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

LiDAR Surveys and Flood Mapping of Casiligan River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

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

Enrico C. Paringit, Dr. Eng., and Prof. Edwin R. Abucay, Joan Pauline P. Talubo

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS" (Paringit, et. Al. 2017).
The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (UPLB). UPLB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 45 river basins in the MIMAROPA Region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Casiligan River Basin

Casiligan River is a 37,651-ha watershed located in Oriental Mindoro. It is bounded on the east by the Pola Bay, in the north by the Municipality of Naujan, on the northwest by Naujan Lake, Socorro Municipality on the west and Pinamalayan Municipality in the south. The entire basin covers 33 barangays including Santa Maria in Naujan, Pagalagala in Pinamalayan; Batuhan, Casiligan, Malibago, Maluanluan, Matulatula, Pahilahan, Panikihan, and Tagbakin in Pola; Bagsok, Bayuin, Bugtong na Tuog, Calubasanhon, Calubayan, Catiningan, Colocmoy, Happy Valley, Leuteboro I, Leuteboro II, Ma. Concepcion, Mabuhay II, Malugay, Matungao, Monteverde, Pasi II, Subaan, Villareal, Zone I, Zone II, Zone III, and Zone IV in Socorro; and Concepcion in Victoria.

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

Casiligan river passes through the municipalities Pola (Batuhan, Calubasanhon, Casiligan, Malibago, Maluanluan, Pahilahan, Panikihan, Tagbakin, Zone I, Zone II) and Socorro (Bagsok, Calocmoy, Calubayan, Catiningan, Leuteboro I and II, Matungao, Monteverde, Zone I to IV). The mouth of the river is densely populated while its outskirts, from the downstream to upstream direction, are dominated by rice paddies and agricultural lands. Based on the 2010 NSO Census of Population and Housing,
Panikihan is the most populated barangay in the area

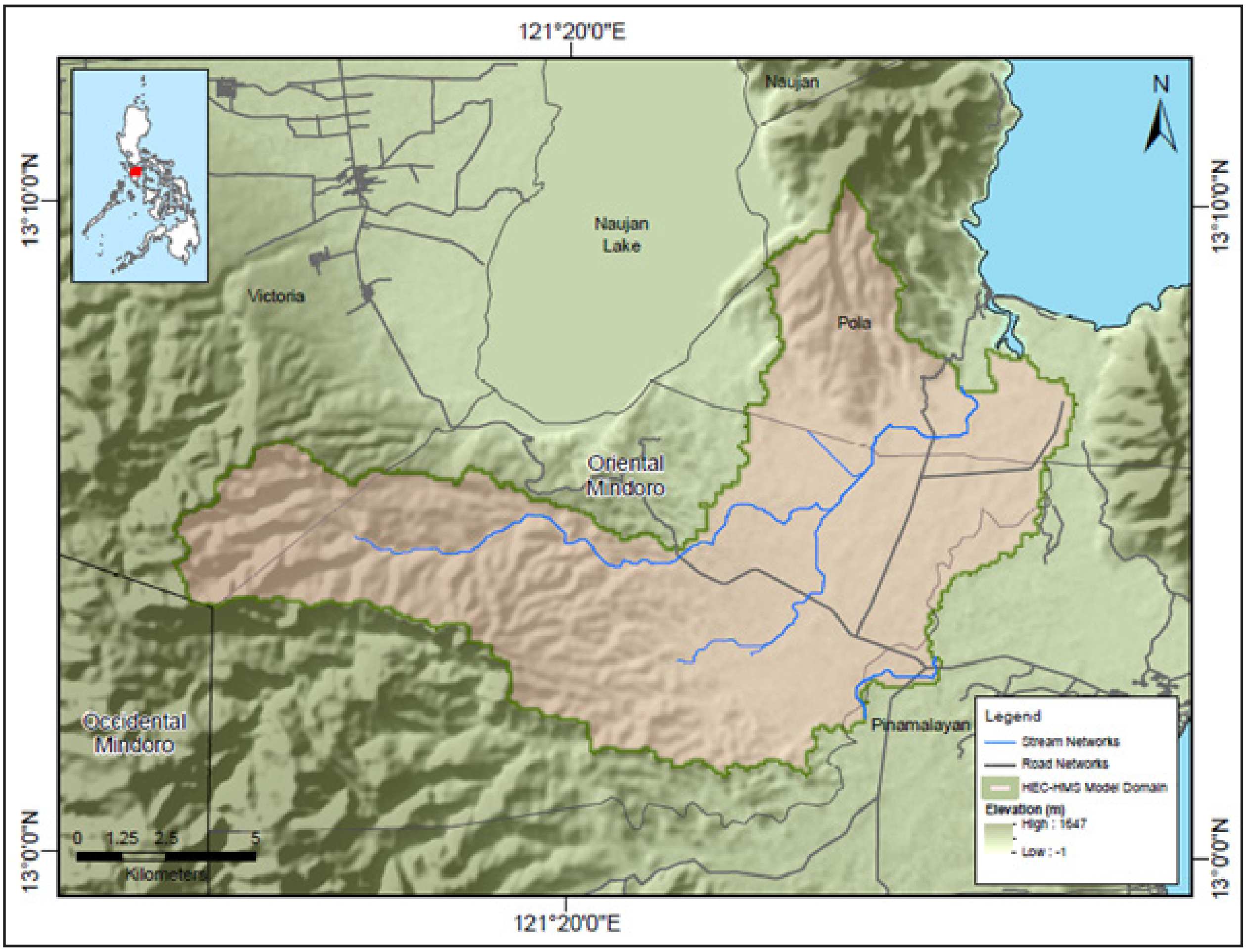

Figure 1. Map of the Casiligan River Basin in brown

Pola exhibits a geomorphologic characteristic that varies from flat alluvial plains to rolling hinterlands, hills and mountainous peaks wherein the two later occupy most of its land area or a four-fifth allocation. Moreover, its highest point is at 594 meter above sea level located at Brgy. Calima and it is primarily drained by the Casiligan and Pula rivers as was stated at the Official Website of Pola, Oriental Mindoro. The geologic classification in the basin area is predominantly Pliocene-Pleistocene, Recent and Pliocene-Quarternary. The soil types that can be found in the area include Bulacan clay loam, Luisiana clay loam, Maranlig gravelly sandy clay loam, Quingua clay loam, San Manuel clay loam, and San Manuel sandy loam. Unclassified soils (rough mountainous land) and Hydrosols can also be found in the area. Owing to its generally flat topography, cultivated area mixed with brushland/grassland occupies large land in the basin area. Other land cover types include crop land mixed with coconut plantation and arable land (crops mainly cereals and sugar).

Based on the studies conducted by the Mines and Geosciences Bureau, no barangay susceptible to flooding. However, all barangays have low to high susceptibilities to flooding. Barangay Batuhan in Pola has high susceptibility to flooding. The field surveys conducted by the PHIL-LiDAR 1 validation team showed only two notable weather disturbances that caused flooding in 2005 (Lando) and 2013 (Yolanda). For landslides, all barangays have varying susceptibilities ranging from low to high. Barangays Bacungan, Pahilahan, Pula, Tagbakin, and Zone I in Pola; Fortuna and Concepcion inSocorro has moderate to high susceptibilities to landslides.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CASILIGAN FLOODPLAIN

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

2.1 Flight Plans

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

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Max Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28A	750	30	36	50	45	130	5
BLK28B	600	30	36	50	45	130	5
BLK28C	600	30	36	50	45	130	5
BLK28D	600	30	36	50	45	130	5
BLK28E	600	30	36	50	45	130	5
BLK28F	600	30	36	50	45	130	5
BLK28G	600	30	36	50	45	130	5
BLK28GS	600	30	36	50	45	130	5
BLK28H	600	30	36	50	45	130	5
BLK28I	600	30	36	50	45	130	5
BLK28J	600	30	36	50	45	130	5

Table 2. Flight planning parameters for Gemini LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Max Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28A	800, 1000, 1200	30	30, 36, 40	100	50	130	5
BLK28AS	800, 1000, 1200	30	30, 36, 40	100	50	130	5
BLK28B	800, 1000, 1200	30	30, 36, 40	100	50	130	5
BLK28C	800, 1000, 1200	30	30, 36, 40	100	50	130	5
BLK28D	800, 1000, 1200	30	30, 36, 40	100	50	130	5
BLK28F	800, 1200	30	30, 40	100	50	130	5
BLK28H	1000	30	36	100	50	130	5
BLK28GS	600	30	36	50	45	130	5
BLK28H	600	30	36	50	45	130	5
BLK28I	600	30	36	50	45	130	5
BLK28J	600	30	36	50	45	130	5

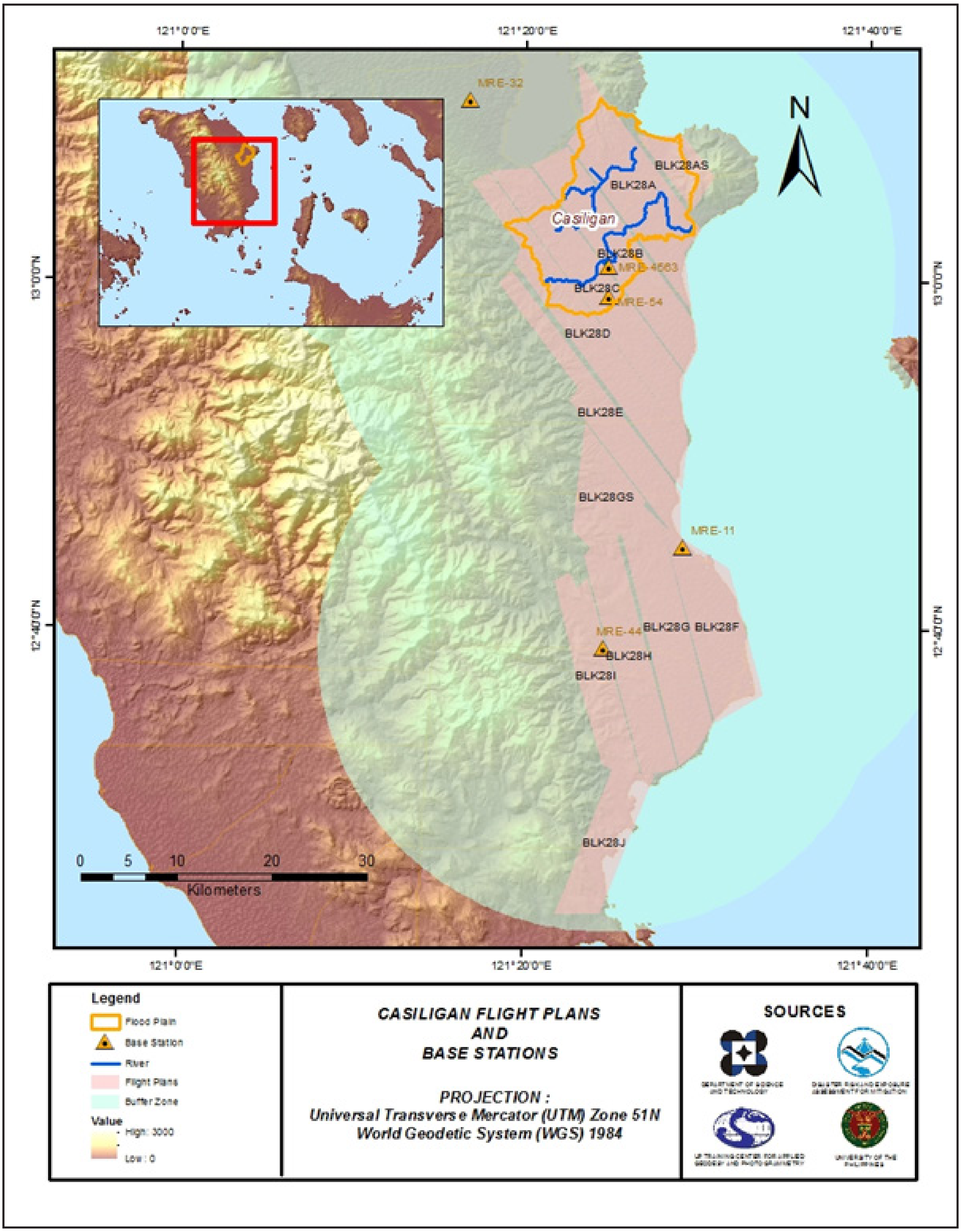


Figure 2. Flight plan and base stations used for Casiligan floodplain.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: MRE-54, MRE-44, and MRE-32 which are of second (2nd) order accuracy. The project team also re-established ground control points MRE-11 which is of third (3rd) order accuracy, and MRE-4563 which is of fourth (4th) order accuracy. The certifications for the NAMRIA reference points are found in Annex 2 the while the baseline processing report for the established ground control point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 2 - 13, 2014 and October 22 - 23, 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 Casiligan floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 7 show the details about the following NAMRIA control stations and established points while Table 8 shows the list of all ground control points occupied during the acquisition together with the dates the corresponding dates of utilization.

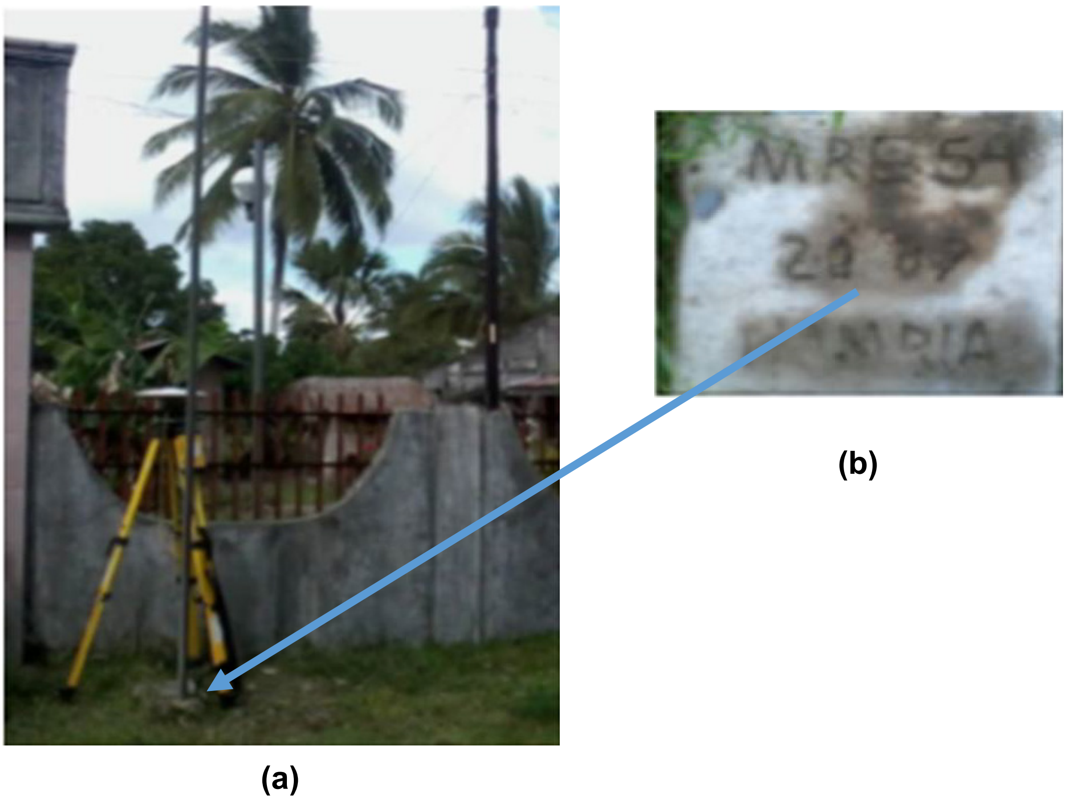
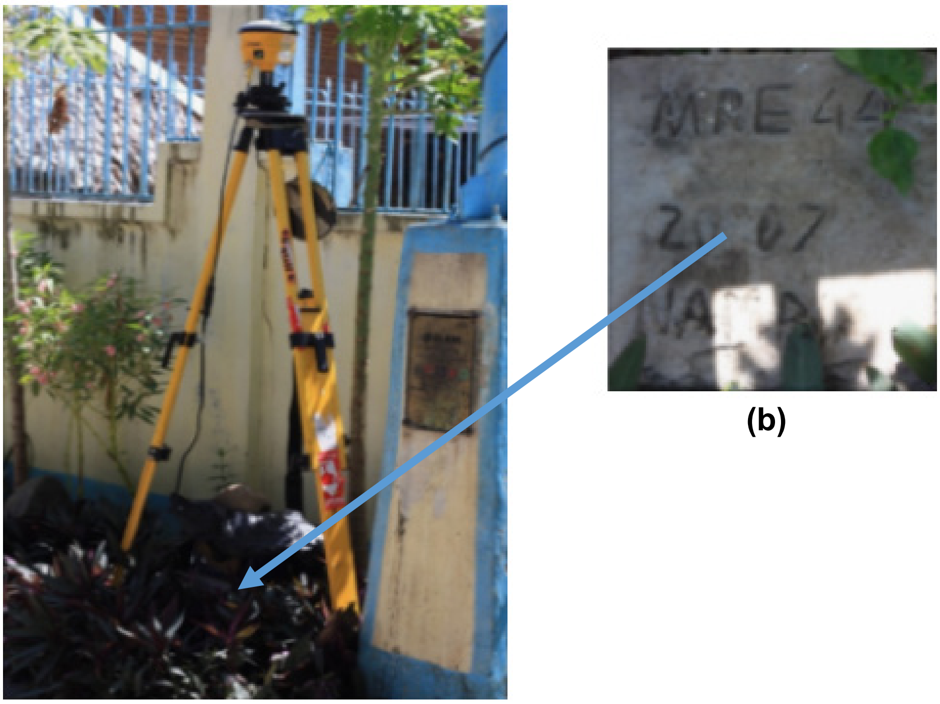


Figure 3. GPS set-up over MRE-54 as recovered inside the compound of the barangay hall of Maliangcog, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-54 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MRE-54 used as base station for the LiDAR acquisition.

Station Name	MRE-54	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°59'12.43671'' North 121°24'46.52637'' East 42.40800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	544797.009 meters 1436124.562 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°59'7.43505'' North 122°41'8.09853'' East 91.39500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	327864.09 meters 1436121.49 meters

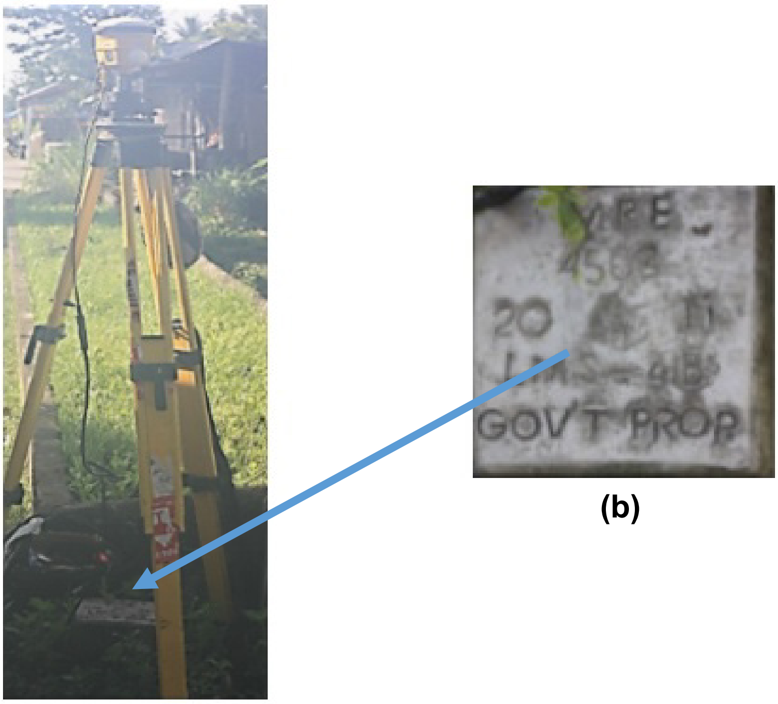


(a) (b)

Figure 4. GPS set-up over MRE-44 as recovered just outside the compound of the barangay hall of Happy Valley, municipality of Roxas, Oriental Mindoro (a) NAMRIA reference point MRE-44 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point MRE-44 used as base station for the LiDAR acquisition.

Station Name	MRE-44	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°38'59.03778" North 121°24'32.60444" East 87.94200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	544436.519 meters 1398838.995 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°38'54.11733" North 121°24'37.66392" East 137.80400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	327214.81 meters 1398840.08 meters



(b)

(a)

Figure 5. GPS set-up over MRE-4563 as recovered, just outside the compound of the barangay hall of Brgy. Pagala-gala, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-4563 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRE-4563 used as base station for the LiDAR acquisition with reprocessed coordinates.

Station Name	MRE-4563	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°00'53.01692'' North 121°24'51.45337'' East 73.715 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	328034.015 meters 1439300.319 meters

Table 6. Details of the recovered NAMRIA horizontal control point MRE-32 used as base station for the LiDAR acquisition.

Station Name	MRE-32	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°10'28.85064'' North 121°16'38.44761'' East 19.49300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	530065.679 meters 1456889.419 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°10'23.79251'' North 121°16'43.46244'' East 67.64700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	313296.85 meters 1457002.75 meters

Table 7. Details of the recovered NAMRIA horizontal control point MRE-11 used as base station for the LiDAR acquisition.

Station Name	MRE-11	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°44'50.41380'' North 121°29'7.80130'' East 5.11500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	552720.766 meters 1409650.153 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°44'45.47630'' North 121°29'12.85191'' East 54.91100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	335581.55 meters 1409587.05 meters

Table 8. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
2-Feb-14	1054A	3BLK28B033B	MRE-54
3-Feb-14	1056A	3BLK28C034A	MRE-54
3-Feb-14	1058A	3BLK28CD034B	MRE-54
5-Feb-14	1066A	3BLK28DS036A	MRE-54, MRE-4563
6-Feb-14	1070A	3BLK28DSE037A	MRE-54, MRE-4563
12-Feb-14	1092A	3BLK28ABES043A	MRE-54, MRE-4563
12-Feb-14	1094A	3BLK28BS043B	MRE-54, MRE-4563
13-Feb-14	1096A	3BLK28NAJ044A	MRE-32, MRE-44
13-Feb-14	1098A	3BLK28JSI044B	MRE-44, MRE-32
22-Oct-15	8300G	2BLK28ABC295A	MRE-54, MRE-11
22-Oct-15	8301G	2BLK28CD295B	MRE-54, MRE-11
23-Oct-15	8302G	2BLK28ASEHI296A	MRE-54, MRE-11

2.3 Flight Missions

Twelve (12) missions were conducted to complete the LiDAR Data Acquisition in Casiligan floodplain, for a total of forty-four hours and forty minutes (44+40) of flying time for RP-C9122 and RP-C9322. All missions were acquired using the Aquarius and Gemini LiDAR systems. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for LiDAR data acquisition in Casiligan floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
2-Feb-14	1054A	103.26	90.45	36.25	54.19	1093	3	41
3-Feb-14	1056A	118.79	89.97	27.81	62.16	1111	3	41
3-Feb-14	1058A	236	100.03	37.61	62.42	1016	3	23
5-Feb-14	1066A	117.20	95.19	15.80	79.38	1088	3	35
6-Feb-14	1070A	204.55	134.14	1.89	132.25	1517	4	29
12-Feb-14	1092A	322.44	225.61	44.87	180.73	1176	4	5
12-Feb-14	1094A	103.26	51.18	20.55	30.62	500	2	29
13-Feb-14	1096A	101.12	102.83	3.83	99.00	571	3	35
13-Feb-14	1098A	248.23	76.86	4.40	72.46	909	3	59
22-Oct-15	8300G	251.55	141.96	91.94	50.02	430	3	50
22-Oct-15	8301G	436.28	176.03	80.18	95.85	776	4	6
23-Oct-15	8302G	366.66	117.20	1.59	115.61	443	3	47
TOTAL		**2609.34**	**1401.43**	**366.73**	**1034.70**	**10630**	**44**	**40**

Table 10. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1054A	1100, 650	30	40	70, 50	50	130	5
1056A	650	30	36	50	50	130	5
1058A	650	30	36	50	50	130	5
1066A	650	30	36	50	40	130	5
1070A	650	30	36	50	40	130	5
1092A	650	30	36	50	40	130	5
1094A	650	30	36	50	40	130	5
1096A	1100	30	30	33	40	130	5
1098A	650	30	36	50	50	130	5
8300G	1200, 1100	30	36	100	50	130	5
8301G	1100	30	30, 36	100	50	130	5
8302G	1300	30	30	100	50	130	5

2.4 Survey Coverage

Casiligan floodplain is located in the province of Oriental Mindoro, with majority of the floodplain situated within the municipality of Socorro. Municipalities of Socorro, Pola, Gloria, and Pinamalayan are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Casiligan floodplain is presented in Figure 5.

