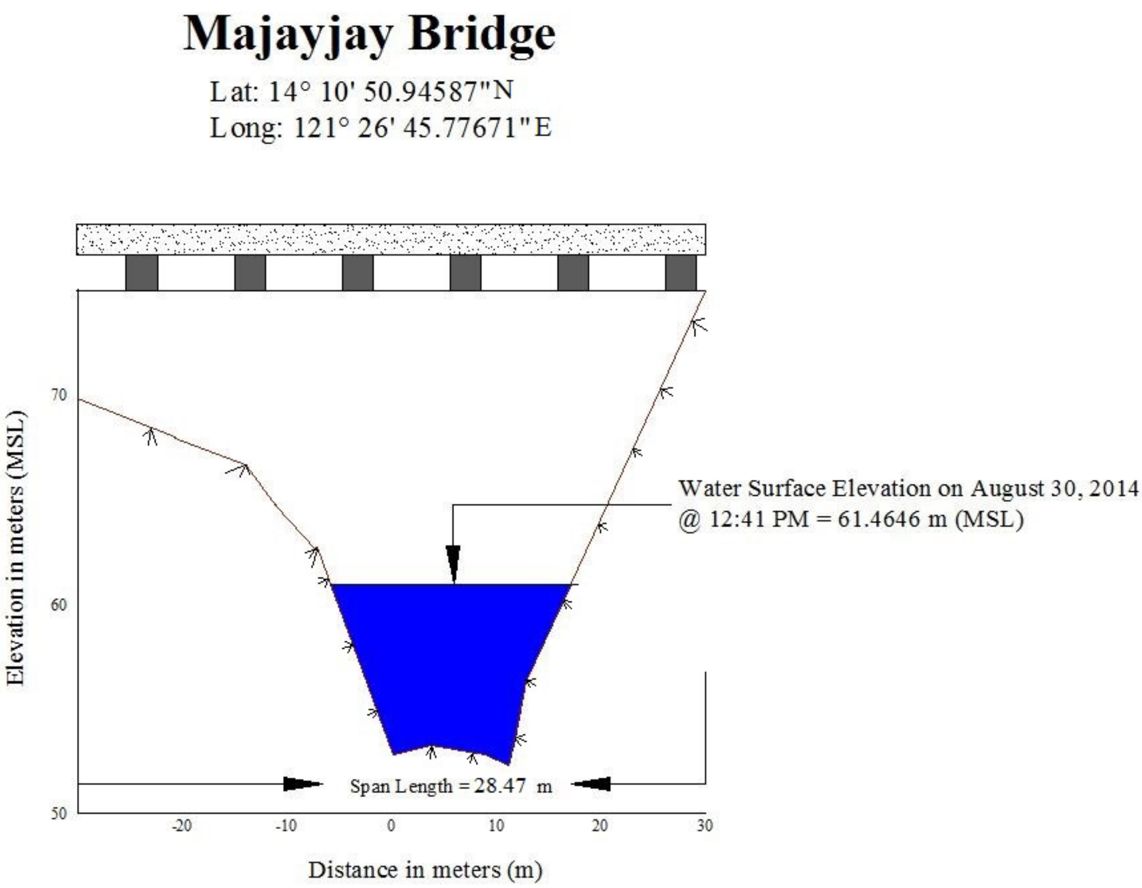


Figure 35. Cross-section diagram of the Majayjay Bridge in Barangay Burlungan, Magdalena

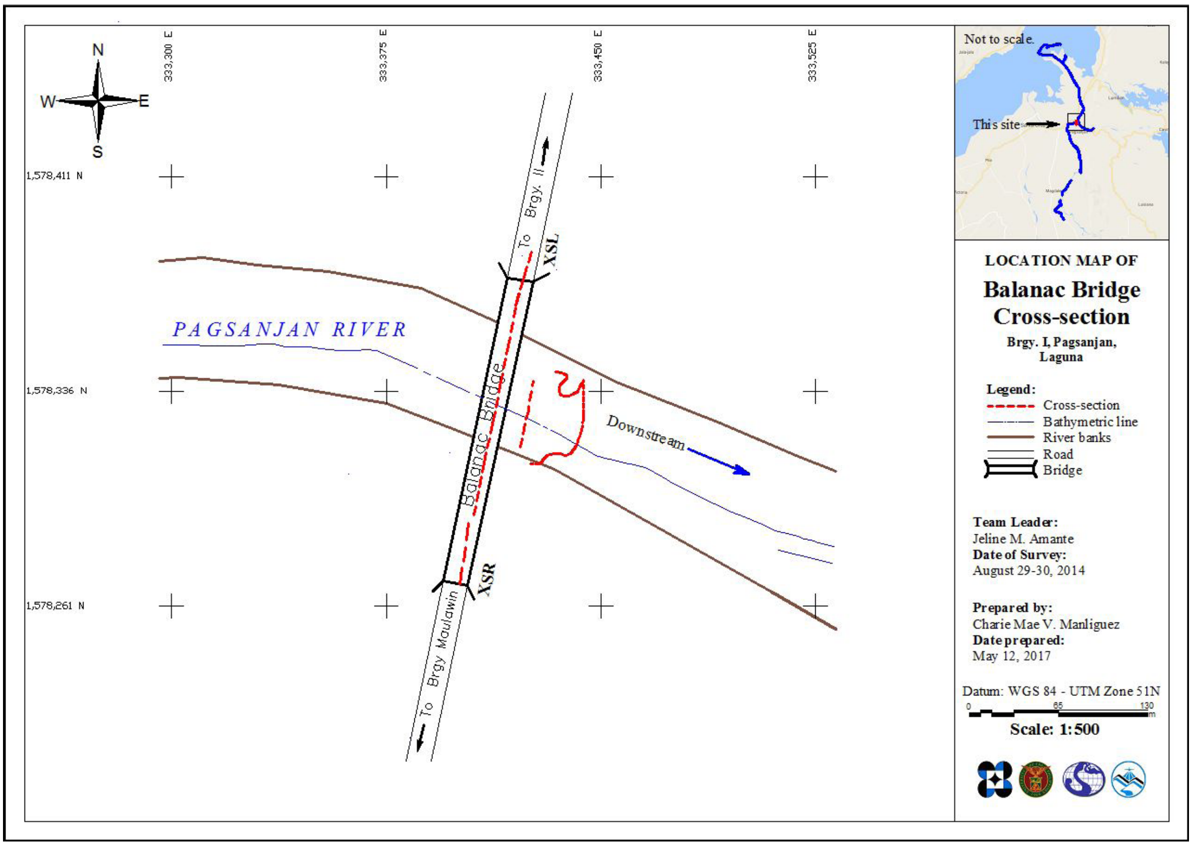


Figure 36. Balanac Bridge cross-section location map

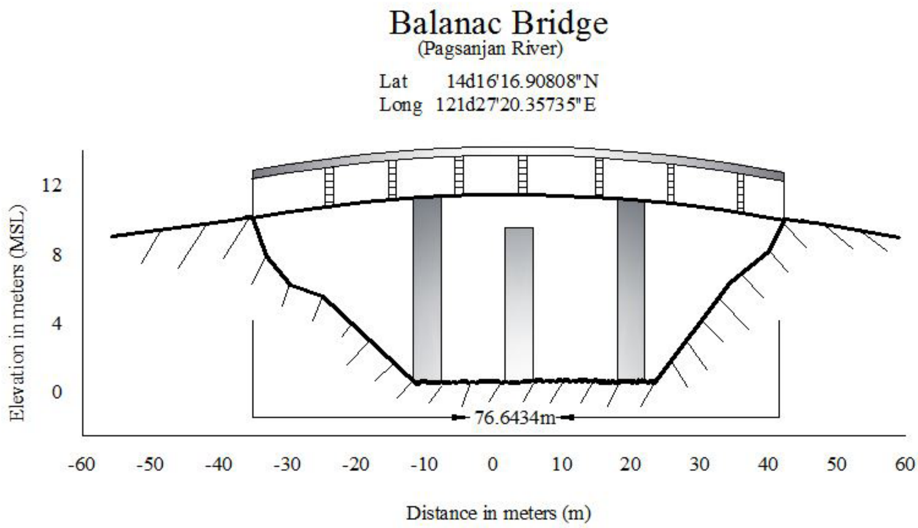


Figure 37. Cross-section diagram of the Balanac Bridge

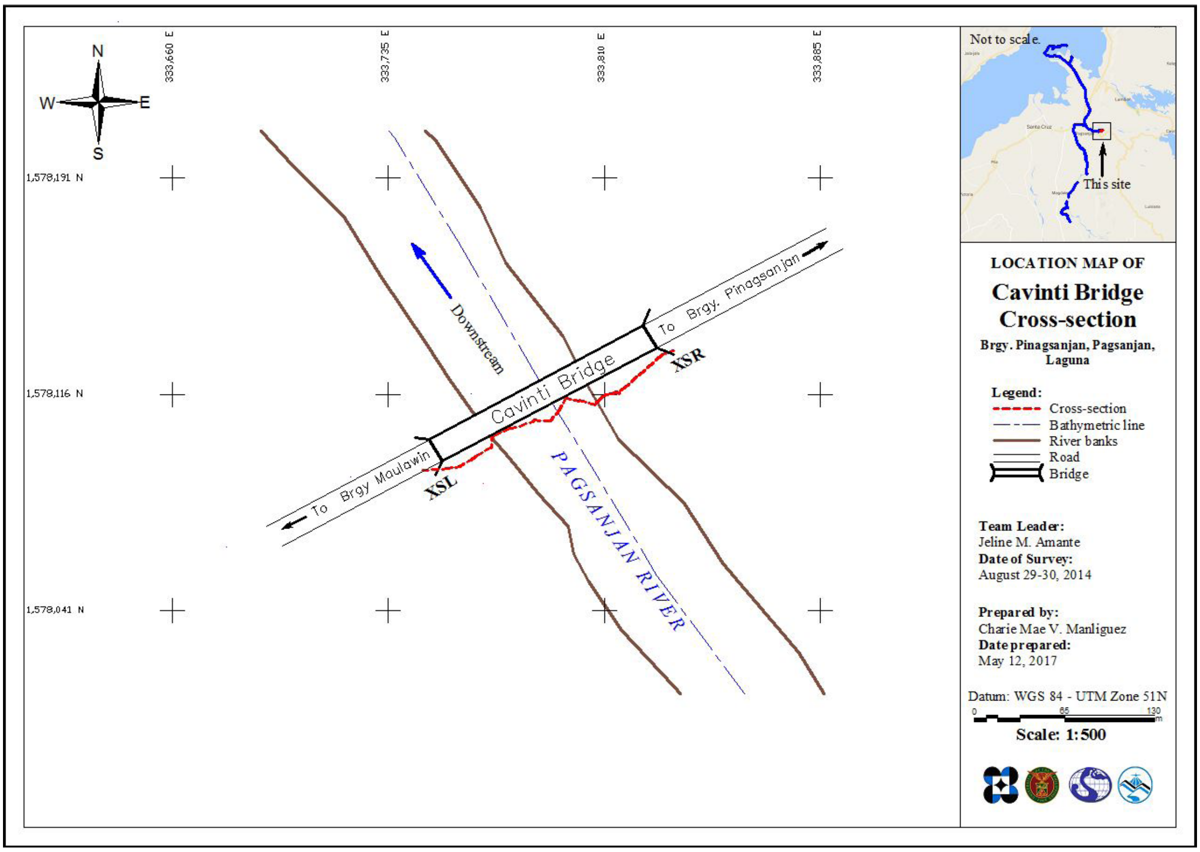


Figure 38. Cavinti Bridge cross-section location map

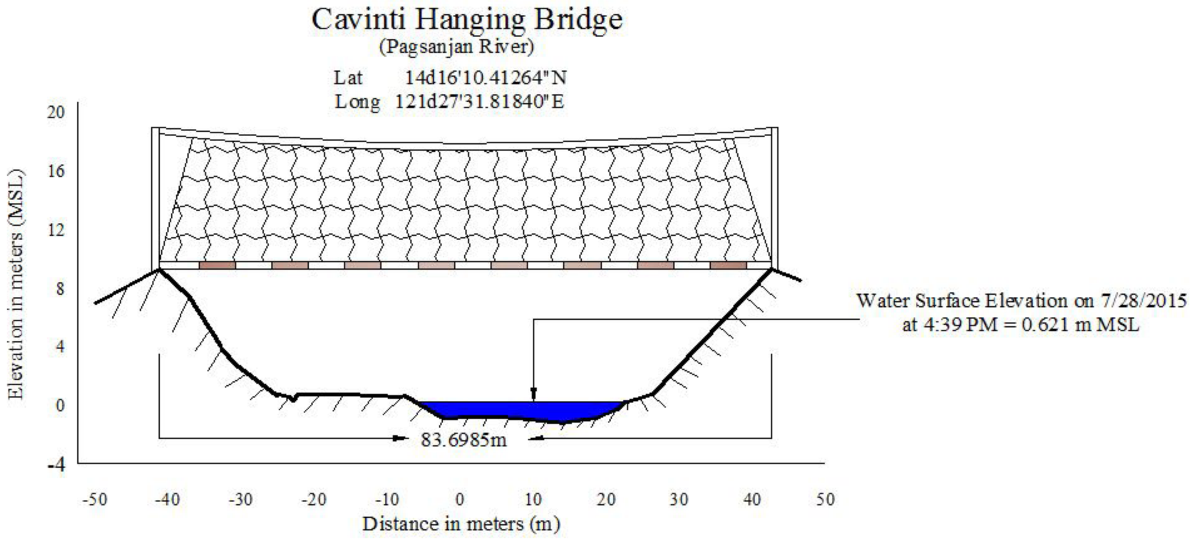


Figure 39. Cross-section diagram of the Cavinti Hanging Bridge

Bridge Data Form

Bridge Name: Majayjay Bridge

Date: August 30, 2014

River Name: Pagsanjan-Balanac River

Time: 12:41:32 PM

Location (Brgy, City, Region): Brgy. Burlungan, Magdalena

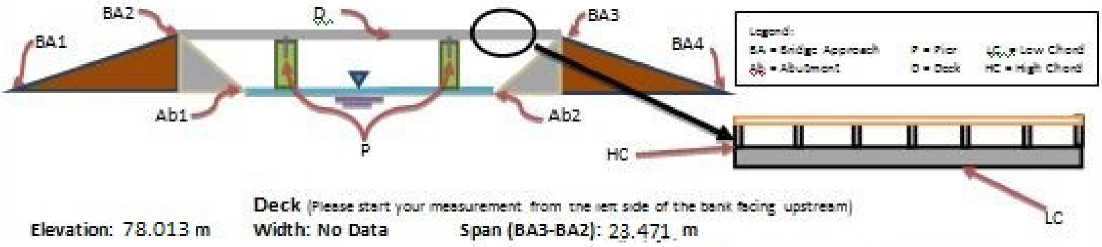
Survey Team: Pagsanjan River Survey Team

Flow condition: low normal high

Weather Condition: fair rainy

Latitude: 14d10'50.94587" N

Longitude: 121d26'45.77671" E



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

Elevation: 78.013 m Width: No Data Span (BA3-BA2): 23.471 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not Applicable	No Data	No Data
2	Not Applicable	-	-

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0		BA3	42.912 m	77.941 m
BA2	14.440 m	78.013 m	BA4	No data	-

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

	Station (Distance from BA1)	Elevation
Ab1	No Abutment	-
Ab2	No Abutment	-

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

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

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	No Pier	-	-
Pier 2	No Pier	-	-
Pier 3	No Pier	-	-

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 40. Bridge Data Form of the Majayjay Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 2-6, 2014 using a survey-grade GNSS receiver, Trimble®SPS985. The receiver was mounted on a pole that was attached to the side of a vehicle, as demonstrated in Figure 41. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna height of 1.92 meters was measured from the ground up to the bottom of the notch of the GNSS receiver. It was set on continuous topo method, utilizing PPK survey technique. Points were gathered along the concrete roads of the national highway from Calamba City to Sta. Cruz, Laguna, observing a vehicle speed of 10-20 kilometers per hour. The GNSS base station was set up over RB-1, located at the rooftop of Asian Bloom Hotels in Barangay Patimbao, Sta. Cruz, Laguna.

The survey began in the Municipality of Pangil, Laguna, and ended in Los Baños Laguna. The ground validation line is approximately 47.5 kilometers in length, with 5,108 points gathered. The map in Figure 42 illustrates the coverage of the ground validation survey.

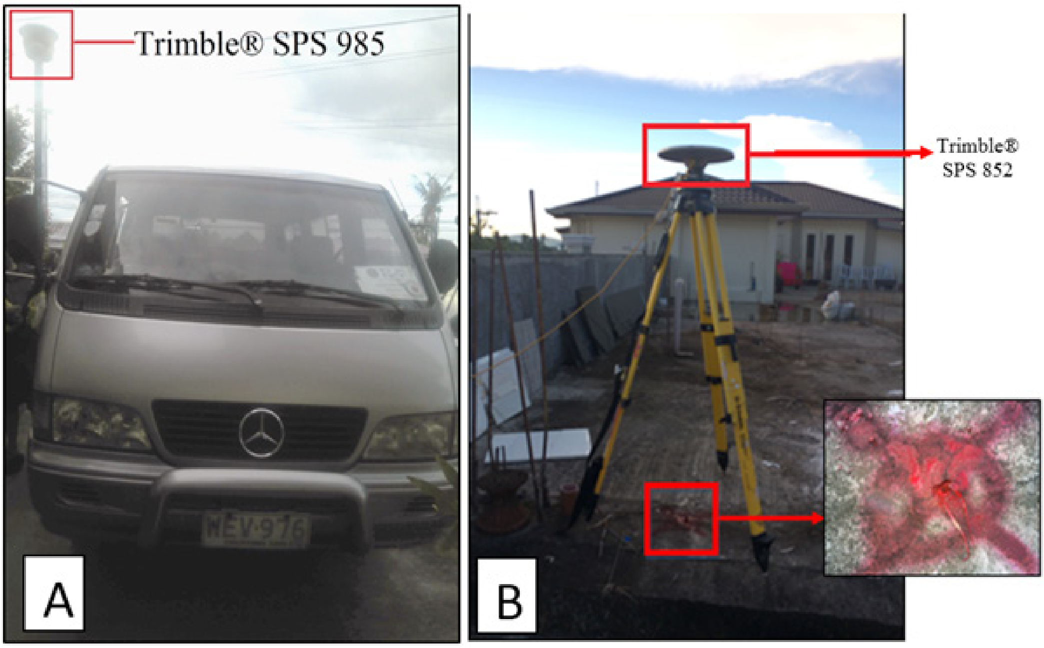


Figure 41. (A) Trimble® SPS 985 GNSS Receiver set-up on a vehicle; and (B) GNSS base set-up at RB-1, located at the rooftop of Asian Bloom Hotel, Barangay Patimbao, Sta. Cruz, Laguna

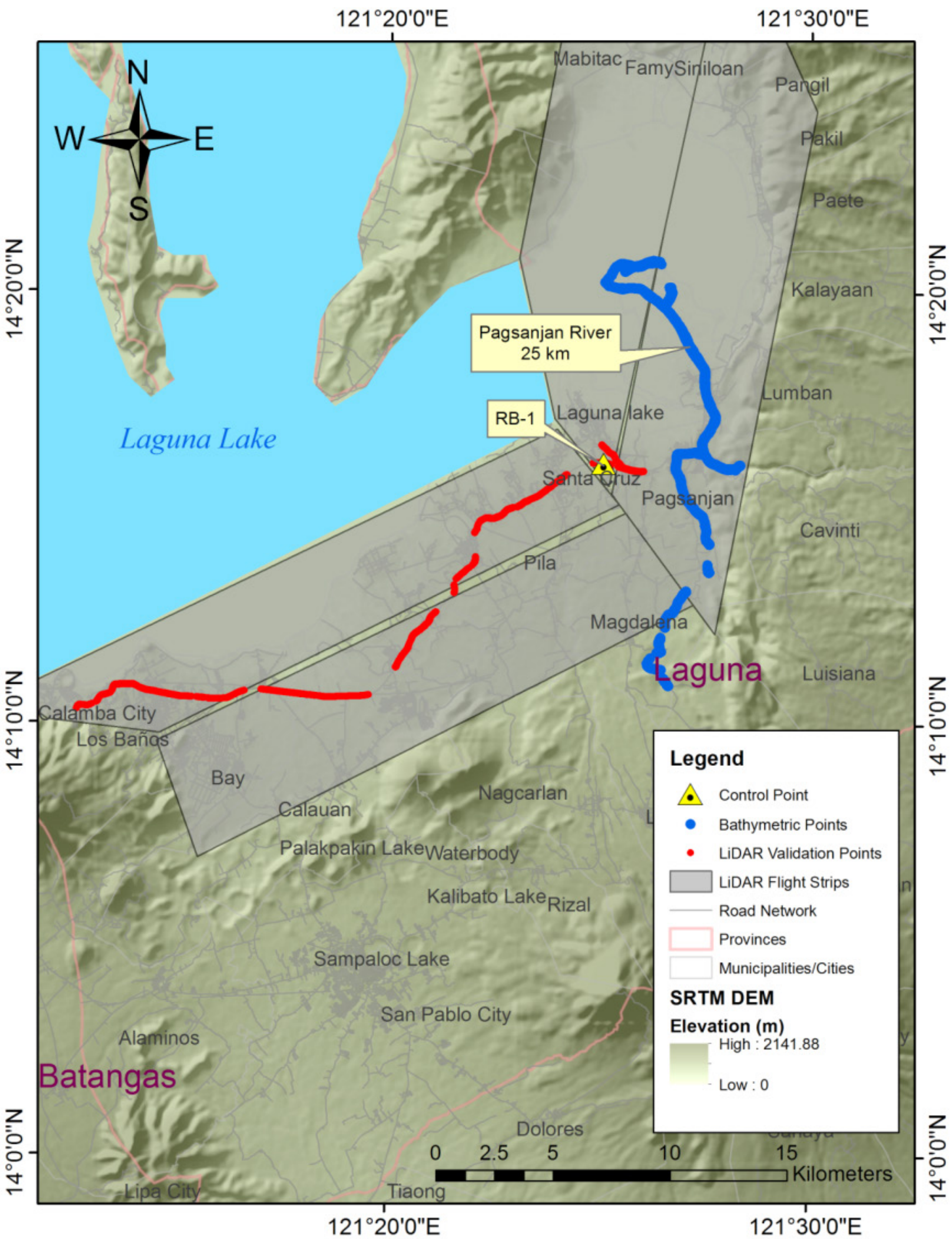


Figure 42. Extent of the LiDAR ground validation survey from Calamba City to Sta. Cruz, Laguna

4.7 Bathymetric Survey

A bathymetric survey was conducted on August 27 - 29, 2014 using a Hi-Target™ HD 370 single beam echo sounder integrated with a roving GNSS receiver, Trimble®SPS882, installed on a boat implementing PPK survey technique, as depicted in Figure 43. The survey started in the midstream part of the river in Barangay Sabang, with coordinates 14˚13'42.22060" 121˚27'34.98064"; and extended down to the mouth of the river in Barangay Wawa, Municipality of Lumban, with coordinates 14˚20'44.09778" 121 ˚ 26'20.30032".

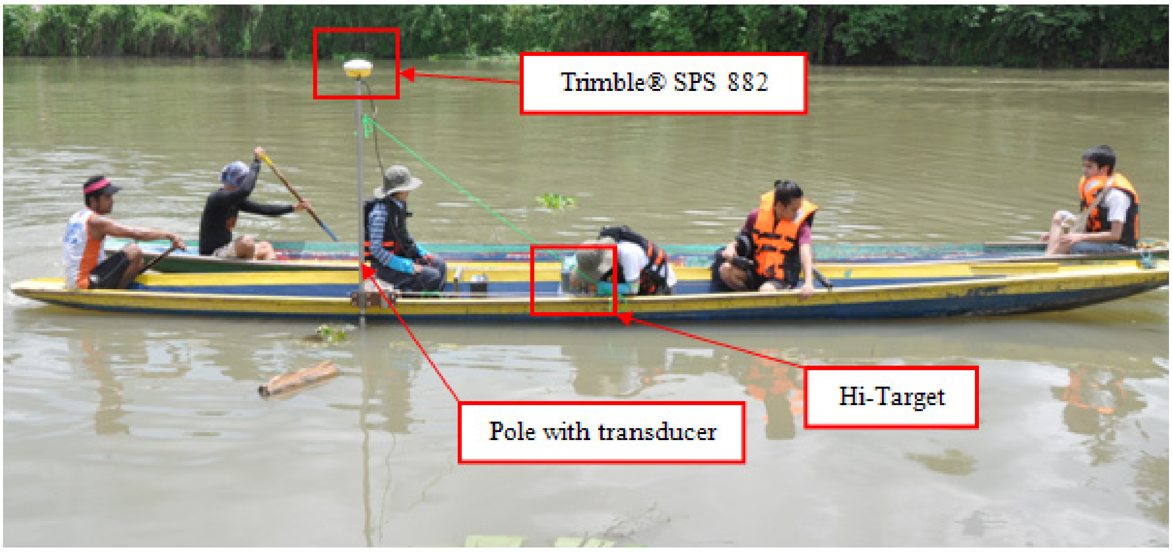


Figure 43. Set-up of the bathymetric survey for the Pagsanjan River Survey

On August 28, 2014, a manual bathymetric survey was performed in the shallow parts of the upstream portion of the Pagsanjan River. The survey started in Barangay Burlungan, Magdalena, with coordinates 14˚10'54.45082" 121 ˚ 26'39.93135"; and ended at the starting point of the bathymetric survey by boat.

The bathymetric survey for the Pagsanjan River gathered a total of 3,664 points covering approximately 25 kilometers, traversing Barangay Burlungan in Magdalena down to the Laguna Lake (Figure 44). A CAD drawing of the centerline riverbed profile was also produced via these points, as presented in Figures 45 and 46. The profile demonstrates that an elevation drop of 57.5 meters was observed within the distance of approximately 26 kilometers. The lowest elevation, -10.7324 meters (in MSL), was recorded at Barangay Sampaloc in the Municipality of Pagsanjan, which is approximately 11.6 kilometers from the Majayjay Bridge.

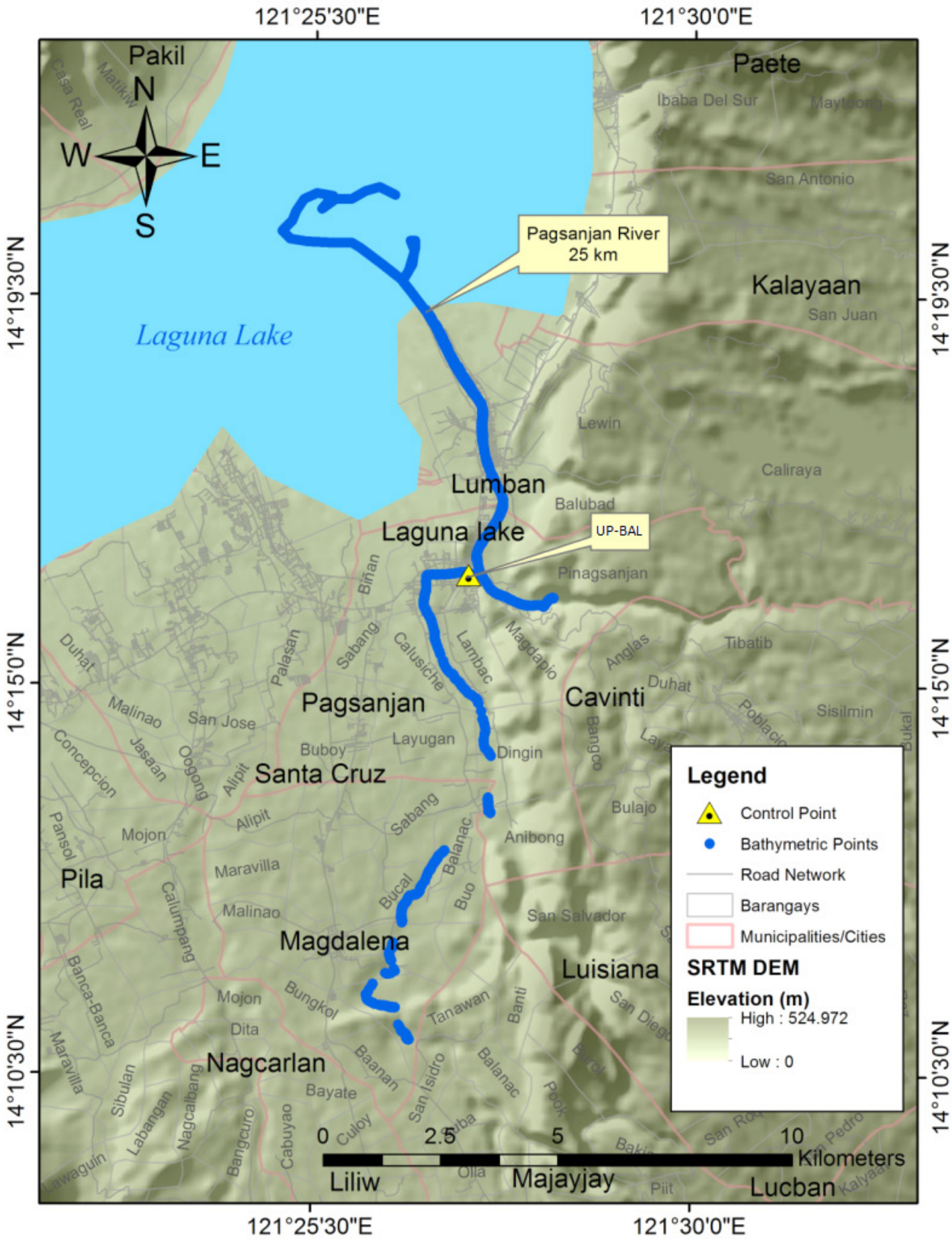


Figure 44. Extent of the bathymetric survey of Pagsanjan River

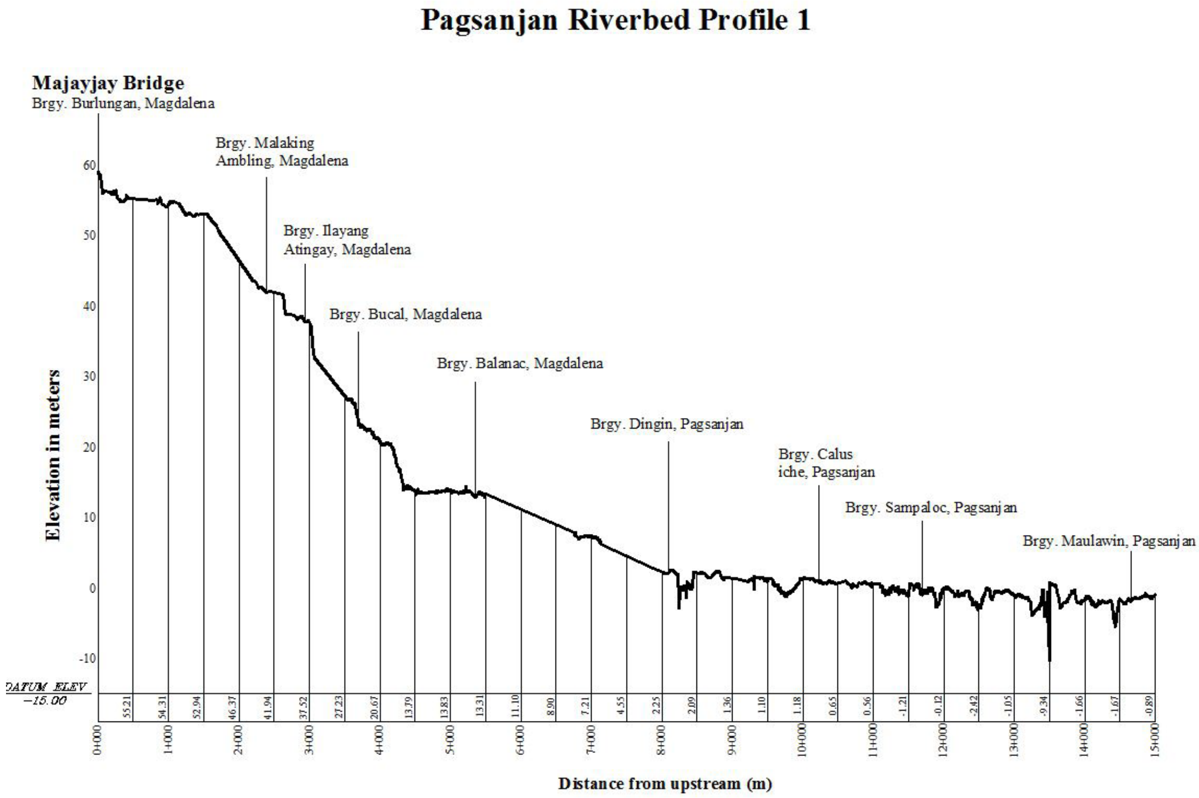


Figure 45. Riverbed profile of the Pagsanjan River

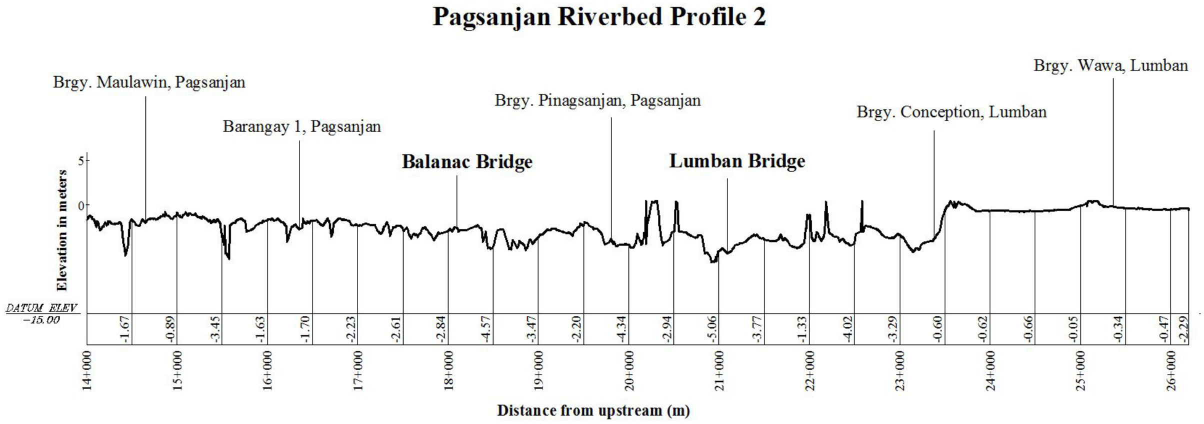


Figure 46. Riverbed profile of the Pagsanjan River

CHAPTER 5: FLOOD MODELING AND MAPPING

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Kevin M. Manalo

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from three (3) Automatic Rain Gauge (ARG) stations within the watershed boundaries, which are in: (i.) Cavinti (14.246850° N, 121.500390°E); (ii.) Kalayaan (14.336010° N, 121.498290° E); and (iii.) Majayjay (14.115120° N, 121.503550° E). The locations of the rain gauges are seen in Figure 47.

The total precipitation collections for each rain gauge station were as follows: (i.) 10.0 millimeters in the Cavinti ARG; (ii.) 9.0 millimeters in the Kalayaan ARG; and (iii.) 111.20 millimeters in the Majayjay ARG. The peak rainfall amounts were: (i.) 1.80 millimeters on December 4, 2015 at 23:45 hrs. in the Cavinti ARG; (ii.) 3.80 millimeters on December 5, 2015 at 02:00 hrs. in the Kalayaan ARG; and (iii.) 8.80 millimeters on December 5, 2015 at 04:45 hrs. in the Majayjay ARG.

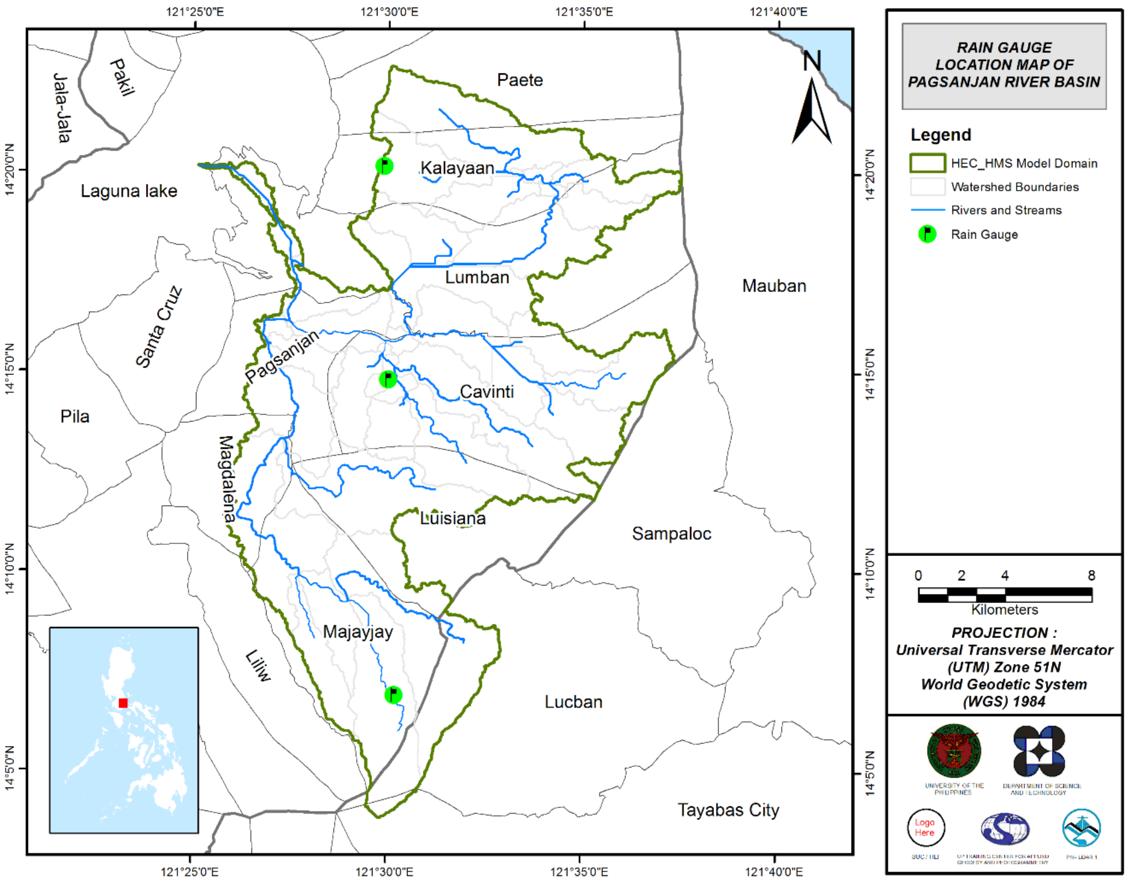
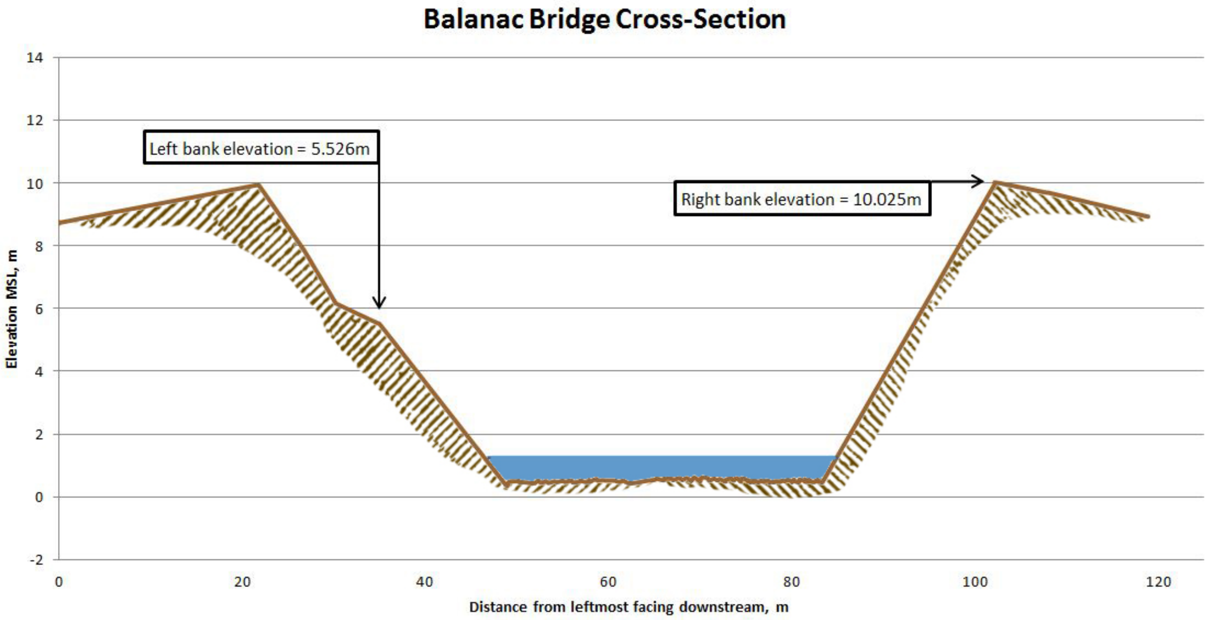


Figure 47. Location map of the Pagsanjan HEC-HMS mode, which was used for calibration

5.1.3 Rating Curves and River Outflow

Rating curves were computed at the Balanac Bridge (14.271773°N, 121.455752°E) and the Cavinti Hanging Bridge (14.269901°N, 121.459404°E) using the Manning's Bankful Method (Figure 48). The rating curve establishes the relationship between the observed change in water levels and the outflow of the watershed at the location of the cross-section.

For the Balanac Bridge, the rating curve is expressed as $Q = 0.0015e^{5.0841x}$; and for the Cavinti Bridge, it is expressed as $Q = 0.0063e^{6.6005x}$ (Figure 49).



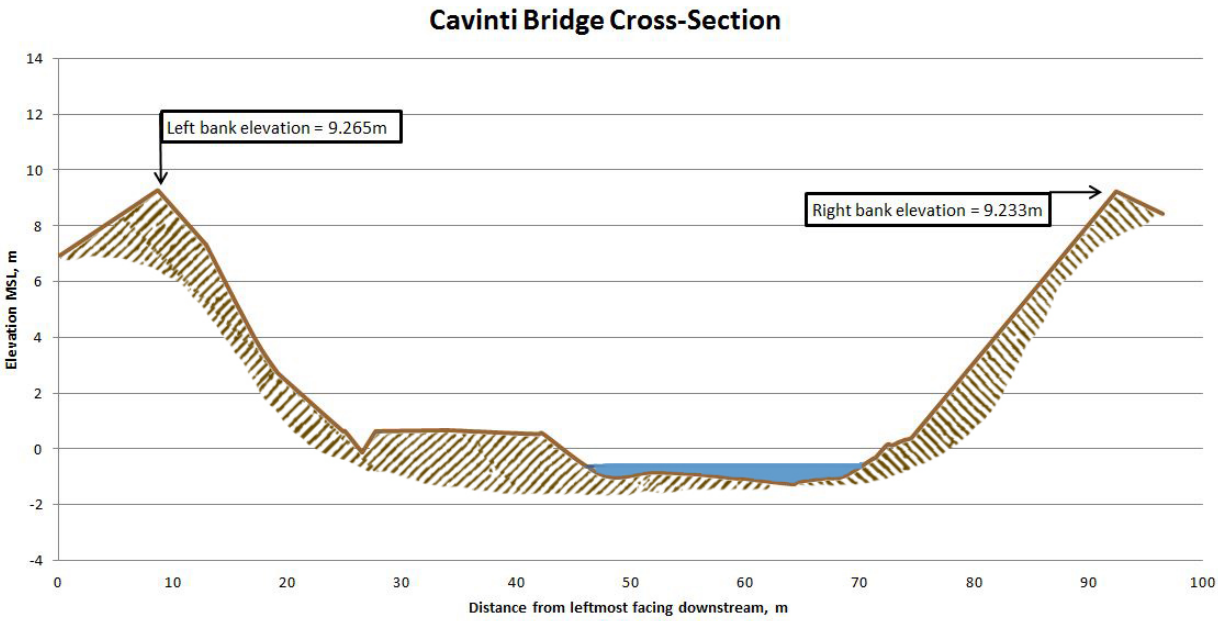
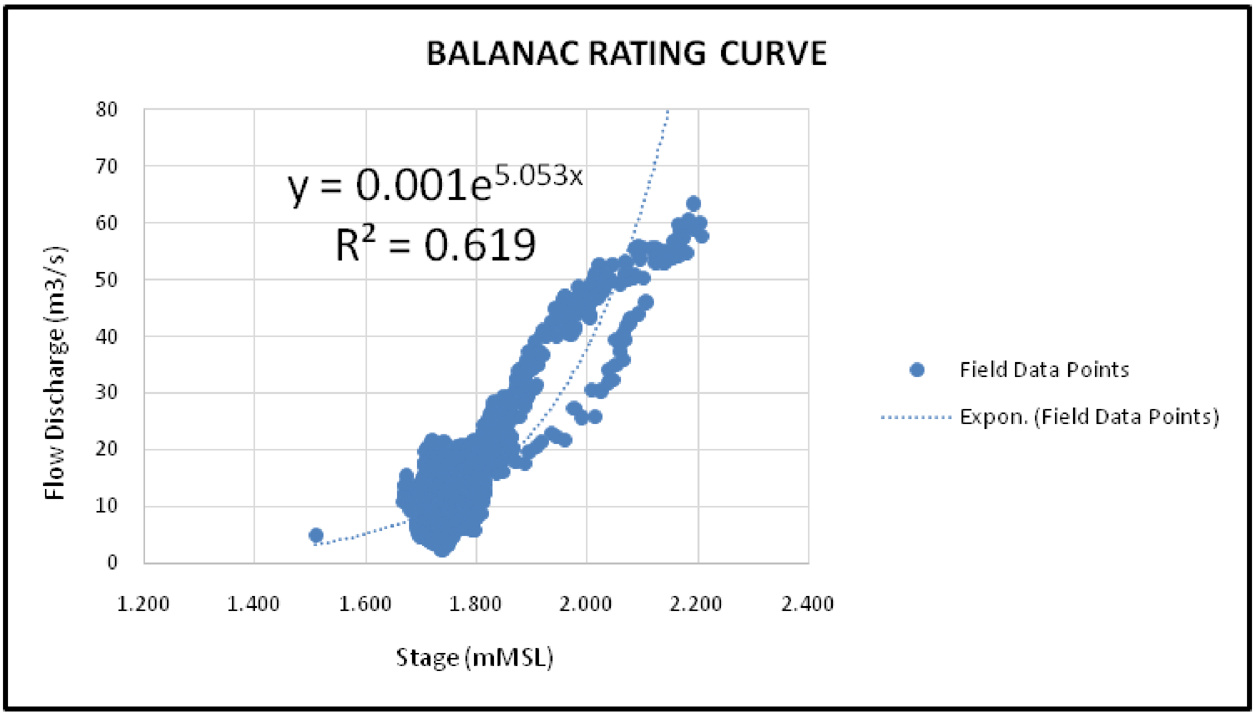


Figure 48. Cross-section plot of the Balanac and Cavinti Bridges



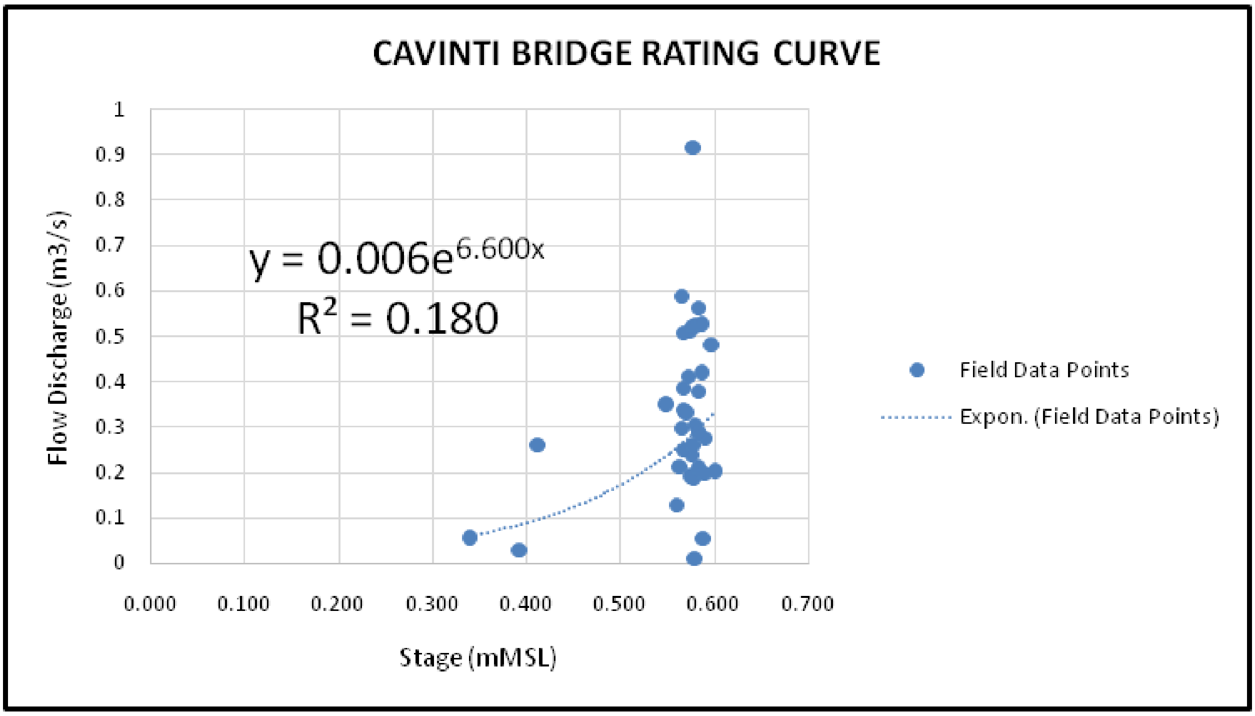
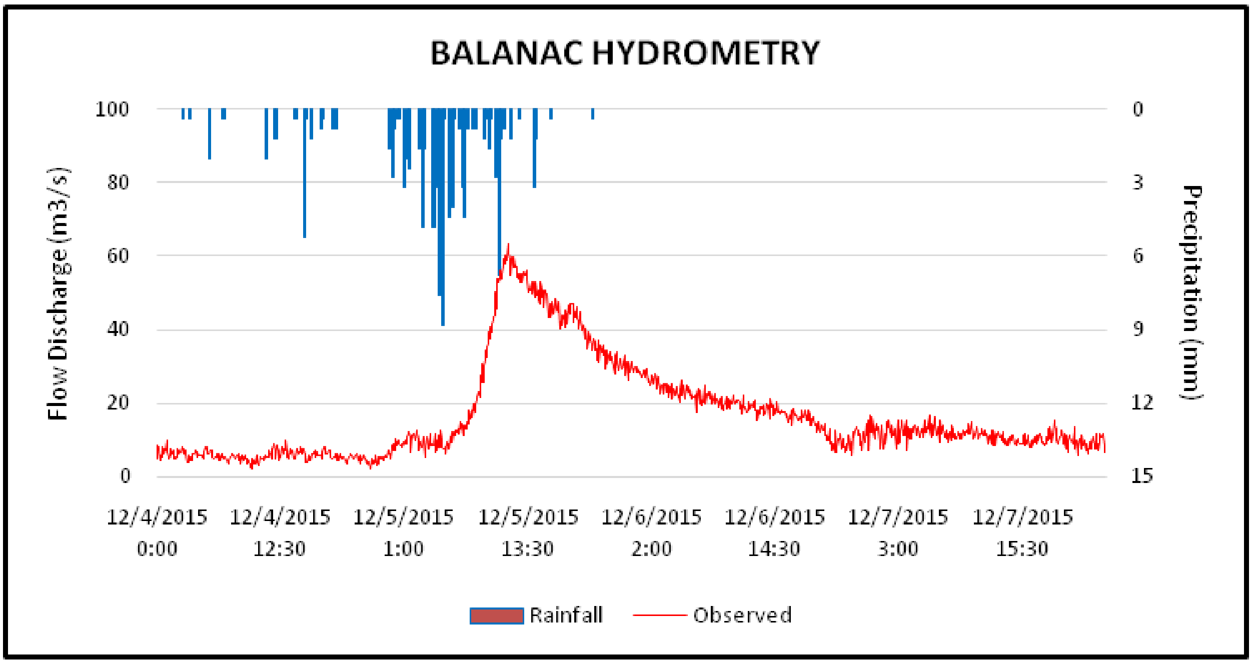


Figure 49. Rating Curve at Pagsanjan, Laguna

For the calibration of the HEC-HMS model, presented in Figure 50, actual flow discharge during a rainfall event was collected from both the Balanac Bridge and the Cavinti Bridge. The corresponding peak discharge measurements were as follows: (i.) 106.89 cu.m/s on December 5, 2015 at 11:15 hrs. for the Cavinti Bridge; and (ii.) 63.20 cu.m/s on December 5, 2015 at 11:30 hrs. for the Balanac Bridge.



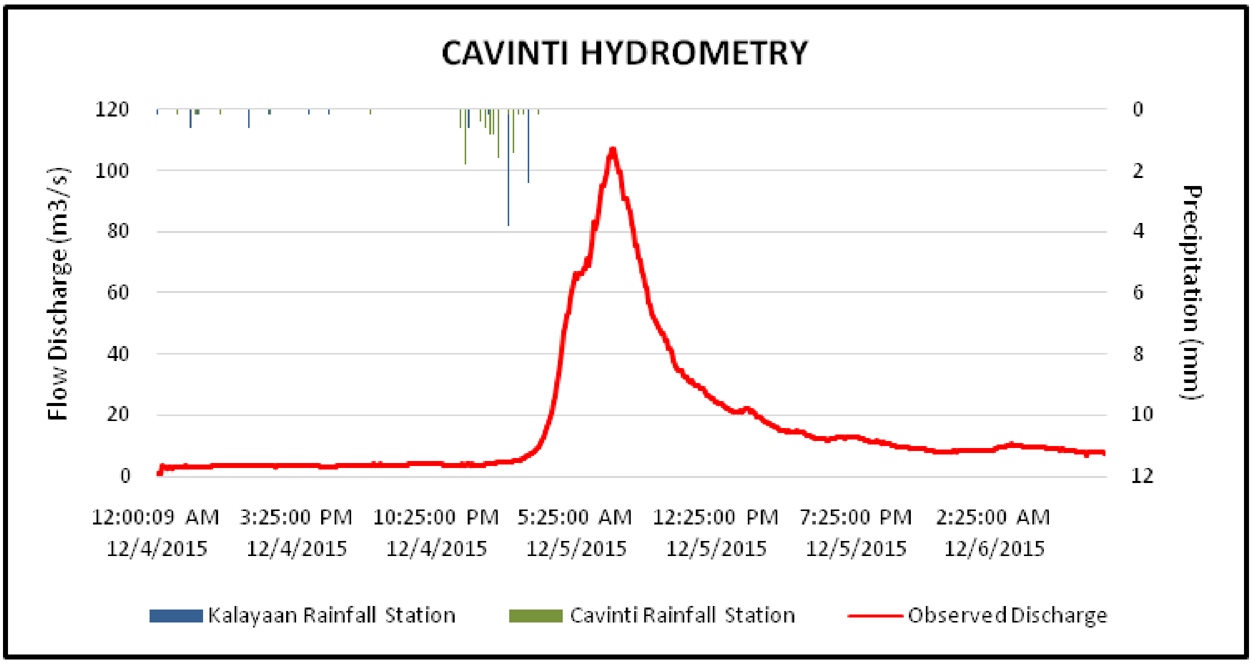


Figure 50. Rainfall and outflow data at the Pagsanjan River, which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Tayabas Rain Gauge (Table 29). This station was selected based on its proximity to the Pagsanjan watershed (Figure 51). The RIDF rainfall amount for 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 41-year record.

Table 29. RIDF values for the Tayabas 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	21	32.7	42	59.3	83	99.9	128.2	161.5	195.9
5	29.6	42.1	52.5	77.3	116.1	143	192.6	232.3	279.5
10	35.4	48.3	59.4	89.2	138	171.5	235.2	279.3	334.9
15	38.6	51.8	63.3	96	150.3	187.6	259.3	305.7	366.1
20	40.9	54.3	66.1	100.7	159	198.9	276.1	324.3	388
25	42.6	56.2	68.2	104.3	165.7	207.5	289.1	338.5	404.8
50	48	62	74.7	115.5	186.2	234.3	329.1	382.5	456.7
100	53.4	67.8	81.1	126.6	206.6	260.8	368.8	426.2	508.3

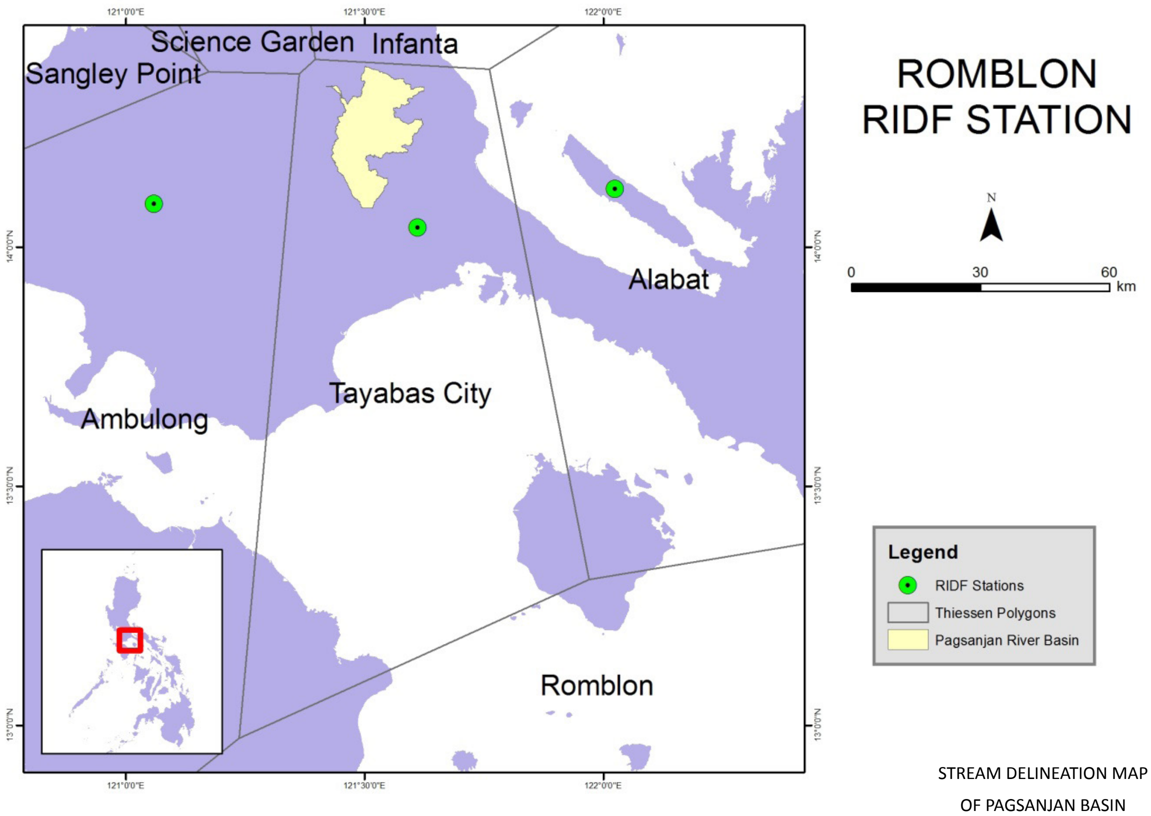


Figure 51. Location of the Tayabas RIDF Station, relative to the Pagsanjan River Basin

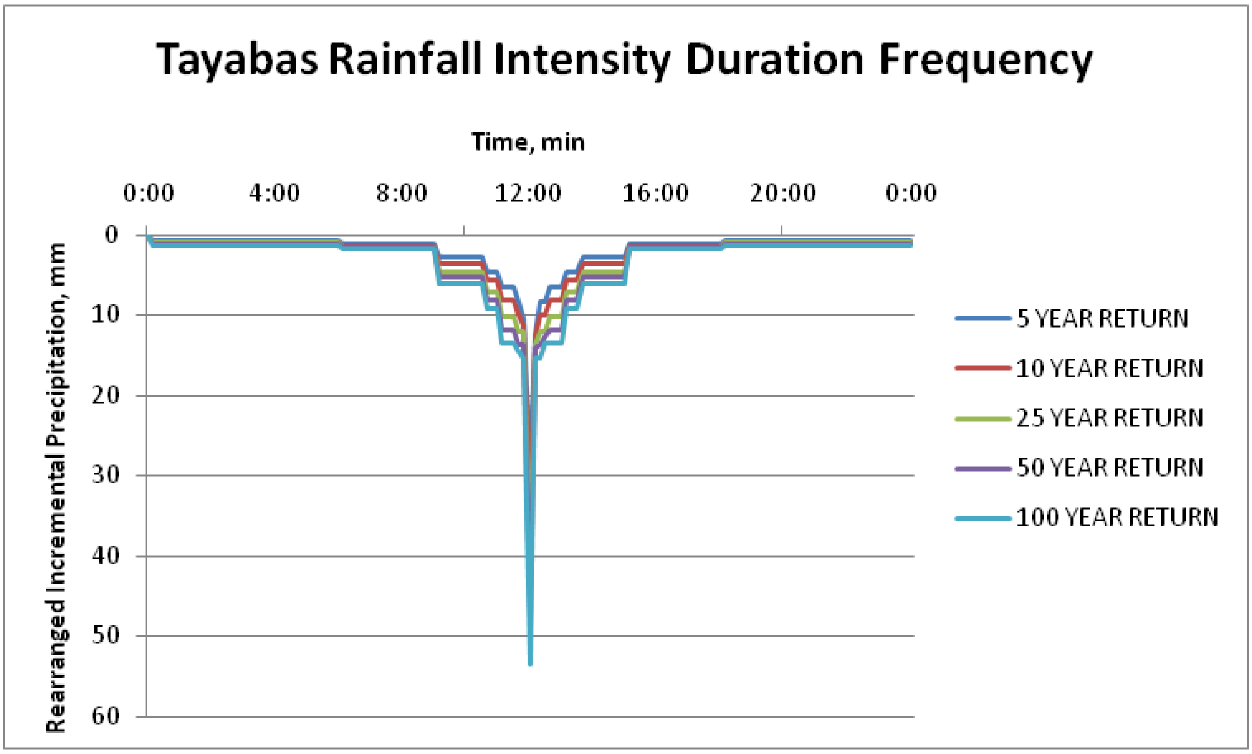


Figure 52. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

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

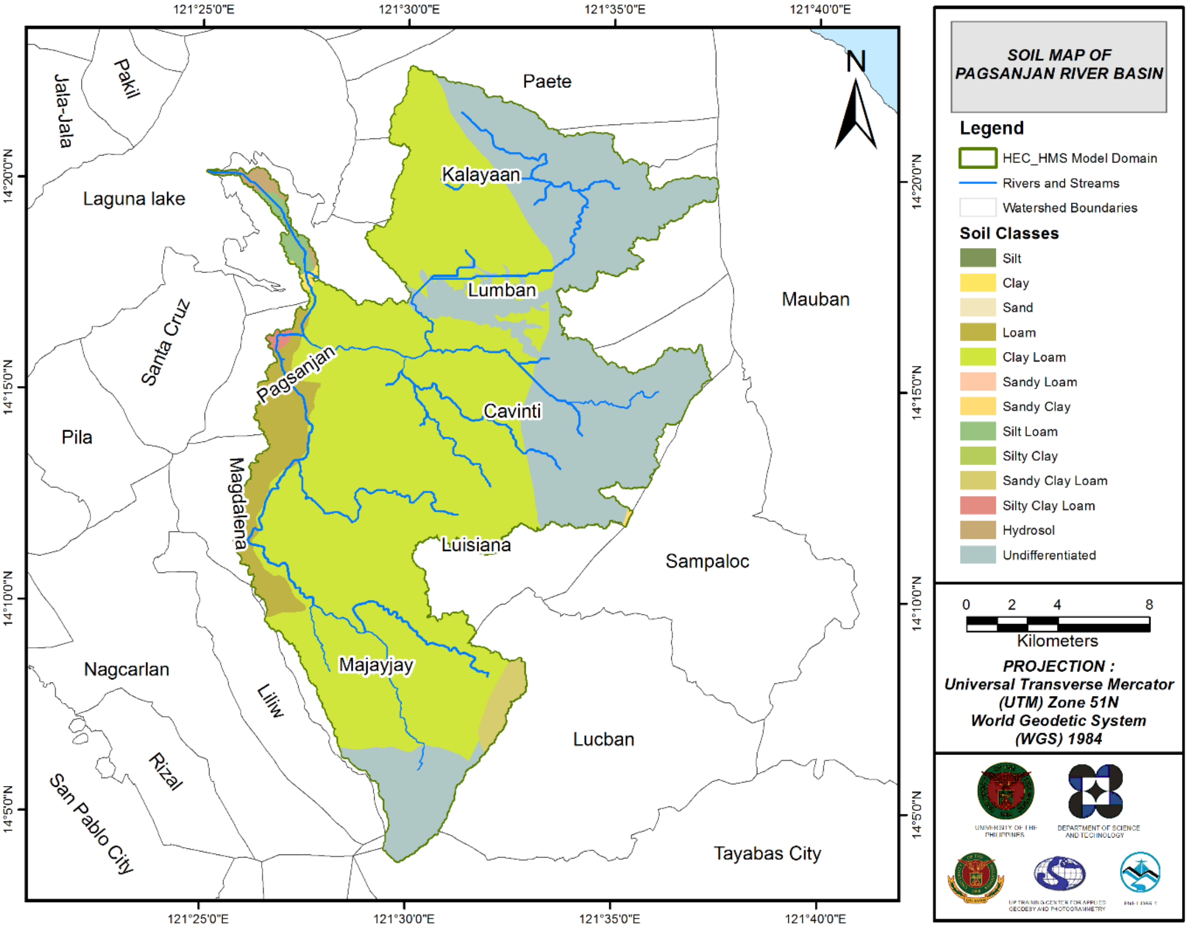


Figure 53. The soil map of the Pagsanjan River Basin, used for the estimation of the CN parameter (Source: DA)

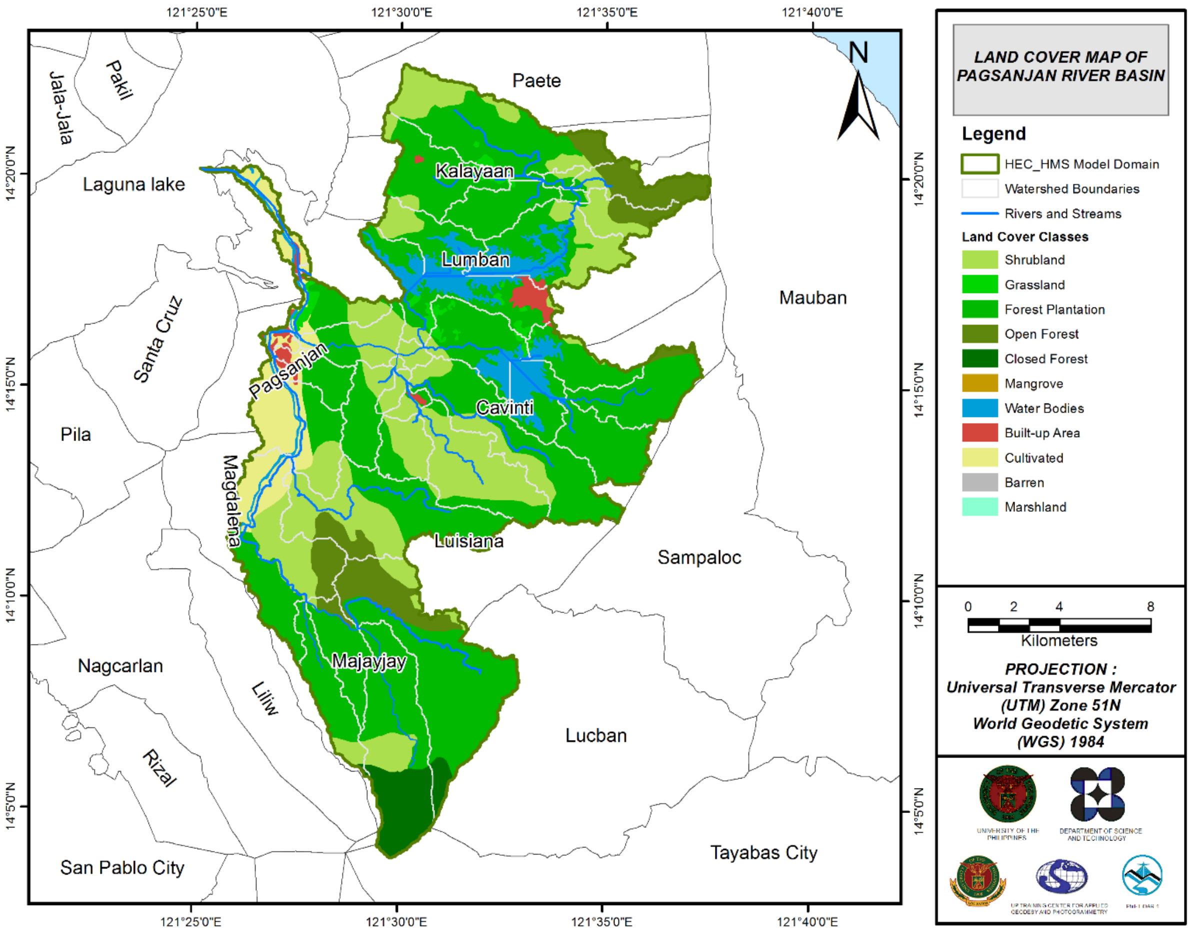


Figure 54. The land cover map of the Pagsanjan River Basin, used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model (Source: NAMRIA)

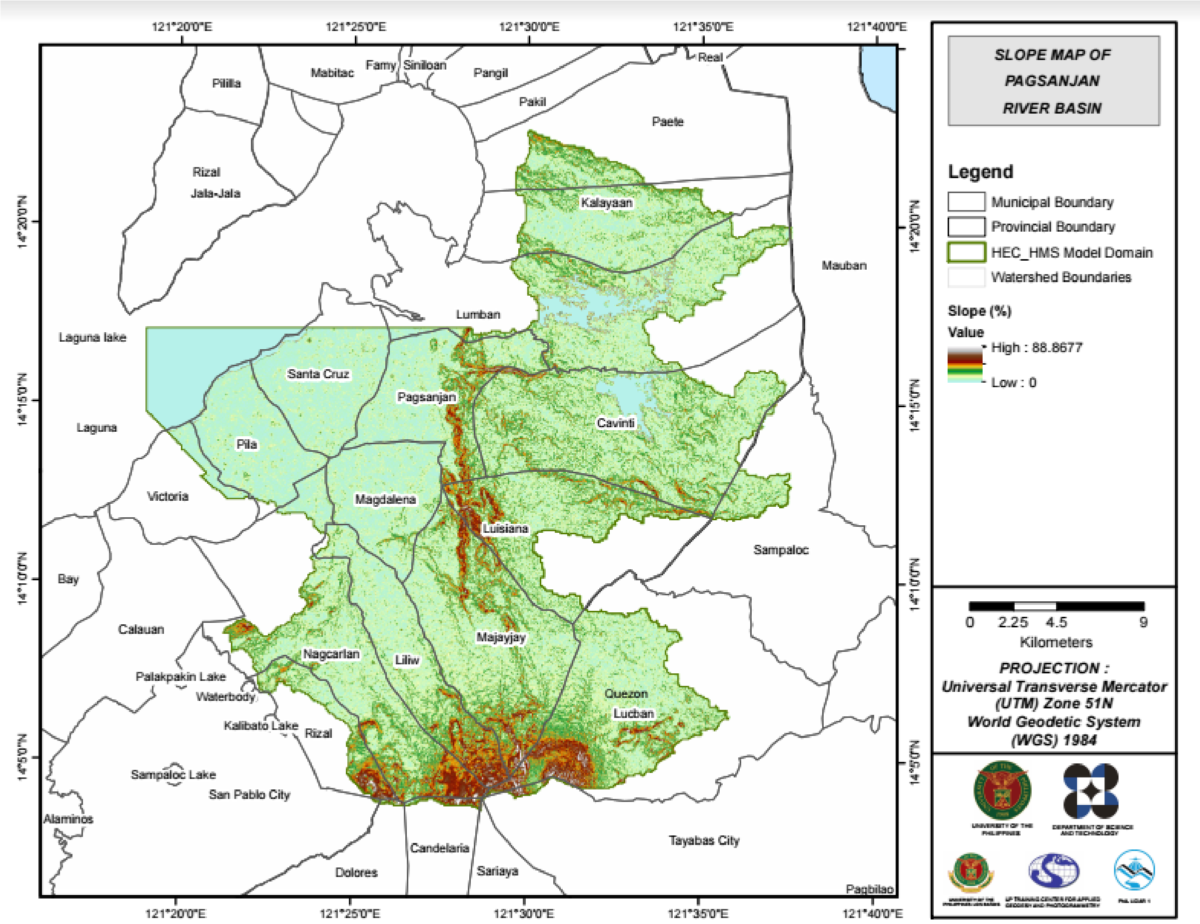


Figure 55. Slope map of the Pagsanjan River Basin

The Pagsanjan basin area bears rock types that have two (2) geological classifications, Pliocene-Quaternary rocks, and Oligocene-Miocene rocks, with the former being the most dominant type. The river basin is characterized by its mostly rolling to moderately steep slopes, and an elevation of more than 300 meters above mean sea level. The soil types in the basin include Luisiana clay loam, Antipolo sandy clay, Calumpang clay, Lipa loam, Luisiana sandy clay loam, Macolod clay loam, Marikina silt loam, Marikina silty clay loam, and Paete clay loam. Unclassified mountain soils and hydrosols are also present in the area. The basin also has a variety of land cover types, the most dominant of which are coconut plantations. Other land cover types are: crop lands mixed with coconut plantations; arable land, with mainly cereal and sugar crops; closed and open canopies; cultivated areas mixed with brush lands or grasslands; and marshy areas and swamps.

