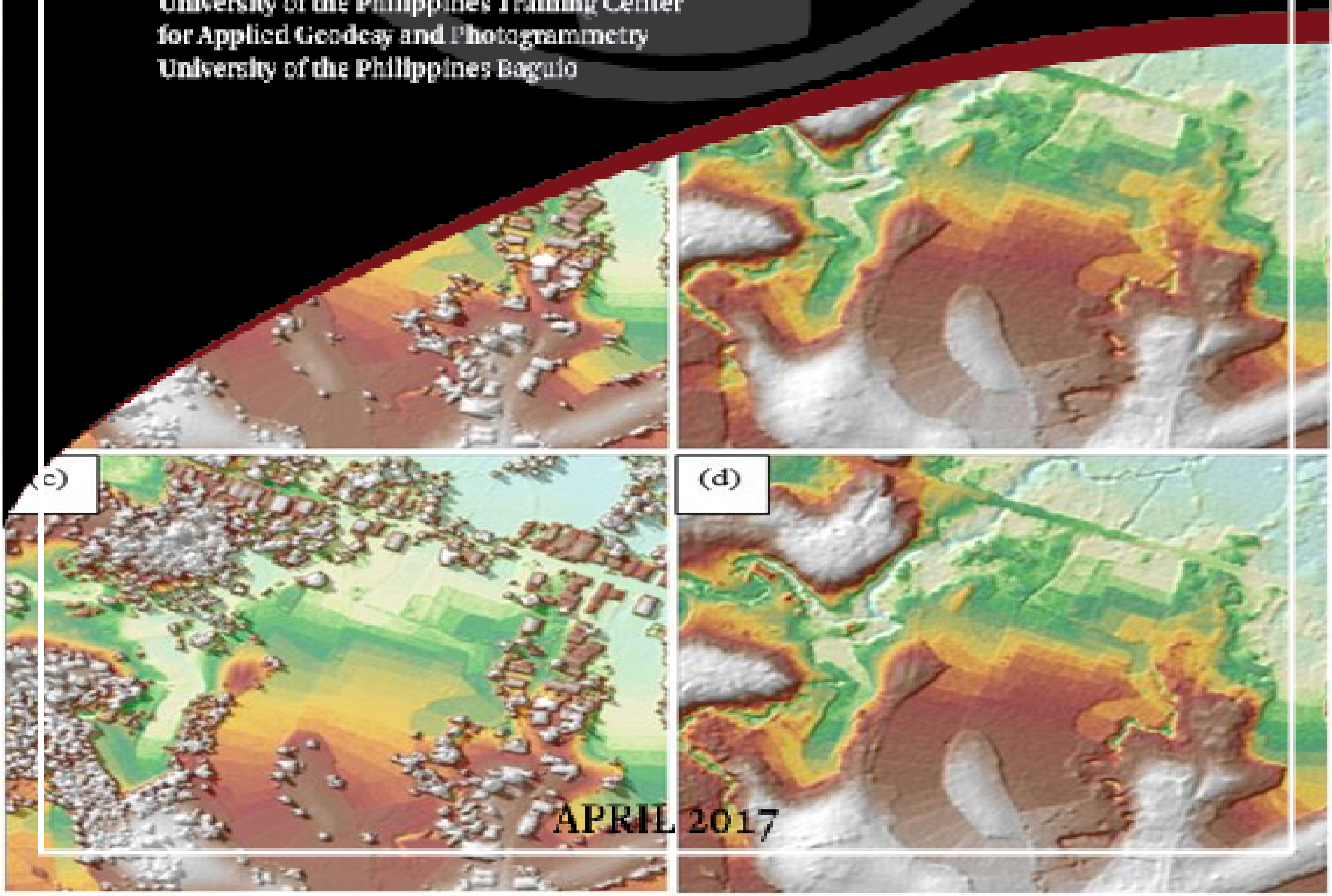
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Baroro River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Baguio



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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
UPB	University of the Philippines Baguio
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 BARORO RIVER

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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).

1.1 Background of the Phil-LiDAR 1 Program

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

Also, tThe 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, Baguio (UPB). UPB 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 12 river basins in the Northern Luzon Region . The university is located in Baguio City in the province of CebuBenguet.

1.2 Overview of the Baroro River Basin

Baroro River Basin is situated in the province of La Union, covering the City of San Fernando, and the Municipalities of San Juan, Bacnotan, and San Gabriel. According to DENR – River Basin Control Office, it has a drainage area of 191 km2 and an estimated 467 million cubic meter (MCM) annual run-off (River Basin Control Office, 2017).

Its main stem, Baroro River, is part of the 13 river systems the Northern Luzon Region. According to the 2015 national census of NSO, a total of 6,608 locals are residing in the immediate vicinity of the river (Philippine Statistics Authority, 2016). Aside from providing fishery resources to its locals, Baroro River contributes to the tourism industry in the area. La Union's first river cruise is operating on its waters since May 2014.

Locals near Baroro River has recently experienced flooding last July 5-9, 2015 due to torrential rains brought by the Severe Tropical Storm "Egay" followed by a Southwest Monsoon (Habagat) enhanced by another typhoon on the Pacific, Typhoon Falcon.

The event was also experienced by DVBC team as they went to La Union on July 3-27, 2015 to conduct a field survey. It supposed to cover following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section and as-built survey of

Cabaroan Bridge; validation points acquisition survey within Baroro River Basin; and bathymetric survey from Brgy. Cabaroan down to the mouth of the river in Brgy. Nagsimbaanan, with an estimated length of 10.92 km using an OHMEX™ Single Beam echo sounder and GNSS PPK survey technique. In addition, UP Baguio also conducted flow data gathering throughout the survey period.

The team was able to complete their field activities except the bathymetric survey because of the bad weather. On November 24-26, 2015, another team was sent to La Union to complete another 7 kilometers of the river by manual bathymetry.

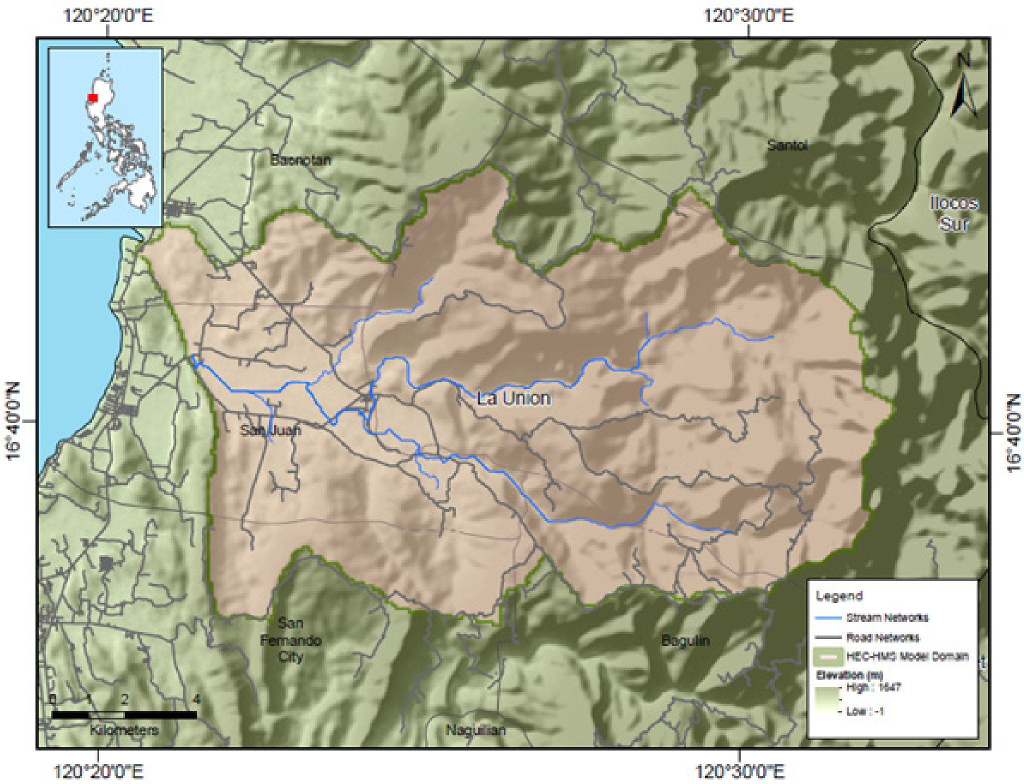

Figure 1. Map of the Baroro River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION IN BARORO 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).

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Baroro Floodplain in La Union. These missions were planned for 16 lines and ran for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Baroro 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 Frequecy (Hx)	Average Speed (kts)	Average Turn Time (Minutes)
10A	1200	30	50	200	30	130	5
10B	1200	30	50	200	30	130	5
10C	1200 / 1500 / 1800	30	50	200	30	130	5
10D	1200 / 1500	30	50	200	30	130	5
10G	1500	30	50	200	30	130	5

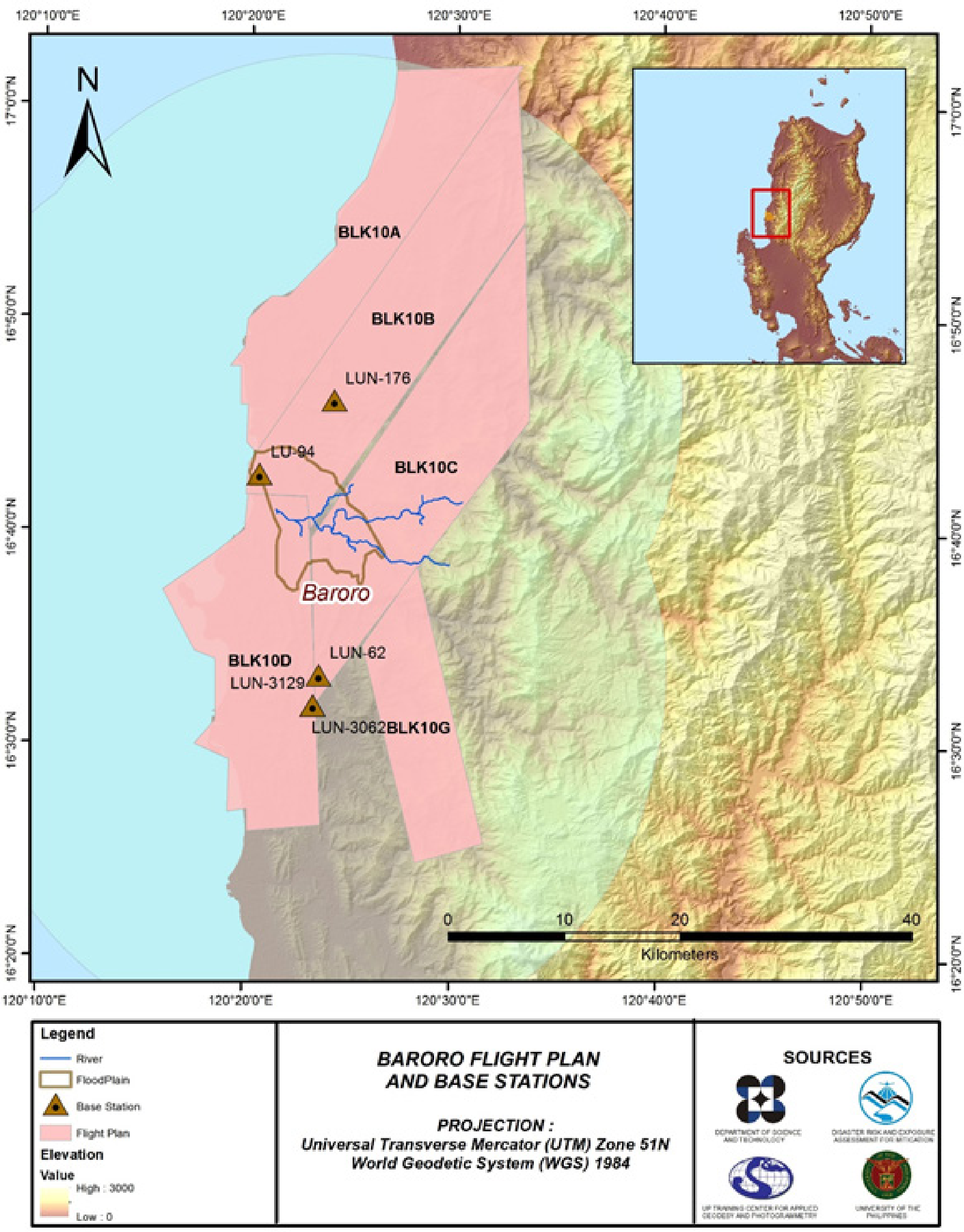


Figure 2. Flight plan and base stations used for Baroro Floodplain

2.2 Ground Base Stations

The project team was able to two (2) NAMRIA reference stations (LUN-62 and LUN-176) with second (2nd) -order accuracy, two (2) (LUN-3062 and LUN-3129) with fourth (4th)- order accuracy, and Benchmark (BM LU-94) with first (1st))-order accuracy. The certifications for the NAMRIA reference points are found in ANNEX A-2. These points were used as base stations during flight operations for the entire duration of the survey (February 25 – March 8, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Baroro Floodplain are shown in Figure 2.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area., Iin addition, Table 2 to Table 6 show the details about the following NAMRIA reference stations and established points, Table 7 shows the lists of all ground control points occupied during the acquisition together with the dates they these are utilized during the survey.

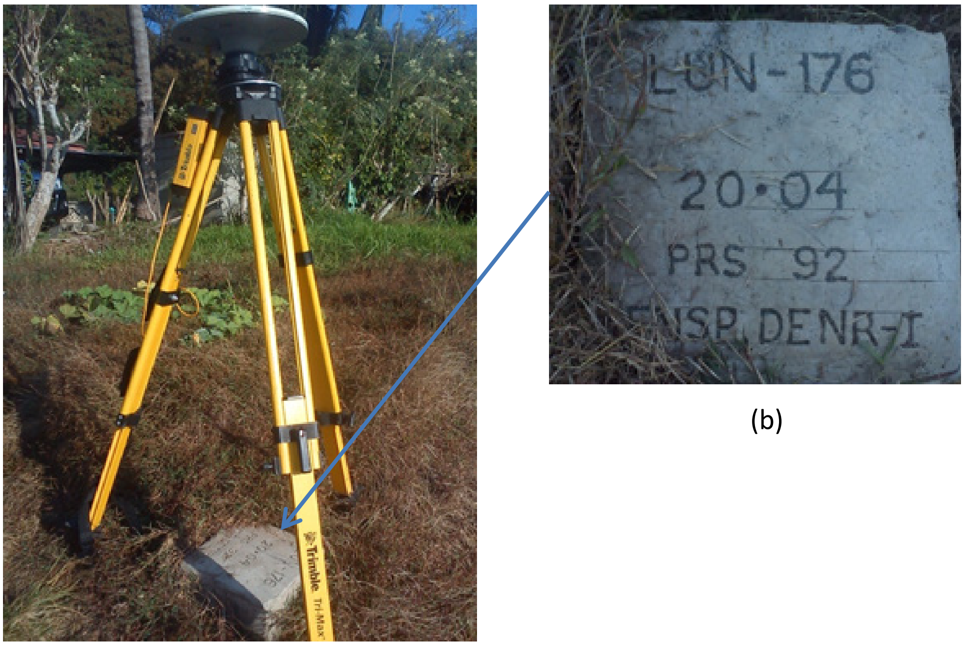
(b)

(a)

Figure 3. a) GPS set-up over LUN-62 as recovered 15 m S from the first access ladder of the river control and about 100 m N from the end,, it is also situated 300 m S of a hanging bridge;. b) NAMRIA reference point LUN-62 as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal reference point LUN-62 used as base station for the LiDAR acquisition.

Station Name		LUN-62
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	16° 33’ 19.98115” 120° 23’ 28.76004” 33.18400 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	435034.926 m 1831016.667 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 33’ 14.07106” 120° 23’ 33.49149” 69.44500 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	221592.72 m 1832084.35 m



(a) (b)

Figure 4. a) GPS set-up over LUN-176 recovered near a corner of a farm dike, about 15 m SE of the well and about 20 m SW of the nearest house;. b) NAMRIA reference point LUN-176 as recovered by the field team..

Table 3. Details of the recovered NAMRIA horizontal reference point LUN-176 used as base station for the LiDAR acquisition.

Station Name	LUN-176	
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	16° 46' 14.35394" 120° 24' 5.41918" 35.63300 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	436193.115 m 1854816.574 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 46' 8.39718" 120° 24' 10.13252" 71.25300 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	222990.04 m 1855884.50 m

(a)

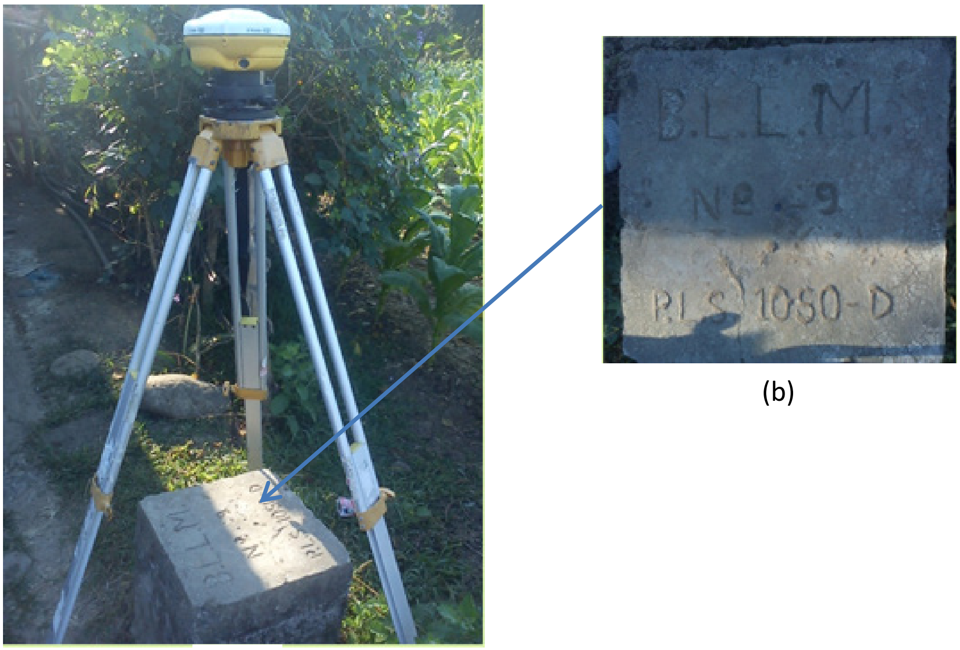
(b)

Figure 5. a) GPS set-up over LUN-3062 recovered at the top of a dike, approximately 100 m north of Philippine Central College of Arts Sciences & Technology and 80 m north of Naguilian emission testing center in Brgy. Natividad, Naguilian, La Union;. b) NAMRIA reference point LUN-3062 as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal reference point LUN-3062 used as base station for the LiDAR acquisition.

Station Name	**LUN-3062**
Order of Accuracy	4th
Relative Error (horizontal positioning)	1 in 10,000

Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	16° 31' 55.00993" 120° 23' 12.50504" 25.32100 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	434545.028 m 1828406.255 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 31' 49.10470" 120° 23' 17.23850" 61.64400 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	221076.59 m 1829477.48 m



(b)

(a)

Figure 6. a) GPS set-up over LUN-3129 recovered beside the National Road about 50 meters northeast of the nearest house;. b) NAMRIA reference point LUN-3129 as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal referencereference point LUN-3129 used as base station for the LiDAR acquisition.

Station Name	**LUN-3129**	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1 in 10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	16° 31’ 55.00993” 120° 23’ 12.50504” 25.32100 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	434545.028 m 1828406.255 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 31’ 49.10470” 120° 23’ 17.23850” 61.64400 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	221076.59 m 1829477.48 m

Figure 7. GPS set-up over LU-94 recovered on the S edge of Baroro bridge 4 m SE of the centerline of the national highway, 30 m SE of Baroro National Memorial Monument;. b) NAMRIA reference point LU-94 as recovered by the field team.

Table 6. Details of the recovered NAMRIA referencel point LU-94 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	**LU-94**	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	16°42' 38.64674" 120°20'35.05091" 49.582 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	21672.143 m 1849445.472 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16°42' 38.64674" 120°20'35.05091" 49.582 m

Table 7. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 25, 2014	1151P	1BLK10A056A	LUN-176 and LUN-3129
February 25, 2014	1153P	1BLK10AS056B	LUN-176 and LUN-3129
February 26, 2014	1155P	1BLK10C057A	LUN-176 and LU-94
February 27, 2014	1159P	1BLK10GD058A	LUN-62 and LUN-302
March 2, 2014	1171P	1BLK10CDS061A	LUN-62 and LUN-3062
March 2, 2014	1173P	1BLK10DS061B	LUN-62 and LUN-3062
March 3, 2014	1175P	1BLK10BS062A	UN-176 and LUN-3129
March 3, 2014	1177P	1BLK10CS062B	LUN-176 and LUN-3129
March 3, 2014	1197P	1BLK10GCS067B	LUN-62 and LUN-3062

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR data acquisition in Baroro Floodplain, for a total of fifty nine hours and twenty five minutes (59+25) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Baroro 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 25, 2014	1151P	224.93	287.057	0.096	286.961	NA	3	53
February 25, 2014	1153P	224.93	374.971	34.864	286.961	NA	1	55
February 26, 2014	1155P	298.8	387.642	38.864	348.778	574	3	41
February 27, 2014	1159P	390.68	499.092	51.053	448.039	76	3	41
March 2, 2014	1171P	298.8	200.683	38.244	162.439	334	3	25
March 2, 2014	1173P	254.02	169.709	0	169.709	334	2	23
March 3, 2014	1175P	284.97	323.091	38.317	284.774	675	3	35
March 3, 2014	1177P	298.8	400.221	39.873	360.348	501	2	53
March 8, 2014	1197P	134.22	108.873	0	108.873	257	2	59
TOTAL		2410.15	2751.34	240.69	2510.65	2751.00	59	25

Table 9. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (Hz)	Scan Frequency (kHz)	Average Speed (kts)	Average Turn Time (Minutes)
1151P	1200	30	50	200	30	130	5
1153P	1200	30	50	200	30	130	5
1155P	1200	30	50	200	30	130	5
1159P	1200	30	50	200	30	130	5
1171P	1500	30	50	200	30	130	5
1173P	1200	30	50	200	30	130	5
1175P	1200	30	50	200	30	130	5
1177P	1800	30	50	200	30	130	5
1197P	1500	30	50	200	30	130	5

2.4 Survey Coverage

Baroro Floodplain is located in the province of La Union with majority of the floodplain situated within the municipalities of Bacnotan, Bagulin, San Fernando City, San Gabriel, and San Juan. Municipalities of Bacnotan, Balaoan, Bangar, Luna, San Fernando City, San Juan, Sudipen, Bauang, and Santol are fully covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Baroro Floodplain is presented in Figure 8.

Table 10. List of municipalities and cities surveyed during Baroro Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of area Surveed
La Union	Bacnotan	80.67	80.67	100.00%
	Balaoan	60.96	60.96	100.00%
	Bangar	45.12	45.12	100.00%
	Luna	50.66	50.66	100.00%
	San Fernando City	121.05	121.05	100.00%
	San Juan	53.44	53.44	100.00%
	Sudipen	75.75	75.75	100.00%
	Bauang	85.26	85.18	99.91%
	Santol	97.97	97.65	99.67%
	Burgos	51.92	45.45	87.54%
	San Gabriel	154.19	95.20	61.74%
	Naguilian	86.39	52.56	60.84%
	Bagulin	77.97	36.31	46.57%
	Caba	56.19	22.70	40.40%
	Aringay	95.65	12.31	12.87%
	Pugo	60.54	0.10	0.16%
Ilocos Sur	Tagudin	54.35	54.35	100.00%
	Suyo	148.52	78.31	52.73%
	Alilem	132.18	41.57	31.45%
	Sugpon	180.28	50.89	28.23%
	Santa Cruz	105.96	23.26	21.95%
	Sigay	98.45	0.00	0.00%
Benguet	Sablan	90.22	41.33	45.81%
	Tuba	322.02	19.66	6.10%
TOTAL		2385.69	1244.47	52.16%

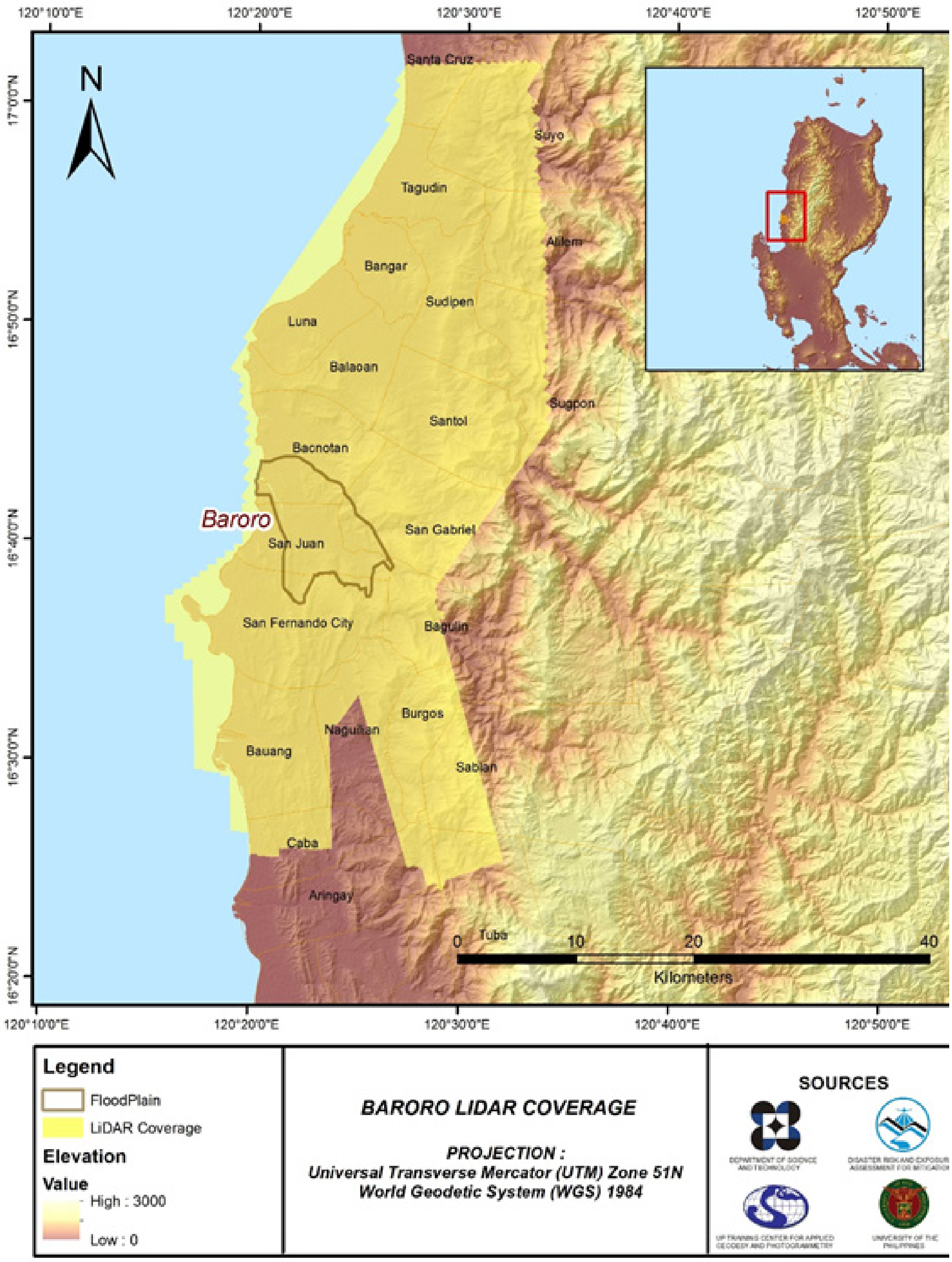


Figure 8. Actual LiDAR survey coverage for Baroro Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE BARORO FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Harmond F. Santos, Jovy Anne S. Narisma, Engr. Ma. Ailyn L. Olanda, Engr. Justine Y. Francisco, Engr. Kenneth A. Solidum, Engr. Jommer M. Medina, Carl Joshua S. Lacsina

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) are 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 is was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are were subject for quality checking to ensure that the required accuracies of the program, which are were the minimum point density, vertical and horizontal accuracies, are were met. The point clouds are 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 are were calibrated. Portions of the river that are were barely penetrated by the LiDAR system are were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component (DVBC). LiDAR acquired temporally are were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is 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 9.

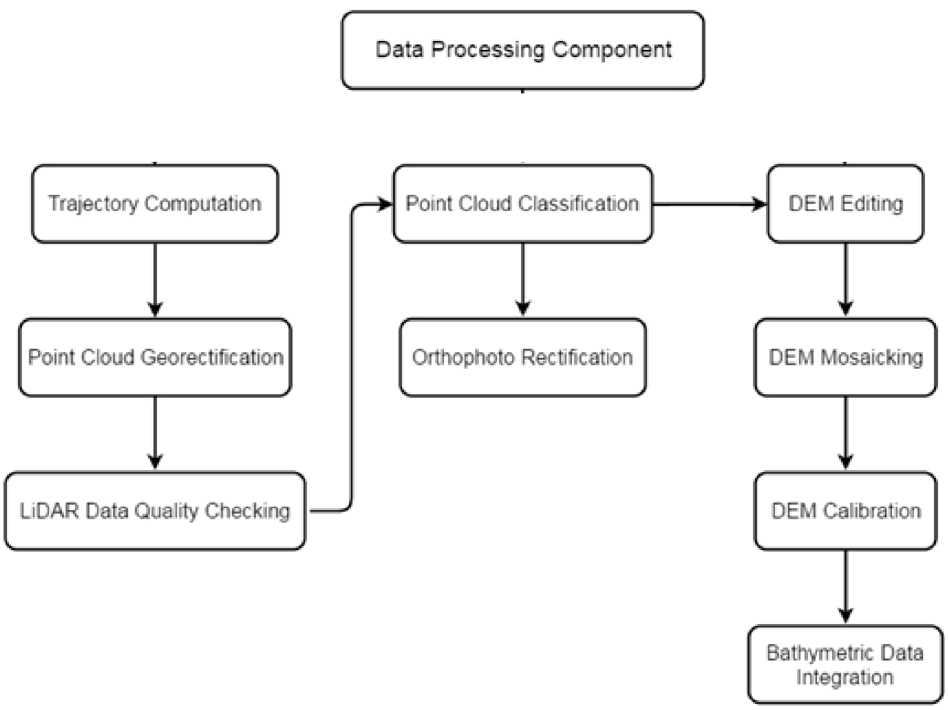


Figure 9. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Baroro Floodplain can be found in ANNEX A-5. Missions flown during the survey conducted on March 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over La Union. The Data Acquisition Component (DAC) transferred a total of 161.38 Gigabytes of Range data, 1.44 Gigabytes of POS data, 55.49 Megabytes of GPS base station data, and 157.8 Gigabytes of raw image data to the data server on March 17, 2014. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Baroro was fully transferred on March 17, 2014, as indicated on the data transfer sheets for Baroro Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1175P, one of the Baroro flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on March 3, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

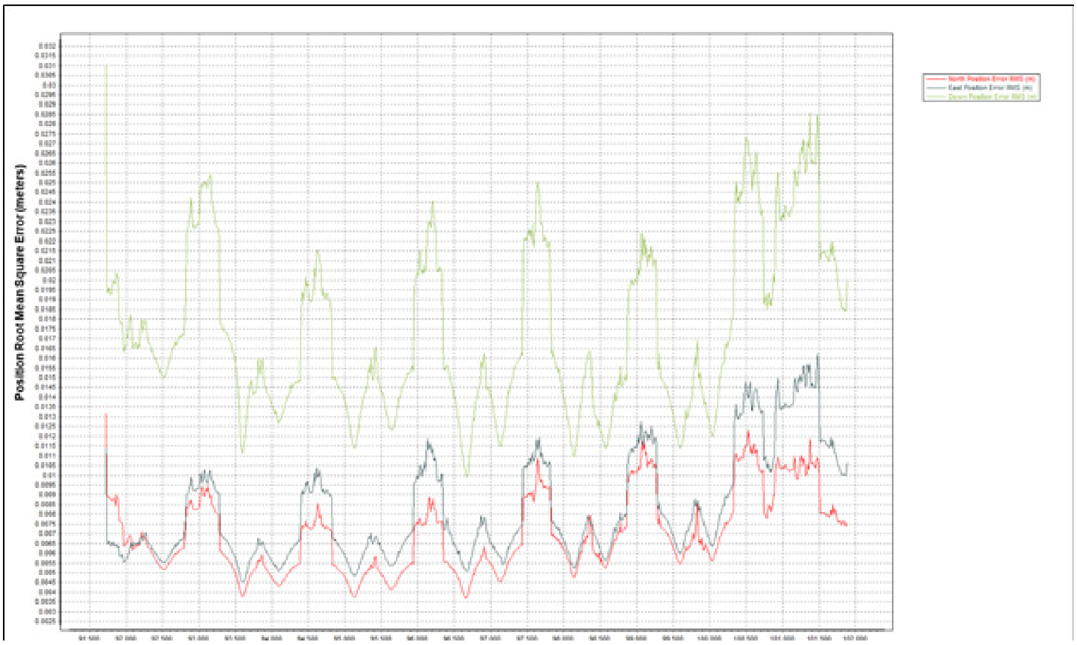


Figure 10. Smoothed Performance Metric of a Baroro Flight 1175P.

The time of flight was from 91500 seconds to 102000 seconds, which corresponds to morning of March 3, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.24 centimeters, the East position RMSE peaks at 1. 48 centimeters, and the Down position RMSE peaks at 2.74 centimeters, which are within the prescribed accuracies described in the methodology.

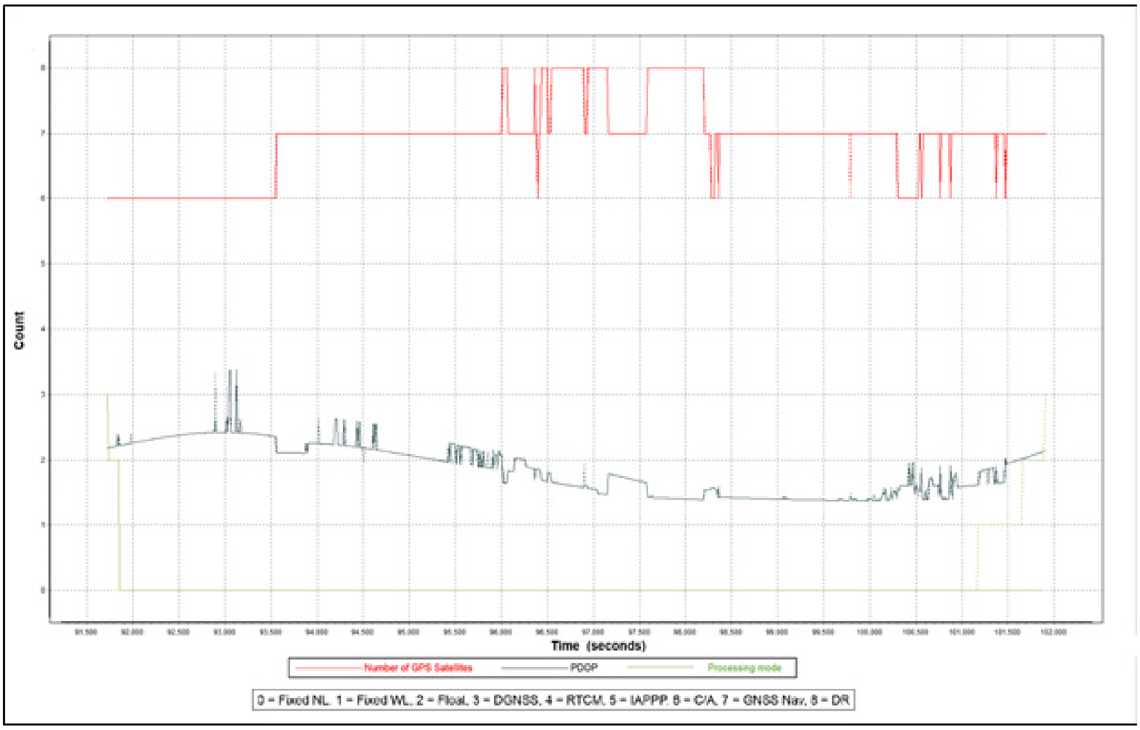
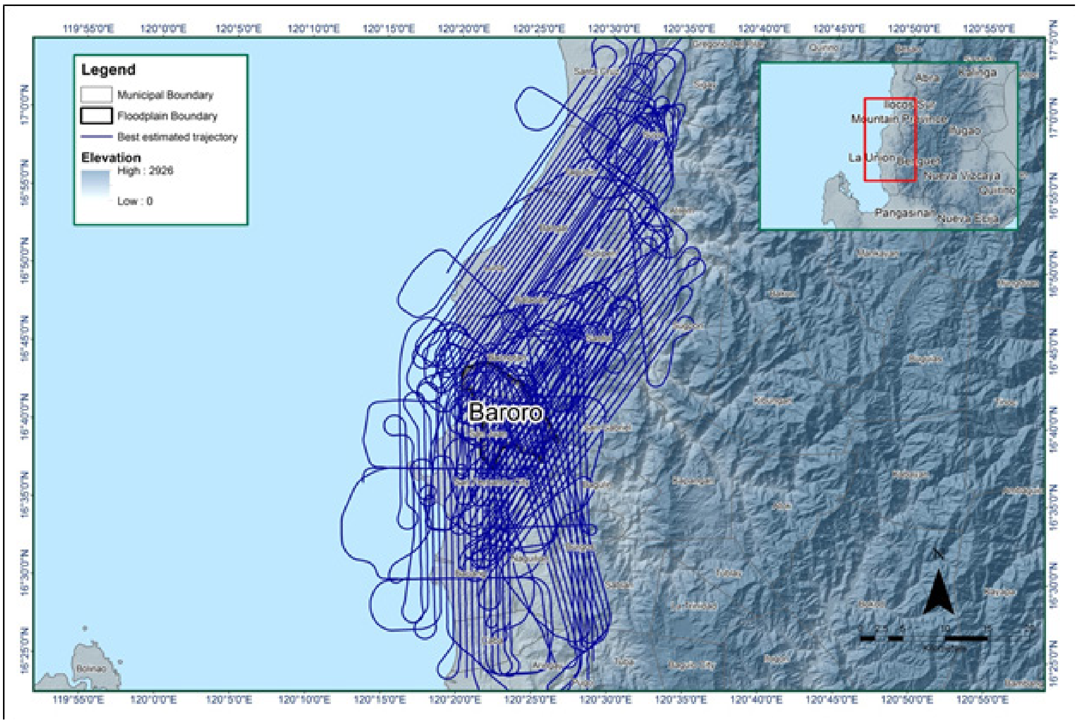


Figure 11. Solution Status Parameters of Baroro Flight 1175P.

The Solution Status parameters of flight 1175P, one of the Baroro flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. 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 8. The PDOP value also did not go above the value of 3.4, 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 Baroro flights is shown in Figure 12.

Figure 12. Best estimated trajectory of the LiDAR missions conducted over Baroro



Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 153 flight lines, with each flight line containing two channels, since Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Baroro Floodplain are given in Table 11.

Table 11. Self-calibration results values for Baroro flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000398
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.022977
GPS Position Z-correction stdev (<0.01meters)	0.007

The optimum accuracy was obtained for all Baroro 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 Baroro Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

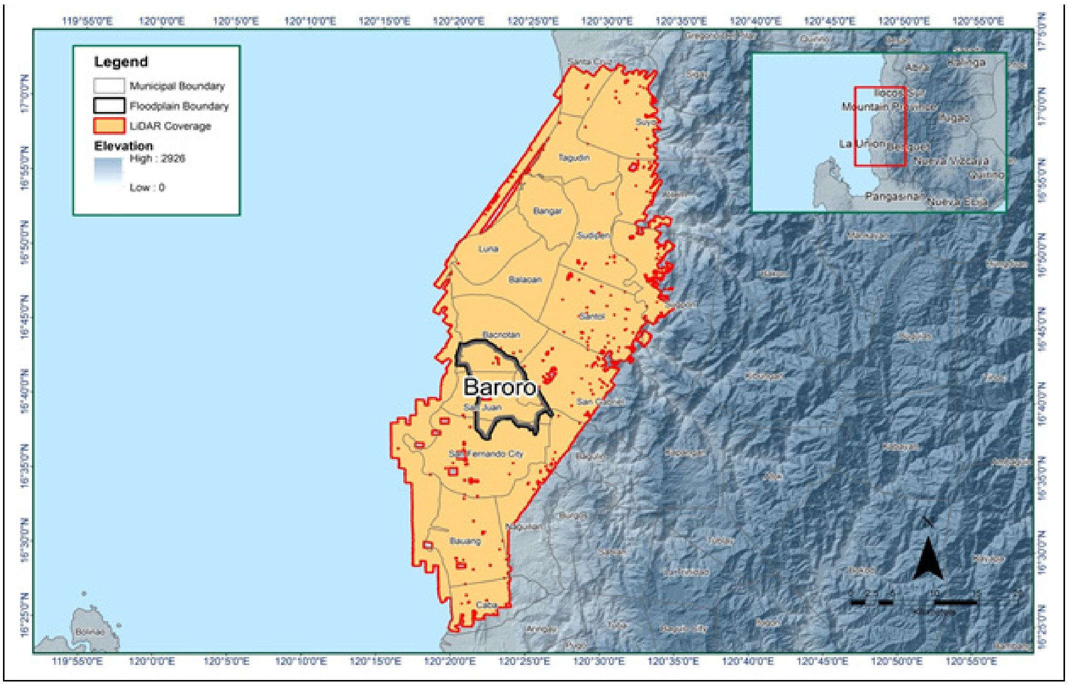


Figure 13. Boundary of the processed LiDAR data over Baroro Floodplain

The total area covered by the Baroro missions is 1,688.78 sq km that is comprised of eleven (11) flight acquisitions grouped and merged into five (5) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Baroro Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq km)
LaUnion_Blk10A	1151P	277.55
LaUnion_Blk10B	1151P	379.39
	1173P	
LaUnion_Blk10C	1153P	402.25
	1169P	
	1175P	
	1197P	
LaUnion_Blk10C_additional	1175P	302.89
LaUnion_Blk10D	1157P	326.70
	1159P	
	1171P	
TOTAL		**1688.78 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 14. Since the Pegasus system employs two channels, we would expect 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.

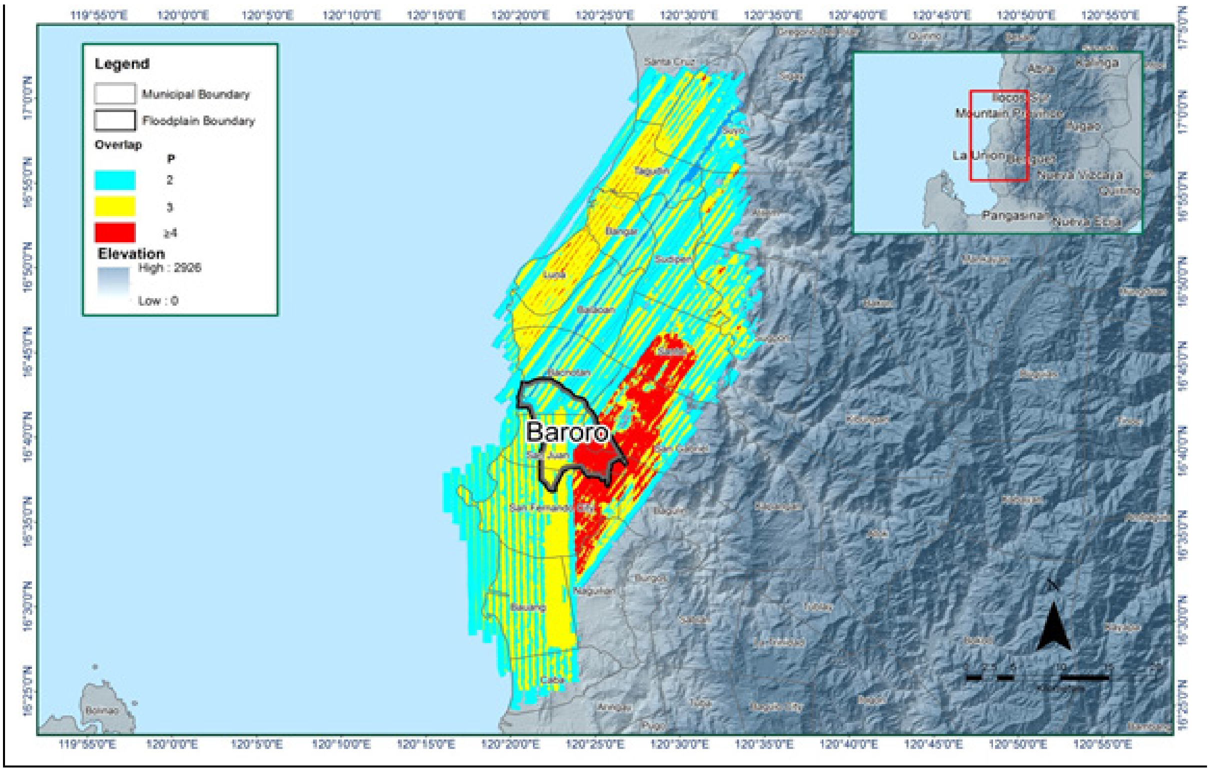


Figure 14. Image of data overlap for Baroro Floodplain.

The overlap statistics per block for the Baroro Floodplain can be found in Annex B-1ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 35.05% and 68.41%, 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 15. It was determined that all LiDAR data for Baroro Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.14 points per square meter.

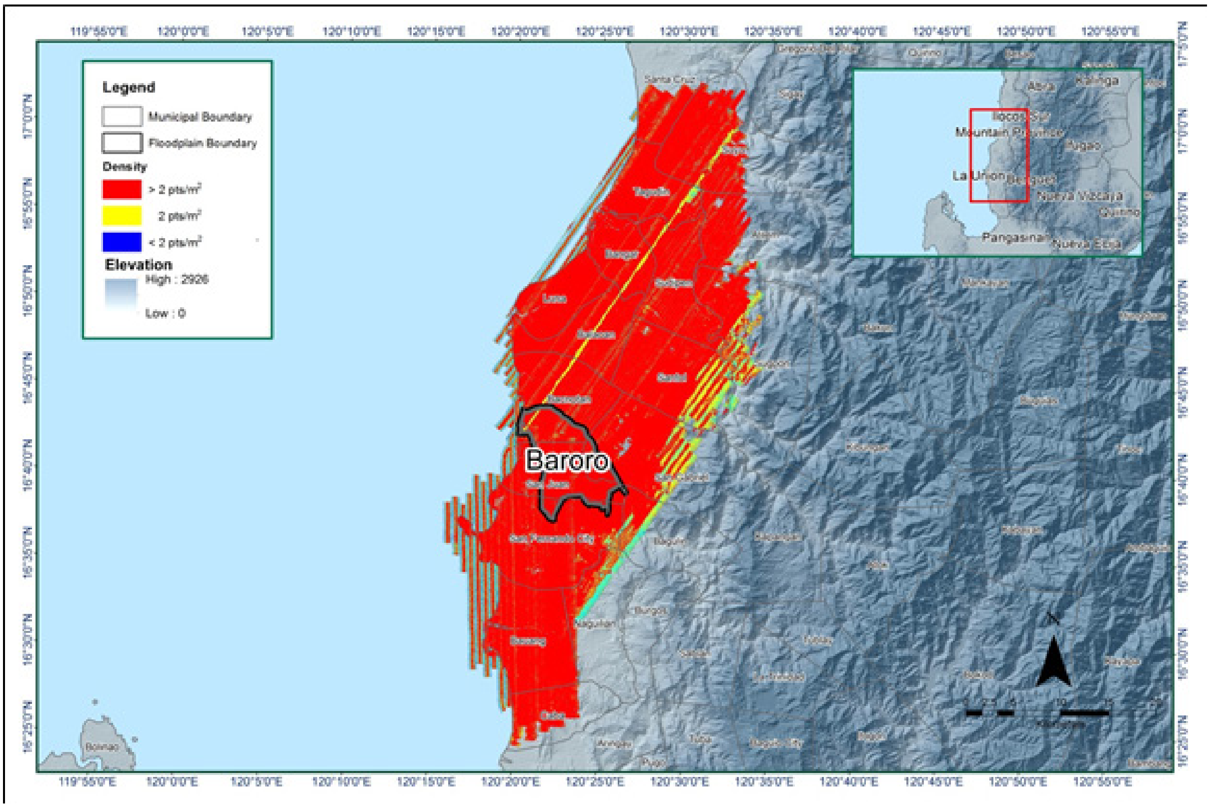


Figure 15. Pulse density map of merged LiDAR data for Baroro Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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.

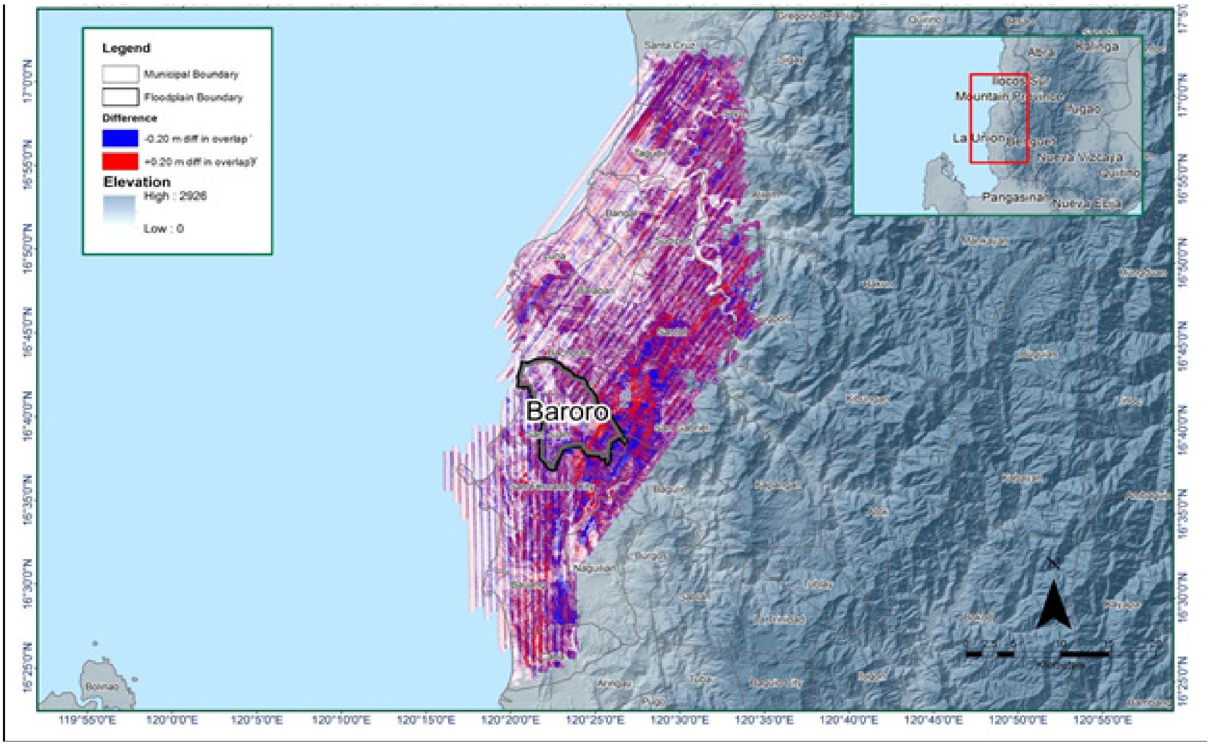


Figure 16. Elevation difference map between flight lines for Baroro Floodplain.

A screen capture of the processed LAS data from a Baroro flight 1175P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

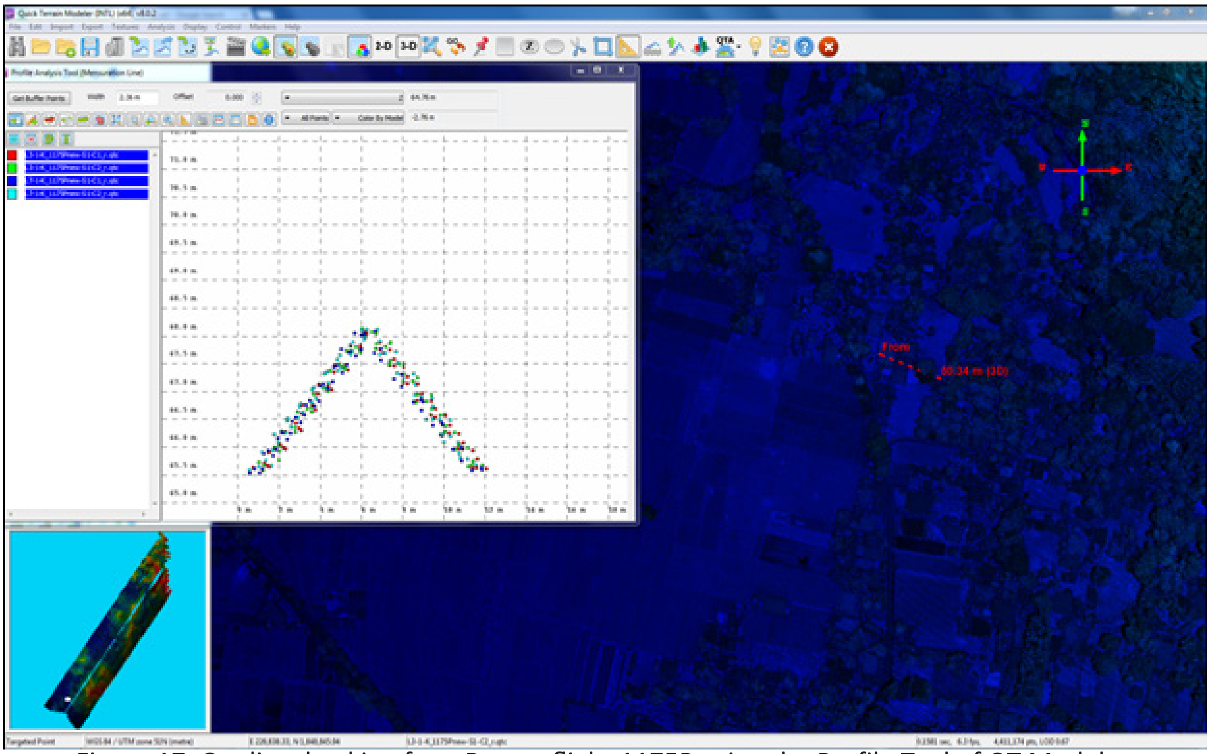


Figure 17. Quality checking for a Baroro flight 1175P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Baroro classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,416,863,843
Low Vegetation	1,218,730,121
Medium Vegetation	2,129,531,612
High Vegetation	2,406,578,603
Building	124,357,098

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Baroro Floodplain is shown in Figure 18. A total of 2,109 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 1,038.87 meters and 40.04 meters, respectively.

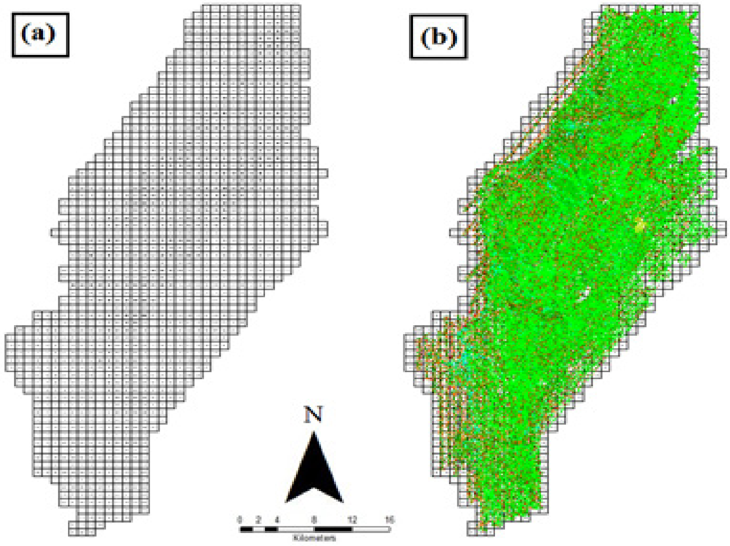


Figure 18. Tiles for Baroro Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

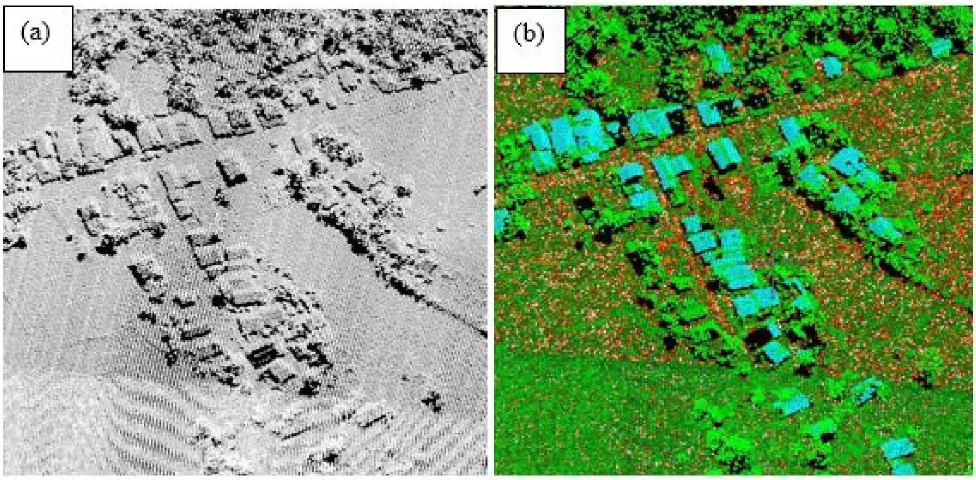


Figure 19. Point cloud before (a) and after (b) classification.

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 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

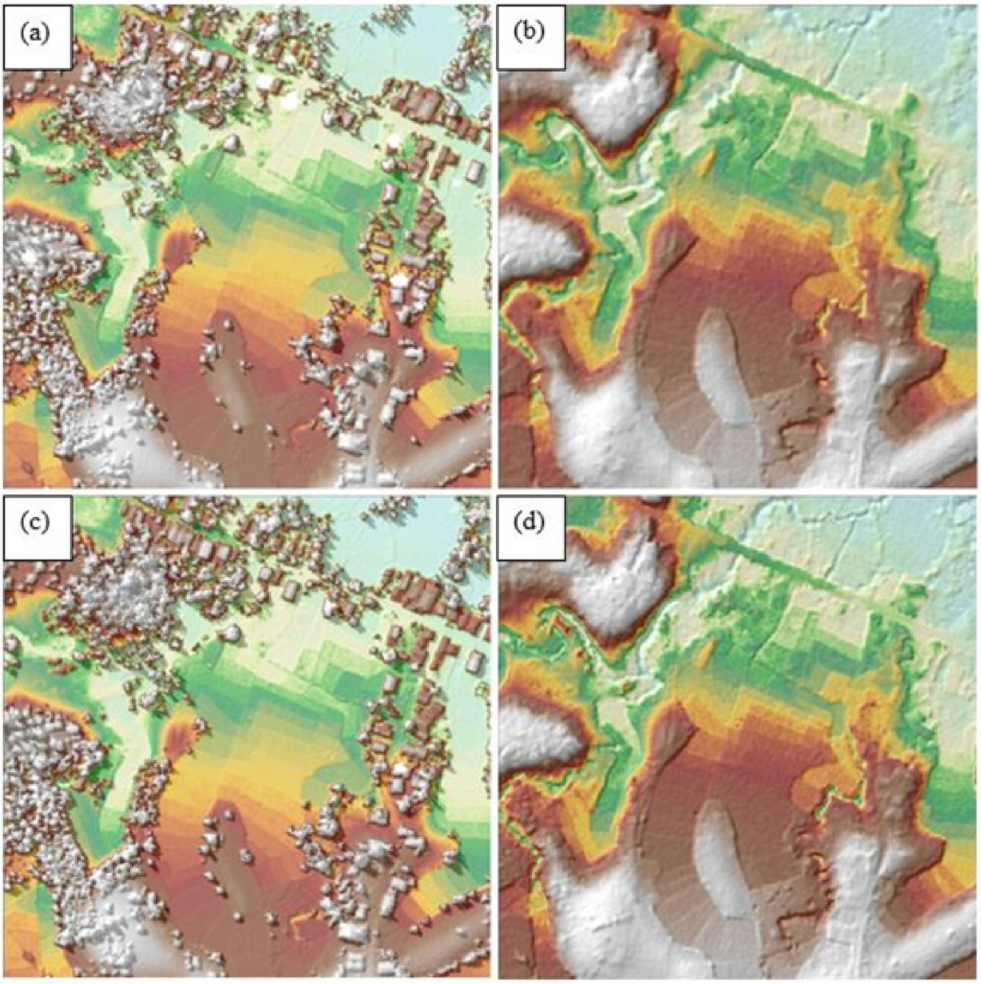


Figure 20. The production of last return DSM (a) and DTM (b);, first return DSM (c) and secondary DTM (d) in some portion of Baroro Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,526 1 km by 1 km tiles area covered by Baroro Floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Baroro Floodplain attaiinedattained a total of 850.31 sq km in orthophotogaph coverage comprised of 2,417 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

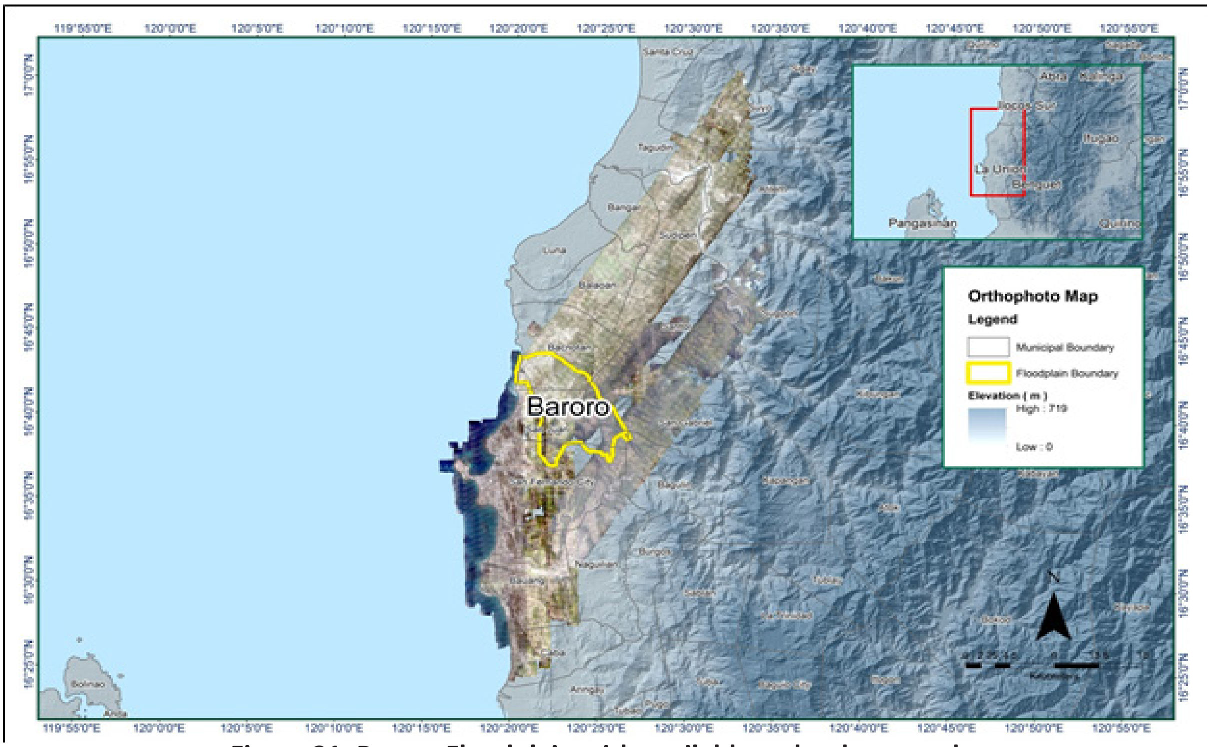


Figure 21. Baroro Floodplain with available orthophotographs

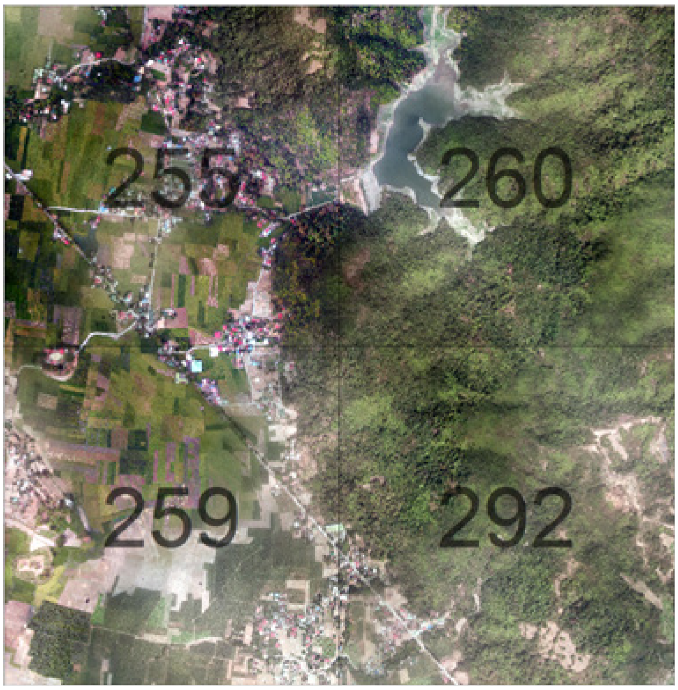


Figure 22. Sample orthophotograph tiles for Baroro Floodplain

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Baroro Floodplain. These blocks are composed of La Union blocks with a total area of 1,688.78 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq km)
LaUnion_Blk10A	277.55
LaUnion_Blk10B	379.39
LaUnion_Blk10C	402.25
LaUnion_Blk10C_additional	302.89
LaUnion_Blk10D	326.70
TOTAL	**1688.78 sq km**

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. The paddy field (Figure 23c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23d) to allow the correct flow of water.