Table 11. List of municipalities and cities surveyed during Casiligan floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Oriental Mindoro	Socorro	206.05	151.42	73.48%
	Pola	127.04	89.22	70.23%
	Gloria	327.28	184.91	56.50%
	Pinamalayan	206.87	114.36	55.28%
	Bansud	197.00	60.76	30.84%
	Naujan Lake	76.11	11.79	15.49%
	Roxas	90.14	12.80	14.20%
	Bongabong	493.74	56.70	11.48%
	Naujan	431.57	48.53	11.24%
	Mansalay	477.24	42.10	8.82%
	Victoria	216.22	10.56	4.88%
	Bulalacao	365.58	5.42	1.48%
TOTAL		**1230.49**	**625.26**	**50.81%**

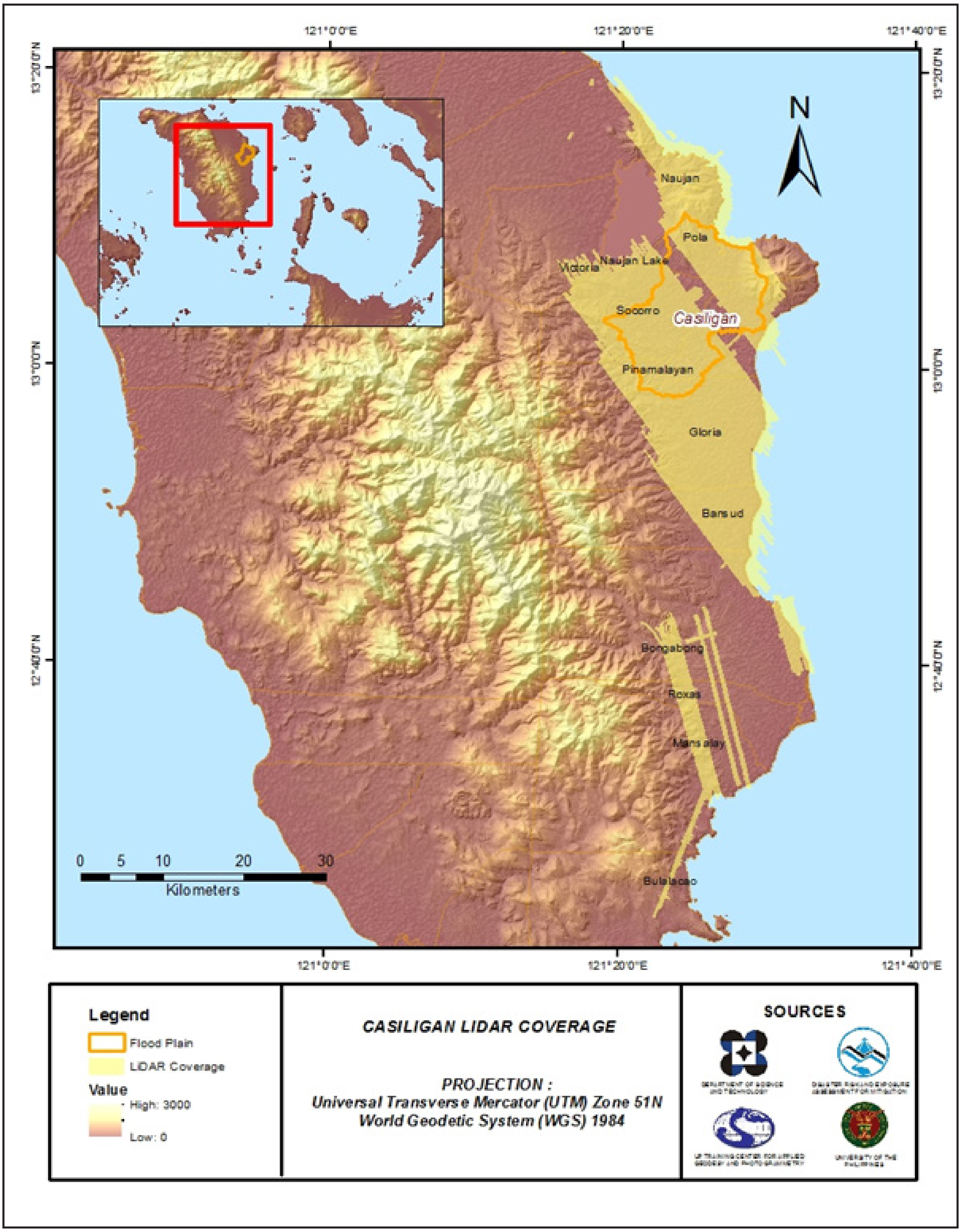


Figure 6. Actual LiDAR survey coverage for Casiligan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE CASILIGAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

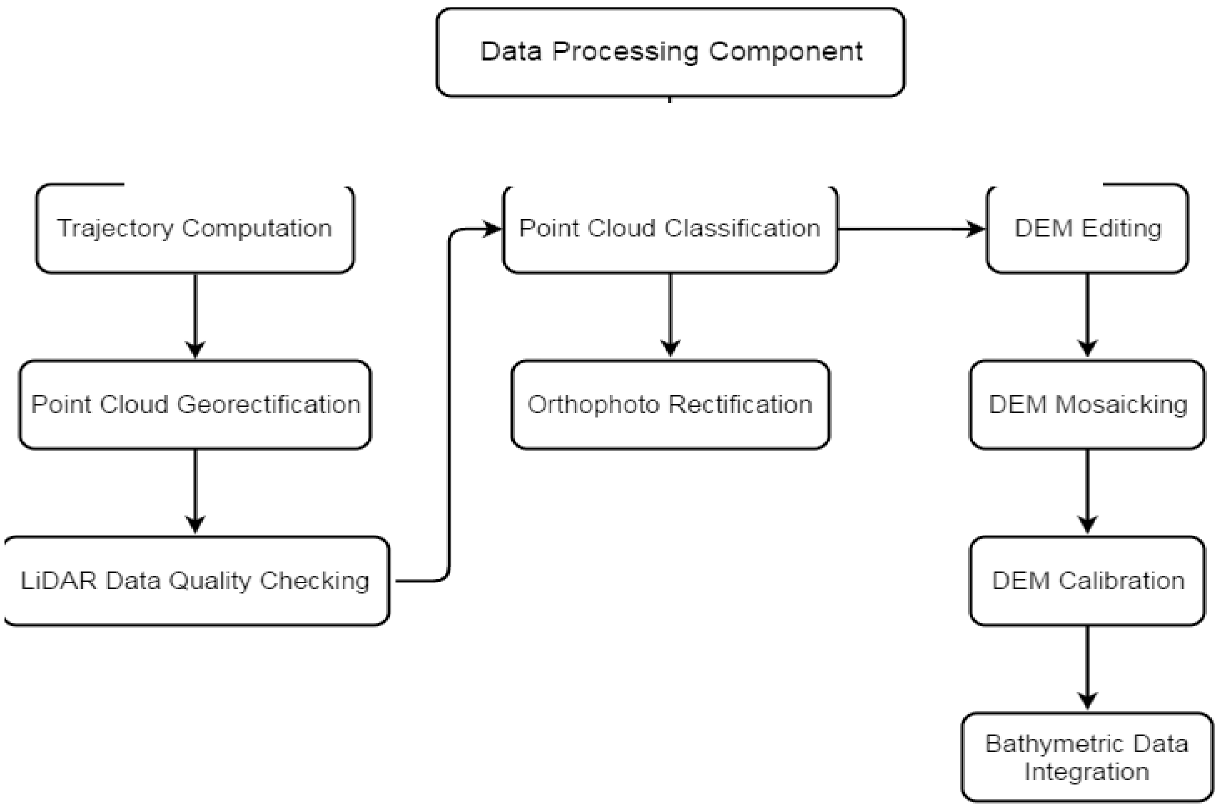

Figure 7.Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Casiligan floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on October 2015 were flown using the Gemini system over Pola, Oriental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 132.15 Gigabytes of Range data, 2.138 Gigabytes of POS data, 120 Megabytes of GPS base station data, and 462.46 Gigabytes of raw image data to the data server on February 6, 2014 for the first survey and November 12, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Casiligan was fully transferred on November 12, 2015, as indicated on the Data Transfer Sheets for Casiligan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1054A, one of the Casiligan flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 1, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

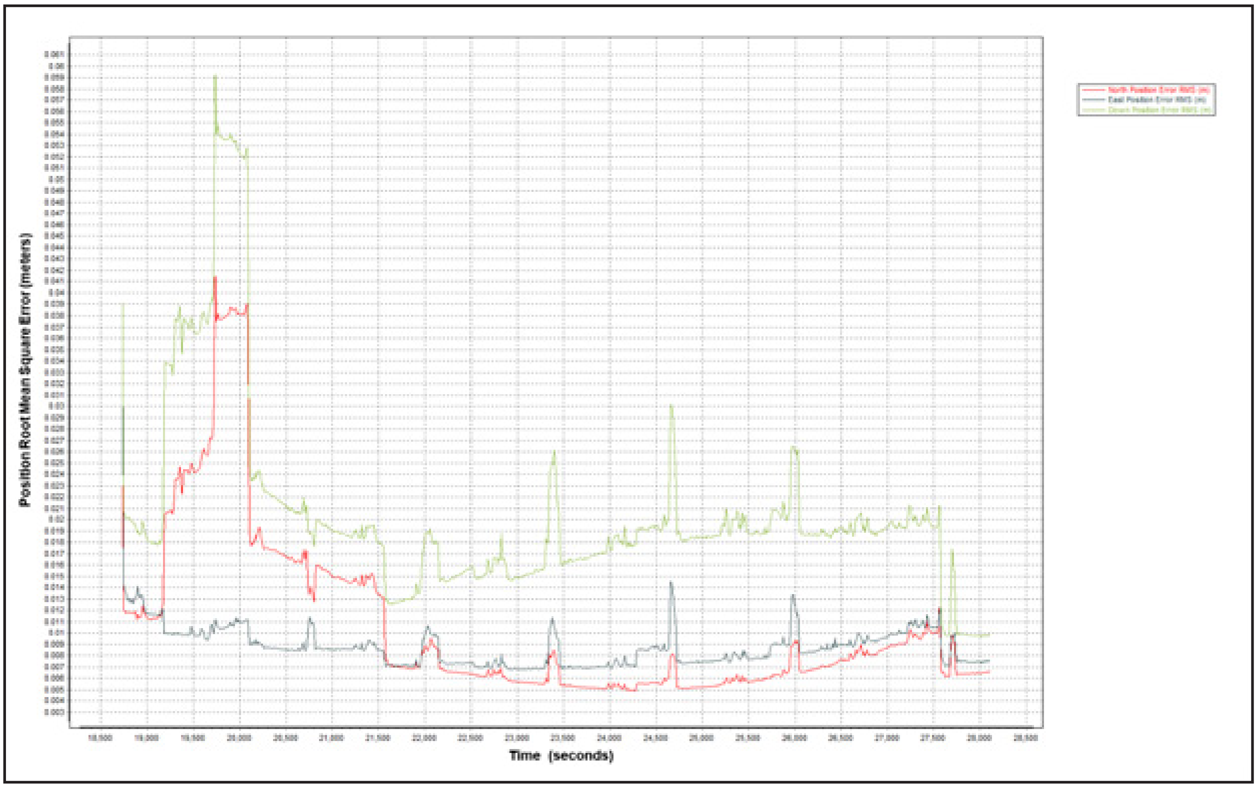

Figure 8. Smoothed Performance Metric Parameters of a Casiligan Flight 1054A.

The time of flight was from 18300 seconds to 28100 seconds, which corresponds to afternoon of February 1, 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 8 shows that the North position RMSE peaks at 2.60 centimeters, the East position RMSE peaks at 1.50 centimeters, and the Down position RMSE peaks at 5.90 centimeters, which are within the prescribed accuracies described in the methodology.

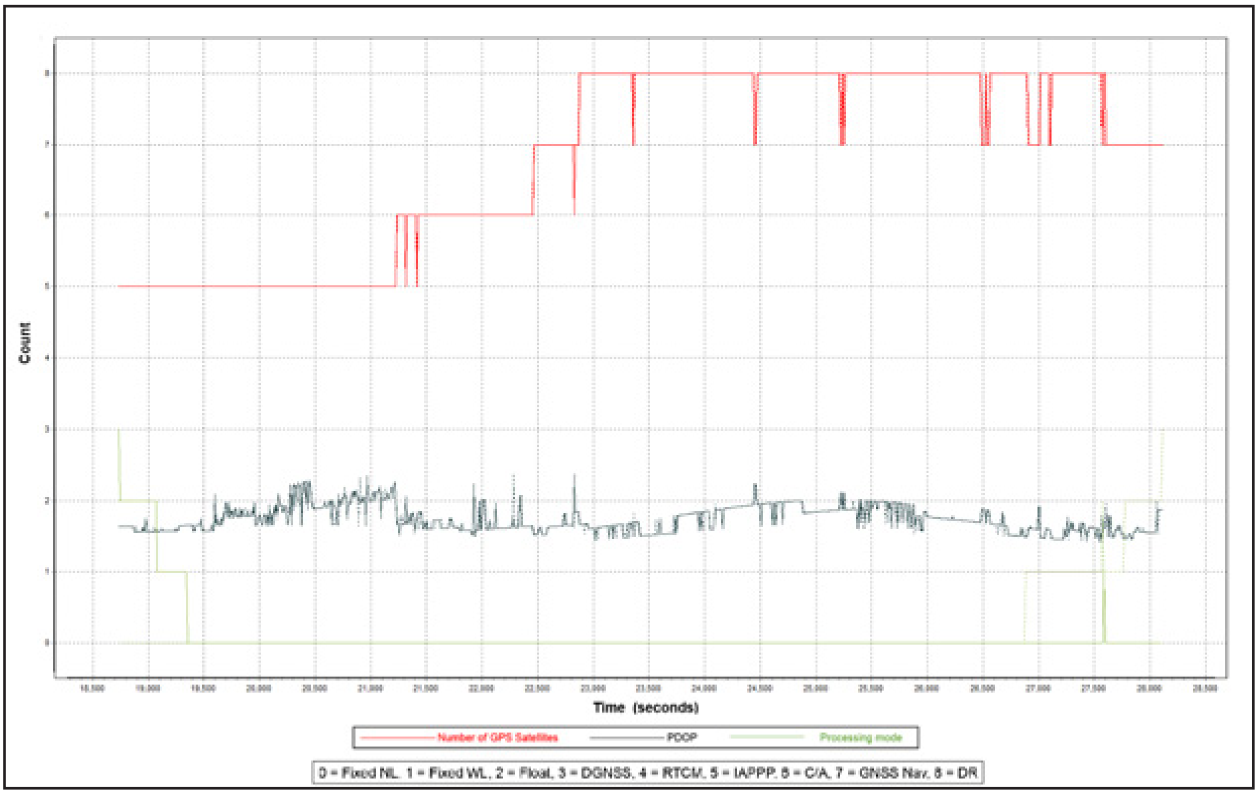

Figure 9. Solution Status Parameters of Casiligan Flight 1054A.

The Solution Status parameters of flight 1054A, one of the Casiligan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition. 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, 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 Casiligan flights is shown in Figure 10.

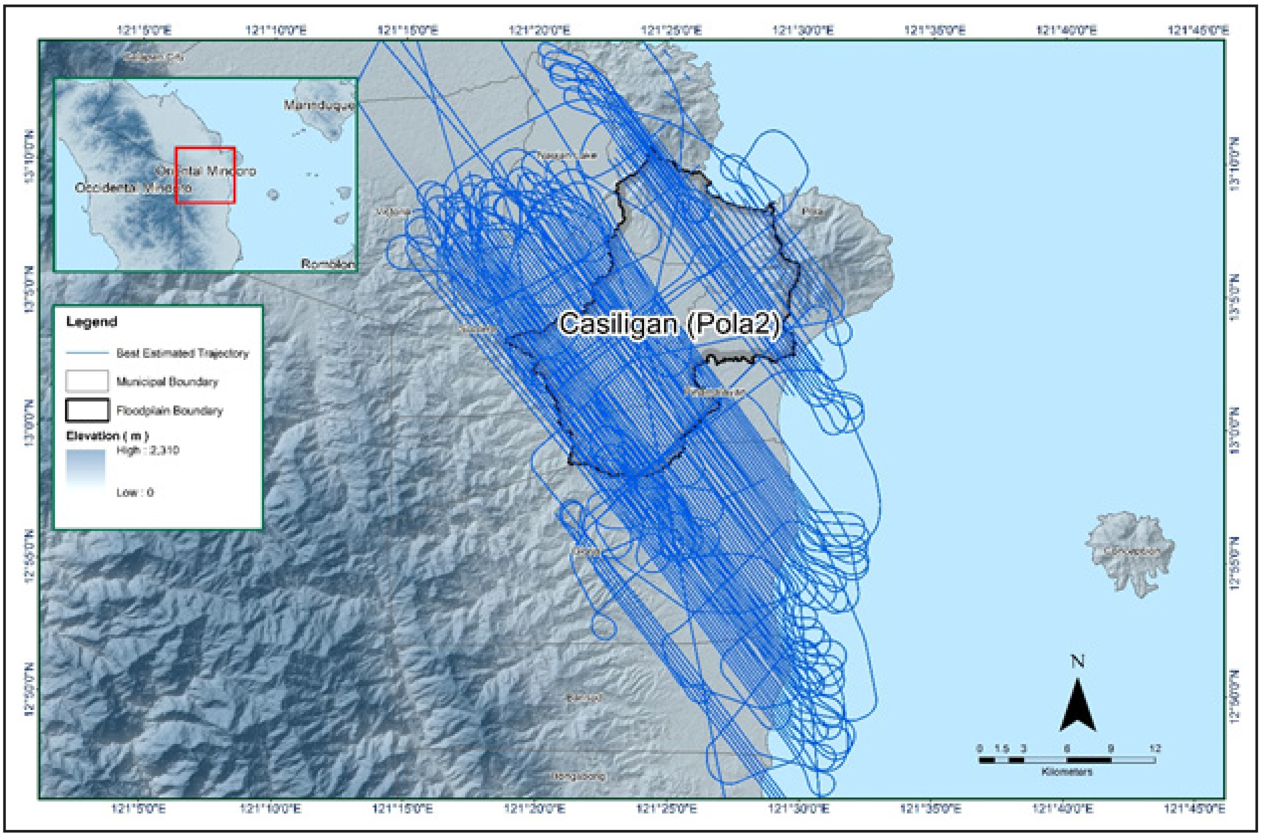

Figure 10. The best estimated trajectory of the LiDAR missions conducted over the Casiligan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 116 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Casiligan floodplain are given in Table 12.

Table 12. Self-Calibration Results values for Casiligan flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000424
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000955
GPS Position Z-correction stdev)	<0.01meters	0.0019

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

3.5 LiDAR Data Quality Checking

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

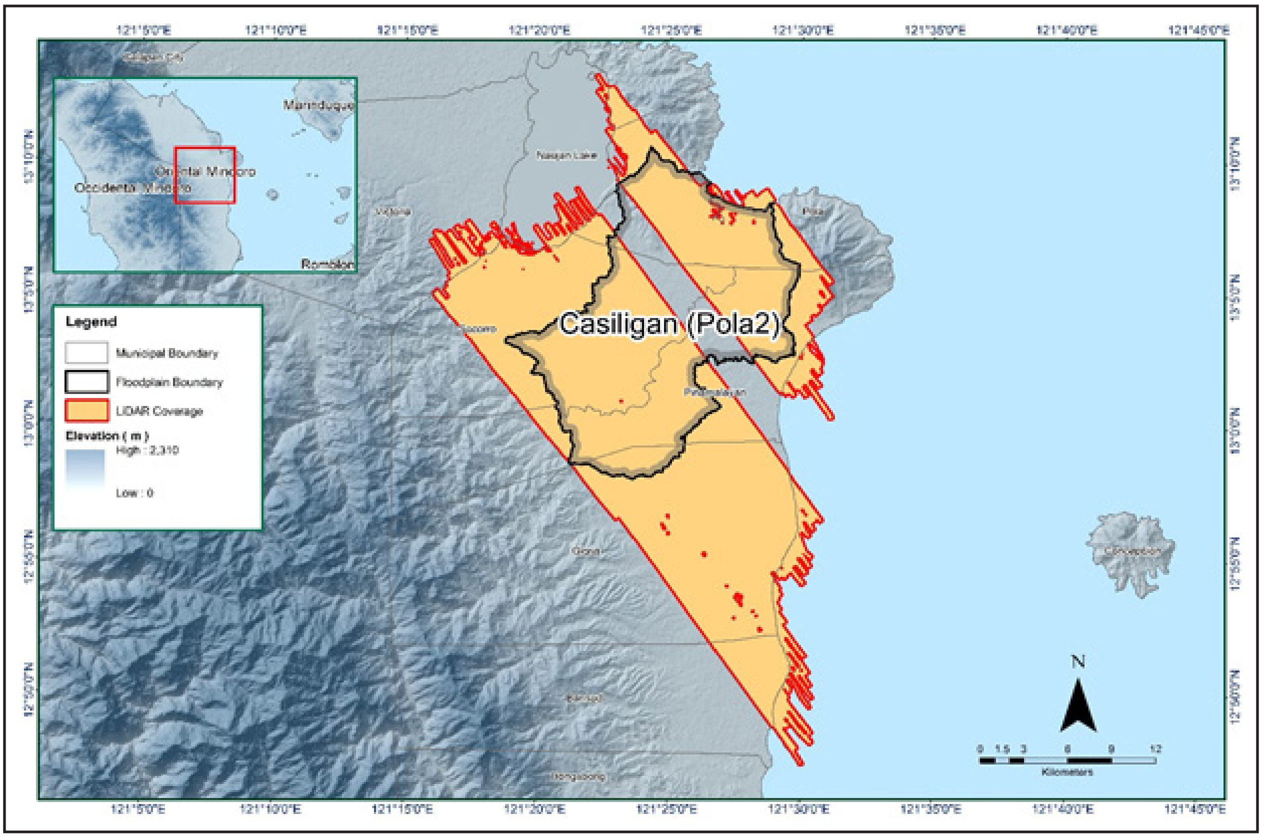

Figure 11. Boundary of the processed LiDAR data over Casiligan Floodplain

The total area covered by the Casiligan missions is 688.64 sq.km that is comprised of ten (10) flight acquisitions grouped and merged into eleven (11) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Casiligan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OrientalMindoro_Blk28A_supplement	1092A	60.86
OrientalMindoro_Blk28B	1054A	75.67
OrientalMindoro_Blk28B_supplement	1094A	48.08
OrientalMindoro_Blk28Bs_additional	1098A	11.67
OrientalMindoro_Blk28C	1056A	29.65
OrientalMindoro_Blk28D	1058A	68.57
OrientalMindoro_Blk28D_supplement	1066A	90.29
OrientalMindoro_Reflights_Blk28A	8300G	81.71
OrientalMindoro_Reflights_Blk28A_ supplement	8300G	38.57
	8302G	
OrientalMindoro_Reflights_Blk28B	8301G	74.40
	8300G	
OrientalMindoro_Reflights_Blk28D	8301G	109.17
TOTAL		**688.64 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Gemini and Aquarius systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

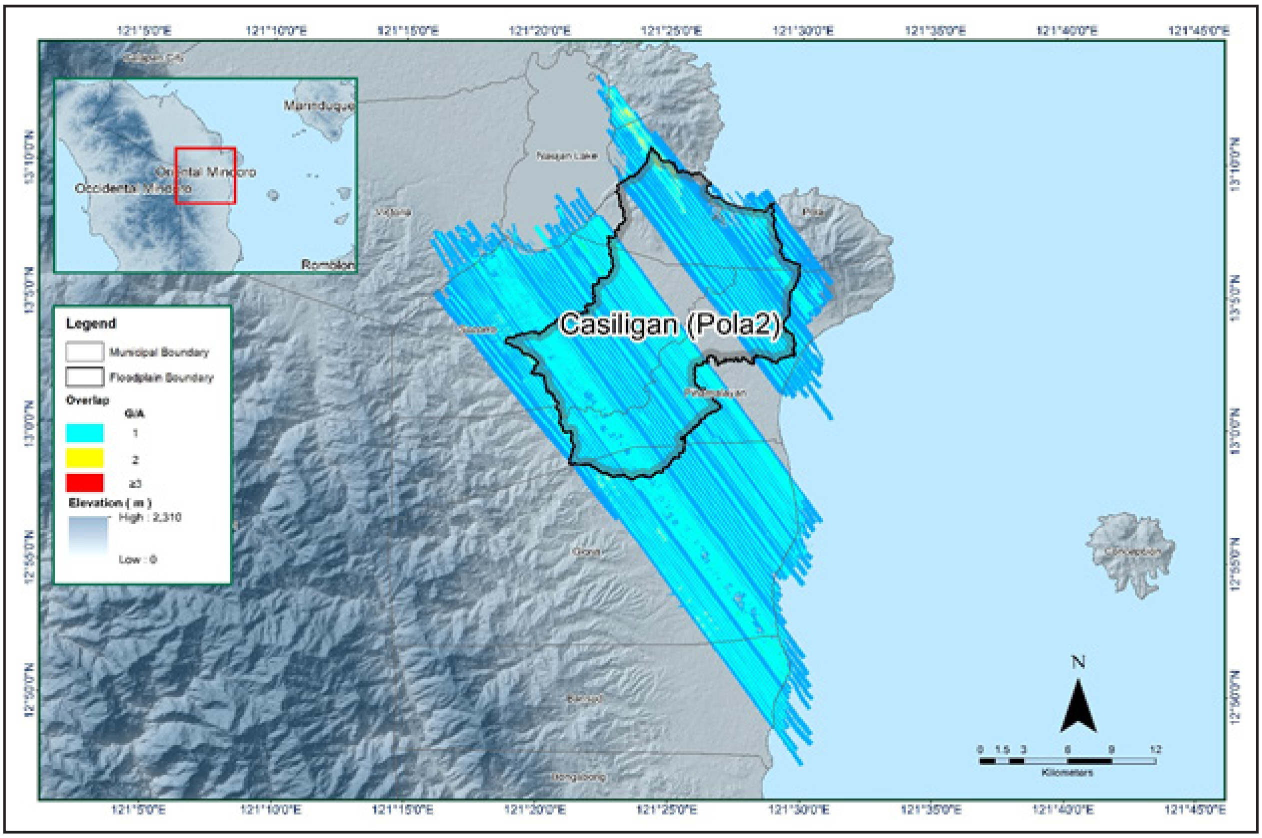

Figure 12. Image of data overlap for Casiligan floodplain.

The overlap statistics per block for the Casiligan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 31.26% and 65.39% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Casiligan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.442 points per square meter.