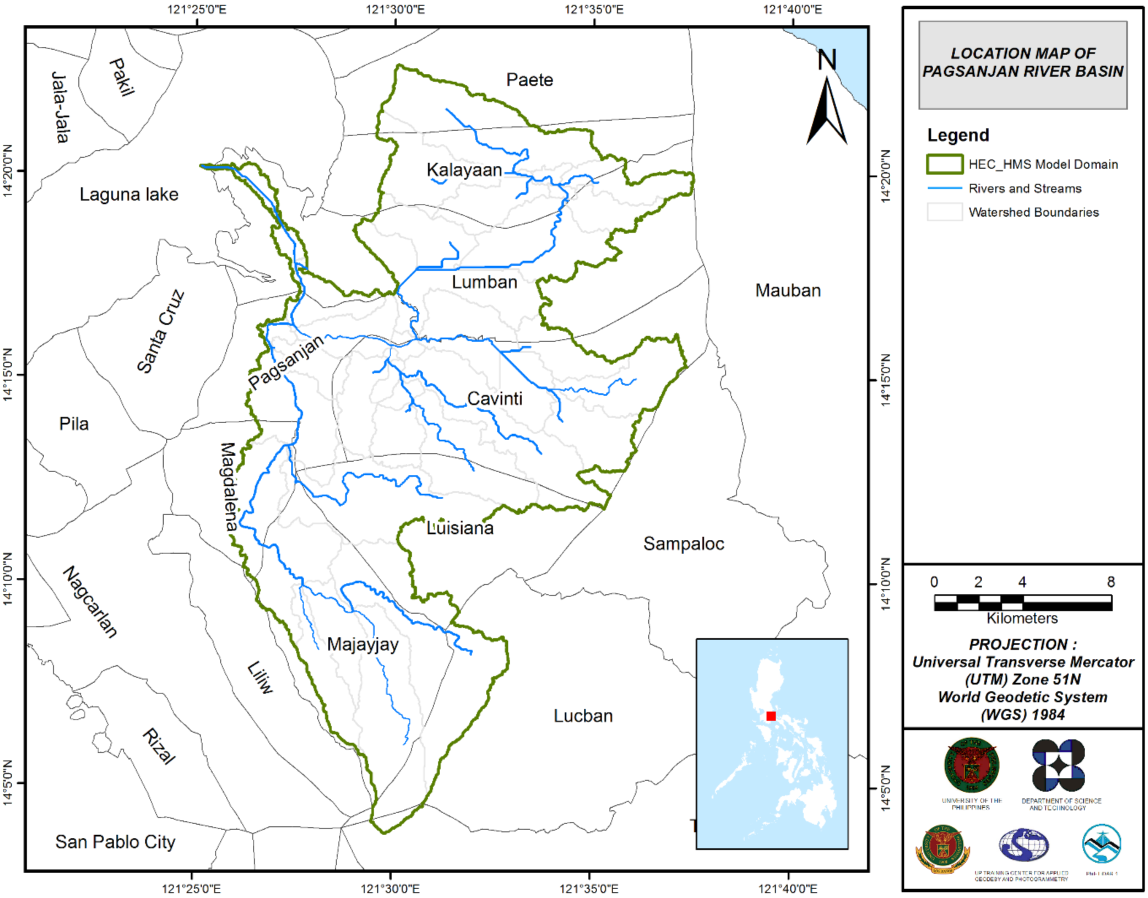


Figure 56. Stream delineation map of the Pagsanjan River Basin

Using the SAR-based DEM, the Pagsanjan basin was delineated and further subdivided into sub-basins. The Balanac Bridge model consists of twelve (12) sub-basins, six (6) reaches, and six (6) junctions; while the Cavinti Bridge model consists of twenty-eight (28) sub-basins, fourteen (14) reaches, and fourteen (14) junctions. The outlet of each model is a common sink element, which corresponds to the main outlet of the Pagsanjan River Basin: Element 78 for the Balanac model, and Element 93 for the Cavinti model. The two (2) HMS models are illustrated in Figure 57. The basins were identified based on the soil and land cover characteristics of the area. Precipitation was taken from three (3) Automated Rain Gauge sensors installed in Cavinti (14.246850° N, 121.500390°E), Kalayaan (14.336010° N, 121.498290° E) and Majayjay (14.115120° N, 121.503550° E). Finally, the models were calibrated using the flow data collected from the Balanac Bridge and Cavinti Hanging Bridge. See Annex 10 for the Balanac and Cavinti (Pagsanjan) Model Reach Parameters.

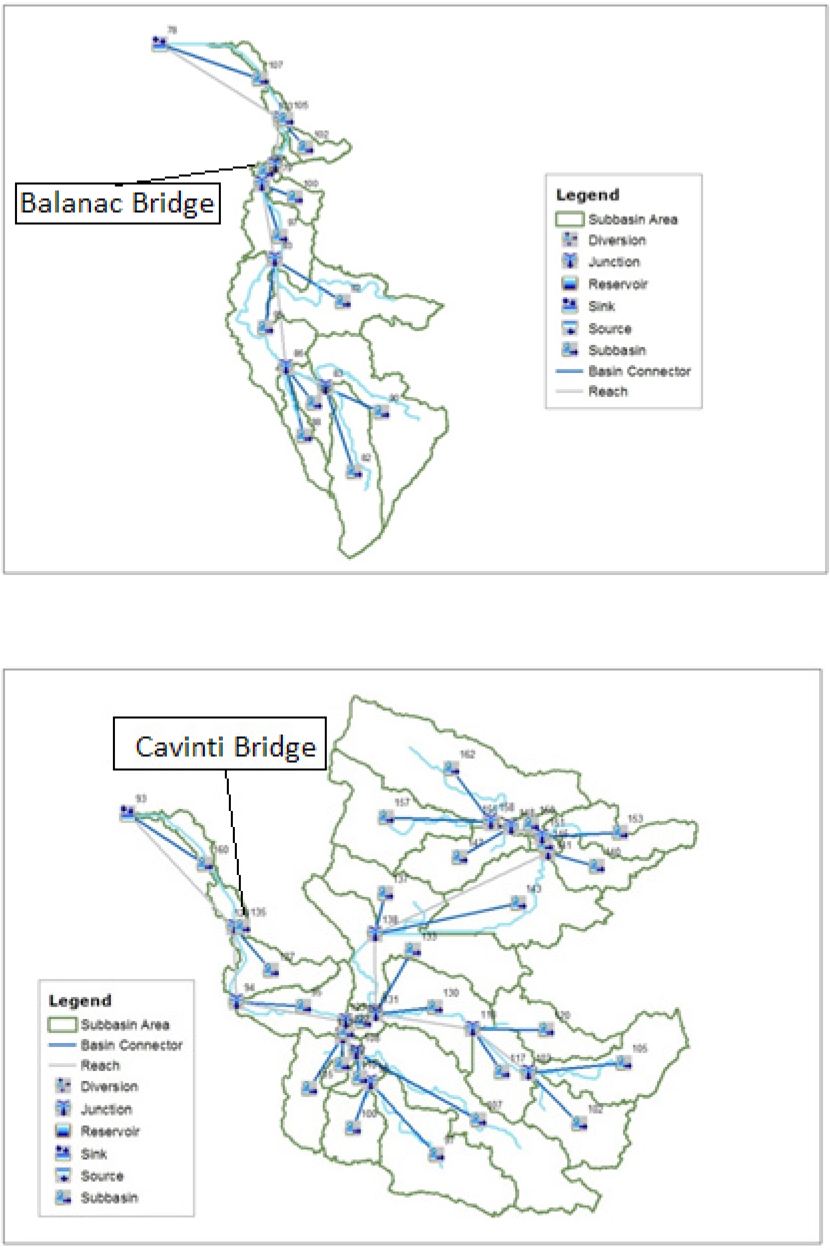


Figure 57. The Pagsanjan River Basin model, generated using HEC-HMS

5.4 Cross-section Data

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

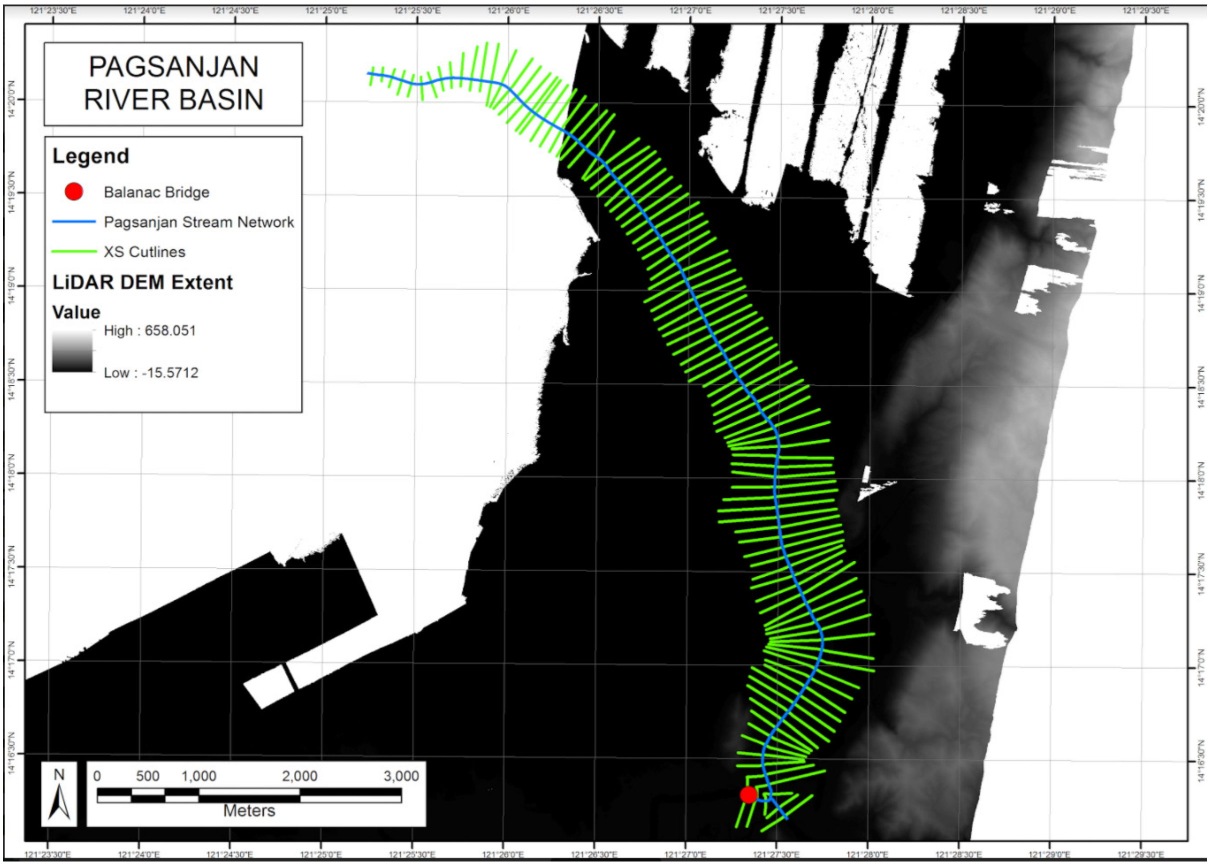


Figure 58. River cross-section of the Pagsanjan River, generated through ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

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

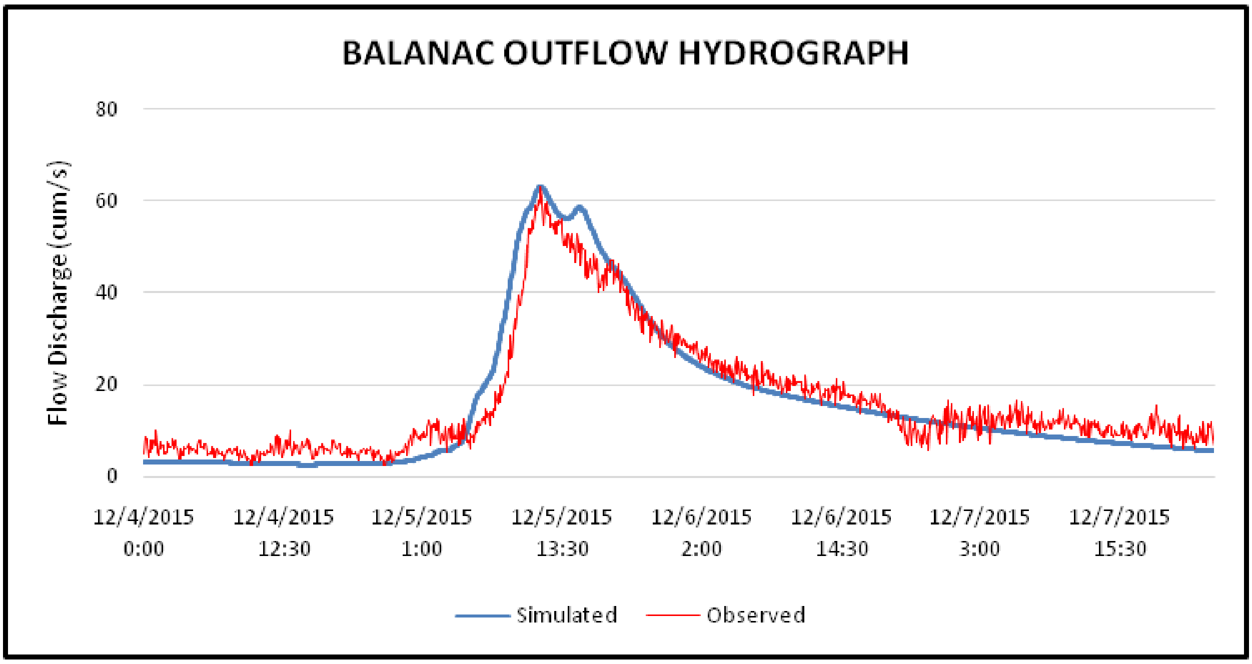
The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 126.57959 hours. After the simulation, the FLO-2D Mapper Pro was used to transform the simulation results into spatial data that show the flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depths and velocity values for Low, Medium, and High generated the flood hazard map. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (maximum depth) was set at 0.2 meters; while the minimum vh (product of maximum velocity (v) and maximum depth (h)) was set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically generated a flow depth map, depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 23775100.00 m^2.

There was a total of 1281282208.54 m^3 of water that entered the model. Of this amount, 11740227.71 m^3 was due to rainfall, while 1269541980.84 m^3 was inflow from areas outside the model. 2054632.50 m^3 of this water was lost to infiltration and interception, while 160542688.39 m^3 was stored by the floodplain. The rest, amounting to up to 1120082869.77 m^3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Pagsanjan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 depicts the comparison between the two discharge data. The Balanac and Cavinti (Pagsanjan) Model Basin Parameters are available in Annex 9.



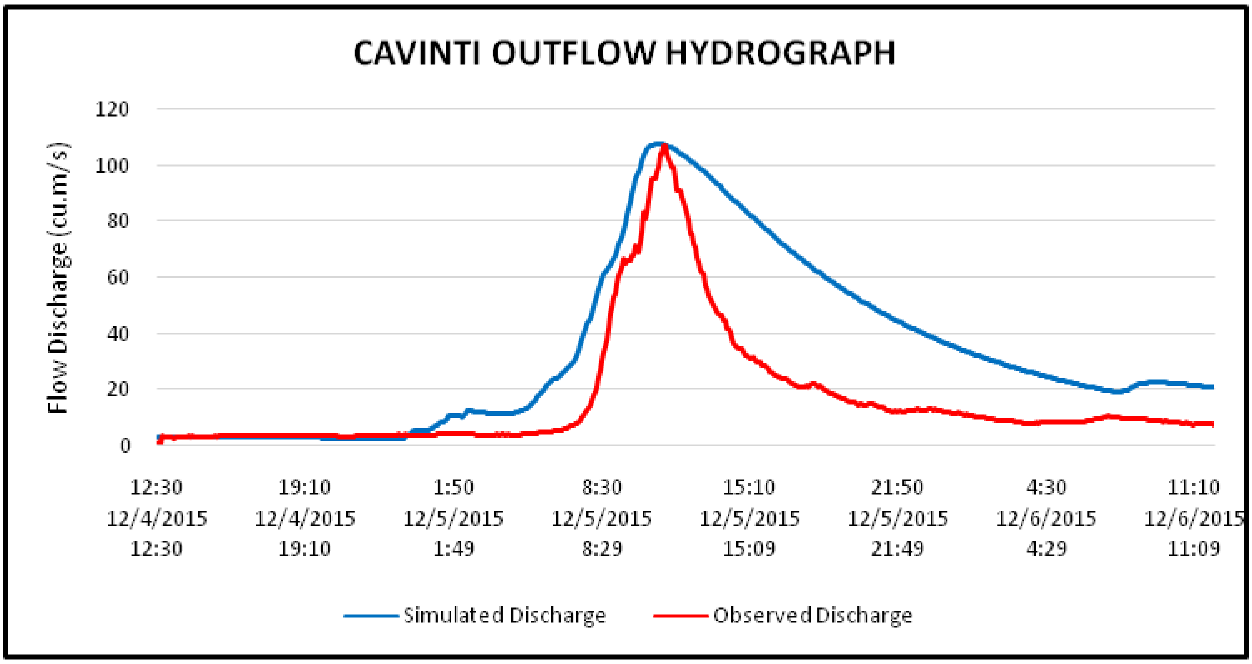


Figure 60. Outflow hydrograph of Pagsanjan produced by the HEC-HMS model, compared with observed outflow

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

Table 30. Range of calibrated values for the Pagsanjan model

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values (Balanac)	Range of Calibrated Values (Cavinti)
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1 - 6	0.2 - 5
			Curve Number	37 - 50	68 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 5	0.03 - 5
			Storage Coefficient (hr)	1 - 17	0.02 - 2
	Baseflow	Recession	Recession Constant	0.48	0.006 – 0.1
			Ratio to Peak	0.33	1
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.04	0.3 - 1

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. A range of values of 0.2 – 6 millimeters for the initial abstraction signifies a minimal 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. For the Balanac model, a range of 37 - 50 was obtained for the curve number, which is lower than the advisable range for Philippine watersheds. For the Cavinti model, the range attained was 68 – 99, which is within the advisable range (M. Horritt, personal communication, 2012).

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. A range of calibrated values from 0.02 hours to 17 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. The characteristics of the Pagsanjan watershed, particularly for the recession constant parameter, differ for every reach.

A Manning’s roughness coefficient of 0.03 to 1 also indicates varying characteristics of the river’s reaches.

Table 31. Efficiency Test of the Pagsanjan HMS Model

	Balanac	Cavinti
Root Mean Square Error (RMSE)	4.3443	11.485
Pearson Correlation Coefficient (r^2)	0.972	0.956
Nash-Sutcliffe (E)	0.894	0.756
Percent Bias (PBIAS)	5.463	-52.913
Observation Standard Deviation Ratio (RSR)	0.325	0.494

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. This was identified at 4.3443 for the Balanac model, and at 11.485 for the Cavinti model.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 signifies an almost perfect match of the observed discharge and the resulting discharge from the HEC-HMS model. This was measured at 0.972 for the Balanac model, and at 0.956 for the Cavinti model.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here, the optimal value is 1. The Balanac and Cavinti models attained efficiency coefficients of 0.894 and of 0.756, respectively.

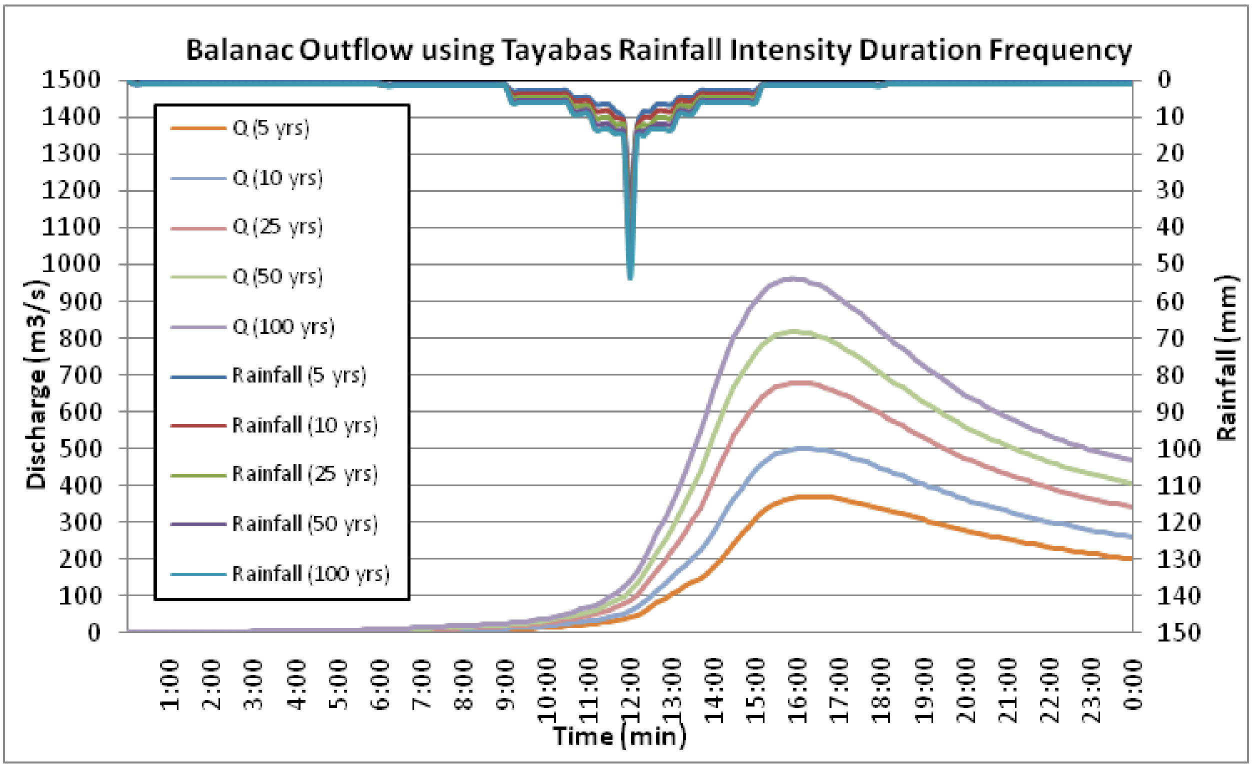
A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. The PBIAS is 5.463 for the Balanac model, and -52.913 for the Cavinti model.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model attained RSR values of 0.325 for the Balanac model, and 0.494 for the Cavinti model.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph in Figure 61 illustrates the Pagsanjan outflow using the Tayabas RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.



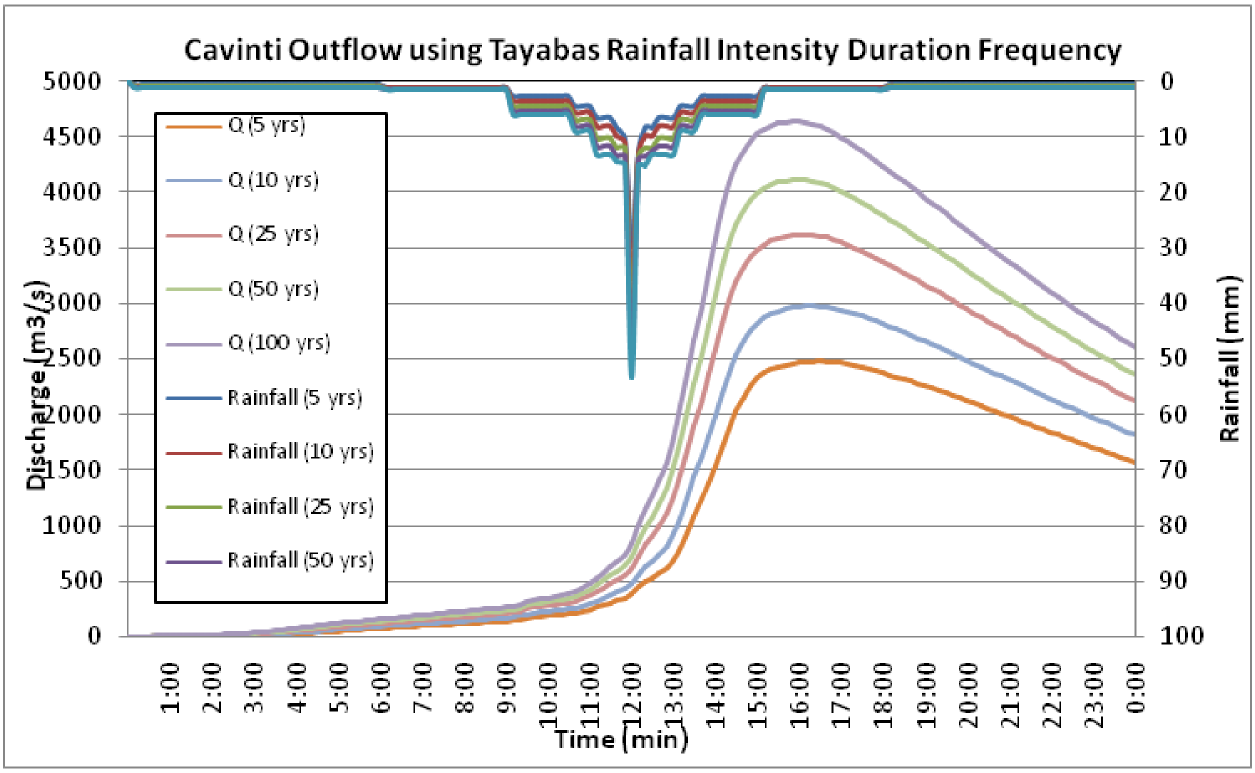


Figure 61. Outflow hydrograph at the Pagsanjan Station generated using Tayabas RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak, and lag time of the Pagsanjan discharge using the Tayabas RIDF curves in five (5) different return periods is given in Table 32.

Table 32. Peak values of the Balanac and Cavinti HEC-HMS Model outflow, using the Tayabas RIDF

RIDF PERIOD	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak	Lag Time
5-yr	279.50	29.60	371.248	16 hours 20 minutes	4 hours 20 minutes
10-yr	334.90	35.40	501.084	16 hours 10 minutes	4 hours 10 minutes
25-yr	404.80	42.60	679.233	16 hours	4 hours
50-yr	456.70	48.0	818.345	16 hours	4 hours
100-yr	508.30	53.40	961.664	15 hours 50 minutes	3 hours 50 minutes

RIDF PERIOD	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak	Lag Time
5-yr	279.50	29.60	2477.836	16 hours 30 minutes	4 hours 30 minutes
10-yr	334.90	35.40	2977.207	16 hours 20 minutes	4 hours 20 minutes
25-yr	404.80	42.60	3621.824	16 hours 10 minutes	4 hours 10 minutes
50-yr	456.70	48.0	4115.462	16 hours	4 hours
100-yr	508.30	53.40	4636.945	15 hours 50 minutes	3 hours 50 minutes

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

The computed river discharge values for the Pagsanjan floodplain are shown in Figure 62; and the peak values are summarized in Table 33.

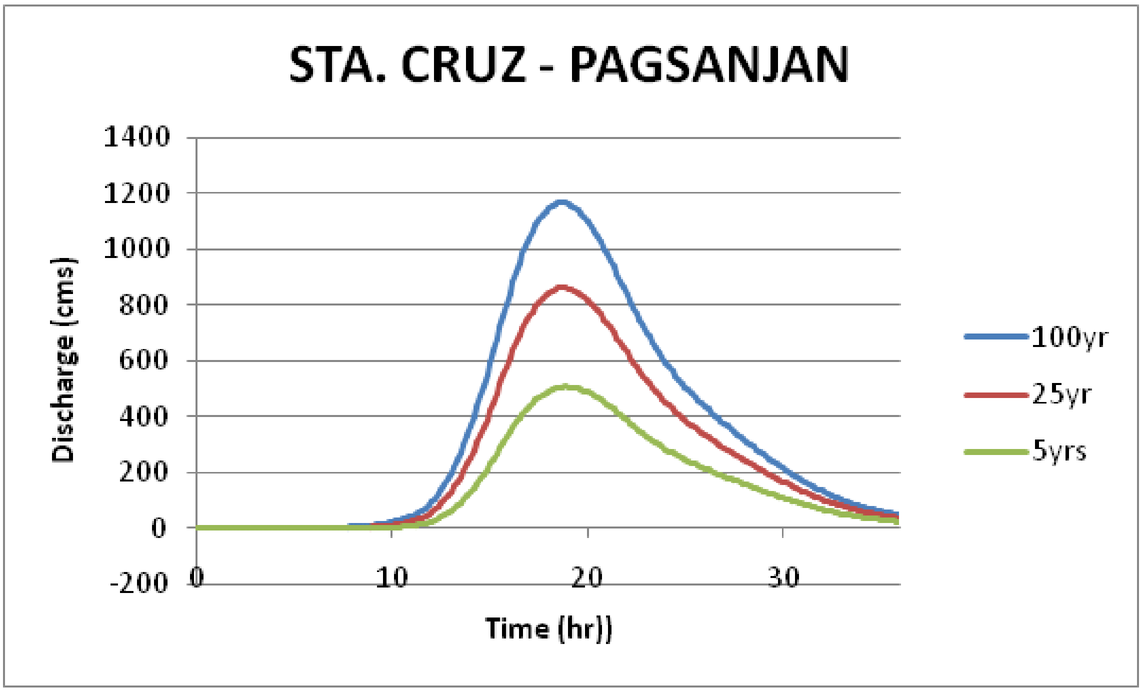


Figure 62. Sta. Cruz-Pagsanjan River generated discharge using 5-, 25-, and 100-year Tayabas City RIDF in HEC-HMS

Table 33. Summary of Sta. Cruz-Pagsanjan River discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1167.5	6 hours, 6 minutes
25-Year	860.9	6 hours, 6 minutes
5-Year	506	6 hours, 6 minutes

Table 34. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Sta. Cruz-Pagsanjan	445.280	643.274	686.876	PASS	PASS

The results of the HEC-HMS river discharge estimates were able to satisfy the conditions for validation, using the bankful and specific discharge methods. The passing values are based on theory but are supported by other discharge computation methods; hence, they were appropriate for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges to obtain higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website. The sample map of the Pagsanjan River using the HMS base flow is displayed in Figure 63.

Figure 63. Pagsanjan HEC-RAS sample output map

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps for the 5-year, 25-year, and 100-year rain return scenarios of the Pagsanjan floodplain are exhibited in Figures 64 to 69. The floodplain, with an area of 214.03 square kilometers, covers thirteen (13) municipalities, namely Calauan, Cavinti, Laguna Lake, Liliw, Luisiana, Lumban, Magdalena, Majayjay, Nagcarlan, Pagsanjan, Pila, Santa Cruz, and Victoria. Table 35 summarizes the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in the Pagsanjan floodplain

Municipality	Total Area	Area Flooded	% Flooded
Calauan	79.44	4.34	5.45
Cavinti	96.78	0.91	0.94
Laguna lake	892.20	0.92	0.10
Liliw	36.20	0.82	2.26
Luisiana	61.01	3.07	5.03
Lumban	117.34	22.32	19.02
Magdalena	29.61	27.08	91.42
Majayjay	64.40	3.77	5.86
Nagcarlan	81.20	28.61	35.24
Pagsanjan	40.77	32.87	80.61
Pila	28.77	28.38	98.63
Santa Cruz	37.63	36.50	97
Victoria	28.37	24.44	86.17

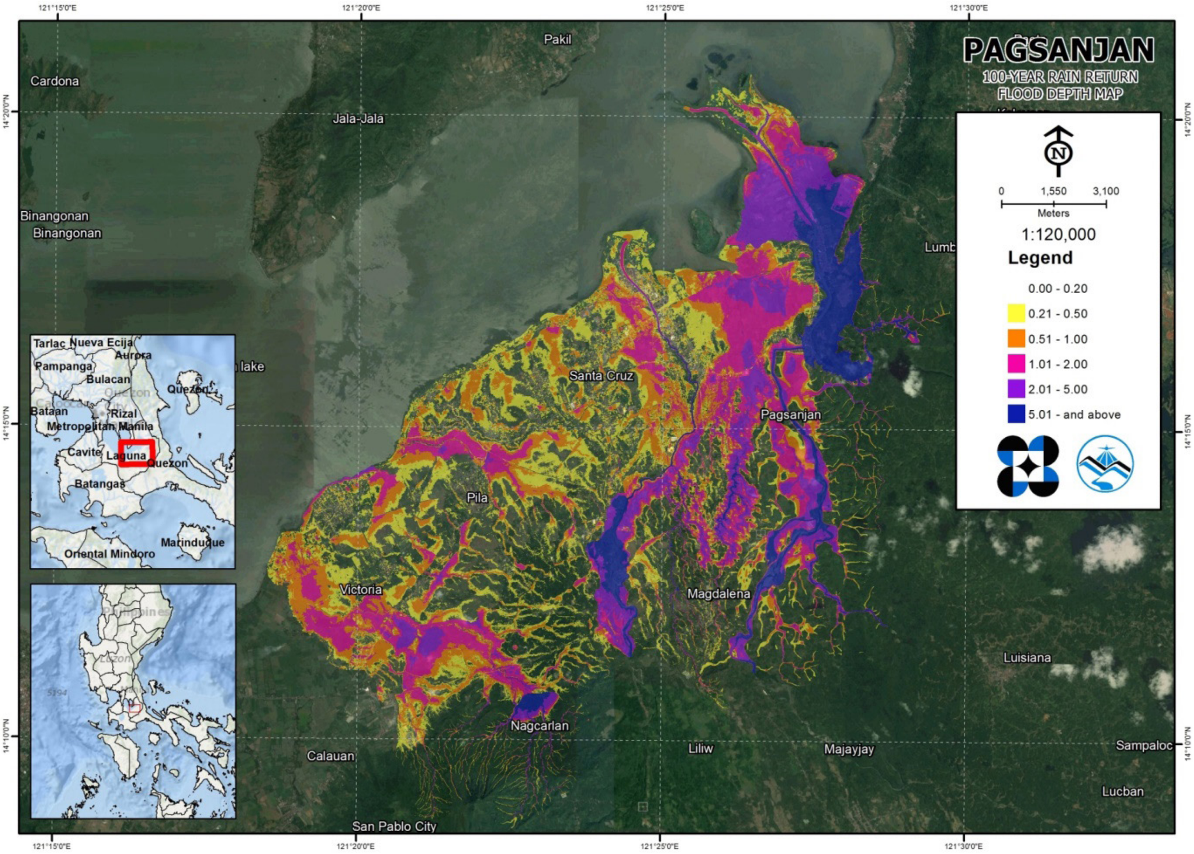


Figure 64. 100-year flood hazard map for the Pagsanjan floodplain

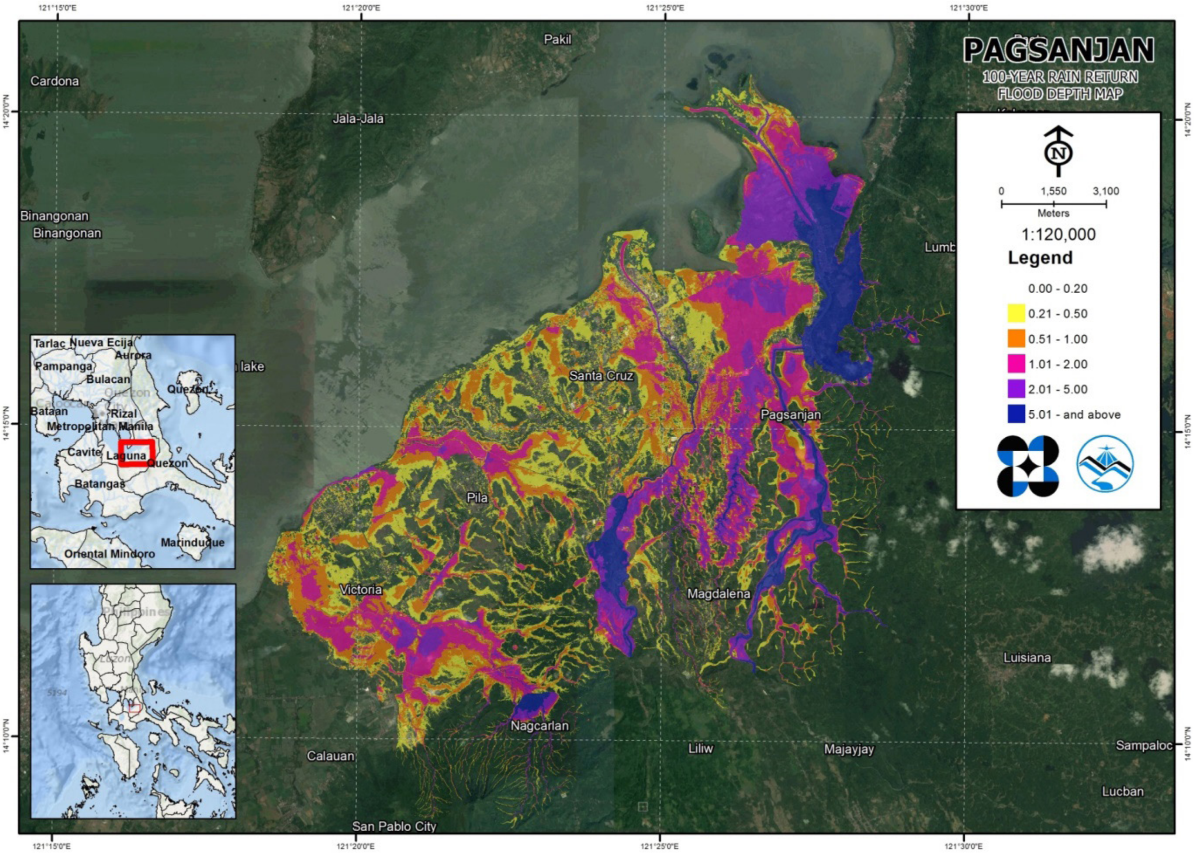


Figure 65. 100-year flow depth map for the Pagsanjan floodplain

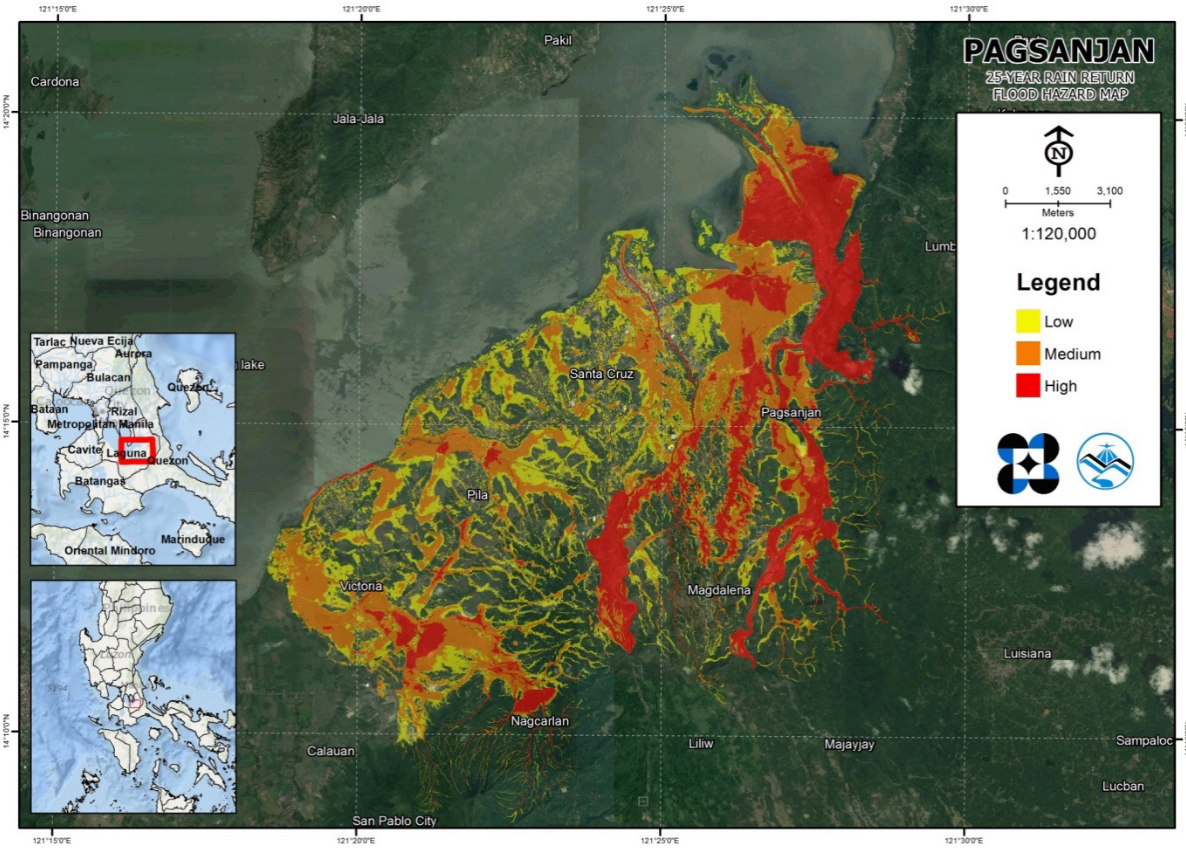


Figure 66. 25-year flood hazard map for the Pagsanjan floodplain

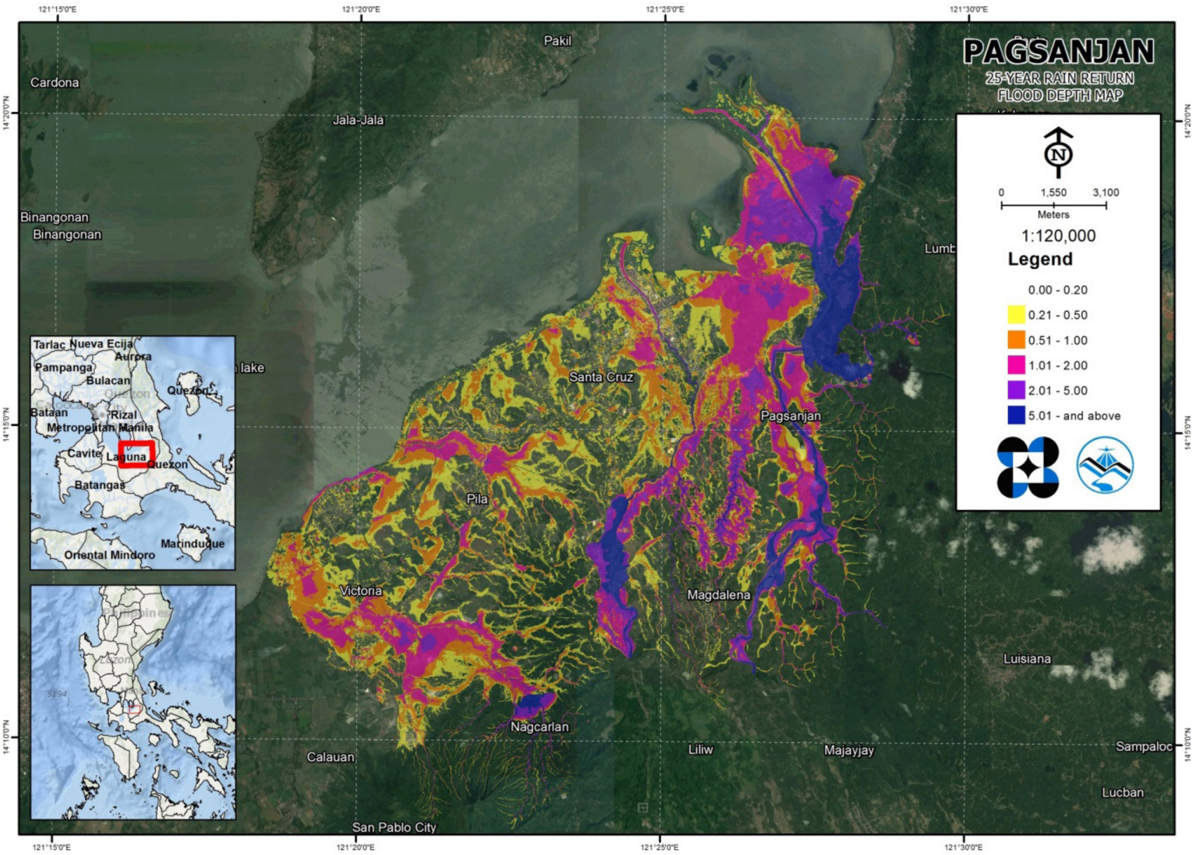


Figure 67. 25-year flow depth map for the Pagsanjan floodplain

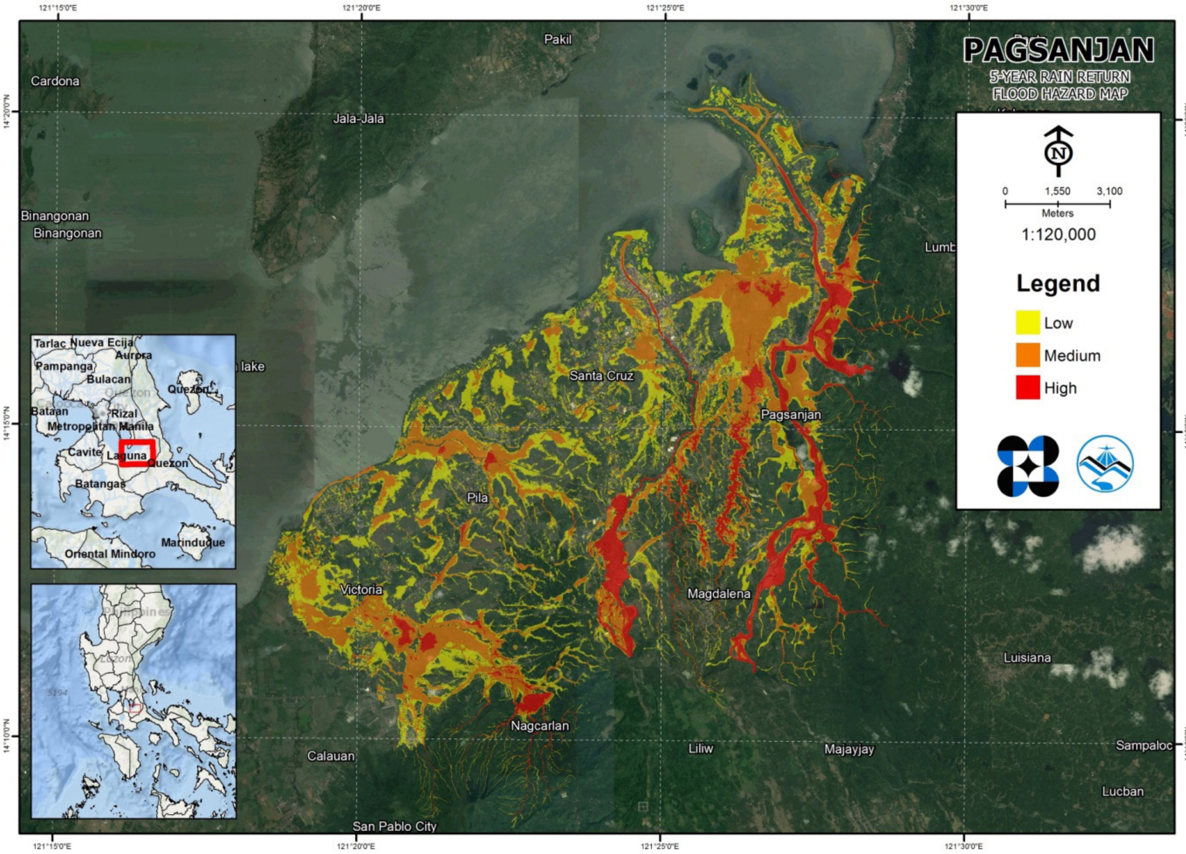


Figure 68. 5-year flood hazard map for the Pagsanjan floodplain

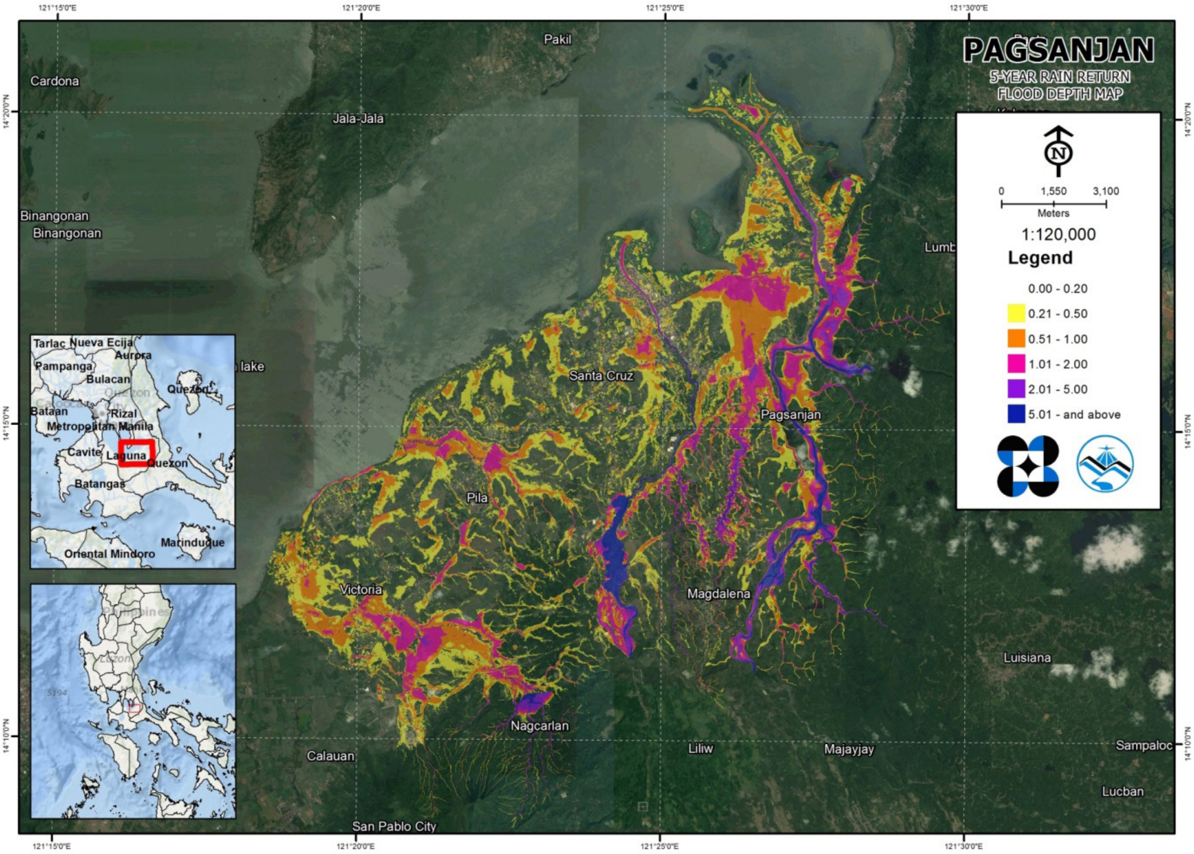


Figure 69. 5-year flow depth map for the Pagsanjan floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Listed below are the barangays affected by the Pagsanjan River Basin, grouped accordingly by municipality. For the said basin, thirteen (13) municipalities consisting of one hundred and forty-three (143) barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 4.34% of the municipality of Calauan, with an area of 79.44 square kilometers, will experience flood levels of less than 0.20 meters; while 0.74% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.31%, 0.06%, 0.02%, and 0.0004% 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. Table 36 depicts the areas affected in Calauan, in square kilometers, by flood depth per barangay.

Table 36. Affected areas in Calauan, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Calauan		
	Dayap	Lamot 2	Santo Tomas
0.03-0.20	0.519656	2.685204	0.242387
0.21-0.50	0.132354	0.180214	0.275645
0.51-1.00	0.087544	0.058126	0.102184
1.01-2.00	0.015864	0.022687	0.009419
2.01-5.00	0	0.007995	0.004905
> 5.00	0	0.0003	0

Among the barangays in the Municipality of Calauan, Lamot 2 is projected to have the highest percentage of area that will experience flood levels, at 3.72%. On the other hand, Dayap posted the second highest percentage of area that may be affected by flood depths, at 0.95%.

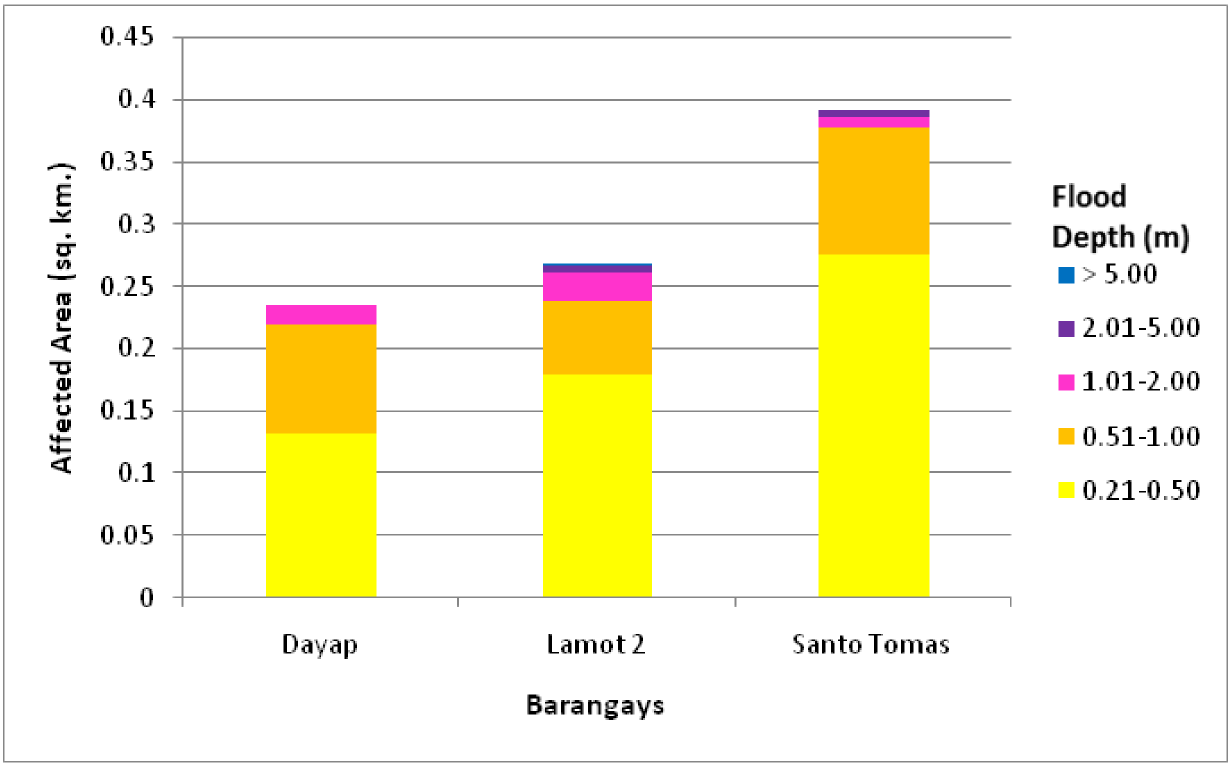


Figure 70. Affected areas in Calauan, Laguna during a 5-year rainfall return period

For the Municipality of Cavinti, with an area of 96.78 square kilometers, 0.90% will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.01%, 0.005%, 0.004%, and 0.0002% 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. Table 37 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Cavinti, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Cavinti		
	Anglas	Bangco	Bulajo
0.03-0.20	0.44	0.43	0.002591
0.21-0.50	0.014	0.014	0
0.51-1.00	0.0079	0.0049	0
1.01-2.00	0.0010	0.0032	0
2.01-5.00	0.0015	0.0026	0
> 5.00	0	0.0002	0

Among the barangays in the Municipality of Cavinti, Anglas is projected to have the highest percentage of area that will experience flood levels, at 0.48%. On the other hand, Bangco posted the second highest percentage of area that may be affected by flood depths, at 0.47%.

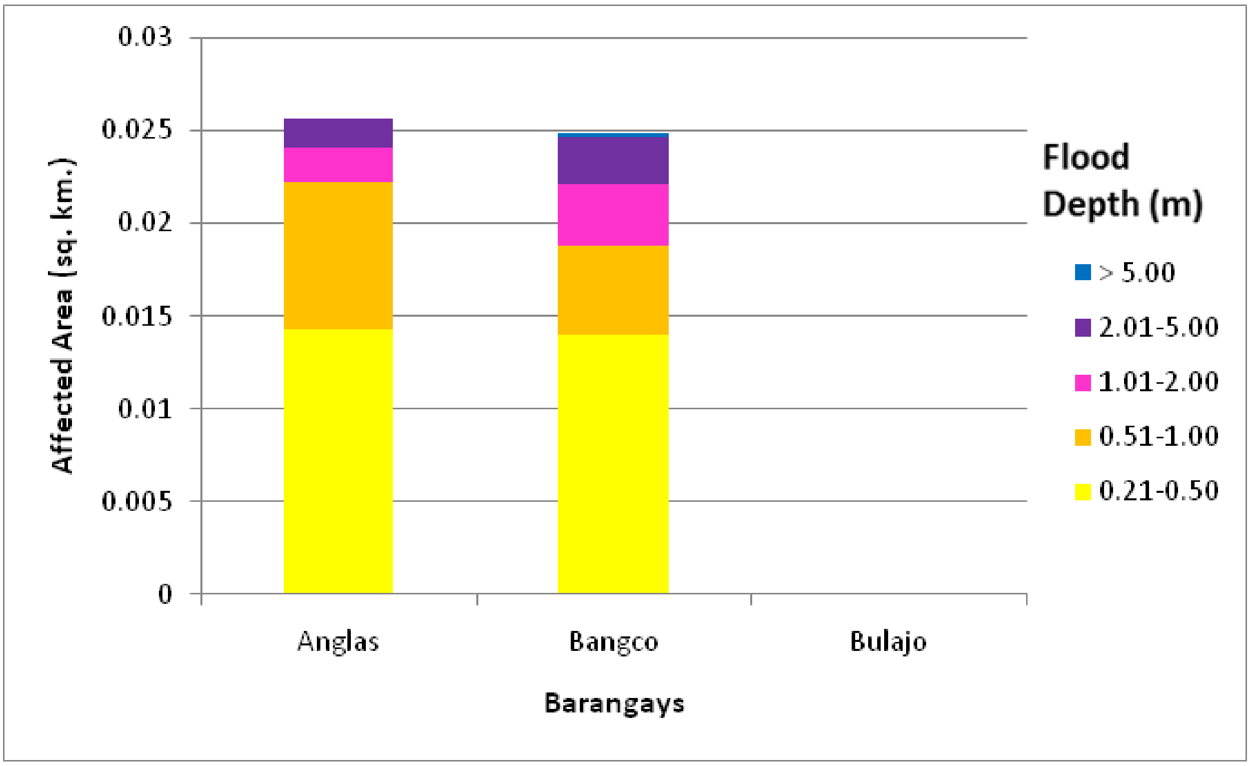


Figure 71. Areas affected by flooding in Cavinti, Laguna for a 5-year return period rainfall event

For the Municipality of Laguna Lake, with an area of 892.20 square kilometers, 0.05% will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.02%, 0.02%, 0.001%, and 0.001% 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. Table 38 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Laguna Lake, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Laguna lake Laguna Lake
0.03-0.20	0.47
0.21-0.50	0.12
0.51-1.00	0.14
1.01-2.00	0.19
2.01-5.00	0.012
> 5.00	0

Barangay Laguna Lake in the Municipality of Laguna Lake is projected to experience flood levels at 0.10% of its area.

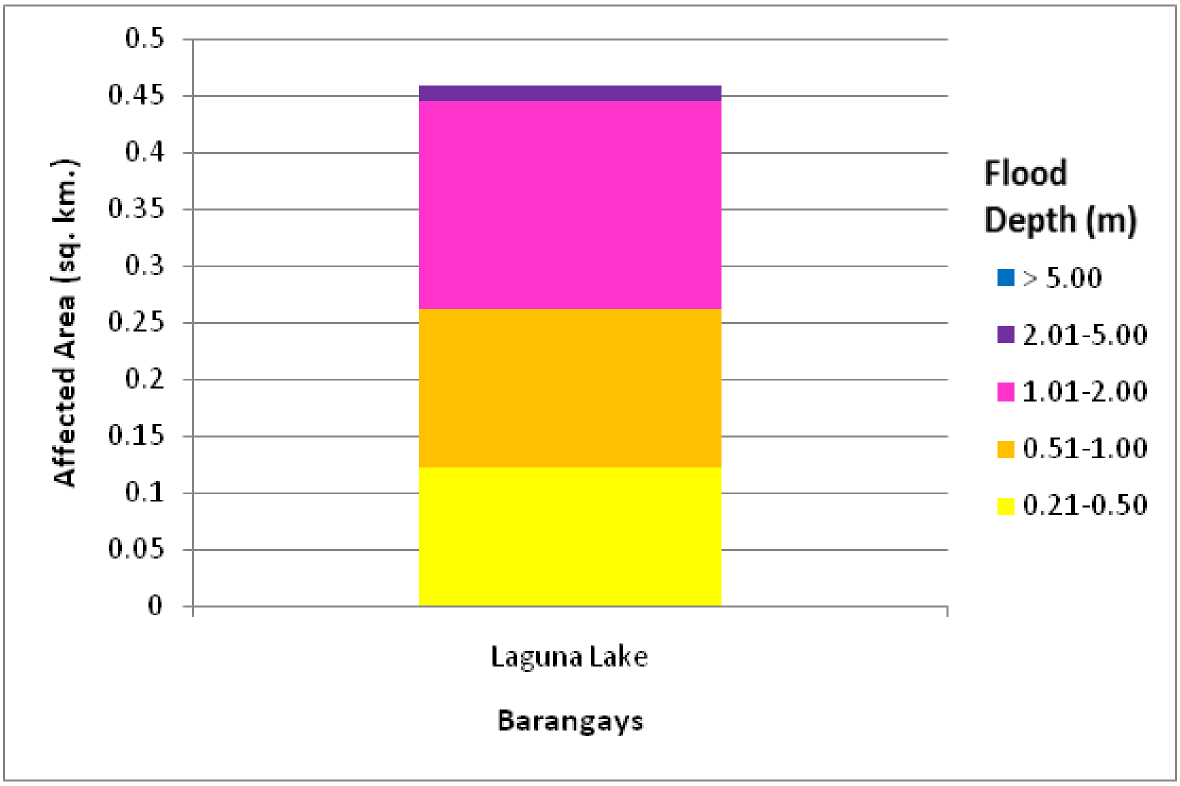


Figure 72. Areas affected by flooding in Laguna Lake, Laguna for a 5-year return period rainfall event

For the Municipality of Liliw, with an area of 36.20 square kilometers, 1.62% will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.09%, 0.22%, 0.19%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 39 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Liliw, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Liliw			
	Dagatan	Daniw	Dita	Mojon
0.03-0.20	0.52	2.69	0.24	0.434537
0.21-0.50	0.13	0.18	0.28	0.033911
0.51-1.00	0.088	0.058	0.1	0.031247
1.01-2.00	0.016	0.023	0.0094	0.079884
2.01-5.00	0	0.008	0.0049	0.068548
> 5.00	0	0.0003	0	0.016414

Among the barangays in the Municipality of Liliw, Mojon is projected to have the highest percentage of area that will experience flood levels, at 1.84%. On the other hand, Daniw posted the second highest percentage of area that may be affected by flood depths, at 0.24%.

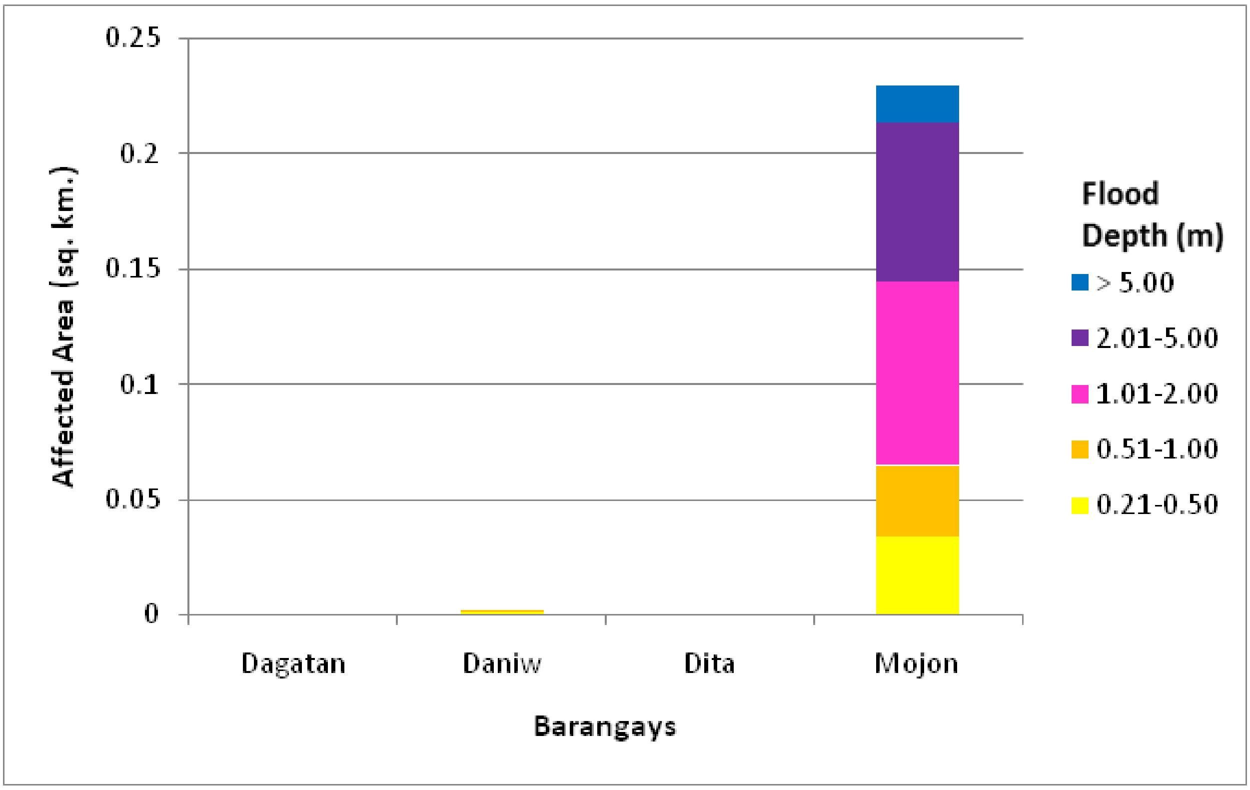


Figure 73. Areas affected by flooding in Liliw, Laguna for a 5-year return period rainfall event

For the Municipality of Luisiana, with an area of 61.01 square kilometers, 4.63% will experience flood levels of less than 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.07%, 0.06%, 0.13%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 40 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Luisiana, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Luisiana	
	San Diego	San Salvador
0.03-0.20	0.0012	2.82
0.21-0.50	0	0.054
0.51-1.00	0	0.04
1.01-2.00	0	0.034
2.01-5.00	0	0.077
> 5.00	0	0.038

Among the barangays in the Municipality of Luisiana, San Salvador is projected to have the highest percentage of area that will experience flood levels, at 5.03%. On the other hand, San Diego posted the second highest percentage of area that may be affected by flood depths, at 0.002%.

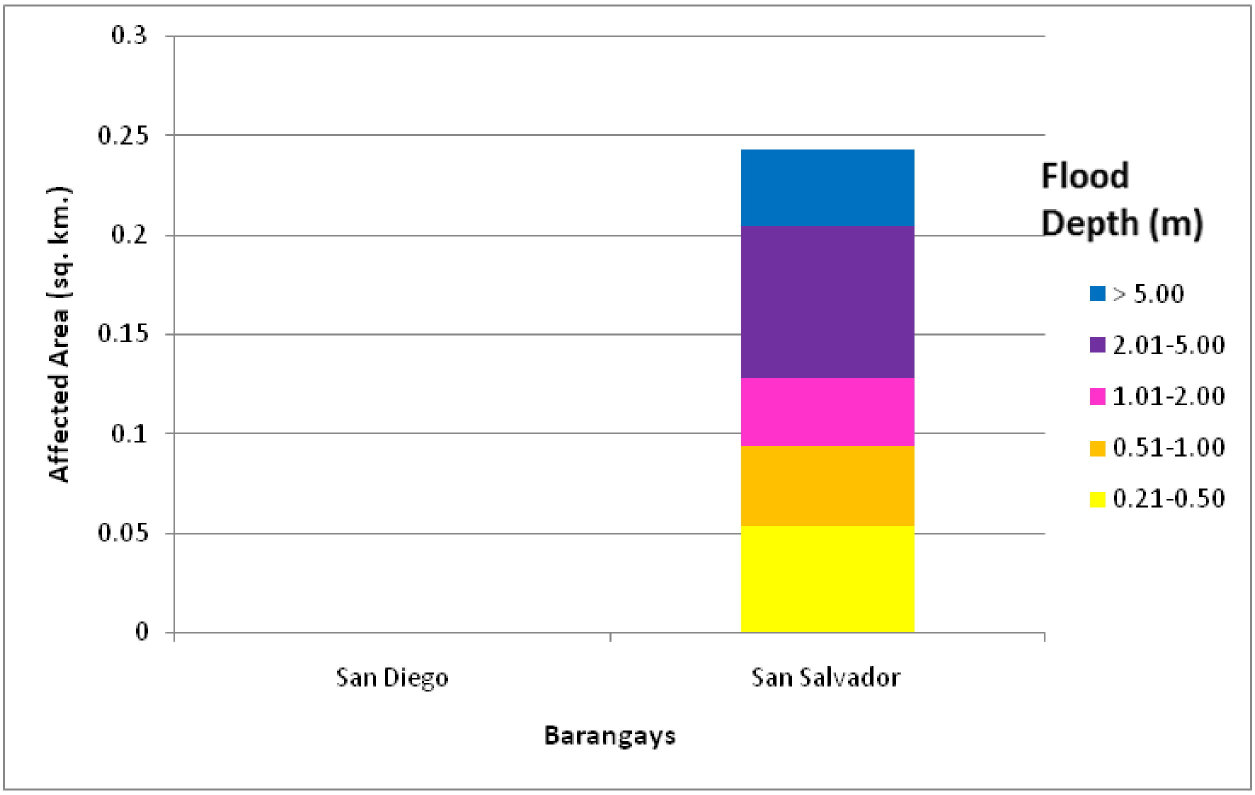


Figure 74 . Areas affected by flooding in Luisiana, Laguna for a 5-year return period rainfall event

For the Municipality of Lumban, with an area of 117.34 square kilometers, 10.74% will experience flood levels of less than 0.20 meters. 3.88% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.33%, 1.82%, 0.70%, and 0.0001% 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. Table 41 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Lumban, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Lumban							
	Bagong Silang	Balimbingan	Balubad	Caliraya	Concepcion	Lewin	Maracta	Maytalang I
0.03-0.20	0.0012	2.82	1.886293	0.017124	1.183065	0.950484	0.167821	0.42728
0.21-0.50	0	0.054	0.179629	0	0.234194	0.089048	0.072821	0.221892
0.51-1.00	0	0.04	0.302326	0	0.092646	0.166001	0.026717	0.183187
1.01-2.00	0	0.034	0.343397	0	0.037068	0.085399	0	0.032656
2.01-5.00	0	0.077	0.056972	0	0.079569	0.0015	0	0.099814
> 5.00	0	0.038	0	0	0	0	0	0.000153

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Lumban							
	Maytalang II	Primera Parang	Primera Pulo	Salac	Santo Niño	Segunda Parang	Segunda Pulo	Wawa
0.03-0.20	0.68	0.17	0.035	0.15	0.44	0.17	0.061	5.35
0.21-0.50	0.73	0.055	0.015	0.061	0.18	0.06	0.06	2.53
0.51-1.00	1.18	0.032	0.028	0.093	0.053	0.045	0.016	0.48
1.01-2.00	1.46	0.008	0	0.003	0.0024	0.011	0	0.16
2.01-5.00	0.000066	0.037	0	0	0	0.026	0	0.52
> 5.00	0	0	0	0	0	0	0	0

Among the barangays in the Municipality of Lumban, Wawa is projected to have the highest percentage of area that will experience flood levels, at 7.71%. On the other hand, Maytalang II posted the second highest percentage of area that may be affected by flood depths, at 3.46%.