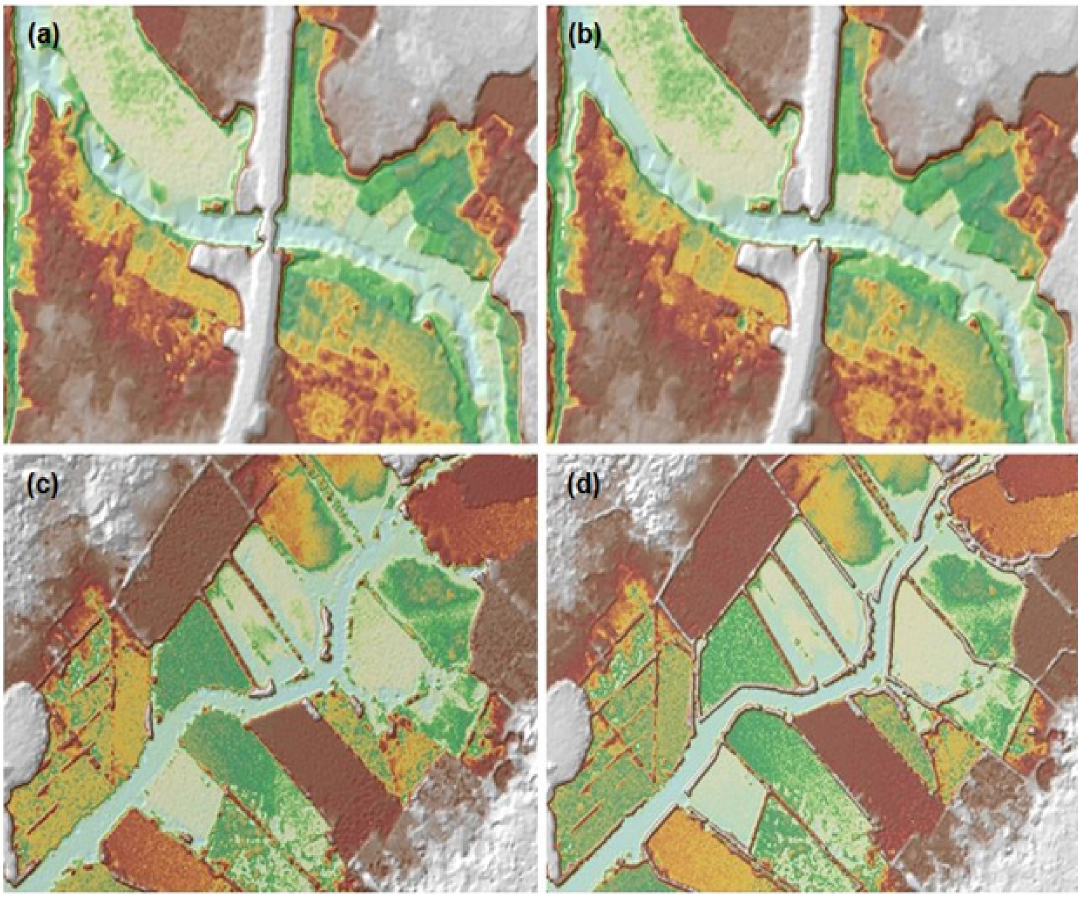


Figure 23. Portions in the DTM of Baroro Floodplain— – a bridge before (a) and after (b) manual editing; and a paddy field before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

LaUnion_Blk10A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Baroro Floodplain is shown in Figure 24. It can be seen that the entire Baroro flodplain is 100% covered by LiDAR data.

Table 15. Shift values of each LiDAR Block of Baroro Floodplain.

Mission Blocks	**Shift Values (meters)**		
	x	**y**	**z**
LaUnion_Blk10A	0.00	0.00	0.00
LaUnion_Blk10B	0.00	0.00	0.00
LaUnion_Blk10C	0.00	0.00	0.00
LaUnion_Blk10C_additional	0.00	0.00	0.00
LaUnion_Blk10D	0.00	0.00	0.00

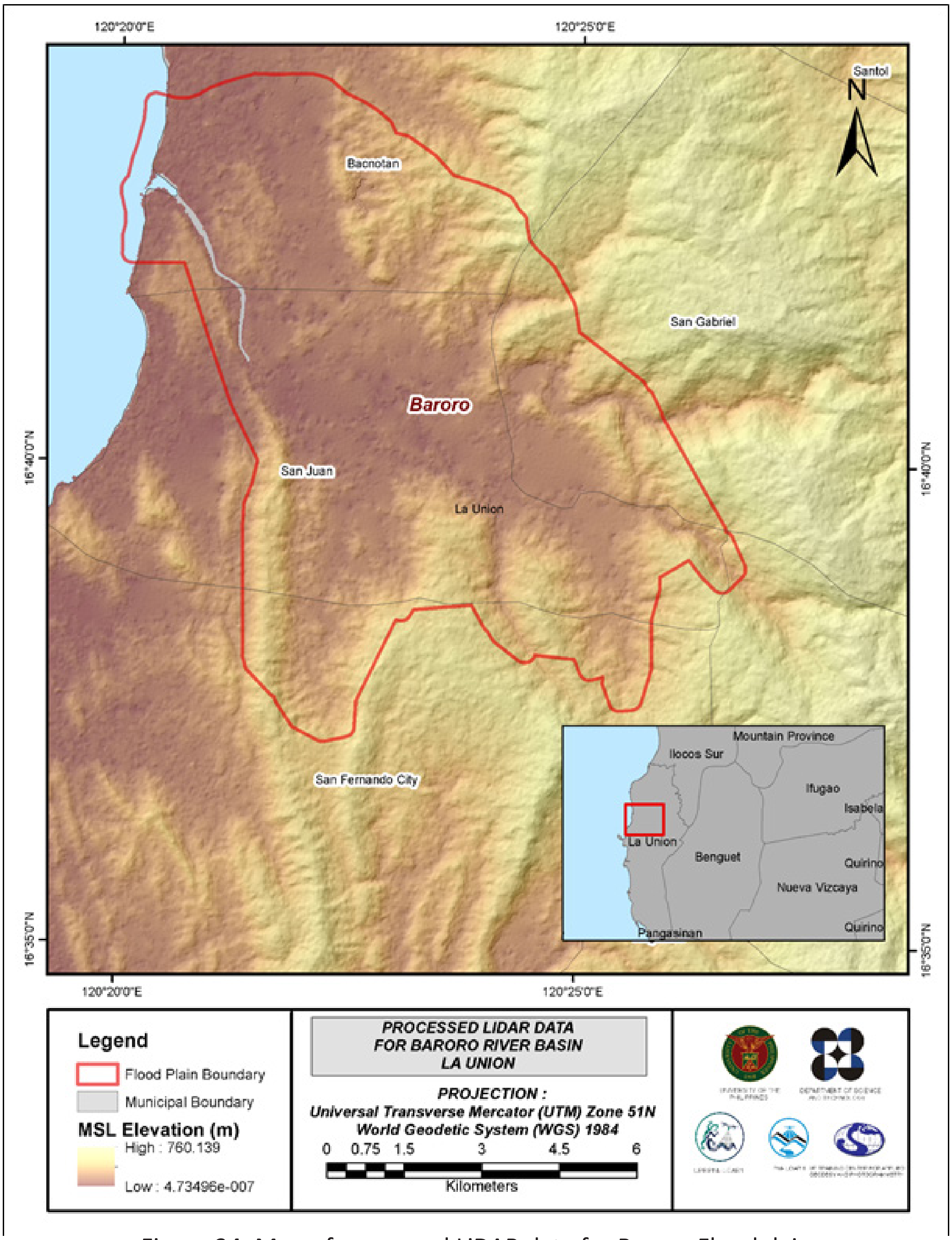


Figure 24. Map of processed LiDAR data for Baroro Floodplain.

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 Baroro to collect points with which the LiDAR dataset is was validated is shown in Figure 25. A total of 4,794 survey points were used for calibration and validation of Baroro LiDAR data. Random selection of 80%Eighty percent of the survey points, which are randomly selected, resulting to in 3,835 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 3.64 meters with a standard deviation of 0.17 meters. Calibration of Baroro LiDAR data was done by subtracting the height difference value, 3.64 meters, to Baroro mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

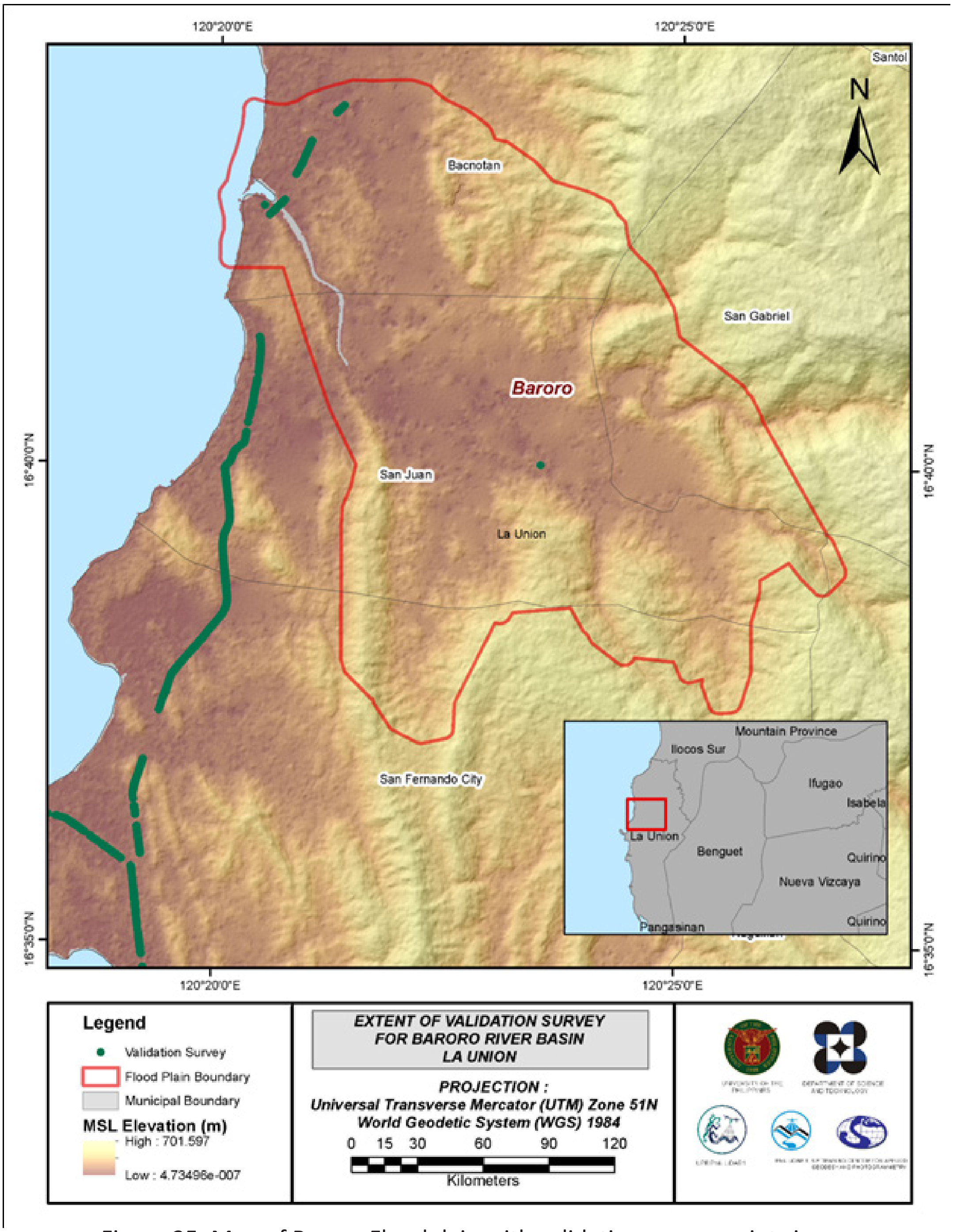


Figure 25. Map of Baroro Floodplain with validation survey points in green.

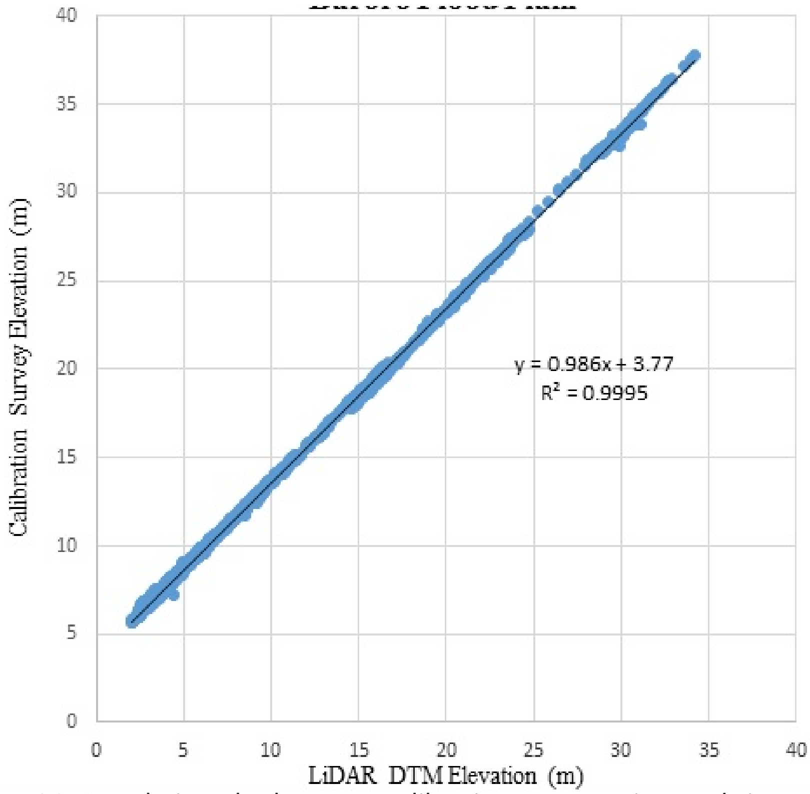


Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 16. Calibration statistical measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.64
Standard Deviation	0.17
Average	-3.64
Minimum	-3.98
Maximum	-3.29

The remaining 20% of the total survey points, resulting to in 201 points, were used for the validation of calibrated Baroro 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.11 meters, as shown in Table 17.

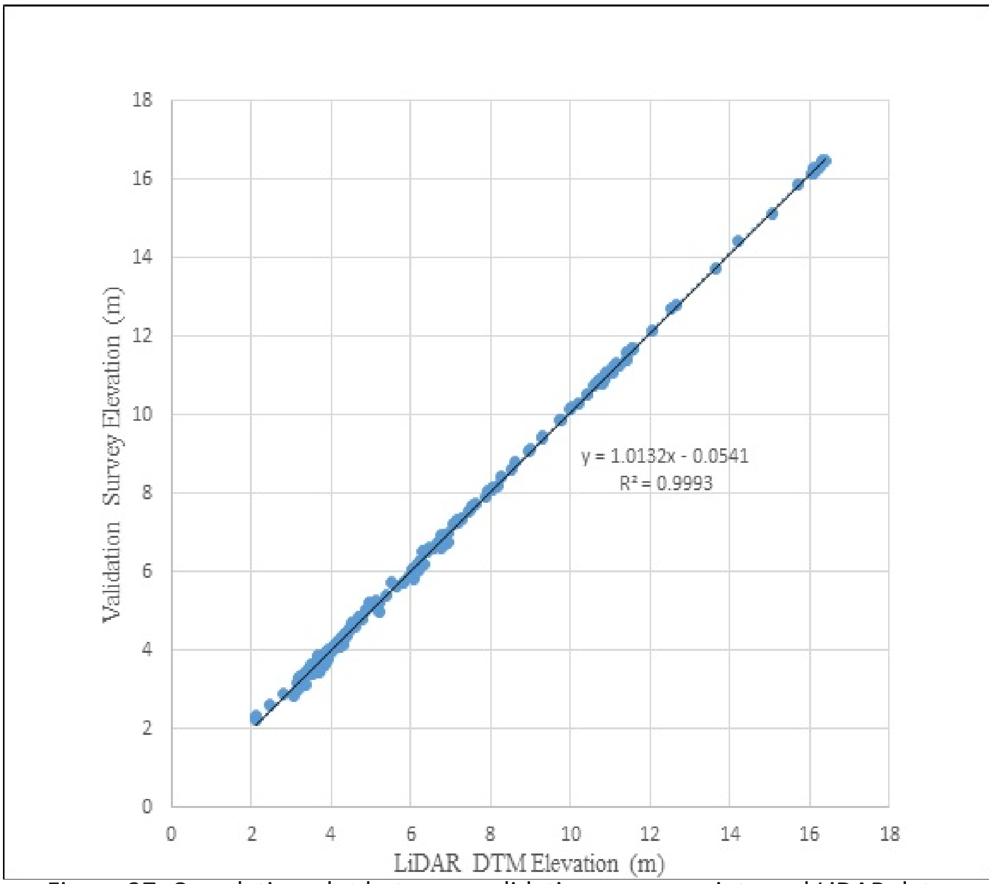


Figure 27. Correlation plot between validation survey points and LiDAR data

Table 17. Validation statistical measures.

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.11
Average	-0.02
Minimum	-0.23
Maximum	0.23

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and some cross-section data was available for Baroro with 3,827 bathymetric survey points. The resulting raster surface produced was done by Local Polynomial interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is was represented by the computed RMSE value of 0.46 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Baroro integrated with the processed LiDAR DEM is shown in Figure 28.

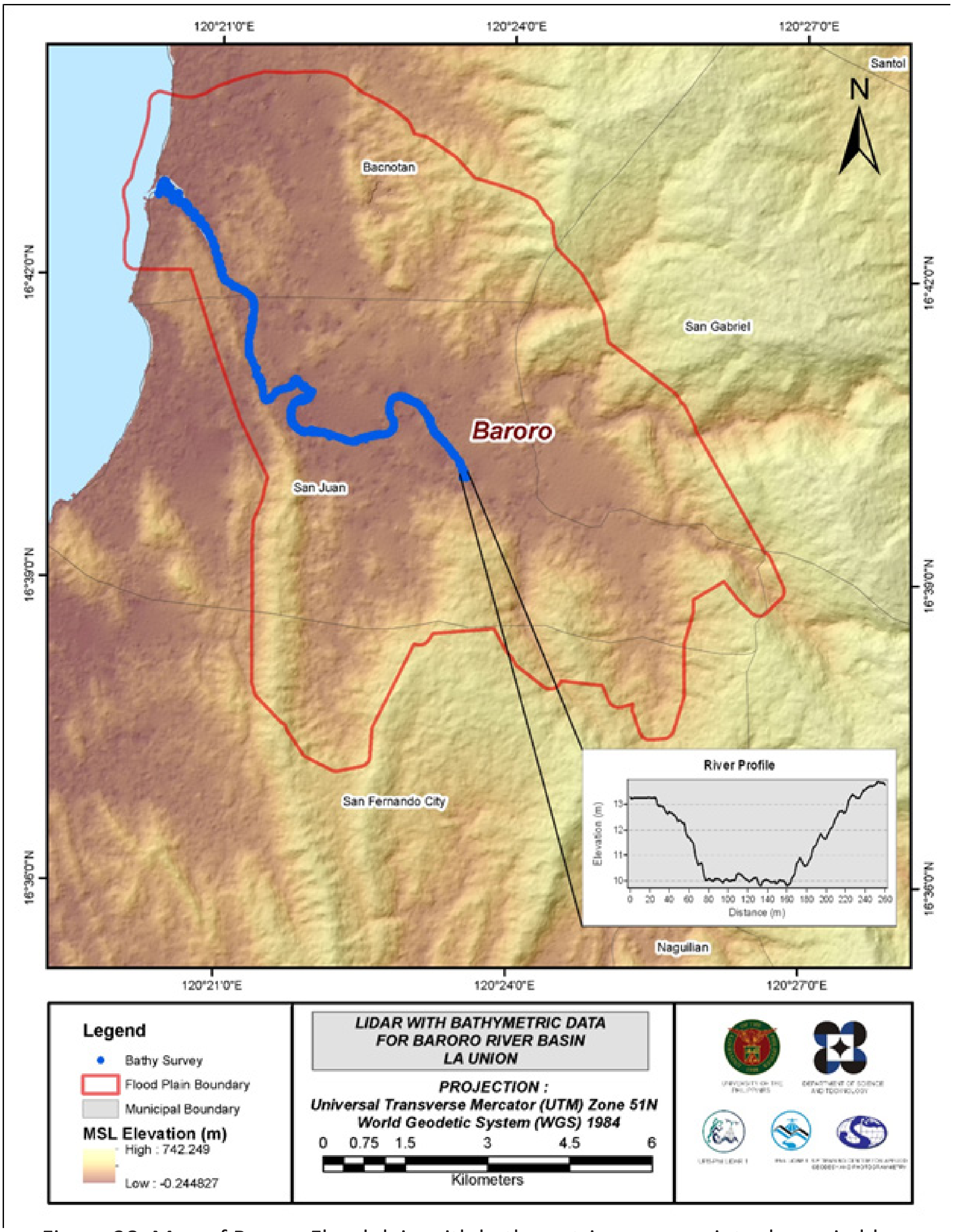


Figure 28. Map of Baroro Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Baroro Floodplain, including its 200 m buffer, has a total area of 85.5 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 228 building features, are considered for QC. Figure 29 shows the QC blocks for Baroro Floodplain.

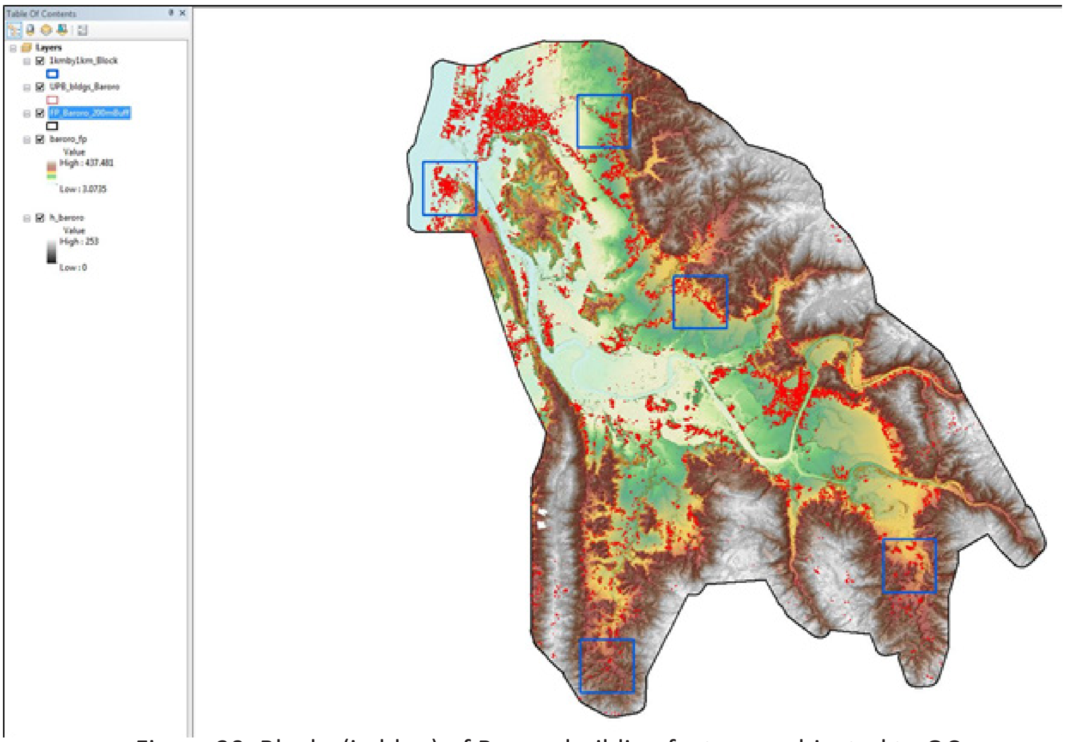


Figure 29. Blocks (in blue) of Baroro building features subjected to QC

Quality checking of Baroro building features resulted in the ratings shown in Table 18.

Table 18. Quality checking ratings for Baroro building features.

Floodplain	Completeness	Correctness	Quality	Remarks
Baroro	99.84	99.77	90.94	PASSED

3.12.2 Height Extraction

Height extraction was done for 13,239 building features in Baroro Floodplain. Of these building features, 542 buildings were filtered out after height extraction, resulting to in 12,697 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 14.45 m.

3.12.3 Feature Attribution

Data collected from various sources which includes OpenStreetMap and Google Maps/Earth were used in the attribution of building features. Areas where there is no available data were subjected for field attribution using ESRI's Collector App. The app can be accessed offline and data collected can be synced to ArcGIS Online when WiFi or mobile data is available.

Table 19 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Building features extracted for Baroro Floodplain.

Facility Type	No. of Features
Residential	12,233
School	216
Market	20
Agricultural/Agro-Industrial Facilities	19
Medical Institutions	7
Barangay Hall	28
Military Institution	0
Sports Center/Gymnasium/Covered Court	9
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	4
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	5
Water Supply/Sewerage	4
Religious Institutions	24
Bank	4
Factory	0
Gas Station	15
Fire Station	1
Other Government Offices	11
Other Commercial Establishments	96
Total	**12,697**

Table 20. Total length of extracted roads for Baroro Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Baroro	45.90	40.79	17.22	4.36	0.00	**112.27**

Table 21. Number of extracted water bodies for Baroro Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Baroro	7	2	0	0	0	**9**

A total of 29 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 shows the Digital Surface Model (DSM) of Baroro Floodplain overlaid with its ground features.

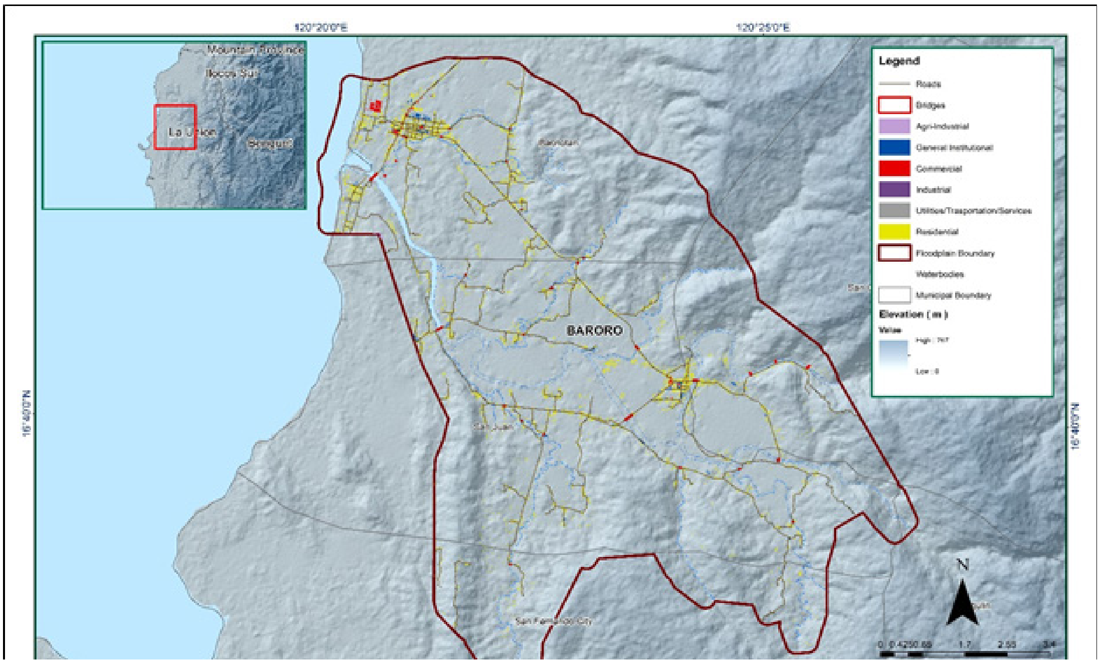


Figure 30. Extracted features for Baroro Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BARORO 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, For. Rodel C. Alberto, Cybil Claire Atacador, Engr. Lorenz R. Taguse

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

Locals near Baroro River has recently experienced flooding last July 5–-9, 2015 due to torrential rains brought by the Severe Tropical Storm “Egay” followed by a Southwest Monsoon (Habagat) enhanced by another typhoon on the Pacific, Typhoon Falcon.

The event was also experienced by DVBC team as they went to La Union on July 3–-27, 2015 to conduct a field survey. It They planned tosupposed to cover following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section and as-built survey of Cabaroan Bridge; validation points acquisition survey within Baroro River Basin; and bathymetric survey from Brgy. Cabaroan down to the mouth of the river in Brgy. Nagsimbaanan, with an estimated length of 10.92 km using an OHMEX™ Single Beam echo sounder and GNSS PPK survey technique. In addition, UP Baguio also conducted flow data gathering throughout the survey period.

The team was able to complete their field activities except the bathymetric survey because of the bad weather. On November 24–-26, 2015, another team was sent to La Union to complete another 7 kilometers of the river by manual bathymetry.

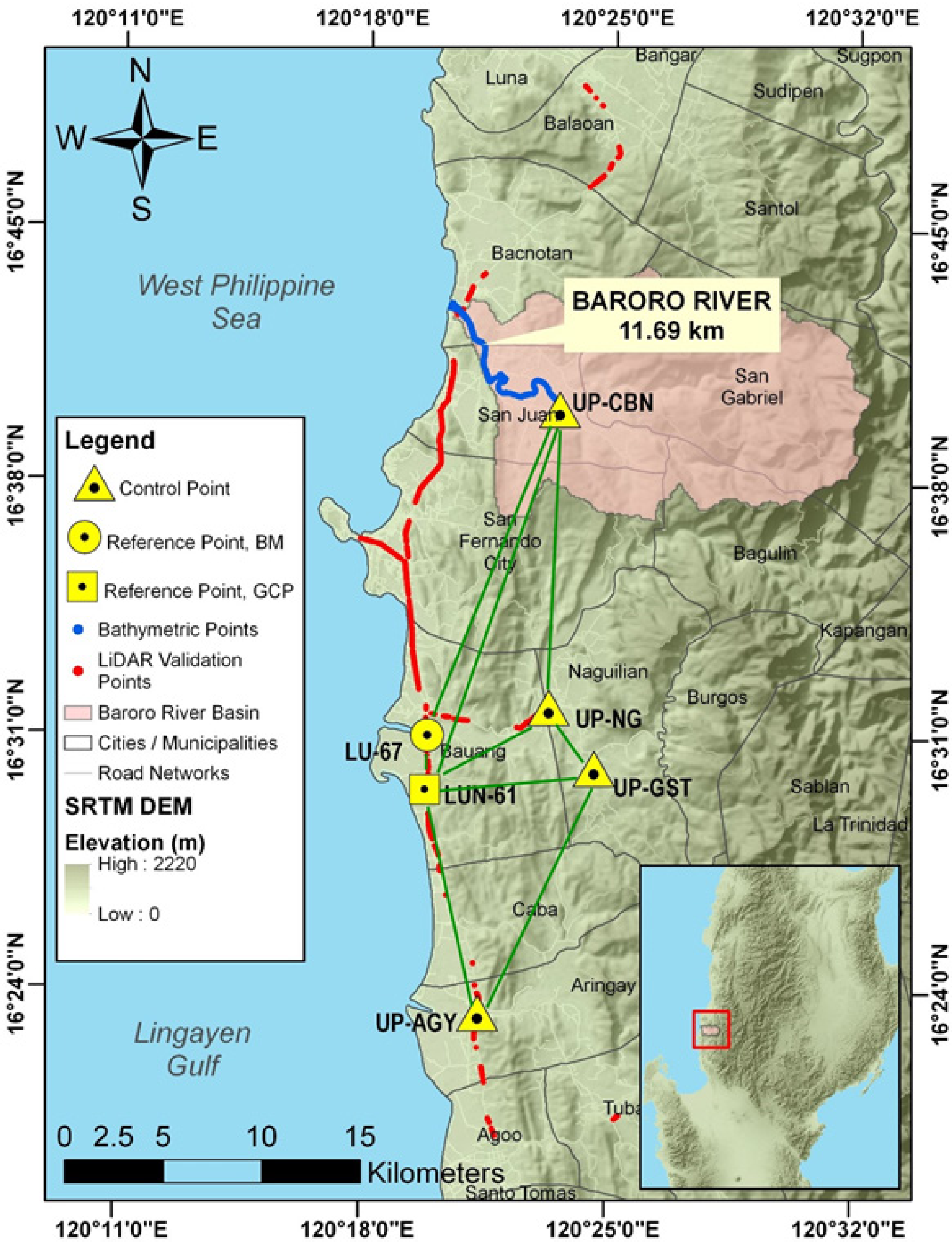


Figure 31. Extent of the bathymetric survey (in blue) Baroro River and the LiDAR data validation survey (in red)

4.2 Control Survey

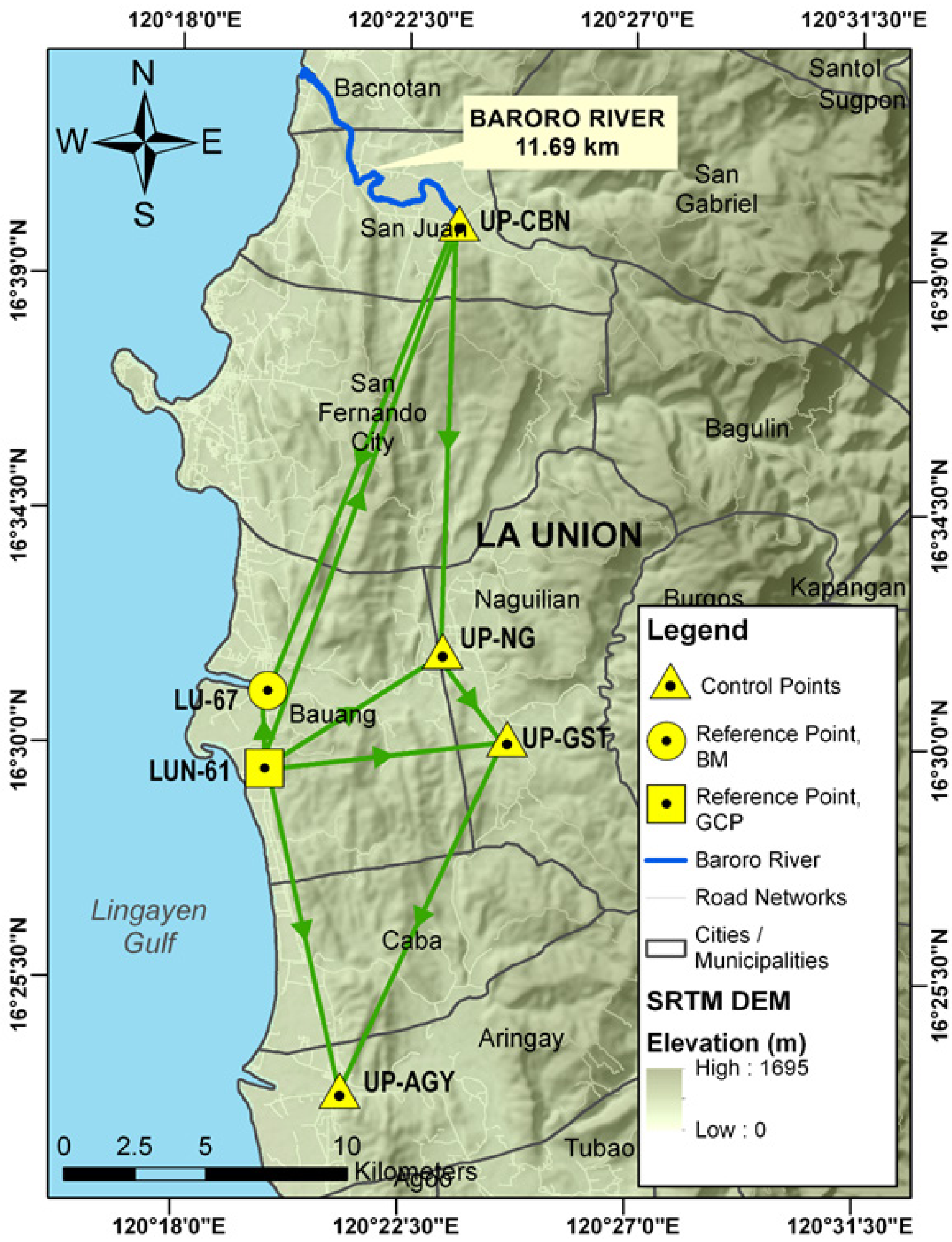


Figure 32. GNSS Network of La Union field survey

The GNSS network used for Baroro River Basin is composed of four (4) loops established on July 4 and 11, 2015 occupying the following reference points: LUN-61 a second order GCP in Brgy. Guerrero, Municipality of Bauang, La Union; and LU-67 a first order BM in Brgy. Nagrebcan, also in Municipality of Bauang, La Union.

Four (4) control points were established along approach of bridges namely: UP-AGY, located at Aringay Bridge, Brgy. Poblacion, Municipality of Aringay; UP-CBN, at Cabaroan Bridge in Brgy. Cabaroan, Municipality of Bacnotan; UP-NG, at Guesset Bridge in Brgy. Guesset, Municipality of UP-GST; and UP-NG at Naguillian Bridge in Brgy. Cabaritan, Municipality of Naguillian, La Union.

The summary of refeencesreferences and control points and its the respective location is summarized in Table 22 while the GNSS network established for the survey is illustrated in Figure 32.

Table 22. List of references and control points used in La Un ion fieldwork on July 3–-17, 2015 (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation in MSL (m)	Date Established
LUN-61	1st order, BM	16°29'30.73239"	120°19'46.68075"	49.954	9.213	2007
LU-67	2nd order, GCP	-	-	49.515	-	2007
UP-AGY	UP Established	-	-	-	-	7-4-2015
UP-CBN	UP Established	-	-	-	-	7-11-2015
UP-GST	UP Established	-	-	-	-	7-4-2015
UP-NG	UP Established	-	-	-	-	7-11-2015

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 33 to Figure 37.

Figure 33. GNSS receiver set set-up, Trimble® SPS 852 at LUN-61, a second order GCP located along the sidewalk of BPPC Road, Brgy. Guerrero in Bauang, La Union

Figure 34. GNSS base set set-up, Trimble® SPS 985 at LU-67 benchmark located at Bauang Bridge 1 along Mac Arthur Highway in Brgy. Nagrebcan, Bauang, La Union

Figure 35. Trimble® SPS 882 receiver set-up at UP-AGY, a UP-established control point located at Aringay Bridge along Mac Arthur Highway, Brgy. Poblacion, Aringay, La Union

Figure 36. Trimble® SPS 882 receiver set-up at UP-CBN, an established control point located at Cabaroan Bridge along San Juan-San Gabriel Road, Brgy. Cabaroan, Bacnotan, La Union

Figure 37. GNSS base set-up, Trimble® SPS 985, at UP-GST, an established control point located at Guesset Bridge in Brgy. Guesset, Naguilian, La Union

Figure 38. GNSS receiver set-up, Trimble® SPS 952, at UP-NG, an established control point located at Naguilian Bridge along Bauang-Baguio Road, Brgy. Cabaritan Sur, Naguilian, La Union

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 +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is 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 Baroro River Basin is summarized in Table 23 generated TBC software.

Table 23. Baseline processing report for Baroro River survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsiod Dist. (Meter)	ΔHeight (Meter)
UPAGY --- LUN61	7-4-2015	Fixed	0.004	0.027	166°05'07"	11694.520	0.436
LUN61 --- UPGST	7-4-2015	Fixed	0.003	0.018	82°19'22"	8640.260	13.306
LU67 --- LUN61	7-4-2015	Fixed	0.002	0.010	1°33'38"	2754.678	-0.469
UPAGY --- UPGST	7-4-2015	Fixed	0.005	0.025	24°42'08"	13764.436	12.818
UPAGY --- UPNG	7-11-2015	Fixed	0.004	0.019	12°25'55"	15950.207	7.998
UPAGY --- UPNG	7-11-2015	Fixed	0.007	0.030	12°25'56"	15950.202	8.024
UPNG --- LU67	7-11-2015	Fixed	0.002	0.011	76°34'58"	6342.089	8.805
UPCBN --- LU67	7-11-2015	Fixed	0.003	0.014	21°30'22"	17868.131	3.769
UPNG --- UPGST	7-11-2015	Fixed	0.003	0.013	142°57'42"	3848.102	4.774
UPNG --- LUN61	7-11-2015	Fixed	0.003	0.013	235°55'50"	7539.286	-8.335
UPNG --- LUN61	7-11-2015	Fixed	0.003	0.019	235°55'50"	7539.295	-8.524
UPNG --- UPCBN	7-11-2015	Fixed	0.004	0.017	1°27'31"	15157.305	-5.053
UPCBN --- LUN61	7-11-2015	Fixed	0.004	0.018	198°53'37"	20479.168	-3.321

As shown in Table 23, a total of six (6) baselines were processed and all of them passed the required accuracy set by the project.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is 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 from:

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

Where:

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

The six (6) control points, LUN-61, LU-67, UP-AGY, UP-CBN, UP-GST, and UP-NG were occupied and observed simultaneously to form a GNSS loop. Coordinates of LUN-61 and elevation values of LU-67 held fixed during the processing of the control points as presented in Table 24. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 24. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LU67	Grid				Fixed
LUN61	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 25. All fixed control points have no values for grid and elevation errors.

Table 25. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LU67	215027.120	0.008	1827985.553	0.007	8.867	?	e
LUN61	214915.551	?	1825231.473	?	9.213	0.047	LL
UPAGY	217579.313	0.012	1813837.247	0.010	9.197	0.089	
UPCBN	221802.212	0.011	1844530.550	0.009	12.830	0.064	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 26. Using the equation $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10$ cm for the vertical,; below is the computation for accuracy that passed the required precision:

LUN-61

Horizontal accuracy	=	Fixed
Vertical accuracy	=	4.7 cm < 10 cm

LU-67

Horizontal accuracy	=	$\sqrt{((0.8)^2 + (0.7)^2}$
	=	$\sqrt{(0.64+ 0.49)}$
	=	1.06 cm < 20 cm
Vertical accuracy	=	Fixed

UP-AGY
Horizontal accuracy = √ ((1.2) ² + (1.0) ²
= √(1.44 + 1.0)
= 1.56 cm < 20 cm
Vertical accuracy = 8.9 cm < 10 cm

UP-CBN
Horizontal accuracy = √ ((1.1) ² + (0.9) ²
= √(1.21 + 0.81)
= 2.02 cm < 20 cm
Vertical accuracy = 6.4 cm < 10 cm

UP-GSN
Horizontal accuracy = √ ((1.0) ² + (0.9) ²
= √(1.0 + 0.81)
= 1.34 cm < 20 cm
Vertical accuracy = 7.5 cm < 10 cm

UP-NG
Horizontal accuracy = √ ((0.7) ² + (0.7) ²
= √(0.49 + 0.49)
= 0.98 cm < 20 cm
Vertical accuracy = 5.0 cm < 10 cm

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

Table 26. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
LU67	N16°31'00.31120"	E120°19'49.21075"	49.515	?	e
LUN61	N16°29'30.73239"	E120°19'46.68075"	49.954	0.047	LL
UPAGY	N16°23'21.45560"	E120°21'21.45371"	50.363	0.089	
UPCBN	N16°40'01.07082"	E120°23'30.27604"	53.288	0.064	
UPGSN	N16°30'08.22705"	E120°24'35.41408"	63.176	0.075	
UPNG	N16°31'48.15542"	E120°23'17.25573"	58.355	0.050	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 27.

Table 27. References and control points used and the its respective locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM Zone 51		
		Latitude	Longitude	Ellipsoid Height (m)	Northing	Easting	Elevation in MSL (m)
LUN-61	1st order, BM	16°29'30.73239"	120°19'46.68075"	49.954	1825231.473	214915.551	9.213
LU-67	2nd order, GCP	16°31'00.31120"	120°19'49.21075"	49.515	1827985.553	215027.12	8.867
UP-AGY	UP Estab-lished	16°23'21.45560"	120°21'21.45371"	50.363	1813837.247	217579.313	9.197

UP-CBN	UP Estab-lished	16°40'01.07082"	120°23'30.27604"	53.288	1844530.559	221802.212	12.83
UP-GST	UP Estab-lished	16°30'08.22705"	120°24'35.41408"	63.176	1826272.861	223497.8	21.702
UP-NG	UP Estab-lished	16°31'48.15542"	120°23'17.25573"	58.355	1829376.051	221218.673	17.207

4.5 Cross-section and As-built Survey

Cross-section and as-built survey was performed on July 9 and July 4, respectively, along the downstream side of Cabaroan Bridge in Brgy. Cabaroan, Municipality of Bacnotan, La Union. The survey was conducted with the application of PPK technique using a survey grade GPS, Trimble® SPS 882 as shown in Figure 40.

Figure 39. Cabaroan bridge facing upstream

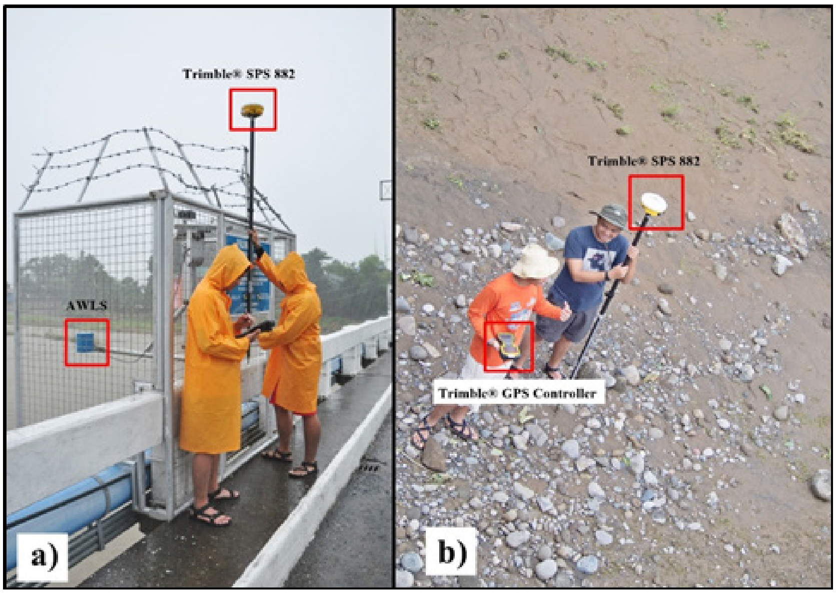


Figure 40. a) Getting the elevation of an installed AWLS during as-built survey and b) cross-section survey along the downstream side of Cabaroan Bridge after the river water has subsided

The cross-sectional line length of Cabaroan Bridge is 267.95 m with a total of 47 points acquired using UP-CBN as the GNSS base station. The planimetric map, cross-section diagram, and as built form are illustrated and Figure 41 to Figure 43, respectively.

The water surface elevation of Baroro River was acquired using PPK survey technique on July 9, 2015 at 5:48 pm. The resulting water surface elevation data with a value of 7.25 m MSL was translated onto the bridge's pier to serve as reference for the depth gauge deployment and flow meter gathering of partner HEI.

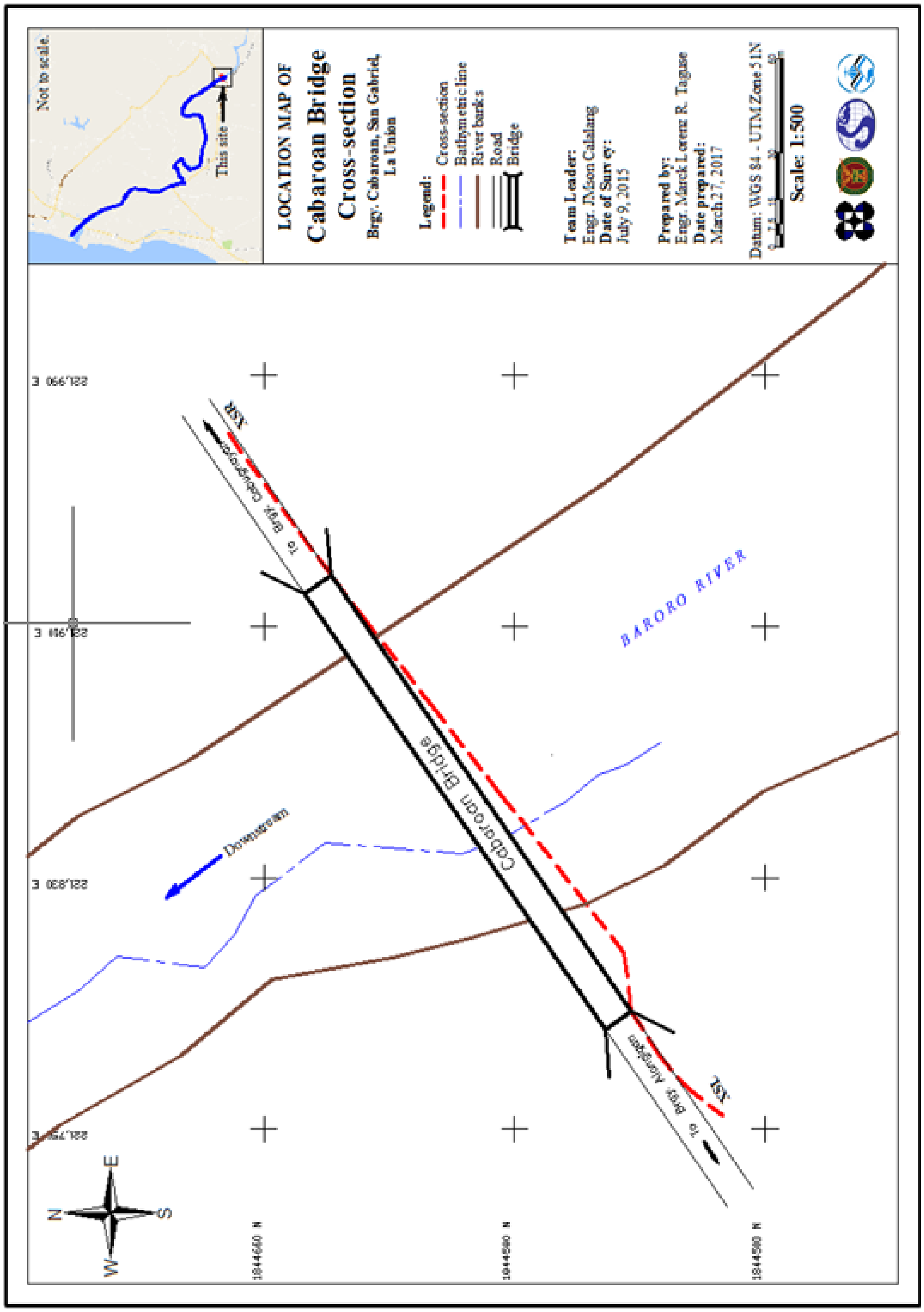


Figure 41. Cabaroan bridge cross-section planimetric map

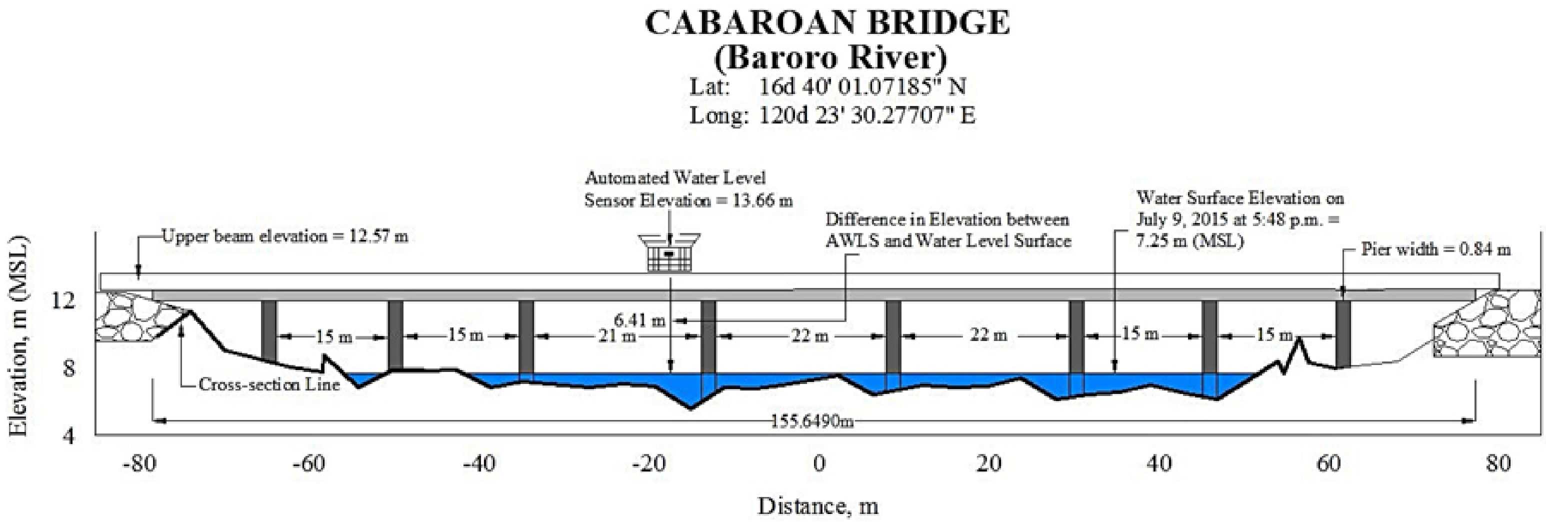


Figure 42. Cabaroan Bridge cross-section diagram

Bridge Data Form

Bridge Name: Cabaroan Bridge **Date:** July 9, 2015

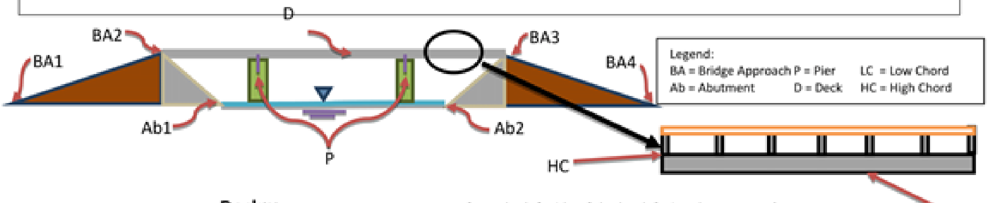
River Name: BARORO RIVER **Time:** 4:04 p.m.

Location (Brgy, City,Region): Brgy. Cabaroan, San Juan, La Union

Survey Team: Aringay, Bauang, Barroro Survey Team

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

Latitude: 16d40'01.07185"N **Longitude:** 120d23'30.27707"E



LC

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

Elevation: 12.55 m **Width:** no data **Span (BA3-BA2):** 168.87 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 2 (88.32)	12.57	11.57
2	Pier 4 (125.60)	12.55	11.55
3	Pier 6 (184.75)	12.60	11.60

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	11.18	BA3	219.03	12.57
BA2	54.11	12.37	BA4	274.58	11.64

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

	Station (Distance from BA1)	Elevation
Ab1	64.33	13.60
Ab2	211.88	9.65

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

Shape: Oblong **Number of Piers:** Eight (8) **Height of column footing:** n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	72.81	12.57	0.84
Pier 2	88.32	12.54	0.84
Pier 3	103.99	12.53	0.84
Pier 4	125.59	12.55	0.84
Pier 5	147.39	12.60	0.84
Pier 6	169.03	12.60	0.84
Pier 7	184.72	12.59	0.84
Pier 8	200.36	12.57	0.84

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

Figure 43. Cabaroan Bridge data form

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on July 13–-14, 2015 using A Trimble® SPS 985 attached in front of a vehicle, utilizing continuous topo method in a PPK survey technique as shown in Figure 44. The height of instrument was measured and noted a 2.43-meter distance from the ground up to the bottom of notch. Points were gathered along major concrete roads with the aid of a vehicle which moved at a speed of 20–-40 kph, cutting across the flight strips of the DAC with the aid of available topographic maps and Google EarthTM images.

On July 13, validation points acquisition survey ran going south from Brgy. Pagbennecan, Balaoan, La Union to Brgy. Poro, San Fernando City, La Union via Mac Arthur Highway. Point UP-CBN was utilized during this survey. On July 14, the survey started from Naguilian Bridge going west to Brgy. Central East in Bauang, via Bauang-Baguio Road. The other route started from Brgy. Gonzales, Municipality of Tubao going west to Brgy. Consolacion, Municipality of Agoo via Aspiras-Palispis Highway then going north to Brgy. Sevilla, San Fernando City via Mac Arthur Highway. The control points UP-AGY and UP-NG were used as base for July 14 validation points acquisition survey.

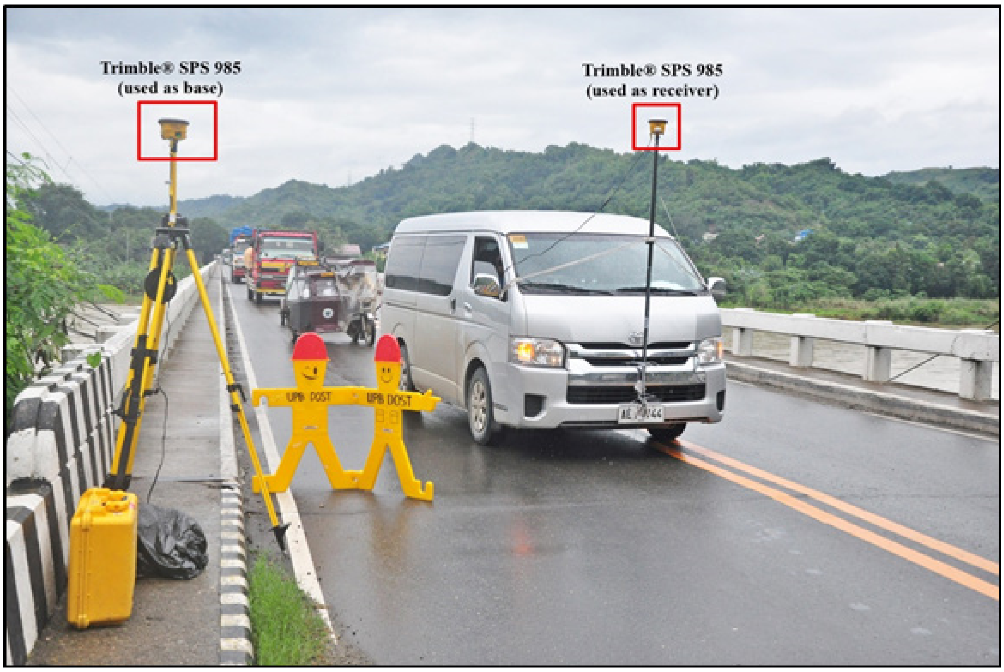


Figure 44. Validation points acquisition survey set-up: A Trimble® SPS 985, attached in front of a vehicle

The map in Figure 45 displays the extent of the ground validation survey which acquired a total of 3,824 ground validation points with an approximate length of 84 km.

