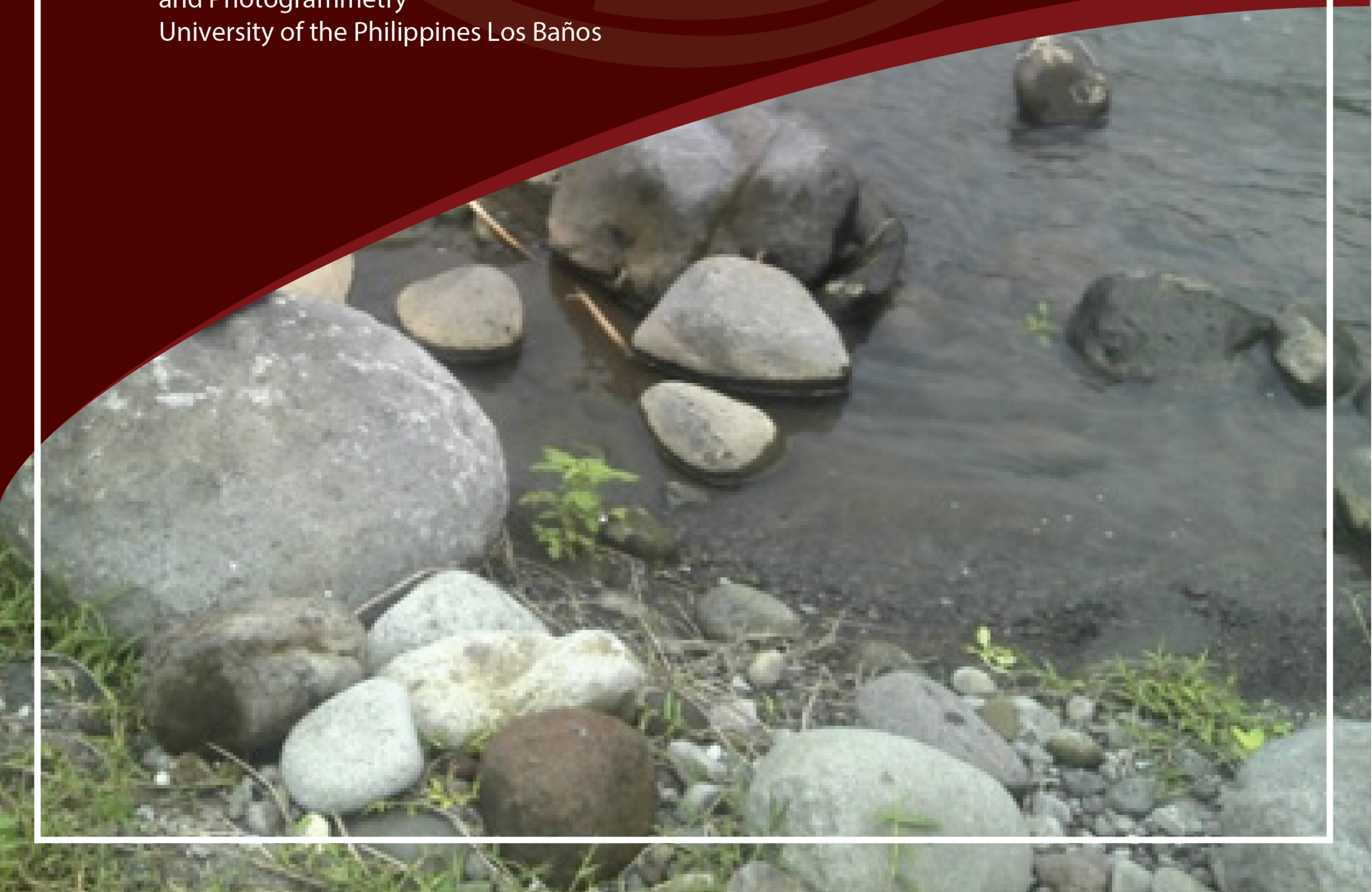
Hazard Mapping of the Philippines Using LIDAR (Phil-LiDAR 1)

LiDAR Surveys and Flood Mapping of Santa Cruz River

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



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

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

E.C. Paringit and E.R. Abucay (2017), LiDAR Surveys and Flood Mapping of Sta. Cruz River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-183pp

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National Library of the Philippines
ISBN: 978-621-430-158-4

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and and Ms. Mia 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 in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

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 45 river basins in the MIMAROPA. The university is located in the Municipality of Los Baños in the province of Laguna.

1.2 Overview of the Sta. Cruz River Basin

Sta. Cruz River Basin is a 15,050-hectare watershed located in the municipality of Sta. Cruz, Laguna. It is situated in the south-eastern side of Laguna Lake and has a drainage area of 128 km^2 with an estimated runoff of 120 MCM. It covers the municipalities of Calauan, Liliw, Lumban, Magdalena, Majayjay, Nagcarlan, Pagsanjan, Pila, Rizal, San Pablo City, and Sta. Cruz in Laguna; and Candelaria, Dolores, Lucban, Sariaya, and Tayabas in Quezon. The basin area has two geological classifications with Pliocene-Quaternary as the most dominant type while others are Recent. The river basin is generally characterized by 3–8% slope and elevation of more than 2,200 meters above mean sea level. The river basin has different soil types dominated by Lipa loam. Other soils include Marikina silt loam, Marikina silty clay loam, Luisiana clay loam, Macolod clay loam, and Calumpang clay. Other areas are still unclassified (mountain soils). Coconut plantation is predominant in the area followed by built-up area, cultivated area mixed with brushland/grassland, closed canopy, open canopy, arable land with crops mainly cereals and sugar, crop land mixed with coconut plantations, lake and marshy area, and swamp. Aquaculture is also present along coastal communities.

Its main stem, Sta. Cruz River, is one of the main tributaries of the Sta. Cruz River Basin. The river is connected to a larger stream network which connects itself to the Pila River in the municipality of Pila. The Sta. Cruz River is measured to be approximately 14.48 km in length, flowing towards Laguna Lake. Sta. Cruz River passes through the municipalities of Liliw, Magdalena, Nagcarlan, Pagsanjan, Pila, and Sta. Cruz leading down to the Laguna de Bay. There are a total of 36,739 people living within the immediate vicinity of the river according to the 2010 census conducted by NSO. Moreover, based on the 2010 NSO Census of Population and Housing, Santisima Cruz in Sta. Cruz is the most populated barangay in the area.

Climate Type I and III prevails in MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

According to Mines and Geosciences Bureau (MGB), the Sta. Cruz River Basin was generally classified to be highly susceptible to flooding, and a combination of low and high risk when it comes to landslide susceptibility. As stated in the Ecological Profile of Laguna (2011), most municipalities in the 2nd, 3rd and 4th districts of the province are affected by flood hazards and rain-induced to landslide hazard as assessed by the Office of Civil Defence (OCD), DENR-Mines Geosciences Bureau, and NAMRIA. On the other hand, municipalities including Calauan, Cavinti, Lumban, Mabitac, Nagcarlan, Paete, Rizal, Siniloan and Sta. Maria are susceptible to soil and river bank erosion. Meanwhile, the municipalities of Bay, Biñan, Cabuyao, Calamba, Famy , Kalayaan, Los Baños, Lumban, Paete, Pagsanjan, Pakil, Pangil, Mabitac, San Pedro, Sta. Cruz, Sta. Rosa, Sta. Maria, Siniloan, and Victoria are prone to liquefaction. Moreover, municipalities of San Pedro and Calamba are also prone to highly ground rupture hazard.

The field surveys conducted by the PHIL-LiDAR 1 validation team found that several weather disturbances caused flooding in 2006 (Milenyo), 2009 (Ondoy and Santi), 2013 (Yolanda), and 2014 (Glenda). Heavy rains brought by southwest monsoon in 2012 also caused flooding affecting several barangays in Sta. Cruz (San Pablo Norte, Sto. Angel Norte) and Lumba (Wawa).

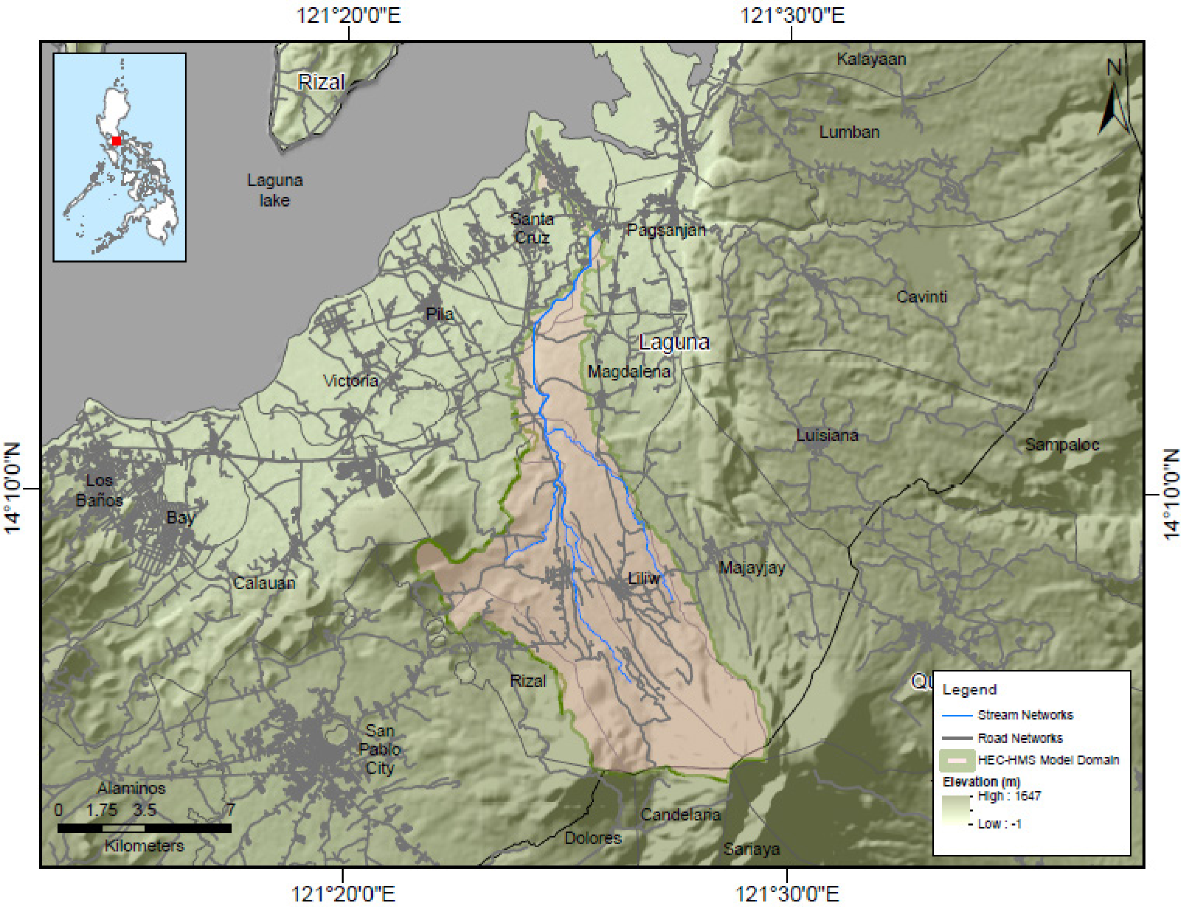

Figure 1. Map of the Sta. Cruz River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN STA. CRUZ FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Sta. Cruz Floodplain in Cavite. These missions were planned for 6 lines that run for at most three (3) hours including take-off, landing, and turning time. The flight planning parameters for Pegasus LiDAR system is found in Table 1. Figure 2 shows the flight plan for Sta. Cruz Floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK18 H	1200	20	50	200	50	130	5
BLK18 I	1000	30	50	200	50	130	5
BLK18 J	1000	30	50	200	50	130	5
BLK18 K	1000	30	50	200	50	130	5

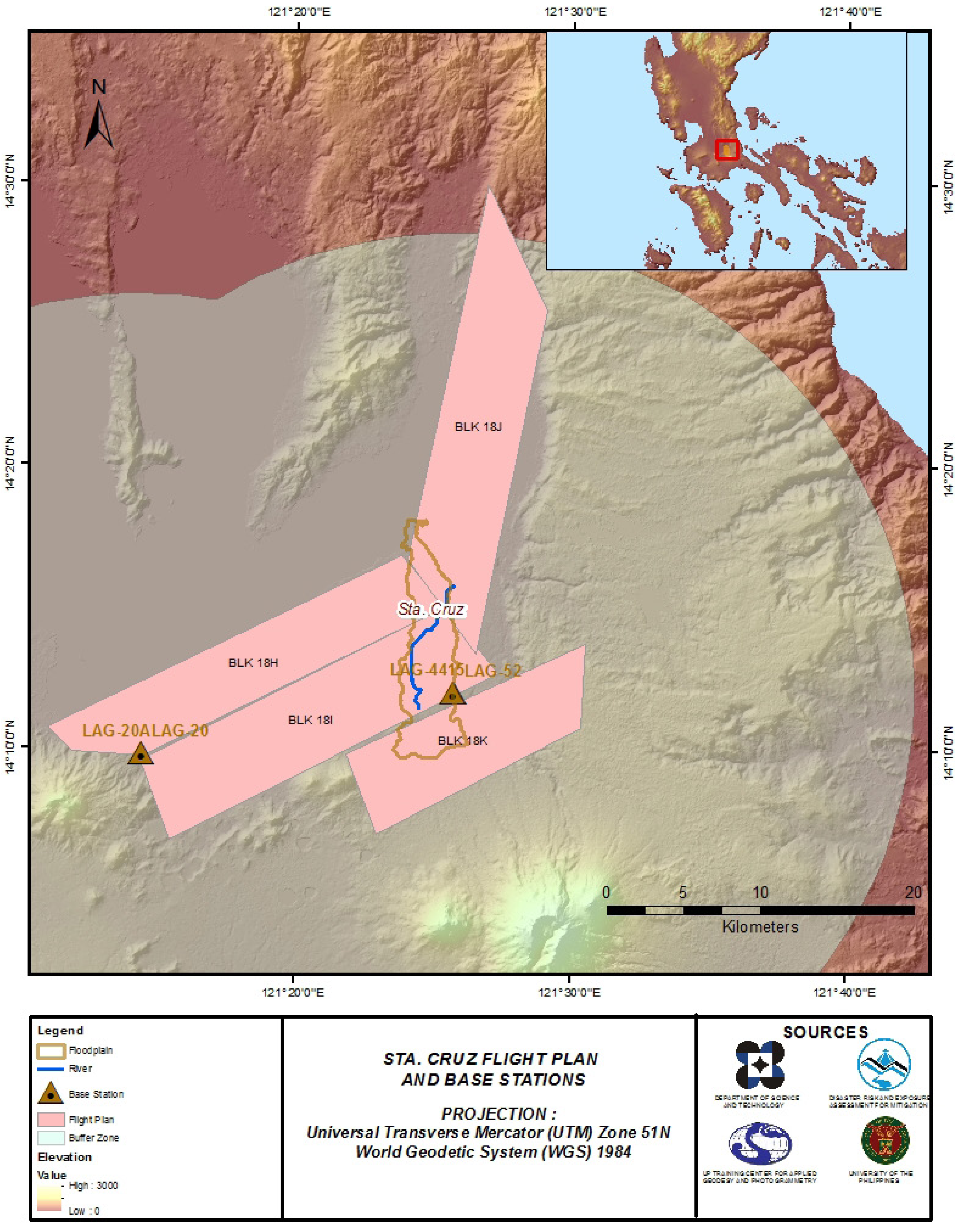

Figure 2. Flight plans and base stations for Sta. Cruz Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: LAG-52 which is of second (2nd)-order accuracy and LAG-20 which is of third (3rd)-order accuracy. The project team also established two (2) ground control points: LAG-20A and LAG-52A. The certifications for the base stations are found in ANNEX 2 while the baseline processing reports for the established points are found in ANNEX 3. These points were used as base stations during flight operations for the entire duration of the survey (February 4–8, 2014 and August 15, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Sta. Cruz Floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points and established points within the area. In addition, Table 2 to Table 5 present the details about the NAMRIA control stations while Table 6 shows the list of all ground control points occupied during the acquisition together with the dates they were utilized during the survey.

(a)

(b)

Figure 3. GPS set-up over LAG-20 near the freedom park in UP Los Baños (a) and NAMRIA reference point LAG-20 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point LAG-20 used as 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 Longitude Ellipsoidal Height	14° 9' 53.86904" North 121° 14' 20.35180" East 39.91400 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	525799.268 meters 1566435.481 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°9 '53.86904" North 121°14'25.28172"East 85.26600 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	309934.22 meters 1566588.99 meters

Figure 4. LAG-20A as established inside the UP Los Baños compound near LAG-20

Table 3. Details of the established horizontal control point LAG-20A with processed coordinates used as base station for the LiDAR acquisition

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° 9' 53.86904" North 120° 24' 5.41918" East 35.63300 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	436193.115 meters 1854816.574 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 46' 8.39718" North 120° 24' 10.13252" East 71.25300 meters

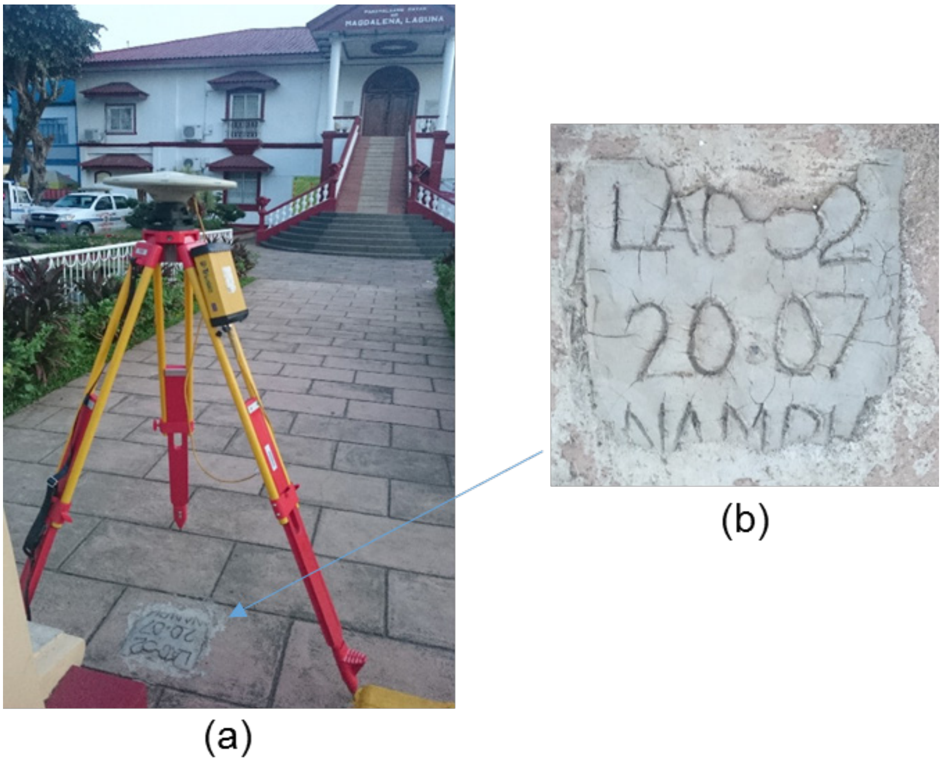

Figure 5. GPS set-up over LAG-52 near the flag pole of Magdalena Municipal Hall (a) and NAMRIA reference point LAG-52 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point LAG-52 used as base station for the LiDAR acquisition

Station Name	LAG-52	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	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 WGS 1984)	Easting Northing	330382.29 meters 1570462.41 meters

Table 5. Details of the recovered NAMRIA horizontal control point LAG-4415 used as base station for the LiDAR acquisition

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' 05.34595" North 121° 25' 39.04510" East 65.12200 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	330313.757 meters 1570484.318 meters

Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 12' 00.05622" North 121° 25' 43.97080" East 110.83200 meters

Table 6. Ground control points used during LiDAR Data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 4, 2014	1067P	1BLK18H035A	LAG-20 and LAG-20A
February 5, 2014	1071P	1BLK18I036A	LAG-20 and LAG-20A
February 8, 2014	1083P	1BLK18J39A	LAG-52
August 15, 2015	3299P	1BLK18KS227A	LAG-52 and LAG-4415

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR data acquisition in Sta. Cruz Floodplain, for a total of eleven hours and forty six minutes (11+46) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Sta. Cruz Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 4, 2014	1067P	213.3	108.53	9.73	98.80	221	2	55
February 5, 2014	1071P	213.3	190.64	24.49	166.15	311	2	47
February 8, 2014	1083P	223.1	139.63	0.48	139.15	372	3	29
August 15, 2015	3299P	84.54	84.53	9.56	74.97	NA	2	35
TOTAL		734.24	523.33	44.26	479.07	904	11	46

Table 8. Actual parameters used during LiDAR data acquisition

Date Surveyed	Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	Scan Frequency (kHz)	Speed of Plane (Kts)
February 4, 2014	1067P	1200	20	50	30	130
February 5, 2014	1071P	1000	30	50	30	130
February 8, 2014	1083P	1000	30	50	30	130
August 15, 2015	3299P	1000	30	50	30	130

2.4 Survey Coverage

Sta. Cruz Floodplain is situated within the municipalities in Laguna. The municipalities of Magdalena, Pila, and Victoria are mostly covered during the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Sta. Cruz Floodplain is presented in Figure 6.

Table 9. List of municipalities/cities surveyed during Sta. Cruz Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/ City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Laguna	Magdalena	29.61	29.49	99.57%
	Pila	28.77	28.41	98.72%
	Victoria	28.37	27.41	96.62%
	Sta. Cruz	37.63	33.15	88.10%
	Pagsanjan	40.773	32.86	80.60%
	Bay	40.80	29.35	71.94%
	Calauan	79.44	53.81	67.74%
	Nagcarlan	81.20	49.01	60.36%
	Sinoloan	26.18	14.82	56.62%
	Famy	33.43	18.25	54.60%
	Pangil	35.64	17.58	49.34%
	Liliw	36.20	14.47	39.97%
	Los Baños	50.48	18.08	35.82%
	Luisiana	61.00	16.96	27.80%
	Majayjay	64.40	16.44	25.53%
	Lumban	117.34	25.27	21.54%
	Pakil	30.02	6.10	20.32%
	Kalayaan	52.63	5.49	10.42%
	Rizal	24.02	1.95	8.11%
	Paete	78.9	5.74	7.27%
	Santa Maria	137.35	5.21	3.79%
	Cavinti	96.78	1.83	1.89%
Total		1210.96	451.68	37.30%

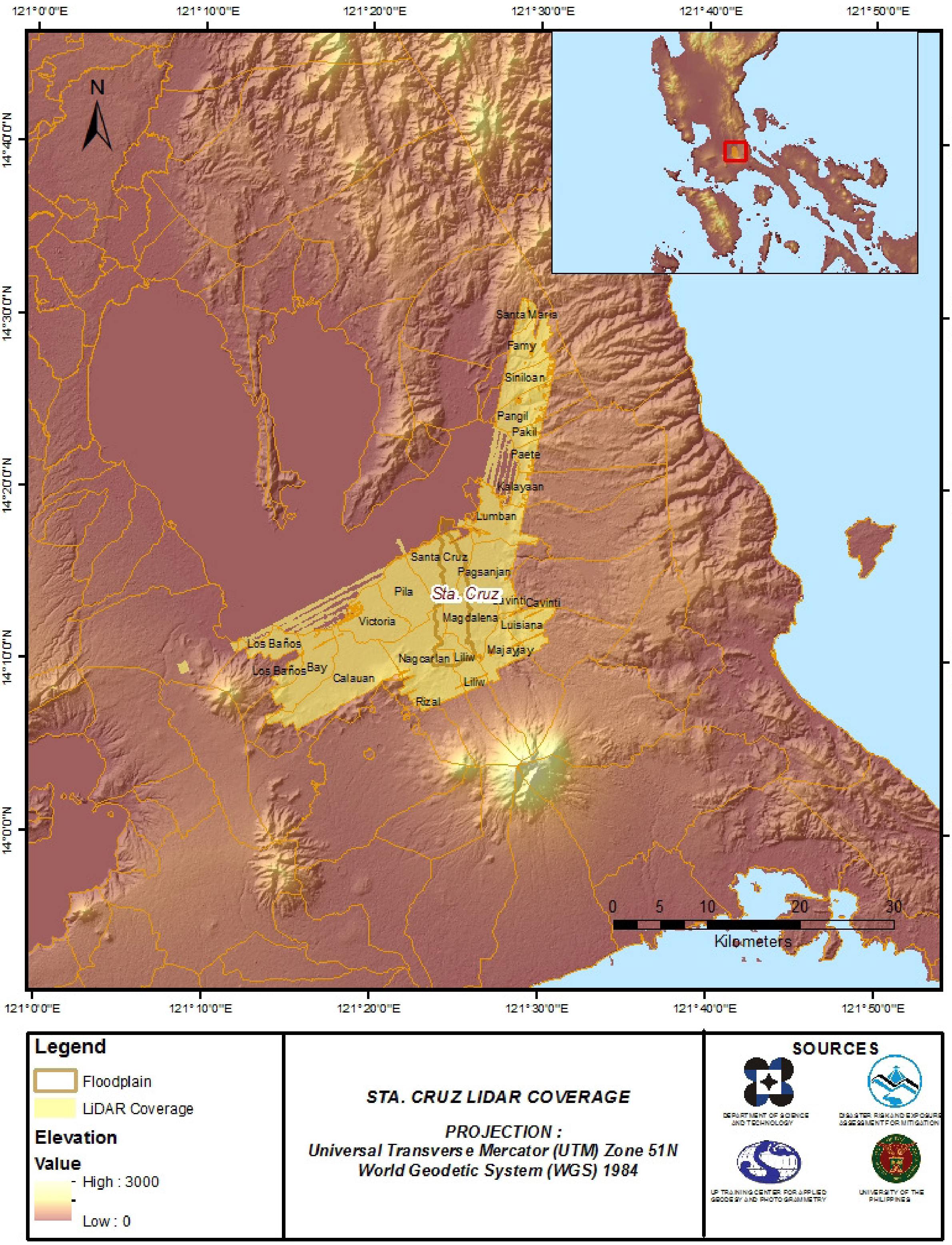

Figure 6. Actual LiDAR survey coverage for Sta. Cruz Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR STA. CRUZ FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 7.

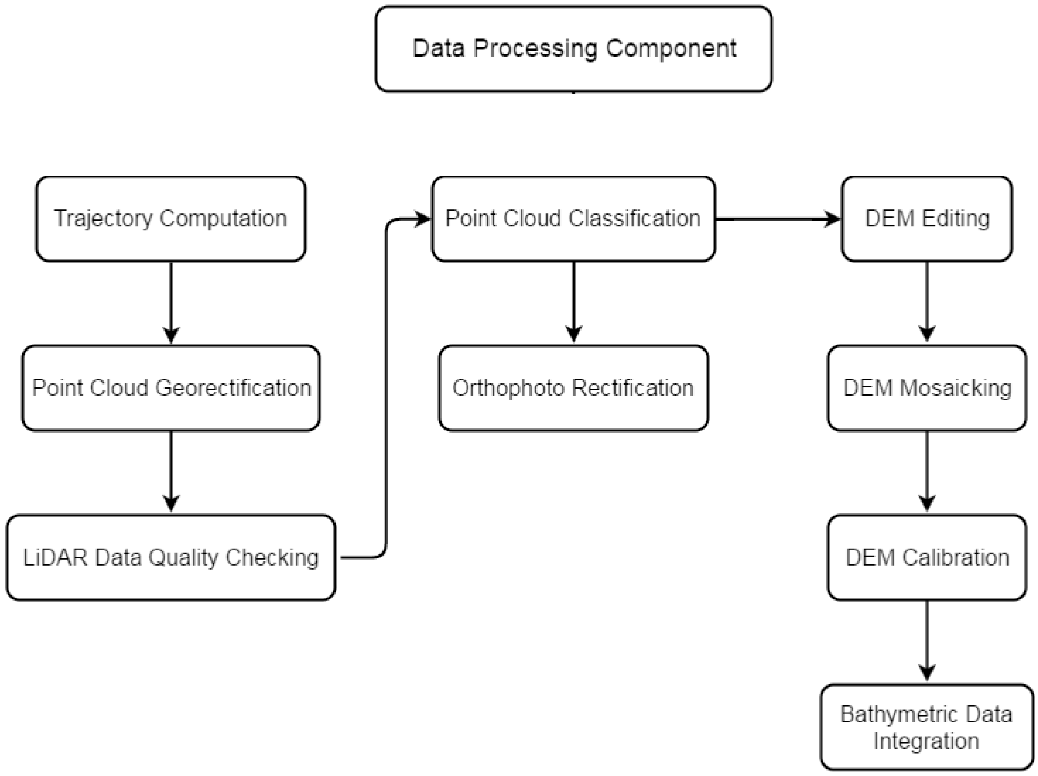

Figure 7. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Sta. Cruz Floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. The missions acquired during the second survey on September 2015 were flown using the same system over Sta. Cruz, Laguna. The Data Acquisition Component transferred a total of 67.28 Gigabytes of Range data, 862.7 Megabytes of POS data, 30.13 Megabytes of GPS base station data, and 50.29 Gigabytes of raw image data to the data server on February 20, 2014 for the first survey and September 7, 2015 for the second survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sta. Cruz was fully transferred on September 10, 2015, as indicated on the data transfer sheets for Sta. Cruz Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3299P, one of the Sta. Cruz flights, which is the North, East, and Down position RMSE values are shown 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 on that week fell on August 15, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

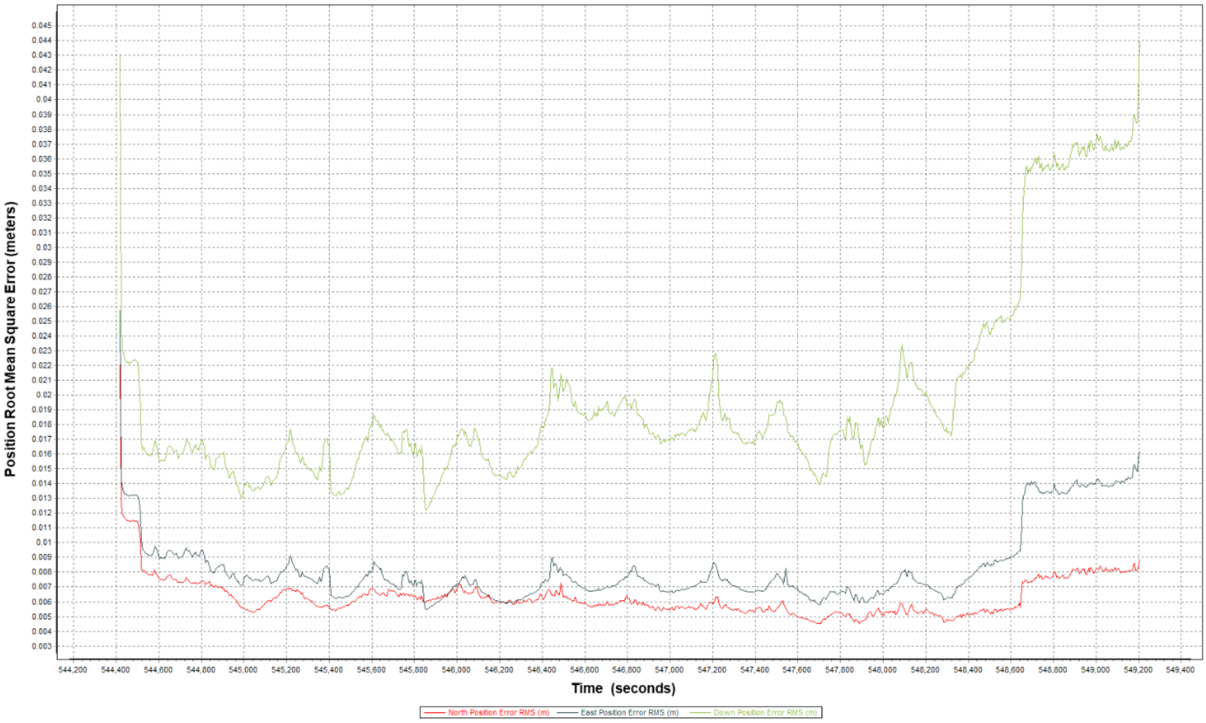

Figure 8. Smoothed Performance Metrics of a Sta. Cruz Flight 3299P.

The time of flight was from 544400 seconds to 549200 seconds, which corresponds to morning of August 15, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the time the POS system started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 0.73 centimeters, the East position RMSE peaks at 0.90 centimeters, and the Down position RMSE peaks at 2.28 centimeters, which are within the prescribed accuracies described in the methodology.

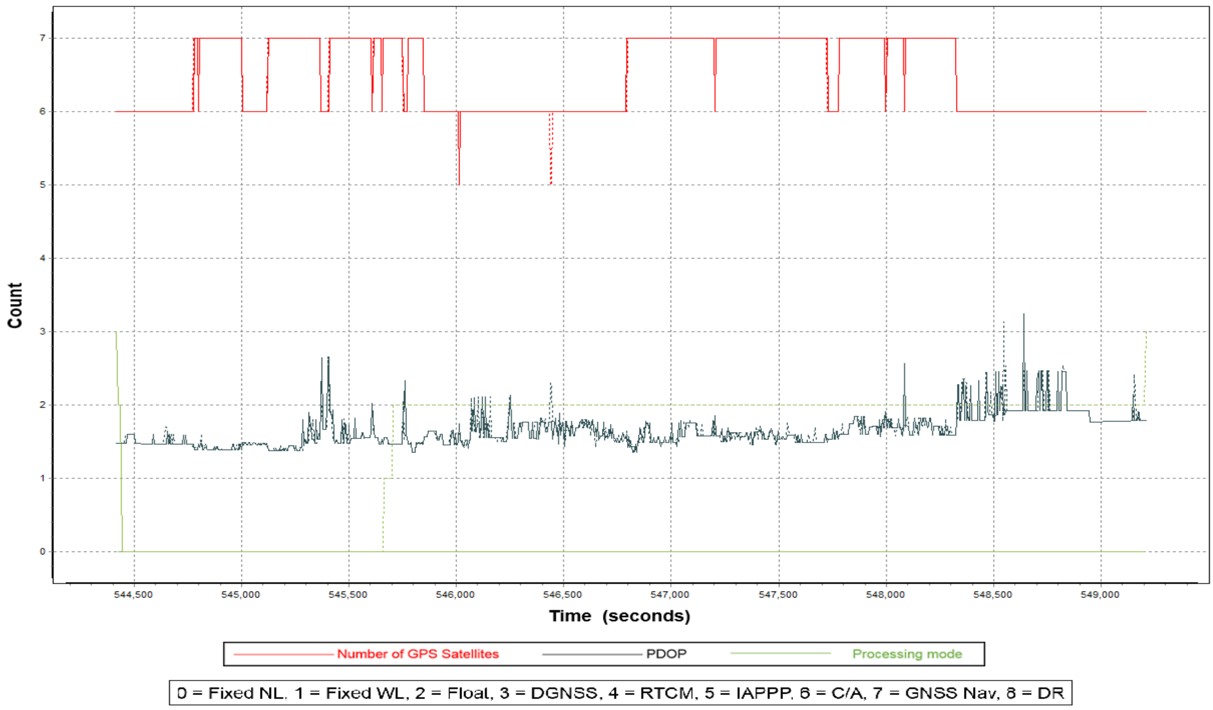

Figure 9. Solution Status Parameters of Sta. Cruz Flight 3299P.

The Solution Status parameters of flight 3299P, one of the Sta. Cruz flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown 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 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 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 adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sta. Cruz flights is shown in Figure 10.

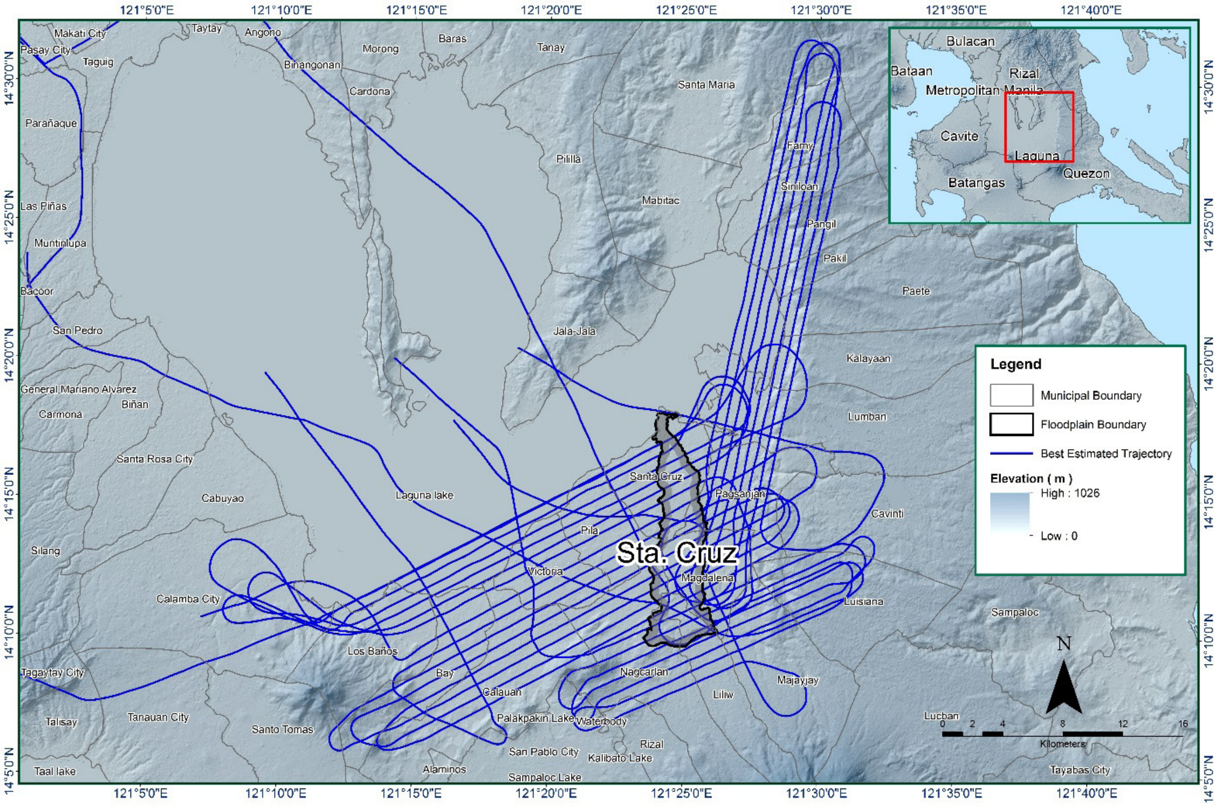

Figure 10. Best estimated trajectory of LiDAR missions conducted over Sta. Cruz Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 39 flight lines, with each flight line containing two channels, since the Pegasus system was used. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Sta. Cruz Floodplain are given in Table 10.

Table 10. Self-calibration results values for Sta. Cruz flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000301
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000964
GPS Position Z-correction stdev	(<0.01meters)	0.0029

The optimum accuracy is obtained for all Sta. Cruz flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in ANNEX 8.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Sta. Cruz Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

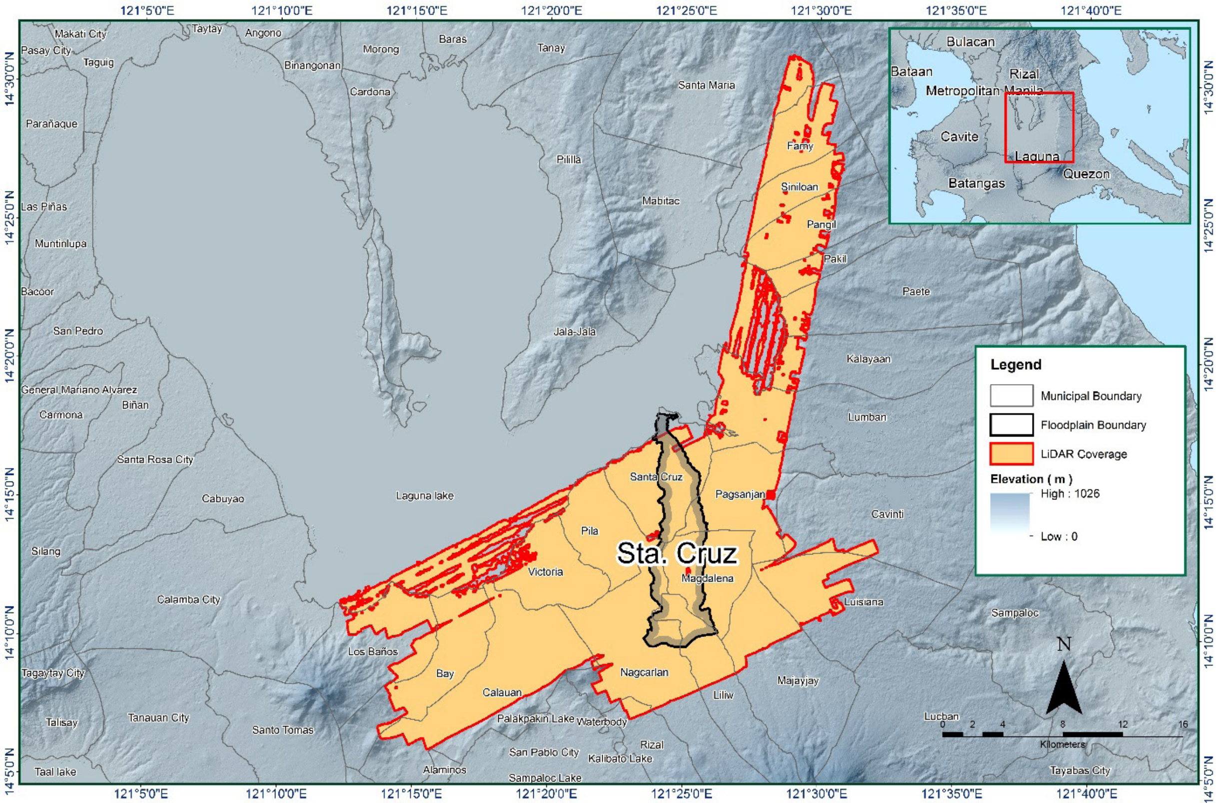

Figure 11. Boundary of the processed LiDAR data over Sta. Cruz Floodplain

The total area covered by the Sta. Cruz missions is 512.62 sq km comprised of five (5) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Sta. Cruz Floodplain

LiDAR Blocks	Flight Numbers	Area (sq km)
CALABARZON_Blk18I_supplement	3299P	89.26
	3377P	
Laguna_Blk18H	1067P	102.25
Laguna_Blk18J	1083P	133.00
Cavite_Blk18I	1071P	188.11
TOTAL		512.62 sq km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is shown in Figure 12. Since the Pegasus system employs two channels, an average value of 2 (blue) would be expected 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.

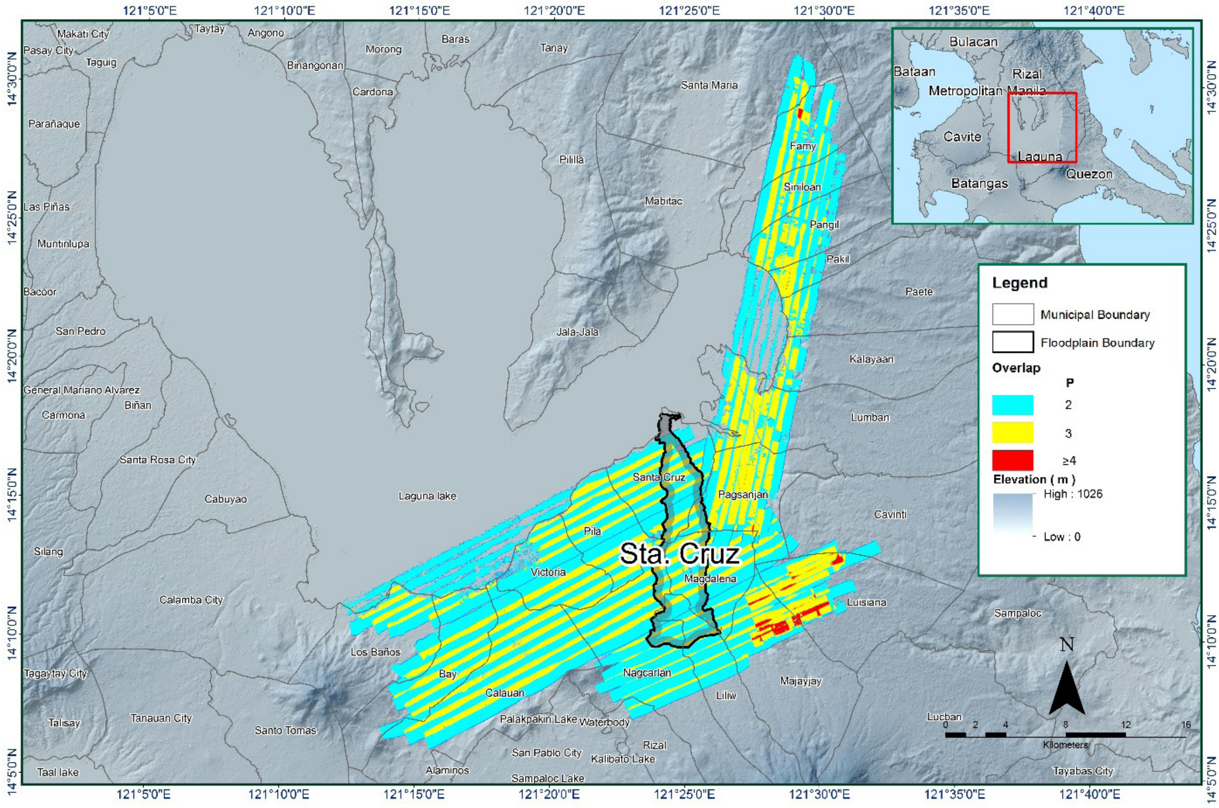

Figure 12. Image of data overlap for Sta. Cruz Floodplain

The overlap statistics per block for the Sta. Cruz Floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.06% and 43.53%, respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion, is shown in Figure 13. It was determined that all LiDAR data for Sta. Cruz Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.83 points per square meter.

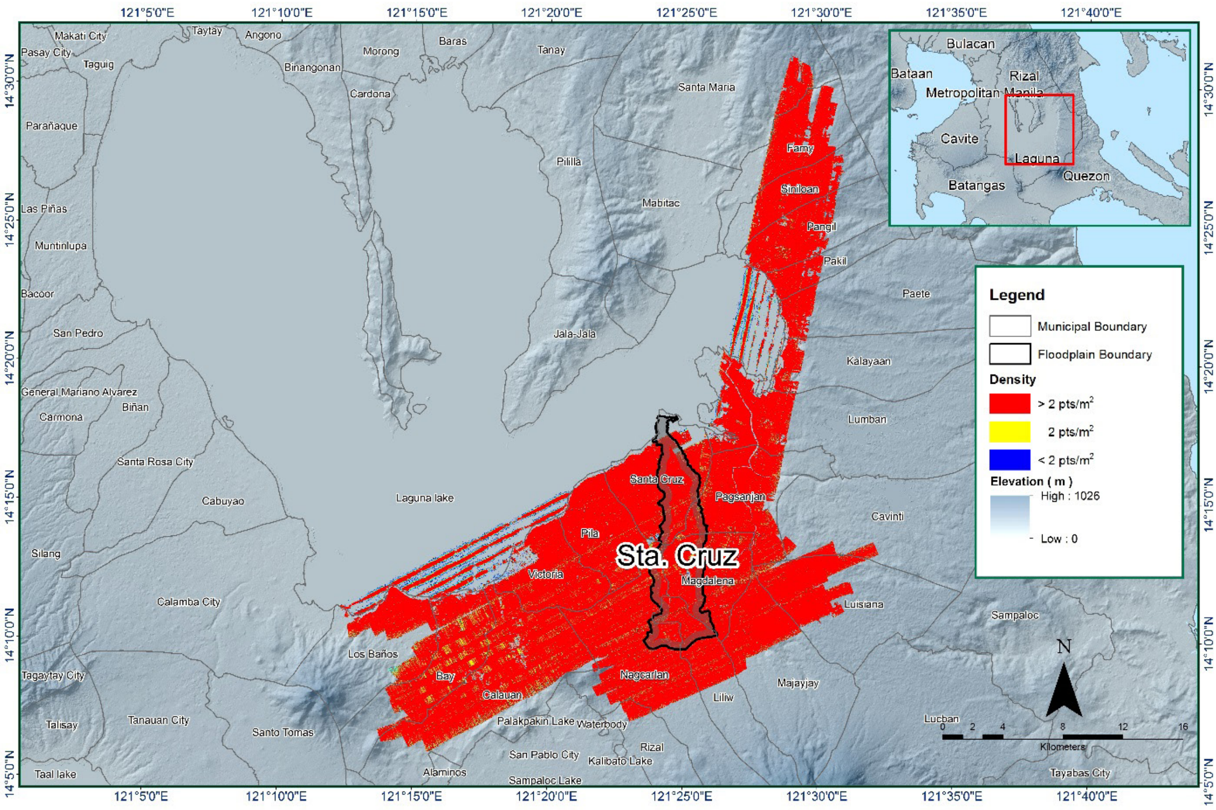

Figure 13. Pulse density map of merged LiDAR data for Sta. Cruz Floodplain

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

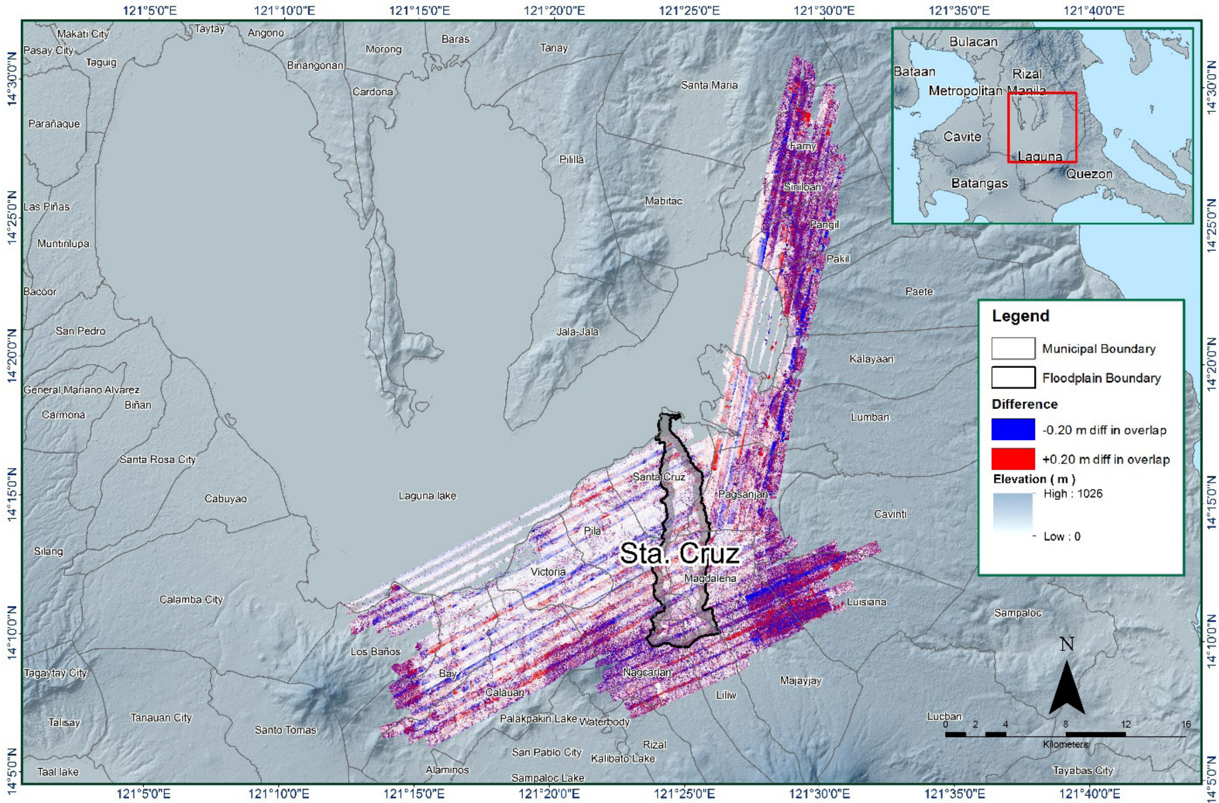

Figure 14. Elevation difference map between flight lines for Sta. Cruz Floodplain

A screen capture of the processed LAS data from a Sta. Cruz flight 3299P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

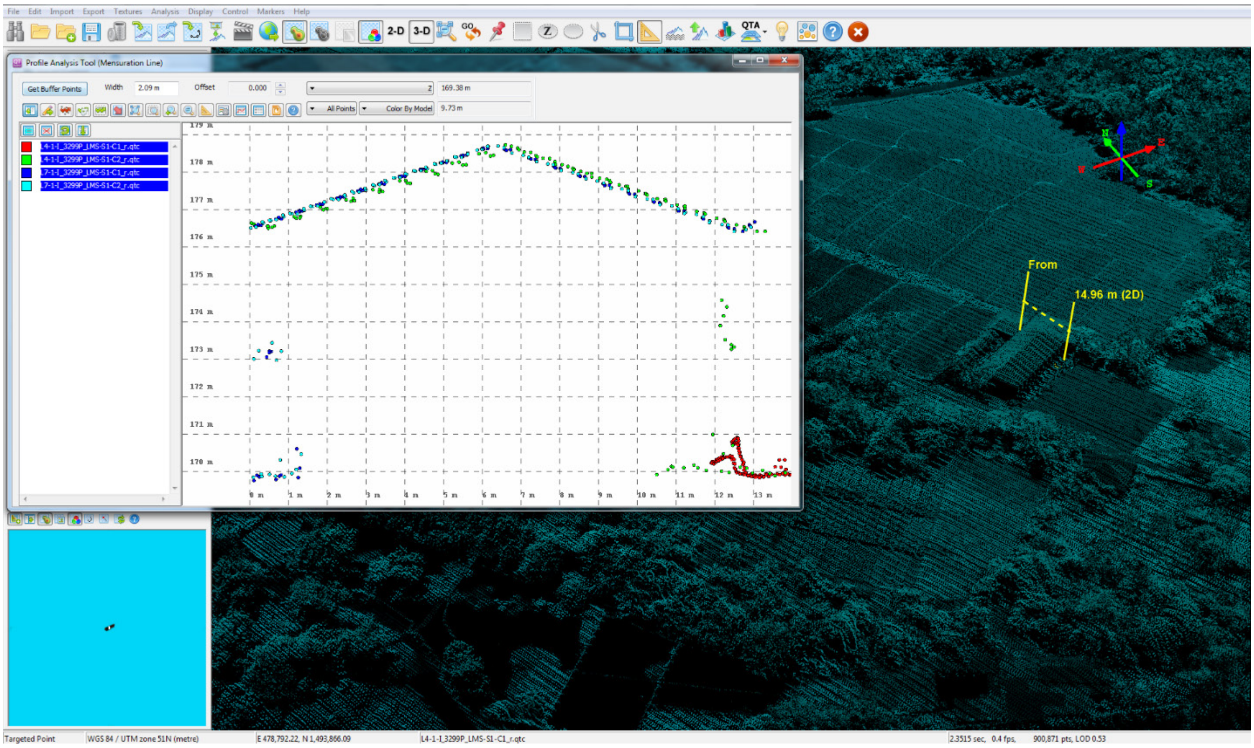

Figure 15. Quality checking for a Sta. Cruz flight 3299P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Sta. Cruz classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	414,922,423
Low Vegetation	362,470,450
Medium Vegetation	464,323,716
High Vegetation	771,958,524
Building	55,010,794

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sta. Cruz Floodplain is shown in Figure 16. A total of 728 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 978.05 meters and 37.58, respectively.