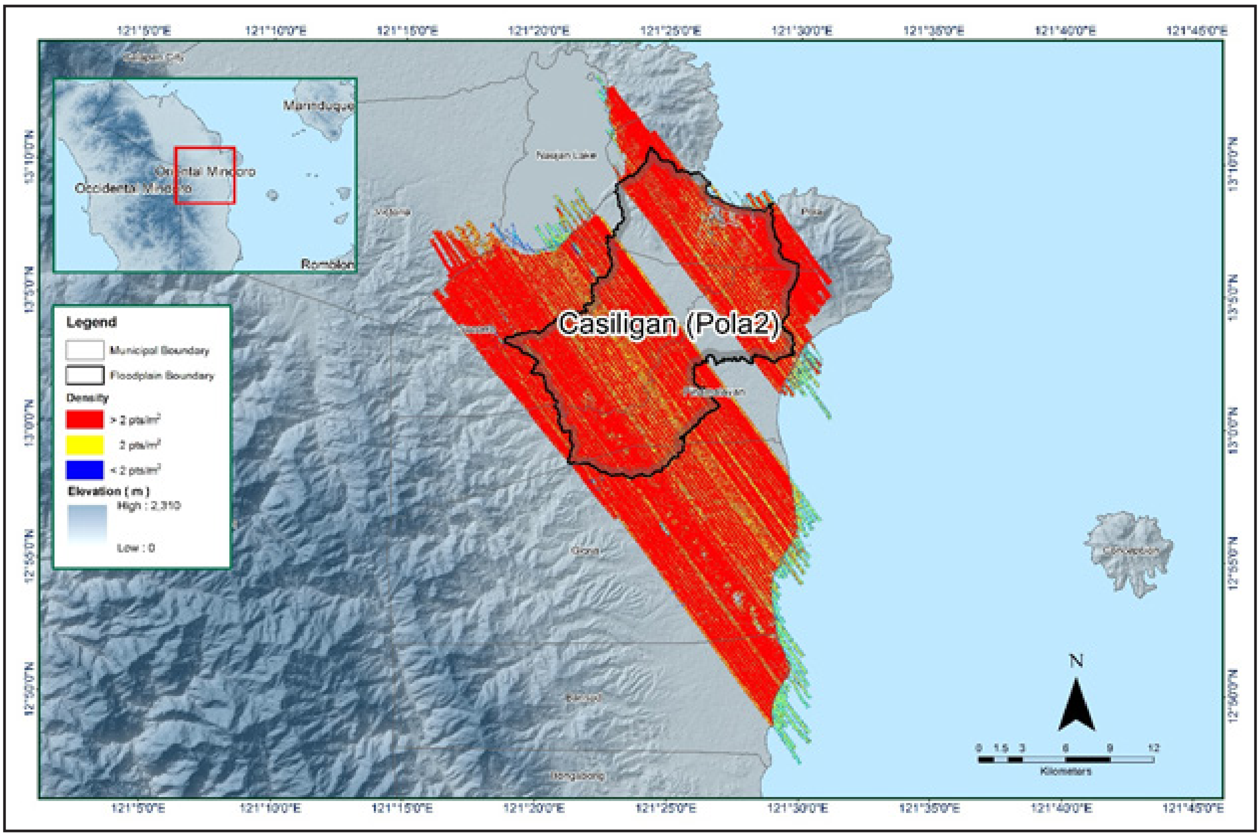

Figure 13. Density map of merged LiDAR data for Casiligan floodplain.

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

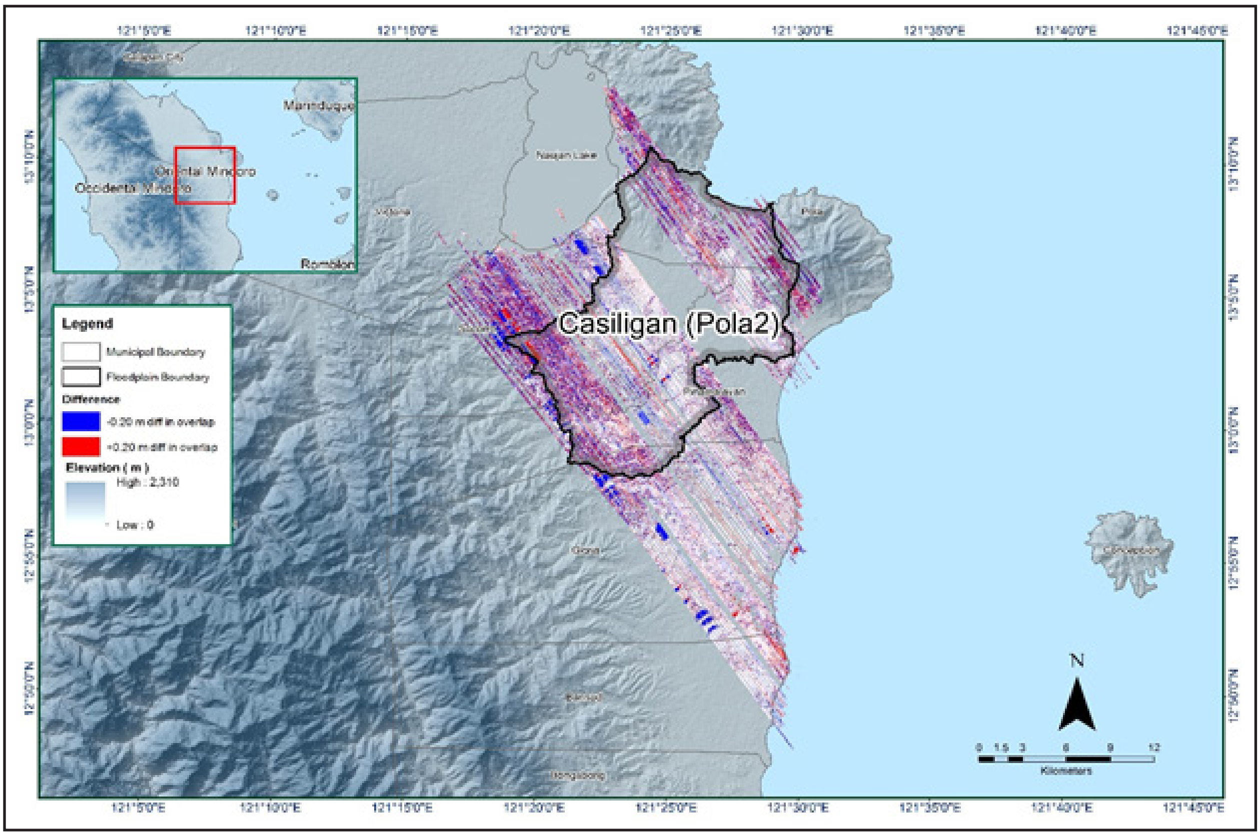

Figure 14. Elevation difference map between flight lines for Casiligan floodplain.

A screen capture of the processed LAS data from a Casiligan flight 1054A loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed 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.

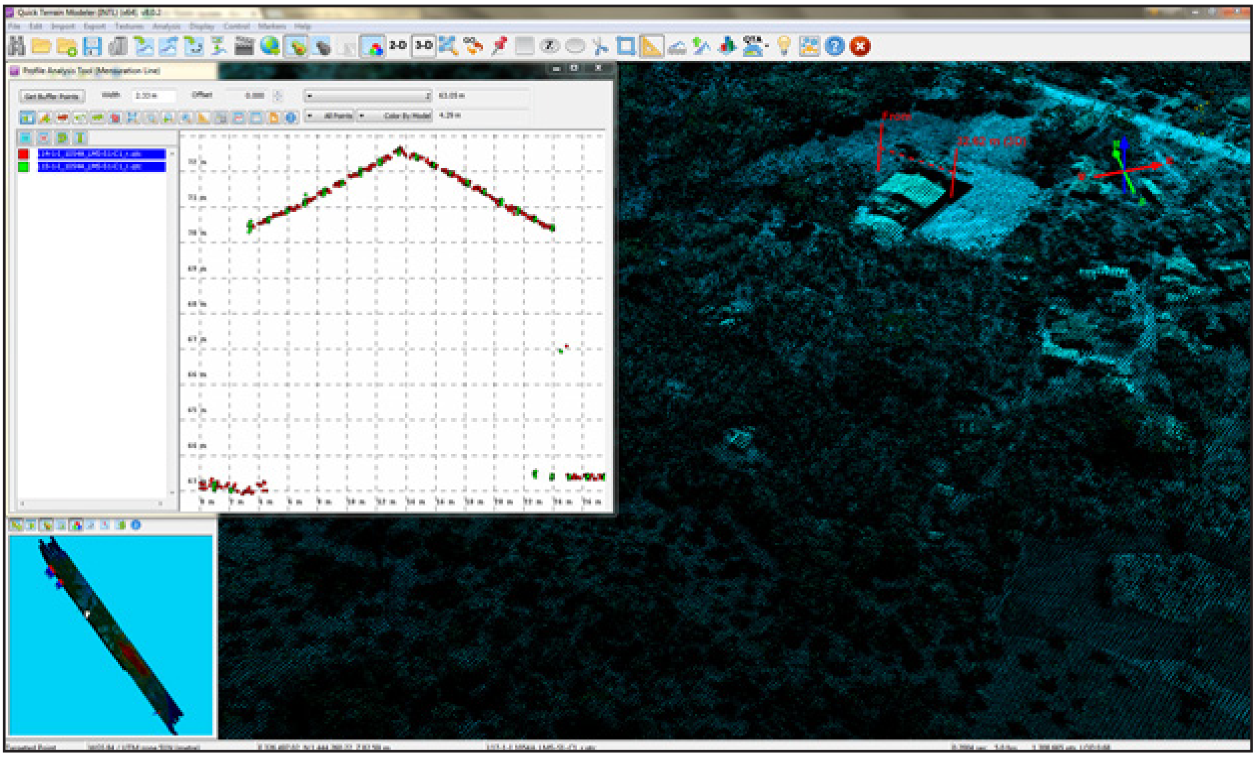

Figure 15. Quality checking for a Casiligan flight 1054A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Casiligan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	357,009,765
Low Vegetation	444,662,437
Medium Vegetation	574,660,953
High Vegetation	935,427,708
Building	27,973,763

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Casiligan floodplain is shown in Figure 16. A total of 1,203 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 673.05 meters and 45.57 meters respectively.

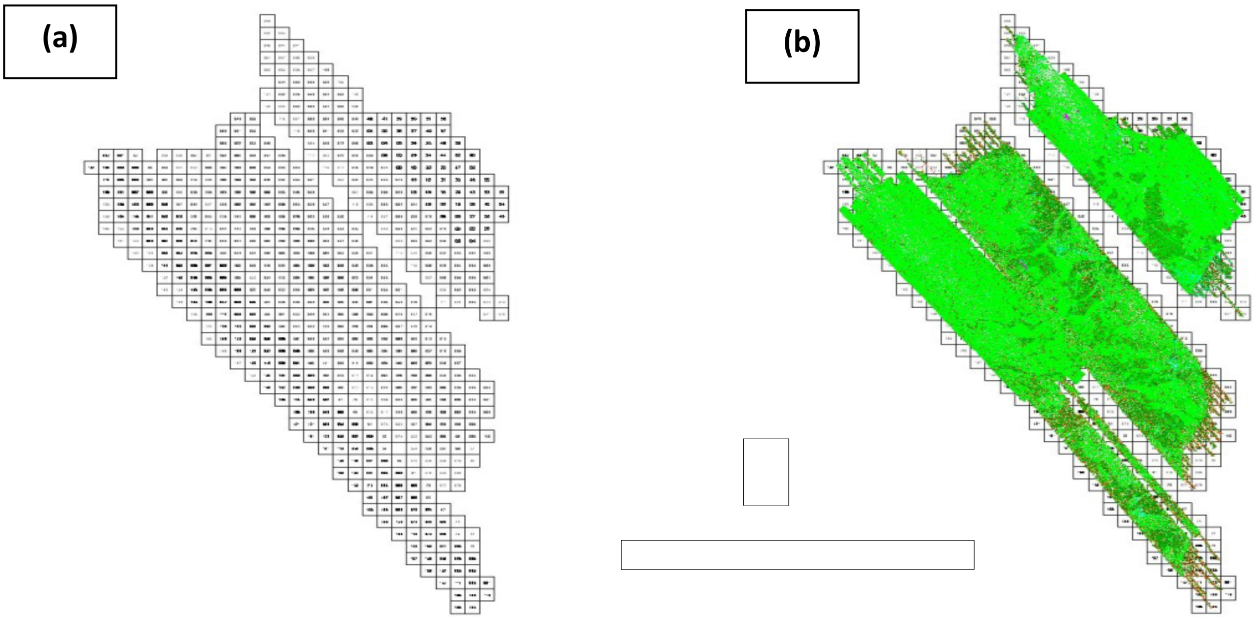

Figure 16. Tiles for Casiligan floodplain (a) and classification results (b) in TerraScan.

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

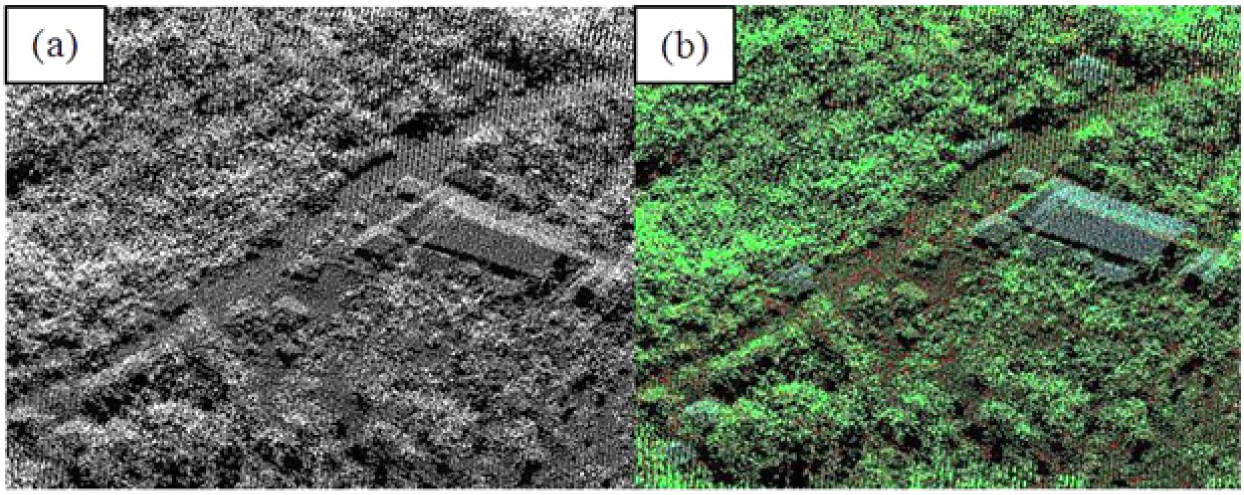

Figure 17. Point cloud before (a) and after (b) classification.

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

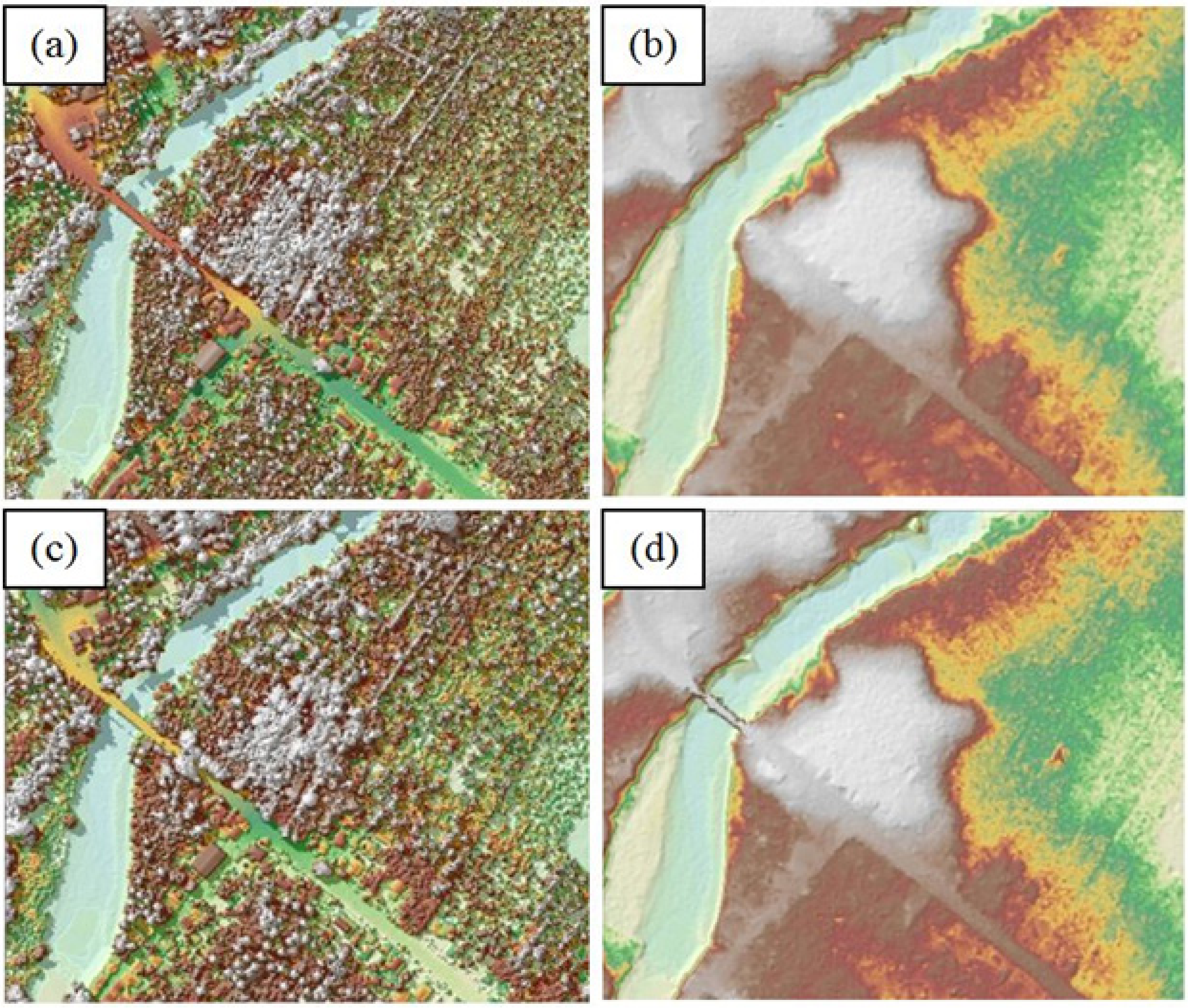

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Casiligan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,044 1km by 1km tiles area covered by Casiligan floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Casiligan floodplain survey attained a total of 382.36 km2 in orthophotogaph coverage, comprised of 3,793 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

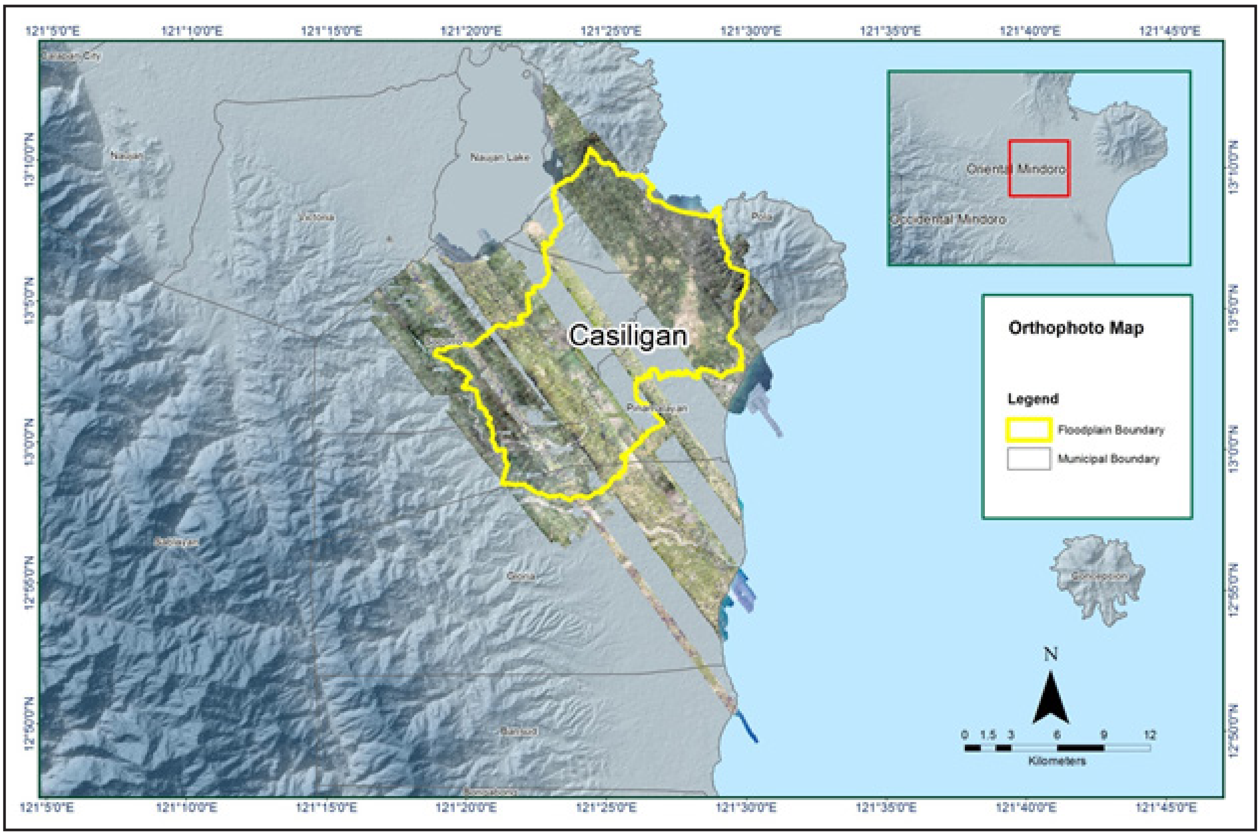

Figure 19. Casiligan floodplain with available orthophotographs.

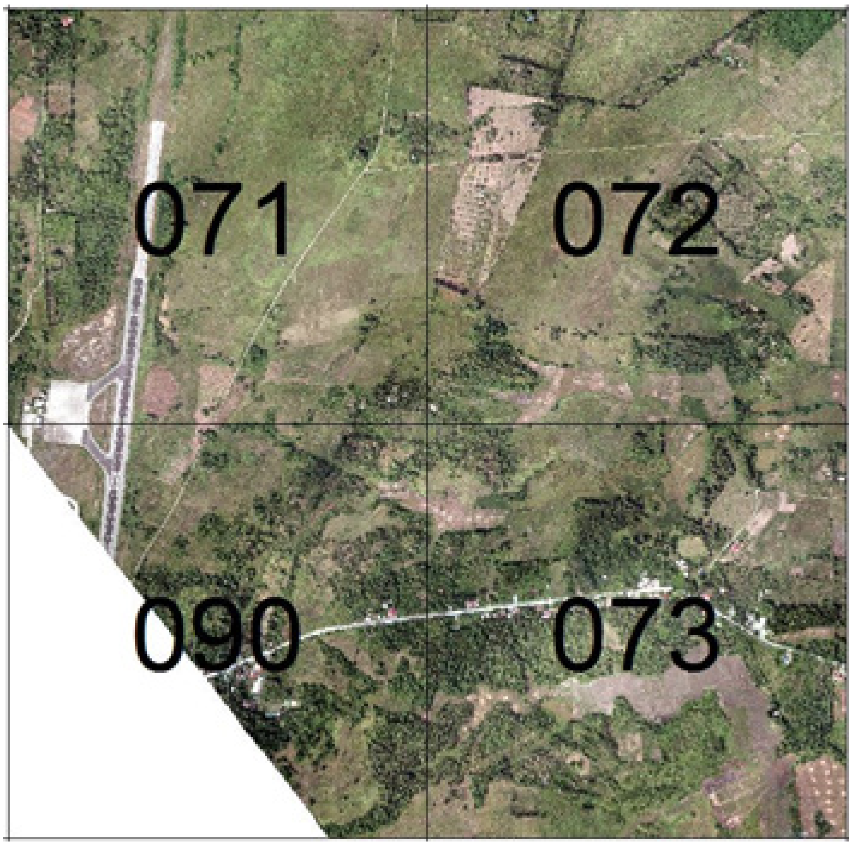

Figure 20. Sample orthophotograph tiles for Casiligan floodplain.

3.8 DEM Editing and Hydro-Correction

Eleven (11) mission blocks were processed for Casiligan flood plain. These blocks are composed of OrientalMindoro and OrientalMindoro_reflights blocks with a total area of 688.64 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
OrientalMindoro_Blk28A_supplement	60.86
OrientalMindoro_Blk28B	75.67
OrientalMindoro_Blk28B supplement	48.08
OrientalMindoro_Blk28Bs_additional	11.67
OrientalMindoro_Blk28C	29.65
OrientalMindoro_Blk28D	68.57
OrientalMindoro_Blk28D_supplement	90.29
OrientalMindoro_Reflights_Blk28A	81.71
OrientalMindoro_Reflights_Blk28A_ supplement	38.57
OrientalMindoro_Reflights_Blk28B	74.40
OrientalMindoro_Reflights_Blk28D	109.17
TOTAL	**688.64 sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. The pit (Figure 21c) has been misclassified and removed during classification process and has to be interpolated to complete the surface (Figure 21d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 21e) and has to be removed through manual editing (Figure 21f).