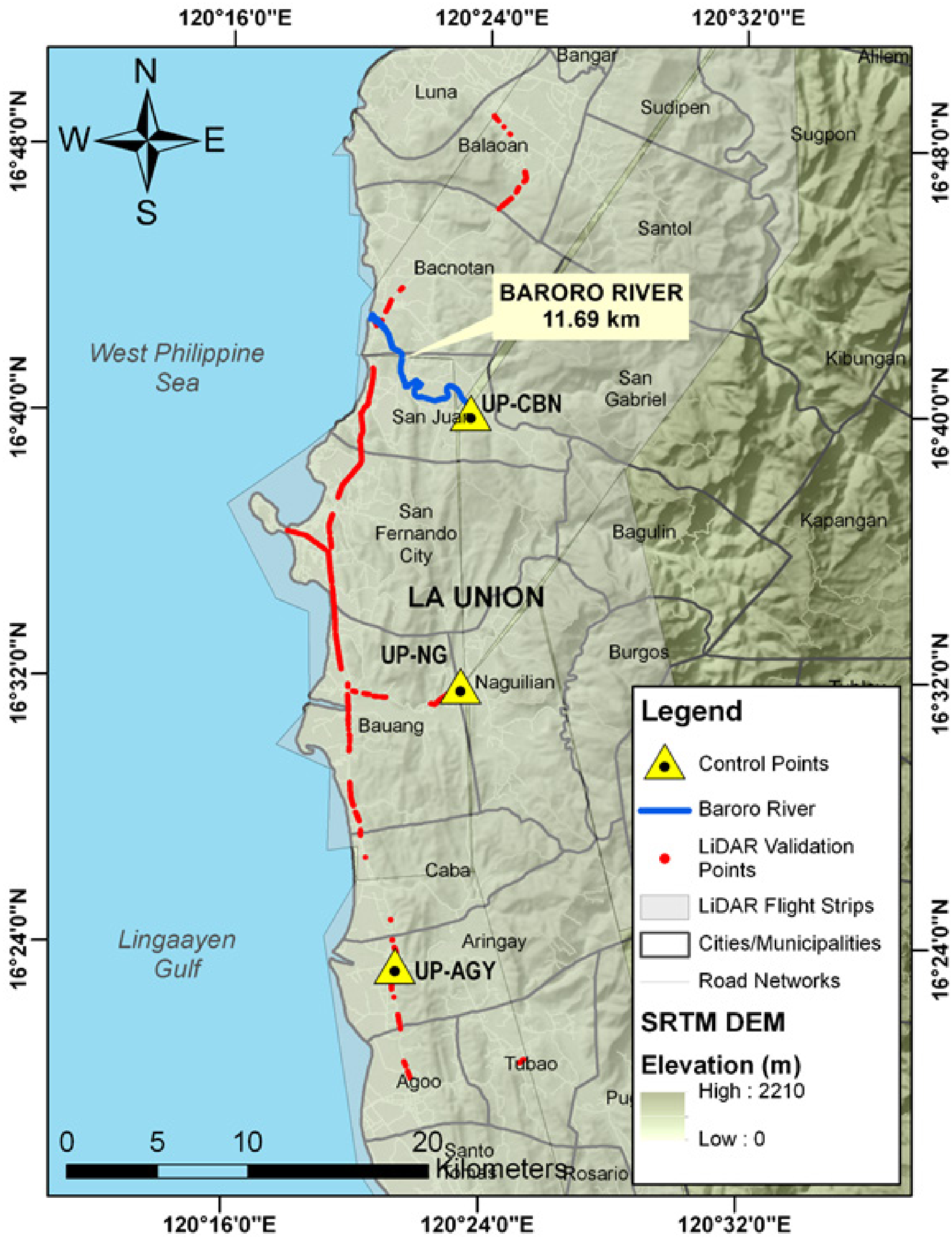


Figure 45. Validation points acquisition survey in La Union

4.7 River Bathymetric Survey

Bathymetric survey at Baroro River was conducted on July 13, 2015 using Ohmex™ single- beam echo sounder and a Trimble® SPS 882 GNSS mounted on a boat utilizing PPK in continuous topo mode as shown in Figure 46. The survey started in Brgy. Calincamasa, Municipality of San Juan with coordinates 16°41'15.05929" 120°21'17.71132", down to its mouth in Brgy. Nagsimbaanan, Municipality of Bacnotan with coordinates 16°42'52.61673" 120°20'22.15136".

Figure 46. Bathymetric survey set-up using OHMEX™ single beam echo sounder and a mounted with a Trimble® SPS 882

Manual bathymetry was also conducted on November 25–-27, 2015 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 47. The survey started in the upstream part of the river in Brgy. Cabaroan, Municipality of San Juan with coordinates 16°40'01.33061" 120°23'32.54469", traversed down the river by foot and ended at the starting point of bathymetric survey using a boat. The control point UP-CBN was used as the GNSS base station all throughout the survey.

Figure 47. Manual bathymetry in Baroro River

Figure 48. Bathymetric survey along Baroro River

.A CAD drawing was also produced to illustrate riverbed profile of Baroro River. As illustrated in Figure 48, the highest and lowest elevation has a 9-meter difference. The highest elevation observed was 6.501 m above MSL in located Brgy. Cabaroan, San Juan, La Union while the lowest was 2.76 m below MSL located in Brgy. Baroro, Bacnotan, La Union. The bathymetric survey gathered 7,555 points and produced a centerline profile covering 11.69 km of the river as shown in Figure 49.

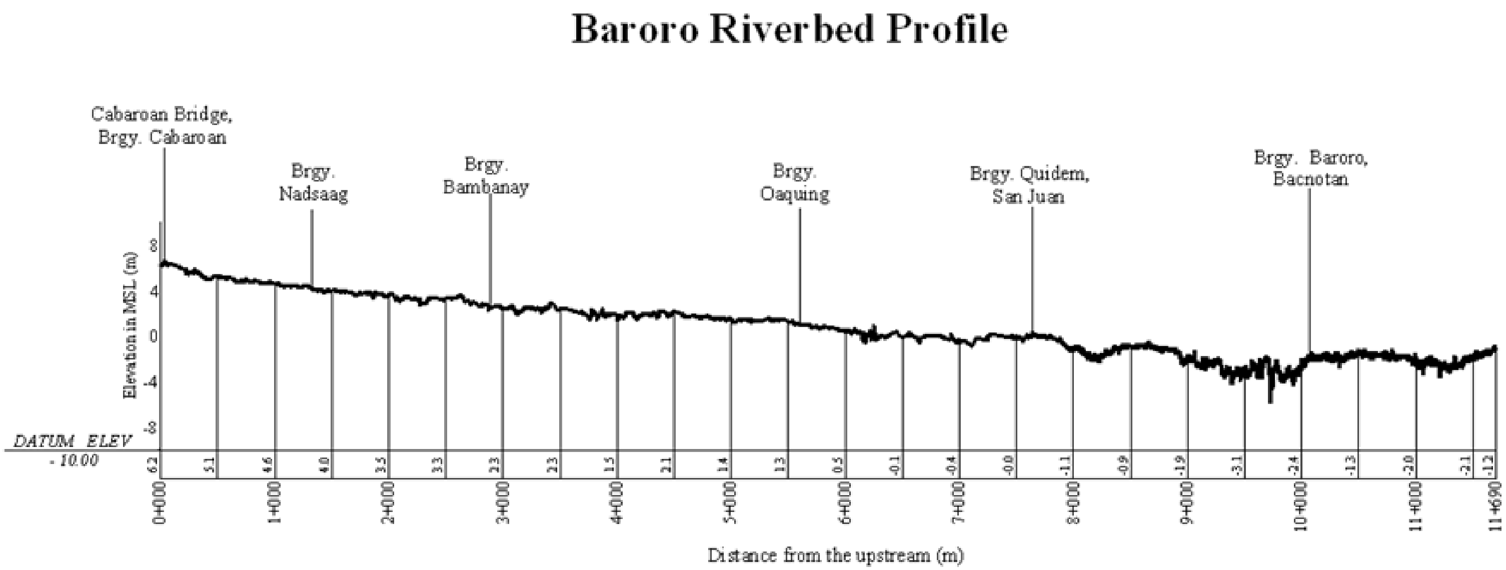


Figure 49. Riverbed profile of Baroro River

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, Hannah Aventurado

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the river basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge is the Cabaroan Bridge ARG, located in Brgy. Cabaroan, San Juan, La Union (Figure 50). The precipitation data collection started from September 17, 2014 at 12:00 AM to September 24, 2014 at 11:50 PM with a 10-minute recording interval.

The total precipitation for this event in Cabaroan Bridge ARG was 253.6 mm. It has a peak rainfall of 8.4 mm. on September 19, 2014 at 4:20 PM. The lag time between the peak rainfall and discharge is 10 hours and 10 minutes.

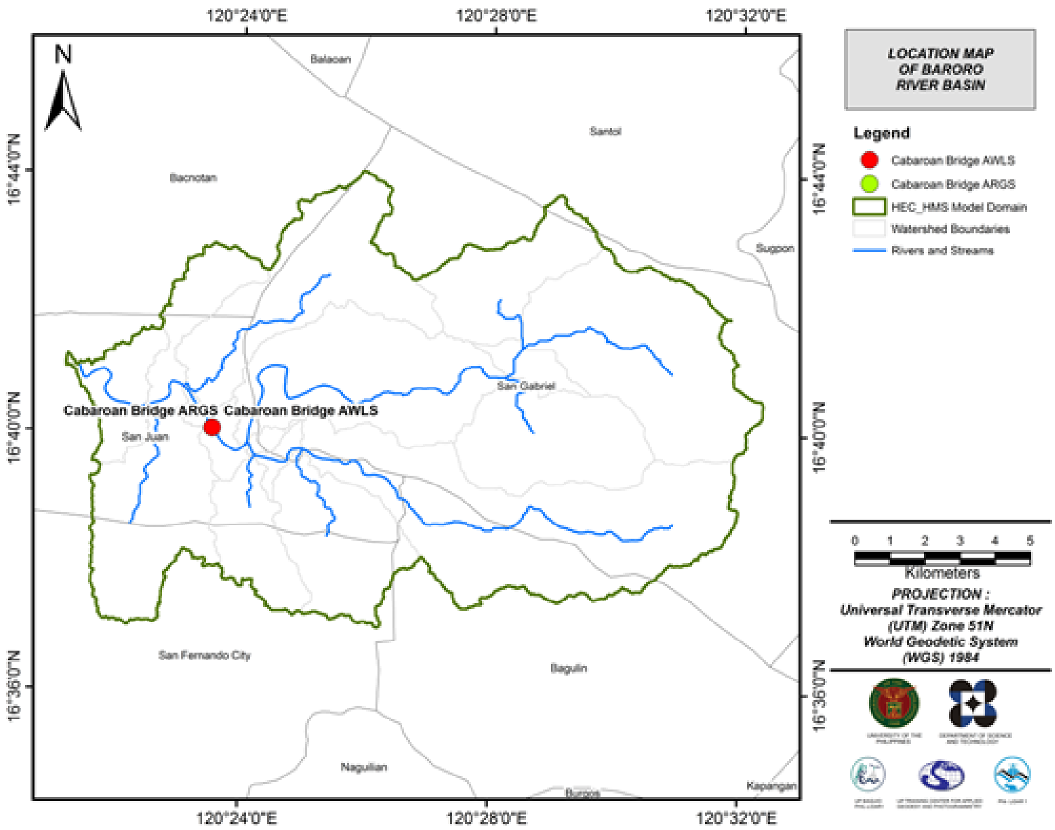


Figure 50. The location map of the Baroro HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at the same location, at Cabaroan Bridge, San Juan, La Union (16° 40’ 3.1” N, 120° 23’ 32.2” E). It gives the relationship between the observed water level at the Cabaroan Bridge and outflow of the watershed at this location.

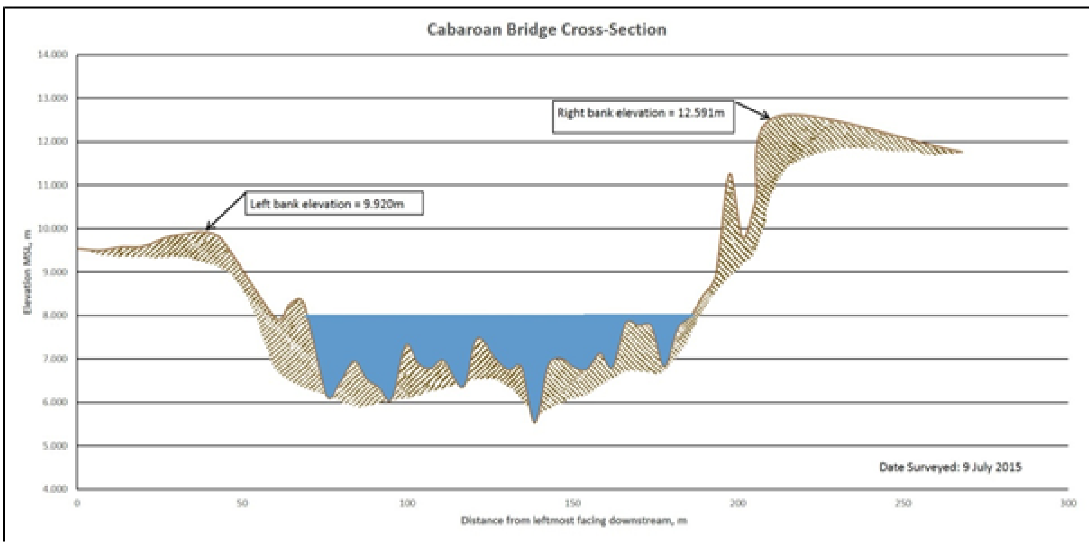


Figure 51. Cross-Section Plot of Cabaroan Bridge

For Cabaroan Bridge, the rating curve is expressed as Q = 6E-06e1.7347h as shown in Figure 52.

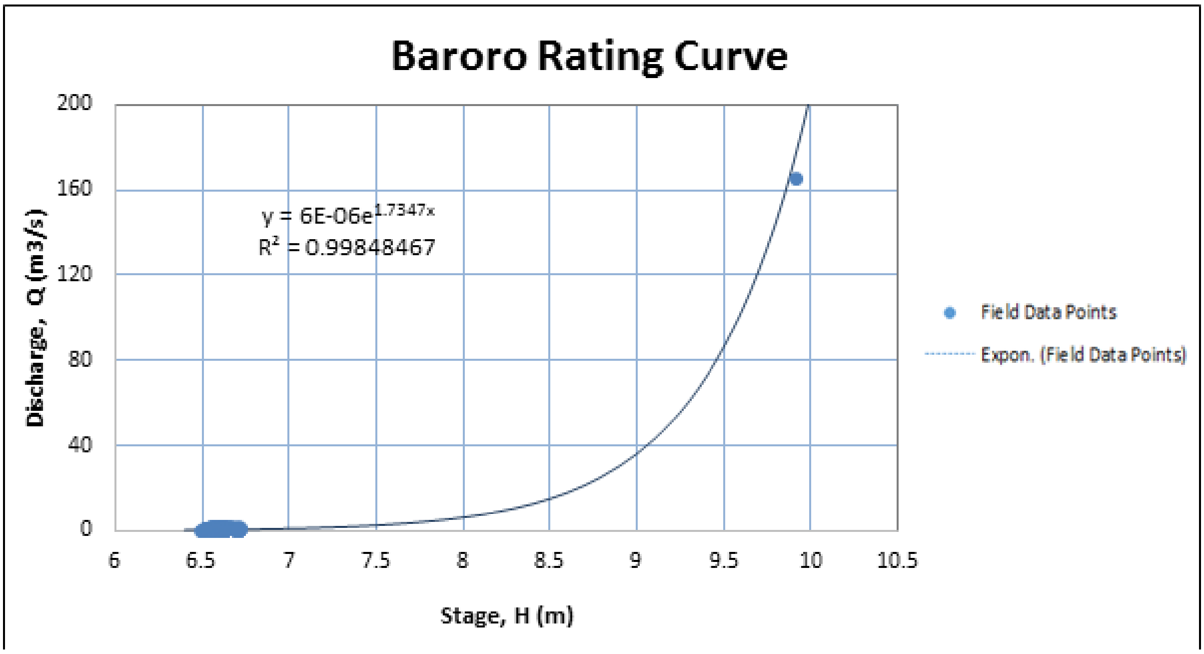


Figure 52. Rating Curve at Cabaroan Bridge, San Juan, La Union

The rating curve equation was used to compute for the river outflow at Cabaroan Bridge for the calibration of the HEC-HMS model for Baroro, as shown in Figure 53. The total rainfall for this event is 253.6 mm and the peak discharge is 388.44 m3/s at 2:30 AM of September 20, 2014.

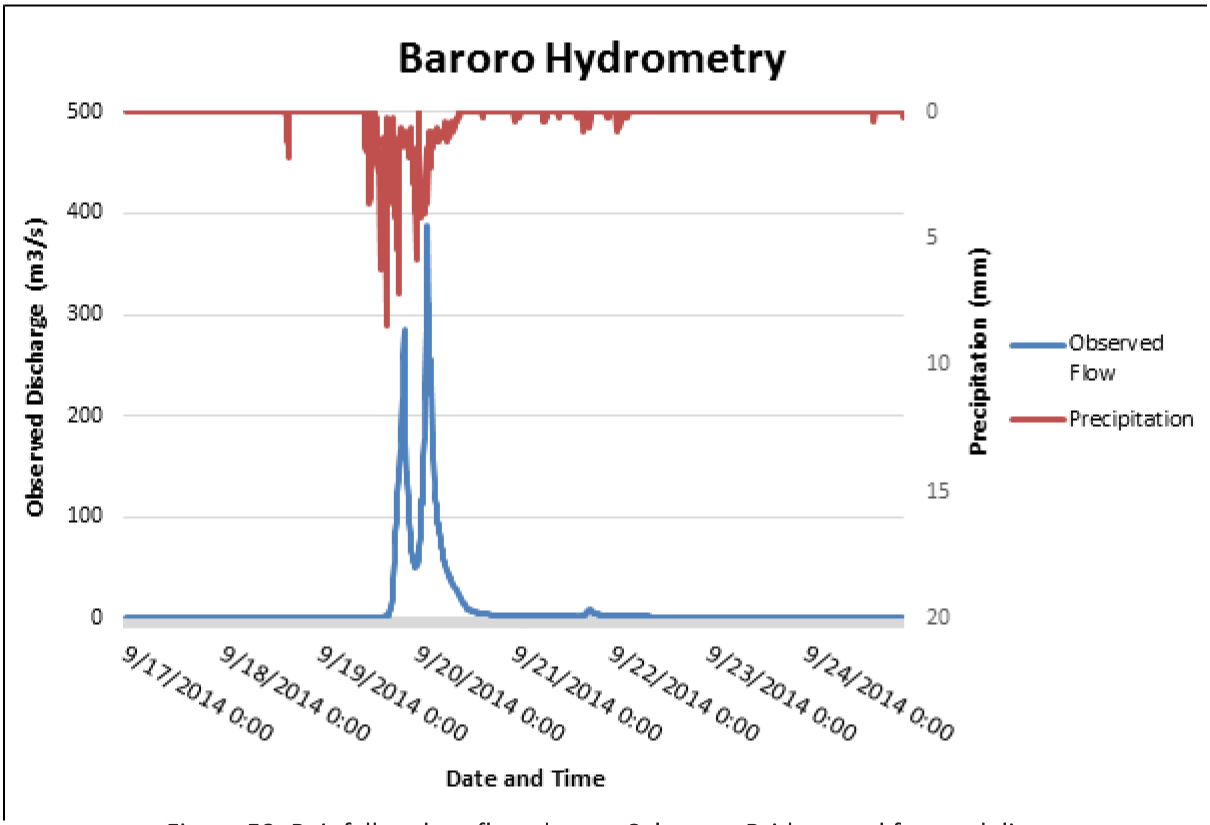


Figure 53. Rainfall and outflow data at Cabaroan Bridge used for modeling

It can also be seen from Figure 53 that the discharge graph has two peaks that correspond to two peak rainfalls from the precipitation graph. The first peak rainfall (8.4 mm) was recorded at 4:20 PM of September 19, 2014 followed by the first peak discharge (284.26 m3/s) recorded at 8:40 PM, September 19, 2014. The second peak rainfall (5.5 mm) was recorded at 11:40 PM of September 19, 2014 followed by the second peak discharge (388.44 m3/s) recorded at 2:30 AM, September 20, 2014. The lag time for the first rainfall and discharge is 4 hours and 20 minutes while the second rainfall-discharge lag time is 2 hours and 50 minutes.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Baguio 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 Baroro watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 28. RIDF values for Baguio 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	27.4	41.6	51.9	72.5	108	136.3	199.5	258.6	355.1
5	49.3	75.2	94.2	127.7	189.7	235.7	334.8	436.9	563.6
10	63.8	97.5	122.1	164.3	243.8	301.5	424.3	555	701.7
15	72	110	137.9	184.9	274.4	338.6	474.8	621.6	779.6
20	77.7	118.8	149	199.3	295.7	364.6	510.2	668.2	834.1
25	82.1	125.6	157.5	210.5	312.2	384.6	537.5	704.1	876.1
50	95.8	146.4	183.7	244.7	362.9	446.3	621.4	814.8	1005.5
100	109.3	167.1	209.7	278.7	413.2	507.5	704.7	924.7	1134

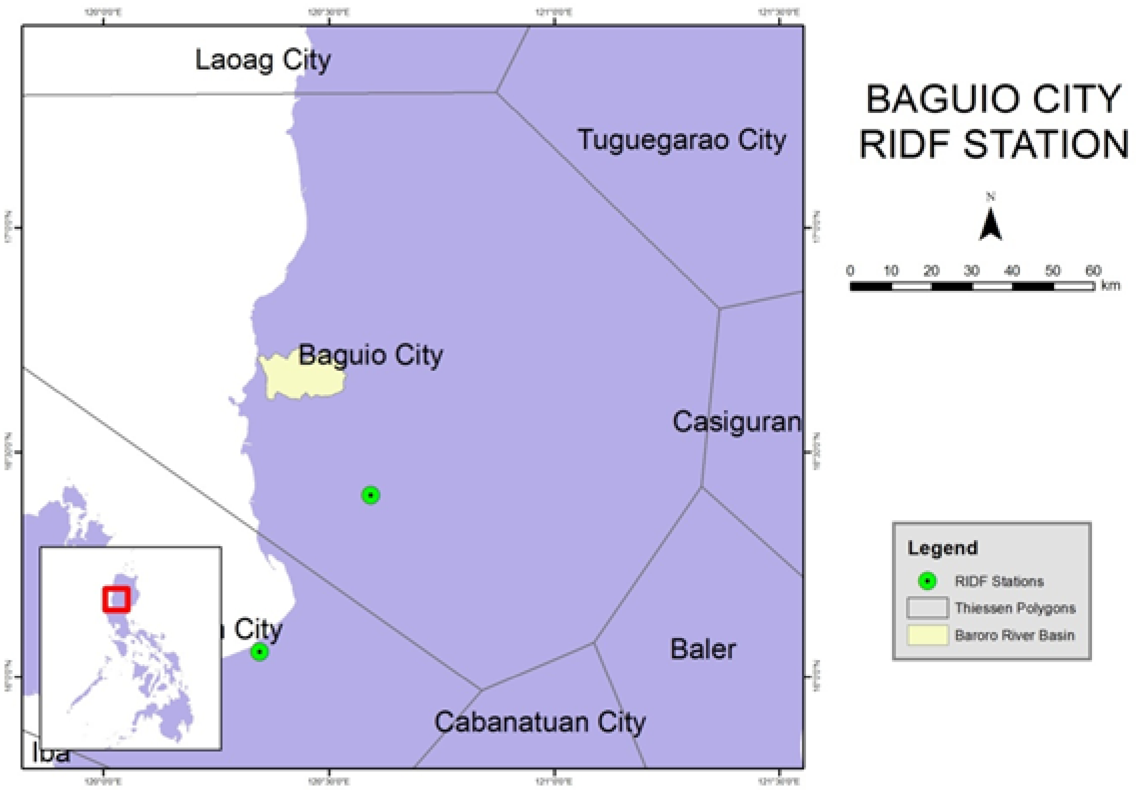


Figure 54. Location of Baguio RIDF Station relative to Baroro River Basin

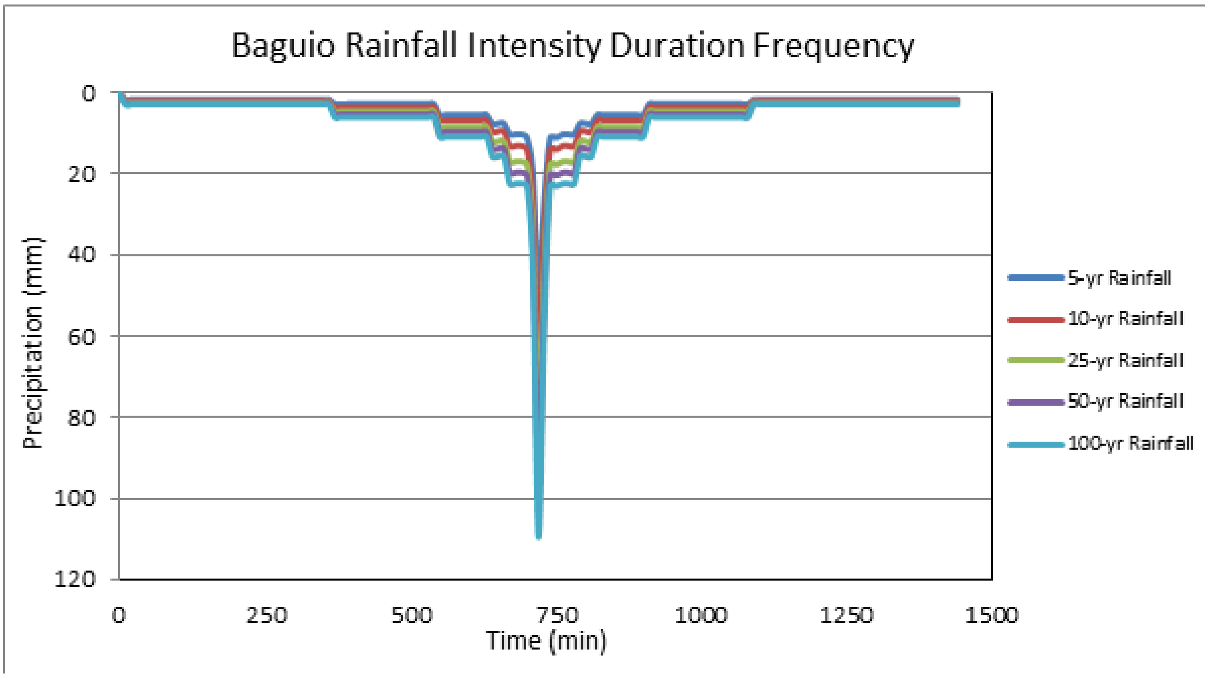


Figure 55. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Baroro River Basin are shown in Figure 56 and Figure 57, respectively.

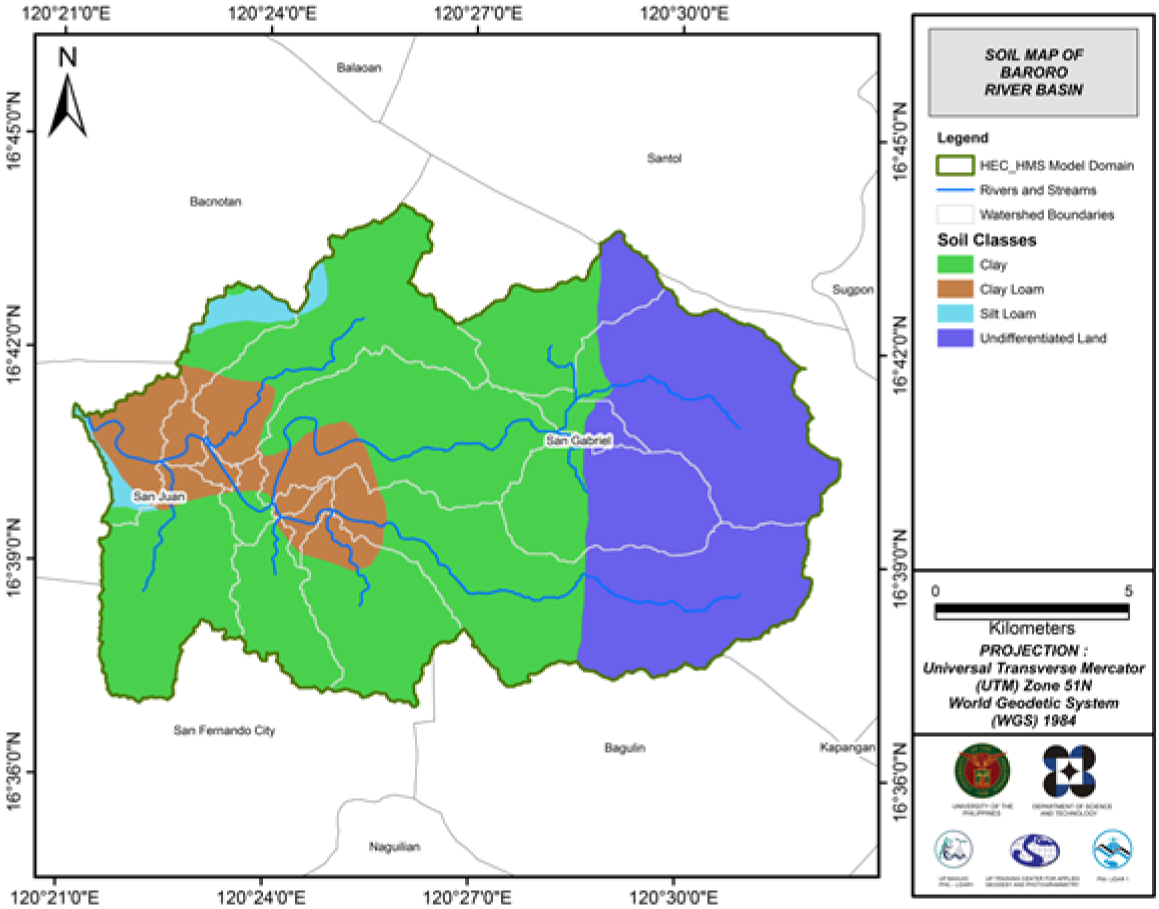


Figure 56. Soil map of Baroro River Basin

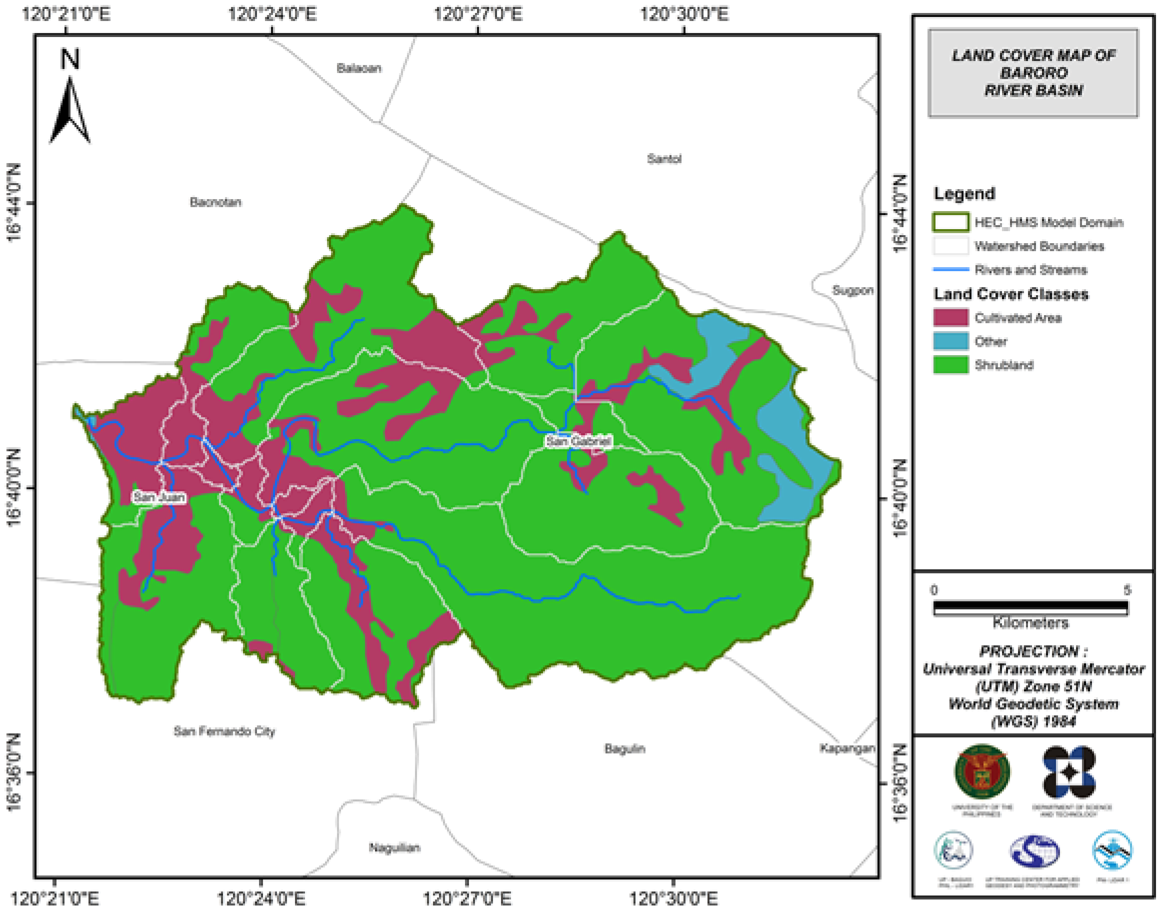


Figure 57. Land cover map of Baroro River Basin

For Baroro, four soil classes were identified. These are clay, clay loam, silt loam, and undifferentiated land. Moreover, three land cover classes were identified. These are shrublands, others, and cultivated areas.

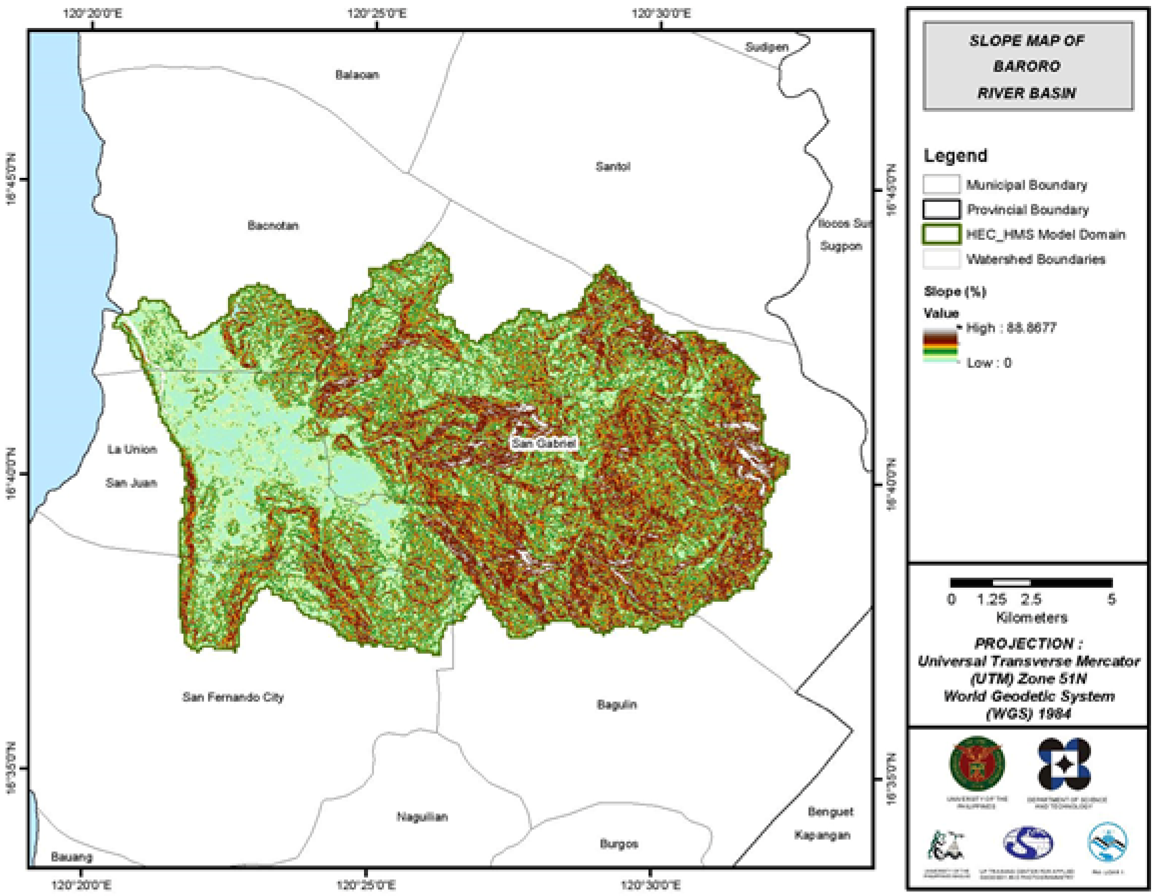


Figure 58. Slope map of Baroro River Basin

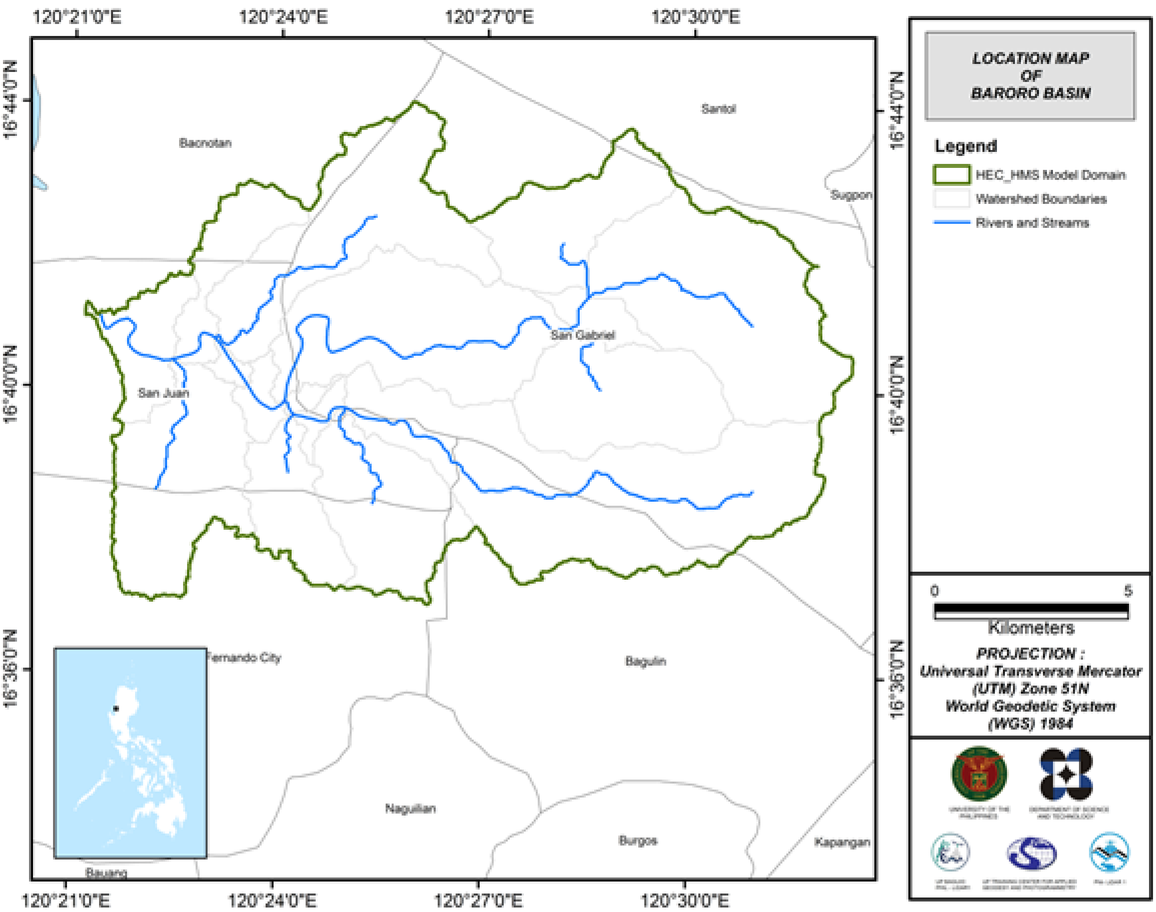


Figure 59. Stream delineation map of Baroro River Basin

Using the SAR-based DEM, the Baroro basin was delineated and further subdivided into subbasins. The model consists of 16 subbasins, 8 reaches, and 8 junctions, as shown in Figure 60. The main outlet is 53.

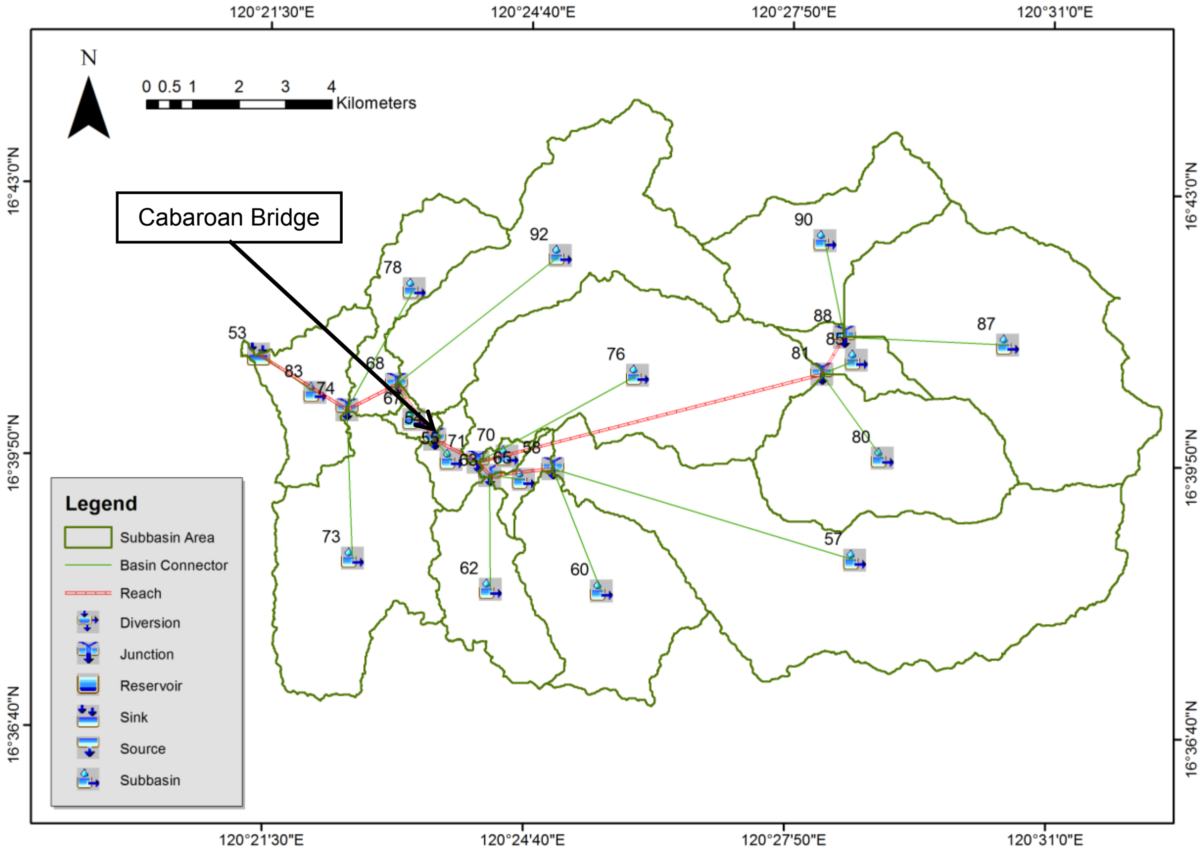


Figure 60. The Baroro river basin model generated using HEC-HMS

5.4 Cross-Section Data

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

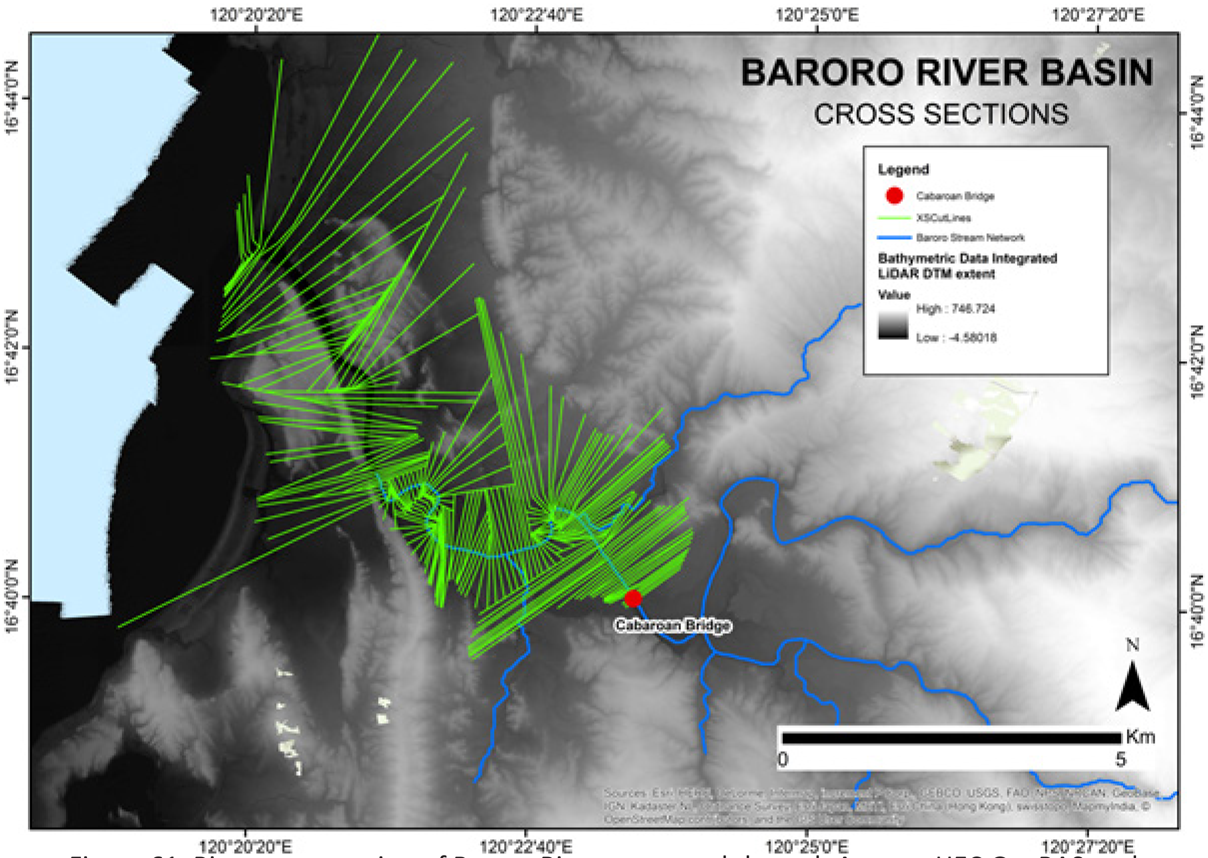


Figure 61. River cross-section of Baroro River generated through Arcmap HEC GeoRAS tool

5.5 FLO 2D Model

The automated modeling process allowed for the creation of a model with boundaries that were almost exactly coincidental with that of the catchment area. As such, they had 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 east side of the model to the west, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements, respectively

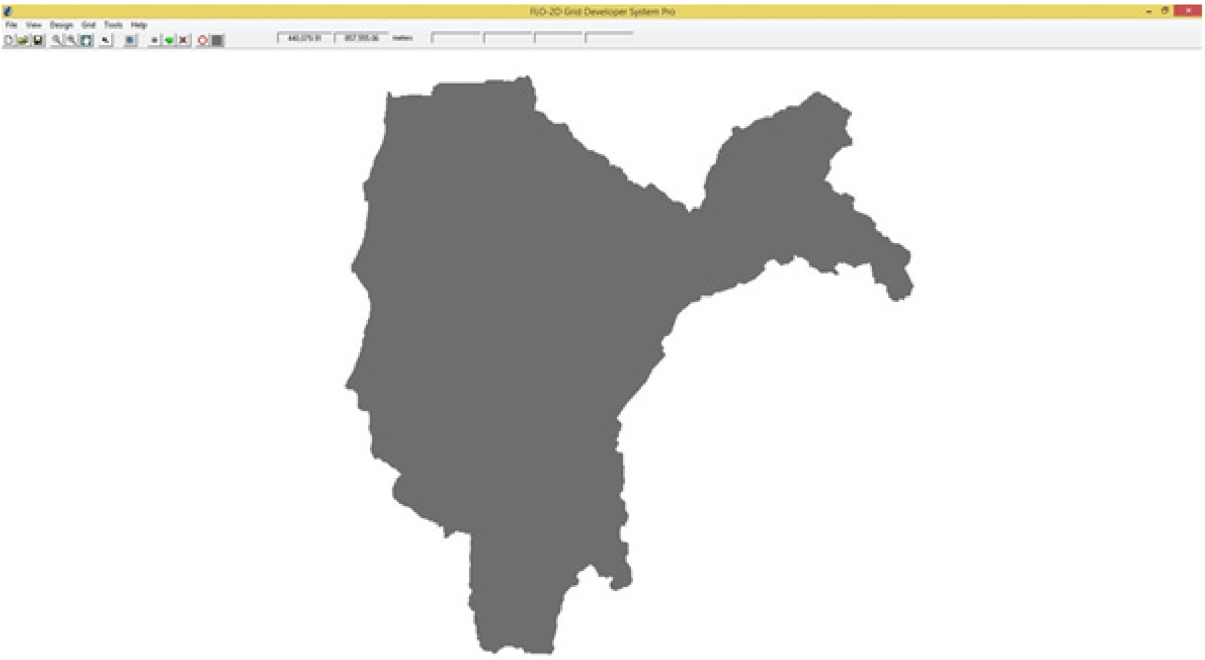


Figure 62. A screenshot of the river subcatchment with the computational area to be modeled in FLO 2D Grid Developer System Pro (FLO 2D GDS Pro)

The simulation was then run through FLO 2D GDS Pro. This particular model had a computer run time of 136.68347 hours. After the simulation, FLO 2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High created the food 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 m2/s. The generated hazard maps for Baroro are in Figure 66, Figure 68, and Figure 70.

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 80,394,720.00 m2. The generated flood depth maps for Baroro are in Figure 67, Figure 69, and Figure 71.

There is a total of 163,820,286.47 m3 of water entering the model. Of this amount, 68,176,860.06 m3 is due to rainfall while 95,643,426.41 m3 is inflow from other areas outside the model. 13,540,970.00 m3 of this water is lost to infiltration and interception, while 45,777,090.32 m3 is stored by the floodplain. The rest, amounting up to 104,502,195.27 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Baroro HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

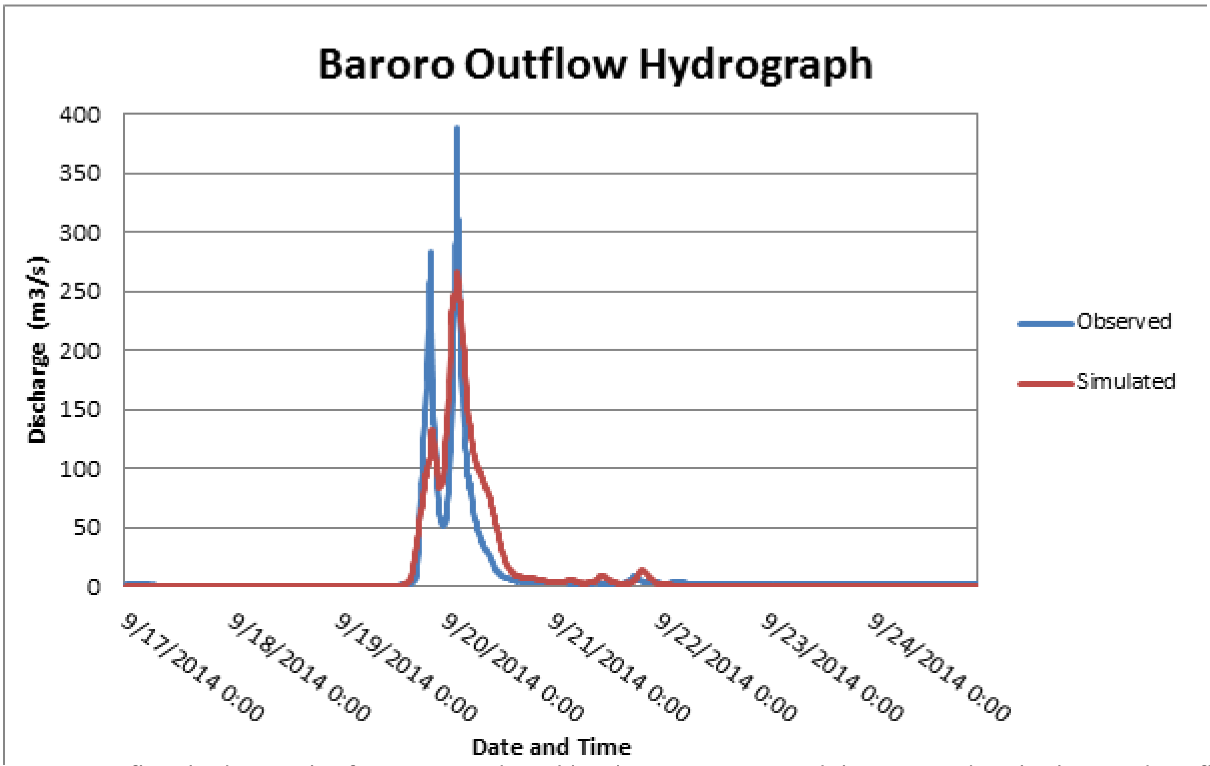


Figure 63. Outflow hydrograph of Baroro produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of calibrated values for Baroro

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	4.3896 – 65.129
			Curve Number	35 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.069 – 0.852
			Storage Coefficient (hr)	0.057 – 0.699
	Baseflow	Recession	Recession Constant	0.002 – 0.039
			Ratio to Peak	0.00027 – 0.0033
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.072 – 0.315

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 4.3896 mm to 65.129 mm means that the amount of infiltration or rainfall interception by vegetation all over the basin varies greatly.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area area (M. Horritt, personal communication, 2012). For Baroro, the basin consists mainly of shrublands and the soil consists of mostly undifferentiated land and clay.

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 0.057 hours to 0.852 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 values within the range of 0.002 to 0.039 indicate that the basin is highly likely to quickly go back to its original discharge. Values of ratio to peak within the range of 0.00027 to 0.0033 indicate a much steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Baroro River Basin reaches Manning's coefficients ranging from 0.072 to 0.315, showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

Table 30. Summary of the efficiency test of Baroro HMS Model

RMSE	18
r2	0.8096
NSE	0.78
PBIAS	-14.98
RSR	0.46

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 18 m3/s.

The Pearson correlation coefficient (r2) 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 0.8096.

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 0.78.

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 -14.98.

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 0.46.

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

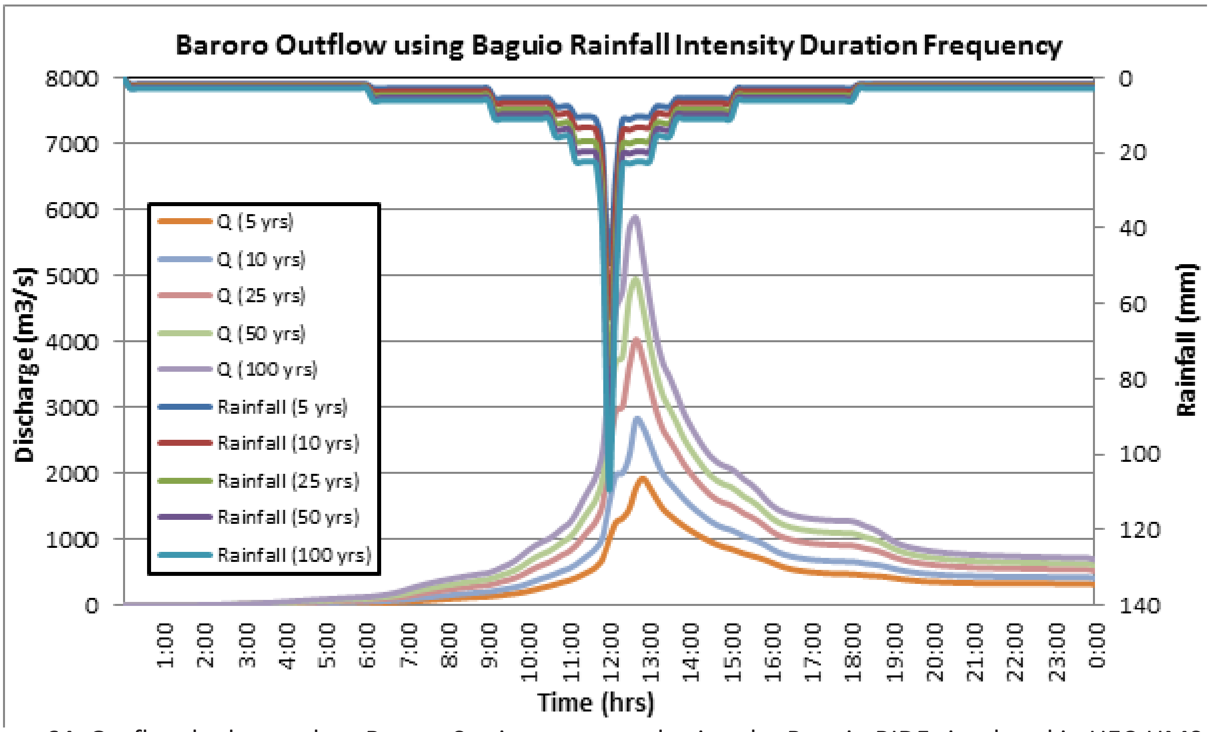


Figure 64. Outflow hydrograph at Baroro Station generated using the Baguio RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Baroro discharge using the Baguio RIDF in five different return periods is shown in Table 31.

Table 31. Peak values of the Baroro HEC-HMS Model outflow using the Baguio RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m3/s)	Time to Peak
5-Year	563.85	49.3	1923.7	50 minutes
10-Year	701.7	63.8	2809.9	40 minutes
25-Year	876.1	82.1	4027.8	40 minutes
50-Year	1005.5	95.8	4943.4	40 minutes
100-Year	1134	109.3	5870.3	40 minutes

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 was used in determining the flooded areas within the model. The simulated model would 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. For this publication, only a sample output map river is shown. The sample generated map of Baroro River using the calibrated HMS base flow is found in Figure 65.