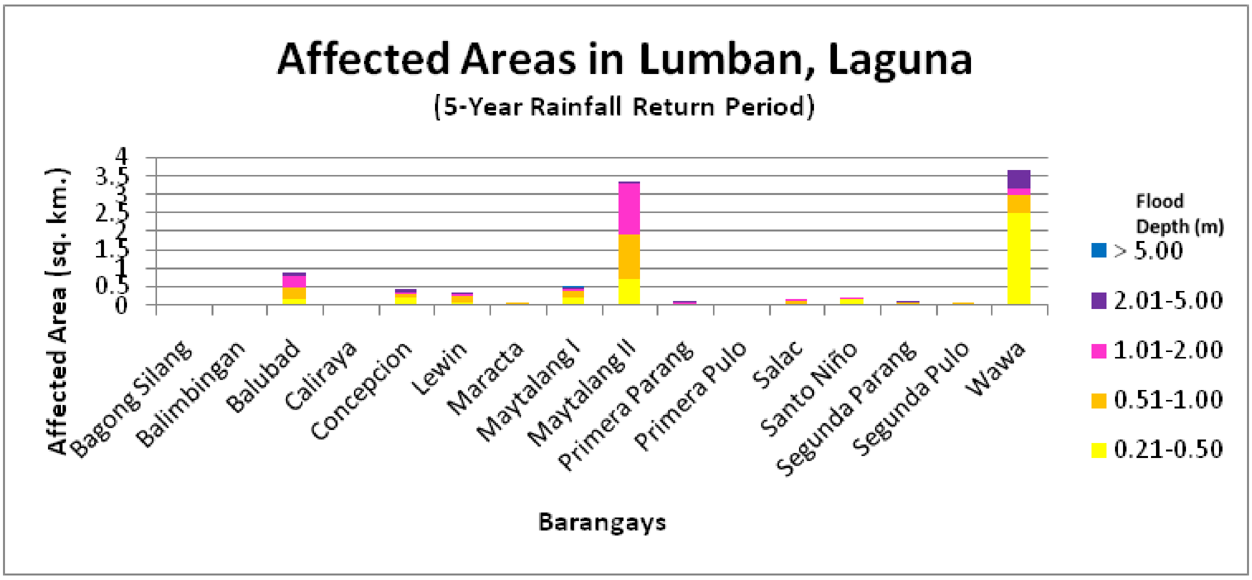


Figure 75. Areas affected by flooding in Lumban, Laguna for a 5-year return period rainfall event

For the Municipality of Magdalena, with an area of 29.61 square kilometers, 65.36% will experience flood levels of less than 0.20 meters. 8.42% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.04%, 4.03%, 4.63%, and 4.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 42 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in Magdalena, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Magdalena							
	Alipit	Baanan	Balanac	Bucal	Buenavista	Bungkol	Buo	Burlungan
0.03-0.20	1.41	0.33	0.58	0.69	0.93	1.84	0.6	1.22
0.21-0.50	0.12	0.026	0.2	0.21	0.19	0.13	0.067	0.098
0.51-1.00	0.077	0.0097	0.19	0.045	0.15	0.022	0.067	0.034
1.01-2.00	0.07	0.004	0.13	0.016	0.13	0.019	0.054	0.086
2.01-5.00	0.054	0.0011	0.21	0.081	0.081	0.02	0.046	0.12
> 5.00	0.078	0	0.29	0.14	0.004	0.0002	0.027	0.03

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Magdalena							
	Cigaras	Halayhayin	Ibabang Atingay	Ibabang Butnong	Ilayang Atingay	Ilayang Butnong	Ilog	Malaking Ambling
0.03-0.20	0.56	0.99	0.31	1.02	0.8	0.44	0.23	0.47
0.21-0.50	0.12	0.071	0.053	0.068	0.14	0.011	0.069	0.034
0.51-1.00	0.12	0.011	0.029	0.049	0.11	0.013	0.076	0.017
1.01-2.00	0.14	0.024	0.026	0.042	0.053	0.019	0.087	0.032
2.01-5.00	0.14	0.099	0.054	0.0062	0.067	0.014	0.05	0.06
> 5.00	0.04	0.061	0.11	0	0.013	0.0049	0.0014	0.021

Affected Area	Affected Barangays in Magdalena							
(sq. km.) by flood depth (in m.)	Malinao	Maravilla	Munting Ambling	Poblacion	Sabang	Salasad	Tanawan	Tipunan
0.03-0.20	0.94	1.28	0.5	0.51	1.72	0.89	0.58	0.52
0.21-0.50	0.12	0.28	0.034	0.036	0.24	0.1	0.036	0.03
0.51-1.00	0.036	0.086	0.014	0.012	0.18	0.097	0.03	0.014
1.01-2.00	0.011	0.032	0.009	0.009	0.1	0.066	0.023	0.0066
2.01-5.00	0.01	0.041	0.0085	0.0047	0.18	0.026	0.0006	0.0013
> 5.00	0.015	0.32	0.0056	0	0.071	0.0002	0	0

Among the barangays in the Municipality of Magdalena, Sabang is projected to have the highest percentage of area that will experience flood levels, at 8.39%. On the other hand, Maravilla posted the second highest percentage of area that may be affected by flood depths, at 6.87%.

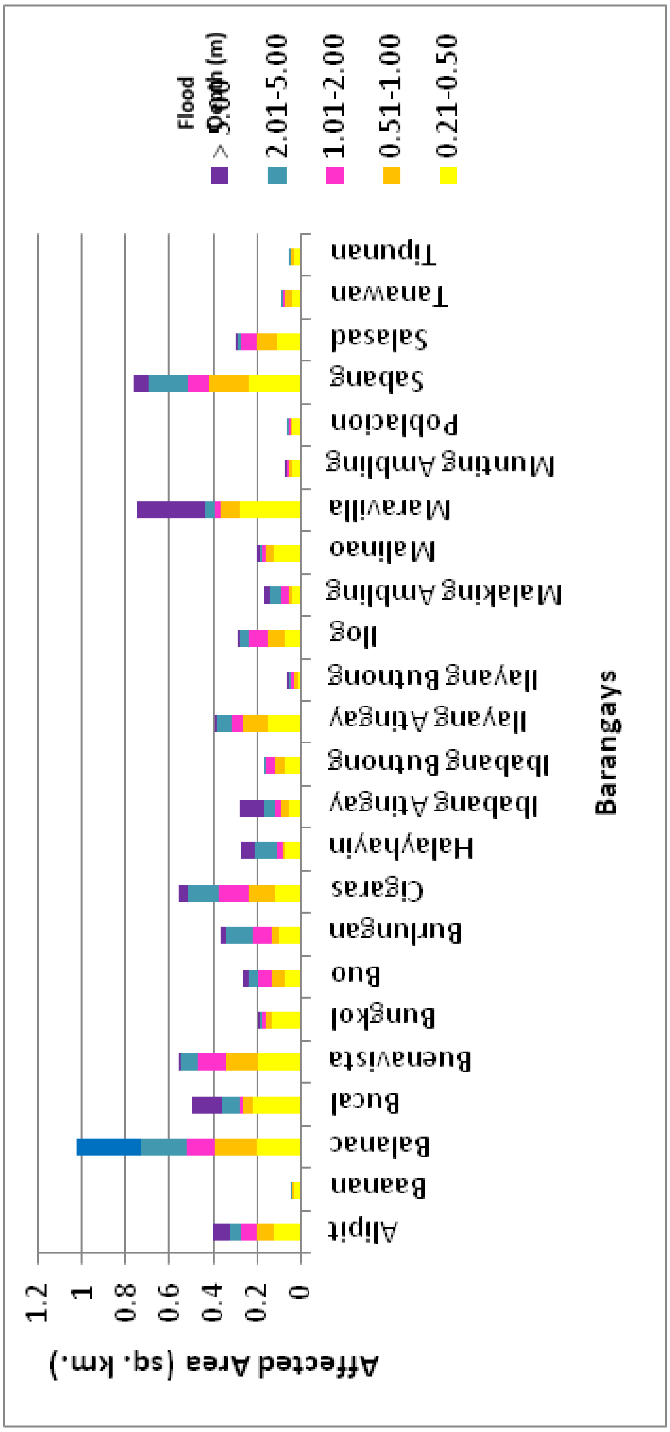


Figure 76. Areas affected by flooding in Magdalena, Laguna for a 5-year return period rainfall event

For the Municipality of Majayjay, with an area of 64.40 square kilometers, 5.29% will experience flood levels of less than 0.20 meters. 0.30% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.17%, 0.07%, 0.03%, and 0.008% 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. Table 43 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Majayjay, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Majayjay					
	Balanac	Banilad	Banti	Burol	San Isidro	Tanawan
0.03-0.20	0.084	1.04	0.74	0.032	0.012	1.5
0.21-0.50	0.002	0.072	0.028	0	0.0016	0.087
0.51-1.00	0.0001	0.055	0.0098	0	0.00081	0.043
1.01-2.00	0	0.022	0.0027	0	0	0.02
2.01-5.00	0	0.018	0	0	0	0.002
> 5.00	0	0.0051	0	0	0	0

Among the barangays in the Municipality of Majayjay, Tanawan is projected to have the highest percentage of area that will experience flood levels, at 2.56%. On the other hand, Banilad posted the second highest percentage of area that may be affected by flood depths, at 1.88%.

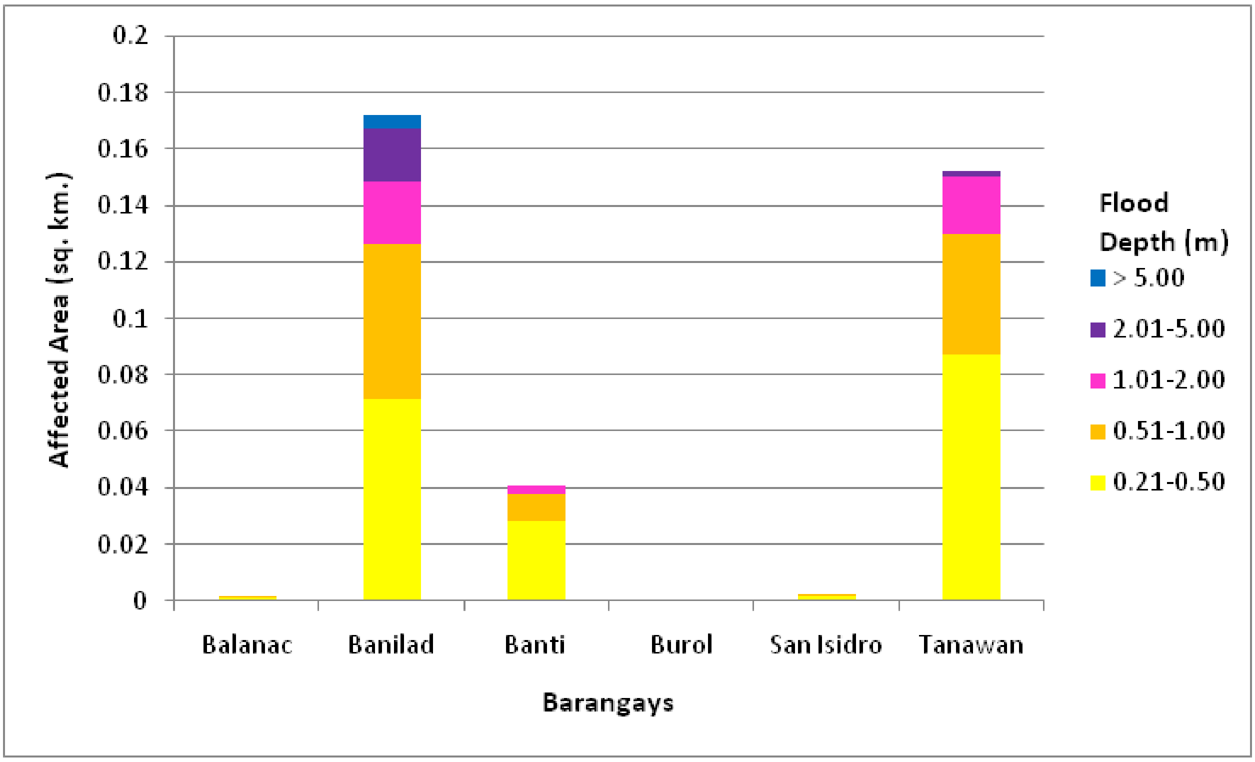


Figure 77. Areas affected by flooding in Majayjay, Laguna for a 5-year return period rainfall event

For the Municipality of Nagcarlan, with an area of 81.20 square kilometers, 25.81% will experience flood levels of less than 0.20 meters. 3.58% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.54%, 1.82%, 0.84%, and 0.78% 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. Table 44 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Nagcarlan, Laguna during a 5-year rainfall return period

Affected Area	Affected Barangays in Nagcarlan							
(sq. km.) by flood depth (in m.)	Balayong	Banca-Banca	Bayaquitos	Buenavista	Buhanginan	Calumpang	Kanluran Ka-bubuhayan	Labangan
0.03-0.20	0.32	2.38	0.51	3.03	1.39	1.69	0.81	0.68
0.21-0.50	0.011	0.58	0.014	0.15	0.27	0.32	0.1	0.022
0.51-1.00	0.0028	0.33	0.0088	0.081	0.028	0.43	0.025	0.011
1.01-2.00	0.0006	0.27	0.0048	0.03	0.00001	0.55	0.0016	0.0042
2.01-5.00	0.0002	0.1	0.0015	0.018	0	0.16	0.0012	0.00041
> 5.00	0	0.0053	0	0.0032	0	0.51	0	0

Affected Area	Affected Barangays in Nagcarlan							
(sq. km.) by flood depth (in m.)	Lagulo	Lawaguin	Manaol	Maravilla	Sabang	Sibulan	Silangan Ka-bubuhayan	Wakat
0.03-0.20	0.41	2.29	0.88	2.05	0.33	1.63	0.26	2.3
0.21-0.50	0.0091	0.077	0.23	0.62	0.014	0.087	0.019	0.38
0.51-1.00	0.0044	0.03	0.055	0.63	0.0013	0.034	0.0076	0.39
1.01-2.00	0.0025	0.025	0.00058	0.31	0.00037	0.032	0.003	0.24
2.01-5.00	0.0017	0.027	0.0011	0.31	0.00017	0.048	0	0.011
> 5.00	0.0001	0.0018	0	0.11	0.000039	0.0022	0	0.0003

Among the barangays in the Municipality of Nagcarlan, Maravilla is projected to have the highest percentage of area that will experience flood levels, at 4.95%. On the other hand, Calumpang posted the second highest percentage of area that may be affected by flood depths, at 4.52%.

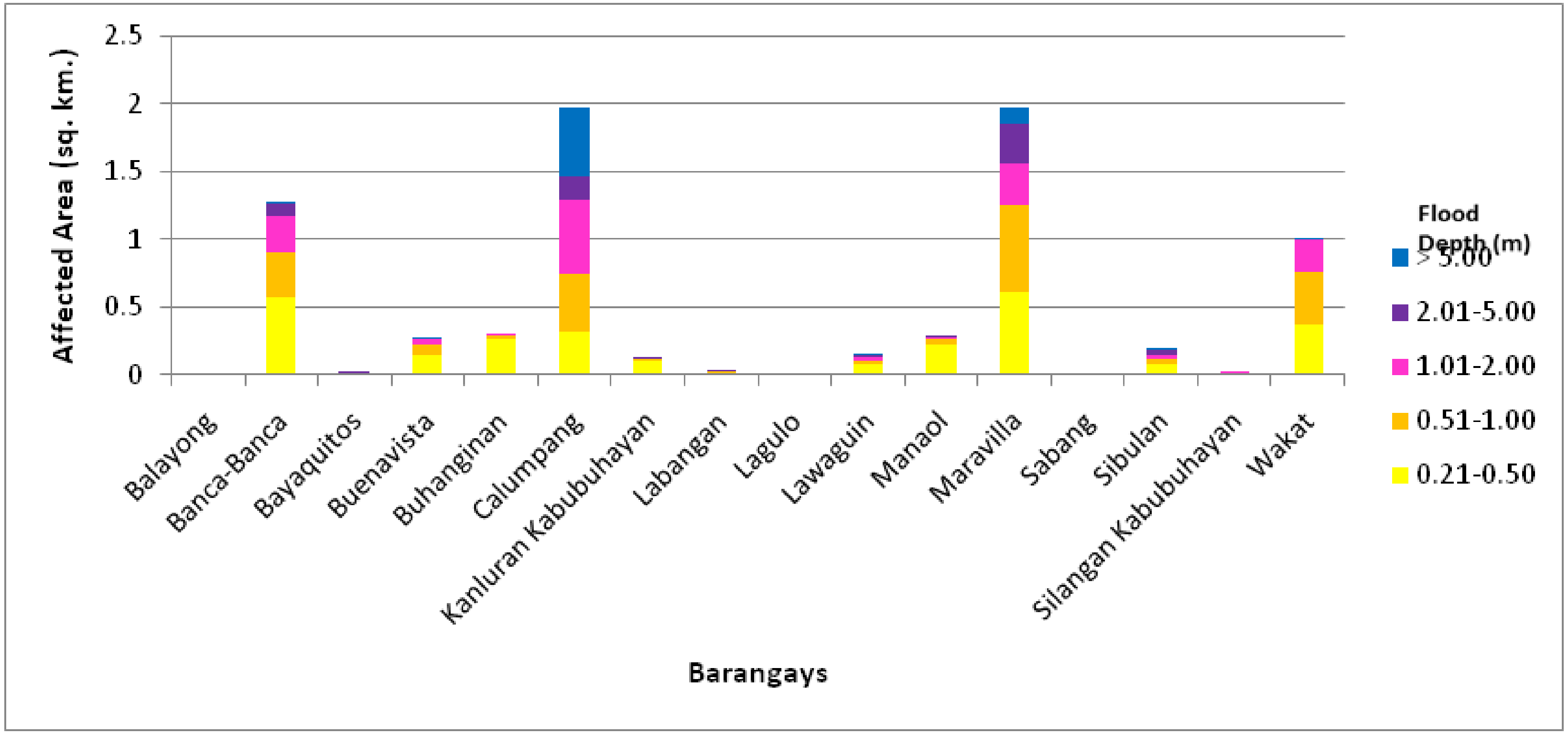


Figure 78 . Areas affected by flooding in Nagcarlan, Laguna for a 5-year return period rainfall event

For the Municipality of Pagsanjan, with an area of 40.77 square kilometers, 46.40% will experience flood levels of less than 0.20 meters. 8.56% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 10.85%, 9.26%, 3.57%, and 2.26% 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. Table 45 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Pagsanjan, Laguna during a 5-year rainfall return period

Affected Area	Affected Barangays in Pagsanjan							
(sq. km.) by flood depth (in m.)	Anibong	Barangay I	Barangay II	Biñan	Buboy	Cabanbanan	Calusiche	Dingin
0.03-0.20	2.49	0.074	0.23	0.21	2.17	0.73	0.88	2.82
0.21-0.50	0.17	0.017	0.025	0.39	0.3	0.15	0.33	0.17
0.51-1.00	0.09	0.027	0.000012	0.86	0.27	0.15	0.51	0.15
1.01-2.00	0.12	0.095	0	0.22	0.33	0.22	0.72	0.23
2.01-5.00	0.13	0.044	0	0.0037	0.18	0.075	0.19	0.17
> 5.00	0.13	0.032	0	0	0.046	0.022	0.17	0.25

Affected Area	Affected Barangays in Pagsanjan							
(sq. km.) by flood depth (in m.)	Lambac	Layugan	Magdapio	Maulawin	Pinagsanjan	Sabang	Sampaloc	San Isidro
0.03-0.20	1.01	2.36	1.64	0.14	3.09	0.49	0.24	0.36
0.21-0.50	0.34	0.63	0.064	0.035	0.29	0.31	0.15	0.13
0.51-1.00	0.49	0.46	0.044	0.051	0.44	0.29	0.51	0.088
1.01-2.00	0.21	0.27	0.056	0.18	0.6	0.21	0.3	0.025
2.01-5.00	0.0024	0.2	0.043	0.017	0.3	0.0032	0.1	0
> 5.00	0	0.012	0	0.01	0.22	0	0.032	0

Among the barangays in the Municipality of Pagsanjan, Pinagsanjan is projected to have the highest percentage of area that will experience flood levels, at 12.14%. On the other hand, Layugan posted the second highest percentage of area that may be affected by flood depths, at 9.60%.

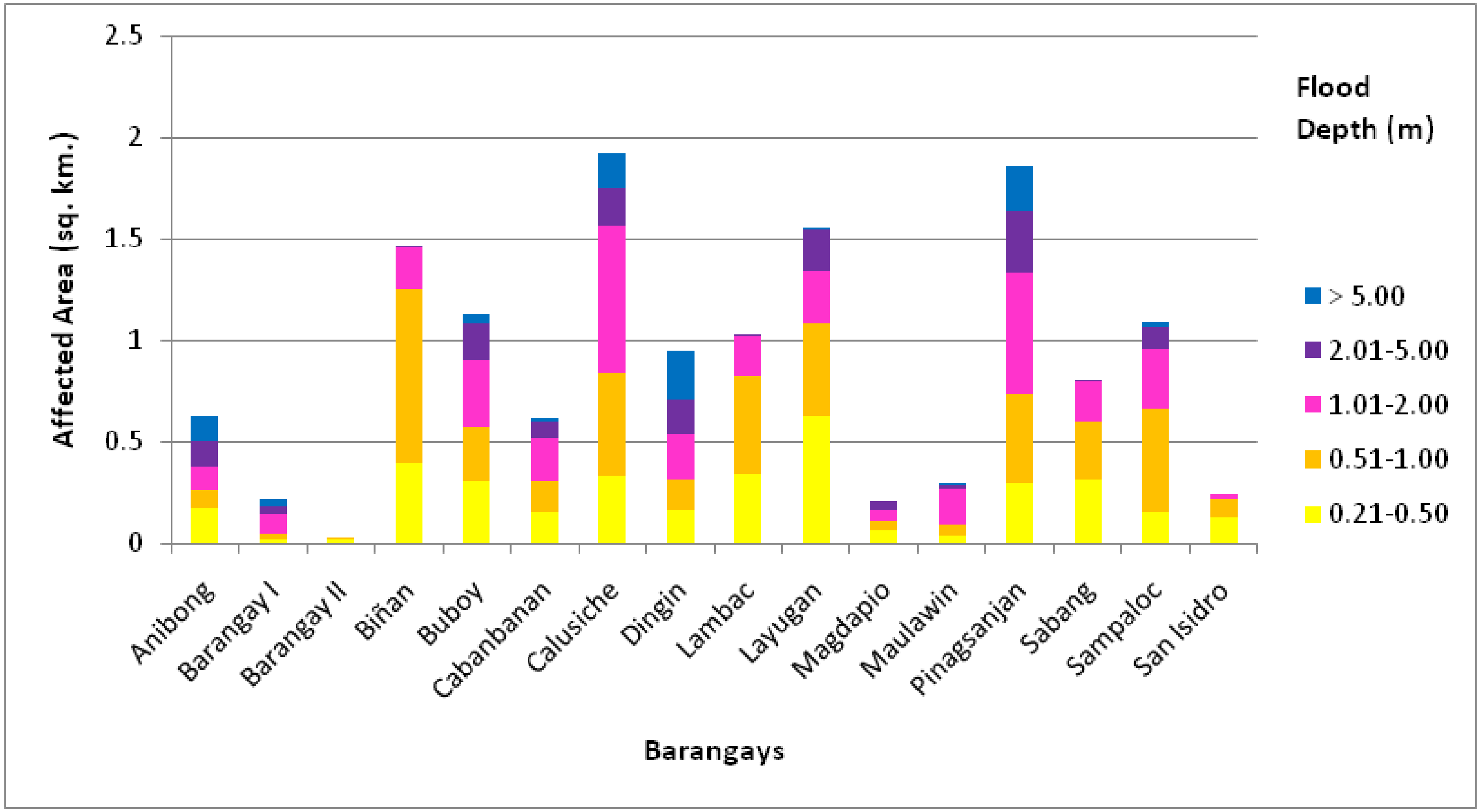


Figure 79. Areas affected by flooding in Pagsanjan, Laguna for a 5-year return period rainfall event

For the Municipality of Pila, with an area of 28.77 square kilometers, 64.99% will experience flood levels of less than 0.20 meters. 19.21% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 10.16%, 3.86%, 0.28%, and 0.58% 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. Table 46 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Pila, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pila							
	Aplaya	Bagong Pook	Bukal	Bulilan Norte	Bulilan Sur	Concepcion	Labuin	Linga
0.03-0.20	0.43	1.35	0.98	0.35	0.43	2.07	0.71	0.47
0.21-0.50	0.13	0.45	0.15	0.085	0.36	0.92	0.28	0.25
0.51-1.00	0.047	0.12	0.046	0.34	0.067	0.59	0.17	0.1
1.01-2.00	0.001	0.0001	0.011	0.19	0.061	0.22	0.11	0
2.01-5.00	0	0	0	0.0056	0.0001	0.0049	0	0
> 5.00	0	0	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pila								
	Masico	Mojon	Pansol	Pinagbayanan	San Antonio	San Miguel	Santa Clara Norte	Santa Clara Sur	Tubuan
0.03-0.20	0.8	2.17	2.01	0.73	1.54	1.65	0.46	0.65	1.92
0.21-0.50	0.17	0.35	0.4	0.3	0.37	0.3	0.097	0.17	0.74
0.51-1.00	0.058	0.15	0.15	0.17	0.2	0.051	0.056	0.043	0.56
1.01-2.00	0.018	0.082	0.046	0.06	0.13	0.0023	0.071	0.00085	0.11
2.01-5.00	0	0.051	0	0	0.011	0	0.0062	0	0.0011
> 5.00	0	0.17	0	0	0	0	0	0	0

Among the barangays in the Municipality of Pila, Concepcion is projected to have the highest percentage of area that will experience flood levels, at 13.24%. On the other hand, Tubuan posted the second highest percentage of area that may be affected by flood depths, at 11.56%.

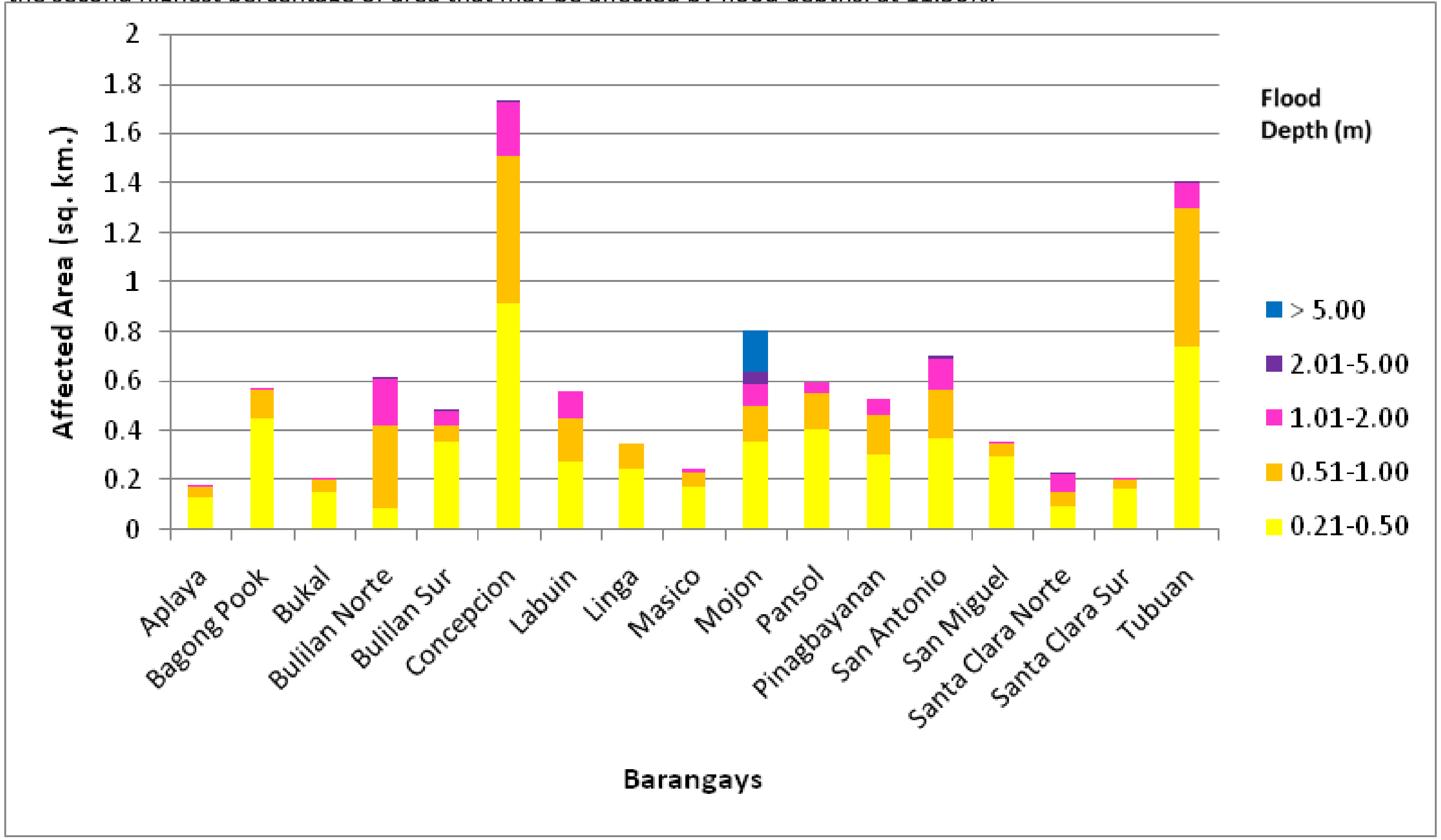


Figure 80. Areas affected by flooding in Pila, Laguna for a 5-year return period rainfall event

For the Municipality of Santa Cruz, with an area of 37.63 square kilometers, 62.31% will experience flood levels of less than 0.20 meters. 23.90% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 7.55%, 1.84%, 0.52%, and 0.99% 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. Table 47 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Santa Cruz, Laguna during a 5-year rainfall return period

Affected Area	Affected Barangays in Santa Cruz								
(sq. km.) by flood depth (in m.)	Alipit	Bagumbayan	Baran-gay I	Barangay II	Barangay III	Barangay IV	Barangay V	Bubukal	Calios
0.03-0.20	0.42	2.18	0.059	0.078	0.041	0.095	0.079	1.29	0.77
0.21-0.50	0.13	0.75	0.039	0.018	0.0067	0.042	0.031	0.38	0.49
0.51-1.00	0.16	0.13	0.011	0.0026	0.000062	0.0093	0.014	0.081	0.29
1.01-2.00	0.086	0.0046	0	0	0	0	0	0.0017	0.032
2.01-5.00	0.025	0	0	0	0	0	0	0	0
> 5.00	0.13	0	0	0	0	0	0	0	0

Affected Area	Affected Barangays in Santa Cruz								
(sq. km.) by flood depth (in m.)	Duhat	Gatid	Jasaan	Labuin	Malinao	Oogong	Pagsawi-tan	Palasan	Patimbao
0.03-0.20	1.92	2.24	1.11	0.77	0.87	0.9	1.69	1.81	1
0.21-0.50	0.74	0.92	0.24	0.27	0.54	0.17	0.44	0.78	0.58
0.51-1.00	0.068	0.22	0.022	0.11	0.15	0.058	0.084	0.34	0.56
1.01-2.00	0	0.0074	0.0034	0.0073	0.015	0.059	0.026	0.071	0.18
2.01-5.00	0	0	0	0	0	0.03	0	0.037	0.038
> 5.00	0	0	0	0	0	0.15	0	0.055	0.042

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz							
	San Jose	San Juan	San Pablo Norte	San Pablo Sur	Santisima Cruz	Santo Angel Central	Santo Angel Norte	Santo Angel Sur
0.03-0.20	1.81	1.17	0.29	1.07	0.4	0.38	0.75	0.25
0.21-0.50	0.61	0.46	0.17	0.55	0.15	0.084	0.3	0.087
0.51-1.00	0.086	0.07	0.006	0.25	0.015	0.013	0.061	0.033
1.01-2.00	0.00062	0.0061	0	0.09	0	0.028	0.068	0.011
2.01-5.00	0.00013	0.0003	0	0	0	0.023	0	0.042
> 5.00	0.000007	0	0	0	0	0	0	0

Among the barangays in the Municipality of Santa Cruz, Gatid is projected to have the highest percentage of area that will experience flood levels, at 9%. On the other hand, Palasan posted the second highest percentage of area that may be affected by flood depths, at 8.23%.

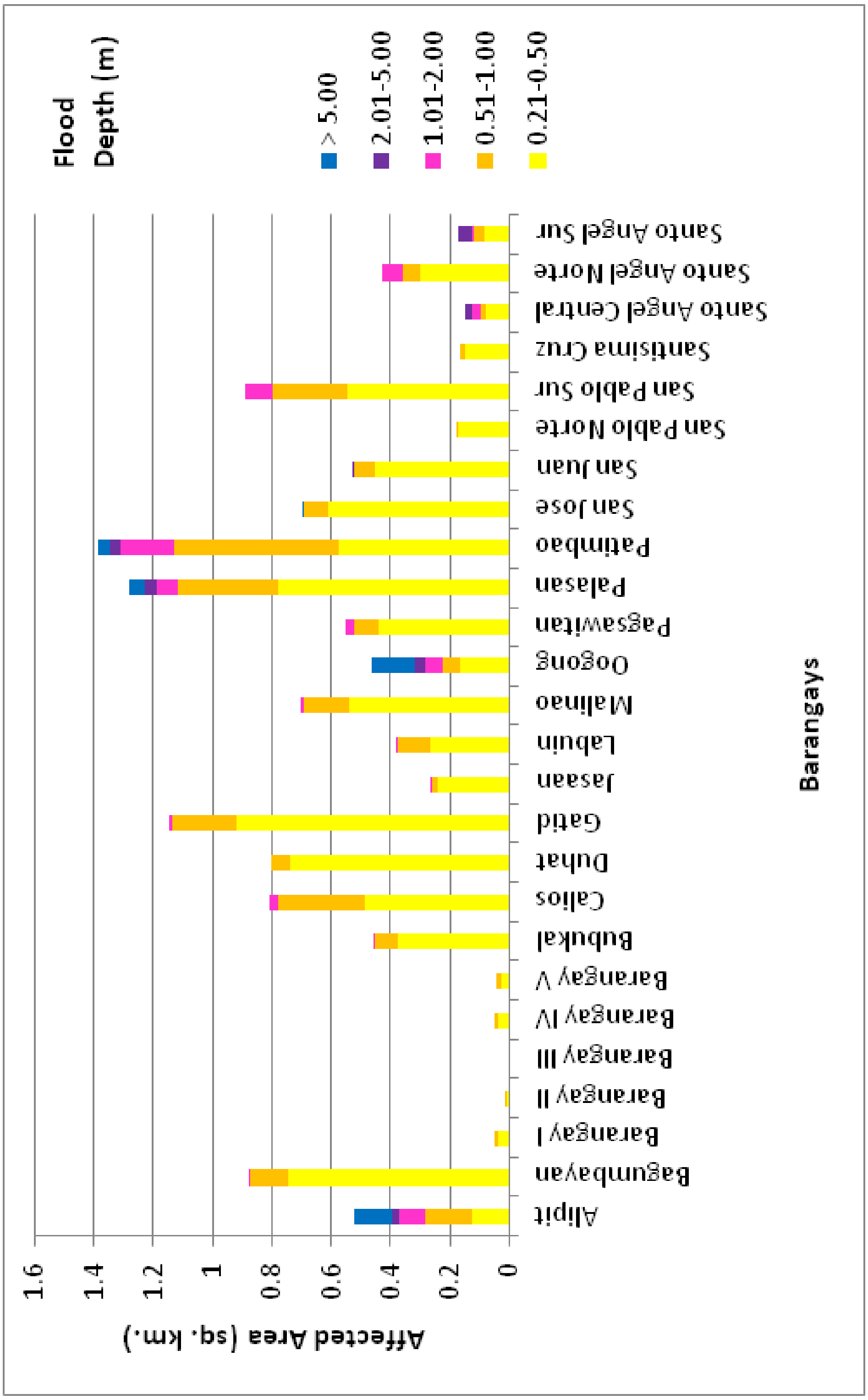


Figure 81. Areas affected by flooding in Santa Cruz, Laguna for a 5-year return period rainfall event

For the Municipality of Victoria, with an area of 28.37 square kilometers, 44.75% will experience flood levels of less than 0.20 meters. 19.82% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 14.60%, 6.98%, and 0.35% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 48 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in Victoria, Laguna during a 5-year rainfall return period

Affected Area	Affected Barangays in Victoria								
(sq. km.) by flood depth (in m.)	Banca-Ban-ca	Daniw	Masapang	Nanhaya	Pagalangan	San Benito	San Felix	San Francis-co	San Roque
0.03-0.20	1.72	2.17	0.58	0.9	0.96	0.74	2.09	1.98	1.56
0.21-0.50	0.46	1.13	0.46	0.22	0.42	0.53	1.8	0.26	0.35
0.51-1.00	0.11	1.27	0.57	0.041	0.29	0.68	1.12	0.03	0.031
1.01-2.00	0.081	1.3	0.34	0.0069	0.025	0.068	0.16	0.002	0.00011
2.01-5.00	0.0026	0.078	0.014	0	0	0.0016	0.0011	0.0001	0
> 5.00	0	0	0	0	0	0	0	0	0

Among the barangays in the Municipality of Victoria, Daniw is projected to have the highest percentage of area that will experience flood levels, at 20.96%. On the other hand, San Felix posted the second highest percentage of area that may be affected by flood depths, at 18.21%.

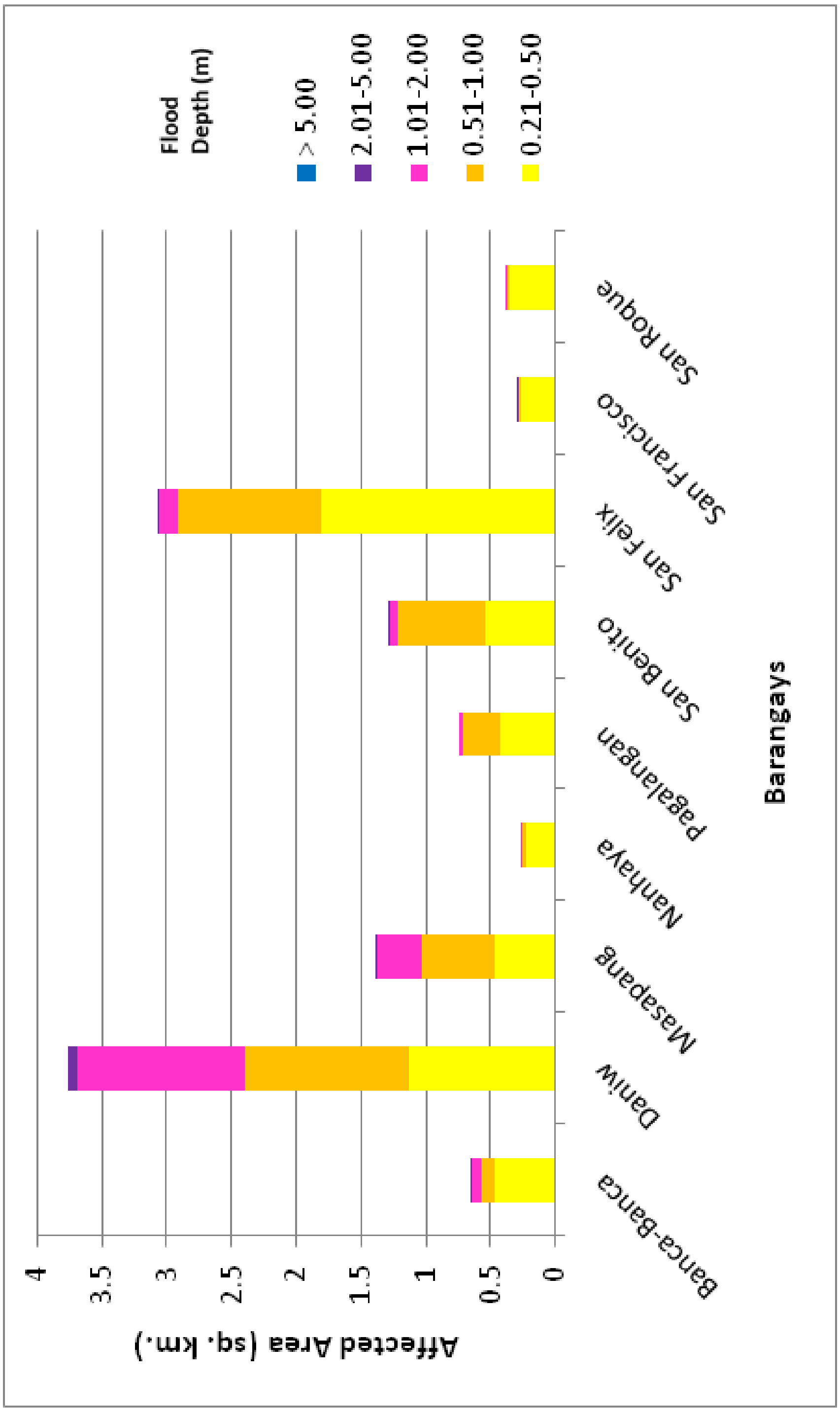


Figure 82. Areas affected by flooding in Victoria, Laguna for a 5-year return period rainfall event

For the 25-year return period, 4.08% of the Municipality of Calauan, with an area of 79.44 square kilometers, will experience flood levels of less than 0.20 meters. 0.82% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.44%, 0.11%, 0.02%, and 0.0004% 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. Table 49 depicts the areas affected in Calauan, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in Calauan, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Calauan		
	Dayap	Lamot 2	Santo Tomas
0.03-0.20	0.45	2.61	0.18
0.21-0.50	0.16	0.22	0.27
0.51-1.00	0.11	0.081	0.16
1.01-2.00	0.039	0.031	0.014
2.01-5.00	0	0.014	0.0056
> 5.00	0	0.0003	0

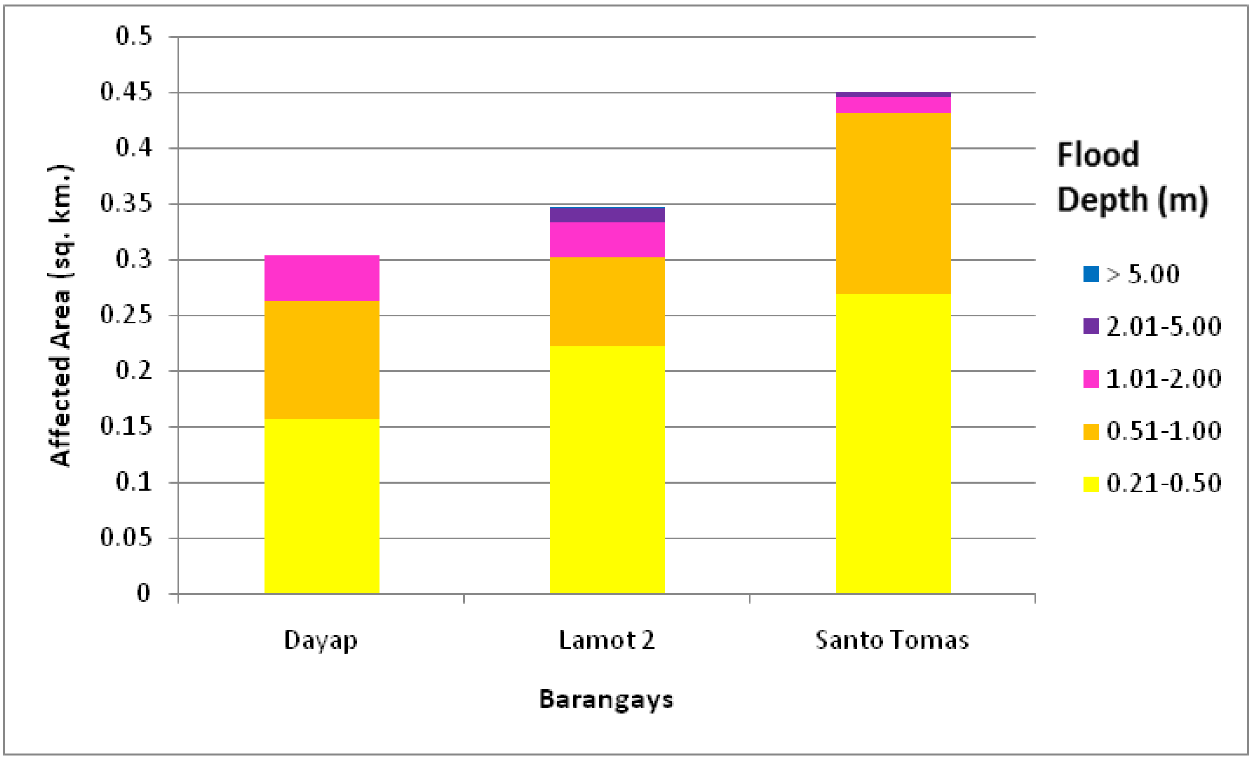


Figure 83. Affected areas in Calauan, Laguna during a 25-year rainfall return period

For the Municipality of Cavinti, with an area of 96.78 square kilometers, 0.91% will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.02%, 0.009%, 0.006%, and 0.0003% 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. Table 50 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Cavinti, Laguna during a 25-year rainfall return period

Affected Area	Affected Barangays in Cavinti		
(sq. km.) by flood depth (in m.)	Anglas	Bangco	Bulajo
0.03-0.20	0.46	0.42	0.0026
0.21-0.50	0.016	0.018	0
0.51-1.00	0.011	0.0066	0
1.01-2.00	0.0036	0.0048	0
2.01-5.00	0.0018	0.0044	0
> 5.00	0	0.0003	0

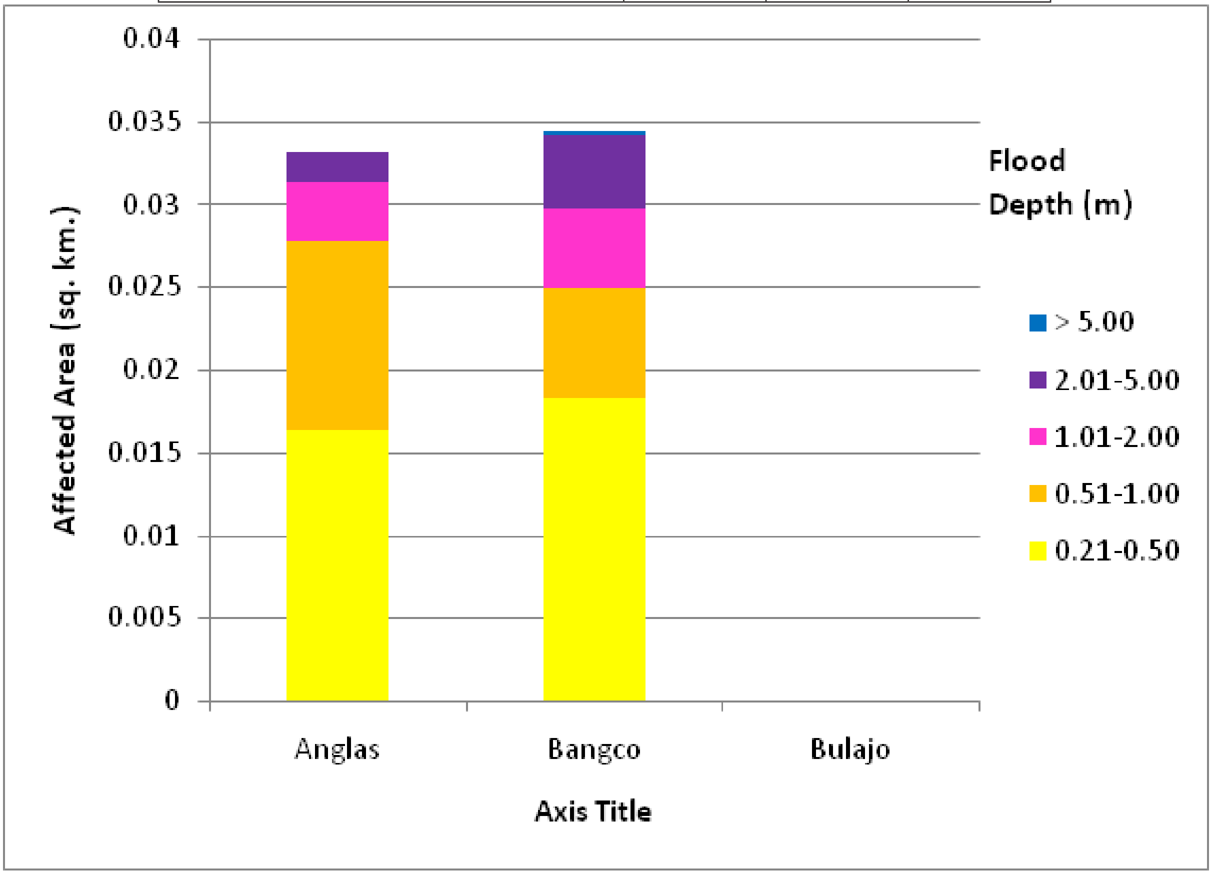


Figure 84. Areas affected by flooding in Cavinti, Laguna for a 25-year return period rainfall event

For the Municipality of Laguna Lake, with an area of 892.20 square kilometers, 0.04% will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.009%, 0.03%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 51 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Laguna Lake, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Laguna lake Laguna Lake
0.03-0.20	0.4
0.21-0.50	0.14
0.51-1.00	0.084
1.01-2.00	0.28
2.01-5.00	0.029
> 5.00	0

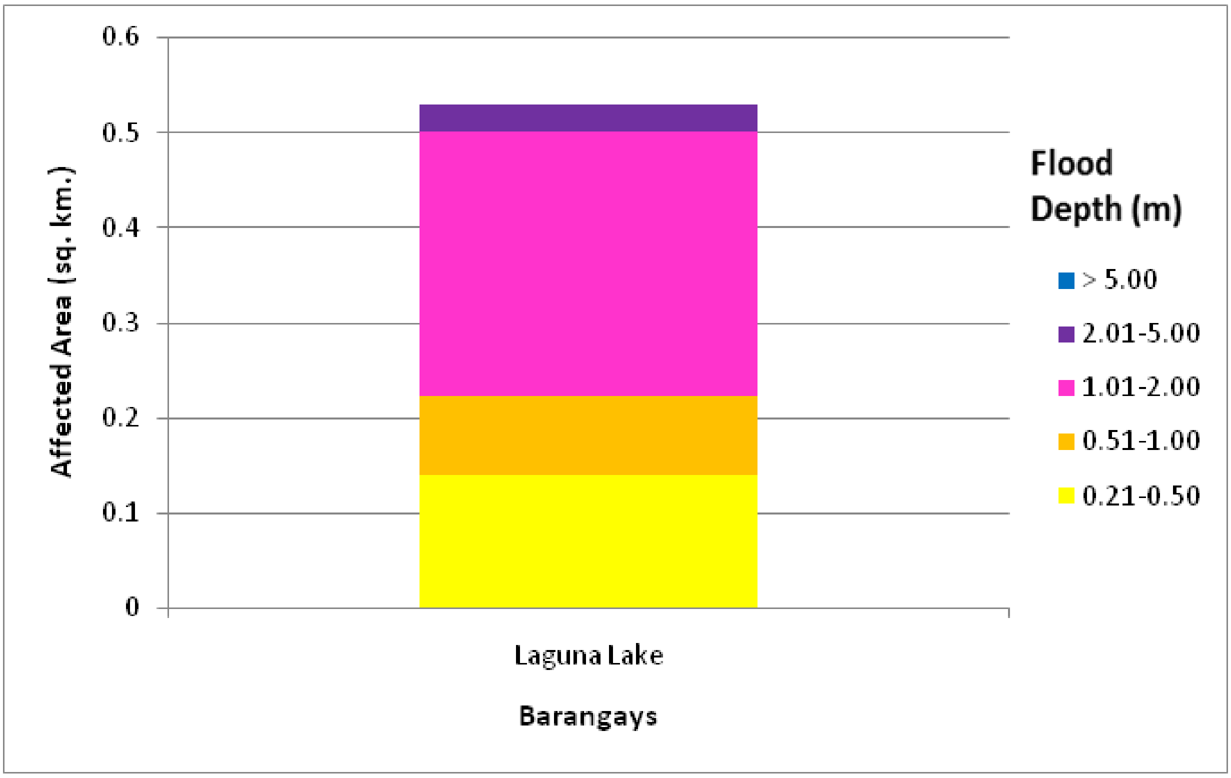


Figure 85. Areas affected by flooding in Laguna Lake, Laguna for a 25-year return period rainfall event

For the Municipality of Liliw, with an area of 36.20 square kilometers, 1.55% will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.06%, 0.19%, 0.26%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 52 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Liliw, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Liliw			
	Dagatan	Daniw	Dita	Mojon
0.03-0.20	0.056	0.083	0.012	0.41
0.21-0.50	0.0002	0.0021	0.00044	0.041
0.51-1.00	0	0.00052	0.00035	0.02
1.01-2.00	0.000047	0.000091	0.000009	0.069
2.01-5.00	0	0	0	0.094
> 5.00	0	0	0	0.031

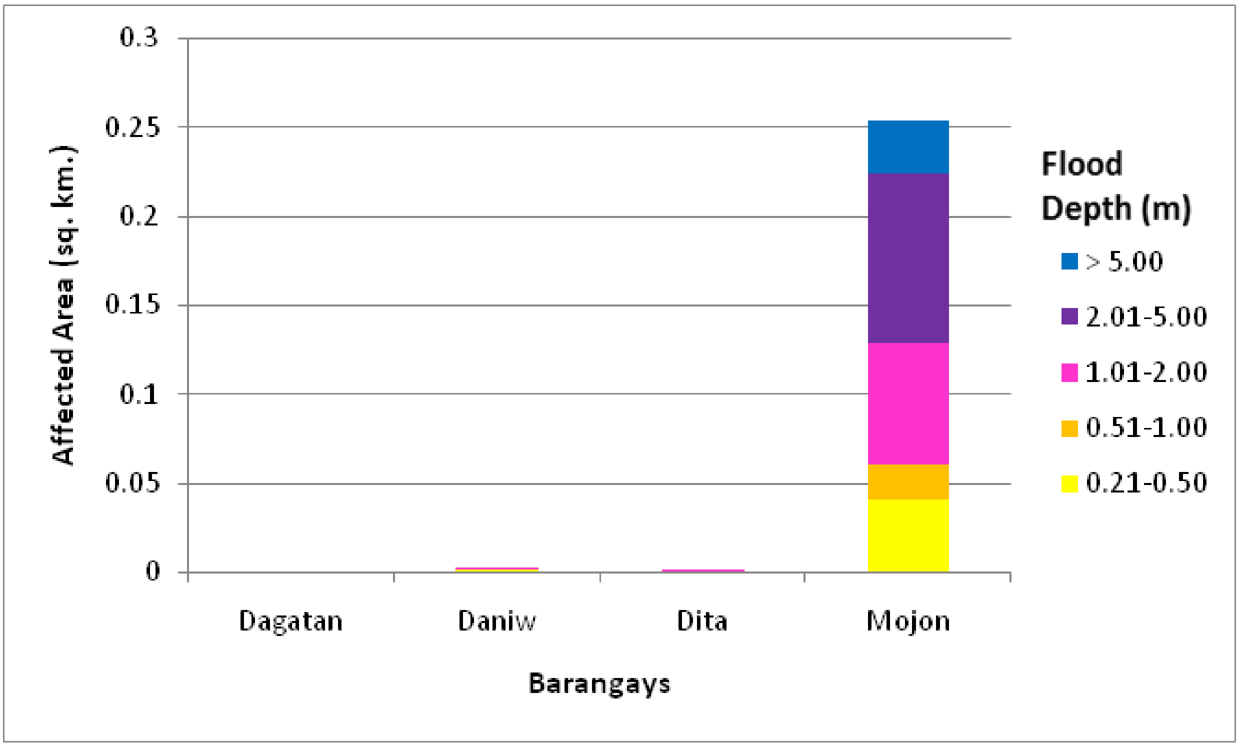


Figure 86. Areas affected by flooding in Liliw, Laguna for a 25-year return period rainfall event

For the Municipality of Luisiana, with an area of 61.01 square kilometers, 4.56% will experience flood levels of less than 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.07%, 0.07%, 0.14%, and 0.10% 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. Table 53 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Luisiana, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Luisiana	
	San Diego	San Salvador
0.03-0.20	0.0012	2.78
0.21-0.50	0	0.056
0.51-1.00	0	0.045
1.01-2.00	0	0.043
2.01-5.00	0	0.083
> 5.00	0	0.06

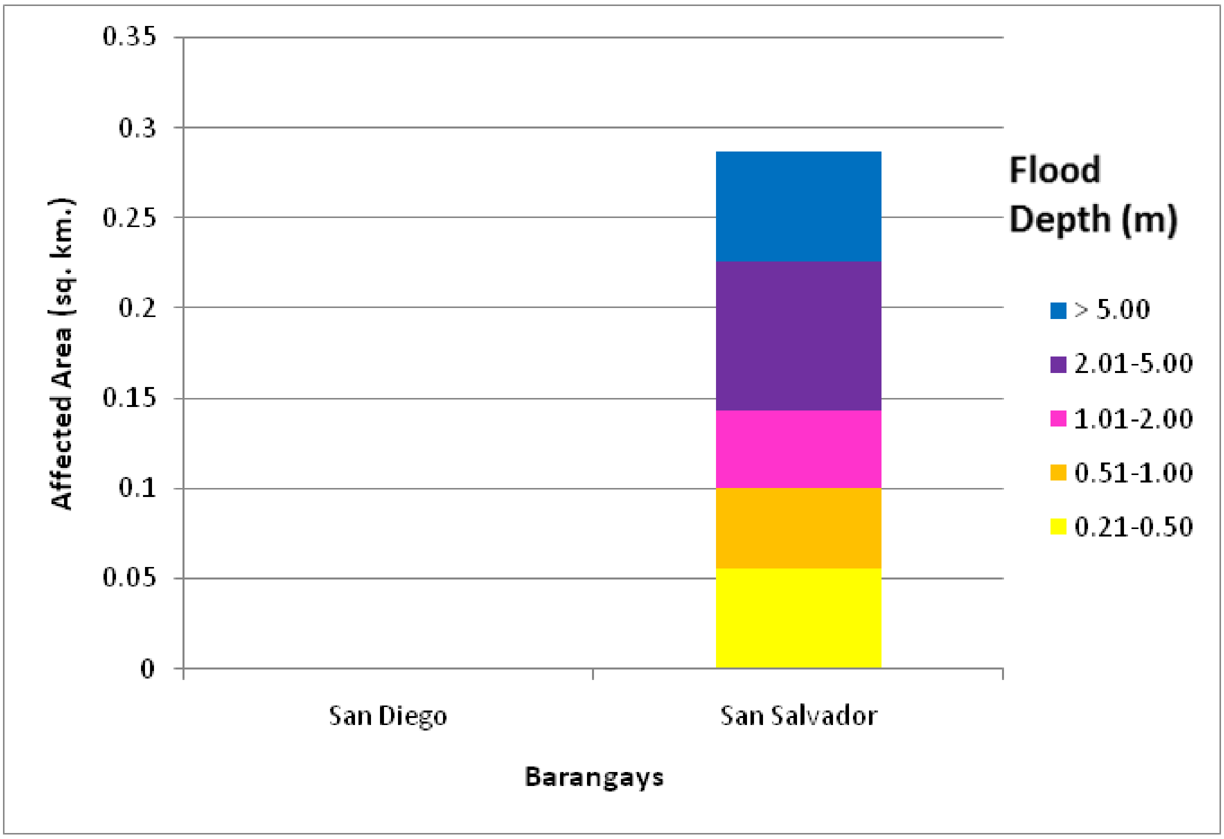


Figure 87. Areas affected by flooding in Luisiana, Laguna for a 25-year return period rainfall event

For the Municipality of Lumban, with an area of 117.34 square kilometers, 9.41% will experience flood levels of less than 0.20 meters. 3.68% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.59%, 2.81%, 1.13%, and 0.0002% 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. Table 54 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 54. Affected areas in Lumban, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Lumban							
	Bagong Silang	Balimbingan	Balubad	Caliraya	Concepcion	Lewin	Maracta	Maytalang I
0.03-0.20	0.79	0.084	1.79	0.017	1.11	0.91	0.14	0.33
0.21-0.50	0.036	0.024	0.16	0	0.29	0.087	0.06	0.16
0.51-1.00	0.016	0.012	0.21	0	0.15	0.16	0.069	0.24
1.01-2.00	0.0046	0.019	0.45	0	0.048	0.14	0	0.21
2.01-5.00	0	0	0.16	0	0.086	0.0061	0	0.11
> 5.00	0	0	0.000088	0	0.000015	0	0	0.00017

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Lumban							
	Maytalang II	Primera Parang	Primera Pulo	Salac	Santo Niño	Segunda Parang	Segunda Pulo	Wawa
0.03-0.20	0.41	0.13	0.03	0.12	0.33	0.14	0.047	4.66
0.21-0.50	0.57	0.073	0.016	0.061	0.22	0.062	0.065	2.44
0.51-1.00	0.64	0.049	0.0061	0.1	0.12	0.057	0.011	1.2
1.01-2.00	2.13	0.011	0.027	0.026	0.013	0.017	0.015	0.19
2.01-5.00	0.37	0.038	0	0	0	0.026	0	0.52
> 5.00	0	0	0	0	0	0	0	0

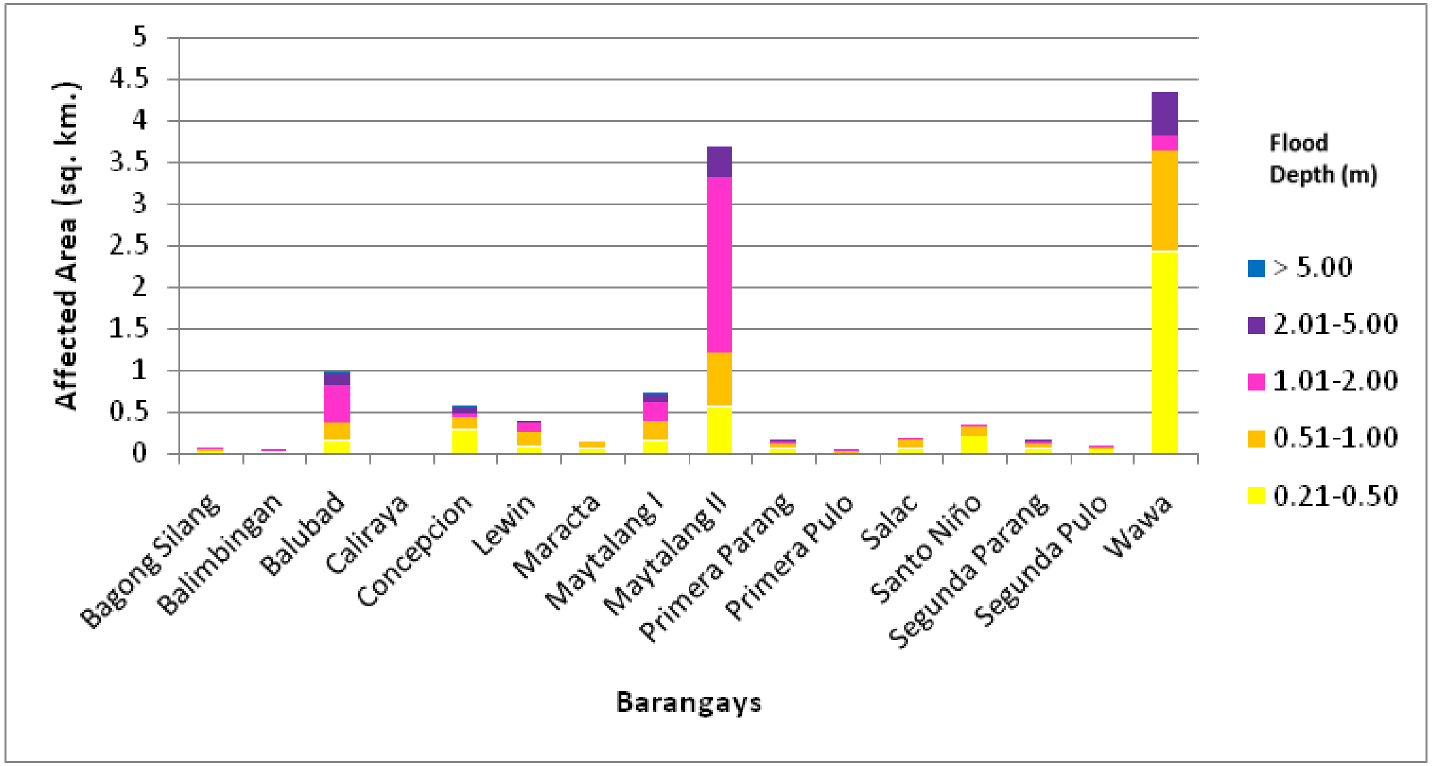


Figure 88. Areas affected by flooding in Lumban, Laguna for a 25-year return period rainfall event

For the Municipality of Magdalena, with an area of 29.61 square kilometers, 56.83% will experience flood levels of less than 0.20 meters. 9.37% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.44%, 6.92%, 6.54%, and 5.59% 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. Table 55 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected areas in Magdalena, Laguna during a 25-year rainfall return period

Affected Area	Affected Barangays in Magdalena							
(sq. km.) by flood depth (in m.)	Alipit	Baanan	Balanac	Bucal	Buenavista	Bungkol	Buo	Burlungan
0.03-0.20	1.2	0.32	0.3	0.59	0.59	1.76	0.56	1.16
0.21-0.50	0.17	0.032	0.13	0.27	0.19	0.19	0.07	0.12
0.51-1.00	0.096	0.012	0.24	0.065	0.25	0.027	0.071	0.031
1.01-2.00	0.11	0.0052	0.3	0.022	0.28	0.021	0.068	0.073
2.01-5.00	0.15	0.0013	0.28	0.033	0.19	0.025	0.064	0.16
> 5.00	0.087	0	0.35	0.2	0.0092	0.0013	0.034	0.039

Affected Area	Affected Barangays in Magdalena							
(sq. km.) by flood depth (in m.)	Cigaras	Halayhayin	Ibabang Atingay	Ibabang Butnong	Ilayang Atingay	Ilayang But-nong	Ilog	Malaking Ambling
0.03-0.20	0.23	0.94	0.26	0.98	0.74	0.42	0.11	0.44
0.21-0.50	0.098	0.1	0.051	0.081	0.14	0.015	0.039	0.042
0.51-1.00	0.19	0.016	0.049	0.047	0.14	0.013	0.078	0.015
1.01-2.00	0.28	0.015	0.033	0.055	0.071	0.019	0.17	0.022
2.01-5.00	0.26	0.11	0.044	0.019	0.061	0.018	0.11	0.072
> 5.00	0.057	0.07	0.14	0.00061	0.037	0.0078	0.0052	0.041

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Magdalena							
	Malinao	Maravilla	Munting Ambling	Poblacion	Sabang	Salasad	Tanawan	Tipunan
0.03-0.20	0.82	1.15	0.48	0.49	1.4	0.78	0.57	0.5
0.21-0.50	0.14	0.33	0.043	0.049	0.29	0.1	0.041	0.038
0.51-1.00	0.06	0.1	0.019	0.016	0.22	0.11	0.035	0.018
1.01-2.00	0.067	0.035	0.012	0.0095	0.22	0.12	0.03	0.0093
2.01-5.00	0.031	0.072	0.01	0.0086	0.16	0.07	0.002	0.002
> 5.00	0.019	0.35	0.0078	0	0.19	0.0011	0	0

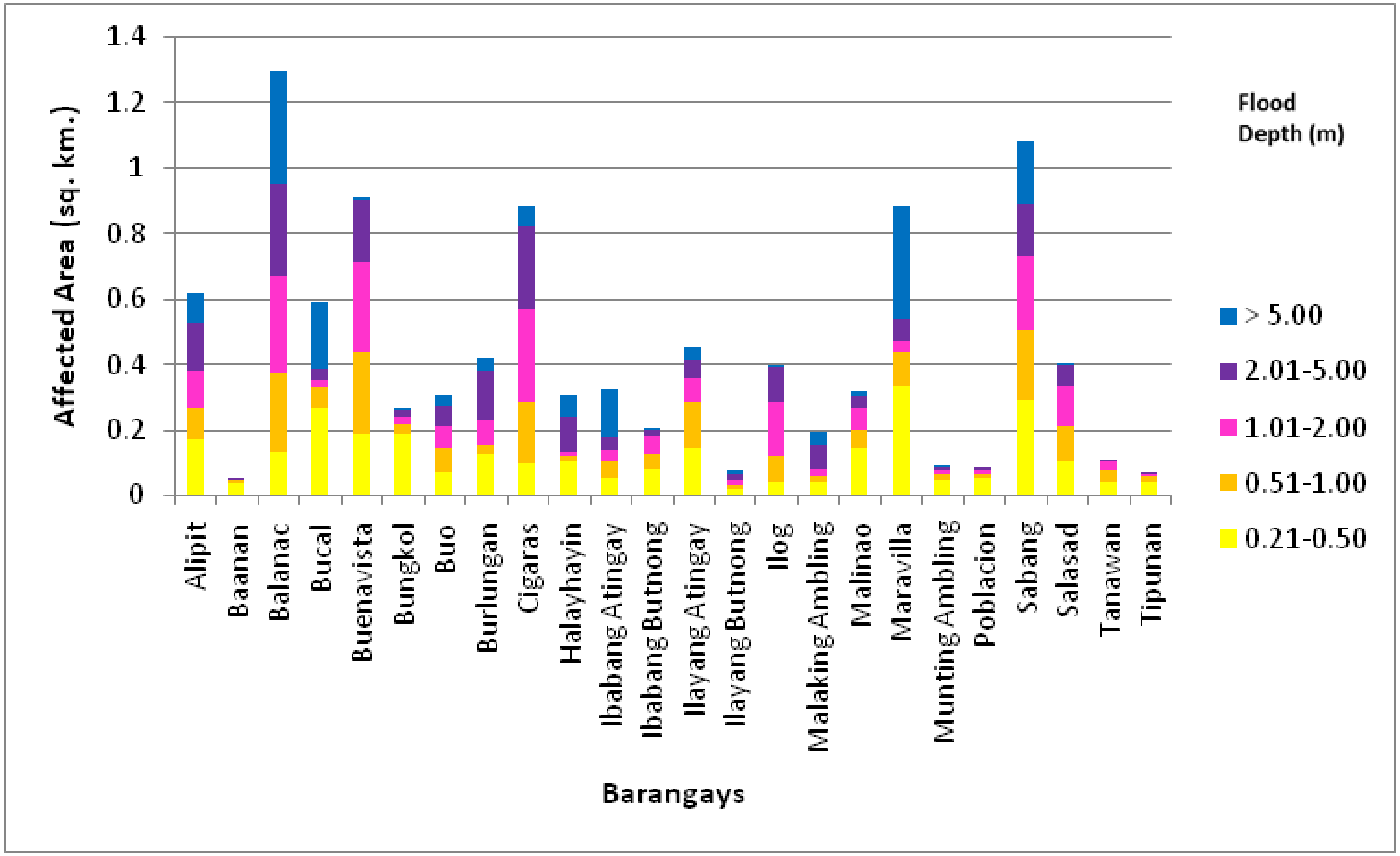


Figure 89. Areas affected by flooding in Magdalena, Laguna for a 25-year return period rainfall event

For the Municipality of Majayjay, with an area of 64.40 square kilometers, 5.18% will experience flood levels of less than 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.20%, 0.09%, 0.05%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 56 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 56. Affected areas in Majayjay, Laguna during a 25-year rainfall return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Majayjay					
	Balanac	Banilad	Banti	Burol	San Isidro	Tanawan
0.03-0.20	0.082	1.01	0.73	0.032	0.012	1.47
0.21-0.50	0.0034	0.08	0.032	0.000037	0.0013	0.095
0.51-1.00	0.00028	0.064	0.014	0	0.0013	0.051
1.01-2.00	0	0.026	0.0044	0	0	0.028
2.01-5.00	0	0.027	0	0	0	0.0053
> 5.00	0	0.0076	0	0	0	0