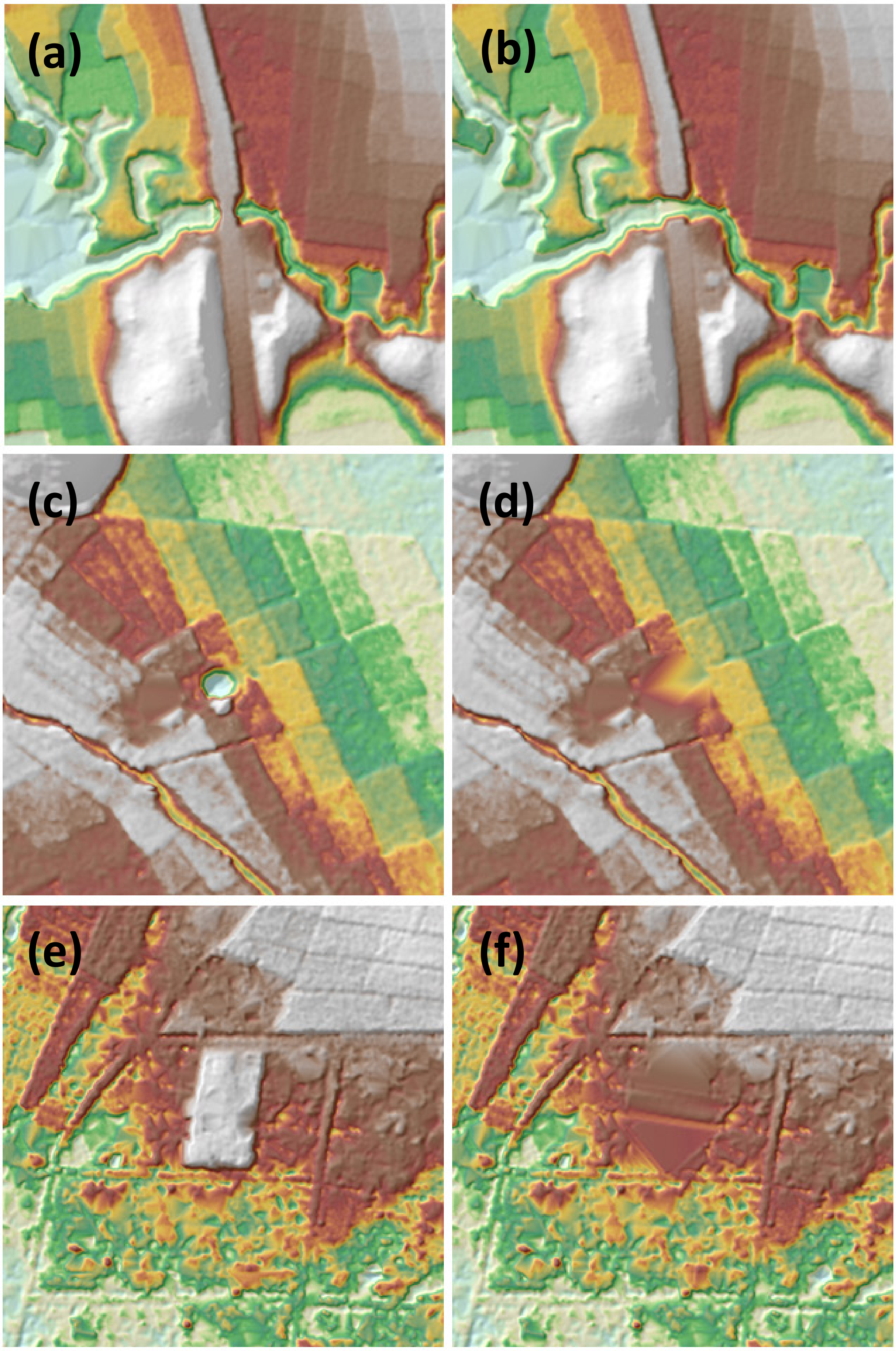

Figure 21. Portions in the DTM of Casiligan floodplain – a bridge before (a) and after (b) manual editing; a pit before (c) and after (d) interpolation; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

OrientalMindoro_Blk29M 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 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Casiligan floodplain is shown in Figure 22. The entire Casiligan flood plain is 86.26% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 16. Shift Values of each LiDAR Block of Casiligan floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
OrientalMindoro_Blk28A_supplement	0.00	0.00	0.94
OrientalMindoro_Blk28B	0.00	0.00	0.90
OrientalMindoro_Blk28B_supplement	0.00	0.00	0.68
OrientalMindoro_Blk28Bs_additional	0.00	0.00	0.68
OrientalMindoro_Blk28C	0.00	0.00	0.68
OrientalMindoro_Blk28C_supplement	-0.17	0.00	0.68
OrientalMindoro_Blk28D	0.00	0.00	0.75
OrientalMindoro_Blk28D_supplement	0.00	0.00	0.92
OrientalMindoro_Reflight28A	0.00	0.00	0.04
OrientalMindoro_Reflight28A_supplement	0.00	0.00	0.00
OrientalMindoro_Reflight28B	0.00	0.00	0.00
OrientalMindoro_Reflight28D	0.00	0.00	-0.12

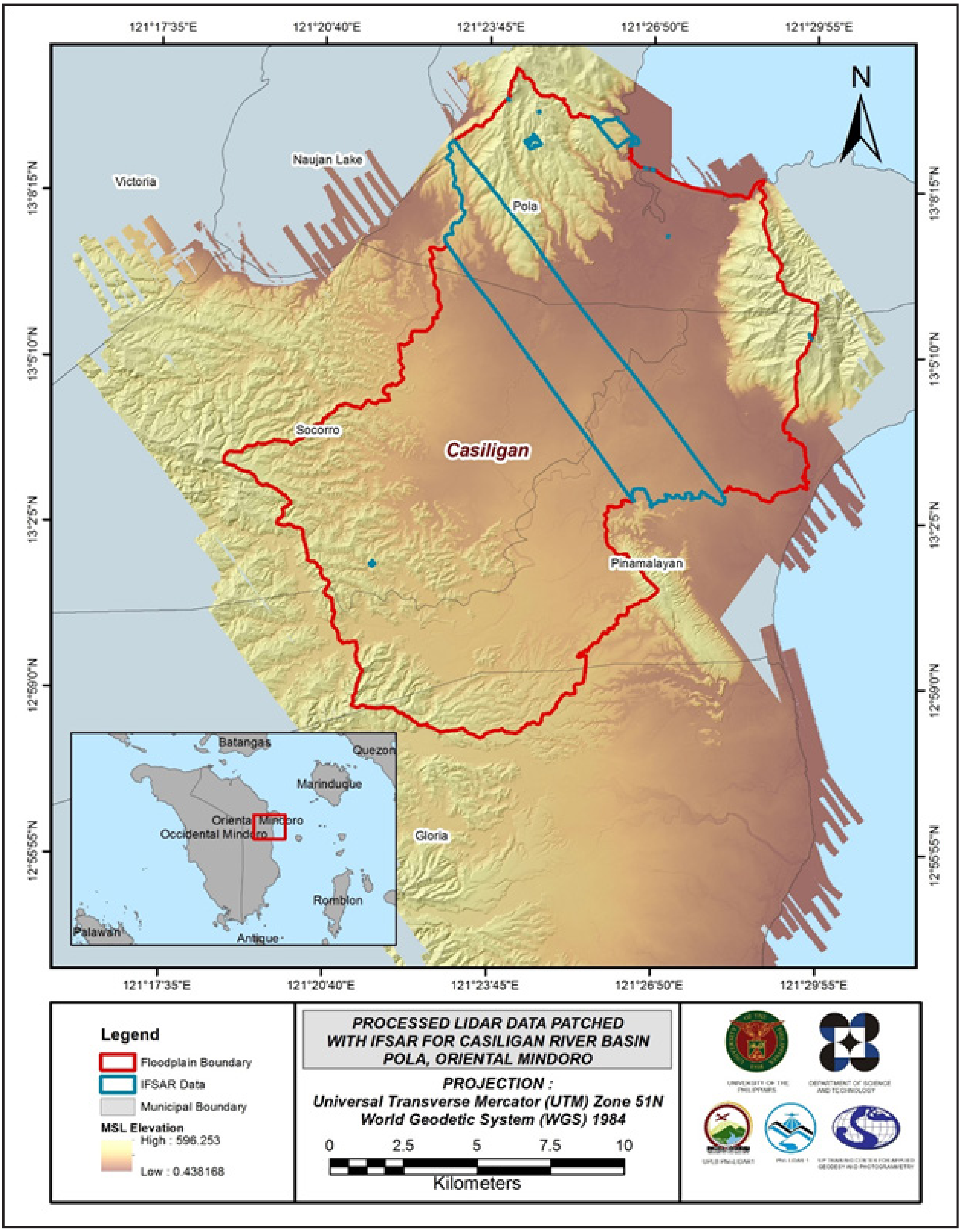

Figure 22. Map of Processed LiDAR Data for Casiligan Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Casiligan to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 19,114 survey points were used for calibration and validation of Casiligan LiDAR data. Random selection of 80% of the survey points, resulting to 15,291 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 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.60 meters with a standard deviation of 0.17 meters. Calibration of Casiligan LiDAR data was done by subtracting the height difference value, 2.60 meters, to Casiligan mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

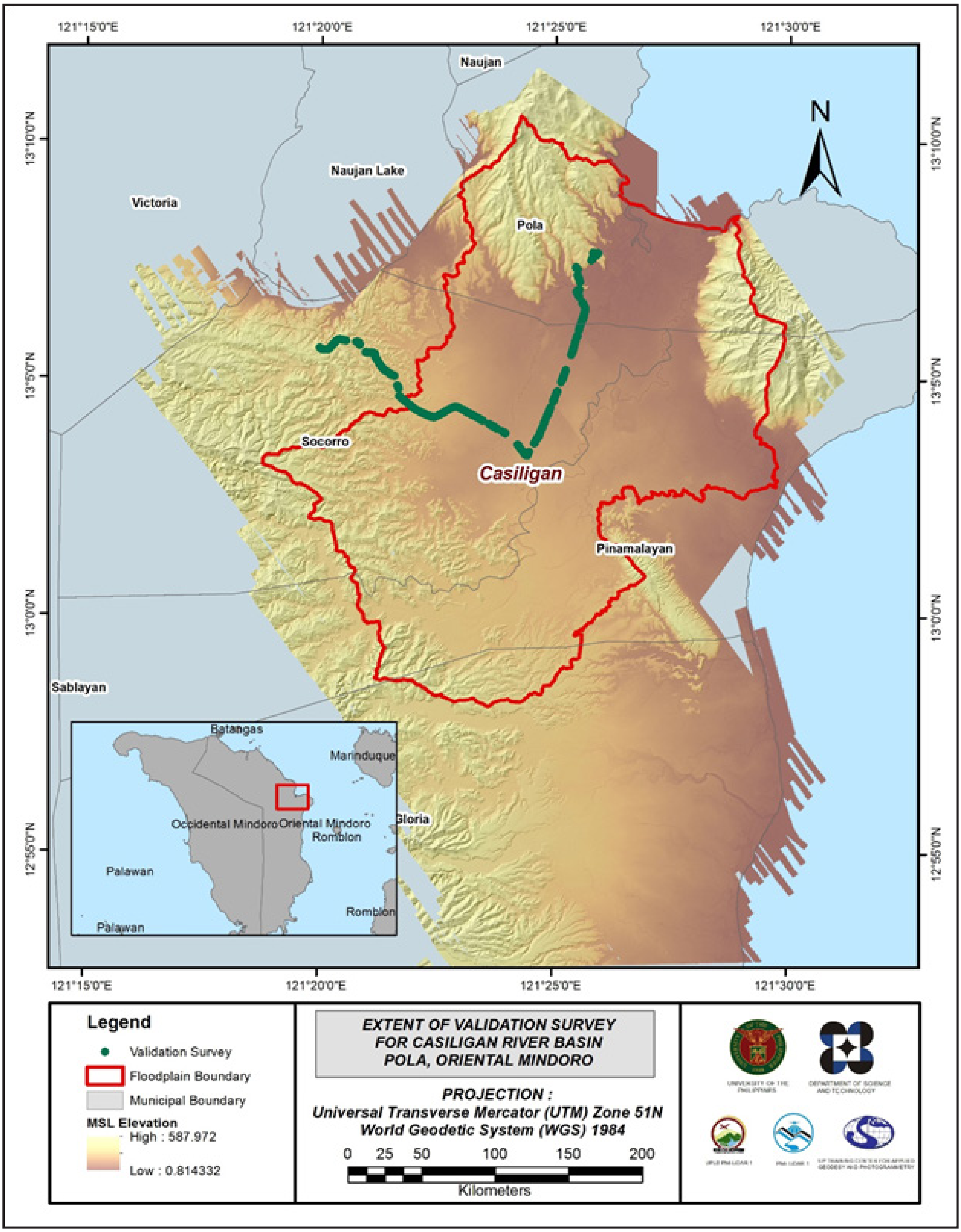

Figure 23. Map of Casiligan Flood Plain with validation survey points in green.

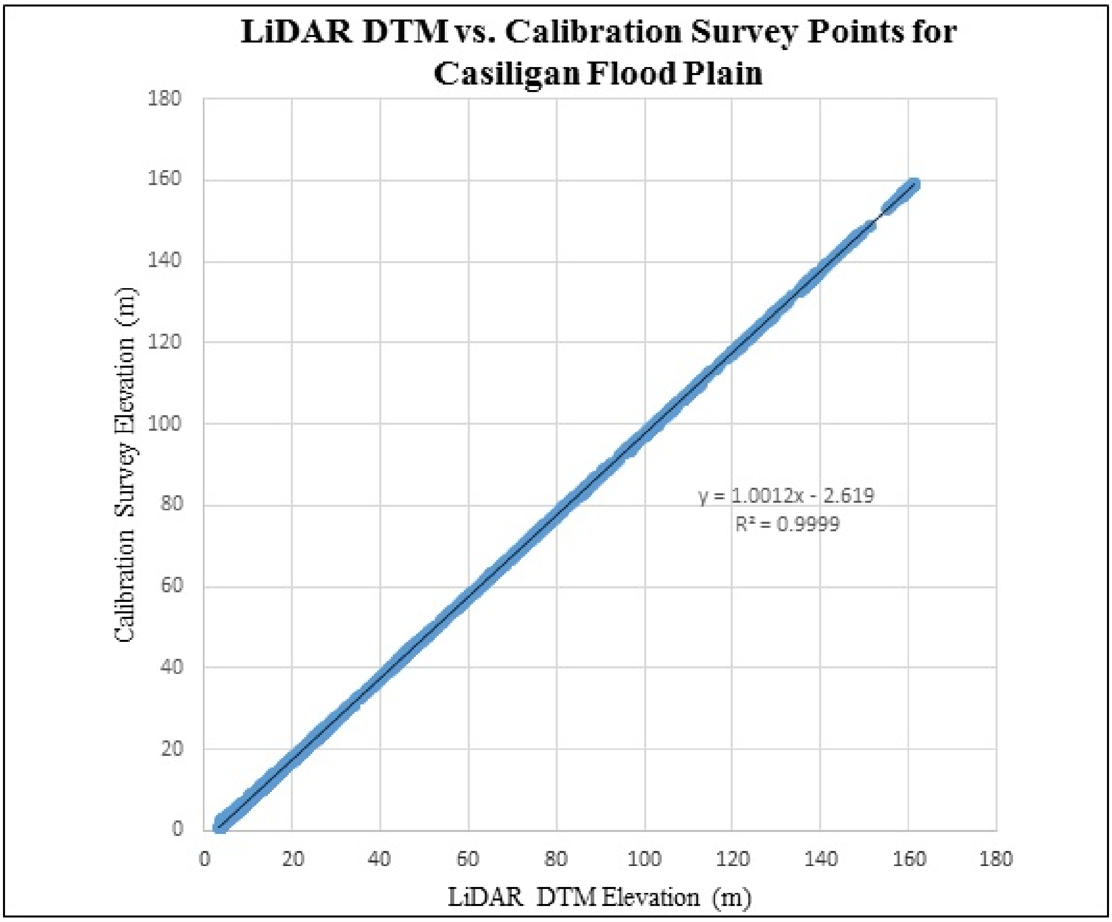

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 17. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.60
Standard Deviation	0.17
Average	-2.59
Minimum	-3.03
Maximum	-1.70

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 469 points. These were used for the validation of calibrated Casiligan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.10 meters with a standard deviation of 0.10 meters, as shown in Table 18.

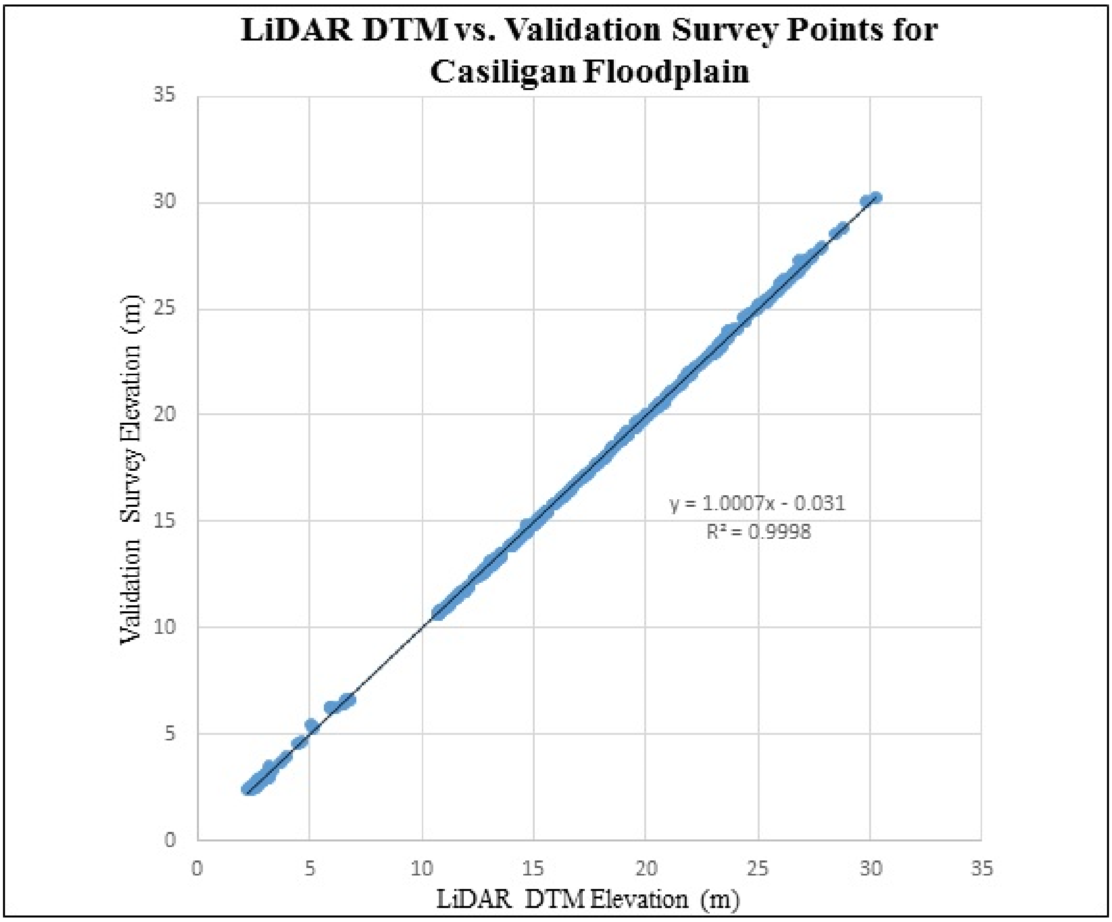

Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.10
Standard Deviation	0.10
Average	-0.02
Minimum	-0.29
Maximum	0.45

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Casiligan with 4,510 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barrier method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.49 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Casiligan integrated with the processed LiDAR DEM is shown in Figure 26.

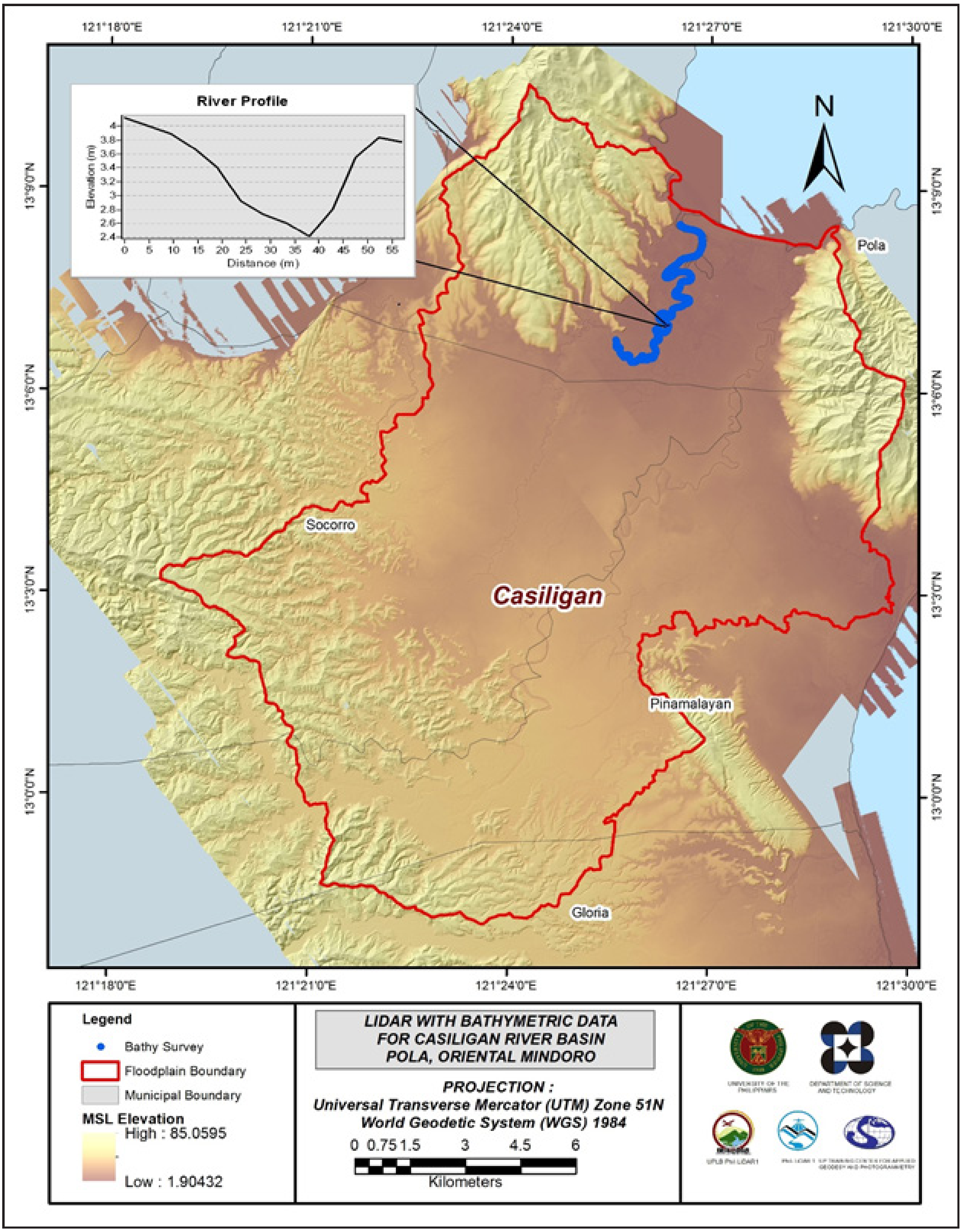

Figure 26. Map of Casiligan Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Abra floodplain, including its 200 m buffer, has a total area of 776.76 sq km. For this area, a total of 24.0 sq km, corresponding to a total of 5,893 building features, are considered for QC. Figure 28 shows the QC blocks for Abra floodplain.

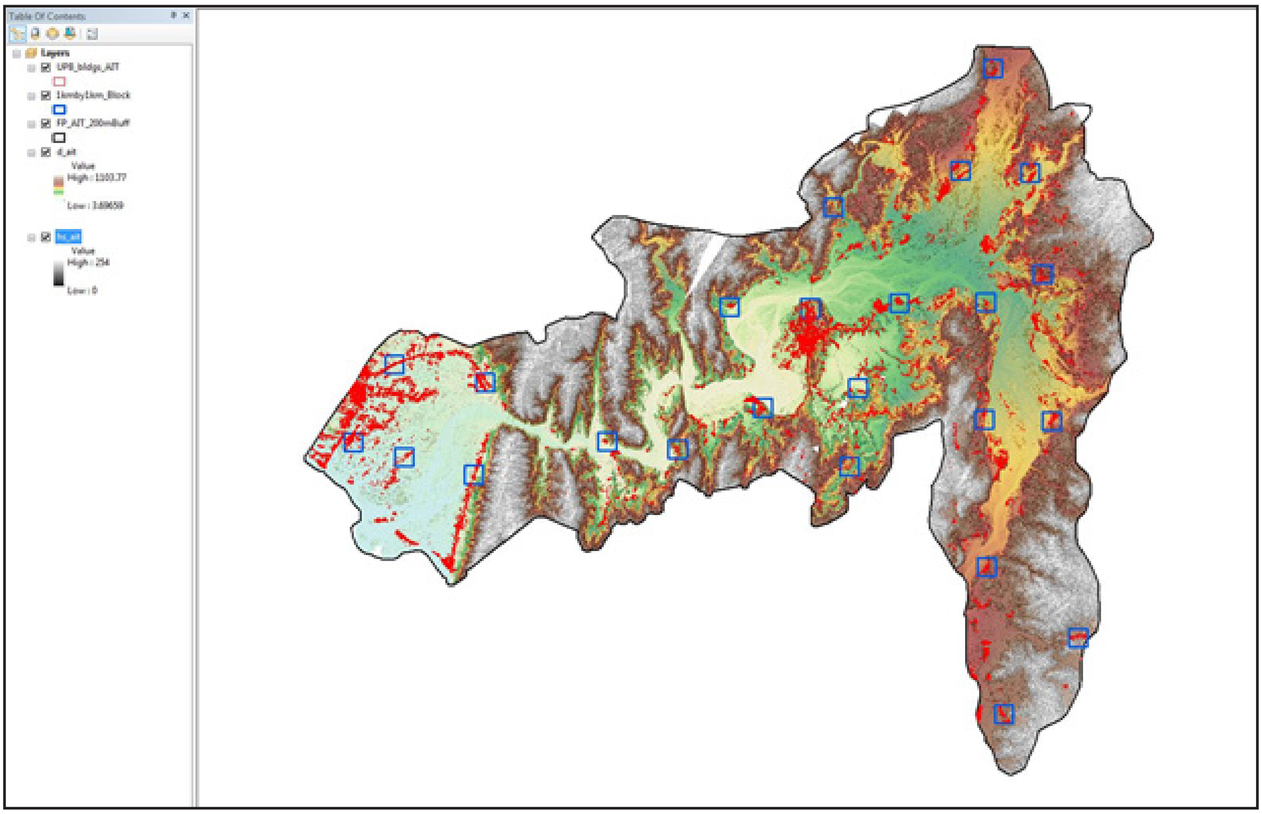

Figure 28. Blocks (in blue) of Abra building features that was subjected to QC.

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

Table 20. Details of the quality checking ratings for the building features extracted for the Abra River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Abra	99.44	99.98	97.30	PASSED

3.12.2 Height Extraction

Height extraction was done for 51,234 building features in Abra floodplain. Of these building features, 843 were filtered out after height extraction, resulting to 50,391 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 14.87 meters.

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 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21. Building features extracted for Abra Floodplain.

Facility Type	No. of Features
Residential	49,140
School	749
Market	37
Agricultural/Agro-Industrial Facilities	4
Medical Institutions	38
Barangay Hall	6
Military Institution	0
Sports Center/Gymnasium/Covered Court	11
Telecommunication Facilities	2
Transport Terminal	16
Warehouse	3
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	3
Water Supply/Sewerage	0
Religious Institutions	56
Bank	10
Factory	32
Gas Station	23
Fire Station	2
Other Government Offices	51
Other Commercial Establishments	207
Total	50,391

Table 22. Total length of extracted roads for Abra Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Abra	382.5	225.68	12.17	100.03	0.00	720.38

Table 23. Number of extracted water bodies for Abra Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Abra	147	164	0	0	0	311

A total of 25 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 29 shows the completed Digital Surface Model (DSM) of the Abra floodplain overlaid with its ground features.