Figure 65. Sample output of Baroro RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. The 100-, 25-, and 5-year rain return scenarios of the Baroro Floodplain are shown in Figure 66 to Figure 71. The floodplain, with an area of 131.23 sq km, covers five municipalities. Table 32 shows the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Baroro Floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
La Union	Bacnotan	80.67	25.71	31.87%
La Union	Bagulin	77.97	3.20	4.10%
La Union	San Fernando City	121.05	17.73	14.65%
La Union	San Gabriel	154.19	35.15	22.80%
La Union	San Juan	53.44	49.12	91.92%

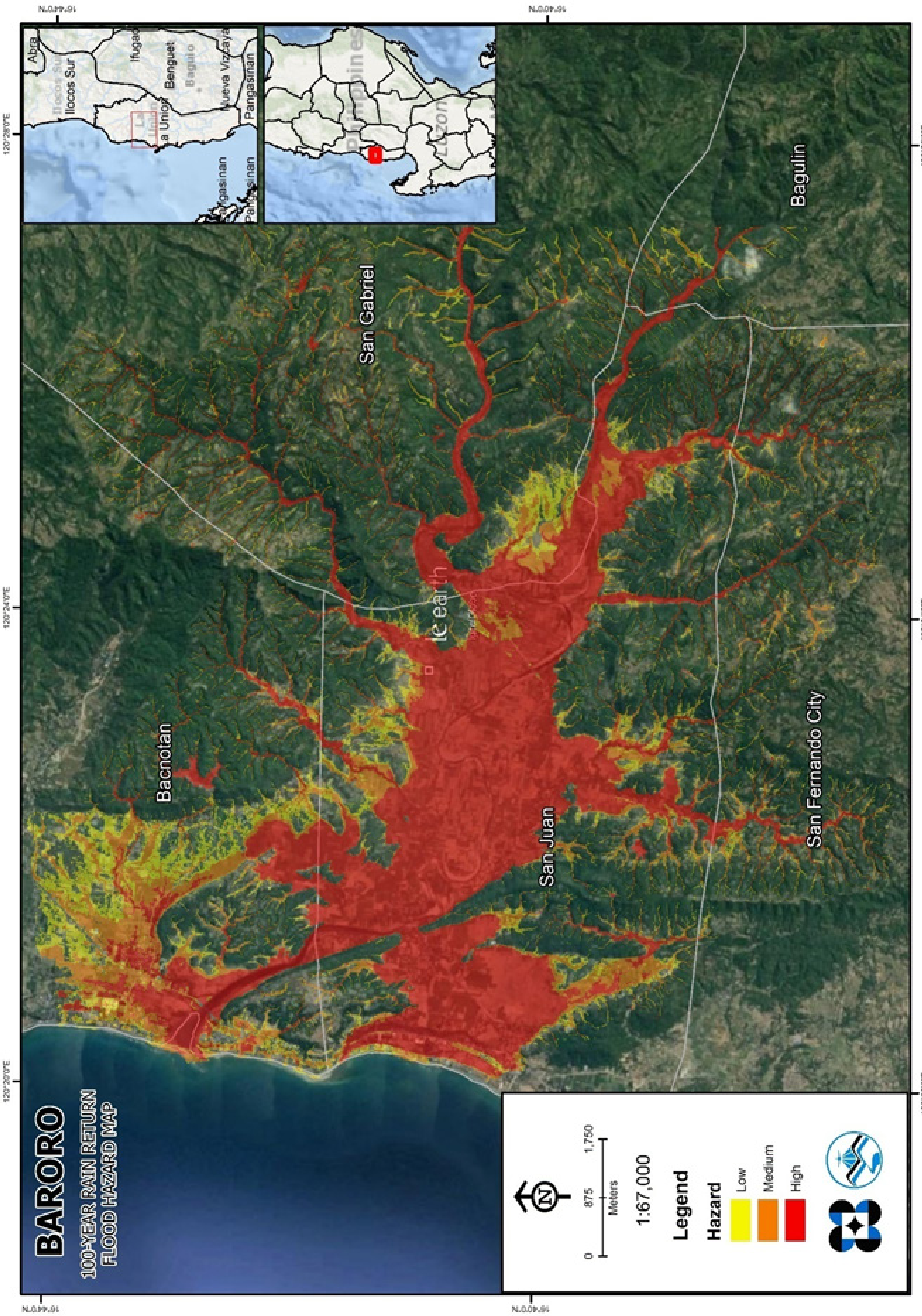


Figure 66. 100-year flood hazard map for Baroro Floodplain overlaid on Google Earth imagery

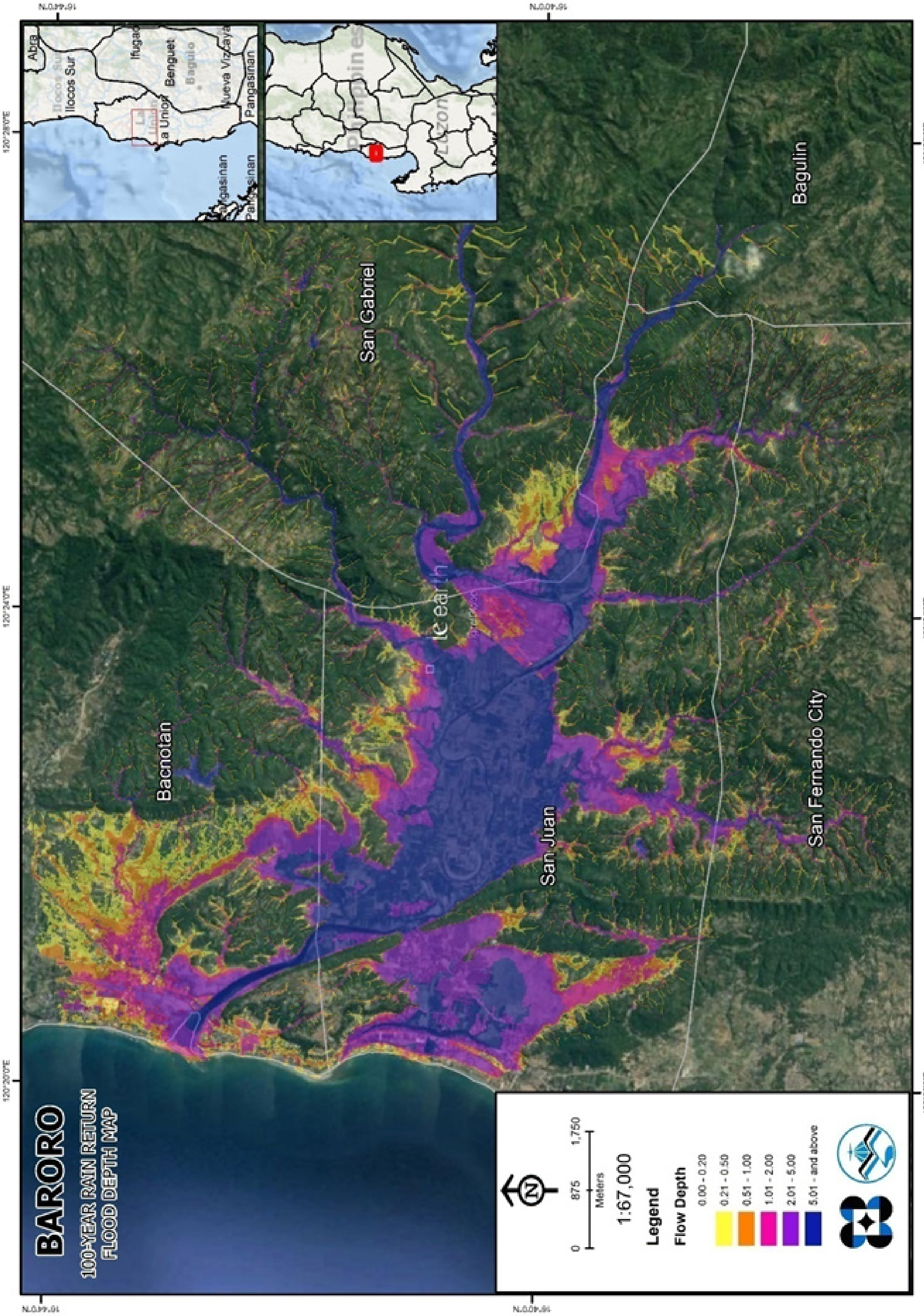


Figure 67. 100-year flow depth map for Baroro Floodplain overlaid on Google Earth imagery

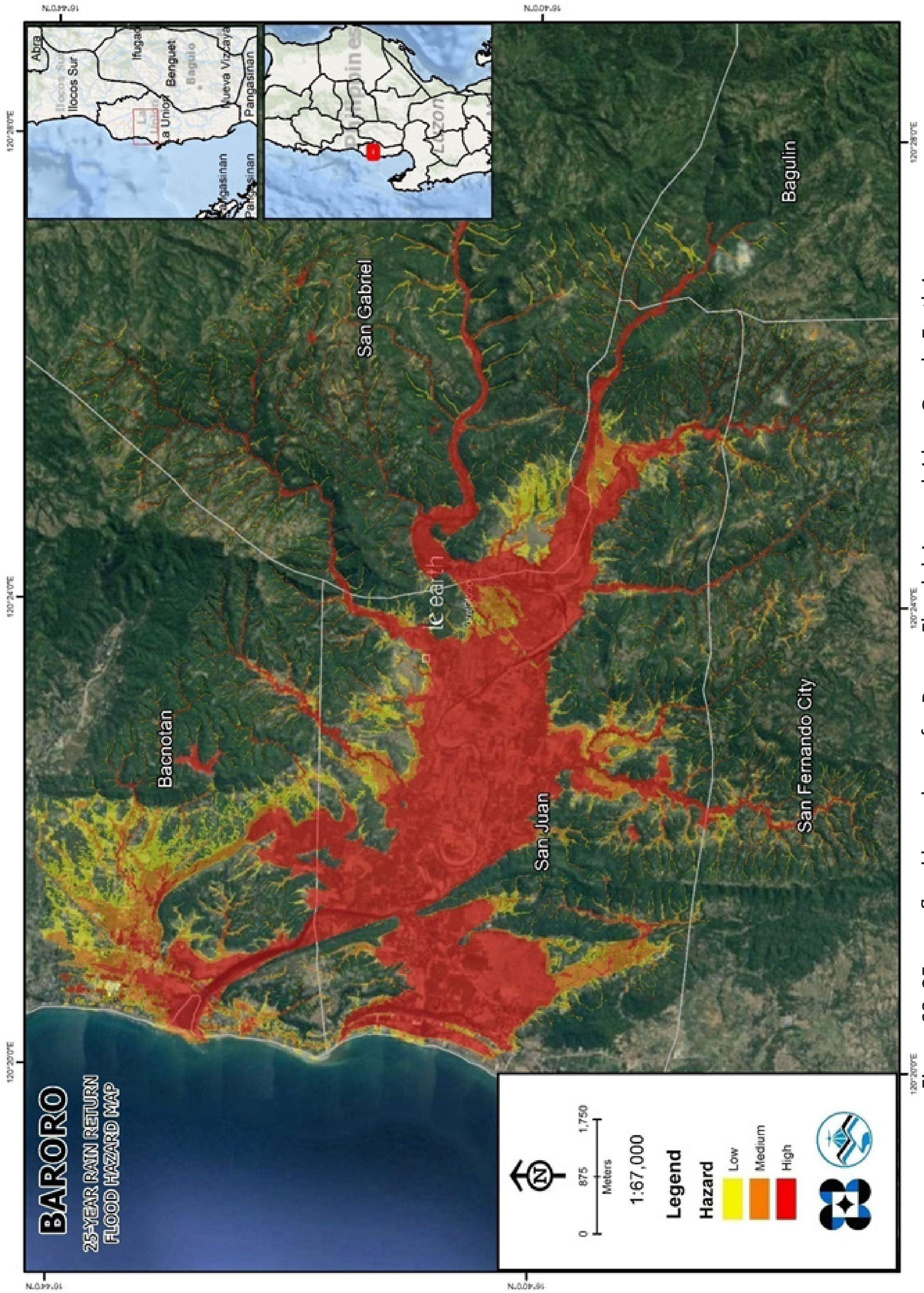


Figure 68. 25-year flood hazard map for Baroro Floodplain overlaid on Google Earth imagery

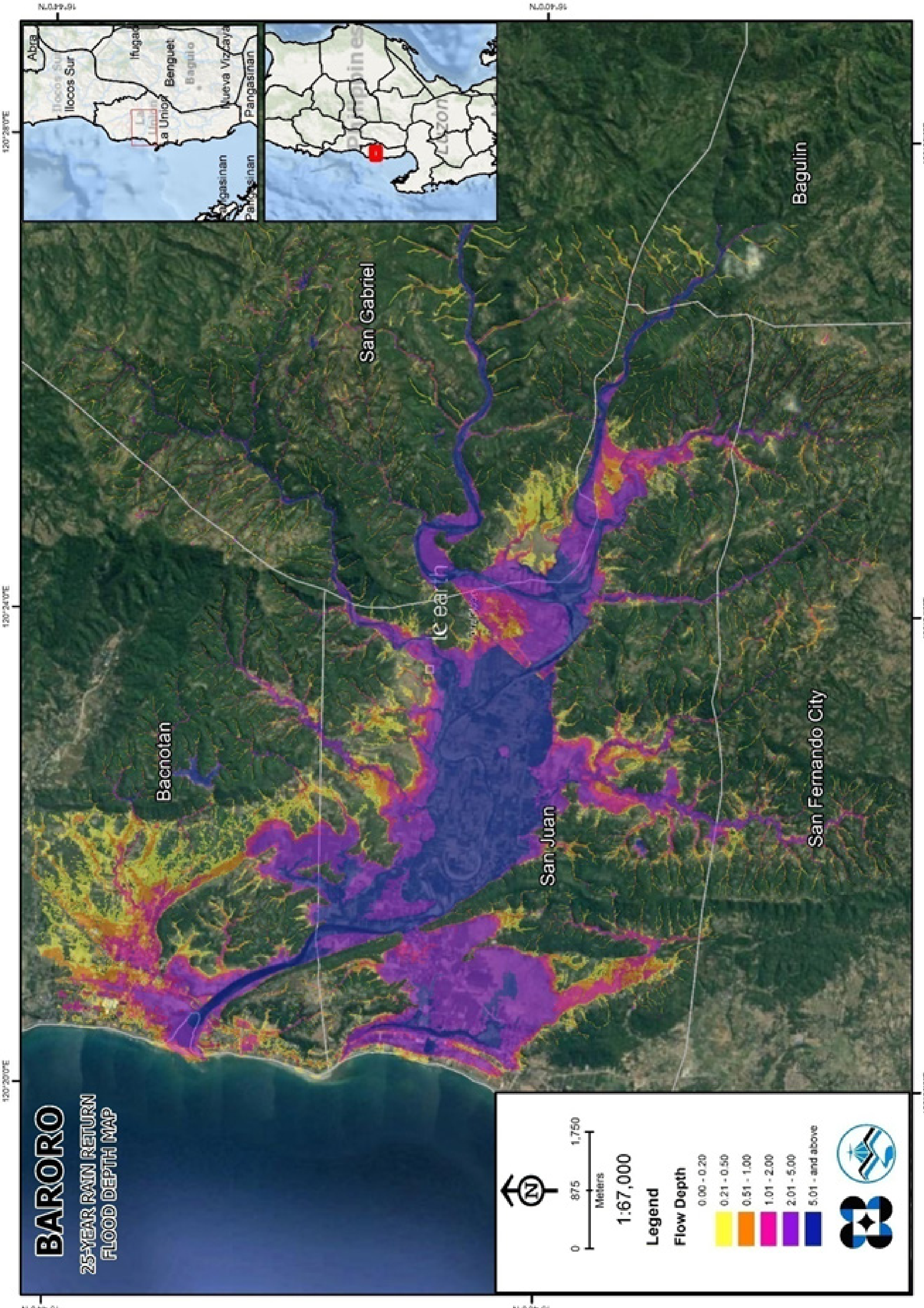


Figure 69. 25-year flow depth map for Baroro Floodplain overlaid on Google Earth imager

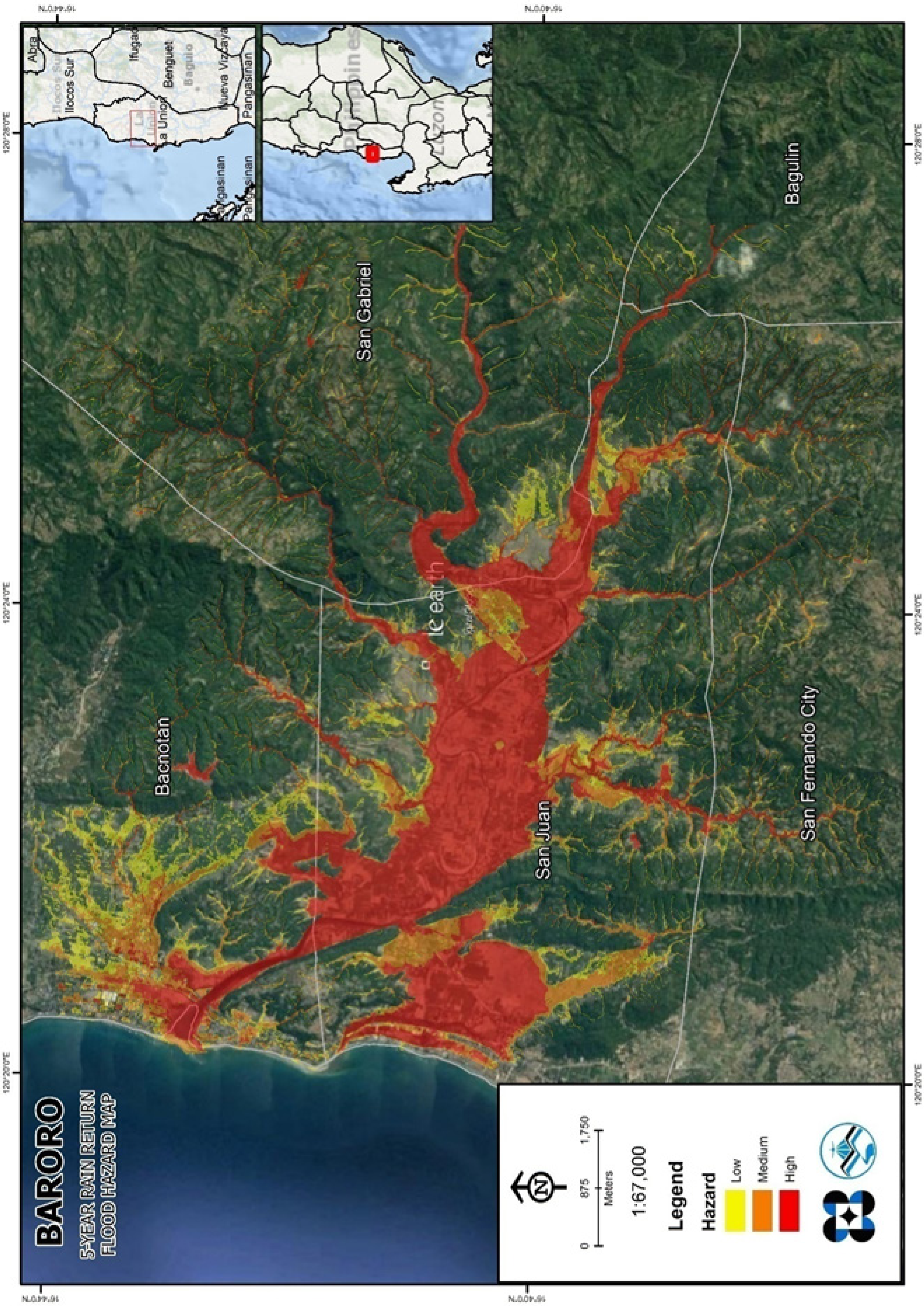


Figure 70. 5-year flood hazard map for Baroro Floodplain overlaid on Google Earth imagery

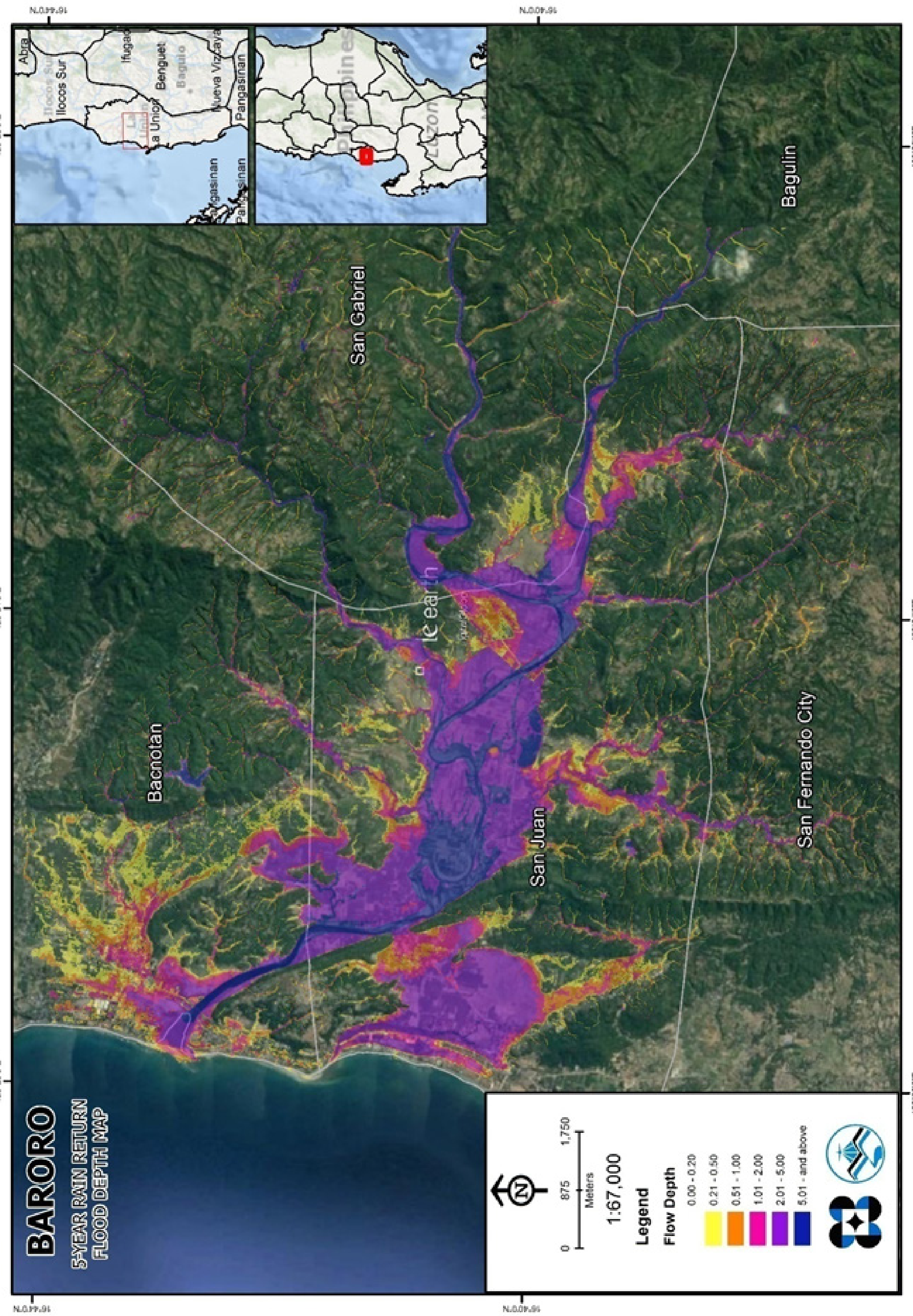


Figure 71. 5-year flow depth map for Baroro Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Baroro River Basin, grouped by municipality, are listed below. For the said basin, five municipalities consisting of 56 barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 10.43% of the municipality of Bacnotan with an area of 80.67 sq km will experience flood levels of less than 0.20 meters; 1.21% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.75%, 1.04%, 1.20%, and 0.41% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 and Table 34 are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected areas in Bacnotan, La Union during a 5-year rainfall return period

BARORO BASIN		Area of affected barangays in Bacnotan (in sq. km)						
		Agtipal	Bacsil	Baroro	Burayoc	Bussaoit	Legleg	Lisqueb
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.58	0.97	0.068	0.52	1.63	1.7	1.15
	0.21-0.50	0.024	0.1	0.015	0.15	0.18	0.17	0.1
	0.51-1.00	0.021	0.09	0.0047	0.056	0.066	0.079	0.054
	1.01-2.00	0.029	0.23	0.0019	0.021	0.029	0.1	0.047
	2.01-5.00	0.013	0.24	0	0.0013	0.026	0.16	0.14
	> 5.00	0.0001	0.21	0	0	0.064	0.0017	0.01

Table 34. Affected areas in Bacnotan, La Union during a 5-year rainfall return period

BARORO BASIN		Area of affected barangays in Bacnotan (in sq. km)						
		Nagsarabo-an	Nagsim-baanan	Poblacion	Salincob	Sapilang	Zaragosa	
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.22	0.098	0.16	0.024	0.26	1.03	
	0.21-0.50	0.0097	0.025	0.049	0.00052	0.0098	0.14	
	0.51-1.00	0.003	0.054	0.098	0.0004	0.0088	0.069	
	1.01-2.00	0.0012	0.094	0.14	0	0.013	0.14	
	2.01-5.00	0	0.18	0.09	0.00016	0.0078	0.11	
	> 5.00	0	0.042	0	0	0.0001	0.0007	

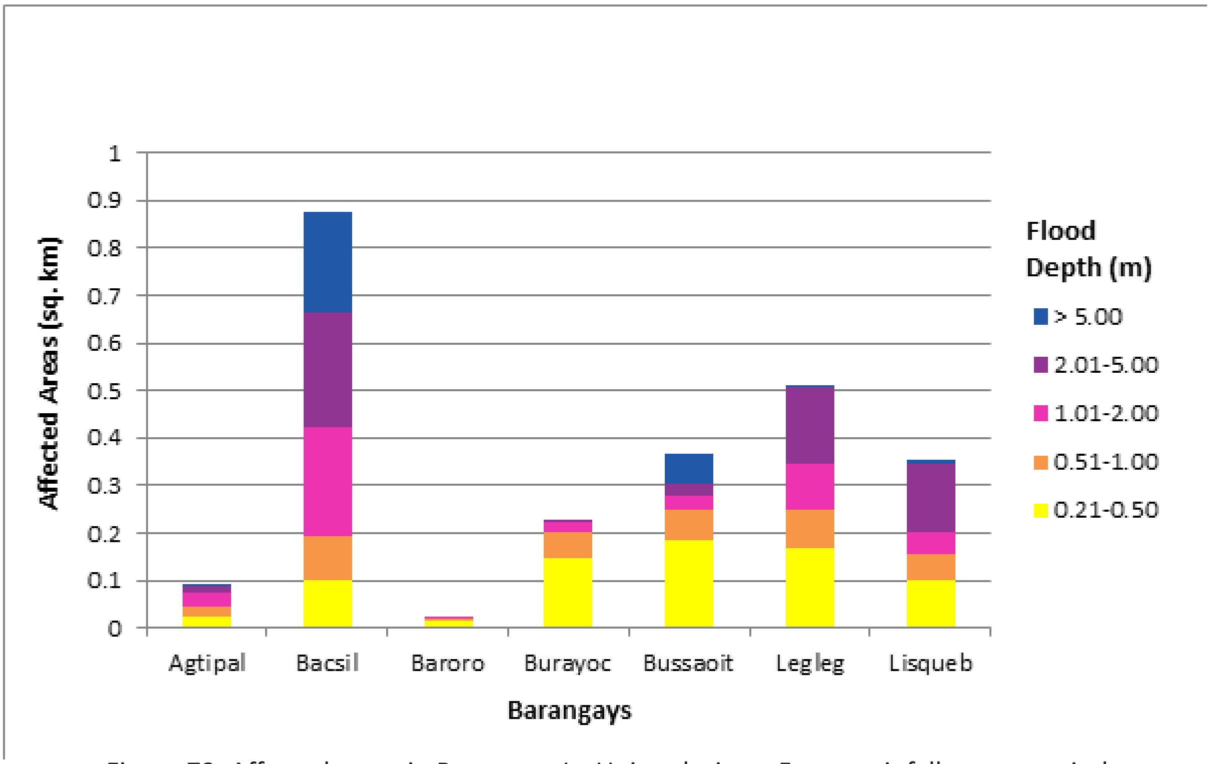


Figure 72. Affected areas in Bacnotan, La Union during a 5-year rainfall return period

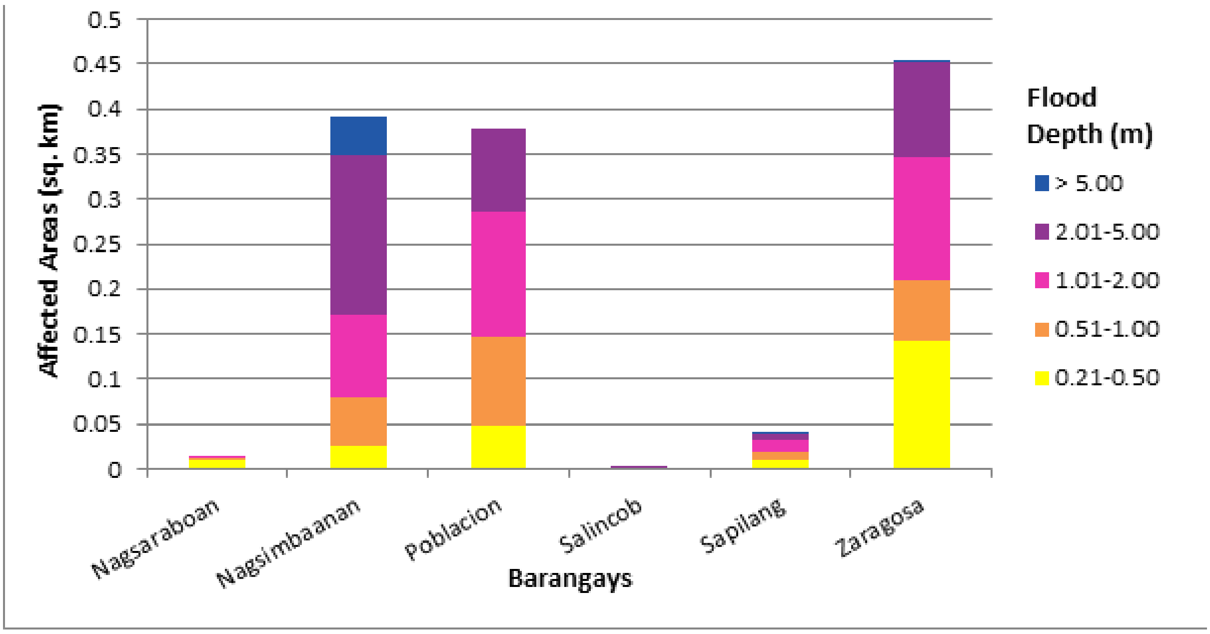


Figure 73. Affected areas in Bacnotan, La Union during a 5-year rainfall return period

For the 5-year return period, 0.09% of the municipality of Bagulin with an area of 77.97 sq km will experience flood levels of less than 0.20 meters; 0.00% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.00% of the area will experience flood depths of

0.51 to 1 meter. Listed in Table 35 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Bagulin, La Union during a 5-year rainfall return period

BARORO BASIN		Area of affected barangay in Bagulin (in sq. km)
		Dagup
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.072
	0.21-0.50	0.0018
	0.51-1.00	0.001
	1.01-2.00	0.0015
	2.01-5.00	0.0014
	> 5.00	0.0043

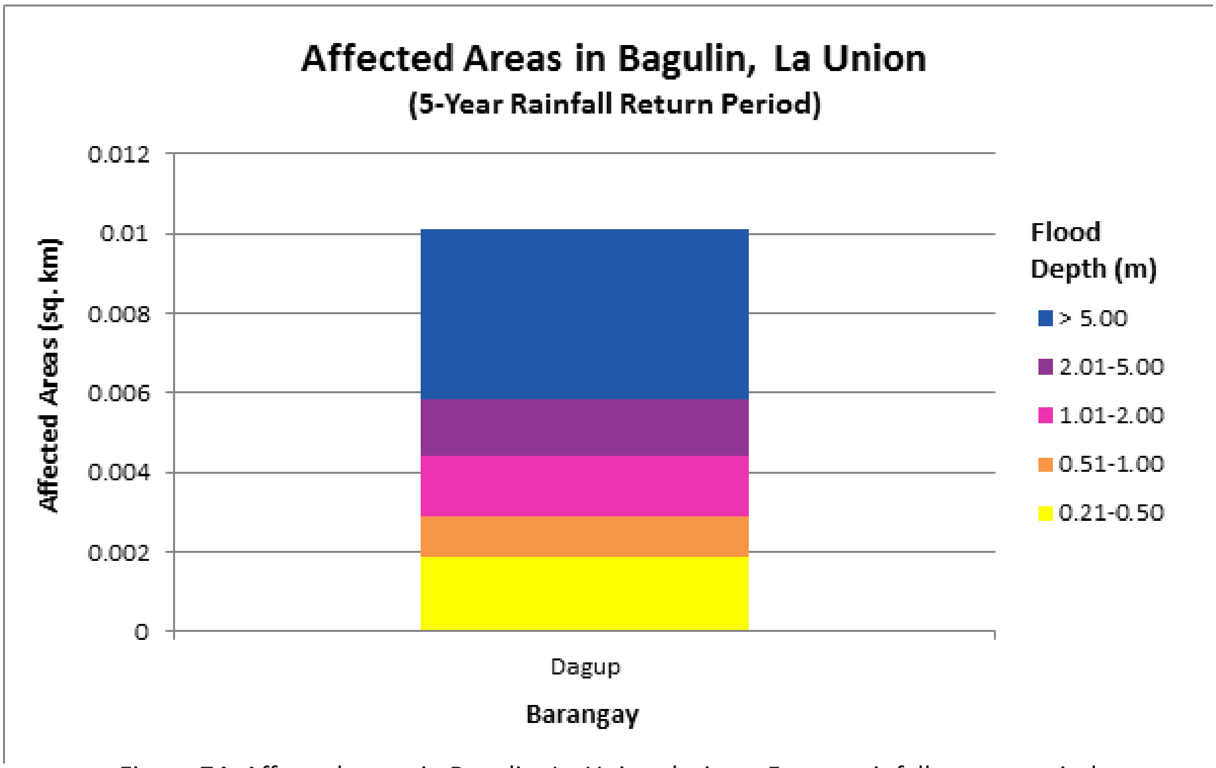


Figure 74. Affected areas in Bagulin, La Union during a 5-year rainfall return period

For the 5-year return period, 2.98% of the municipality of San Fernando City with an area of 121.05 sq km will experience flood levels of less than 0.20 meters; 0.22% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.18%, 0.14%, 0.14%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected areas in San Fernando City, La Union during a 5-year rainfall return period

BARORO BASIN		Area of affected barangays in San Fernando City (in sq. km)							
		Abut	Bangban-golan	Baraoas	Cala-bugao	Nagyubuyuban	Nam-tutan	Puspus	Saoay
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	1.41	0.13	0.76	0.051	0.24	0.53	0.44	0.037
	0.21-0.50	0.13	0.0045	0.056	0.0023	0.017	0.033	0.024	0.0021
	0.51-1.00	0.11	0.0037	0.038	0.0023	0.011	0.037	0.017	0.00078
	1.01-2.00	0.073	0.009	0.03	0.0012	0.017	0.029	0.011	0.0018
	2.01-5.00	0.097	0.011	0.02	0.00036	0.029	0.0085	0.0082	0.0002
	> 5.00	0.0015	0.0003	0.0081	0	0.0002	0.0001	0.0009	0

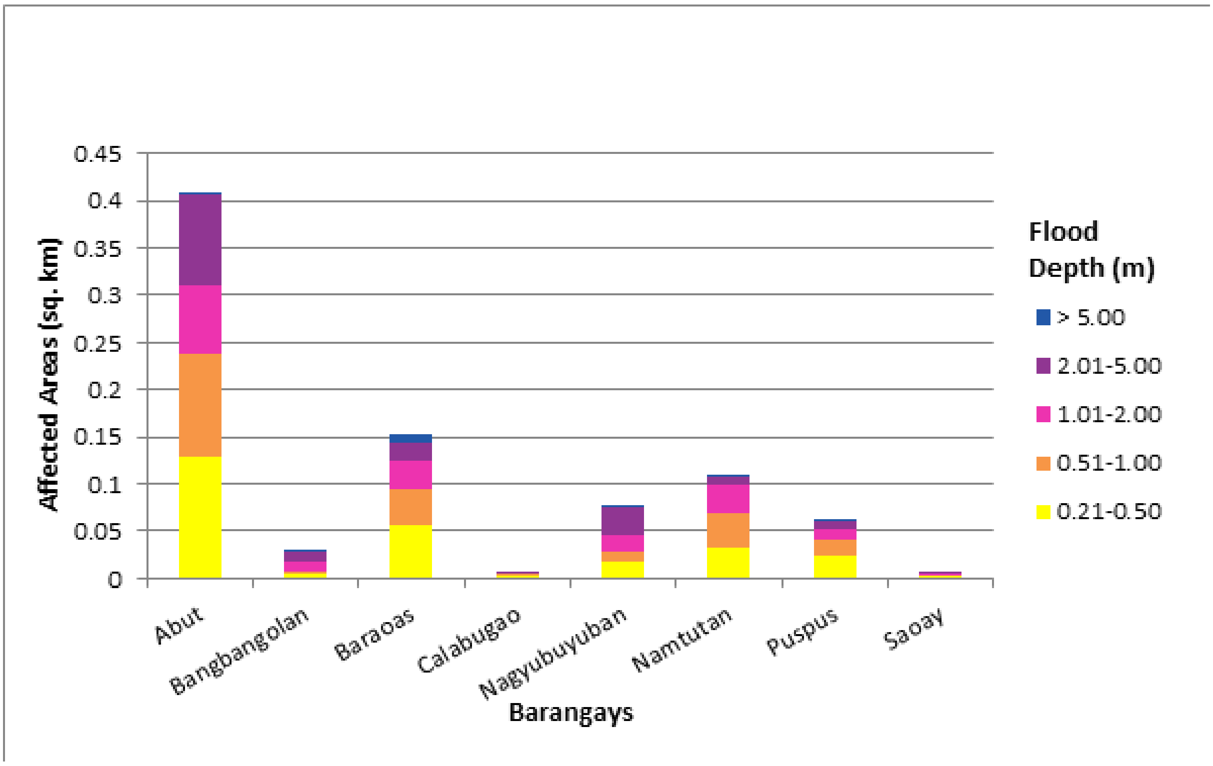


Figure 75. Affected areas in San Fernando City, La Union during a 5-year rainfall return period

For the 5-year return period, 3.17% of the municipality of San Gabriel with an area of 154.19 sq km will experience flood levels of less than 0.20 meters; 0.29% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.11%, 0.17%, 0.70%, and 0.31% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in San Gabriel, La Union during a 5-year rainfall return period

BARORO BASIN		Area of affected barangays in San Gabriel (in sq. km)		
		Bucao	Bumbuneg	Poblacion
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.8	1.52	2.57
	0.21-0.50	0.021	0.061	0.37
	0.51-1.00	0.018	0.022	0.14
	1.01-2.00	0.016	0.028	0.22
	2.01-5.00	0.015	0.051	1.02
	> 5.00	0.015	0.1	0.37

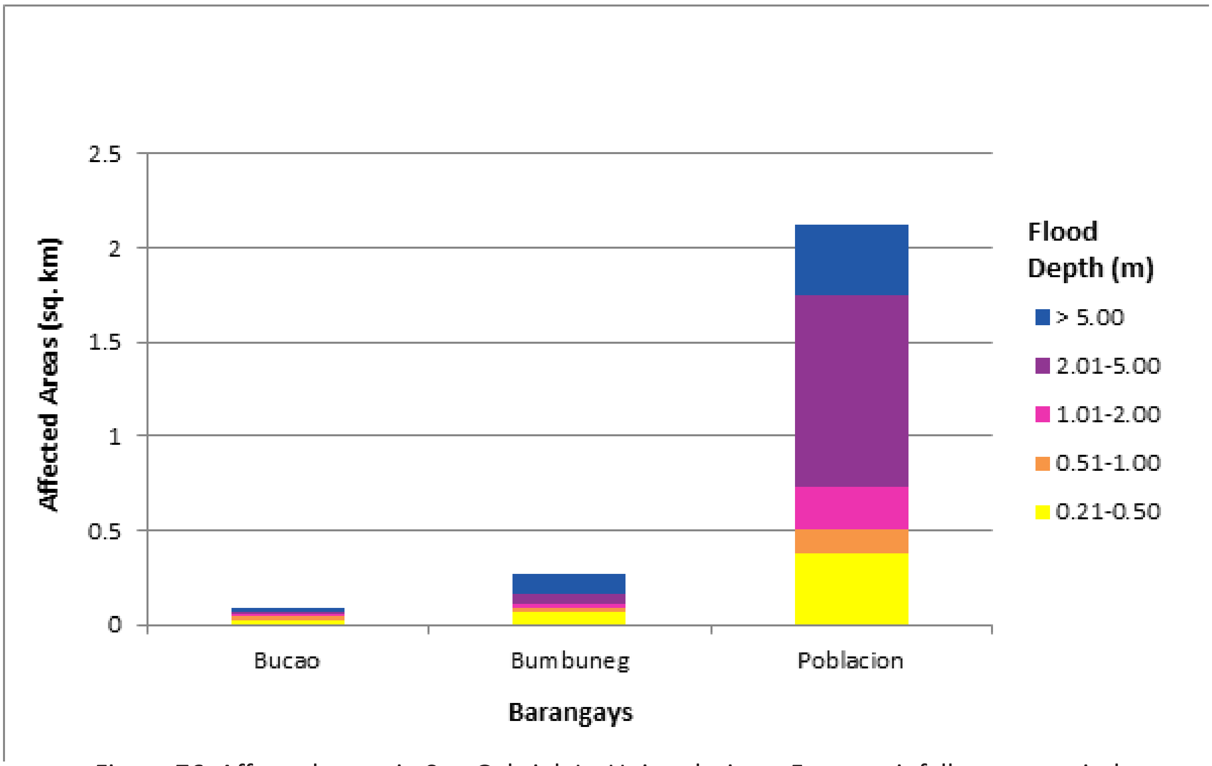


Figure 76. Affected areas in San Gabriel, La Union during a 5-year rainfall return period

For the 5-year return period, 28.34% of the municipality of San Juan with an area of 53.44 sq km will experience flood levels of less than 0.20 meters; 3.34% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.34%, 3.96%, 13.14%, and 6.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 to Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected areas in San Juan, La Union during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in San Juan (in sq. km)										
		Allangi-gan	Aludaid	Bacsayan	Balbal-losa	Bamban-ay	Bugbug-cao	Caarusi-pan	Cabaroan	Cabug-nayan	Cacapian	Caculan-gan
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.62	0.85	0.6	0.68	0	1.36	0.32	0.051	0.24	0.011	0.052
	0.21-0.50	0.042	0.079	0.048	0.075	0	0.22	0.055	0.082	0.035	0	0.0009
	0.51-1.00	0.02	0.032	0.044	0.13	0	0.15	0.037	0.13	0.04	0	0.0008
	1.01-2.00	0.015	0.039	0.081	0.21	0	0.16	0.045	0.13	0.11	0	0.0042
	2.01-5.00	0.093	0.042	0.14	0.14	0.38	0.075	0.43	1.06	0.18	0	0.071
	> 5.00	0.1	0.00063	0.014	0.019	0.53	0	0.26	0.25	0.02	0	0.029

Table 39. Affected areas in San Juan, La Union during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in San Juan (in sq. km)									
		Calin-camasan	Catdon-gan	Dangdan-gla	Dasay	Dinanum	Duplas	Guin-guinabang	Legleg	Nadsaag	Nagsabaran
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.35	0.29	0.17	0.57	0.32	1.18	0.72	0.23	0.033	1
	0.21-0.50	0.017	0.043	0.069	0.034	0.013	0.2	0.18	0.027	0.015	0.061
	0.51-1.00	0.016	0.046	0.1	0.018	0.0065	0.14	0.095	0.036	0.022	0.062
	1.01-2.00	0.065	0.025	0.18	0.01	0.001	0.11	0.028	0.072	0.029	0.074
	2.01-5.00	0.93	0.26	0.15	0.11	0.0002	0.14	0.023	0.094	0.76	0.24
	> 5.00	0.17	0.0092	0.057	0.033	0	0.21	0.0006	0	0.35	0.15

Table 40. Affected areas in San Juan, La Union during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in San Juan (in sq. km)									
		Naguirangan	Nagyubuyuban	Oaquing	Pacpacac	Pagdildilan	Quidem	San Fe-lipe	Santa Rosa	Santo Rosario	Saracat
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.023	0.94	0.38	0.8	0.93	0.033	1.67	0.0063	0.032	0.68
	0.21-0.50	0.038	0.057	0.008	0.11	0.11	0.0013	0.13	0.0003	0.00011	0.043
	0.51-1.00	0.12	0.052	0.0062	0.24	0.14	0.0019	0.082	0.0012	0.00026	0.027
	1.01-2.00	0.1	0.087	0.011	0.29	0.12	0.0091	0.063	0.025	0.0041	0.015
	2.01-5.00	0.54	0.054	0.13	0.21	0.15	0.18	0.064	0.37	0.0035	0.008
	> 5.00	0.12	0.0042	0.6	0.0083	0.0091	0.087	0.013	0.17	0	0.0001

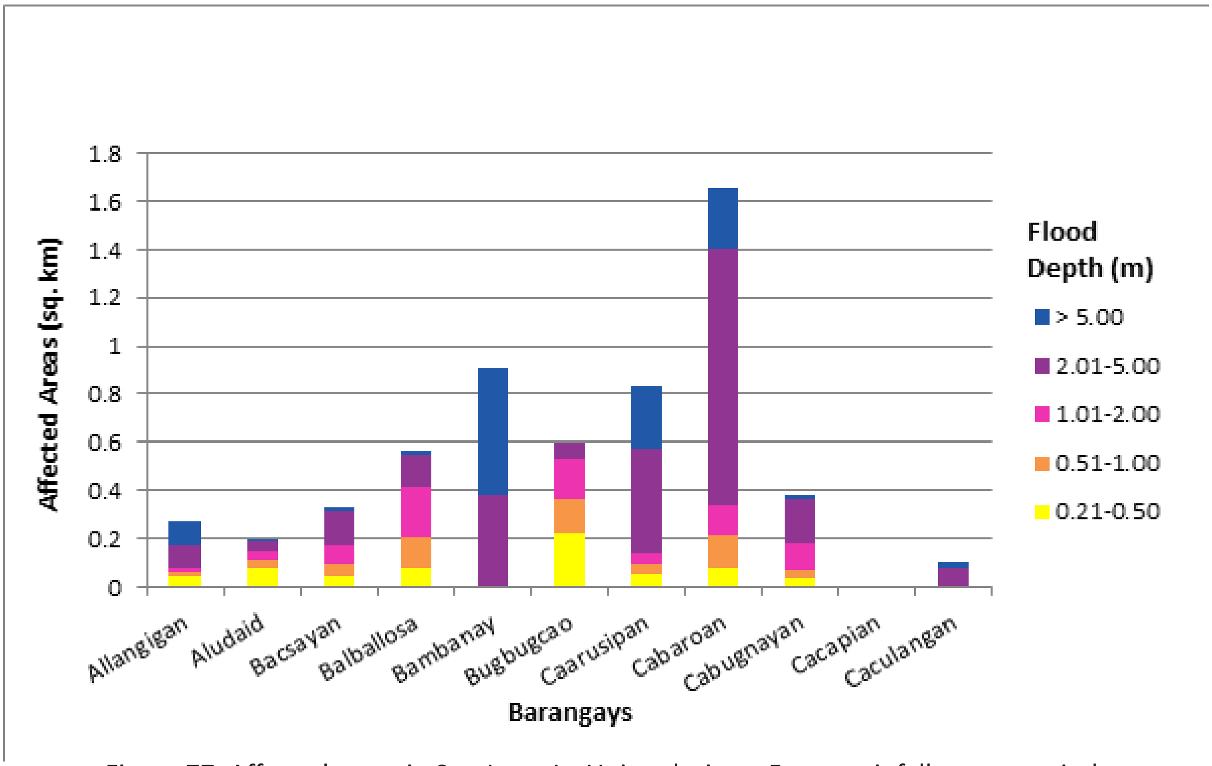


Figure 77. Affected areas in San Juan, La Union during a 5-year rainfall return period

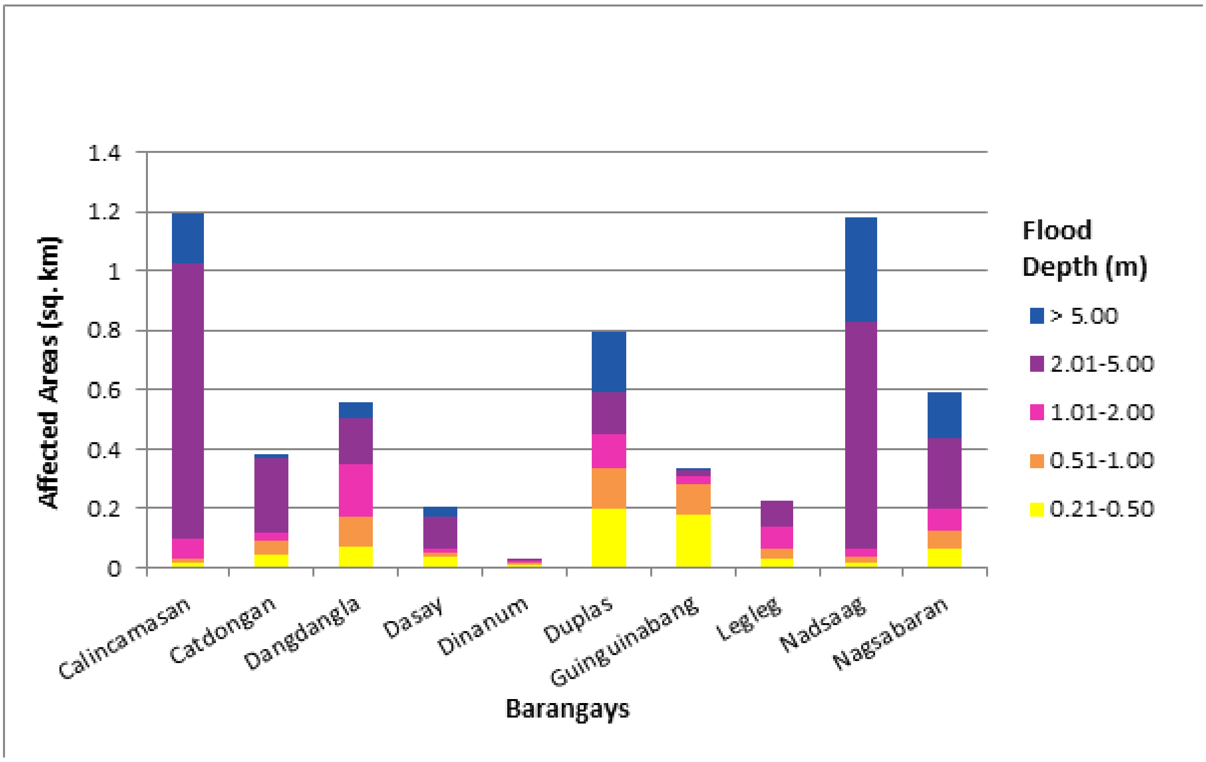


Figure 78. Affected areas in San Juan, La Union during a 5-year rainfall return period

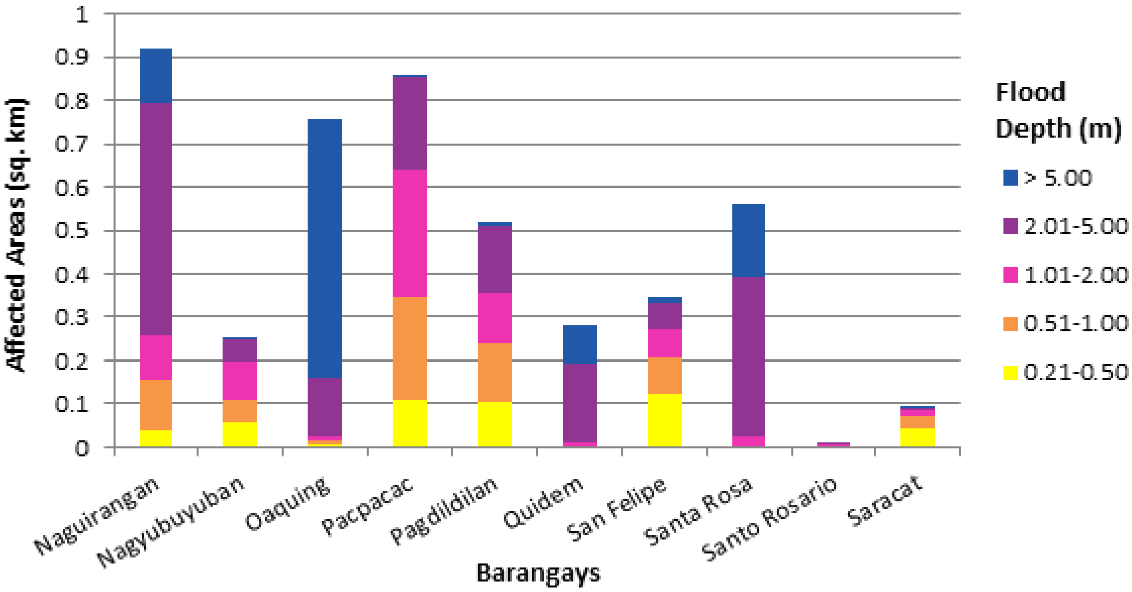


Figure 79. Affected areas in San Juan, La Union during a 5-year rainfall return period

For the 25-year return period, 9.42% of the municipality of Bacnotan with an area of 80.67 sq km will experience flood levels of less than 0.20 meters; 1.33% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.90%, 1.04%, 1.72%, and 0.63% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 and Figure 42 are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected areas in Bacnotan, La Union during a 25-year rainfall return period

BARORO BASIN		Area of affected barangays in Bacnotan (in sq. km)						
		Agtipal	Bacsil	Baroro	Burayoc	Bussaoit	Legleg	Lisqueb
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.56	0.9	0.058	0.41	1.44	1.57	1.07
	0.21-0.50	0.025	0.086	0.019	0.2	0.22	0.19	0.11
	0.51-1.00	0.021	0.098	0.011	0.09	0.13	0.11	0.072
	1.01-2.00	0.03	0.17	0.0028	0.042	0.066	0.096	0.054
	2.01-5.00	0.025	0.33	0	0.0015	0.058	0.23	0.13
	> 5.00	0.0078	0.26	0	0	0.089	0.018	0.078

Table 42. Affected areas in Bacnotan, La Union during a 25-year rainfall return period

BARORO BASIN		Area of affected barangays in Bacnotan (in sq. km)					
		Nagsarabo	Nagsimbaanan	Poblacion	Salincob	Sapilang	Zaragosa
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.21	0.077	0.12	0.023	0.25	0.91
	0.21-0.50	0.015	0.025	0.037	0.00074	0.0091	0.14
	0.51-1.00	0.0061	0.042	0.077	0.0004	0.0072	0.067
	1.01-2.00	0.0027	0.091	0.16	0.0002	0.013	0.11
	2.01-5.00	0	0.2	0.14	0.00016	0.016	0.25
	> 5.00	0	0.049	0	0	0.0002	0.0017

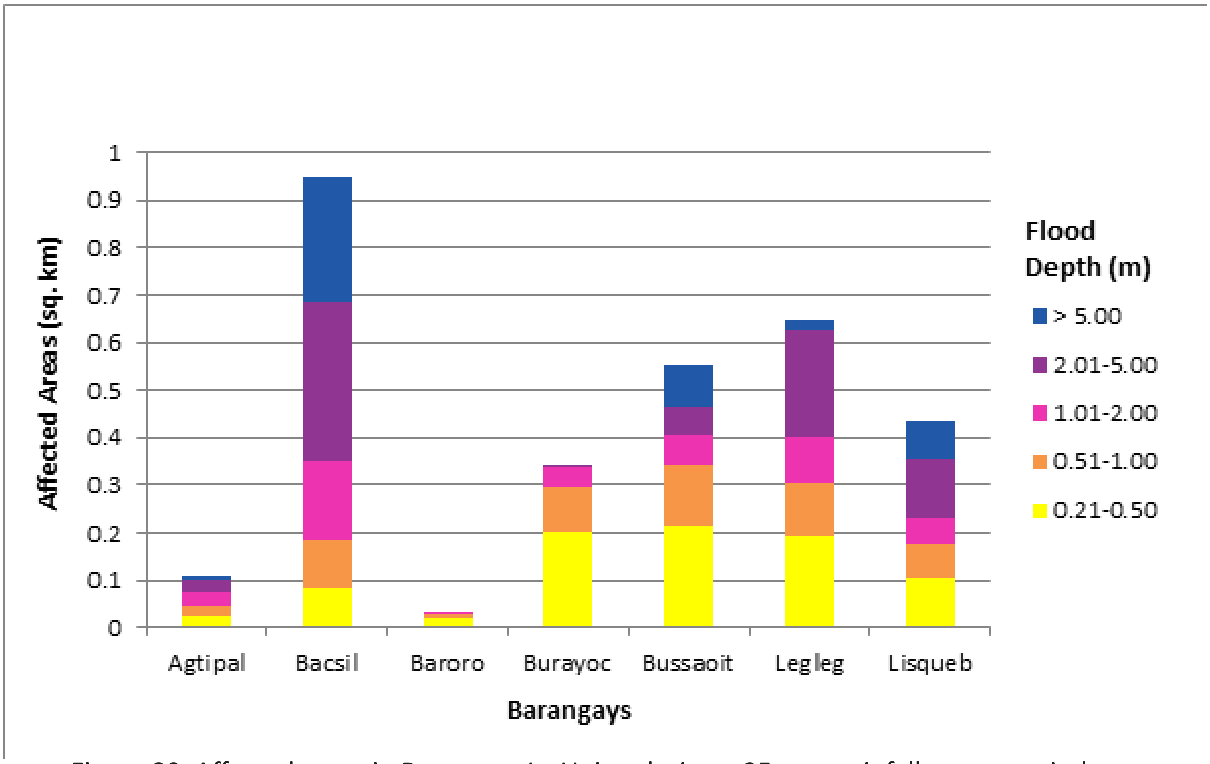


Figure 80. Affected areas in Bacnotan, La Union during a 25-year rainfall return period

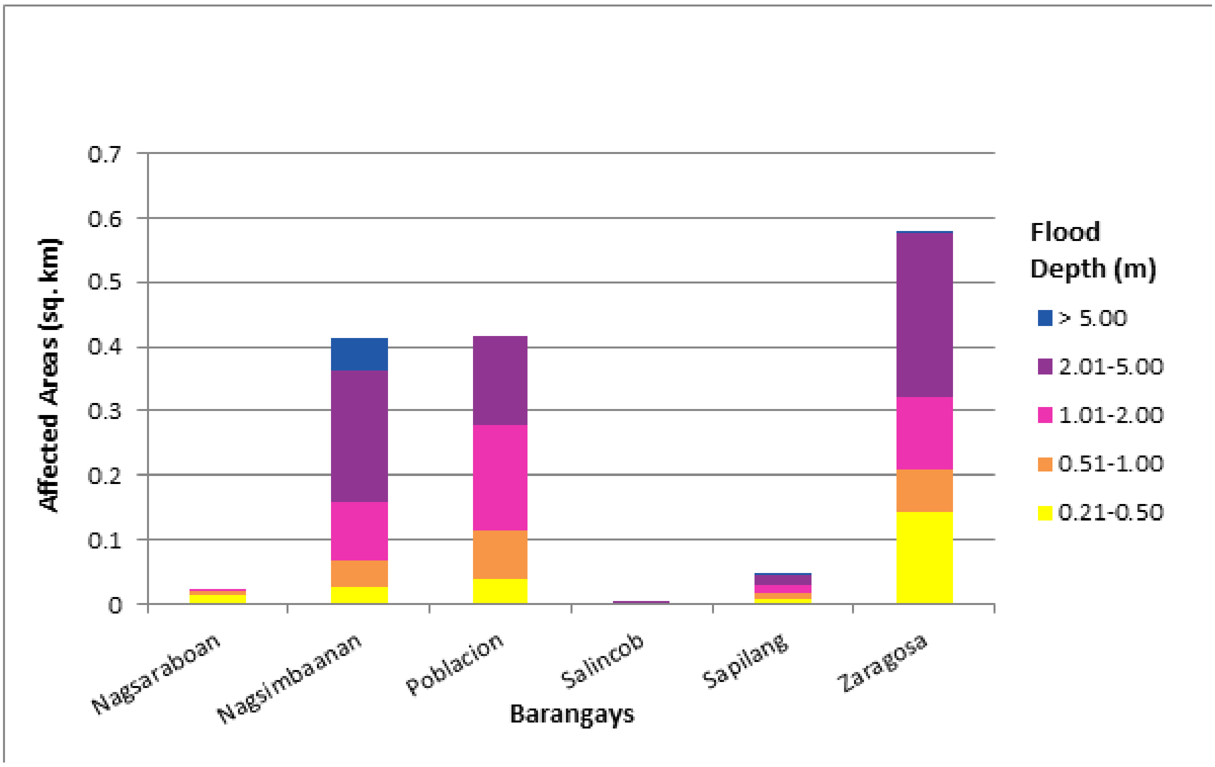


Figure 81. Affected areas in Bacnotan, La Union during a 25-year rainfall return period

For the 25-year return period, 0.09% of the municipality of Bagulin with an area of 77.97 sq km will experience flood levels of less than 0.20 meters; 0.00% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Bagulin, La Union during a 25-year rainfall return period

BARORO BASIN		Area of affected barangay in Bagulin (in sq. km)
		Dagup
AffAffected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.07
	0.21-0.50	0.0016
	0.51-1.00	0.001
	1.01-2.00	0.0013
	2.01-5.00	0.0023
	> 5.00	0.0059

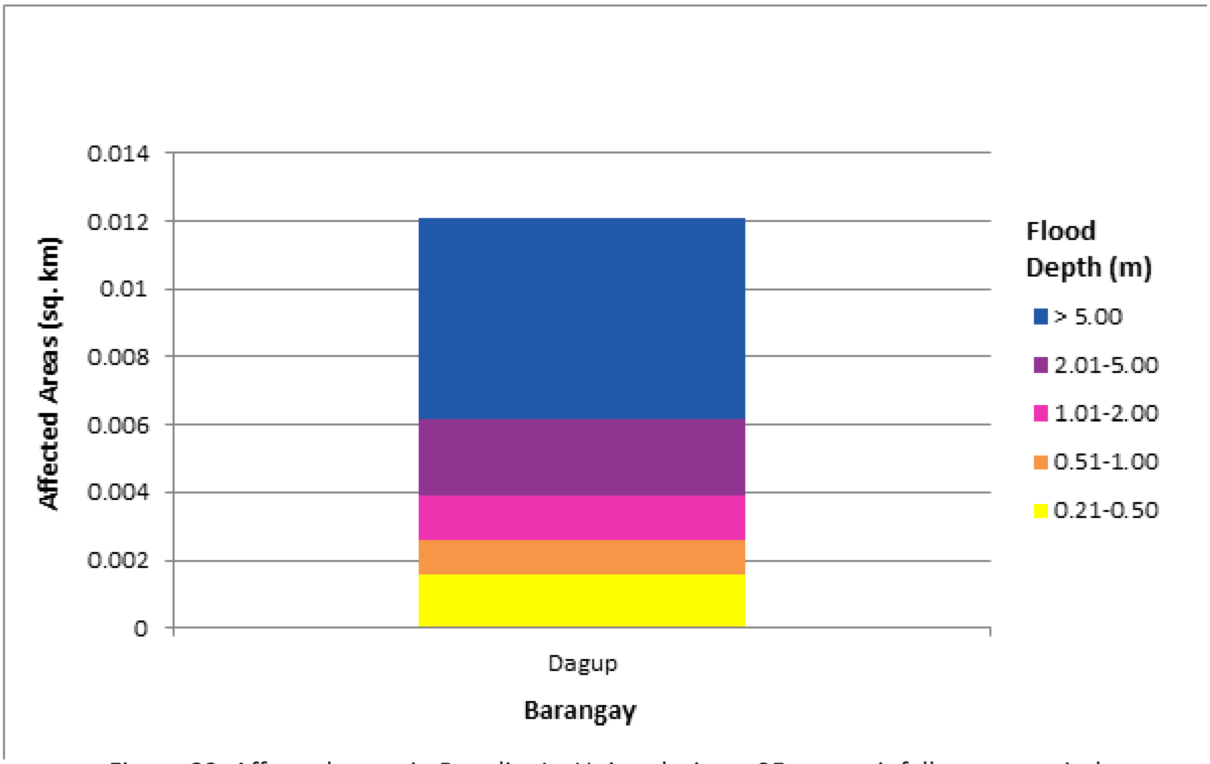


Figure 82. Affected areas in Bagulin, La Union during a 25-year rainfall return period

For the 25-year return period, 2.81% of the municipality of San Fernando City with an area of 121.05 sq km will experience flood levels of less than 0.20 meters; 0.23% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.20%, 0.19%, 0.21%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected areas in San Fernando City, La Union during a 25-year rainfall return period

BARORO BASIN		Area of affected barangays in San Fernando City (in sq. km)							
		Abut	Bangban-golan	Baraoas	Cala-bugao	Nagyu buyuban	Namtut-an	Puspus	Saoay
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	1.31	0.13	0.72	0.05	0.22	0.51	0.42	0.036
	0.21-0.50	0.13	0.0039	0.067	0.002	0.018	0.03	0.028	0.0026
	0.51-1.00	0.12	0.0046	0.042	0.0023	0.013	0.034	0.02	0.0017
	1.01-2.00	0.12	0.0052	0.04	0.0024	0.014	0.041	0.013	0.0015
	2.01-5.00	0.14	0.017	0.03	0.00052	0.042	0.021	0.013	0.00086
	> 5.00	0.012	0.0028	0.014	0	0.0032	0.0007	0.0028	0

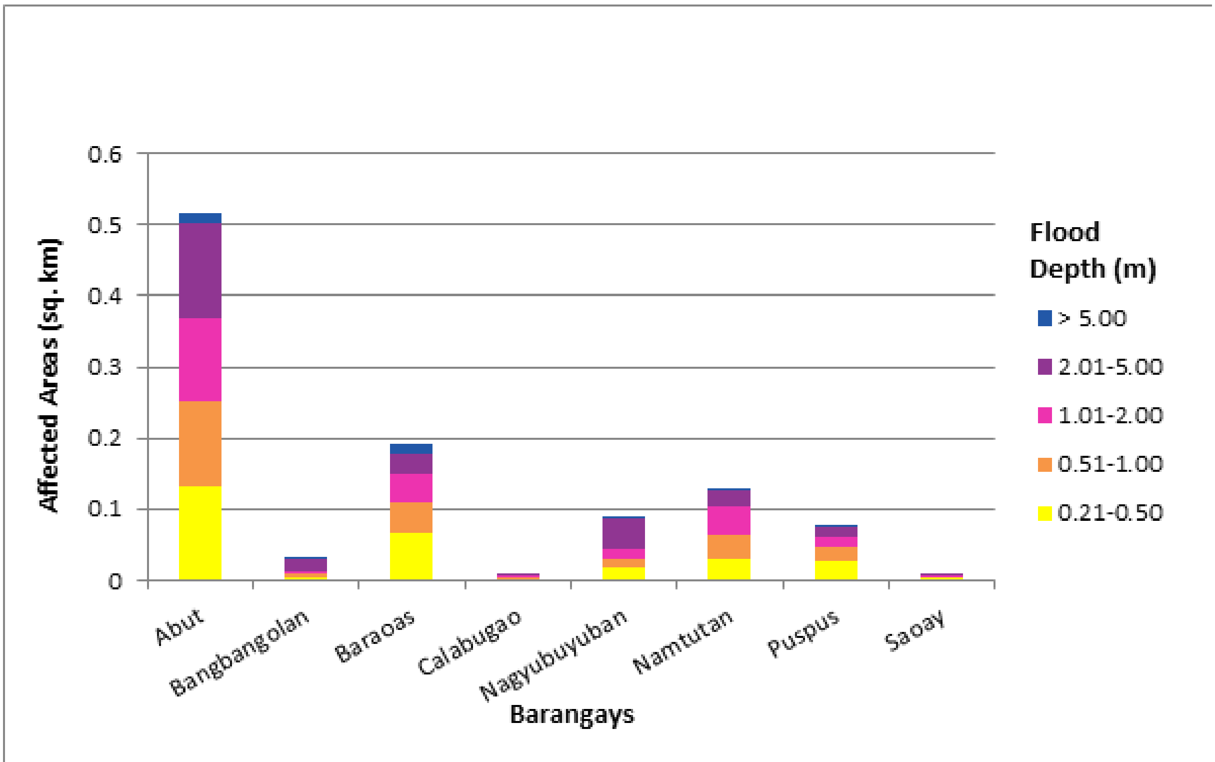


Figure 83. Affected areas in San Fernando City, La Union during a 25-year rainfall return period