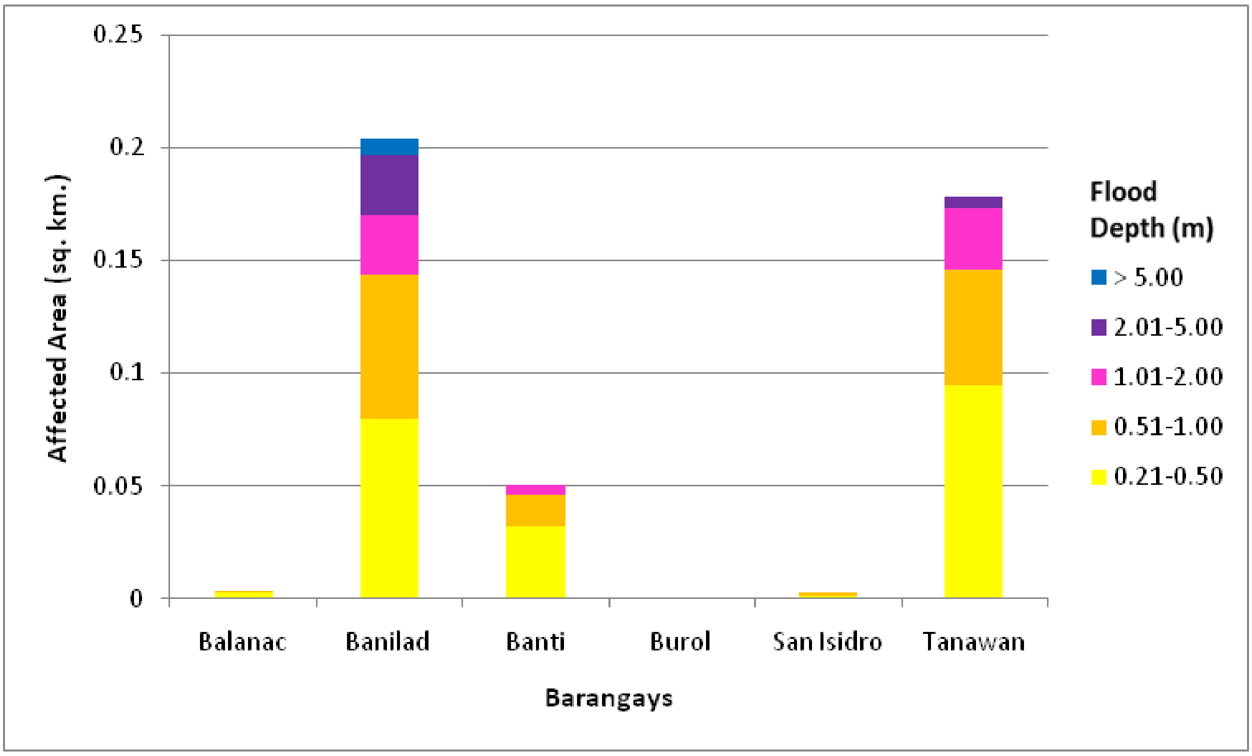


Figure 90. Areas affected by flooding in Majayjay, Laguna for a 25-year return period rainfall event

For the Municipality of Nagcarlan, with an area of 81.20 square kilometers, 23.93% will experience flood levels of less than 0.20 meters. 3.76% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.68%, 2.40%, 1.54%, and 1.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 57 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 57. Affected areas in Nagcarlan, Laguna during a 25-year rainfall return period

Affected Area	Affected Barangays in Nagcarlan							
(sq. km.) by flood depth (in m.)	Balayong	Banca-Banca	Bayaquitos	Buenavista	Buhanginan	Calumpang	Kanluran Ka-bubuhayan	Labangan
0.03-0.20	0.31	2.06	0.51	2.98	1.28	1.41	0.77	0.67
0.21-0.50	0.014	0.64	0.014	0.16	0.37	0.25	0.12	0.024
0.51-1.00	0.004	0.42	0.011	0.1	0.048	0.21	0.039	0.014
1.01-2.00	0.0011	0.34	0.006	0.045	0.0023	0.58	0.0068	0.0064
2.01-5.00	0.0002	0.16	0.0024	0.02	0	0.65	0.0017	0.00093
> 5.00	0	0.037	0	0.0066	0	0.58	0	0

Affected Area	Affected Barangays in Nagcarlan							
(sq. km.) by flood depth (in m.)	Lagulo	Lawaguin	Manaol	Maravilla	Sabang	Sibulan	Silangan Ka-bubuhayan	Wakat
0.03-0.20	0.41	2.25	0.78	1.8	0.33	1.54	0.24	2.09
0.21-0.50	0.012	0.096	0.28	0.5	0.021	0.11	0.028	0.41
0.51-1.00	0.0057	0.042	0.092	0.68	0.0024	0.055	0.009	0.44
1.01-2.00	0.0029	0.026	0.0014	0.5	0.00061	0.055	0.0041	0.37
2.01-5.00	0.0019	0.034	0.0012	0.3	0.00023	0.062	0.0002	0.017
> 5.00	0.0001	0.0027	0.000093	0.25	0.000078	0.0043	0	0.00081

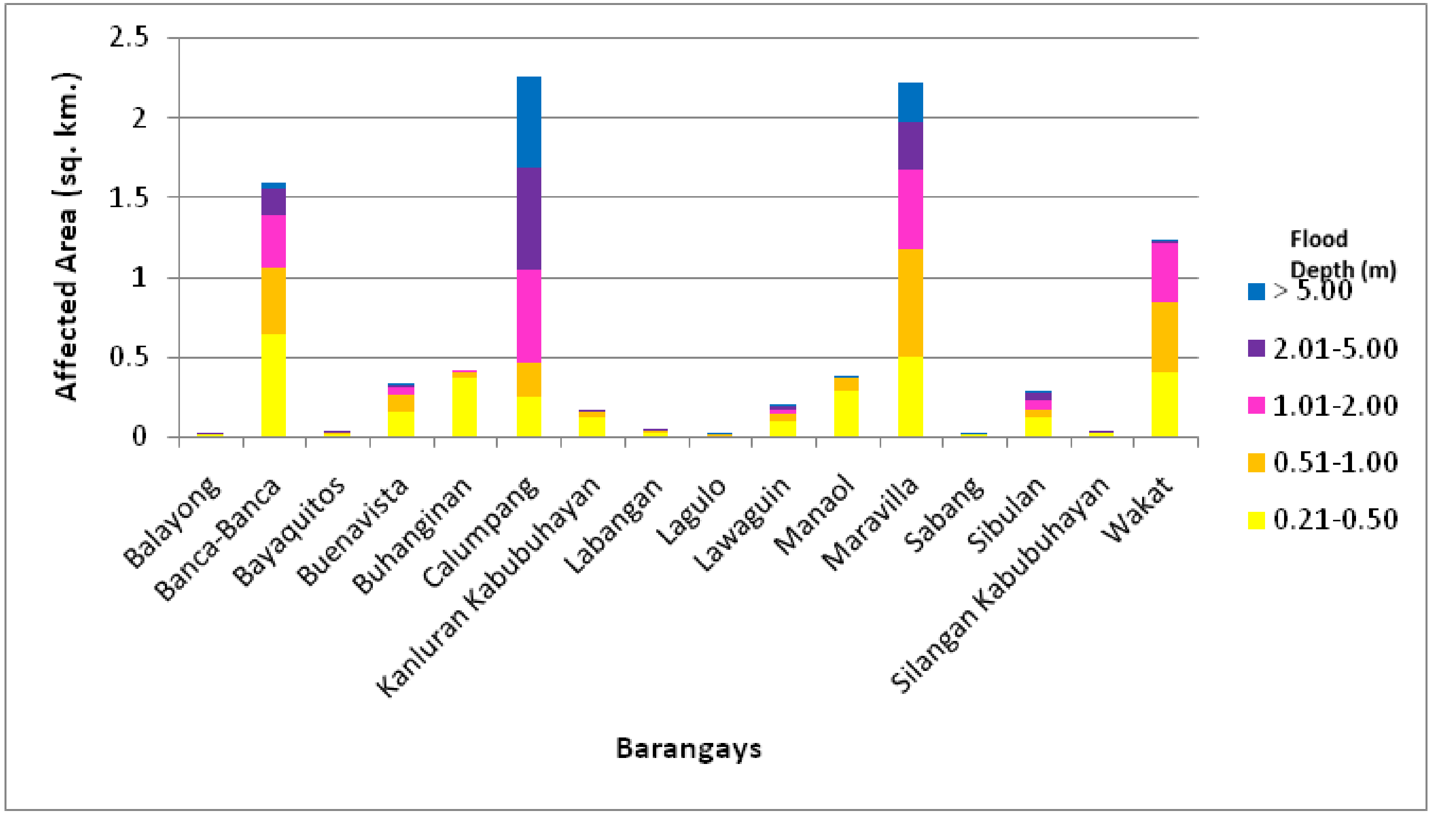


Figure 91. Areas affected by flooding in Nagcarlan, Laguna for a 25-year return period rainfall event

For the Municipality of Pagsanjan, with an area of 40.77 square kilometers, 38.03% will experience flood levels of less than 0.20 meters. 6.47% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 9.77%, 9.26%, 16.99%, and 2.76% 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. Table 58 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 58. Affected areas in Pagsanjan, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pagsanjan							
	Anibong	Barangay I	Barangay II	Biñan	Buboy	Cabanbanan	Calusiche	Dingin
0.03-0.20	2.39	0.081	0.19	0.069	1.61	0.47	0.5	2.69
0.21-0.50	0.16	0.021	0.052	0.074	0.38	0.18	0.28	0.15
0.51-1.00	0.071	0.029	0.0066	0.47	0.35	0.25	0.42	0.11
1.01-2.00	0.14	0.092	0.000012	1.04	0.51	0.24	0.9	0.15
2.01-5.00	0.21	0.057	0	0.033	0.39	0.19	0.54	0.38
> 5.00	0.15	0.035	0	0	0.071	0.024	0.19	0.29

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pagsanjan							
	Lambac	Layugan	Magdapio	Maulawin	Pinagsanjan	Sabang	Sampaloc	San Isidro
0.03-0.20	0.85	1.4	1.72	0.11	2.93	0.16	0.18	0.16
0.21-0.50	0.18	0.41	0.073	0.032	0.23	0.2	0.09	0.12
0.51-1.00	0.37	0.61	0.048	0.056	0.35	0.42	0.23	0.18
1.01-2.00	0.65	0.98	0.051	0.15	0.74	0.48	0.68	0.14
2.01-5.00	0.012	0.48	0.069	0.09	0.51	0.04	0.13	0
> 5.00	0.000054	0.032	0	0.012	0.29	0	0.034	0

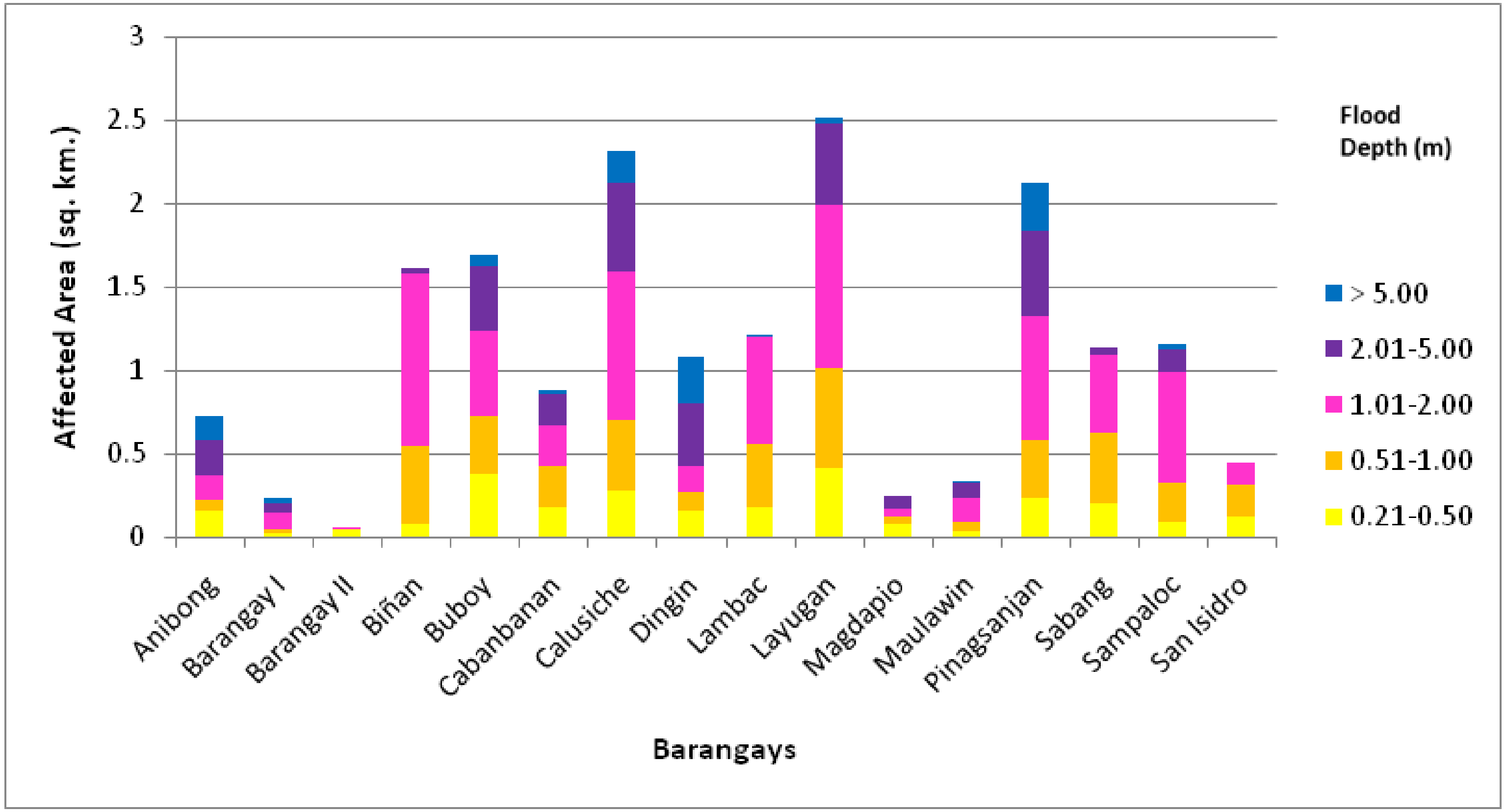


Figure 92. Areas affected by flooding in Pagsanjan, Laguna for a 25-year return period rainfall event

For the Municipality of Pila, with an area of 28.77 square kilometers, 53.69% will experience flood levels of less than 0.20 meters. 23.14% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 13.97%, 6.74%, 0.95%, and 0.69% 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. Table 59 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 59. Affected areas in Pila, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pila							
	Aplaya	Bagong Pook	Bukal	Bulilan Norte	Bulilan Sur	Concepcion	Labuin	Linga
0.03-0.20	0.38	1.07	0.85	0.29	0.26	1.45	0.58	0.39
0.21-0.50	0.16	0.57	0.22	0.074	0.4	1.15	0.3	0.24
0.51-1.00	0.075	0.27	0.095	0.17	0.17	0.76	0.2	0.2
1.01-2.00	0.0012	0.004	0.026	0.41	0.081	0.43	0.18	0.0002
2.01-5.00	0	0	0.0002	0.01	0.0045	0.015	0.0002	0
> 5.00	0	0	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pila								
	Masico	Mojon	Pansol	Pinagbayanan	San Antonio	San Miguel	Santa Clara Norte	Santa Clara Sur	Tubuan
0.03-0.20	0.71	1.95	1.76	0.62	1.3	1.45	0.43	0.49	1.46
0.21-0.50	0.23	0.46	0.56	0.34	0.34	0.45	0.11	0.25	0.8
0.51-1.00	0.081	0.14	0.21	0.2	0.35	0.098	0.061	0.1	0.82
1.01-2.00	0.026	0.042	0.075	0.097	0.22	0.0081	0.067	0.0026	0.26
2.01-5.00	0	0.19	0.0003	0	0.025	0	0.02	0	0.0025
> 5.00	0	0.2	0	0	0	0	0	0	0

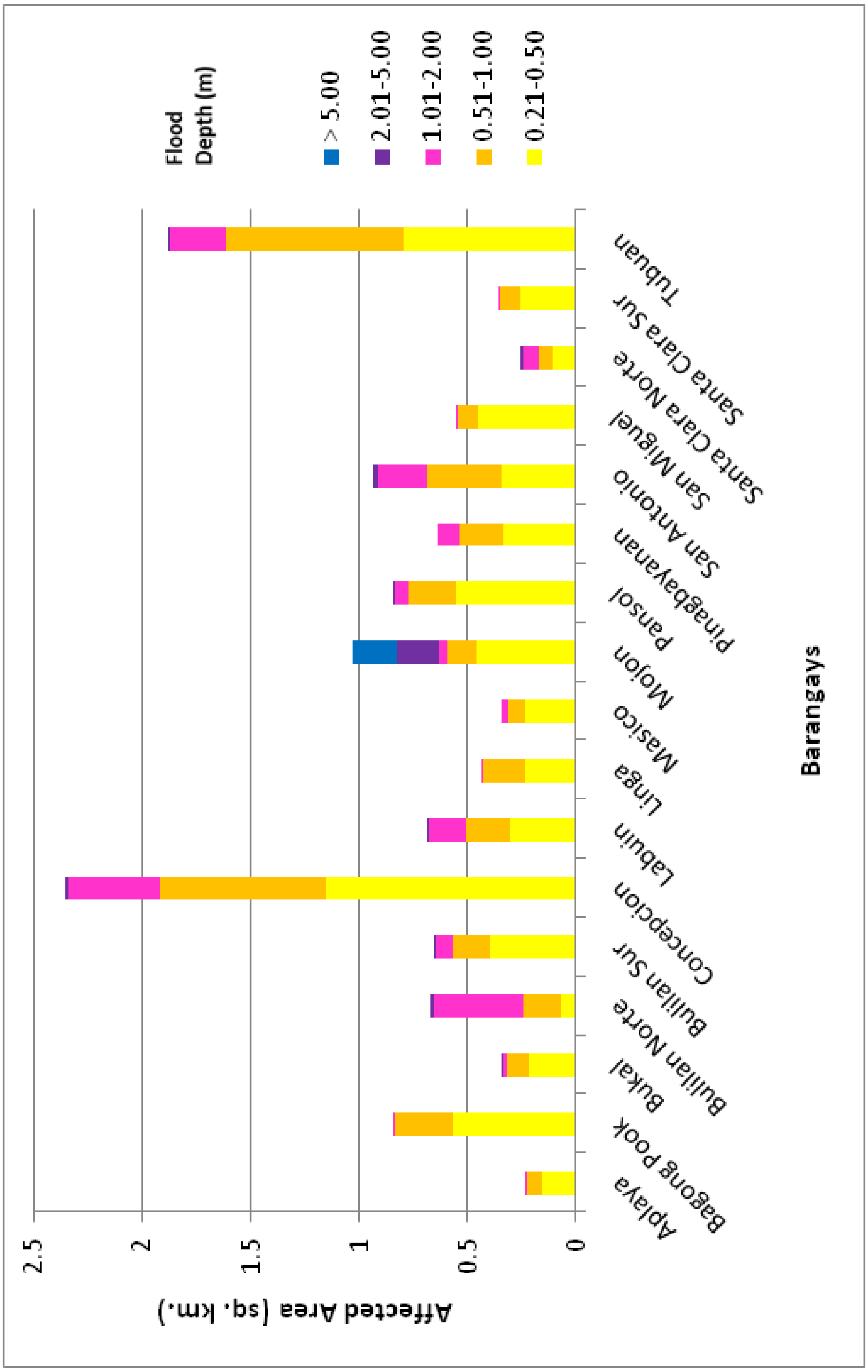


Figure 93. Areas affected by flooding in Pila, Laguna for a 25-year return period rainfall event

For the Municipality of Santa Cruz, with an area of 37.63 square kilometers, 44.06% will experience flood levels of less than 0.20 meters. 29.01% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 14.83%, 5.01%, 1.40%, and 1.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 60 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 60. Affected areas in Santa Cruz, Laguna during a 25-year rainfall return period

Affected Area	Affected Barangays in Santa Cruz								
(sq. km.) by flood depth (in m.)	Alipit	Bagumbayan	Baran-gay I	Barangay II	Barangay III	Barangay IV	Barangay V	Bubukal	Calios
0.03-0.20	0.13	1.81	0.053	0.073	0.039	0.082	0.07	1.05	0.3
0.21-0.50	0.063	0.96	0.039	0.02	0.0078	0.049	0.034	0.51	0.49
0.51-1.00	0.12	0.28	0.017	0.0049	0.00043	0.015	0.019	0.18	0.56
1.01-2.00	0.27	0.015	0	0	0	0	0.000054	0.0075	0.23
2.01-5.00	0.22	0	0	0	0	0	0	0	0.0021
> 5.00	0.13	0	0	0	0	0	0	0	0

Affected Area	Affected Barangays in Santa Cruz								
(sq. km.) by flood depth (in m.)	Duhat	Gatid	Jasaan	Labuin	Malinao	Oogong	Pagsawitan	Palasan	Patimbao
0.03-0.20	1.52	1.75	0.89	0.65	0.67	0.79	1.07	0.83	0.73
0.21-0.50	1.02	1.15	0.45	0.3	0.59	0.2	0.85	0.88	0.42
0.51-1.00	0.18	0.45	0.036	0.19	0.28	0.071	0.25	1.01	0.64
1.01-2.00	0.0058	0.038	0.0073	0.017	0.031	0.041	0.072	0.22	0.52
2.01-5.00	0	0	0	0	0	0.097	0.0003	0.099	0.038
> 5.00	0	0	0	0	0	0.17	0	0.06	0.043

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz							
	San Jose	San Juan	San Pablo Norte	San Pablo Sur	Santisima Cruz	Santo Angel Central	Santo Angel Norte	Santo An-gel Sur
0.03-0.20	1.47	0.96	0.14	0.61	0.34	0.34	0	0.18
0.21-0.50	0.76	0.48	0.24	0.63	0.21	0.11	0.36	0.11
0.51-1.00	0.29	0.24	0.081	0.45	0.022	0.023	0.075	0.079
1.01-2.00	0.0069	0.01	0	0.28	0.000046	0.025	0.073	0.02
2.01-5.00	0.00021	0.0003	0	0	0	0.026	0	0.042
> 5.00	0.000007	0	0	0	0	0	0	0

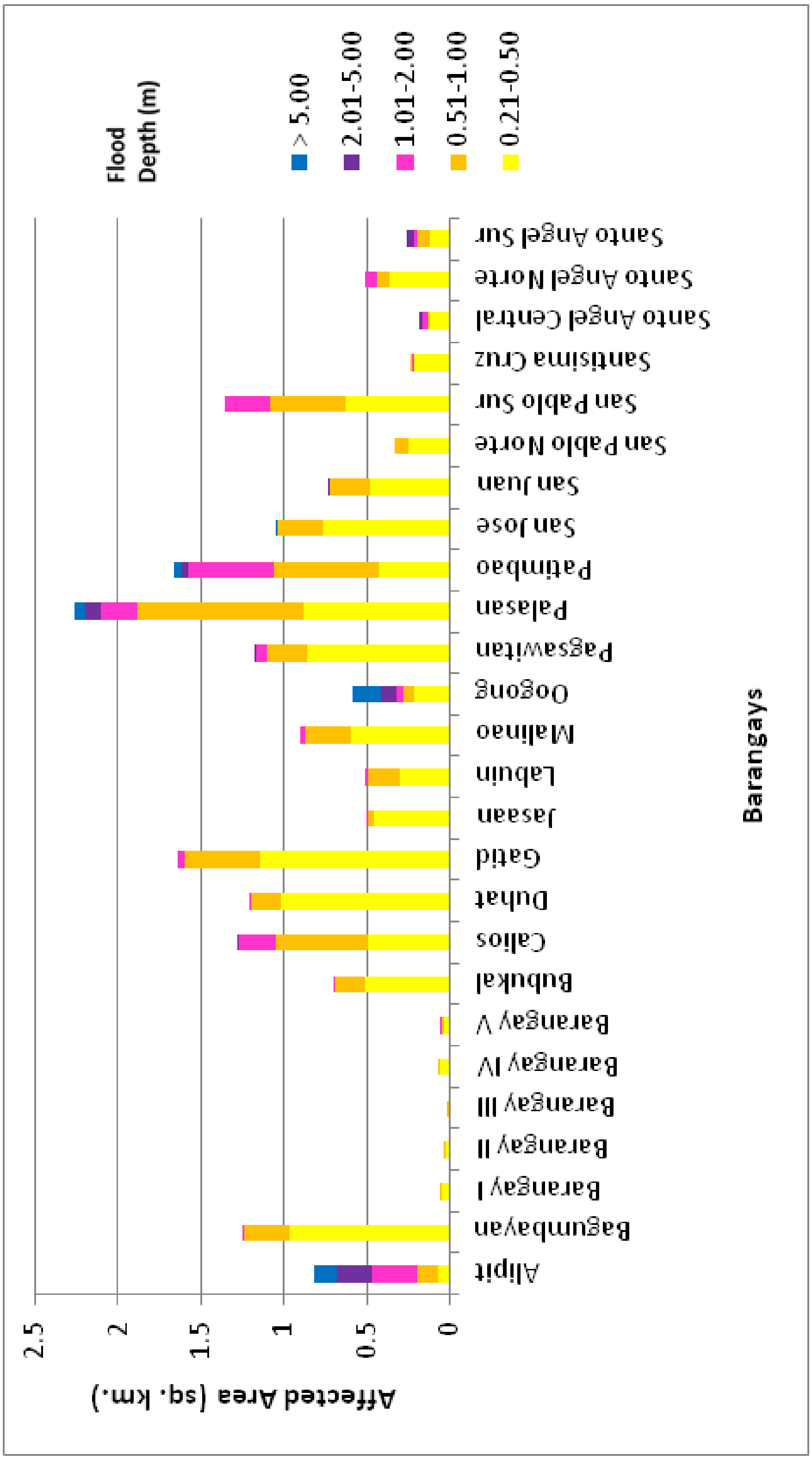


Figure 94. Areas affected by flooding in Santa Cruz, Laguna for a 25-year return period rainfall event

For the Municipality of Victoria, with an area of 28.37 square kilometers, 33.33% will experience flood levels of less than 0.20 meters. 19.29% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 18.87%, 13.47%, and 1.66% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 61 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 61. Affected areas in Victoria, Laguna during a 25-year rainfall return period

Affected Area	Affected Barangays in Victoria								
(sq. km.) by flood depth (in m.)	Banca-Ban-ca	Daniw	Masapang	Nanhaya	Pagalangan	San Benito	San Felix	San Francis-co	San Roque
0.03-0.20	1.47	0.96	0.14	0.61	0.34	0.34	0	0.18	1.309812
0.21-0.50	0.76	0.48	0.24	0.63	0.21	0.11	0.36	0.11	0.446305
0.51-1.00	0.29	0.24	0.081	0.45	0.022	0.023	0.075	0.079	0.180863
1.01-2.00	0.0069	0.01	0	0.28	0.000046	0.025	0.073	0.02	0.003971
2.01-5.00	0.00021	0.0003	0	0	0	0.026	0	0.042	0
> 5.00	0.000007	0	0	0	0	0	0	0	0

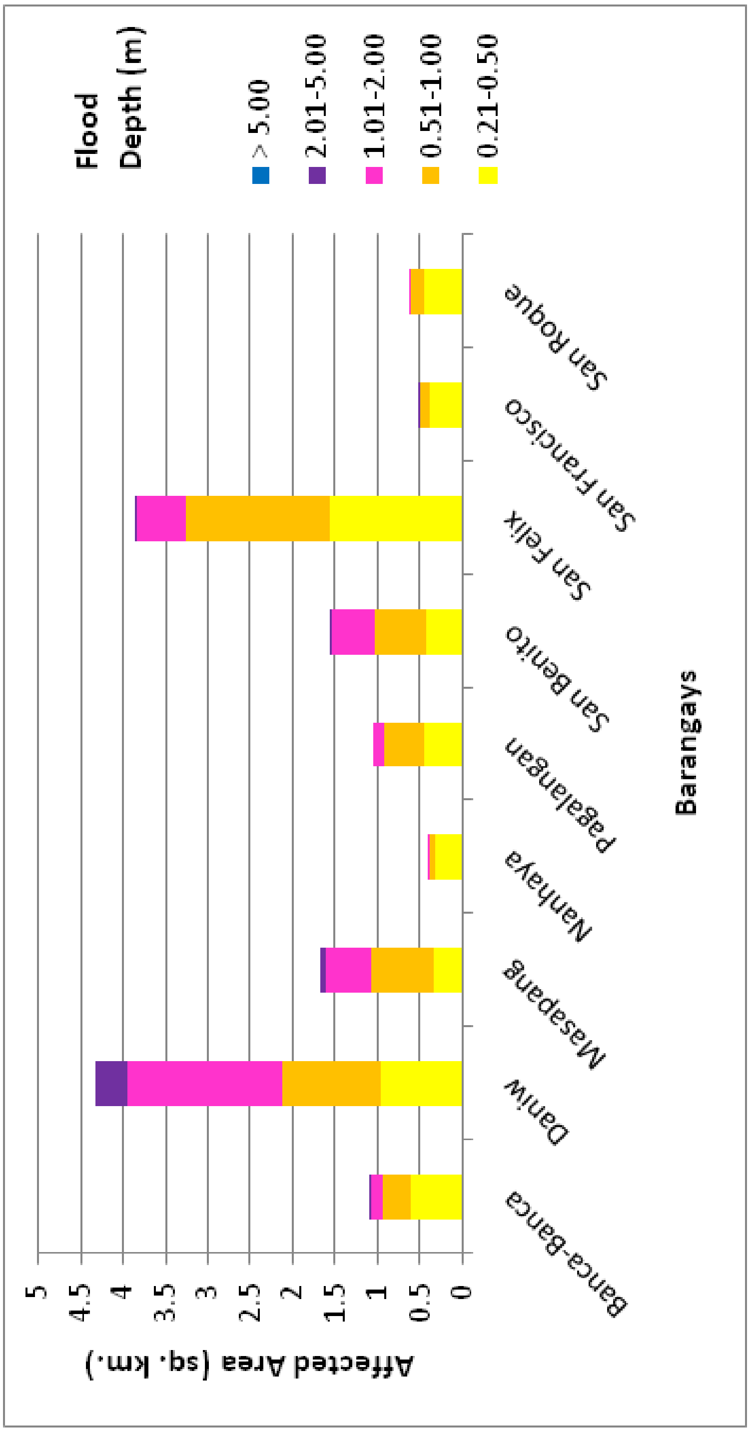


Figure 95. Areas affected by flooding in Victoria, Laguna for a 25-year return period rainfall event

For the 100-year return period, 3.86% of the Municipality of Calauan, with an area of 79.44 square kilometers, will experience flood levels of less than 0.20 meters; while 0.84% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.56%, 0.14%, 0.03%, and 0.0004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Table 62 depicts the areas affected in Calauan, in square kilometers, by flood depth per barangay.

Table 62. Affected areas in Calauan, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Calauan		
	Dayap	Lamot 2	Santo Tomas
0.03-0.20	0.4	2.53	0.14
0.21-0.50	0.16	0.25	0.25
0.51-1.00	0.13	0.098	0.21
1.01-2.00	0.052	0.036	0.021
2.01-5.00	0.000065	0.019	0.0062
> 5.00	0	0.0003	0

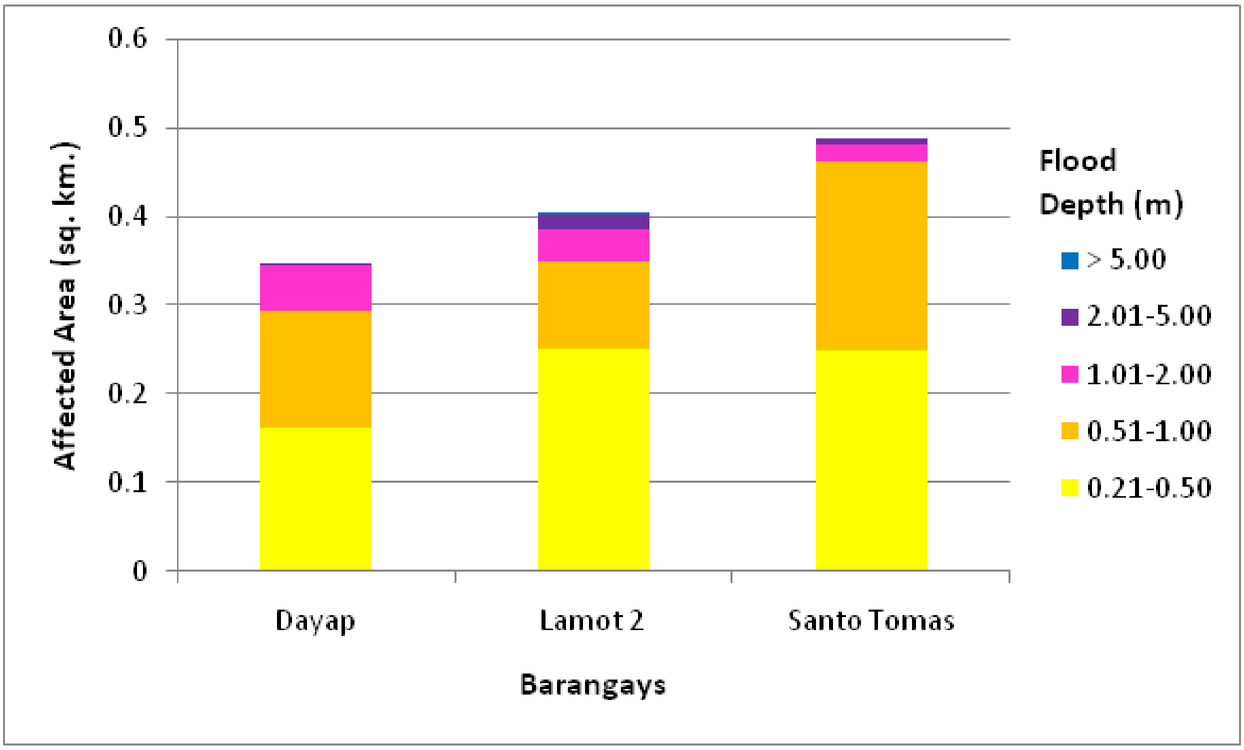


Figure 96. Affected areas in Calauan, Laguna during a 100-year rainfall return period

For the Municipality of Cavinti, with an area of 96.78 square kilometers, 0.90% will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.02%, 0.01%, 0.01%, and 0.001% 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. Table 63 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 63. Affected areas in Cavinti, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Cavinti		
	Anglas	Bangco	Bulajo
0.03-0.20	0.45	0.42	0.0026
0.21-0.50	0.018	0.021	0
0.51-1.00	0.013	0.009	0
1.01-2.00	0.0052	0.0052	0
2.01-5.00	0.0021	0.0055	0
> 5.00	0.0002	0.0007	0

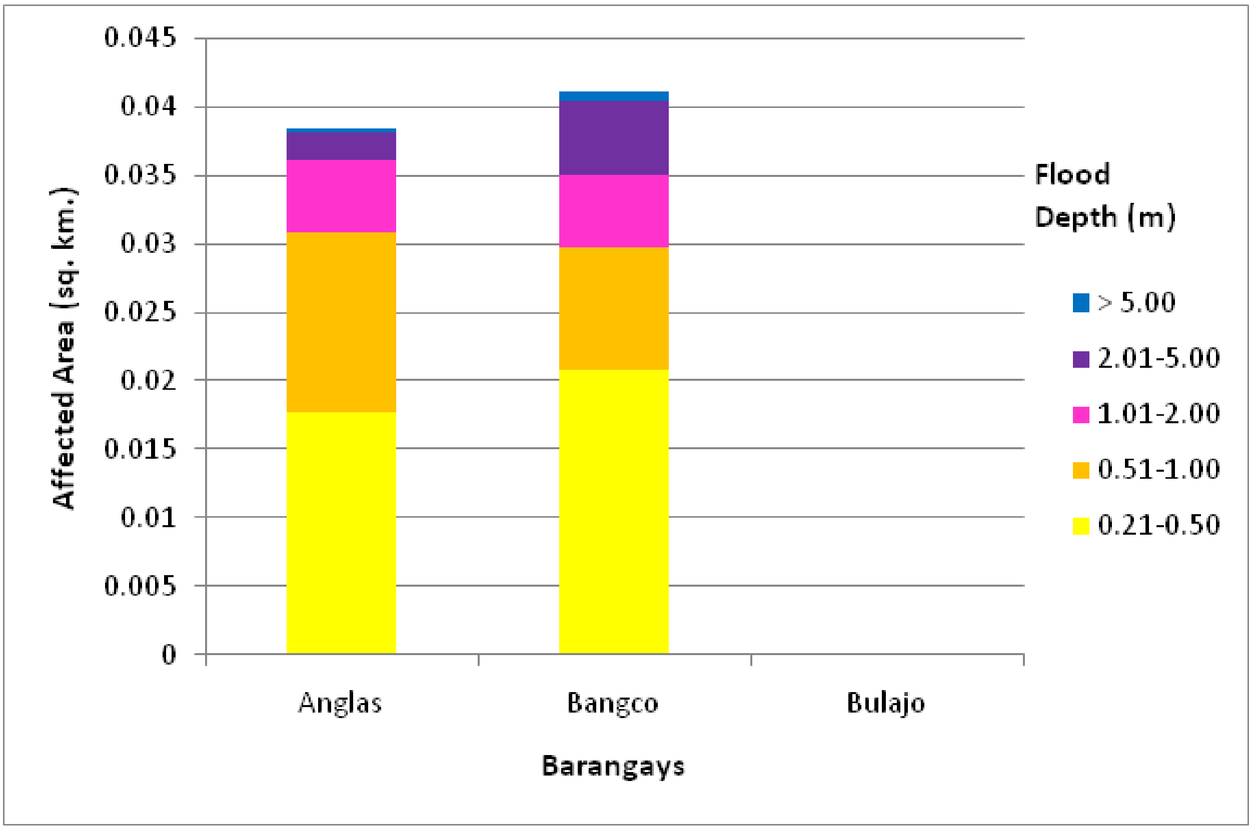


Figure 97. Areas affected by flooding in Cavinti, Laguna for a 100-year return period rainfall event

For the Municipality of Laguna Lake, with an area of 892.20 square kilometers, 0.03% will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.01%, 0.03%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 64 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 64. Affected areas in Laguna Lake, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Laguna lake Laguna Lake
0.03-0.20	0.26
0.21-0.50	0.15
0.51-1.00	0.071
1.01-2.00	0.25
2.01-5.00	0.083
> 5.00	0

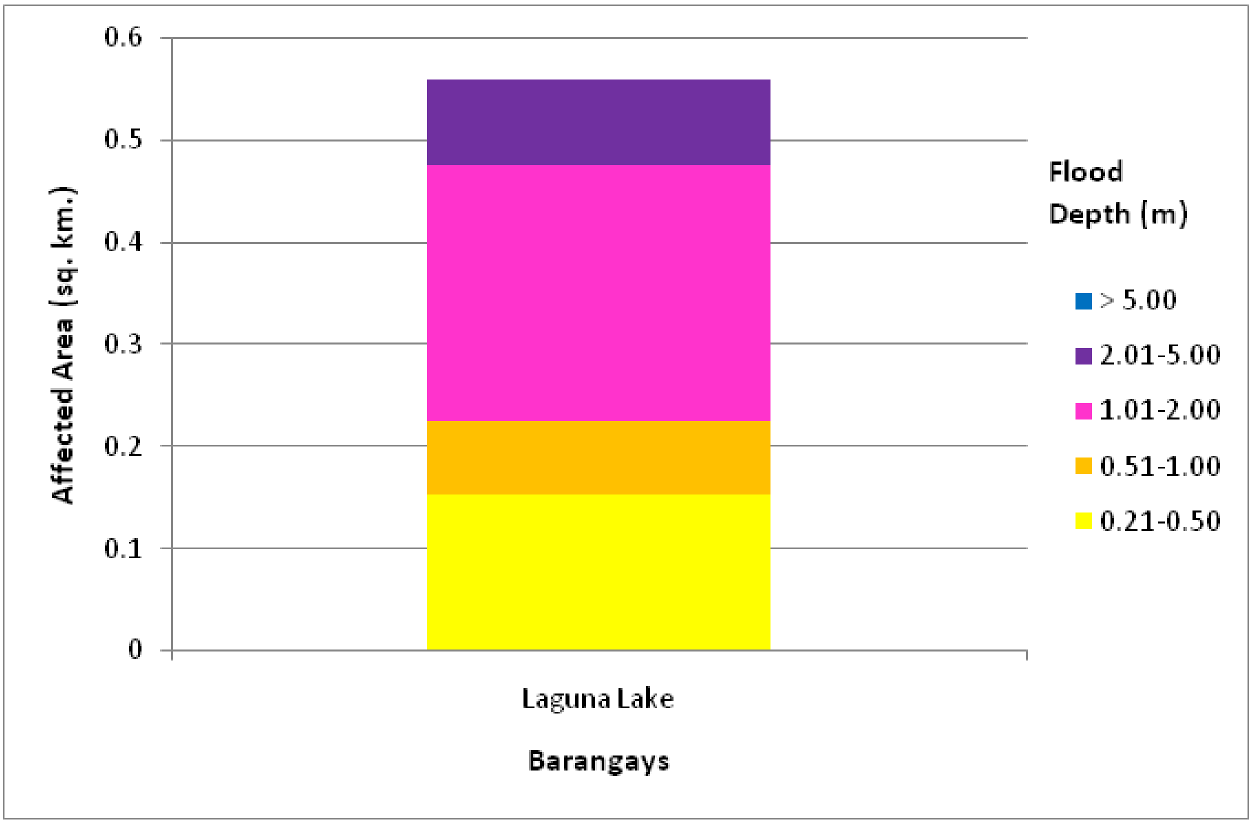


Figure 98. Areas affected by flooding in Laguna Lake, Laguna for a 100-year return period rainfall event

For the Municipality of Liliw, with an area of 36.20 square kilometers, 1.47% will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.09%, 0.35%, and 0.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 65 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 65. Affected areas in Liliw, Laguna during a 100-year rainfall return period

Affected Area	Affected Barangays in Liliw			
(sq. km.) by flood depth (in m.)	Dagatan	Daniw	Dita	Mojon
0.03-0.20	0.054	0.08	0.012	0.38
0.21-0.50	0.0003	0.0025	0.00055	0.041
0.51-1.00	0	0.00052	0.00035	0.017
1.01-2.00	0	0.00029	0.000009	0.031
2.01-5.00	0	0	0	0.13
> 5.00	0	0	0	0.05

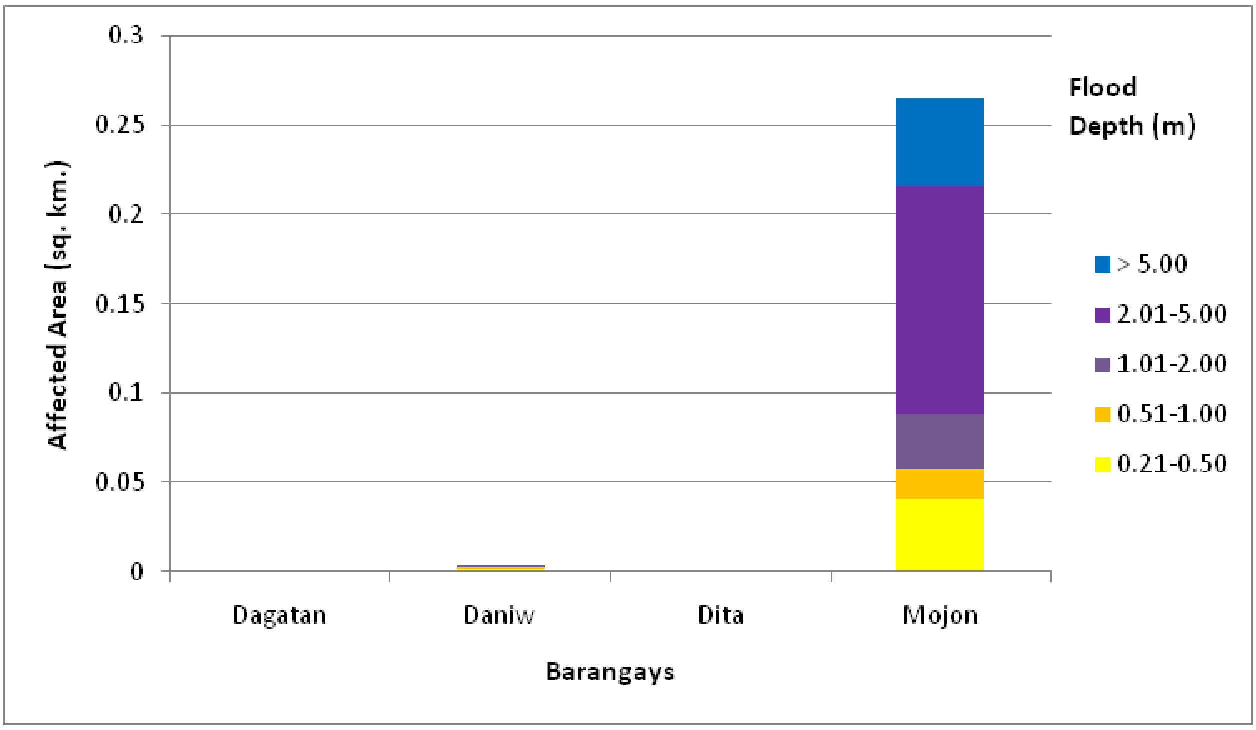


Figure 99. Areas affected by flooding in Liliw, Laguna for a 100-year return period rainfall event

For the Municipality of Luisiana, with an area of 61.01 square kilometers, 4.50% will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.07%, 0.07%, 0.15%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 66 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 66. Affected areas in Luisiana, Laguna during a 100-year rainfall return period

Affected Area	Affected Barangays in Luisiana	
(sq. km.) by flood depth (in m.)	San Diego	San Salvador
0.03-0.20	0.0012	2.75
0.21-0.50	0	0.065
0.51-1.00	0	0.045
1.01-2.00	0	0.044
2.01-5.00	0	0.09
> 5.00	0	0.077

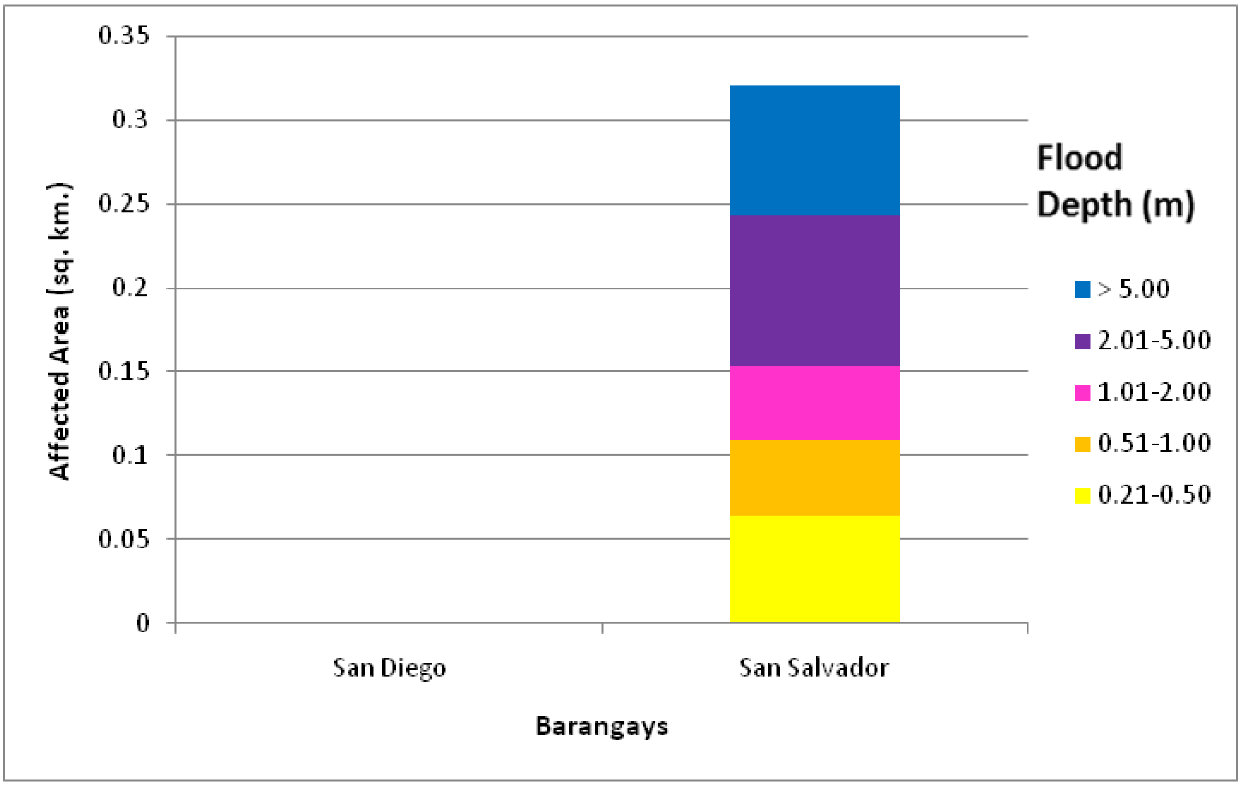


Figure 100. Areas affected by flooding in Luisiana, Laguna for a 100-year return period rainfall event

For the Municipality of Lumban, with an area of 117.34 square kilometers, 8.81% will experience flood levels of less than 0.20 meters. 3.50% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.89%, 2.71%, 1.88%, and 0.001% 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. Table 67 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 67. Affected areas in Lumban, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Lumban							
	Bagong Silang	Balimbingan	Balubad	Caliraya	Concepcion	Lewin	Maracta	Maytalang I
0.03-0.20	0.78	0.078	1.73	0.017	1.19	0.88	0.12	0.32
0.21-0.50	0.04	0.022	0.17	0	0.33	0.092	0.063	0.13
0.51-1.00	0.022	0.017	0.18	0	0.14	0.13	0.087	0.16
1.01-2.00	0.0063	0.021	0.44	0	0.084	0.18	0	0.36
2.01-5.00	0	0	0.25	0	0.092	0.012	0	0.12
> 5.00	0	0	0.00079	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Lumban							
	Maytalang II	Primera Parang	Primera Pulo	Salac	Santo Niño	Segunda Parang	Segunda Pulo	Wawa
0.03-0.20	0.33	0.11	0.026	0.11	0.28	0.13	0.04	4.22
0.21-0.50	0.49	0.081	0.015	0.055	0.2	0.055	0.06	2.3
0.51-1.00	0.55	0.063	0.01	0.097	0.18	0.066	0.023	1.65
1.01-2.00	1.62	0.013	0.028	0.052	0.021	0.028	0.016	0.31
2.01-5.00	1.14	0.04	0	0	0	0.028	0	0.52
> 5.00	0	0	0	0	0	0	0	0

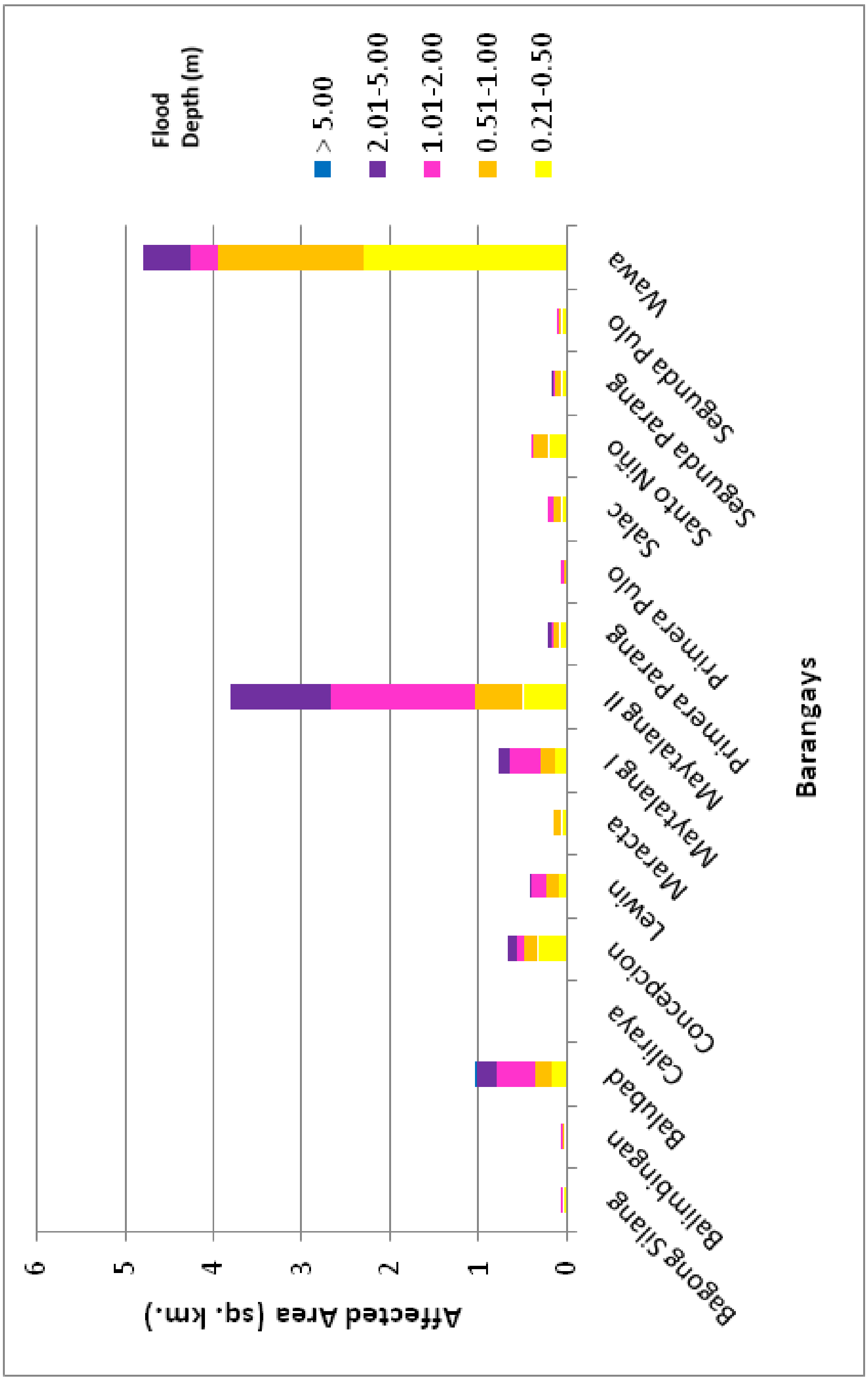


Figure 101. Areas affected by flooding in Lumban, Laguna for a 100-year return period rainfall event

For the Municipality of Magdalena, with an area of 29.61 square kilometers, 52.26% will experience flood levels of less than 0.20 meters. 9.97% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.53%, 7.92%, 8.56%, and 6.40% 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. Table 68 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 68. Affected areas in Magdalena, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Magdalena							
	Alipit	Baanan	Balanac	Bucal	Buenavista	Bungkol	Buo	Burlungan
0.03-0.20	1.04	0.3	0.16	0.53	0.51	1.68	0.53	1.12
0.21-0.50	0.22	0.034	0.092	0.29	0.16	0.25	0.071	0.14
0.51-1.00	0.13	0.015	0.18	0.089	0.25	0.033	0.072	0.032
1.01-2.00	0.13	0.0063	0.36	0.03	0.34	0.024	0.078	0.048
2.01-5.00	0.2	0.0012	0.43	0.031	0.23	0.028	0.072	0.19
> 5.00	0.094	0	0.39	0.22	0.012	0.0023	0.039	0.05

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Magdalena							
	Cigaras	Halayhayin	Ibabang Atingay	Ibabang Butnong	Ilayang Atingay	Ilayang Butnong	Ilog	Malaking Ambling
0.03-0.20	0.15	0.91	0.23	0.96	0.69	0.41	0.086	0.42
0.21-0.50	0.056	0.12	0.049	0.094	0.15	0.019	0.029	0.052
0.51-1.00	0.11	0.023	0.054	0.051	0.14	0.013	0.057	0.016
1.01-2.00	0.34	0.014	0.04	0.059	0.095	0.021	0.16	0.016
2.01-5.00	0.38	0.098	0.041	0.026	0.056	0.021	0.17	0.069
> 5.00	0.077	0.083	0.17	0.00066	0.057	0.0092	0.0094	0.061

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Magdalena							
	Malinao	Maravilla	Munting Ambling	Poblacion	Sabang	Salasad	Tanawan	Tipunan
0.03-0.20	0.78	1.05	0.46	0.47	1.21	0.73	0.56	0.49
0.21-0.50	0.16	0.36	0.052	0.063	0.28	0.12	0.045	0.046
0.51-1.00	0.064	0.14	0.02	0.022	0.27	0.095	0.036	0.019
1.01-2.00	0.042	0.053	0.014	0.011	0.27	0.14	0.034	0.012
2.01-5.00	0.073	0.052	0.014	0.011	0.24	0.097	0.0036	0.0026
> 5.00	0.021	0.38	0.0098	0	0.22	0.0017	0	0

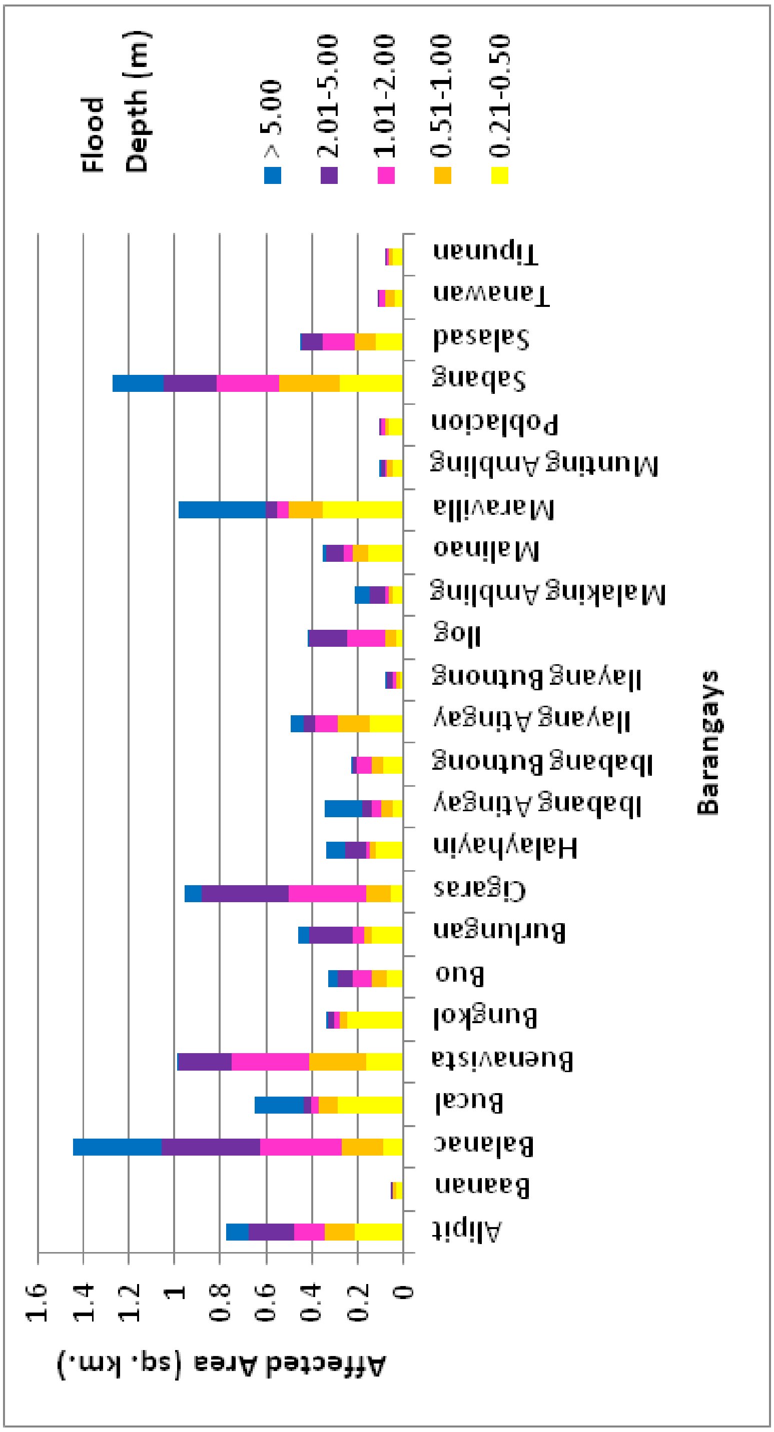


Figure 102. Areas affected by flooding in Magdalena, Laguna for a 100-year return period rainfall event

For the Municipality of Majayjay, with an area of 64.40 square kilometers, 5.09% will experience flood levels of less than 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.22%, 0.11%, 0.06%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 69 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 69. Affected areas in Majayjay, Laguna during a 100-year rainfall return period

Affected Area	Affected Barangays in Majayjay					
(sq. km.) by flood depth (in m.)	Balanac	Banilad	Banti	Burol	San Isidro	Tanawan
0.03-0.20	0.081	0.99	0.72	0.032	0.012	1.45
0.21-0.50	0.0039	0.084	0.036	0.00024	0.0011	0.1
0.51-1.00	0.00058	0.068	0.017	0	0.0015	0.057
1.01-2.00	0	0.034	0.0063	0	0	0.033
2.01-5.00	0	0.032	0.0002	0	0	0.0074
> 5.00	0	0.009	0	0	0	0

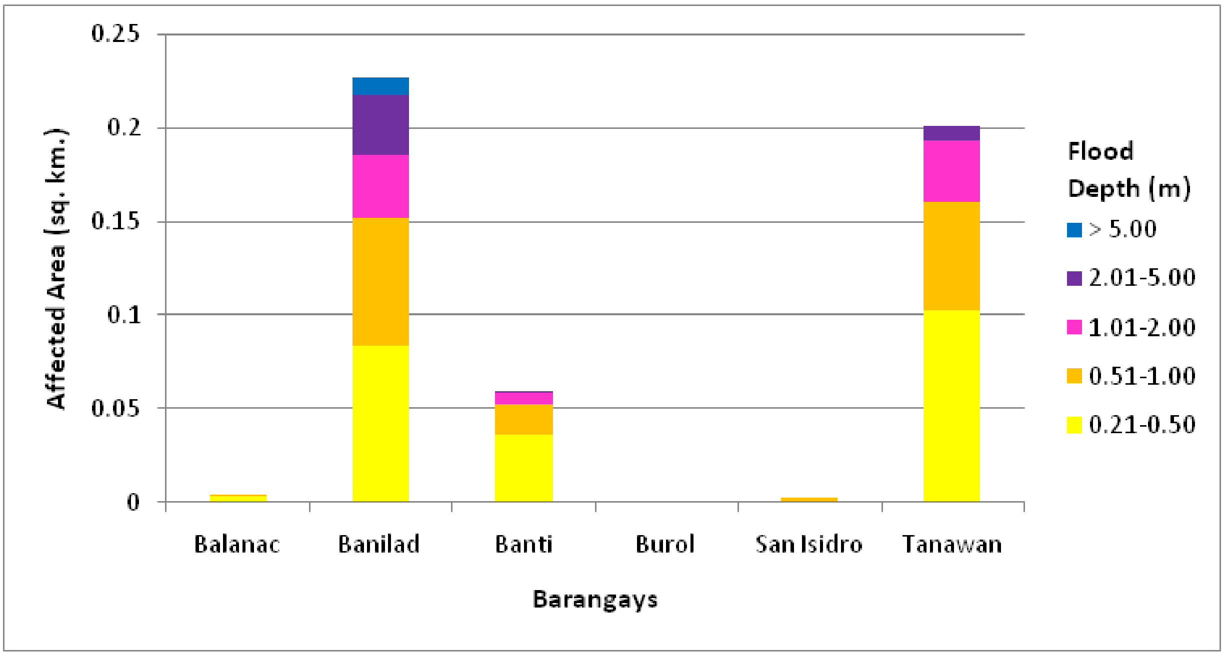


Figure 103. Areas affected by flooding in Majayjay, Laguna for a 100-year return period rainfall event

For the Municipality of Nagcarlan, with an area of 81.20 square kilometers, 22.65% will experience flood levels of less than 0.20 meters. 3.90% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.82%, 2.53%, 1.96%, and 1.46% 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. Table 70 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 70. Affected areas in Nagcarlan, Laguna during a 100-year rainfall return period

Affected Area	Affected Barangays in Nagcarlan							
(sq. km.) by flood depth (in m.)	Balayong	Banca-Banca	Bayaquitos	Buenavista	Buhanginan	Calumpang	Kanluran Ka-bubuhayan	Labangan
0.03-0.20	0.3	1.85	0.5	2.95	1.22	1.29	0.74	0.65
0.21-0.50	0.017	0.69	0.016	0.17	0.42	0.25	0.14	0.024
0.51-1.00	0.0048	0.48	0.011	0.12	0.061	0.14	0.046	0.015
1.01-2.00	0.0011	0.37	0.0066	0.053	0.0018	0.38	0.014	0.0075
2.01-5.00	0.0003	0.19	0.0032	0.024	0	0.89	0.0028	0.00091
> 5.00	0	0.081	0	0.0074	0	0.73	0	0

Affected Area	Affected Barangays in Nagcarlan							
(sq. km.) by flood depth (in m.)	Lagulo	Lawaguin	Manaol	Maravilla	Sabang	Sibulan	Silangan Ka-bubuhayan	Wakat
0.03-0.20	0.4	2.2	0.72	1.62	0.31	1.46	0.23	1.95
0.21-0.50	0.013	0.11	0.32	0.41	0.027	0.13	0.036	0.41
0.51-1.00	0.006	0.049	0.13	0.68	0.004	0.063	0.01	0.48
1.01-2.00	0.0026	0.028	0.0026	0.66	0.00047	0.068	0.0052	0.46
2.01-5.00	0.0019	0.038	0.0016	0.31	0.00034	0.1	0.0004	0.03
> 5.00	0.0001	0.004	0.000093	0.35	0.00011	0.0082	0	0.0013

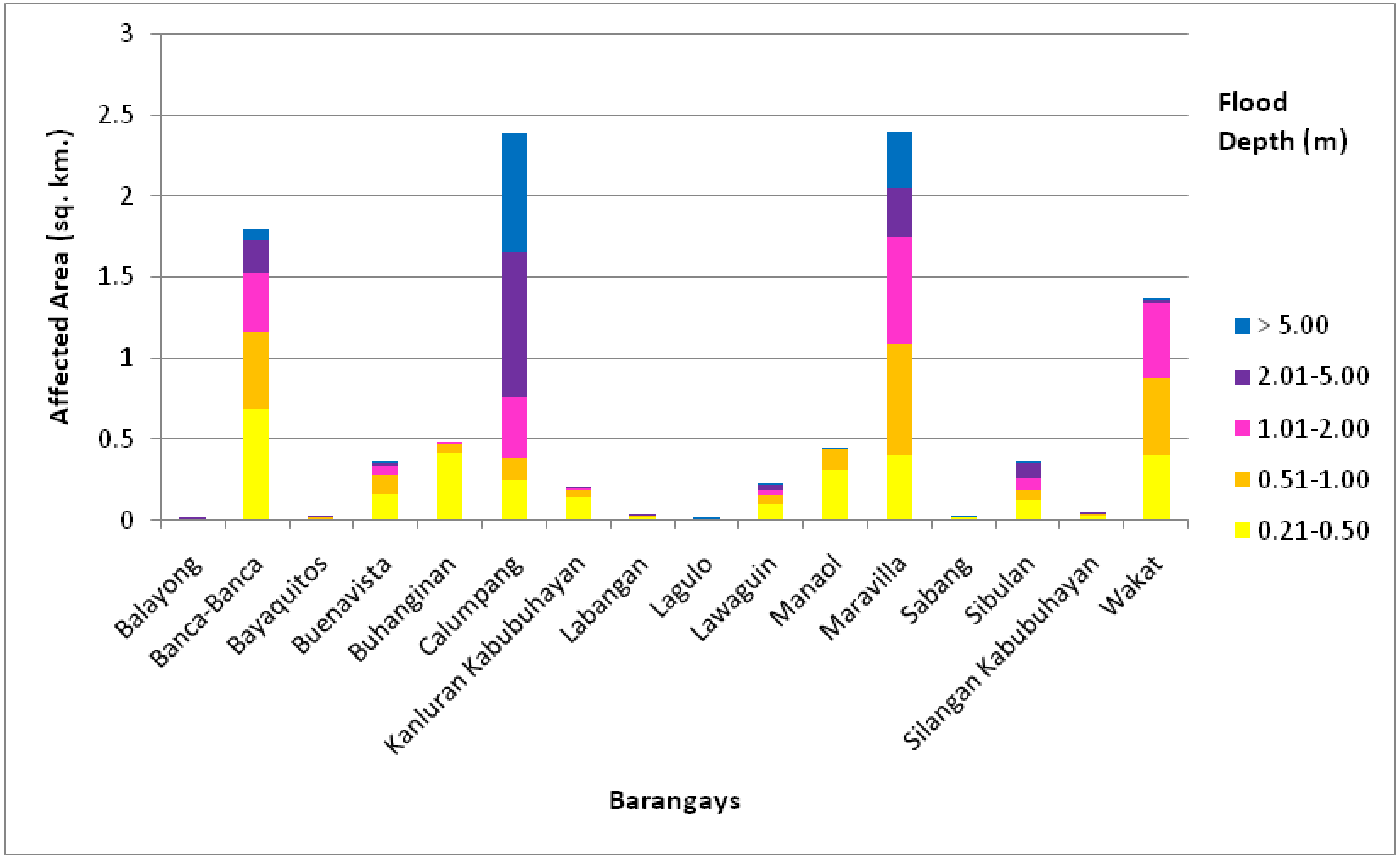


Figure 104. Areas affected by flooding in Nagcarlan, Laguna for a 100-year return period rainfall event

For the Municipality of Pagsanjan, with an area of 40.77 square kilometers, 37.38% will experience flood levels of less than 0.20 meters. 5.57% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 8.51%, 18.25%, 11.49%, and 3.11% 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. Table 71 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 71. Affected areas in Pagsanjan, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pagsanjan							
	Anibong	Barangay I	Barangay II	Biñan	Buboy	Cabanbanan	Calusiche	Dingin
0.03-0.20	2.34	0.12	0.25	0.03	1.24	0.26	0.42	2.63
0.21-0.50	0.16	0.021	0.061	0.036	0.43	0.17	0.21	0.16
0.51-1.00	0.068	0.03	0.034	0.16	0.45	0.3	0.37	0.11
1.01-2.00	0.076	0.089	0.0045	1.29	0.57	0.32	0.82	0.13
2.01-5.00	0.29	0.062	0	0.17	0.51	0.27	0.82	0.43
> 5.00	0.18	0.036	0	0	0.093	0.026	0.2	0.31

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pagsanjan							
	Lambac	Layugan	Magdapio	Maulawin	Pinagsanjan	Sabang	Sampaloc	San Isidro
0.03-0.20	0.86	1.21	1.87	0.095	3.49	0.086	0.14	0.19
0.21-0.50	0.19	0.26	0.077	0.036	0.24	0.077	0.067	0.067
0.51-1.00	0.4	0.47	0.05	0.057	0.35	0.34	0.15	0.13
1.01-2.00	0.62	1.02	0.049	0.13	0.74	0.64	0.67	0.26
2.01-5.00	0.012	0.88	0.088	0.11	0.54	0.15	0.28	0.056
> 5.00	0.0001	0.071	0.001	0.013	0.3	0	0.036	0