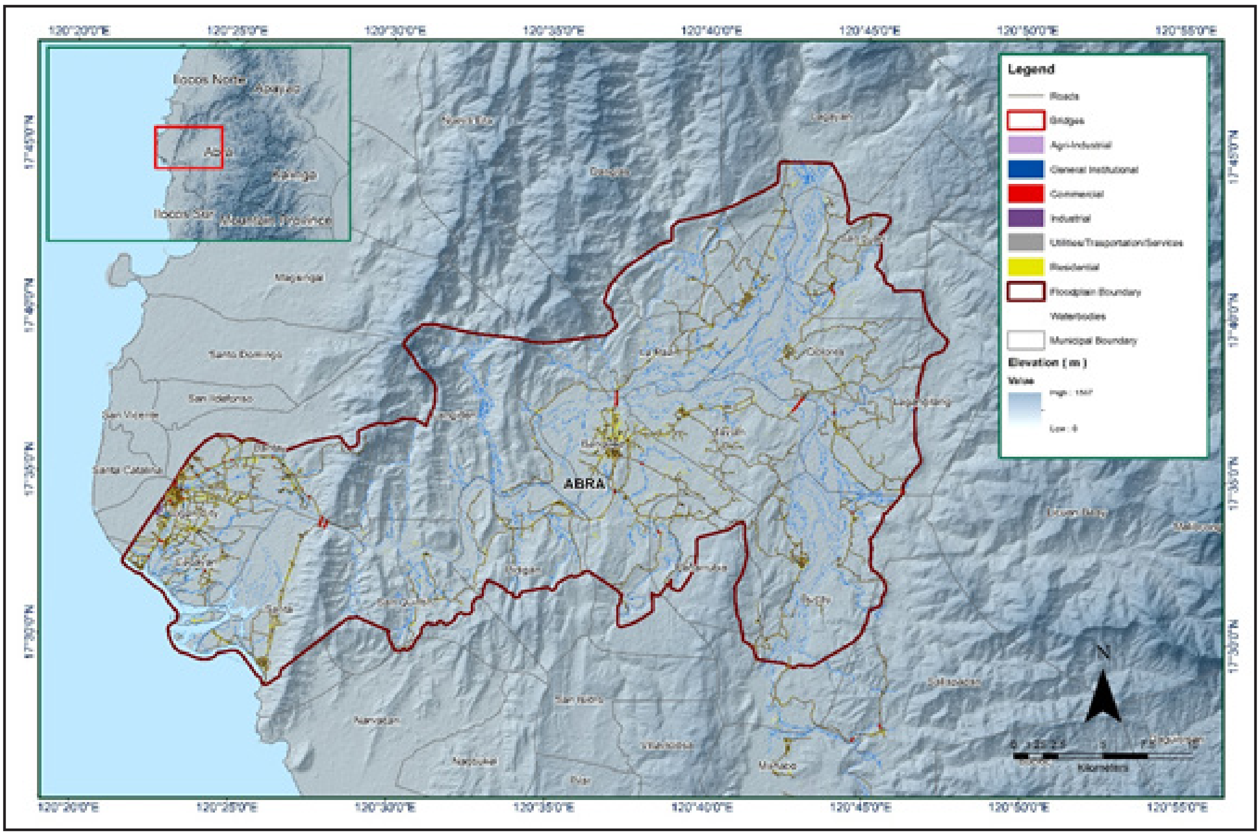

Figure 29. Extracted features of the Abra Floodplain.

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

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

4.1 Summary of Activities

The project team conducted a field survey in Casiligan River on May 30 to June 11, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; ground validation data acquisition of about 15.41 km; and bathymetric survey from Brgy. Casiligan to Brgy. Batuhan in the Municipality of Pola, Oriental Mindoro with an approximate length of 3.77 km. A follow up survey commenced from October 27, 2014 to November 3, 2014 with the following activities: courtesy call to the LGU of Socorro and University of the Philippines Los Baños as partner SUC assigned in Casiligan River; bridge as-built and water level marking of Pola Bridge in Brgy. Casiligan, Municipality of Pola, Oriental Mindoro .

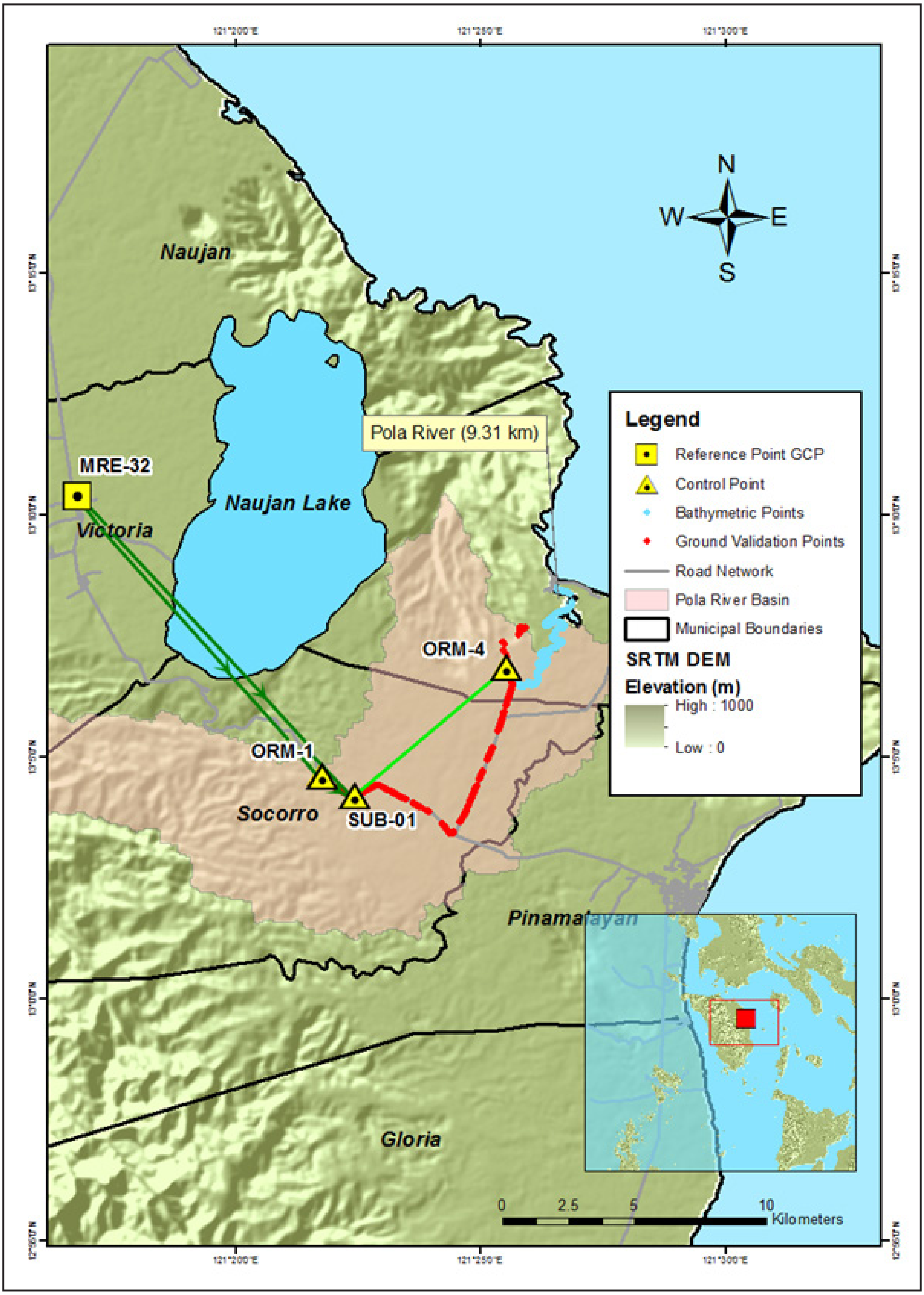


Figure 27. Extent of the bathymetric survey (light blue line) in Casiligan River and the LiDAR data validation survey (red)

4.2 Control Survey

A GNSS network was established for previous PHIL-LiDAR fieldwork in Mindoro on February 28 – March 11, 2013 occupying MR-178, a first-order BM located at the approach of Panggalaan Bridge in Brgy. Bucayao, Calapan City, Oriental Mindoro; and MRE-32, a second order GCP in Brgy. Poblacion 1, Mun. of Victoria, Oriental Mindoro.

The GNSS network used for Pola River Basin is composed of two (2) loops and four (4) baselines established on May 30 and May 31, 2014 occupying the reference point MRE-32, a second-order GCP fixed from the previous field survey in Mindoro Oriental for Mag Asawang Tubig river.

Three (3) control points were established namely: ORM-1, located in Subaan Bridge in Barangay Subaan, Municipality of Socorro; ORM-4 in Pola Bridge, Brgy. Casiligan, Municipality of Pola; and SUB-01, located within the Maramot Residence in Brgy. Subaan, Municipality of Socorro. An LMS-established control point namely MRE-4650, located at Bansud Bridge, Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro was also occupied to use as marker in the survey.

The summary of references and control points and its location is summarized in Table 19 while the GNSS network established is illustrated in Figure 28.

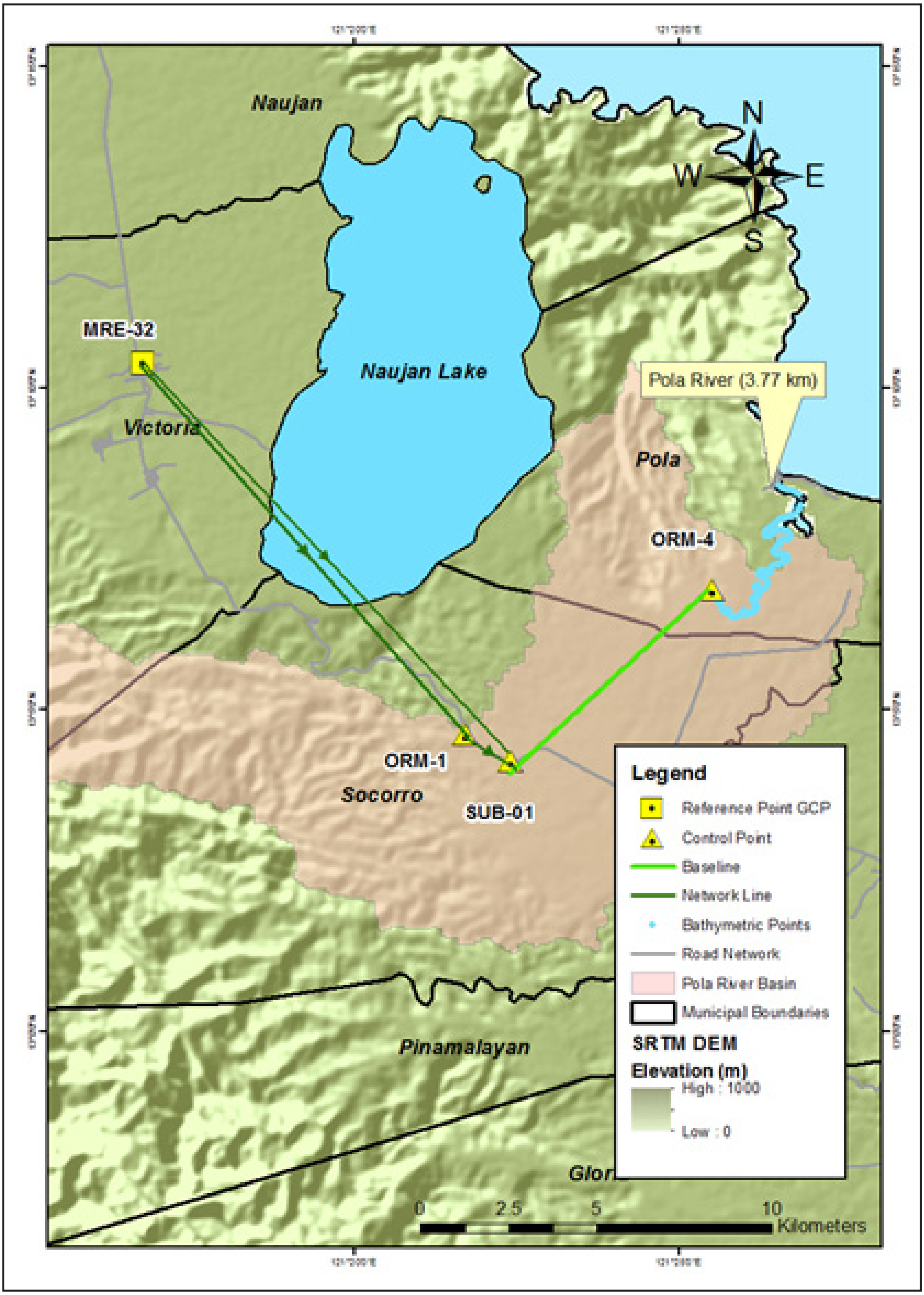


Figure 28. GNSS Network of Pola River field survey

Table 19. List of reference and control points occupied in Casiligan River (Pola) survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
MRE-32	2nd order, GCP	13°10'23.79251"	121°16'43.46244"	65.638	17.175	2007
ORM-1	UP Established	-	-	-	-	5-30-2014
ORM-4	UP Established	-	-	-	-	5-31-2014
SUB-01	UP Established	-	-	-	-	5-31-2014

The GNSS setup in the recovered reference point, MRE-32; and control points, SUB-1, ORM-1 and ORM-4 are shown in Figure 29 to Figure 32.

Figure 29. GNSS receiver Trimble® SPS 882 setup at MRE-32, located in the Municipal Park of Victoria, in front of the statue of the former Mayor Alfredo G. Ortega Sr., Oriental Mindoro

Figure 30. GPS setup of Trimble® SPS 985 at SUB-1, an established control point located at Maramot Residence in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

Figure 31. GNSS receiver Trimble® SPS 852 setup at ORM-1, located at Subaan Bridge in Barangay Subaan, Municipality of Socorro, Oriental Mindoro

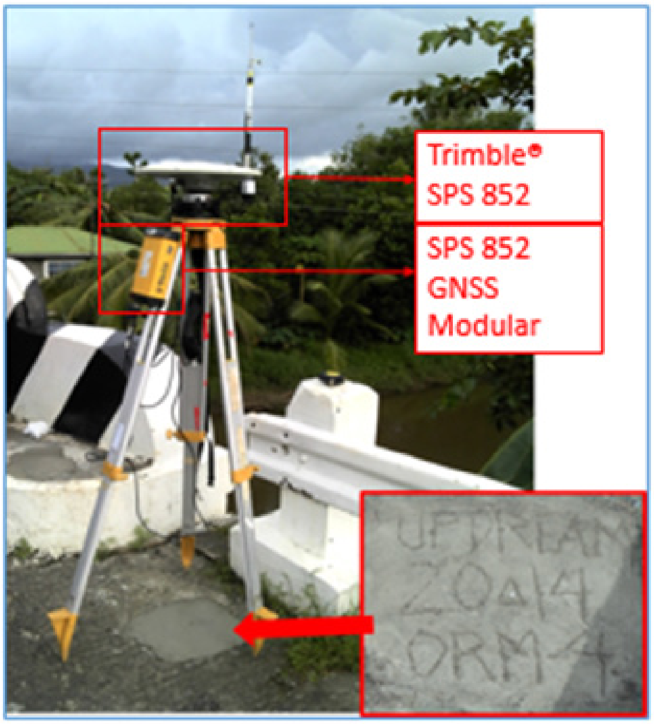


Figure 32. GNSS receiver Trimble® SPS 852 setup at ORM-4, located at the right side of the approach of Pola Bridge in Barangay Casiligan, Municipality of Pola

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking is 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 used in Pola River Basin survey is summarized in Table 20 generated by TBC software.

Table 20. Baseline processing report for Pola River Basin control survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ORM-1 --- SUB-01	05-30-2014	Fixed	0.004	0.006	301°40'27"	1466.251	4.823
SUB-01 --- MRE-32	05-30-2014	Fixed	0.010	0.031	318°11'52"	15342.18	-9.283
SUB-01 --- ORM-4	6-1-2014	Fixed	0.003	0.022	48°43'17"	7475.934	-19.149
ORM-1 --- MRE 32	05-30-2014	Fixed	0.010	0.032	319°54'33"	13942.72	-14.146

As shown in Table 20, a total of four (4) 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 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:

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

where:

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

The four control points, MRE-32, ORM-1, ORM-4 and SUB-01 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of MRE-32 were held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 21. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MRE-32	Grid	Fixed	Fixed	Fixed	Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 22. All fixed control points have no values for grid and elevation errors.

Table 22. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MRE-32	313449.201	?	1456936.499	?	17.175	?	ENe
ORM-1	322358.982	0.007	1446211.774	0.003	30.565	0.028	
SUB-01	323601.847	0.007	1445433.872	0.003	25.687	0.028	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 23. Using the equation $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal accuracy, and $z_e<10\ cm$ for the vertical; below is the computation for accuracy that passed the required precision:

a. **MRE-32**

Horizontal Accuracy	=	Fixed
Vertical Accuracy	=	Fixed

b. **ORM-1**

Horizontal Accuracy	=	√((0.7)² + (0.3)²
	=	√ (0.49 + 0.90)
	=	1.2 cm < 20 cm
Vertical Accuracy	=	2.8 cm < 10 cm

c. **SUB-01**

Horizontal Accuracy	=	√((0.7)² + (0.3)²
	=	√ (0.49 + 0.90)
	=	1.2 cm < 20 cm
Vertical Accuracy	=	2.8 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the five (5) occupied control points are within the required accuracy of the project.

Table 23. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
MRE-32	N13°10'23.79251"	E121°16'43.46244"	65.368	?	ENe
ORM-1	N13°04'36.74731"	E121°21'41.63863"	79.500	0.028	
SUB-01	N13°04'11.69491"	E121°22'23.06063"	74.676	0.028	

Table 24. List of references and control points used in Pola (Casiligan) River Survey (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)					
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MRE-32	2nd Order, GCP	13°10'23.79251"	121°16'43.46244"	65.368	1456936.499	313449.201	17.175
ORM-1	UP Established	13°04'36.74731"	121°21'41.63863"	79.5	1446211.774	322358.982	30.565
ORM-4	UP Established	13°06'52.16736"	121°25'29.58456"	55.523	1450329.531	329251.554	6.585
SUB-01	UP Established	13°04'11.69491"	121°22'23.06063"	74.676	1445433.872	323601.847	25.687

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

Cross-section and as-built surveys were conducted on June 9, 2014 at the ustream side of Pola Bride in Brgy. Casiligan, Municipality of Pola, Oriental Mindoro using a GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 33.

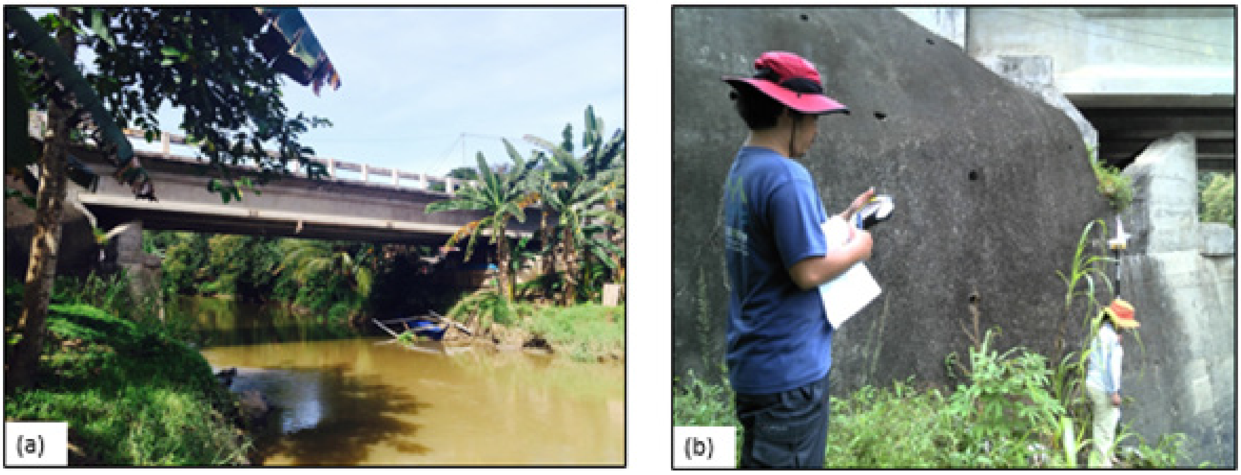


Figure 33. (a) Span of Pola Bridge from the upstream and (b) cross-section survey at Pola Bridge, Brgy. Casiligan, Municipality of Pola, Oriental Mindoro

The cross-sectional line length in Pola Bridge is about 84.02 m with 20 cross-sectional points acquired using ORM-4 as the GNSS base station for this survey. The summary of gathered cross-section, its location map, and as-built data for Pola Bridge are indicated in Figure 34 to Figure 36.

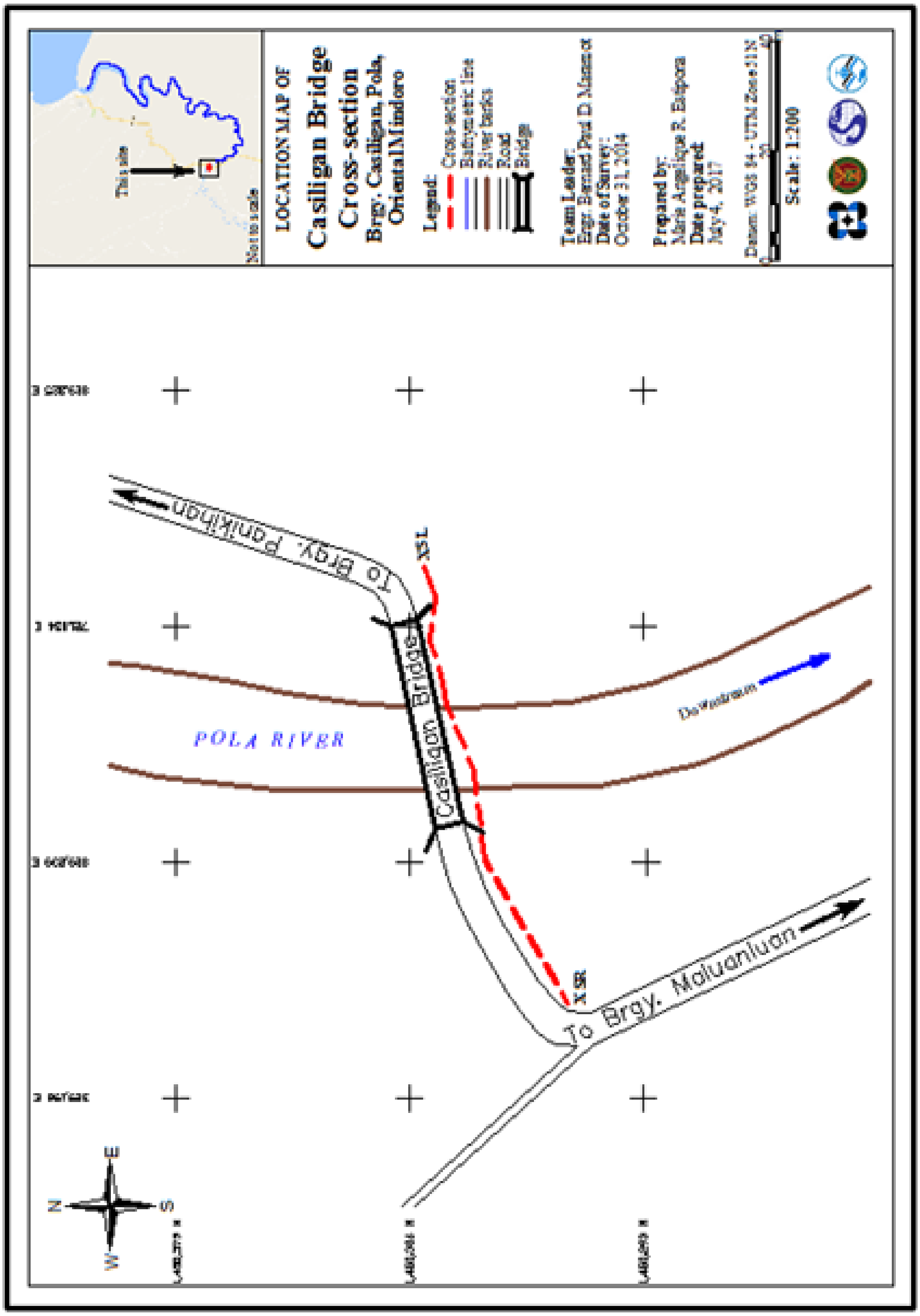


Figure 34. Casiligan bridge cross-section location map

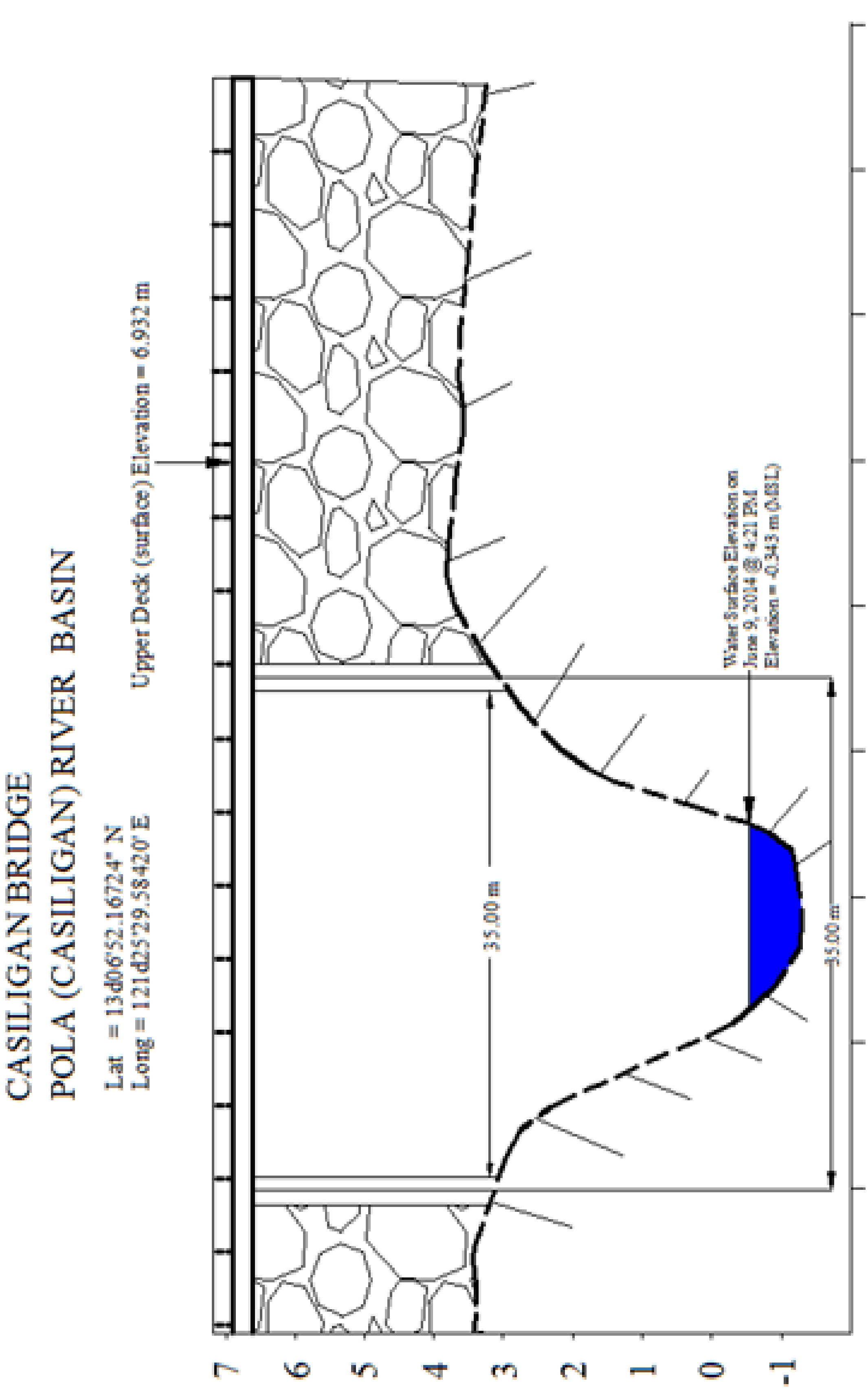
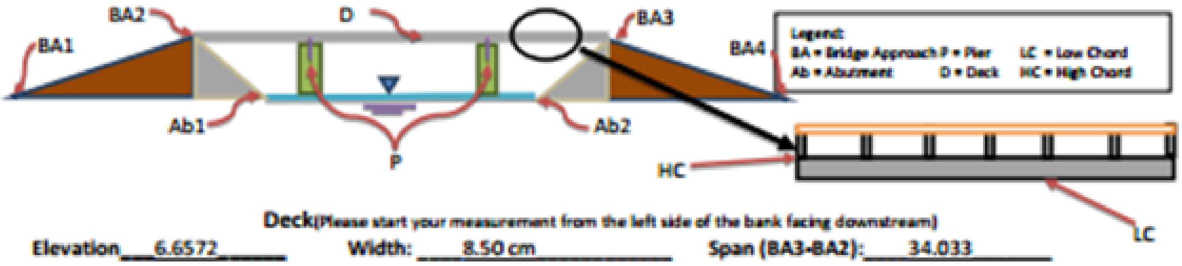


Figure 39. Location map of the Old Quirino Bridge Cross Section.