For the 25-year return period, 2.90% of the municipality of San Gabriel with an area of 154.19 sq km will experience flood levels of less than 0.20 meters; 0.41% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.16%, 0.14%, 0.71%, and 0.45% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected areas in San Gabriel, La Union during a 25-year rainfall return period

BARORO BASIN		Area of affected barangays in San Gabriel (in sq. km)		
		Bucao	Bumbuneg	Poblacion
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.78	1.47	2.21
	0.21-0.50	0.026	0.077	0.53
	0.51-1.00	0.019	0.029	0.2
	1.01-2.00	0.02	0.027	0.17
	2.01-5.00	0.019	0.052	1.02
	> 5.00	0.021	0.13	0.55

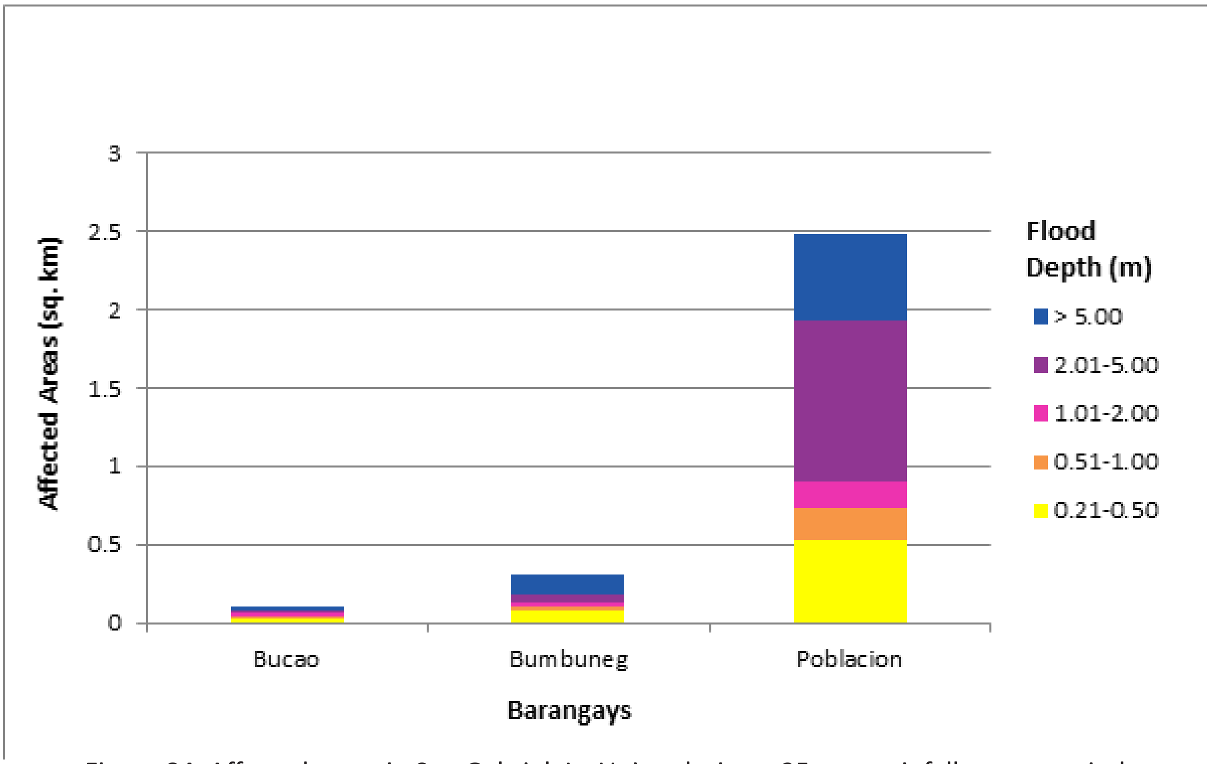


Figure 84. Affected areas in San Gabriel, La Union during a 25-year rainfall return period

For the 25-year return period, 24.20% of the municipality of San Juan with an area of 53.44 sq km will experience flood levels of less than 0.20 meters; 2.90% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.91%, 4.44%, 9.43%, and 14.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 to Table 48 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected areas in San Juan, La Union during a 25-year rainfall return period

BARORO BASIN		Area of affected barangays in San Juan (in sq. km)										
		Allangi-gan	Aludaid	Bacsayan	Balbal-losa	Bamban-ay	Bugbug-cao	Caarusipan	Cabaroan	Cabug-nayan	Cacapian	Caculan-gan
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.51	0.78	0.55	0.62	0	1.16	0.051	0.011	0.13	0.011	0.05
	0.21-0.50	0.044	0.099	0.058	0.077	0	0.2	0.028	0.025	0.033	0.000003	0.00023
	0.51-1.00	0.038	0.062	0.033	0.059	0	0.21	0.052	0.081	0.026	0	0.001
	1.01-2.00	0.062	0.026	0.059	0.17	0	0.22	0.12	0.2	0.077	0	0.0027
	2.01-5.00	0.066	0.072	0.19	0.27	0	0.17	0.23	0.15	0.17	0	0.067
	> 5.00	0.18	0.002	0.044	0.047	0.91	0.00019	0.67	1.24	0.18	0	0.038

Table 47. Affected areas in San Juan, La Union during a 25-year rainfall return period

BARORO BASIN		Area of affected barangays in San Juan (in sq. km)									
		Calin-camasan	Catdon-gan	Dangdan-gla	Dasay	Dinanum	Duplas	Guin-guinabang	Legleg	Nadsaag	Nagsaba-ran
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.31	0.26	0.053	0.55	0.31	0.96	0.53	0.18	0	0.94
	0.21-0.50	0.015	0.029	0.0094	0.036	0.016	0.12	0.21	0.019	0	0.057
	0.51-1.00	0.013	0.04	0.024	0.024	0.009	0.18	0.18	0.019	0	0.043
	1.01-2.00	0.026	0.029	0.089	0.024	0.0035	0.27	0.096	0.046	0.01	0.08
	2.01-5.00	0.57	0.089	0.41	0.097	0.0002	0.19	0.035	0.19	0.1	0.2
	> 5.00	0.62	0.23	0.15	0.051	0.0001	0.25	0.002	0.0034	1.1	0.27

Table 48. Affected areas in San Juan, La Union during a 25-year rainfall return period

BARORO BASIN		AArea of affected barangays in San Juan (in sq. km)									
		Nagu-irangan	Nagyubuyuban	Oaquing	Pacpacac	Pagdild-ilan	Quidem	San Felipe	Santa Rosa	Santo Rosario	Saracat
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.001	0.87	0.36	0.71	0.83	0.029	1.49	0.0048	0.032	0.65
	0.21-0.50	0.011	0.066	0.0087	0.069	0.083	0.001	0.17	0.0002	0.0001	0.053
	0.51-1.00	0.047	0.066	0.0061	0.094	0.12	0.0013	0.096	0.0004	0	0.038
	1.01-2.00	0.16	0.078	0.0068	0.21	0.17	0.0038	0.099	0.0013	0.00038	0.021
	2.01-5.00	0.56	0.099	0.034	0.48	0.22	0.084	0.13	0.14	0.0076	0.014
	> 5.00	0.16	0.015	0.72	0.095	0.027	0.19	0.027	0.42	0	0.00051

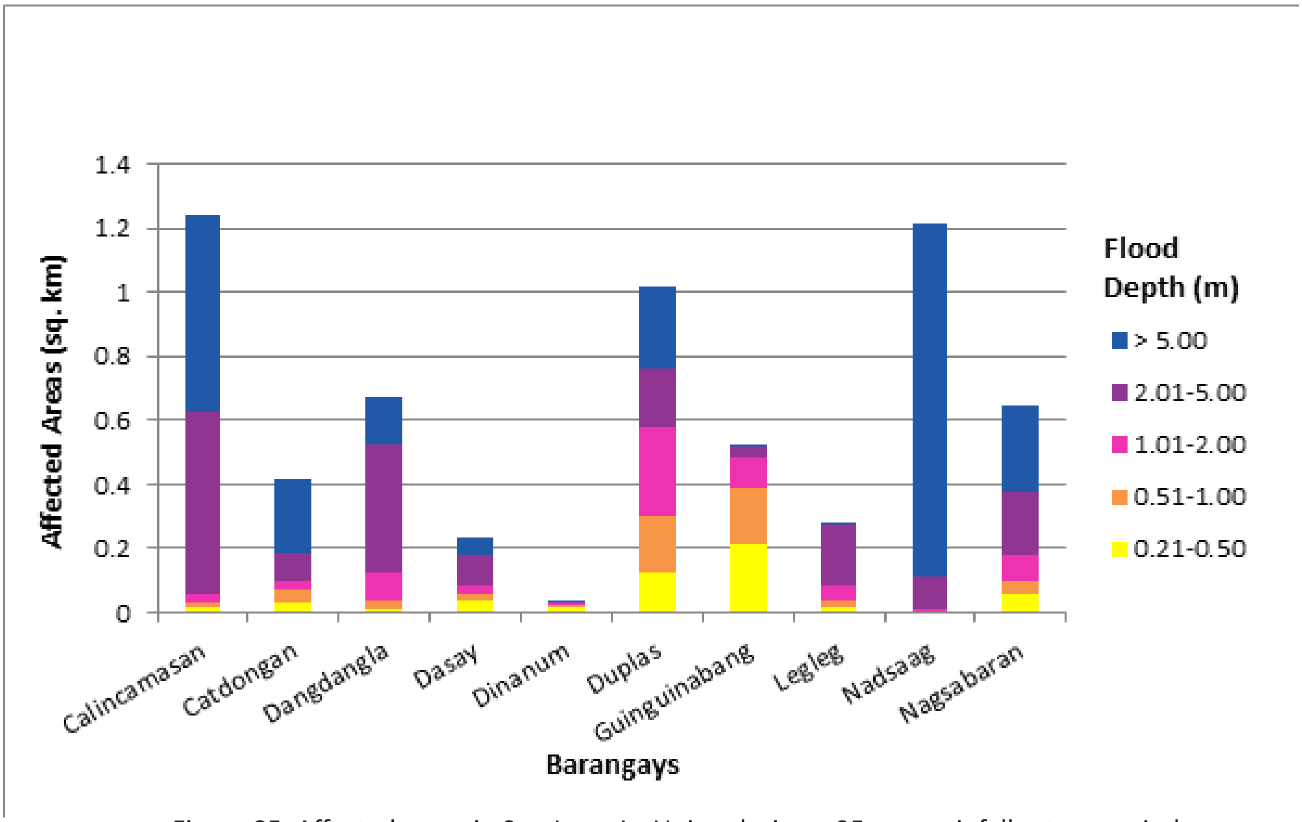


Figure 85. Affected areas in San Juan, La Union during a 25-year rainfall return period

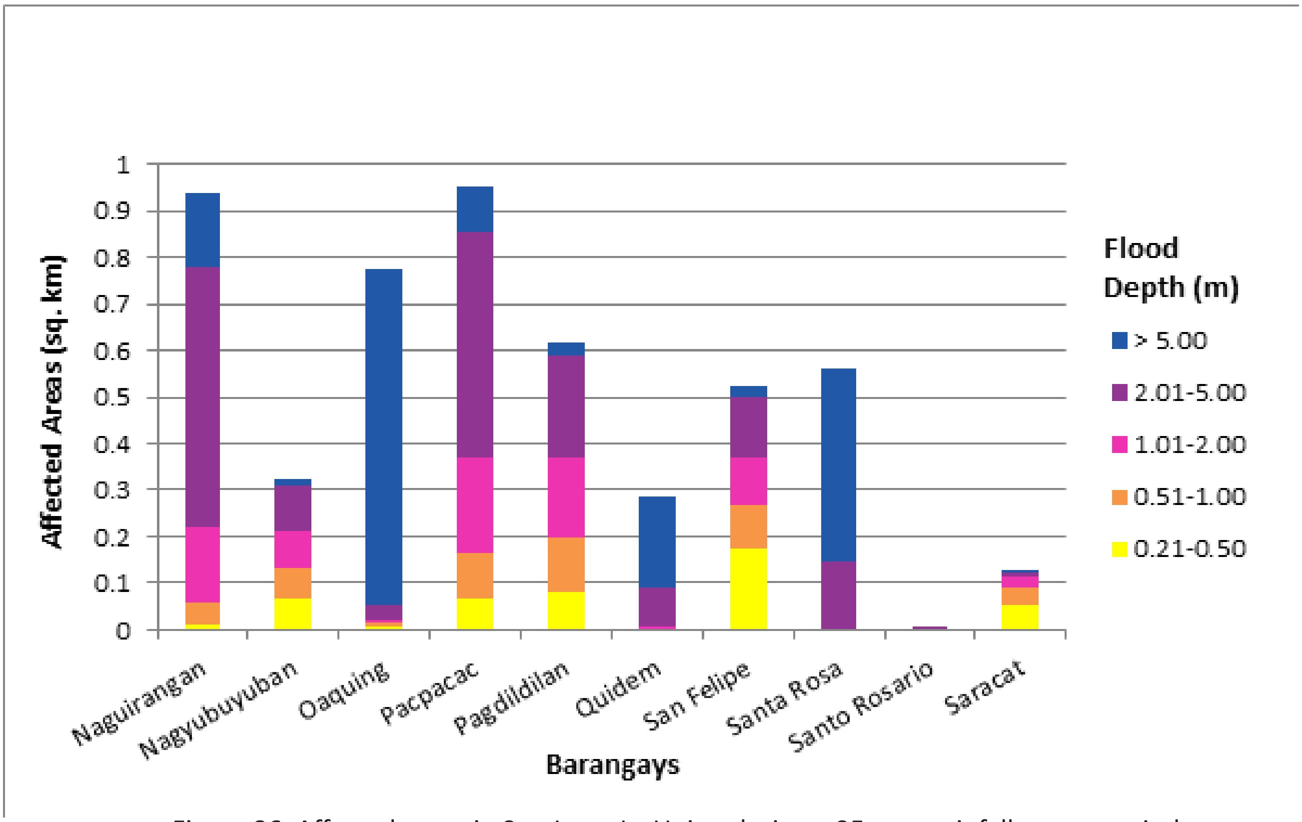


Figure 86. Affected areas in San Juan, La Union during a 25-year rainfall return period

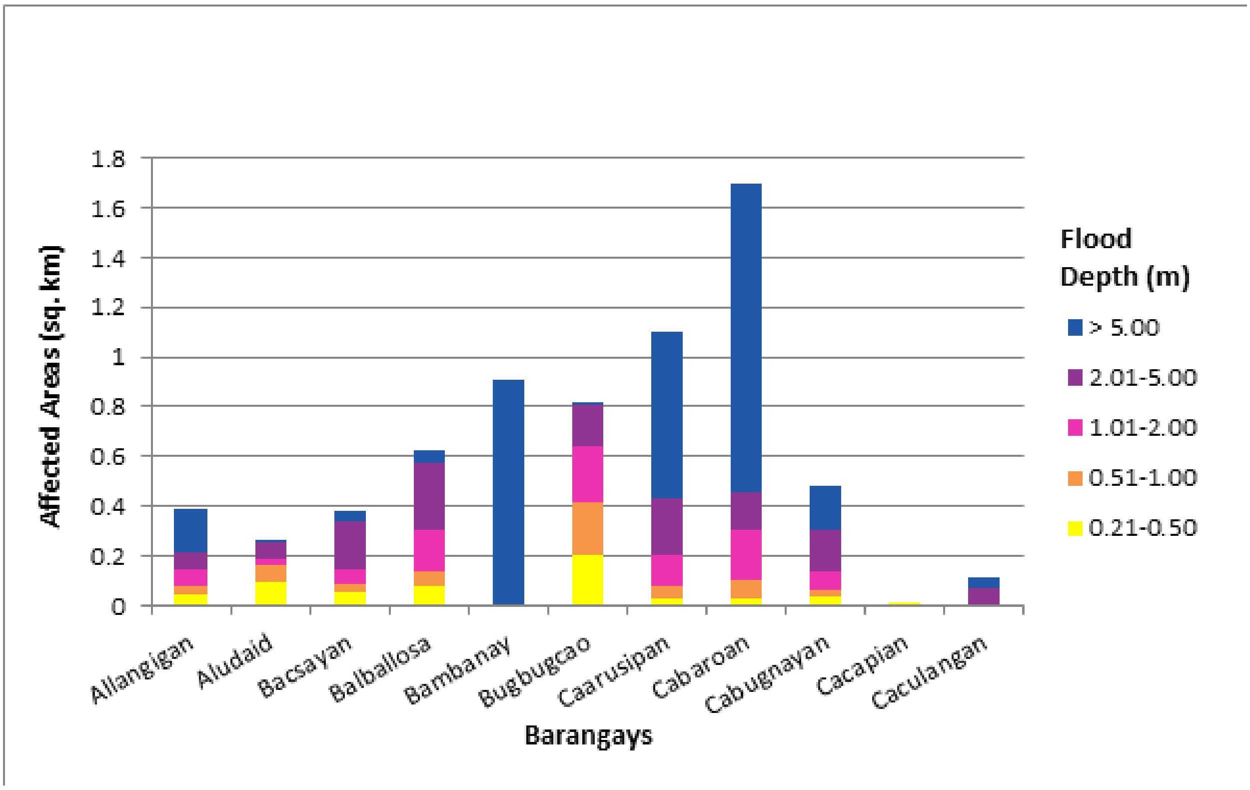


Figure 87. Affected areas in San Juan, La Union during a 25-year rainfall return period

For the 100-year return period, 8.86% of the municipality of Bacnotan with an area of 80.67 sq km. willkm will experience flood levels of less than 0.20 meters;. 1.35% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.96%, 1.13%, 1.89%, and 0.85% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the Table 49 and Table 50 are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected areas in Bacnotan, La Union during a 100-year rainfall return period

BARORO BASIN		**Area of affected barangays in Bacnotan (in sq. km)**						
		Agtipal	Bacsil	Baroro	Burayoc	Bussaoit	Legleg	Lisqueb
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.55	0.87	0.047	0.33	1.33	1.49	1.03
	0.21-0.50	0.028	0.07	0.022	0.23	0.24	0.18	0.1
	0.51-1.00	0.016	0.097	0.018	0.098	0.12	0.14	0.083
	1.01-2.00	0.025	0.15	0.0034	0.083	0.12	0.1	0.054
	2.01-5.00	0.037	0.39	0.00031	0.0058	0.085	0.22	0.11
	> 5.00	0.017	0.28	0	0	0.1	0.069	0.12

Table 50. Affected areas in Bacnotan, La Union during a 100-year rainfall return period

BARORO BASIN		**Area of affected barangays in Bacnotan (in sq. km)**						
		Nagsaraboan	Nagsim-baanan	Poblacion	Salincob	Sapilang	Zaragosa	Lisqueb
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.21	0.064	0.099	0.023	0.25	0.86	1.03304
	0.21-0.50	0.017	0.026	0.033	0.00093	0.0079	0.13	0.102269
	0.51-1.00	0.008	0.039	0.064	0.00042	0.0092	0.079	0.082732
	1.01-2.00	0.0038	0.09	0.17	0.0002	0.011	0.099	0.054333
	2.01-5.00	0.000066	0.21	0.17	0.00016	0.021	0.29	0.105819
	> 5.00	0	0.058	0	0	0.0002	0.034	0.124243

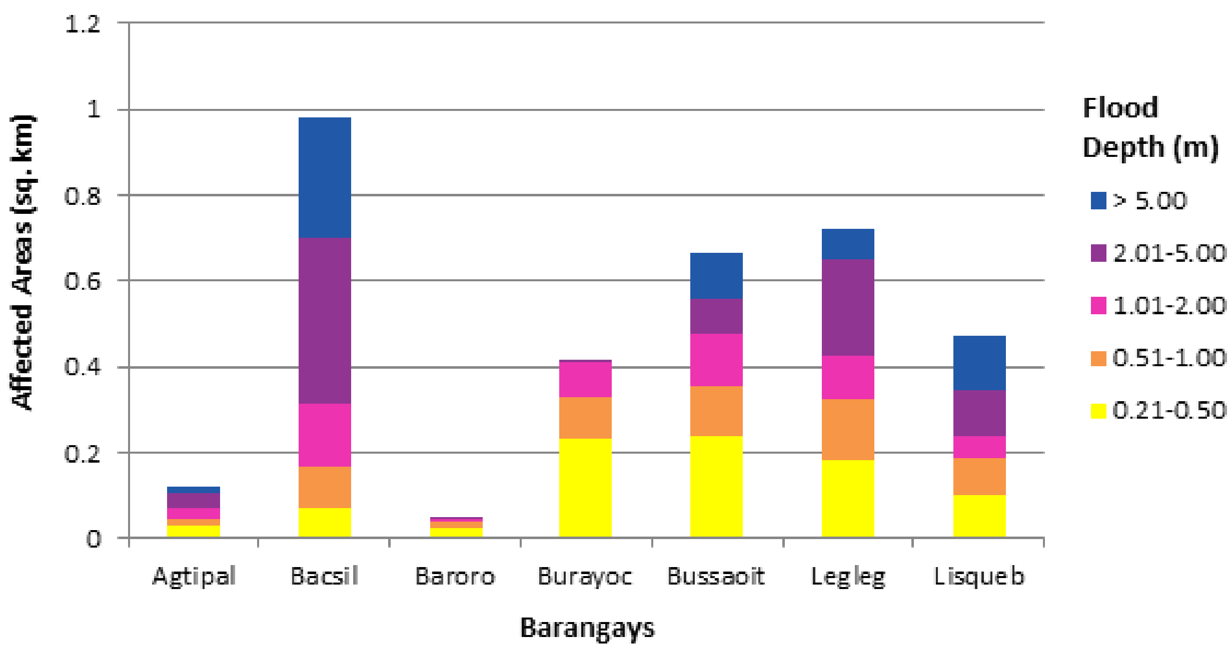


Figure 88. Affected areas in Bacnotan, La Union during a 100-year rainfall return period

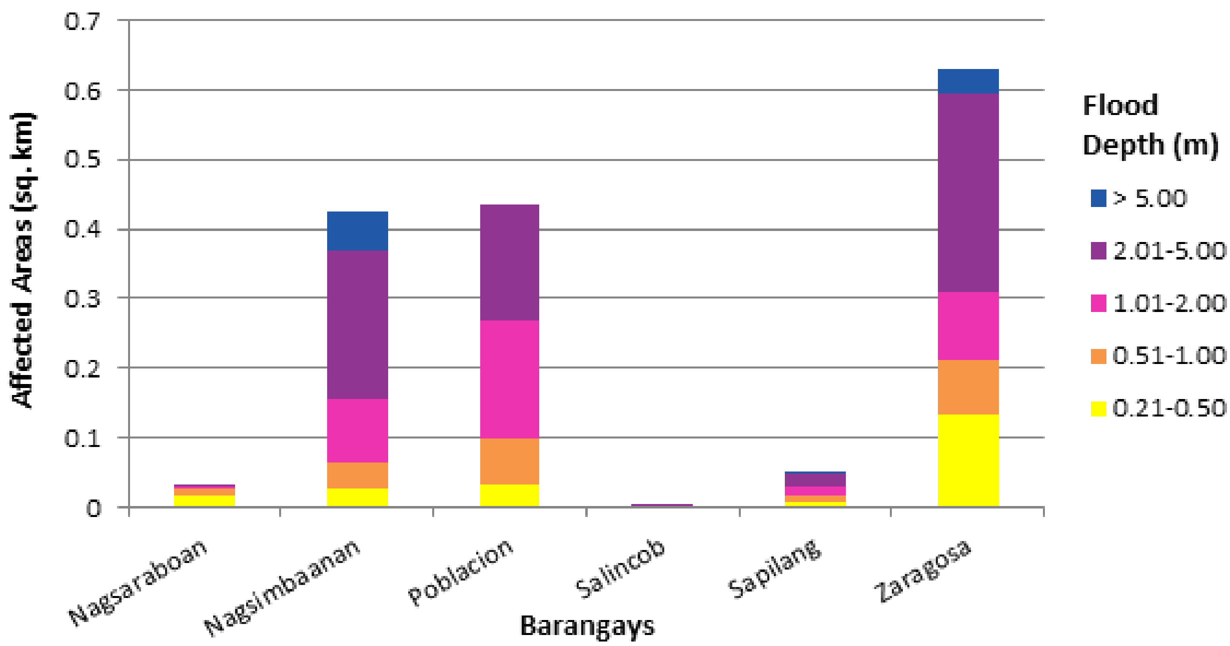


Figure 89. Affected areas in Bacnotan, La Union during a 100-year rainfall return period

For the 100-year return period, 0.09% of the municipality of Bagulin with an area of 77.97 sq km. willkm will experience flood levels of less than 0.20 meters. ; 0.00% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the Table 51 are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected areas in Bagulin, La Union during a 100-year rainfall return period

BARORO BASIN		Area of affected barangay in Bagulin (in sq. km)
		Dagup
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.069
	0.21-0.50	0.0022
	0.51-1.00	0.00079
	1.01-2.00	0.0012
	2.01-5.00	0.0013
	> 5.00	0.0082

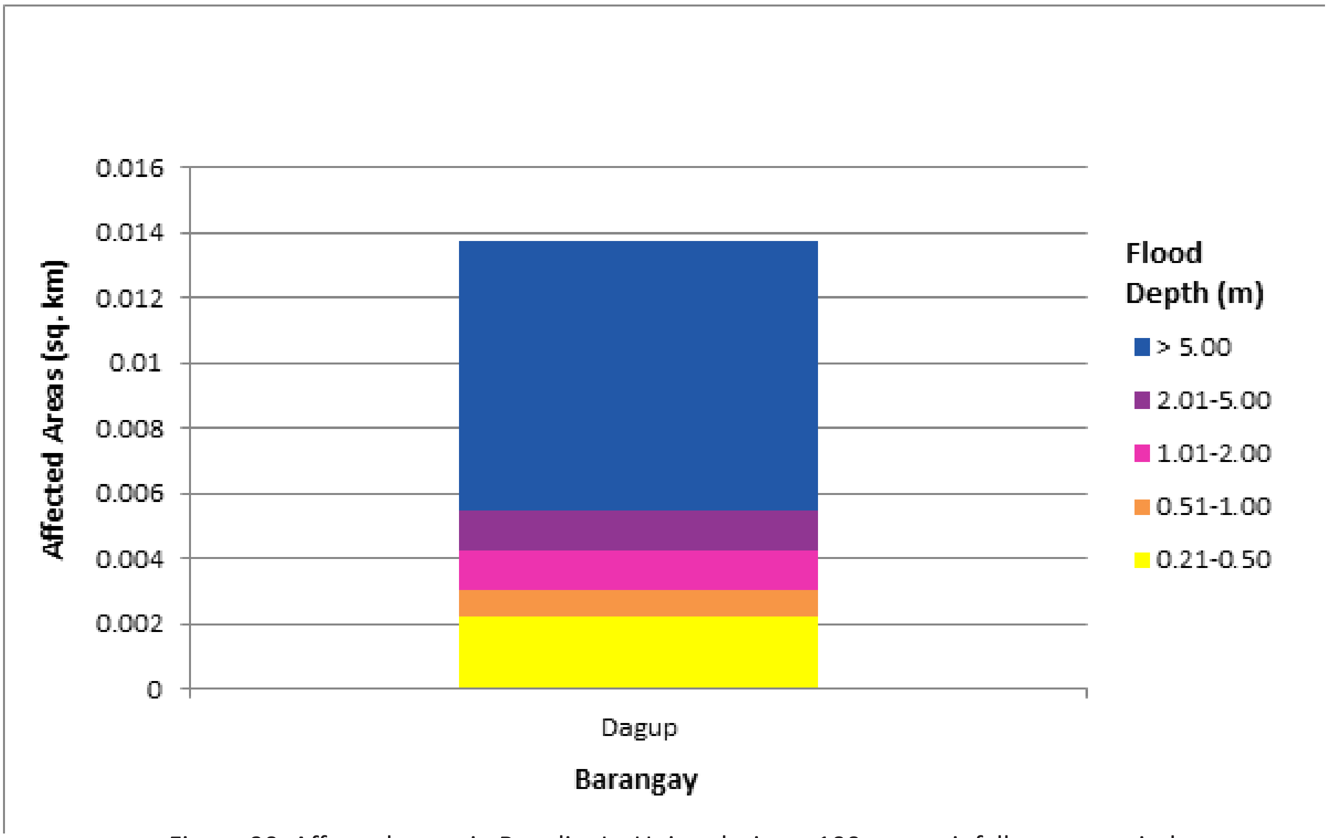


Figure 90. Affected areas in Bagulin, La Union during a 100-year rainfall return period

For the 100-year return period, 2.72% of the municipality of San Fernando City with an area of 121.05 sq km. willkm will experience flood levels of less than 0.20 meters. ; 0.23% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.20%, 0.21%, 0.25%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the Table 52 are the affected areas in square kilometers by flood depth per barangay.

Table 52. Affected areas in San Fernando City, La Union during a 100-year rainfall return period

BARORO BASIN		**Area of affected barangays in San Fernando City (in sq. km)**							
		Abut	Bangban-golan	Baraoas	Cala-bugao	Nagyu buyuban	Namtut-an	Puspus	Saoay
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	1.25	0.12	0.7	0.049	0.22	0.5	0.41	0.035
	0.21-0.50	0.12	0.0051	0.07	0.0025	0.018	0.03	0.031	0.0032
	0.51-1.00	0.12	0.0035	0.048	0.0025	0.012	0.03	0.02	0.0018
	1.01-2.00	0.12	0.0056	0.046	0.0025	0.016	0.045	0.016	0.0012
	2.01-5.00	0.16	0.016	0.034	0.00089	0.04	0.03	0.015	0.0016
	> 5.00	0.041	0.0066	0.018	0	0.011	0.0008	0.0042	0

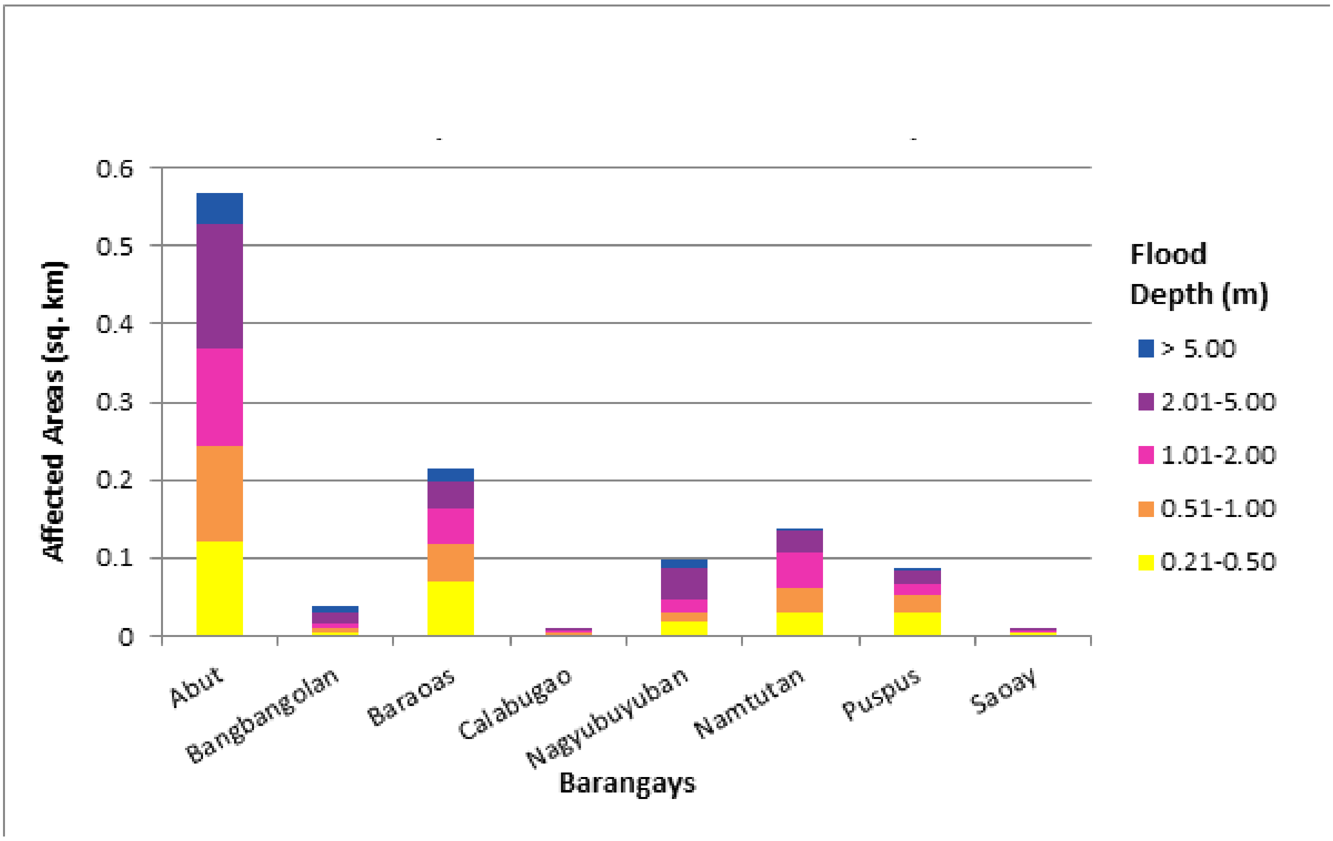


Figure 91. Affected areas in San Fernando City, La Union during a 100-year rainfall return period

For the 100-year return period, 2.65% of the municipality of San Gabriel with an area of 154.19 sq km. willkm will experience flood levels of less than 0.20 meters. ; 0.44% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.26%, 0.18%, 0.62%, and 0.62% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the Table 53 are the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected areas in San Gabriel, La Union during a 100-year rainfall return period

BARORO BASIN		Area of affected barangays in San Gabriel (in sq. km)		
		Bucao	Bumbuneg	Poblacion
Affected Area (sq. km.) by flood depth (in m.)	0.03-0.20	0.77	1.44	1.87
	0.21-0.50	0.028	0.088	0.56
	0.51-1.00	0.021	0.035	0.34
	1.01-2.00	0.02	0.024	0.24
	2.01-5.00	0.022	0.056	0.88
	> 5.00	0.025	0.14	0.8

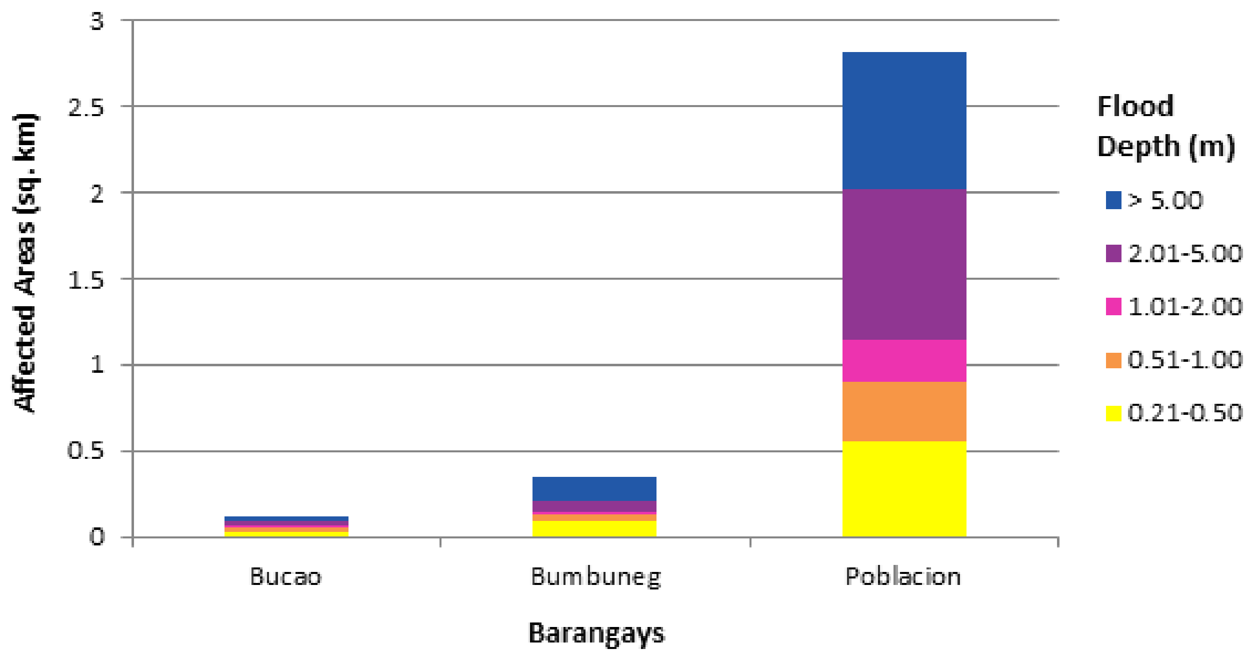


Figure 92. Affected areas in San Gabriel, La Union during a 100-year rainfall return period

For the 100-year return period, 22.07% of the municipality of San Juan with an area of 53.44 sq km. willkm will experience flood levels of less than 0.20 meters. ; 2.65% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.39%, 3.80%, 9.36%, and 17.89% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the Table 54 to Table 56 are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected areas in San Juan, La Union during 100a 100-year rainfall return period

BARORO BASIN		Area of affected barangays in San Juan (in sq. km)										
		Allangigan	Aludaid	Bacsayan	Balballosa	Bambanay	Bugbugcao	Caarusipan	Cabaroan	Cabugnayan	Cacapian	Caculangan
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.46	0.73	0.51	0.58	0	1.04	0.0038	0.0023	0.099	0.011	0.048
	0.21-0.50	0.038	0.11	0.061	0.086	0	0.17	0.0044	0.011	0.017	0.000003	0.0007
	0.51-1.00	0.03	0.083	0.029	0.053	0	0.2	0.0071	0.038	0.024	0	0.00078
	1.01-2.00	0.029	0.04	0.048	0.089	0	0.2	0.037	0.17	0.041	0	0.0015
	2.01-5.00	0.13	0.077	0.14	0.35	0	0.33	0.34	0.22	0.15	0	0.034
	> 5.00	0.21	0.0032	0.14	0.079	0.91	0.017	0.76	1.27	0.29	0	0.074

Table 55. Affected areas in San Juan, La Union during a 100-year rainfall return period

BARORO BASIN		Area of affected barangays in San Juan (in sq. km)									
		Calincamasan	Catdongan	Dangdangla	Dasay	Dinanum	Duplas	Guinguinabang	Legleg	Nadsaag	Nagsabaran
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0.29	0.23	0.026	0.52	0.3	0.88	0.45	0.15	0	0.91
	0.21-0.50	0.013	0.03	0.004	0.037	0.016	0.1	0.18	0.019	0	0.063
	0.51-1.00	0.01	0.025	0.0067	0.029	0.011	0.079	0.18	0.021	0	0.041
	1.01-2.00	0.023	0.035	0.019	0.028	0.0052	0.3	0.15	0.036	0	0.063
	2.01-5.00	0.23	0.062	0.33	0.042	0.0004	0.3	0.093	0.2	0.042	0.19
	> 5.00	0.99	0.29	0.34	0.12	0.0001	0.32	0.0033	0.033	1.17	0.33

Table 56. Affected areas in San Juan, La Union during a 100-year rainfall return period

BARORO BASIN		Area of affected barangays in San Juan (in sq. km)									
		Naguirangan	Nagyubuyuban	Oaquing	Pacpacac	Pagdildilan	Quidem	San Felipe	Santa Rosa	Santo Rosario	Saracat
Affected Area (sq. km.) by flood depth (in m.)	**0.03-0.20**	0	0.841298	0.350527	0.650427	0.774013	0.026473	1.2299	0.004412	0.031556	0.63041
	0.21-0.50	0.0005	0.055414	0.00964	0.057774	0.085117	0.000885	0.190238	0.0001	0.0001	0.059206
	0.51-1.00	0.017597	0.05933	0.005226	0.048856	0.100326	0.001241	0.133887	0.0002	0	0.041431
	1.01-2.00	0.145556	0.079958	0.006117	0.097466	0.178888	0.002833	0.179921	0.000767	0.000216	0.028164
	2.01-5.00	0.574466	0.126506	0.027357	0.388909	0.261486	0.0296	0.224142	0.077797	0.00771	0.016924
	> 5.00	0.20248	0.028913	0.737245	0.421591	0.048375	0.25182	0.056509	0.48411	0.000171	0.00082

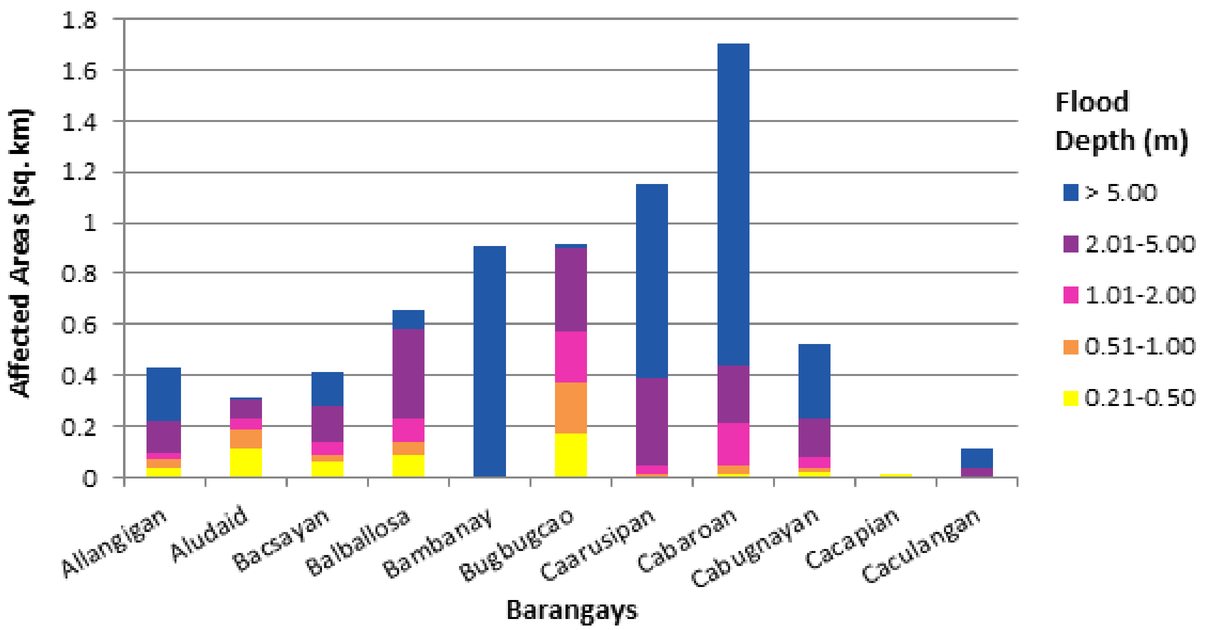


Figure 93. Affected areas in San Juan, La Union during a 100-year rainfall return period

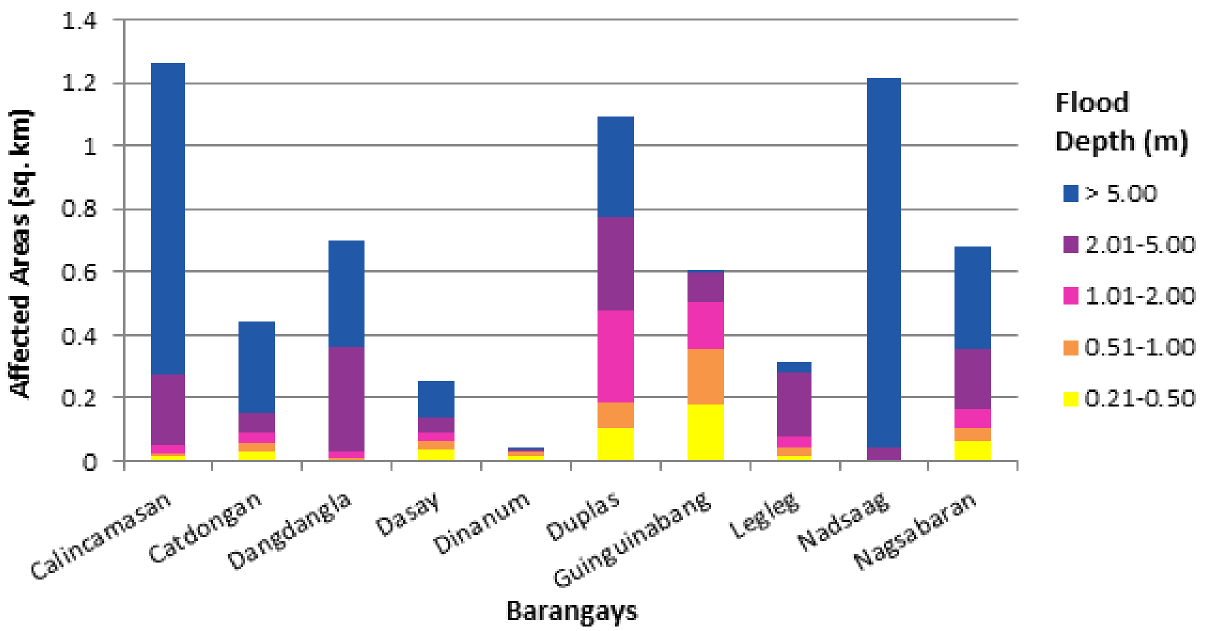


Figure 94. Affected areas in San Juan, La Union during a 100-year rainfall return period

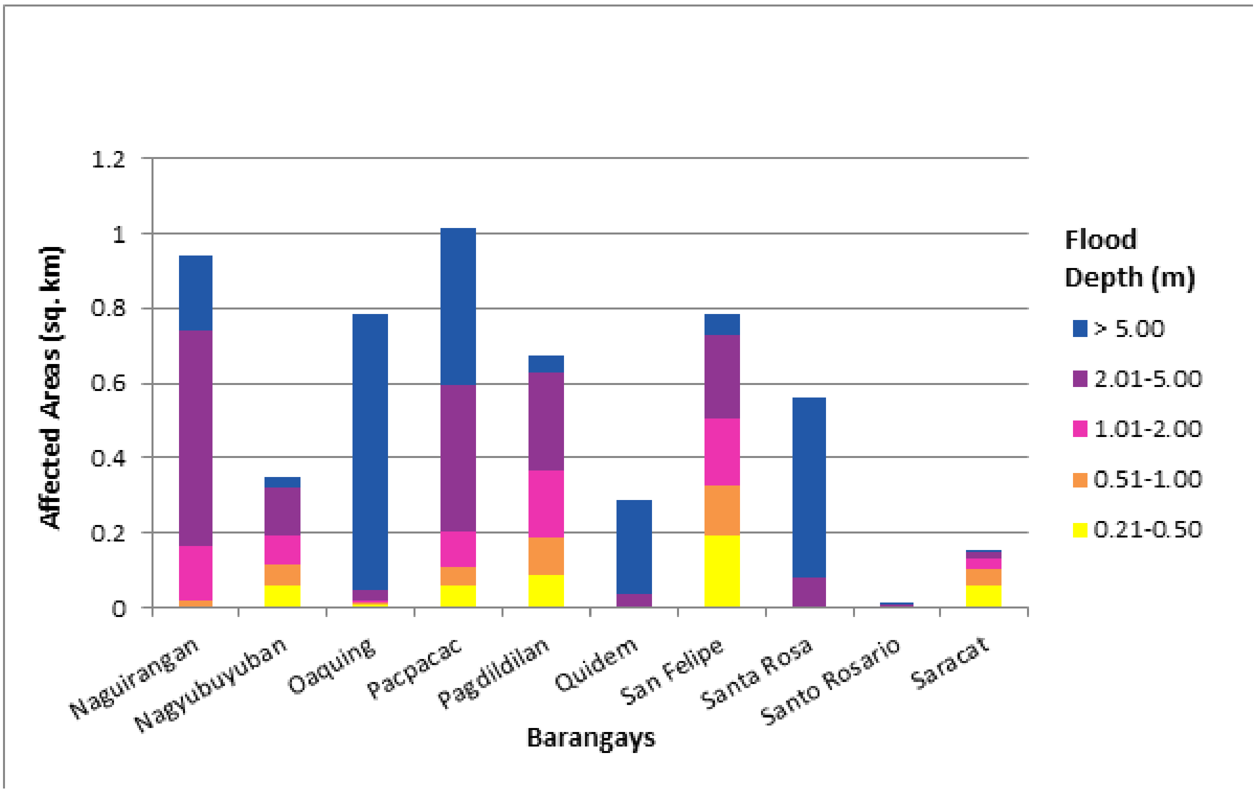


Figure 95. Affected areas in San Juan, La Union during a 100-year rainfall return period

Among the barangays in the municipality of Bacnotan in La Union, Legleg is projected to have the highest percentage of area that will experience flood levels at 2.74%. Meanwhile, Bussaoit posted the second highest percentage of area that may be affected by flood depths at 2.47%.

Brgy. Dagup is the only barangay affected in the municipality of Bagulin in La Union. The barangay is projected to experience flood in 0.11% of the municipality.

Among the barangays in the municipality of San Fernando City in La Union, Abut is projected to have the highest percentage of area that will experience flood levels at 1.51%. Meanwhile, Baraoas posted the second highest percentage of area that may be affected by flood depths at 0.76%.

Among the barangays in the municipality of San Gabriel in La Union, Poblacion is projected to have the highest percentage of area that will experience flood levels at 3.04%. Meanwhile, Bumbuneg posted the second highest percentage of area that may be affected by flood depths at 1.16%.

Among the barangays in the municipality of San Juan in La Union, San Felipe is projected to have the highest percentage of area that will experience flood levels at 3.77%. Meanwhile, Duplas posted the second highest percentage of area that may be affected by flood depths at 3.69%.

The flood validation data were obtained on January 2017

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

Table 57. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq km.		
	5 year	25 year	100 year
Low	3.56	3.59	3.50
Medium	4.59	4.70	4.47
High	15.01	18.51	20.91
TOTAL	**23.16**	**26.8**	**28.88**

Of the 29 identified educational institutions in the Baroro Floodplain, three (3) schools were assessed to be exposed to the High high-level flooding for all three rainfall scenarios. These are the Cabaroan Elementary School in Brgy. Cabaroan, Don Eusebio Lim Multi-Purpose Hall (Oaquing Day Care Center) in Brgy. Oaquing, and Sta. Rosa Elementary School in Brgy. Santa Rosa. Five (5) other institutions were found to be susceptible to flooding, experiencing Medium medium-level flooding in the 5-year return period, and Hhigh -level flooding in the 25- and 100-year rainfall scenarios. See Appendix DANNEX 12 for a detailed enumeration of schools in the Baroro Floodplain.

Three (3) medical health institutions were identified in the Baroro Floodplain. Rural Health Unit in Brgy. Cabaroan was found to be relatively prone to flooding, having Low low-level flooding in the 5-year return period, and Medium medium-level flooding in the other two rainfall scenarios. See Appendix EANNEX 13 for a detailed enumeration of hospitals and clinics in the Baroro Floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is was 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 are were identified for validation.

The validation personnel will then gowent to the specified points identified in a river basin and will gathered data regarding the actual flood level in each location. Data gathering can was be done through by contacting 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 will bewere compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation survey was conducted in January 2017. The flood validation consists of 254 points randomly selected all over the Baroro Floodplain. It has an RMSE value of 1.18.

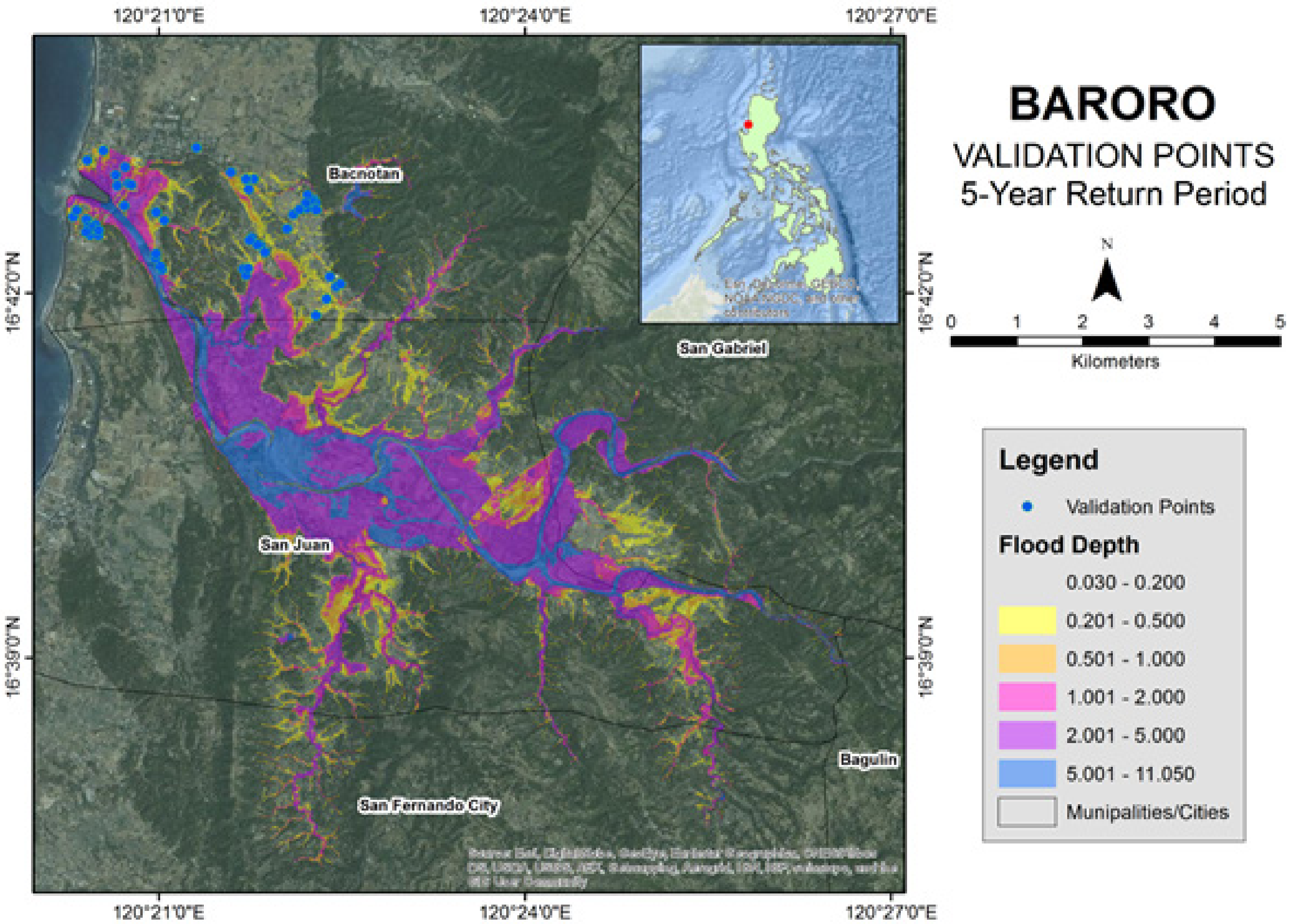


Figure 96. Flood validation points for Baroro River Basin

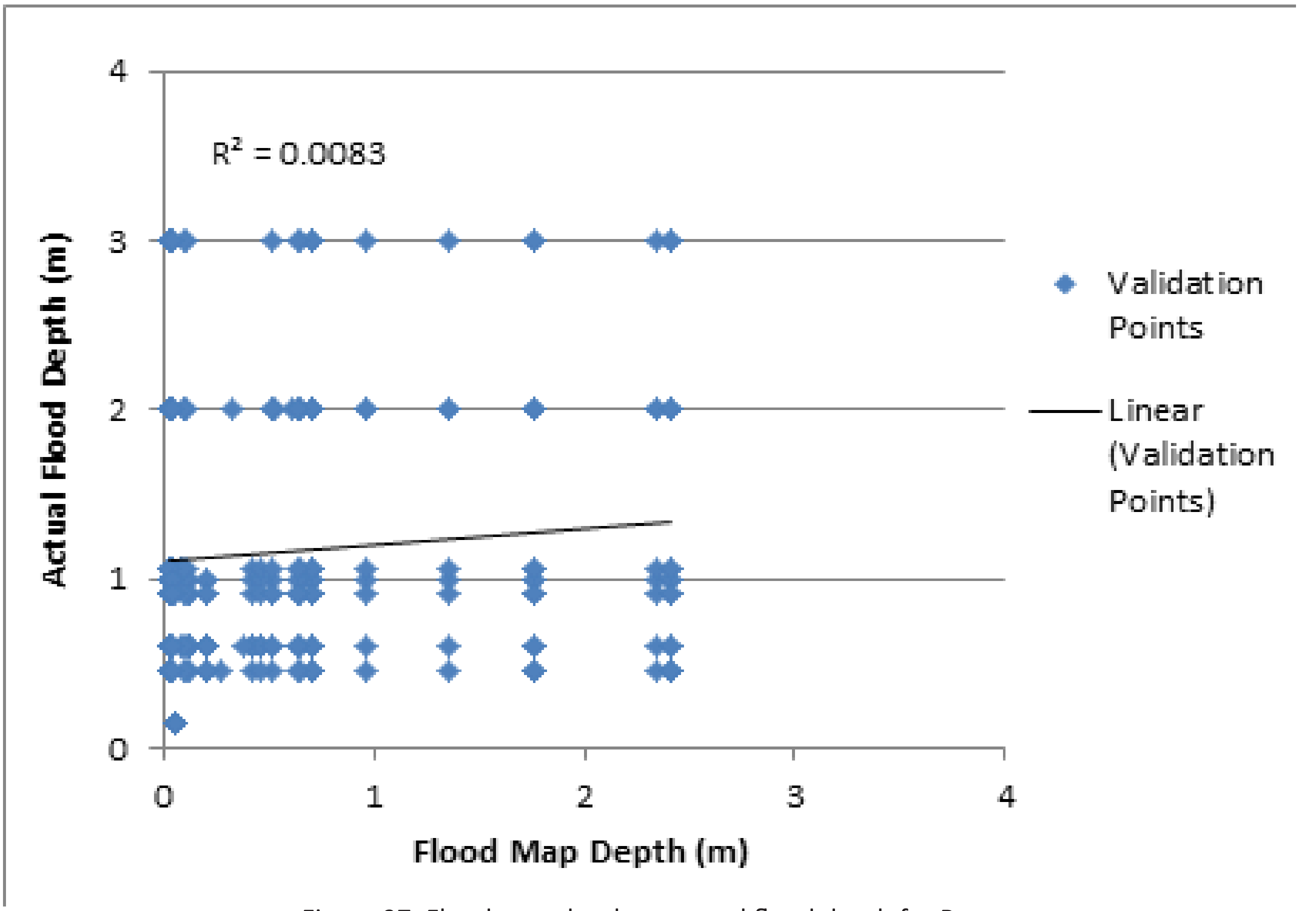


Figure 97. Flood map depth vs. actual flood depth for Baroro

Table 58. Actual flood depth vs. simulated flood depth in Baroro

BARORO BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	13	0	0	0	0	0	13
	0.21-0.50	11	6	8	4	5	0	34
	0.51-1.00	44	25	25	9	9	0	112
	1.01-2.00	30	3	22	8	8	0	71
	2.01-5.00	11	0	7	3	3	0	24
	> 5.00	0	0	0	0	0	0	0
	Total	109	34	62	24	25	0	254

The overall accuracy generated by the flood model is estimated at 21.65%, with 55 points correctly matching the actual flood depths. In addition, there were 86 points estimated one level above and below the correct flood depths while there were 67 points and 46 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 43 points were overestimated while a total of 156 points were underestimated in the modelled flood depths of Baroro.

Table 59. Summary of Accuracy Assessment in Baroro

	No. of Points	%
Correct	55	21.65
Overestimated	43	16.93
Underestimated	156	61.42
Total	254	100

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. OPTECH Technical Specification of the Pegasus Sensor

Table A-1.1. Technical specifications of the 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

LUN-62

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

March 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: **LA UNION**
Station Name: **LUN-62**
Order: **2nd**

Island: **LUZON**
Municipality: **NAGUILIAN**
Barangay: **BARAOAS NORTE**

PRS92 Coordinates

Latitude:	**16º 33' 19.98115"**	Longitude:	**120º 23' 28.76004"**	Ellipsoidal Hgt:	**33.18400 m.**

WGS84 Coordinates

Latitude:	**16º 33' 14.07106"**	Longitude:	**120º 23' 33.49149"**	Ellipsoidal Hgt:	**69.44500 m.**

PTM Coordinates

Northing:	**1831016.667 m.**	Easting:	**435034.926 m.**	Zone:	**3**

UTM Coordinates

Northing:	**1,832,084.35**	Easting:	**221,592.72**	Zone:	**51**

Location Description

LUN-62
From Naguilian Town Hall, travel N to Brgy. Baraoas Norte until reaching the rough road and the river control. Station is located 15 m. S from the first access ladder of the river control and about 100 m. N from the end. It is also situated 300 m. S of a hanging bridge. Mark is the head of a 4 in. copper nail centered and embedded in a 0.3 m. x 0.3 m. cement putty, with inscriptions "LUN-62 2007 NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-451**

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

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

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

Figure A-2.1. LUN-62

LUN-176

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

March 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: **LA UNION**
Station Name: **LUN-176**
Order: **2nd**

Island: **LUZON**
Municipality: **BALAOAN**
Barangay: **BUNGOL**

PRS92 Coordinates

Latitude: **16° 46' 14.35394"**	Longitude: **120° 24' 5.41918"**	Ellipsoidal Hgt: **35.63300 m.**

WGS84 Coordinates

Latitude: **16° 46' 8.39718"**	Longitude: **120° 24' 10.13252"**	Ellipsoidal Hgt: **71.25300 m.**

PTM Coordinates

Northing: **1854816.574 m.**	Easting: **436193.115 m.**	Zone: **3**

UTM Coordinates

Northing: **1,855,884.60**	Easting: **222,990.04**	Zone: **51**

Location Description

LUN-176 (FNSP-DENR)

From Candon City, Ilocos Sur, travel S to the province of La Union passing through Balaoan town proper until reaching Km. Post No. 292 on the left side of the highway. Travel more for about 300 m. until reaching a concrete waiting shed on the right side of the highway, before reaching a highway curve and the road leading to Magic Star Fireworks Factory. Beside the concrete shed is a trail, follow this trail until reaching a house with an artesian well beside a series of Coconut trees. It is located on a corner of a farm dike, about 15 m. SE of the well and about 20 m. SW of the nearest house.