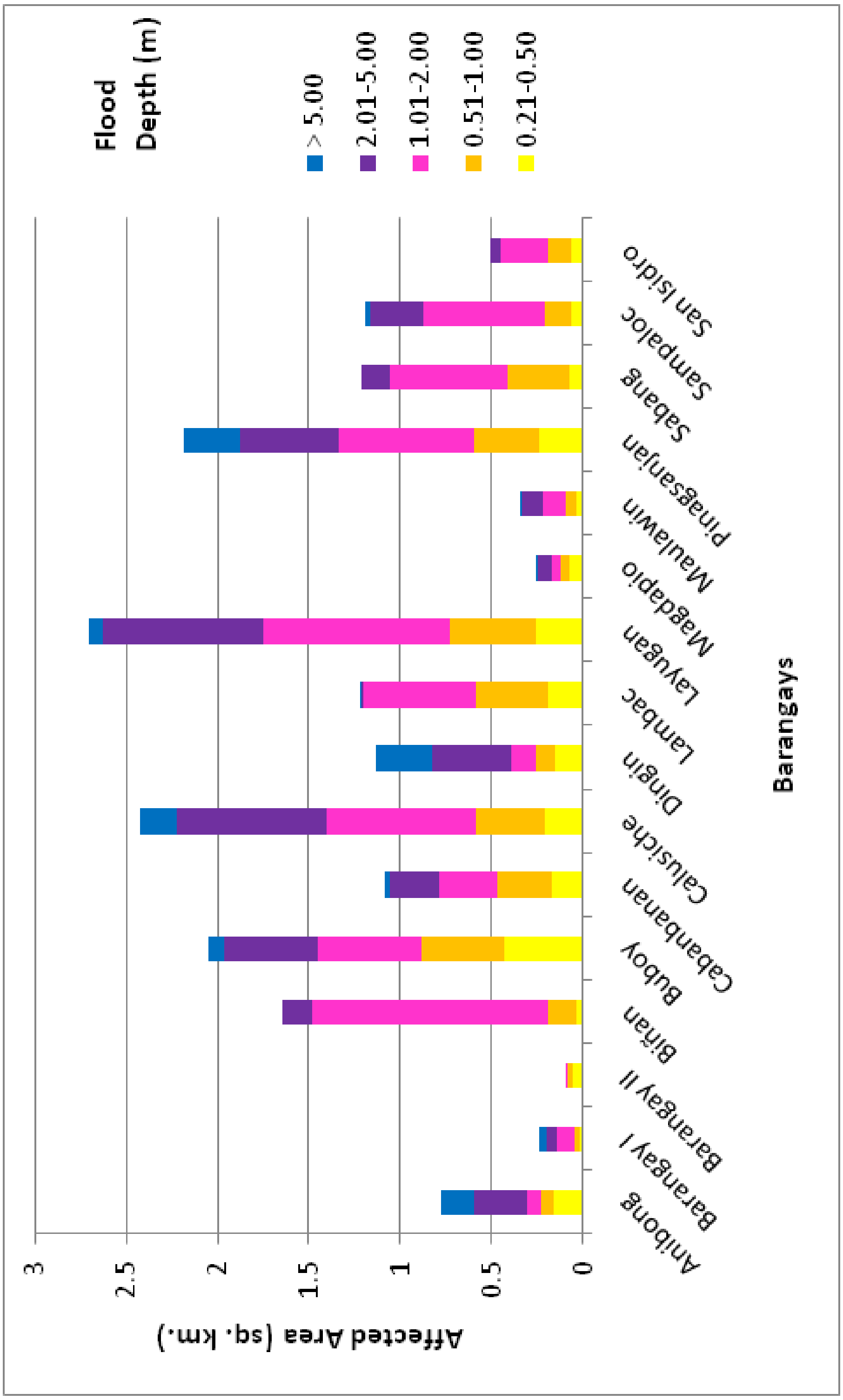


Figure 105. Areas affected by flooding in Pagsanjan, Laguna for a 100-year return period rainfall event

For the Municipality of Pila, with an area of 28.77 square kilometers, 52.20% will experience flood levels of less than 0.20 meters. 22.48% of the area will experience flood levels of 0.21 to 0.50 meters, Meanwhile, 13.74%, 8.60%, 1.01%, and 1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Table 72 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 72. Affected areas in Pila, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pila							
	Aplaya	Bagong Pook	Bukal	Bulilan Norte	Bulilan Sur	Concepcion	Labuin	Linga
0.03-0.20	0.32	0.88	0.84	0.31	0.43	1.17	0.5	0.33
0.21-0.50	0.17	0.62	0.21	0.035	0.36	1.13	0.3	0.17
0.51-1.00	0.097	0.4	0.11	0.072	0.046	0.89	0.22	0.29
1.01-2.00	0.0047	0.0083	0.031	0.51	0.059	0.58	0.24	0.024
2.01-5.00	0	0	0.0005	0.033	0.025	0.033	0.0053	0
> 5.00	0	0	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pila								
	Masico	Mojon	Pansol	Pinagbayanan	San Antonio	San Miguel	Santa Clara Norte	Santa Clara Sur	Tubuan
0.03-0.20	0.79	1.81	2.01	0.53	1.37	1.33	0.44	0.65	1.3
0.21-0.50	0.18	0.55	0.41	0.33	0.36	0.55	0.089	0.17	0.84
0.51-1.00	0.059	0.16	0.15	0.26	0.25	0.11	0.062	0.043	0.72
1.01-2.00	0.018	0.048	0.046	0.13	0.24	0.006	0.065	0.00085	0.47
2.01-5.00	0	0.12	0	0	0.031	0.00038	0.03	0	0.0054
> 5.00	0	0.29	0	0	0	0	0	0	0

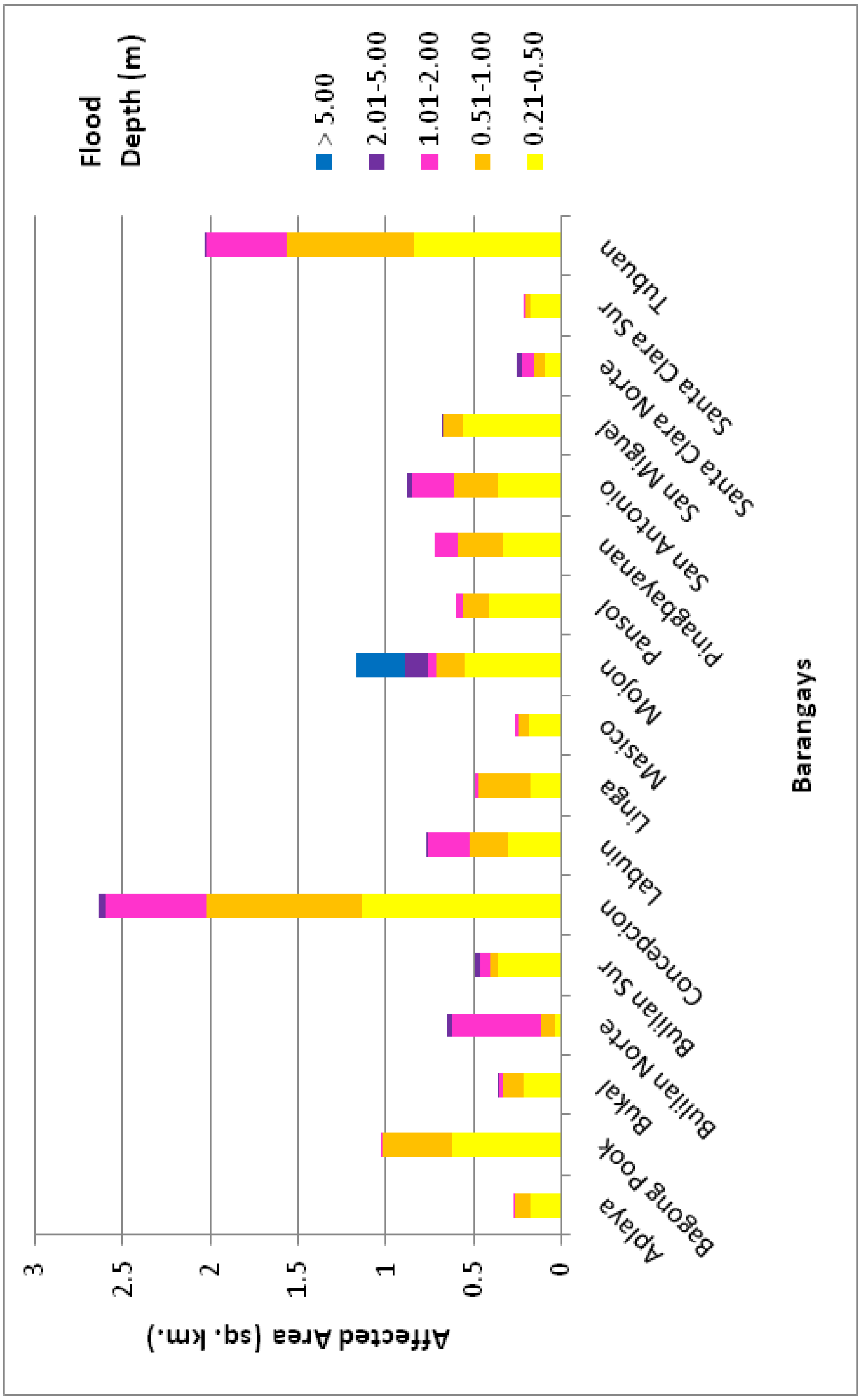


Figure 106. Areas affected by flooding in Pila, Laguna for a 100-year return period rainfall event

For the Municipality of Santa Cruz, with an area of 37.63 square kilometers, 36.71% will experience flood levels of less than 0.20 meters. 29.70% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 19.26%, 8.29%, 2.10%, and 1.11% 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. Table 73 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 73. Affected areas in Santa Cruz, Laguna during a 100-year rainfall return period

Affected Area	Affected Barangays in Santa Cruz								
(sq. km.) by flood depth (in m.)	Alipit	Bagumbayan	Baran-gay I	Barangay II	Barangay III	Barangay IV	Barangay V	Bubukal	Calios
0.03-0.20	0.074	1.53	0.048	0.07	0.037	0.074	0.063	0.87	0.12
0.21-0.50	0.026	1.05	0.043	0.038	0.016	0.049	0.037	0.57	0.32
0.51-1.00	0.094	0.43	0.018	0.0061	0.001	0.021	0.023	0.28	0.67
1.01-2.00	0.23	0.029	0	0	0	0	0.00025	0.035	0.46
2.01-5.00	0.38	0	0	0	0	0	0	0	0.0083
> 5.00	0.14	0	0	0	0	0	0	0	0

Affected Area	Affected Barangays in Santa Cruz								
(sq. km.) by flood depth (in m.)	Duhat	Gatid	Jasaan	Labuin	Malinao	Oogong	Pagsawitan	Palasan	Patimbao
0.03-0.20	1.27	1.4	0.71	0.58	0.54	0.73	0.69	0.56	0.56
0.21-0.50	1.08	1.27	0.61	0.3	0.58	0.25	0.97	0.71	0.36
0.51-1.00	0.37	0.62	0.055	0.25	0.41	0.084	0.39	1.18	0.54
1.01-2.00	0.01	0.074	0.01	0.03	0.049	0.034	0.18	0.45	0.85
2.01-5.00	0	0	0	0	0	0.12	0.018	0.13	0.039
> 5.00	0	0	0	0	0	0.17	0	0.063	0.043

Affected Area	Affected Barangays in Santa Cruz							
(sq. km.) by flood depth (in m.)	San Jose	San Juan	San Pablo Norte	San Pablo Sur	Santisima Cruz	Santo Angel Central	Santo Angel Norte	Santo An-gel Sur
0.03-0.20	1.32	0.84	0.088	0.36	0.29	0.3	0.57	0.13
0.21-0.50	0.75	0.51	0.16	0.6	0.24	0.13	0.41	0.11
0.51-1.00	0.43	0.33	0.19	0.56	0.027	0.049	0.11	0.11
1.01-2.00	0.04	0.017	0	0.48	0.0025	0.024	0.078	0.042
2.01-5.00	0.003	0.0003	0	0.021	0	0.028	0	0.043
> 5.00	0.00004	0	0	0	0	0	0	0

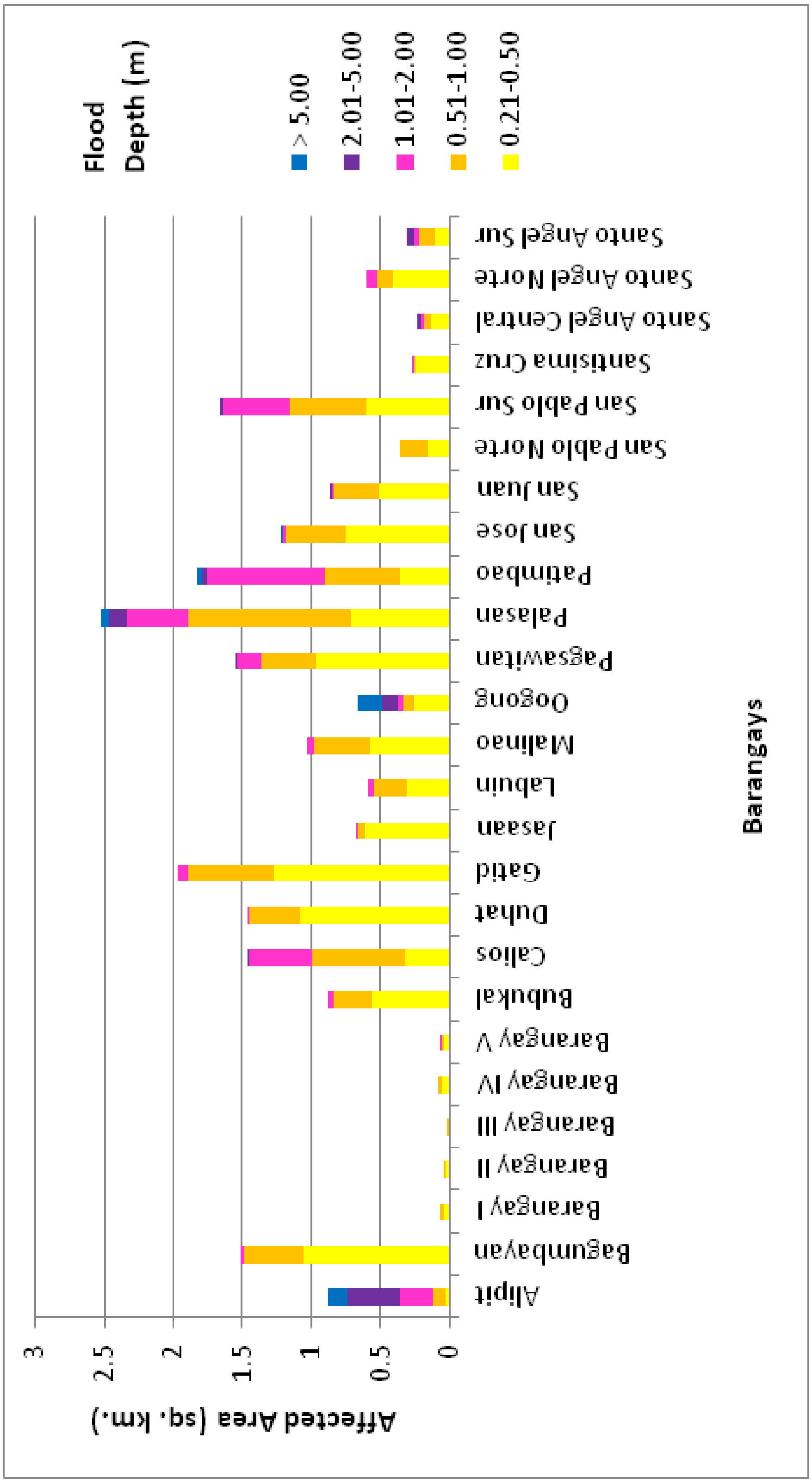


Figure 107. Areas affected by flooding in Santa Cruz, Laguna for a 100-year return period rainfall event

For the Municipality of Victoria, with an area of 28.37 square kilometers, 26.70% will experience flood levels of less than 0.20 meters. 17.56% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 21%, 17.48%, and 3.67% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 74 depicts the affected areas, in square kilometers, by flood depth per barangay.

Table 74. Affected areas in Victoria, Laguna during a 100-year rainfall return period

Affected Area	Affected Barangays in Victoria								
(sq. km.) by flood depth (in m.)	Banca-Ban-ca	Daniw	Masapang	Nanhaya	Pagalangan	San Benito	San Felix	San Francis-co	San Roque
0.03-0.20	1.02	1.35	0.16	0.68	0.45	0.27	0.92	1.55	1.16
0.21-0.50	0.55	0.75	0.23	0.33	0.44	0.31	1.39	0.54	0.45
0.51-1.00	0.55	1.14	0.76	0.13	0.5	0.57	1.87	0.13	0.31
1.01-2.00	0.2	1.84	0.73	0.022	0.31	0.8	0.97	0.053	0.03
2.01-5.00	0.056	0.87	0.095	0.0011	0.00016	0.0069	0.0051	0.0004	0
> 5.00	0	0	0	0	0	0	0	0	0

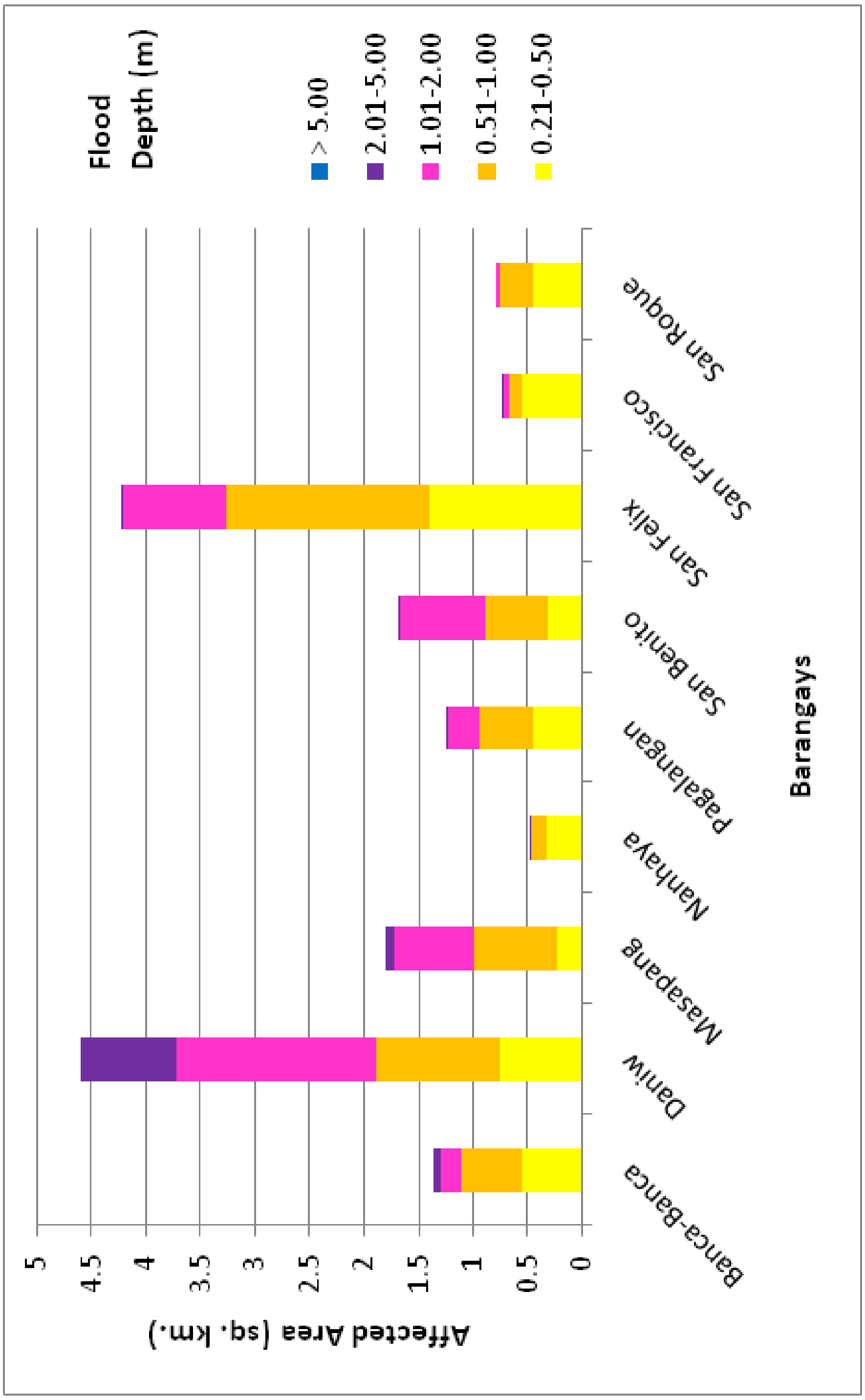


Figure 108. Areas affected by flooding in Victoria, Laguna for a 100-year return period rainfall event

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map The points in the flood map versus the corresponding validation depths are illustrated in Figure 110.

The flood validation consists of two hundred seventy (270) points, randomly selected all over the Pagsanjan floodplain. Comparing this with the flood depth map of the nearest storm event, an RMSE value of 1.27 meters was attained. Table 75 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

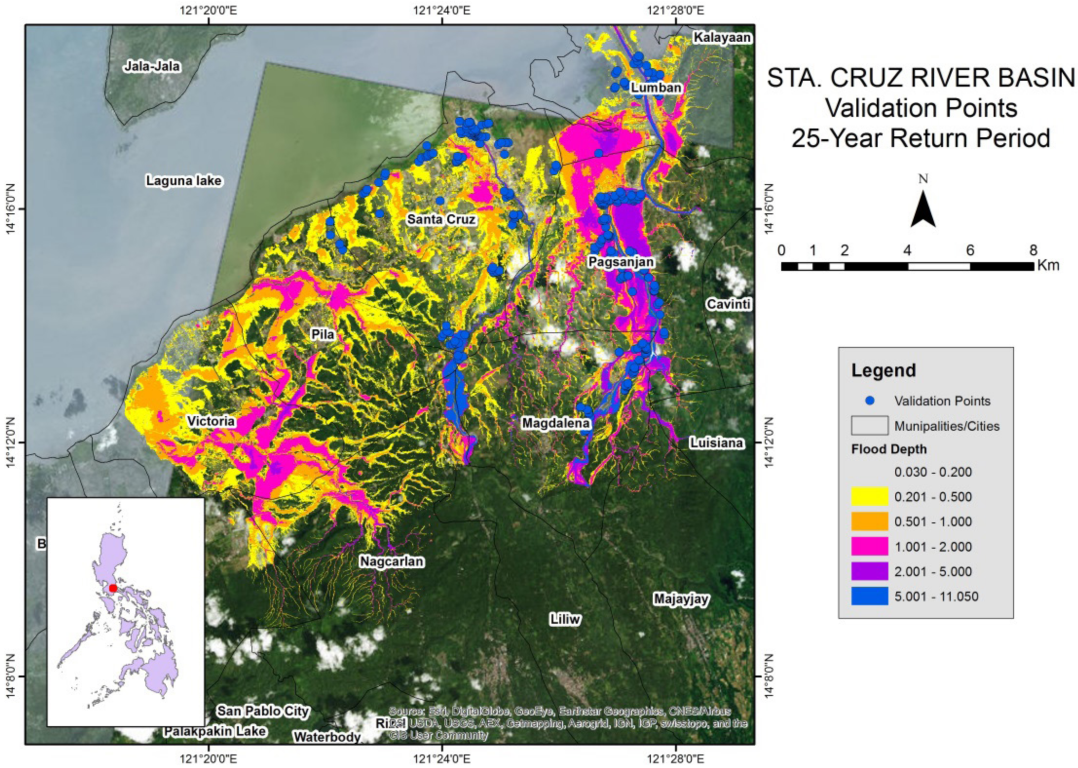


Figure 109. Validation points for the 25-year flood depth map of the Pagsanjan floodplain

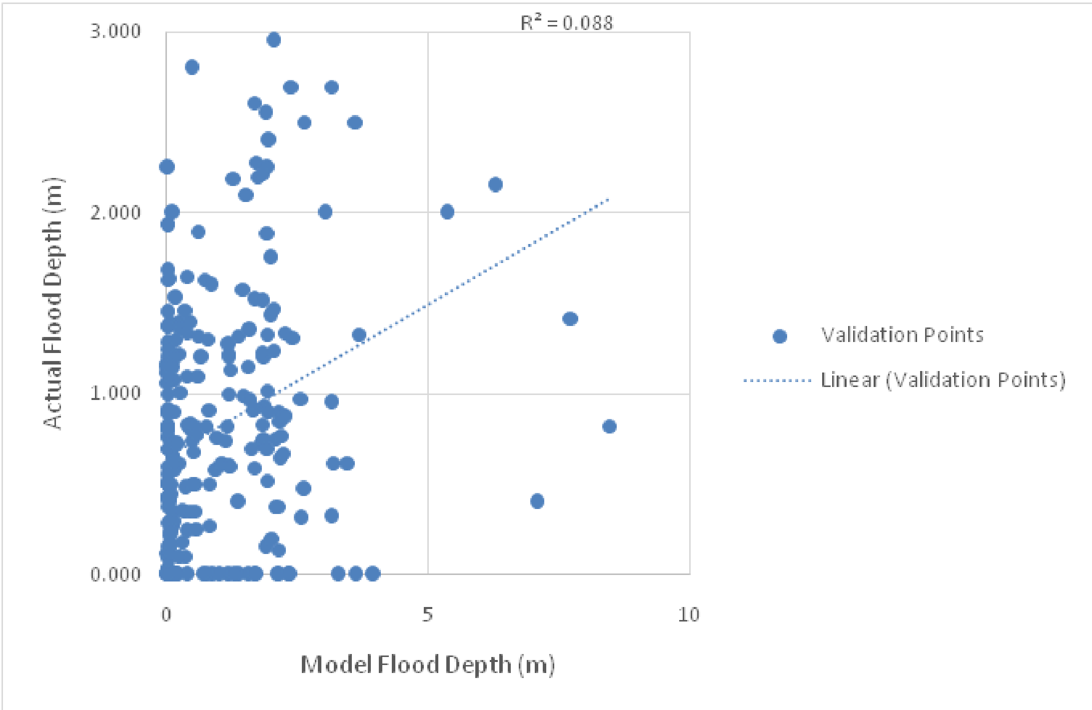


Figure 110. Flood map depth vs. actual flood depth

Table 75. Actual flood depth vs. simulated flood depth at different levels in the Pagsanjan River Basin

PAGSANJAN BASIN 0-0.20		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	41	7	3	8	9	0	68
	0.21-0.50	23	5	7	1	5	1	42
	0.51-1.00	26	7	7	19	11	1	71
	1.01-2.00	29	9	7	17	6	2	70
	2.01-5.00	1	1	0	9	7	1	19
	> 5.00	0	0	0	0	0	0	0
	Total	120	29	24	54	38	5	270

The overall accuracy generated by the flood model is estimated at 28.52%, with seventy-seven (77) points correctly matching the actual flood depths. In addition, there were seventy-nine (79) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were fifty-two (52) points and fifty-five (55) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of (four) 4 points were overestimated, while a total of one hundred and twelve (112) points were underestimated in the modeled flood depths of Pagsanjan. Table 76 depicts the summary of the Accuracy Assessment in the Pagsanjan River Basin Survey.

Table 76. Summary of the Accuracy Assessment in the Pagsanjan River Basin Survey

No. of Points		%
Correct	77	28.52
Overestimated	81	30.00
Underestimated	112	41.48
Total	270	**100.00**

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the Pegasus LiDAR Sensor used in the Pagsanjan Floodplain Survey

Figure A-1.1. Pegasus Sensor

Table A-1.1. Technical specifications of the Pegasus sensor

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

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

1. LAG-20

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

February 04, 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: **LAGUNA**
Station Name: **LAG-20**
Order: **3rd**

Island: **LUZON**
Municipality: **LOS BAÑOS**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **14° 9' 53.86904"**	Longitude: **121° 14' 20.35180"**	Ellipsoidal Hgt: **39.91400 m.**

WGS84 Coordinates

Latitude: **14° 9' 48.57270"**	Longitude: **121° 14' 25.28172"**	Ellipsoidal Hgt: **85.26600 m.**

PTM Coordinates

Northing: **1566435.481 m.**	Easting: **525799.268 m.**	Zone: **3**

UTM Coordinates

Northing: **1,566,588.99**	Easting: **309,934.22**	Zone: **51**

Location Description

LAG-20
Is located inside the UP Los Baños compound 25 m. NW from the Umali Hall building along Sanggumay Rd.; at the center of a concrete pavement, 0.7 m. from the edge of the stairs. Mark is a 2 mm. dia. brass rod centered on a 0.13 m. x 0.13 m. cement putty with inscription "LAG-20 NAMRIA 2000"

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-199**

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

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

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

Figure A-2.1. LAG-20

2. LAG-52

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

February 13, 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: **LAGUNA**
Station Name: **LAG-52**
Order: **2nd**

Island: **LUZON** Municipality: **MAGDALENA**		Barangay: **POBLACION**
	PRS92 Coordinates	
Latitude: **14° 12' 4.64805"**	Longitude: **121° 25' 41.33587"**	Ellipsoidal Hgt: **66.69800 m.**
	WGS84 Coordinates	
Latitude: **14° 11' 59.35842"**	Longitude: **121° 25' 46.26158"**	Ellipsoidal Hgt: **112.41000 m.**
	PTM Coordinates	
Northing: **1570483.553 m.**	Easting: **546212.761 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,570,462.41**	Easting: **330,382.29**	Zone: **51**

Location Description

LAG-52
Is located inside the compound of Magdalena Mun. Hall, less that a foot away S of the mun. flagpole. The said flagpole is about 20 m. N of the mun. bldg. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. cement putty, with inscriptions "LAG-52 2007 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8795355 A**
T.N.: **2014-318**

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

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

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

Figure A-2.2. LAG-52

3. RZL-28

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

June 14, 2016

CERTIFICATION

To whom it may concern:

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

Province: **RIZAL**
Station Name: **RZL-28**
Order: **2nd**

Island: **Luzon**
Municipality: **TANAY**
Barangay: **SAN ISIDRO (POB.)**
MSL Elevation:

PRS92 Coordinates

Latitude: **14° 29' 49.44078"** Longitude: **121° 16' 32.56146"** Ellipsoidal Hgt: **5.86600 m.**

WGS84 Coordinates

Latitude: **14° 29' 44.06939"** Longitude: **121° 16' 37.46276"** Ellipsoidal Hgt: **50.37100 m.**

PTM / PRS92 Coordinates

Northing: **1603180.963 m.** Easting: **529720.085 m.** Zone: **3**

UTM / PRS92 Coordinates

Northing: **1,603,302.05** Easting: **314,172.78** Zone: **51**

Location Description

The station is located near at the light house beside fish port and approximately 300 m going to Pang-alaalng Paaralang Elementarya ng Patricio Jarin,

Mark is the head of a 4" copper nail centered and set on top of a 30 cm. x 30 cm. cement putty, with inscription "RZL-28, 2004, NAMRIA".

Requesting Party: **UP Lidar 1**
Purpose: **Reference**
OR Number: **8094772**
T.N.: **2016-1261**

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

9906142016162838

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/47C1/12/09/814

Figure A-2.3. RZL-28

4. LA-204

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

February 13, 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: **LAGUNA**
Station Name: **LA-204**

Island: **LUZON**	Municipality: **LUMBAN**	Barangay: **PRIMERA PARANG**
Elevation: **8.5636 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LA 204 is in Brgy. Primera 1st Parang, Lumban, Laguna. It is on top of the SE corner of the concrete sidewalk of Lumban Bridge, Station is along the national highway, 4m SE of road centerline. It is 10m SW of the barangay hall. 5m NE of the station is KM 94 post. Mark is the head of a 4" copper nail set on a drilled hole. Inscriobed on top of the 25cm x 25cm cement putty is
"BM LA 204, 2007, NAMRIA."

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8795355 A**
T.N.: **2014-321**

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

9902132014164807

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

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

Figure A-2.4. LA-204

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

LAG-20A

Table A-3.1. LAG-20A

Vector Components (Mark to Mark)

From:	LAG-20				
Grid		Local		Global	
Easting	309934.222 m	Latitude	N14°09'53.86923"	Latitude	N14°09'48.57270"
Northing	1566588.991 m	Longitude	E121°14'20.35184"	Longitude	E121°14'25.28172"
Elevation	39.976 m	Height	39.914 m	Height	85.266 m

To:	LAG-20A				
Grid		Local		Global	
Easting	309926.998 m	Latitude	N14°09'53.79129"	Latitude	N14°09'48.49477"
Northing	1566586.650 m	Longitude	E121°14'20.11156"	Longitude	E121°14'25.04144"
Elevation	39.960 m	Height	39.898 m	Height	85.250 m

Vector					
ΔEasting	-7.224 m	NS Fwd Azimuth	251°36'51"	ΔX	5.865 m
ΔNorthing	-2.341 m	Ellipsoid Dist.	7.593 m	ΔY	4.225 m
ΔElevation	-0.016 m	ΔHeight	-0.016 m	ΔZ	-2.326 m

LAG-20B

Table A-3.2. LAG-20B

Vector Components (Mark to Mark)

From:	LAG-20				
Grid		Local		Global	
Easting	309934.222 m	Latitude	N14°09'53.86923"	Latitude	N14°09'48.57270"
Northing	1566588.991 m	Longitude	E121°14'20.35184"	Longitude	E121°14'25.28172"
Elevation	39.976 m	Height	39.914 m	Height	85.266 m

To:	LAG-20B				
Grid		Local		Global	
Easting	309929.658 m	Latitude	N14°09'53.79862"	Latitude	N14°09'48.50209"
Northing	1566586.855 m	Longitude	E121°14'20.20020"	Longitude	E121°14'25.13008"
Elevation	39.943 m	Height	39.882 m	Height	85.234 m

Vector					
ΔEasting	-4.564 m	NS Fwd Azimuth	244°29'28"	ΔX	3.629 m
ΔNorthing	-2.136 m	Ellipsoid Dist.	5.039 m	ΔY	2.786 m
ΔElevation	-0.032 m	ΔHeight	-0.032 m	ΔZ	-2.112 m

LAG-52A

Table A-3.3. LAG-52A

Vector Components (Mark to Mark)

From:	LAG-52				
Grid		Local		Global	
Easting	330382.293 m	Latitude	N14°12'04.64805"	Latitude	N14°11'59.35842"
Northing	1570462.409 m	Longitude	E121°25'41.33587"	Longitude	E121°25'46.26158"
Elevation	66.500 m	Height	66.698 m	Height	112.410 m

To:	LAG-52A				
Grid		Local		Global	
Easting	330381.851 m	Latitude	N14°12'04.74360"	Latitude	N14°11'59.45397"
Northing	1570465.349 m	Longitude	E121°25'41.32045"	Longitude	E121°25'46.24615"
Elevation	66.420 m	Height	66.618 m	Height	112.330 m

Vector					
ΔEasting	-0.443 m	NS Fwd Azimuth	351°03'01"	ΔX	0.811 m
ΔNorthing	2.939 m	Ellipsoid Dist.	2.973 m	ΔY	-0.440 m
ΔElevation	-0.080 m	ΔHeight	-0.080 m	ΔZ	2.827 m

LA-204

Table A-3.4. LAG-204

Vector Components (Mark to Mark)

From:	LAG-52				
Grid		Local		Global	
Easting	330382.293 m	Latitude	N14°12'04.64805"	Latitude	N14°11'59.35842"
Northing	1570462.409 m	Longitude	E121°25'41.33587"	Longitude	E121°25'46.26158"
Elevation	66.500 m	Height	66.698 m	Height	112.410 m

To:	BMLA-204				
Grid		Local		Global	
Easting	333766.797 m	Latitude	N14°17'36.26369"	Latitude	N14°17'30.95486"
Northing	1580630.698 m	Longitude	E121°27'31.97236"	Longitude	E121°27'36.89005"
Elevation	11.120 m	Height	11.533 m	Height	57.061 m

Vector					
ΔEasting	3384.504 m	NS Fwd Azimuth	18°01'23"	ΔX	-1493.032 m
ΔNorthing	10168.288 m	Ellipsoid Dist.	10717.309 m	ΔY	-3915.466 m
ΔElevation	-55.379 m	ΔHeight	-55.165 m	ΔZ	9864.324 m

LAG-4521

Table A-3.5. LAG-4521

Vector Components (Mark to Mark)

From:	LAG-52				
Grid		Local		Global	
Easting	330382.293 m	Latitude	N14°12'04.64805"	Latitude	N14°11'59.35842"
Northing	1570462.409 m	Longitude	E121°25'41.33587"	Longitude	E121°25'46.26158"
Elevation	66.500 m	Height	66.698 m	Height	112.410 m

To:	LAG-4521				
Grid		Local		Global	
Easting	331675.815 m	Latitude	N14°16'04.88594"	Latitude	N14°15'59.58151"
Northing	1577836.520 m	Longitude	E121°26'22.83065"	Longitude	E121°26'27.75062"
Elevation	10.989 m	Height	11.309 m	Height	56.861 m

Vector					
ΔEasting	1293.522 m	NS Fwd Azimuth	9°33'46"	ΔX	-86.455 m
ΔNorthing	7374.111 m	Ellipsoid Dist.	7487.052 m	ΔY	-2243.469 m
ΔElevation	-55.511 m	ΔHeight	-55.389 m	ΔZ	7142.756 m

LAG-4415

Table A-3.6. LAG-4415

Vector Components (Mark to Mark)

From:	LAG-52				
Grid		Local		Global	
Easting	330382.293 m	Latitude	N14°12'04.64805"	Latitude	N14°11'59.35842"
Northing	1570462.409 m	Longitude	E121°25'41.33587"	Longitude	E121°25'46.26158"
Elevation	66.500 m	Height	66.698 m	Height	112.410 m

To:	LAG-4415				
Grid		Local		Global	
Easting	330313.993 m	Latitude	N14°12'05.16704"	Latitude	N14°11'59.87733"
Northing	1570478.818 m	Longitude	E121°25'39.05421"	Longitude	E121°25'43.97990"
Elevation	66.286 m	Height	66.482 m	Height	112.192 m

Vector					
ΔEasting	-68.300 m	NS Fwd Azimuth	283°07'25"	ΔX	60.526 m
ΔNorthing	16.409 m	Ellipsoid Dist.	70.247 m	ΔY	32.156 m
ΔElevation	-0.214 m	ΔHeight	-0.216 m	ΔZ	15.408 m

RZL-28 to RZL-28A

Table A-3.7. RZL-28 to RZL-28A

Vector Components (Mark to Mark)

From:	RZL-28				
Grid		Local		Global	
Easting	314172.786 m	Latitude	N14°29'49.44078"	Latitude	N14°29'44.06939"
Northing	1603302.052 m	Longitude	E121°16'32.56145"	Longitude	E121°16'37.46276"
Elevation	4.971 m	Height	5.866 m	Height	50.371 m

To:	RZL-28A				
Grid		Local		Global	
Easting	314178.417 m	Latitude	N14°29'49.51048"	Latitude	N14°29'44.13909"
Northing	1603304.152 m	Longitude	E121°16'32.74896"	Longitude	E121°16'37.65027"
Elevation	5.151 m	Height	6.047 m	Height	50.552 m

Vector					
ΔEasting	5.631 m	NS Fwd Azimuth	69°07'04"	ΔX	-4.611 m
ΔNorthing	2.100 m	Ellipsoid Dist.	6.010 m	ΔY	-3.223 m
ΔElevation	0.181 m	ΔHeight	0.181 m	ΔZ	2.119 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)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
	RA	MA. REMEDIOS VILLANUEVA	UP-TCAGP
	RA	RENAN PUNTO	UP-TCAGP
	RA	KRISTINE JOY ANDAYA	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	VERLINA TONGA	UP-TCAGP
	RA		UP-TCAGP
LiDAR Operation	Airborne Security	SSG. EMMANUEL TANDOC	PHILIPPINE AIR FORCE (PAF)
	Airborne Security	SSG. LEE JAY PUNZALAN	PAF
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. FRANCO PEPITO	AAC
	Pilot	CAPT. RAUL SAMAR	AAC
	Pilot	CAPT. NEIL AGAWIN	AAC
	Pilot	CAPT. JAMAL CLEMENTE	AAC
	Pilot	CAPT. JUSTIN JOYA	AAC
	Pilot	CAPT. CESAR ALFONSO III	AAC
	Pilot	CAPT. RANDY LAGCO	AAC

Annex 5. Data Transfer Sheets for the Pagsanjan Floodplain Flights

DATA TRANSFER SHEET - Calabarzon
28-02-2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	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	
2014-02-10	1091	1BLK18W41A	Pegasus	2.17 GB	66.58 KB	8.64 MB	171.94 MB	32.74 GB	256.61 KB	20.23 GB	0 B	10.18 MB	N/A	426 B	0 B	1091	Z:\DAC\RAWDATA\1091P
2014-02-13	1103	1BLK18VWS44A	Pegasus	2.13 GB	604.1 KB	9.23 MB	221.75 MB	0 B	N/A	19.89 GB	0 B	16.63 MB	305 B	429 B	0 B	1103	Z:\DAC\RAWDATA\1103P
2014-02-11	1095	1BLK18U42A	Pegasus	1.17 GB	76.99 KB	9.5 MB	235.93 MB	96.99 MB	1.62 KB	14.94 GB	0 B	11.41 MB	205 B	287 B	0 B	1095	Z:\DAC\RAWDATA\1095P
2014-02-08	1083	1BLK18J39A	Pegasus	1.48 GB	1.25 MB	7.49 MB	198.29 MB	22.62 GB	N/A	16.53 GB	0 B	12.44 MB	180 B	604 B	0 B	1083	Z:\DAC\RAWDATA\1083P
2014-02-04	1067	1BLK18H035A	Pegasus	921.78 MB	912.67 KB	6.39 MB	167.97 MB	11.65 GB	N/A	11.55 GB	0 B	5.03 MB	138 B	383 B	63.3 KB	1067	Z:\DAC\RAWDATA\1067P

Received from

Name R. Punto group
Position RA
Signature

Received by

Name AC Bongat group DPPC
Position SSRS
Signature 2/28/16

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

DATA TRANSFER SHEET - Calabarzon
28-02-2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	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	
2014-02-15	1111	1BLK18QRS46A	Pegasus	1.39 GB	71.57 KB	7.97 MB	194.4 MB	19.72 GB	N/A	14.73 GB	0 B	10.94 MB	215 B	559 B	0 B	1111	Z:\DAC\RAWDATA\1111P
2014-02-05	1071	1BLK18I036A	Pegasus	1.62 GB	95.66 KB	6.73 MB	157.44 MB	16.02 GB	N/A	15.4 GB	0 B	2.5 MB	193 B	411 B	0 B	1071	Z:\DAC\RAWDATA\1071P
2014-02-02	1059	1BLK18F033A	Pegasus	1.04 GB	421 B	6.75 MB	167.09 MB	11.73 GB	N/A	10.15 GB	0 B	6 MB	201 B	421 B	133.96 KB	1059	Z:\DAC\RAWDATA\1059P
2014-01-31	1051	1BLK18E031A	Aquarius	2.56 GB	1.06 MB	14.17 MB	379.85 MB	14.49 GB	N/A	13.37 GB	0 B	4.56 MB	217 B	504 B	0 B	1051	Z:\DAC\RAWDATA\1051P
2014-02-03	1063	1BLK18D034A	Pegasus	1.18 GB	29.61 KB	6.01 MB	144.55 MB	19.2 GB	N/A	18.52 GB	0 B	5.96 MB	191 B	321 B	0 B	1063	Z:\DAC\RAWDATA\1063P

Received from

Name R. Punto group
Position RA
Signature

Received by

Name AC Bongat c-group PPPC
Position SSRS
Signature 2/28/16

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

DATA TRANSFER SHEET
CALABARZON 9/7/2015

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
15-Aug	3299P	1BLK18KS227A	PEGASUS	535	614	5.45	143	na	na	10.4	na	3.73	1KB	1KB	222	NA	Z:\DAC\RAW DATA
26-Aug	3341P	1BLK18AbS238A	PEGASUS	1.49	NA	10.1	240	na	na	16.1	na	7.02	1KB	1KB	69	NA	Z:\DAC\RAW DATA
26-Aug	3343P	1BLK18AcS238B	PEGASUS	1.84	NA	9.44	214	na	na	17.9	na	5.96	1KB	1KB	59	NA	Z:\DAC\RAW DATA
27-Aug	3345P	1BLK18TS239A	PEGASUS	2.5	NA	7.11	177	na	na	22.5	na	5.99	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
27-Aug	3347P	1BLK18TS239B	PEGASUS	0.99	NA	6.27	152	na	na	9.85	na	4.13	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
29-Aug	3353P	1BLK18QRS241A	PEGASUS	1.91	NA	10.3	246	na	na	18.8	na	7.19	1KB	1KB	87.1	NA	Z:\DAC\RAW DATA
1-Sep	3365P	1BLK18BCS244A	PEGASUS	1.92	NA	8.57	192	na	na	18.2	na	8.61	1KB	1KB	41	NA	Z:\DAC\RAW DATA
2-Sep	3369P	1BLK18CS245A	PEGASUS	1.34	NA	7.43	154	na	na	13.5	na	35	1KB	1KB	54	NA	Z:\DAC\RAW DATA

Received from
Name C. JOAQUIN
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature 9/8/15

Figure A-5.3. Data Transfer Sheet for Pagsanjan Floodplain – C

DATA TRANSFER SHEET
Calabarzon 9/10/15

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
17-Aug	3307P	1BLK18JS229B	Pegasus	972	756	6.66	171	na	na	9.59	na	18.4	1KB	1KB	1/42	na	Z:\DAC\RAW DATA
18-Aug	3309P	1BLK18AsS230A	Pegasus	1.17	757	7.65	202	na	na	11.9	na	19.4	1KB	1KB	88	na	Z:\DAC\RAW DATA
3-Sep	3373P	1BLK18OS246A	Pegasus	1.81	2.06	9.59	212	na	na	18.2	na	7.67	1KB	1KB	1	na	Z:\DAC\RAW DATA
4-Sep	3377P	1BLK18JS247A	Pegasus	1.29	777	8.1	196	na	na	13.4	na	6.43	1KB	1KB	61.6	na	Z:\DAC\RAW DATA
5-Sep	3381P	1BLK18OS248A	Pegasus	2.12	1.54	10.3	256	na	na	20.6	na	9.05	1KB	1KB	59/59	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name KC Bongat 9/11/15
Position SSRS
Signature

15-25

Figure A-5.4. Data Transfer Sheet for Pagsanjan Floodplain – D

DATA TRANSFER SHEET
CALABARZON 7/12/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
June 11, 2016	23444P	1BLK18RL163A	PEGASUS	2.04	408	9.01	185	NA	NA	20.1	NA	306	1KB	NA	180	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

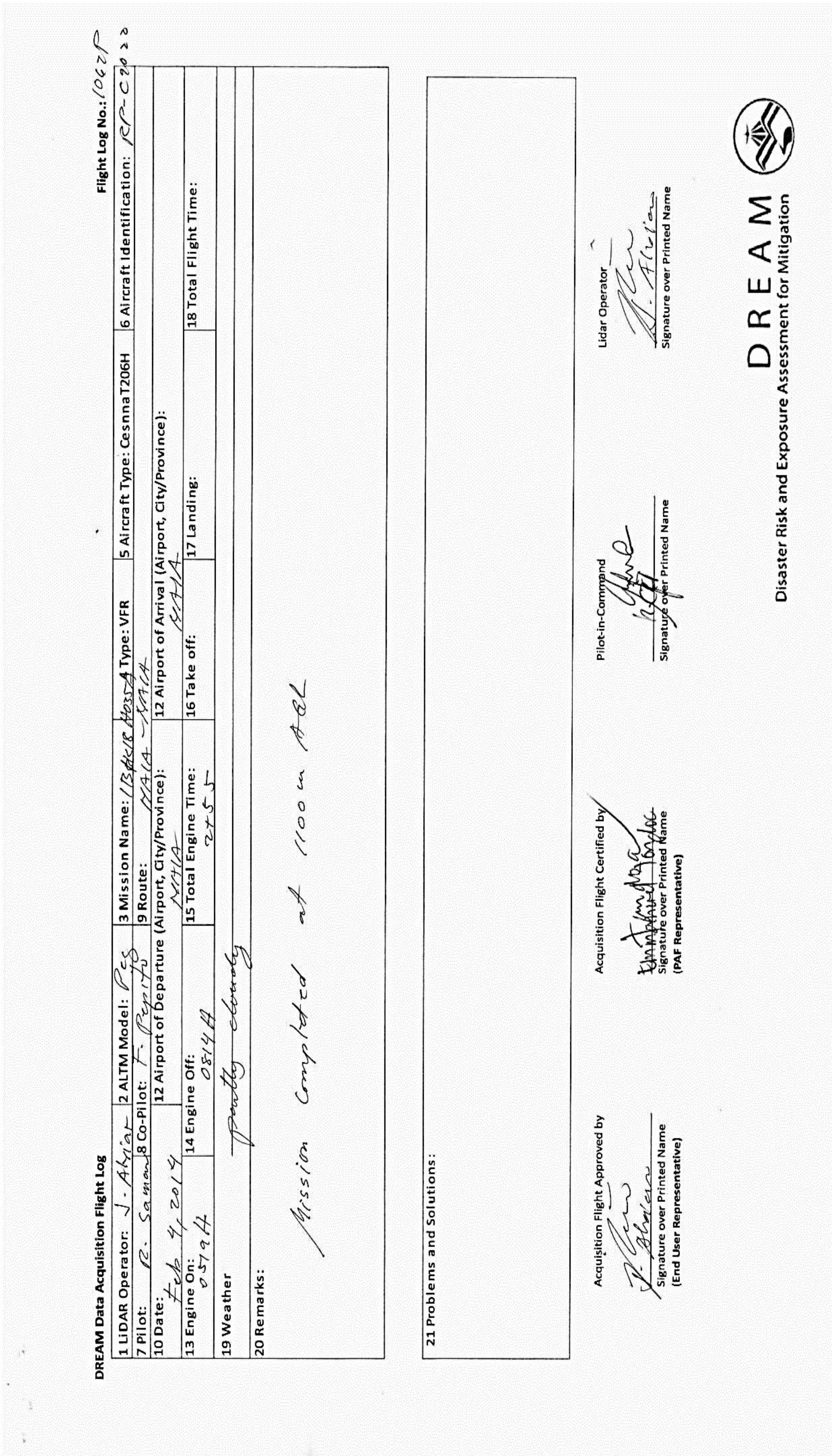
Name A C Bongat
Position SS RS
Signature 7/12/16

16-43

Figure A-5.5. Data Transfer Sheet for Pagsanjan Floodplain – E

Annex 6. Flight Logs for the Flight Missions

Flight Log for 1BLK18H35A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1062P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18H35A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samonte	8 Co-Pilot: F. Pepito	9 Route: NAIA - NAIA			
10 Date: Feb 4, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0519H	14 Engine Off: 0814H	15 Total Engine Time: 2+55	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					
20 Remarks: Mission completed at 1100m AGL					

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)

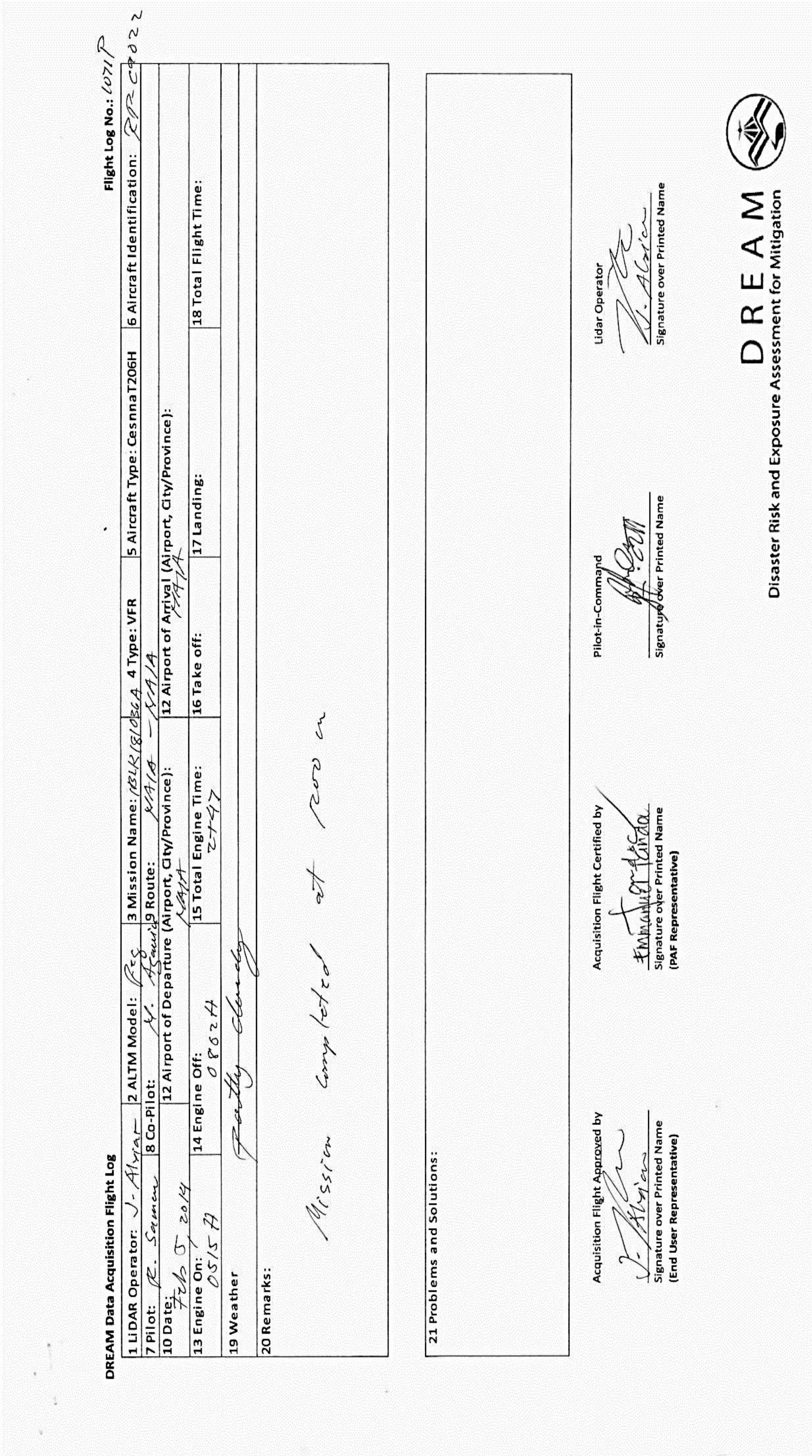
Pilot-in-Command — Signature over Printed Name

Lidar Operator — J. Alviar — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1BLK18H35A

Flight Log for 1BLK18J39A Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1071P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK18I036A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samson	8 Co-Pilot: M. Aguirre	9 Route: NAIA - NAIA			
10 Date: Feb 5, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0515H	14 Engine Off: 0802H	15 Total Engine Time: 2+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					
20 Remarks: Mission completed at 1200 m					
21 Problems and Solutions:					

Acquisition Flight Approved by: J. Alviar — Signature over Printed Name (End User Representative)

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

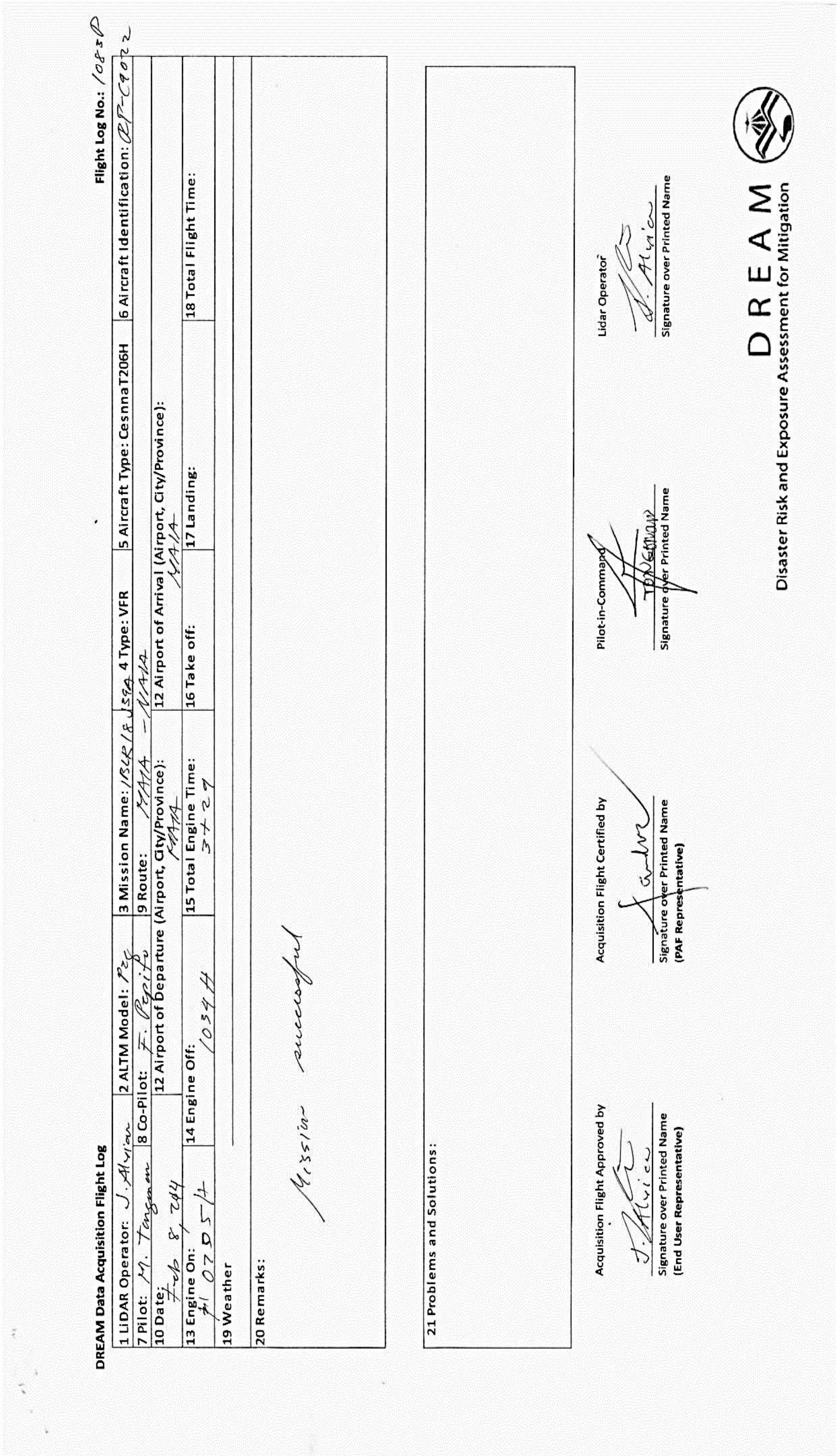
Pilot-in-Command: Signature over Printed Name

Lidar Operator: J. Alviar — Signature over Printed Name

DREAM Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2. Flight Log for Mission 1BLK18J39A

Flight Log for 1BLK18I036A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1085P

1 LIDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK18I39A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. Tangonan	8 Co-Pilot: F. Pepito	9 Route: MAIA - MAIA			
10 Date: Feb 8, 2014	12 Airport of Departure (Airport, City/Province): MAIA		12 Airport of Arrival (Airport, City/Province): MAIA		
13 Engine On: 0705H	14 Engine Off: 1034H	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission successful					

21 Problems and Solutions:

Acquisition Flight Approved by: J. Alviar — Signature over Printed Name (End User Representative)

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

Pilot-in-Command: T. Tangonan — Signature over Printed Name

Lidar Operator: J. Alviar — Signature over Printed Name

DREAM — Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 1BLK18I036A

Flight Log for 1BLK18K40A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1087P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK18K040A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Clemente	8 Co-Pilot: M. Asawin	9 Route: NAIA - NAIA			
10 Date: Feb 9, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0725H	14 Engine Off: 1030H	15 Total Engine Time: 3+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Very cloudy					

20 Remarks:

Data acquired but mission not completed due to heavy build up

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. Clemente

Signature over Printed Name

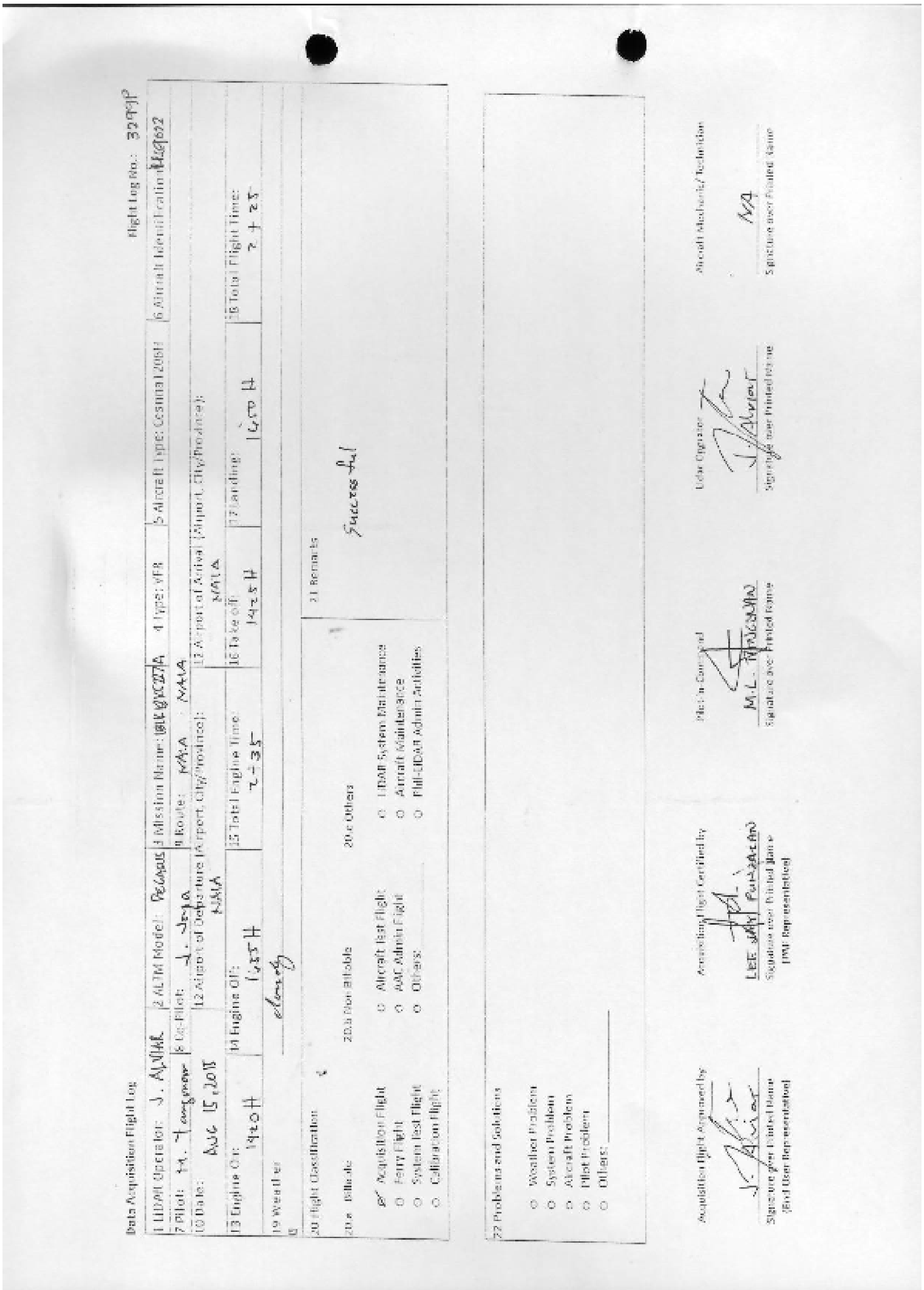
Lidar Operator

Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4. Flight Log for Mission 1BLK18K40A

Flight log for 1BLK18KS227A Mission


Data Acquisition Flight Log — Flight Log No.: 3299P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18KS227A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Jeca	9 Route: NAIA			
10 Date: AUG 15, 2018	12 Airport of Departure (Airport, City/Province): NAIA		13 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 1420H	14 Engine Off: 1655H	15 Total Engine Time: 2+35	16 Take off: 1425H	17 Landing: 1650H	18 Total Flight Time: 2+25
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

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

Acquisition Flight Approved by: J. Alviar — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: Lee Jay Punzalan — Signature over Printed Name (PAF Representative)

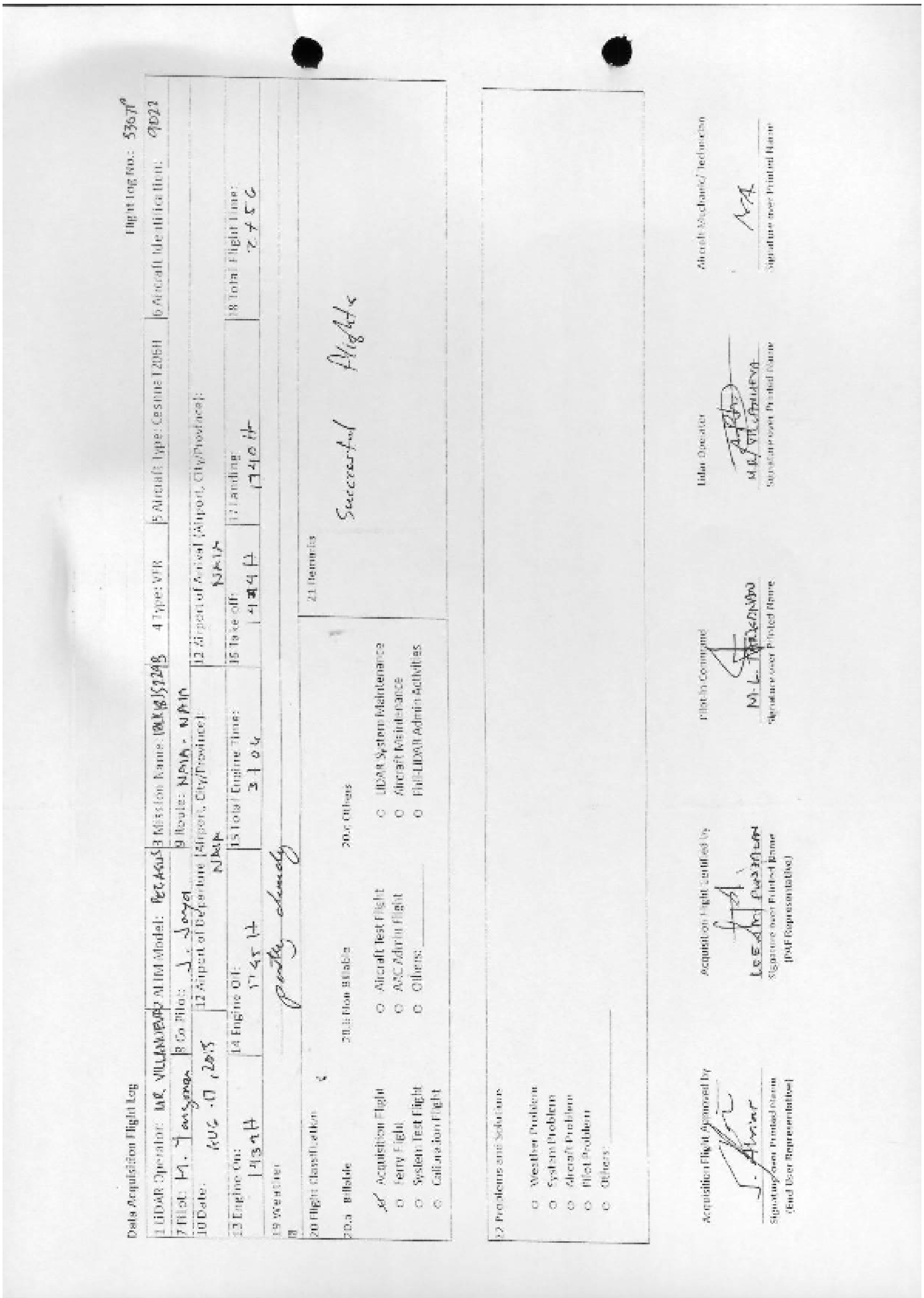
Pilot-in-Command: M.L. Tangonan — Signature over Printed Name

Lidar Operator: J. Alviar — Signature over Printed Name

Aircraft Mechanic/Technician: NA — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1BLK18KS227A

Flight Logs for 1BLK18JS229B Mission



Data Acquisition Flight Log

Flight Log No.: 5367P

1 LiDAR Operator: MR. VILLANUEVA	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK18JS229B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co Pilot: J. Jaya	9 Route: NAIA - NAIA			
10 Date: AUG 17, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 1439H	14 Engine Off: 1745H	15 Total Engine Time: 3+06	16 Take off: 1444H	17 Landing: 1740H	18 Total Flight Time: 2+56
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

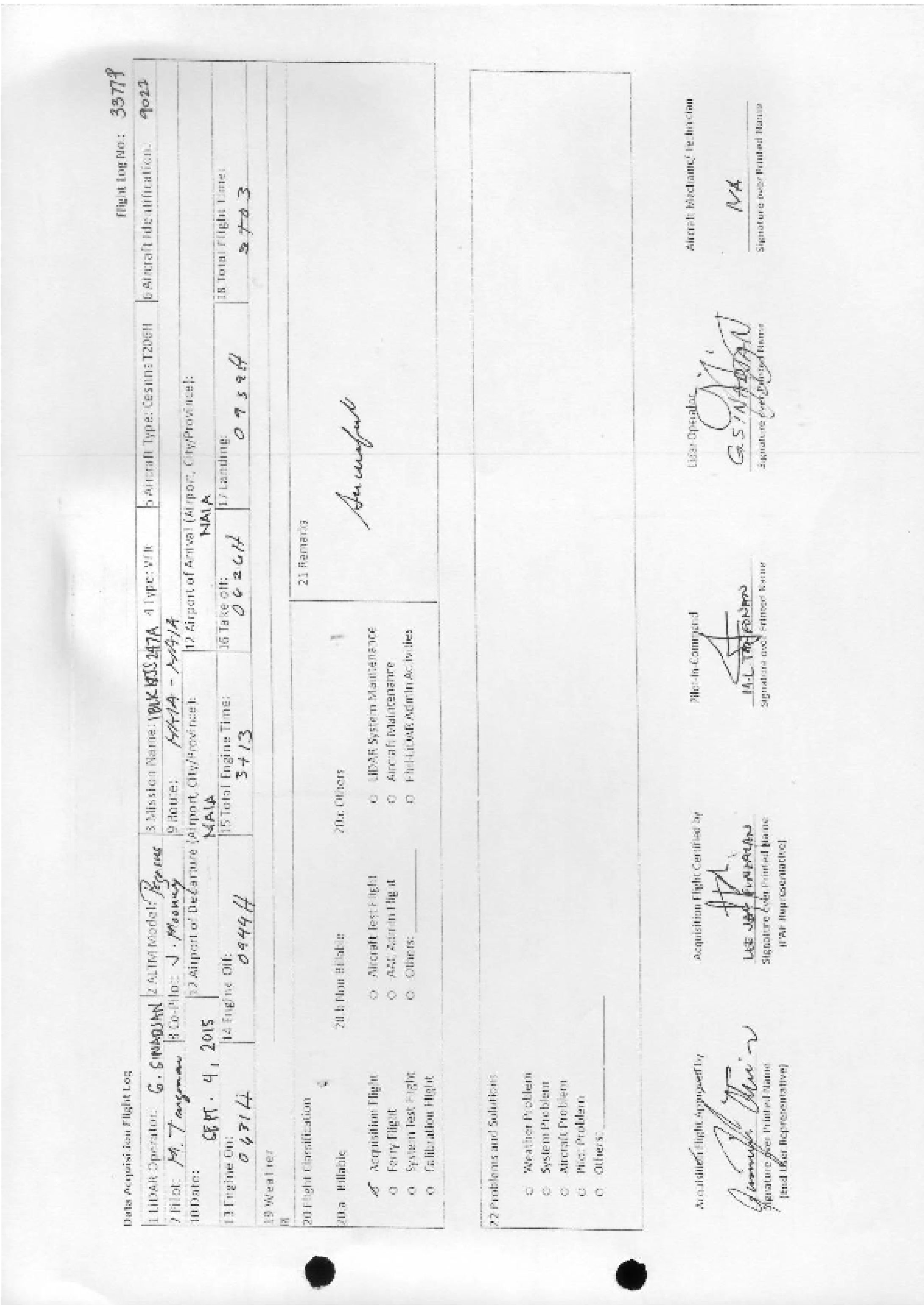
Successful Flight

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/ Technician
J. Alviar	Lee Ann Pusaran	M. L. Tangonan	M.R. Villanueva	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-6.6. Flight Log for Mission 1BLK18JS229B

Flight Logs for 1BLK18JS247A Mission


Data Acquisition Flight Log

Flight Log No.: 33779

1 LIDAR Operator: G. SINADJAN	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18JS247A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Meong	9 Route: NAIA - NAIA			
10 Date: SEPT. 4, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0631H	14 Engine Off: 0944H	15 Total Engine Time: 3+13	16 Take off: 0626H	17 Landing: 0939H	18 Total Flight Time: 3+03