Bridge Data Form

Bridge Name: POLA BRIDGE Date: October 31, 2014
River Name: POLA RIVER Time: 4:30 pm
Location (Brgy, City,Region): Brgy. Casiligan, Municipality of Pola, Oriental Mindoro,
Survey Team: Team Bernard
Flow condition: low (normal) high Weather Condition: (fair) rainy
Latitude: 13d06'52.16724" N Longitude: 121d25'29.58420" E



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

Elevation: 6.6572 Width: 8.50 cm Span (BA3-BA2): 34.033

	Station	High Chord Elevation	Low Chord Elevation
1		5.031 m	6.933 m
2			
3			
4			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	4.309 m	BA3	60.878	6.694 m
BA2	27.590	6.923 m	BA4	147.382	2.782 m

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

	Station(Distance from BA1)	Elevation
Ab1	33.038	3.503 m
Ab2	57.063	1.093 m

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

Shape: RECTANGULAR Number of Piers: 2 Height of column footing: ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	29.76869	6.932 m	
Pier 2	58.26116	6.652 m	
Pier 3			
Pier 4			
Pier 5			
Pier 6			
Pier 7			

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

Figure 36. Pola Bridge Data Form

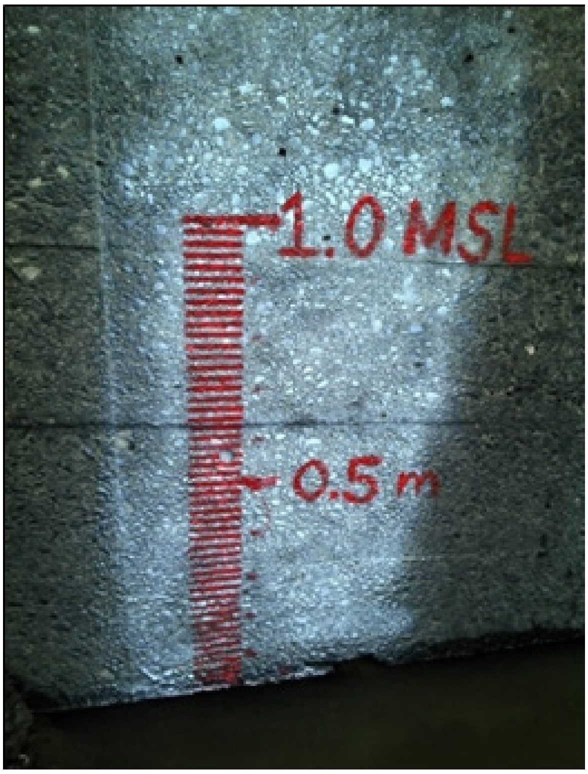


Figure 37. Water Marking at Pola Bridge

Figure 38. Marking of the pier at Pola Bridge

Water surface elevation of Pola River was determined using a Trimble® SPS 882 in PPK mode survey on June 9, 2014 at 4:21 PM at Pola Bridge. The elevation that was referred to MSL was at 0.343 m. The water surface elevation was then translated onto marking the bridge's pier thru Digital Level. The marked pier will serve as reference for flow data gathering and depth gauge deployment by the accompanying SUC, University of the Philippines Los Baños, who is responsible for monitoring Casiligan River.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 31, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 39. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The antenna height is 1.498 m from the ground. The survey was conducted using PPK technique on a continuous topography mode.

Figure 39. Validation points acquisition survey setup by the survey team: A Trimble® SPS 882 is mounted in a 2 m pole and attached in front of the vehicle

The survey acquired 1,415 validation points with an approximate length of 15.41 km as shown in the map in Figure 40. The activity started from the Municipality of Socorro to the Municipality of Pola traversing the main national high way and the control point SUB-01 served as the GNSS base station for the survey,

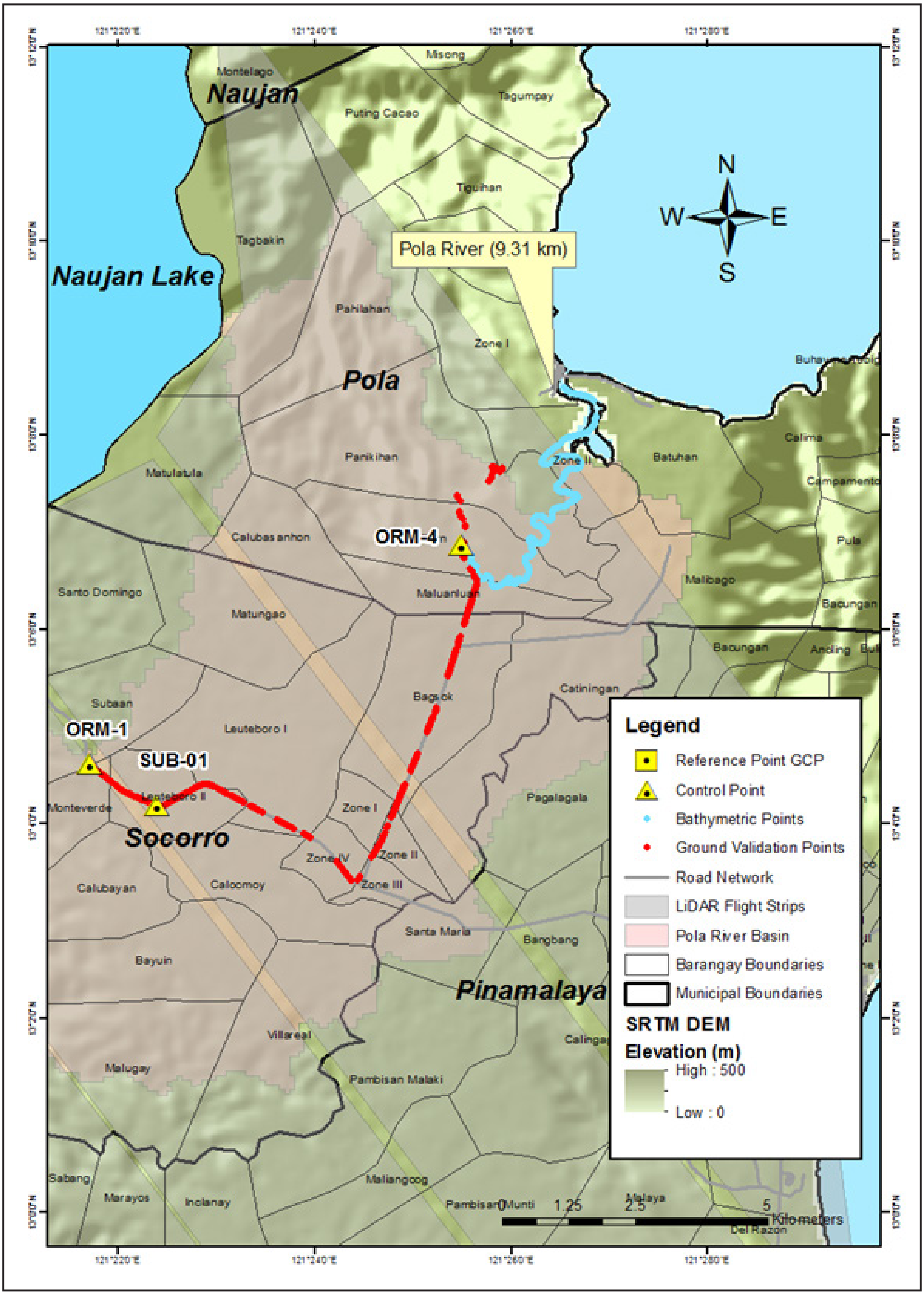


Figure 40. Validation points acquisition survey along Pola River Basin

4.7 River Bathymetric Survey

Bathymetric survey was done on June 9, 2014 using Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ Single Beam Echosounder attached to a boat as shown in Figure 41. The survey started in the upstream part of the river in Brgy. Casiligan, Municipality of Pola with coordinates 13°06'45.58405" 121°25'35.35263", down to the mouth of the river in Brgy. Batuhan, also in Pola with coordinates 13°08'29.24420" 121°26'32.48795". The control point ORM-4 was occupied as the GNSS base station all throughout the survey.

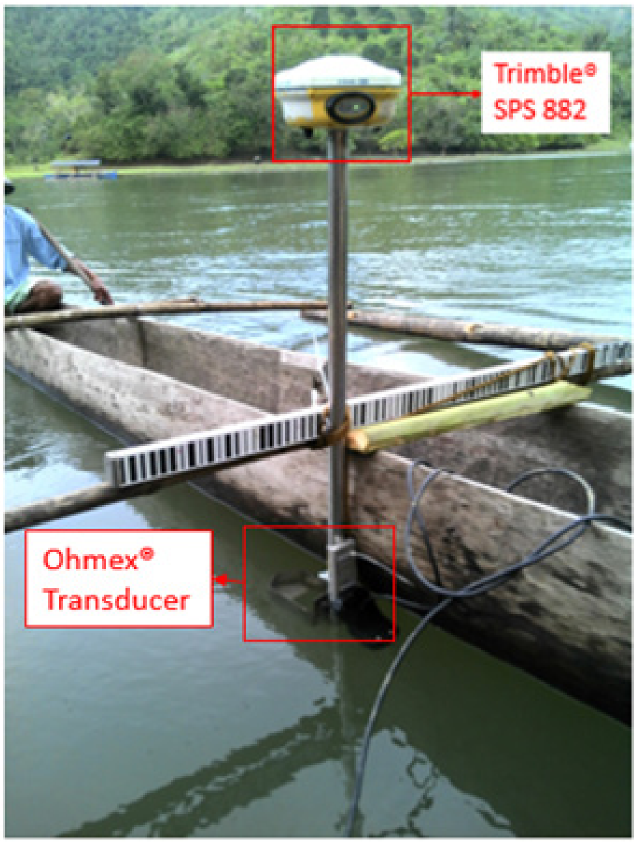


Figure 41. Bathymetric survey setup in a banca with "katig" on the sides in Casiligan-Pola River

The bathymetric survey gathered about 9.3 km of bathymetry line with 4,483 points covering four barangays in Municipality of Pola namely: Panikihan, Batuhan and Poblacion, as shown in Figure 42. A CAD drawing was also produced to illustrate the Pola riverbed profile, as shown in Figure 43. An elevation drop of 0.50 m was observed within the approximate distance of 9.31 km.

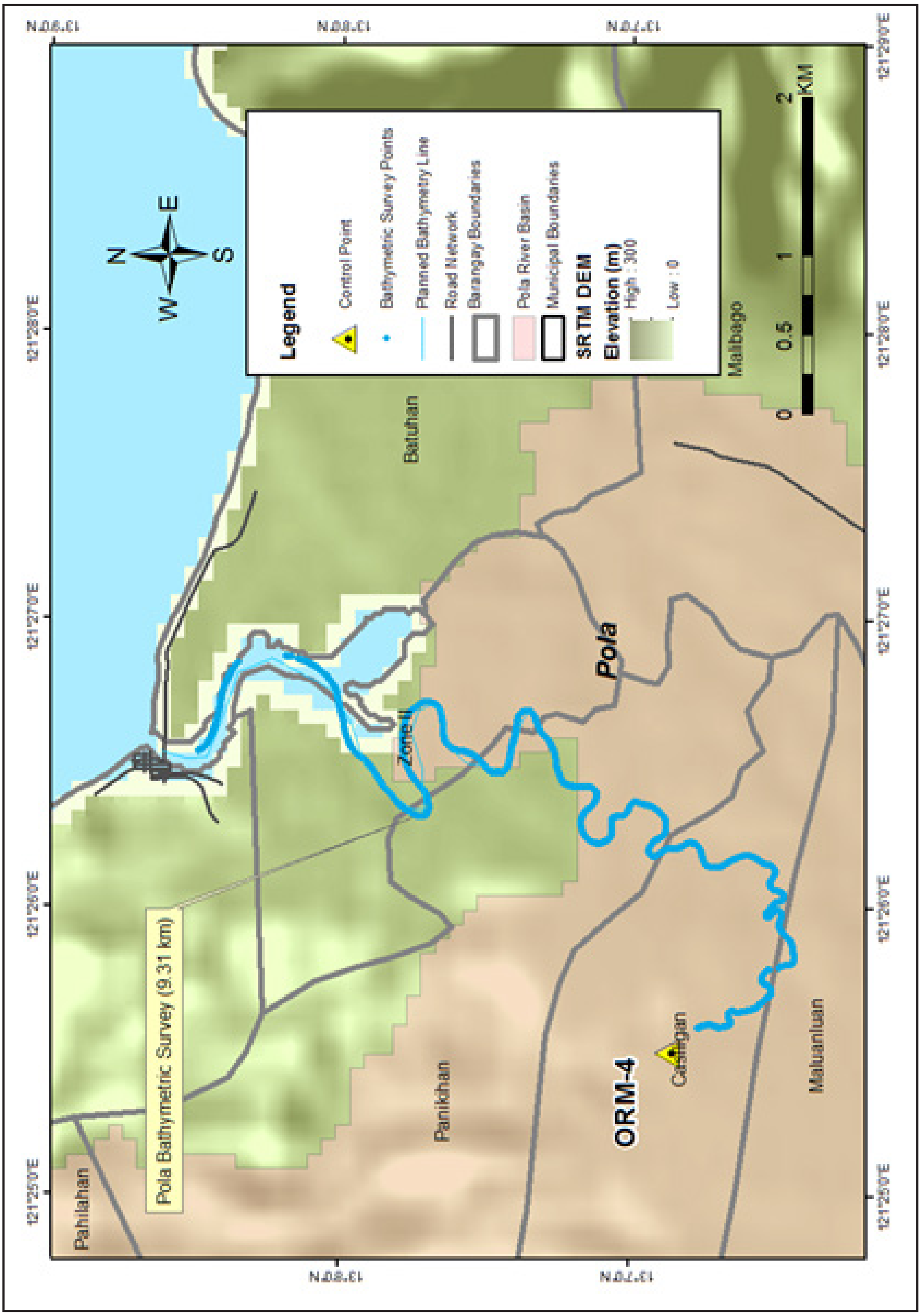


Figure 42. Bathymetric survey of Casiligan River

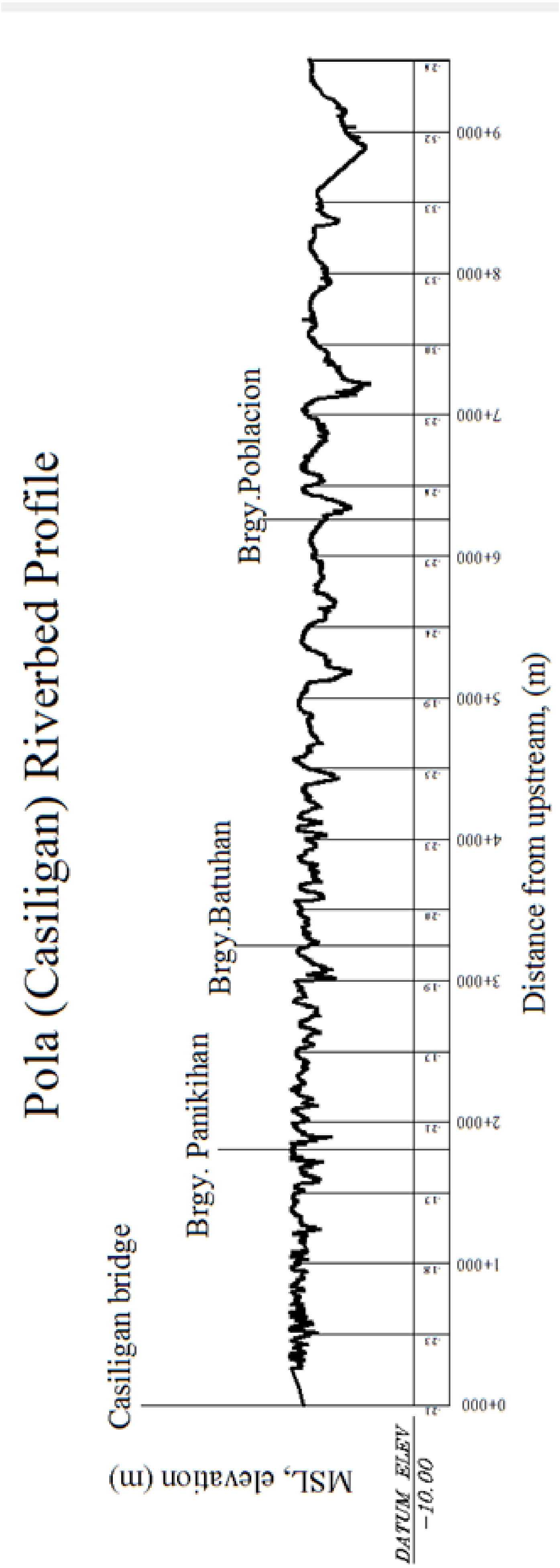


Figure 43. Riverbed Profile of Pola River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

No gathered rainfall data for Casiligan river basin. The HMS model is not calibrated. The values generated HMS model are by default.

5.2 RIDF Station

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

Table 25. RIDF values for Tayabas Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	21	32.7	42	59.3	83	99.9	128.2	161.5	195.9
5	29.6	42.1	52.5	77.3	116.1	143	192.6	232.3	279.5
10	35.4	48.3	59.4	89.2	138	171.5	235.2	279.3	334.9
15	38.6	51.8	63.3	96	150.3	187.6	259.3	305.7	366.1
20	40.9	54.3	66.1	100.7	159	198.9	276.1	324.3	388
25	42.6	56.2	68.2	104.3	165.7	207.5	289.1	338.5	404.8
50	48	62	74.7	115.5	186.2	234.3	329.1	382.5	456.7
100	53.4	67.8	81.1	126.6	206.6	260.8	368.8	426.2	508.3

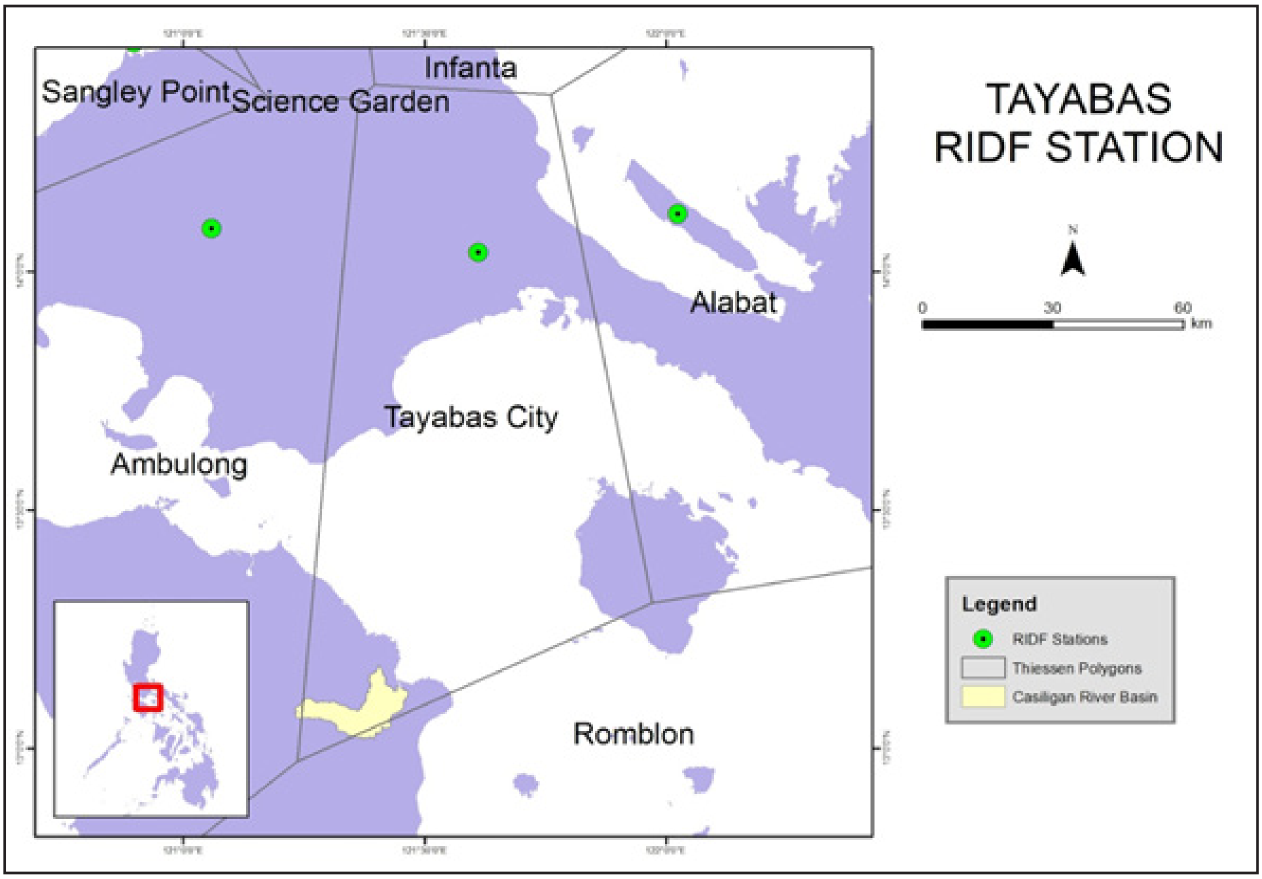


Figure 44. Location of Puerto Princesa RIDF relative to Casiligan River Basin

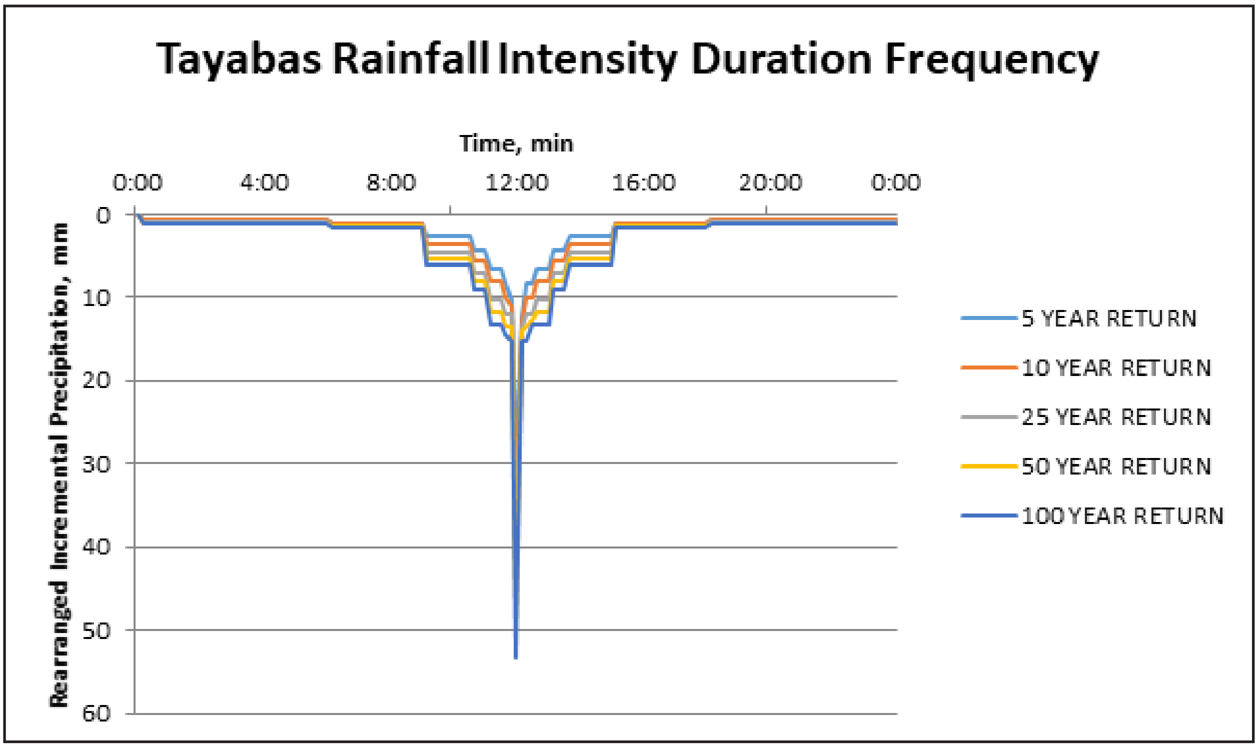


Figure 45. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

5.3 HMS Model

The soil shape file (dated pre-2004) was taken from the Bureau of Soils and Water Management under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil map and the land cover map can be found in Figures 46 and Annex 47, respectively.