Mark is the head of a 3 in. concrete nail embedded and centered on a 30 cm. x 30 cm. concrete monument protruding by about 5 cm., with inscriptions "LUN-176, 2004, PRS-92, FNSP-DENR-I".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-453**

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

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

Figure A-2.2. LUN-176

LUN-3062

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

March 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: **LA UNION**
Station Name: **LUN-3062**
Order: **4th**

Island:	**LUZON**			Barangay:	**NATIVIDAD (POB.)**
Municipality:	**NAGUILIAN**				
		PRS92 Coordinates			
Latitude:	**16° 31' 55.00993"**	Longitude:	**120° 23' 12.50504"**	Ellipsoidal Hgt:	**25.32100 m.**
		WGS84 Coordinates			
Latitude:	**16° 31' 49.10470"**	Longitude:	**120° 23' 17.23850"**	Ellipsoidal Hgt:	**61.64400 m.**
		PTM Coordinates			
Northing:	**1828406.255 m.**	Easting:	**434545.028 m.**	Zone:	**3**
		UTM Coordinates			
Northing:	**1,829,477.48**	Easting:	**221,076.59**	Zone:	**51**

Location Description

LUN-3062

Is located at barangay Natividad, Naguilian, La Union. The station is erected at the top of a dike. It is approximately 100 m north of Philippine Central College of Arts Science & Technology and 80 m north of Naguilian emission testing center.
Mark in the head of a 3 inches concrete nail embedded and centered on a 30 cm x 30 cm x 100 cm standard concrete monument protruding by about 20 cm, with the inscription LUN-3062 PRS-92 DENR-FNSP R-1.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-455**

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

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

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

Figure A-2.3. LUN-3062

LUN-3129

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

March 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: **LA UNION**
Station Name: **LUN-3129 (BLLM-9)**
Order: **4th**

Island: **LUZON**		Barangay: **BUNGOL**
Municipality: **BALAOAN**		
	PRS92 Coordinates	
Latitude: **16° 46' 13.75662"**	Longitude: **120° 24' 16.12821"**	Ellipsoidal Hgt: **37.03000 m.**
	WGS84 Coordinates	
Latitude: **16° 46' 7.80013"**	Longitude: **120° 24' 20.84154"**	Ellipsoidal Hgt: **72.65800 m.**
	PTM Coordinates	
Northing: **1854797.26 m.**	Easting: **436510.212 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,855,862.08**	Easting: **223,307.10**	Zone: **51**

Location Description

LUN-3129 (BLLM-9)

The station is located of National road about 50 meters northeast of the house of Engr. Whitney Valdez.

Station mark is the head of a 3" concrete nail embedded and centered on a 30cm. x 30cm. x 100 cm. standard concrete monument protruding about 20cm. with inscription "LUN-3129 (BLLM-9); 2008; DENR/LMS I."

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-456**

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

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

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

Figure A-2.3. LUN-3129

LU-94

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

March 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: **LA UNION**
Station Name: **LU-94**

Island: **LUZON**	Municipality: **BACNOTAN**	Barangay: **BARORO**
Elevation: **7.3488 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LU-94
Station is located in Brgy. Baroro, Bacnotan, La Union along the national highway set on the S edge of Baroro bridge, 4 m SE of the centerline of the national highway, 30 m SE of Baroro national memorial monument.

Mark is the head of a 4" copper nail set on a drilled hole and cemented flushed on top of a 10 cm x 10 cm cement putty with inscription LU-94 2007 NAMRIA.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-449**

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

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

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

Figure A-2.4. LU-94

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

Table A-3.1. LUN-176

Vector Components (Mark to Mark)

From:	LUN-176				
Grid		Local		Global	
Easting	223129.137 m	Latitude	N16°46'08.61931"	Latitude	N16°46'08.61931"
Northing	1855819.084 m	Longitude	E120°24'10.06092"	Longitude	E120°24'10.06092"
Elevation	31.168 m	Height	70.997 m	Height	70.997 m

To:	LU-94				
Grid		Local		Global	
Easting	216672.143 m	Latitude	N16°42'38.64674"	Latitude	N16°42'38.64674"
Northing	1849445.472 m	Longitude	E120°20'35.05091"	Longitude	E120°20'35.05091"
Elevation	9.967 m	Height	49.582 m	Height	49.582 m

Vector					
ΔEasting	-6456.994 m	NS Fwd Azimuth	224°37'26"	ΔX	4564.890 m
ΔNorthing	-6373.612 m	Ellipsoid Dist.	9067.628 m	ΔY	4806.440 m
ΔElevation	-21.201 m	ΔHeight	-21.415 m	ΔZ	-6187.390 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000159225		
Y	-0.0000194629	0.0000365086	
Z	-0.0000081542	0.0000147591	0.0000075754

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	LOVELY GRACIA ACUNA	UP-TCAGP
	Research Associate (RA)	RENAN PUNTO	UP-TCAGP
	RA	FAITH JOY SABLE	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. OLIVER SACLOT	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK LAWRENCE TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC

Annex 5. Data Transfer Sheet for Baroro Floodplain

(CLA 4H(ON))

DATA TRANSFER SHEET
Mar 17, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2/25/2014	1151P	1BLK10A056A	PEGASUS	3.03GB	NA	12.3MB	229MB	N/A	N/A	19.8	N/A	6.5	1KB	459B	35	NA	X:\Airborne_Raw\1151P
2/25/2014	1153P	1BLK10AS056B	PEGASUS	836MB	NA	3.57MB	84.5MB	N/A	N/A	8.02	N/A	6.51	1KB	244B	38	N/A	X:\Airborne_Raw\1153P
2/26/2014	1155P	1BLK10C057A	PEGASUS	2.64GB	NA	11MB	220MB	33.1GB	289KB	26.4	N/A	6.95	1KB	610B	44	N/A	X:\Airborne_Raw\1155P
2/26/2014	1157P	1BLK10B057B	PEGASUS	1.85GB	NA	6.62MB	129MB	25.6GB	229KB	17.4	N/A	6.95	1KB	485B	45	N/A	X:\Airborne_Raw\1157P
2/27/2014	1159P	1BLK10GD058A	PEGASUS	2.76GB	NA	11.4MB	221MB	4.7GB	148KB	27.9	N/A	6.55	1KB	669B	29	N/A	X:\Airborne_Raw\1159P
2/27/2014	1161P	1BLK10DS058B	PEGASUS	1.28GB	NA	7.08MB	152MB	22.3GB	186KB	15.6	N/A	6.55	1KB	474B	50	N/A	X:\Airborne_Raw\1161P
2/28/2014	1163P	1BLK10F059A	PEGASUS	3.42GB	NA	12MB	216MB	53.2GB	416KB	31.7	N/A	6.05	1KB	328B	31	N/A	X:\Airborne_Raw\1163P
2/28/2014	1165P	1BLK10E059B	PEGASUS	1.41GB	NA	7.12MB	143MB	25.6GB	208KB	16.7	N/A	6.05	1KB	502B	n/a	N/A	X:\Airborne_Raw\1165P
3/1/2014	1167P	1BLK10H060A	PEGASUS	831MB	NA	7.42MB	170MB	17.5GB	145KB	8.66	N/A	6.64	1KB	318B	20	N/A	X:\Airborne_Raw\1167P
3/1/2014	1169P	1BLK10ES060B	PEGASUS	2.05GB	NA	7.17MB	133MB	28.6GB	224KB	19.1	N/A	6.64	1KB	304B	45	N/A	X:\Airborne_Raw\1169P
3/2/2014	1171P	1BLK10CDS061A	PEGASUS	1.72GB	NA	9.73MB	206MB	21GB	170KB	17	N/A	7.08	1KB	310B	32	N/A	X:\Airborne_Raw\1171P
3/2/2014	1173P	1BLK10DS061B	PEGASUS	1.52GB	NA	5.95MB	116MB	20.3GB	169KB	14.5	N/A	7.08	1KB	481B	50	N/A	X:\Airborne_Raw\1173P
3/3/2014	1175P	1BLK10BS062A	PEGASUS	3.14GB	NA	11.8MB	214MB	43.1GB	341KB	29.5	N/A	6.74	1KB	305B	38	N/A	X:\Airborne_Raw\1175P
3/3/2014	1177P	1BLK10CS062B	PEGASUS	1.18GB	NA	8.31MB	157MB	30GB	254KB	11.3	N/A	6.74	1KB	741B	42	N/A	X:\Airborne_Raw\1177P
Mar 4, 2014	1179P	1BLK27B063A	PEGASUS	3.54GB	NA	14MB	260MB	39.3GB	361KB	34.5	N/A	5.86	1KB	1KB	38	N/A	X:\Airborne_Raw\1179P
Mar 5, 2014	1183P	1BLK12AC064A	PEGASUS	1.5GB	NA	10.3MB	206MB	35.6GB	304KB	22.5GB	N/A	5.94	1KB	1KB	42/38/33/4234	N/A	X:\Airborne_Raw\1183P
Mar 5, 2014	1185P	1BLK10D064B	PEGASUS	1.18GB	NA	5.86MB	151MB	16.4GB	142KB	11.7GB	N/A	5.94	1KB	1KB	n/a	N/A	X:\Airborne_Raw\1185P
Mar 6, 2014	1187P	1BLK12DS065A	PEGASUS	2.34GB	NA	11MB	212MB	35.3GB	302KB	24.4GB	N/A	6.62	1KB	1KB	36	N/A	X:\Airborne_Raw\1187P
Mar 6, 2014	1189P	1BLK12CS065B	PEGASUS	2.06GB	NA	8.08MB	151MB	37.7GB	332KB	19.7GB	N/A	6.62	1KB	1KB	42	N/A	X:\Airborne_Raw\1189P
Mar 8, 2014	1195P	1BLK27ABS067A	PEGASUS	915MB	NA	4.91MB	110MB	16.1GB	130KB	10.2GB	N/A	From Ilocos	1KB	1KB	36	N/A	X:\Airborne_Raw\1195P
Mar 8, 2014	1197P	1BLK10CGS067B	PEGASUS	714MB	NA	4.95MB	112MB	14.5GB	131KB	8.16GB	N/A	1.44MB	1KB	1KB	27	N/A	X:\Airborne_Raw\1197P

Received from

Name CHRIS JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

ANNEX 6. Flight Logs for the Flight Missions

Flight Log for 1151P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1151P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK10A056A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION AREA			
10 Date: FEB. 25, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0912	14 Engine Off: 1305	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time: 3+43
19 Weather: cloudy					

20 Remarks: SUCCESSFUL FLIGHT

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	OLIVER SAELOT	M.C. TANGONAN	REGINO PUNTO
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-6.1. Flight Log for 1151P Mission

Flight Log for 1153P Mission

DREAM Data Acquisition Flight Log Flight Log No.: 1153P

1 LiDAR Operator: F. SAGLE	2 ALTM Model: PEG	3 Mission Name: 1BLK10ASD56B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION			
10 Date: FEB. 25, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0912	14 Engine Off: 1805	15 Total Engine Time: 1+53	16 Take off:	17 Landing:	18 Total Flight Time: 1+45
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

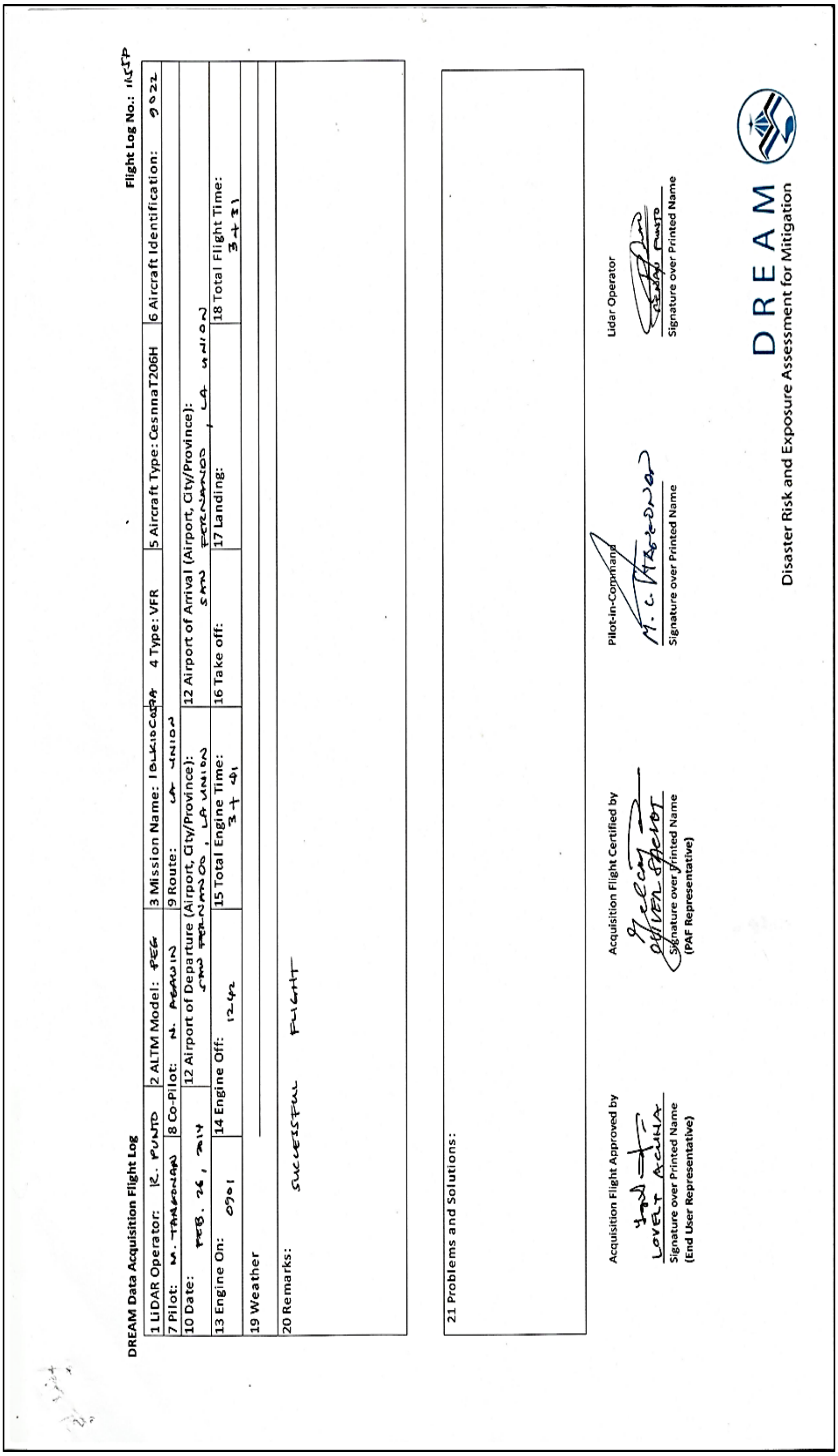
21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	OLIVER SACLOT	M.C TANGONAN	
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-6.2. Flight Log for 1153P Mission

Flight Log for 1155P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1155P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK1DC057A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION			
10 Date: FEB. 26, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0901	14 Engine Off: 1242	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time: 3+31
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

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

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

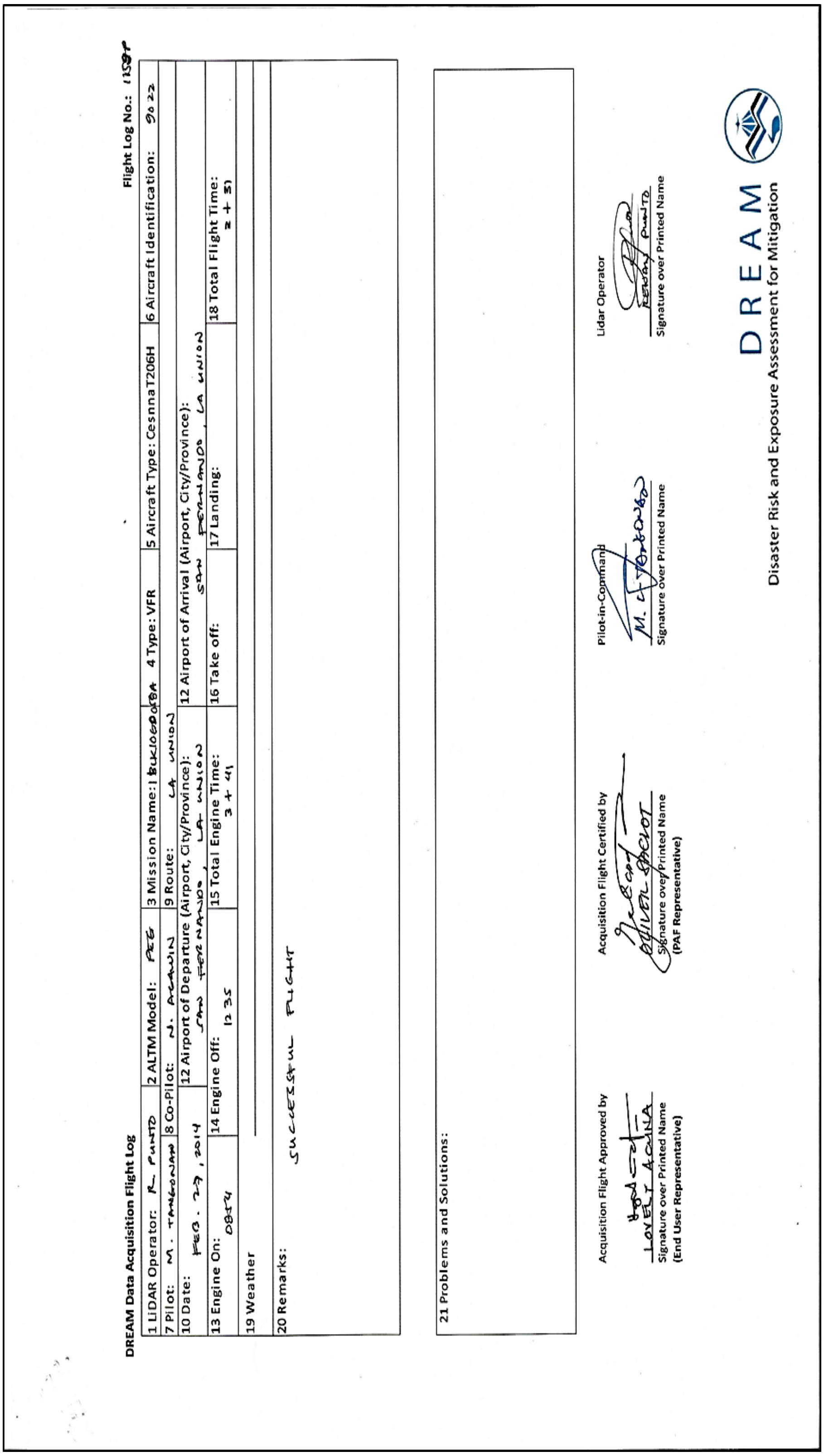
Pilot-in-Command
M. C. TANGONAN
Signature over Printed Name

Lidar Operator
RENATO PUNTO
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for 1155P Mission

Flight Log for 1159P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1159P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK10BDOG	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. ACAWIN	9 Route: LA UNION			
10 Date: FEB. 27, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0854	14 Engine Off: 1235	15 Total Engine Time: 3 + 41	16 Take off:	17 Landing:	18 Total Flight Time: 2 + 31
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

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

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

Pilot-in-Command
M. C. TANGONAN
Signature over Printed Name

Lidar Operator
RENAN PUNTO
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4. Flight Log for 1159P Mission

Flight Log for 1171P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1171P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK10CDS061A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION			
10 Date: MAR. 2, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0912	14 Engine Off: 1241	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time: 3+29
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	OLIVER BACLOT	M. I. TANGONAN	R. PUNTO
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-6.5. Flight Log for 1171P Mission

Flight Log for 1173P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1173P

1 LiDAR Operator: F. SABLE	2 ALTM Model: PEG	3 Mission Name: 1BLK1D50G18	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. AGAWIN	9 Route: LA UNION			
10 Date: MAR. 2, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 1324	14 Engine Off: 1542	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time: 2+13
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

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

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

Pilot-in-Command
M.C. TANGONAN
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.6. Flight Log for 1173P Mission

Flight Log for 1175P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1175P

1 LiDAR Operator: K. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK10BS062A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route: LA UNION			
10 Date: MAR. 3, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0903	14 Engine Off: 1238	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time: 3+25
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

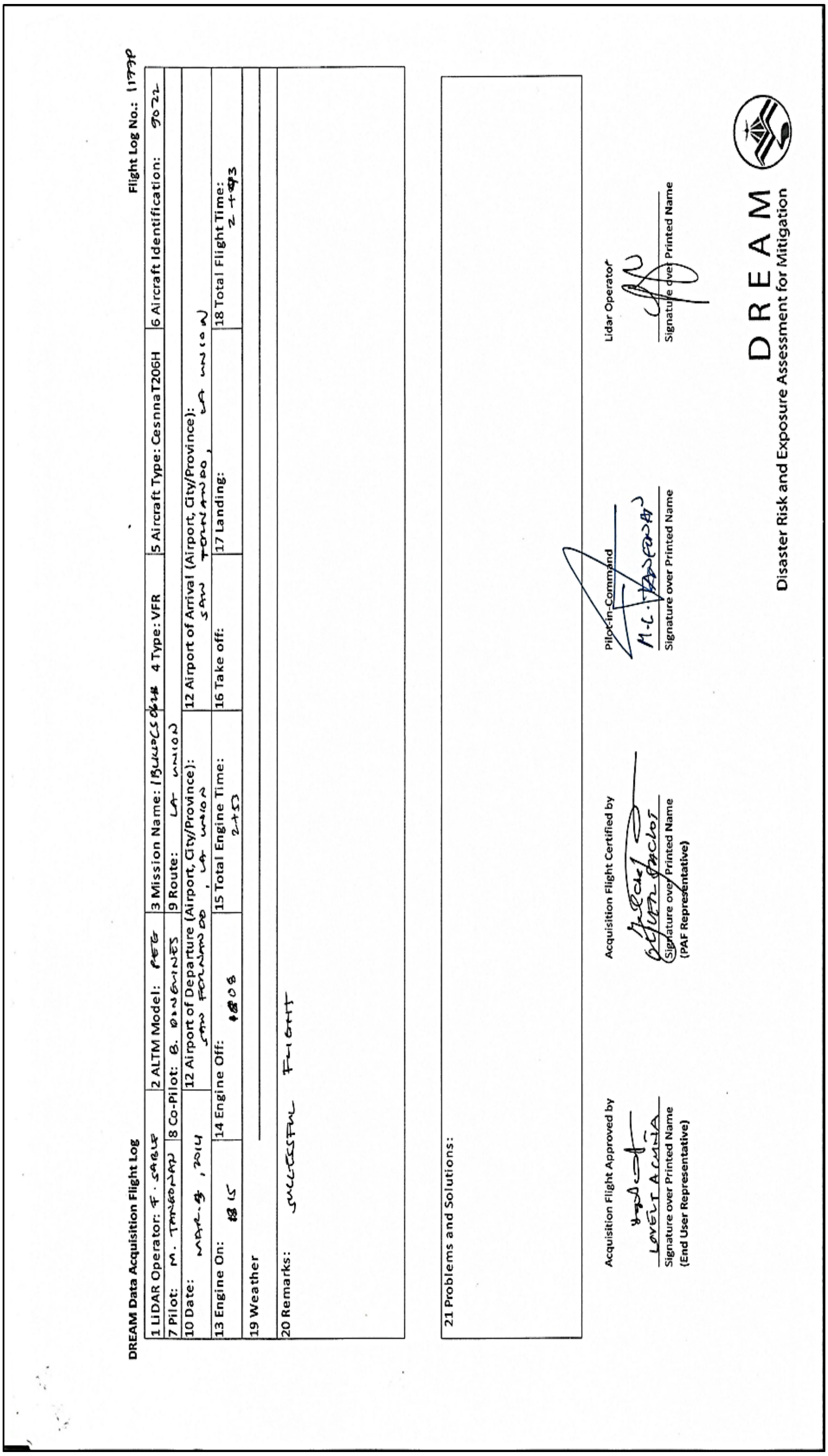
21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA			
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-6.7. Flight Log for 1175P Mission

Flight Log for 1177P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1177P

1 LiDAR Operator: F. SABLE	2 ALTM Model: PEG	3 Mission Name: 1BLK1CS062B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route: LA UNION			
10 Date: MAR. 3, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 815	14 Engine Off: 1808	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time: 2+53
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

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

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

Pilot-in-Command
M.C. TANGONAN
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.8. Flight Log for 1177P Mission

Flight Log for 1179P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1179P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK27B063A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route: LA UNION			
10 Date: MAR. 4, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0851	14 Engine Off: 1306	15 Total Engine Time: 4+15	16 Take off:	17 Landing:	18 Total Flight Time: 4+05
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	OLIVER PACLOT	M. J. TANGONAN	R. PUNTO
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-6.9. Flight Log for 1179P Mission

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

LA UNION

(February 25 to March 8, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1151P	BLOCK 10A	1BLK10A056A	R. PUNTO	February 25, 2014	Finish the survey with voids due to eye safety, laser sets off; renamed from 1149P
1153P	BLOCK 10A	1BLK10AS056B	F. SABLE	February 25, 2014	Survey voids of Block10A and 1 line Blk10B; renamed from 1151P
1155P	BLOCK 10C	1BLK10C057A	R. PUNTO	February 26, 2014	Survey Block 10C with data voids due to eye safety, laser sets off; renamed from 1153P
1159P	BLOCK 10GD	1BLK10GD058A	R. PUNTO	February 27, 2014	Survey Block 10G and 10D with data voids due to eye safety, laser sets off; renamed from 1157P
1171P	BLOCK 10D & BLOCK 10C	1BLK10CDS061A	R. PUNTO	March 2, 2014	Supplementary flight to cover voids for Block10D & Block10C; renamed from 1169P
1173P	BLOCK 10D	1BLK10DGS061B	F. SABLE	March 2, 2014	Supplementary flight to complete Block 10D; renamed from 1171P
1175P	BLOCK 10B	1BLK10BS062A	R. PUNTO	March 3, 2014	Supplementary flight to complete Block 10B; renamed from 1173P
1177P	BLOCK 10C	1BLK10CS062B	F. SABLE	March 3, 2014	Supplementary flight to cover voids in Block 10C; renamed from 1175P
1197P	BLOCK 10G,10C	1BLK10GCS067B	R.PUNTO	March 8, 2014	Mission Complete

LAS BOUNDARIES PER FLIGHT

Flight No. : 1151P

Area: BLK 10A

Mission Name: 1BLK10A056A

Parameters: Altitude: 1200m; Scan Frequency: 30Hz;

Scan Angle: 25deg; Overlap: 30%

LAS

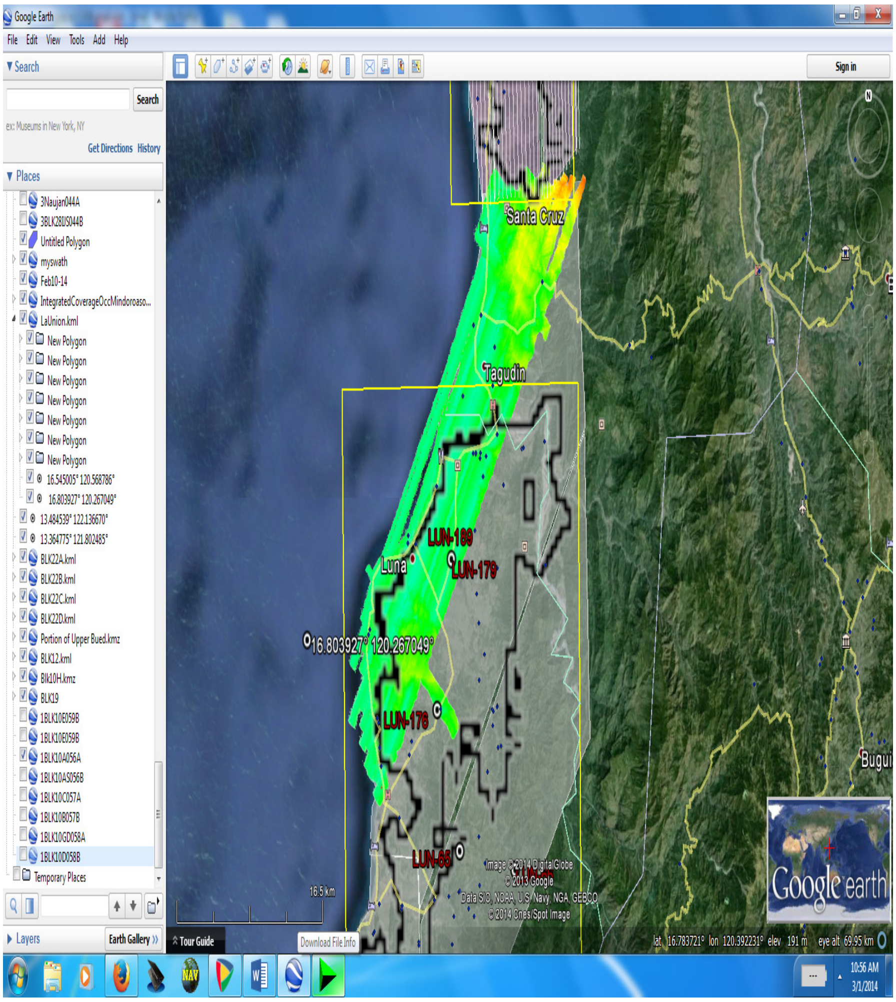


Figure A-7.1. Swath for Flight No. 1151P

Flight No. : 1153P

Area: BLK 10A

Mission Name: 1BLK10BAS056B

Parameters: Altitude: 1200m; Scan Frequency: 30Hz;

Scan Angle: 25deg; Overlap: 30%

LAS

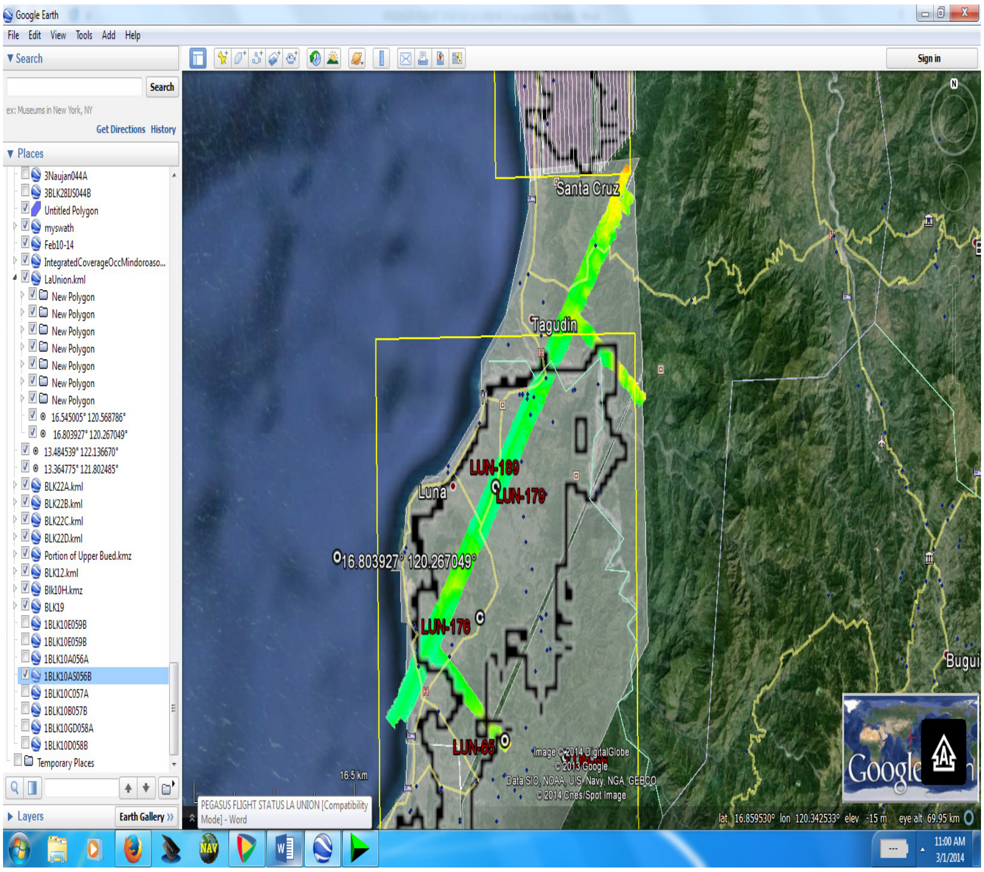


Figure A-7.2. Swath for Flight No. 1153P

Flight No. : 1155P

Area: BLK 10C

Mission Name: 1BLK10C057A

Parameters: Altitude: 1200 m; Scan Frequency: 30Hz;

Scan Angle: 25deg; Overlap: 30%

LAS

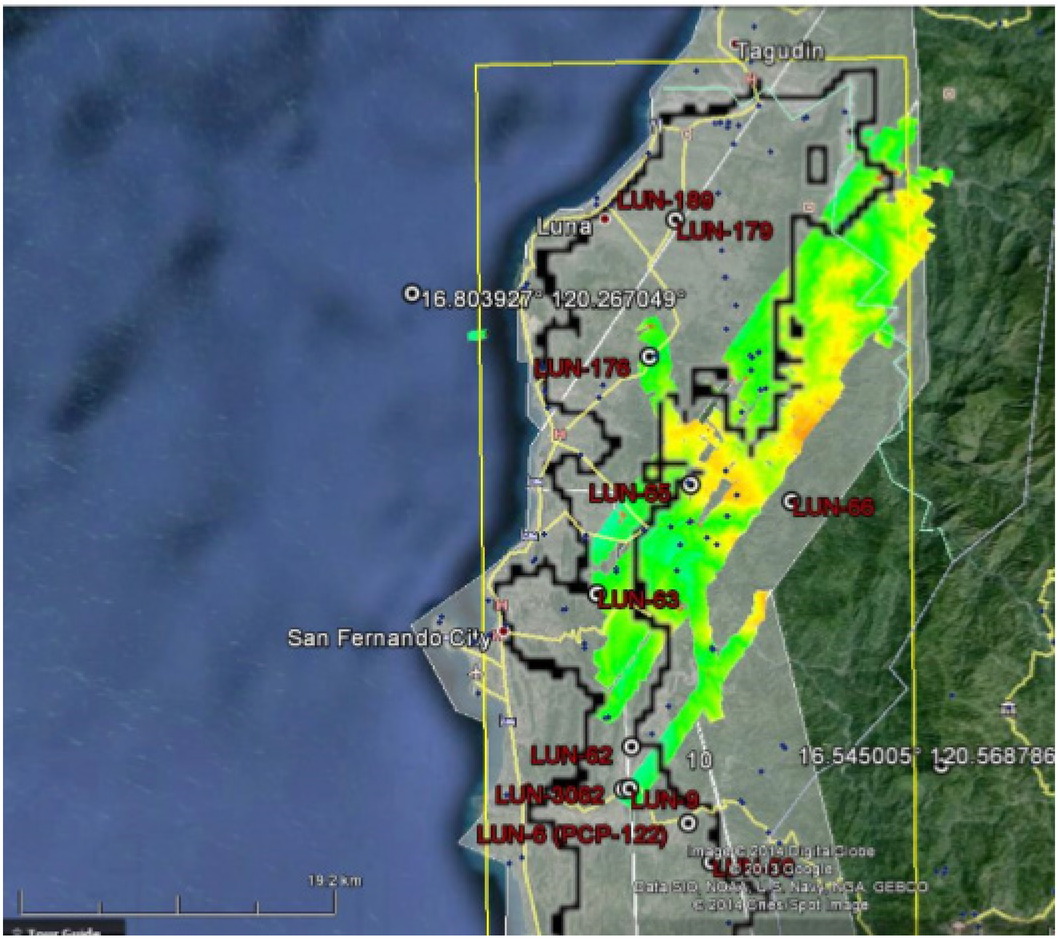


Figure A-7.3. Swath for Flight No. 1155P

Flight No. : 1159P

Area: BLK 10G

Mission Name: 1BLK10GD058A

Parameters: Altitude: 1200m; Scan Frequency: 30Hz;

Scan Angle: 25 deg; Overlap: 30%

LAS

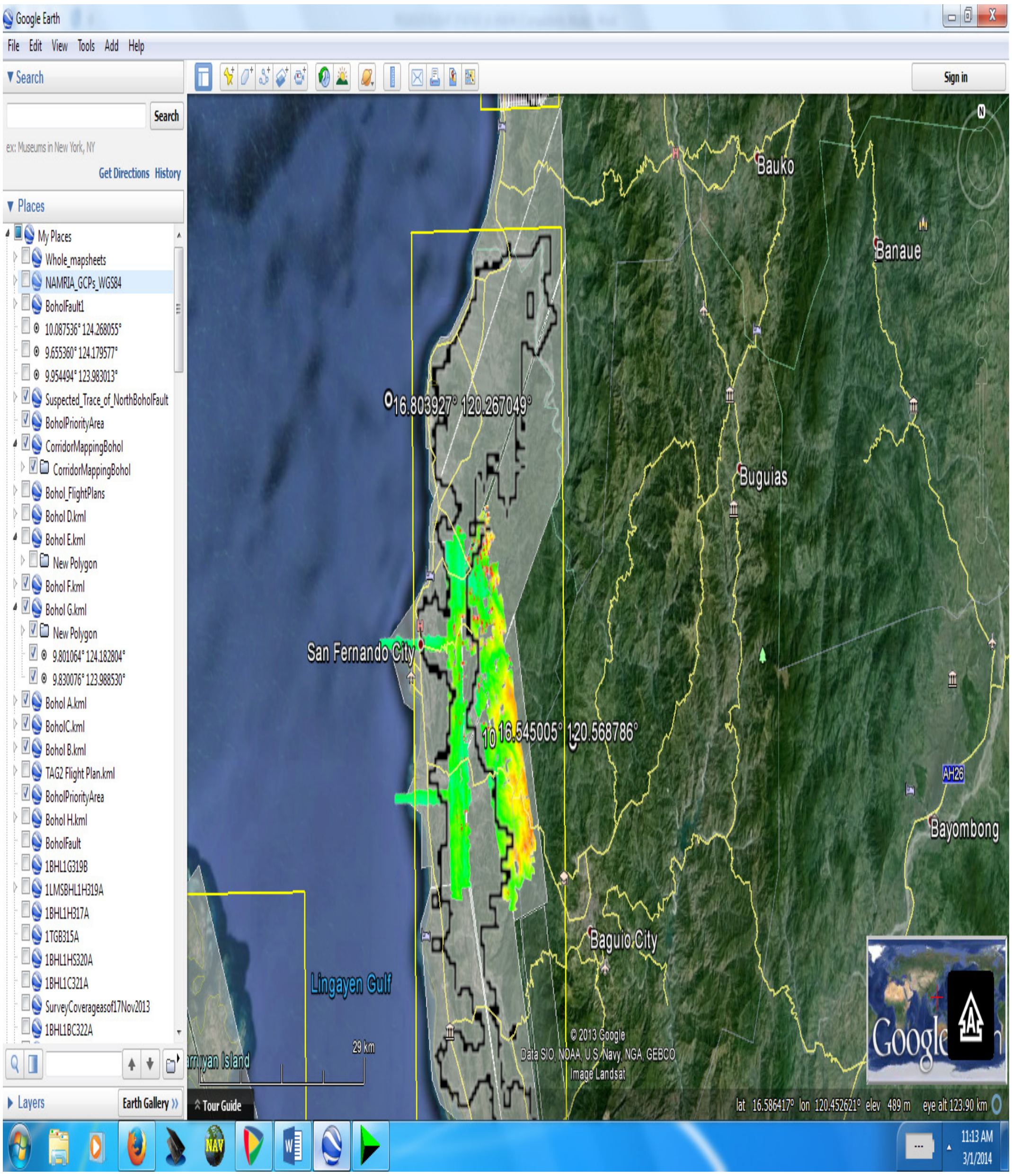


Figure A-7.4. Swath for Flight No. 1159P

Flight No. : 1171P

Area: BLK 10C

Mission Name: 1BLK10CDS061A

Parameters: Altitude: 1500m; Scan Frequency: 30Hz;

Scan Angle: 25 deg; Overlap: 30%

LAS

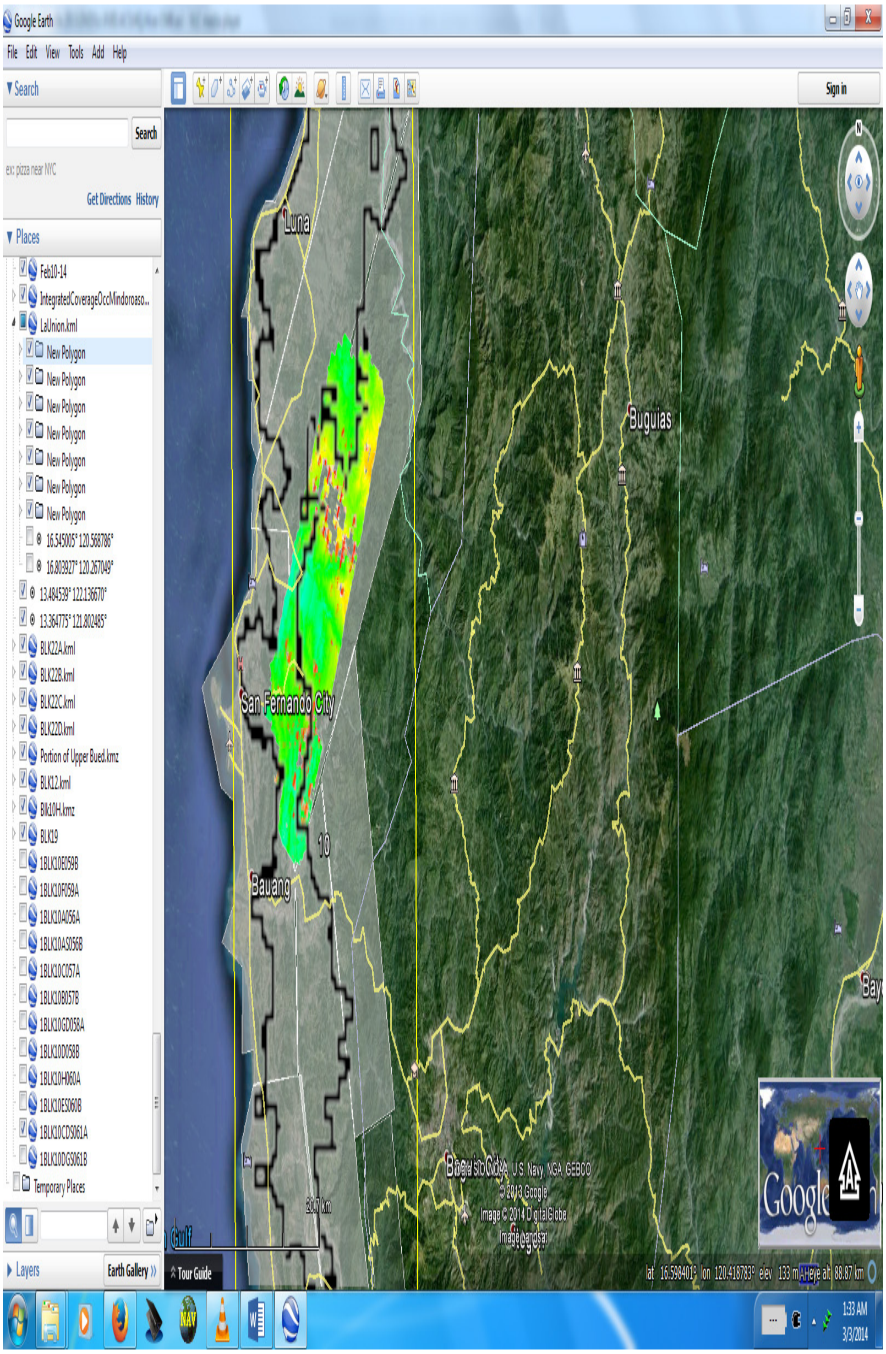


Figure A-7.5. Swath for Flight No. 1171P

Flight No. : 1173P

Area: BLK 10D

Mission Name: 1BLK10DS061B

Parameters: Altitude: 1200m; Scan Frequency: 30Hz;

Scan Angle: 25 deg; Overlap: 30%

LAS

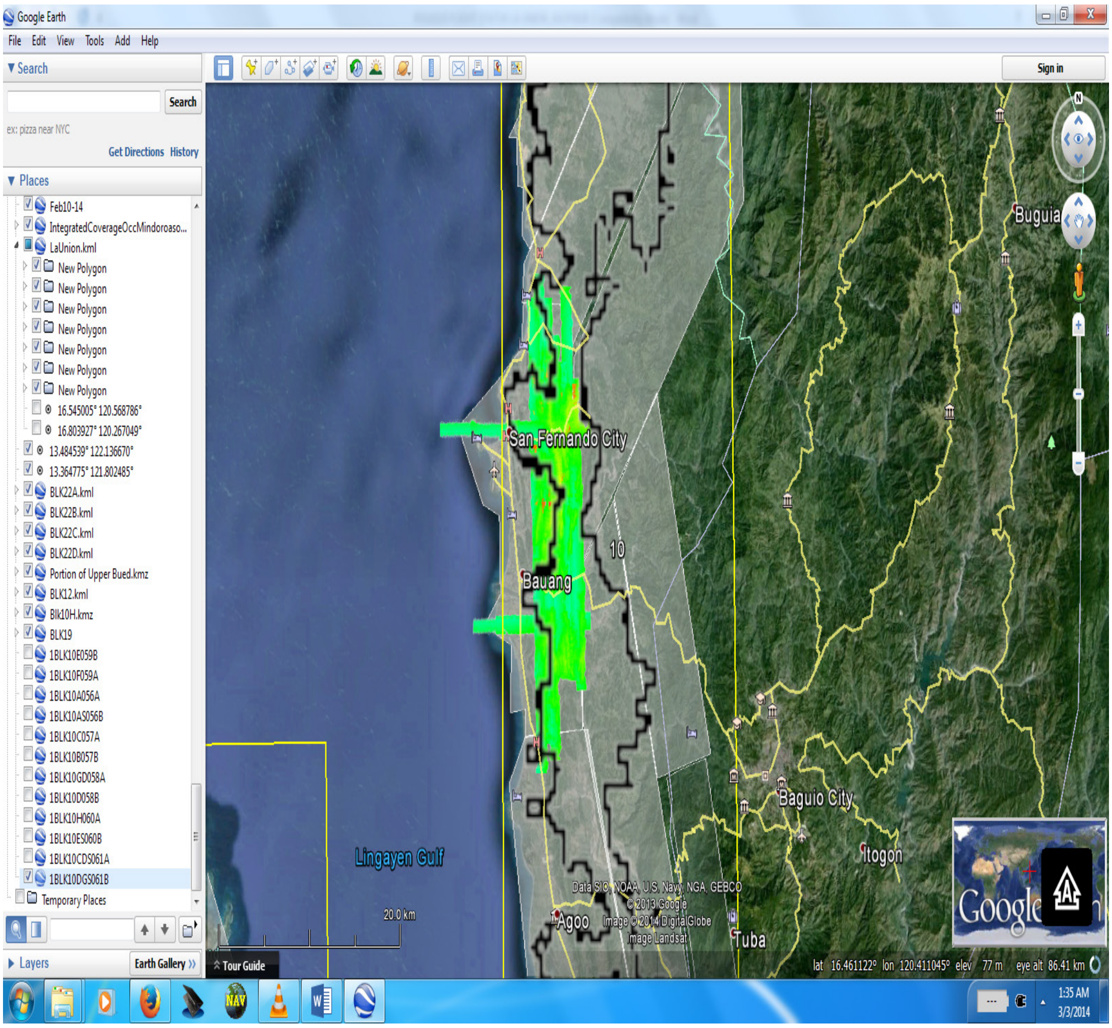


Figure A-7.7. Swath for Flight No. 1173P

Flight No. : 1175P

Area: BLK 10B

Mission Name: 1BLK10BS062A

Parameters: Altitude: 1200m; Scan Frequency: 30Hz;

Scan Angle: 25 deg; Overlap: 30%

LAS

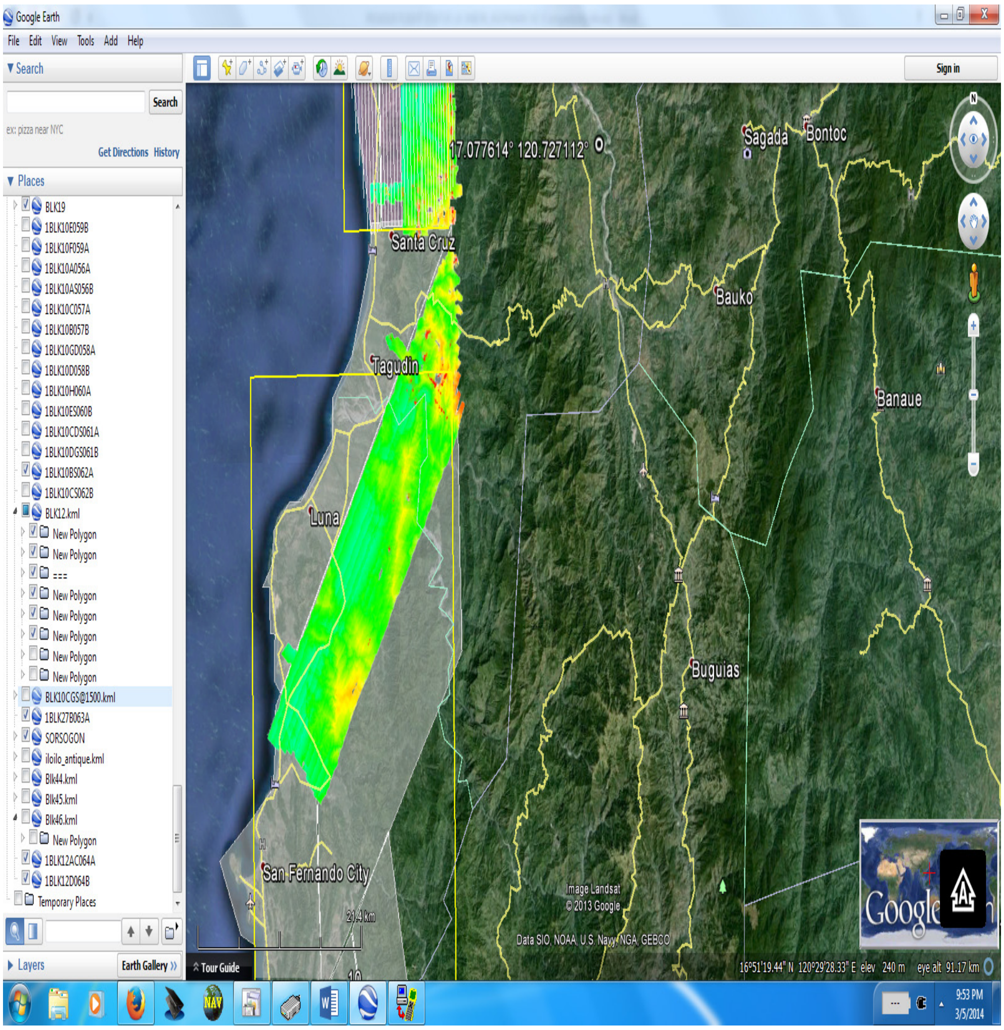


Figure A-7.8. Swath for Flight No. 1175P

Flight No. : 1177P

Area: BLK 10C

Mission Name: 1BLK10CS062B

Parameters: Altitude: 1800m; Scan Frequency: 30Hz;

Scan Angle: 25 deg; Overlap: 30%

LAS

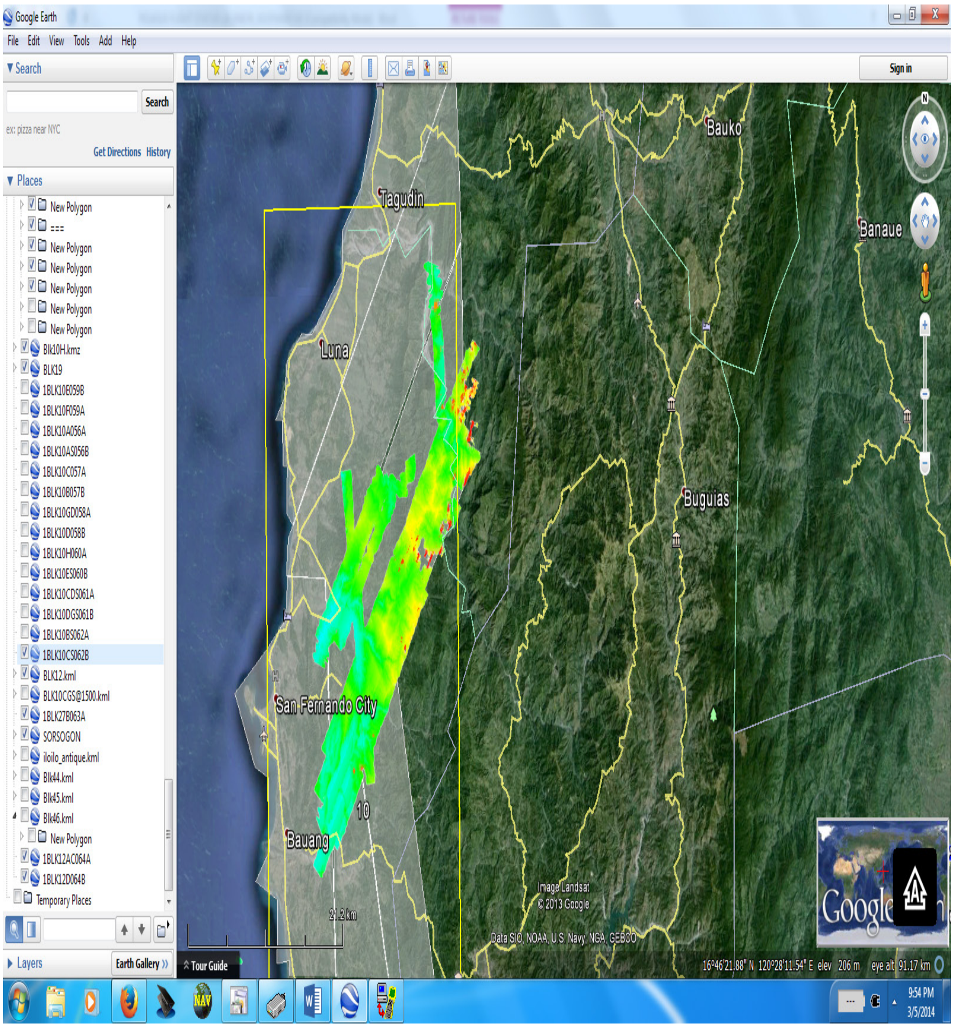


Figure A-7.9. Swath for Flight No. 1177P

Flight No. : 1177P

Area: BLK 10G and 10C

Mission Name: 1BLK10GCS067B

Parameters: Altitude: 1500m; Scan Frequency: 30Hz;

Scan Angle: 25 deg; Overlap: 30%

LAS

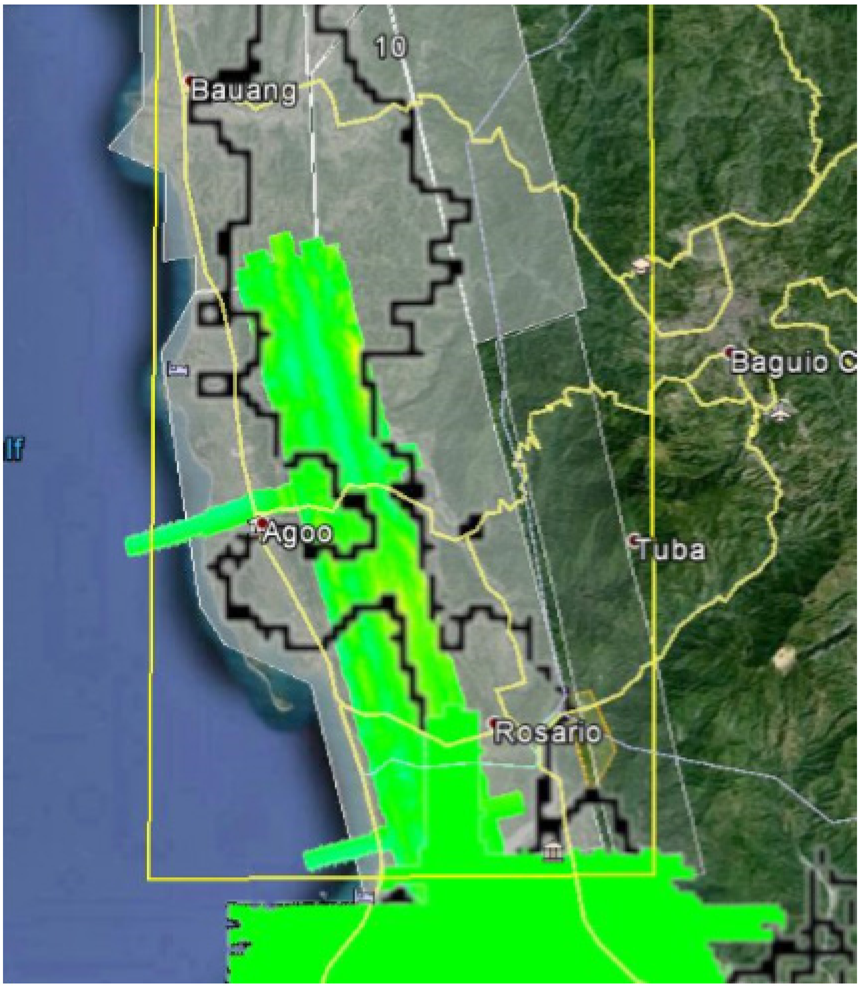


Figure A-7.10. Swath for Flight No. 1177P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk10A

Flight Area	La Union
Mission Name	Blk10A
Inclusive Flights	1151P
Range data size	19.8 GB
POS	229 MB
Base data size	6.5 MB
Image	n/a
Transfer date	February 25, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.6
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	8.3
Boresight correction stdev (<0.001deg)	0.000566
IMU attitude correction stdev (<0.001deg)	0.004107
GPS position stdev (<0.01m)	0.0104
Minimum % overlap (>25)	64.34%
Ave point cloud density per sq.m. (>2.0)	2.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	363
Maximum Height	872.34 m
Minimum Height	40.04 m
Classification (# of points)	
Ground	251,566,818
Low vegetation	258,692,292
Medium vegetation	271,117,698
High vegetation	270,170,604
Building	19,016,823
Orthophoto	No
Processed by	Engr. Carlyn Ibañez, Engr. Merven Natino Engr. Roa Redo