19 Weather

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

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

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

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

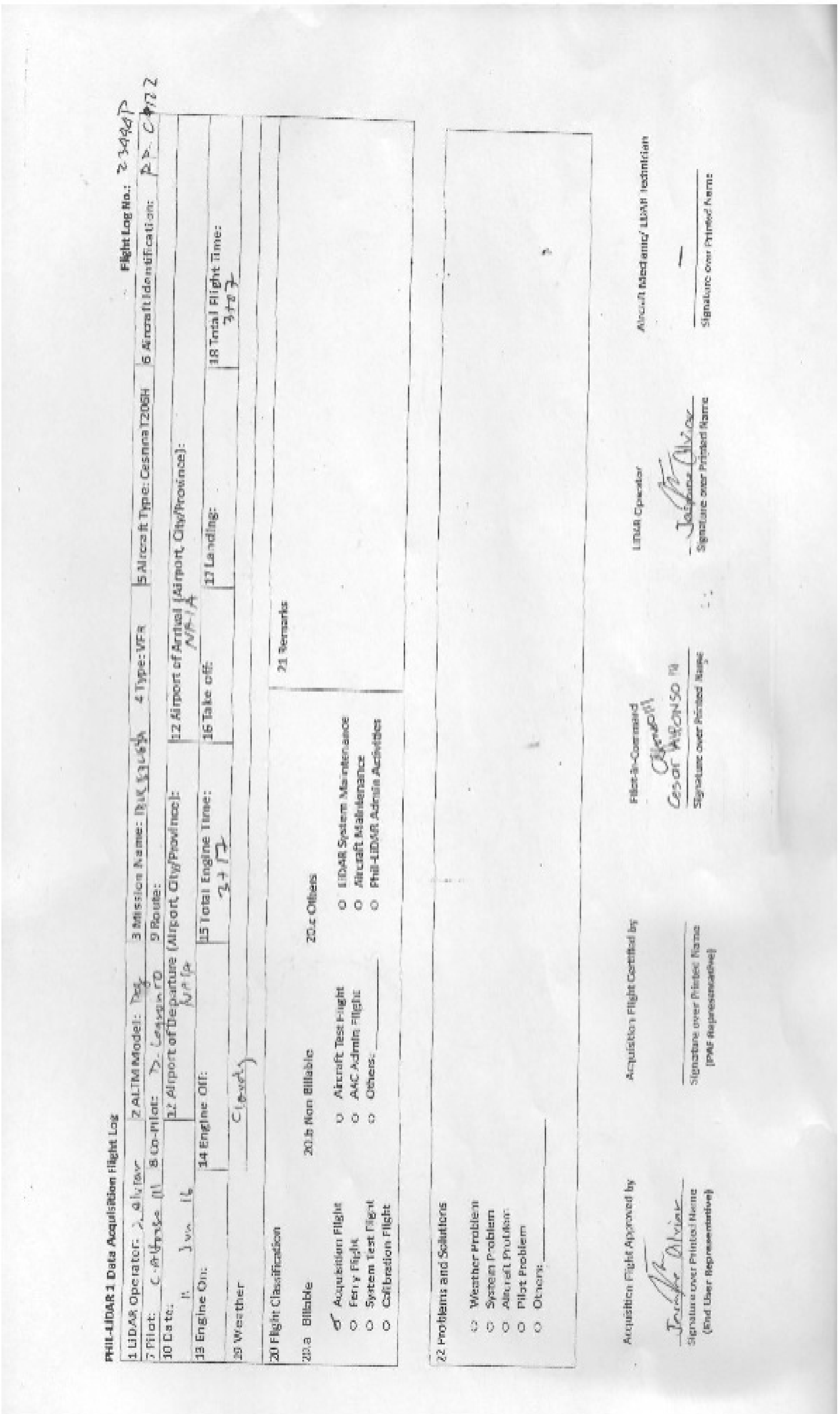
Pilot-in-Command — M.L. TANGONAN — Signature over Printed Name

Lidar Operator — G. SINADJAN — Signature over Printed Name

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

Figure A-6.7. Flight Log for Mission 1BLK18JS247A

Flight Logs for 1BLK18RL163A Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

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

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

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

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

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

Pilot-in-Command — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.8. Flight Log for Mission 1BLK18RL163A

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT CALABARZON February 2014; August 15-September 5, 2015; June 11, 2016					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
1067P	BLK18H	1BLK18H035A	J. ALVIAR	04-Feb-14	Mission completed at 1100m AGL
1071P	BLK18I	1BLK18I036A	J. ALVIAR	05-Feb-14	Mission completed at 1100m AGL
1083P	BLK18J	1BLK18J39A	J. ALVIAR	08-Feb-14	Mission successful at 1200m
1087P	BLK18K	1BLK18K40A	J. ALVIAR	09-Feb-14	Data acquired but mission not completed due to cloud build up
3299P	BLK 18KS	1BLK18KS227A	J. ALVIAR	AUG 15	4 lines, flight aborted due to bad weather Without Digitizer and Camera
3307P	BLK 18JS	1BLK18JS229B	MR VILLANUEVA	AUG 17	Hazy with precipitation throughout the survey Without Digitizer and Camera
3377P	BLK 18JS	1BLK18JS247A	G. SINADJAN	SEPT 4	Laser off due to Clouds Line cut due to low visibility on terrain Without Digitizer and Camera
23444P	Rizal, Laguna	1BLK18RL163A	J ALVIAR	JUNE 11	SURVEYED BLK 18RL @ 1100-1200m Flight altitude unstable to updraft and terrain 180 SQ.KM

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	1067P				
Parameters:	PRF 200	SF	30	FOV	50

LAS/SWATH

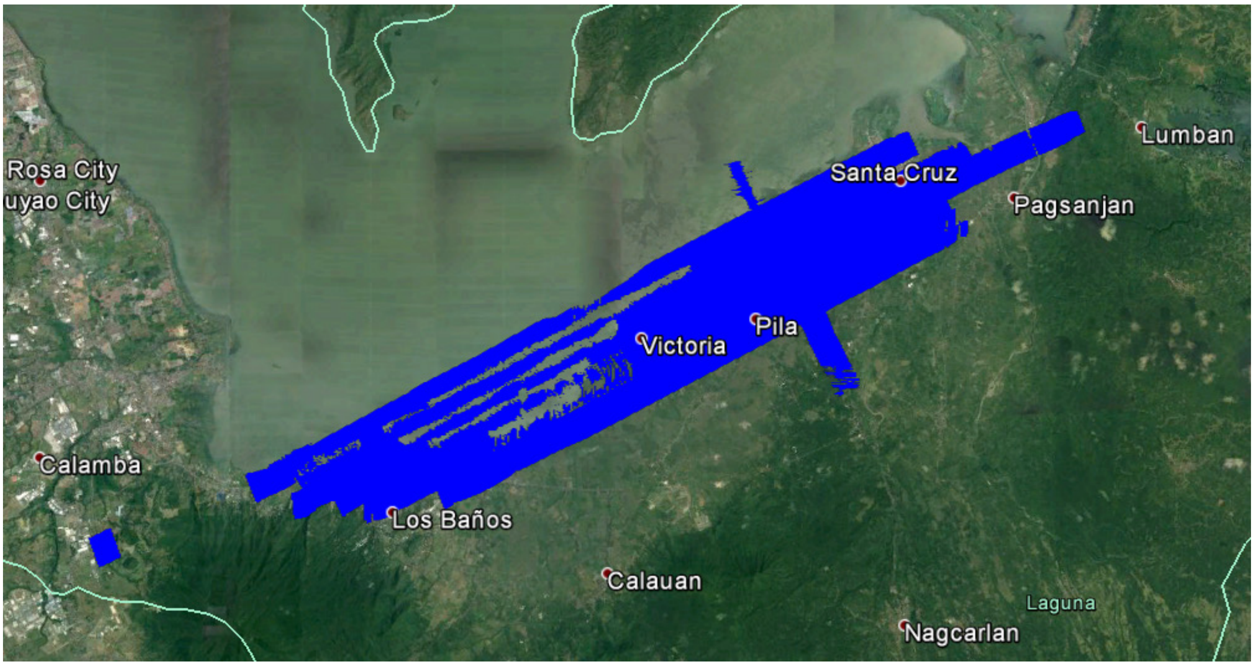


Figure A-7.1. Swath for Flight No. 1067P

Flight No. :	1071P				
Parameters:	PRF 200	SF	30	FOV	50

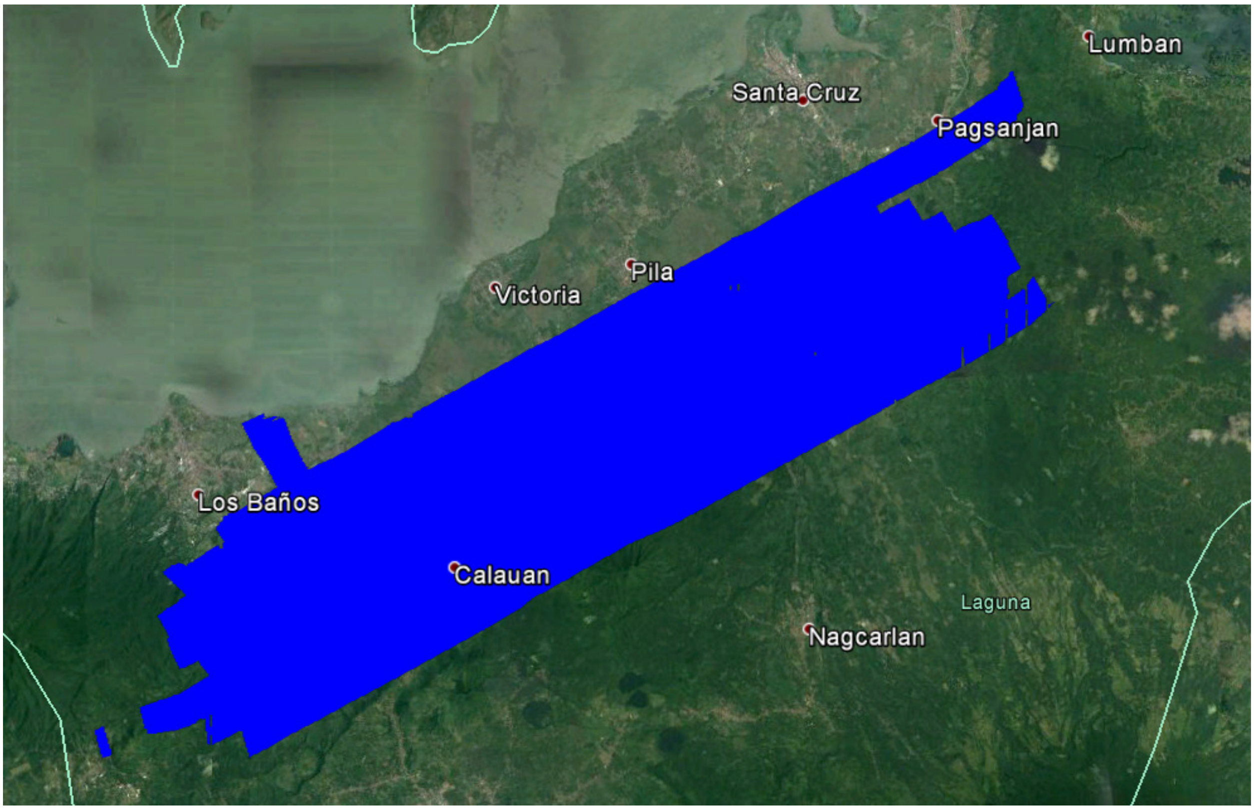


Figure A-7.2. Swath for Flight No. 1071P

Flight No. :	1083P				
Parameters:	PRF 200	SF	30	FOV	50

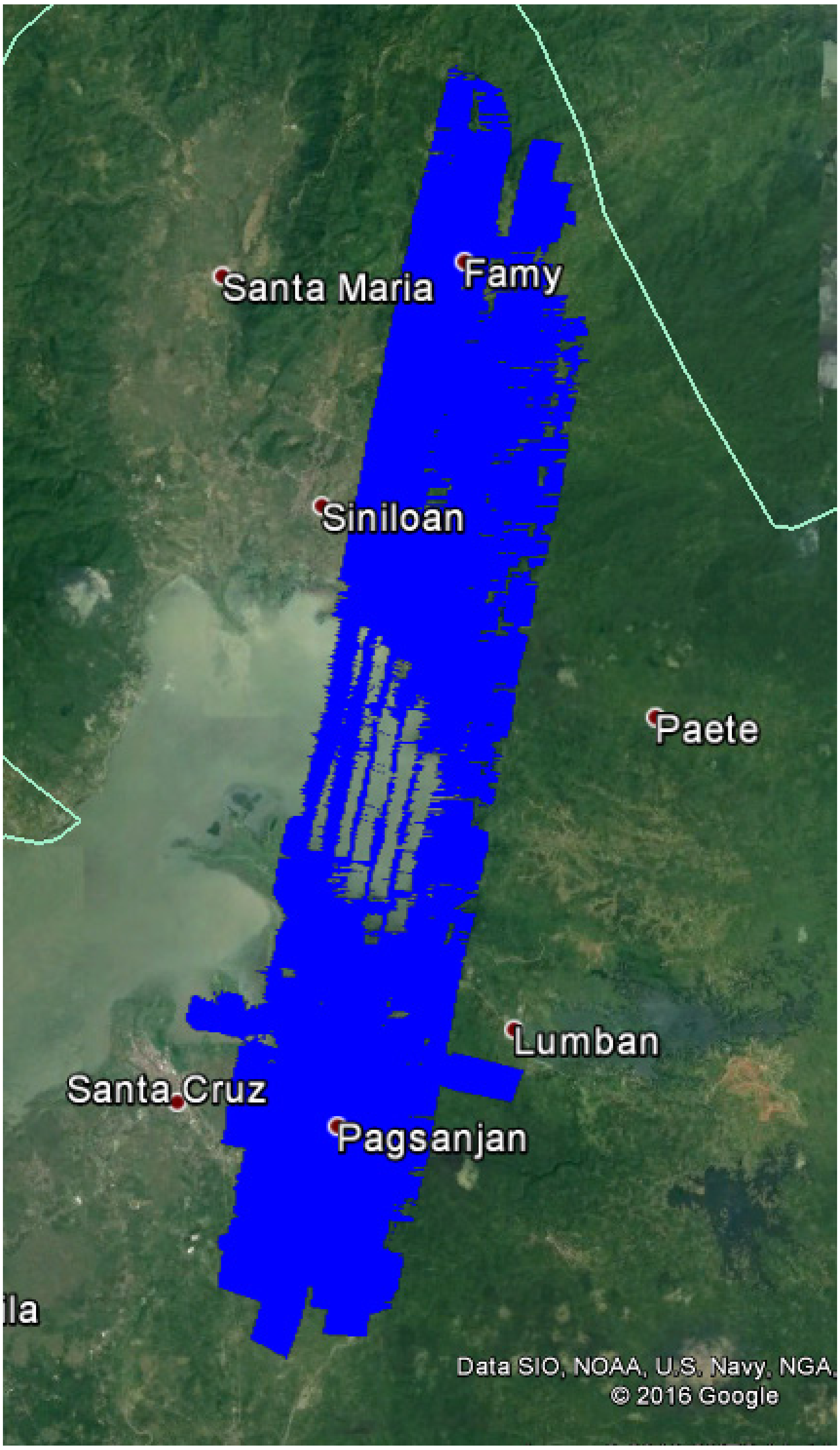


Figure A-7.3. Swath for Flight No. 1083P

Flight No. :	1087P				
Parameters:	PRF 200	SF	30	FOV	50

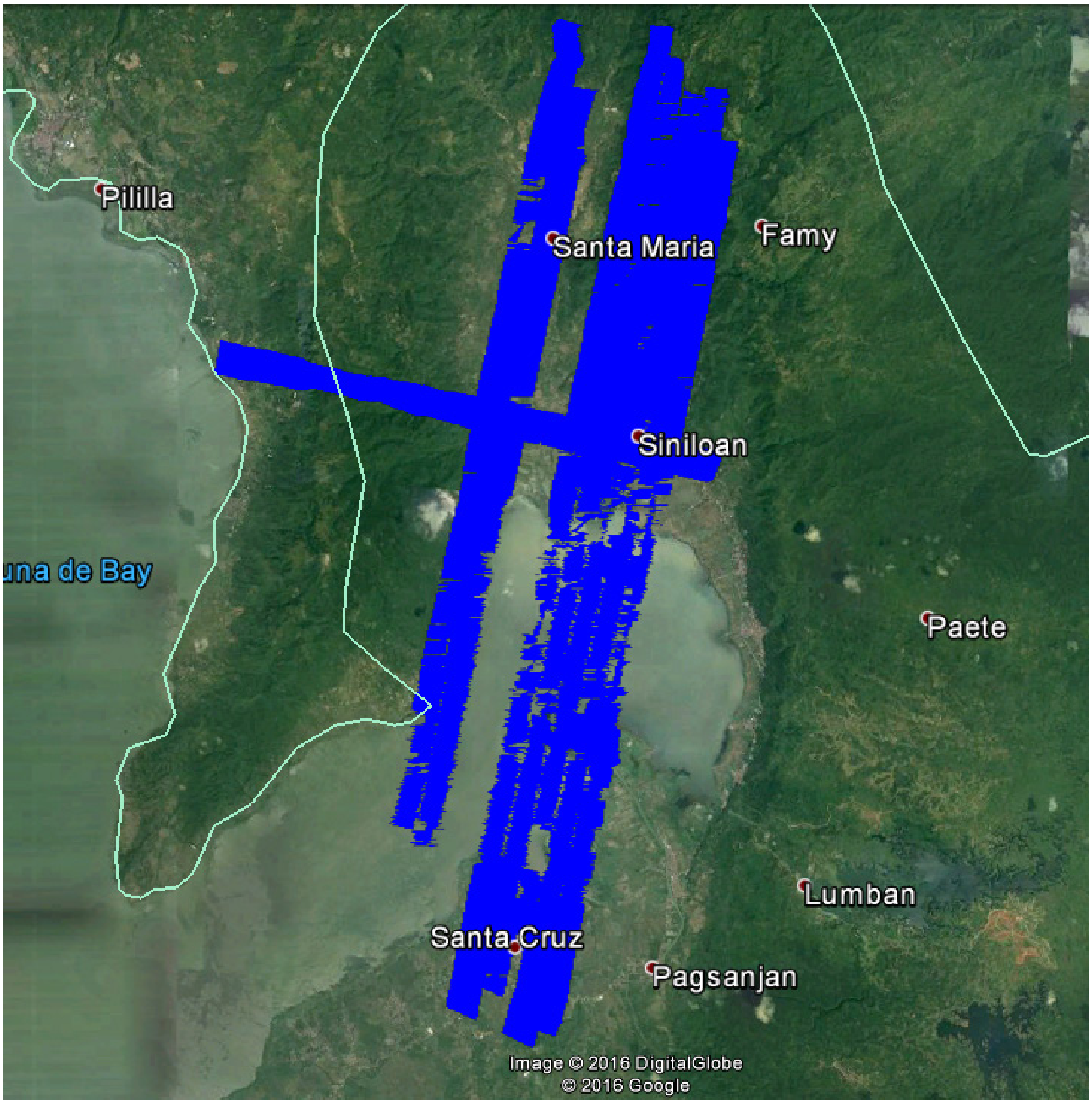


Figure A-7.4. Swath for Flight No. 1087P

Flight No. : 3299P
Area: BLK 18KS
Mission Name: 1BLK18KS227A
Area: 88.5 sq. km
Parameters (Ht, PRF, SCAN Angle, SCAN FREQ): 1000, 200, 25, 30

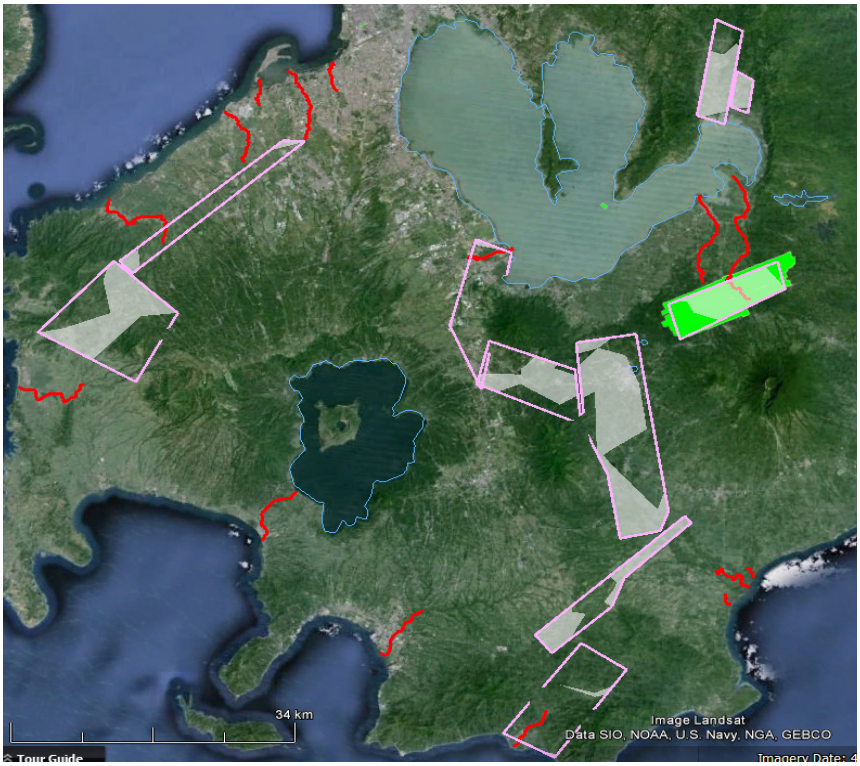


Figure A-7.5. Swath for Flight No. 3299P

Flight No. : 3307P
Area: BLK 18JS
Mission Name: 1BLK18JS229B
Area: 81.02 sq. km

Parameters (Ht, PRF, SCAN Angle, SCAN FREQ): 1000, 200, 25, 30

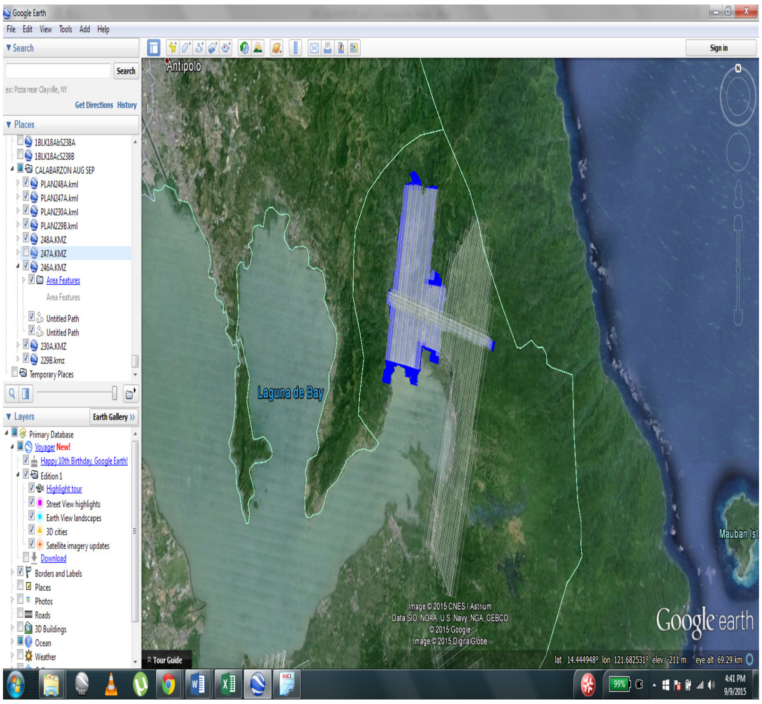


Figure A-7.6. Swath for Flight No. 3307P

Flight No. : 3377P
Area: BLK
Mission Name: 1BLK18JS247A
Area: 130.67 sq. km
Parameters (Ht, PRF, SCAN Angle, SCAN FREQ): 1100, 200, 25, 30

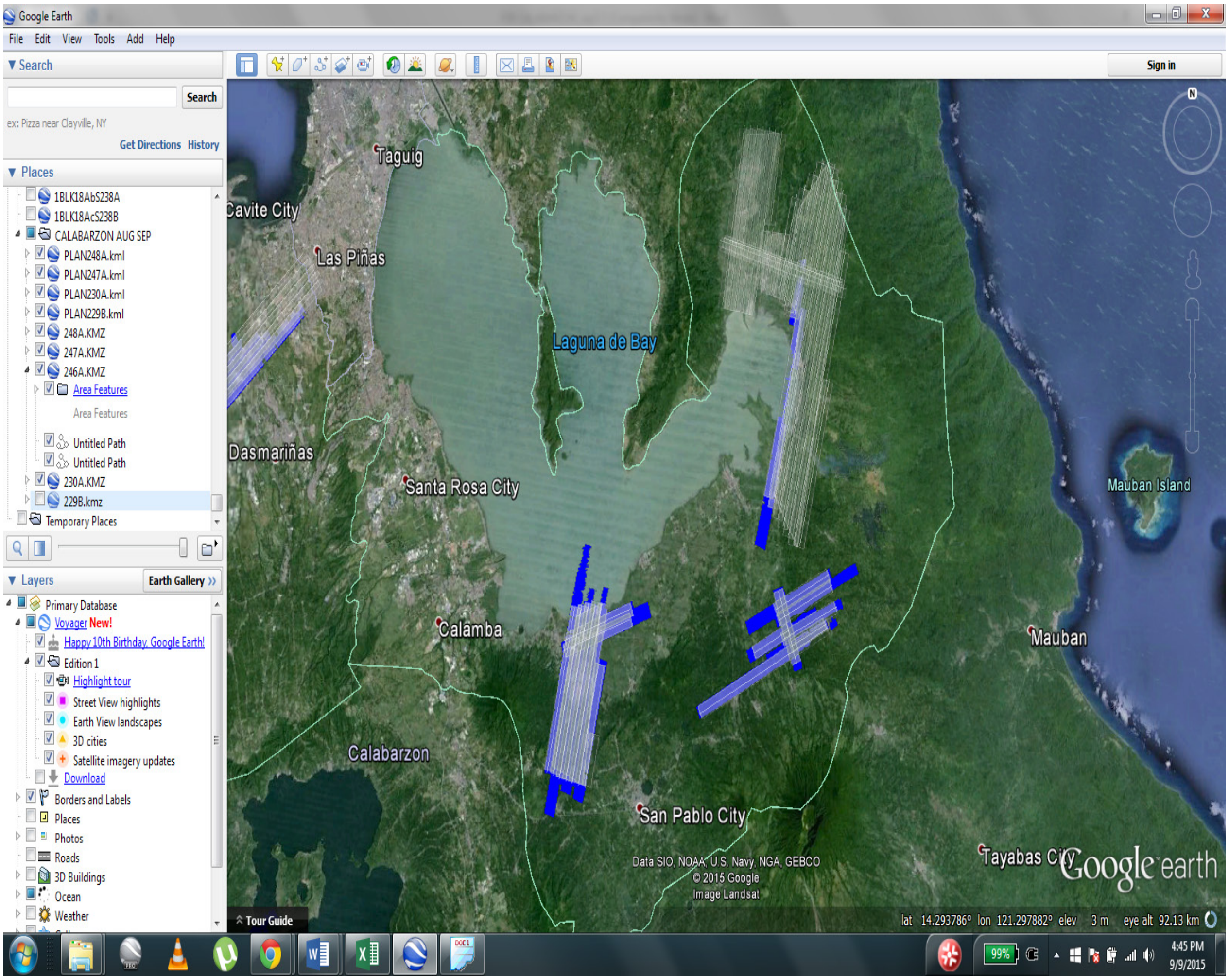


Figure A-7.7. Swath for Flight No. 3377P

Flight No. :	23444P				
Parameters:	PRF 200	SF	30	FOV	50

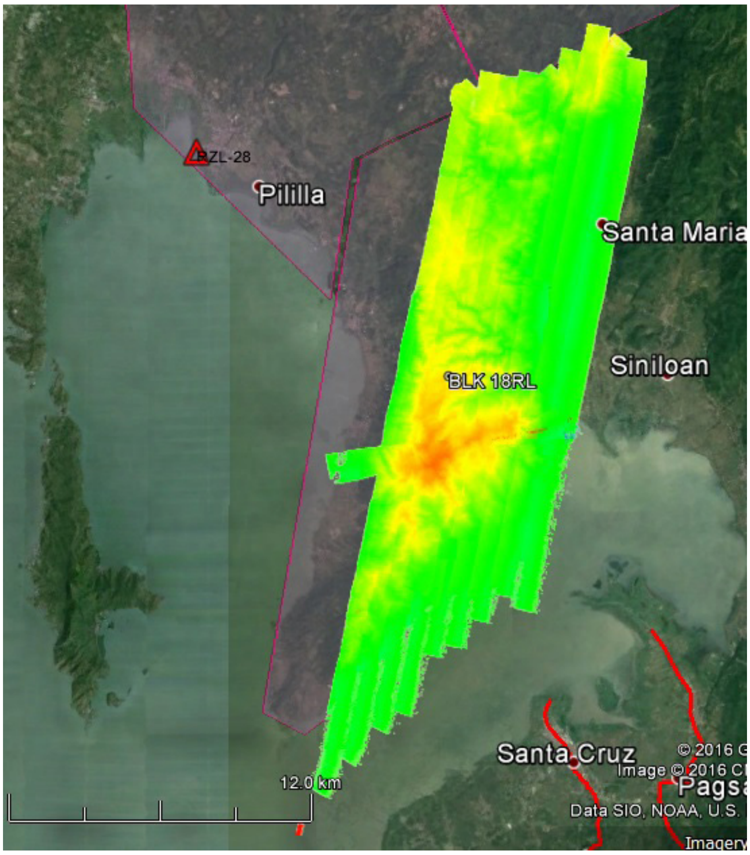


Figure A-7.8. Swath for Flight No. 23444P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk18J_supplement

Flight Area	CALABARZON
Mission Name	Blk18J_supplement
Inclusive Flights	3377P
Range data size	13.4 GB
Base data size	6.43 MB
POS	196 MB
Image	N/A
Transfer date	09/11/2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000301
IMU attitude correction stdev (<0.001deg)	0.012698
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	3.05%
Ave point cloud density per sq.m. (>2.0)	1.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	55
Maximum Height	501.72 m
Minimum Height	48.48 m
Classification (# of points)	
Ground	22,092,054
Low vegetation	19,211,327
Medium vegetation	19,282,090
High vegetation	39,575,866
Building	5,114,877
Orthophoto	No
Processed By	Engr. Sheila-Maye Santillan, Aljon Rie Araneta, Maria Tamsyn Malabanan

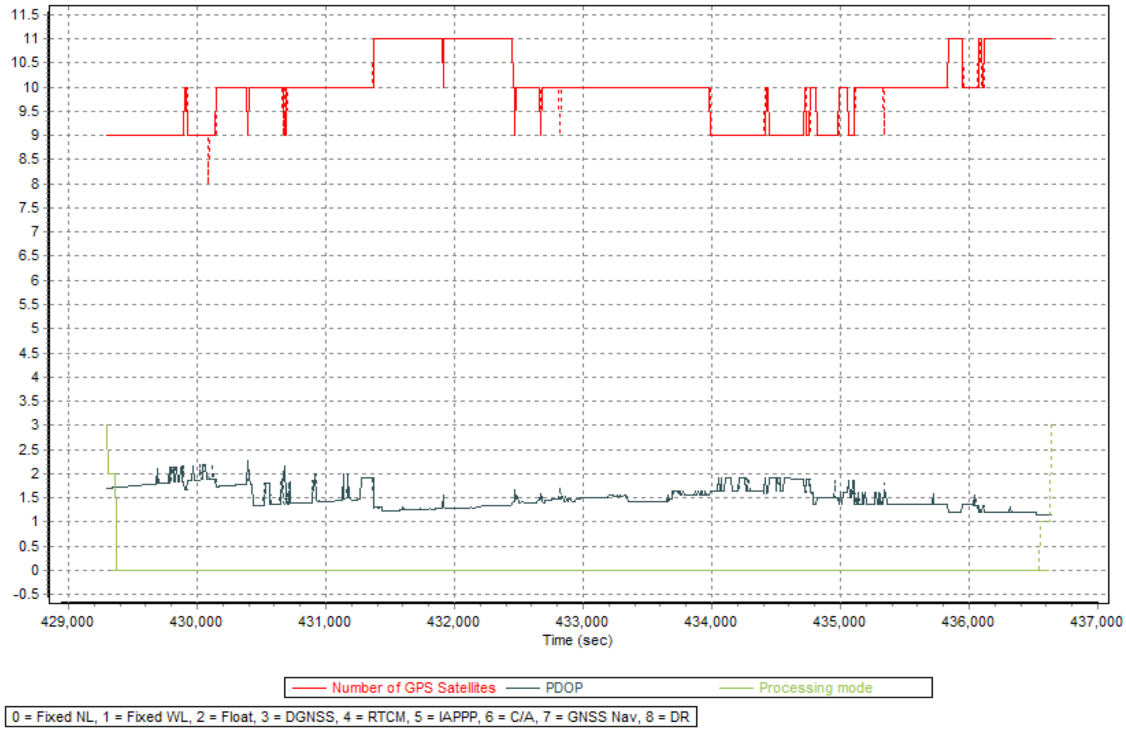


Figure A-8.1. Solution Status

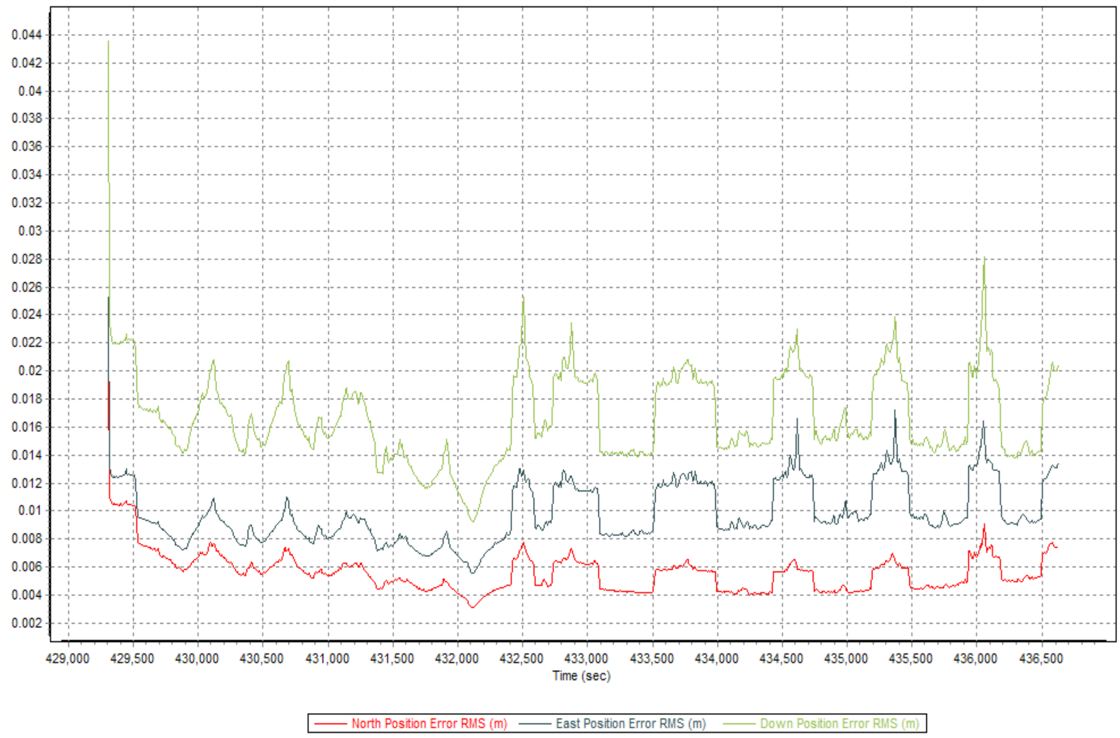


Figure A-8.2. Smoothed Performance Metrics Parameters

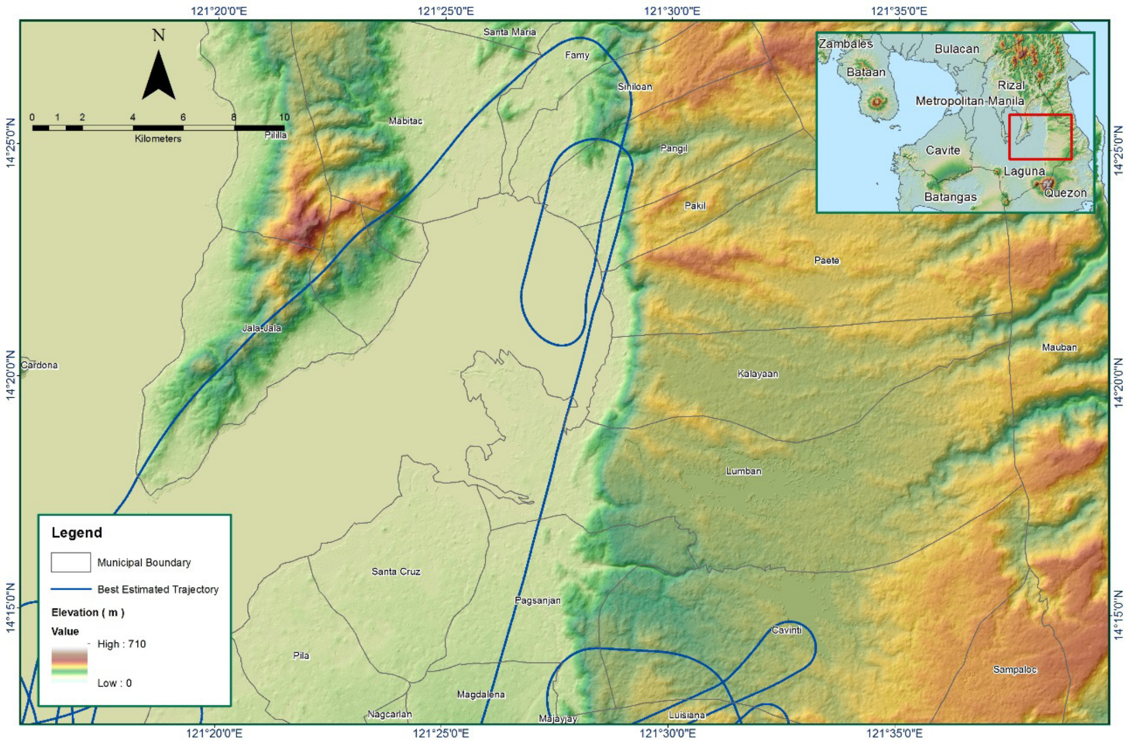


Figure A-8.3. Best Estimated Trajectory

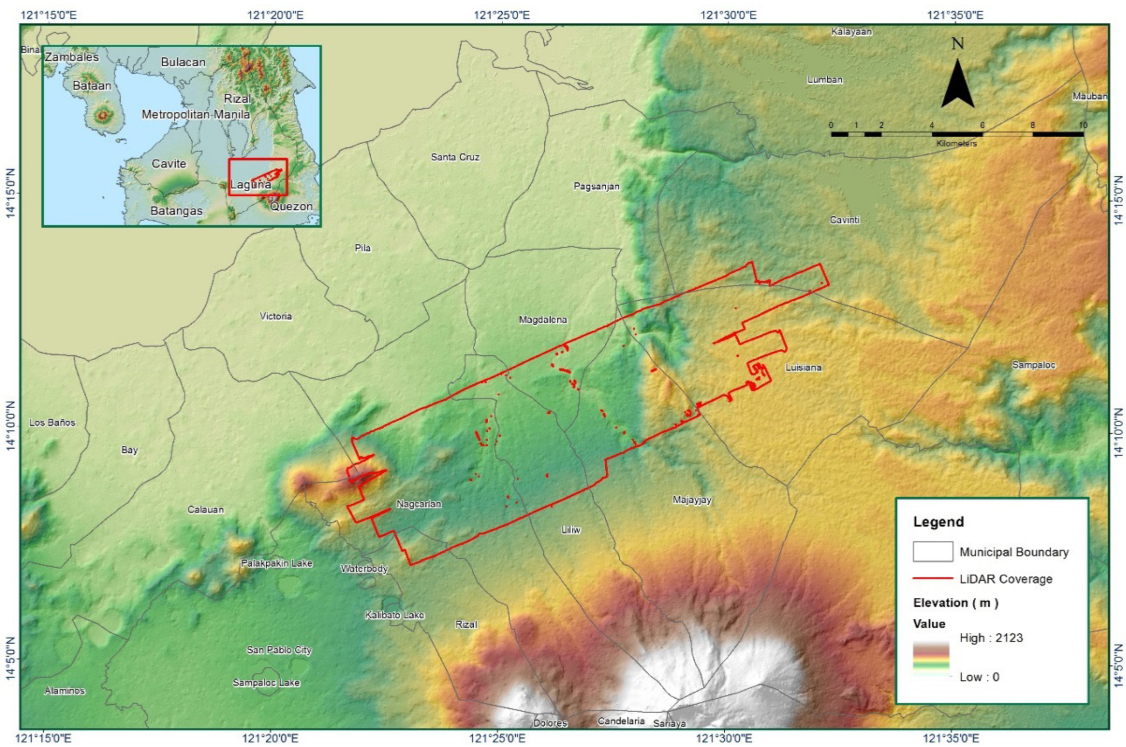


Figure A-8.4. Coverage of LiDAR data

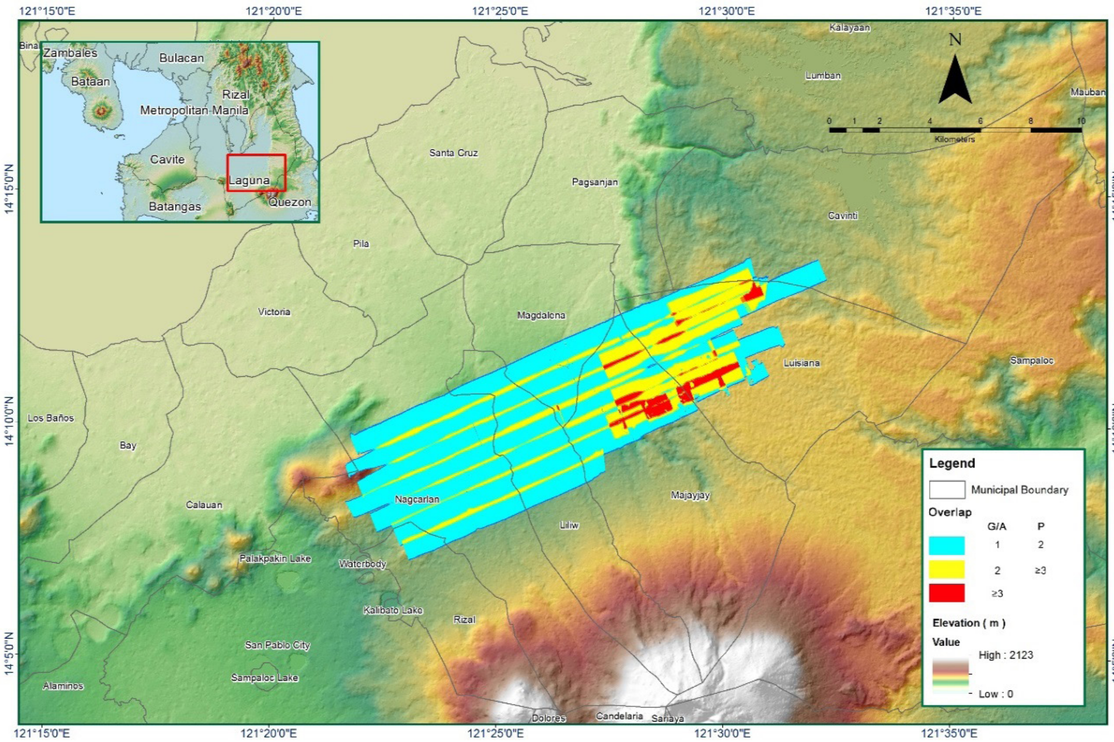


Figure A-8.5. Image of data overlap

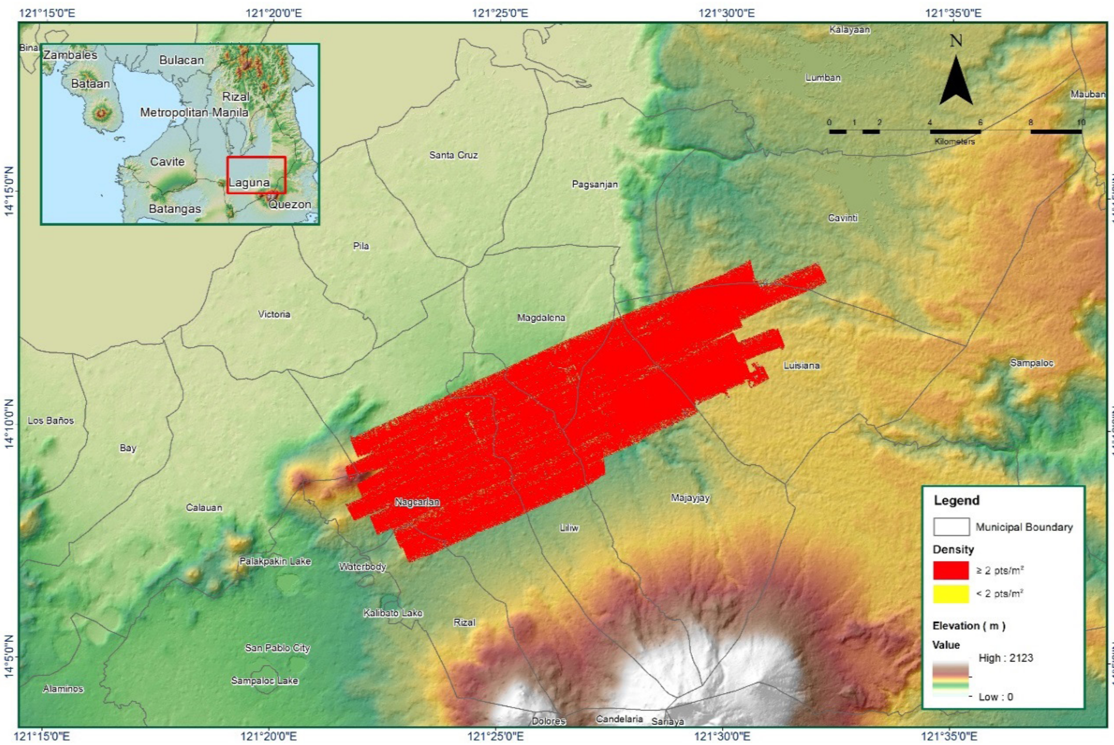


Figure A-8.6. Density map of merged LiDAR data

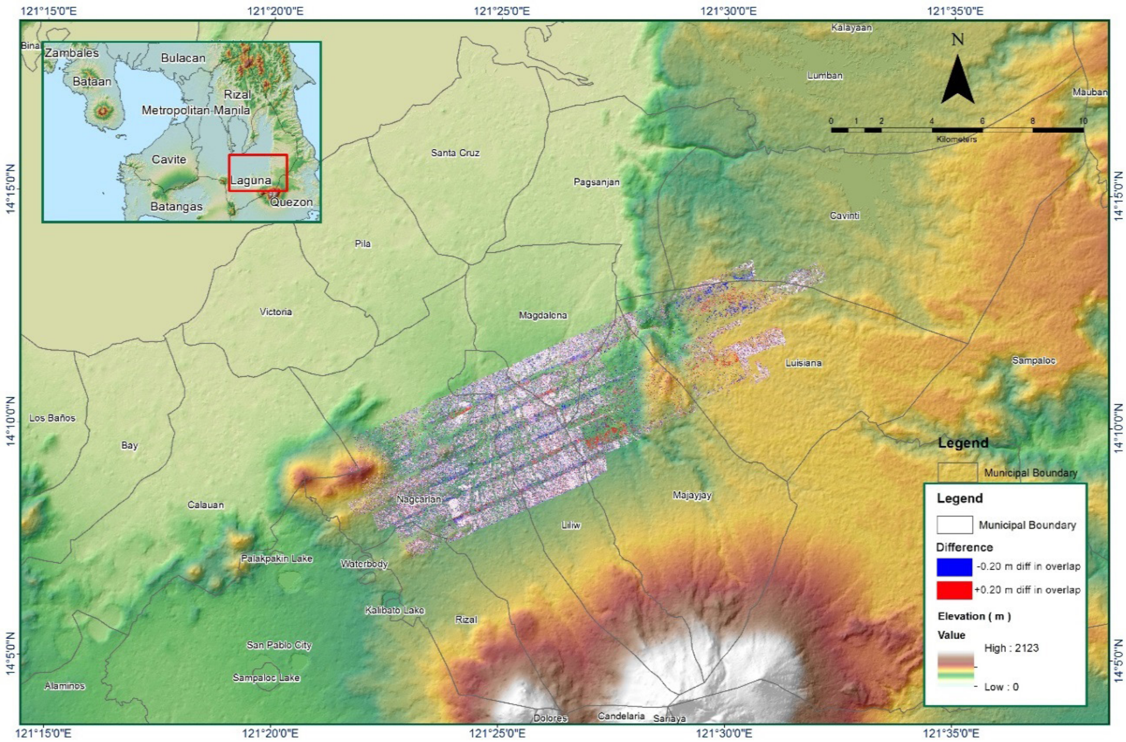


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk18I_supplement

Flight Area	**CALABARZON**
Mission Name	Blk18I_supplement
Inclusive Flights	3299P, 3377P
Range data size	23.8 GB
Base data size	10.16 MB
POS	339 MB
Image	N/A
Transfer date	09/11/2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.9
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.9
Boresight correction stdev (<0.001deg)	0.000301
IMU attitude correction stdev (<0.001deg)	0.012698
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	34.56%
Ave point cloud density per sq.m. (>2.0)	4.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	124
Maximum Height	715.82 m
Minimum Height	72.48 m
Classification (# of points)	
Ground	51,435,640
Low vegetation	36,221,058
Medium vegetation	169,763,632
High vegetation	405,680,252
Building	8,514,938
Orthophoto	No
Processed By	Engr. Irish Cortez, Engr. Chelou Prado, Jovy Narisma

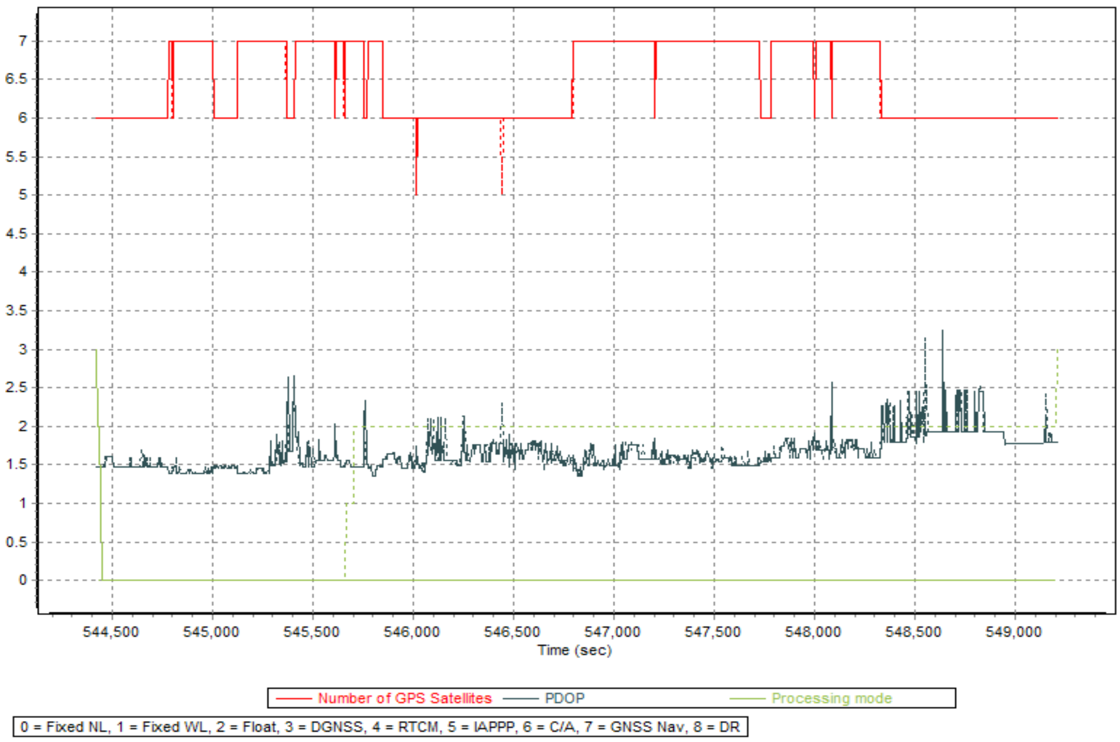


Figure A-8.8. Solution Status

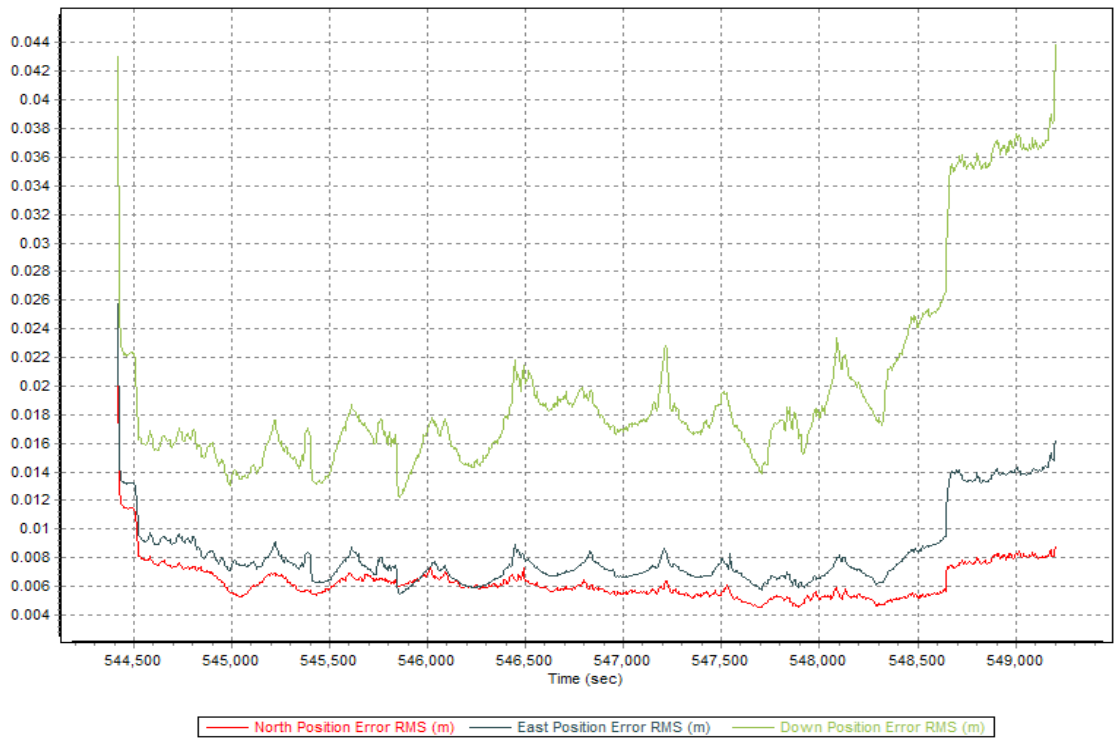


Figure A-8.9. Smoothed Performance Metrics Parameters

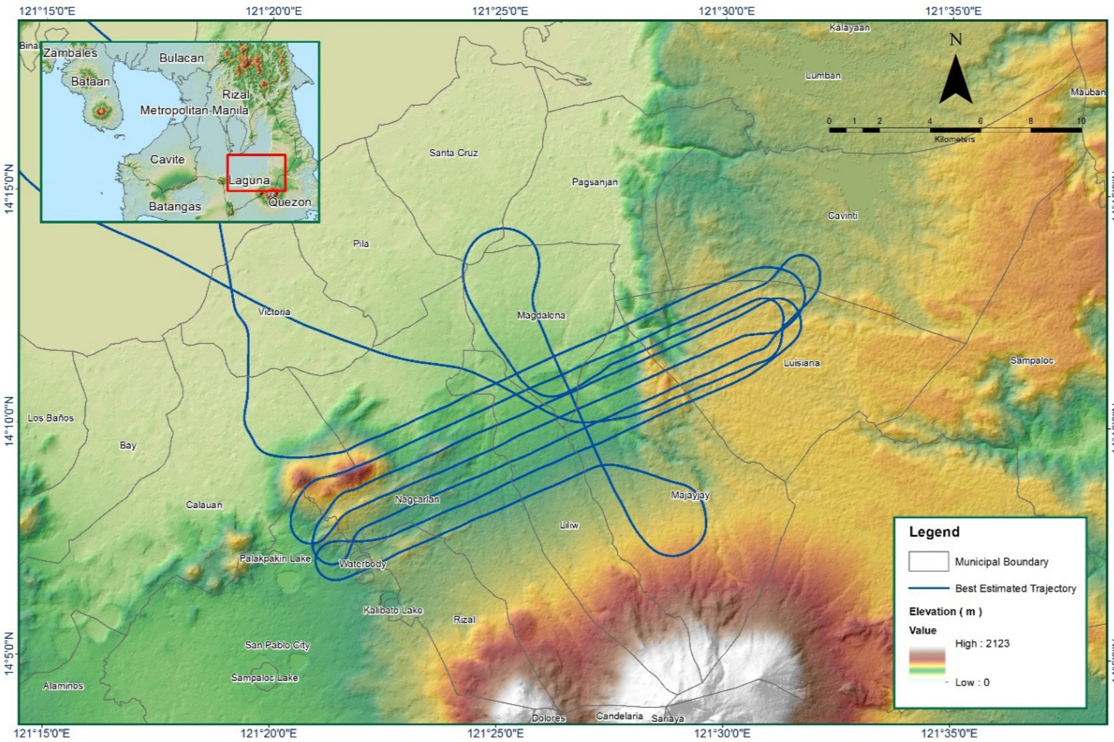


Figure A-8.10. Best Estimated Trajectory

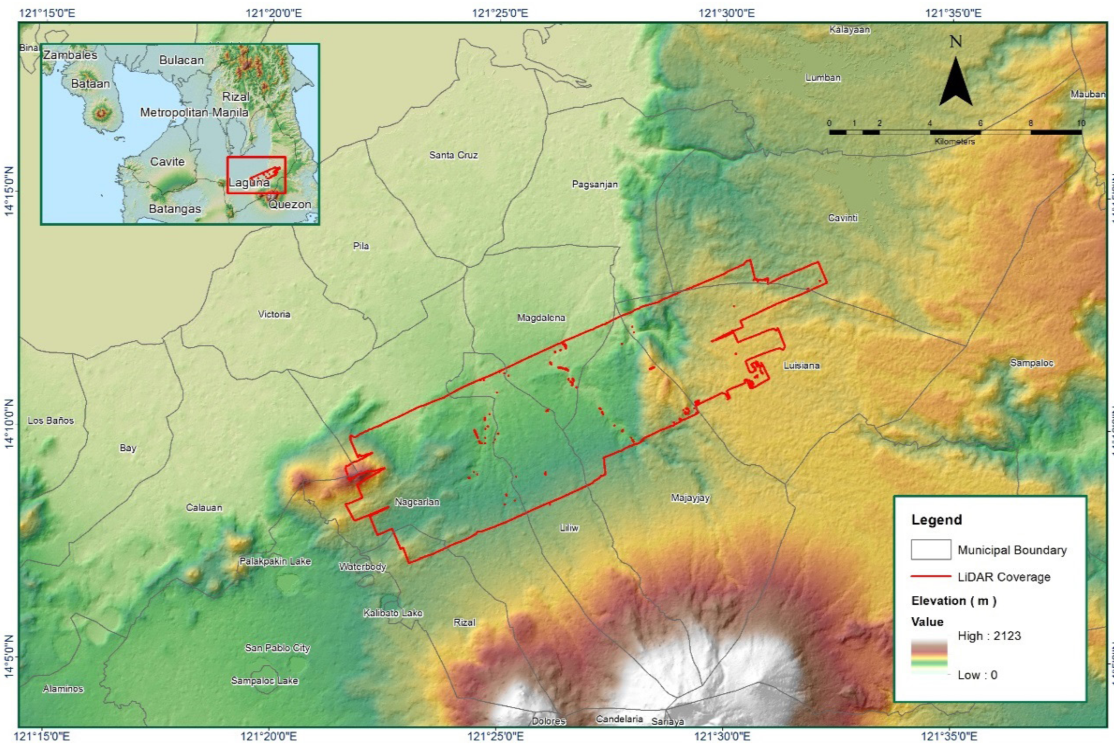


Figure A-8.11. Coverage of LiDAR data

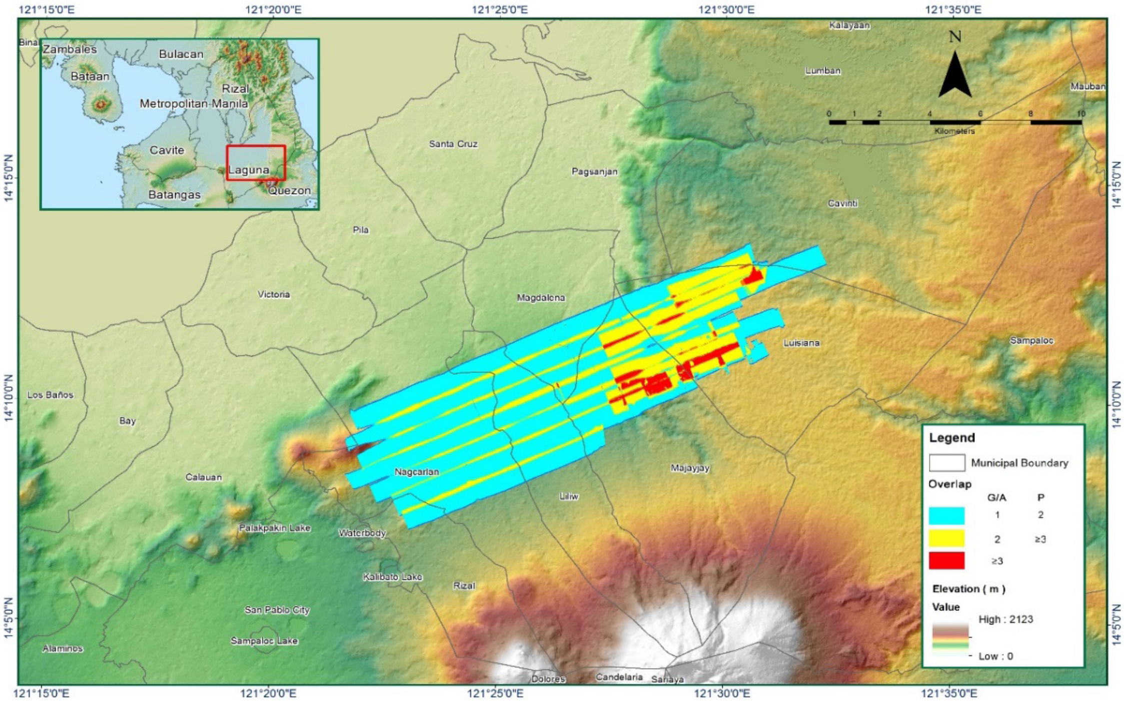


Figure A-8.12. Image of data overlap

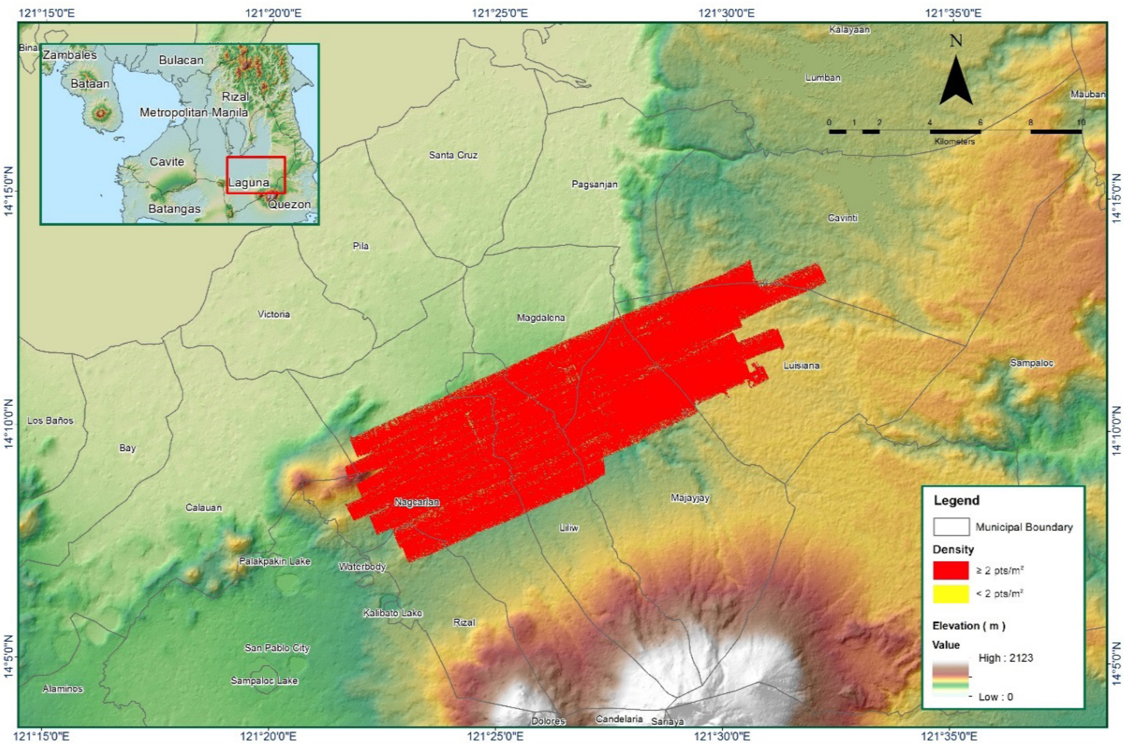


Figure A-8.13. Density map of merged LiDAR data

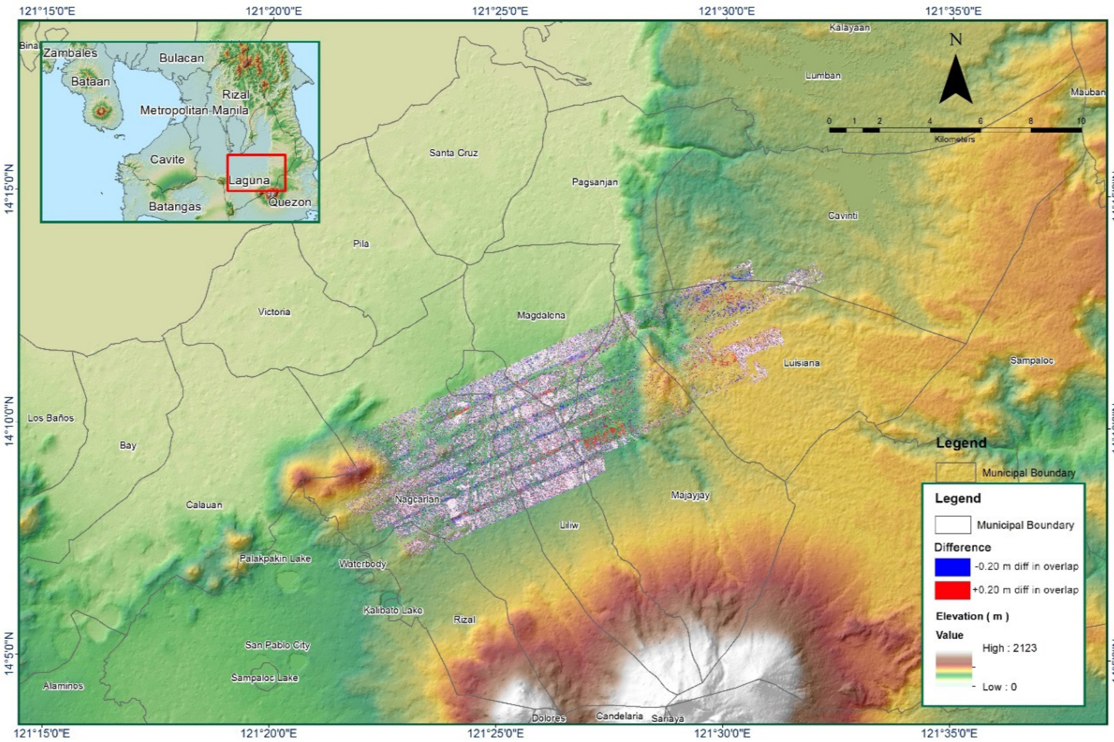


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk18K_supplement

Flight Area	CALABARZON
Mission Name	Blk18K_supplement
Inclusive Flights	3307P
Range data size	9.59 GB
Base data size	18.4 MB
POS	171 MB
Image	N/A
Transfer date	09/11/2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.6
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.3
Boresight correction stdev (<0.001deg)	0.000337
IMU attitude correction stdev (<0.001deg)	0.000744
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	45.57%
Ave point cloud density per sq.m. (>2.0)	2.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	118
Maximum Height	575.37 m
Minimum Height	40.37 m
Classification (# of points)	
Ground	86,593,971
Low vegetation	67,647,067
Medium vegetation	85,255,713
High vegetation	158,122,988
Building	7,764,902
Orthophoto	No
Processed By	Engr. Sheila-Maye Santillan, Engr. Melanie Hingpit, Engr. Elainne Lopez