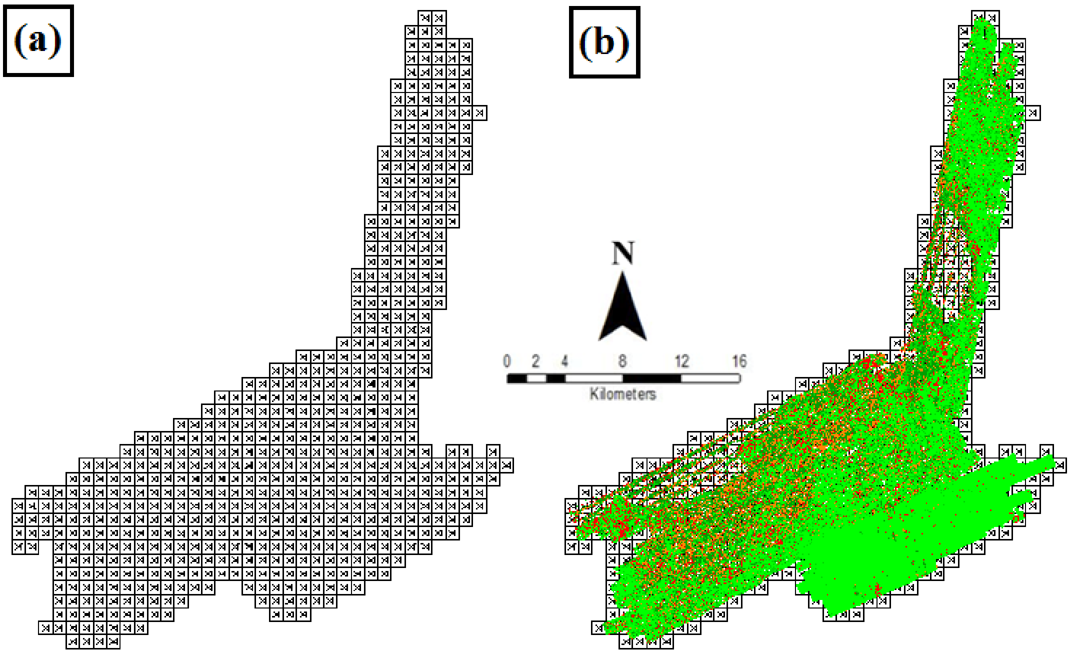

Figure 16. Tiles for Sta. Cruz Floodplain (a) and classification results (b) in TerraScan

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

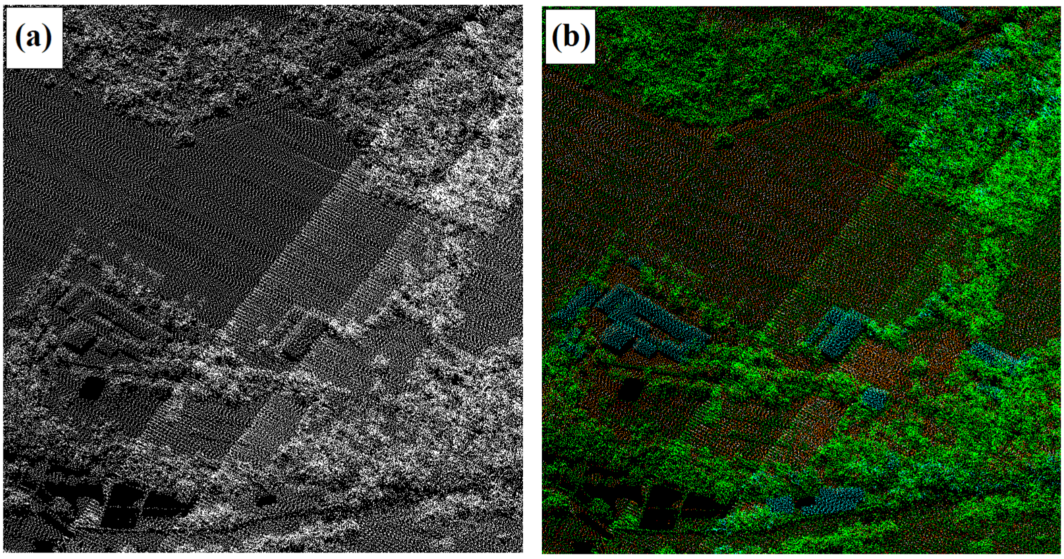

Figure 17. Point cloud before (a) and after (b) classification

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

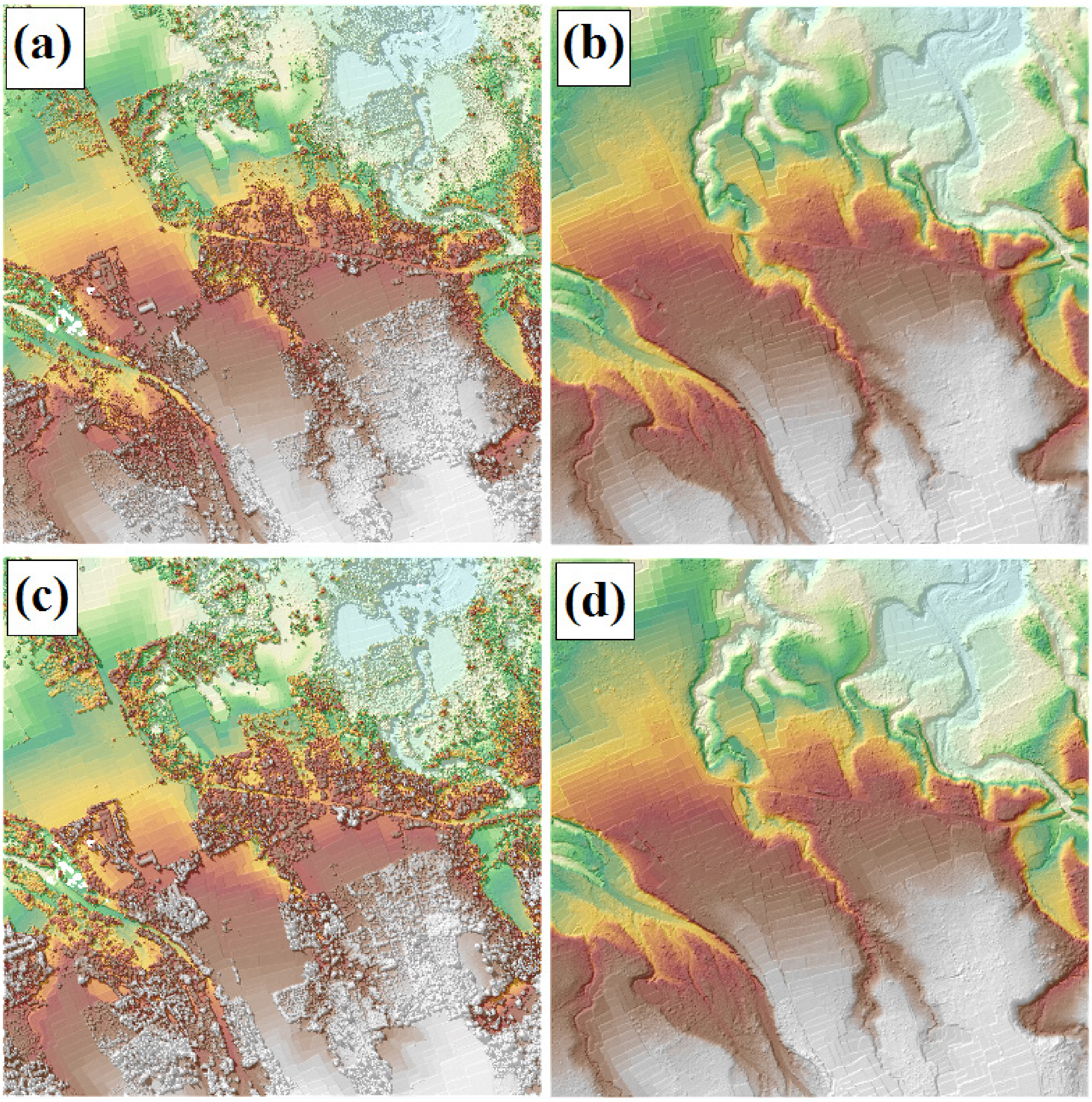

Figure 18. The production of last return DSM (a) and DTM (b); first return DSM (c) and secondary DTM (d) in some portion of Sta. Cruz Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 333 1 km by 1 km tiles area covered by Sta. Cruz Floodplain is shown in Figure 19. After tie-point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Sta. Cruz Floodplain attained a total of 229.19 sq km in orthophotogaph coverage comprised of 566 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

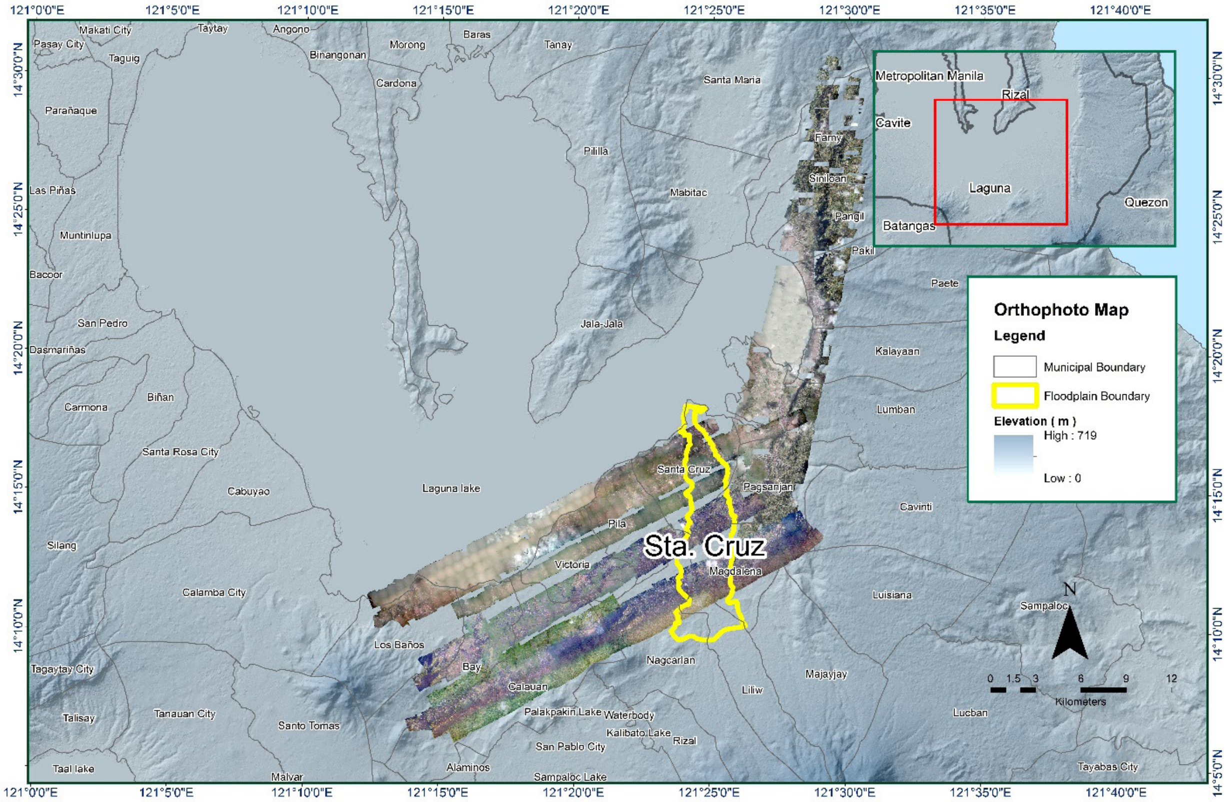

Figure 19. Sta. Cruz Floodplain with available orthophotographs

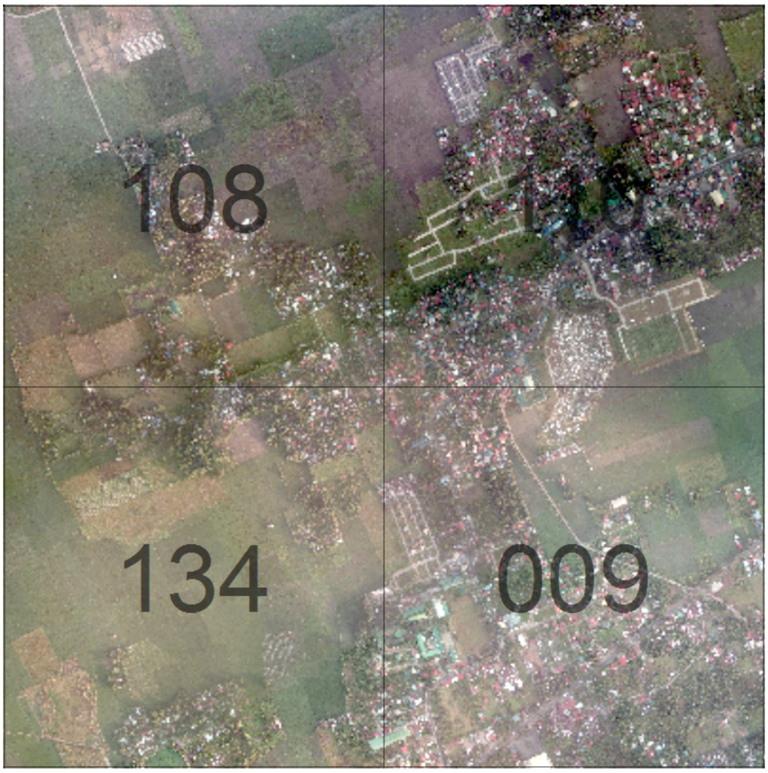

Figure 20. Sample orthophotograph tiles for Sta. Cruz Floodplain

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Sta. Cruz Floodplain. These blocks are composed of Calabarzon, Laguna, and Cavite blocks with a total area of 512.62 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with their corresponding area

LiDAR Blocks	Area (sq km)
CALABARZON_18I_supplement	89.26
Laguna_Blk18H	102.25
Laguna_Blk18J	133
Cavite_Blk18I	188.11
TOTAL	512.62 sq km

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) was considered to be an impedance to the flow of water along the river and had to be removed (Figure 21b) in order to hydrologically correct the river. A portion of hill also (Figure 21c) had been misclassified and needed to be retrieved to retain the correct terrain (Figure 21d). Object retrieval used the secondary DTM (t_layer) to fill in these areas.

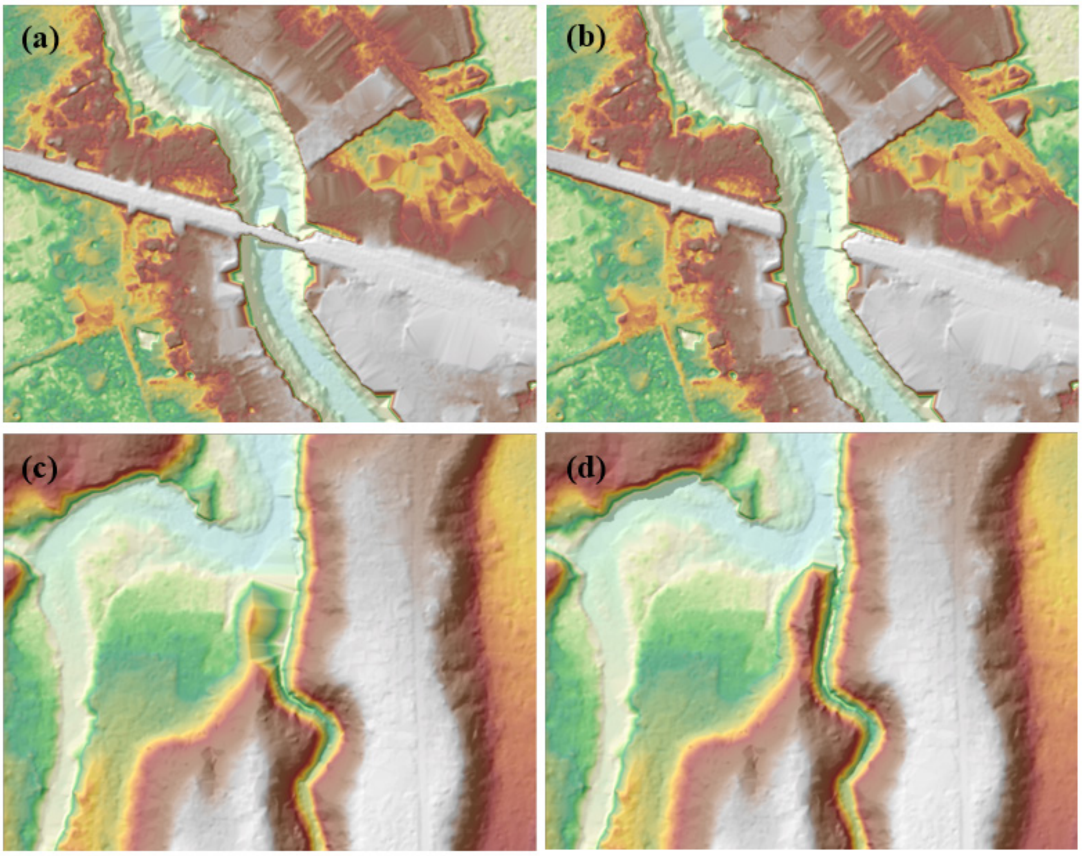

Figure 21. Portions in the DTM of Sta. Cruz Floodplain—a bridge before (a) and after (b) manual editing; and a misclassified hill before (d) and after (e) manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Calabarzon DEM overlapping with the blocks to be mosaicked. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Sta. Cruz Floodplain is shown in Figure 22. It can be seen that the entire Sta. Cruz Floodplain is 96.60% covered by LiDAR data.

Table 14. Shift values of each LiDAR Block of Sta. Cruz Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
CALABARZON_18I_supplement	0.00	0.00	-0.74
Laguna_Blk18H	0.00	0.00	0.30
Laguna_Blk18J	0.00	0.00	0.00
Cavite_Blk18I	-0.21	-0.08	0.30

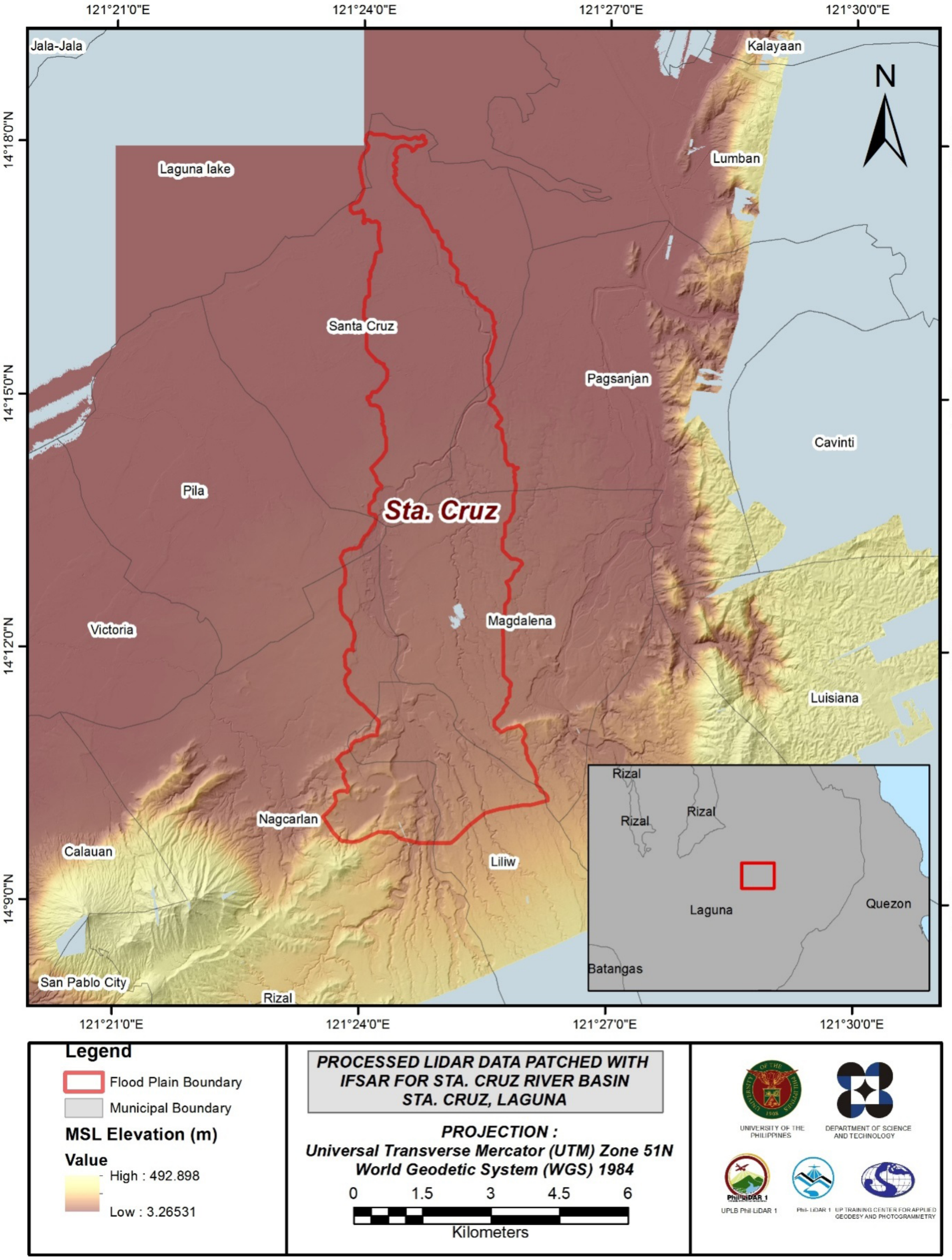

Figure 22. Map of processed LiDAR data for Sta. Cruz Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Sta. Cruz to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 24,251 survey points were gathered for all the flood plains within the provinces of CALABARZON wherein the Sta. Cruz floodplain is located. Random selection of 80% of the survey points, resulting to 19,401 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 2.97 meters with a standard deviation of 0.20 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 2.97 meters, to the mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

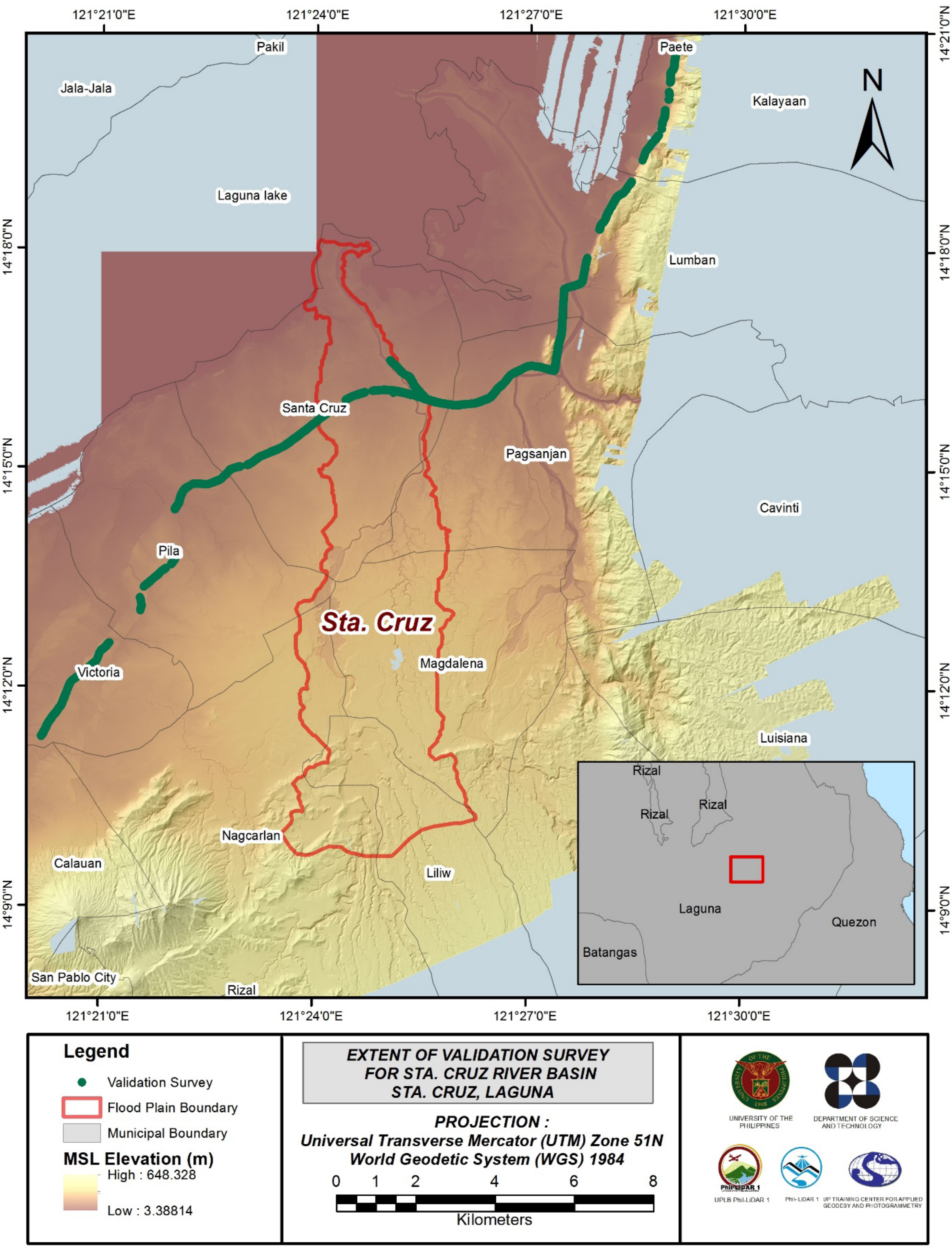

Figure 23. Map of Sta. Cruz Floodplain with validation survey points in green

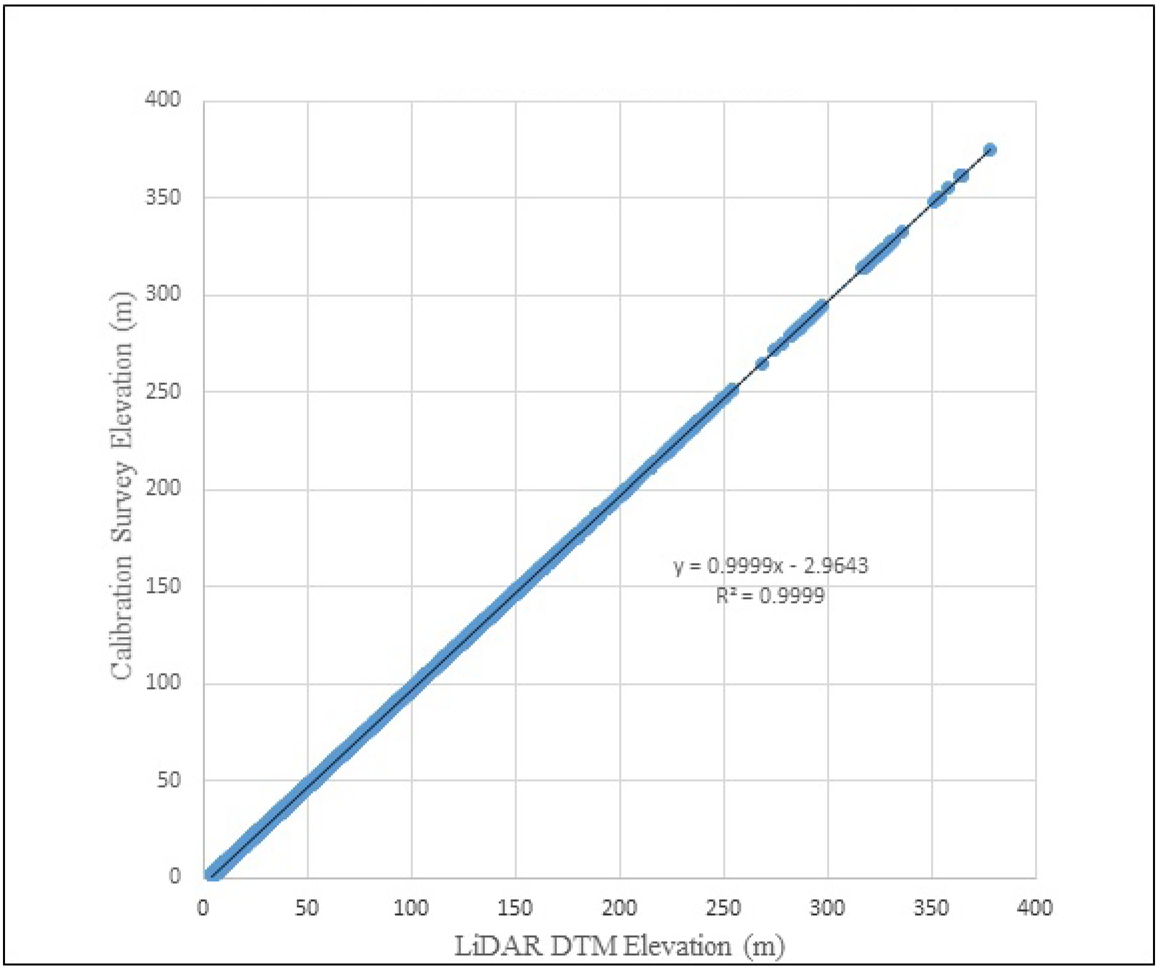

Figure 24. Correlation plot between calibration survey points and LiDAR data

Table 15. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.97
Standard Deviation	0.20
Average	-2.97
Minimum	-3.48
Maximum	-2.40

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 58 points, were used for the validation of calibrated Sta Cruz DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.14 meters with a standard deviation of 0.05 meters, as shown in Table 16.

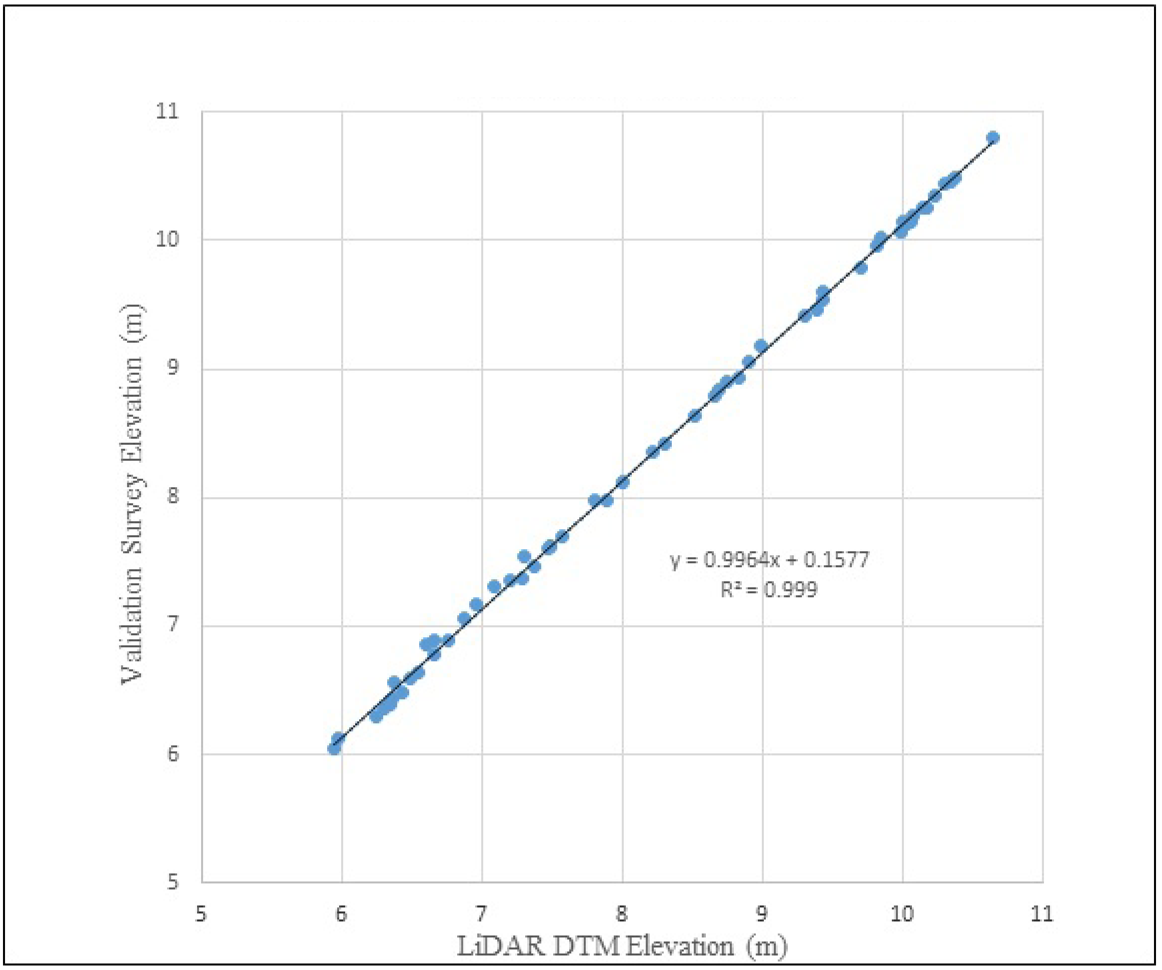

Figure 25. Correlation plot between validation survey points and LiDAR data

Table 16. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.14
Standard Deviation	0.05
Average	0.13
Minimum	0.04
Maximum	0.26

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Sta. Cruz with 2,192 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface was represented by the computed RMSE value of 0.44 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sta. Cruz integrated with the processed LiDAR DEM is shown in Figure 26.

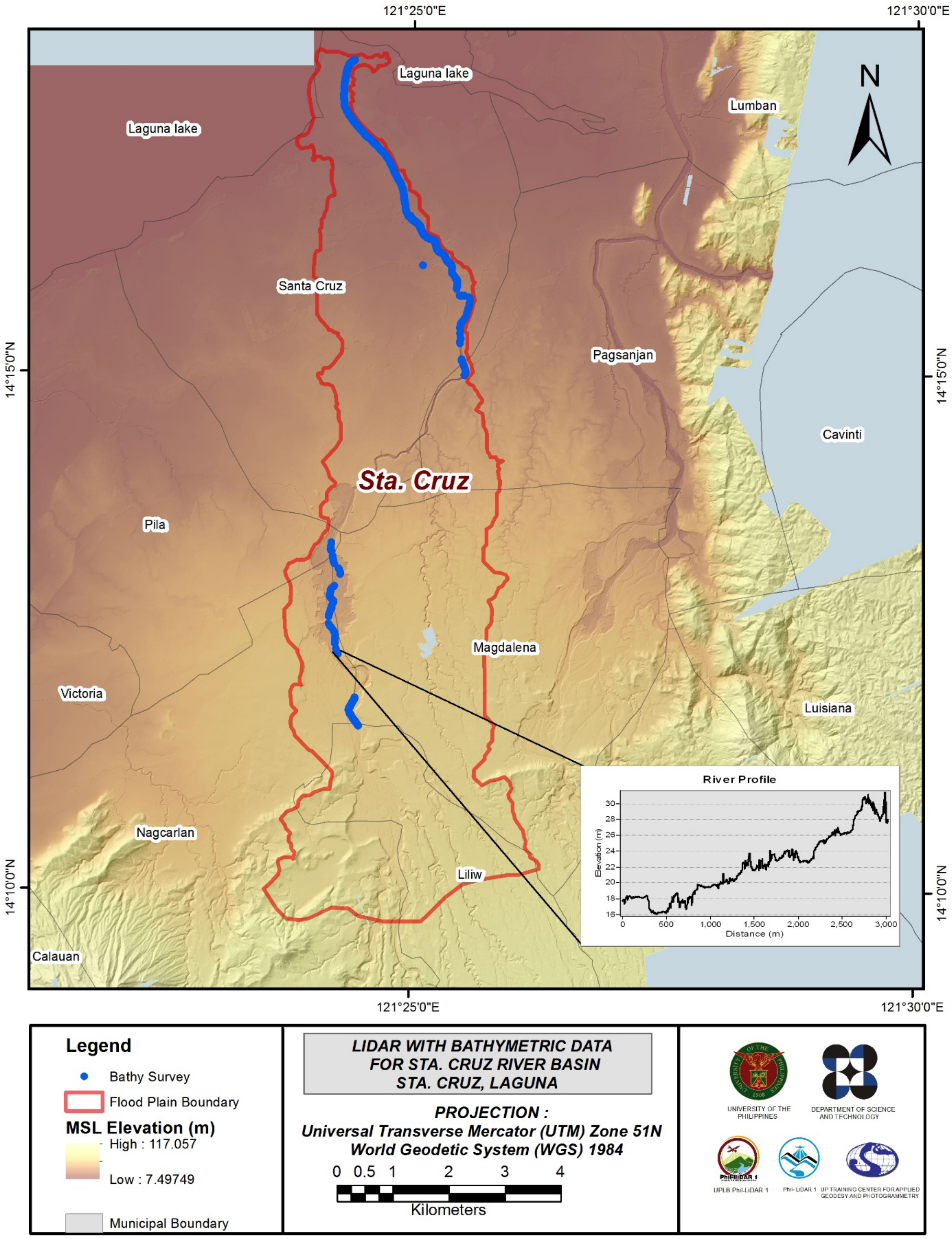

Figure 26. Map of Sta. Cruz Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS IN THE STA. CRUZ RIVER BASIN

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

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

4.1 Summary of Activities

The DVBC conducted field survey in Sta. Cruz River on September 2 to 6, 2014 in partnership with the University of The Philippines Los Baños. The survey covered the bathymetry and ground validation of the river. The bathymetry survey was conducted using an echo sounder to determine the depth of the river while a Trimble® SPS 882 rover GPS gathered the coordinates and elevation values of the survey points.

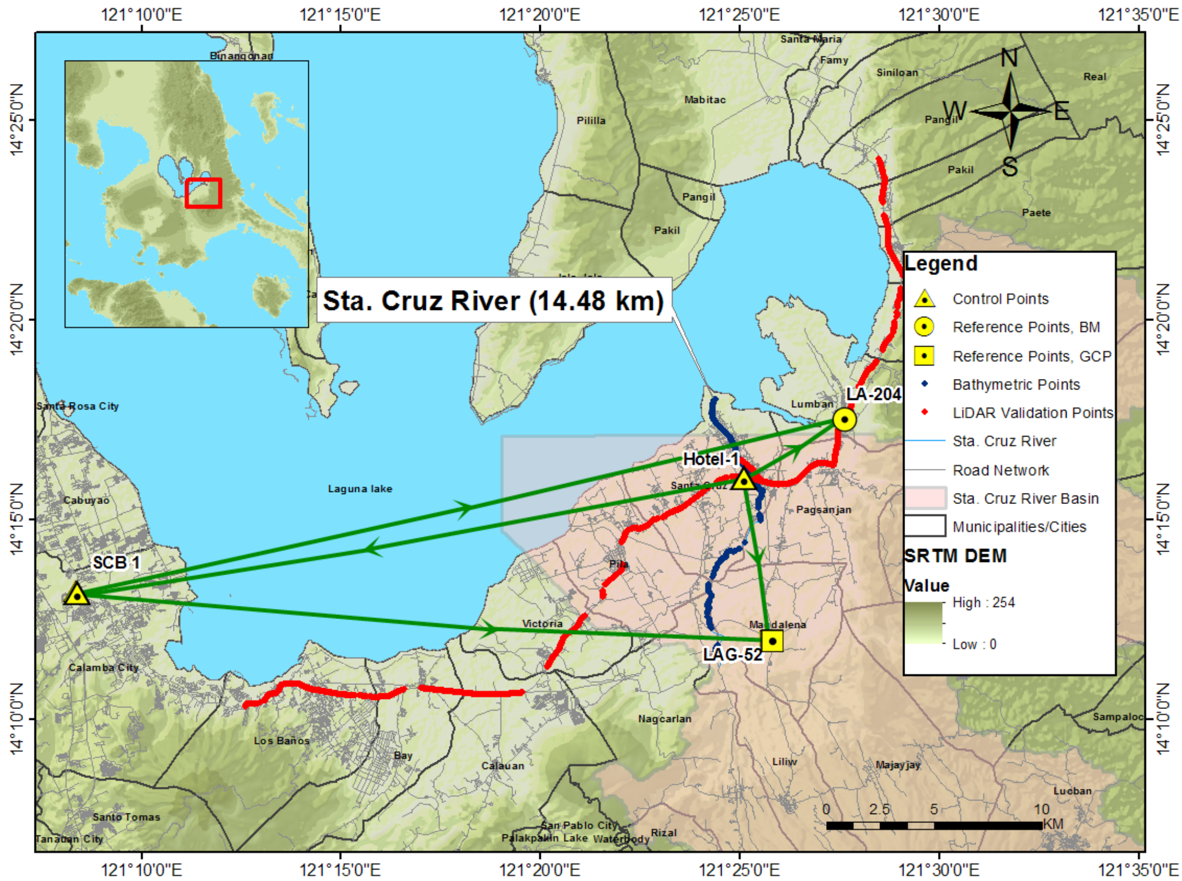

Figure 27. Extent of the bathymetric survey (in blue) in Sta. Cruz River and the LiDAR validation survey (in red)

4.2 Control Survey

The GNSS network used for Sta. Cruz Survey is composed of two loops established on Sept 2, 2014 occupying the following reference points: LAG-52, second-order GCP located in Brgy. Poblacion, Municipality of Magdalena, Laguna; and LA-204, first-order BM located in Brgy. Balubad, Municipality of Lumban, Laguna.

A control point was established on the approach of San Cristobal Bridge, UP-SCB-1, in Brgy. Paciano Rizal, Calamba City, Laguna; and RB-1, on top of a hotel in Brgy. Patimbao, Municipality of Sta. Cruz Laguna, to be used as marker.

The summary of control points used is found in Table 21, while the GNNS network established is illustrated in Figure 30.

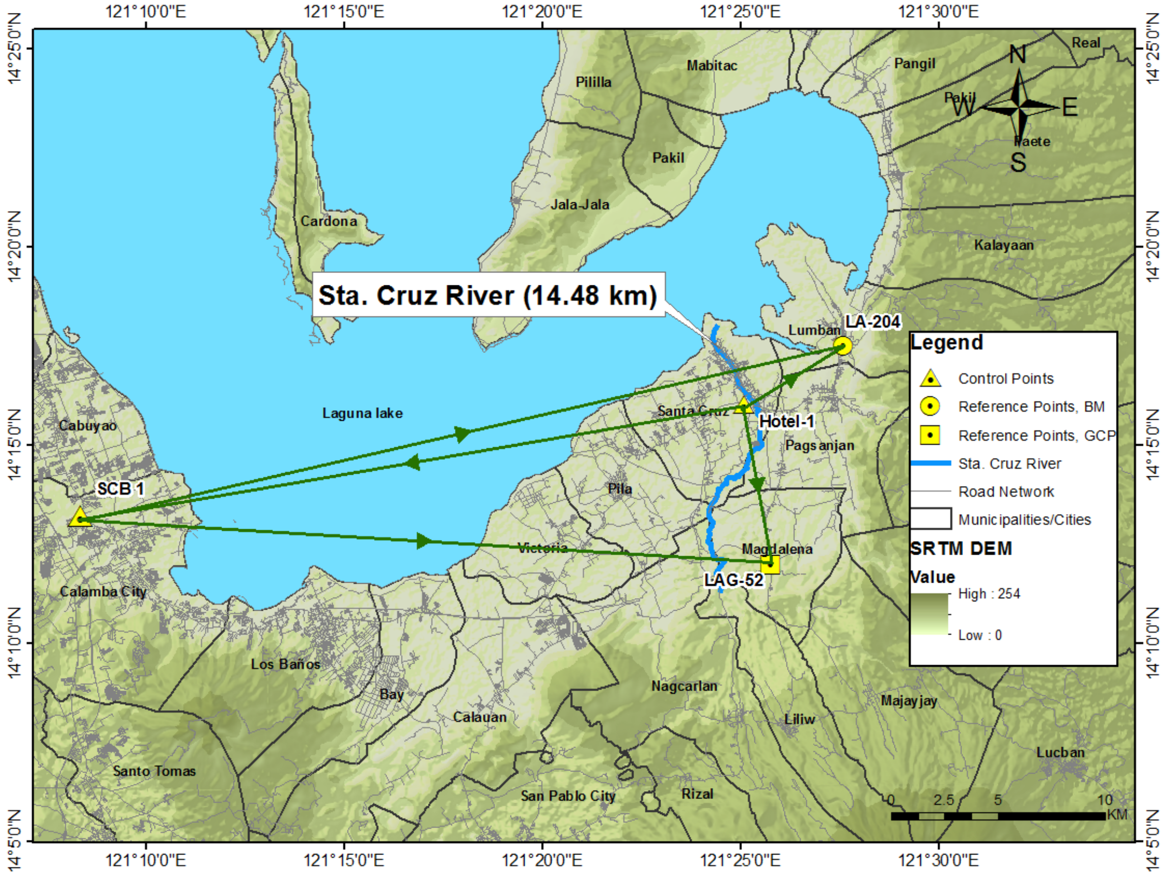

Figure 28. GNSS network of Sta. Cruz River field survey

Table 17. List of references and control points used in Sta. Cruz 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	-	-	-	-	Sept 2, 2014
UP SCB-1	UP Established	-	-	-	-	2007

The GNSS set-ups in reference points used in the survey are exhibited in Figure 30 to Figure 33.

Figure 29. GNSS receiver set-up, Trimble® SPS 985 at LAG-52 in the Municipality of Magdalena, Laguna

Figure 30. GNSS receiver set-up, Trimble® SPS 882 at LA-204 in the Municipality of Lumban, Laguna

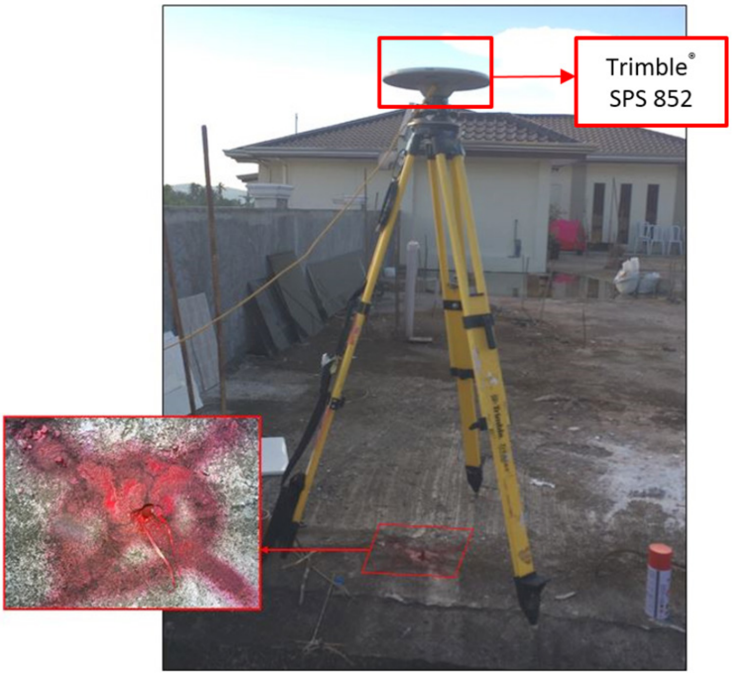

Figure 31. GNSS base receiver set-up, Trimble® SPS 852 at RB-1, located at the roof top of Asia Blooms Hotel, Brgy. Patimbao, Sta. Cruz, Laguna

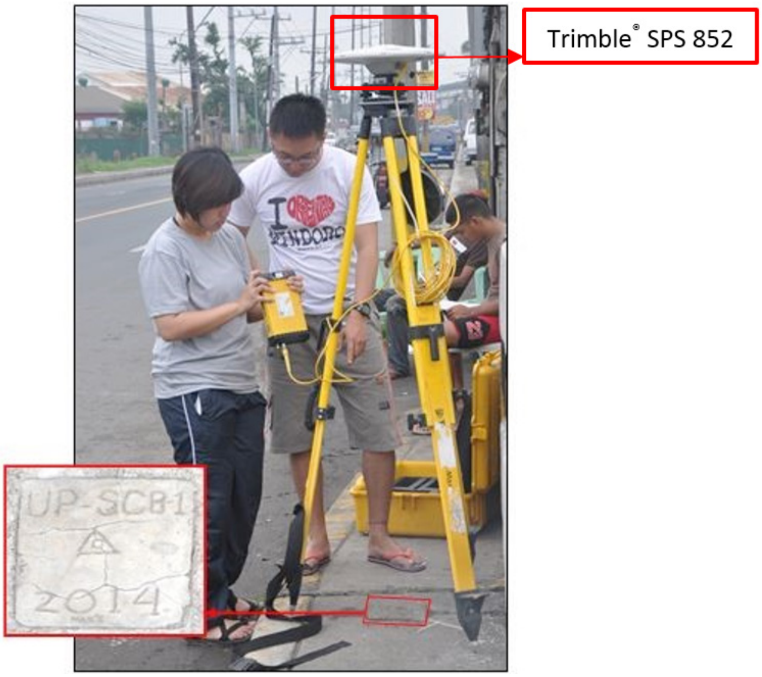

Figure 32. GNSS base receiver set-up, Trimble® SPS 852 at UP-SCB-1, San Cristobal Bridge in Calamba City, Laguna

4.3 Baseline Processing

GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Sta. Cruz River Basin is summarized in Table 22 generated by TBC software.

Table 18. Baseline processing report for Sta. Cruz River static survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
UP-SCB --- LA-204	9-2-14	Fixed	0.006	0.022	77°03’30”	35520.745	-10.879
UP-SCB --- RB-1	9-2-14	Fixed	0.002	0.008	260°12’22”	30546.000	5.472
RB-1 --- LA-204	9-2-14	Fixed	0.005	0.017	59°01’24”	5280.226	-5.355
UP-SCB --- LAG-52	9-2-14	Fixed	0.012	0.053	274°09’49”	31395.596	-44.499
RB-1 --- LAG-52	9-2-14	Fixed	0.006	0.028	170°47’21”	7571.511	49.751
RB-1 --- UP-SCB	9-2-14	Fixed	0.006	0.034	260°12’22”	30546.038	5-284

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 cm and z less than 10 cm or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for the complete details.

Table 19. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LA-204	Grid				Fixed
LAG-52	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The four (4) control points, LA-204, LAG-52, RB-1, and UP-SCB, were occupied and observed simultaneously to form a GNSS loop. Coordinates of LAG-52 and elevation of LA-204 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 20. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LA-204	333915.290	0.028	1580563.904	0.022	8.564	?	e
LAG-52	330531.105	?	1570395.630	?	63.727	0.150	LL
RB-1	329369.956	0.023	1577877.257	0.019	14.109	0.065	
UP-SCB	299233.666	0.025	1572885.788	0.020	20.595	0.068	

The network is fixed at NAMRIA reference points LAG-52 and LA-204 for grid and elevation, respectively. With the mentioned equation, for horizontal and for the vertical, the computations for the accuracy for the horizontal and vertical accuracy are as follows:

LAG-52
Horizontal accuracy = fixed
Vertical accuracy = 1.5 cm < 10 cm

LA-204
Horizontal accuracy = √((2.8)² + (2.2)²
= √(7.84 + 4.84)
= 3.56 cm < 20 cm
Vertical accuracy = fixed

UP-SCB-1
horizontal accuracy = √((2.5)² + (2.0)²
= √(6.25 + 4.0)
= 3.20 cm < 20 cm
vertical accuracy = 6.8 cm < 10 cm

RB-1

horizontal accuracy $= \sqrt{((2.3)^2 + (1.9)^2}$
$= \sqrt{(5.29 + 3.61)}$
$= 2.98\ cm < 20\ cm$

vertical accuracy $= 6.5\ cm < 10\ cm$

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

Table 21. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
LA-204	N14°17'30.95410"	E121°27'36.89050"	54.504	?	e
LAG-52	N14°11'59.35842"	E121°25'46.26158"	109.637	0.150	LL
RB-1	N14°16'02.54128"	E121°25'05.84019"	59.879	0.065	
UP-SCB	N14°13'12.89108"	E121°08'21.83033"	65.355	0.068	

Corresponding geodetic coordinates of LA-204 RB-1 and UP-SCB which were derived from LAG-52 are within the required accuracy as shown in Table 26. Based on the result of the computation, the accuracy condition is satisfied, hence the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 22. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
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

4.5 Bridge Cross-section and As-built Survey, and Water Level Marking

<no content?>

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 5, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 35. It was secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of notch of the GNSS Rover receiver. The antenna's height is 2.12 meters from the ground. The activity started from the Municipality of Calamba to Pangil in Laguna.

Figure 33. Validation points acquisition set-up for Sta. Cruz River Basin

A total of 5,108 ground validation points were acquired with an approximate length of 47.5 km using Hotel-1 as the GNSS base station, as shown in the map in Figure 36.

Figure 34. Validation points acquisition survey covering the length of Sta, Cruz River Basin

4.7 River Bathymetric Survey

Bathymetric survey of Sta. Cruz River was conducted on September 3, 2014 using a GNSS Rover receiver, Trimble® SPS 882 in PPK survey technique mounted on top of a pole with Ohmex™ single-beam echo sounder below and submerged on water and attached to a boat as shown in Figure 37. The survey started in the upstream in Brgy. Palasan with coordinates 14°14’58.80610” 121°25’30.99189” down to the mouth of the river in Laguna Lake with coordinates 14°18’00.40324” 121°24’23.33698”. The control point RB-1 was used as the base station.

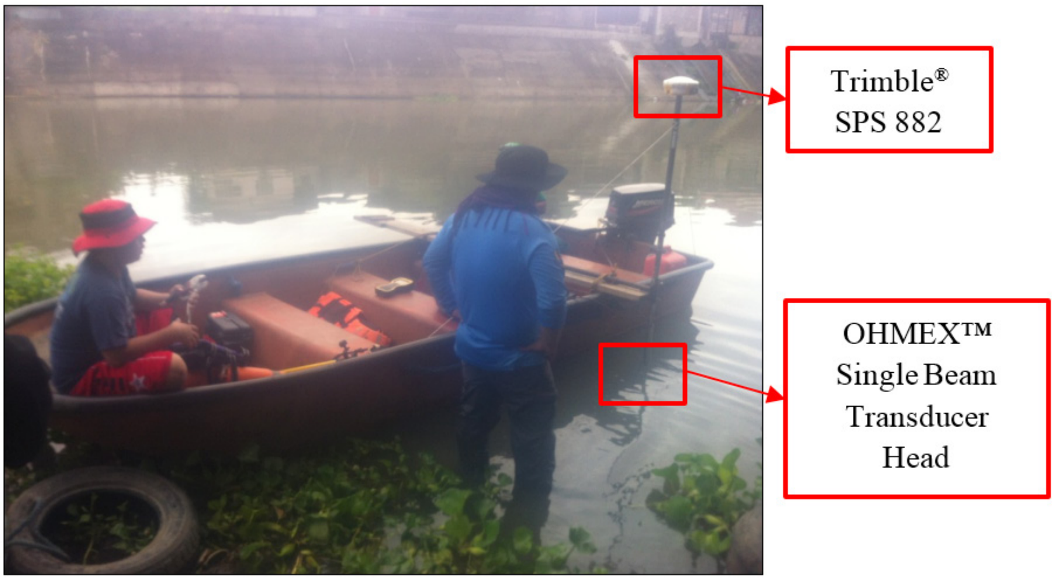

Figure 35. Bathymetric survey with echo sounder in Sta, Cruz River

On September 4–5, 2015, manual bathymetric survey was done on the shallow parts of the river using a GNSS Rover receiver, Trimble® SPS 882 in PPK survey technique mounted on top of a pole and measured the bathymetric points by foot as shown in Figure 38. The survey started in the upstream in Brgy. Mojon, Municipality of Liliw with coordinates 14°11'35.29203" 121°24'28.98574", traversed down the river and ended in Brgy. Mojo, Municipality of Pila with coordinates 14°13'21.58337" 121°24'12.64197". RB-01 was used as the GNSS base station all throughout the survey.

Figure 36. Manual Bathymetric survey in Sta. Cruz River

A total of 2,638 bathymetric points were acquired with an approximate length of 2.81 km as illustrated in the map in Figure 39. A CAD drawing was also produced to illustrate the Sta. Cruz Riverbed profile from Brgy. Halayhayin down to Brgy. Pagsawitan as shown in Figure 40. An elevation drop of 42.65 meters with respect to MSL was observed within the approximated distance of 14.48 kilometers. A 3-km gap was not surveyed due to absence of satellite signal in the area.

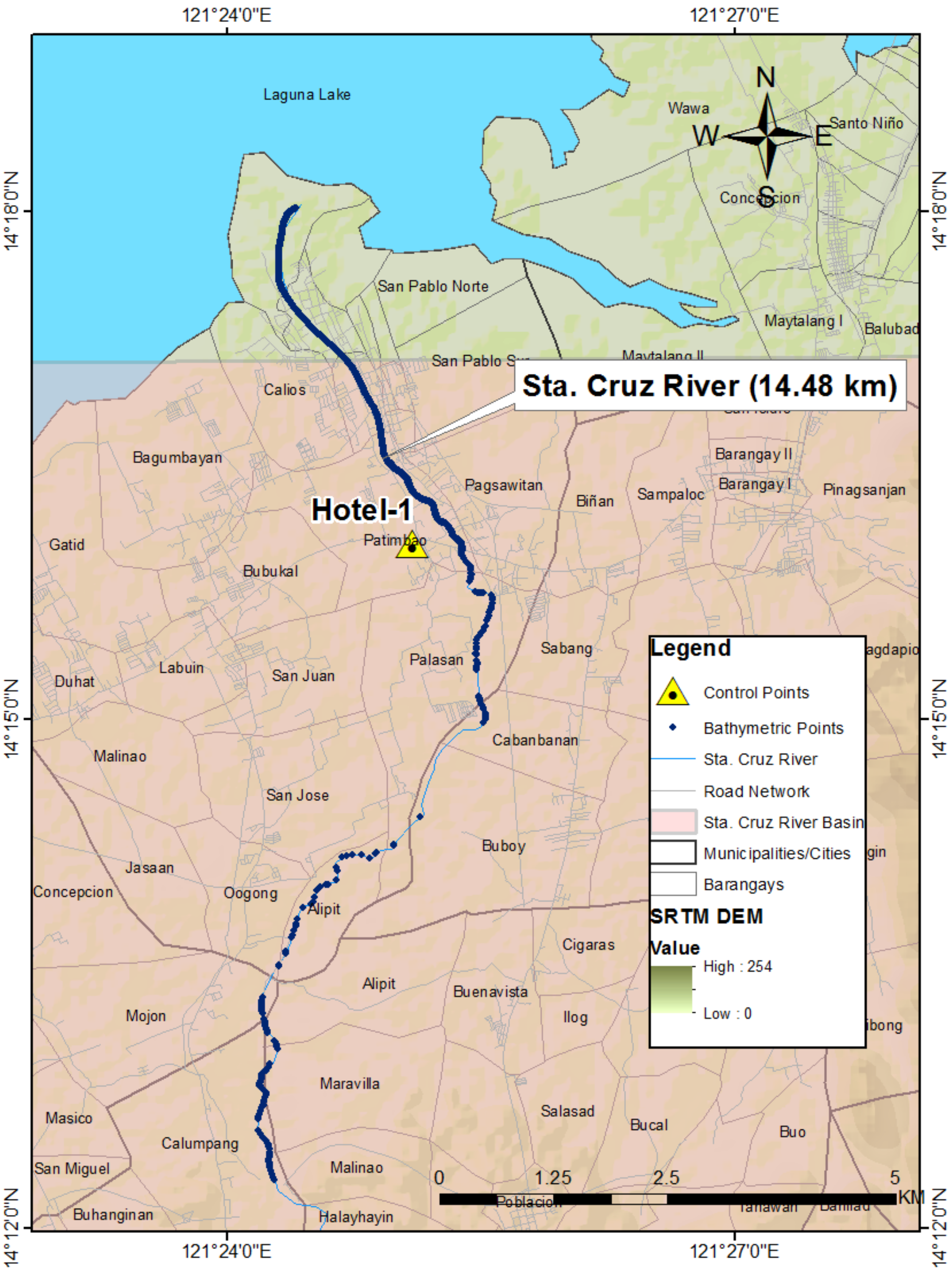

Figure 37. Bathymetric survey coverage of Sta. Cruz River

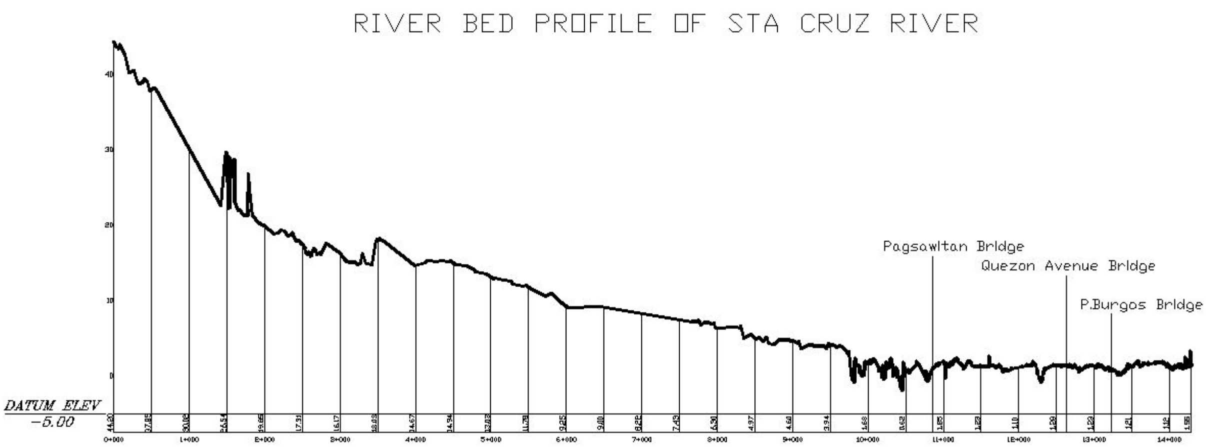

Figure 38. Riverbed profile of Sta. Cruz River

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Khristoffer Quinton, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, Raphael P. Gonzales, and 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

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

5.1.2 Precipitation

Precipitation data was taken from four Automatic Rain Gauge (ARG) Stations and one portable rain gauge. The ARGs were installed on Brgy. Bubukal (14.251435°N, 121.402060°E), Cavinti (14.246850°N, 121.500390°E), Magdalena (14.80002°N, 121.4464006°E), Majayjay (14.115120°N, 121.503550°E), and Rizal (14.111040°N, 121.391240°E). The location of the rain gauges is seen in Figure 41.