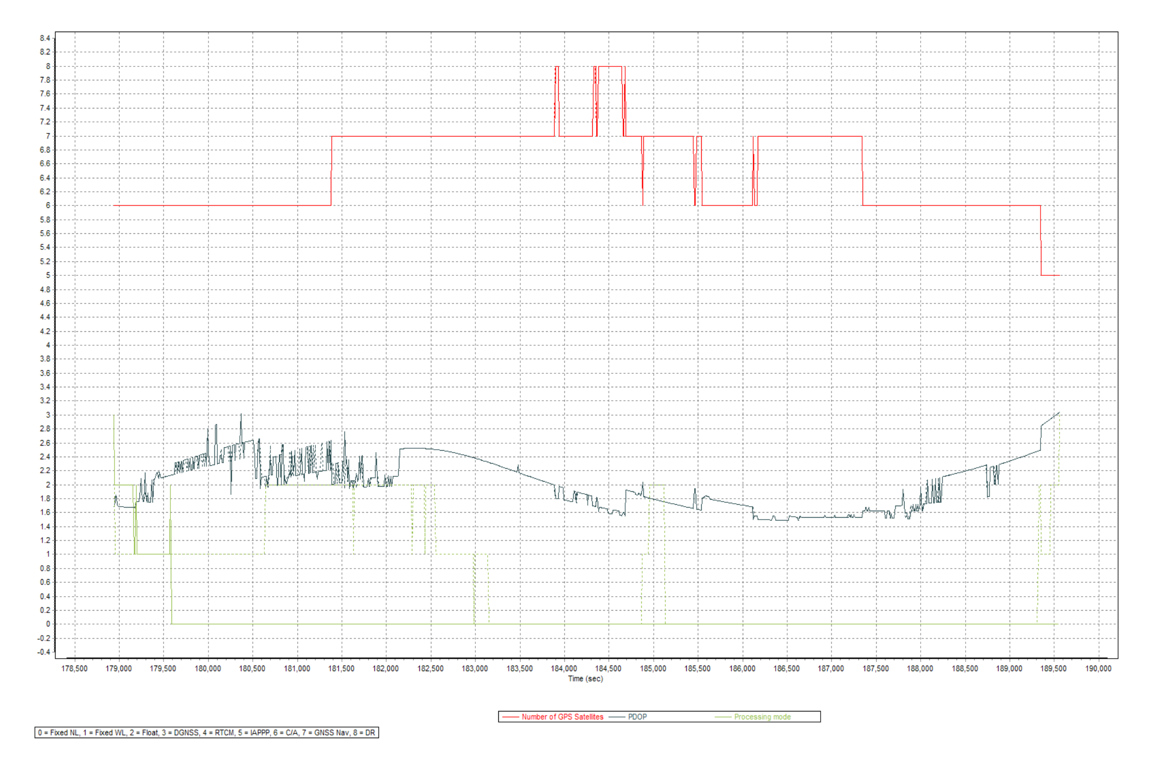


Figure A.2.1 Solution Status

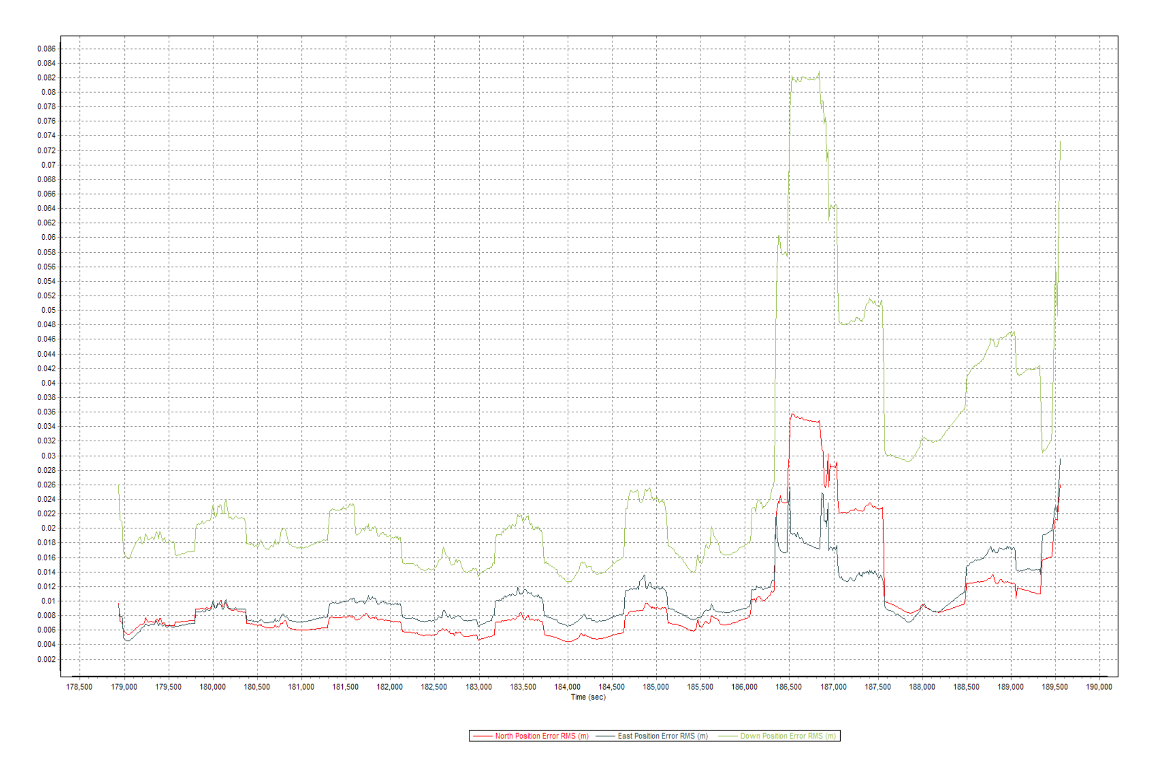


Figure A.8.2 Smoothed Performance Metric Parameters

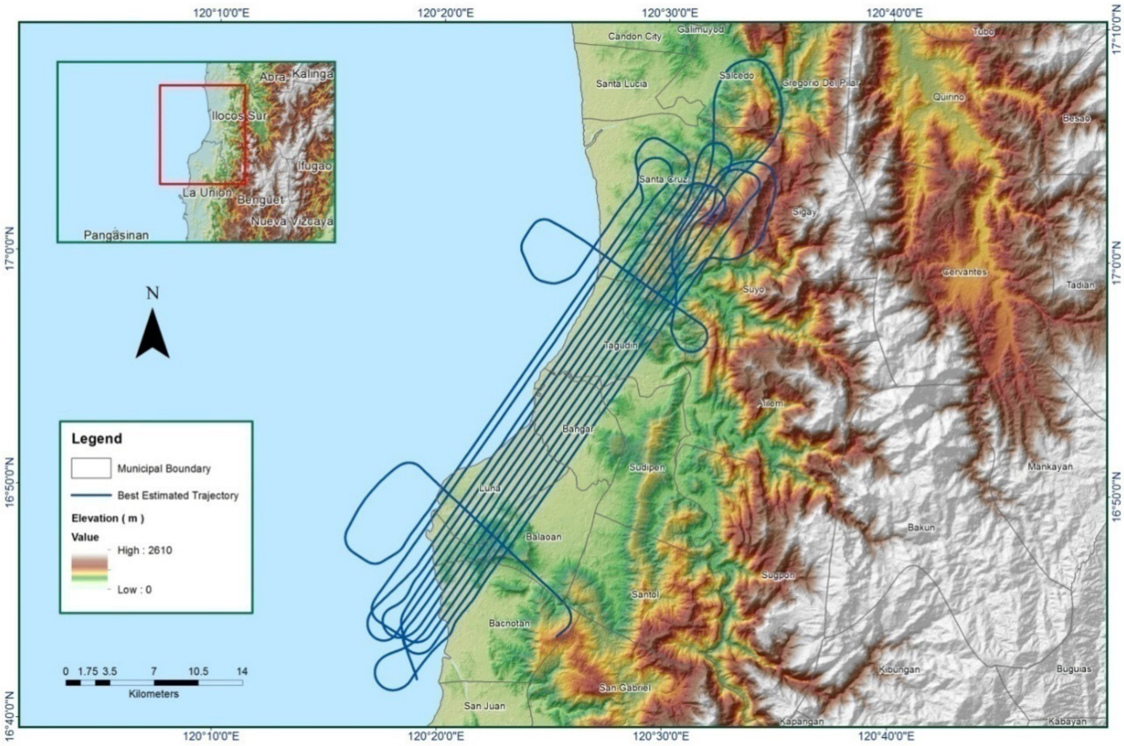


Figure A.8.3 Best Estimated Trajectory

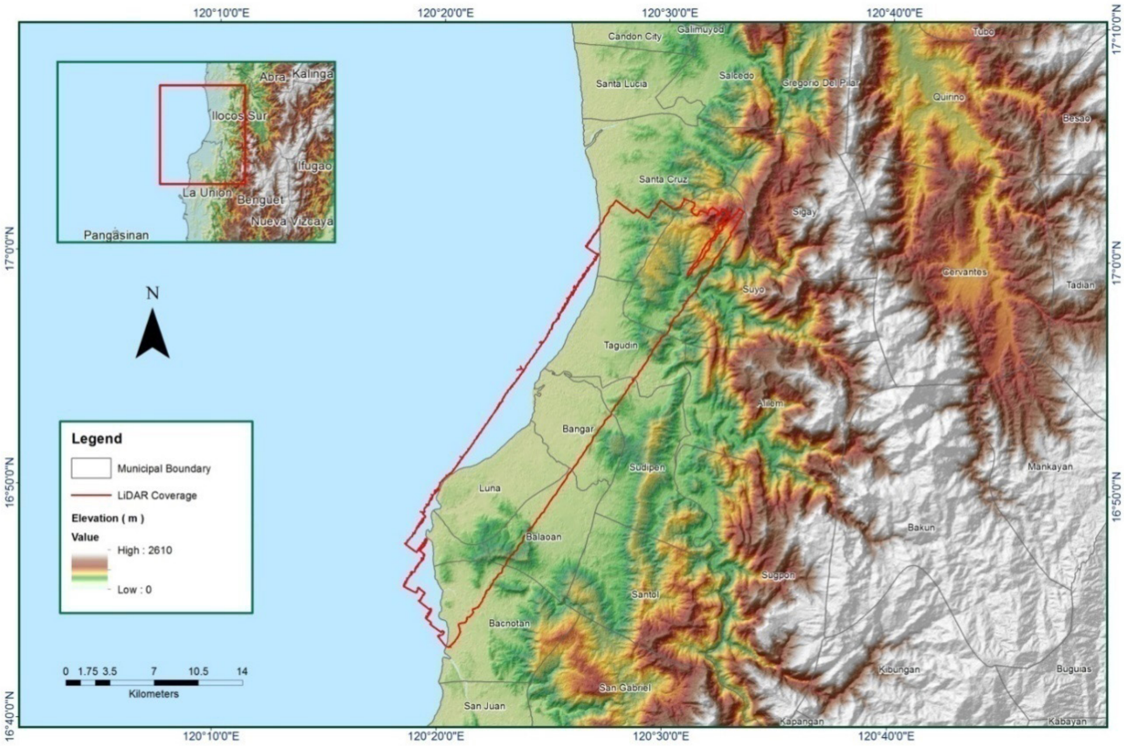


Figure A.8.4 Coverage of LIDAR data

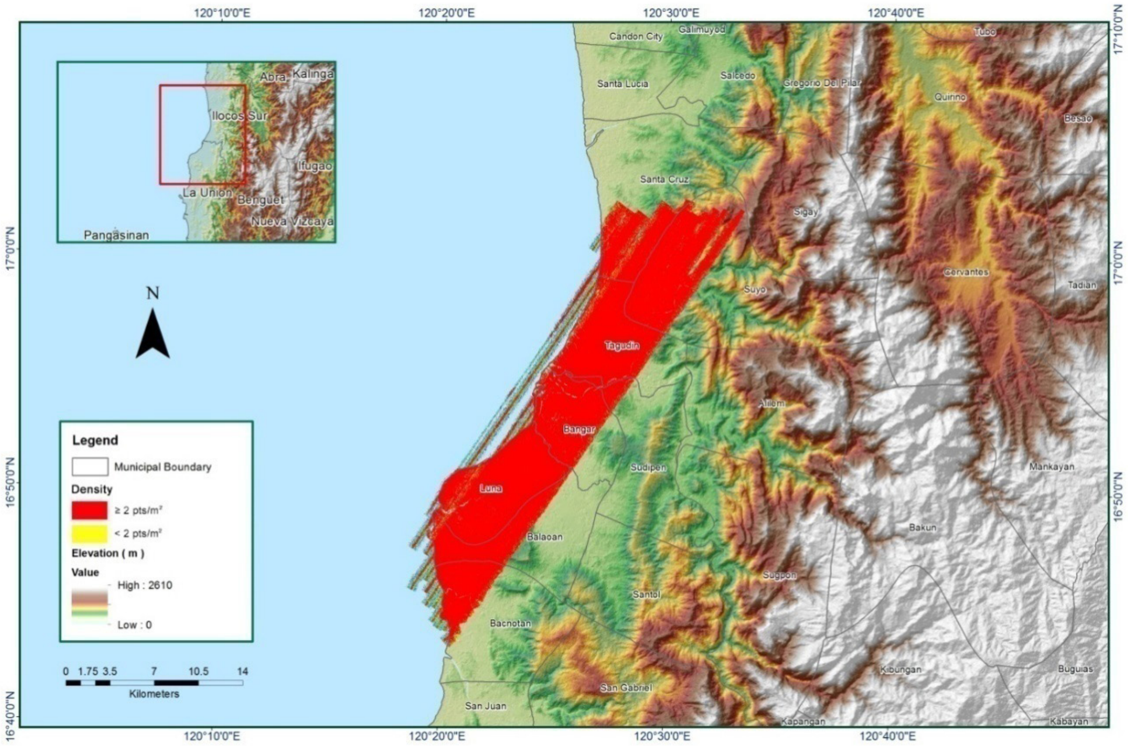


Figure A.8.5 Image of Data Overlap

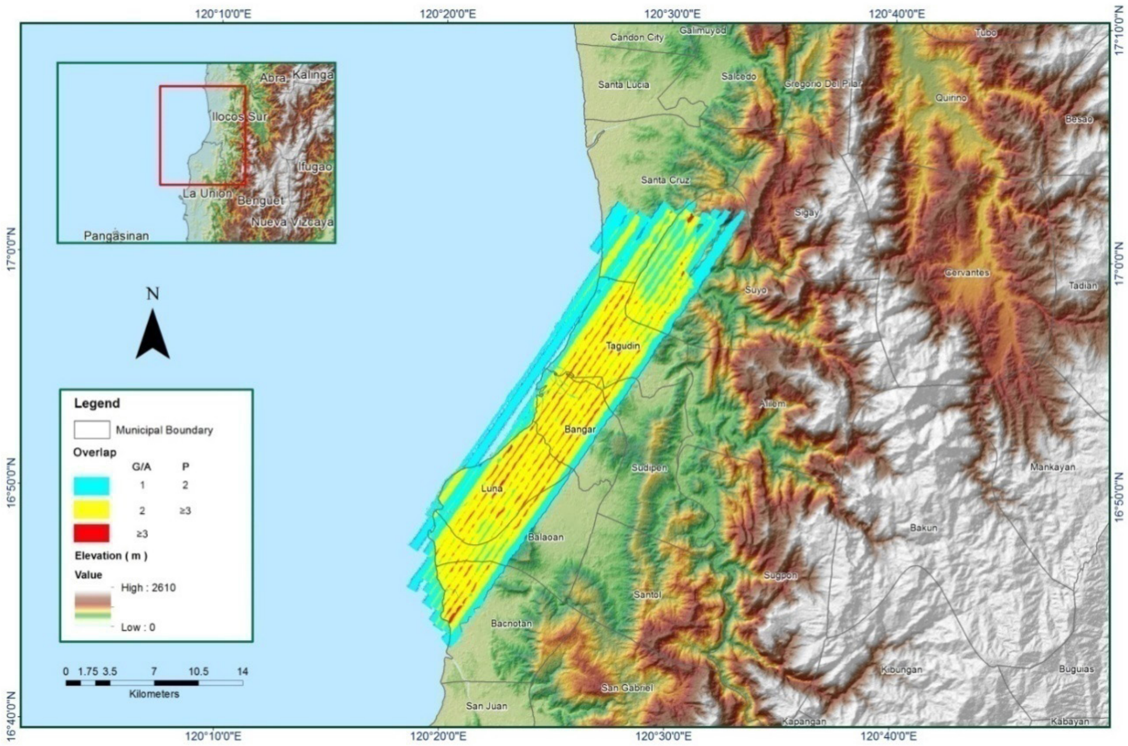


Figure A.8.6 Density map of merged LIDAR data

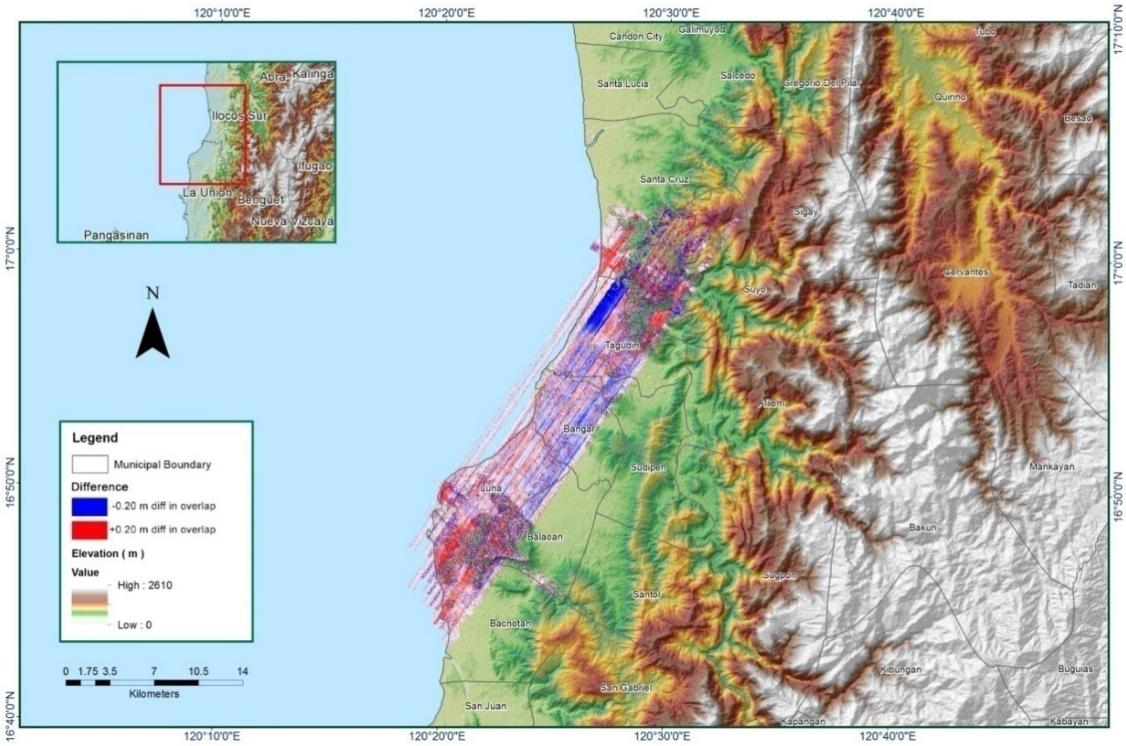


Figure A.8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk10B

Flight Area	La Union
Mission Name	Blk10B
Inclusive Flights	1153P, 1157P, 1175P
Range data size	54.92 GB
POS	114MB
Base data size	20.21MB
Image	68.7 GB
Transfer date	March 03, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.66
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	3.58
Boresight correction stdev (<0.001deg)	0.00027
IMU attitude correction stdev (<0.001deg)	0.0028
GPS position stdev (<0.01m)	0.0065
Minimum % overlap (>25)	61.20%
Ave point cloud density per sq.m. (>2.0)	4.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	455
Maximum Height	967.51
Minimum Height	42.13
Classification (# of points)	
Ground	384,680,895
Low vegetation	361,413,391
Medium vegetation	639,589,607
High vegetation	674,742,918
Building	37,030,506
Orthophoto	
Processed by	Engr. Jennifer Saguran, Engr. Charmaine Cruz, Jovy Narisma

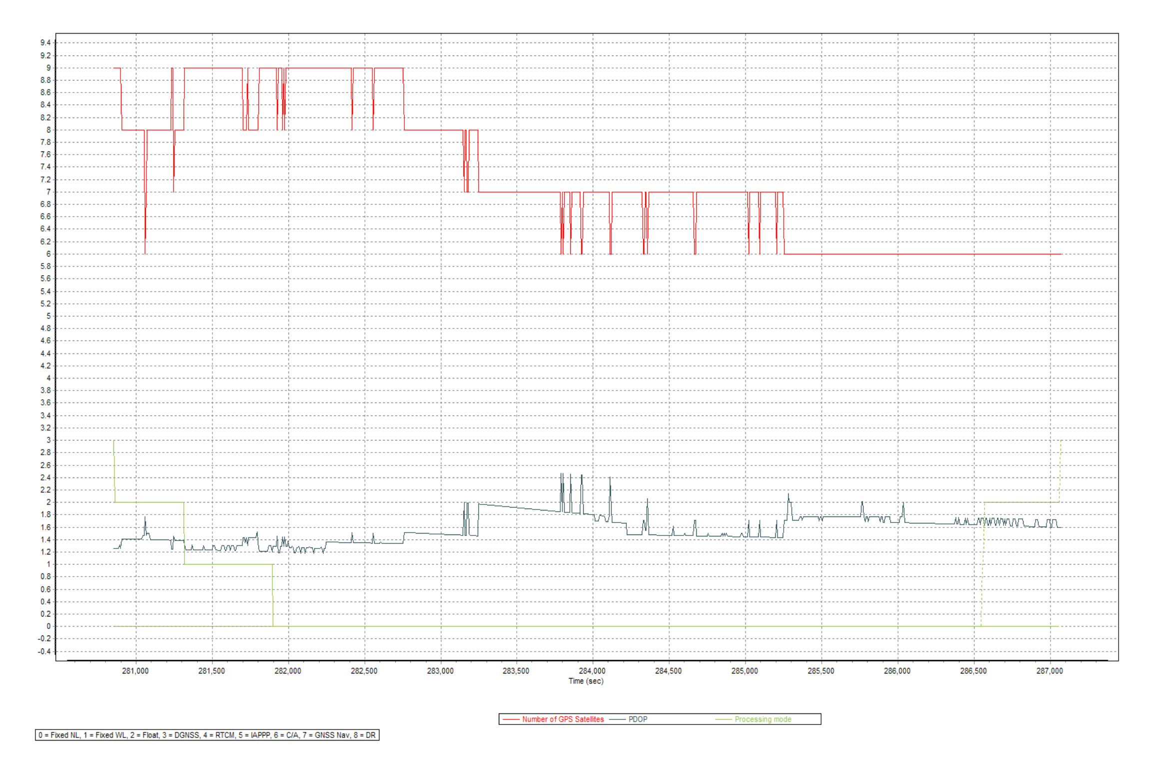


Figure A.8.8 Solution Status

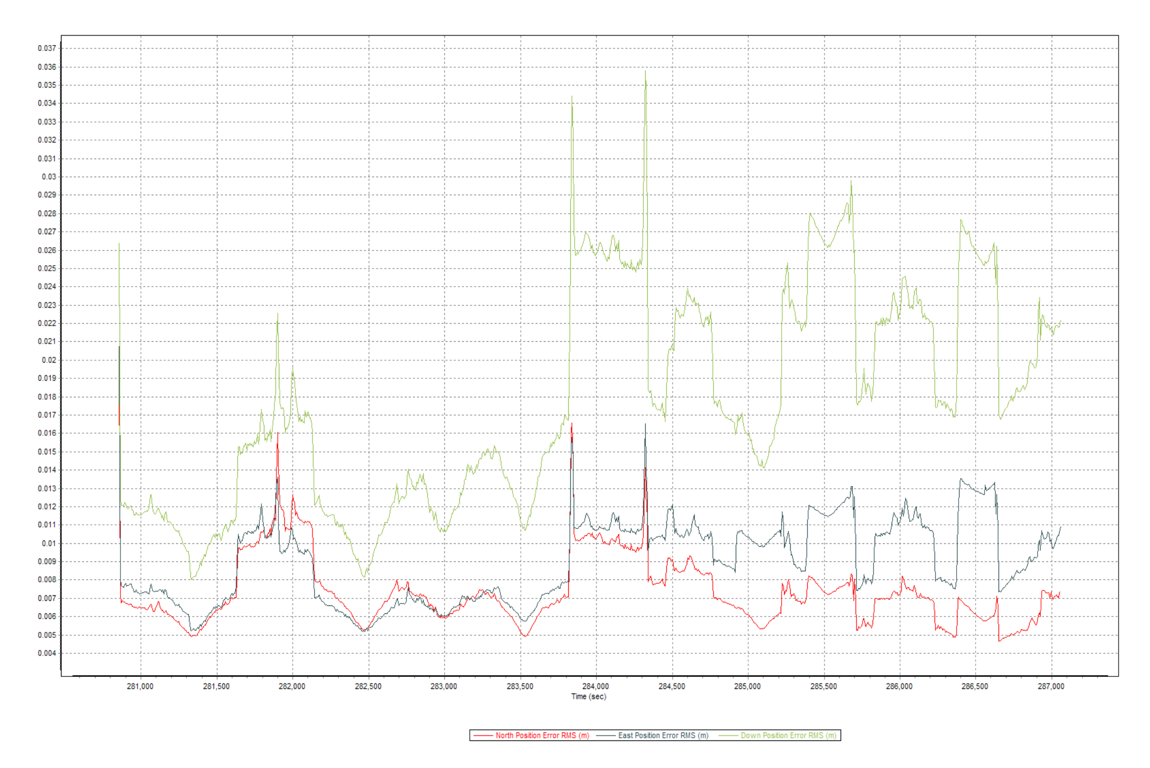


Figure A.8.9 Smoothed Performance Metric Parameters

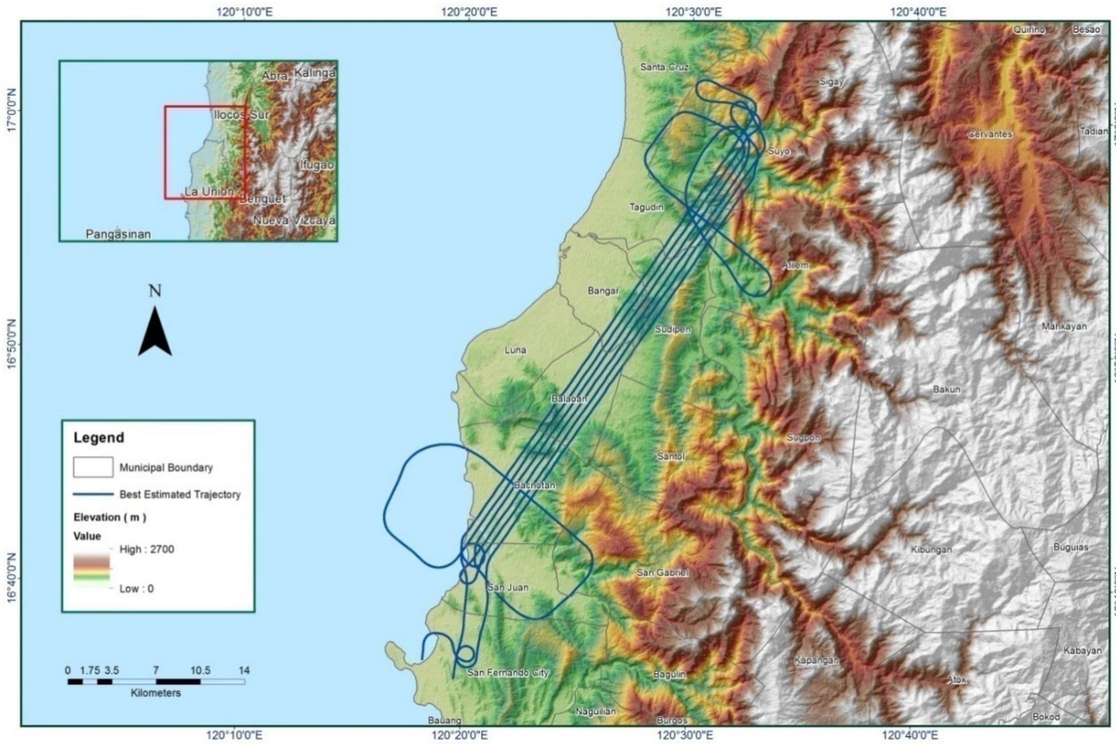


Figure A-8.10 Best Estimated Trajectory

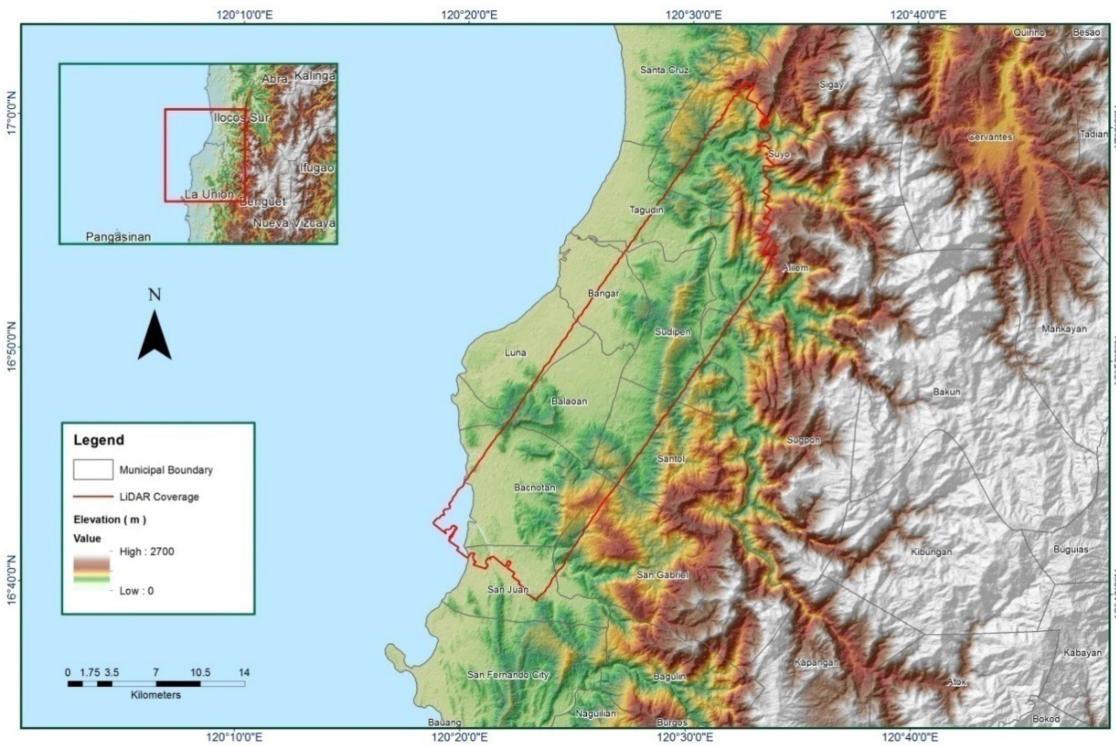


Figure A-8.11 Coverage of LIDAR data

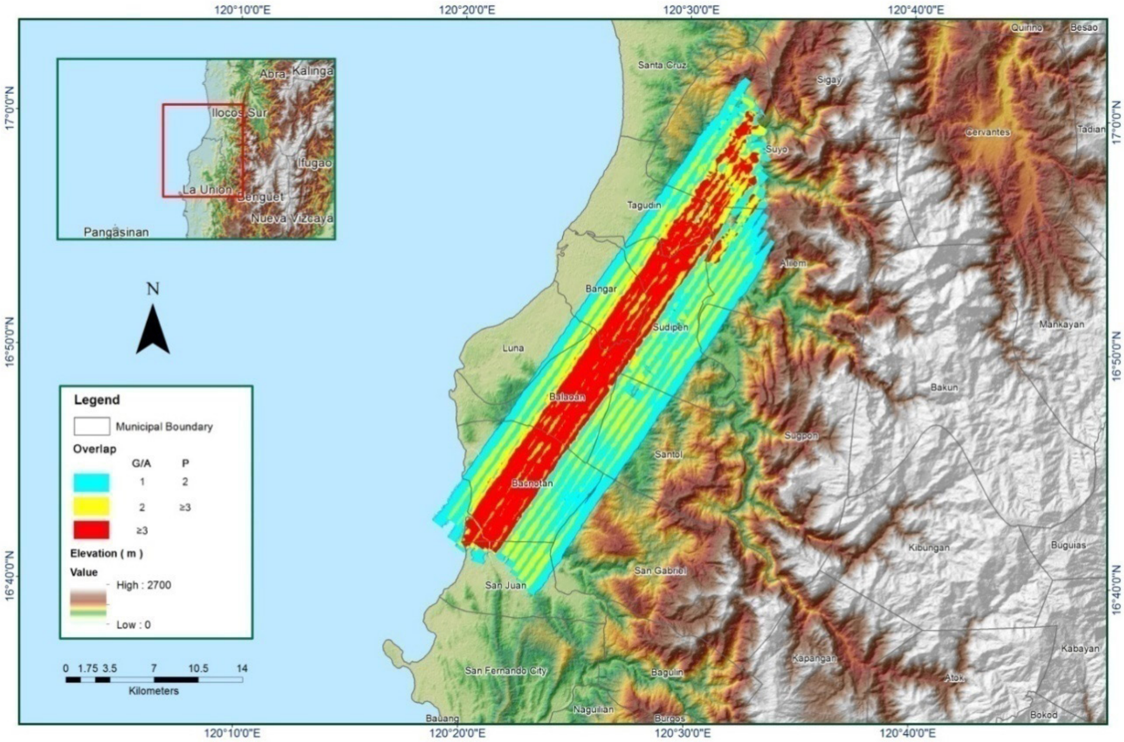


Figure A.8.12 Image of Data Overlap

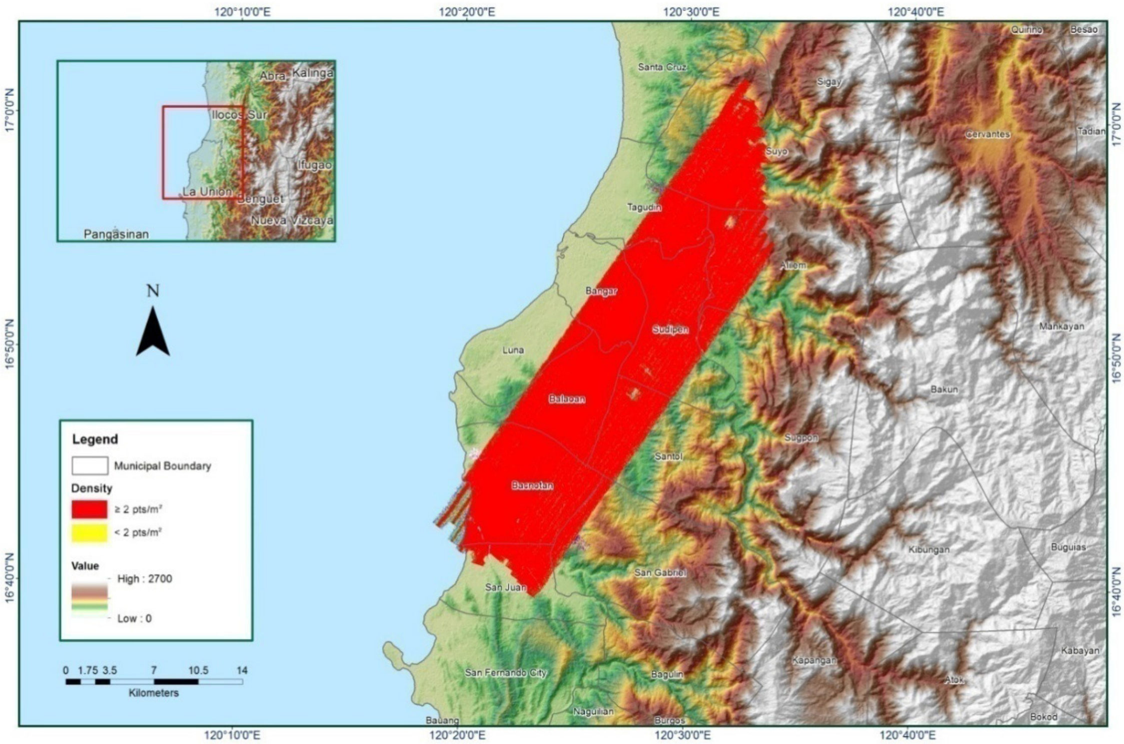


Figure A.8.13 Density map of merged LIDAR data

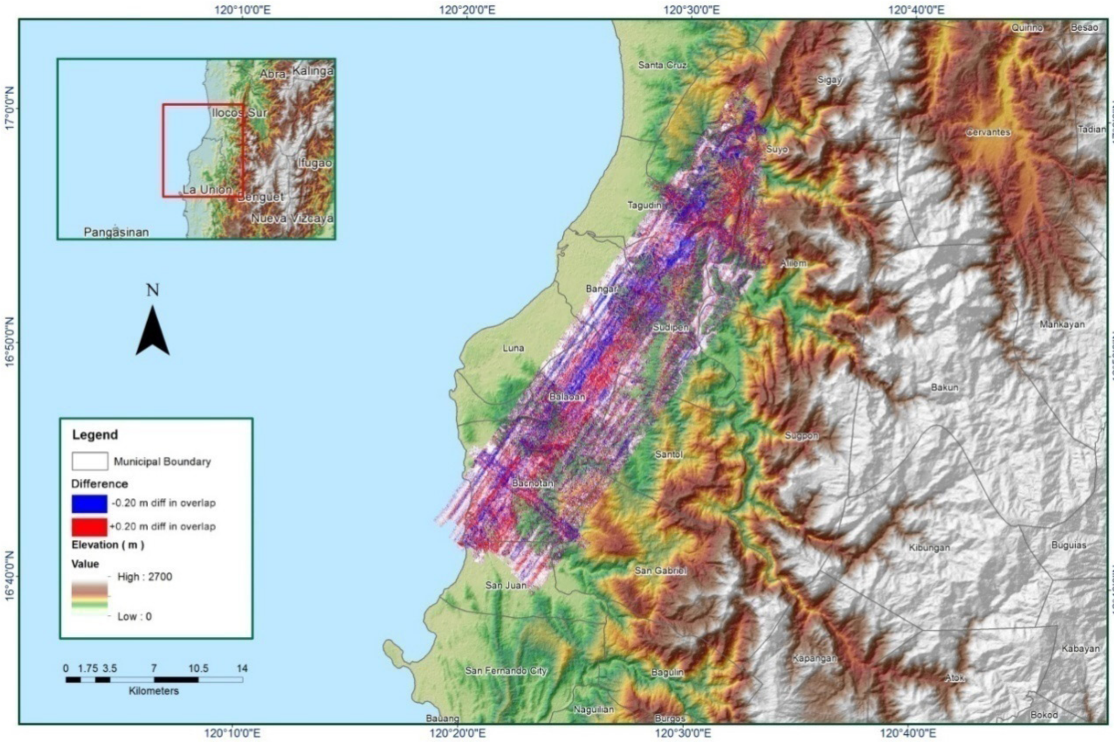


Figure A.8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission BLK10C

Flight Area	La Union
Mission Name	Blk10C
Inclusive Flights	1155P, 1171P, 1177P, 1197P
Range data size	62.86 GB
POS	695 MB
Base data size	22.21
Image	98.6 GB
Transfer date	March 08, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.62
RMSE for East Position (<4.0 cm)	4.3
RMSE for Down Position (<8.0 cm)	6.55
Boresight correction stdev (<0.001deg)	0.000398
IMU attitude correction stdev (<0.001deg)	0.017218
GPS position stdev (<0.01m)	0.0267
Minimum % overlap (>25)	35.05%
Ave point cloud density per sq.m. (>2.0)	3.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	505
Maximum Height	1038.87
Minimum Height	45.5
Classification (# of points)	
Ground	270,659,389
Low vegetation	232,081,137
Medium vegetation	638,506,120
High vegetation	737,644,888
Building	23,046,935
Orthophoto	
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Engr. Jeffrey Delica

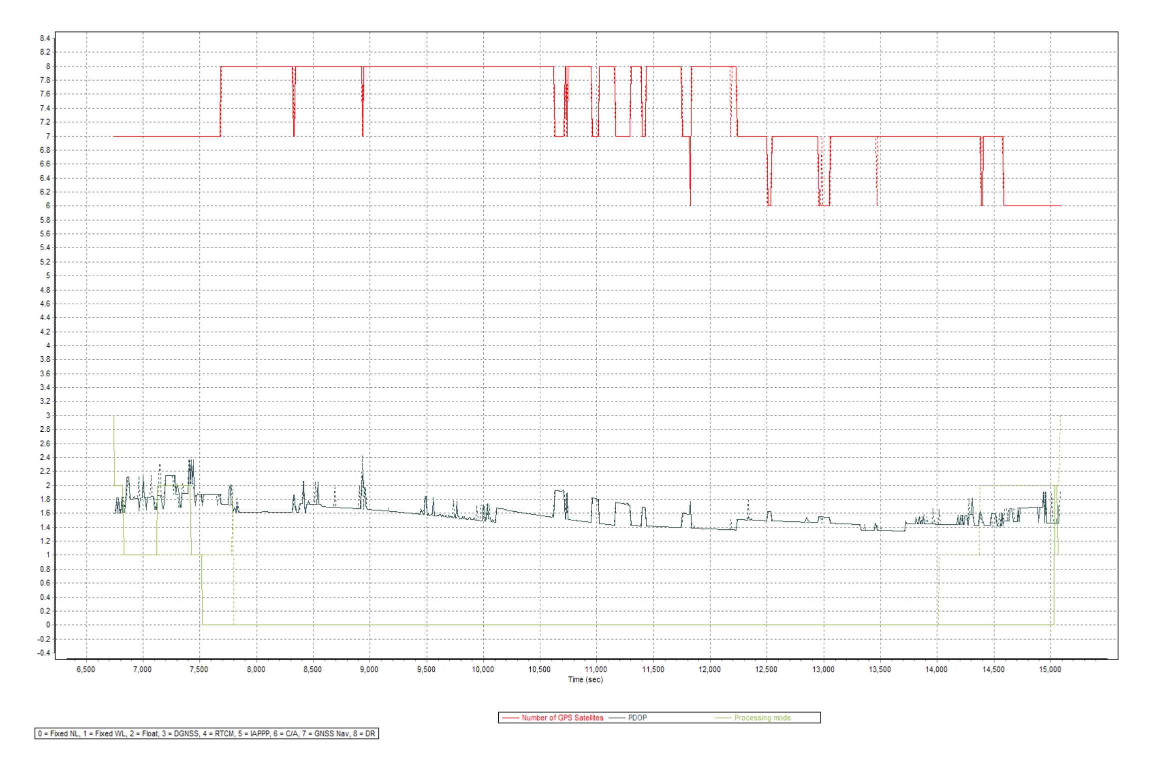


Figure A-8.15 Solution Status

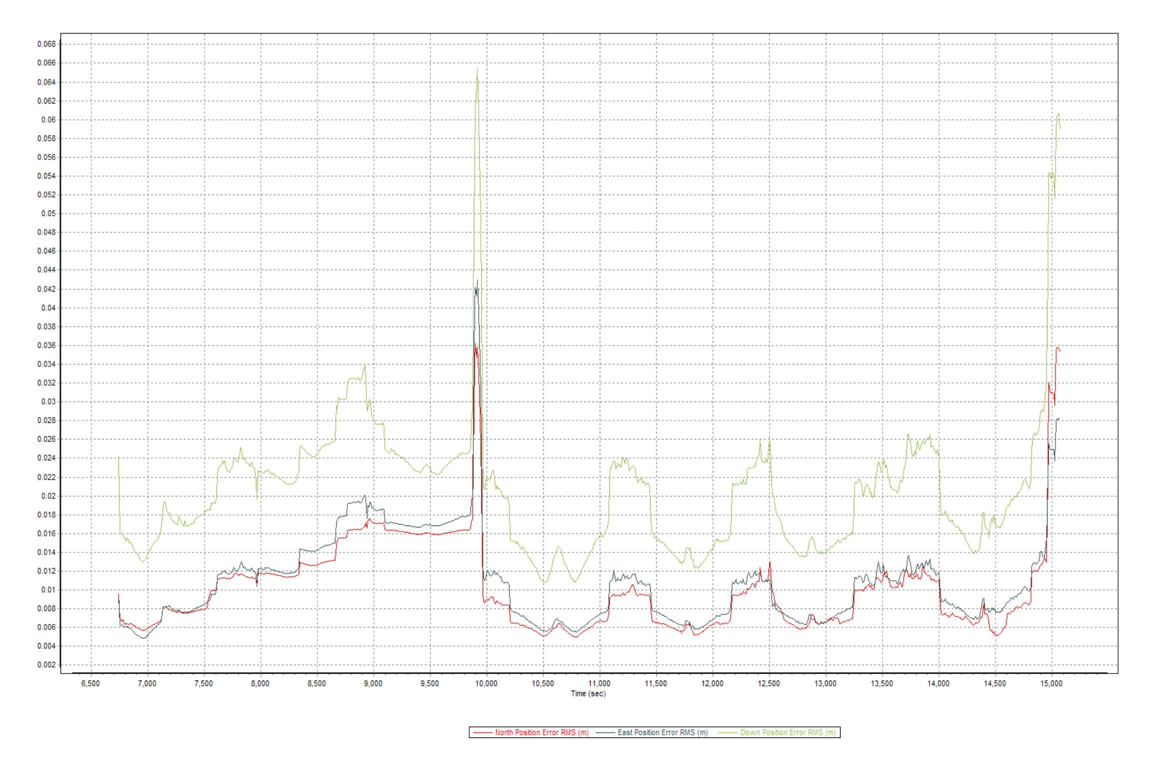


Figure A-8.16 Smoothed Performance Metric Parameters

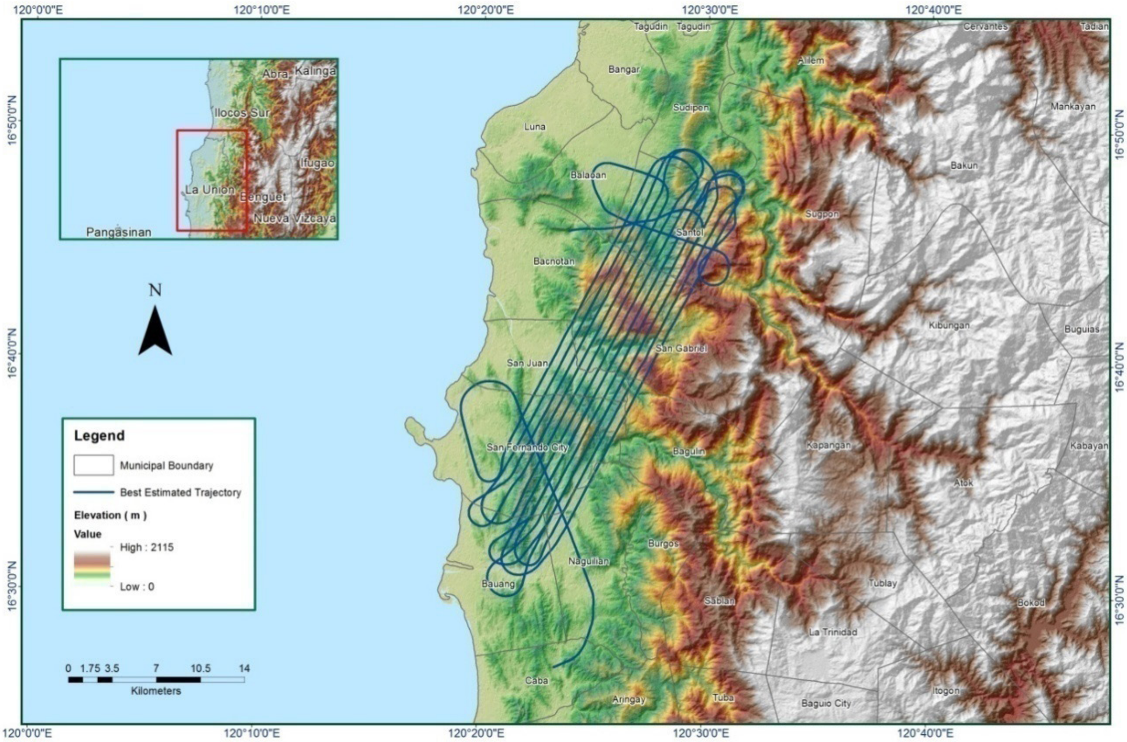


Figure A-8.17 Best Estimated Trajectory

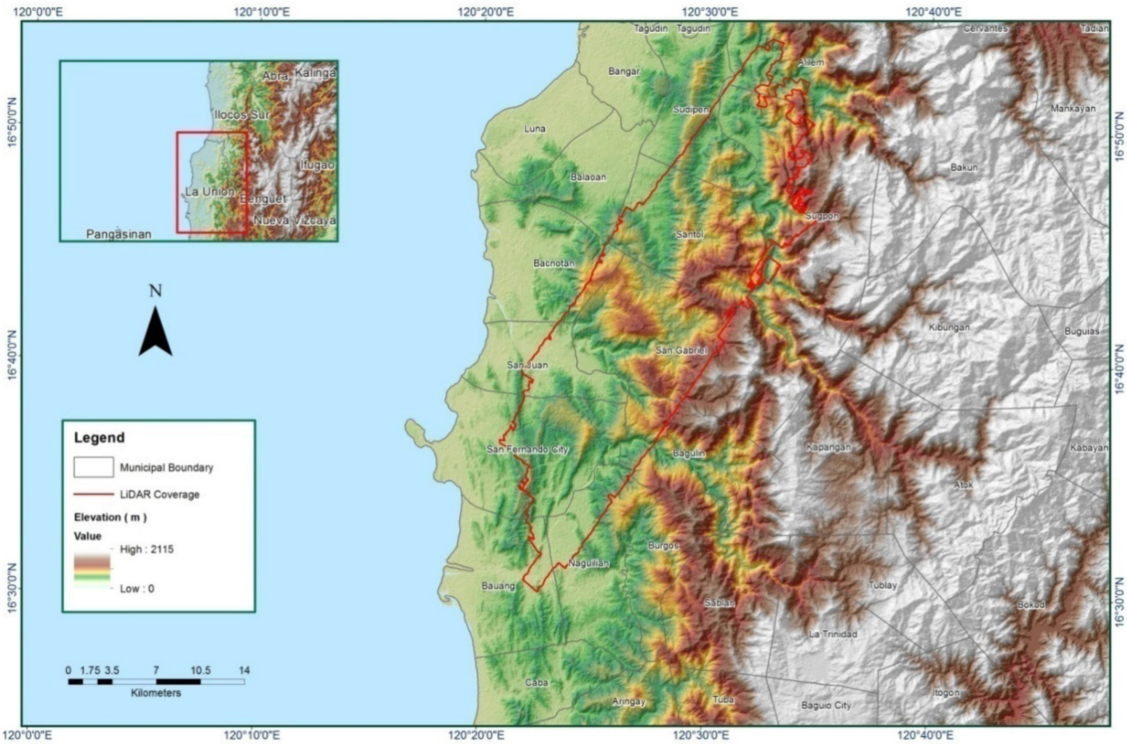


Figure A.8.18 Coverage of LIDAR data

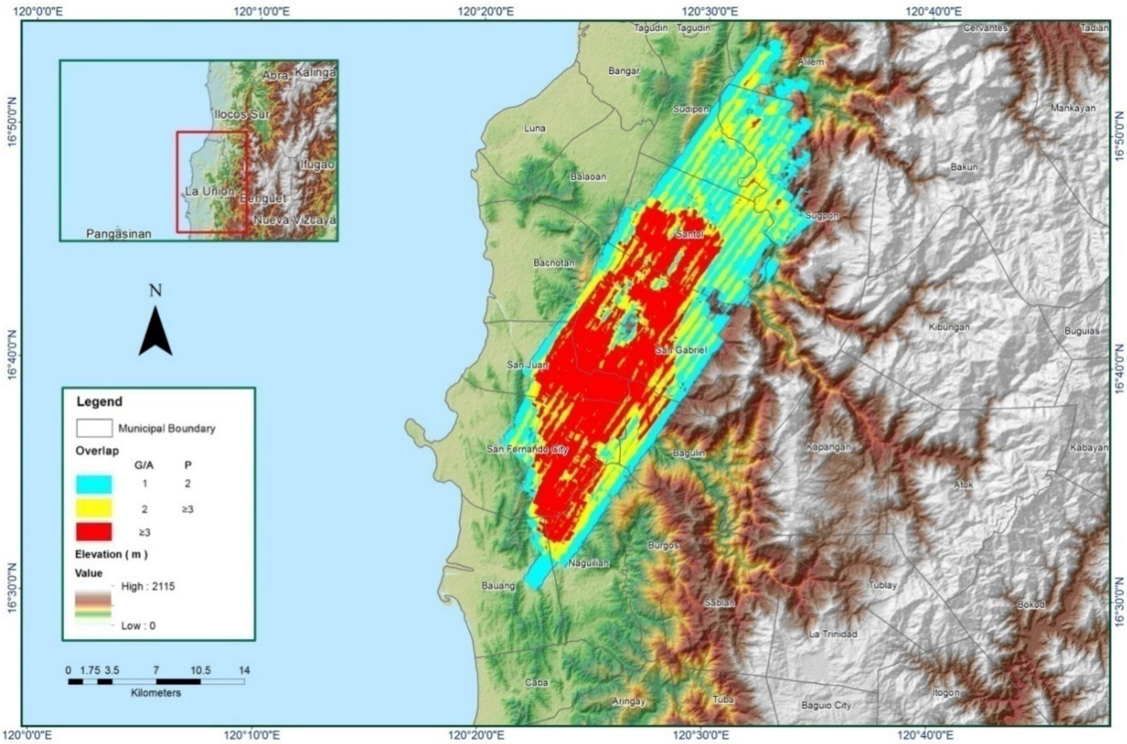


Figure A.8.19 Image of Data Overlap

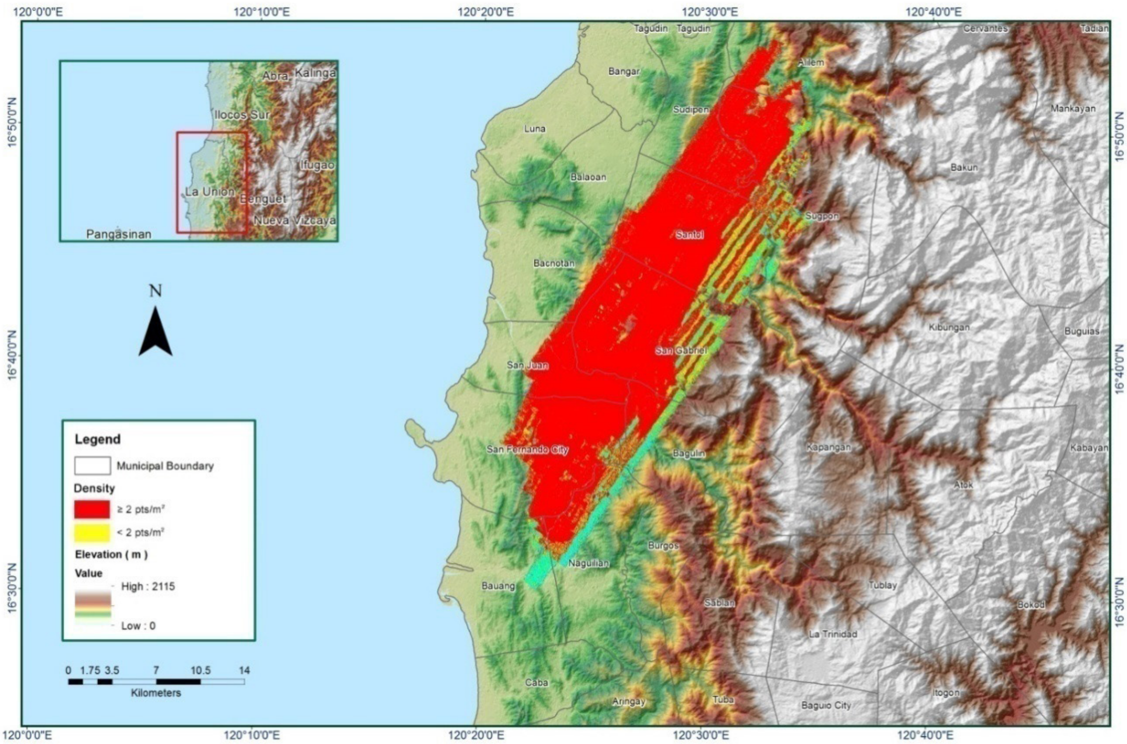


Figure A.8.20 Density map of merged LIDAR data

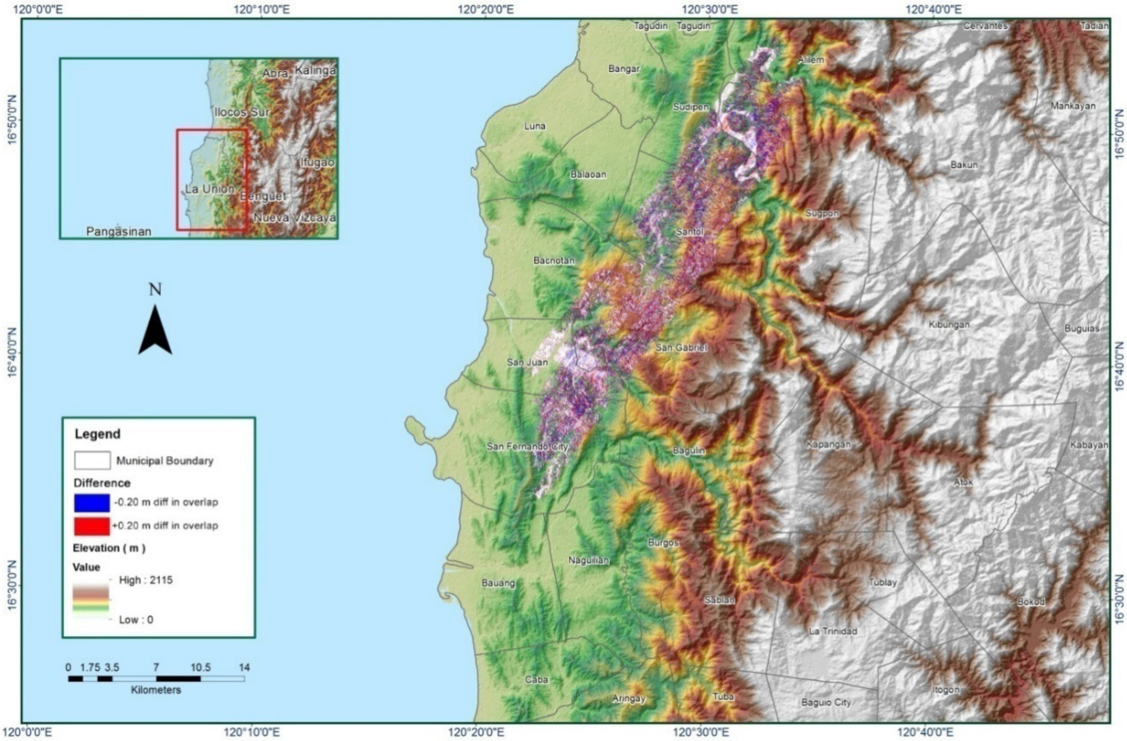


Figure 1.3.21 Elevation difference between flight line

Table A-8.4. Mission Summary Report for Mission Blk10C_additional

Flight Area	La Union
Mission Name	Blk10C_additional
Inclusive Flights	1177P
Range data size	11.3 GB
POS	157 MB
Base data size	6.74
Image	30 GB
Transfer date	March 08, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.24
RMSE for East Position (<4.0 cm)	1.48
RMSE for Down Position (<8.0 cm)	2.74
Boresight correction stdev (<0.001deg)	0.000398
IMU attitude correction stdev (<0.001deg)	0.022977
GPS position stdev (<0.01m)	0.007
Minimum % overlap (>25)	52.15%
Ave point cloud density per sq.m. (>2.0)	2.44
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	391
Maximum Height	1,038.57
Minimum Height	42.19
Classification (# of points)	
Ground	208,543,222
Low vegetation	136,381,901
Medium vegetation	263,283,963
High vegetation	387,854,740
Building	14,766,006
Orthophoto	
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga Jr, Ailyn Biñas