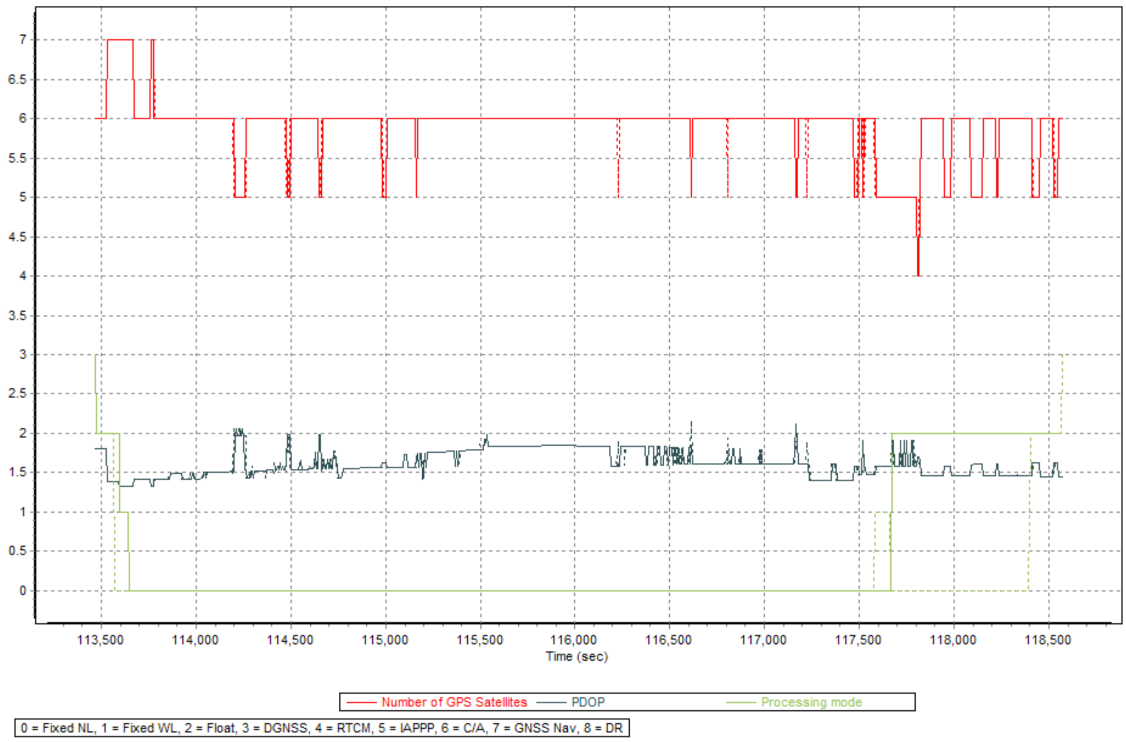


Figure A-8.15. Solution Status

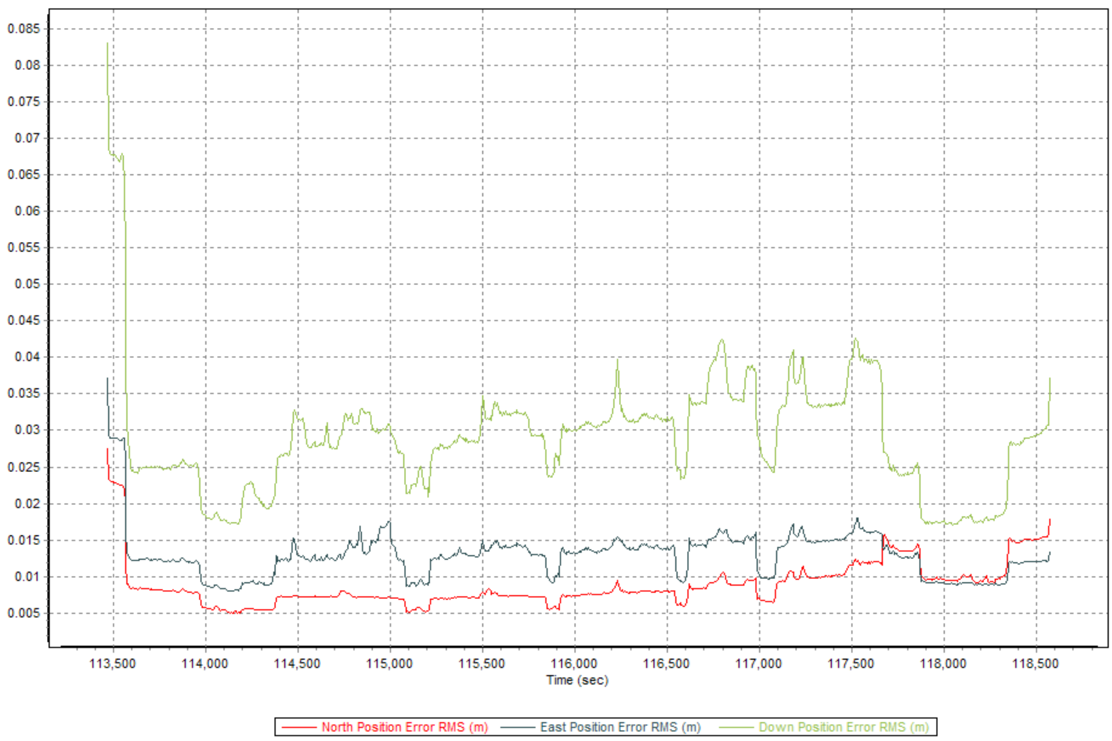


Figure A-8.16. Smoothed Performance Metrics Parameters

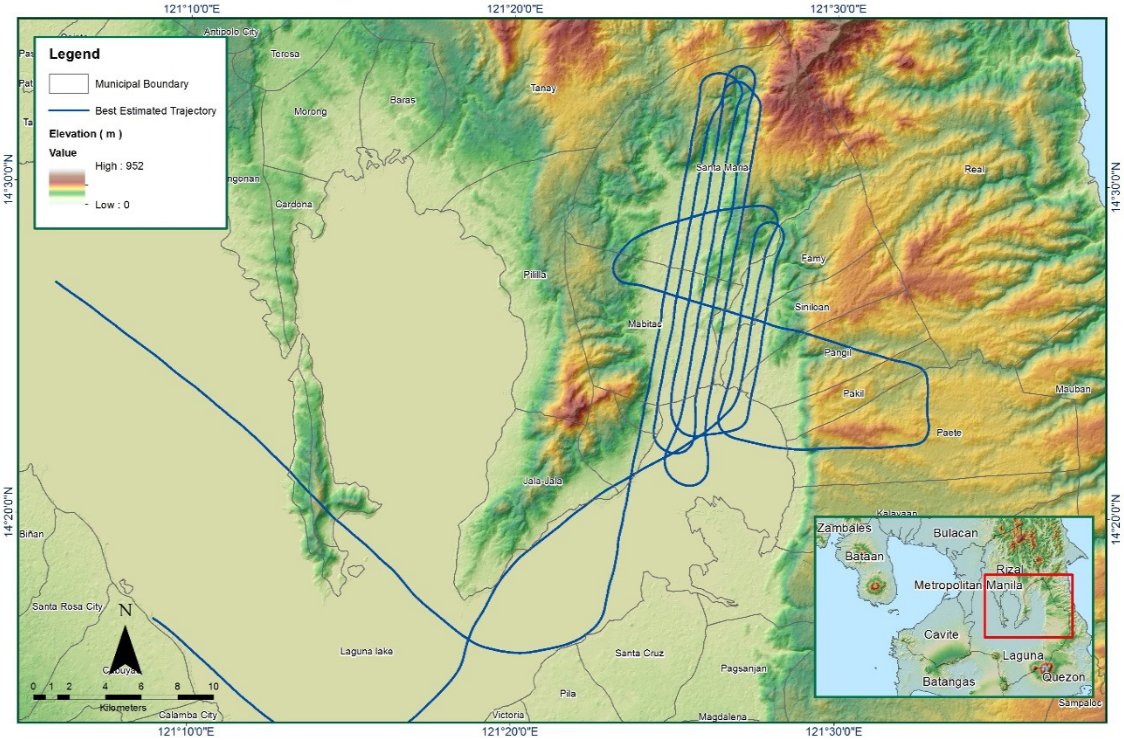


Figure A-8.17. Best Estimated Trajectory

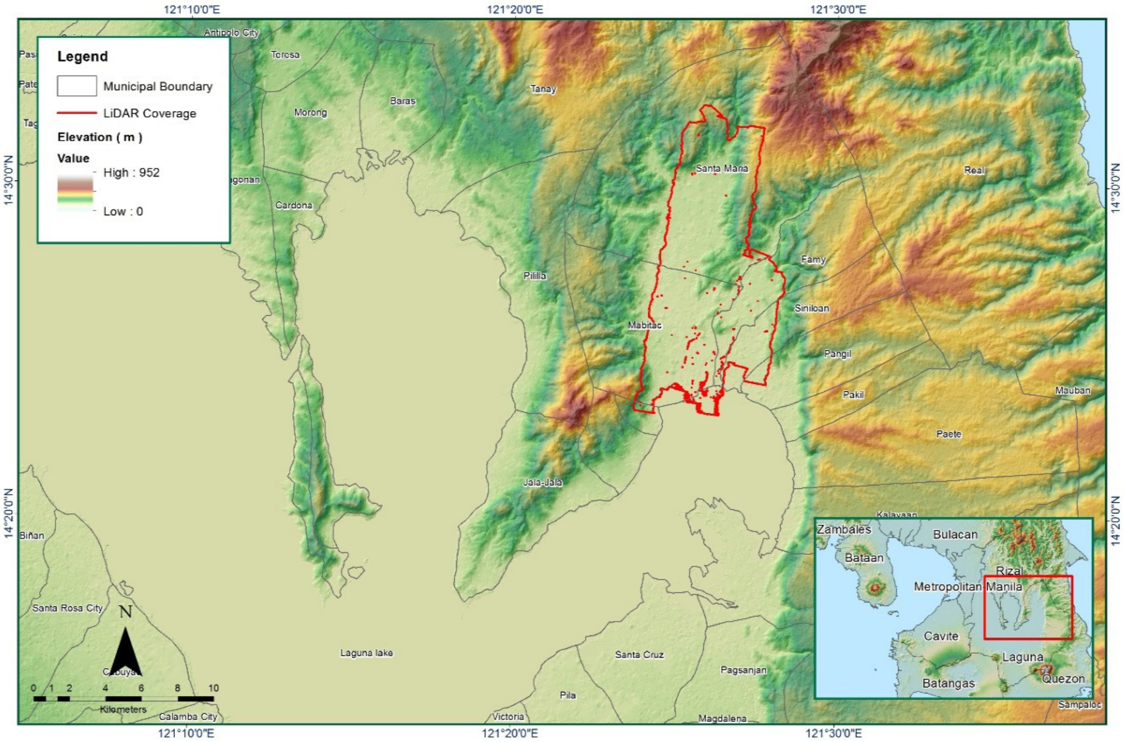


Figure A-8.18. Coverage of LiDAR data

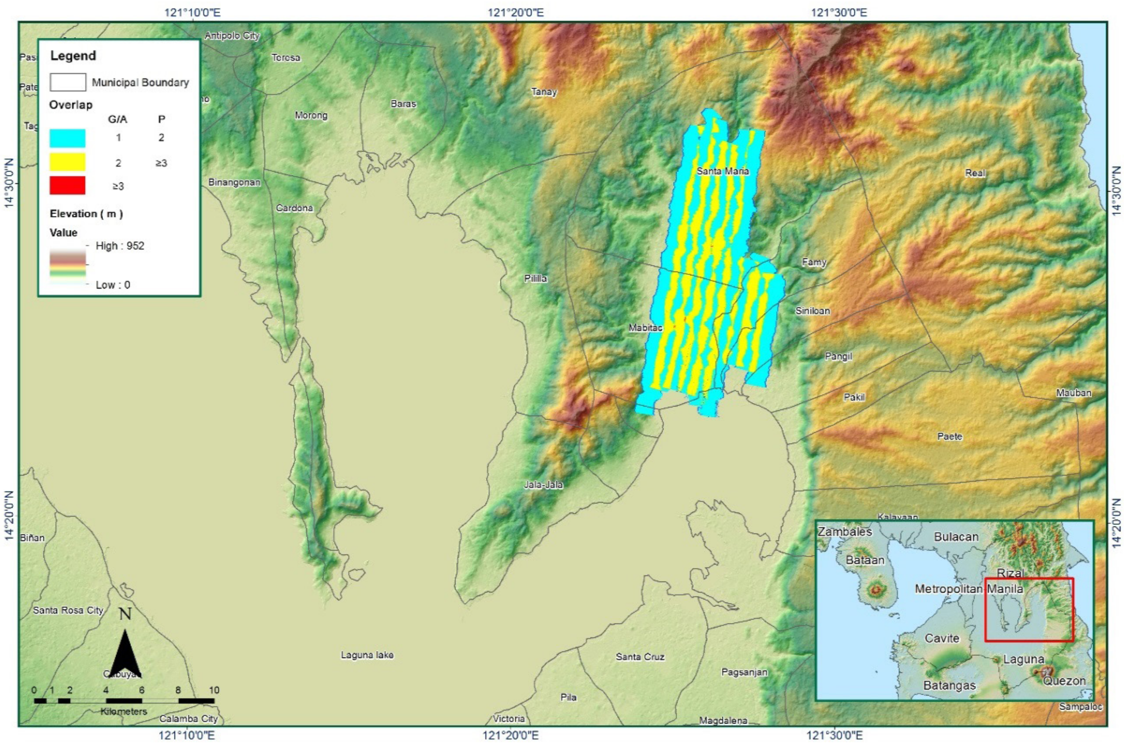


Figure A-8.19. Image of data overlap

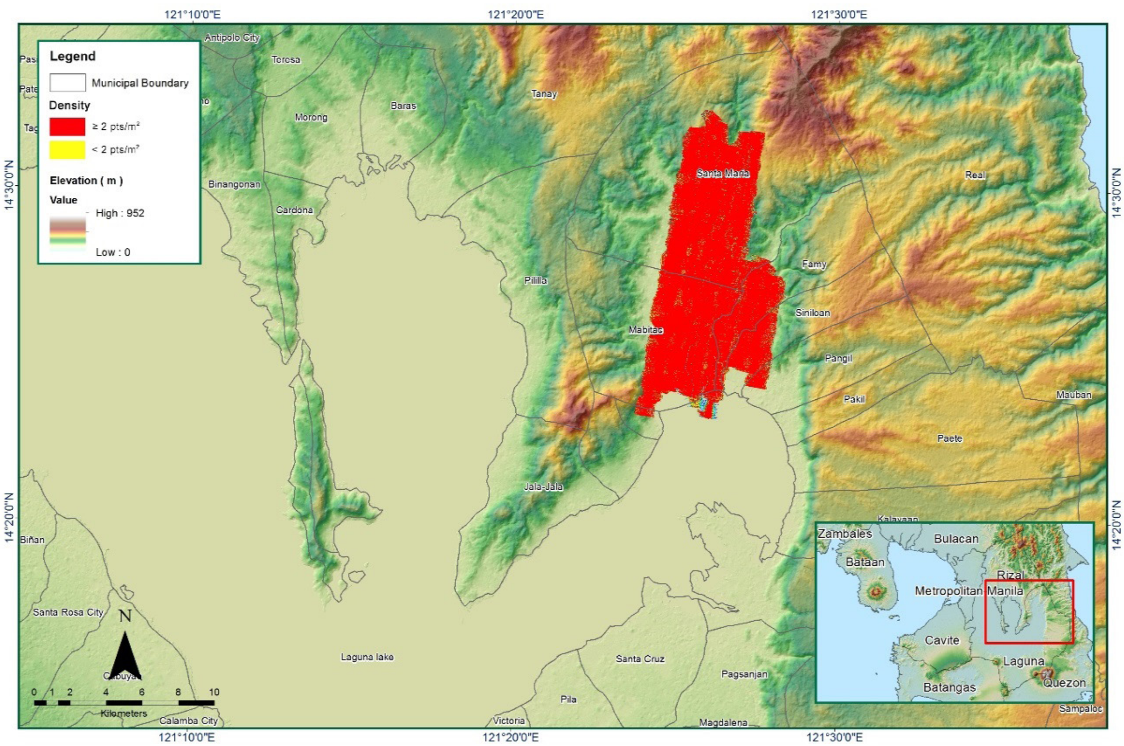


Figure A-8.20. Density map of merged LiDAR data

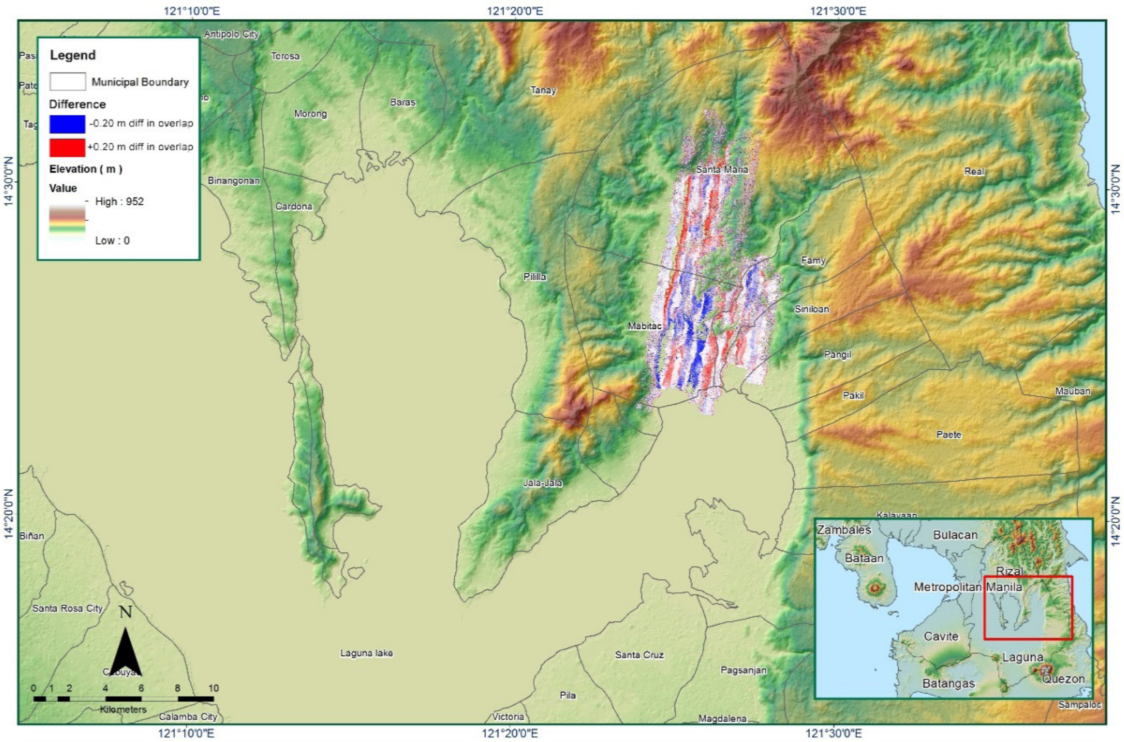


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk18K

Flight Area	CALABARZON Reflights
Mission Name	Blk18K
Inclusive Flights	23444P
Range data size	20.1 GB
Base data size	306 MB
POS	185 MB
Image	N/A
Transfer date	07/12/2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.13
RMSE for East Position (<4.0 cm)	1.44
RMSE for Down Position (<8.0 cm)	2.85
Boresight correction stdev (<0.001deg)	0.000192
IMU attitude correction stdev (<0.001deg)	0.000399
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	47.16%
Ave point cloud density per sq.m. (>2.0)	3.6
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	233
Maximum Height	790.93 m
Minimum Height	19.29 m
Classification (# of points)	
Ground	213,959,707
Low vegetation	94,359,178
Medium vegetation	215,493,548
High vegetation	305,439,204
Building	5,783,362
Orthophoto	No
Processed By	Engr. Irish Cortez, Engr. Merven Matthew Natino, Karl Adrian Vergara

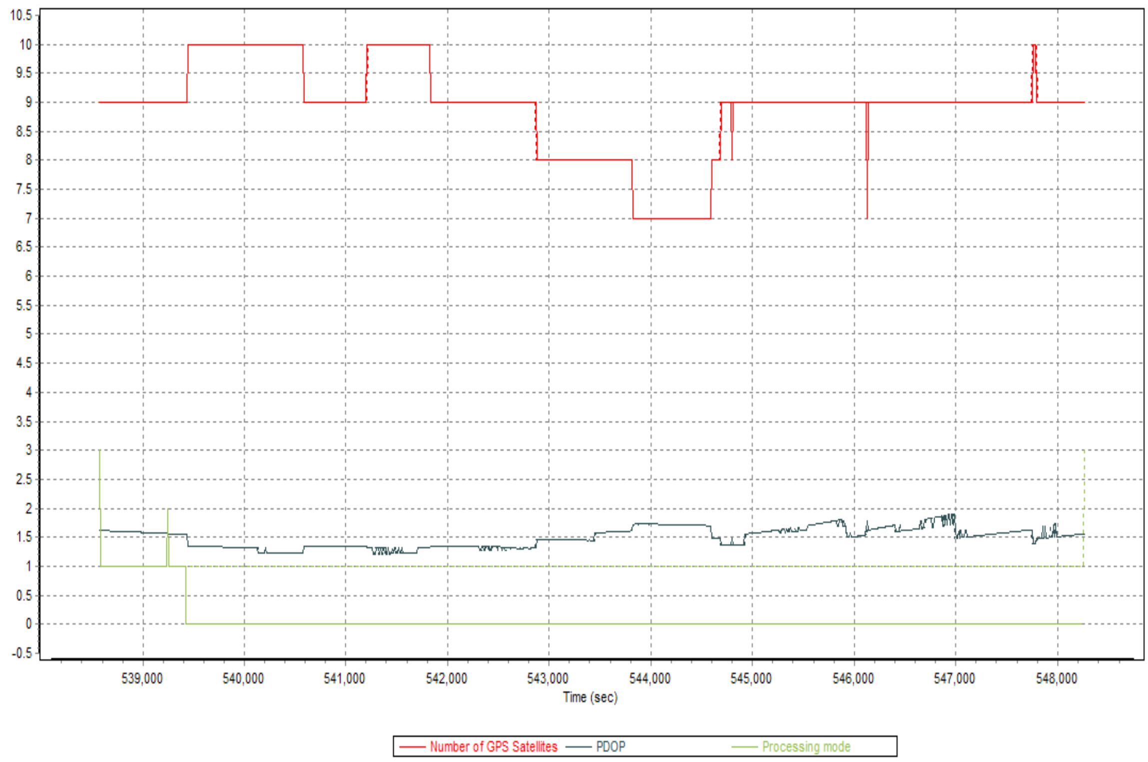


Figure A-8.22. Solution Status

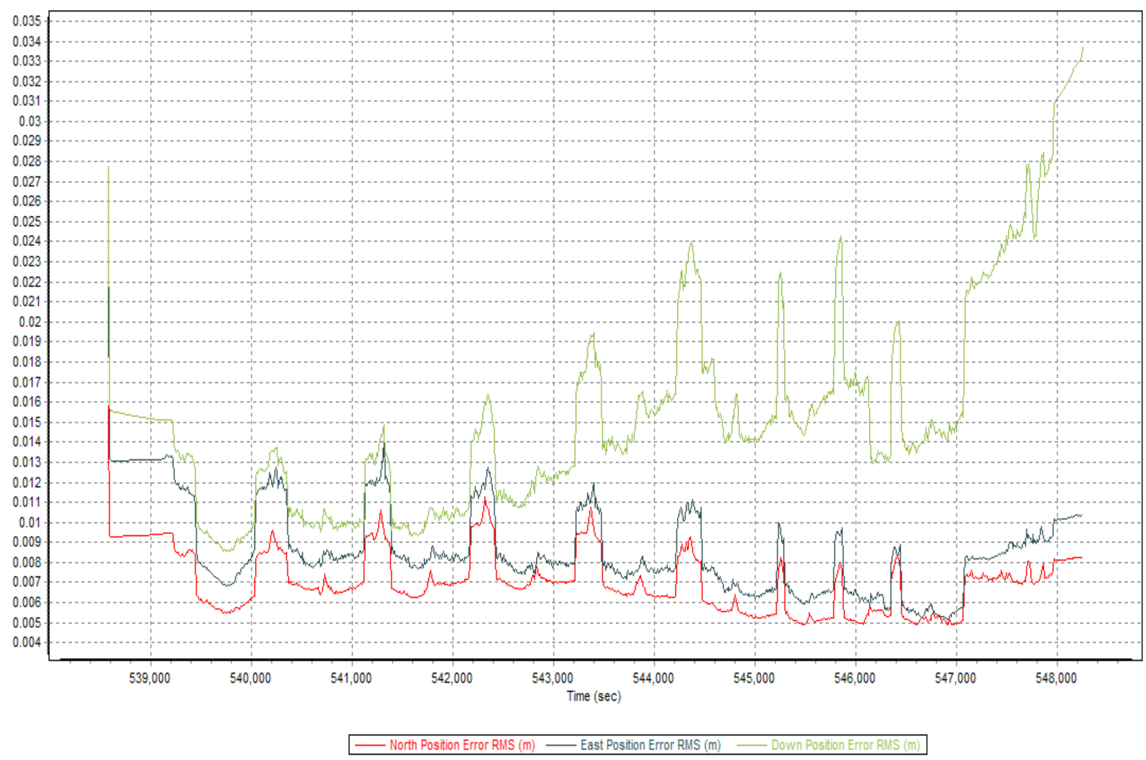


Figure A-8.23. Smoothed Performance Metrics Parameters

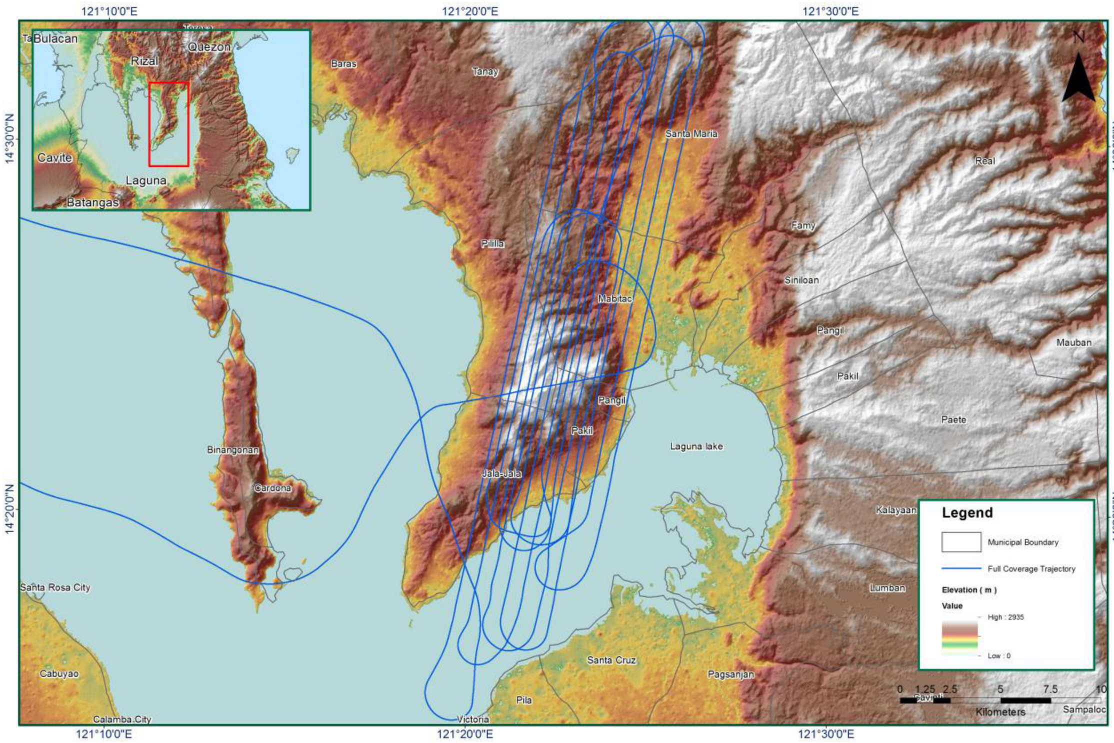


Figure A-8.24. Best Estimated Trajectory

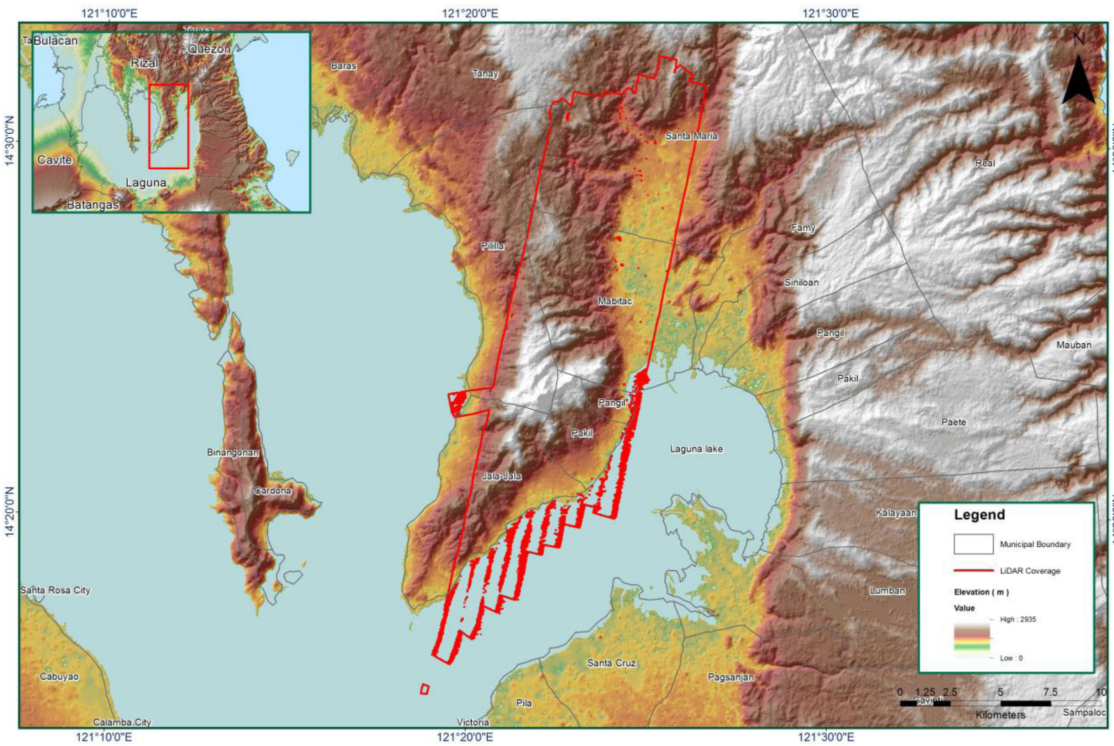


Figure A-8.25. Coverage of LiDAR data

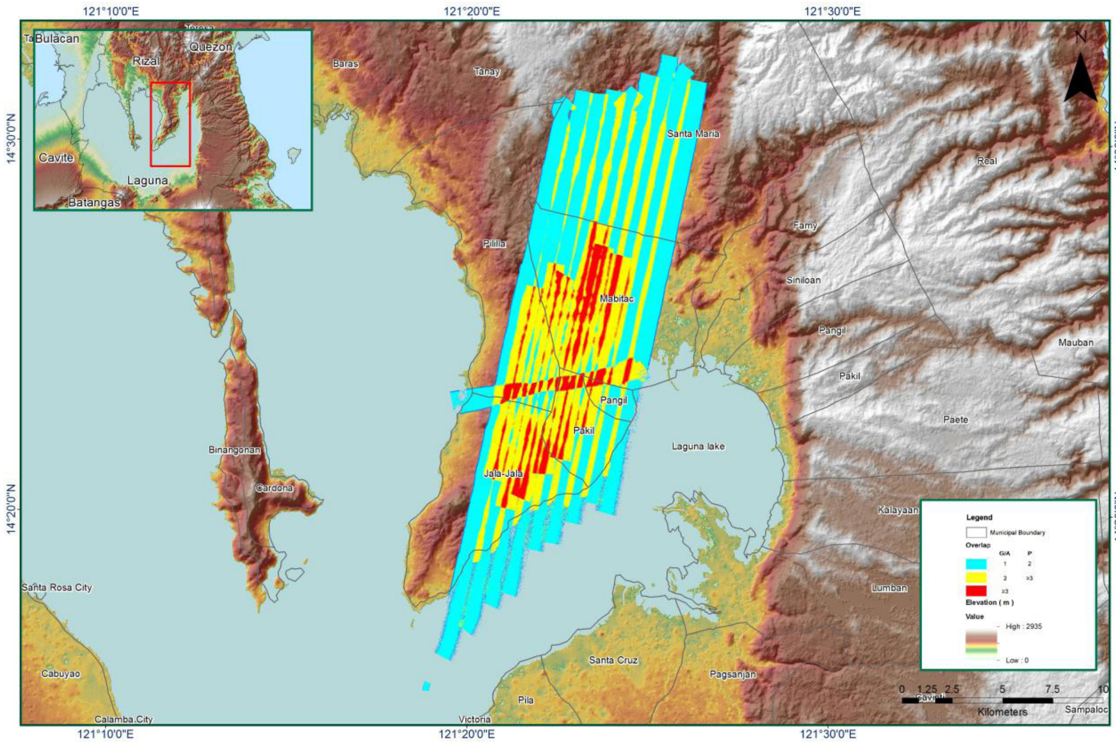


Figure A-8.26. Image of Data Overlap

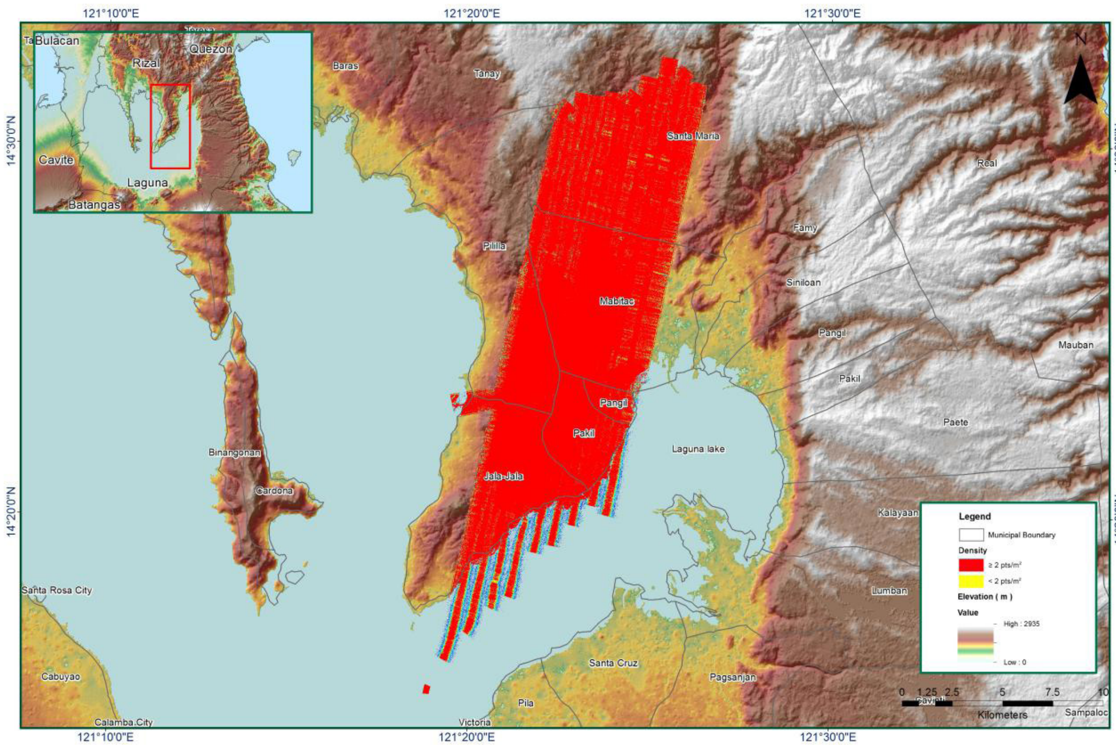


Figure A-8.27. Density map of merged LiDAR data

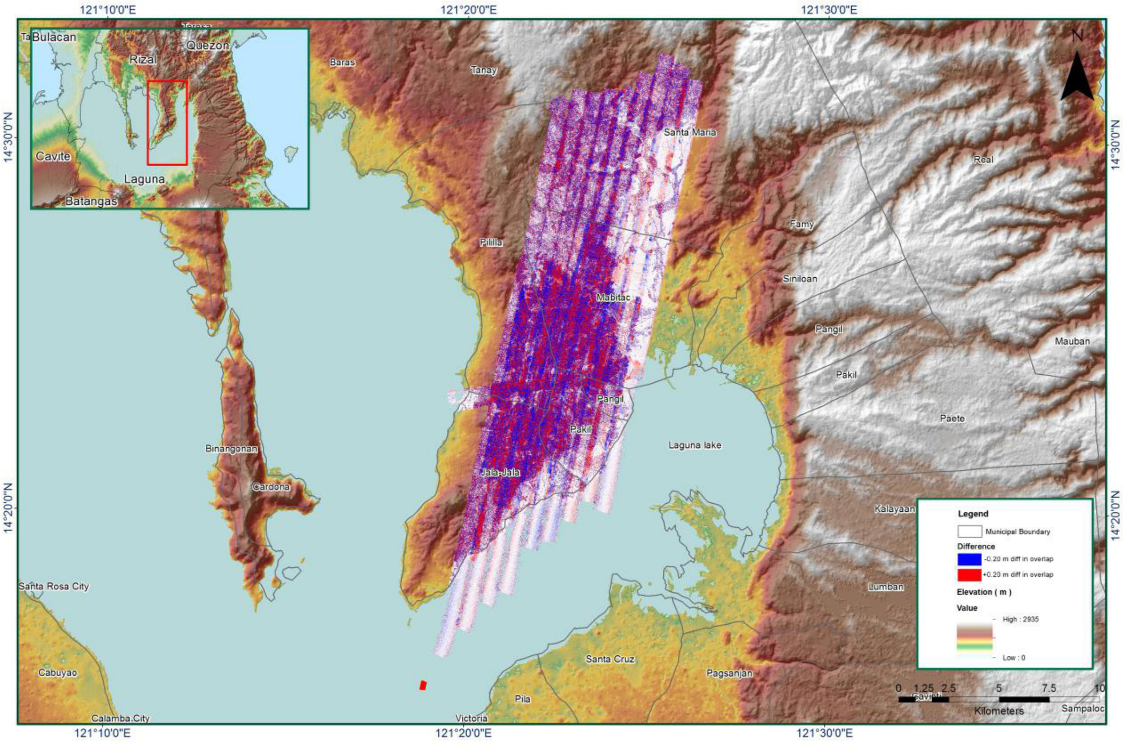


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk18J

Flight Area	**Laguna**
Mission Name	Blk18J
Inclusive Flights	1083P
Range data size	16.5 GB
POS	198 MB
Image	22.6 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
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)	1.4
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000730
IMU attitude correction stdev (<0.001deg)	0.002282
GPS position stdev (<0.01m)	0.0111
Minimum % overlap (>25)	43.53%
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	198
Maximum Height	978.05 m
Minimum Height	39.71 m
Classification (# of points)	
Ground	98,066,387
Low vegetation	96,509,309
Medium vegetation	134,853,601
High vegetation	171,911,755
Building	11,926,035
Orthophoto	Yes
Processed by	Victoria Rejuso, Engr. Harmond Santos, Engr. Gladys Mae Apat

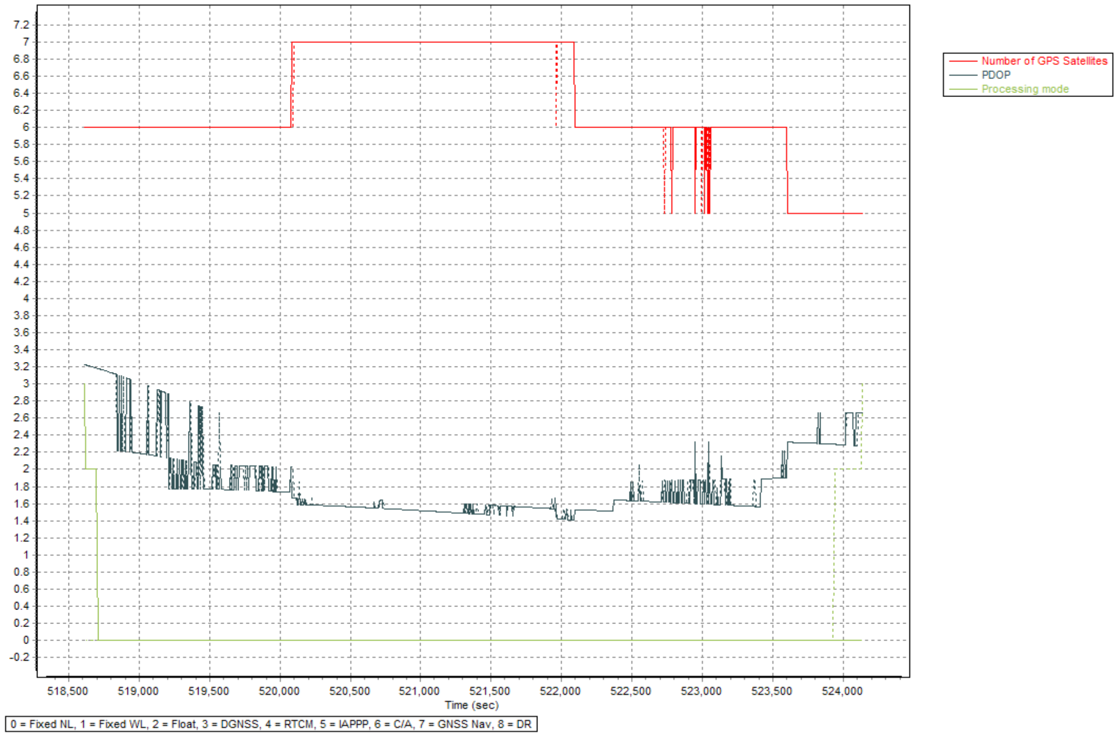


Figure A-8.29. Solution Status

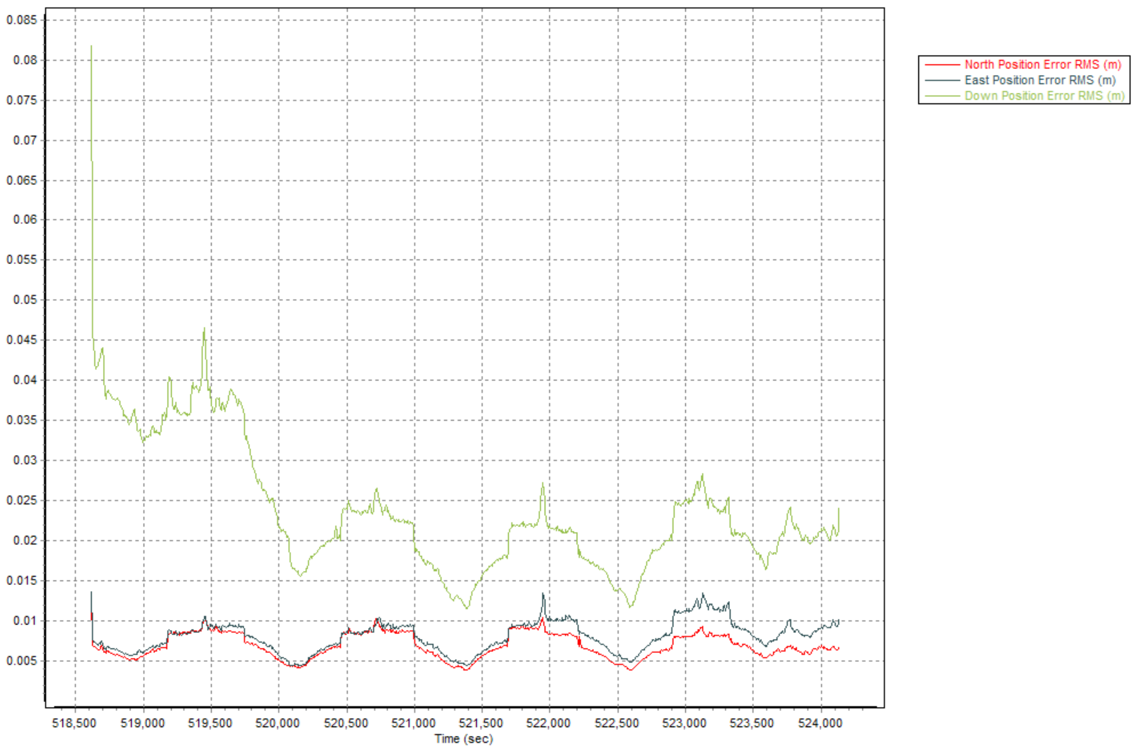


Figure A-8.30. Smoothed Performance Metrics Parameters

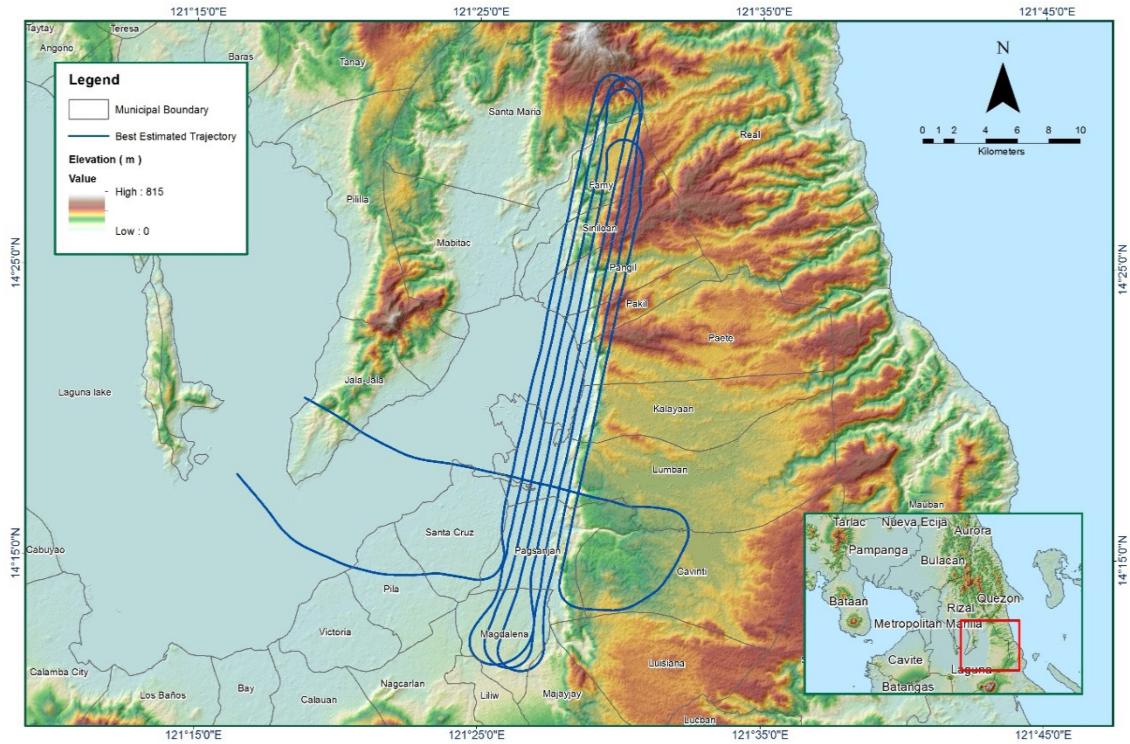


Figure A-8.31. Best Estimated Trajectory

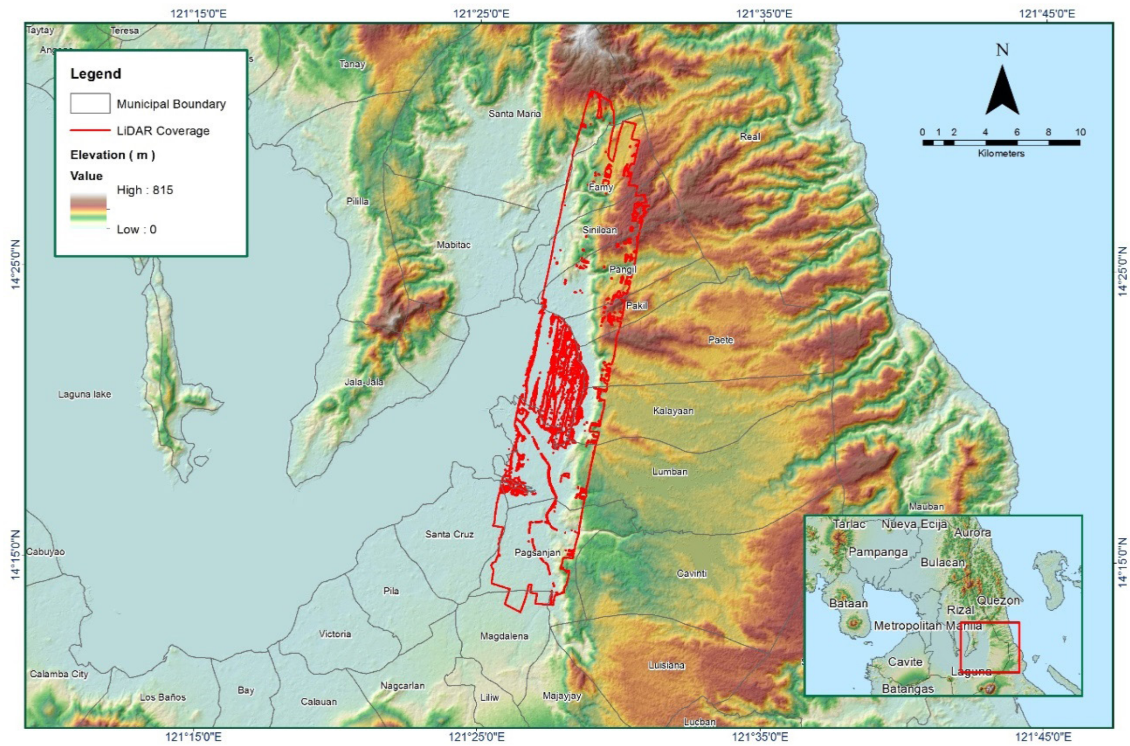


Figure A-8.32. Coverage of Lidar Data

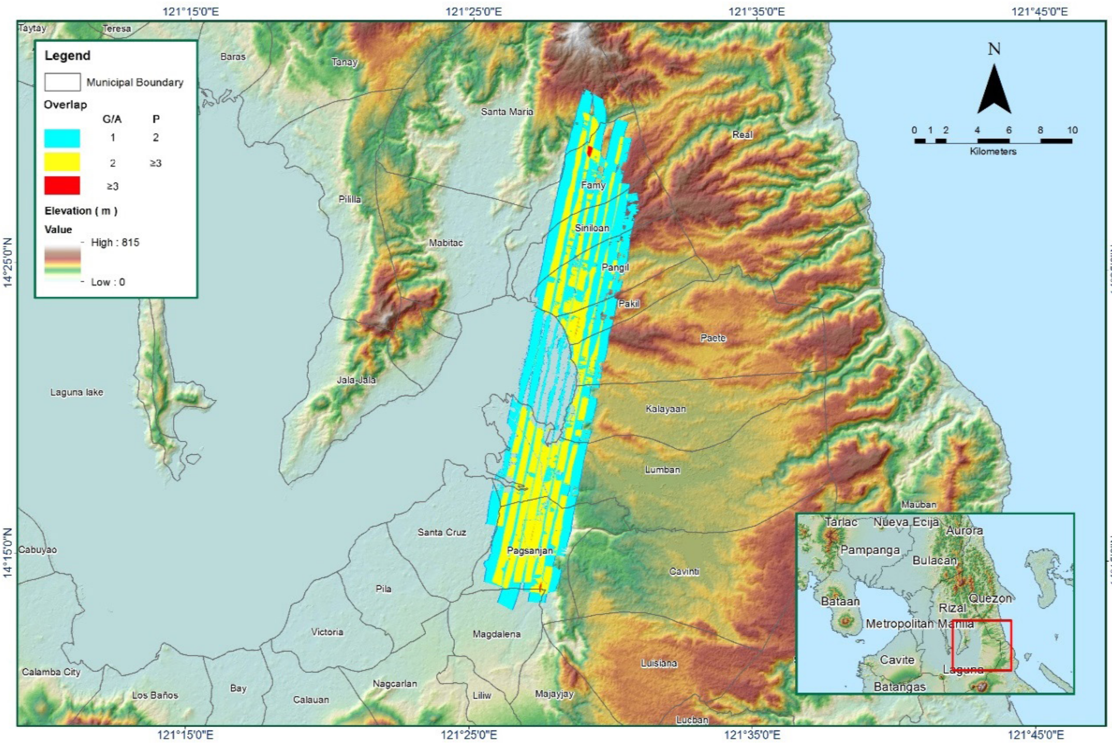


Figure A-8.33. Image of Data Overlap

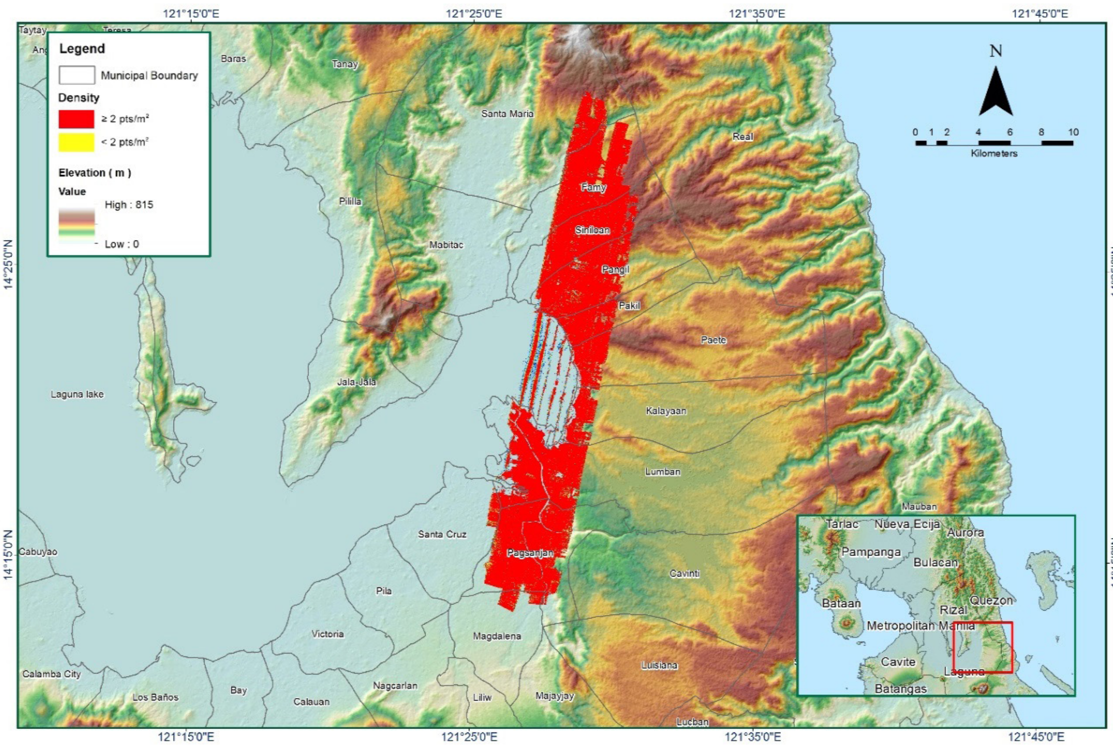


Figure A-8.34. Density map of merged LiDAR data

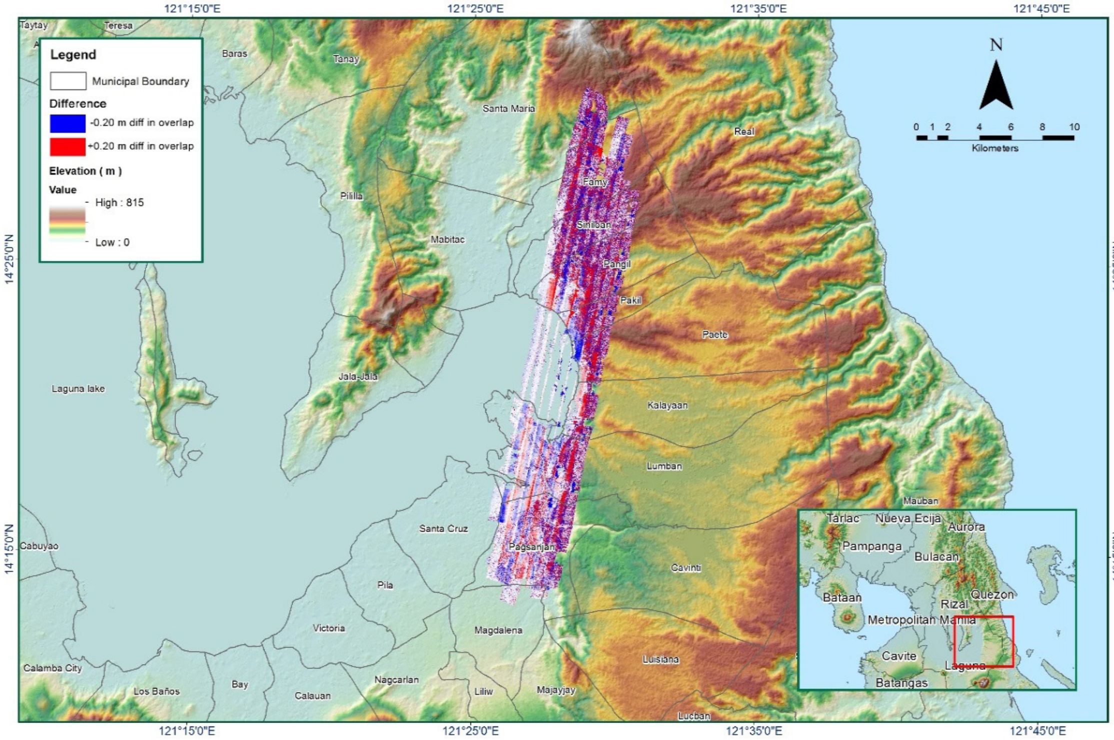


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk18H

Flight Area	**Laguna**
Mission Name	**Blk18H**
Inclusive Flights	1067P
Range data size	11.5 GB
POS	167 MB
Image	11.6 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	8.3
Boresight correction stdev (<0.001deg)	0.000809
IMU attitude correction stdev (<0.001deg)	0.001928
GPS position stdev (<0.01m)	0.0112
Minimum % overlap (>25)	26.06%
Ave point cloud density per sq.m. (>2.0)	1.94
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	163
Maximum Height	310.62 m
Minimum Height	37.58 m
Classification (# of points)	
Ground	102,772,146
Low vegetation	92,083,762
Medium vegetation	40,552,184
High vegetation	34,329,378
Building	21,274,084
Orthophoto	Yes
Processed by	Victoria Rejuso

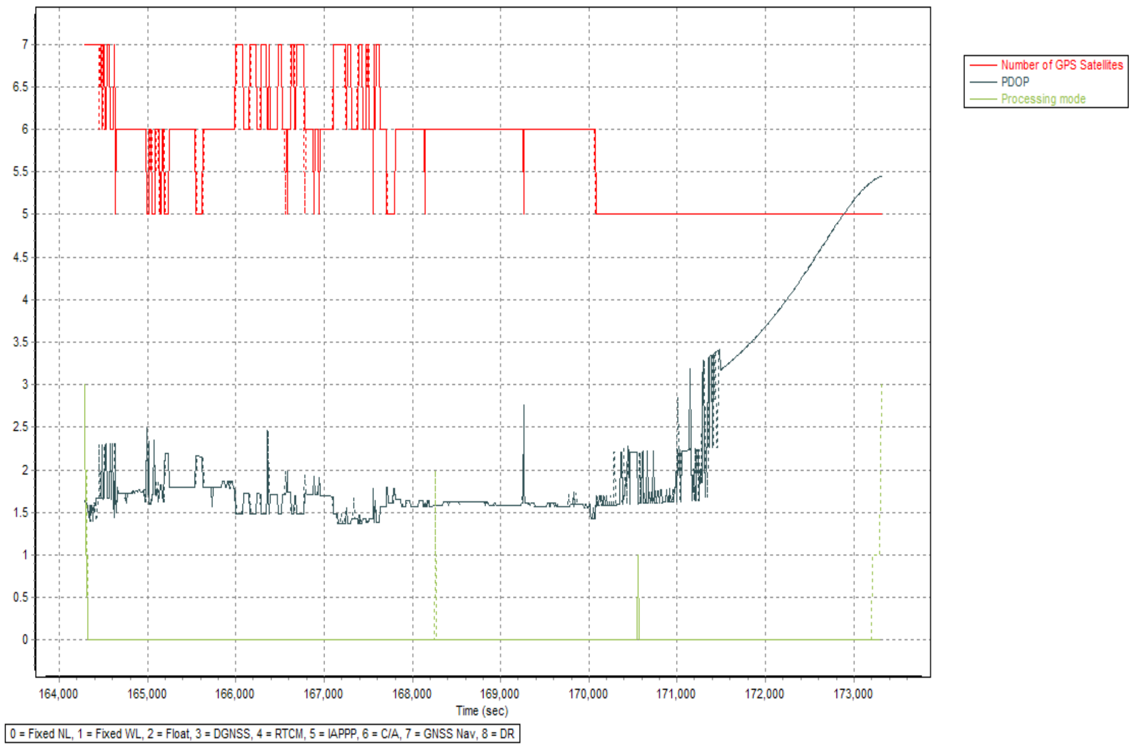


Figure A-8.36. Solution Status

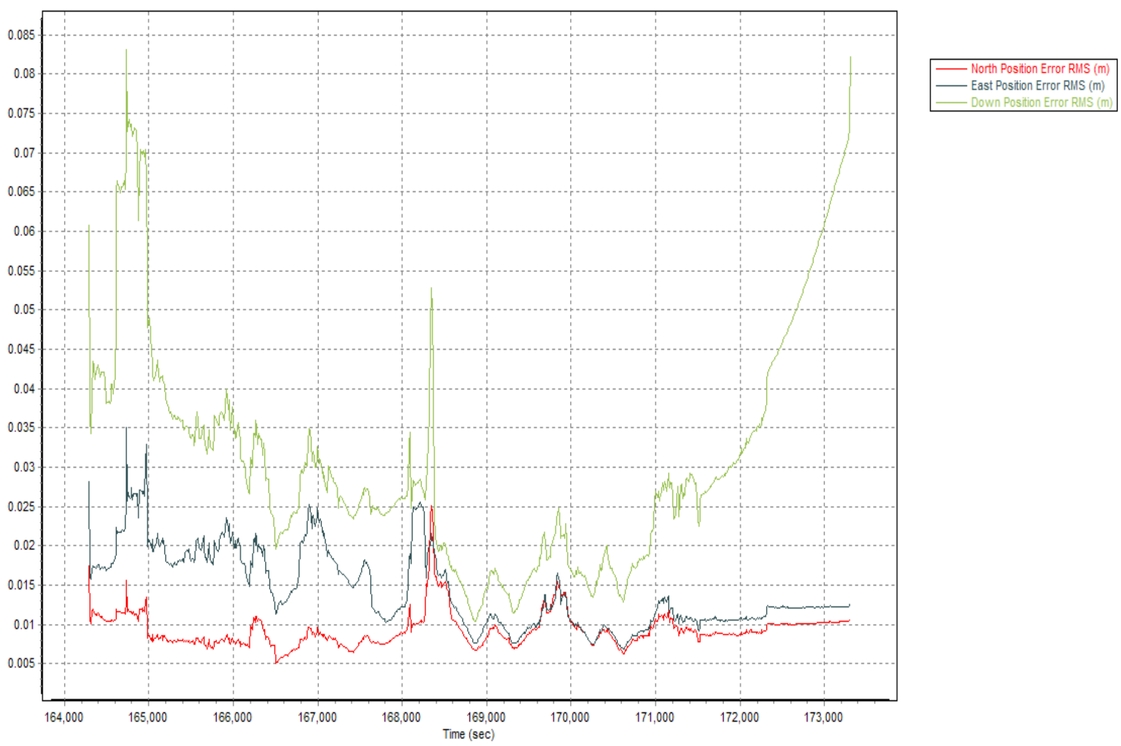


Figure A-8.37. Smoothed Performance Metrics Parameters

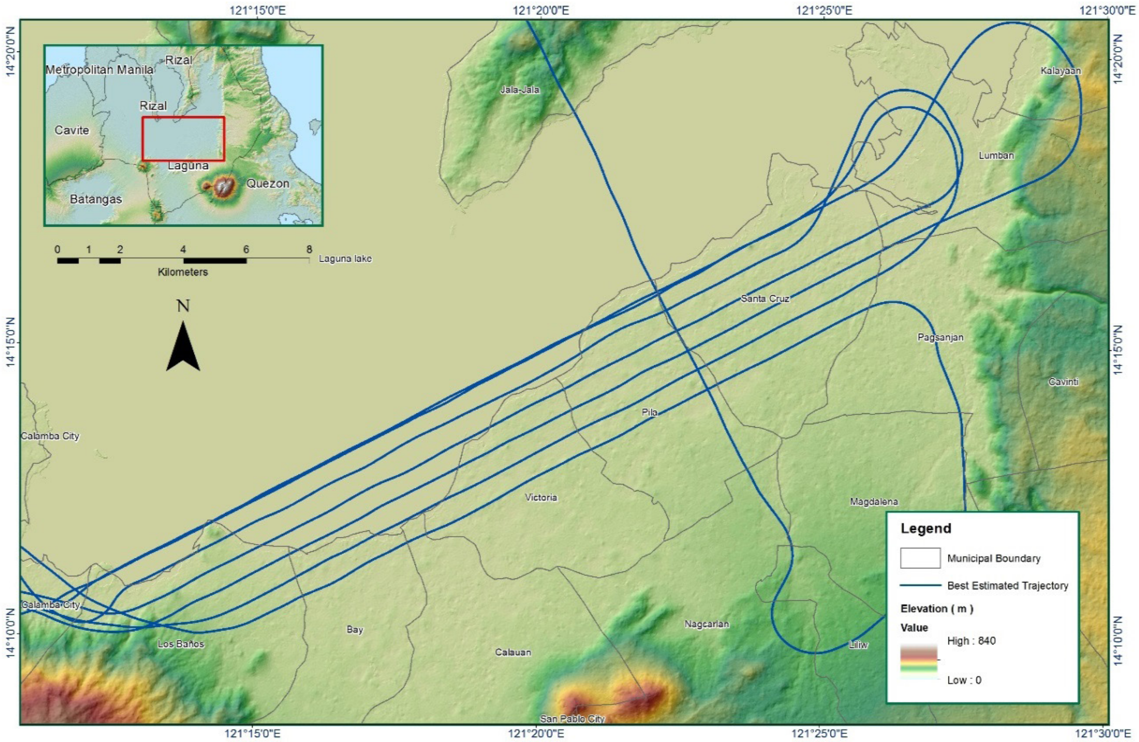


Figure A-8.38. Best Estimated Trajectory

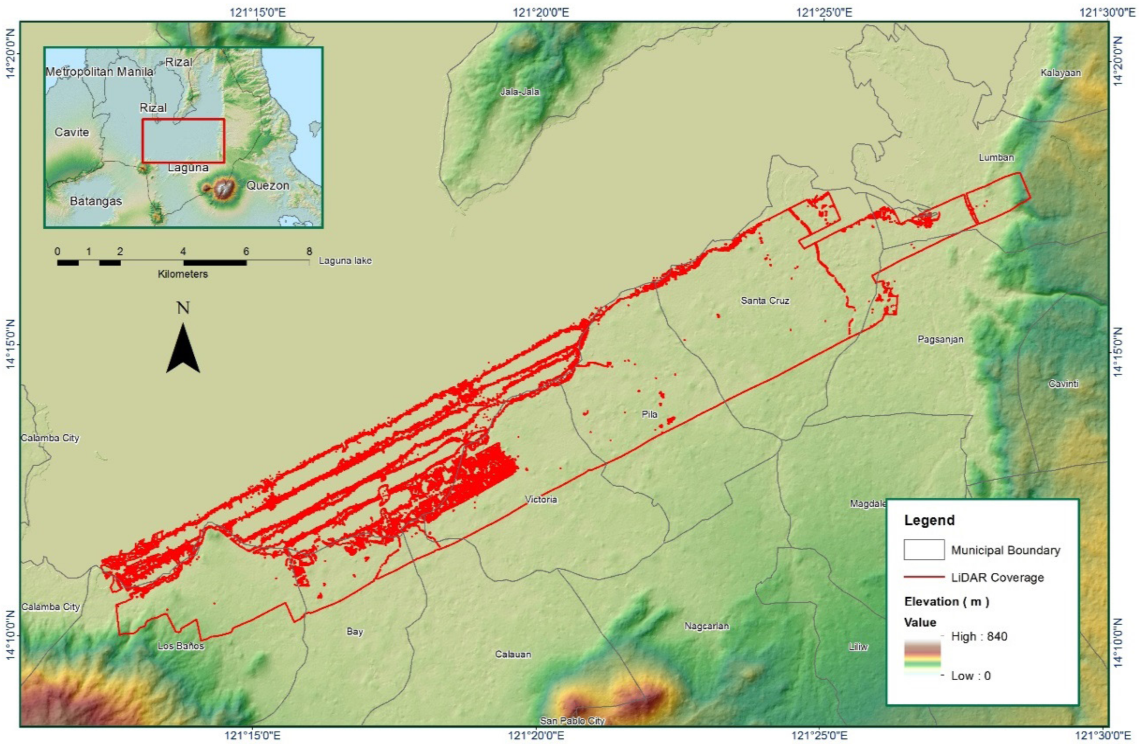


Figure A-8.39. Coverage of Lidar Data

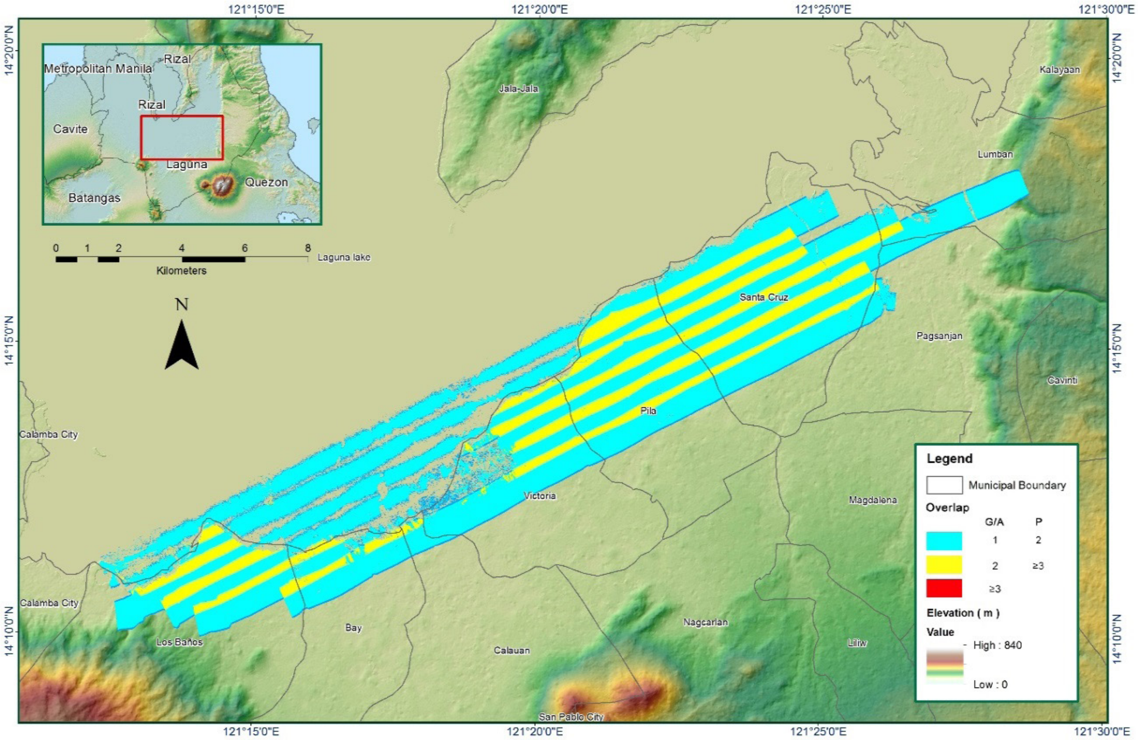


Figure A-8.40. Image of Data Overlap

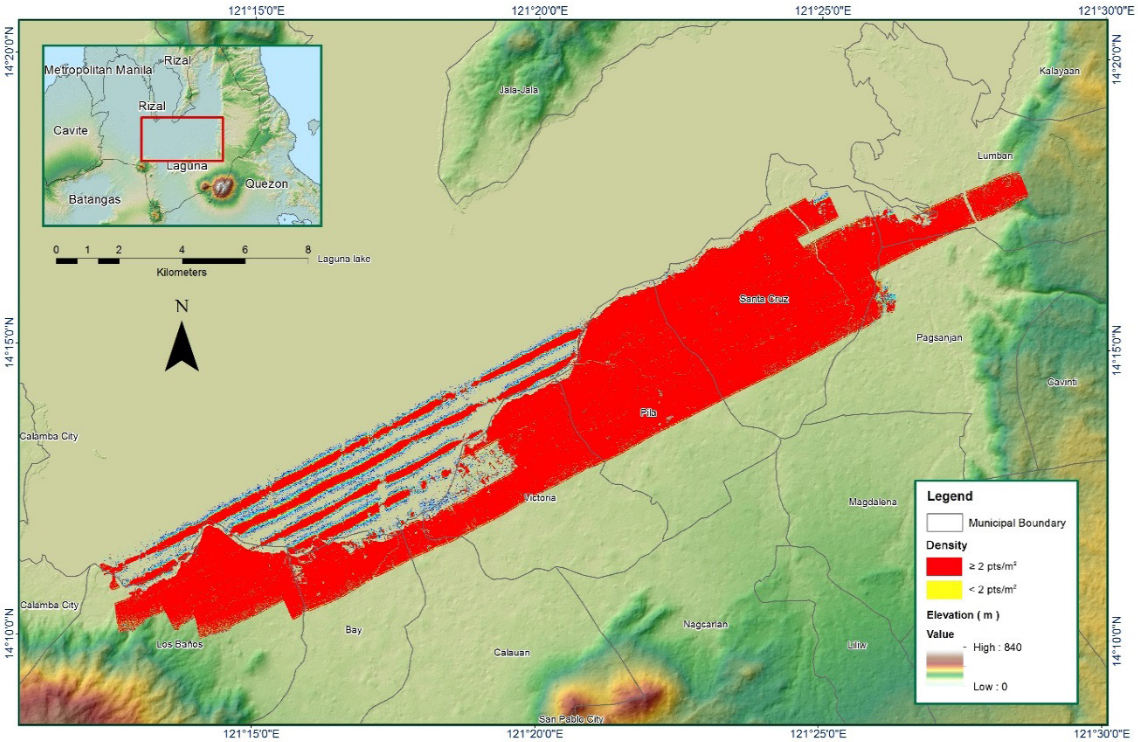


Figure A-8.41. Density map of merged LiDAR data

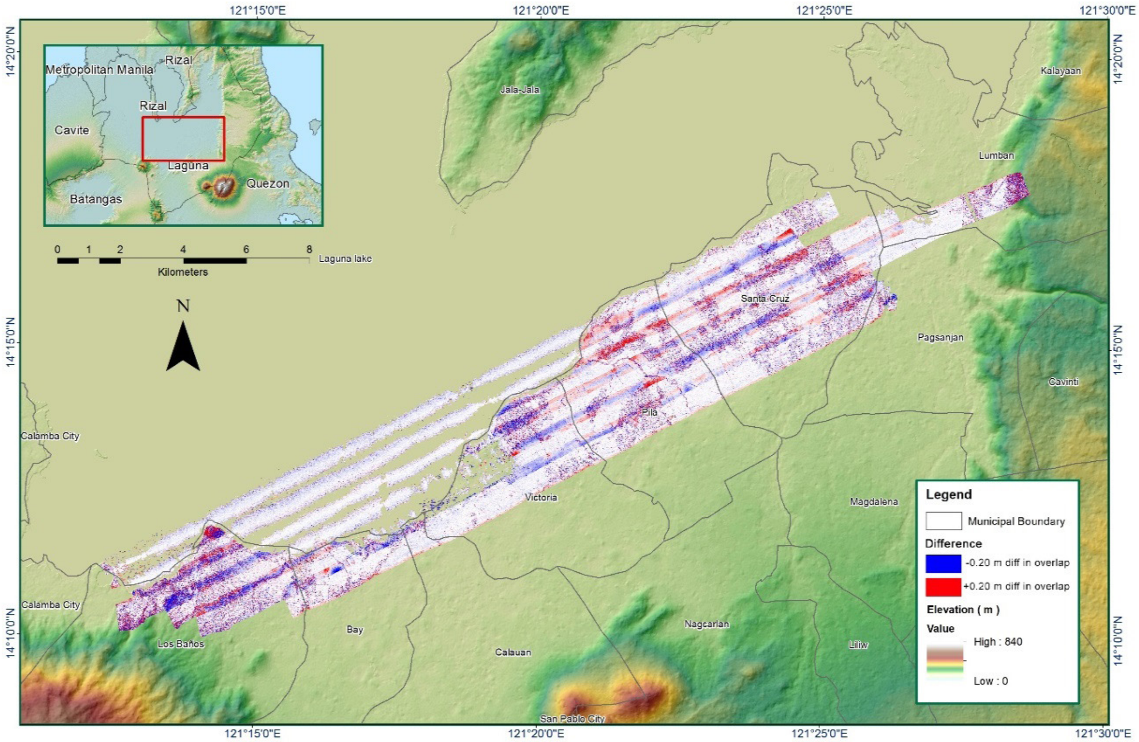


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Laguna_Blk18K

Flight Area	Laguna
Mission Name	Laguna_Blk18K
Inclusive Flights	1087P
Range data size	14.8 GB
POS data size	10.7 MB
Base data size	84.5 MB
Image	n/a
Transfer date	April 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.9
RMSE for East Position (<4.0 cm)	2.5
RMSE for Down Position (<8.0 cm)	5.4
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000532
GPS position stdev (<0.01m)	0.0079
Minimum % overlap (>25)	14.84%
Ave point cloud density per sq.m. (>2.0)	1.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	76
Maximum Height	104.52 m
Minimum Height	49.26 m
Classification (# of points)	
Ground	36,313,648
Low vegetation	42,001,405
Medium vegetation	21,298,010
High vegetation	11,905,512
Building	6,902,781
Orthophoto	No
Processed by	Victoria Maria Rejuso, Engr. Harmond Santos, Engr. Gladys Mae Apat