The total precipitation for each rain gauge is as follows: 3.8 mm for Brgy.Bubukal ARG, 2.2 mm for Cavinti ARG, 7.0 mm for Majayjay ARG, 18.0 mm for Magdalena RG, and 4.60 mm for Rizal ARG. The peak rainfall is as follows: 3.6 mm on December 14, 2015 at 4:00 pm for Brgy. Bubukal ARG, 0.6 mm on December 14, 2015 at 10:45 pm for Cavinti ARG, 48.0 mm on December 14, 2015 at 15:30 pm for Magdalena RG, 3.6 mm on December 14, 2015 at 11:45 pm for Majayjay ARG, and 0.80 mm on December 14, 2015 at 11:00 pm for Rizal ARG.

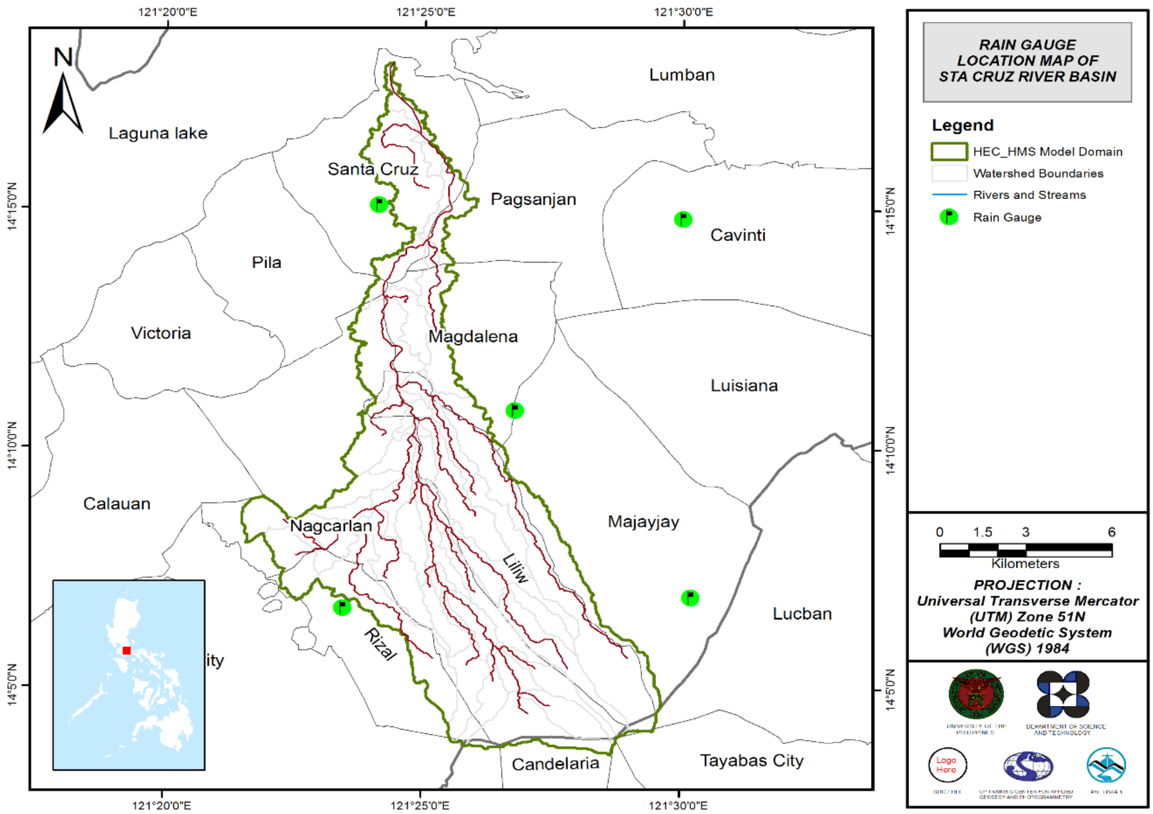

Figure 39. Location map of Sta. Cruz HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sta. Cruz Bridge, Sta. Cruz, Laguna (14.280481° N, 121.414543° E) using actual event flow data gathered. It gives the relationship between the observed change in water and the outflow of the watershed at this location.

For Pagsawitan Bridge, the rating curve is expressed as Q = 129.29x -6494.30 as shown in Figure 43.

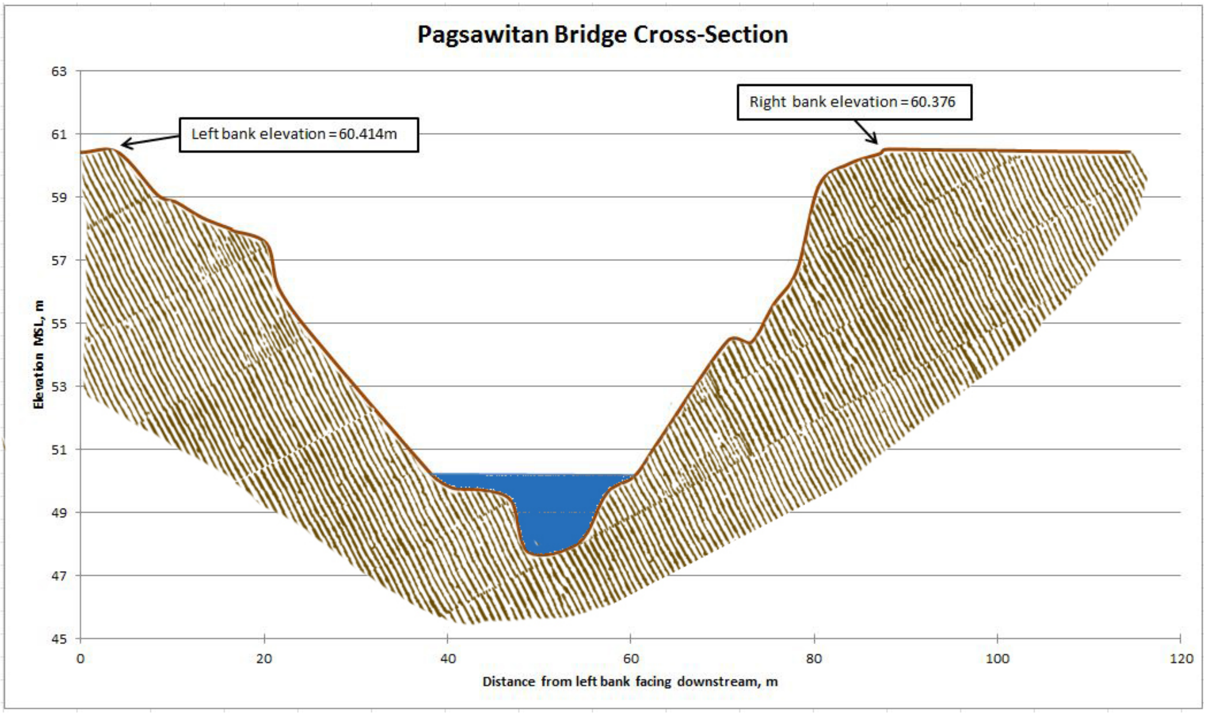

Figure 40. Cross-section plot of Pagsawitan Bridge

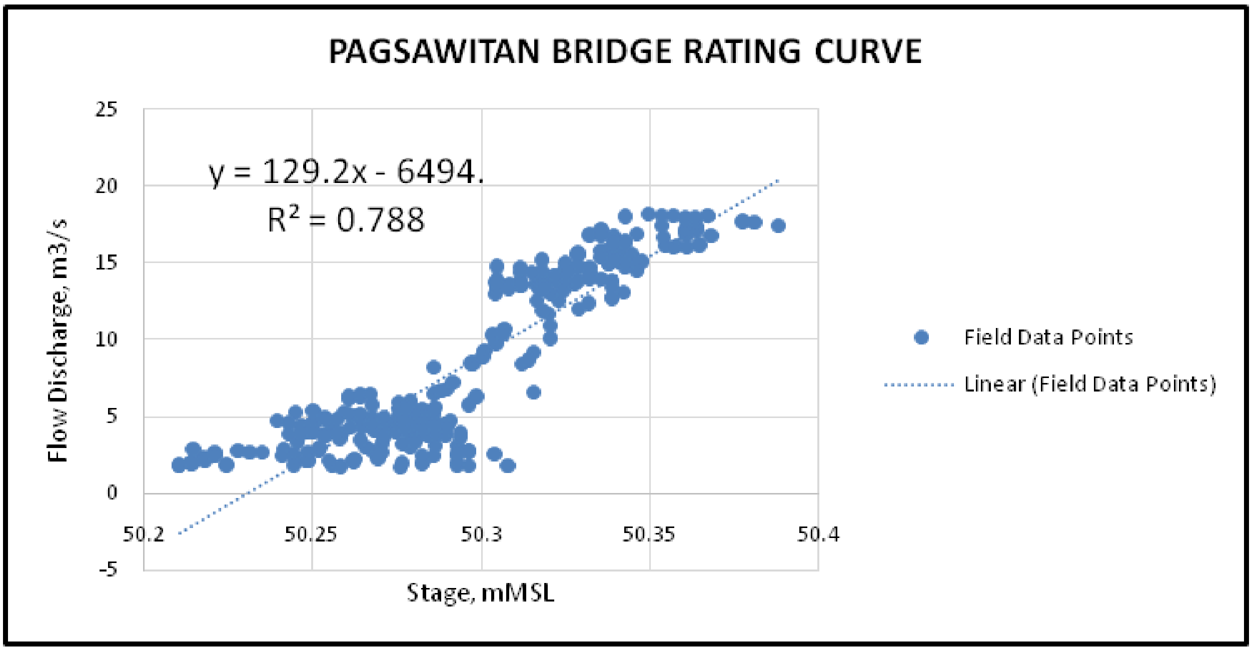

Figure 41. Rating Curve at Pagsawitan Bridge, Laguna

For the calibration of the HEC-HMS model, shown in Figure 44, actual flow discharge during a rainfall event was collected in the Pagsawitan Bridge. Peak discharge is 18.17 m^3/s on December 14, 2015 at 11:40 pm.

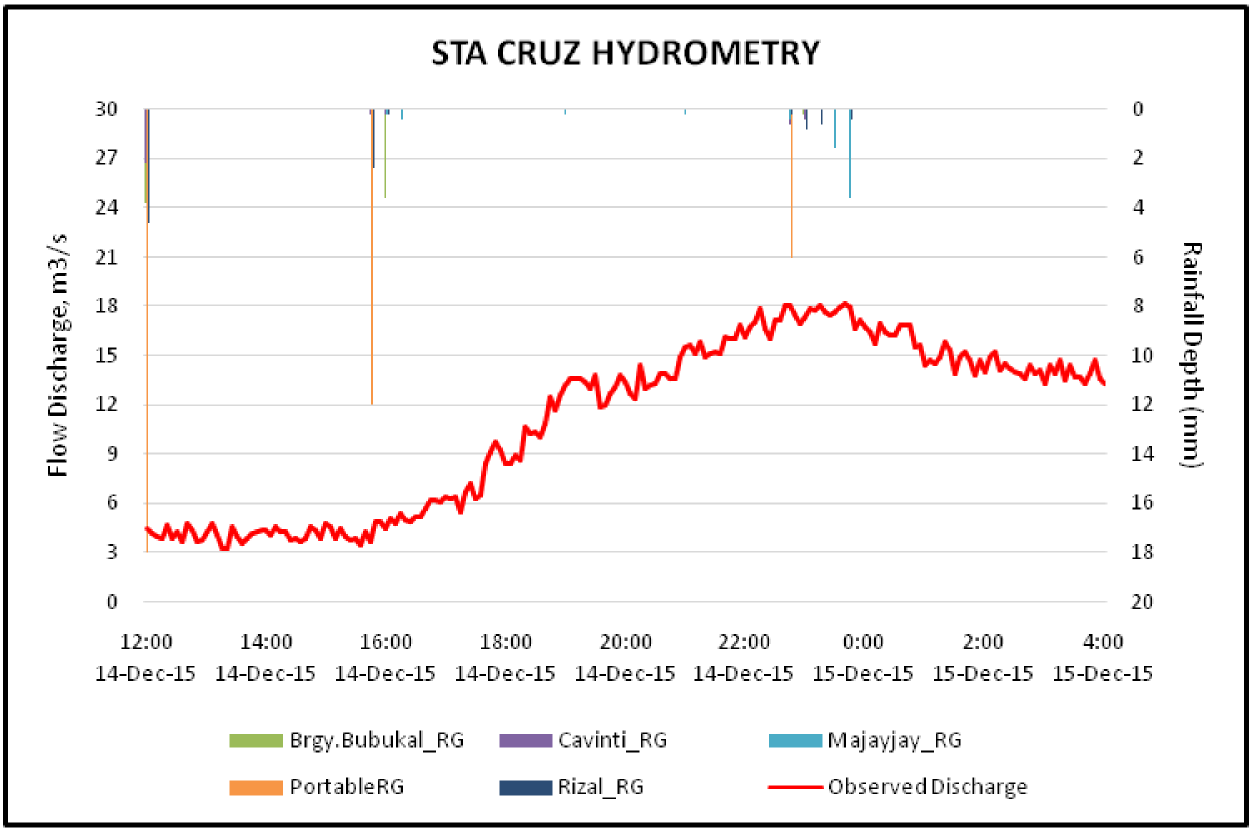

Figure 42. Rainfall and outflow data at Sta. Cruz used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Tayabas Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Sta. Cruz watershed. The extreme values for this watershed were computed based on a 41-year record.

Table 23. RIDF values for 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

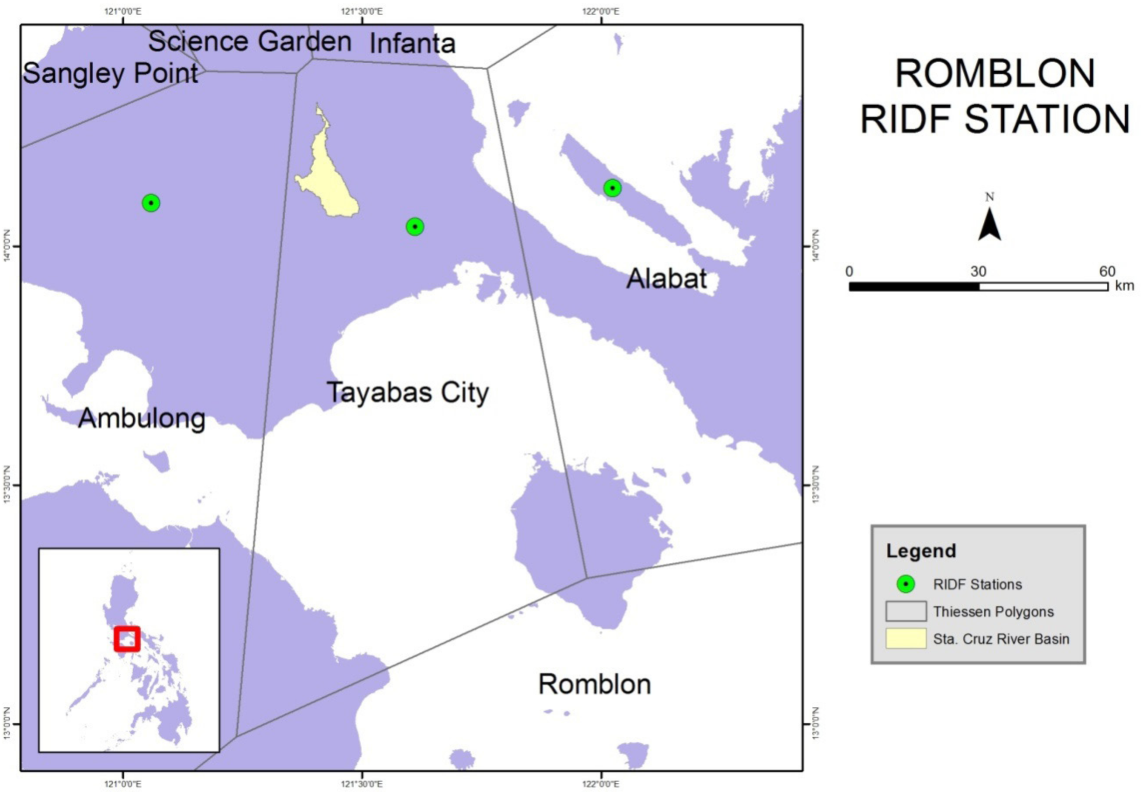

Figure 43. Location of Tayabas RIDF Station relative to Sta. Cruz River Basin

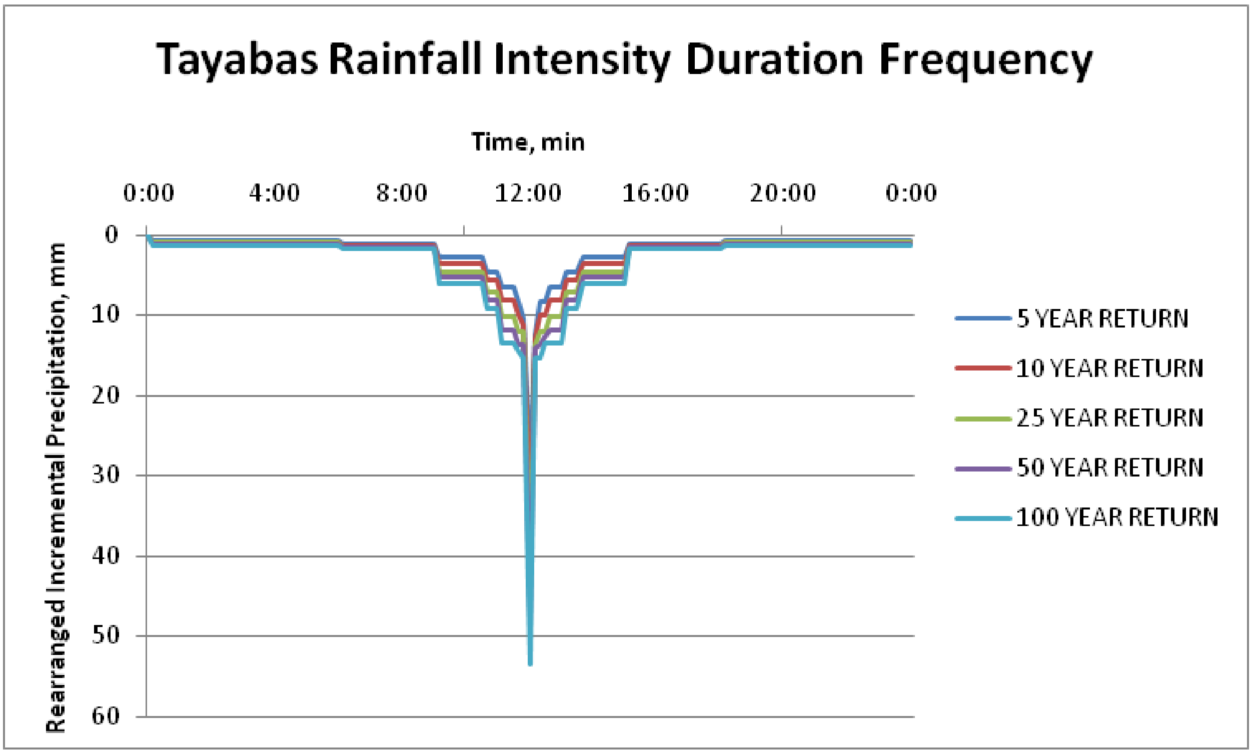

Figure 44. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset was taken from the National Mapping and Resource Information Authority (NAMRIA).

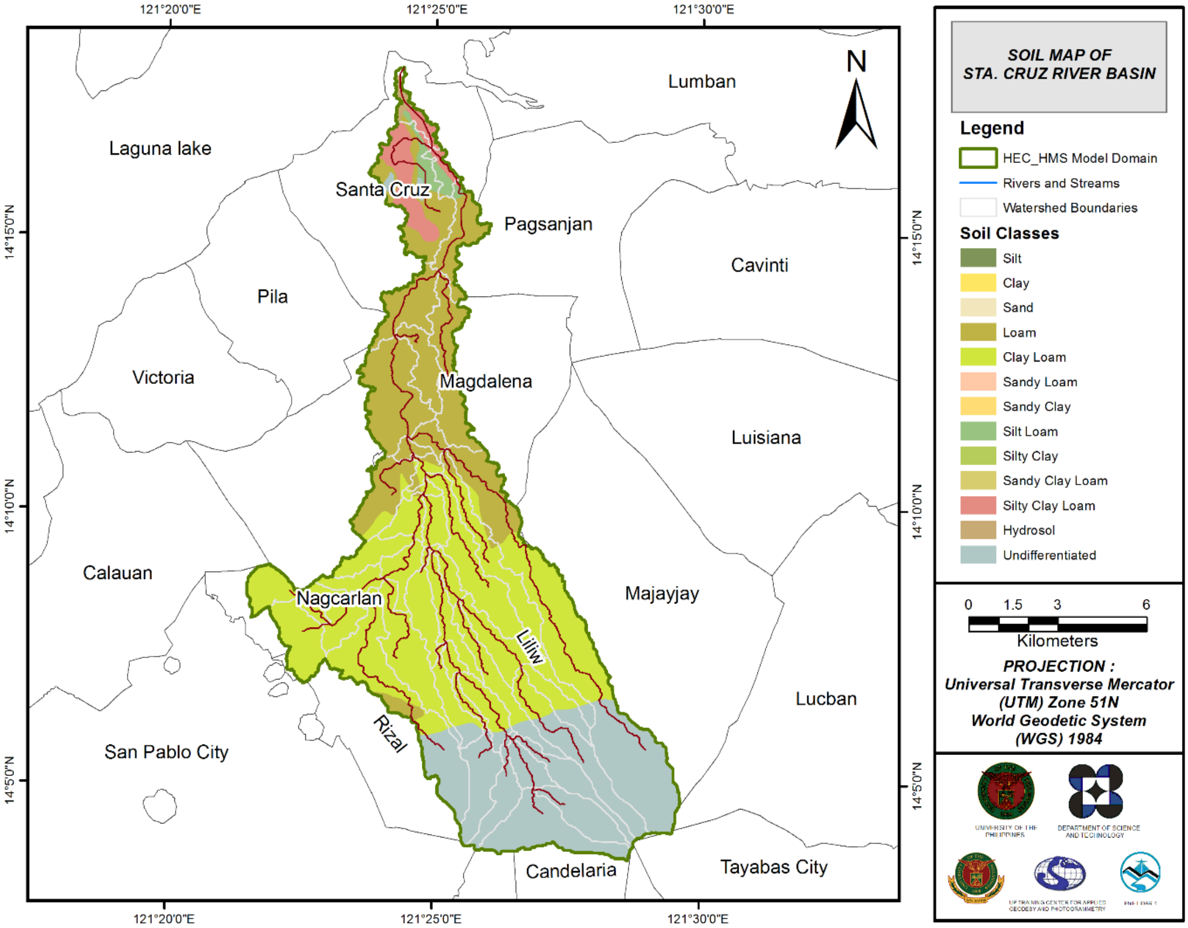

Figure 45. Soil map of the Sta. Cruz River Basin used for the estimation of the CN parameter (Source: DA-BSWM)

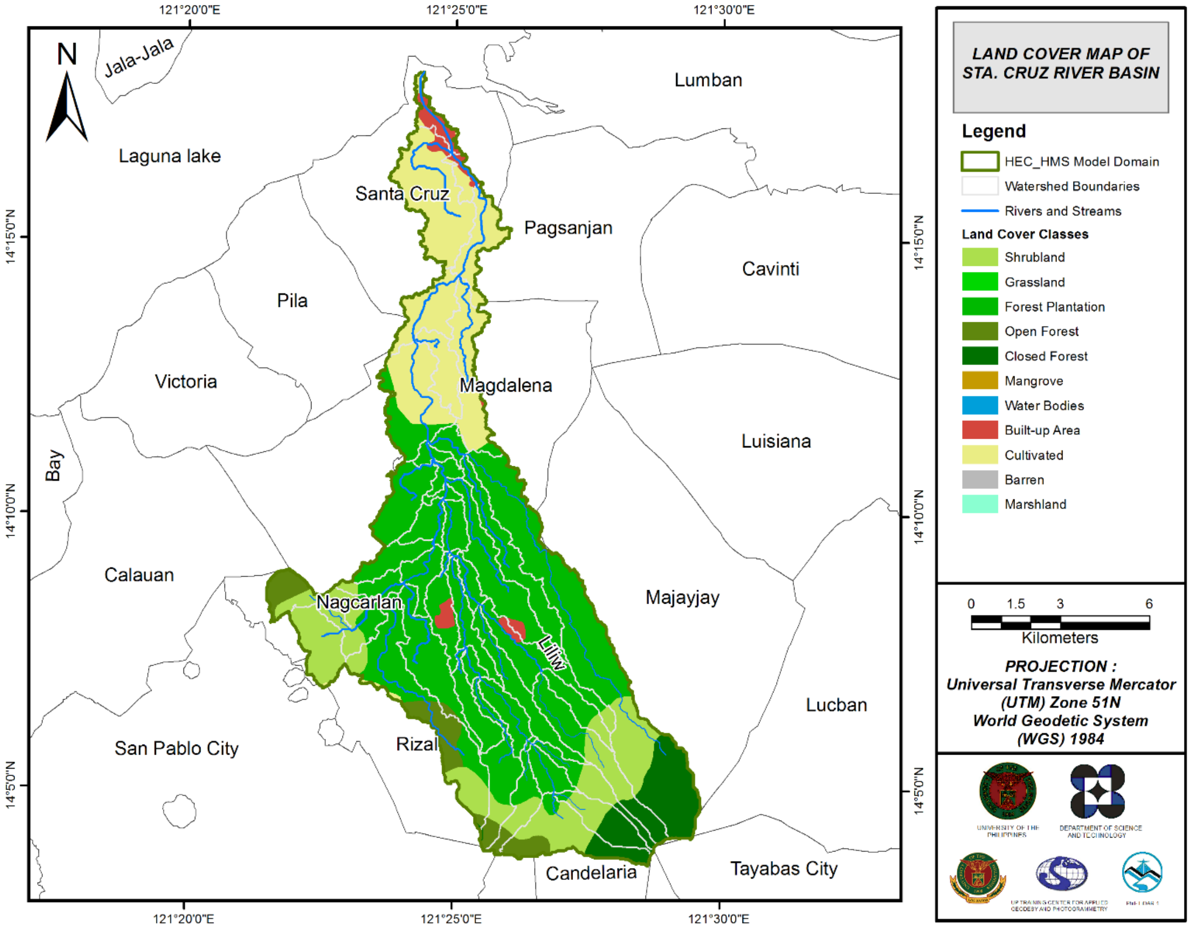

Figure 46. Land cover map of the Sta. Cruz River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model (Source: NAMRIA)

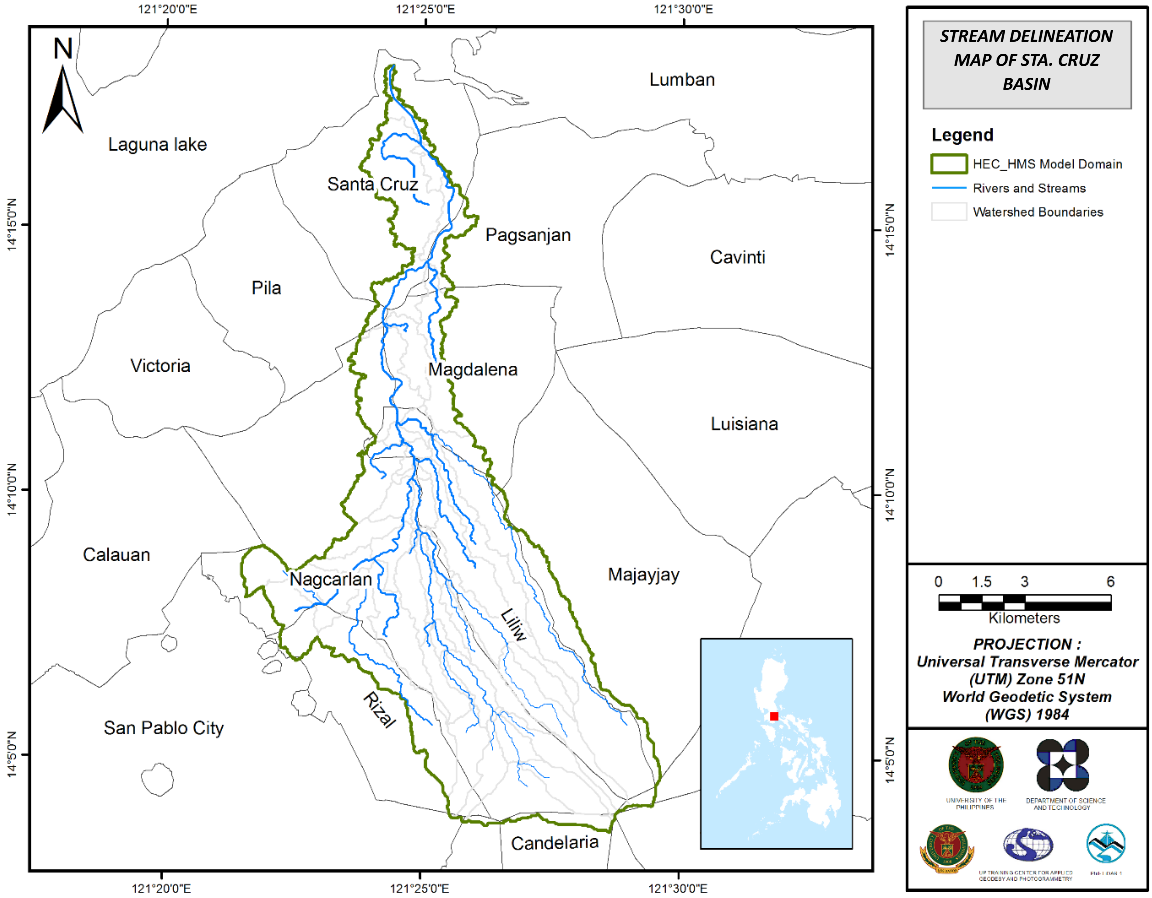

Figure 47. Stream delineation map of the Sta. Cruz River Basin

Using SAR-based DEM, the Sta. Cruz Basin was delineated and further subdivided into subbasins. The model consists of 43 subbasins, 43 reaches, and 22 junctions. The main outlet is labeled as 140. The main outlet is at Sta. Cruz Bridge.

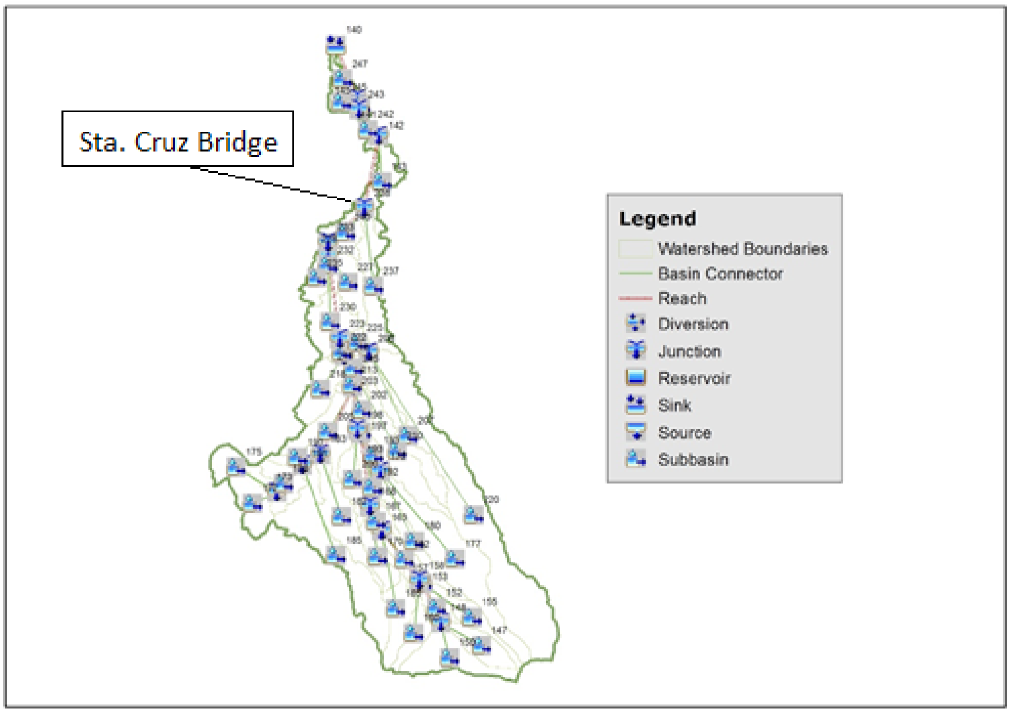

Figure 48. Sta. Cruz River Basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS.

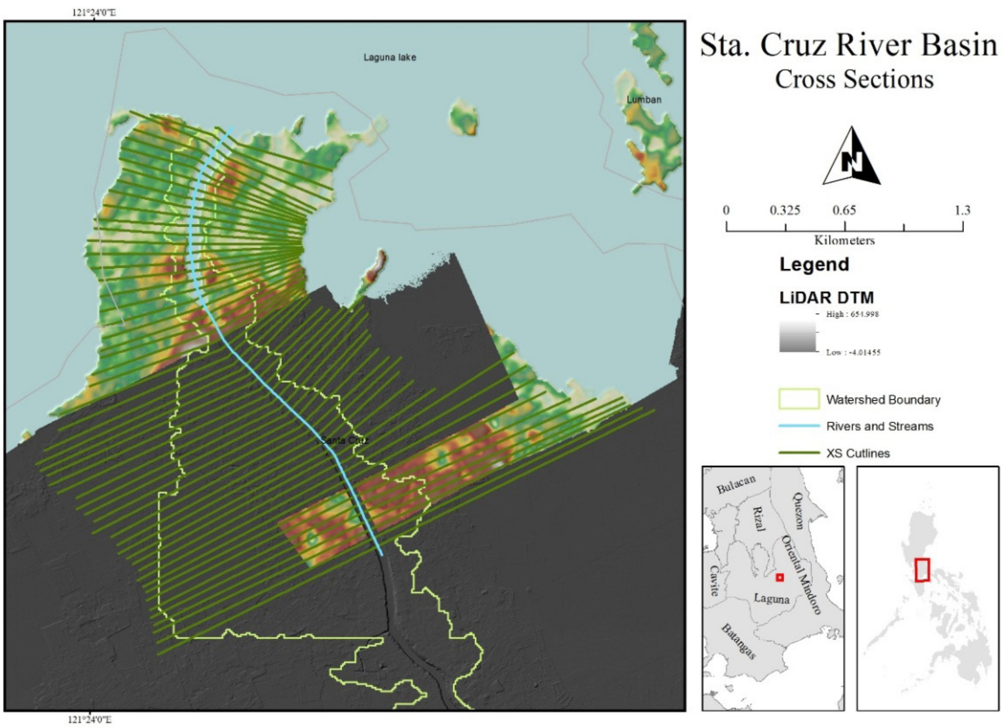

Figure 49. River cross-section of Sta. Cruz River generated through Arcmap HEC GeoRAS tool

5.5 FLO-2D Model

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

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

Figure 50. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

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

The creation of a flood hazard map from the model also automatically created 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 cover a maximum land area of 23775100.00 m^2.

There is a total of 1,281,282,208.54 m^3 of water entering the model. Of this amount, 11,740,227.71 m^3 is due to rainfall while 1,269,541,980.84 m^3 is inflow from other areas outside the model. About 2,054,632.50 m^3 of this water is lost to infiltration and interception, while 160,542,688.39 m^3 is stored by the floodplain. The rest, amounting up to 1,120,082,869.77 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Sta. Cruz HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 53 shows the comparison between the two discharge data.

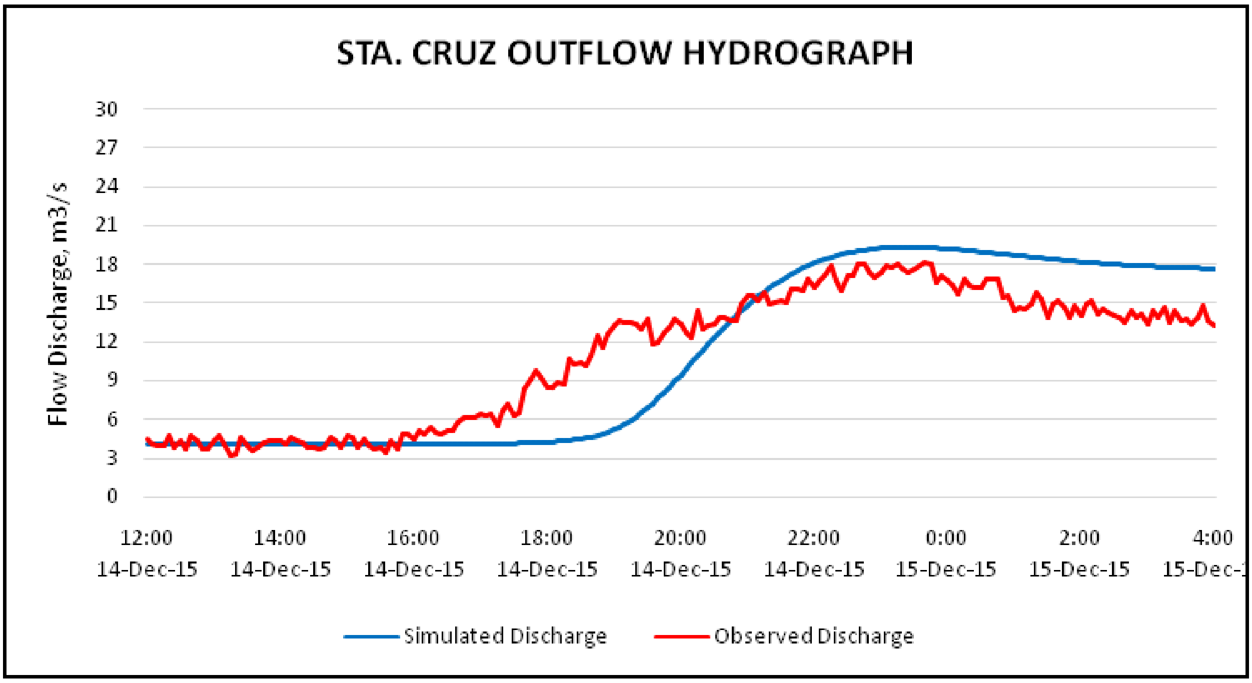

Figure 51. Outflow hydrograph of Sta. Cruz produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 24. Range of calibrated values for Sta. Cruz

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1 - 20
			Curve Number	41 - 73
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 6
			Storage Coefficient (hr)	0.4 - 9
	Baseflow	Recession	Recession Constant	0.07 -0.5
			Ratio to Peak	0.2 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.03

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 1 mm to 20 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 41 to 73 for curve number is lower than the advisable range for Philippine watersheds.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.3 hours to 9 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.07 to 0.5 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.2 to 0.5 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.03 is relatively low compared to the common roughness of watersheds (Brunner, 2010).

Table 25. Summary of the efficiency test of Sta. Cruz HMS Model

Root Mean Square Error (RMSE)	3.103
Pearson Correlation Coefficient (r^2)	0.899
Nash-Sutcliffe (E)	0.631
Percent Bias (PBIAS)	-0.206
Observation Standard Deviation Ratio (RSR)	0.608

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 3.103.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A value close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC-HMS model. Here, it measured 0.899.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here, the optimal value is 1. The model attained an efficiency coefficient of 0.631.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -0.206.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.608.

5.7 Calculated Outflow Hydrographs and Discharge Values for Different Rainfall Return Periods

5.7.1 Hydrograph Using the Rainfall Runoff Model

The summary graph (Figure 54) shows the Sta. Cruz outflow using the Tayabas RIDF curves in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

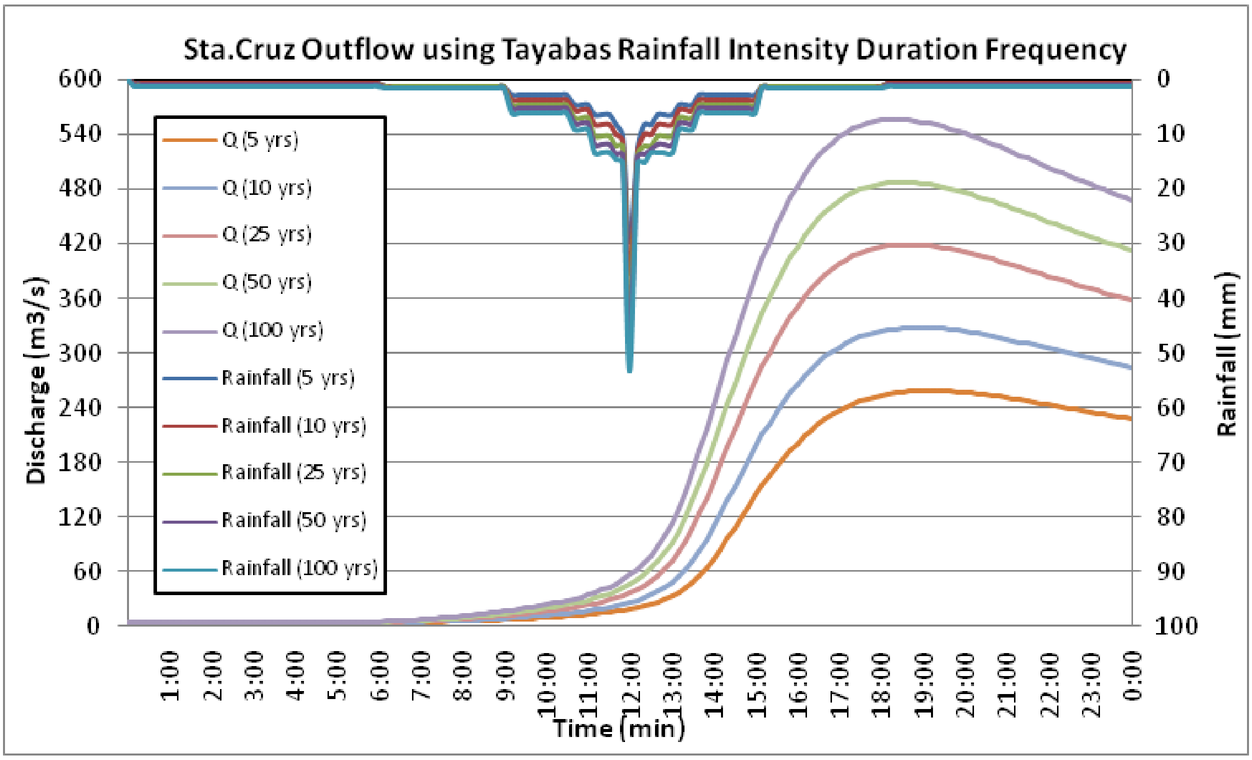

Figure 52. Outflow hydrograph at Sta. Cruz Station generated using Tayabas RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak, and lag time of the Sta. Cruz discharge using the Tayabas RIDF curves in five different return periods is shown in Table 30.

Table 26. Peak values of the Sta. Cruz HEC-HMS Model outflow using the Tayabas RIDF

RIDF PERIOD	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak
5-yr	279.50	29.60	258.637	7 hours 10 minutes
10-yr	334.90	35.40	327.951	6 hours 50 minutes
25-yr	404.80	42.60	418.731	6 hours 40 minutes
50-yr	456.70	48.0	487.468	6 hours 30 minutes
100-yr	508.30	53.40	556.380	6 hours 20 minutes

5.7.2 Discharge Data Using Dr. Horritt's Recommended Hydrologic Method

The river discharge values for the river entering the floodplain with the computed discharge are shown in Figure 55 and the peak values are summarized in Table 31.

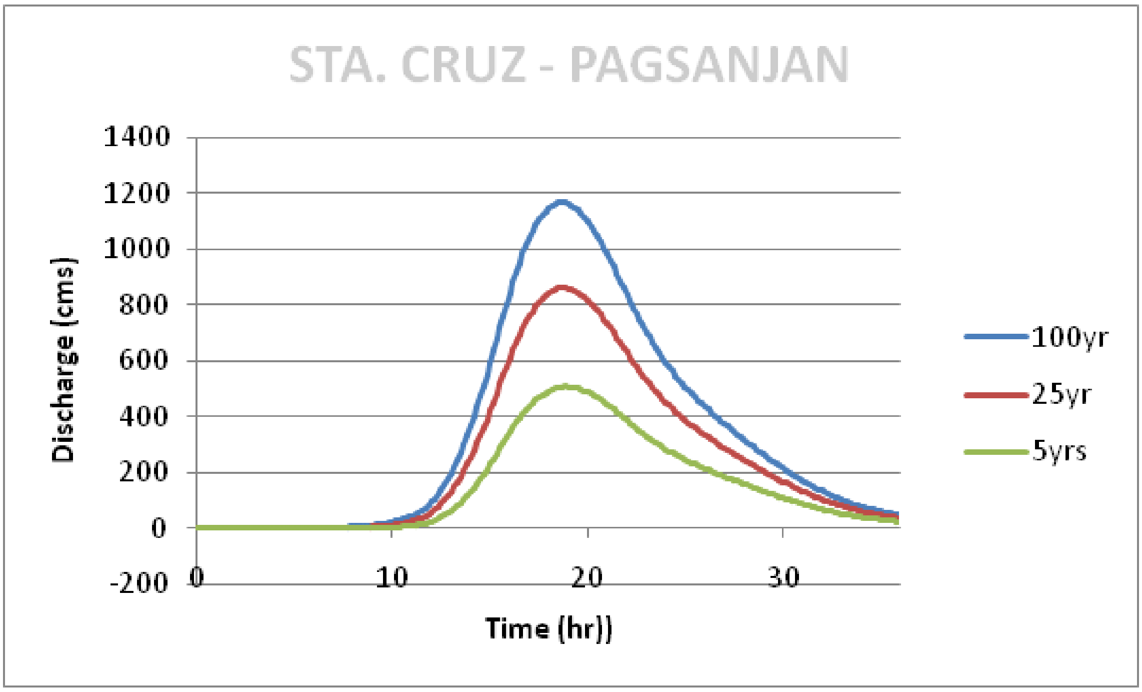

Figure 53. Sta. Cruz–Pagsanjan River generated discharge using 5-, 25-, and 100-year Tayabas City RIDF in HEC-HMS

Table 27. 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 28. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(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 using other discharge computation methods so they were good to use 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 for higher-accuracy modeling.

5.8 River Analysis Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Sta. Cruz River using the HMS base flow is shown on Figure 13 below.

Figure 54. Sta. Cruz HEC-RAS Output

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 100-, 25-, and 5-year rain return scenarios of the Sta. Cruz Floodplain are shown in Figure 57 to 62. The floodplain, with an area of 214.03 sq km, covers thirteen municipalities namely Calauan, Cavinti, Laguna Lake, Liliw, Luisiana, Lumban, Magdalena, Majayjay, Nagcarlan, Pagsanjan, Pila, Sta. Cruz, and Victoria. Table 33 shows the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in Sta. Cruz 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
Sta. Cruz	37.63	36.50	97
Victoria	28.37	24.44	86.17

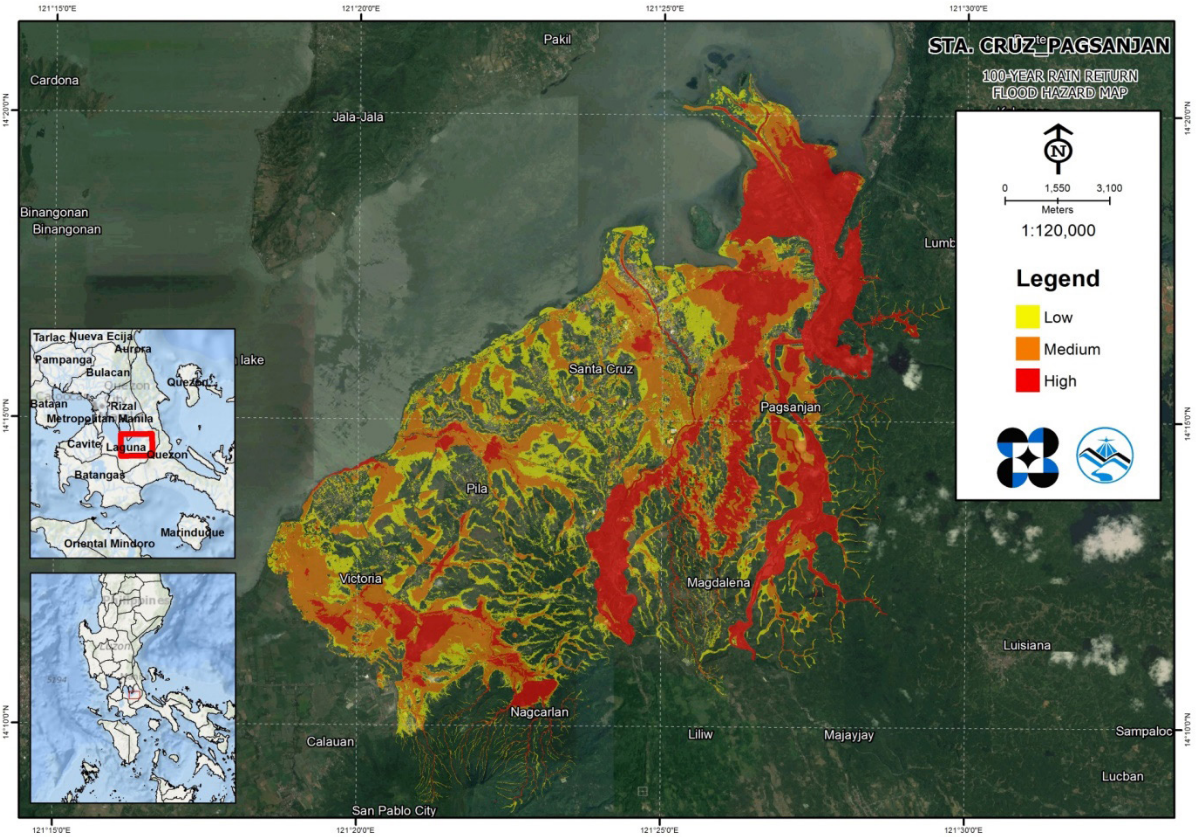

Figure 55. 100-year flood hazard map for Sta. Cruz Floodplain

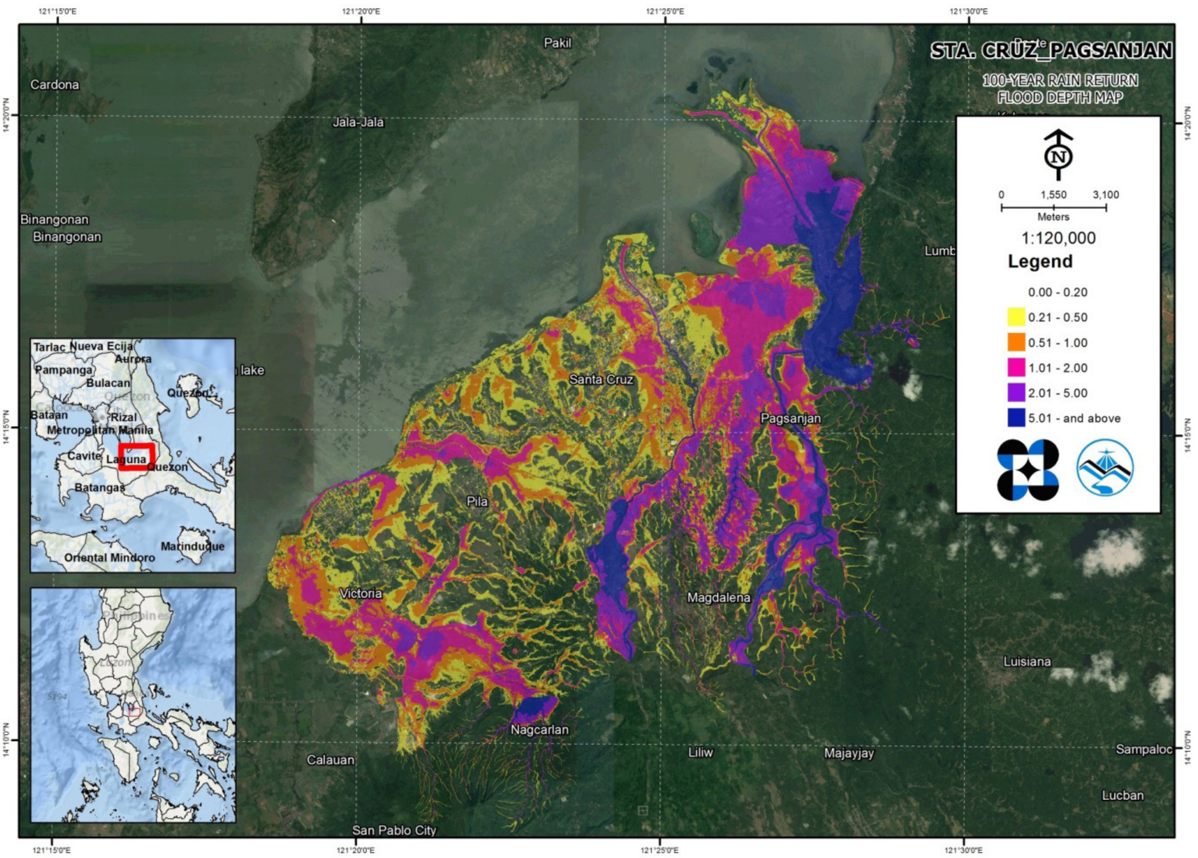

Figure 56. 100-year flow depth map for Sta. Cruz Floodplain

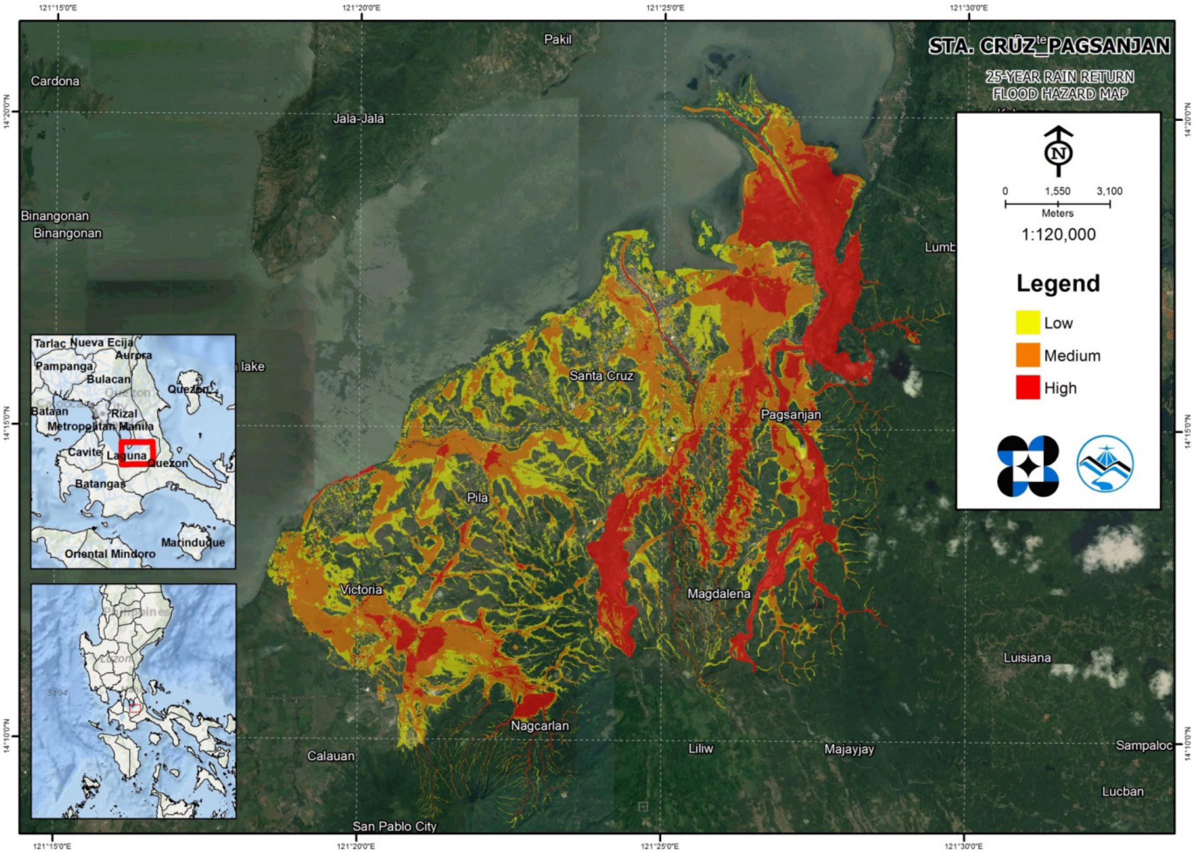

Figure 57. 25-year flood hazard map for Sta. Cruz Floodplain

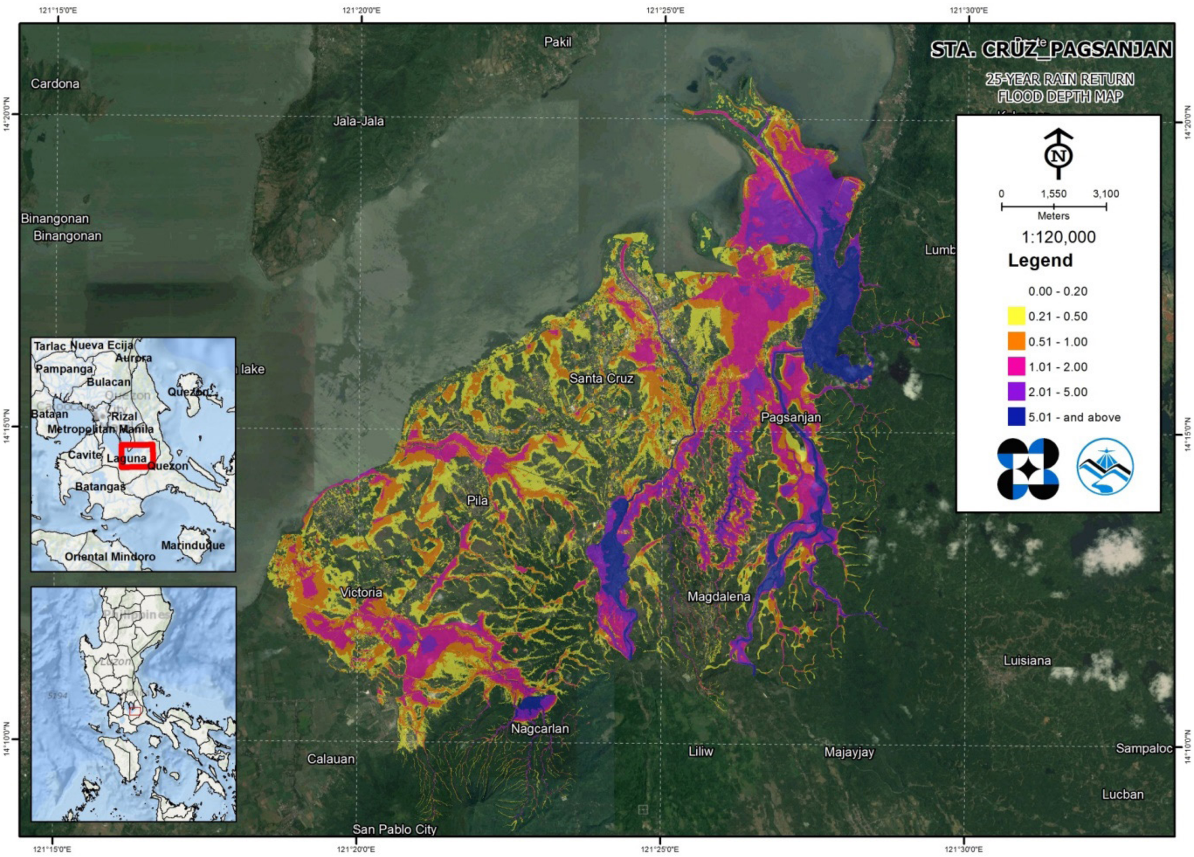

Figure 58. 25-year Flow Depth Map for Sta. Cruz Floodplain

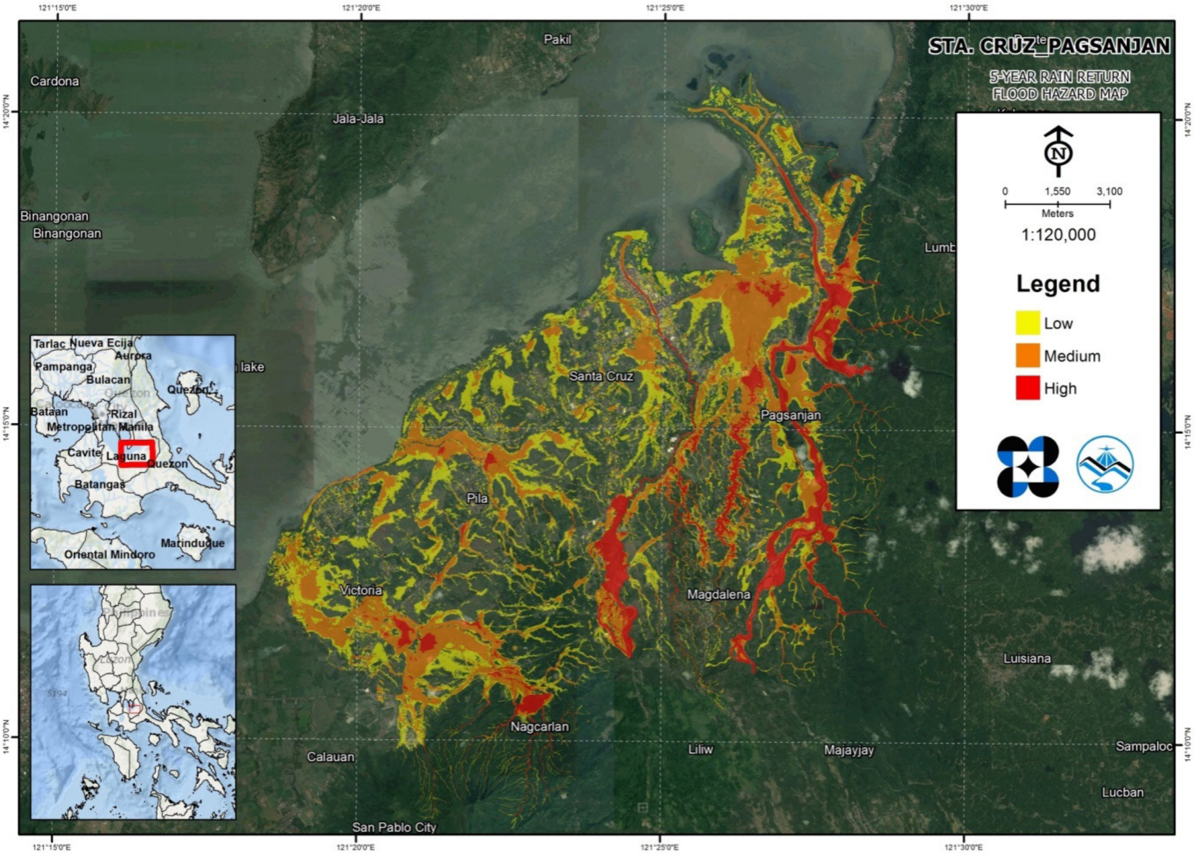

Figure 59. 5-year flood hazard map for Sta. Cruz Floodplain

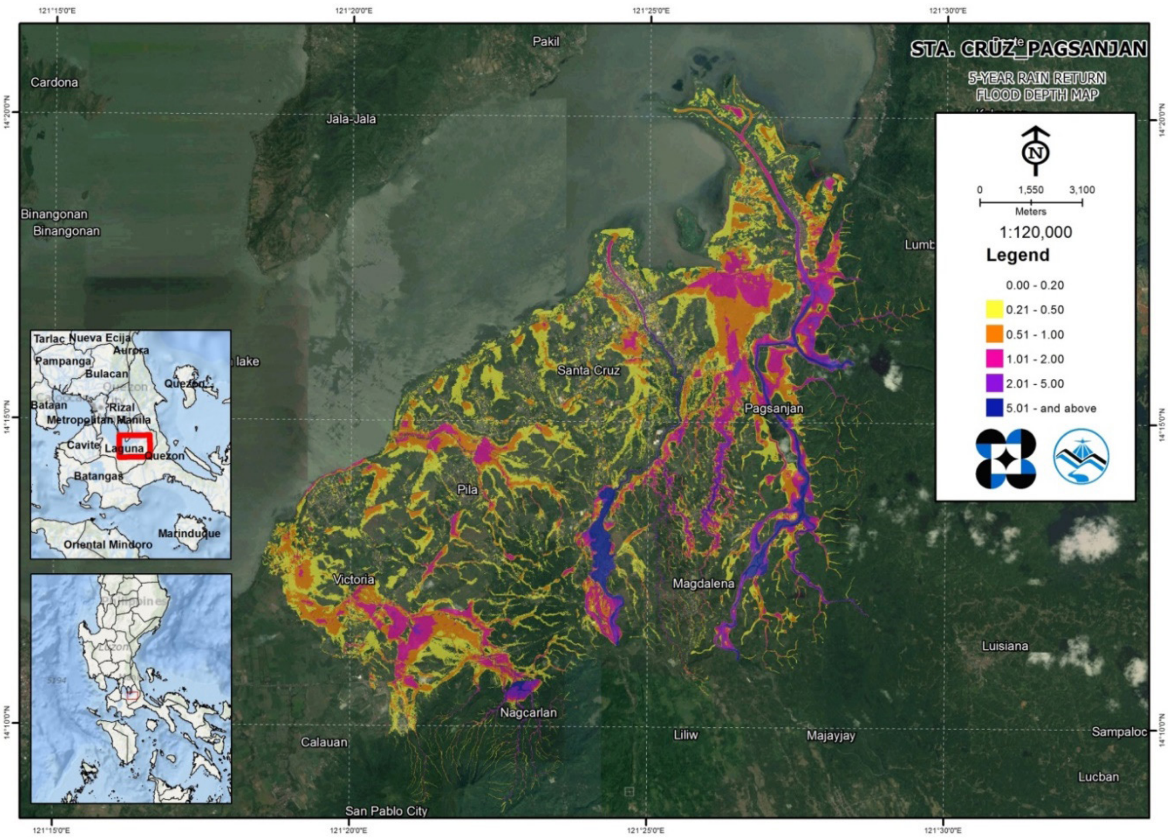

Figure 60. 5-year flow depth map for Sta. Cruz Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Pagsanjan River Basin, grouped accordingly by municipality. For the said basin, thirteen (13) municipalities consisting of 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 sq km will experience flood levels of less 0.20 meters, 0.74% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 t0 5 meters, and more than 5 meters, respectively. Table 34 depicts the areas affected in Calauan in square kilometers by flood depth per barangay.