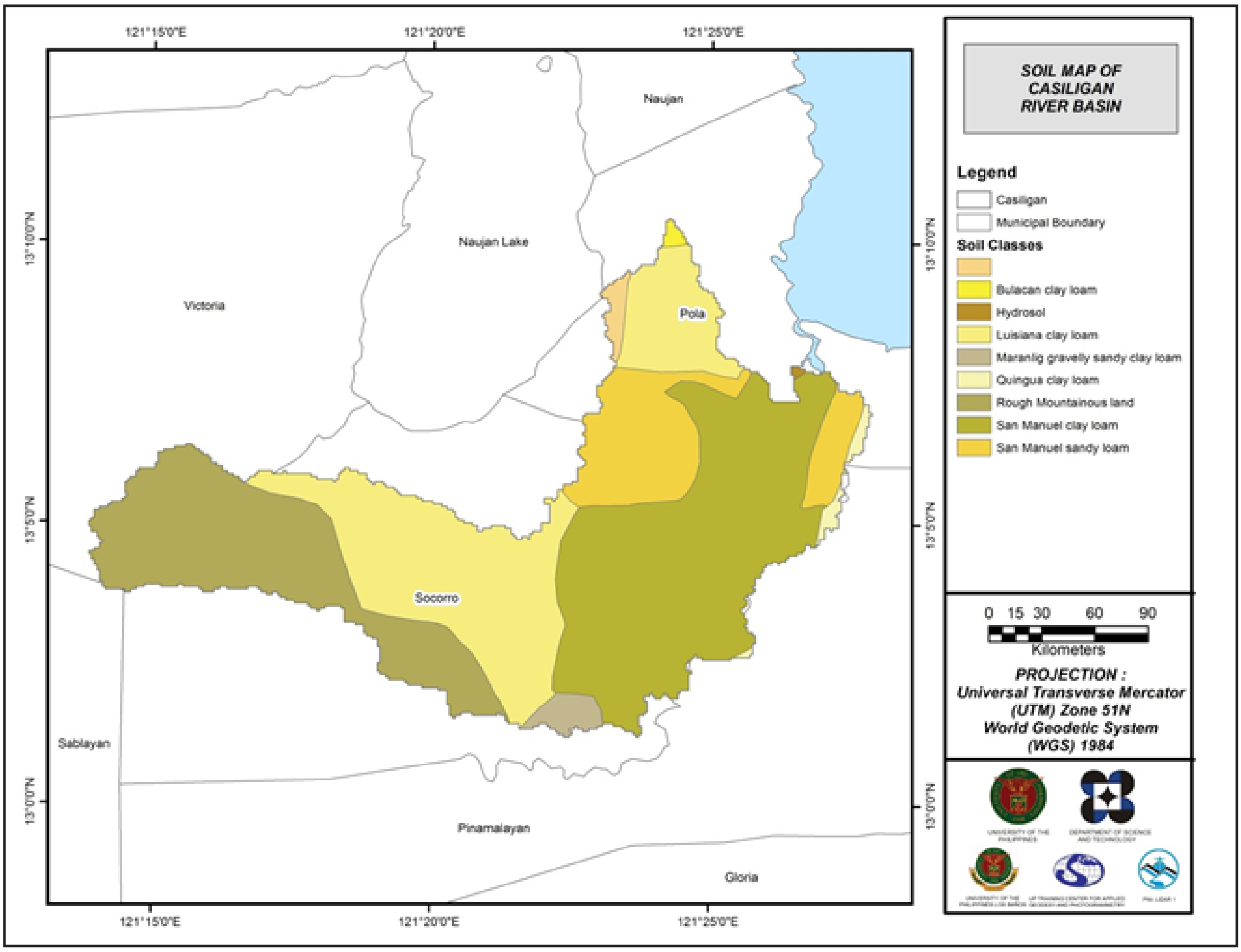


Figure 46. The soil map of the Casiligan River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

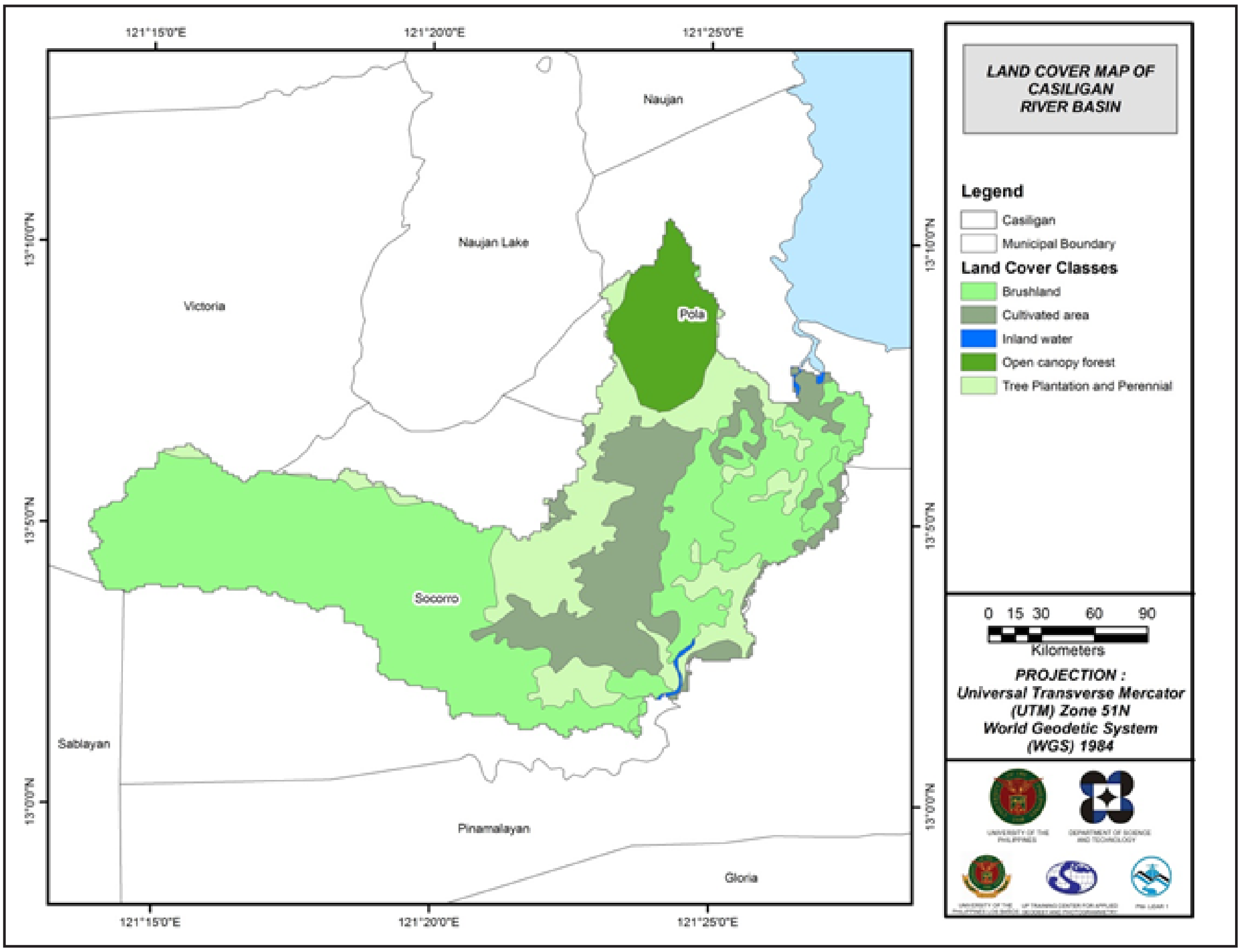


Figure 47. The land cover map of the Casiligan River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: NAMRIA)

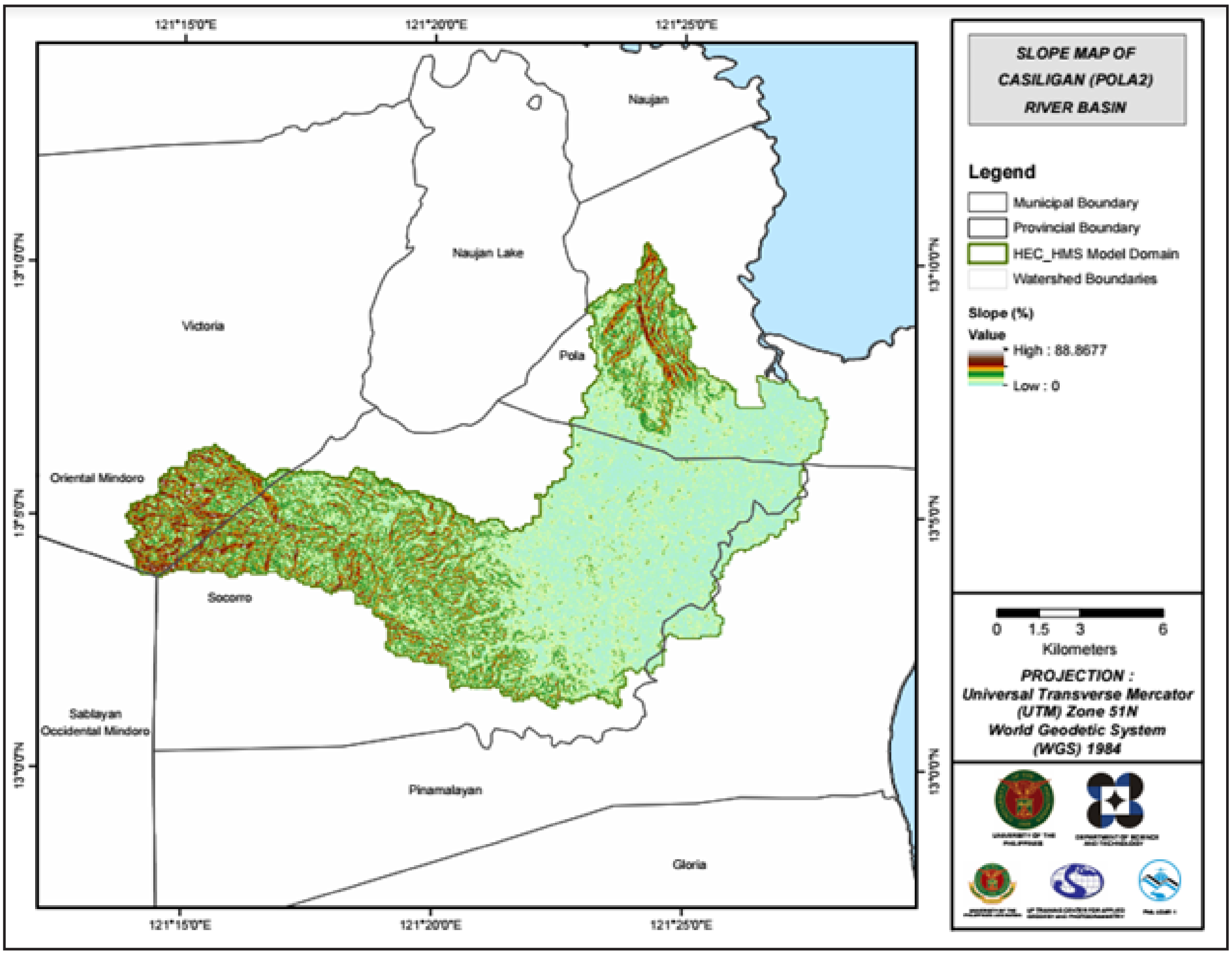


Figure 48. Slope Map of the Casiligan River Basin

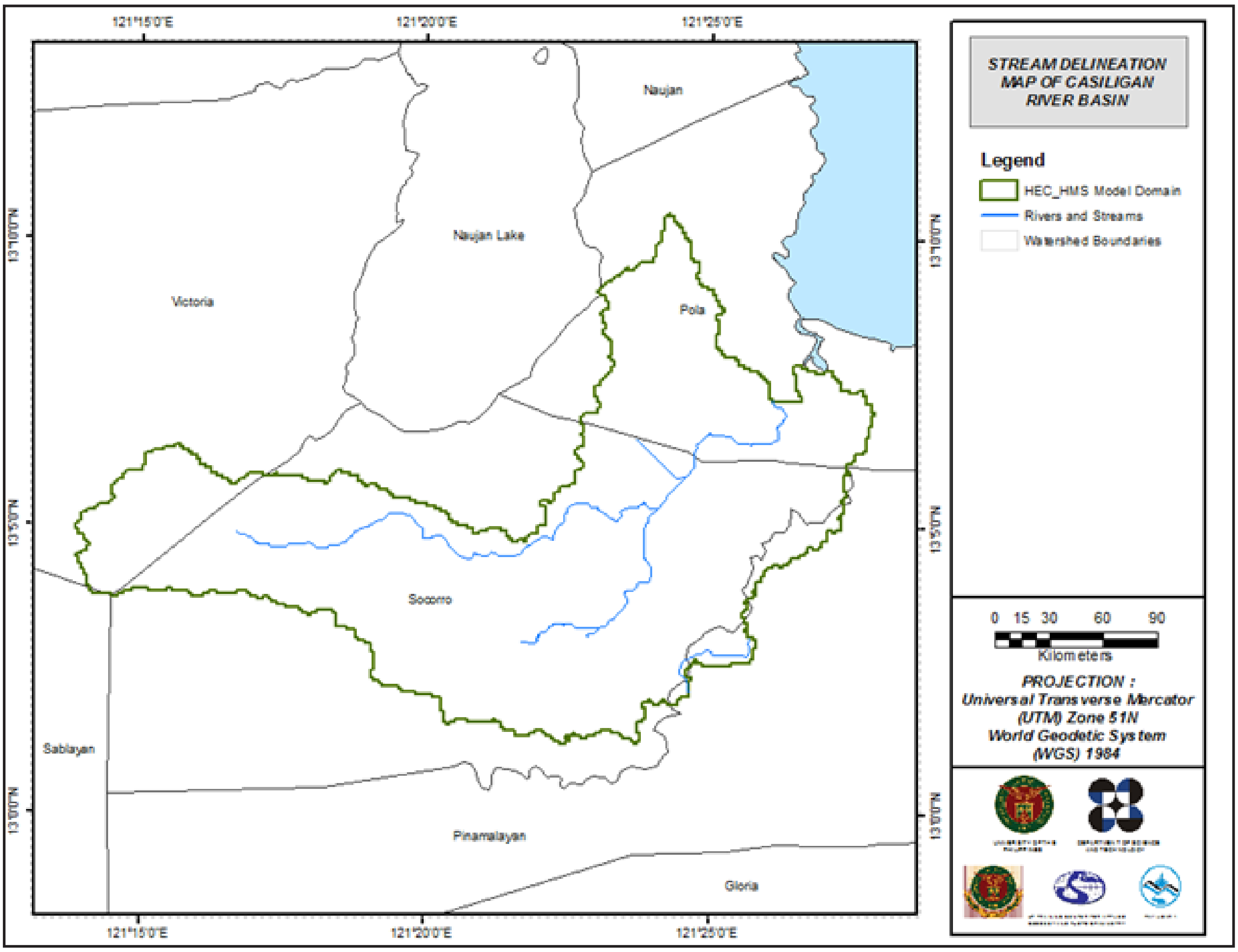


Figure 49. Stream Delineation Map of the Casiligan River Basin

Using SAR-based DEM, the Casiligan basin was delineated and further subdivided into subbasins. The model consists of 51 sub basins, 25 reaches, and 24 junctions. The main outlet is labelled as Casiligan_ outlet. This basin model is illustrated in Figure 50. The basins were identified based on soil and land cover characteristics of the area.

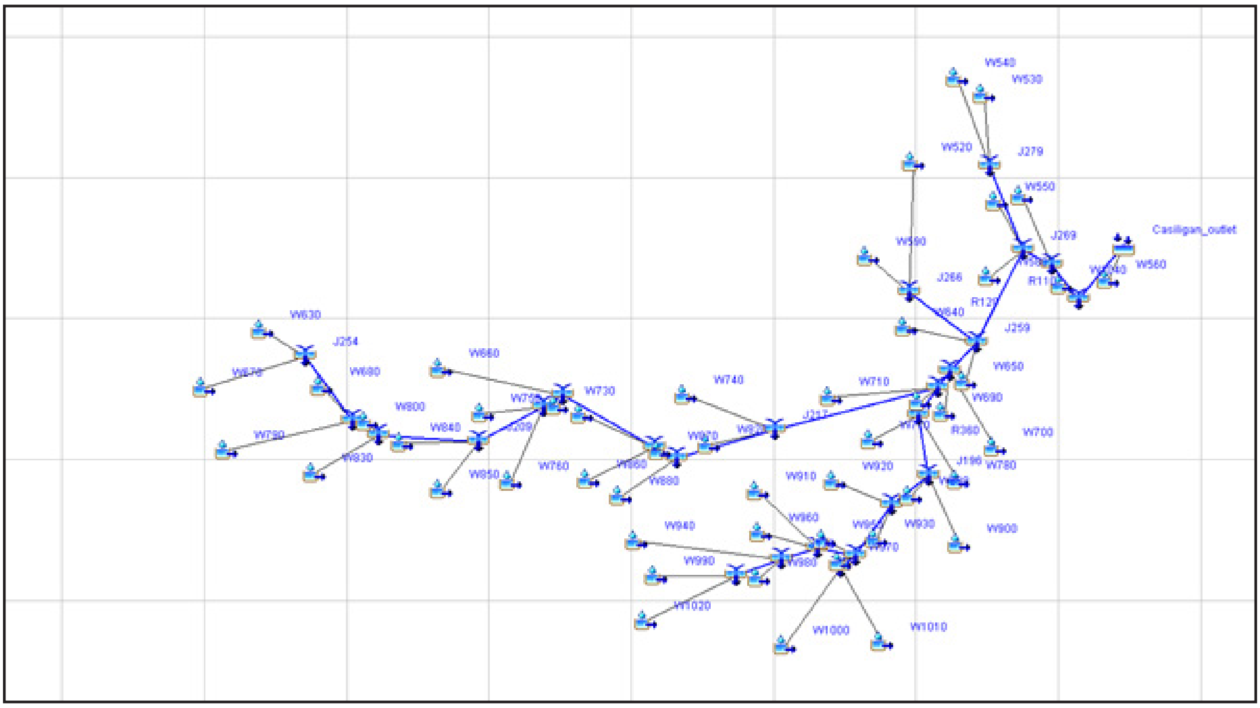


Figure 50. The Casiligan river basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are necessary in the HEC-RAS model setup. 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.

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area is divided into square grid elements, 10 meter by 10 meter in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modelling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are 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 south of the model to the north, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

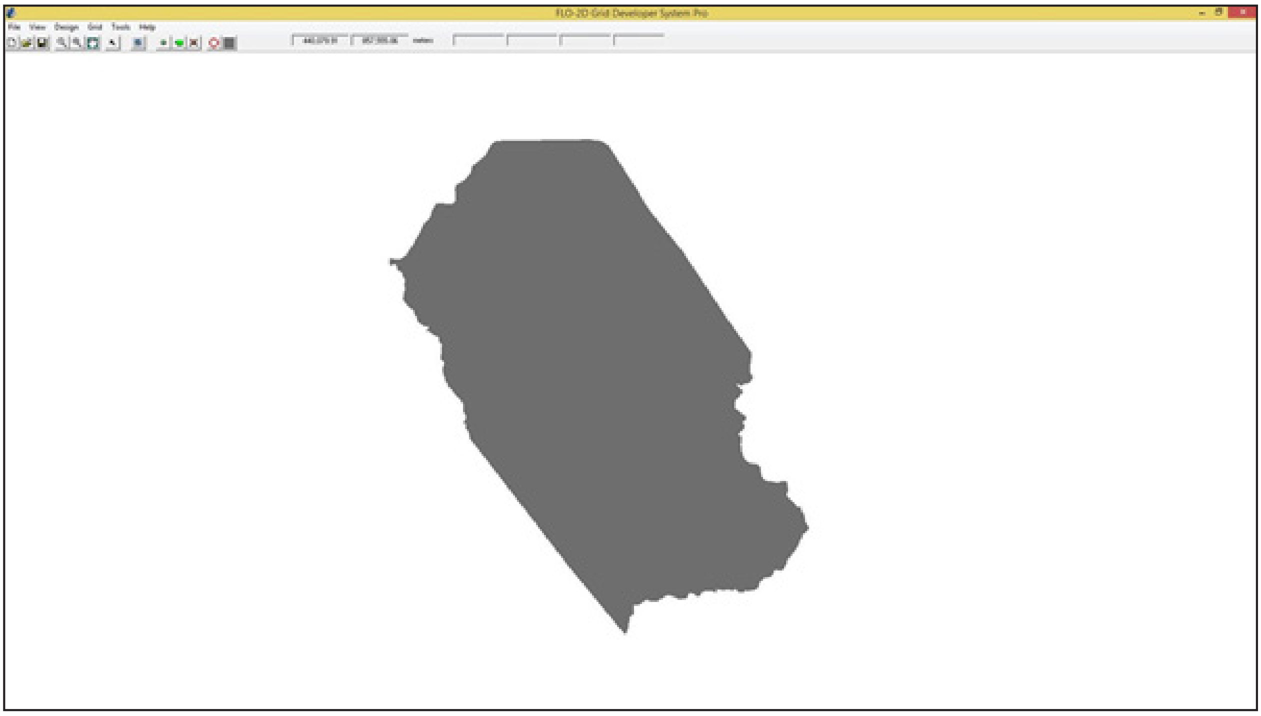


Figure 61. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 100.06329 hours. After the simulation, FLO-2D Mapper Pro is 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 creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Tineg are in Figure 68, 70, and 72.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 63 792 800.00 m2. The generated flood depth maps for Tineg are in Figure 69, 71, and 73.

There is a total of 465 228 177.98 m3 of water entering the model. Of this amount, 25 253 779.51 m3 is due to rainfall while 439 974 398.47 m3 is inflow from other areas outside the model. 11 329 565.00 m3 of this water is lost to infiltration and interception, while 24 641 579.81 m3 is stored by the flood plain. The rest, amounting up to 429 257 024.59 m3, is outflow.

5.6 Results of HMS Calibration

Enumerated in Table 26 are the range of values of the parameters in the model (see also Annex 9: Casiligan Model Basin Parameters).

Table 26. Range of Values for Casiligan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.7 - 14
			Curve Number	35 - 83
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 25
			Storage Coefficient (hr)	0.03 - 6

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 0.7 to 14mm means that there is minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35 to 83 for curve number is lower than the advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.3 hours to 25 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.

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

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Casiligan River using the calibrated HMS base flow is shown in Figure 52.

Figure 52. Sample output of Casiligan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Casiligan floodplain are shown in Figure 17 to 21. The floodplain, with an area of 264.29 sq. km., covers four municipalities namely Gloria, Pinamalayan, Pola, and Socorro. Table 27 shows the percentage of area affected by flooding per municipality.