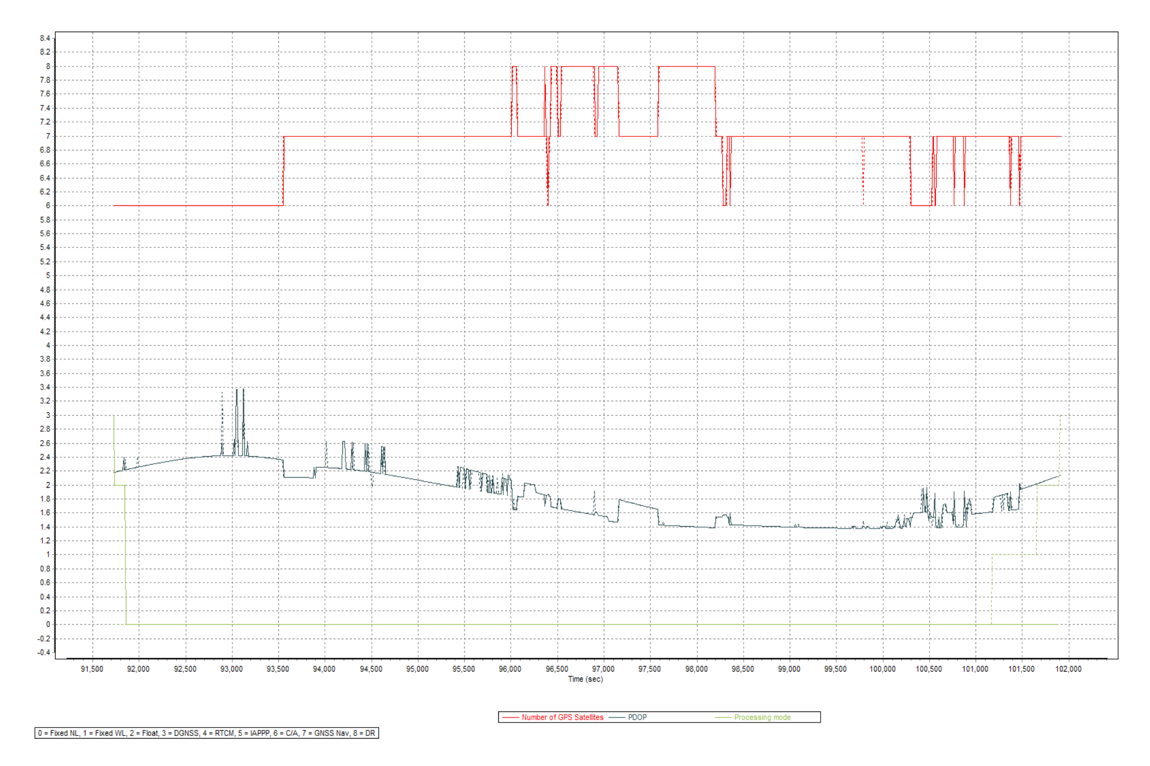


Figure A-8.22 Solution Status

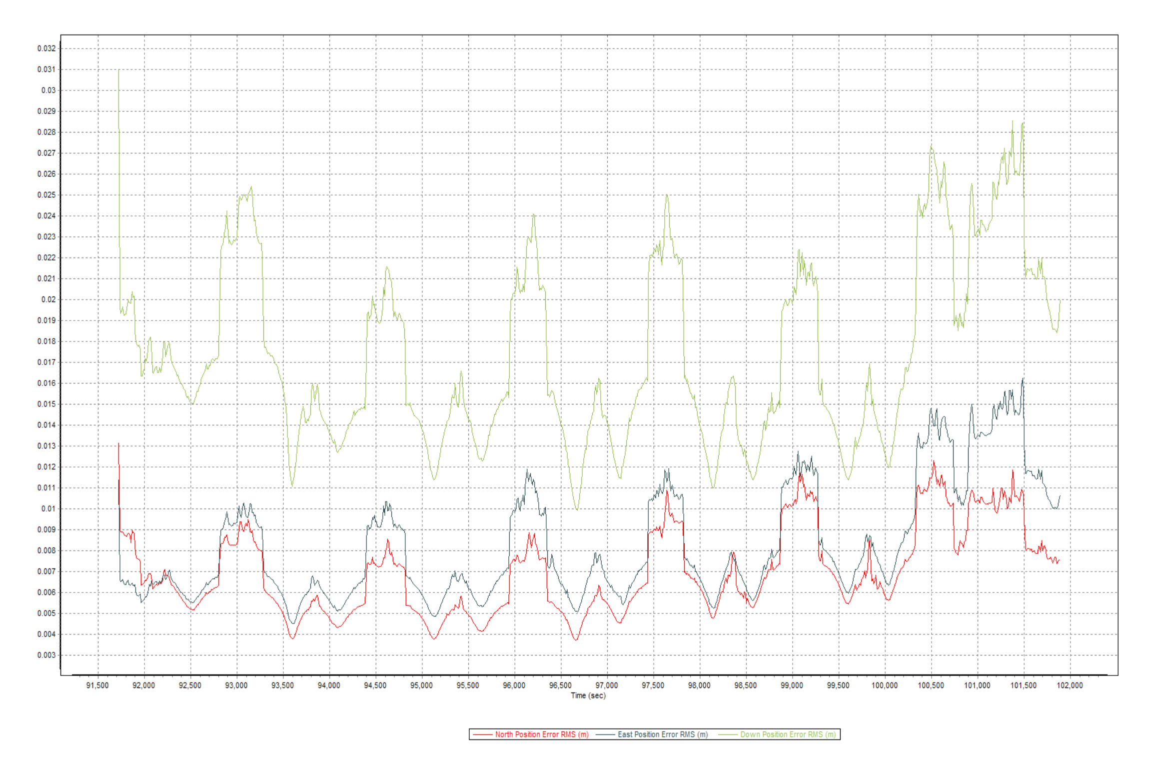


Figure A-8.23 Smoothed Performance Metric Parameters

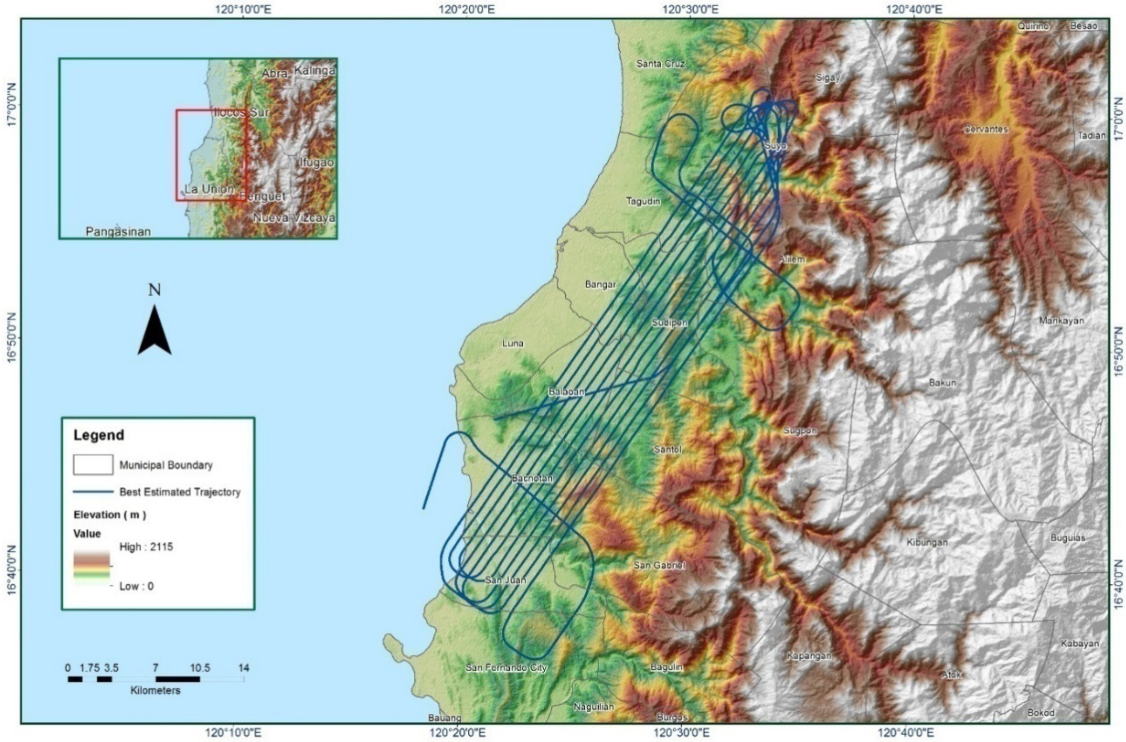


Figure A-8.24 Best Estimated Trajectory

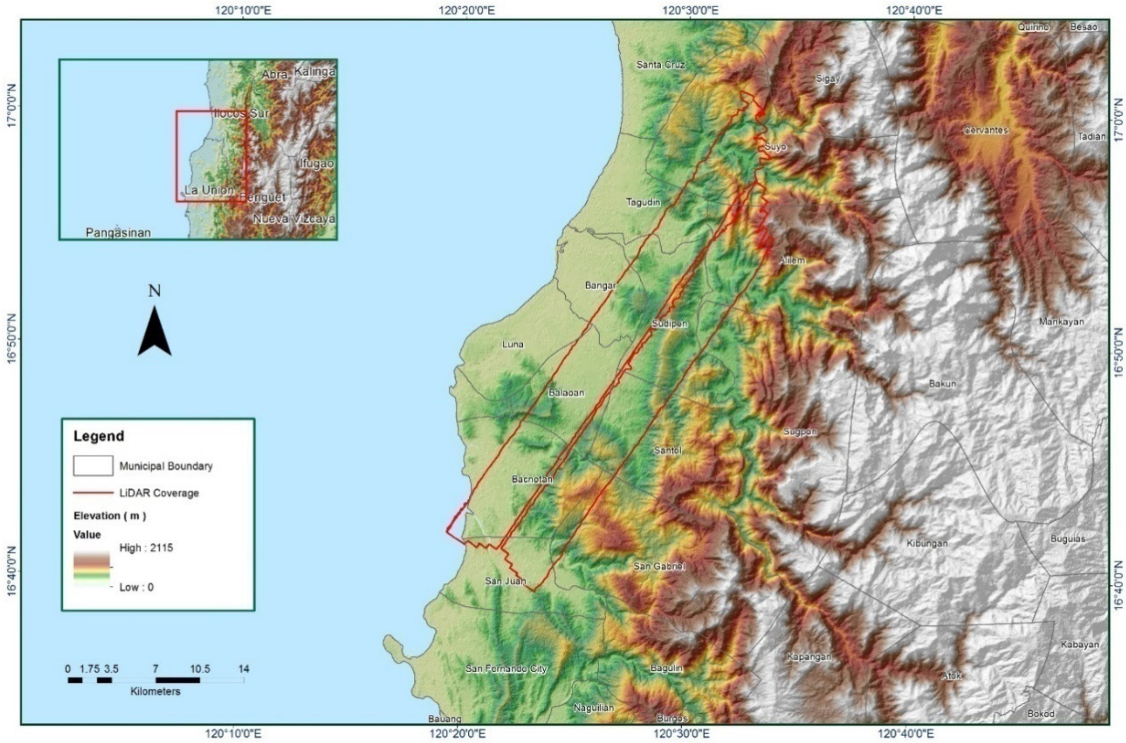


Figure A-8.25 Coverage of LIDAR data

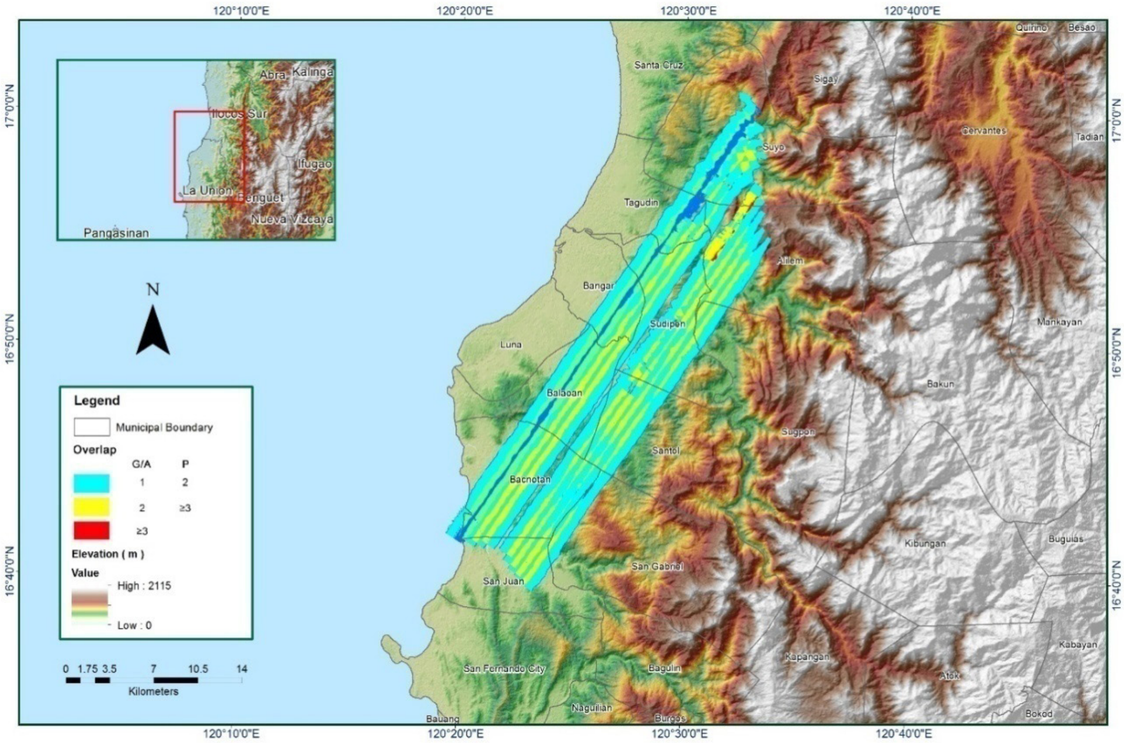


Figure A-8.26 Image of Data Overlap

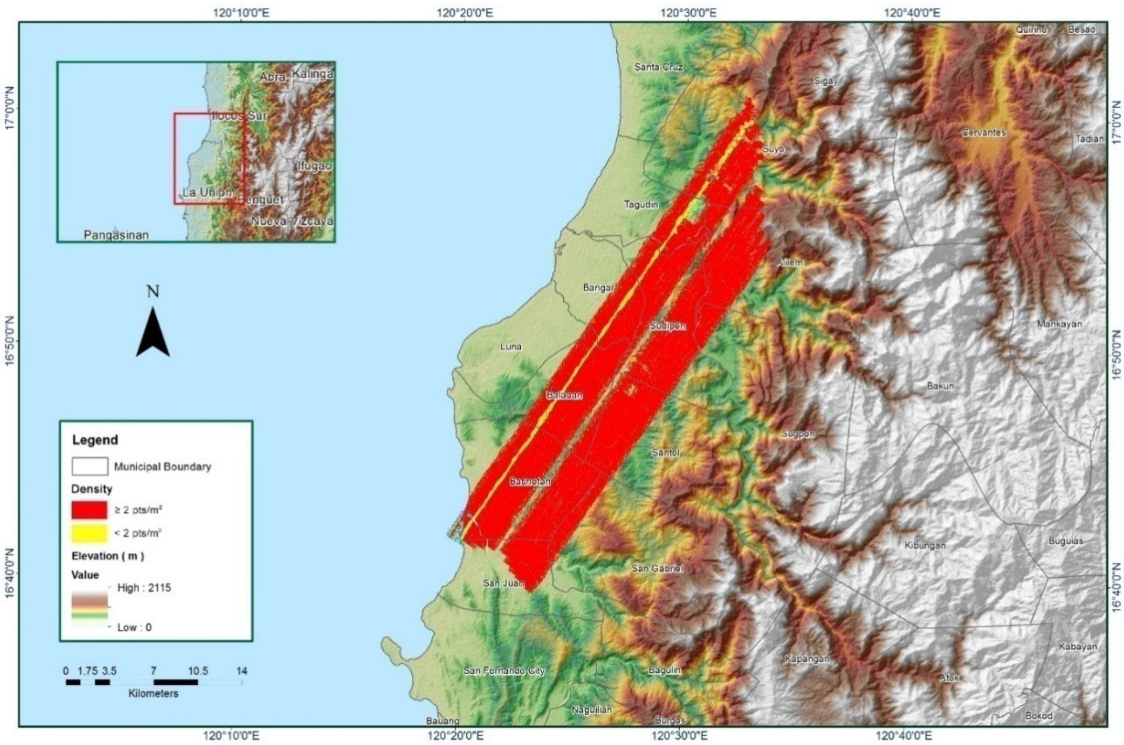


Figure A-8.27 Density map of merged LIDAR data

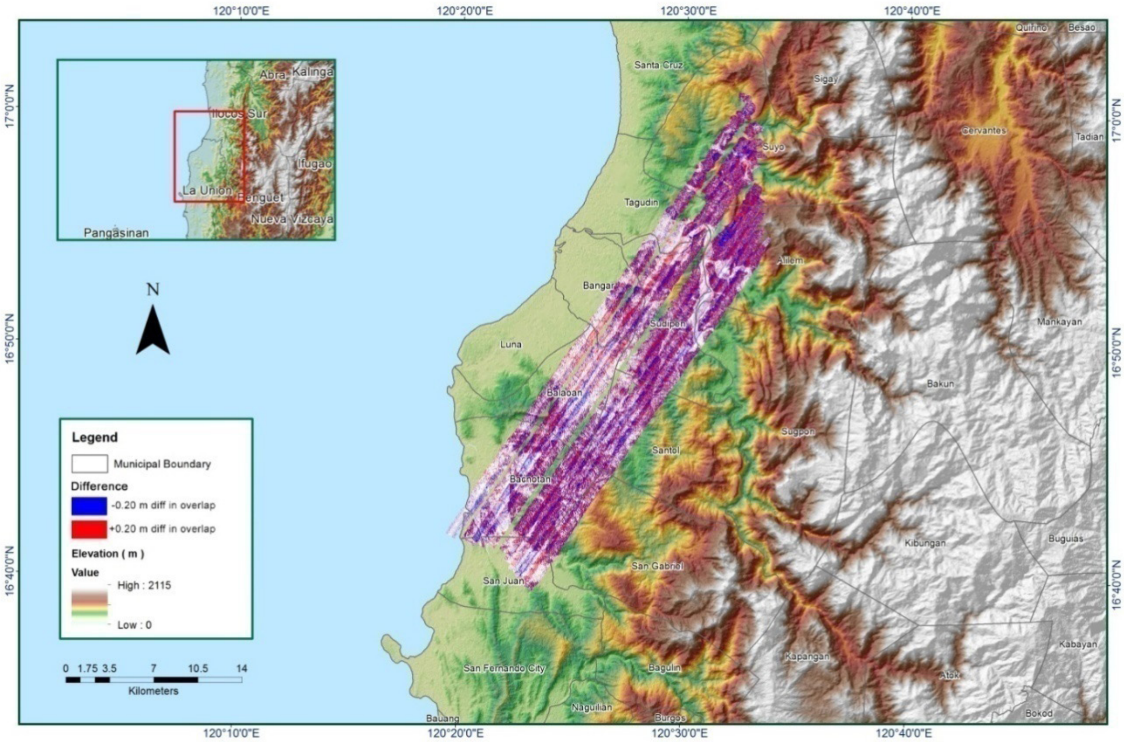


Figure A-8.28 Elevation difference between flight line

Table A-8.5 Mission Summary Report for Mission Blk10D

Flight Area	La Union
Mission Name	Blk10D
Inclusive Flights	1159P, 1161P, 1171P, 1173P
Range data size	75 GB
POS	695 MB
Base data size	27.26
Image	68.3 GB
Transfer date	March 02, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.4
Boresight correction stdev (<0.001deg)	0.000325
IMU attitude correction stdev (<0.001deg)	0.006754
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	68.41%
Ave point cloud density per sq.m. (>2.0)	2.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	394
Maximum Height	401.8
Minimum Height	42.44
Classification (# of points)	
Ground	301,413,519
Low vegetation	230,161,400
Medium vegetation	317,034,224
High vegetation	336,165,453
Building	30,496,828
Orthophoto	
Processed by	Engr. Kenneth Solidum, Engr. Angelo Carlo Bongat, Engr. Benjamin Magallon, Engr. Harmond Santos, Ailyn Biñas

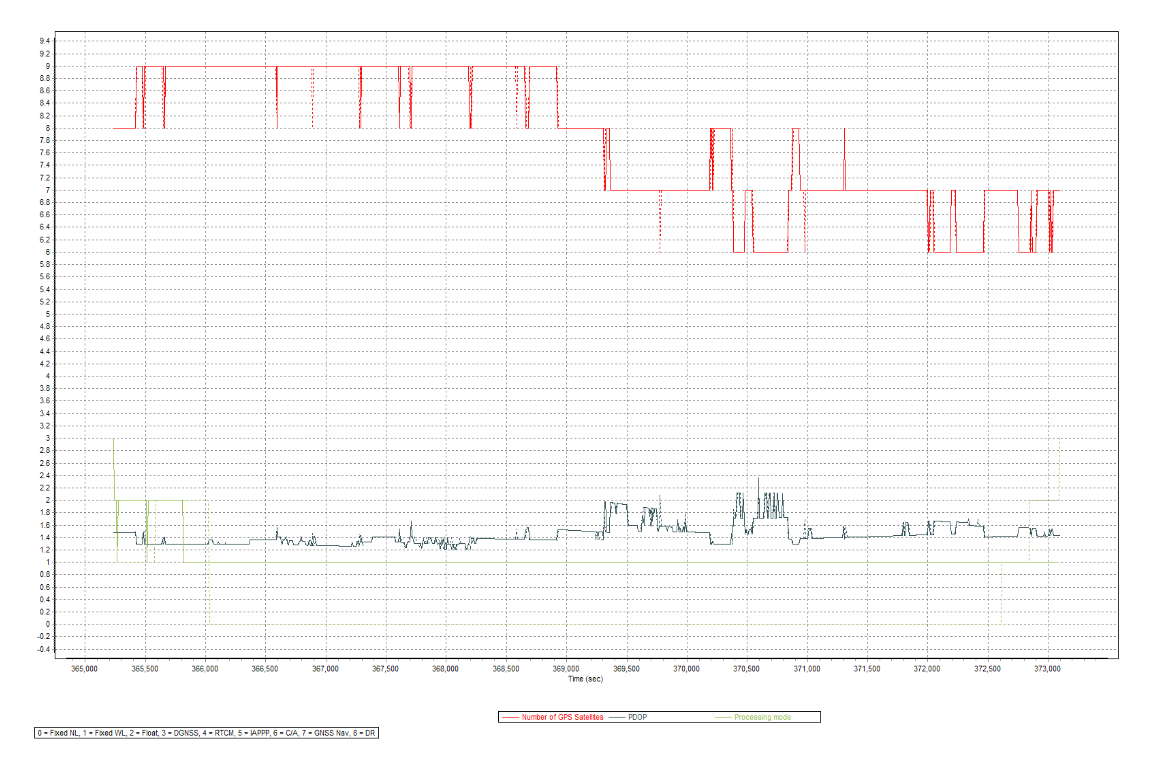


Figure A-8.29 Solution Status

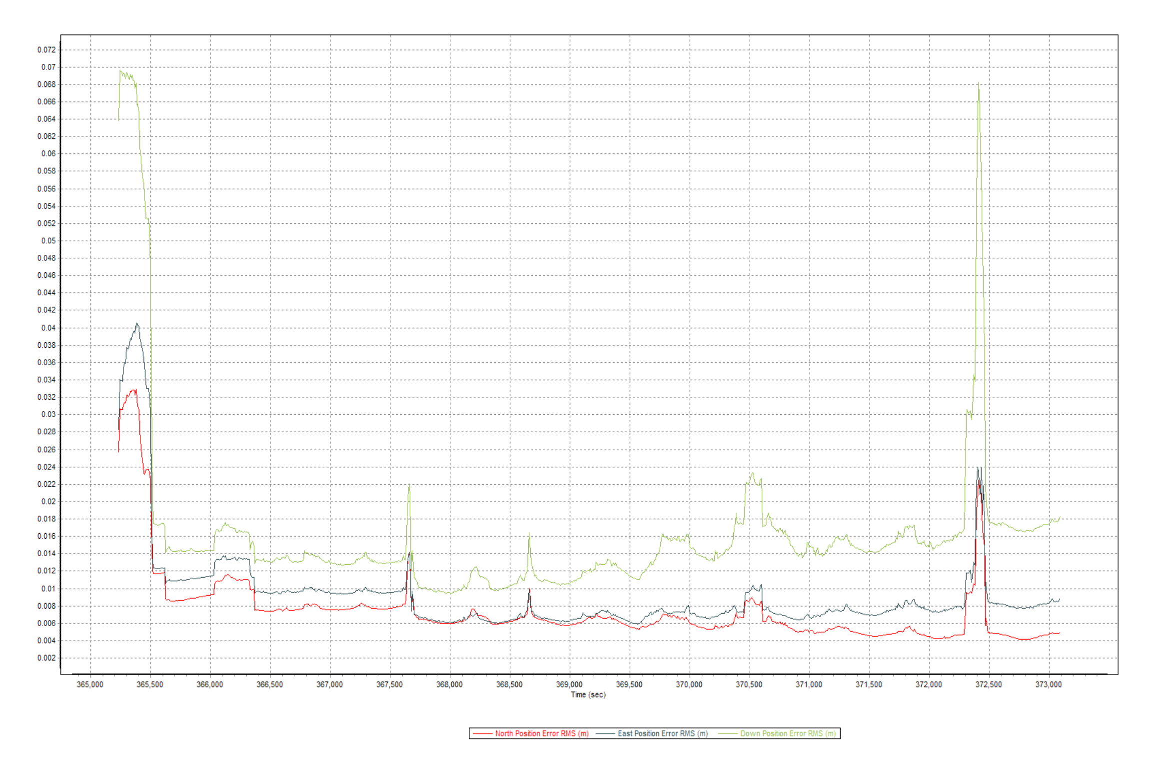


Figure A-8.30 Smoothed Performance Metric Parameters

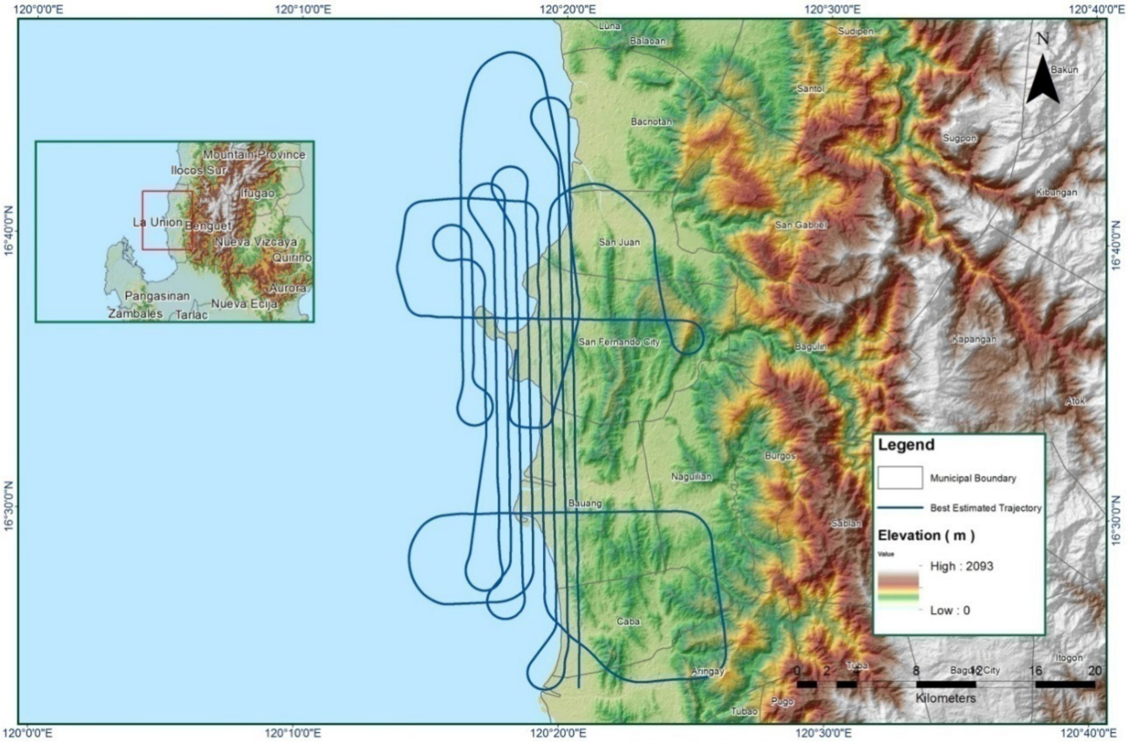


Figure A-8.31 Best Estimated Trajectory

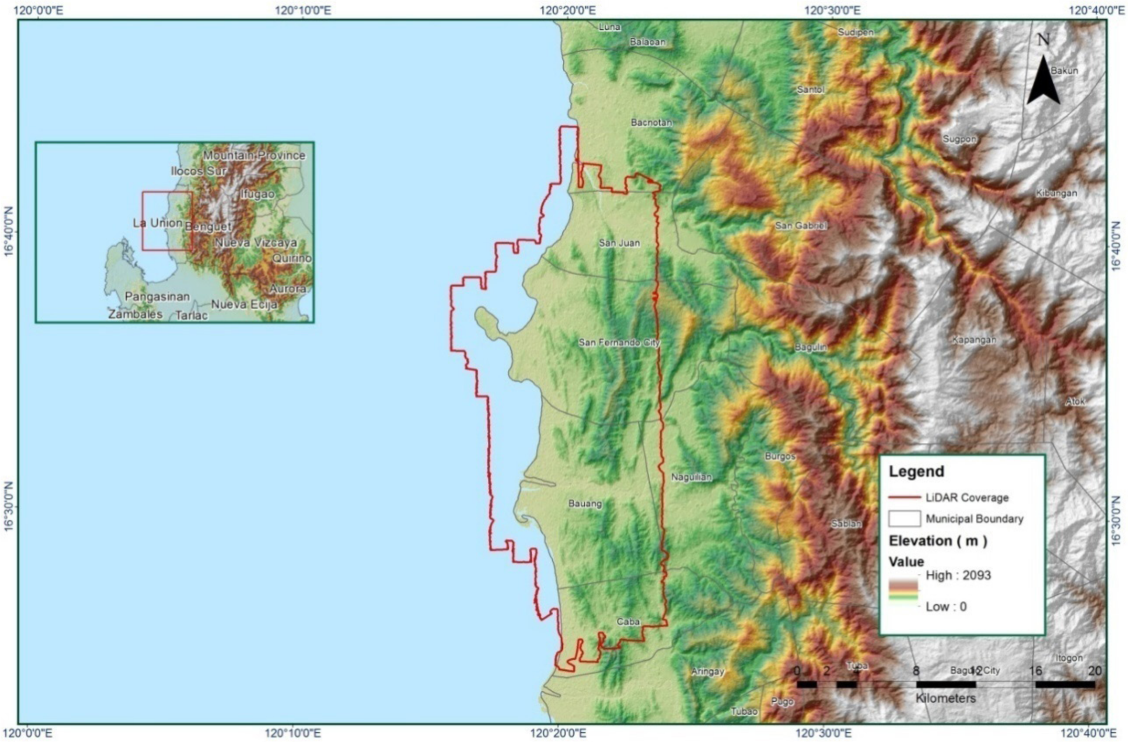


Figure A-8.32 Coverage of LIDAR data

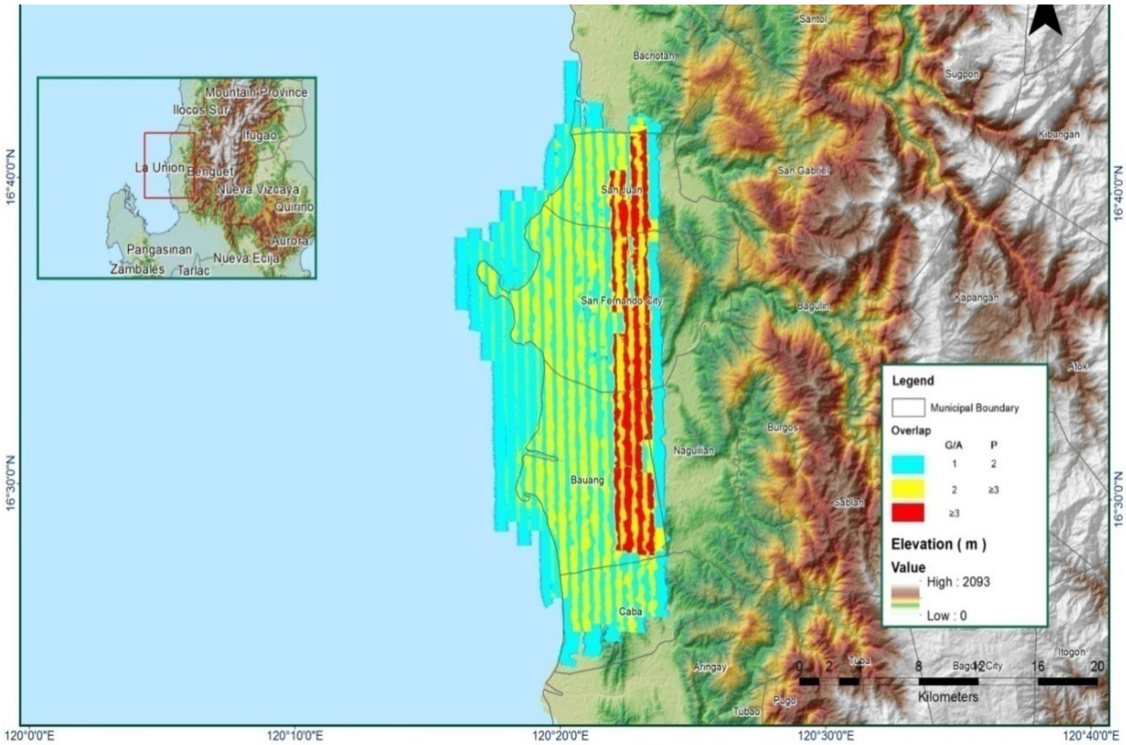


Figure A-8.32 Image of Data Overlap

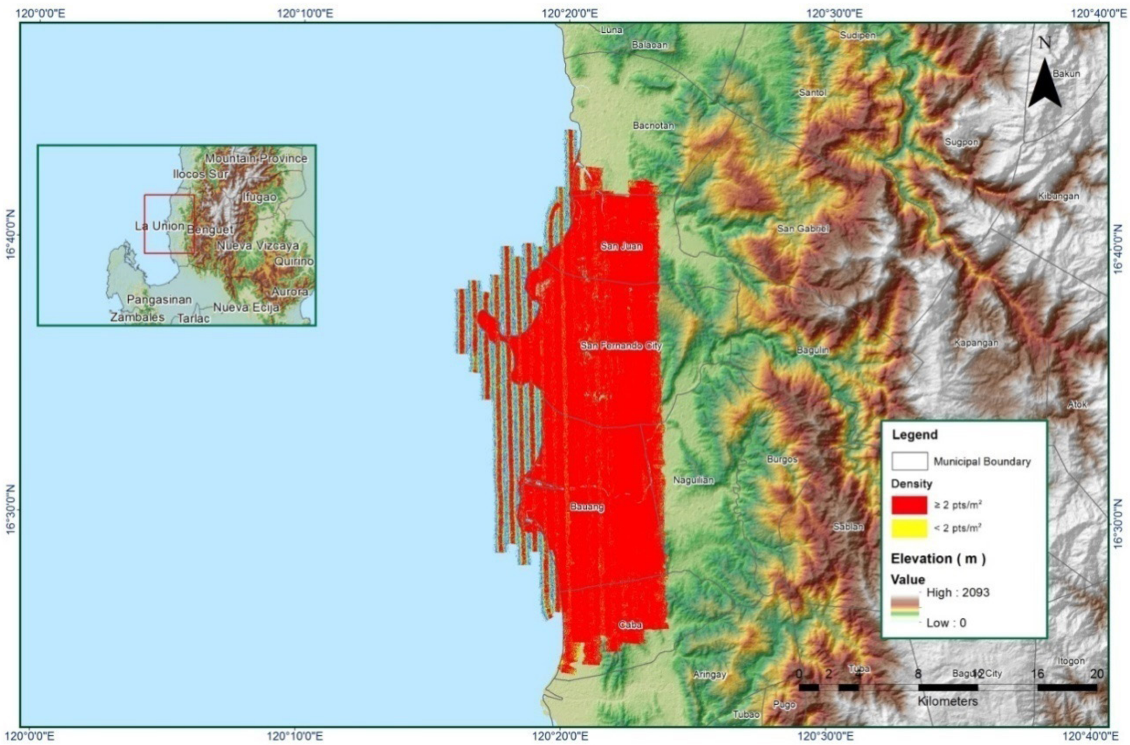


Figure A-8.33 Density map of merged LIDAR data

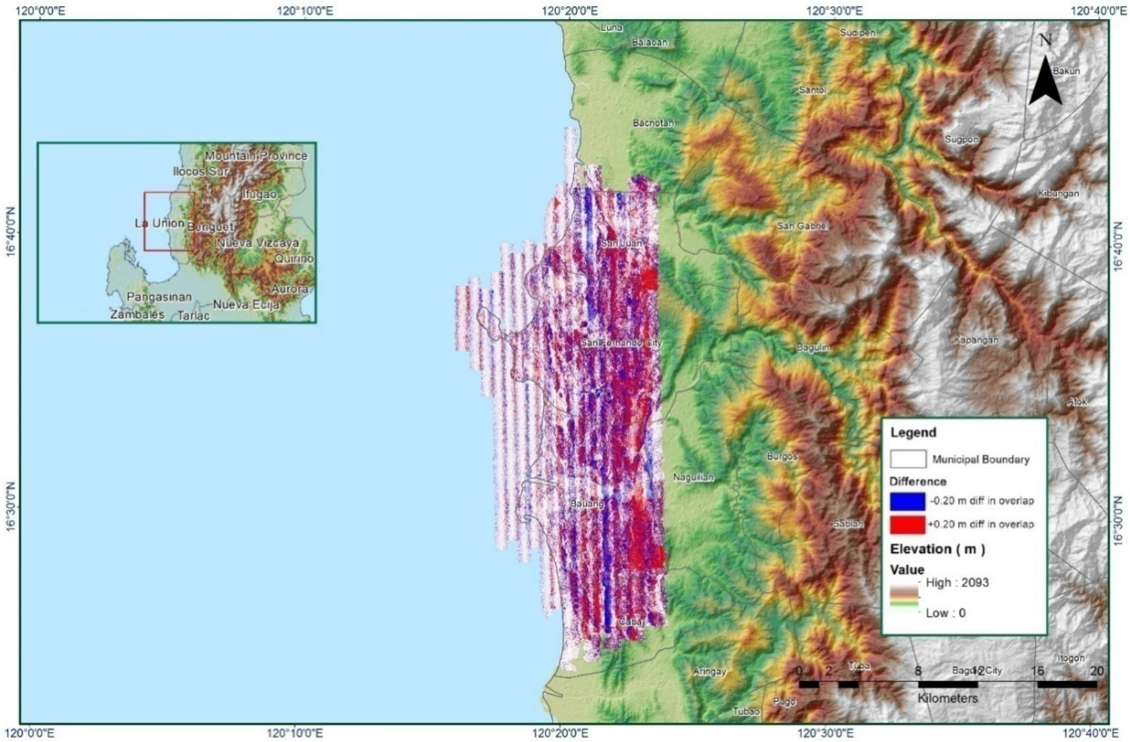


Figure A-8.34 Elevation difference between flight lines

Annex 9. Baroro Model Basin Parameters

Table A-9.1. Baroro Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (m^3/s)	Recession Constant	Threshold Type	Ratio to Peak
W160	36.093	37.3771	0	0.28198	0.230095	Discharge	0.14674	0.0024	Ratio to Peak	0.0024
W170	15.675	45.0200	0	0.16613	0.082987	Discharge	0.081902	0.034716	Ratio to Peak	0.003332
W180	171.39	54.9000	0	5.5295	10.054	Discharge	0.19312	0.023898	Ratio to Peak	0.012258
W190	48.441	99.0000	0	0.12245	0.066617	Discharge	0.019355	0.027288	Ratio to Peak	0.002412
W200	13.5185	39.5750	0	0.37088	0.30264	Discharge	0.043332	0.0024	Ratio to Peak	0.0024
W210	10.747	35.1110	0	0.50398	0.18694	Discharge	0.10947	0.035582	Ratio to Peak	0.002112
W220	23.762	34.9291	0	0.24009	0.195915	Discharge	0.045599	0.0024	Ratio to Peak	0.0024
W230	10.259	35.2030	0	0.16319	0.43711	Discharge	0.1669	0.037694	Ratio to Peak	0.0000584
W240	18.113	37.3469	0	0.29659	0.242015	Discharge	0.11951	0.0024	Ratio to Peak	0.0024
W250	17.685	35.0410	0	0.13073	0.071117	Discharge	0.005058	0.036847	Ratio to Peak	0.002352
W270	44.911	41.4120	0	0.14864	0.073302	Discharge	0.009077	0.03863	Ratio to Peak	0.001004
W280	14.025	48.5330	0	0.11715	0.072772	Discharge	0.055782	0.03865	Ratio to Peak	0.000465
W290	4.3896	37.6370	0	0.13641	0.69863	Discharge	0.098031	0.038587	Ratio to Peak	0.000274
W300	14.387	35.1590	0	0.85212	0.076	Discharge	0.27645	0.002327	Ratio to Peak	0.001864
W320	7.8485	42.7200	0	0.1403	0.42844	Discharge	0.005797	0.0024	Ratio to Peak	0.0024
W330	65.129	40.1410	0	0.069469	0.056685	Discharge	0.01476	0.037753	Ratio to Peak	0.0024

Annex 10. Baroro Model Reach Parameters

Table A-10.1. Labo Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
148R	Automatic Fixed Interval	474.56	0.0037952	0.893218	Trapezoid	129.9	1
152R	Automatic Fixed Interval	1706.4	0.0067092	0.314615	Trapezoid	55.9	1
153R	Automatic Fixed Interval	1051.5	0.0217082	0.175665	Trapezoid	43	1
155R	Automatic Fixed Interval	1371.7	0.000544662	0.090754	Trapezoid	135	1
157R	Automatic Fixed Interval	1619.5	0.000445326	0.084	Trapezoid	96	1
164R	Automatic Fixed Interval	3342.1	0.0001	0.084	Trapezoid	78	1
166R	Automatic Fixed Interval	11739	0.0224938	0.072043	Trapezoid	83.5	1
167R	Automatic Fixed Interval	1519.7	0.000311269	0.084	Trapezoid	119	1

Annex 11. Baroro Field Validation Points

Table A-11.1. Baroro Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	16.71132	120.338784	0.520	0.457	0.004	Egay/ July 4-8, 2015	5-Year
2	16.715582	120.361907	0.050	0.914	0.747	Egay/ July 4-8, 2015	5-Year
3	16.715582	120.361907	0.050	1.067	1.034	Egay/ July 4-8, 2015	5-Year
4	16.715582	120.361907	0.050	1.067	1.034	Egay/ July 4-8, 2015	5-Year
5	16.7128	120.371208	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
6	16.712372	120.3714	0.120	0.457	0.114	Egay/ July 4-8, 2015	5-Year
7	16.711973	120.370996	0.050	2.000	3.803	Egay/ July 4-8, 2015	5-Year
8	16.711604	120.370183	0.040	3.000	8.762	Egay/ July 4-8, 2015	5-Year
9	16.712794	120.370725	0.040	1.000	0.922	Egay/ July 4-8, 2015	5-Year
10	16.713434	120.370307	0.090	0.610	0.270	Egay/ July 4-8, 2015	5-Year
11	16.712319	120.370062	0.130	0.914	0.615	Egay/ July 4-8, 2015	5-Year
12	16.71132	120.338784	0.520	2.000	2.190	Egay/ July 4-8, 2015	5-Year
13	16.711406	120.371488	0.040	1.067	1.054	Egay/ July 4-8, 2015	5-Year
14	16.700866	120.374236	0.050	2.000	3.803	Egay/ July 4-8, 2015	5-Year
15	16.699177	120.372884	0.420	0.610	0.036	Egay/ July 4-8, 2015	5-Year
16	16.71132	120.338784	0.520	3.000	6.150	Egay/ July 4-8, 2015	5-Year
17	16.699177	120.372884	0.420	0.457	0.001	Egay/ July 4-8, 2015	5-Year
18	16.699177	120.372884	0.420	0.610	0.036	Egay/ July 4-8, 2015	5-Year
19	16.699177	120.372884	0.420	0.610	0.036	Egay/ July 4-8, 2015	5-Year
20	16.699177	120.372884	0.420	1.000	0.336	Egay/ July 4-8, 2015	5-Year
21	16.699177	120.372884	0.420	0.610	0.036	Egay/ July 4-8, 2015	5-Year
22	16.699177	120.372884	0.420	0.914	0.244	Egay/ July 4-8, 2015	5-Year
23	16.699177	120.372884	0.420	1.067	0.418	Egay/ July 4-8, 2015	5-Year
24	16.696903	120.371447	0.460	0.610	0.022	Egay/ July 4-8, 2015	5-Year
25	16.696903	120.371447	0.460	0.457	0.000	Egay/ July 4-8, 2015	5-Year
26	16.696903	120.371447	0.460	0.610	0.022	Egay/ July 4-8, 2015	5-Year
27	16.71132	120.338784	0.520	1.000	0.230	Egay/ July 4-8, 2015	5-Year
28	16.696903	120.371447	0.460	0.610	0.022	Egay/ July 4-8, 2015	5-Year
29	16.696903	120.371447	0.460	1.000	0.292	Egay/ July 4-8, 2015	5-Year
30	16.696903	120.371447	0.460	0.610	0.022	Egay/ July 4-8, 2015	5-Year
31	16.696903	120.371447	0.460	0.914	0.206	Egay/ July 4-8, 2015	5-Year
32	16.696903	120.371447	0.460	1.067	0.368	Egay/ July 4-8, 2015	5-Year
33	16.7076	120.362643	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
34	16.70654	120.363884	0.270	0.457	0.035	Egay/ July 4-8, 2015	5-Year
35	16.706642	120.363437	0.330	2.000	2.789	Egay/ July 4-8, 2015	5-Year
36	16.70558	120.364456	0.030	3.000	8.821	Egay/ July 4-8, 2015	5-Year
37	16.707238	120.362387	0.030	1.000	0.941	Egay/ July 4-8, 2015	5-Year
38	16.71132	120.338784	0.520	0.610	0.008	Egay/ July 4-8, 2015	5-Year
39	16.703284	120.361512	0.030	0.610	0.336	Egay/ July 4-8, 2015	5-Year
40	16.702429	120.361895	0.030	0.914	0.782	Egay/ July 4-8, 2015	5-Year
41	16.7034	120.36218	0.090	1.067	0.954	Egay/ July 4-8, 2015	5-Year
42	16.719881	120.355146	0.710	2.000	1.664	Egay/ July 4-8, 2015	5-Year
43	16.719881	120.355146	0.710	0.457	0.064	Egay/ July 4-8, 2015	5-Year
44	16.719881	120.355146	0.710	2.000	1.664	Egay/ July 4-8, 2015	5-Year
45	16.719881	120.355146	0.710	3.000	5.244	Egay/ July 4-8, 2015	5-Year

46	16.719881	120.355146	0.710	1.000	0.084	Egay/ July 4-8, 2015	5-Year
47	16.719881	120.355146	0.710	0.610	0.010	Egay/ July 4-8, 2015	5-Year
48	16.719881	120.355146	0.710	0.914	0.042	Egay/ July 4-8, 2015	5-Year
49	16.71132	120.338784	0.520	0.914	0.156	Egay/ July 4-8, 2015	5-Year
50	16.719881	120.355146	0.710	1.067	0.127	Egay/ July 4-8, 2015	5-Year
51	16.710082	120.340127	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
52	16.710082	120.340127	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
53	16.710082	120.340127	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
54	16.710082	120.340127	0.030	3.000	8.821	Egay/ July 4-8, 2015	5-Year
55	16.710082	120.340127	0.030	1.000	0.941	Egay/ July 4-8, 2015	5-Year
56	16.710082	120.340127	0.030	0.610	0.336	Egay/ July 4-8, 2015	5-Year
57	16.710082	120.340127	0.030	0.914	0.782	Egay/ July 4-8, 2015	5-Year
58	16.710082	120.340127	0.030	1.067	1.075	Egay/ July 4-8, 2015	5-Year
59	16.714974	120.345861	1.360	2.000	0.410	Egay/ July 4-8, 2015	5-Year
60	16.71132	120.338784	0.520	1.067	0.299	Egay/ July 4-8, 2015	5-Year
61	16.714974	120.345861	1.360	0.457	0.815	Egay/ July 4-8, 2015	5-Year
62	16.714974	120.345861	1.360	2.000	0.410	Egay/ July 4-8, 2015	5-Year
63	16.714974	120.345861	1.360	3.000	2.690	Egay/ July 4-8, 2015	5-Year
64	16.714974	120.345861	1.360	1.000	0.130	Egay/ July 4-8, 2015	5-Year
65	16.714974	120.345861	1.360	0.610	0.563	Egay/ July 4-8, 2015	5-Year
66	16.714974	120.345861	1.360	0.914	0.199	Egay/ July 4-8, 2015	5-Year
67	16.714974	120.345861	1.360	1.067	0.086	Egay/ July 4-8, 2015	5-Year
68	16.711973	120.345304	0.960	2.000	1.082	Egay/ July 4-8, 2015	5-Year
69	16.711973	120.345304	0.960	0.457	0.253	Egay/ July 4-8, 2015	5-Year
70	16.711973	120.345304	0.960	2.000	1.082	Egay/ July 4-8, 2015	5-Year

71	16.708517	120.340418	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
72	16.711973	120.345304	0.960	3.000	4.162	Egay/ July 4-8, 2015	5-Year
73	16.711973	120.345304	0.960	1.000	0.002	Egay/ July 4-8, 2015	5-Year
74	16.711973	120.345304	0.960	0.610	0.123	Egay/ July 4-8, 2015	5-Year
75	16.711973	120.345304	0.960	0.914	0.002	Egay/ July 4-8, 2015	5-Year
76	16.711973	120.345304	0.960	1.067	0.011	Egay/ July 4-8, 2015	5-Year
77	16.710445	120.3383	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
78	16.710445	120.3383	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
79	16.710445	120.3383	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
80	16.710445	120.3383	0.030	3.000	8.821	Egay/ July 4-8, 2015	5-Year
81	16.710445	120.3383	0.030	1.000	0.941	Egay/ July 4-8, 2015	5-Year
82	16.708238	120.340992	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
83	16.710445	120.3383	0.030	0.610	0.336	Egay/ July 4-8, 2015	5-Year
84	16.710445	120.3383	0.030	0.914	0.782	Egay/ July 4-8, 2015	5-Year
85	16.710445	120.3383	0.030	1.067	1.075	Egay/ July 4-8, 2015	5-Year
86	16.71472	120.344328	2.340	2.000	0.116	Egay/ July 4-8, 2015	5-Year
87	16.71472	120.344328	2.340	0.457	3.545	Egay/ July 4-8, 2015	5-Year
88	16.71472	120.344328	2.340	2.000	0.116	Egay/ July 4-8, 2015	5-Year
89	16.71472	120.344328	2.340	3.000	0.436	Egay/ July 4-8, 2015	5-Year
90	16.71472	120.344328	2.340	1.000	1.796	Egay/ July 4-8, 2015	5-Year
91	16.71472	120.344328	2.340	0.610	2.994	Egay/ July 4-8, 2015	5-Year
92	16.71472	120.344328	2.340	0.914	2.032	Egay/ July 4-8, 2015	5-Year

93	16.70797	120.340624	0.530	2.000	2.161	Egay/ July 4-8, 2015	5-Year
94	16.71472	120.344328	2.340	1.067	1.621	Egay/ July 4-8, 2015	5-Year
95	16.718172	120.34019	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
96	16.718172	120.34019	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
97	16.718172	120.34019	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
98	16.718172	120.34019	0.030	3.000	8.821	Egay/ July 4-8, 2015	5-Year
99	16.718172	120.34019	0.030	1.000	0.941	Egay/ July 4-8, 2015	5-Year
100	16.718172	120.34019	0.030	0.610	0.336	Egay/ July 4-8, 2015	5-Year
101	16.718172	120.34019	0.030	0.914	0.782	Egay/ July 4-8, 2015	5-Year
102	16.718172	120.34019	0.030	1.067	1.075	Egay/ July 4-8, 2015	5-Year
103	16.714799	120.346261	0.660	2.000	1.796	Egay/ July 4-8, 2015	5-Year
104	16.714799	120.346261	0.660	0.457	0.041	Egay/ July 4-8, 2015	5-Year
105	16.714799	120.346261	0.660	2.000	1.796	Egay/ July 4-8, 2015	5-Year
106	16.714799	120.346261	0.660	3.000	5.476	Egay/ July 4-8, 2015	5-Year
107	16.714799	120.346261	0.660	1.000	0.116	Egay/ July 4-8, 2015	5-Year
108	16.714799	120.346261	0.660	0.610	0.003	Egay/ July 4-8, 2015	5-Year
109	16.714799	120.346261	0.660	0.914	0.065	Egay/ July 4-8, 2015	5-Year
110	16.714799	120.346261	0.660	1.067	0.165	Egay/ July 4-8, 2015	5-Year
111	16.716183	120.34412	2.410	0.457	3.813	Lawin/ October 18-22, 2016	5-Year
112	16.717215	120.345408	1.760	0.457	1.697	Lawin/ October 18-22, 2016	5-Year
113	16.71948	120.342402	0.710	0.457	0.064	Lawin/ October 18-22, 2016	5-Year
114	16.709114	120.34041	0.030	1.000	0.941	Egay/ July 4-8, 2015	5-Year
115	16.716183	120.34412	2.410	2.000	0.168	Egay/ July 4-8, 2015	5-Year
116	16.716183	120.34412	2.410	0.457	3.813	Egay/ July 4-8, 2015	5-Year
117	16.716183	120.34412	2.410	0.457	3.813	Egay/ July 4-8, 2015	5-Year

118	16.716183	120.34412	2.410	2.000	0.168	Egay/ July 4-8, 2015	5-Year
119	16.716183	120.34412	2.410	2.000	0.168	Egay/ July 4-8, 2015	5-Year
120	16.716183	120.34412	2.410	3.000	0.348	Egay/ July 4-8, 2015	5-Year
121	16.716183	120.34412	2.410	3.000	0.348	Egay/ July 4-8, 2015	5-Year
122	16.716183	120.34412	2.410	1.000	1.988	Egay/ July 4-8, 2015	5-Year
123	16.716183	120.34412	2.410	1.000	1.988	Egay/ July 4-8, 2015	5-Year
124	16.716183	120.34412	2.410	0.610	3.241	Egay/ July 4-8, 2015	5-Year
125	16.716183	120.34412	2.410	0.610	3.241	Egay/ July 4-8, 2015	5-Year
126	16.716183	120.34412	2.410	0.914	2.237	Egay/ July 4-8, 2015	5-Year
127	16.716183	120.34412	2.410	0.914	2.237	Egay/ July 4-8, 2015	5-Year
128	16.716183	120.34412	2.410	1.067	1.804	Egay/ July 4-8, 2015	5-Year
129	16.716183	120.34412	2.410	1.067	1.804	Egay/ July 4-8, 2015	5-Year
130	16.717215	120.345408	1.760	2.000	0.058	Egay/ July 4-8, 2015	5-Year
131	16.717215	120.345408	1.760	0.457	1.697	Egay/ July 4-8, 2015	5-Year
132	16.717215	120.345408	1.760	0.457	1.697	Egay/ July 4-8, 2015	5-Year
133	16.717215	120.345408	1.760	2.000	0.058	Egay/ July 4-8, 2015	5-Year
134	16.717215	120.345408	1.760	2.000	0.058	Egay/ July 4-8, 2015	5-Year
135	16.707889	120.341766	0.030	0.914	0.782	Egay/ July 4-8, 2015	5-Year
136	16.717215	120.345408	1.760	3.000	1.538	Egay/ July 4-8, 2015	5-Year
137	16.717215	120.345408	1.760	3.000	1.538	Egay/ July 4-8, 2015	5-Year
138	16.717215	120.345408	1.760	1.000	0.578	Egay/ July 4-8, 2015	5-Year
139	16.717215	120.345408	1.760	1.000	0.578	Egay/ July 4-8, 2015	5-Year
140	16.717215	120.345408	1.760	0.610	1.323	Egay/ July 4-8, 2015	5-Year
141	16.717215	120.345408	1.760	0.610	1.323	Egay/ July 4-8, 2015	5-Year
142	16.717215	120.345408	1.760	0.914	0.715	Egay/ July 4-8, 2015	5-Year
143	16.717215	120.345408	1.760	0.914	0.715	Egay/ July 4-8, 2015	5-Year
144	16.717215	120.345408	1.760	1.067	0.481	Egay/ July 4-8, 2015	5-Year
145	16.717215	120.345408	1.760	1.067	0.481	Egay/ July 4-8, 2015	5-Year
146	16.709365	120.341348	0.080	1.067	0.974	Egay/ July 4-8, 2015	5-Year
147	16.71948	120.342402	0.710	2.000	1.664	Egay/ July 4-8, 2015	5-Year
148	16.71948	120.342402	0.710	0.457	0.064	Egay/ July 4-8, 2015	5-Year
149	16.71948	120.342402	0.710	0.457	0.064	Egay/ July 4-8, 2015	5-Year
150	16.71948	120.342402	0.710	2.000	1.664	Egay/ July 4-8, 2015	5-Year
151	16.71948	120.342402	0.710	2.000	1.664	Egay/ July 4-8, 2015	5-Year
152	16.71948	120.342402	0.710	3.000	5.244	Egay/ July 4-8, 2015	5-Year
153	16.71948	120.342402	0.710	3.000	5.244	Egay/ July 4-8, 2015	5-Year
154	16.71948	120.342402	0.710	1.000	0.084	Egay/ July 4-8, 2015	5-Year
155	16.71948	120.342402	0.710	1.000	0.084	Egay/ July 4-8, 2015	5-Year
156	16.71948	120.342402	0.710	0.610	0.010	Egay/ July 4-8, 2015	5-Year
157	16.704728	120.349558	0.620	2.000	1.904	Egay/ July 4-8, 2015	5-Year
158	16.71948	120.342402	0.710	0.610	0.010	Egay/ July 4-8, 2015	5-Year
159	16.71948	120.342402	0.710	0.914	0.042	Egay/ July 4-8, 2015	5-Year
160	16.71948	120.342402	0.710	0.914	0.042	Egay/ July 4-8, 2015	5-Year
161	16.71948	120.342402	0.710	1.067	0.127	Egay/ July 4-8, 2015	5-Year
162	16.71948	120.342402	0.710	1.067	0.127	Egay/ July 4-8, 2015	5-Year
163	16.710776	120.368355	0.110	0.457	0.121	Egay/ July 4-8, 2015	5-Year
164	16.710776	120.368355	0.110	2.000	3.572	Egay/ July 4-8, 2015	5-Year
165	16.710776	120.368355	0.110	3.000	8.352	Egay/ July 4-8, 2015	5-Year
166	16.710776	120.368355	0.110	1.000	0.792	Egay/ July 4-8, 2015	5-Year
167	16.710776	120.368355	0.110	0.610	0.250	Egay/ July 4-8, 2015	5-Year
168	16.710776	120.368355	0.110	0.914	0.647	Egay/ July 4-8, 2015	5-Year

169	16.710776	120.368355	0.110	1.067	0.915	Egay/ July 4-8, 2015	5-Year
170	16.701214	120.374777	0.030	0.610	0.336	Egay/ July 4-8, 2015	5-Year
171	16.7022	120.37335	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
172	16.708828	120.367519	0.130	0.610	0.230	Egay/ July 4-8, 2015	5-Year
173	16.708828	120.367519	0.130	0.610	0.230	Egay/ July 4-8, 2015	5-Year
174	16.708828	120.367519	0.130	1.000	0.757	Egay/ July 4-8, 2015	5-Year
175	16.708828	120.367519	0.130	0.610	0.230	Egay/ July 4-8, 2015	5-Year
176	16.708828	120.367519	0.130	0.914	0.615	Egay/ July 4-8, 2015	5-Year
177	16.703186	120.350447	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
178	16.708828	120.367519	0.130	0.610	0.230	Egay/ July 4-8, 2015	5-Year
179	16.711449	120.369185	0.100	2.000	3.610	Egay/ July 4-8, 2015	5-Year
180	16.711449	120.369185	0.100	0.457	0.128	Egay/ July 4-8, 2015	5-Year
181	16.711449	120.369185	0.100	2.000	3.610	Egay/ July 4-8, 2015	5-Year
182	16.711449	120.369185	0.100	3.000	8.410	Egay/ July 4-8, 2015	5-Year
183	16.711449	120.369185	0.100	1.000	0.810	Egay/ July 4-8, 2015	5-Year
184	16.711449	120.369185	0.100	0.610	0.260	Egay/ July 4-8, 2015	5-Year
185	16.711449	120.369185	0.100	0.914	0.663	Egay/ July 4-8, 2015	5-Year
186	16.711449	120.369185	0.100	1.067	0.935	Egay/ July 4-8, 2015	5-Year
187	16.705398	120.349623	0.030	3.000	8.821	Egay/ July 4-8, 2015	5-Year
188	16.70366	120.350193	0.030	1.000	0.941	Egay/ July 4-8, 2015	5-Year
189	16.711081	120.349659	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
190	16.711081	120.349659	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
191	16.711081	120.349659	0.030	2.000	3.881	Egay/ July 4-8, 2015	5-Year
192	16.711081	120.349659	0.030	3.000	8.821	Egay/ July 4-8, 2015	5-Year
193	16.711081	120.349659	0.030	1.000	0.941	Egay/ July 4-8, 2015	5-Year
194	16.711081	120.349659	0.030	0.610	0.336	Egay/ July 4-8, 2015	5-Year
195	16.711081	120.349659	0.030	0.914	0.782	Egay/ July 4-8, 2015	5-Year
196	16.711081	120.349659	0.030	1.067	1.075	Egay/ July 4-8, 2015	5-Year
197	16.709938	120.350724	0.640	2.000	1.850	Egay/ July 4-8, 2015	5-Year
198	16.709938	120.350724	0.640	0.457	0.033	Egay/ July 4-8, 2015	5-Year
199	16.709938	120.350724	0.640	2.000	1.850	Egay/ July 4-8, 2015	5-Year
200	16.709938	120.350724	0.640	3.000	5.570	Egay/ July 4-8, 2015	5-Year
201	16.709938	120.350724	0.640	1.000	0.130	Egay/ July 4-8, 2015	5-Year
202	16.709938	120.350724	0.640	0.610	0.001	Egay/ July 4-8, 2015	5-Year
203	16.709938	120.350724	0.640	0.914	0.075	Egay/ July 4-8, 2015	5-Year
204	16.709938	120.350724	0.640	1.067	0.182	Egay/ July 4-8, 2015	5-Year
205	16.71132	120.338784	0.520	0.610	0.008	Mario/ September 18-22, 2014	5-Year
206	16.71132	120.338784	0.520	0.914	0.156	Mario/ September 18-22, 2014	5-Year
207	16.708954	120.340957	0.390	0.610	0.048	Mario/ September 18-22, 2014	5-Year
208	16.708348	120.340048	0.050	0.914	0.747	Mario/ September 18-22, 2014	5-Year
209	16.711081	120.349659	0.030	0.610	0.336	Mario/ September 18-22, 2014	5-Year
210	16.711081	120.349659	0.030	0.914	0.782	Mario/ September 18-22, 2014	5-Year
211	16.709938	120.350724	0.640	0.610	0.001	Mario/ September 18-22, 2014	5-Year
212	16.709938	120.350724	0.640	0.914	0.075	Mario/ September 18-22, 2014	5-Year
213	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
214	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
215	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
216	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
217	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
218	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
219	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year

220	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
221	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
222	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
223	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
224	16.708586	120.341783	0.060	0.914	0.730	Egay/ July 4-8, 2015	5-Year
225	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
226	16.708586	120.341783	0.060	0.152	0.009	Egay/ July 4-8, 2015	5-Year
227	16.715619	120.362923	0.210	0.457	0.061	Egay/ July 4-8, 2015	5-Year
228	16.715619	120.362923	0.210	0.457	0.061	Egay/ July 4-8, 2015	5-Year
229	16.715619	120.362923	0.210	0.457	0.061	Egay/ July 4-8, 2015	5-Year
230	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
231	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
232	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
233	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
234	16.715619	120.362923	0.210	1.000	0.624	Egay/ July 4-8, 2015	5-Year
235	16.715619	120.362923	0.210	1.000	0.624	Egay/ July 4-8, 2015	5-Year
236	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
237	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
238	16.715619	120.362923	0.210	0.914	0.496	Egay/ July 4-8, 2015	5-Year
239	16.715619	120.362923	0.210	0.914	0.496	Egay/ July 4-8, 2015	5-Year
240	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
241	16.715619	120.362923	0.210	0.610	0.160	Egay/ July 4-8, 2015	5-Year
242	16.714225	120.362285	0.040	0.457	0.174	Egay/ July 4-8, 2015	5-Year
243	16.716523	120.359836	2.410	0.457	3.813	Egay/ July 4-8, 2015	5-Year
244	16.71132	120.338784	0.520	2.000	2.190	Egay/ July 4-8, 2015	5-Year
245	16.715582	120.361907	0.050	0.457	0.166	Egay/ July 4-8, 2015	5-Year
246	16.715582	120.361907	0.050	2.000	3.803	Egay/ July 4-8, 2015	5-Year
247	16.715582	120.361907	0.050	2.000	3.803	Egay/ July 4-8, 2015	5-Year
248	16.715582	120.361907	0.050	3.000	8.703	Egay/ July 4-8, 2015	5-Year
249	16.715582	120.361907	0.050	3.000	8.703	Egay/ July 4-8, 2015	5-Year
250	16.715582	120.361907	0.050	1.000	0.903	Egay/ July 4-8, 2015	5-Year
251	16.715582	120.361907	0.050	1.000	0.903	Egay/ July 4-8, 2015	5-Year
252	16.715582	120.361907	0.050	0.610	0.313	Egay/ July 4-8, 2015	5-Year
253	16.715582	120.361907	0.050	0.610	0.313	Egay/ July 4-8, 2015	5-Year
254	16.715582	120.361907	0.050	0.914	0.747	Egay/ July 4-8, 2015	5-Year
				3	1.176413		

Annex 12. Educational Institutions Affected by Flooding in Baroro Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Labo Floodplain – Bacnotan, La Union

La Union				
Bacnotan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
STA. VERONICA COLLEGE	Baroro			
BRGY. LISQUEB DAY CARE CENTER	Bussaoit			
ZARAGOSA ELEMENTARY SCHOOL	Bussaoit			
LEGLEG ELEMENTARY SCHOOL	Legleg			
BARORO ELEMENTARY SCHOOL	Nagsimbaanan			
BACNOTAN NATIONAL HIGH SCHOOL	Poblacion			
BACNOTAN NHS	Poblacion			
LORD OF ZION DIVINE SCHOOL	Poblacion			
PARATONG ELEMENTARY SCHOOL	Poblacion		Low	Low
BACNOTAN CENTRAL SCHOOL	Raois			
ZARAGOSA ES	Zaragosa			
San Fernando				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BALBALLOSA ES	Baraoas	Low	Low	Low
San Gabriel				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
SAN GABRIEL VOCATIONAL HIGH SCHOOL	Poblacion	Low	Low	Low
SAN GABRIEL VOCATIONAL HIGH SCHOOL	Poblacion			
San Juan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BACSAYAN ES	Bacsayan			
BUGBUGCAO ES	Bugbugcao			
CABAROAN ELEMENTARY SCHOOL	Cabaroan	High	High	High
SAN GABRIEL ACADEMY	Cabaroan	Medium	High	High
BACSAYAN-CABUGNAYAN ELEM. SCHOOL	Cabugnayan	Medium	High	High
DASAY ES	Dasay		Low	Low
CAAGRASAN ELEMENTARY SCHOOL	Duplas			
DUPLAS ELEM. SCHOOL	Duplas			Low
SAN GABRIEL CENTRAL SCHOOL	Naguirangan	Medium	High	High
NAGUITUBAN ES	Nagyubuyuban			

DON EUSEBIO LIM MULTI-PURPOSE HALL (OAQUING DAY CARE CENTER)	Oaquing	High	High	High
NADSAAG ES	Pacpacac	Medium	High	High
SAN FELIPE ELEMENTARY SCHOOL	San Felipe			
STA. ROSA ELEMENTARY SCHOOL	Santa Rosa	High	High	High
STO. ROSARIO NHS	Sinapangan	Medium	High	High

Annex 13. Health Institutions Affected by Flooding in Baroro Floodplain

Table A-13.1. Health Institutions Affected by Flooding in the Labo Floodplain – Bacnotan, La Union

La Union				
Bacnotan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BACNOTAN DISTRICT HOSPITAL	Bulala			
BACNOTAN RHU	Poblacion			
San Juan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
RURAL HEALTH UNIT	Cabaroan	Low	Medium	Medium

DON EUSEBIO LIM MULTI-PURPOSE HALL (OAQUING DAY CARE CENTER)	Oaquing	High	High	High
NADSAAG ES	Pacpacac	Medium	High	High
SAN FELIPE ELEMENTARY SCHOOL	San Felipe			
STA. ROSA ELEMENTARY SCHOOL	Santa Rosa	High	High	High
STO. ROSARIO NHS	Sinapangan	Medium	High	High

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BACNOTAN RHU	Poblacion			
San Juan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
RURAL HEALTH UNIT	Cabaroan	Low	Medium	Medium

DON EUSEBIO LIM MULTI-PURPOSE HALL (OAQUING DAY CARE CENTER)	Oaquing	High	High	High
NADSAAG ES	Pacpacac	Medium	High	High
SAN FELIPE ELEMENTARY SCHOOL	San Felipe			
STA. ROSA ELEMENTARY SCHOOL	Santa Rosa	High	High	High
STO. ROSARIO NHS	Sinapangan	Medium	High	High

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San Juan				
Building Name	**Barangay**	**Rainfall Scenario**		
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RURAL HEALTH UNIT	Cabaroan	Low	Medium	Medium

DON EUSEBIO LIM MULTI-PURPOSE HALL (OAQUING DAY CARE CENTER)	Oaquing	High	High	High
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		5-year	**25-year**	**100-year**
RURAL HEALTH UNIT	Cabaroan	Low	Medium	Medium