Table 30. 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	0.52	2.69	0.24
0.21-0.50	0.13	0.18	0.28
0.51-1.00	0.088	0.058	0.1
1.01-2.00	0.016	0.023	0.0094
2.01-5.00	0	0.008	0.0049
> 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 percentage of area that may be affected by flood depths at 0.95%.

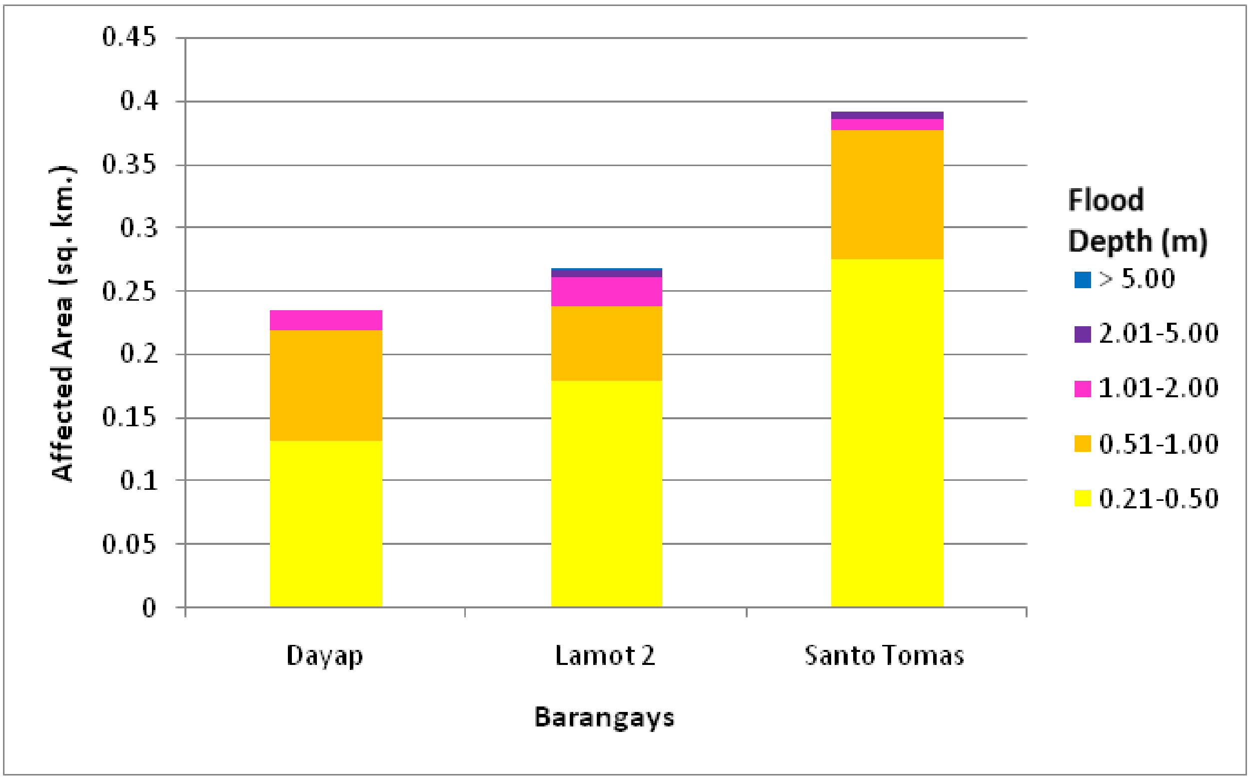

Figure 61. Affected areas in Calauan, Laguna during a 5-year rainfall return period

For the municipality of Cavinti, with an area of 96.78 sq km, 0.90% will experience flood levels of less 0.20 meters; 0.03% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 35 depicts the affected areas in square kilometers by flood depth per barangay.

Table 31. 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	0.0026
0.21-0.50	0.014	0.014	0
0.51-1.00	0.0079	0.0049	0
1.01-2.00	0.0019	0.0033	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 percentage of area that may be affected by flood depths f at 0.47%.

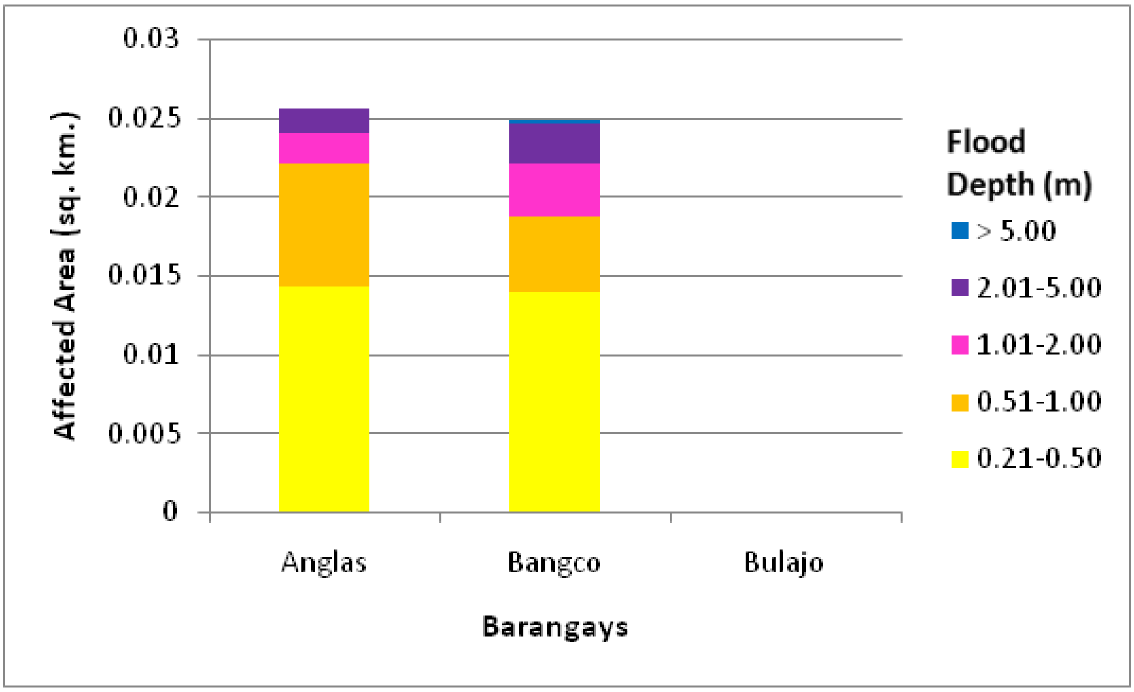

Figure 62. Affected areas in Cavinti, Laguna during a 5-year rainfall return period

For the municipality of Laguna Lake, with an area of 892.20 sq km, 0.05% will experience flood levels of less 0.20 meters; 0.01% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 36 depicts the affected areas in square kilometers by flood depth per barangay.

Table 32. 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

Among the barangays in the Municipality of Laguna Lake, Laguna Lake is projected to have the highest percentage of area that will experience flood levels at 0.10%.

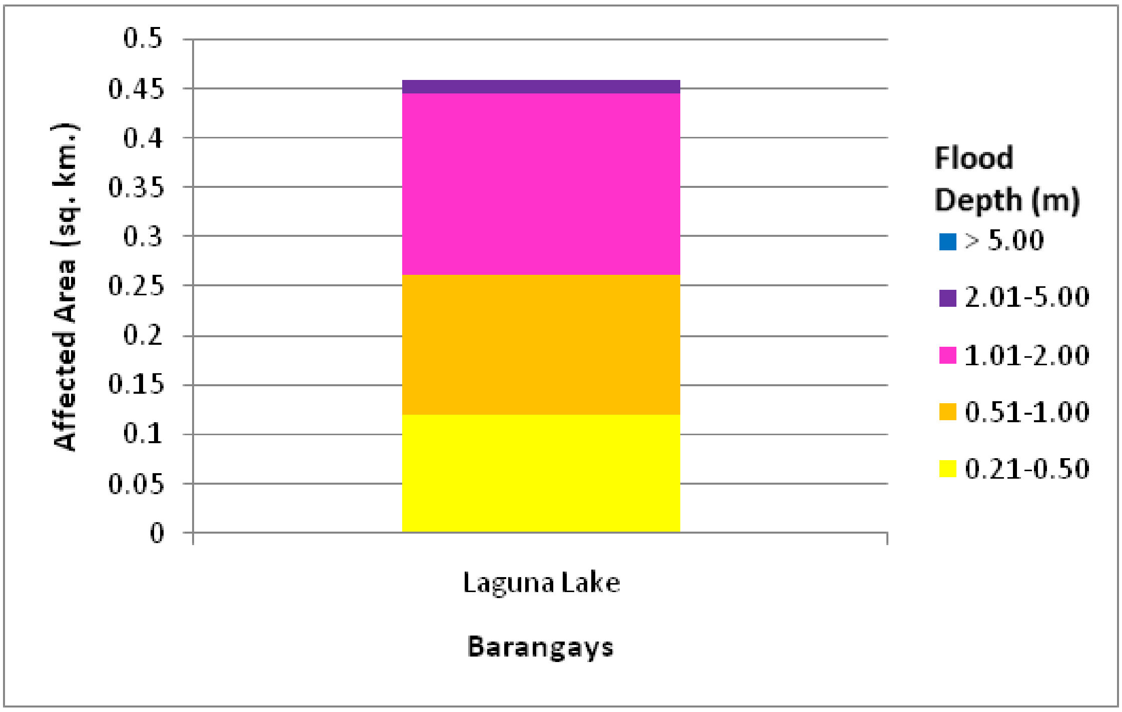

Figure 63. Affected areas in Laguna Lake, Laguna during a 5-year rainfall return period

For the municipality of Liliw, with an area of 36.20 sq km, 1.62% will experience flood levels of less 0.20 meters; 0.10% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 37 depicts the affected areas in square kilometers by flood depth per barangay.

Table 33. 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	0.056	0.084	0.012	0.43
0.21-0.50	0	0.0014	0.00033	0.034
0.51-1.00	0	0.00051	0.00029	0.031
1.01-2.00	0.000047	0	0	0.08
2.01-5.00	0	0	0	0.069
> 5.00	0	0	0	0.016

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 percentage of area that may be affected by flood depths at 0.24%.

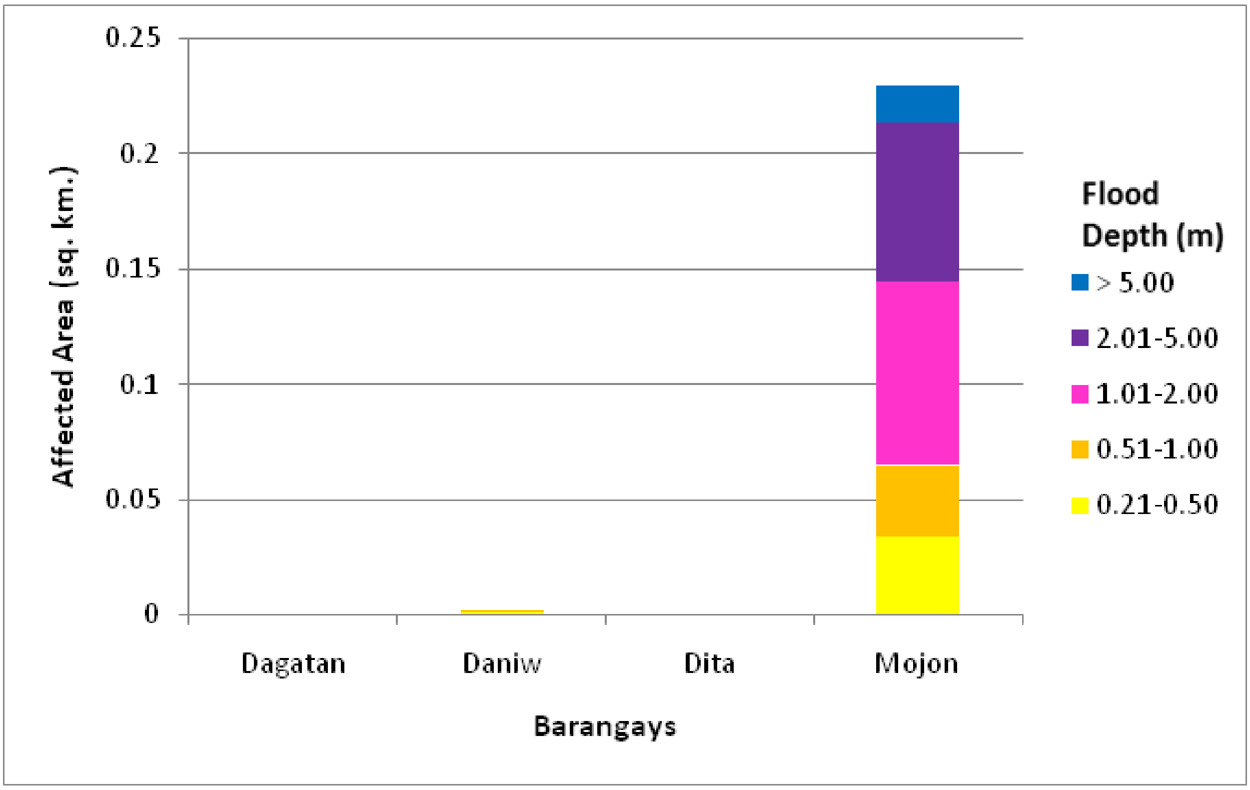

Figure 64. Affected areas in Liliw, Laguna during a 5-year rainfall return period

For the municipality of Luisiana, with an area of 61.01 sq km, 4.63% will experience flood levels of less 0.20 meters; 0.09% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 38 depicts the affected areas in square kilometers by flood depth per barangay.

Table 34. 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 percentage of area that may be affected by flood depths at 0.002%.

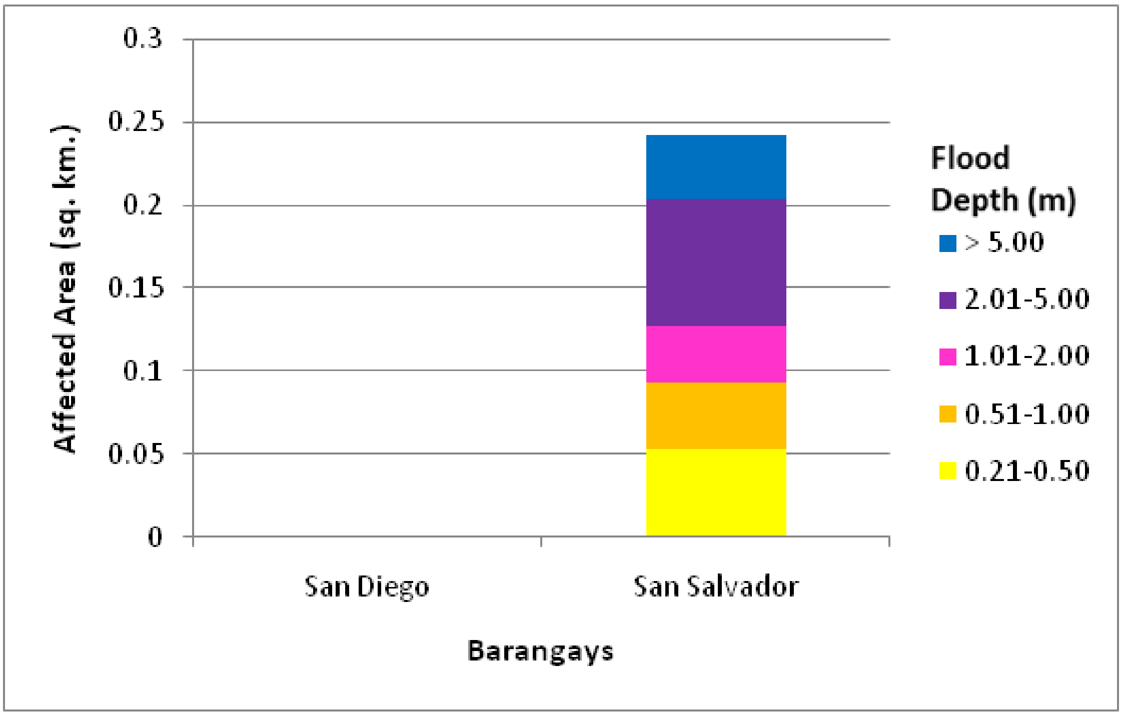

Figure 65. Affected areas in Luisiana, Laguna during a 5-year rainfall return period

For the municipality of Lumban, with an area of 117.34 sq km, 10.74% will experience flood levels of less 0.20 meters; 3.88% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 39 and Table 40 depict the affected areas in square kilometers by flood depth per barangay.

Table 35. 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	0.81	0.097	1.89	0.017	1.18	0.95	0.17	0.43
0.21-0.50	0.031	0.021	0.18	0	0.23	0.089	0.073	0.22
0.51-1.00	0.01	0.021	0.3	0	0.093	0.17	0.027	0.18
1.01-2.00	0.0024	0	0.34	0	0.037	0.085	0	0.033
2.01-5.00	0	0	0.057	0	0.08	0.0015	0	0.1
> 5.00	0	0	0	0	0	0	0	0.00015

Table 36. 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							
	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 percentage of area that may be affected by flood depths at 3.46%.

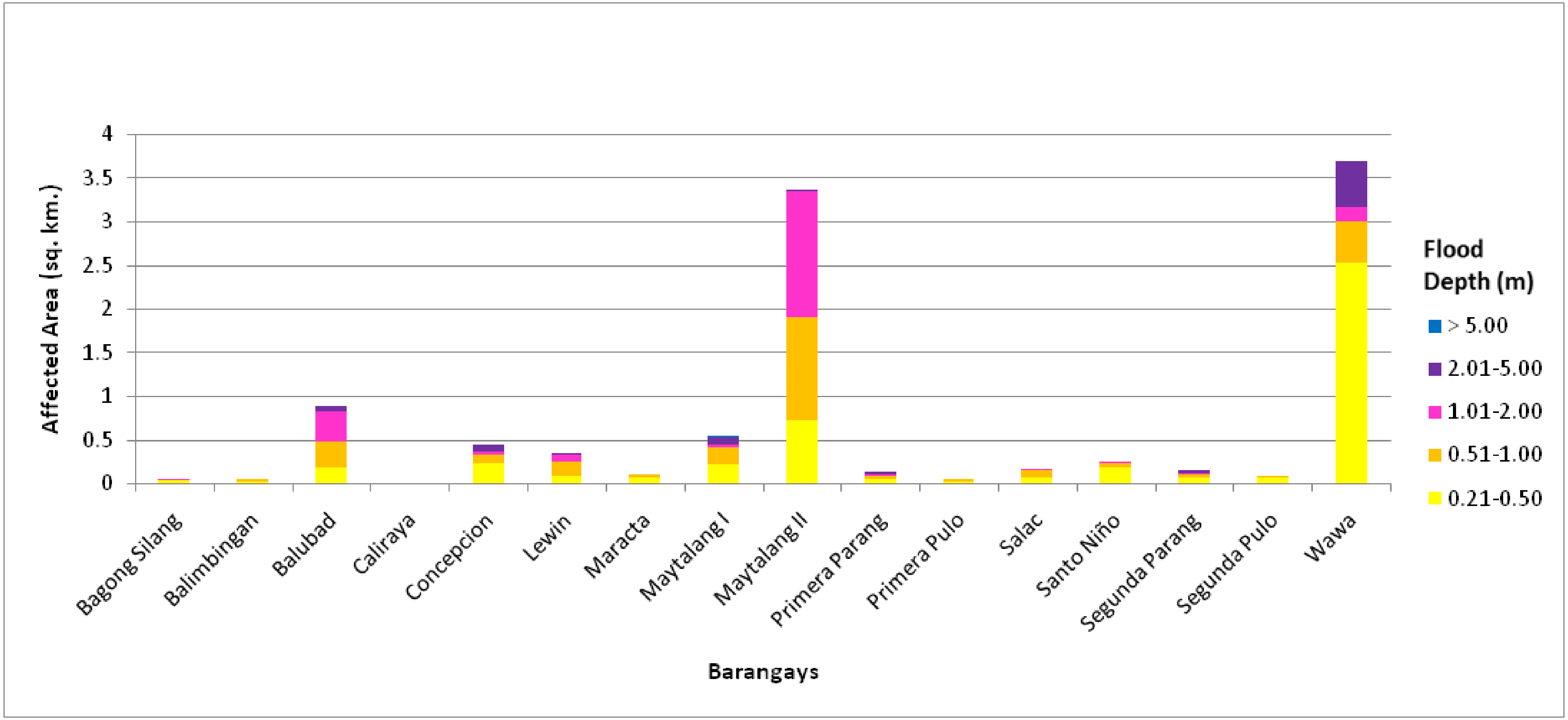

Figure 66. Affected areas in Lumban, Laguna during a 5-year rainfall return period

For the municipality of Magdalena, with an area of 29.61 sq km, 65.36% will experience flood levels of less 0.20 meters; 8.42% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 41 to Table 43 depict the affected areas in square kilometers by flood depth per barangay.

Table 37. 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

Table 38. 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							
	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

Table 39. 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							
	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 percentage of area that may be affected by flood depths at 6.87%.

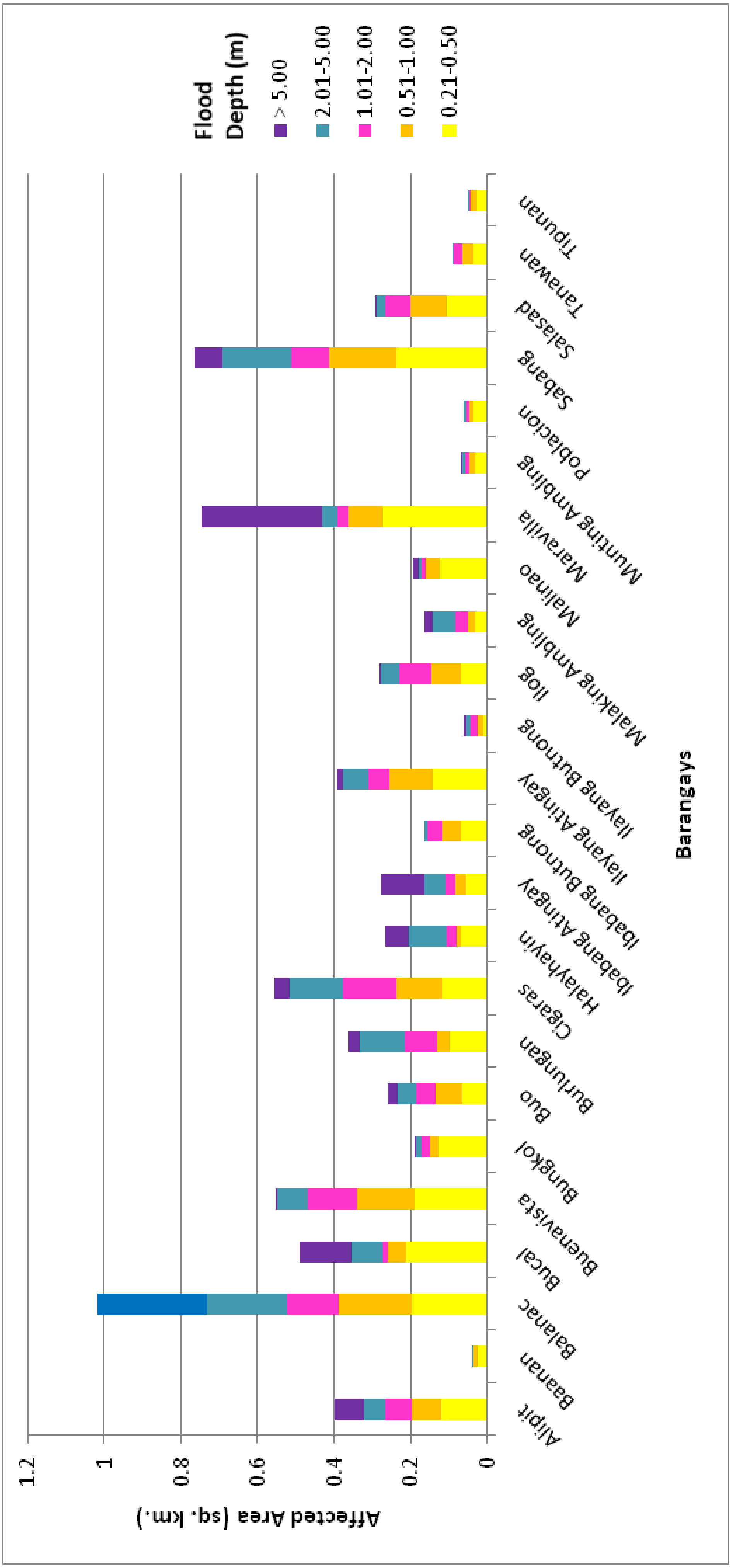

Figure 67. Affected areas in Lumban, Laguna during a 5-year rainfall return period

For the municipality of Majayjay, with an area of 64.40 sq km, 5.29% will experience flood levels of less 0.20 meters; 0.30% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 44 depicts the affected areas in square kilometers by flood depth per barangay.

Table 40. 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 percentage of area that may be affected by flood depths at 1.88%.

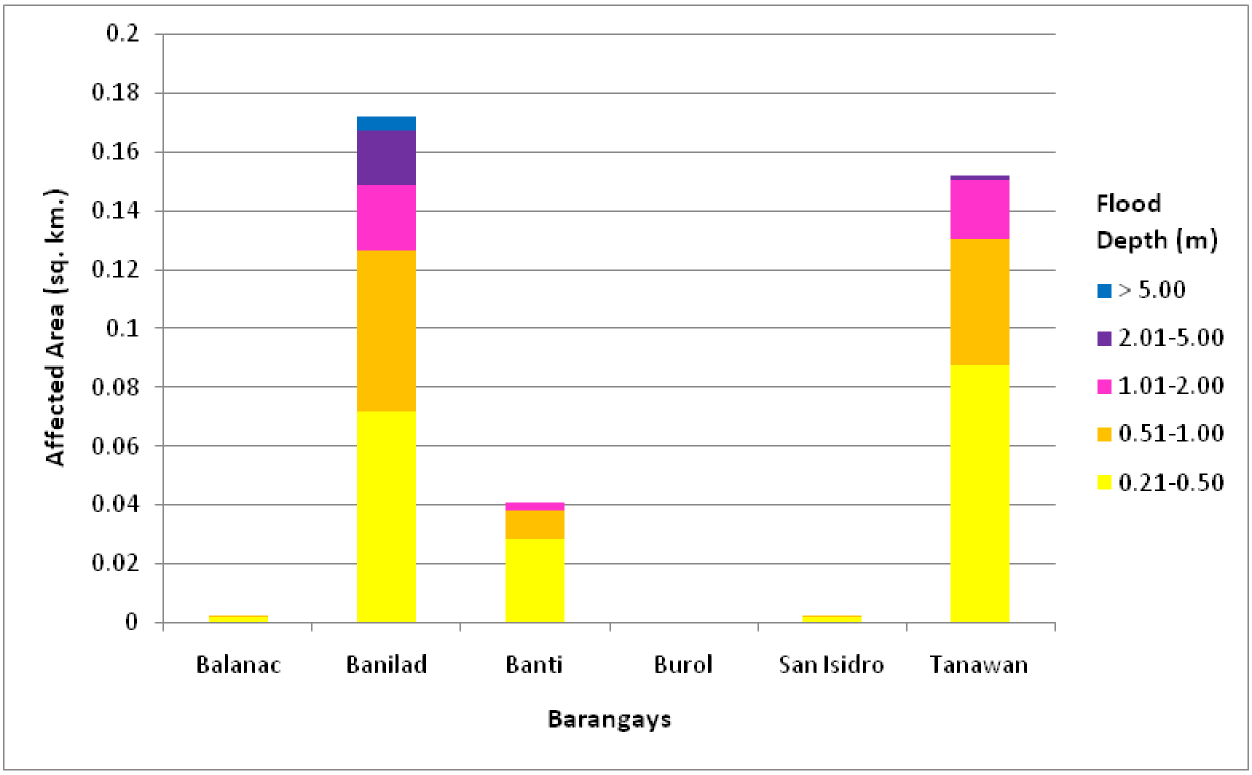

Figure 68. Affected areas in Majayjay, Laguna during a 5-year rainfall return period

For the municipality of Nagcarlan, with an area of 81.20 sq km, 25.81% will experience flood levels of less 0.20 meters; 3.58% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 45 and Table 46 depict the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nagcarlan							
	Balayong	Banca-Banca	Bayaquitos	Buenavista	Buhanginan	Calumpang	Kanluran Kabubuhayan	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

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

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nagcarlan							
	Lagulo	Lawaguin	Manaol	Maravilla	Sabang	Sibulan	Silangan Kabubuhayan	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 percentage of area that may be affected by flood depths at 4.52%.

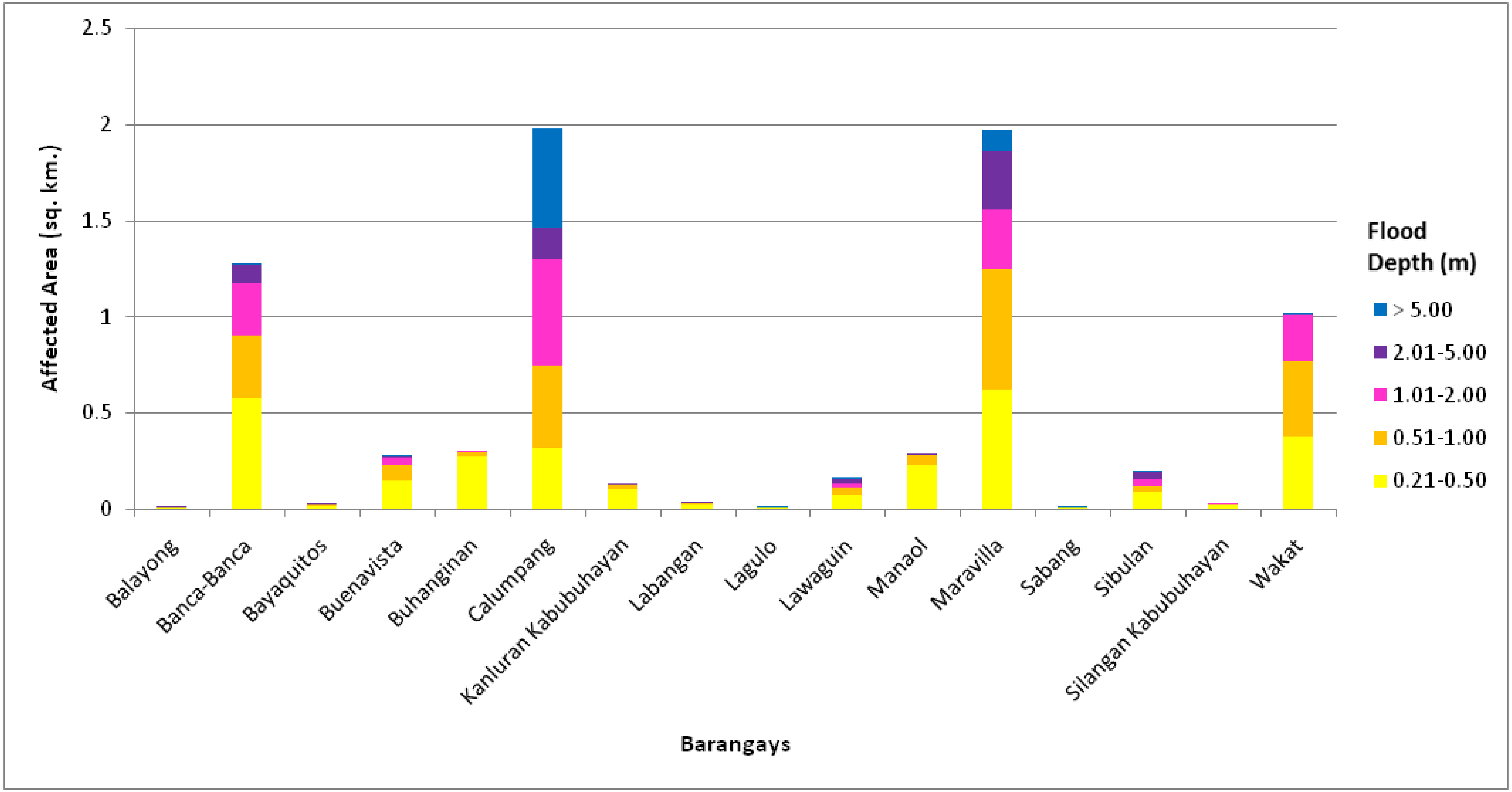

Figure 69. Affected areas in Nagcarlan, Laguna during a 5-year rainfall return period

For the municipality of Pagsanjan, with an area of 40.77 sq km, 46.40% will experience flood levels of less 0.20 meters; 8.56% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 47 and Table 48 depict the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Pagsanjan, Laguna during a 5-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	2.49	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

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

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	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 percentage of area that may be affected by flood depths at 9.60%.

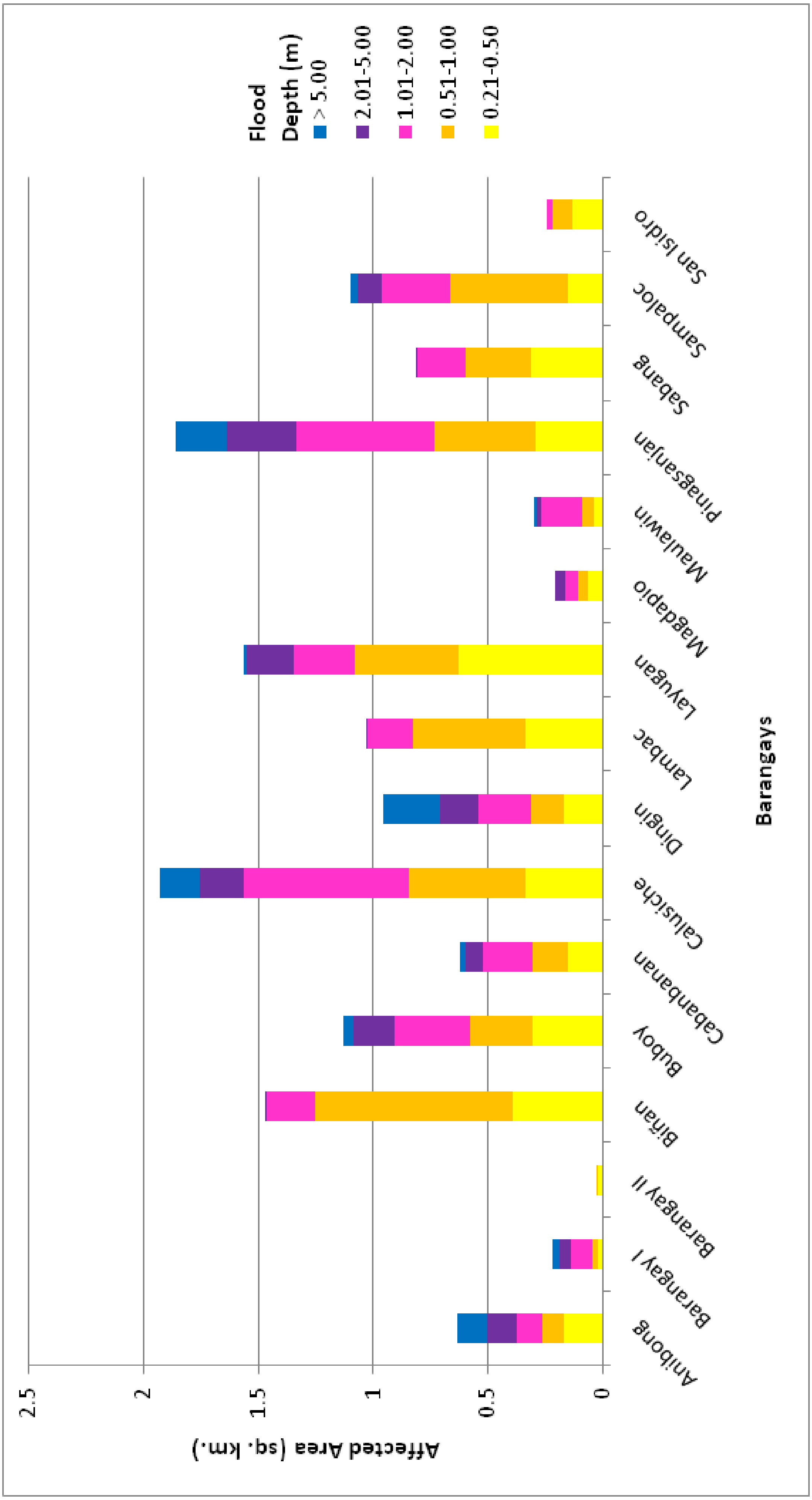

Figure 70. Affected areas in Pagsanjan, Laguna during a 5-year rainfall return period

For the municipality of Pila, with an area of 28.77 sq km, 64.99% will experience flood levels of less 0.20 meters; 19.21% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 49 and Table 50 depict the affected areas in square kilometers by flood depth per barangay.

Table 45. 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

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								
	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, Conception is projected to have the highest percentage of area that will experience flood levels at 13.24%. On the other hand, Tubuan posted the percentage of area that may be affected by flood depths at 11.56%.

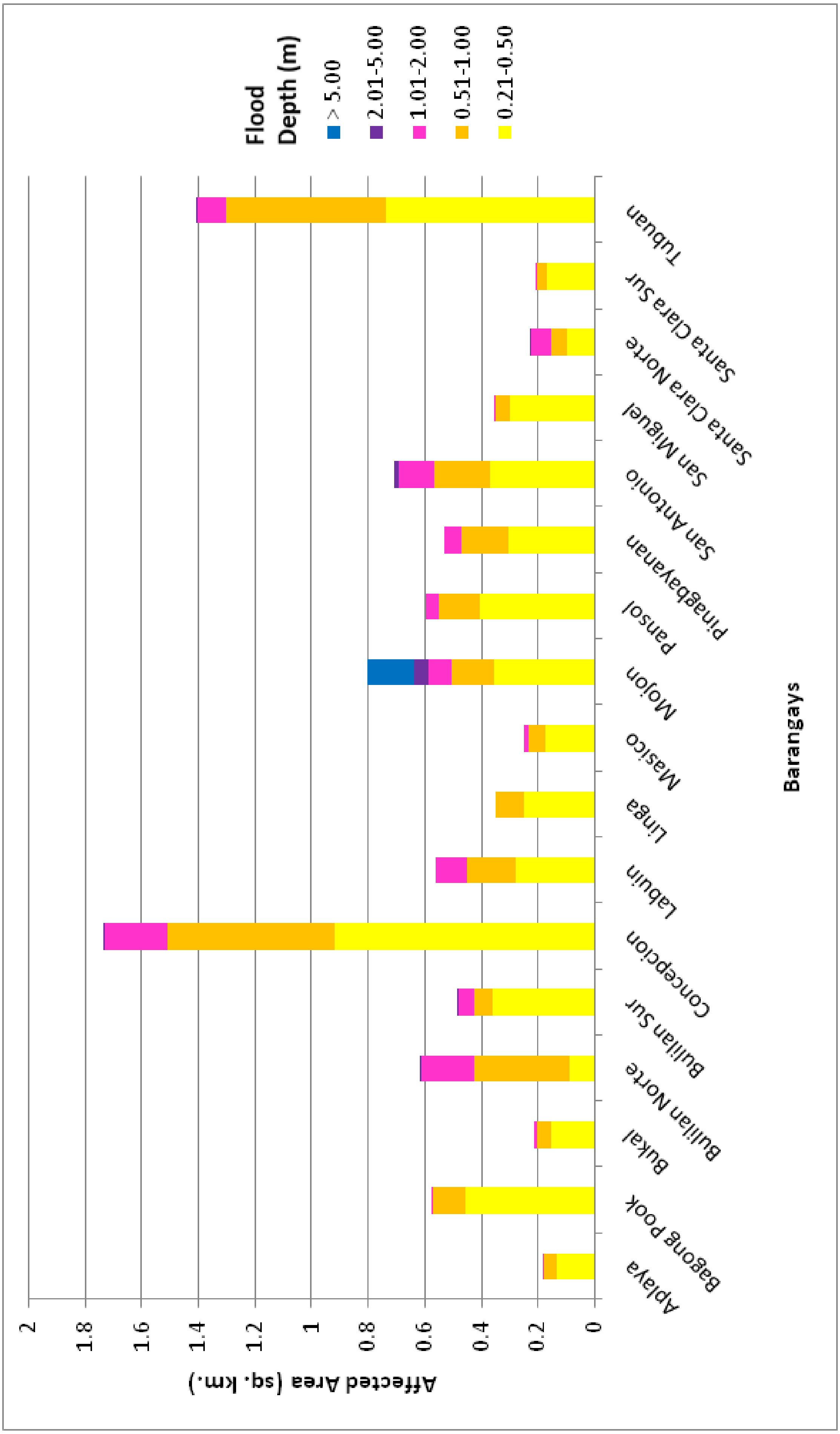

Figure 71. Affected areas in Pila, Laguna during a 5-year rainfall return period

For the municipality of Sta. Cruz, with an area of 37.63 sq km, 62.31% will experience flood levels of less 0.20 meters; 23.90% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 51 to Table 53 depict the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz								
	Alipit	Bagumbayan	Barangay 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

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

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz								
	Duhat	Gatid	Jasaan	Labuin	Malinao	Oogong	Pagsawitan	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

Table 49. Affected areas in Sta. Cruz, Laguna during a 5-year rainfall return period

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 Sta. 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 percentage of area that may be affected by flood depths at 8.23%.

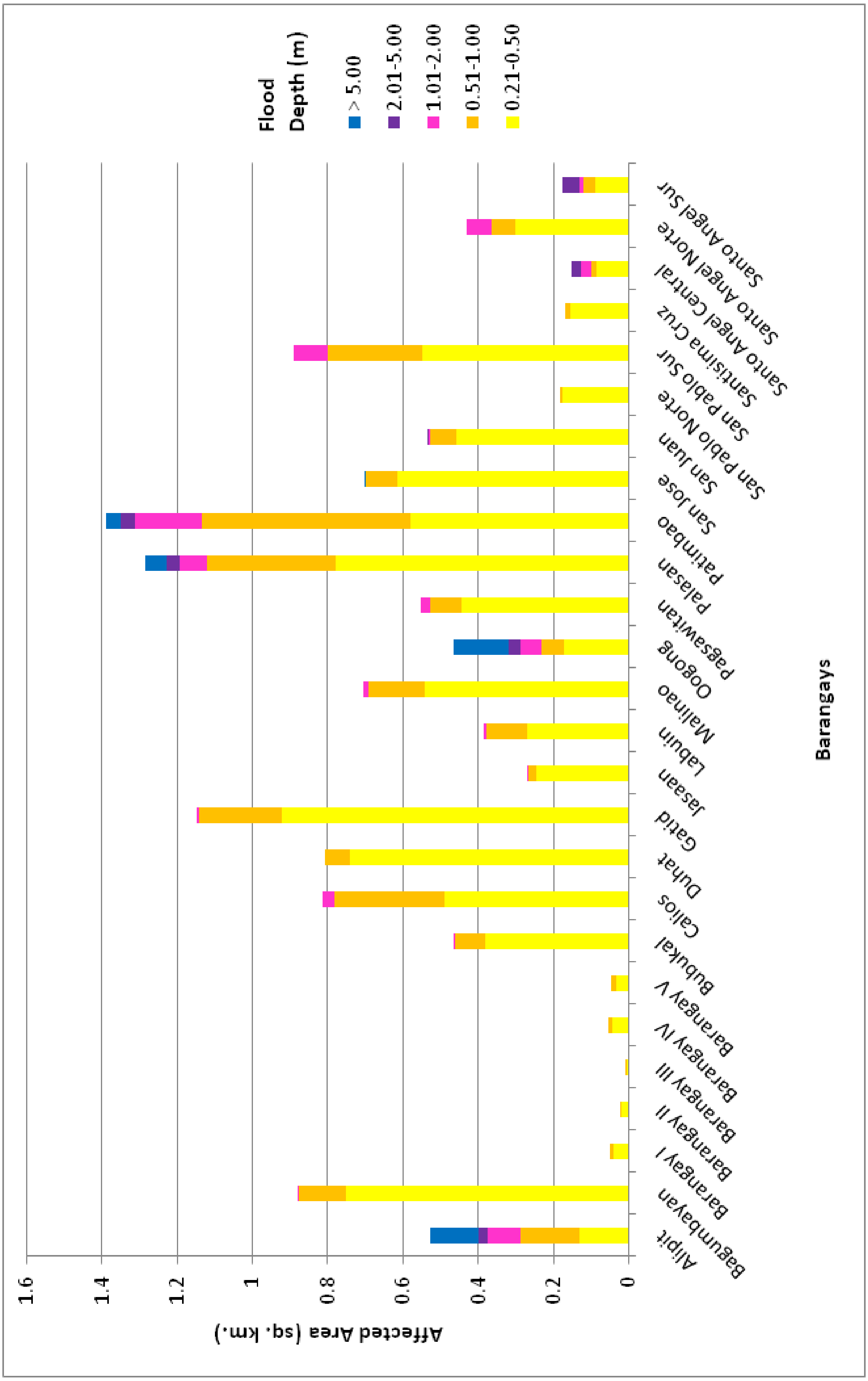

Figure 72. Affected areas in Sta. Cruz, Laguna during a 5-year rainfall return period

For the municipality of Victoria, with an area of 28.37 sq km, 44.75% will experience flood levels of less 0.20 meters; 19.82% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 54 depicts the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected areas in Victoria, Laguna during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Victoria								
	Banca-Banca	Daniw	Masapang	Nanhaya	Pagalangan	San Benito	San Felix	San Francisco	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 percentage of area that may be affected by flood depths at 18.21%.

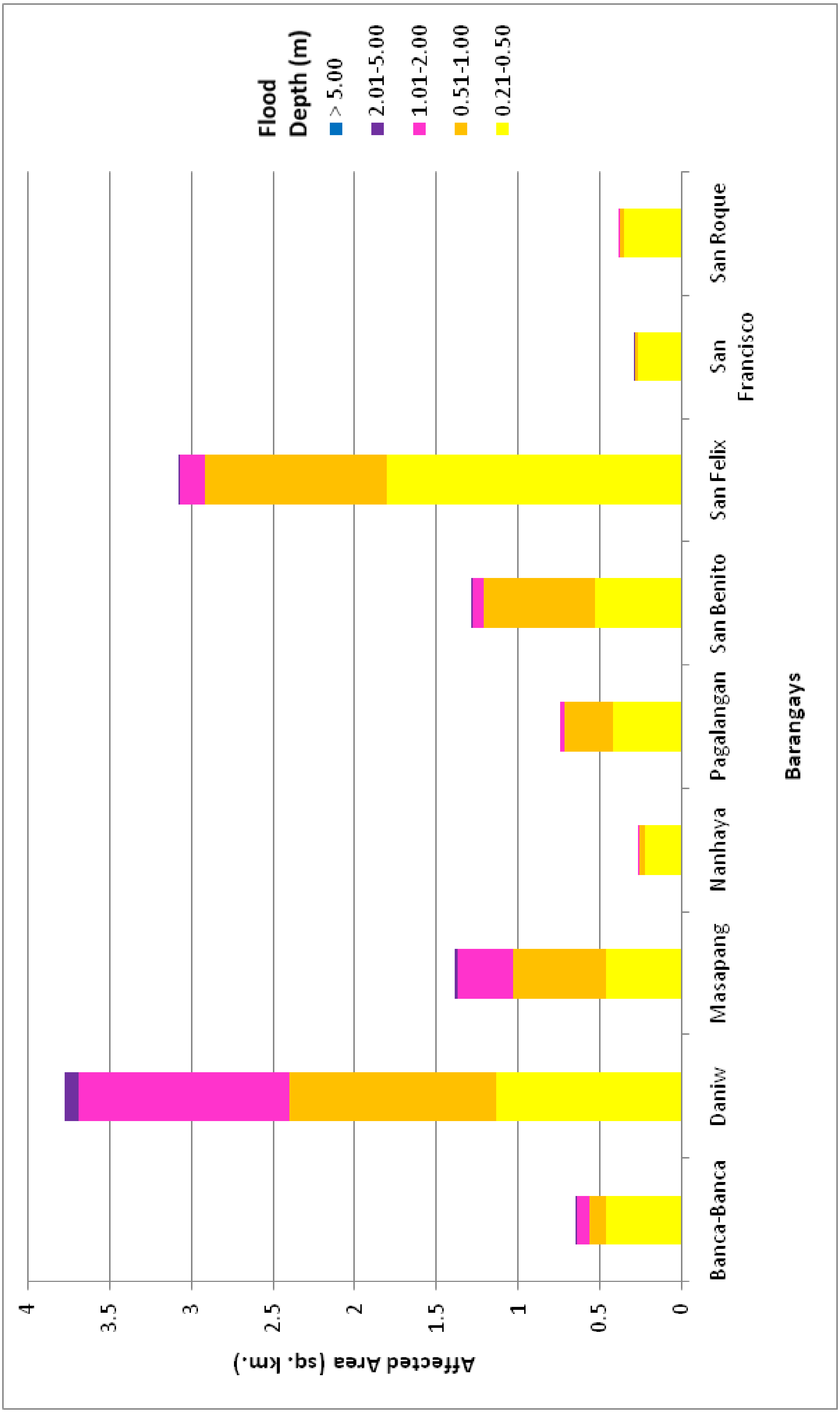

Figure 73. Affected areas in Victoria, Laguna during a 5-year rainfall return period

For the 25-year return period, 4.08% of the municipality of Calauan with an area of 79.44 sq km will experience flood levels of less 0.20 meters; 0.82% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 t0 5 meters, and more than 5 meters, respectively. Table 55 depicts the areas affected in Calauan in square kilometers by flood depth per barangay.