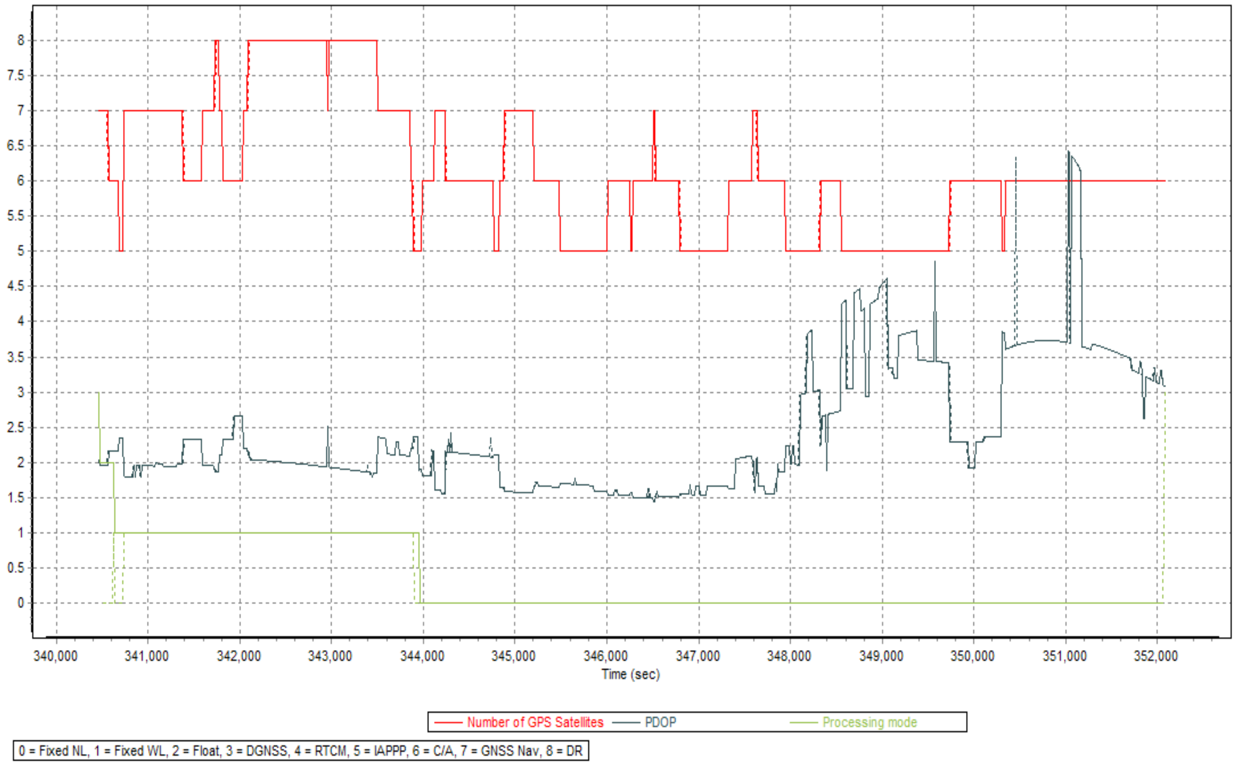


Figure A-8.43. Solution Status

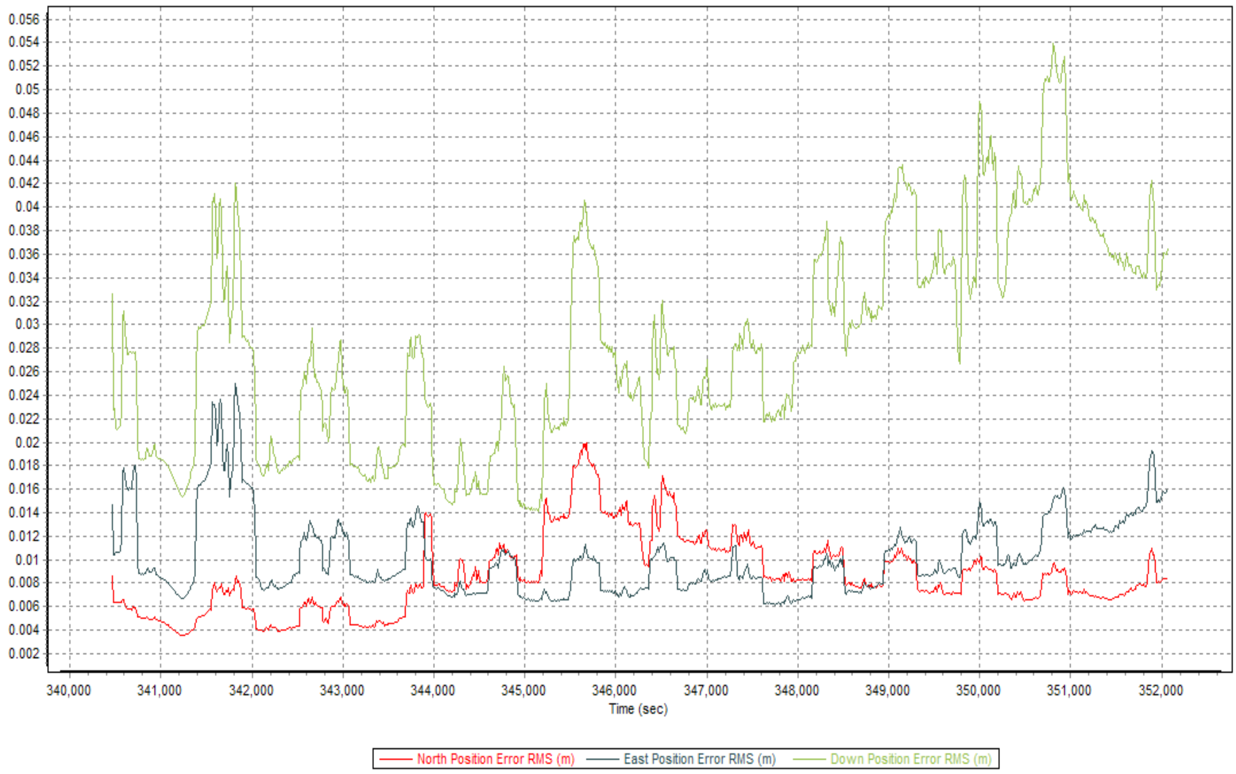


Figure A-8.44. Smoothed Performance Metric Parameters

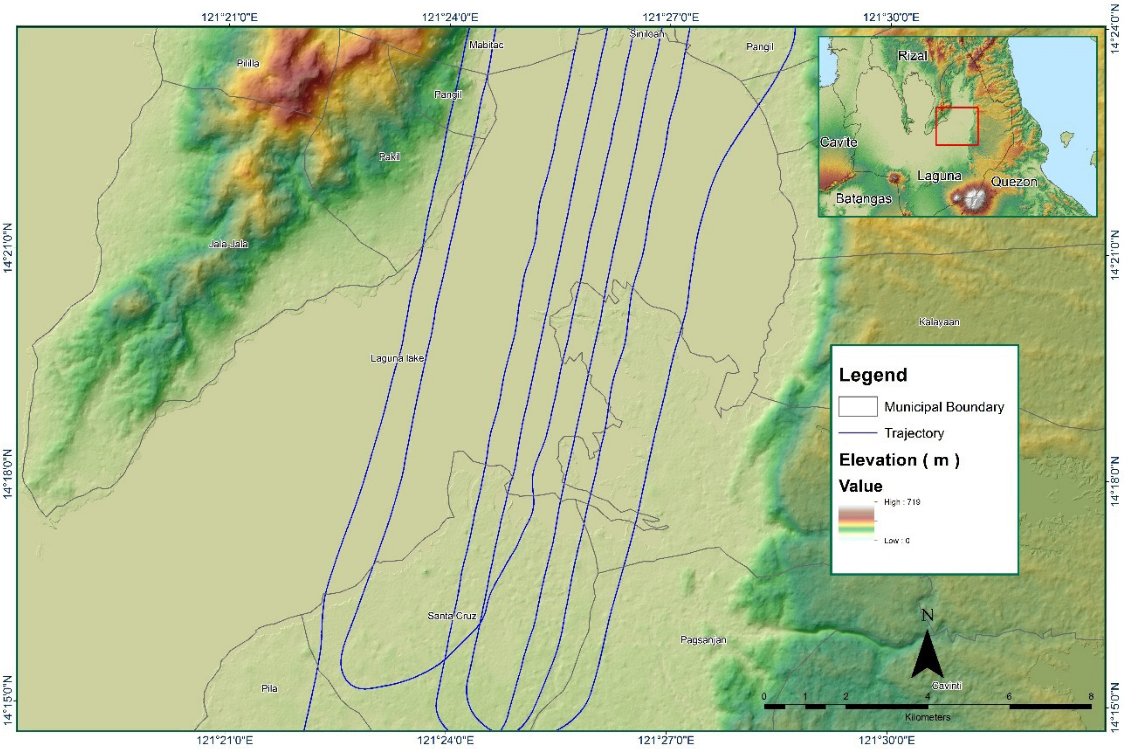


Figure A-8.45. Best Estimated Trajectory

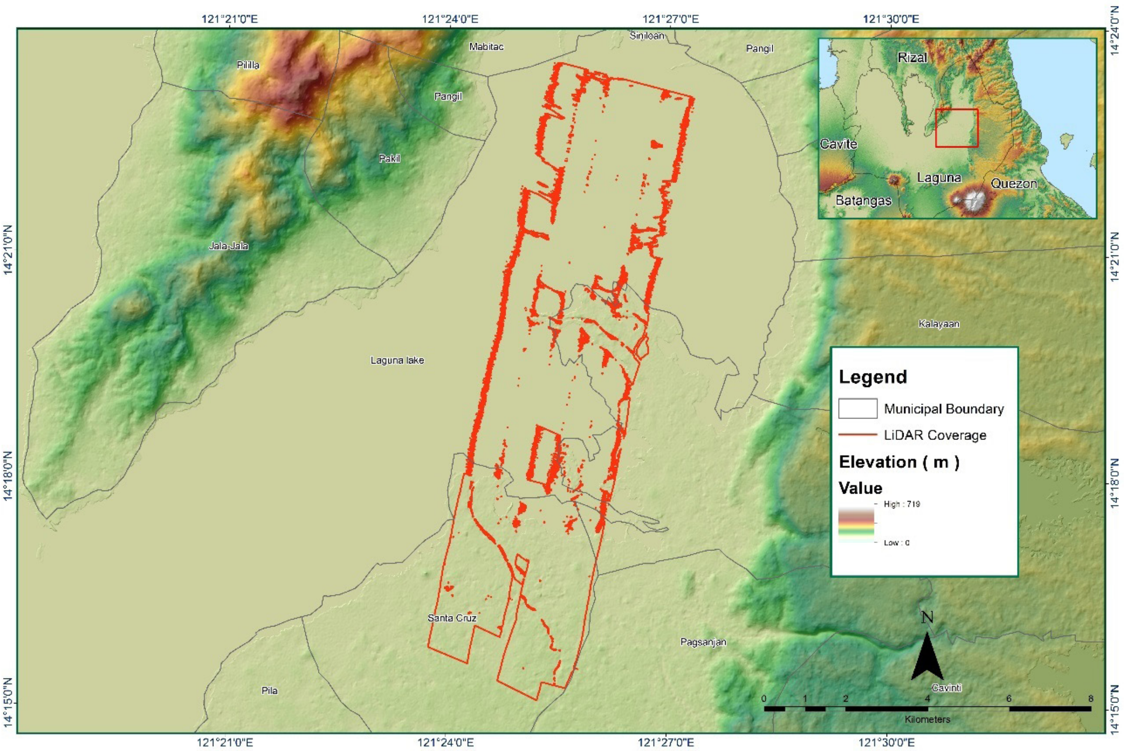


Figure A-8.46. Coverage of LiDAR Data

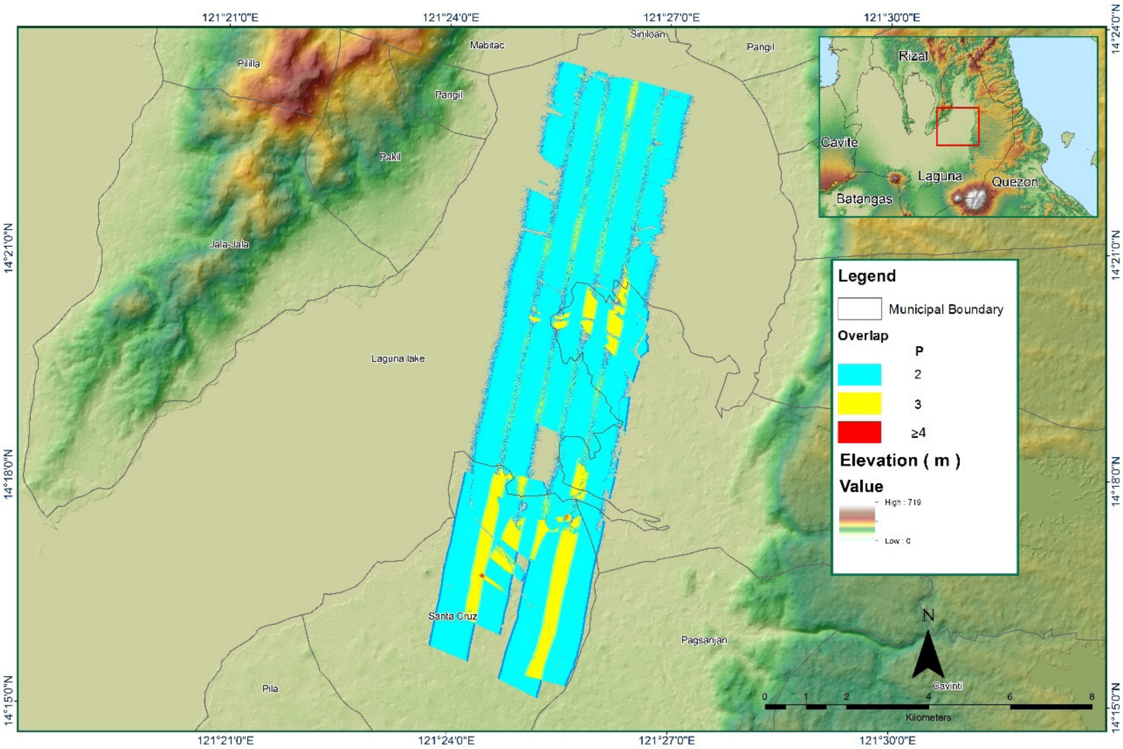


Figure A-8.47. Image of data overlap

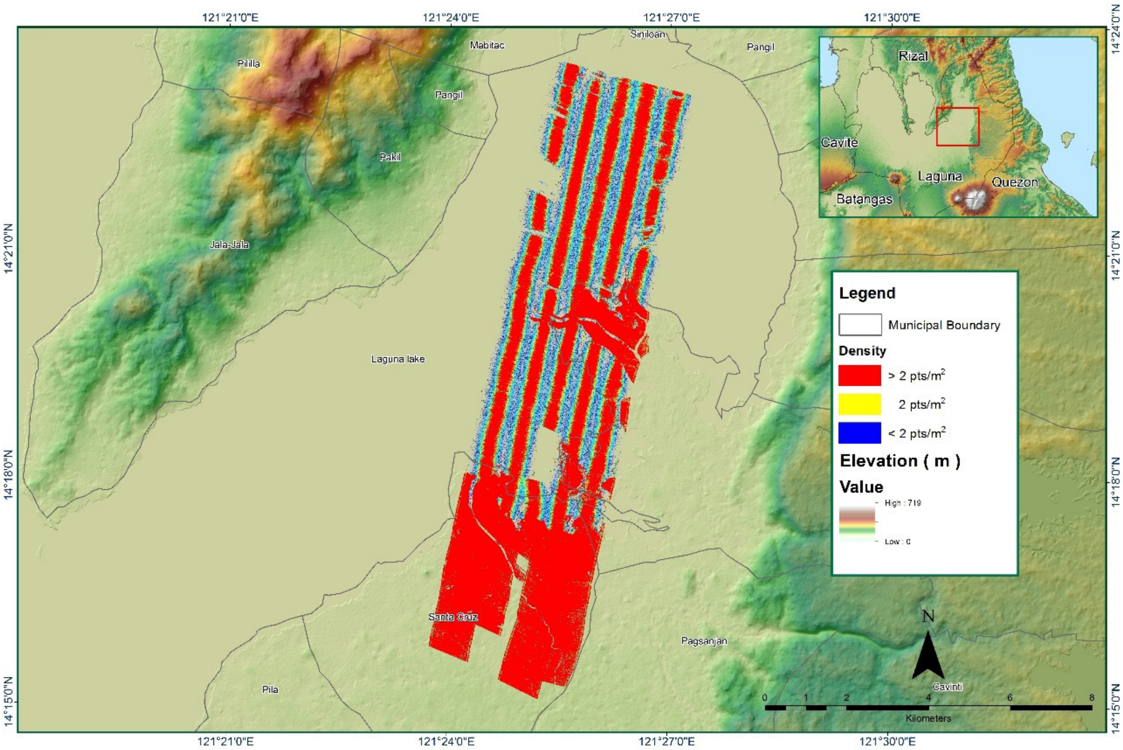


Figure A-8.48. Density map of merged LiDAR data

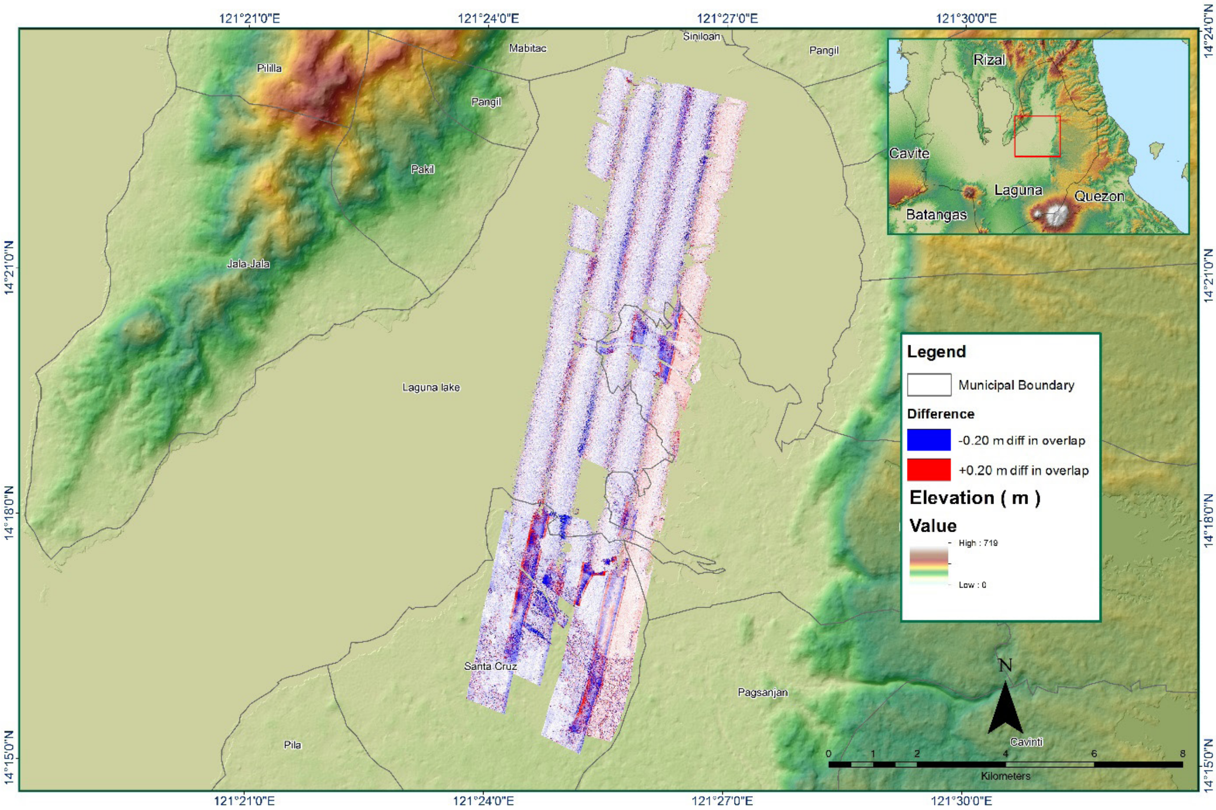


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk18I

Flight Area	Cavite
Mission Name	Blk18I
Inclusive Flights	1071P
Range data size	15.4 GB
POS	157 MB
Image	16 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000444
IMU attitude correction stdev (<0.001deg)	0.000955
GPS position stdev (<0.01m)	0.0111
Minimum % overlap (>25)	38.94%
Ave point cloud density per sq.m. (>2.0)	2.24
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	243
Maximum Height	691.27 m
Minimum Height	48.60 m
Classification (# of points)	
Ground	162,648,250
Low vegetation	137,656,321
Medium vegetation	119,154,299
High vegetation	160,037,139
Building	13,295,737
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

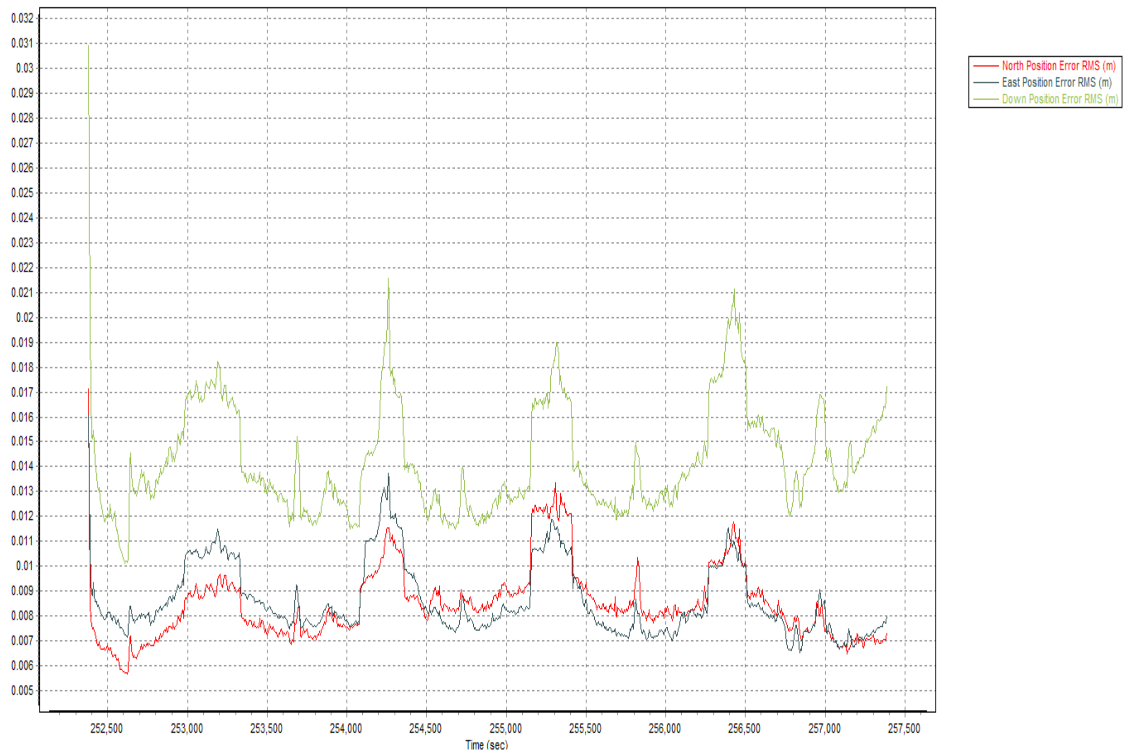


Figure A-8.50. Solution Status

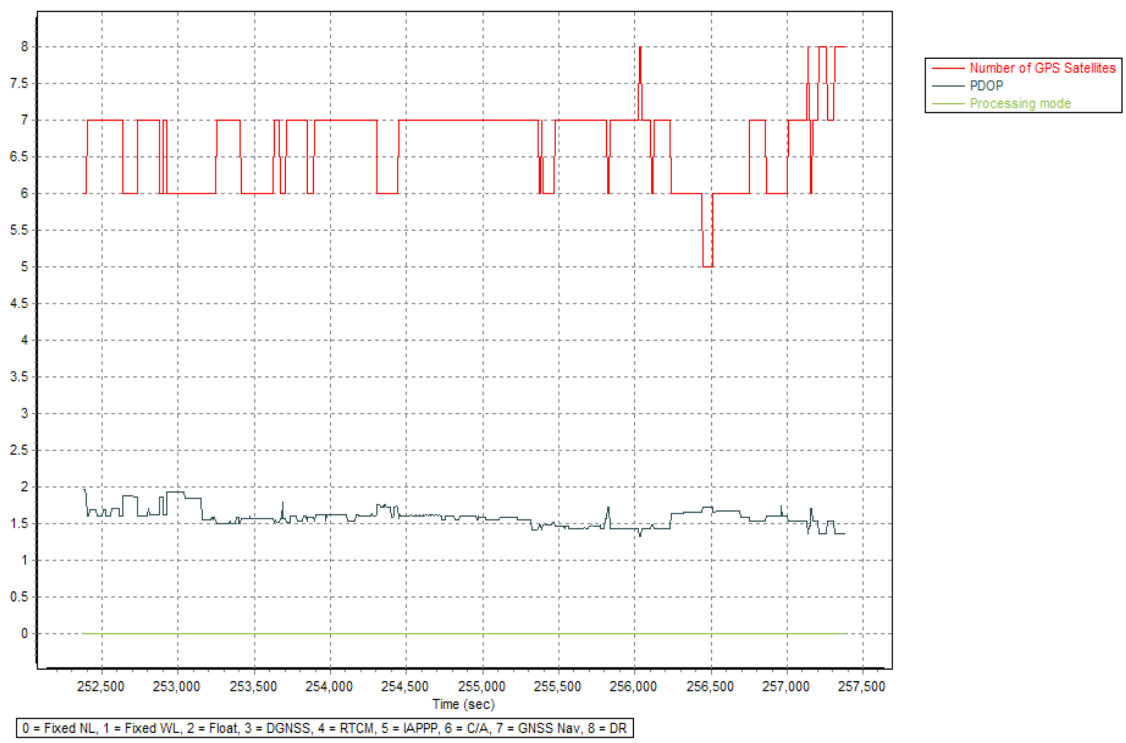


Figure A-8.51. Smoothed Performance Metrics Parameters

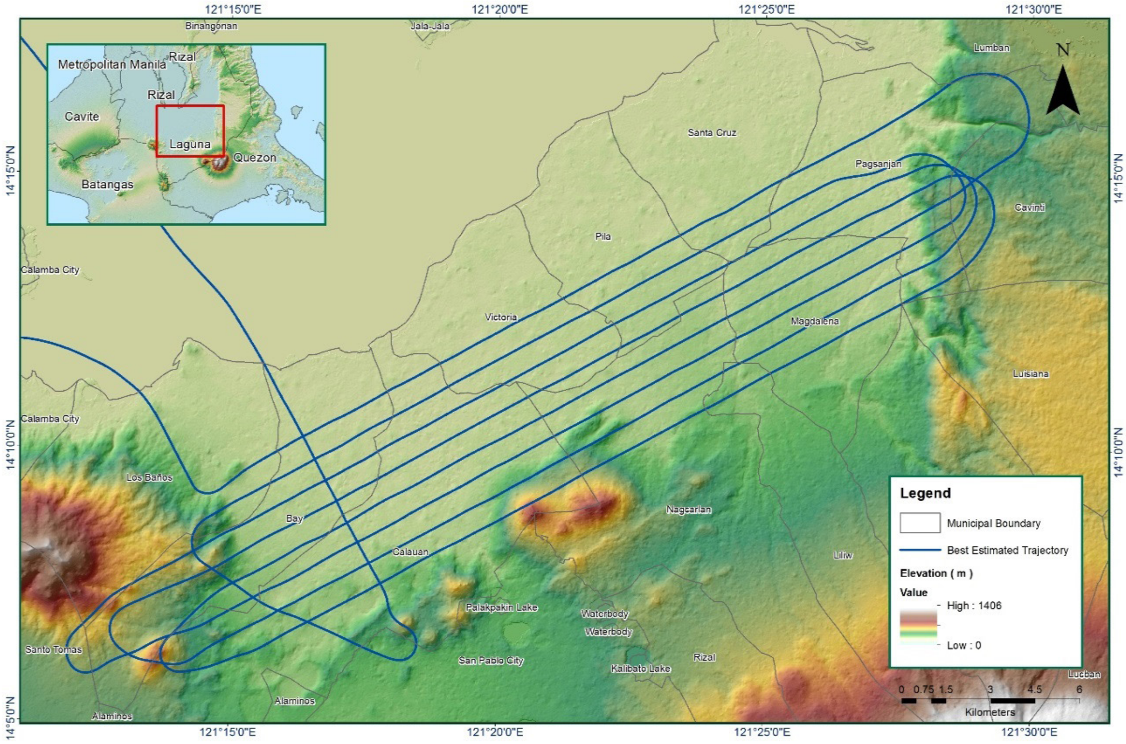


Figure A-8.52. Best Estimated Trajectory

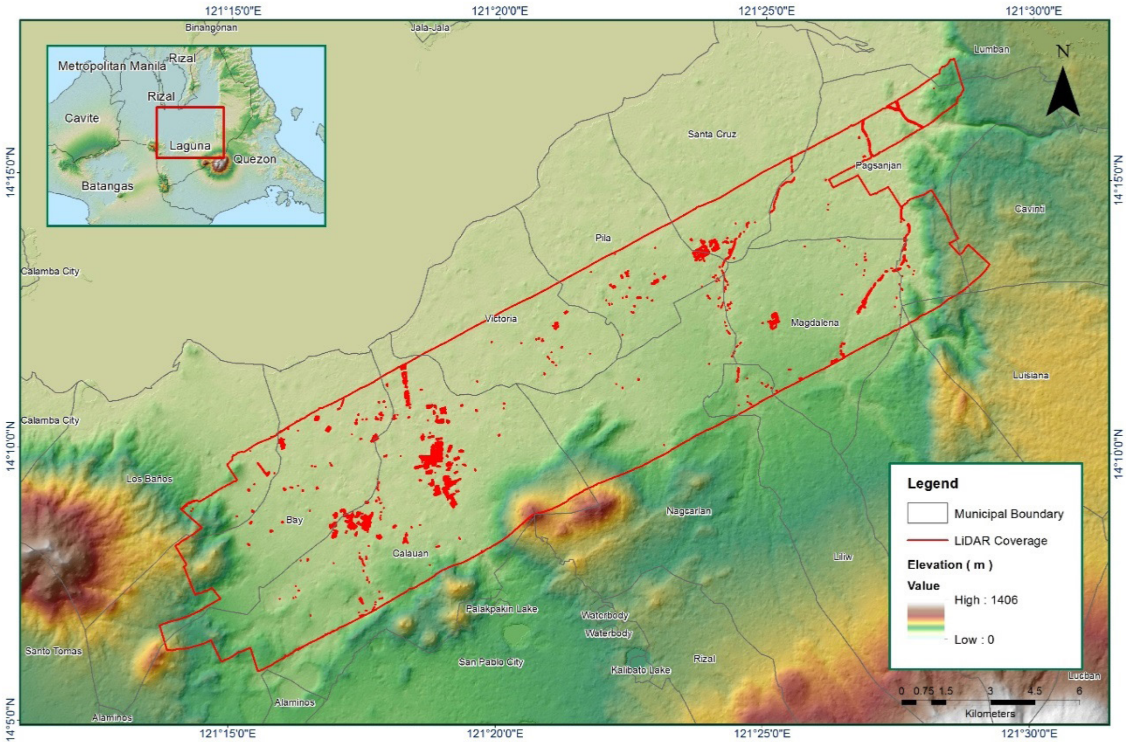


Figure A-8.53. Coverage of Lidar Data

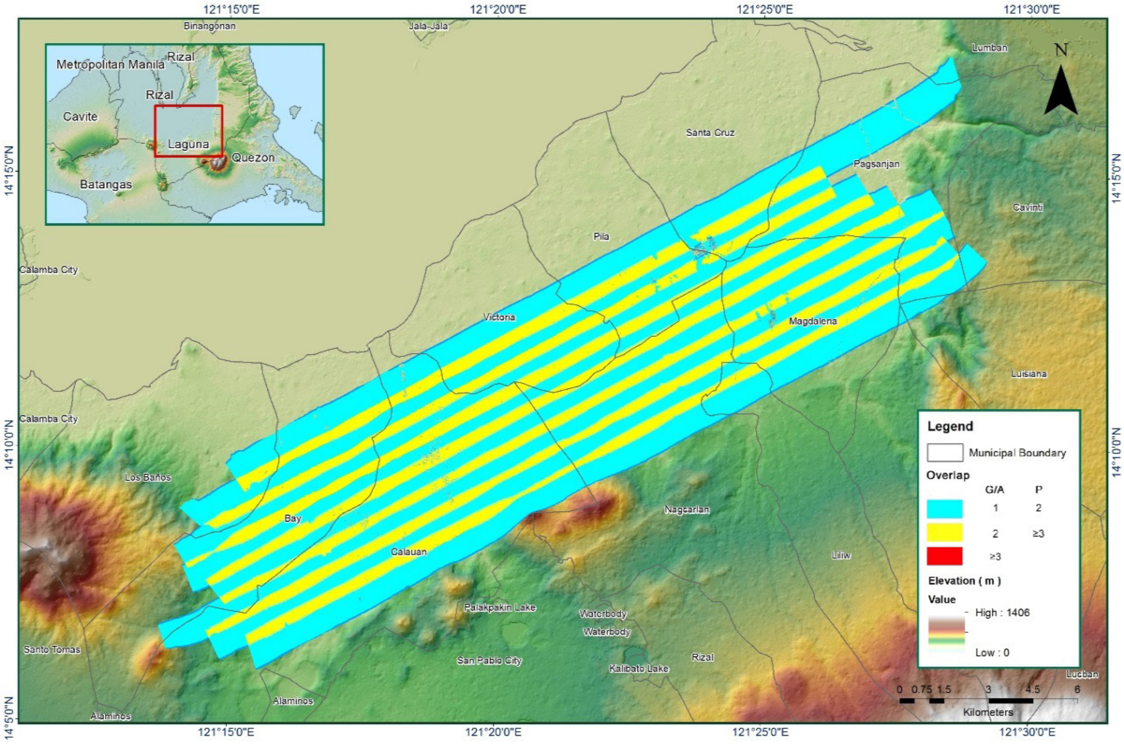


Figure A-8.54. Image of Data Overlap

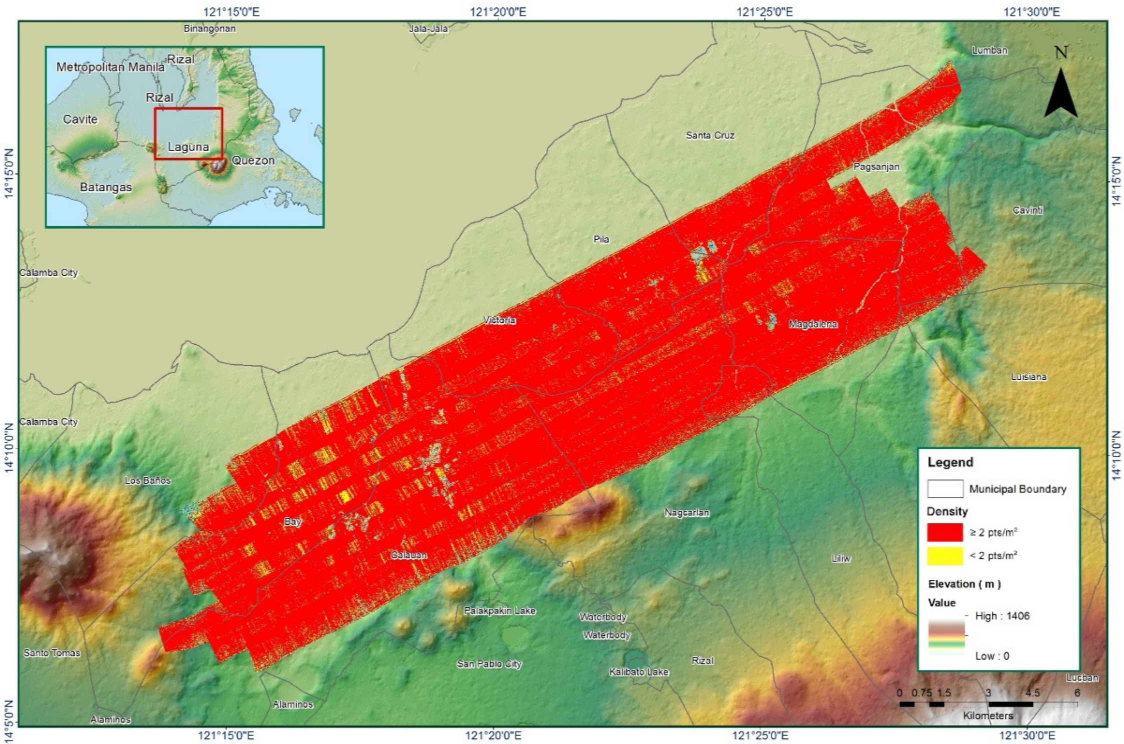


Figure A-8.55. Density map of merged LiDAR data

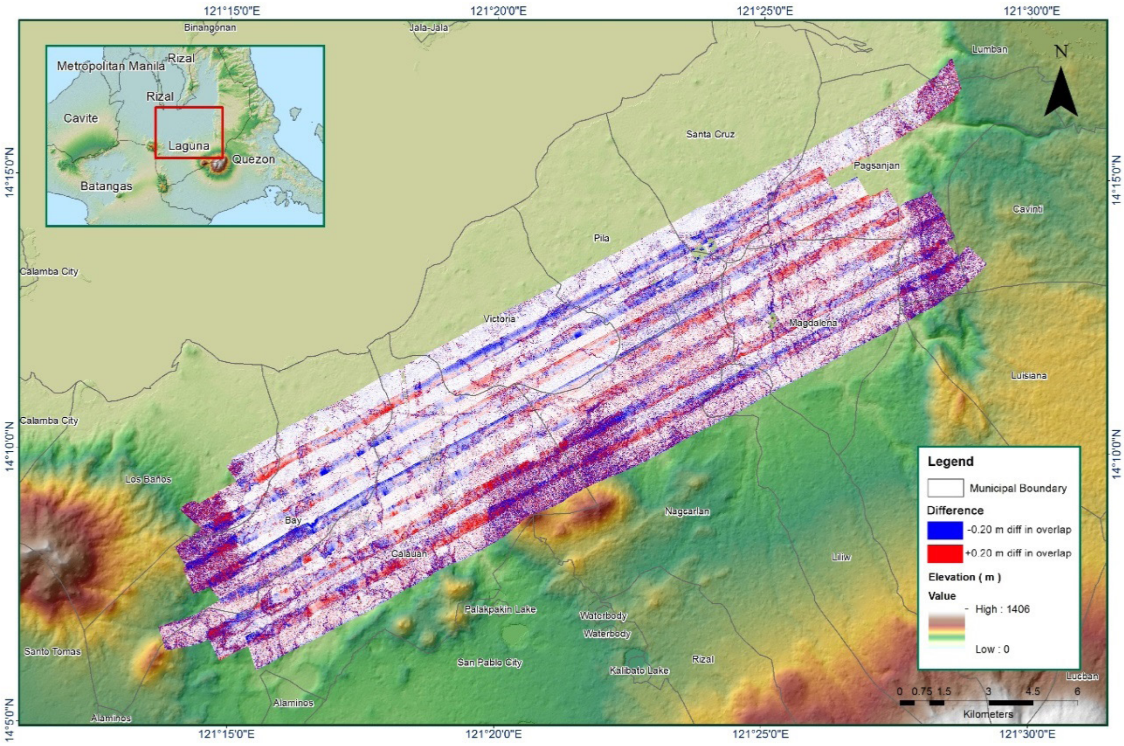


Figure A-8.56. Elevation difference between flight lines

Annex 9. Pagsanjan Model Basin Parameters

Table A-9.1. Balanac and Cavinti (Pagsanjan) Model Basin Parameters

Sub-basin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W120	2.587	44.906	0.0	4.6039	17.281	0.13114	0.47619	0.33333
W130	0.98781	50.153	0.0	0.31649	1.1880	0.0068603	0.47619	0.33333
W150	2.1349	46.275	0.0	0.73809	3.2950	0.13517	0.47619	0.33333
W160	3.0639	43.548	0.0	1.1217	2.7824	0.16463	0.47619	0.32666
W170	3.7192	41.810	0.0	2.3931	6.3153	0.33222	0.47619	0.33333
W180	3.4980	42.381	0.0	2.5688	8.0845	0.49686	0.47619	0.33333
W190	3.4449	42.521	0.0	1.6813	9.4494	0.80958	0.47619	0.33333
W200	3.5015	42.372	0.0	0.97548	6.2771	0.72247	0.47619	0.33333
W210	2.7725	44.368	0.0	0.84565	3.6615	0.26432	0.47619	0.33333
W220	5.8456	37.016	0.0	1.5823	3.1742	0.16990	0.47619	0.33333
W240	2.7712	44.372	0.0	0.87348	5.9392	0.76709	0.47619	0.33333
W250	1.1763	49.472	0.0	0.73961	2.7899	0.0307600	0.47619	0.22222

Sub-basin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W280	1.6668	98.907	0.0	0.45621	0.5555	0.38199	0.011729	1
W290	4.3709625	99	0.0	1.938404	0.6084	0.0630015	0.025	1
W300	0.73206	98.959	0.0	0.63166	0.2127	0.20158	0.0747335	1
W310	2.55	98.23	0.0	0.4398	0.2249	0.0061025	0.005822	1
W320	0.98803	99	0.0	5.3601	1.6674	0.1169	0.0134275	1
W330	1.6737	99	0.0	2.9295	0.4126	0.0185757	0.020028	0.238296
W340	0.7152	99	0.0	0.45707	0.4146	0.12082	0.028241	1

W350	2.4008	99	0.0	1.9784	1.4706	0.0109657	0.01322	1
W360	0.46809	99	0.0	3.8318	0.7239	0.26906	0.0134265	1
W370	1.2028	81.243	0.0	0.50651	0.2445	0.086996	0.0155205	1
W380	0.18826	97.454	0.0	0.22009	0.0689	0.13717	0.097136	1
W390	1.6721	99	0.0	0.2027948	0.0636	0.0032595	0.025	1
W400	1.0737	98.286	0.0	4.844	0.9980	0.26027	0.0959825	1
W410	2.096	99	0.0	0.63529	0.2135	0.18167	0.0448465	1
W430	1.8088	99	0.0	0.11306	0.1798	0.0222309	0.045999	1
W440	3.9917	99	0.0	0.034494	0.0167	0.0050766	0.0686605	1
W450	2.1252	99	0.0	0.62913	0.2098	0.11756	0.008909	1
W460	0.61115	98.55	0.0	0.24603	0.1930	0.11921	0.145472	1
W470	1.646	99	0.0	2.6653	0.7088	0.11687	0.0448475	1
W480	1.6732	69.384	0.0	0.28892	0.0963	0.0240379	0.045545	1
W490	1.7775	99	0.0	0.32874	0.0875	0.0258928	0.0448065	0.8889
W500	1.9972	67.623	0.0	1.1755	0.2461	0.33607	0.012772	1
W510	0.49596	99	0.0	0.11521	0.0568	0.17901	0.029446	1
W520	1.0626	99	0.0	0.0899419	0.0359	0.15487	0.0437315	1
W530	1.1993	98.731	0.0	0.19214	0.0308	0.0954549	0.0649505	1
W540	0.78148	99	0.0	2.5536	0.5168	0.2541591	0.0426575	1
W560	4.6537875	99	0.0	0.524212	0.1645	0.0996157	0.025	1
W570	0.8022	99	0.0	0.49147	0.2614	0.12146	0.0459965	1

Annex 10. Pagsanjan Model Reach Parameters

Table A-10.1. Balanac and Cavinti (Pagsanjan) Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R10	Automatic Fixed Interval	9837.2	.0006711334	0.0380952	Trapezoid	53.395	1
R260	Automatic Fixed Interval	2091.5	0.0035988	0.0380952	Trapezoid	53.395	1
R30	Automatic Fixed Interval	3416.3	.0003887256	0.0380952	Trapezoid	53.395	1
R50	Automatic Fixed Interval	5758.5	.0005770268	0.0380952	Trapezoid	53.395	1
R70	Automatic Fixed Interval	12228	0.0075919	0.0380952	Trapezoid	53.395	1
R80	Automatic Fixed Interval	3698.0	0.0303653	0.0380952	Trapezoid	53.395	1

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R120	Automatic Fixed Interval	9590.6	0.0010085	0.342711	Trapezoid	49.205	1
R130	Automatic Fixed Interval	4523.6	0.0202505	0.903582	Trapezoid	49.205	1
R140	Automatic Fixed Interval	3468.5	0.0103409	0.54	Trapezoid	49.205	1
R150	Automatic Fixed Interval	1348.1	0.0371125	1	Trapezoid	49.205	1
R160	Automatic Fixed Interval	4688.6	0.0206041	0.686772	Trapezoid	49.205	1
R180	Automatic Fixed Interval	684.56	0.0640663	1	Trapezoid	49.205	1
R190	Automatic Fixed Interval	872.25	0.0018675	1	Trapezoid	49.205	1
R20	Automatic Fixed Interval	862.84	0.0022324	1	Trapezoid	49.205	1
R210	Automatic Fixed Interval	2854.2	0.0018675	0.6319755	Trapezoid	49.205	1
R230	Automatic Fixed Interval	1457.8	0.0103409	1	Trapezoid	49.205	1
R40	Automatic Fixed Interval	1702.7	0.0022324	0.546318	Trapezoid	49.205	1
R590	Automatic Fixed Interval	4979.6	0.0277459	0.89316	Trapezoid	49.205	1
R70	Automatic Fixed Interval	860.54	.00052507	0.533412	Trapezoid	49.205	1
R90	Automatic Fixed Interval	7108.9	.00052507	0.54	Trapezoid	49.205	1

Annex 11. Pagsanjan Field Validation Points

Table A-11.1. Pagsanjan Field Flood Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
1	14.224589	121.405963	0.06	0.22	0.22	Glenda / July, 2014	25-Year
2	14.227874	121.402211	0.07	0.09	0.09	Ondoy / Sept. 26, 2009	25-Year
3	14.224845	121.404570	8.46	0.82	0.82	Santi / Oct. 31, 2009	25-Year
4	14.227874	121.402211	0.07	0.00	0.00	Santi / Oct. 31, 2009	25-Year
5	14.223761	121.404884	0.07	0.00	0.00	Ondoy / Sept. 26, 2009	25-Year
6	14.223614	121.404581	0.03	1.20	1.20	Santi / Oct. 31, 2009	25-Year
7	14.230757	121.406508	7.08	0.40	0.40	Santi / Oct. 31, 2009	25-Year
8	14.228207	121.404004	3.27	0.00	0.00	Santi / Oct. 31, 2009	25-Year
9	14.228207	121.404004	3.27	4.00	4.00	Santi / Oct. 31, 2009	25-Year
10	14.228481	121.404619	3.40	4.00	4.00	Santi / Oct. 31, 2009	25-Year
11	14.228308	121.403943	3.04	2.00	2.00	Ondoy / Sept. 26, 2009	25-Year
12	14.228940	121.403647	3.97	0.00	0.00	Ondoy / Sept. 26, 2009	25-Year
13	14.227900	121.403077	0.12	0.00	0.00	Santi / Oct. 31, 2009	25-Year
14	14.231283	121.402108	0.23	1.40	1.40	Santi / Oct. 31, 2009	25-Year
15	14.230165	121.400000	0.10	1.39	1.39	Santi / Oct. 31, 2009	25-Year
16	14.231016	121.400489	0.03	1.12	1.12	Santi / Oct. 31, 2009	25-Year
17	14.233378	121.401258	0.04	1.15	1.15	Santi / Oct. 31, 2009	25-Year
18	14.231788	121.401356	0.04	1.06	1.06	Santi / Oct. 31, 2009	25-Year
19	14.249040	121.416378	0.03	0.90	0.90	Santi / Oct. 31, 2009	25-Year
20	14.248632	121.414954	0.06	0.23	0.23	Ondoy / Sept. 26, 2009	25-Year
21	14.248423	121.414674	0.29	0.18	0.18	Santi / Oct. 31, 2009	25-Year
22	14.248808	121.415565	0.19	1.53	1.53	Ondoy / Sept. 26, 2009	25-Year
23	14.249451	121.414108	0.47	1.40	1.40	Ondoy / Sept. 26, 2009	25-Year
24	14.249400	121.414062	0.99	0.76	0.76	Ondoy / Sept. 26, 2009	25-Year
25	14.250025	121.414519	0.62	1.10	1.10	Ondoy / Sept. 26, 2009	25-Year
26	14.269940	121.418265	0.03	0.38	0.38	Glenda / July, 2014	25-Year
27	14.271200	121.419264	0.13	2.00	2.00	Glenda / July, 2014	25-Year
28	14.270723	121.419285	0.06	0.00	0.00	Ondoy / Sept. 26, 2009	25-Year
29	14.270443	121.419353	0.09	0.00	0.00	Ondoy / Sept. 26, 2009	25-Year
30	14.271063	121.418614	0.06	0.15	0.15	Santi / Oct. 31, 2009	25-Year
31	14.271755	121.417746	0.09	0.45	0.45	Ondoy / Sept. 26, 2009	25-Year
32	14.265042	121.420423	0.51	0.50	0.50	Ondoy / Sept. 26, 2009	25-Year
33	14.264926	121.420440	0.50	0.80	0.80	Ondoy / Sept. 26, 2009	25-Year
34	14.264443	121.420853	0.14	0.90	0.90	Ondoy / Sept. 26, 2009	25-Year
35	14.264897	121.421897	0.28	1.01	1.01	Santi / Oct. 31, 2009	25-Year
36	14.263987	121.420797	0.07	0.50	0.50	Ondoy / Sept. 26, 2009	25-Year
37	14.262112	121.420043	0.23	0.10	0.10	Ondoy / Sept. 26, 2009	25-Year
38	14.288056	121.409722	0.03	1.63	1.63	Ondoy / 2009	25-Year
39	14.287222	121.411389	0.05	1.64	1.64	Ondoy / 2009	25-Year
40	14.287222	121.412500	0.03	1.94	1.94	Ondoy & Santi / 2009, 2013	25-Year
41	14.289167	121.409722	0.24	1.36	1.36	Ondoy / 2009	25-Year
42	14.290556	121.411389	0.03	1.45	1.45	Ondoy & Santi / 2009, 2013	25-Year
43	14.288611	121.409444	0.03	1.93	1.93	Ondoy / 2009	25-Year
44	14.289444	121.409444	0.24	1.22	1.22	Santi & Ondoy / 2013, 2009	25-Year
45	14.288333	121.409444	0.04	2.25	2.25	Santi / 2013	25-Year
46	14.288889	121.408889	0.03	1.68	1.68	Santi / 2013	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
47	14.289167	121.408611	0.03	1.28	1.28	Santi / 2013	25-Year
48	14.288611	121.408889	0.37	1.46	1.46	Santi / 2013	25-Year
49	14.290556	121.408333	0.03	0.82	0.82	Ondoy / 2009	25-Year
50	14.288889	121.409722	0.03	1.17	1.17	Ondoy / 2009	25-Year
51	14.287778	121.410278	0.07	1.25	1.25	Ondoy & Santi / 2009, 2013	25-Year
52	14.280278	121.404167	0.15	1.08	1.08	Ondoy / 2009	25-Year
53	14.280000	121.404100	0.15	0.58	0.58	Ondoy / 2009	25-Year
54	14.282500	121.444722	1.67	0.59	0.59	Ondoy & Santi / 2009, 2013	25-Year
55	14.287500	121.409167	0.03	0.82	0.82	Ondoy & Santi / 2009, 2013	25-Year
56	14.287778	121.409444	2.08	0.75	0.75	Ondoy / 2009	25-Year
57	14.285278	121.410833	0.03	0.92	0.92	Ondoy / 2009	25-Year
58	14.280833	121.405000	0.40	0.24	0.24	Ondoy / 2009	25-Year
59	14.281389	121.405833	0.75	0.82	0.82	Ondoy / 2009	25-Year
60	14.280833	121.405000	0.40	1.10	1.10	Ondoy / 2009	25-Year
61	14.280278	121.404444	0.15	1.19	1.19	Ondoy / 2009	25-Year
62	14.287222	121.409444	0.03	0.80	0.80	Ondoy / 2009	25-Year
63	14.287500	121.409722	2.22	0.77	0.77	Santi & Ondoy / 2013, 20009	25-Year
64	14.287778	121.408333	0.14	0.73	0.73	Santi & Ondoy / 2013, 20009	25-Year
65	14.288389	121.407222	0.16	0.35	0.35	Santi & Ondoy / 2013, 20009	25-Year
66	14.288611	121.406389	0.03	1.00	1.00	Ondoy / 2009	25-Year
67	14.288056	121.408889	1.86	0.94	0.94	Santi & Ondoy / 2013, 20009	25-Year
68	14.288333	121.408611	1.84	0.83	0.83	Santi / 2013	25-Year
69	14.288333	121.408889	1.80	0.72	0.72	Ondoy / 2009	25-Year
70	14.288889	121.405278	0.11	1.15	1.15	Habagat / 2012/2013	25-Year
71	14.288056	121.405556	0.03	0.77	0.77	Ondoy & Habagat / 2009, 2012/2013	25-Year
72	14.281667	121.404444	0.40	0.83	0.83	Habagat / 2012/2013	25-Year
73	14.289722	121.406944	0.03	0.76	0.76	Ondoy / 2009	25-Year
74	14.256690	121.370833	0.03	0.00	0.00	Glenda / 2014	25-Year
75	14.263013	121.368064	0.10	0.30	0.30	Glenda / 2014	25-Year
76	14.259225	121.368158	0.04	0.12	0.12	Glenda / 2014	25-Year
77	14.255027	121.371668	0.03	0.00	0.00	Ondoy & Rosing / 2009, 1995	25-Year
78	14.268979	121.399406	0.35	0.10	0.10	Ondoy / 2009	25-Year
79	14.282048	121.396063	0.04	1.17	1.17	Santi / 2013	25-Year
80	14.281630	121.395943	0.17	1.30	1.30	Santi / 2013	25-Year
81	14.281510	121.395493	0.03	1.16	1.16	Ondoy & Santi / 2009, 2013	25-Year
82	14.280053	121.393328	0.03	0.89	0.89	Ondoy / 2009	25-Year
83	14.281213	121.394183	0.03	0.50	0.50	Habagat & Yolanda / 2012/2013, 2013	25-Year
84	14.282543	121.397496	0.07	0.70	0.70	Ondoy / 2009	25-Year
85	14.282330	121.396966	0.03	1.13	1.13	Ondoy & Santi / 2009, 2013	25-Year
86	14.276823	121.383873	0.05	0.90	0.90	Ondoy & Santi / 2009, 2013	25-Year
87	14.276057	121.383620	0.72	1.63	1.63	Ondoy / 2009	25-Year
88	14.265271	121.382189	0.03	0.15	0.15	Ondoy / 2009	25-Year
89	14.274181	121.381920	0.03	0.80	0.80	Ondoy & Dading / 2009, 1964	25-Year
90	14.272188	121.378597	0.03	0.83	0.83	Santi & Glenda / 2013, 2014	25-Year
91	14.271426	121.378149	0.11	0.65	0.65	Ondoy / 2009	25-Year
92	14.271072	121.377583	0.03	0.29	0.29	Ondoy / 2009	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
93	14.268956	121.454701	2.65	0.47	0.47	Glenda / July, 2014	25-Year
94	14.230807	121.463446	0.03	0.43	0.43	Ondoy / Sept. 26, 2009	25-Year
95	14.231547	121.463348	0.03	0.04	0.04	Ondoy/ Santi / Sept. 26, 2009; Oct. 31, 2009	25-Year
96	14.236500	121.462200	0.03	0.04	0.04	Ondoy/ Santi / Sept. 26, 2009; Oct. 31, 2009	25-Year
97	14.239400	121.461500	3.63	2.50	2.50	Yolanda / Nov. 8, 2013	25-Year
98	14.240058	121.462033	2.10	0.00	0.00	Glenda / July, 2014	25-Year
99	14.243124	121.460466	5.36	2.00	2.00	Santi / Oct. 31, 2009	25-Year
100	14.243207	121.460487	6.29	2.15	2.15	Santi / Oct. 31, 2009	25-Year
101	14.243289	121.460585	2.58	0.97	0.97	Santi / Oct. 31, 2009	25-Year
102	14.244973	121.460574	0.15	0.00	0.00	Santi / Oct. 31, 2009	25-Year
103	14.244387	121.460855	0.03	0.43	0.43	Santi / Oct. 31, 2009	25-Year
104	14.247097	121.458898	2.17	0.64	0.64	Santi / Oct. 31, 2009	25-Year
105	14.247100	121.458997	2.23	0.67	0.67	Santi / Oct. 31, 2009	25-Year
106	14.249251	121.457291	1.46	0.99	0.99	Santi / Oct. 31, 2009	25-Year
107	14.249333	121.457685	1.39	0.40	0.40	Santi / Oct. 31, 2009	25-Year
108	14.251883	121.455120	0.50	0.80	0.80	Glenda / July, 2014	25-Year
109	14.254101	121.454505	2.16	0.38	0.38	Glenda / July, 2014	25-Year
110	14.254225	121.454384	1.90	0.15	0.15	Santi / Oct. 31, 2009	25-Year
111	14.254628	121.453468	1.93	1.02	1.02	Yolanda / Nov. 8, 2013	25-Year
112	14.269327	121.449792	1.59	0.96	0.96	Ondoy/ Santi / Sept. 26, 2009; Oct. 31, 2009	25-Year
113	14.269222	121.447735	1.16	0.82	0.82	Santi / Oct. 31, 2009	25-Year
114	14.268981	121.447796	0.68	1.20	1.20	Santi / Oct. 31, 2009	25-Year
115	14.270433	121.449267	1.22	1.13	1.13	Santi / Oct. 31, 2009	25-Year
116	14.270286	121.449409	1.20	1.27	1.27	Santi / Oct. 31, 2009	25-Year
117	14.268613	121.449986	1.98	1.43	1.43	Ondoy / Sept. 26, 2009	25-Year
118	14.269374	121.450217	1.71	2.28	2.28	Santi / Oct. 31, 2009	25-Year
119	14.271544	121.450796	7.74	1.42	1.42	Santi / Oct. 31, 2009	25-Year
120	14.270370	121.451138	1.18	1.00	1.00	Santi / Oct. 31, 2009	25-Year
121	14.271062	121.451358	1.30	2.19	2.19	Santi / Oct. 31, 2009	25-Year
122	14.269460	121.451984	2.63	2.50	2.50	Santi / Oct. 31, 2009	25-Year
123	14.269237	121.453533	3.16	2.70	2.70	Santi / Oct. 31, 2009	25-Year
124	14.269389	121.454581	2.40	2.70	2.70	Santi / Oct. 31, 2009	25-Year
125	14.269313	121.455019	1.98	1.75	1.75	Santi / Oct. 31, 2009	25-Year
126	14.269432	121.455800	1.88	0.75	0.75	Santi / Oct. 31, 2009	25-Year
127	14.270217	121.456740	0.83	0.50	0.50	Ondoy / Sept. 26, 2009	25-Year
128	14.270298	121.455980	1.13	0.74	0.74	Ondoy / Sept. 26, 2009	25-Year
129	14.270862	121.456671	1.54	2.10	2.10	Santi / Oct. 31, 2009	25-Year
130	14.270504	121.454021	1.75	2.20	2.20	Santi / Oct. 31, 2009	25-Year
131	14.243035	121.454299	1.68	0.00	0.00	Glenda / 2014	25-Year
132	14.247619	121.453101	2.14	0.90	0.90	Santi / 2013	25-Year
133	14.247603	121.453024	2.19	0.85	0.85	Santi / 2013	25-Year
134	14.247428	121.451818	3.68	1.33	1.33	Ondoy, Glenda / 2009, 2014	25-Year
135	14.247088	121.451119	0.90	0.00	0.00	Ondoy / 2009	25-Year
136	14.246688	121.450782	1.38	0.00	0.00	Yolanda / 2013	25-Year
137	14.247041	121.451754	1.20	0.00	0.00	Santi / 2013	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
138	14.249761	121.451229	1.94	1.89	1.89	Santi / 10/30/2016	25-Year
139	14.249761	121.451229	1.94	2.25	2.25	Santi / 10/30/2016	25-Year
140	14.258443	121.447610	1.94	0.70	0.70	Rosing, Santi / 1995, 2013	25-Year
141	14.259119	121.447647	1.33	0.00	0.00		25-Year
142	14.258882	121.447830	1.18	1.20	1.20	Ondoy / 2009	25-Year
143	14.258882	121.447830	1.18	1.22	1.22	Santi / 2013	25-Year
144	14.259134	121.447429	1.68	0.92	0.92	Ondoy / 7/7/2015	25-Year
145	14.259134	121.447429	1.68	1.52	1.52	Rosing / 1995	25-Year
146	14.258119	121.445740	1.62	0.70	0.70	Ondoy / 2009	25-Year
147	14.257679	121.445394	1.60	1.35	1.35	Ondoy, Santi / 7/1/2014	25-Year
148	14.256813	121.445189	2.03	0.20	0.20	Yolanda, Santi / 2013, 2013	25-Year
149	14.255473	121.443885	0.05	0.13	0.13	Santi / 2013	25-Year
150	14.254518	121.443608	0.03	0.00	0.00	Milenyo / 2006	25-Year
151	14.255693	121.443514	0.24	0.62	0.62	Ondoy, Santi / 2009, 2013	25-Year
152	14.261493	121.446689	1.55	1.15	1.15	Ondoy / 2009	25-Year
153	14.259327	121.447279	1.92	1.33	1.33	Rosing, Santi / 1995, 2013	25-Year
154	14.253114	121.448416	2.26	0.87	0.87	Santi / 2013	25-Year
155	14.253021	121.448088	1.88	1.20	1.20	Rosing, Santi / 1995, 2013	25-Year
156	14.253866	121.449064	0.82	0.27	0.27	Ondoy, Santi / 2009, 2013	25-Year
157	14.254682	121.448176	2.04	1.47	1.47	Ondoy / 2009	25-Year
158	14.263819	121.447109	2.26	1.34	1.34	Santi / 2013	25-Year
159	14.263842	121.446347	0.54	0.35	0.35	Ondoy, Santi / 2009, 2013	25-Year
160	14.263406	121.446261	0.79	1.30	1.30	Ondoy, Santi / 2009, 2013	25-Year
161	14.263351	121.445872	1.19	0.61	0.61	Santi / 2013	25-Year
162	14.263395	121.445621	1.37	1.32	1.32	Santi / 2013	25-Year
163	14.267774	121.446308	1.48	1.58	1.58	Santi / 2013	25-Year
164	14.268023	121.445940	2.15	0.14	0.14	Glenda / 2014	25-Year
165	14.267913	121.445544	0.24	0.10	0.10	Santi / 2013	25-Year
166	14.268321	121.445366	0.36	0.48	0.48	Santi / 2013	25-Year
167	14.268251	121.445507	0.12	0.66	0.66	Santi / 2013	25-Year
168	14.268250	121.445956	1.68	2.61	2.61	Santi, Basyang / 2009	25-Year
169	14.268301	121.446663	0.46	0.84	0.84	Santi / 2013	25-Year
170	14.268604	121.446049	1.97	2.40	2.40	Ondoy, Santi / 2009	25-Year
171	14.268581	121.445528	0.06	0.00	0.00		25-Year
172	14.268586	121.445164	0.12	0.27	0.27	Santi / 2013	25-Year
173	14.269375	121.444741	0.61	1.32	1.32	Santi / 2013	25-Year
174	14.269621	121.445344	0.40	1.34	1.34	Rosing / 1995	25-Year
175	14.269393	121.446544	1.84	2.22	2.22	Santi / 2013	25-Year
176	14.269404	121.446545	1.84	1.51	1.51	Santi / 2013	25-Year
177	14.269846	121.446133	0.54	0.50	0.50		25-Year
178	14.269893	121.446181	0.48	2.80	2.80	Santi / 2013	25-Year
179	14.270014	121.446649	1.90	2.55	2.55	Santi, Rosing / 2013, 1995	25-Year
180	14.270109	121.445254	0.51	0.68	0.68	Santi / 2013	25-Year
181	14.270195	121.454683	2.04	1.24	1.24	Santi / Oct. 31, 2009	25-Year
182	14.269703	121.454857	1.83	1.23	1.23	Santi / Oct. 31, 2009	25-Year
183	14.205146	121.441228	0.03	0.00	0.00		25-Year
184	14.204780	121.441186	0.03	0.00	0.00		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
185	14.205184	121.441244	0.03	0.00	0.00		25-Year
186	14.205370	121.441448	0.03	0.00	0.00		25-Year
187	14.207373	121.442269	0.03	0.00	0.00		25-Year
188	14.208289	121.441924	0.03	0.41	0.41	Glenda / 2014	25-Year
189	14.208542	121.441766	0.03	0.00	0.00		25-Year
190	14.209358	121.441623	0.06	0.44	0.44	Ondoy / 2009	25-Year
191	14.209440	121.441422	0.03	0.00	0.00		25-Year
192	14.210204	121.439601	0.30	0.36	0.36	Glenda / 2014	25-Year
193	14.210055	121.439279	0.39	0.00	0.00		25-Year
194	14.204812	121.441857	0.03	0.00	0.00		25-Year
195	14.204558	121.441702	0.75	0.00	0.00		25-Year
196	14.205284	121.441920	0.03	0.00	0.00		25-Year
197	14.203173	121.440600	0.05	0.00	0.00		25-Year
198	14.203561	121.441041	0.03	0.00	0.00		25-Year
199	14.205130	121.440512	0.04	0.00	0.00		25-Year
200	14.223598	121.456242	1.93	0.52	0.52	Rosing / 1995	25-Year
201	14.225340	121.458010	1.65	0.91	0.91	Milenyo / 2006	25-Year
202	14.225633	121.458167	2.37	0.00	0.00		25-Year
203	14.223524	121.456415	2.13	0.00	0.00		25-Year
204	14.221390	121.454927	2.32	0.00	0.00		25-Year
205	14.221148	121.454882	1.55	0.00	0.00		25-Year
206	14.220420	121.454940	1.01	0.00	0.00		25-Year
207	14.220129	121.454604	0.69	0.00	0.00		25-Year
208	14.219606	121.454481	0.37	0.35	0.35	Yolanda / 2013	25-Year
209	14.216413	121.452266	0.03	0.00	0.00		25-Year
210	14.216402	121.452290	0.03	0.00	0.00		25-Year
211	14.216938	121.453001	0.04	0.00	0.00		25-Year
212	14.216962	121.453042	0.04	0.00	0.00		25-Year
213	14.216301	121.453009	0.11	0.00	0.00		25-Year
214	14.215878	121.452779	0.10	0.00	0.00		25-Year
215	14.215028	121.452063	0.03	0.00	0.00		25-Year
216	14.214896	121.452152	0.03	0.00	0.00		25-Year
217	14.216093	121.452933	0.05	0.00	0.00		25-Year
218	14.216103	121.452876	0.03	0.80	0.80		25-Year
219	14.226651	121.458120	3.15	0.32	0.32	Bagyo /	25-Year
220	14.226643	121.458234	3.18	0.62	0.62	Bagyo /	25-Year
221	14.226715	121.458259	3.16	0.95	0.95	Santi / 2013	25-Year
222	14.226821	121.458388	3.48	0.62	0.62	Bagyo	25-Year
223	14.227218	121.458189	3.62	0.00	0.00		25-Year
224	14.228056	121.456944	2.56	0.31	0.31	Ondoy / 2009	25-Year
225	14.228333	121.457222	2.43	1.31	1.31	Santi / 2013	25-Year
226	14.226944	121.455833	2.07	0.38	0.38	Yolanda / 2013	25-Year
227	14.226667	121.455000	1.73	0.00	0.00		25-Year
228	14.225833	121.450556	0.11	0.00	0.00		25-Year
229	14.298889	121.461944	0.84	0.91	0.91	Ondoy / 2009	25-Year
230	14.302500	121.461944	0.96	0.58	0.58	Ondoy / 2009	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
231	14.302222	121.462222	1.08	0.62	0.62	Ondoy, Santi / 2009, 2013	25-Year
232	14.302778	121.461944	0.86	1.60	1.60	2011	25-Year
233	14.305556	121.458889	0.10	0.17	0.17	Ondoy / 2009	25-Year
234	14.305556	121.460000	0.04	1.11	1.11	Ondoy / 2009	25-Year
235	14.304444	121.460556	0.06	0.42	0.42	Ondoy, Santi / 2009, 2013	25-Year
236	14.305000	121.462222	0.60	1.90	1.90	Ondoy, Santi / 2009, 2013	25-Year
237	14.307500	121.458333	0.10	1.15	1.15	Ondoy / 2009	25-Year
238	14.308889	121.455833	0.14	0.30	0.30	Ondoy / 2009	25-Year
239	14.308056	121.454722	1.97	0.90	0.90	Ondoy / 2009	25-Year
240	14.305278	121.449444	0.03	0.70	0.70	Yolanda / 2013	25-Year
241	14.308056	121.456111	0.05	0.40	0.40	Ondoy / 2009	25-Year
242	14.310000	121.456389	0.09	0.72	0.72	Ondoy / 2009	25-Year
243	14.309722	121.455556	0.22	0.00	0.00	Ondoy / 2009	25-Year
244	14.306111	121.450000	0.10	0.30	0.30	Yolanda / 2013	25-Year
245	14.310278	121.456111	0.08	0.23	0.23	Habagat / 2012/2013	25-Year
246	14.299167	121.456111	0.55	0.82	0.82	Ondoy / 2009	25-Year
247	14.300000	121.461111	0.39	1.65	1.65	Ondoy, Santi / 2009, 2013	25-Year
248	14.301111	121.452222	0.08	0.50	0.50	Ondoy / 2009	25-Year
249	14.301111	121.451667	0.07	0.44	0.44	Ondoy / 2009	25-Year
250	14.301667	121.452500	0.03	1.38	1.38	Ondoy, Santi, Tino / 2009, 2013, 2013	25-Year
251	14.300556	121.449722	0.22	0.00	0.00	Ondoy / 2009	25-Year
252	14.301111	121.449167	0.46	0.35	0.35	Ondoy, Yolanda / 2009, 2013	25-Year
253	14.302500	121.451944	0.03	0.52	0.52	Habagat, Ondoy, Santi, Glenda / 2012/2013, 2009, 2013, 2014	25-Year
254	14.302778	121.451944	1.23	0.60	0.60	Ondoy / 2009	25-Year
255	14.301389	121.449444	0.06	1.39	1.39	Ondoy, Santi / 2009, 2013	25-Year
256	14.301944	121.453333	0.03	1.37	1.37	Ondoy, Santi / 2009, 2013	25-Year
257	14.298889	121.456944	0.49	0.74	0.74	Ondoy, Santi, Pepeng / 2009, 2013, 2009	25-Year
258	14.300000	121.460833	0.59	0.25	0.25	Ondoy, Yolanda / 2009, 2013	25-Year
259	14.300278	121.453611	0.03	0.00	0.00	Ondoy, Santi, Yolanda / 2009, 2013, 2013	25-Year
260	14.279167	121.432500	0.03	0.60	0.60	Ondoy, Habagat / 2009, 2012/2013	25-Year
261	14.278611	121.432778	0.14	0.62	0.62	Ondoy, Santi / 2009, 2013	25-Year
262	14.277500	121.431944	0.03	0.90	0.90	Glenda / 2014	25-Year
263	14.301667	121.458611	2.05	2.95	2.95	Ondoy / 2009	25-Year
264	14.301667	121.458889	0.57	0.78	0.78	Santi / 2013	25-Year
265	14.301667	121.459444	0.03	0.55	0.55	Ondoy / 2009	25-Year
266	14.300278	121.461111	0.53	0.50	0.50	Ondoy / 2009	25-Year
267	14.302222	121.459167	0.05	1.10	1.10	Ondoy / 2009	25-Year
268	14.302778	121.460000	0.03	0.50	0.50	Ondoy / 2009	25-Year
269	14.302500	121.460278	0.22	0.72	0.72	Ondoy / 2009	25-Year
270	14.301944	121.460000	0.03	0.50	0.50	Glenda / 2014	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

Project Leader
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