Table 51. 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

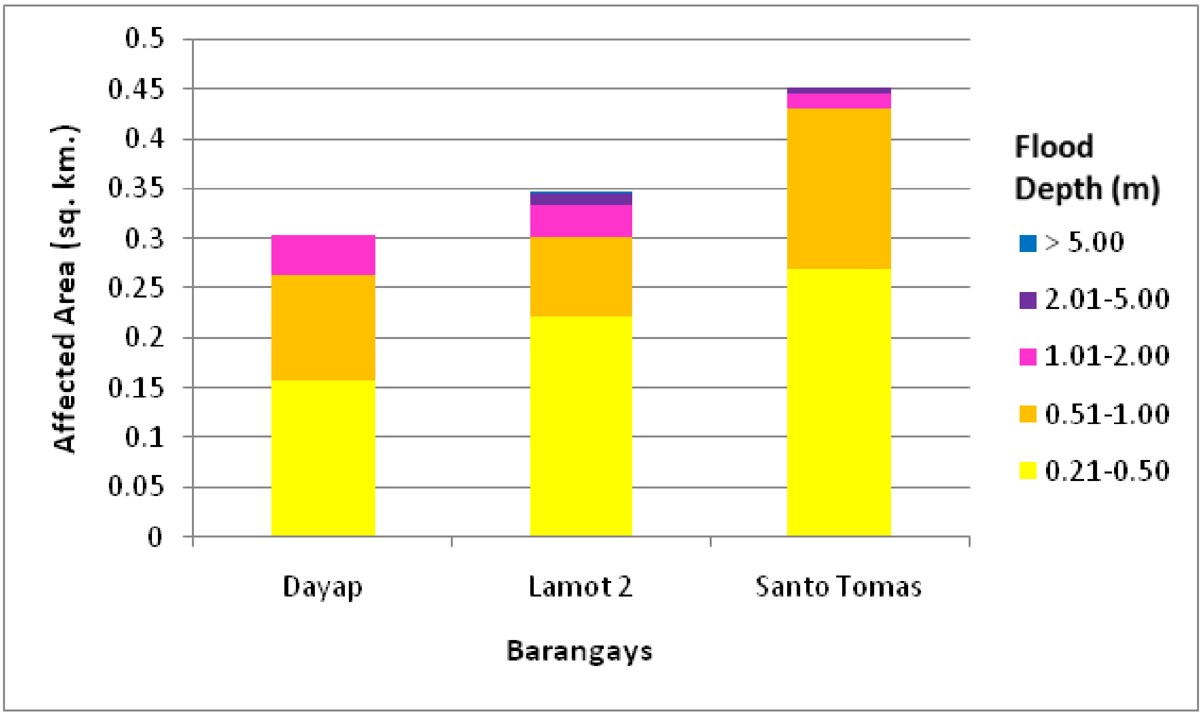

Figure 74. Affected areas in Calauan, Laguna during a 25-year rainfall return period

For the municipality of Cavinti, with an area of 96.78 sq km, 0.91% will experience flood levels of less 0.20 meters; 0.04% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 56 depicts the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Cavinti		
	Anglas	Bangco	Bulajo
0.03-0.20	0.46	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

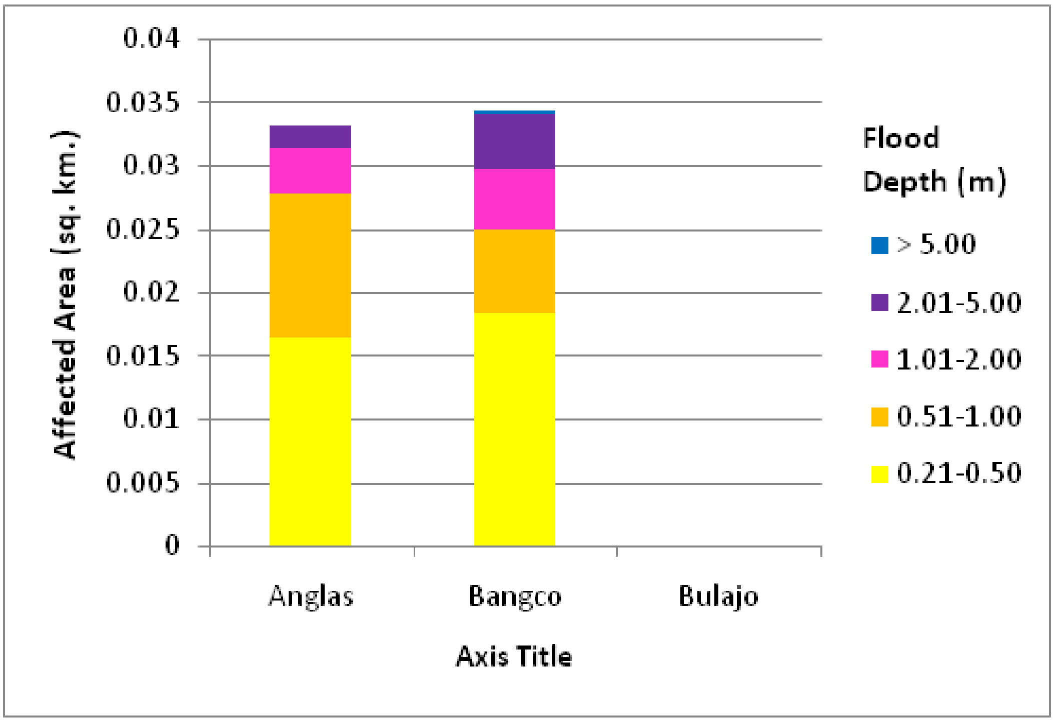

Figure 75. Affected areas in Cavinti, Laguna during a 25-year rainfall return period

For the municipality of Laguna Lake, with an area of 892.20 sq km, 0.04% will experience flood levels of less 0.20 meters; 0.02% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 57 depicts the affected areas in square kilometers by flood depth per barangay.

Table 53. 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

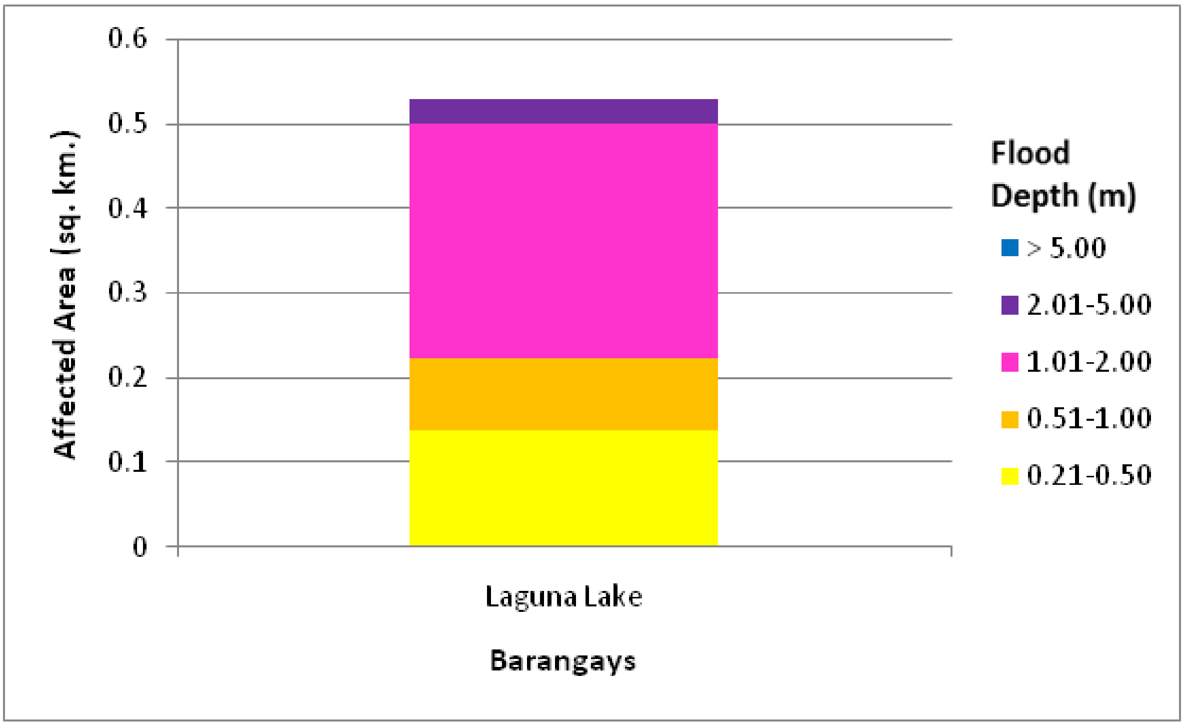

Figure 76. Affected areas in Laguna Lake, Laguna during a 25-year rainfall return period

For the municipality of Liliw, with an area of 36.20 sq km, 1.55% will experience flood levels of less 0.20 meters; 0.12% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 58 depicts the affected areas in square kilometers by flood depth per barangay.

Table 54. 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

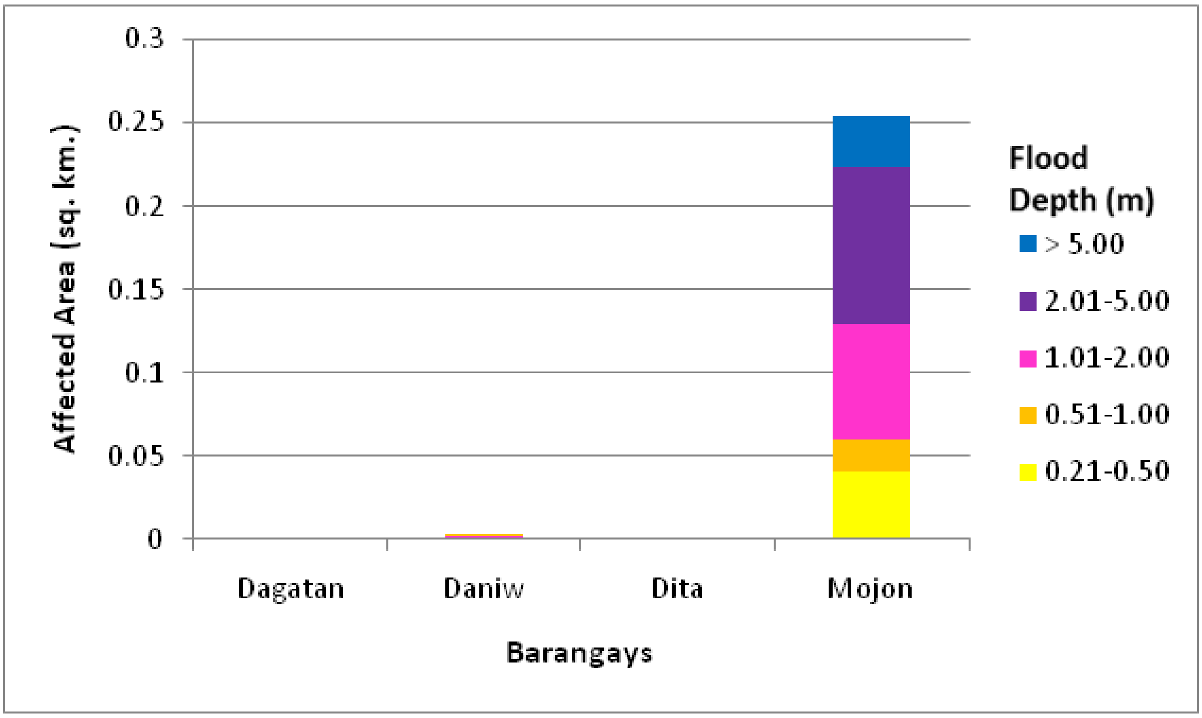

Figure 77. Affected areas in Liliw, Laguna during a 25-year rainfall return period

For the municipality of Luisiana, with an area of 61.01 sq km, 4.56% will experience flood levels of less 0.20 meters; 0.09% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 59 depicts the affected areas in square kilometers by flood depth per barangay.

Table 55. 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

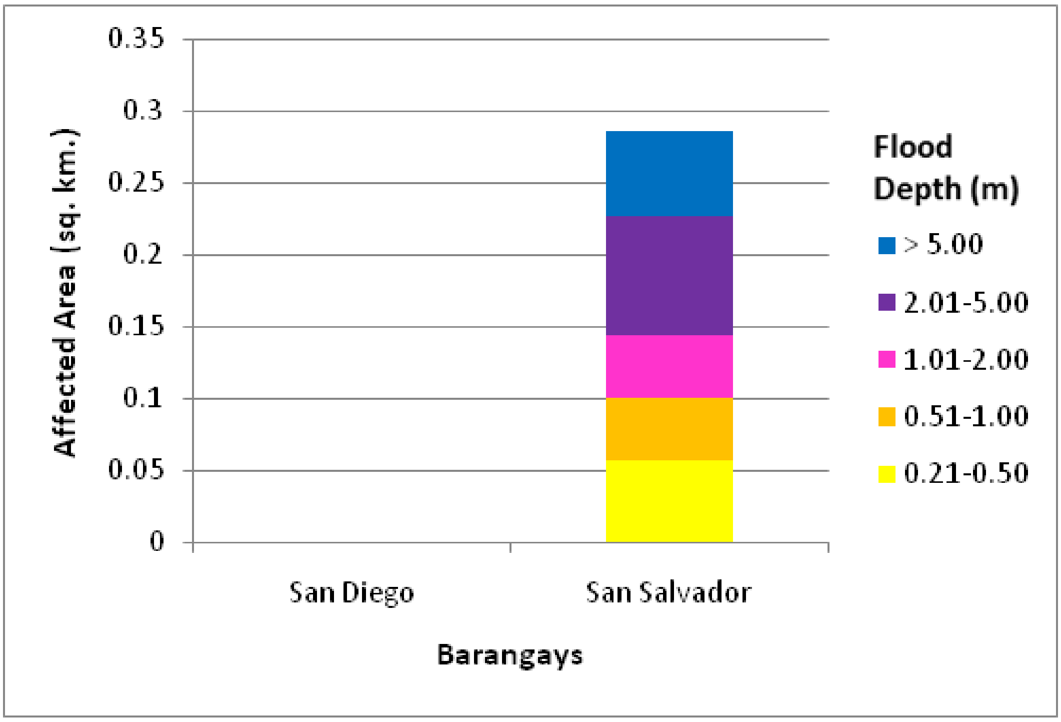

Figure 78. Affected areas in Luisiana, Laguna during a 25-year rainfall return period

For the municipality of Lumban, with an area of 117.34 sq km, 9.41% will experience flood levels of less 0.20 meters; 3.68% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 60 and Table 61 depict the affected areas in square kilometers by flood depth per barangay.

Table 56. 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

Table 57. 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							
	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

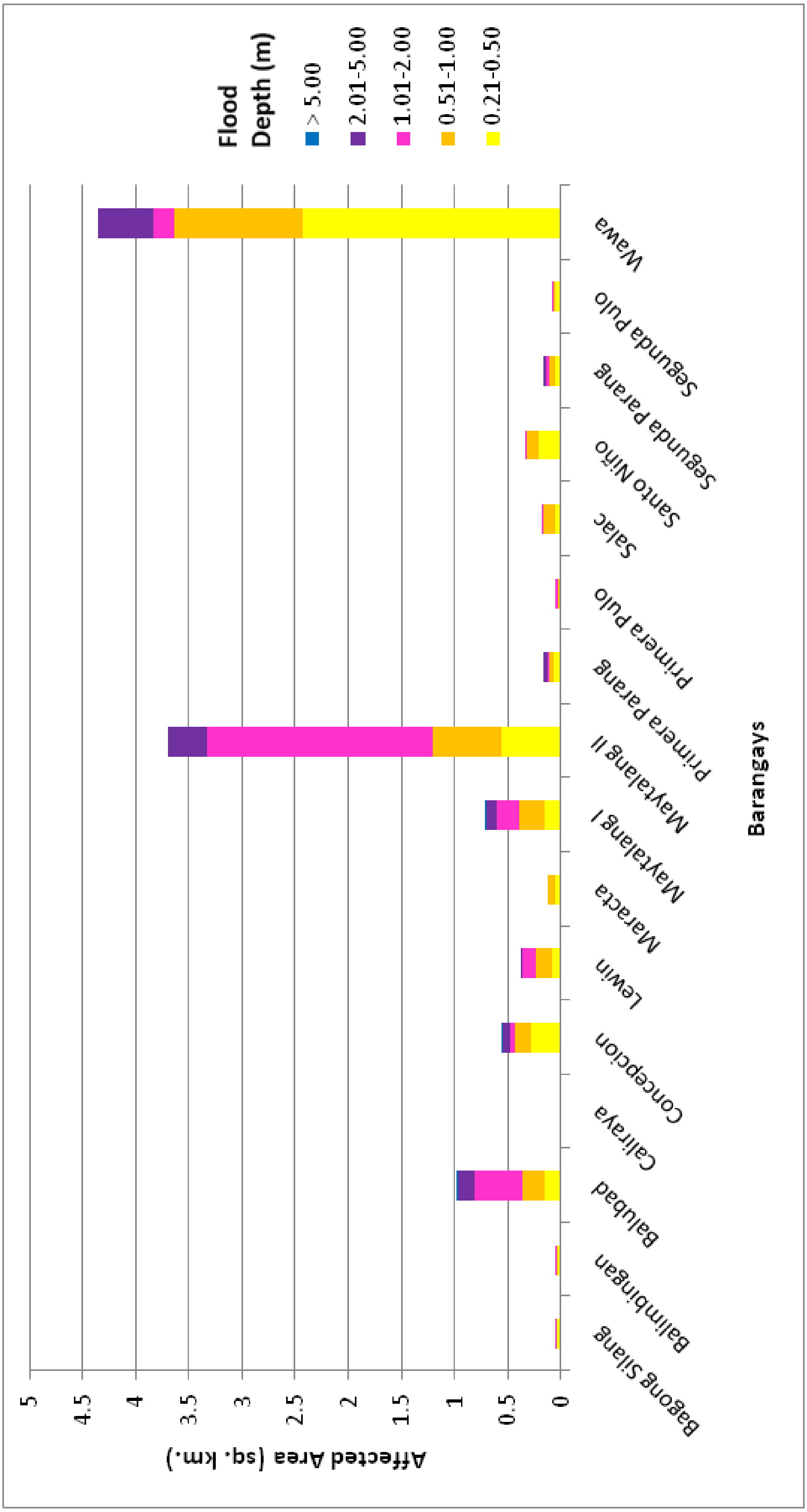

Figure 79. Affected areas in Lumban, Laguna during a 25-year rainfall return period

For the municipality of Magdalena, with an area of 29.61 sq km, 56.83% will experience flood levels of less 0.20 meters; 9.37% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 62 to Table 64 depict the affected areas in square kilometers by flood depth per barangay.

Table 58. Affected areas in Magdalena, Laguna during a 25-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	1.2	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

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

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	0.23	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

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

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

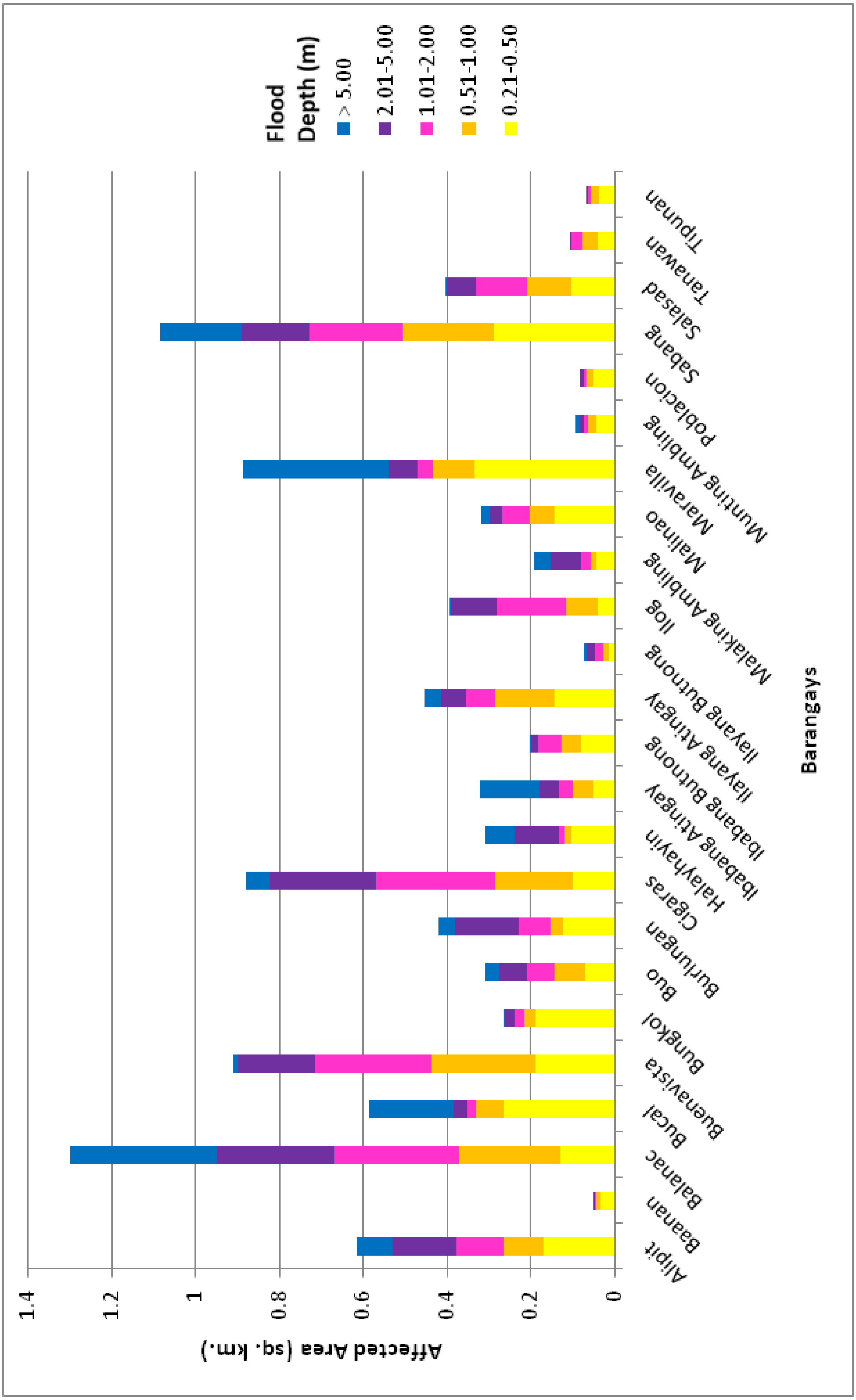

Figure 80. Affected areas in Magdalena, Laguna during a 25-year rainfall return period

For the municipality of Majayjay, with an area of 64.40 sq km, 5.18% will experience flood levels of less 0.20 meters; 0.33% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 65 depicts the affected areas in square kilometers by flood depth per barangay.

Table 61. 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

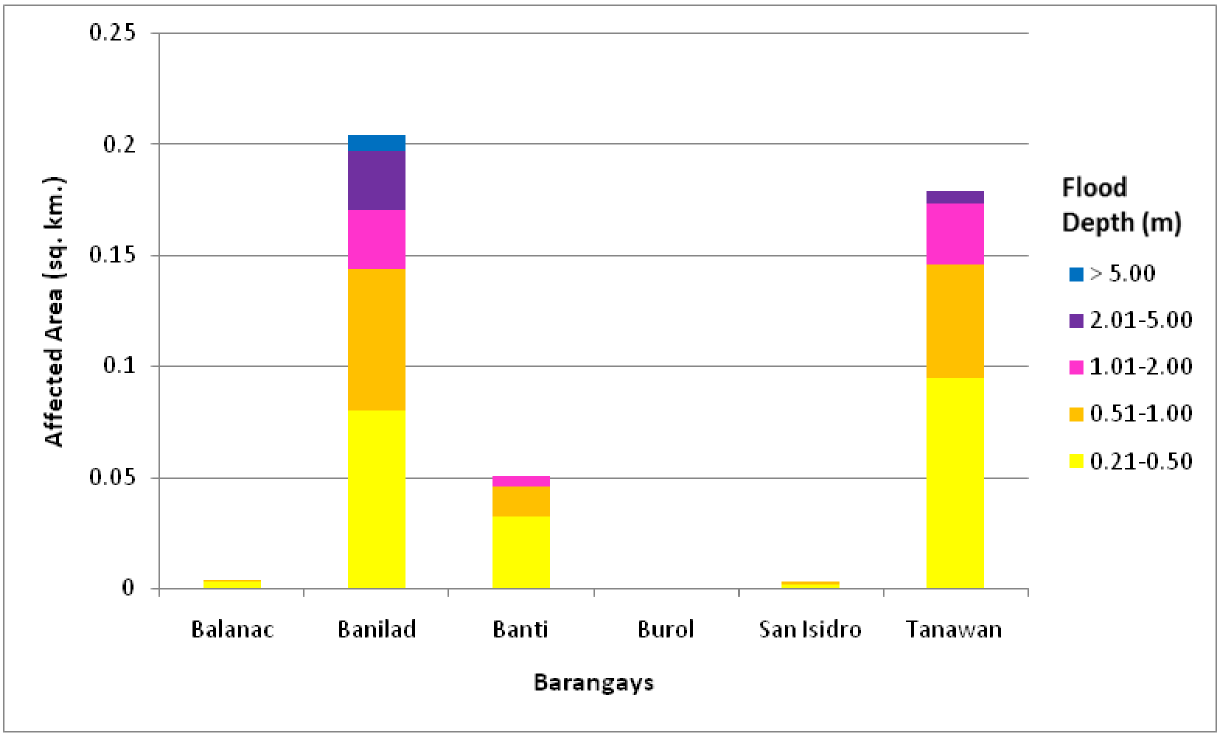

Figure 81. Affected areas in Majayjay, Laguna during a 25-year rainfall return period

For the municipality of Nagcarlan, with an area of 81.20 sq km, 23.93% will experience flood levels of less 0.20 meters; 3.76% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 66 and Table 67 depict the affected areas in square kilometers by flood depth per barangay.

Table 62. Affected areas in Nagcarlan, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nagcarlan							
	Balayong	Banca-Banca	Bayaquitos	Buenavista	Buhanginan	Calumpang	Kanluran Kabubuhayan	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

Table 63. Affected areas in Nagcarlan, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nagcarlan							
	Lagulo	Lawaguin	Manaol	Maravilla	Sabang	Sibulan	Silangan Kabubuhayan	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

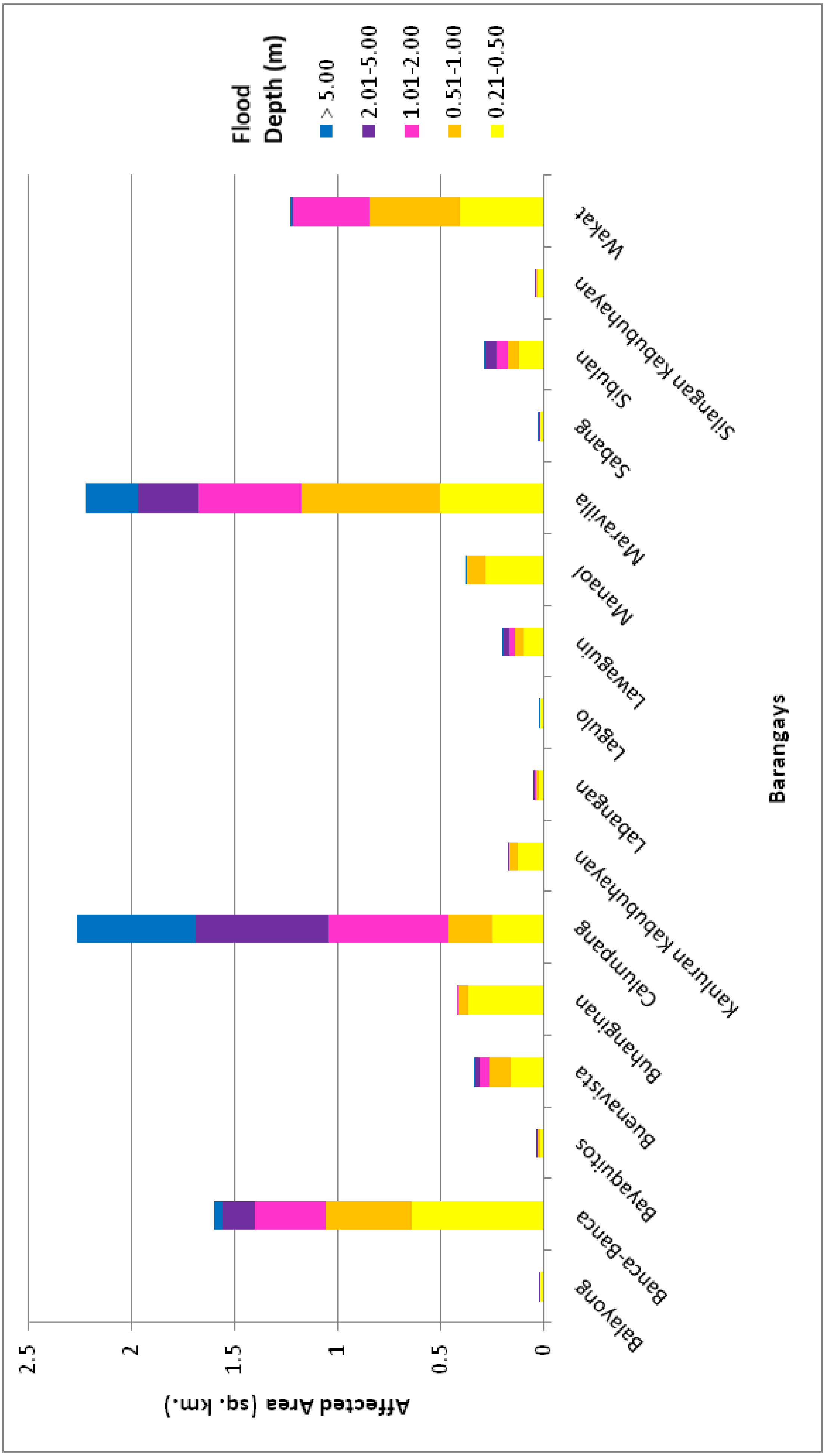

Figure 82. Affected areas in Nagcarlan, Laguna during a 25-year rainfall return period

For the municipality of Pagsanjan, with an area of 40.77 sq km, 38.03% will experience flood levels of less 0.20 meters; 6.47% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 68 and Table 69 depict the affected areas in square kilometers by flood depth per barangay.

Table 64. 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

Table 65. 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							
	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

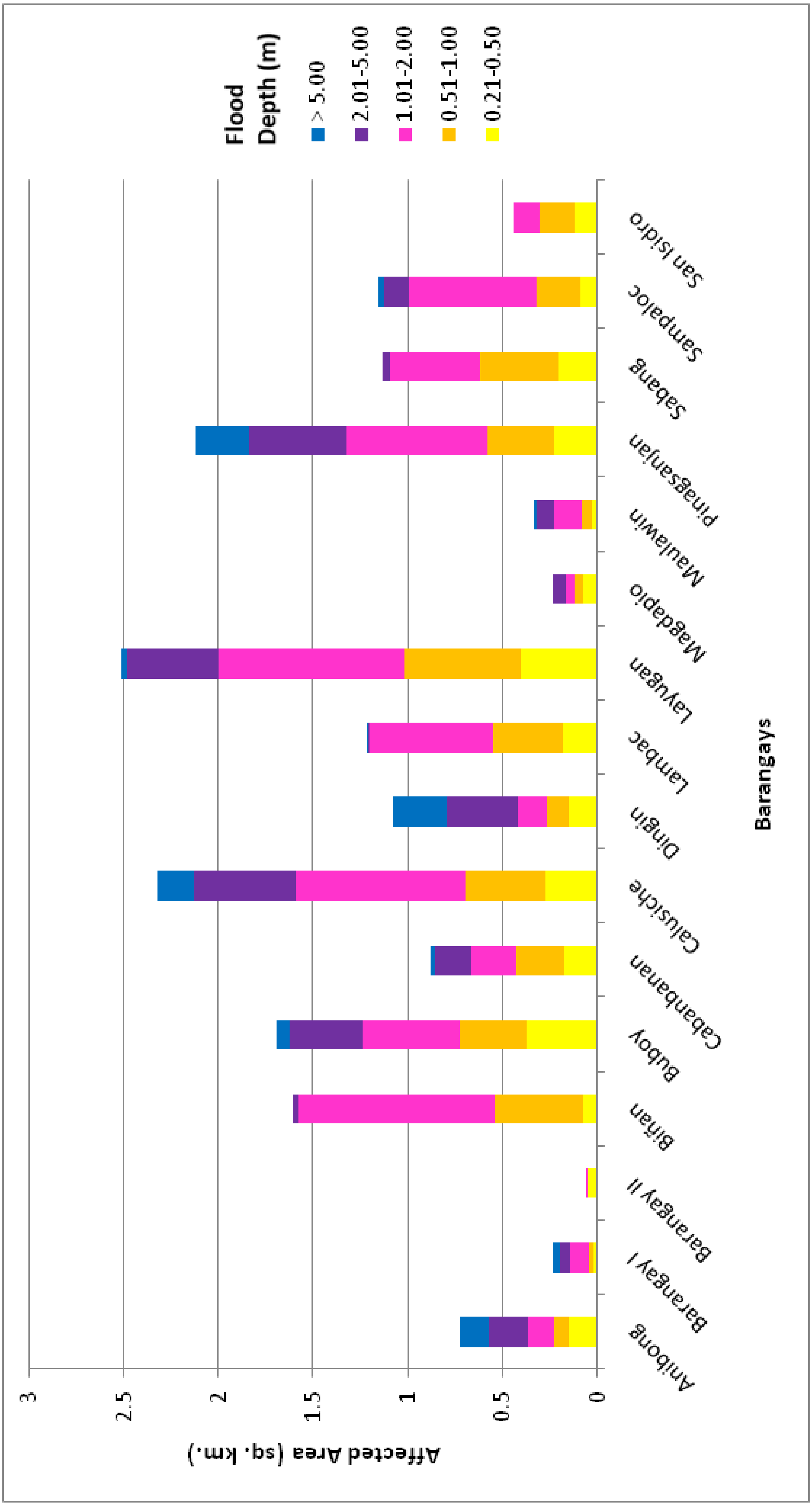

Figure 83. Affected areas in Pagsanjan, Laguna during a 25-year rainfall return period

For the municipality of Pila, with an area of 28.77 sq km, 53.69% will experience flood levels of less 0.20 meters; 23.14% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 70 and Table 71 depict the affected areas in square kilometers by flood depth per barangay.

Table 66. 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

Table 67. 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								
	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

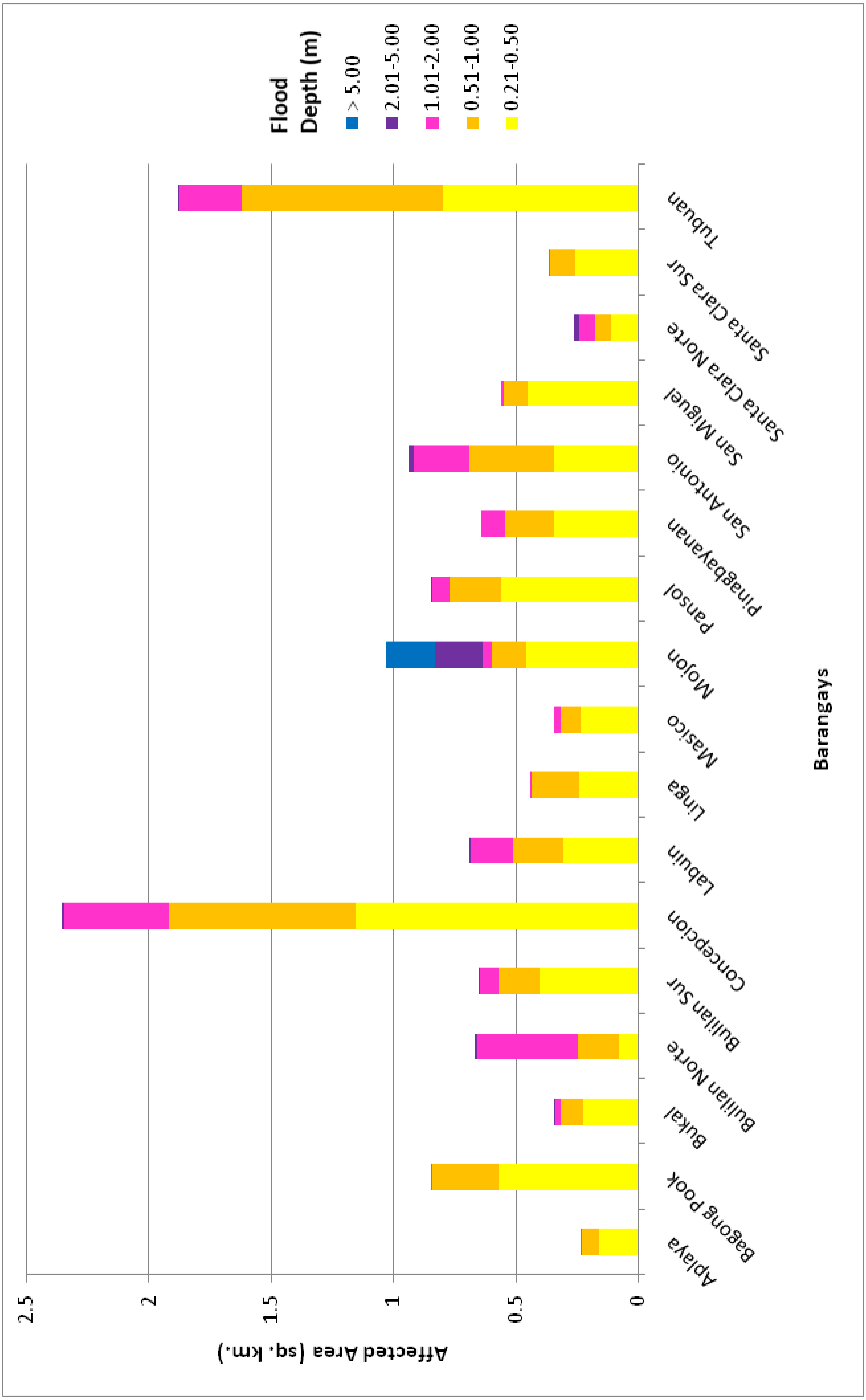

Figure 84. Affected areas in Pila, Laguna during a 25-year rainfall return period

For the municipality of Sta. Cruz, with an area of 37.63 sq km, 44.06% will experience flood levels of less 0.20 meters; 29.01% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 72 to Table 47 depict the affected areas in square kilometers by flood depth per barangay.

Table 68. Affected areas in Sta. Cruz, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz								
	Alipit	Bagumbayan	Barangay 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

Table 69. Affected areas in Sta. Cruz, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz								
	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

Table 70. Affected areas in Sta. Cruz, Laguna during a 25-year rainfall return period

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	1.47	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

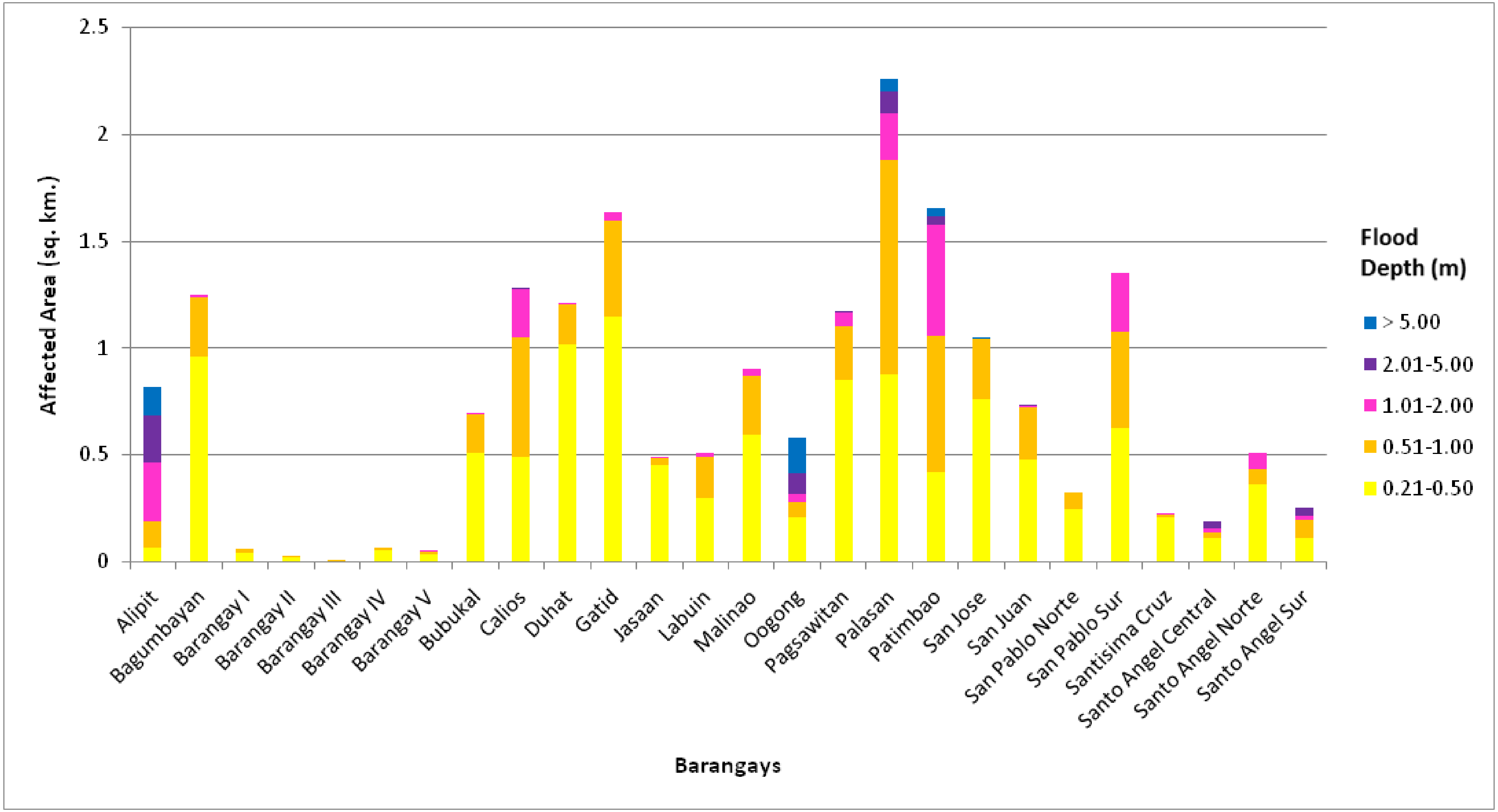

Figure 85. Affected areas in Sta. Cruz, Laguna during a 25-year rainfall return period

For the municipality of Victoria, with an area of 28.37 sq km, 33.33% will experience flood levels of less 0.20 meters; 19.29% of the area will experience flood levels of 0.21 to 0.50 meters; while 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

75 depicts the affected areas in square kilometers by flood depth per barangay.

Table 71. Affected areas in Victoria, Laguna during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Victoria								
	Banca-Banca	Daniw	Masapang	Nanhaya	Pagalangan	San Benito	San Felix	San Francisco	San Roque
0.03-0.20	1.29	1.61	0.31	0.76	0.65	0.45	1.3	1.77	1.31
0.21-0.50	0.61	0.96	0.33	0.31	0.45	0.42	1.55	0.39	0.45
0.51-1.00	0.32	1.15	0.74	0.084	0.46	0.61	1.7	0.11	0.18
1.01-2.00	0.13	1.84	0.53	0.015	0.13	0.54	0.61	0.0091	0.004
2.01-5.00	0.022	0.39	0.054	0	0	0.0027	0.0035	0.0002	0
> 5.00	0	0	0	0	0	0	0	0	0

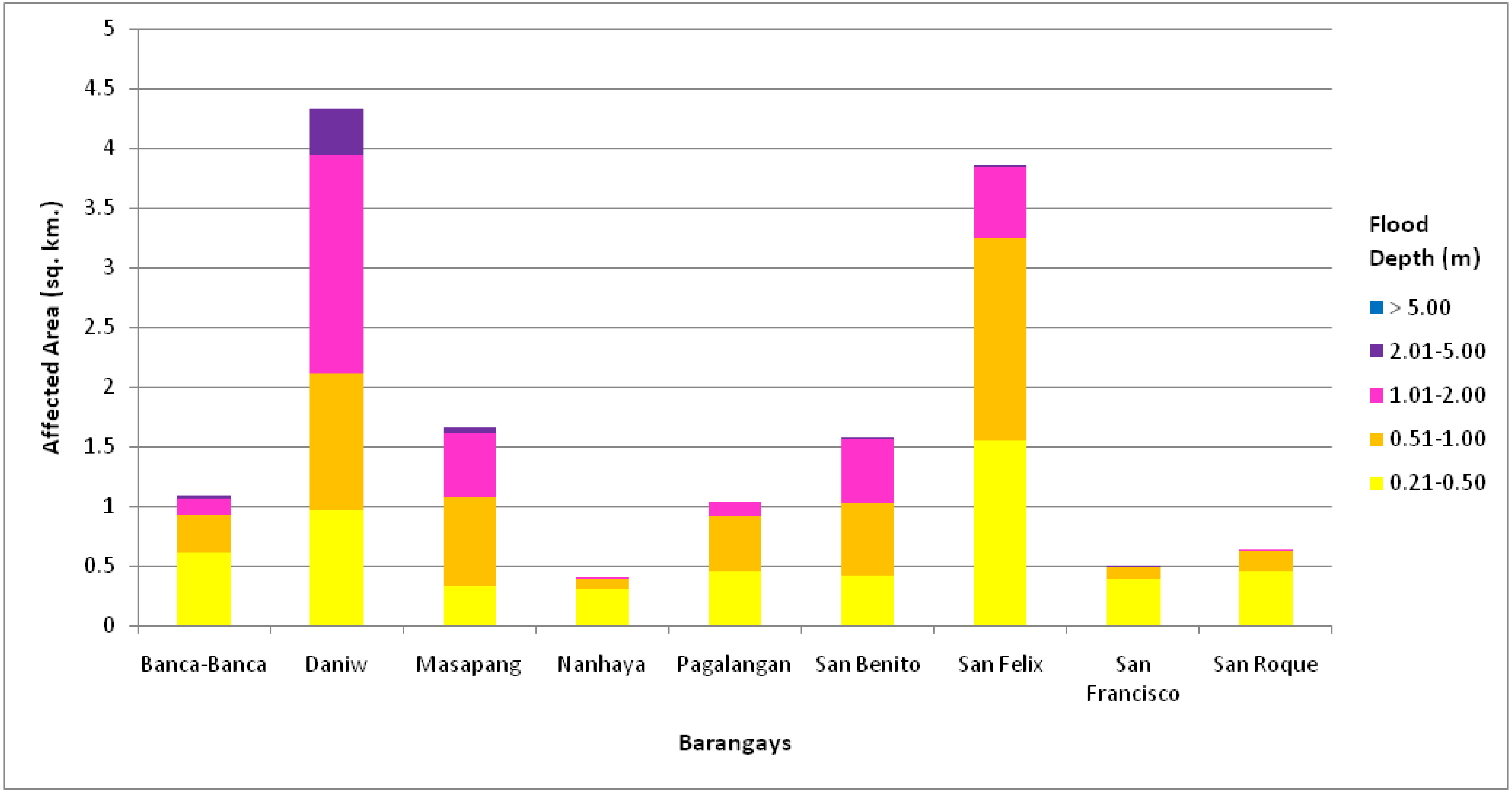

Figure 86. Affected areas in Victoria, Laguna during a 25-year rainfall return period

For the 100-Year return period, 3.86% of the municipality of Calauan with an area of 79.44 sq km will experience flood levels of less 0.20 meters; 0.84% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 76 depicts the areas affected in Calauan in square kilometers by flood depth per barangay.

Table 72. 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

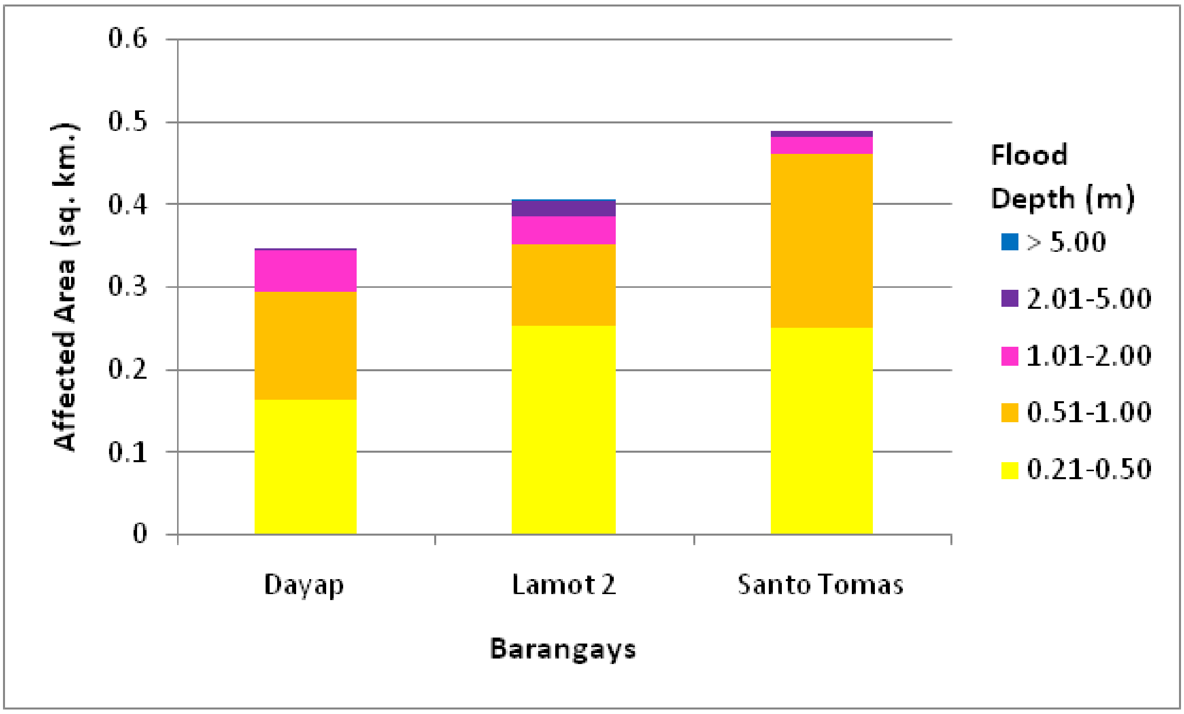

Figure 87. Affected areas in Calauan, Laguna during a 100-year rainfall return period

For the municipality of Cavinti, with an area of 96.78 sq km, 0.90% will experience flood levels of less 0.20 meters; 0.04% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 77 depicts the affected areas in square kilometers by flood depth per barangay.

Table 73. 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	0.44	0.43	0.0026
0.21-0.50	0.014	0.014	0
0.51-1.00	0.0079	0.0049	0
1.01-2.00	0.0019	0.0033	0
2.01-5.00	0.0015	0.0026	0
> 5.00	0	0.0002	0

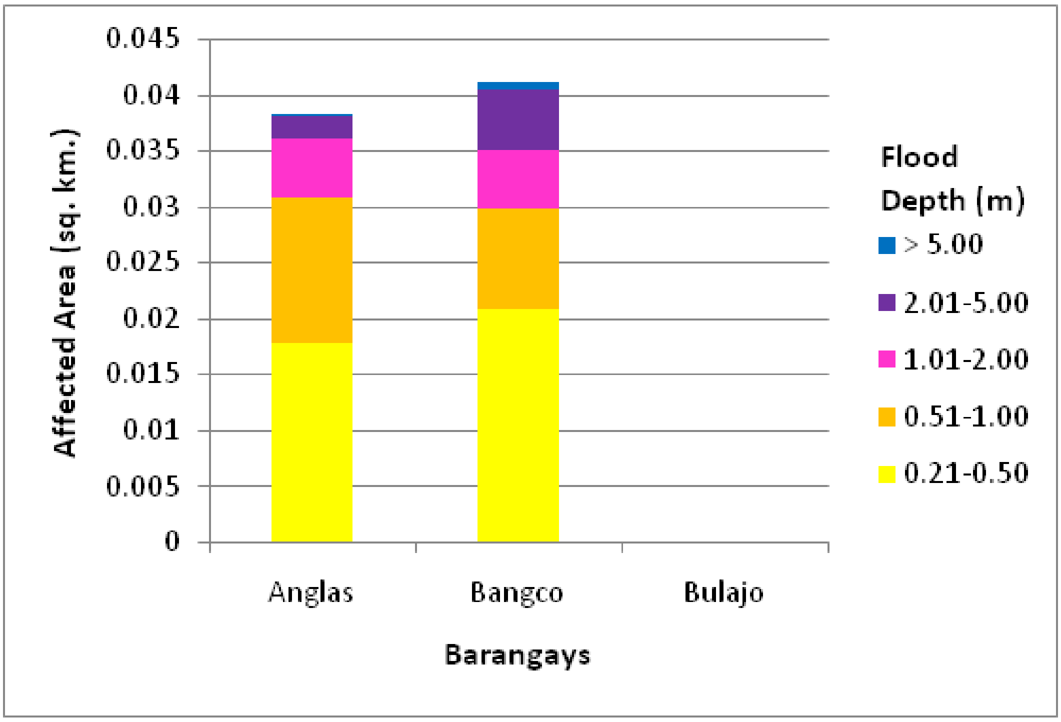

Figure 88. Affected areas in Cavinti, Laguna during a 100-year rainfall return period

For the municipality of Laguna Lake, with an area of 892.20 sq km, 0.03% will experience flood levels of less 0.20 meters; 0.02% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 78 depicts the affected areas in square kilometers by flood depth per barangay.

Table 74. 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

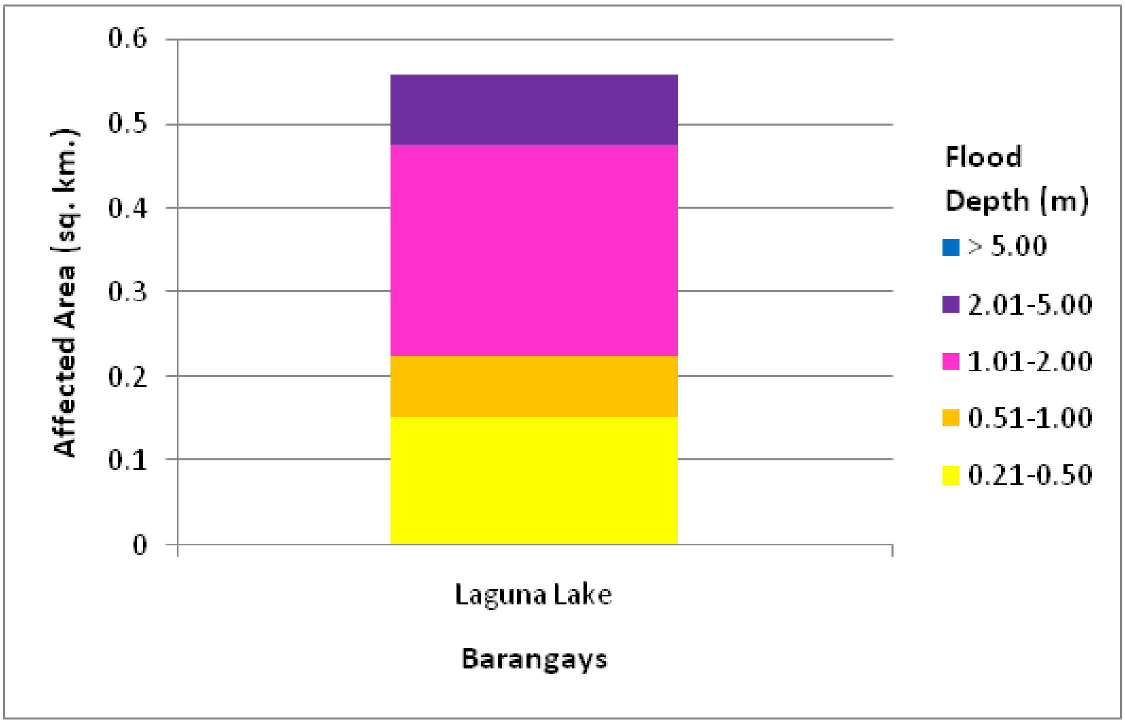

Figure 89. Affected areas in Laguna Lake, Laguna during a 100-year rainfall return period

For the municipality of Liliw, with an area of 36.20 sq km, 1.47% will experience flood levels of less 0.20 meters; 0.12% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 79 depicts the affected areas in square kilometers by flood depth per barangay.

Table 75. Affected areas in Liliw, Laguna during a 100-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	0.054	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

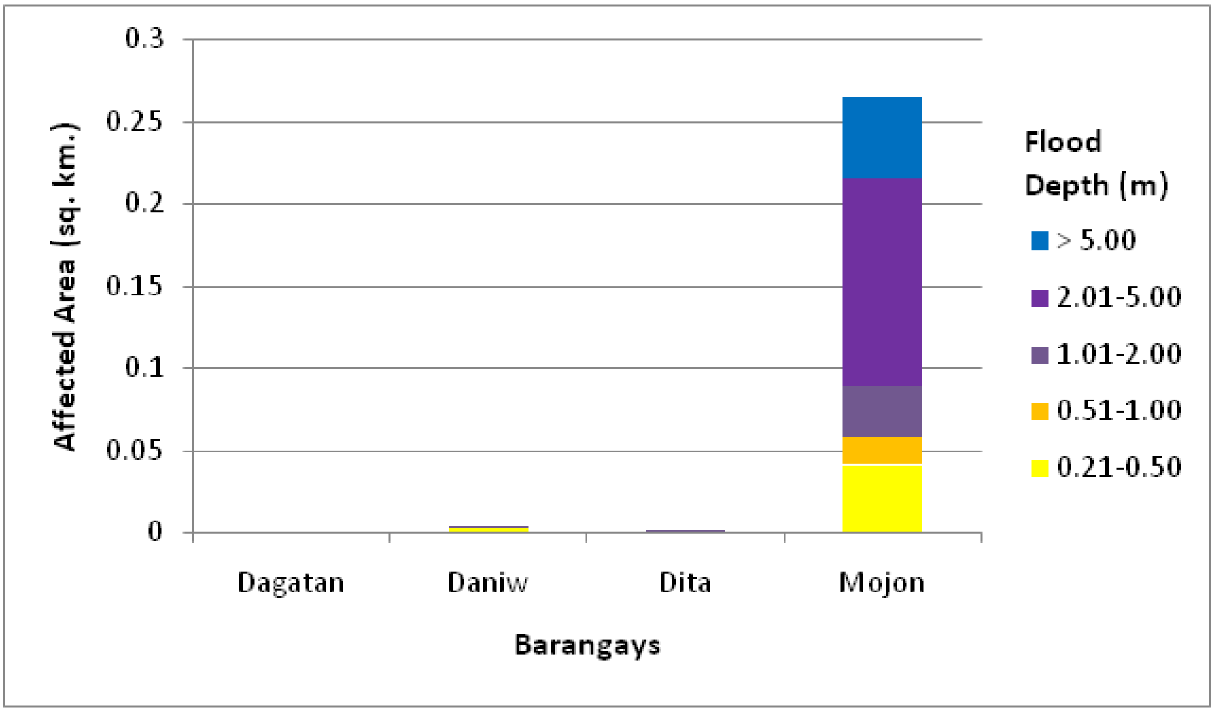

Figure 90. Affected areas in Liliw, Laguna during a 100-year rainfall return period

For the municipality of Luisiana, with an area of 61.01 sq km, 4.50% will experience flood levels of less 0.20 meters; 0.11% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 80 depicts the affected areas in square kilometers by flood depth per barangay.

Table 76. Affected areas in Luisiana, Laguna during a 100-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	2.75
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

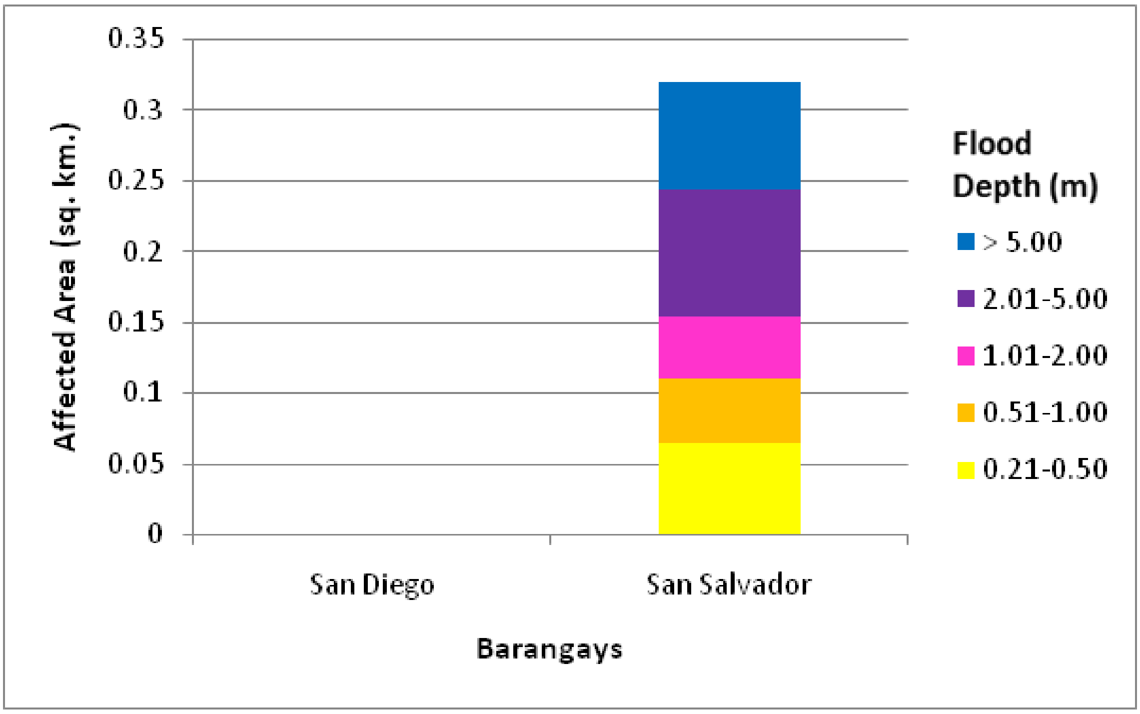

Figure 91. Affected areas in Luisiana, Laguna during a 100-year rainfall return period

For the municipality of Lumban, with an area of 117.34 sq km, 8.81% will experience flood levels of less 0.20 meters; 3.50% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 81 and Table 82 depict the affected areas in square kilometers by flood depth per barangay.

Table 77. 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

Table 78. 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							
	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

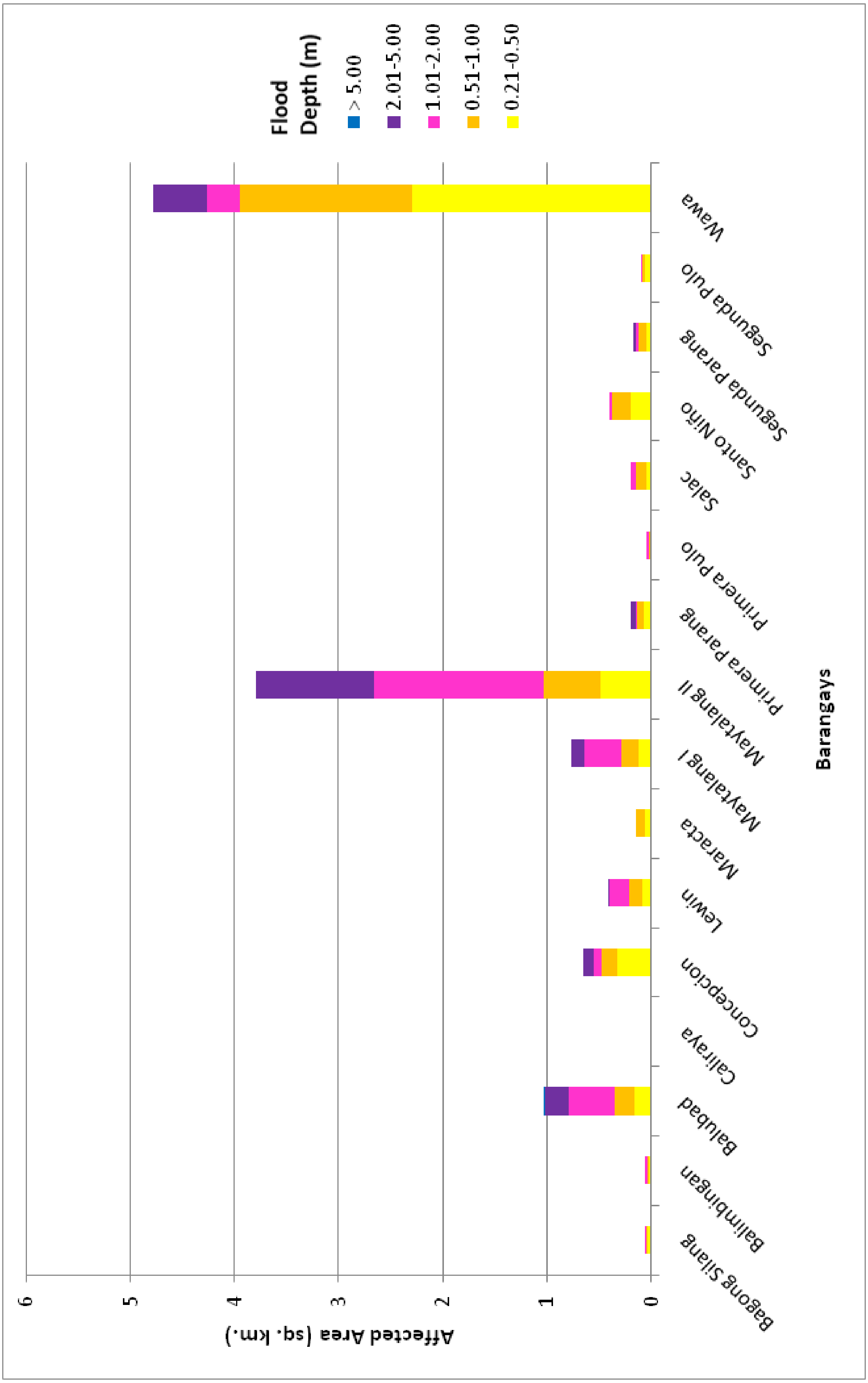

Figure 92. Affected areas in Lumban, Laguna during a 100-year rainfall return period

For the municipality of Magdalena, with an area of 29.61 sq km, 52.26% will experience flood levels of less 0.20 meters; 9.97% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 83 to Table 85 depict the affected areas in square kilometers by flood depth per barangay.

Table 79. 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

Table 80. 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							
	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

Table 81. 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							
	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

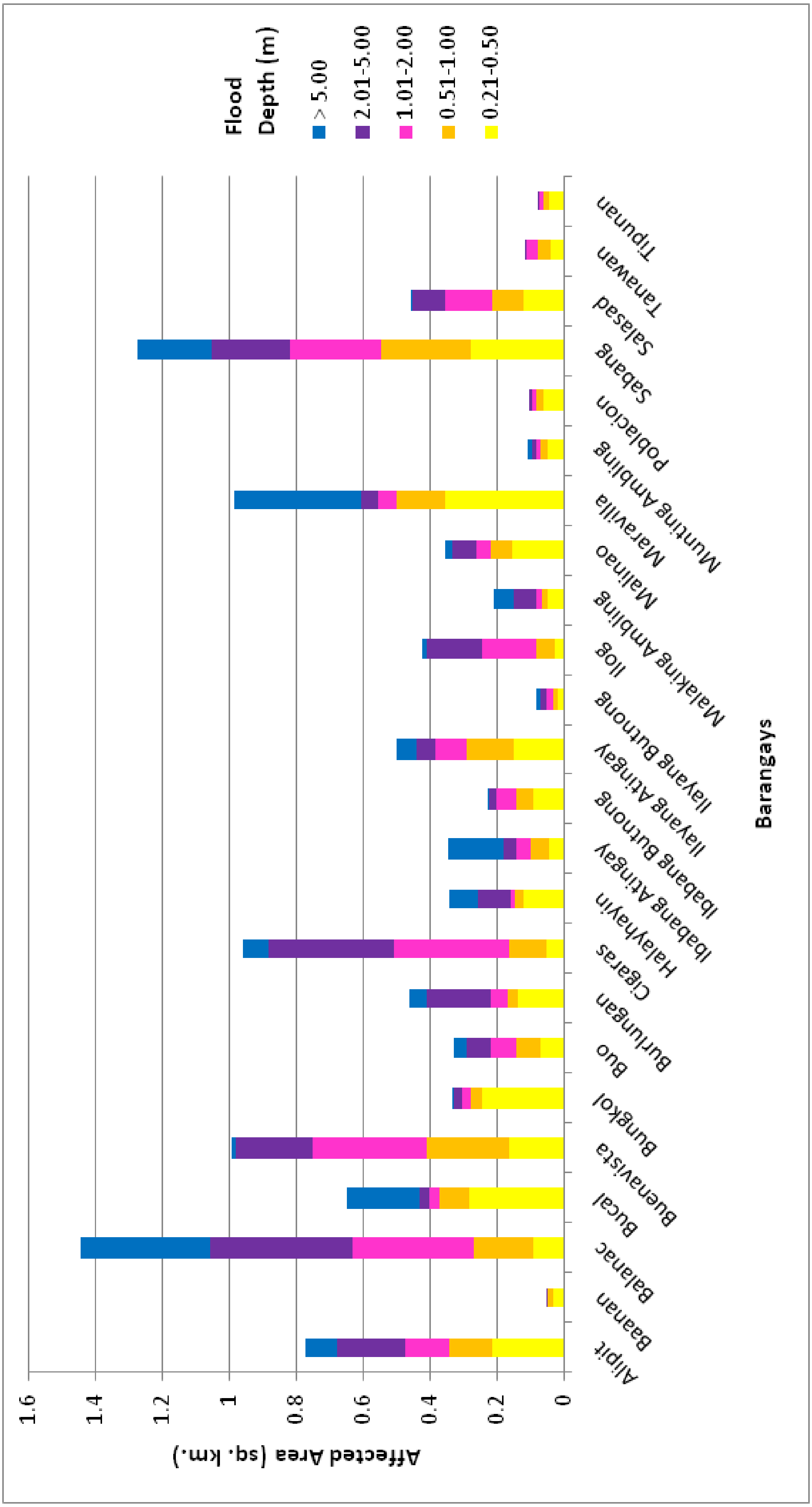

Figure 93. Affected areas in Magdalena, Laguna during a 100-year rainfall return period

For the municipality of Majayjay, with an area of 64.40 sq km, 5.09% will experience flood levels of less 0.20 meters; 0.36% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 86 depicts the affected areas in square kilometers by flood depth per barangay.

Table 82. Affected areas in Majayjay, Laguna during a 100-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	0.081	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

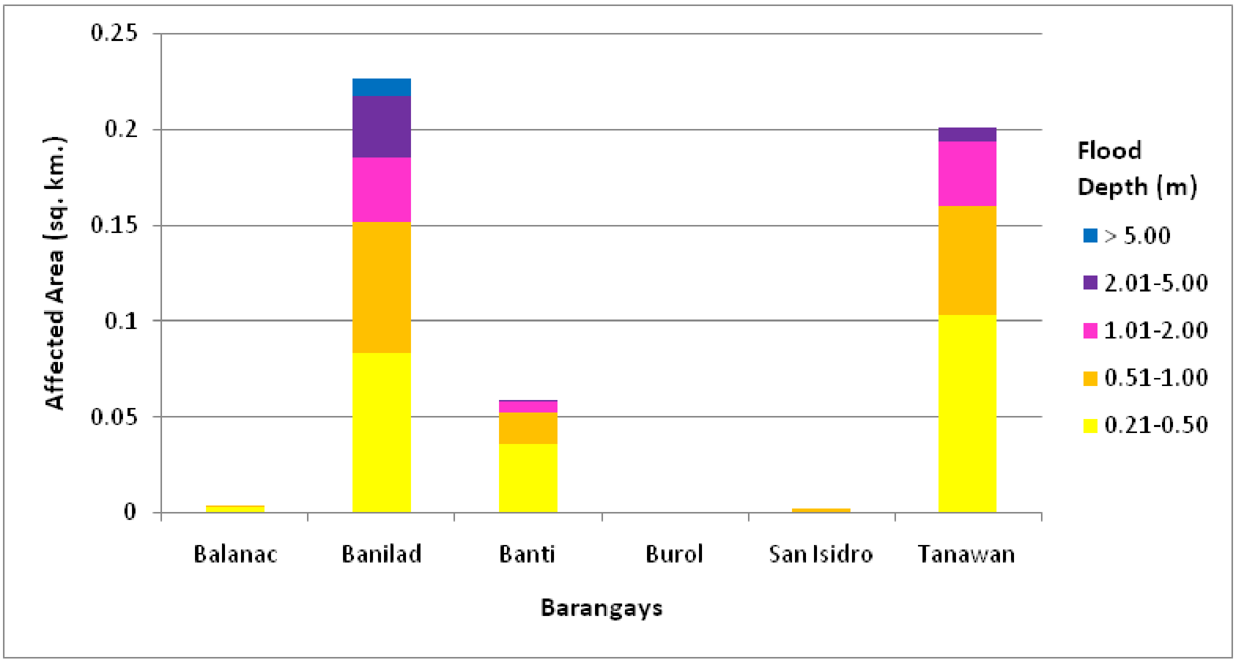

Figure 94. Affected areas in Majayjay, Laguna during a 100-year rainfall return period

For the municipality of Nagcarlan, with an area of 81.20 sq km, 22.65% will experience flood levels of less 0.20 meters; 3.90% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 87 and Table 88 depict the affected areas in square kilometers by flood depth per barangay.

Table 83. Affected areas in Nagcarlan, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nagcarlan							
	Balayong	Banca-Banca	Bayaquitos	Buenavista	Buhanginan	Calumpang	Kanluran Kabubuhayan	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

Table 84. Affected areas in Nagcarlan, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nagcarlan							
	Lagulo	Lawaguin	Manaol	Maravilla	Sabang	Sibulan	Silangan Kabubuhayan	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

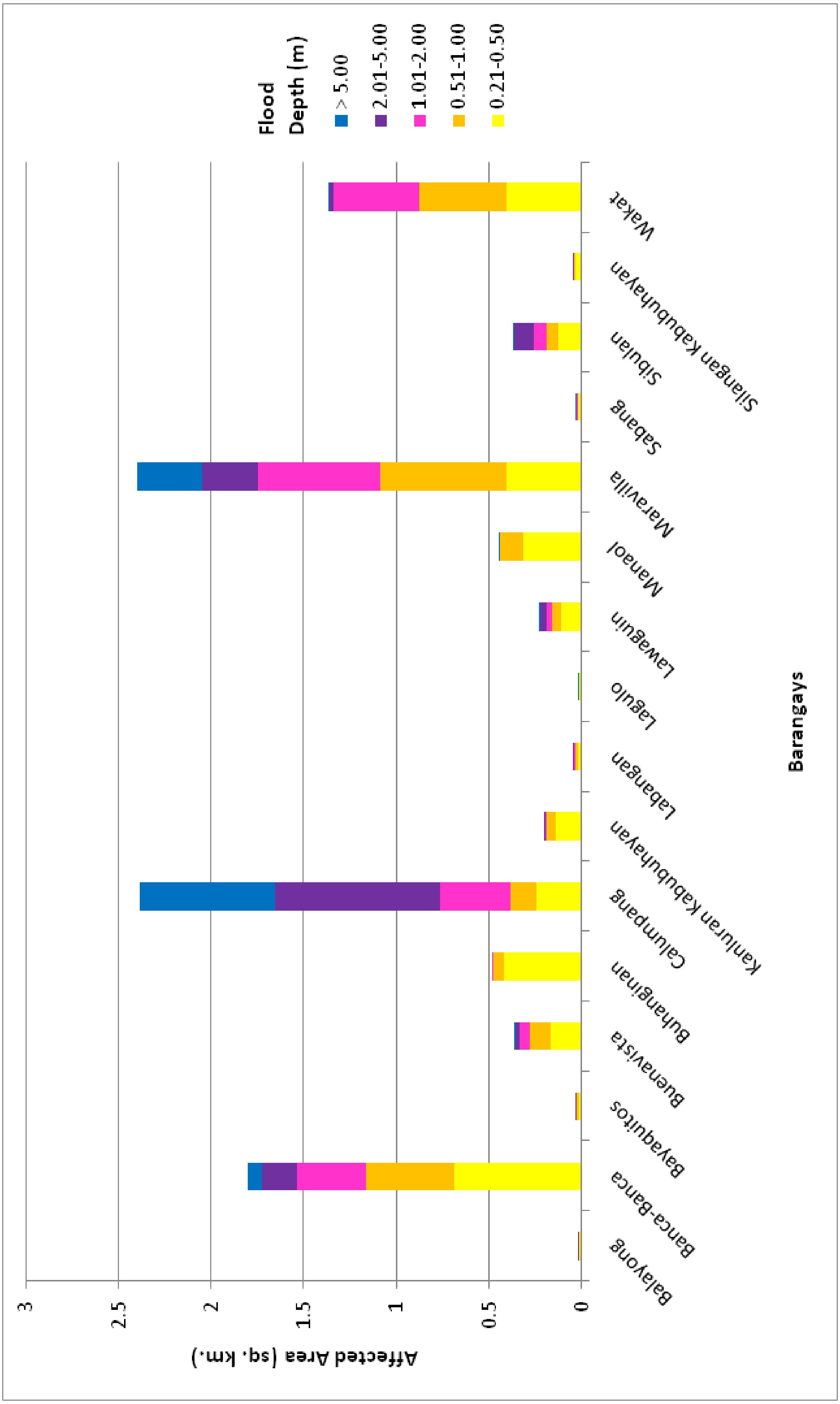

Figure 95. Affected areas in Nagcarlan, Laguna during a 100-year rainfall return period

For the municipality of Pagsanjan, with an area of 40.77 sq km, 37.38% will experience flood levels of less 0.20 meters; 5.57% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 89 and Table 90 depict the affected areas in square kilometers by flood depth per barangay.

Table 85. 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

Table 86. 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							
	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

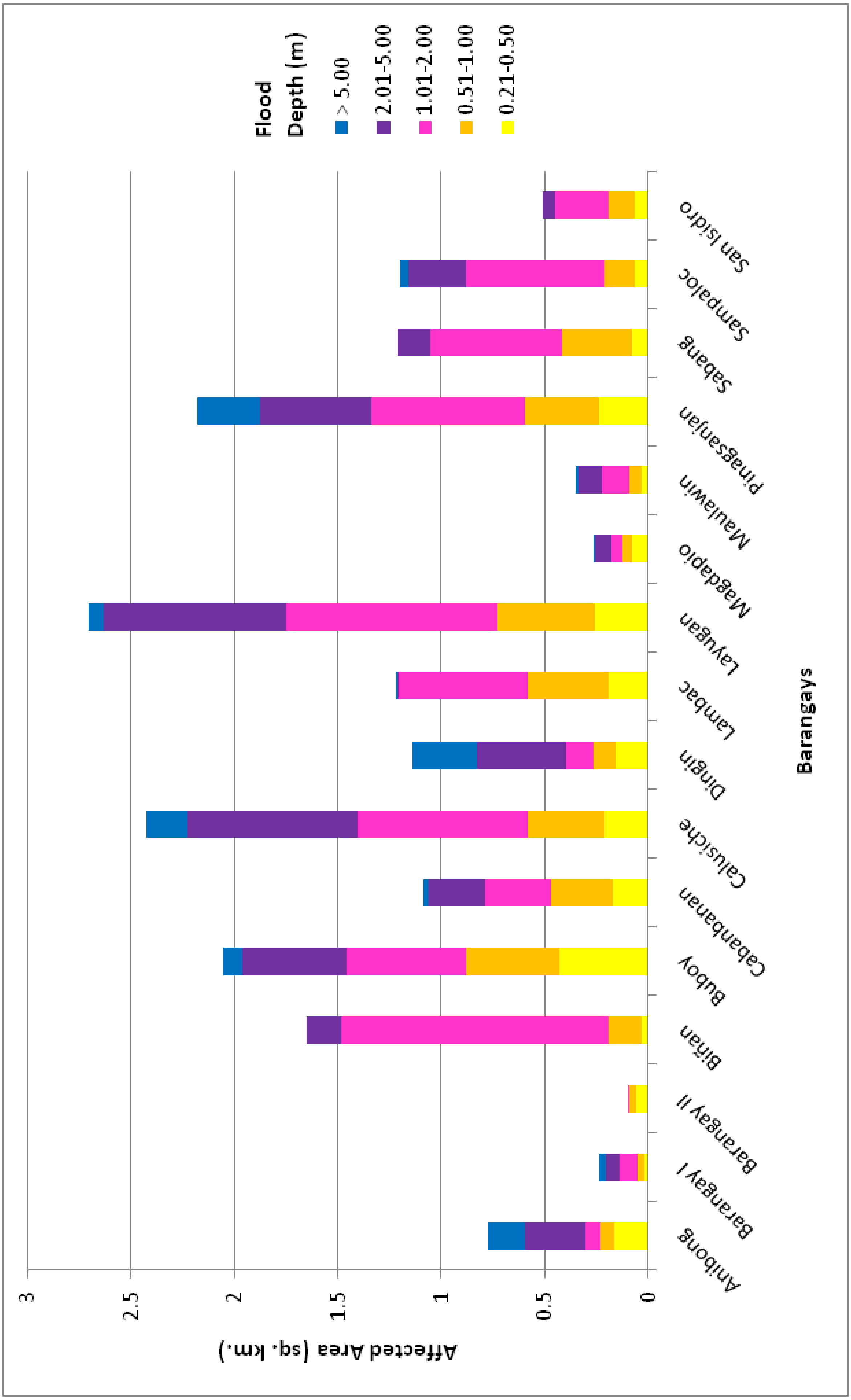

Figure 96. Affected areas in Pagsanjan, Laguna during a 100-year rainfall return period

For the municipality of Pila, with an area of 28.77 sq km, 52.20% will experience flood levels of less 0.20 meters; 22.48% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 91 and Table 92 depict the affected areas in square kilometers by flood depth per barangay.

Table 87. 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

Table 88. 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								
	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

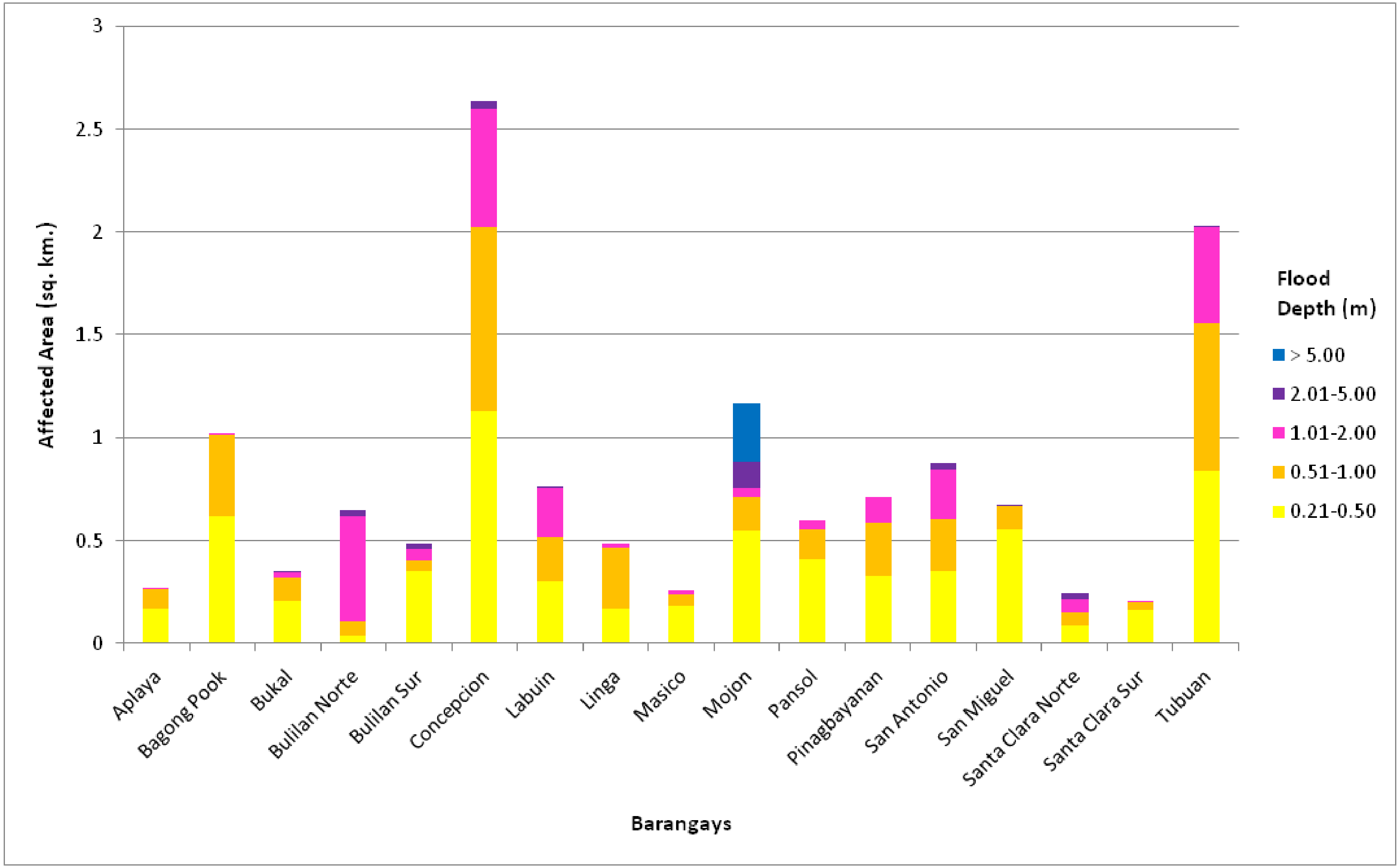

Figure 97. Affected areas in Pila, Laguna during a 100-year rainfall return period

For the municipality of Sta. Cruz, with an area of 37.63 sq km, 36.71% will experience flood levels of less 0.20 meters; 29.70% of the area will experience flood levels of 0.21 to 0.50 meters; while 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 93 to Table 95 depict the affected areas in square kilometers by flood depth per barangay.

Table 89. Affected areas in Sta. Cruz, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz								
	Alipit	Bagumbayan	Barangay 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

Table 90. Affected areas in Sta. Cruz, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Cruz								
	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

Table 91. Affected areas in Sta. Cruz, Laguna during a 100-year rainfall return period

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	1.32	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

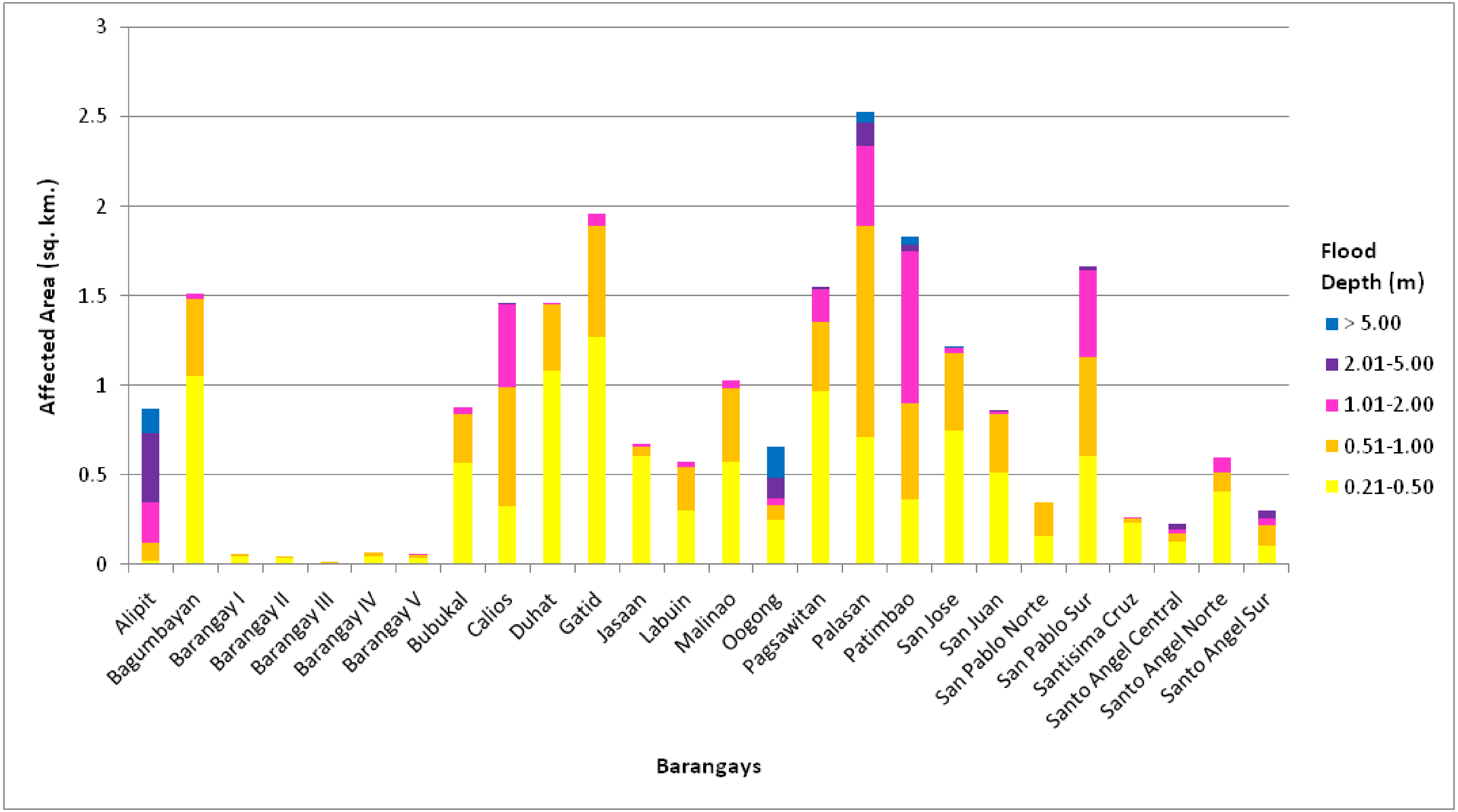

Figure 98. Affected areas in Sta. Cruz, Laguna during a 100-year rainfall return period

For the municipality of Victoria, with an area of 28.37 sq km, 26.70% will experience flood levels of less 0.20 meters; 17.56% of the area will experience flood levels of 0.21

to 0.50 meters; while 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 96 depicts the affected areas in square kilometers by flood depth per barangay.

Table 92. Affected areas in Victoria, Laguna during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Victoria								
	Banca-Banca	Daniw	Masapang	Nanhaya	Pagalangan	San Benito	San Felix	San Francisco	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

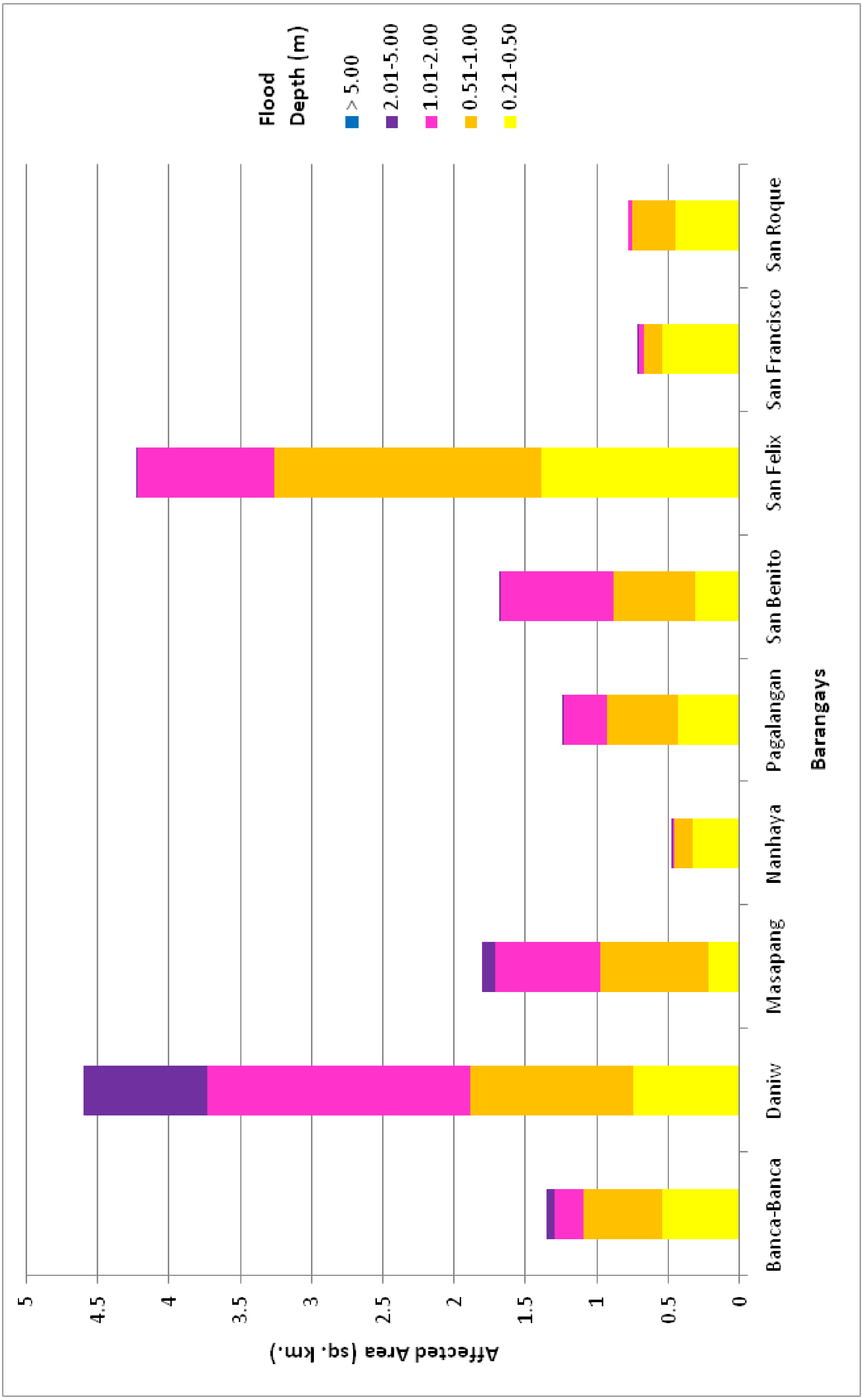

Figure 99. Affected areas in Victoria, Laguna during a 100-year rainfall return period

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the flood depth maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 102.

The flood validation consists of 270 points randomly selected all over the Sta. Cruz Floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.27 m. Table 103 shows a contingency matrix of the comparison.

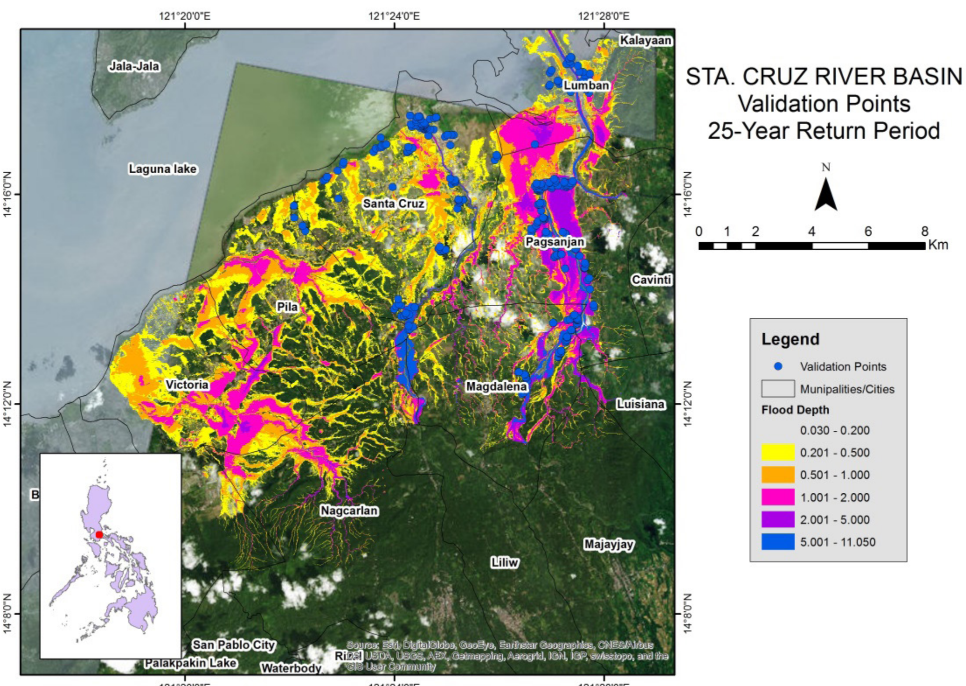

Figure 100. Validation points for 25-year flood depth map of Sta. Cruz Floodplain

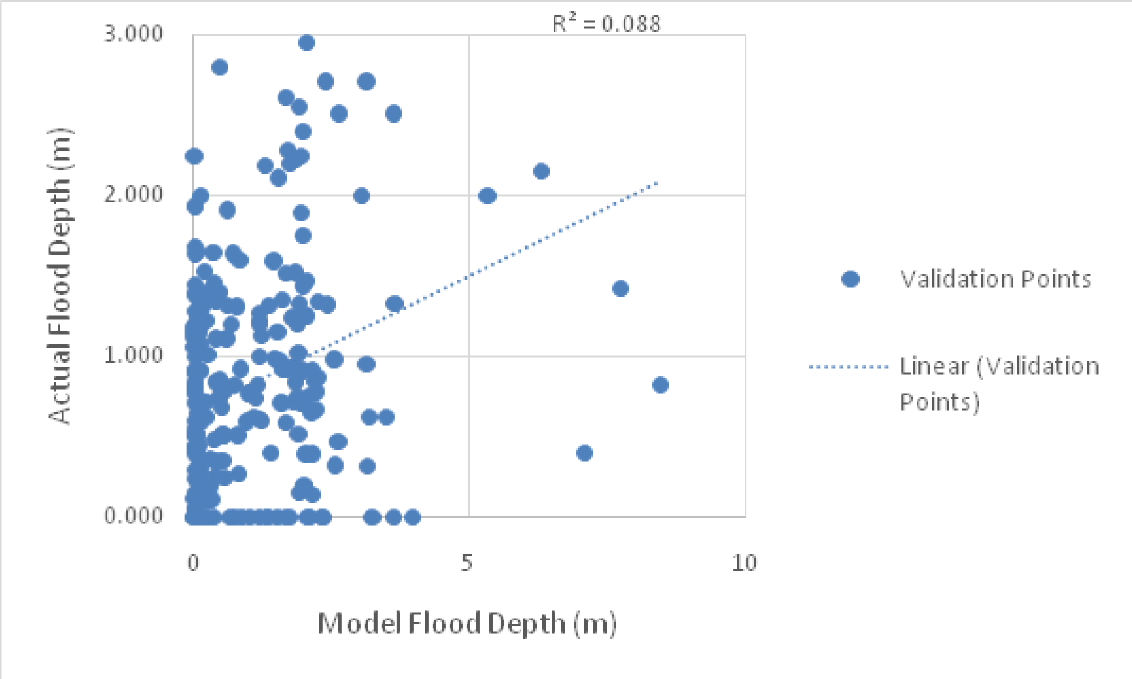

Figure 101. Flood map depth vs. actual flood depth

Table 93. Actual flood depth vs. simulated flood depth at different levels in the Sta. Cruz River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	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 77 points correctly matching the actual flood depths. In addition, there were 79 points estimated one level above and below the correct flood depths while there were 52 points and 55 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 112 points were underestimated in the modeled flood depths of Sta. Cruz. Table 98 depicts the summary of the accuracy assessment in the Sta. Cruz River Basin survey.

Table 94. Summary of accuracy assessment in the Sta. Cruz River Basin survey

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

REFERENCES

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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. OPTECH Technical Specification of the Pegasus Sensor

Table A-1.1. Parameters and Specifications of Pegasus Sensor

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

Annex 2. NAMRIA Certificates 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**

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

9 9 0 2 0 4 2 0 1 4 1 2 5 9 5 8

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

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

Figure A-2.1. 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**	
Island: **LUZON**	Order: **2nd**	Barangay: **POBLACION**
Municipality: **MAGDALENA**		
	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

9902132014164547

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

Annex 3. Baseline Processing Reports of Reference Points Used in the LiDAR Survey

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-20D				
Grid		Local		Global	
Easting	309932.197 m	Latitude	N14°09'53.95582"	Latitude	N14°09'48.65929"
Northing	1566591.667 m	Longitude	E121°14'20.28364"	Longitude	E121°14'25.21352"
Elevation	39.990 m	Height	39.929 m	Height	85.281 m

Vector					
ΔEasting	-2.025 m	NS Fwd Azimuth	322°27'32"	ΔX	2.079 m
ΔNorthing	2.677 m	Ellipsoid Dist.	3.356 m	ΔY	0.516 m
ΔElevation	0.015 m	ΔHeight	0.015 m	ΔZ	2.584 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'26"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000004804		
Y	-0.0000002580	0.0000005806	
Z	-0.0000000914	0.0000001643	0.0000001374

2

Figure A-3.1. LAG-20A

2. LAG-4415

Vector Components (Mark to Mark)

From:	LAG-52				
Grid		Local		Global	
Easting	330382.058 m	Latitude	N14°12'04.82694"	Latitude	N14°11'59.53729"
Northing	1570467.908 m	Longitude	E121°25'41.32678"	Longitude	E121°25'46.25249"
Elevation	65.133 m	Height	65.331 m	Height	111.043 m

To:	LAG-4415				
Grid		Local		Global	
Easting	330313.757 m	Latitude	N14°12'05.34595"	Latitude	N14°12'00.05622"
Northing	1570484.318 m	Longitude	E121°25'39.04510"	Longitude	E121°25'43.97080"
Elevation	64.925 m	Height	65.122 m	Height	110.832 m

Vector					
ΔEasting	-68.301 m	NS Fwd Azimuth	283°07'26"	ΔX	60.523 m
ΔNorthing	16.410 m	Ellipsoid Dist.	70.248 m	ΔY	32.161 m
ΔElevation	-0.208 m	ΔHeight	-0.209 m	ΔZ	15.410 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'02"	σ ΔX	0.002 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.002 m
σ ΔElevation	0.003 m	σ ΔHeight	0.003 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000060248		
Y	-0.0000007218	0.0000052360	
Z	-0.0000002972	0.0000018861	0.0000013878

Figure A-3.2. LAG-4415

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-team	Designation	Name	Agency/Affiliation
Program Leader	Program Leader –I	ENRICO C. PARINGIT, D. Eng.	UP TCAGP
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. CZAR JAKIRI S. SARMIENTO	UP TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		ENGR. LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP TCAGP
	Research Associate	ENGR. LARAH PARAGAS	UP TCAGP
		PAULINE JOANNE ARCEO	UP TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	UP TCAGP
		FAITH JOY SABLE	UP TCAGP
Ground Survey, Data Download and Transfer	Research Associate	MA. VERLINA TONGA	UP TCAGP
		ENGR. KENNETH QUISADO	UP TCAGP
LiDAR Operation/ Ground Survey	Research Associate	ENGR. RENAN PUNTO	UP TCAGP
		ENGR. DAN ALDOVINO	UP TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORP (AAC)
		CAPT. RAUL SAMAR	ASIAN AEROSPACE CORP (AAC)
		CAPT. FRANCO PEPITO	ASIAN AEROSPACE CORP (AAC)
		CAPT. CAESAR ALFONSO II	ASIAN AEROSPACE CORP (AAC)

Annex 5. Data Transfer Sheet for Sta. Cruz Floodplain

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-5.1. Transfer Sheet for Sta. Cruz 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	
2014-02-10	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 [signature]

Received by

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

Figure A-5.2. Transfer Sheet for Sta. Cruz Floodplain (B)

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 [signature]

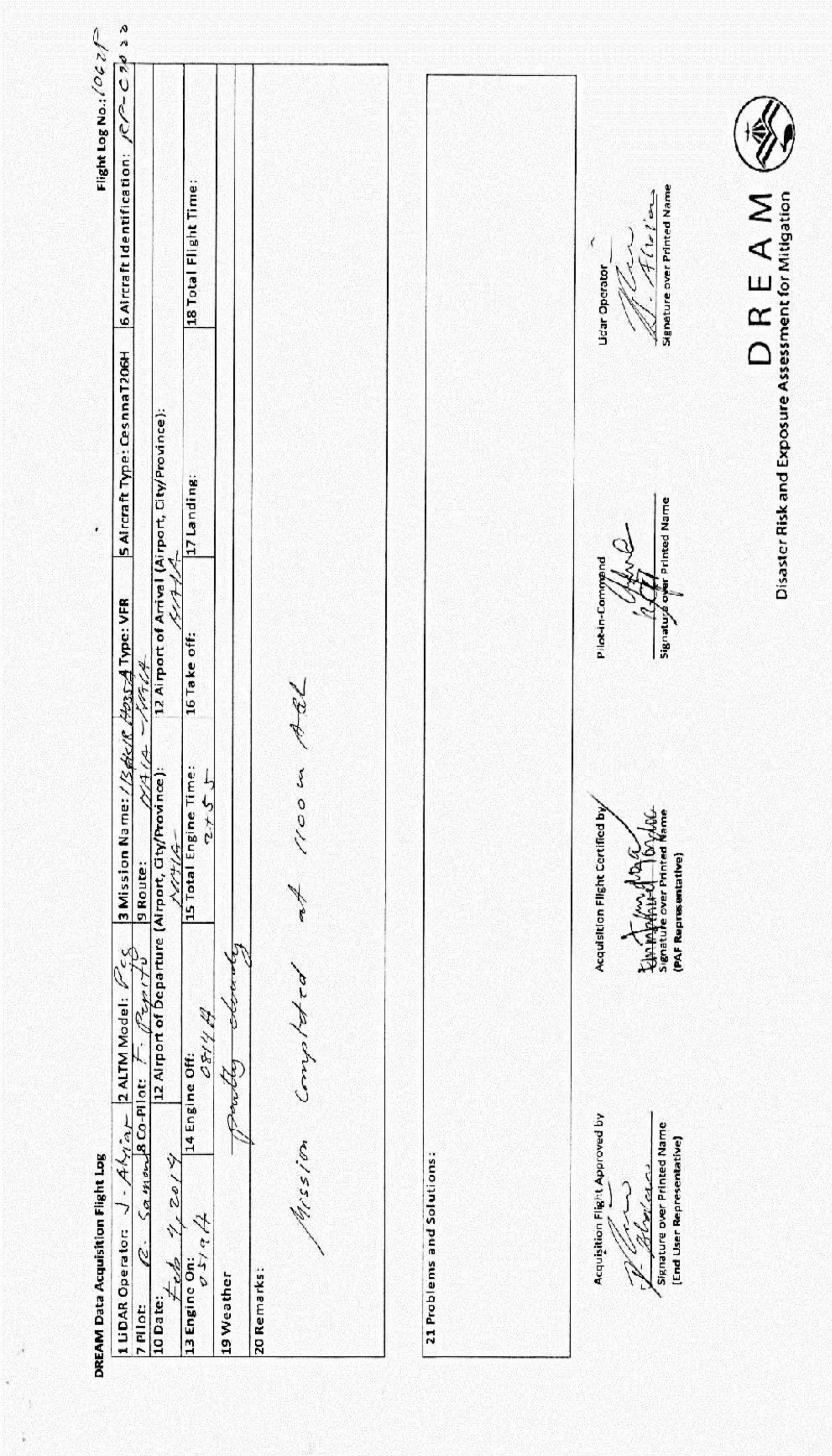
Received by

Name AC Bongat 9/11/15
Position SSRS
Signature [signature]

Figure A-5.3. Transfer Sheet for Sta. Cruz Floodplain (C)

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1067P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1067P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18Ros45A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samson	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: 0517H	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)

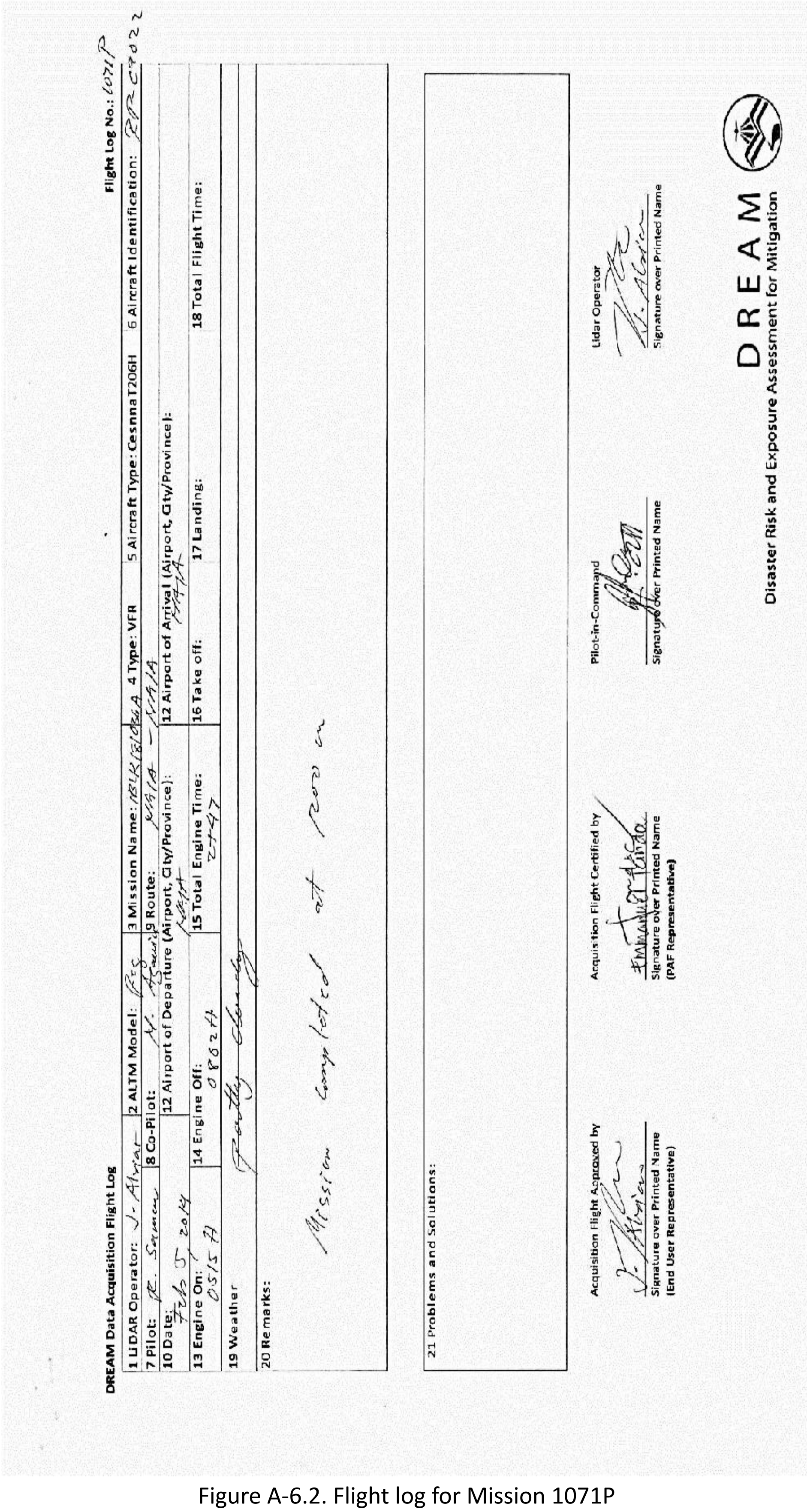
Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

DREAM Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1067P

2. Flight log for 1071P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1071P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	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. Aquino	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: 0515 H	14 Engine Off: 0802 H	15 Total Engine Time: 2+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly Cloudy				

20 Remarks:

Mission completed at [illegible]

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)

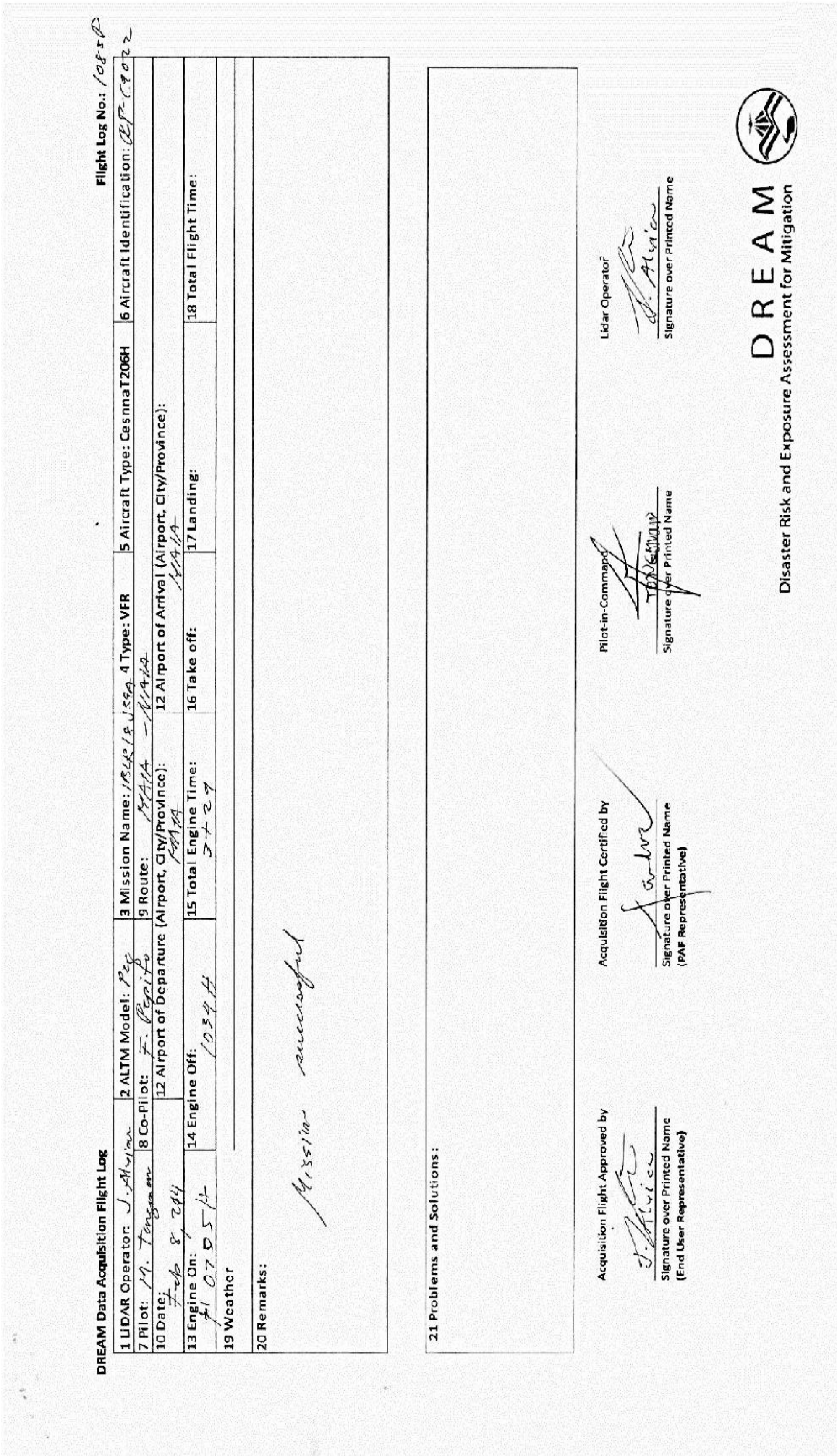
Pilot-in-Command: Signature over Printed Name

Lidar Operator: J. Alviar — Signature over Printed Name

DREAM — Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2. Flight log for Mission 1071P

3. Flight Log for 1083P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1083P

1 LIDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK18	4 Type: VFR	5 Aircraft Type: CesnnaT206H	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

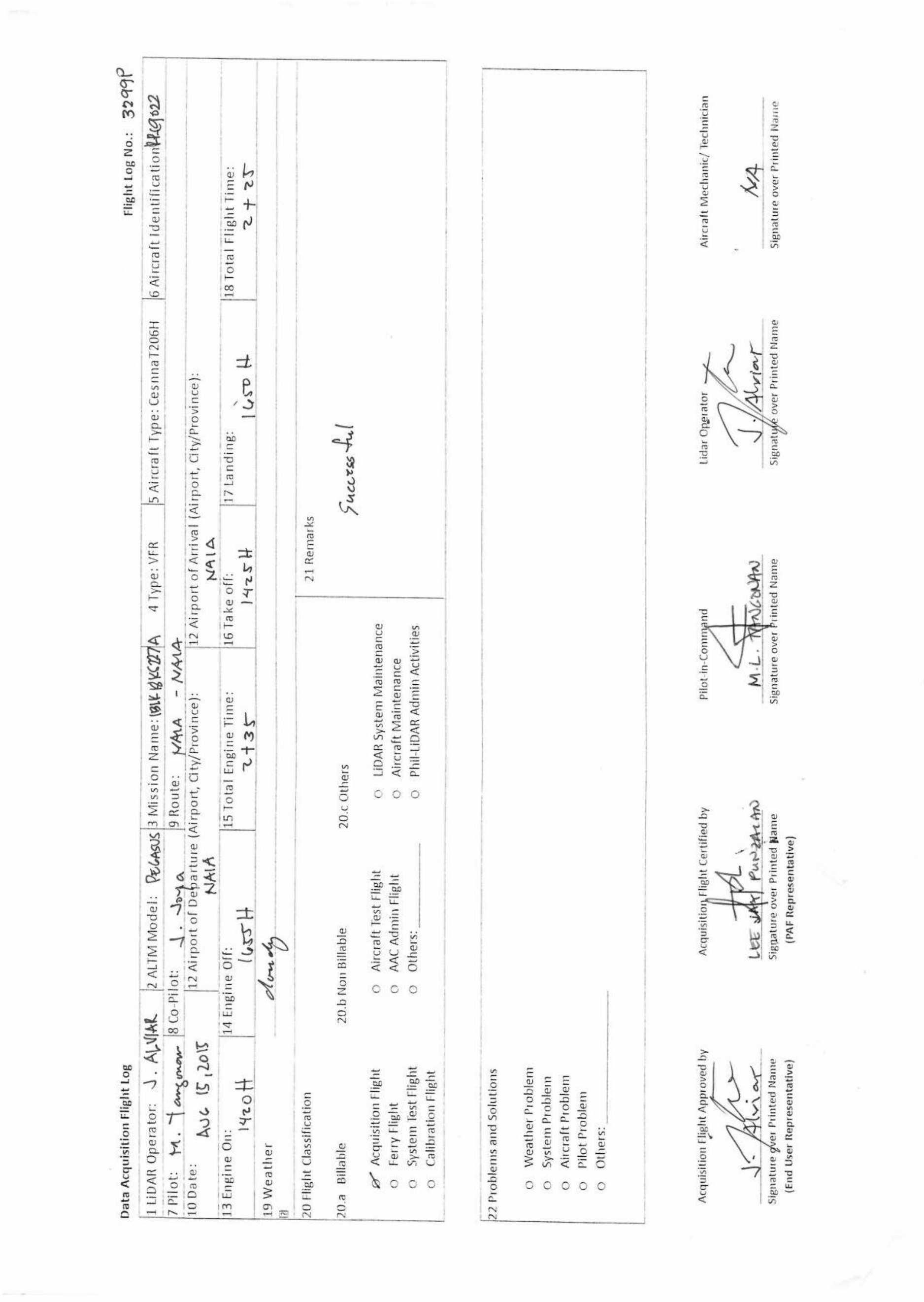
21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 1083P

4. Flight log for 3299P 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: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Joya	9 Route: NAIA - NAIA			
10 Date: AUG 15, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 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	20.b Non Billable	20.c Others
✓ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others:	○ Phil-LiDAR Admin Activities
○ Calibration Flight		

21 Remarks

Successful

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 JAY PUNZALAN	M.L. TANGONAN	J. Alviar	N/A
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-6.4. Flight log for Mission 3299P

Annex 7. Flight Status Reports

CALABARZON

(FEBRUARY 4-8, 2014 and August 15, 2015)

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1067P	BLK 18H	1BLK18H35A	J. Alviar	Feb 4 2014	Mission completed at 1100m AGL
1071P	BLK 18I	1BLK18I036A	J. Alviar	Feb 5 2014	Mission completed at 1100m AGL
1083P	BLK 18J	1BLK18J39A	J. Alviar	Feb 8 2014	Mission completed at 1100m AGL
3299P	BLK 18KS	1BLK18KS227A	J. Alviar	AUG 15 2015	4 lines, flight aborted due to bad weather Without Digitizer and Camera

LAS BOUNDARIES PER MISSION FLIGHT

Flight No. : 1067P
Area: BLK 18H
Mission Name: 1BLK18H35A
LAS

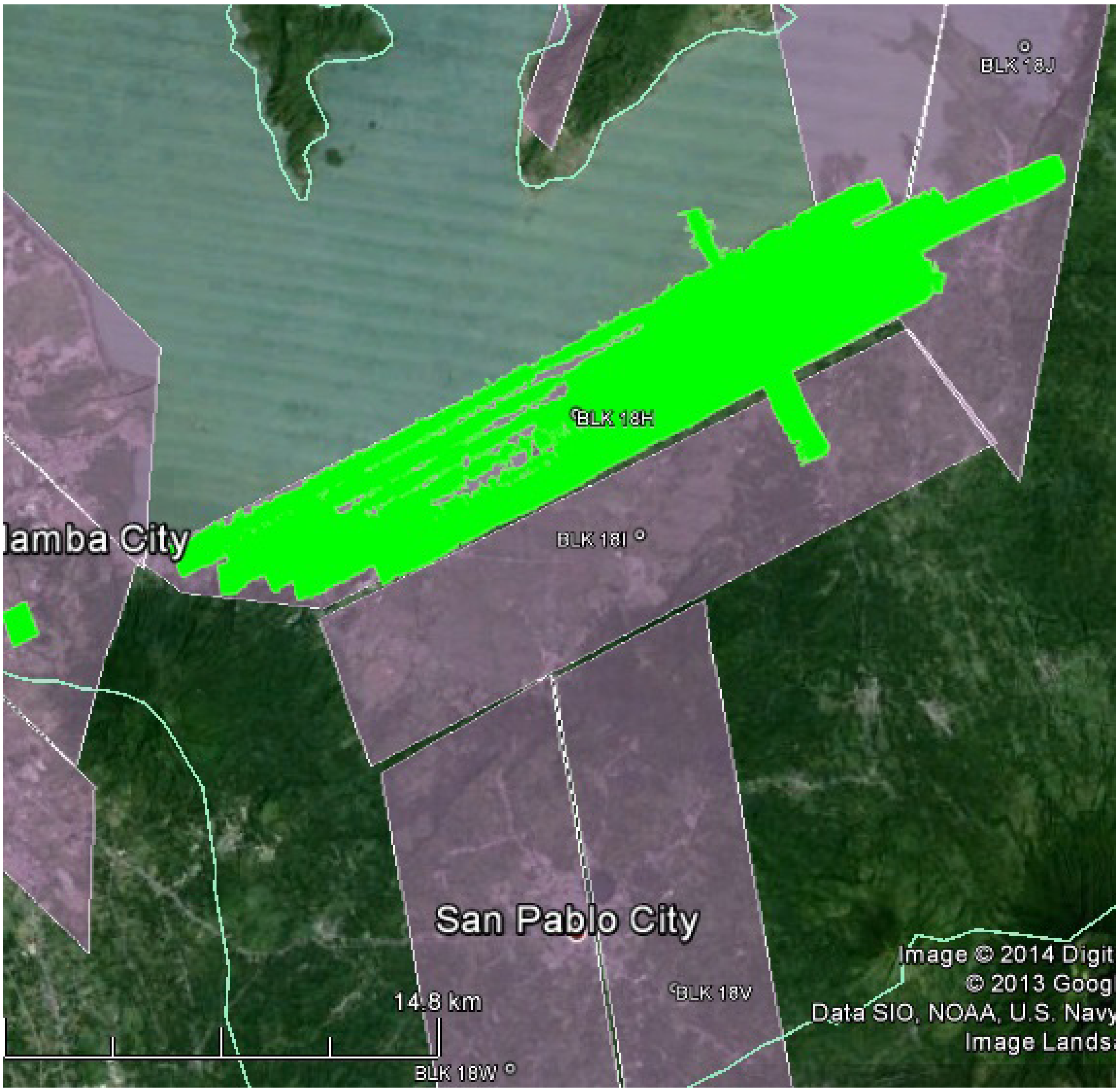


Figure A-7.1. Swath for Flight No. 1067P

Flight No. : 1071P
Area: BLK 18I
Mission Name: 1BLK18I036A
LAS

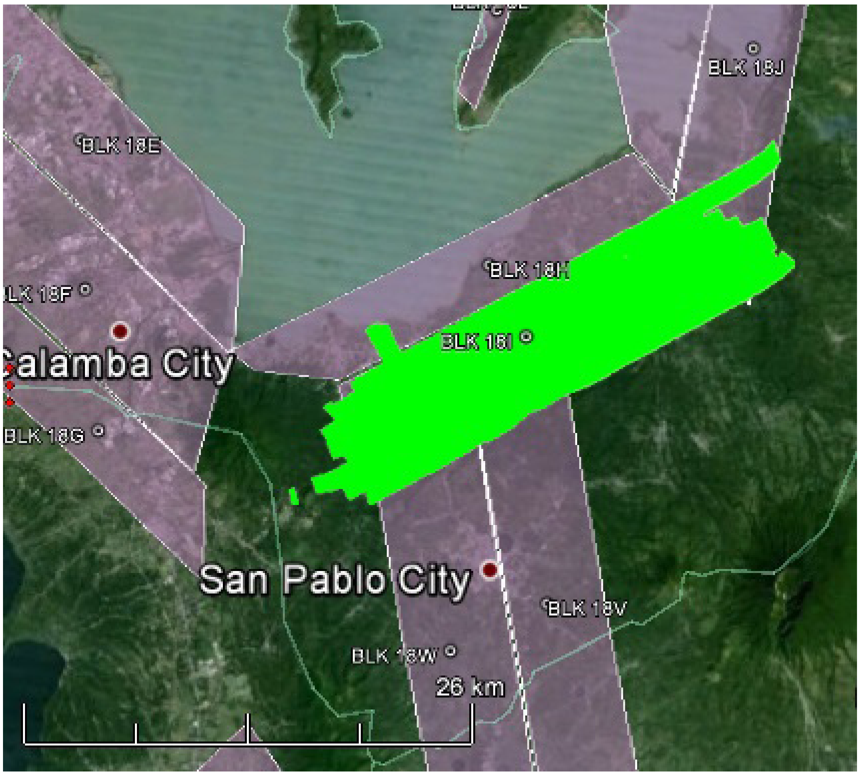


Figure A-7.2. Swath for Flight No. 1071P

Flight No. : 1083P
Area: BLK 18J
Mission Name: 1BLK18J39A

LAS

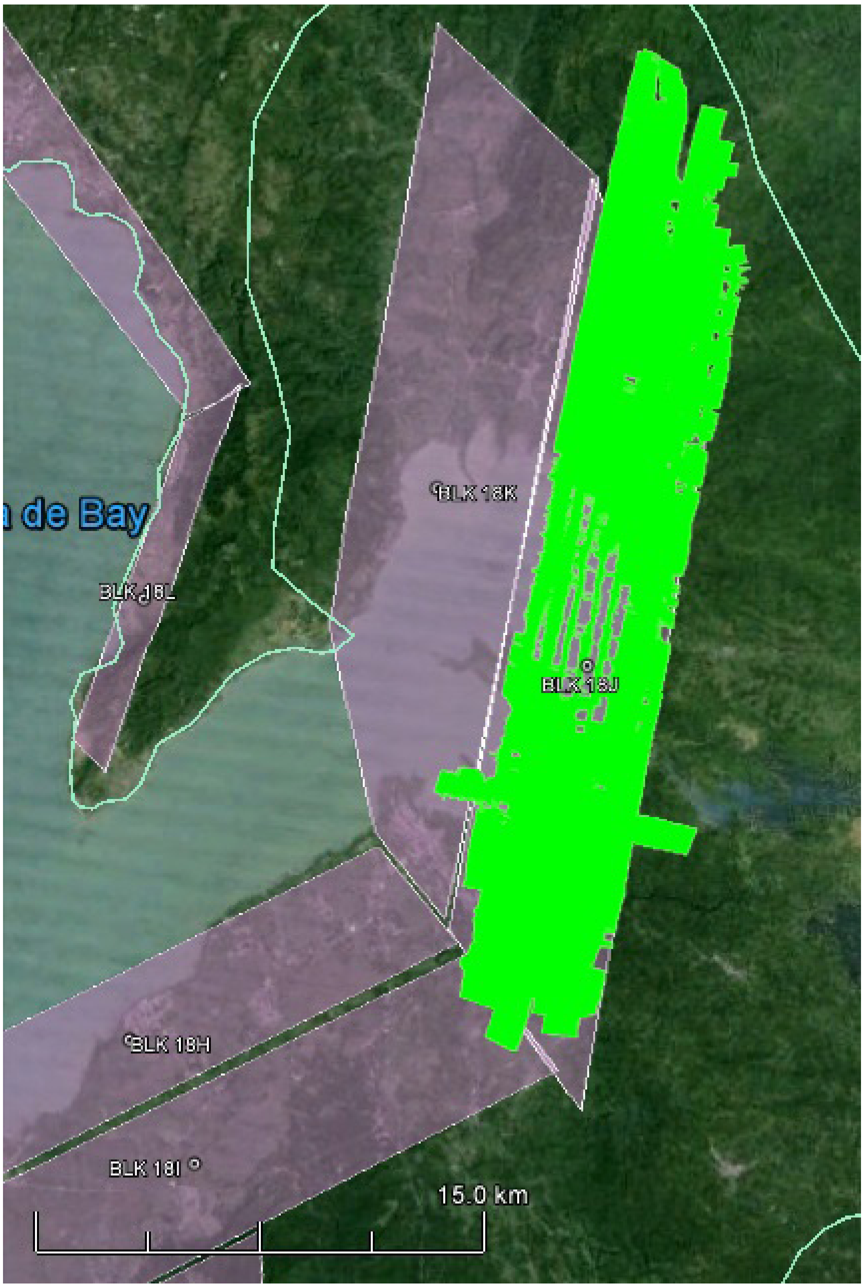


Figure A-7.3. Swath for Flight No. 1083P

FLIGHT LOG NO. 3299P
AREA: BLK 18KS
MISSION NAME: 1BLK18KS227A
PARAMETERS: Alt: 1000 Scan Freq: 25 kHz Scan Angle: 30 deg
SURVEY AREA: 88.5 km^2

LAS

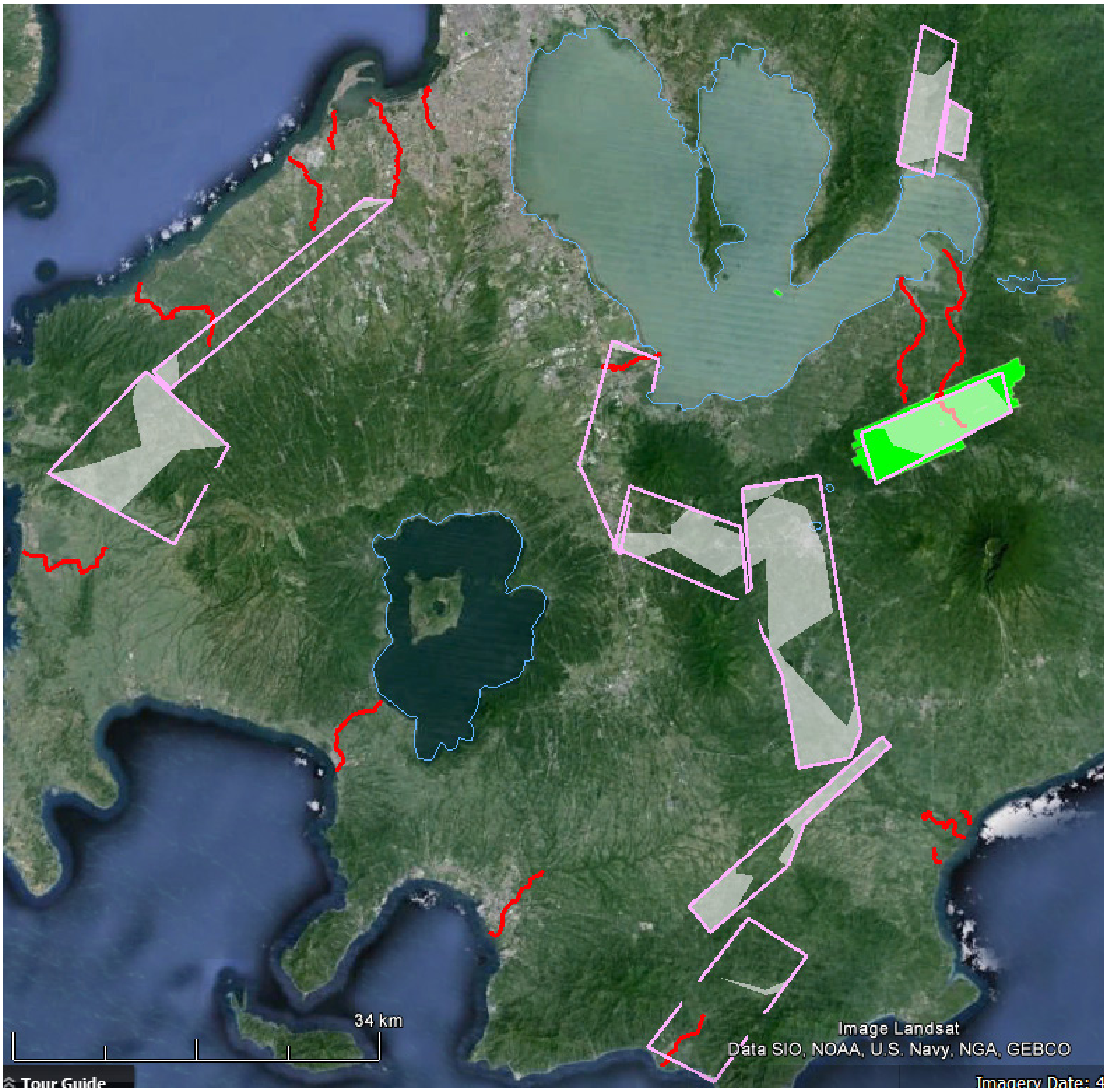


Figure A-7.4. Swath for Flight No. 3299P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk18I_supplement

Flight Area	**CALABARZON**
Mission Name	**Blk18I_supplement**
Inclusive Flights	3299P, 3377P
Range data size	23.8 GB
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 Anne Narisma

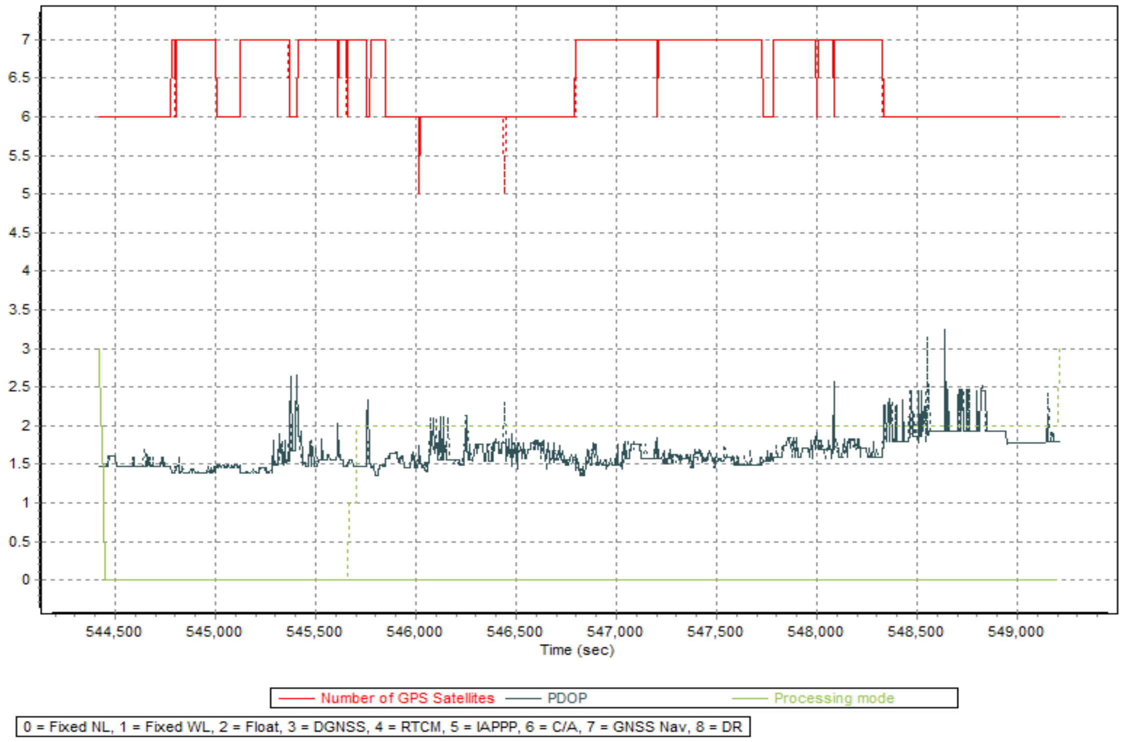


Figure 1.1.1. Solution Status

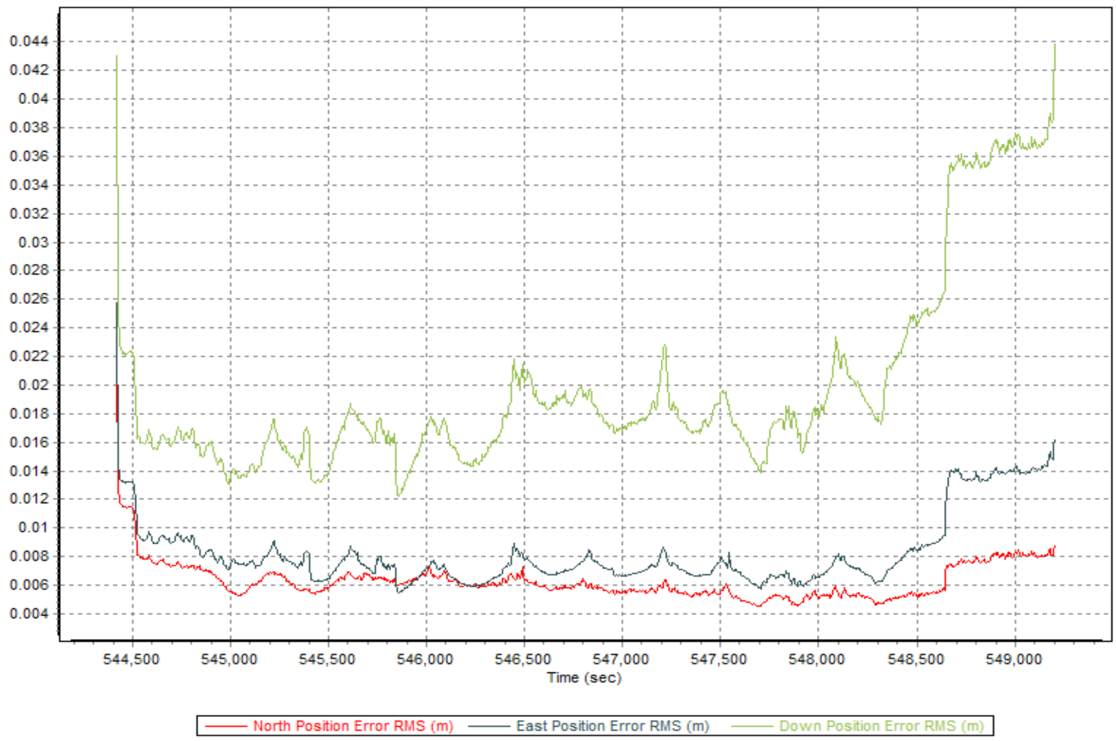


Figure 1.1.2. Smoothed Performance Metrics Parameters

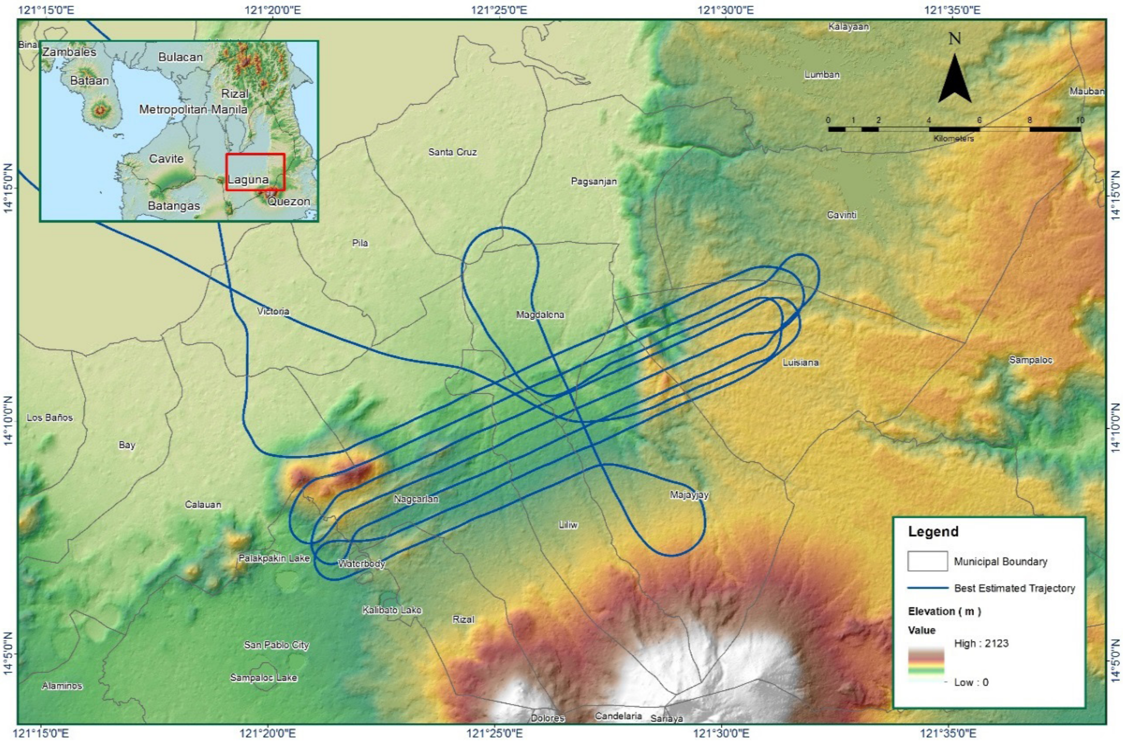


Figure 1.1.3. Best Estimated Trajectory

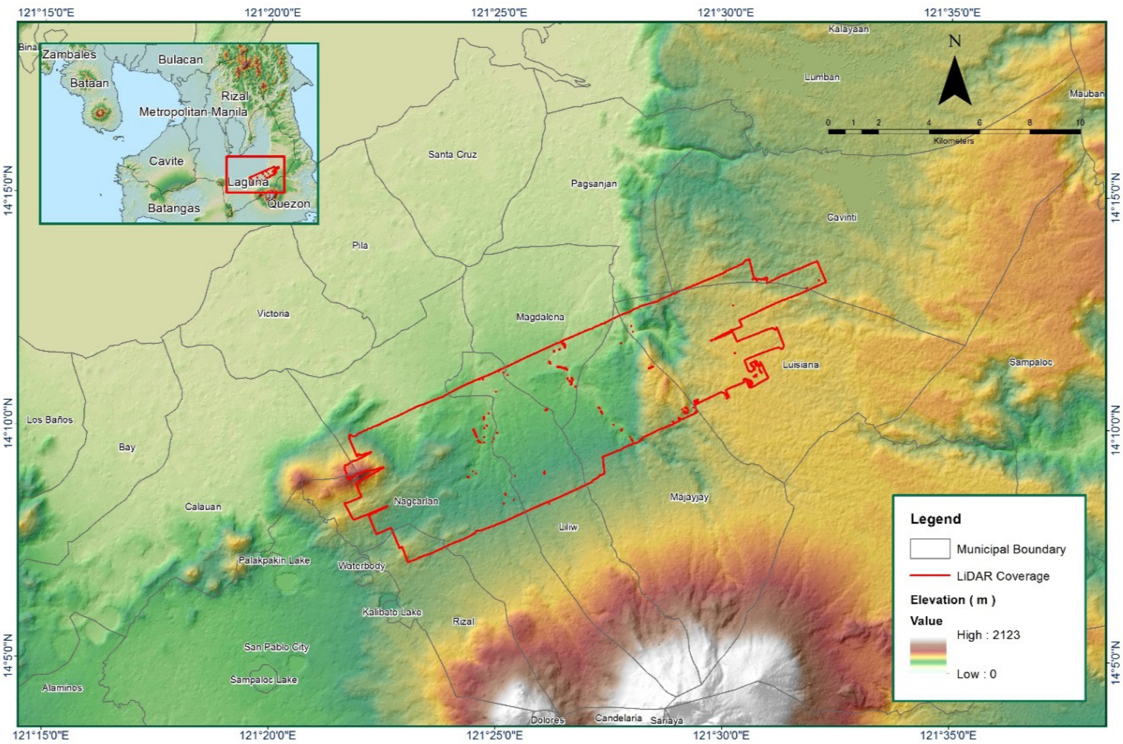


Figure 1.1.4. Coverage of LiDAR data

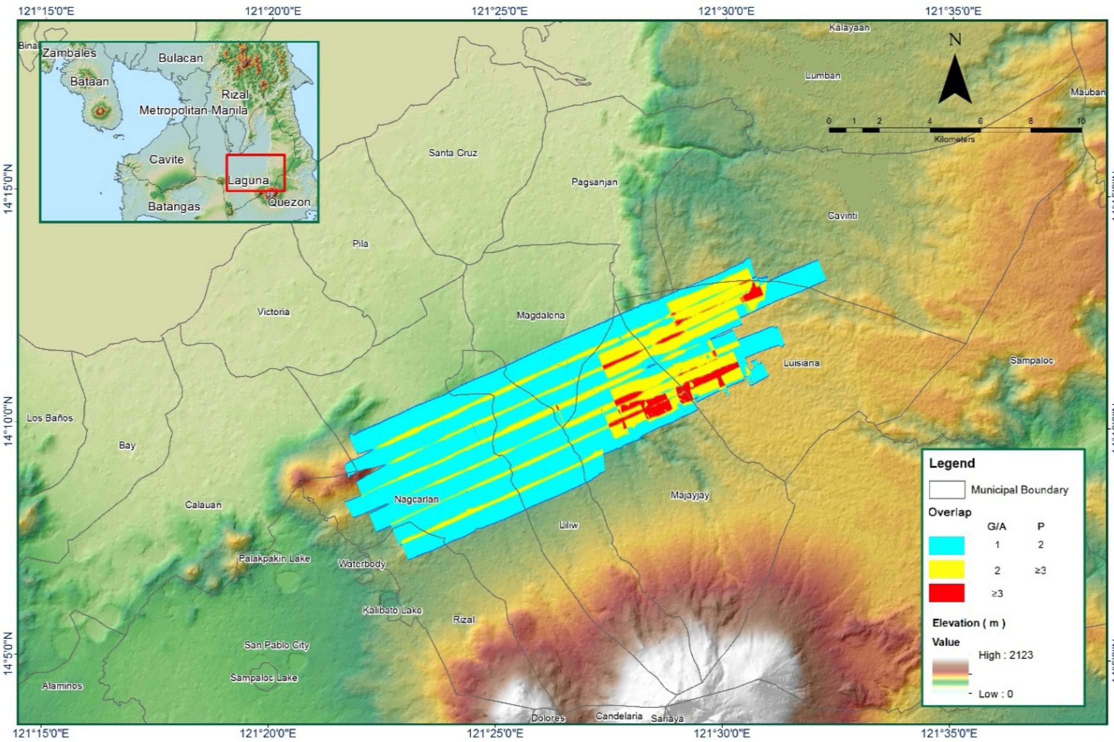


Figure 1.1.5. Image of data overlap

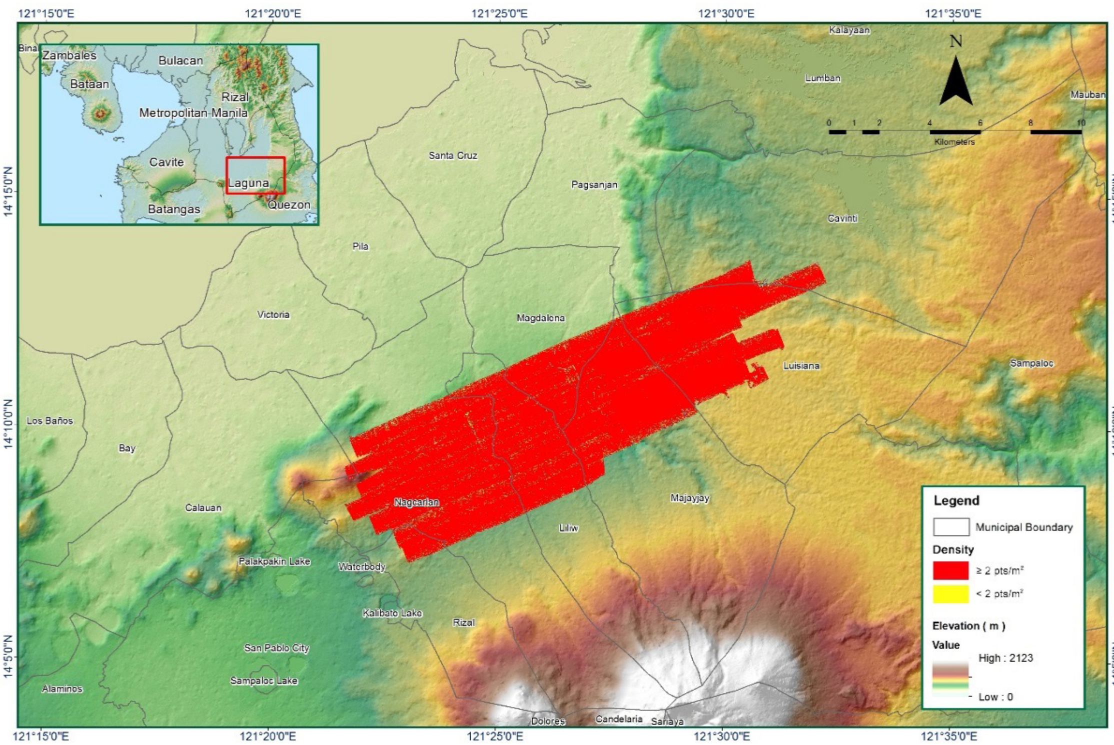


Figure 1.1.6. Density map of merged LiDAR data

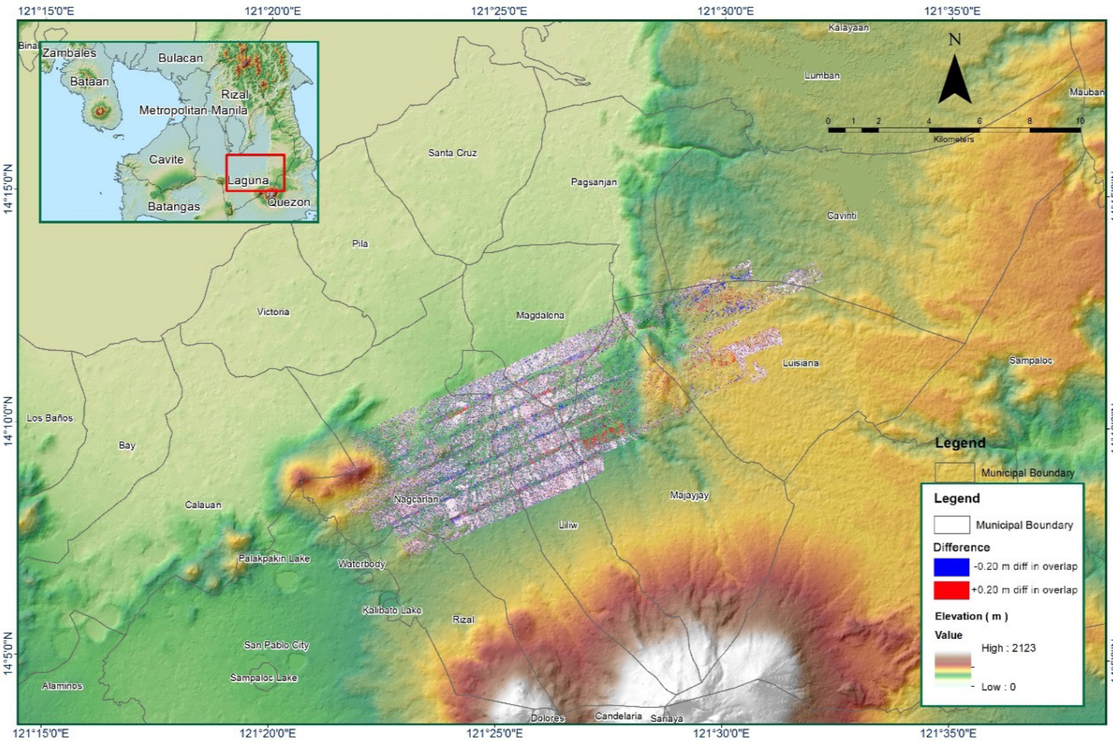


Figure 1.1.7. Elevation difference between flight lines

Table A-8.2. 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	Ma. Victoria Rejuso, Engr. Melanie Hingpit, Engr. Jeffrey Delica

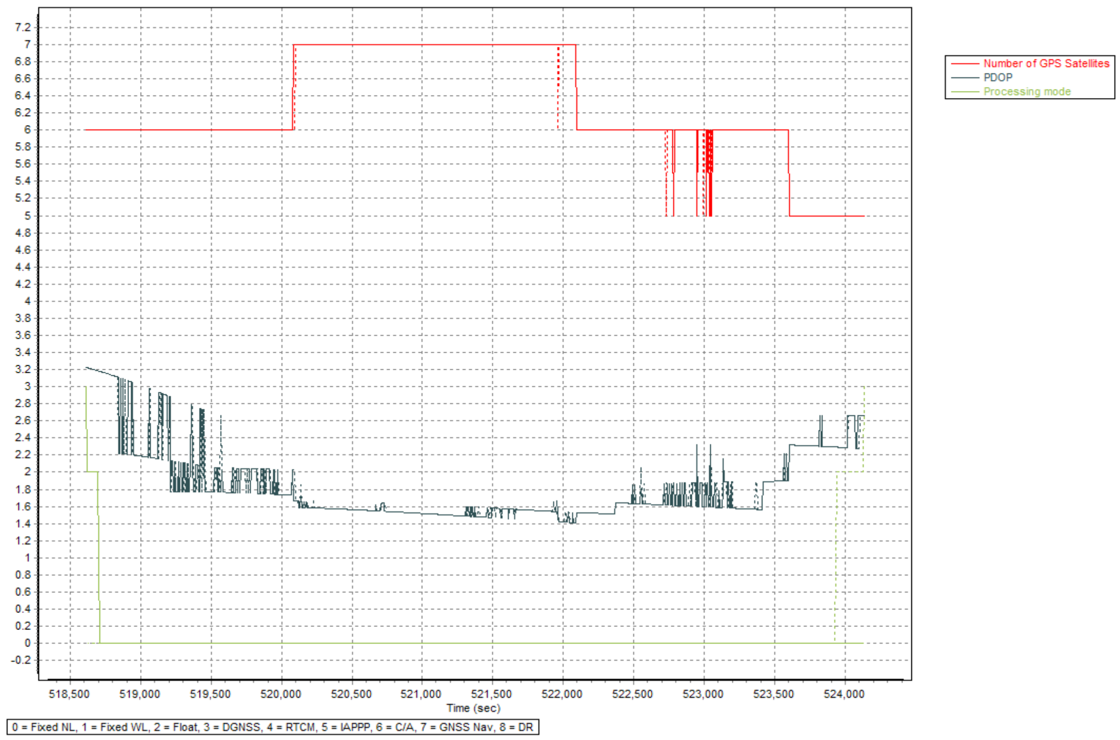


Figure 1.2.1. Solution Status

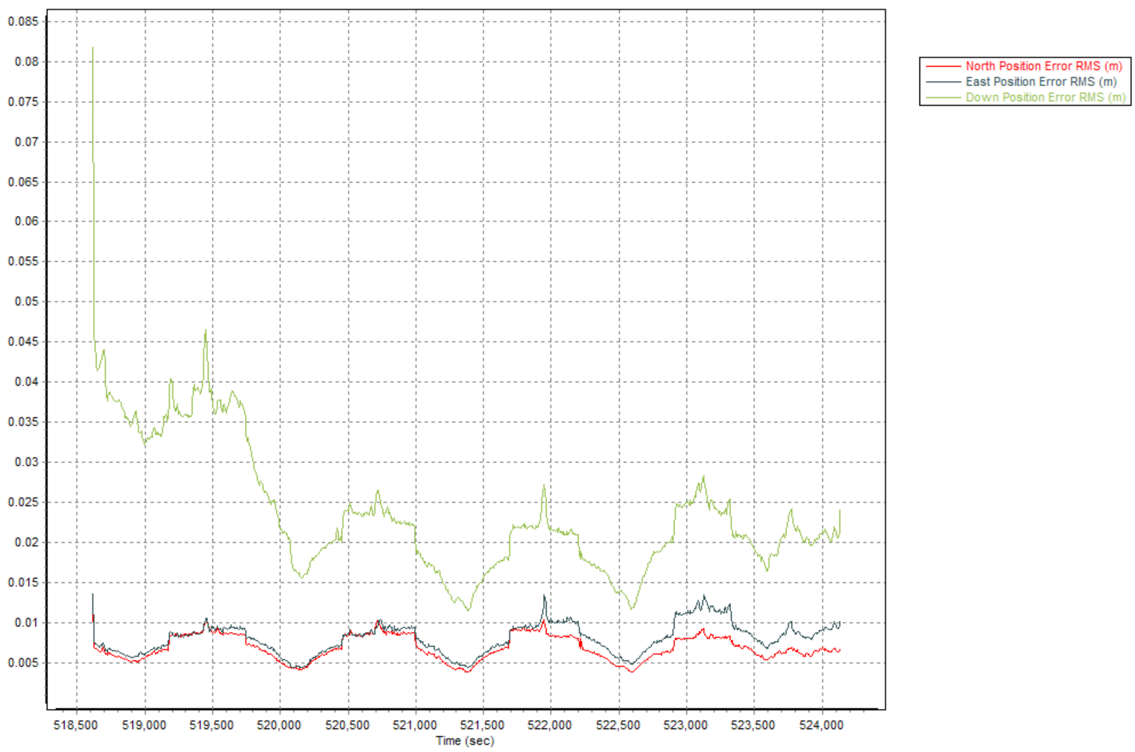


Figure 1.2.2. Smoothed Performance Metrics Parameters

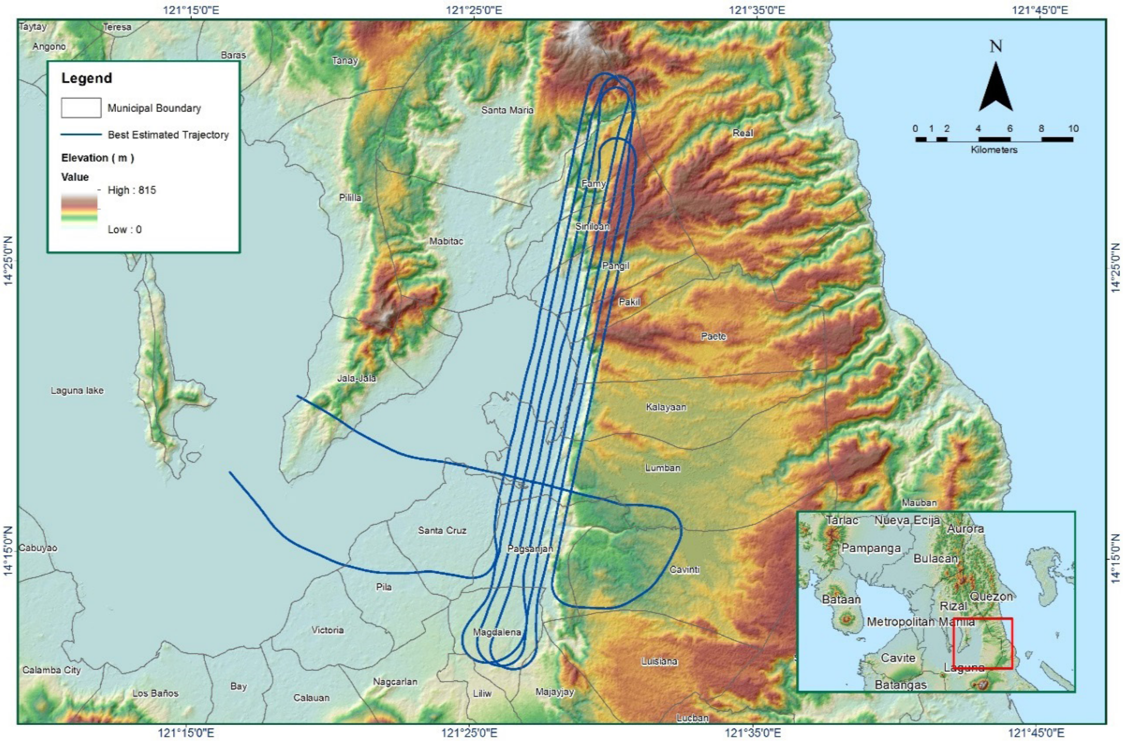


Figure 1.2.3. Best Estimated Trajectory

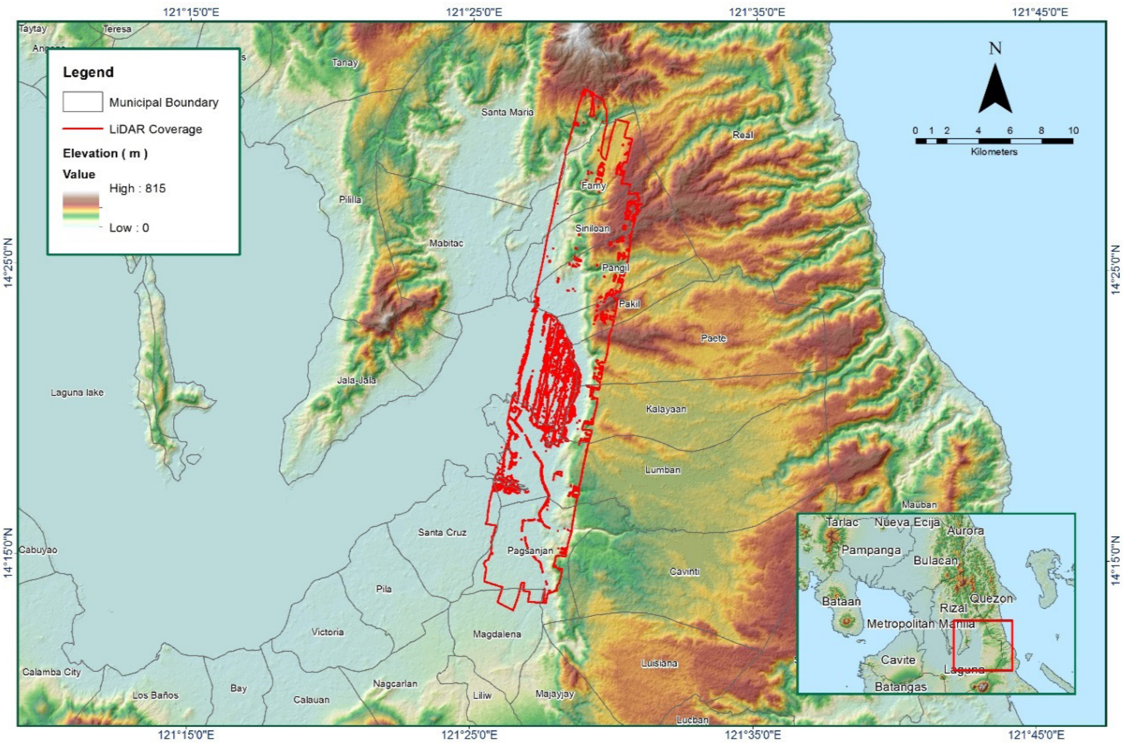


Figure 1.2.4. Coverage of LiDAR data

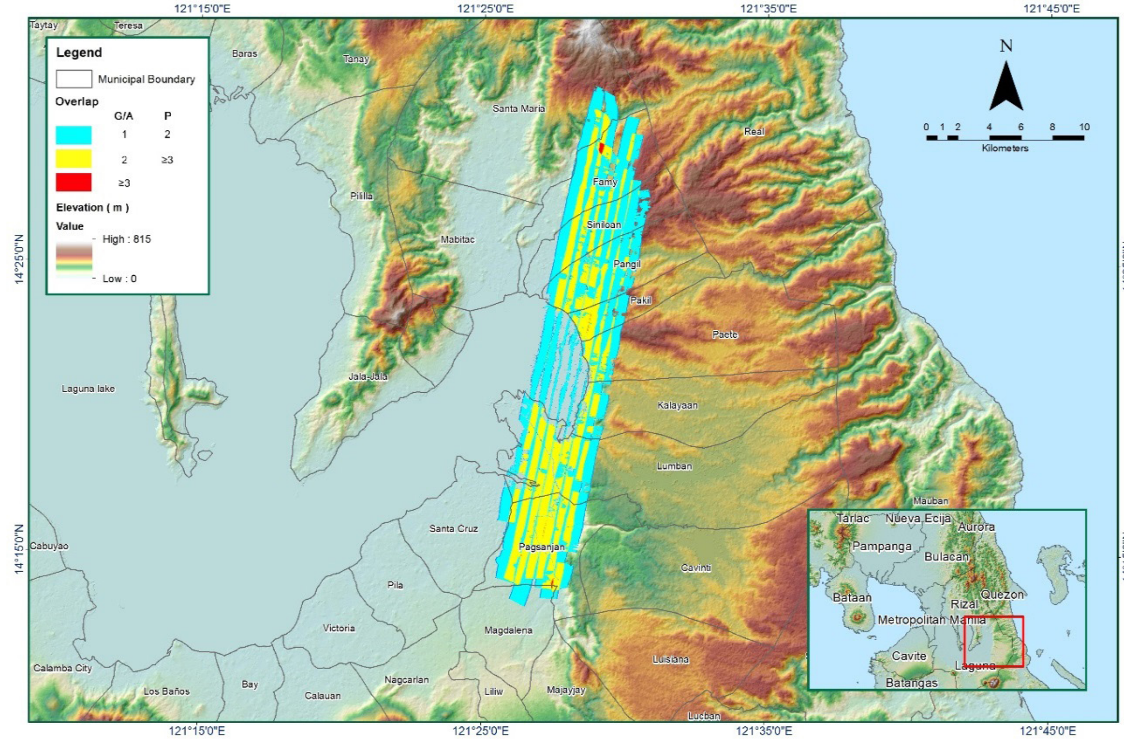


Figure 1.2.5. Image of data overlap

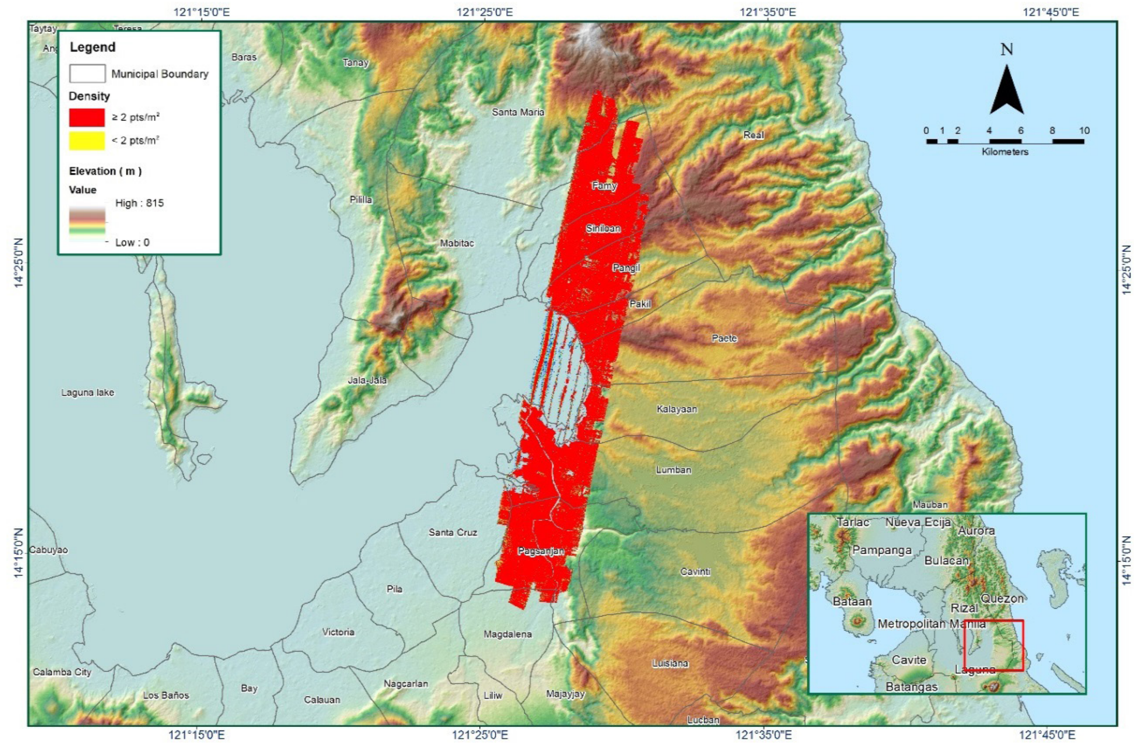


Figure 1.2.6. Density map of merged LiDAR data

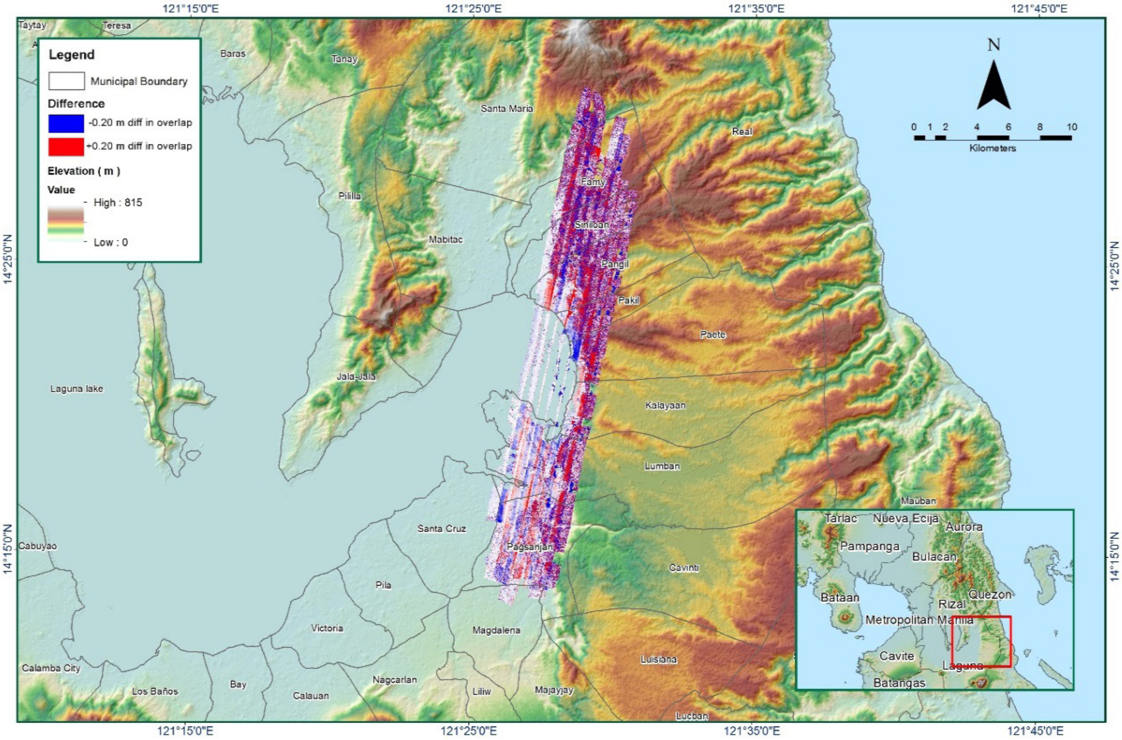


Figure 1.2.7. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk18J

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	Ma. Victoria Rejuso, Engr. Melanie Hingpit, Engr. John Dill Macapagal

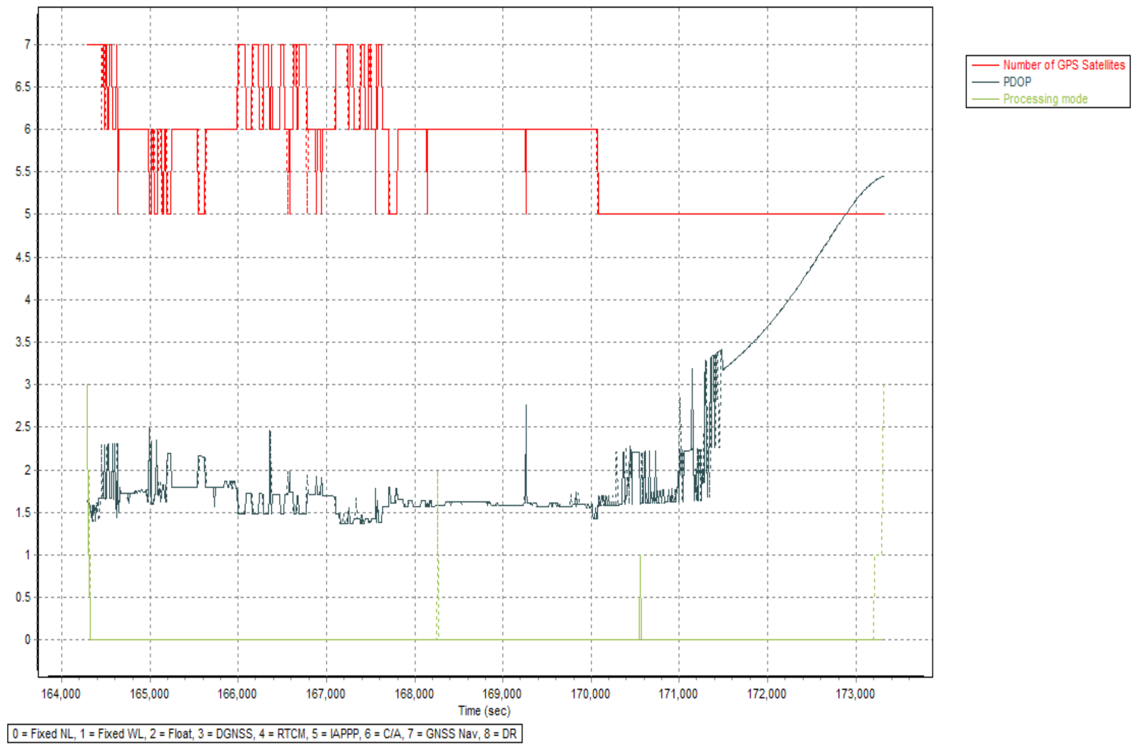


Figure 1.3.1. Solution Status

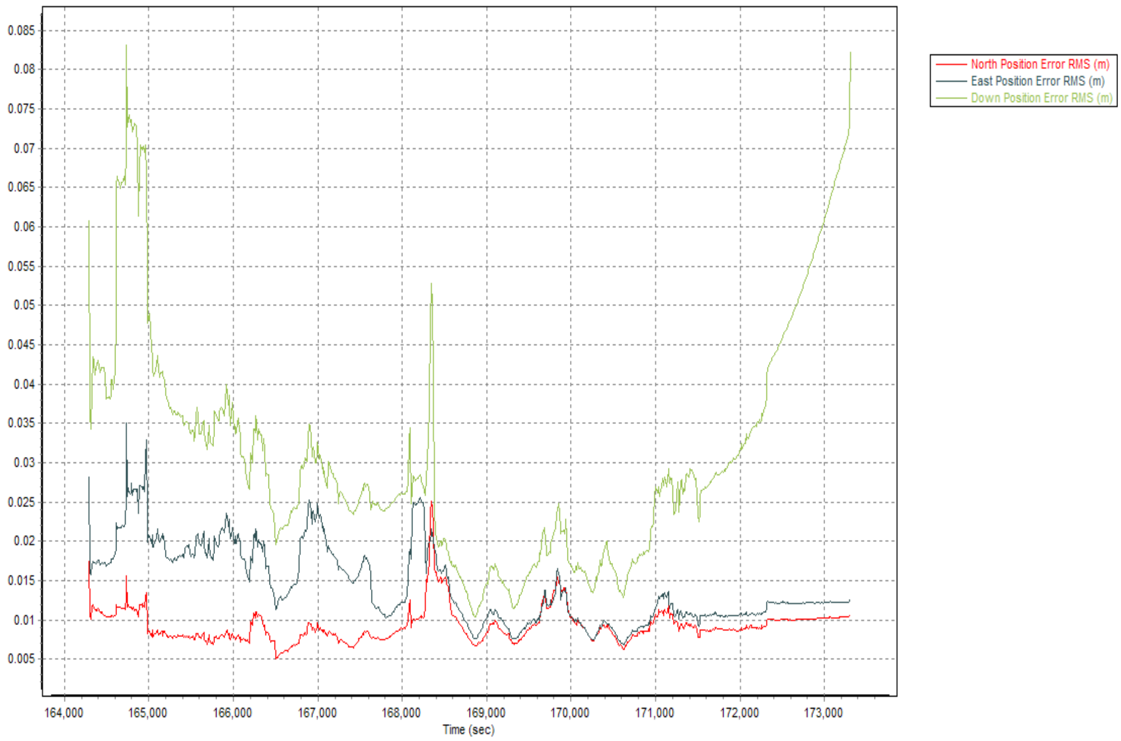


Figure 1.3.2. Smoothed Performance Metrics Parameters

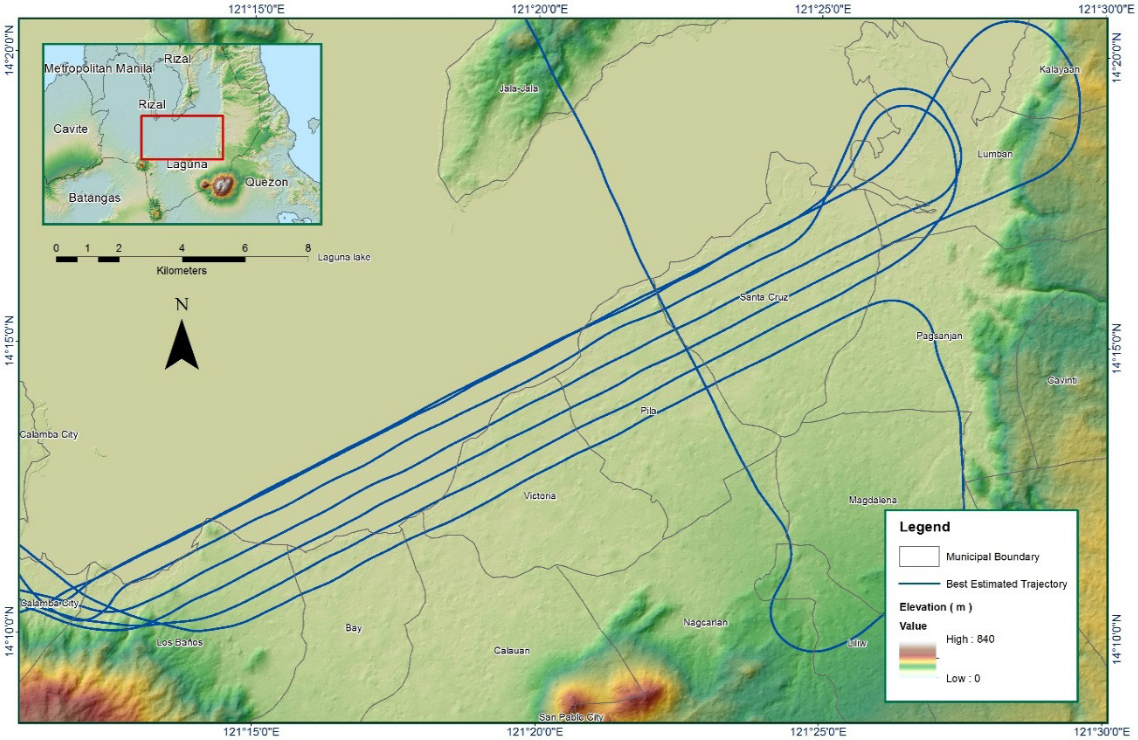


Figure 1.3.3. Best Estimated Trajectory

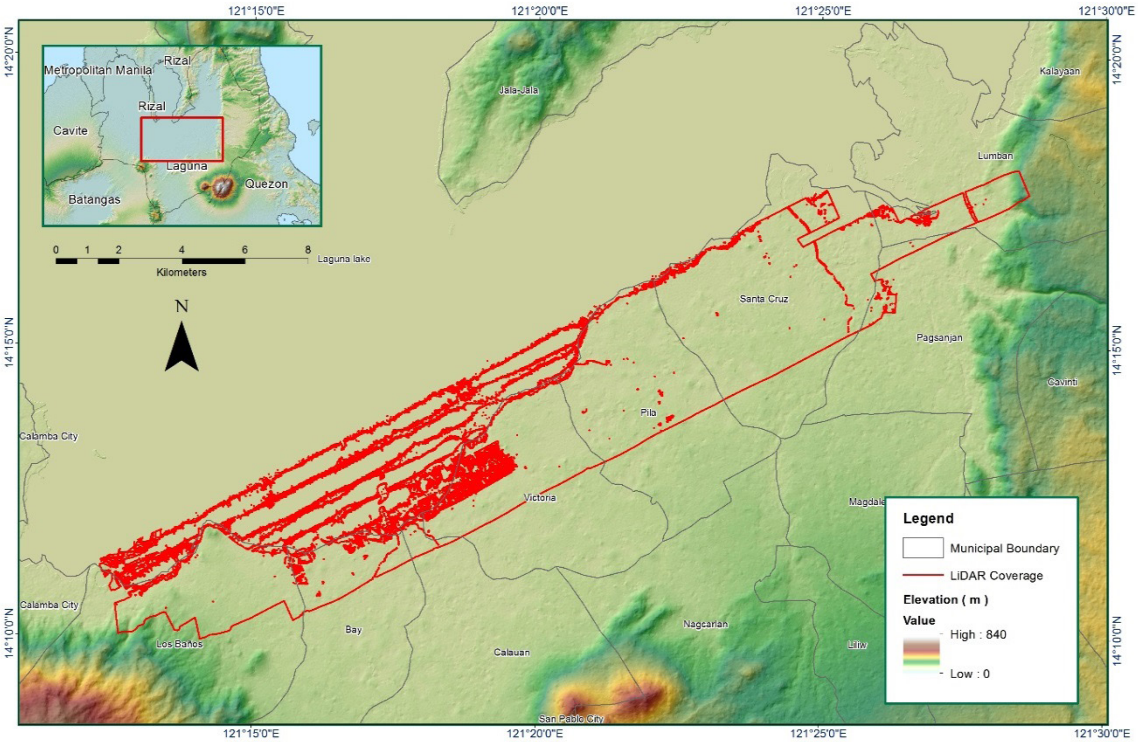


Figure 1.3.4. Coverage of LiDAR data

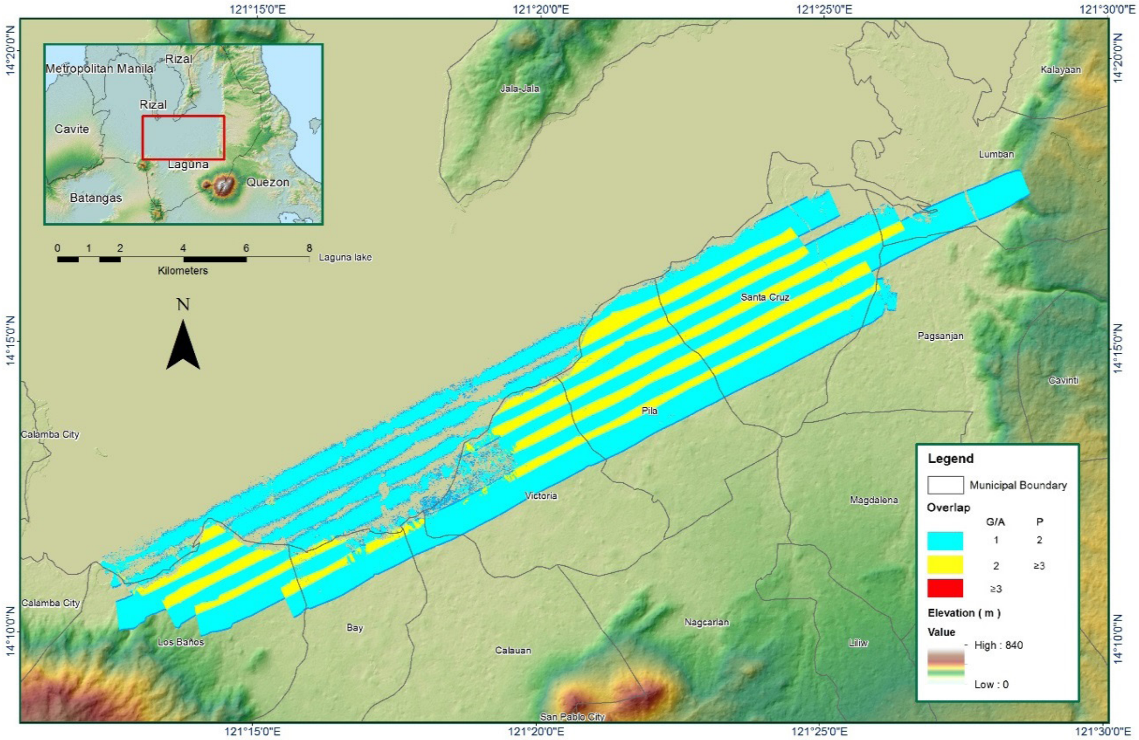


Figure 1.3.5. Image of data overlap

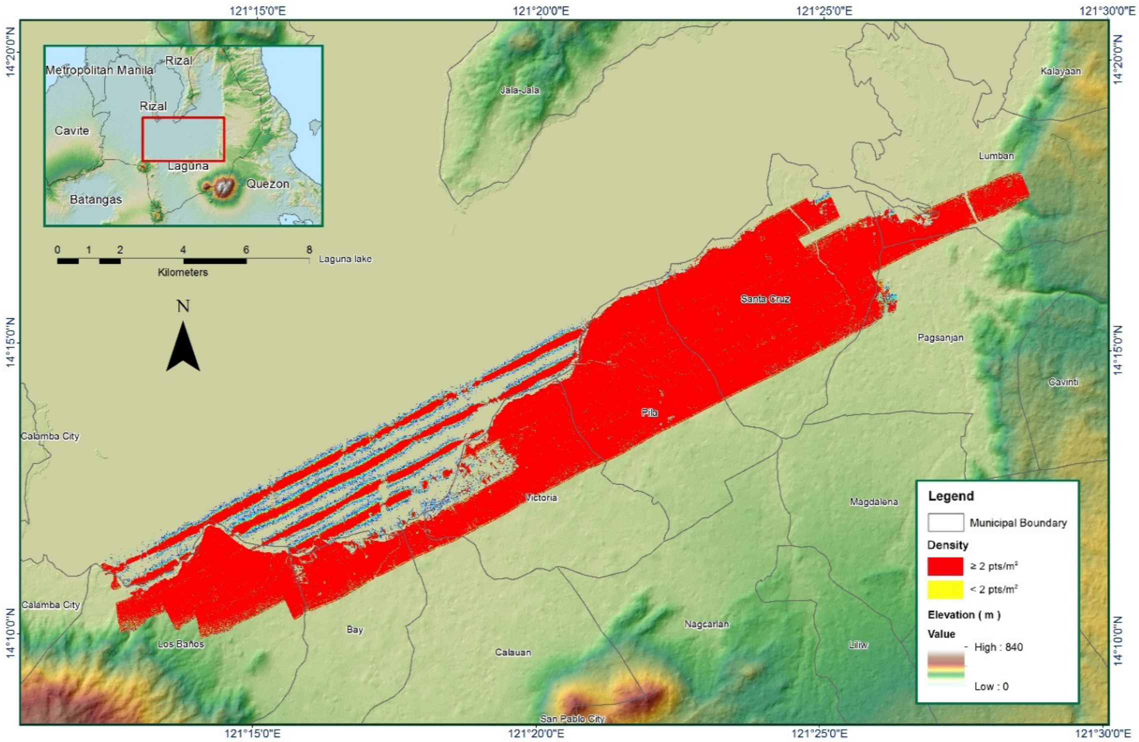


Figure 1.3.6. Density map of merged LiDAR data

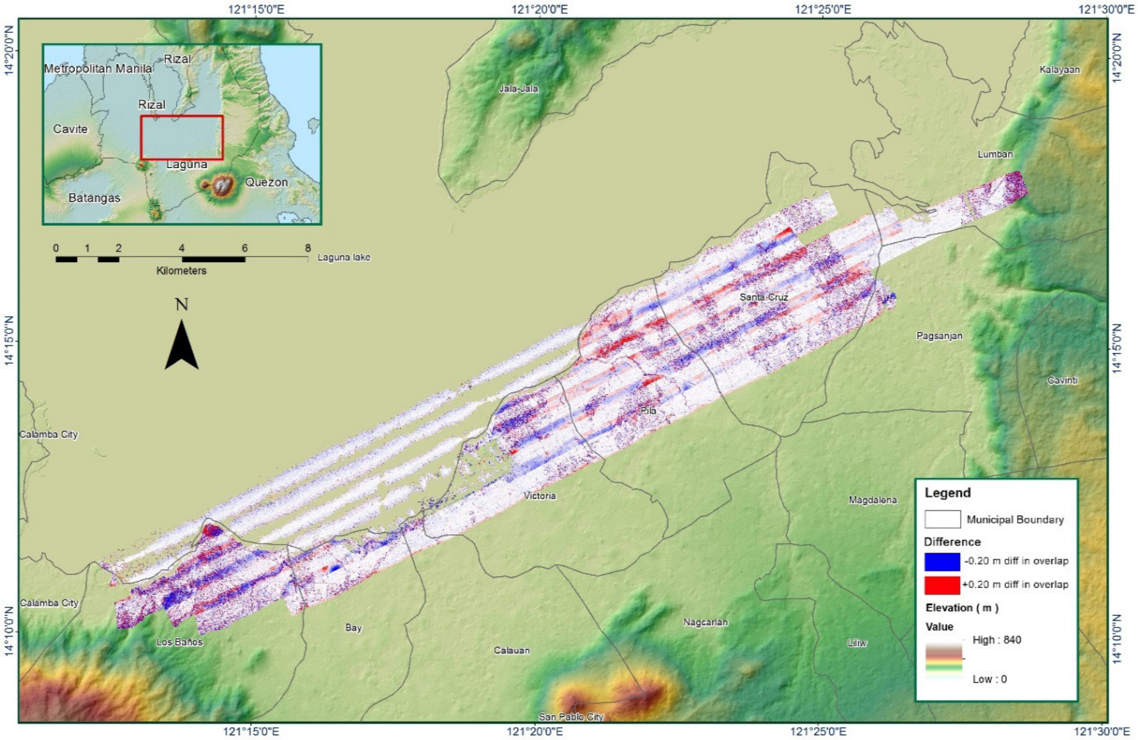


Figure 1.3.7. Elevation difference between flight lines

Table A-8.4. 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, Ryan Nicholai Dizon

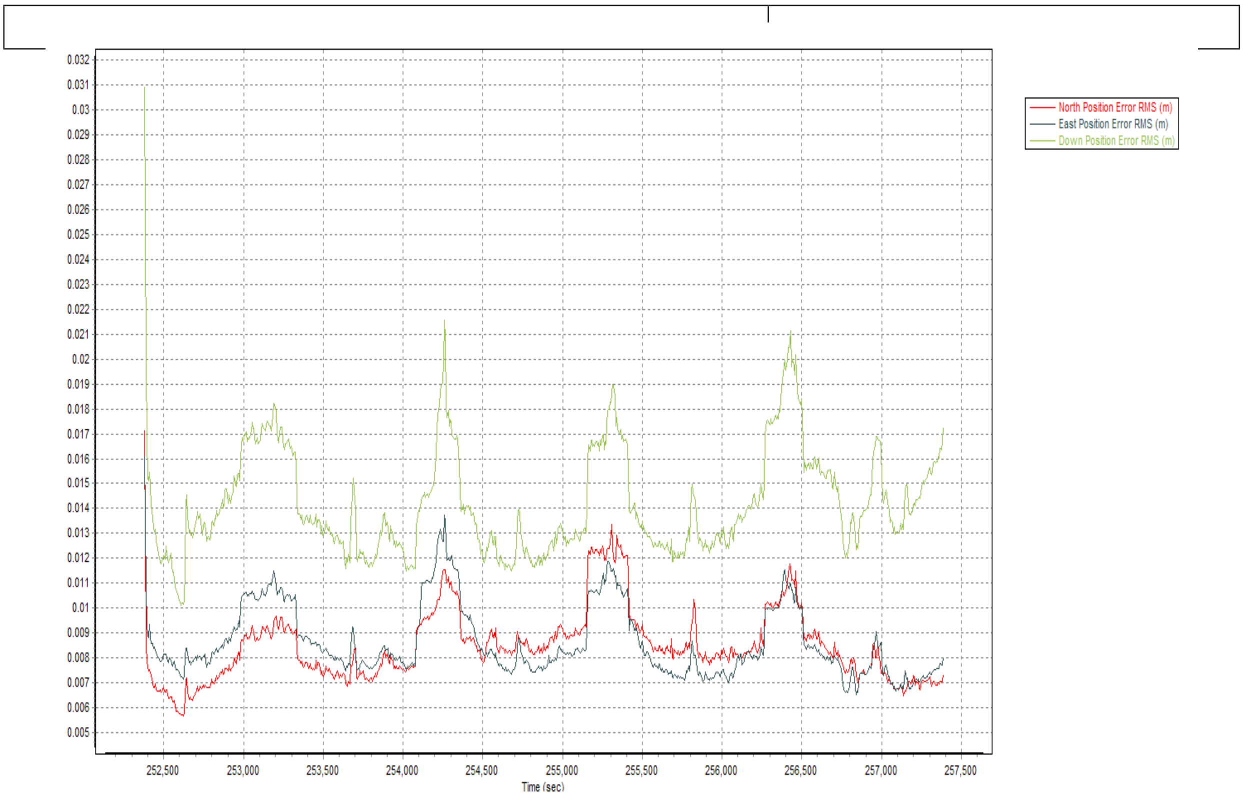


Figure 1.4.1. Solution Status

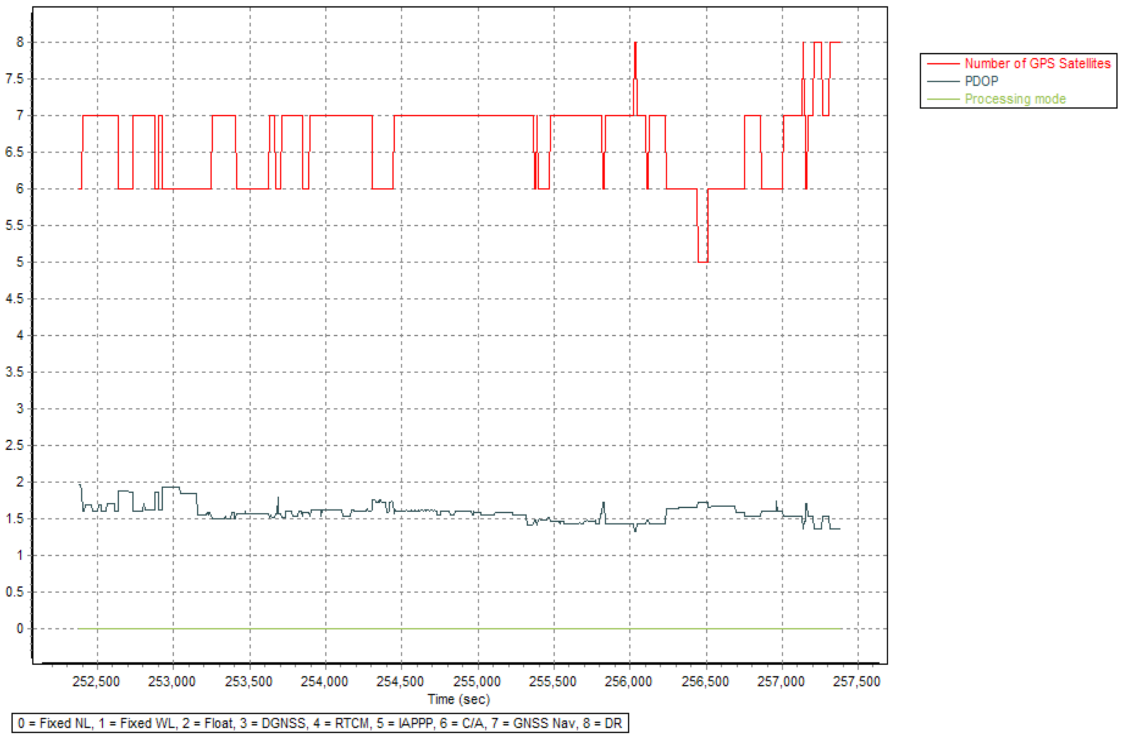


Figure 1.4.2. Smoothed Performance Metrics Parameters

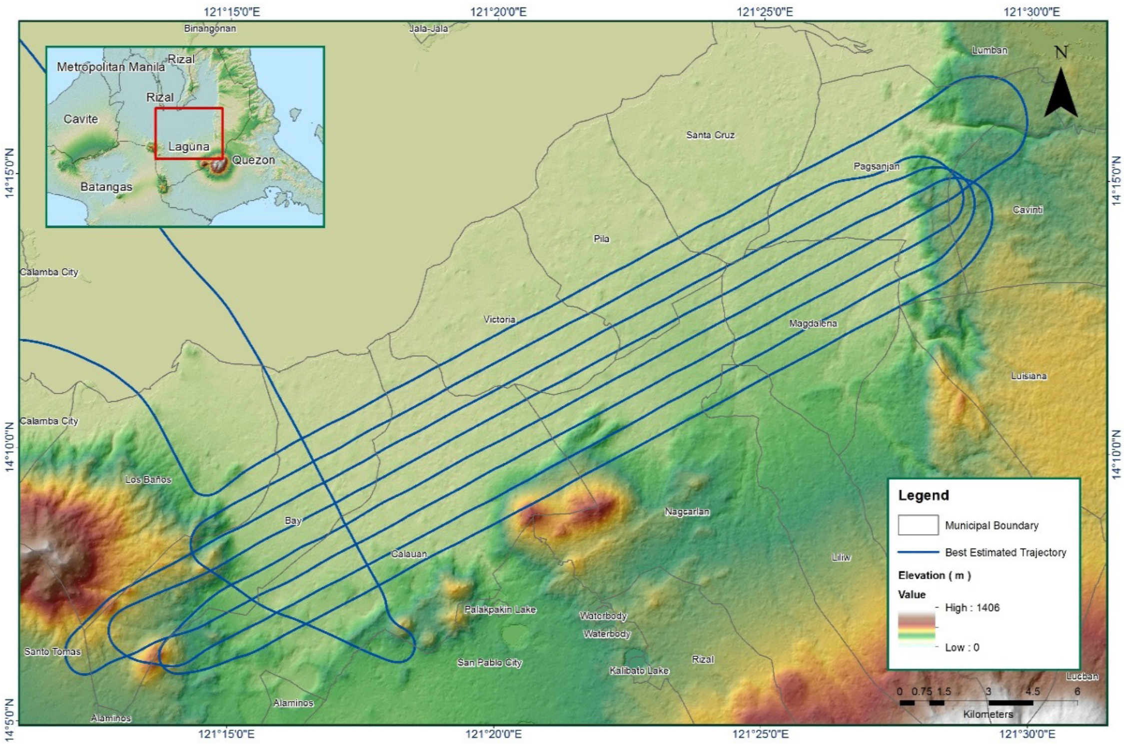


Figure 1.4.3. Best Estimated Trajectory

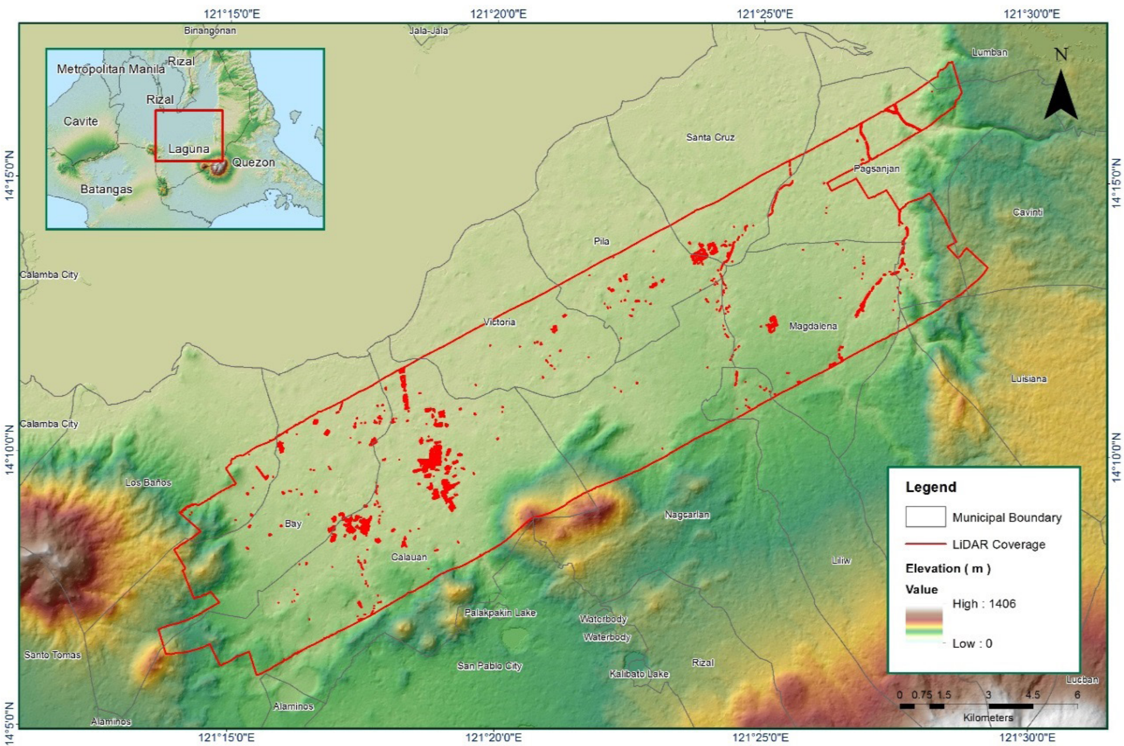


Figure 1.4.4. Coverage of LiDAR data

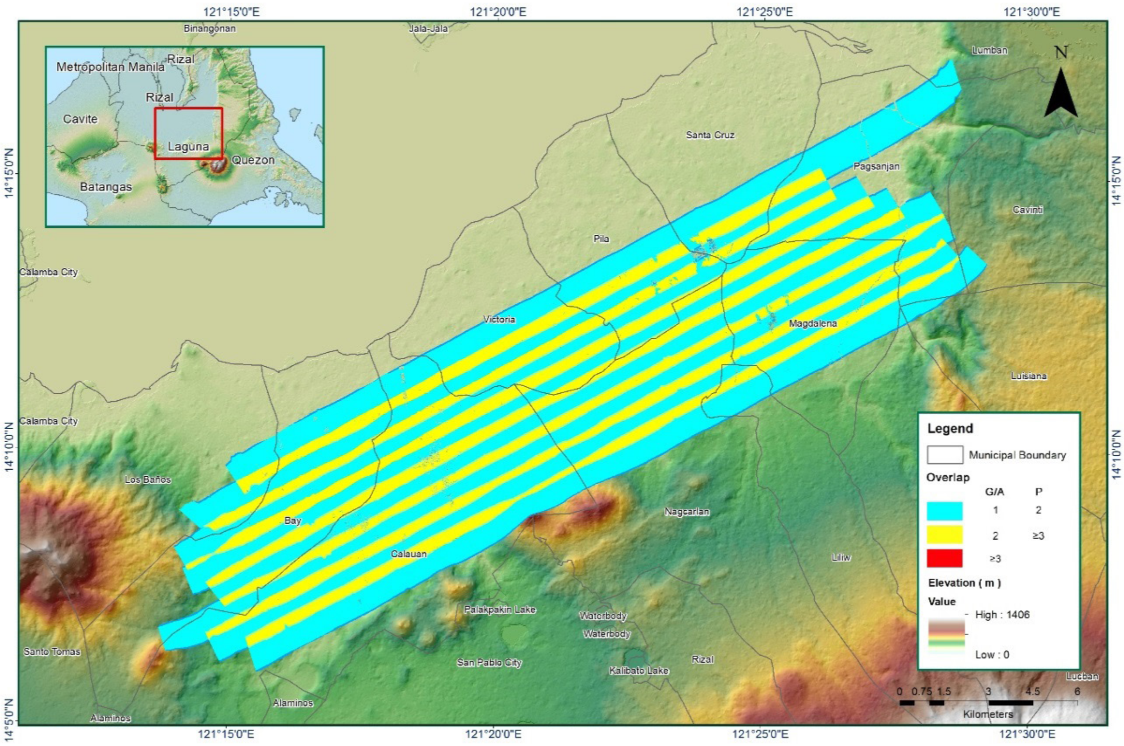


Figure 1.4.5. Image of data overlap

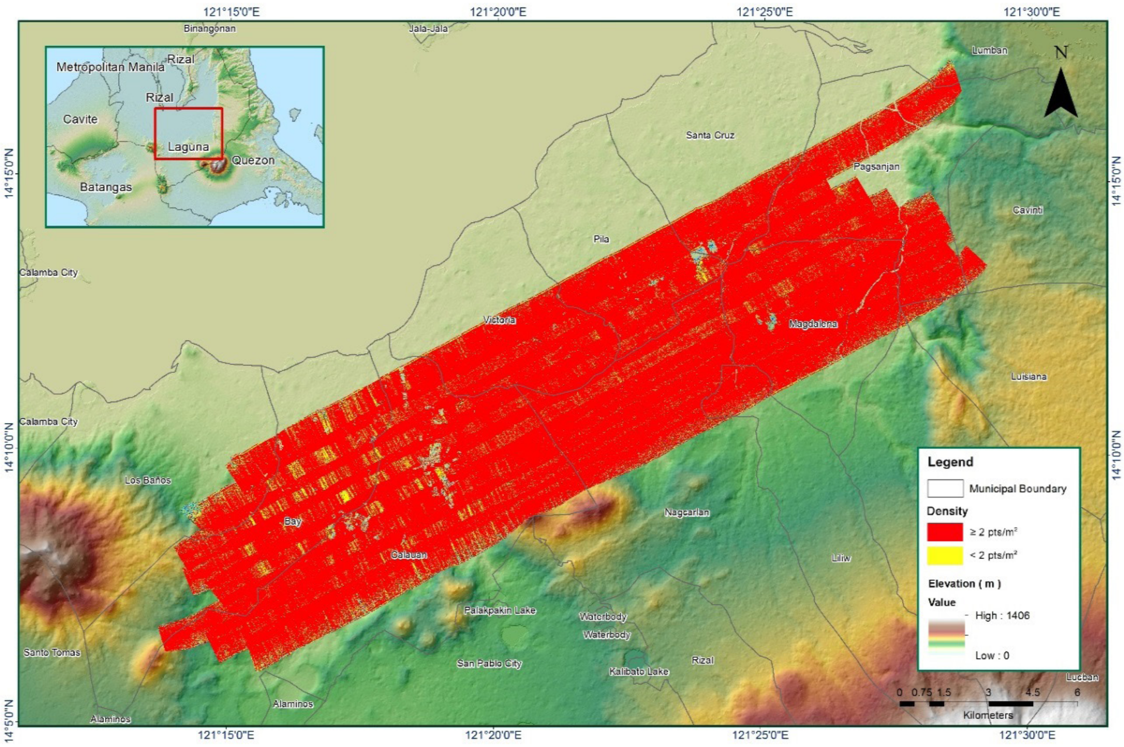


Figure 1.4.6. Density map of merged LiDAR data

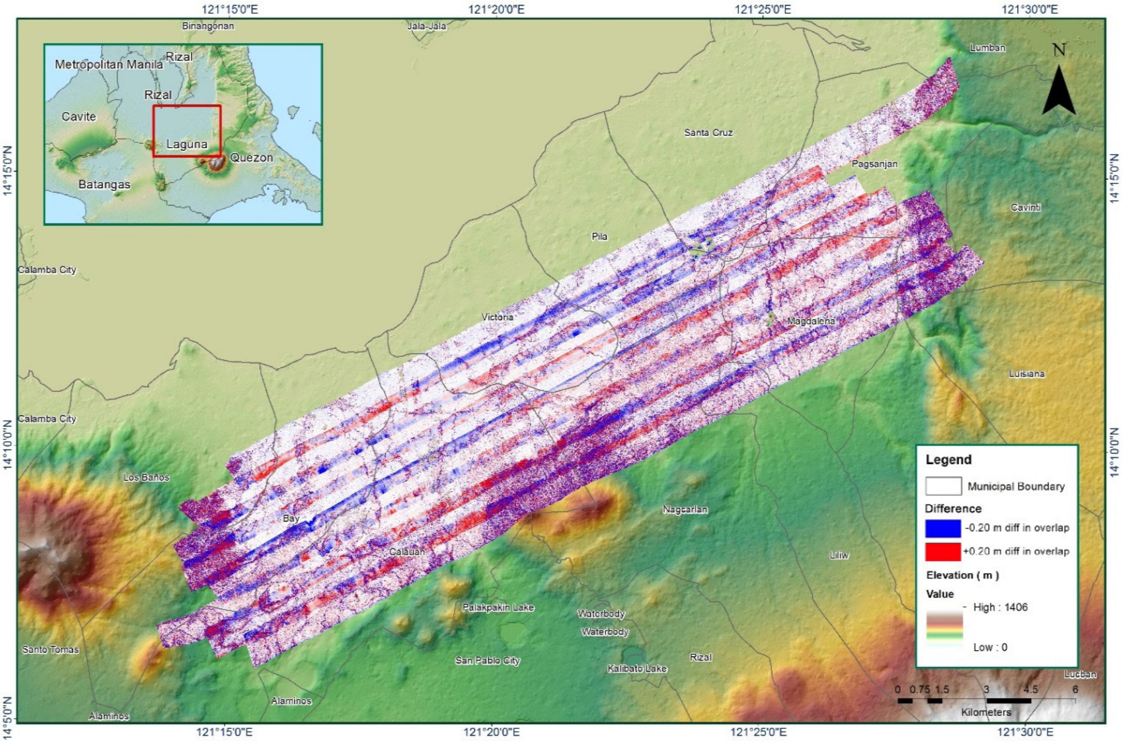


Figure 1.4.7. Elevation difference between flight lines

Table A-8.5. 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	

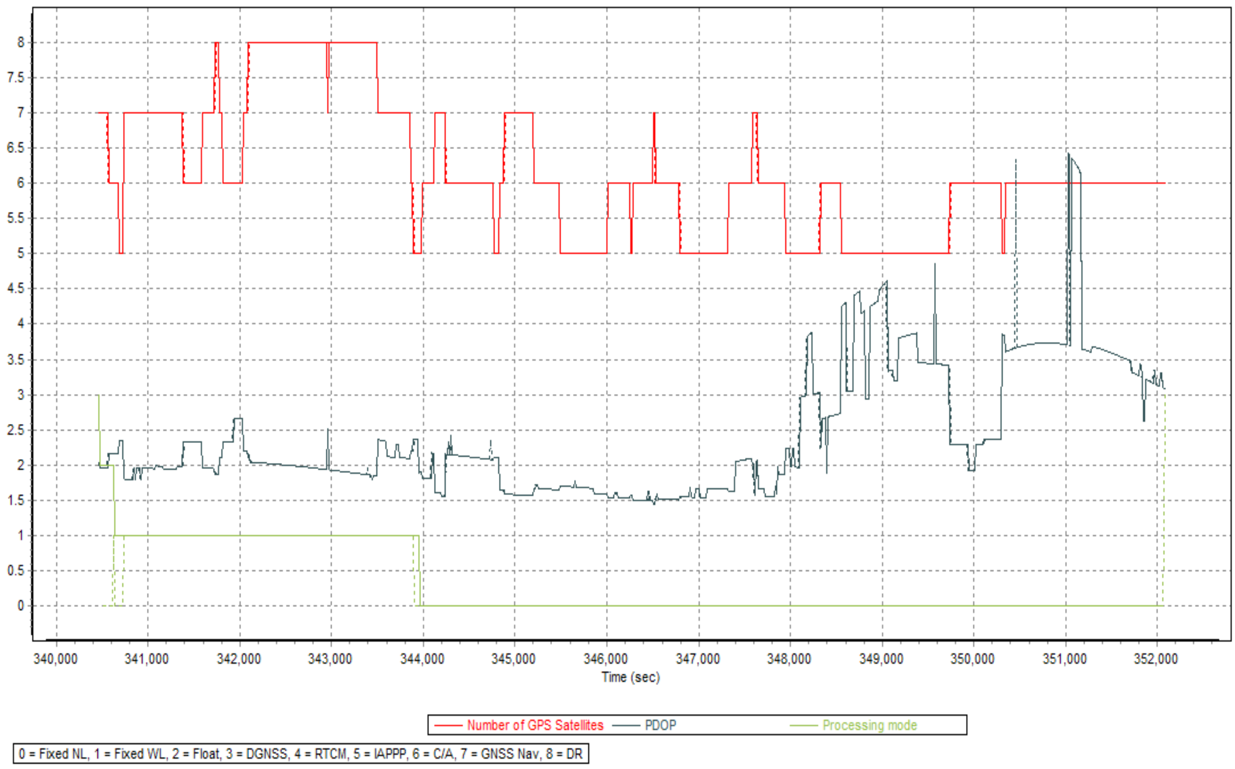


Figure 1.5.1. Solution Status

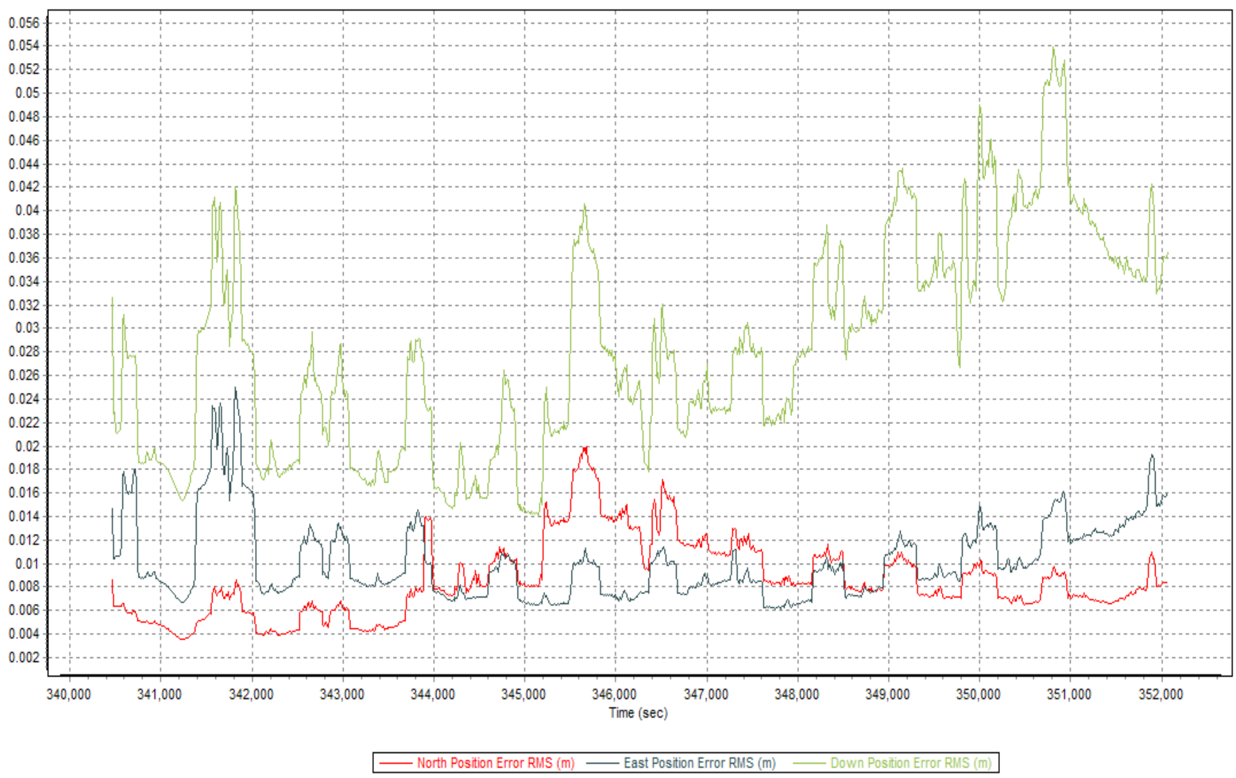


Figure 1.5.2. Smoothed Performance Metric Parameters

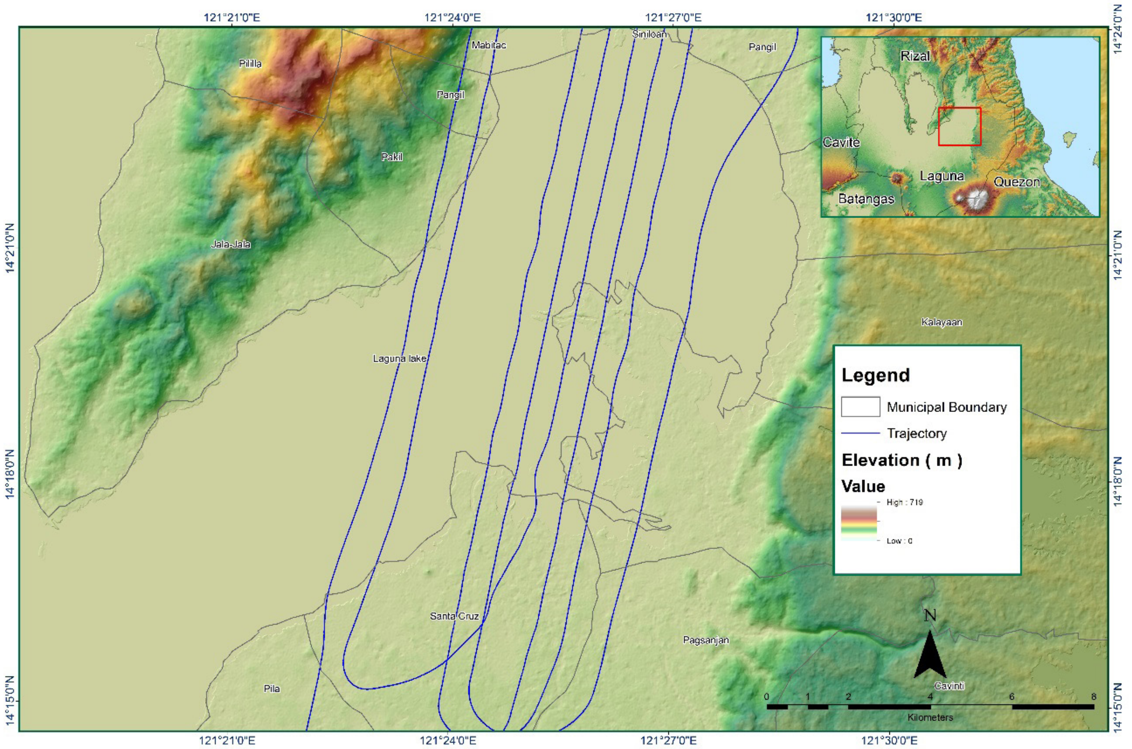


Figure 1.5.3. Best Estimated Trajectory

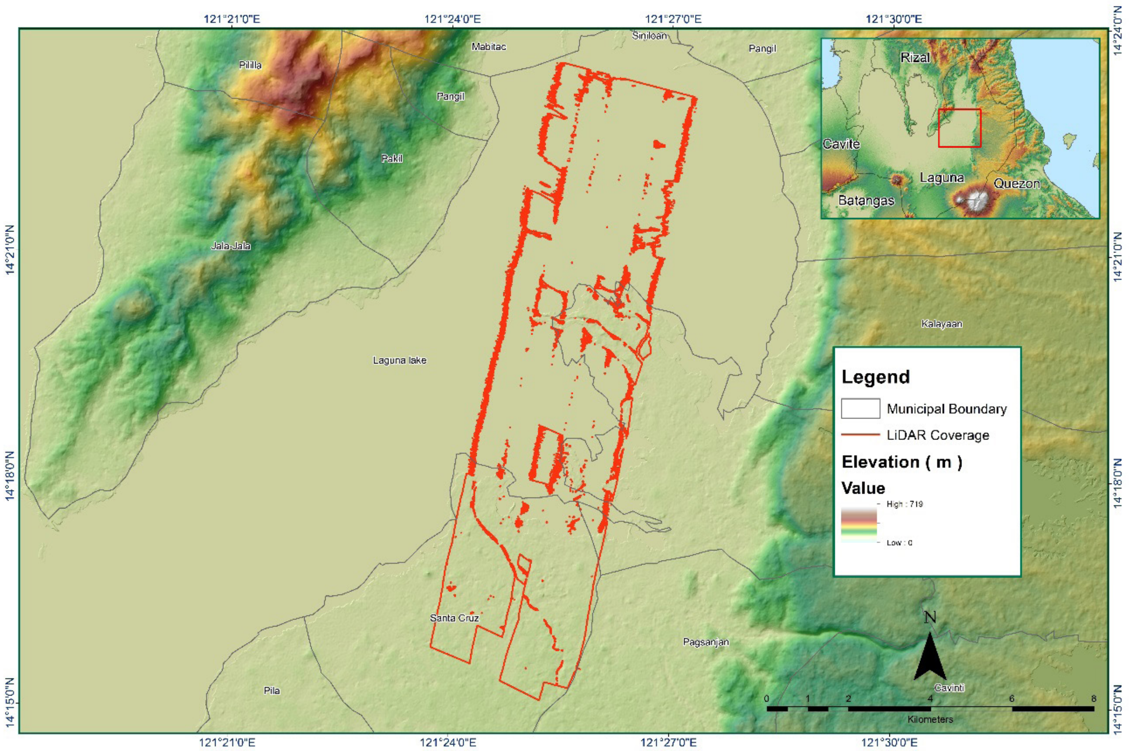


Figure 1.5.4. Coverage of LiDAR Data

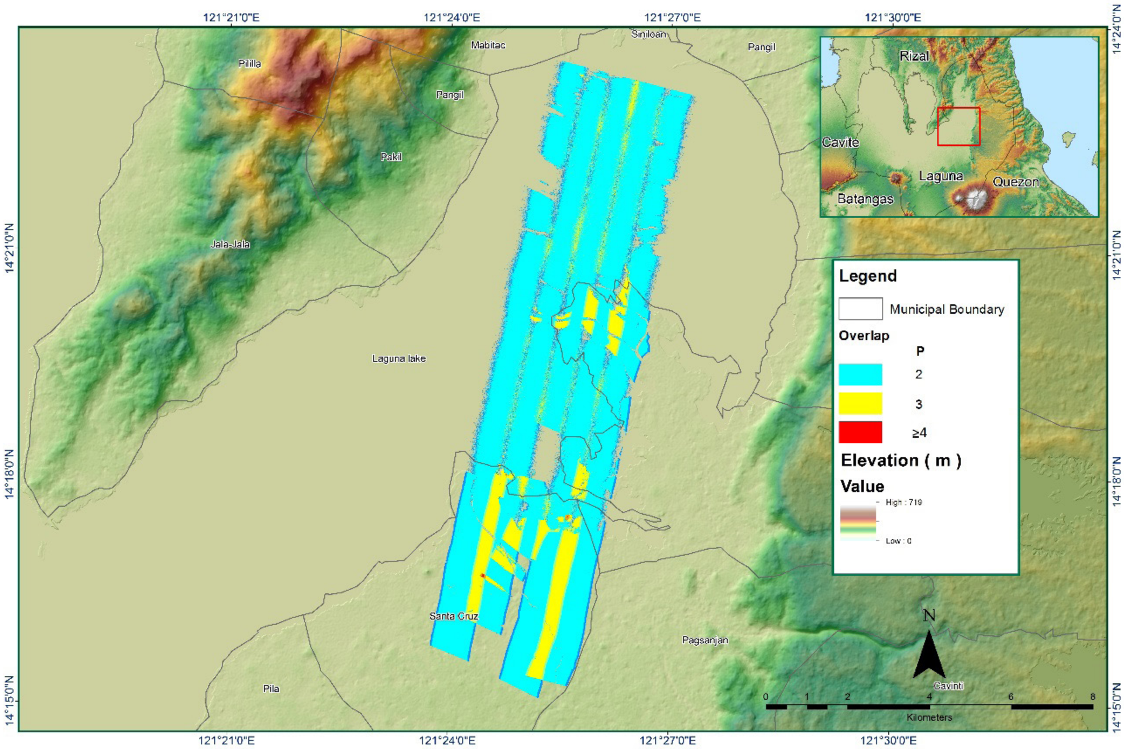


Figure 1.5.5. Image of data overlap

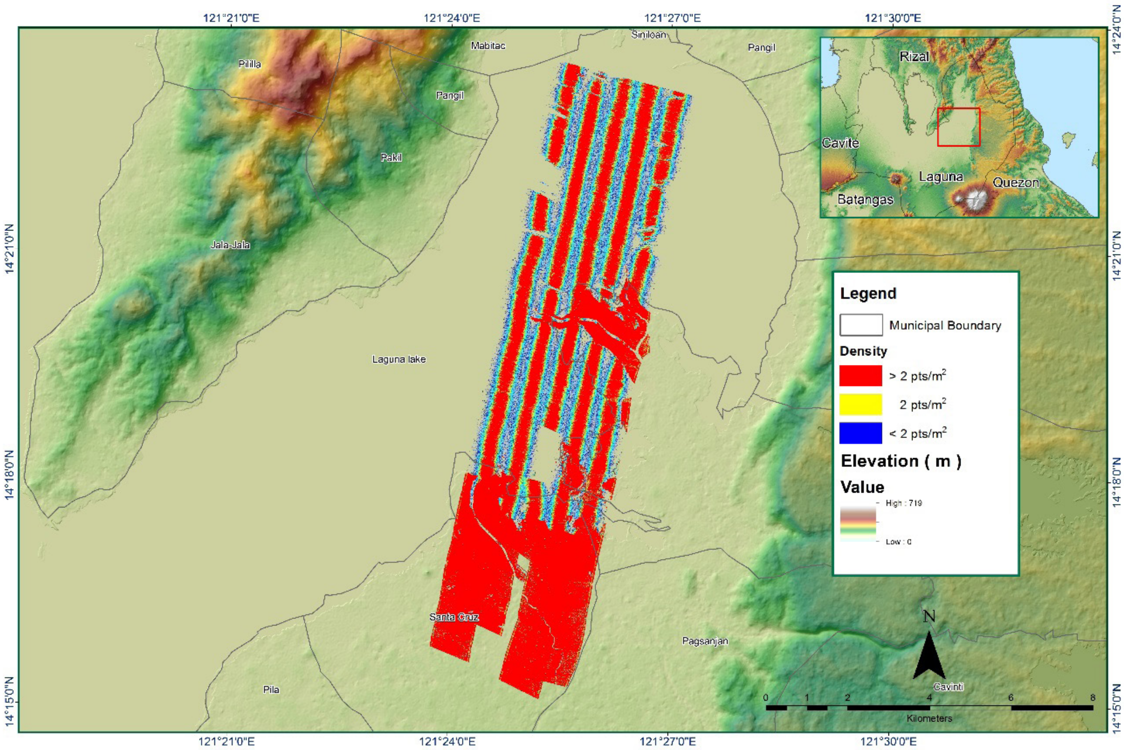


Figure 1.5.6. Density map of merged LiDAR data

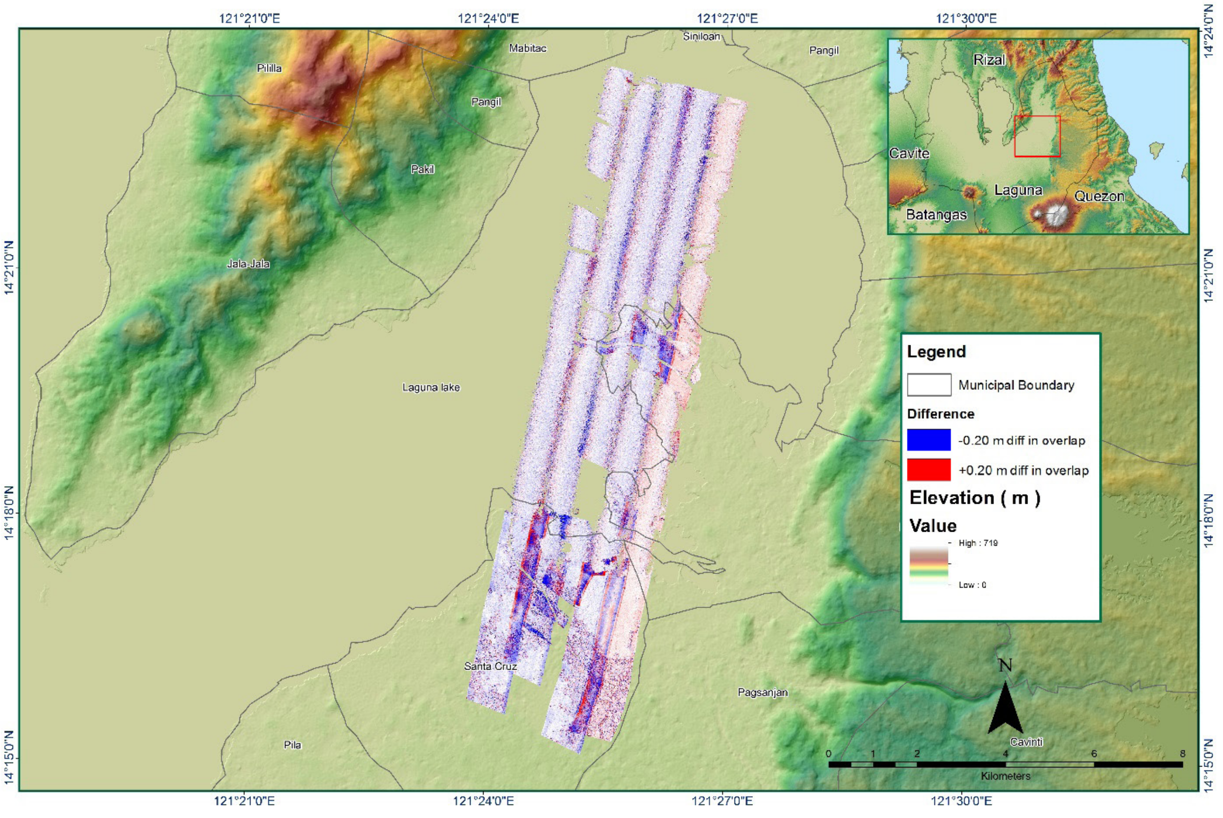


Figure 1.5.7. Elevation difference between flight lines

Annex 9. Sta. Cruz Model Basin Parameters

Table A-9.1. Sta. Cruz Model Basin Parameters

Subbasin	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
W430	3.5764	66.594	0.0	2.7405	4.4588	0.0973454	0.47159	0.52172
W450	6.4117	60.022	0.0	1.7766	2.8857	0.0826677	0.10306	0.52172
W460	6.6644	59.625	0.0	2.1211	3.4479	0.0823056	0.10306	0.16577
W470	7.8823	57.262	0.0	2.6918	4.3793	0.19219	0.48122	0.52172
W480	6.4117	60.022	0.0	3.8494	6.2685	0.31943	0.48122	0.52172
W490	8.6815	55.811	0.0	2.4152	3.9279	0.14537	0.10306	0.52172
W500	6.4117	60.022	0.0	5.5529	9.0486	0.0230945	0.48122	0.52172
W510	11.106	51.827	0.0	3.9399	6.4162	0.27228	0.48122	0.52172
W520	11.722	50.791	0.0	2.4745	4.0246	0.22525	0.22269	0.52172
W530	11.018	51.962	0.0	1.6385	2.6603	0.0838728	0.10306	0.52172
W540	10.188	53.266	0.0	1.3284	2.1542	0.0611484	0.10306	0.52172
W550	7.3877	58.199	0.0	4.3698	7.1178	1.3074	0.32736	0.52172
W560	5.3267	62.457	0.0	2.07	3.3645	0.24125	0.48122	0.52172
W570	4.4917	64.364	0.0	1.04	1.6835	0.0704528	0.10306	0.52172
W580	5.2907	62.536	0.0	0.71642	1.1555	0.0483804	0.10306	0.52172
W590	4.7593	63.74	0.0	2.8494	4.6365	0.36228	0.10306	0.52172
W600	4.7017	63.868	0.0	2.8515	4.6399	0.27605	0.32736	0.52172
W610	4.1626	65.148	0.0	1.9584	3.1823	0.34268	0.15149	0.52172
W620	4.7017	63.868	0.0	1.0575	1.7121	0.10695	0.32736	0.52172
W630	4.7017	63.868	0.0	1.8948	3.0785	0.17166	0.10306	0.52172
W640	4.3694	64.653	0.0	0.25432	0.40133	0.0275854	0.10306	0.52172
W650	5.4723	62.135	0.0	1.0672	1.728	0.0836291	0.10306	0.52172
W660	7.5056	57.974	0.0	1.8546	3.0131	0.1598	0.10306	0.52172

Subbasin	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
W670	9.3981	54.571	0.0	1.0116	1.6372	0.10128	0.10306	0.52172
W680	4.922	63.367	0.0	1.2917	2.0943	0.18686	0.15149	0.52172
W690	6.1869	60.606	0.0	2.9935	4.8717	0.62506	0.48122	0.52172
W700	9.1022	55.077	0.0	2.2774	3.703	0.31872	0.15149	0.52172
W710	6.7303	59.493	0.0	1.8646	3.0293	0.22228	0.15149	0.52172
W720	8.4709	56.187	0.0	2.5046	4.0738	0.69383	0.32736	0.52172
W730	6.1876	60.604	0.0	1.2345	2.0009	0.18329	0.10306	0.52172
W740	4.7017	63.868	0.0	1.8002	2.9243	0.22836	0.10306	0.52172
W750	12.375	49.959	0.0	1.2961	2.1016	0.14685	0.15149	0.52172
W760	5.6566	61.734	0.0	0.63932	1.0297	0.0622679	0.10306	0.52172
W770	14.916	46.598	0.0	2.1343	3.4695	0.25958	0.15149	0.52172
W780	11.722	50.791	0.0	1.1576	1.8755	0.15072	0.32736	0.52172
W790	16.755	44.435	0.0	1.5137	2.4567	0.1578	0.15149	0.52172
W800	11.722	50.791	0.0	0.27032	0.42752	0.0277764	0.22269	0.52172
W810	20.355	40.734	0.0	1.7545	2.8496	0.177	0.22269	0.52172
W820	20.176	40.903	0.0	1.1184	1.8116	0.11819	0.10306	0.52172
W840	3.04362	70.6	0.0	1.5389	2.5116	0.32377	0.52172	0.25
W850	1.1917	73.099	0.0	1.4074	2.2831	0.0309108	0.22269	0.52172
W890	4.0964	65.308	0.0	0.87572	1.4155	0.20594	0.10306	0.52172
W900	6.3372	60.294	0.0	4.1791	6.8065	0.18422	0.065843	0.52172

Annex 10. Sta. Cruz Model Reach Parameters

Table A-10.1. Sta. Cruz 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)
R100	Automatic Fixed Interval	1915.1	0.0123390	0.0285714	Trapezoid	40	1
R110	Automatic Fixed Interval	772.84	0.0081920	0.0285714	Trapezoid	40	1
R120	Automatic Fixed Interval	1009.1	0.0152341	0.0285714	Trapezoid	40	1
R130	Automatic Fixed Interval	702.13	0.0133766	0.0285714	Trapezoid	40	1
R150	Automatic Fixed Interval	2195.1	0.0223386	0.0285714	Trapezoid	40	1
R160	Automatic Fixed Interval	215.56	0.0278991	0.0285714	Trapezoid	40	1
R190	Automatic Fixed Interval	4203.7	0.0209649	0.0285714	Trapezoid	40	1
R20	Automatic Fixed Interval	2734.8	0.0034817	0.0285714	Trapezoid	40	1
R210	Automatic Fixed Interval	1009.5	0.0120658	0.0285714	Trapezoid	40	1
R220	Automatic Fixed Interval	2222.1	0.0206094	0.0285714	Trapezoid	40	1
R240	Automatic Fixed Interval	1726.9	0.0048070	0.0285714	Trapezoid	40	1
R260	Automatic Fixed Interval	3619.1	0.0301077	0.0285714	Trapezoid	40	1
R30	Automatic Fixed Interval	1512.4	.00075708	0.0285714	Trapezoid	40	1
R300	Automatic Fixed Interval	1305.7	0.0369659	0.0285714	Trapezoid	40	1
R310	Automatic Fixed Interval	3201.9	0.0498943	0.0285714	Trapezoid	40	1
R330	Automatic Fixed Interval	211.42	0.0593530	0.0285714	Trapezoid	40	1
R390	Automatic Fixed Interval	2050.7	0.0763791	0.0285714	Trapezoid	40	1
R40	Automatic Fixed Interval	2270.5	0.0041067	0.0285714	Trapezoid	40	1
R60	Automatic Fixed Interval	494.14	.00041263	0.0285714	Trapezoid	40	1
R860	Automatic Fixed Interval	458.99	0.0020036	0.0285714	Trapezoid	40	1
R90	Automatic Fixed Interval	4344.2	0.0063678	0.0285714	Trapezoid	40	1
R920	Automatic Fixed Interval	3924.3	0.0010646	0.0285714	Trapezoid	40	1

Annex 11. Sta. Cruz Field Validation Points

Table A-11.1. Sta. Cruz Field 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

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
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
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

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
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
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

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
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
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

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
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
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

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
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
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

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
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

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Latitude	Longitude					
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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