Table 27. Municipalities affected by flooding in Casiligan floodplain

Municipality	Total Area	Area Flooded	% Flooded
Gloria	327.28	10.17	3.11%
Pinamalayan	206.87	96.65	46.72%
Pola	127.04	58.76	46.26%
Socorro	206.06	98.147	47.63%

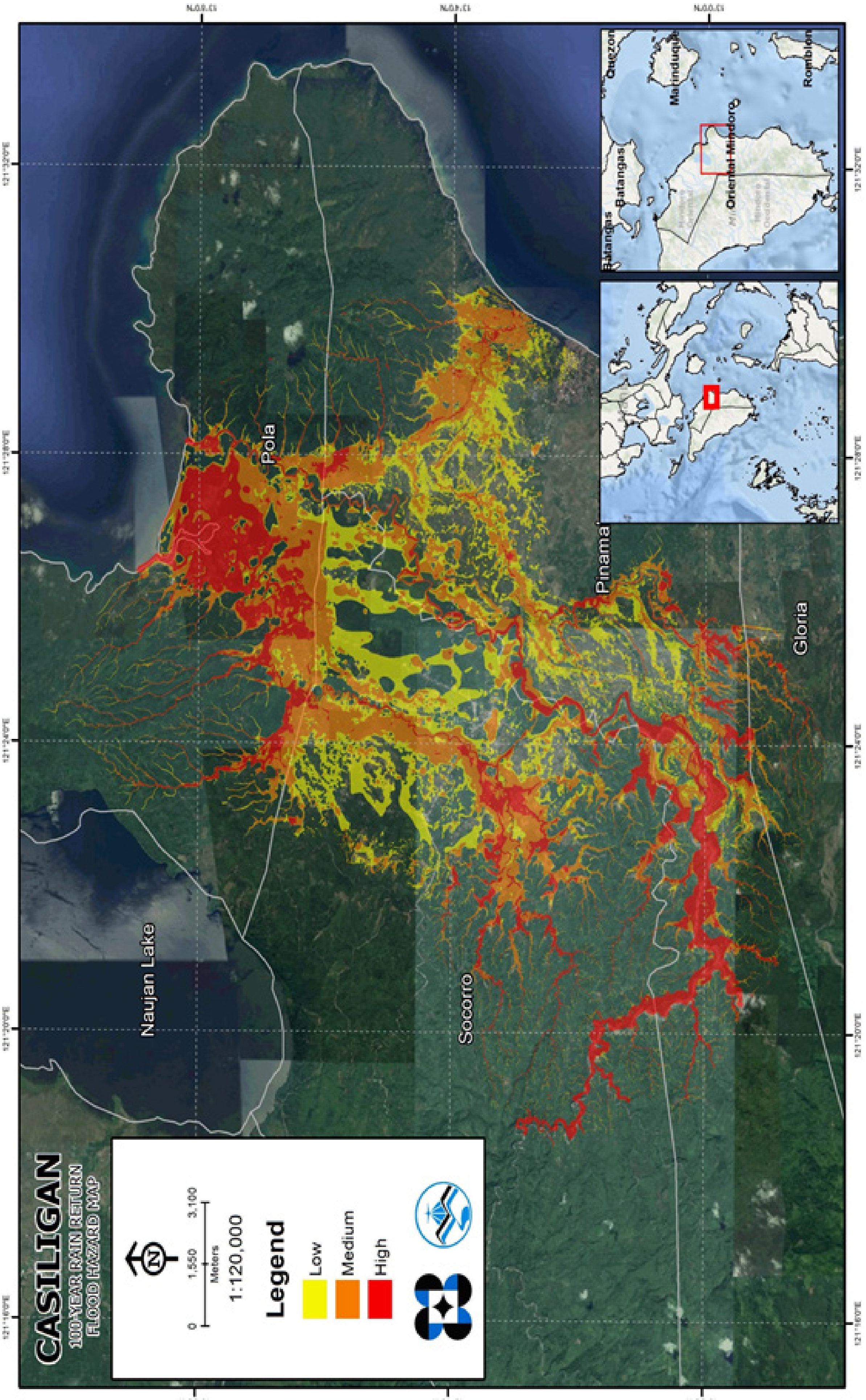


Figure 53. 100-year Flood Hazard Map for Casiligan Floodplain

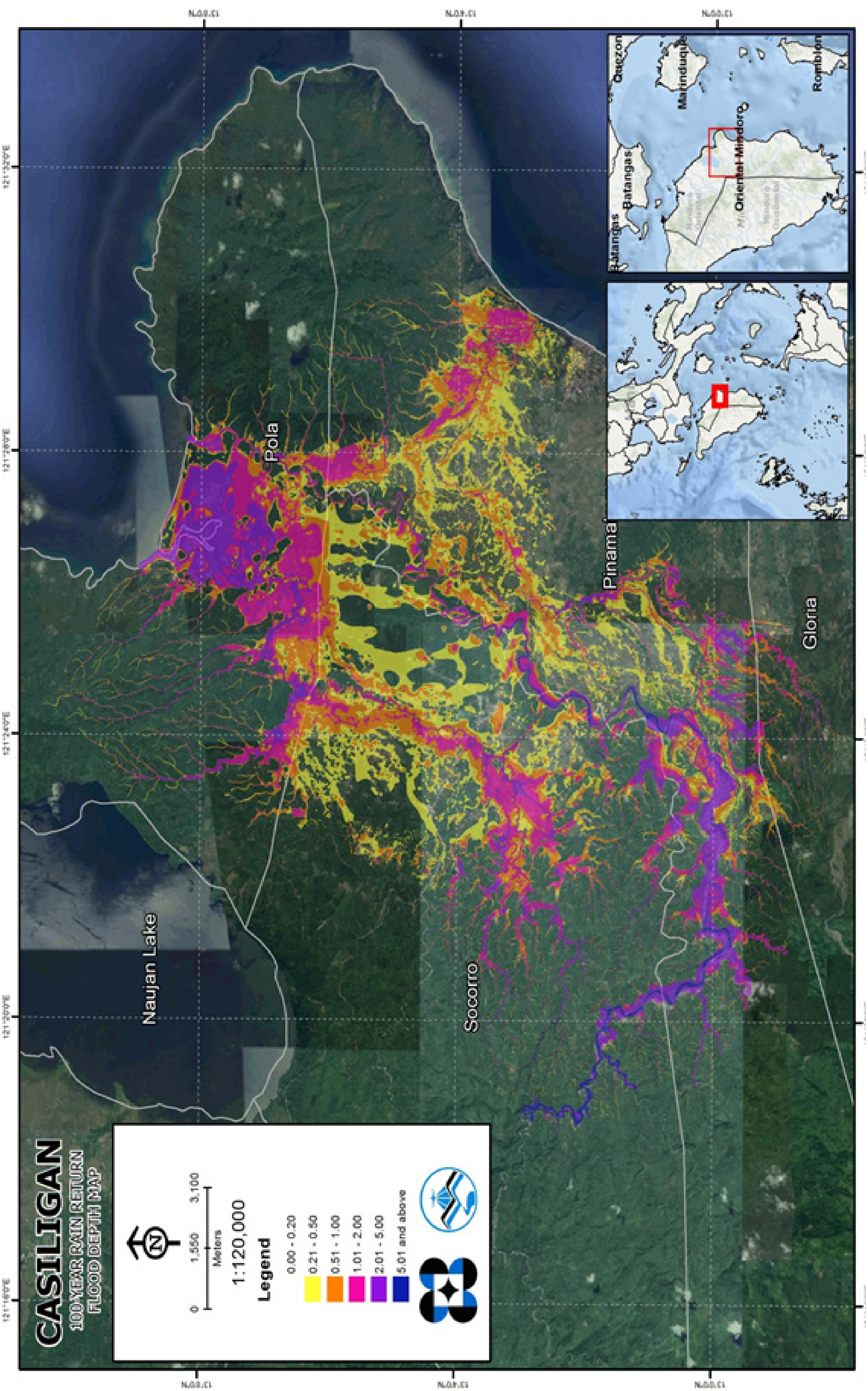


Figure 54. 100-year Flow Depth Map for Casiligan Floodplain

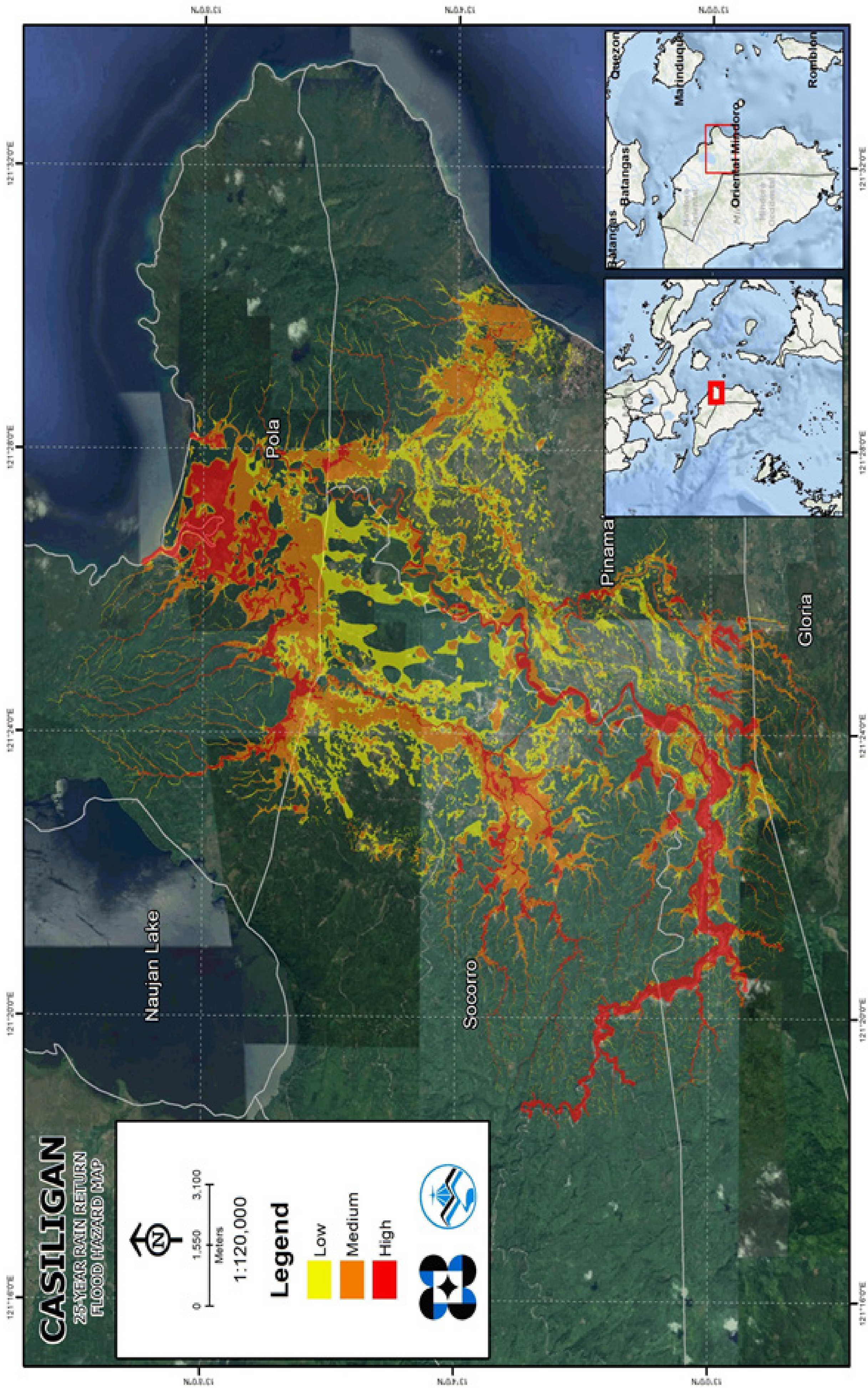


Figure 55. 25-year Flood Hazard Map for Casiligan Floodplain

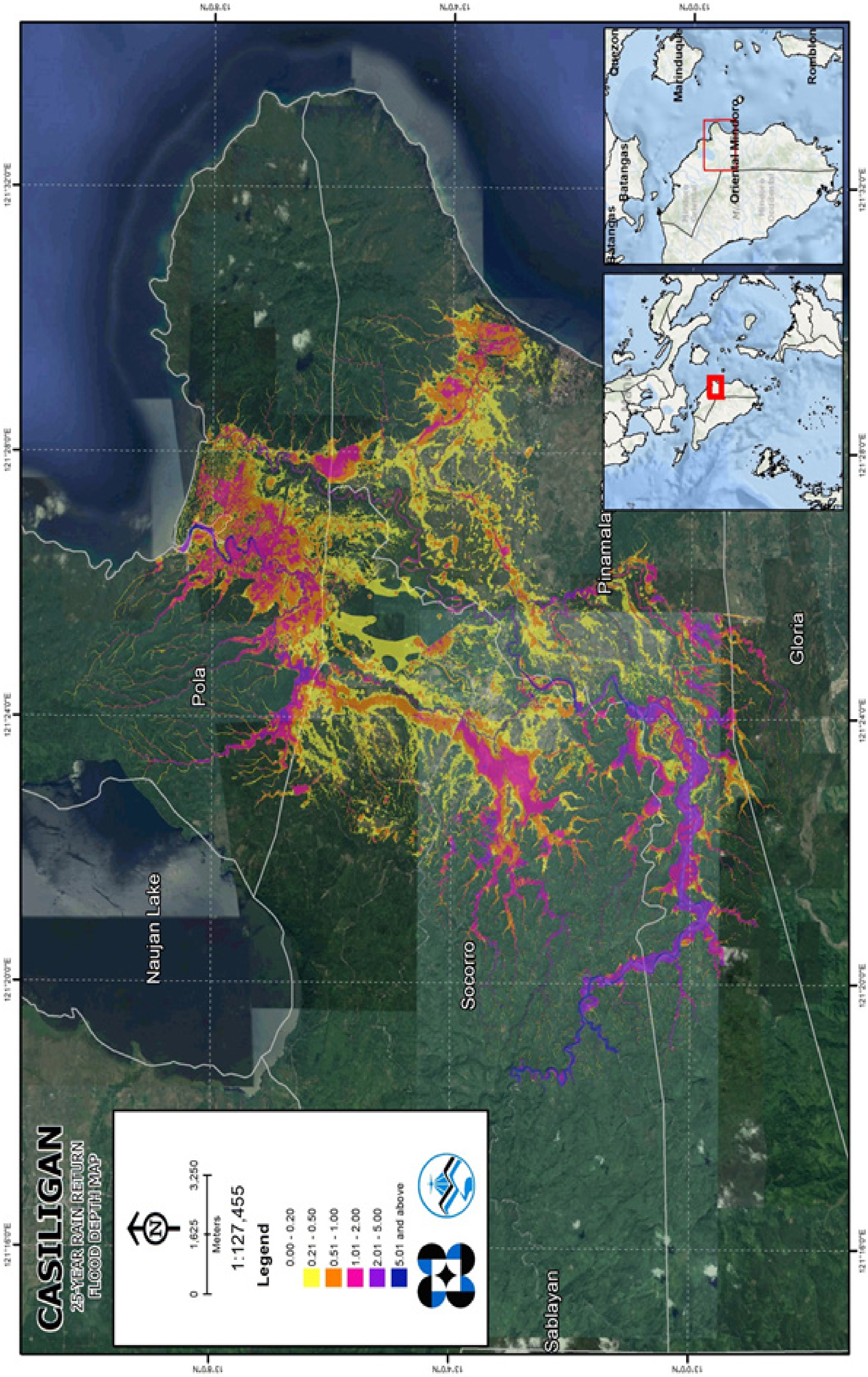


Figure 56. 25-year Flow Depth Map for Casiligan Floodplain

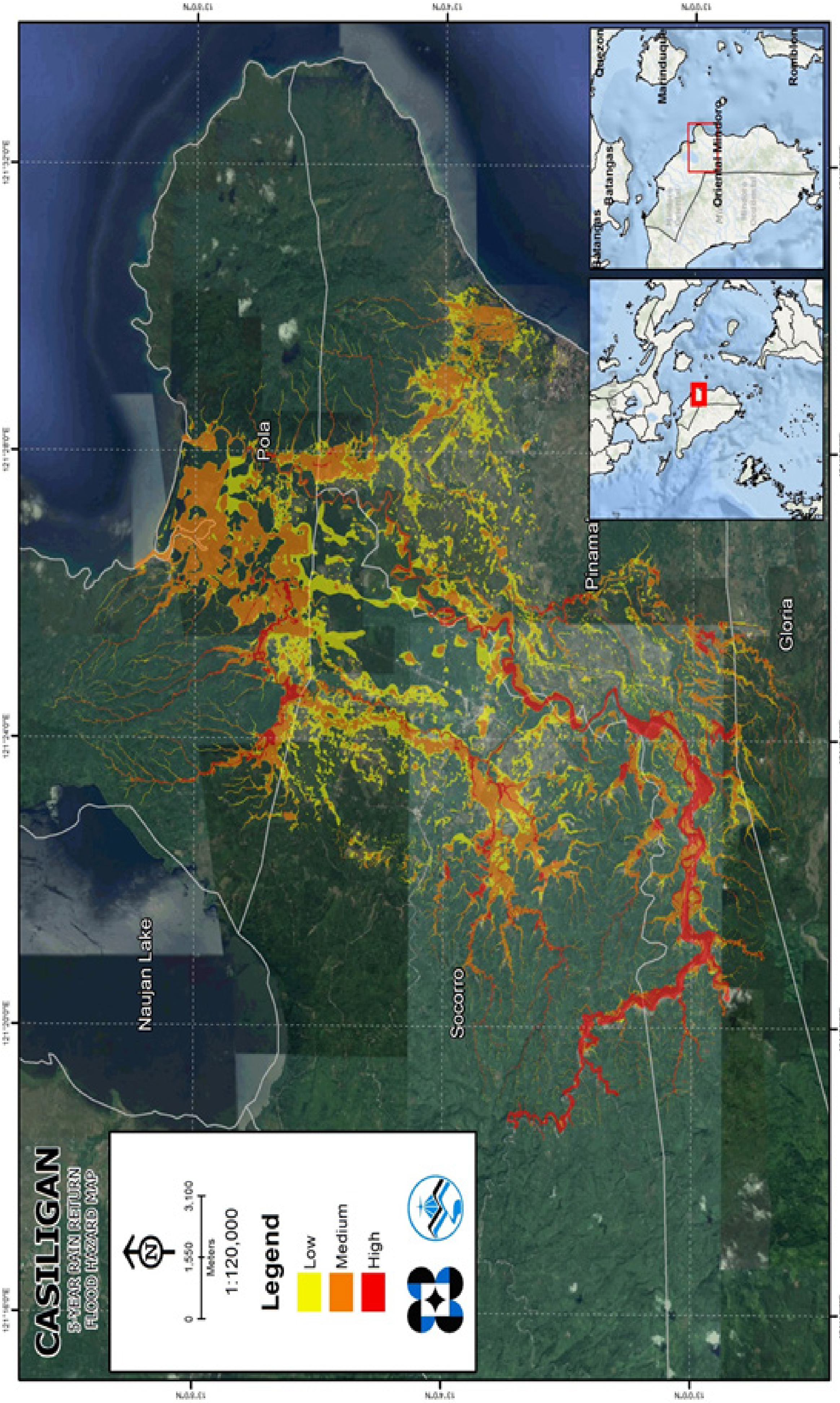


Figure 57. 5-year Flood Hazard Map for Casiligan Floodplain

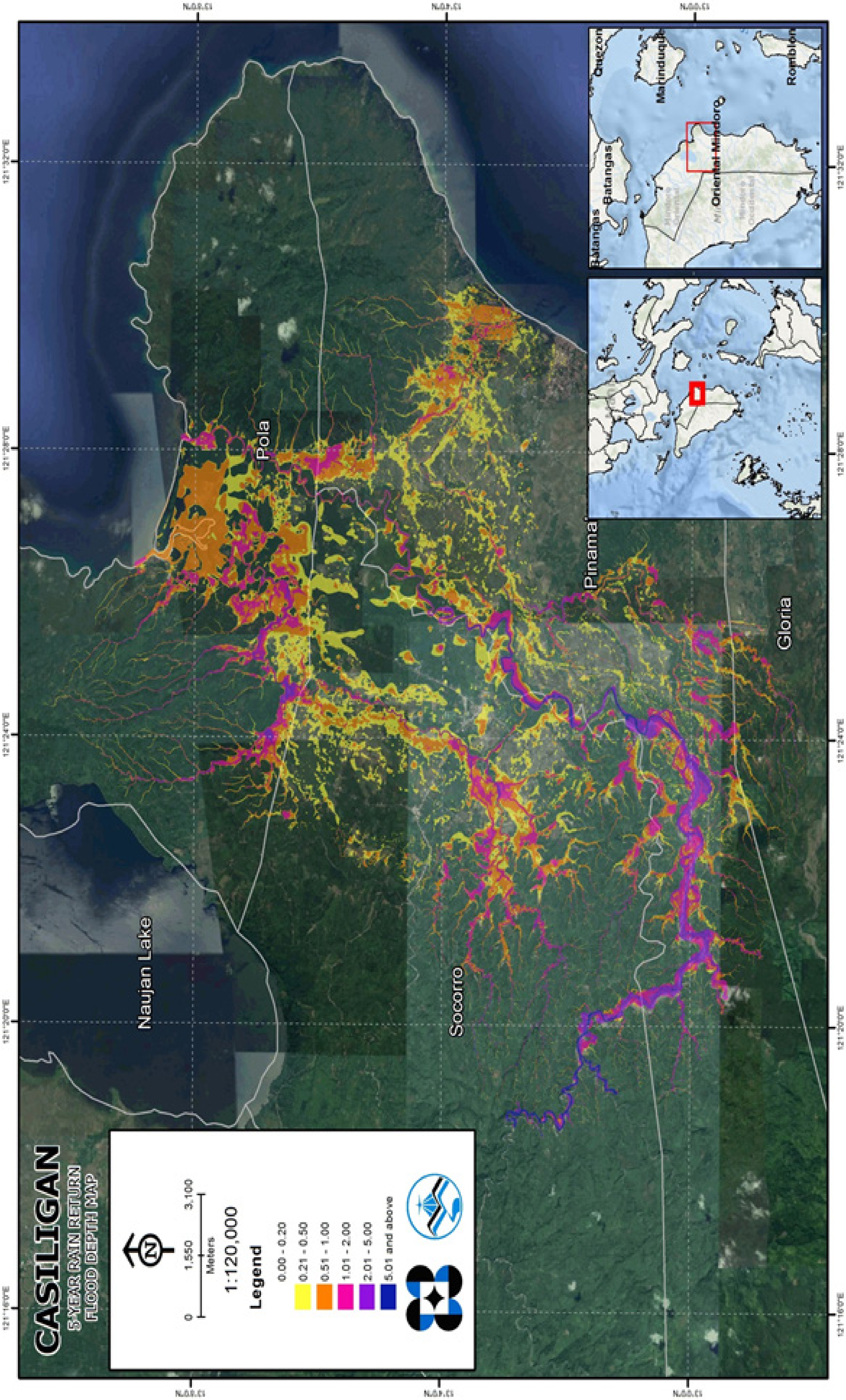


Figure 58. 5-year Flow Depth Map for Casiligan Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Casiligan river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 62 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 2.71% of the municipality of Gloria with an area of 327.28 sq. km. will experience flood levels of less 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.07%, 0.02%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 28 are the affected areas in square kilometres by flood depth per barangay.

Table 28. Affected Areas in Gloria, Oriental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq. km.)		
	Agos	Buong Lupa	Malamig
0.03-0.20	0.58	3.55	4.75
0.21-0.50	0.059	0.17	0.25
0.51-1.00	0.078	0.12	0.31
1.01-2.00	0.035	0.03	0.17
2.01-5.00	0.0002	0.016	0.042
> 5.00	0	0.0022	0.0001

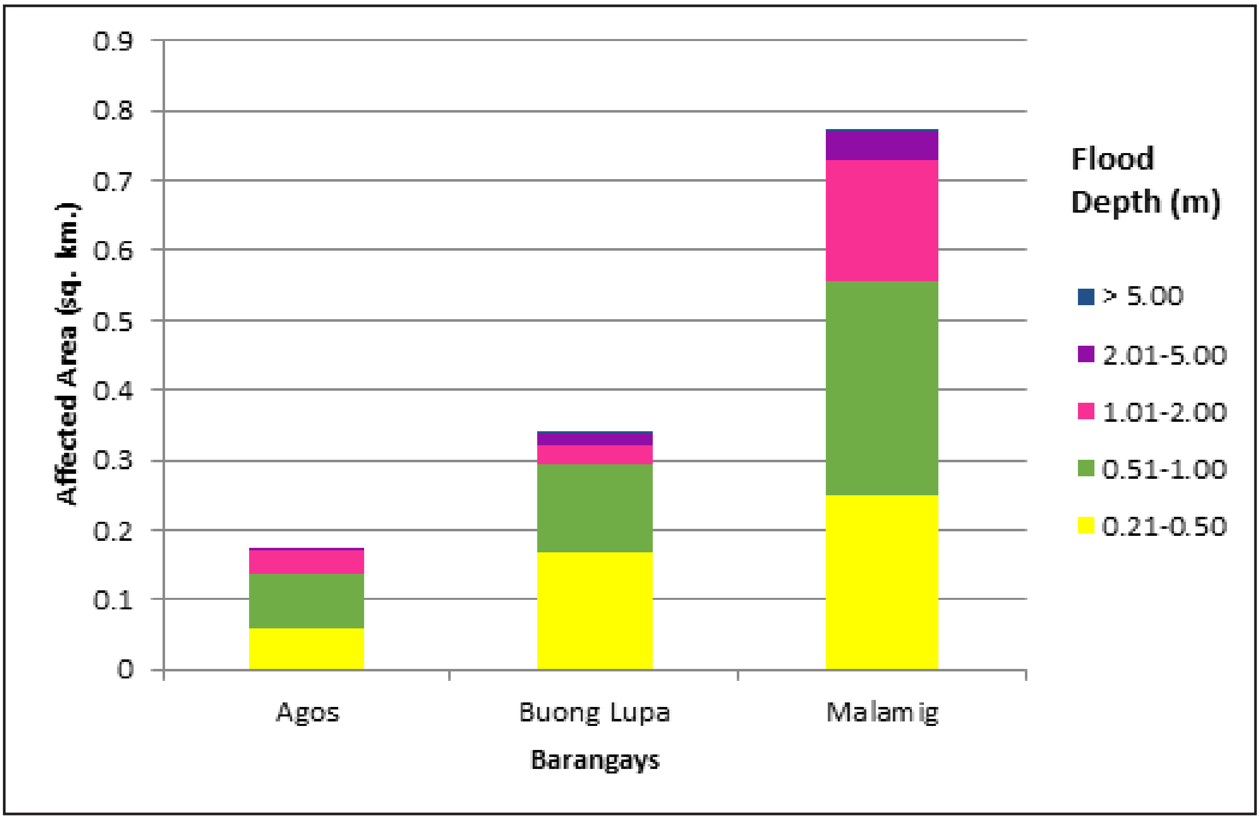


Figure 59. Affected Areas in Gloria, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Pinamalayan, with an area of 206.87 sq. km., 32.77% will experience flood levels of less 0.20 meters. 6.01% of the area will experience flood levels of 0.21 to 0.50 meters while 3.63%, 2.57%, 1.70%, and 0.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 29-30 are the affected areas in square kilometres by flood depth per barangay.

Table 29. Affected Areas in Pinamalayan, Oriental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinamalayan (in sq. km.)												
	Anoling	Bacungan	Bangbang	Buli	Cacawan	Calingag	Inclanay	Maliangcog	Maningcol	Marayos	Marfrancis-co	Nabuslot	Pagalagala
0.03-0.20	0.96	1.11	2.48	0.61	0.02	4.93	2.88	3.59	0.62	4.27	3.4	6.14	4.45
0.21-0.50	0.029	0.25	0.6	0.011	0	0.9	0.47	0.58	0.054	0.25	0.62	1.72	1.28
0.51-1.00	0.019	0.39	0.2	0.0018	0	0.36	0.44	0.22	0.031	0.38	0.29	0.3	0.7
1.01-2.00	0.0093	0.19	0.11	0.0004	0	0.15	0.63	0.24	0.0013	0.52	0.089	0.1	0.24
2.01-5.00	0.0013	0.0015	0.05	0.0013	0	0.024	0.54	0.25	0	0.27	0.0028	0.028	0.21
> 5.00	0	0.0014	0.0052	0.0009	0	0	0	0.0044	0	0	0	0	0.0068

Table 30. Affected Areas in Pinamalayan, Oriental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinamalayan (in sq. km.)												
	Palayan	Pambisan Malaki	Pambisan Munti	Panggulayan	Papandayan	Sabang	Santa Maria	Santa Rita	Santo Niño	Zone I	Zone II	Zone III	Zone IV
0.03-0.20	3.57	6.58	3.46	3.66	0.54	9.05	1.77	0.4	0.98	0.82	0.46	0.49	0.55
0.21-0.50	1.12	1.08	0.33	0.76	0.079	0.38	0.81	0.013	0.25	0.29	0.29	0.096	0.18
0.51-1.00	0.48	0.55	0.52	0.48	0.0025	0.47	0.42	0.0097	0.3	0.29	0.37	0.099	0.18
1.01-2.00	0.097	0.66	0.63	0.13	0	0.84	0.44	0.005	0.11	0.032	0.033	0.041	0.024
2.01-5.00	0.012	0.67	0.13	0.01	0	1.09	0.14	0.0001	0.026	0.014	0.0046	0	0.037
> 5.00	0.00064	0.18	0	0.0028	0	0.02	0.077	0	0	0.0001	0	0	0

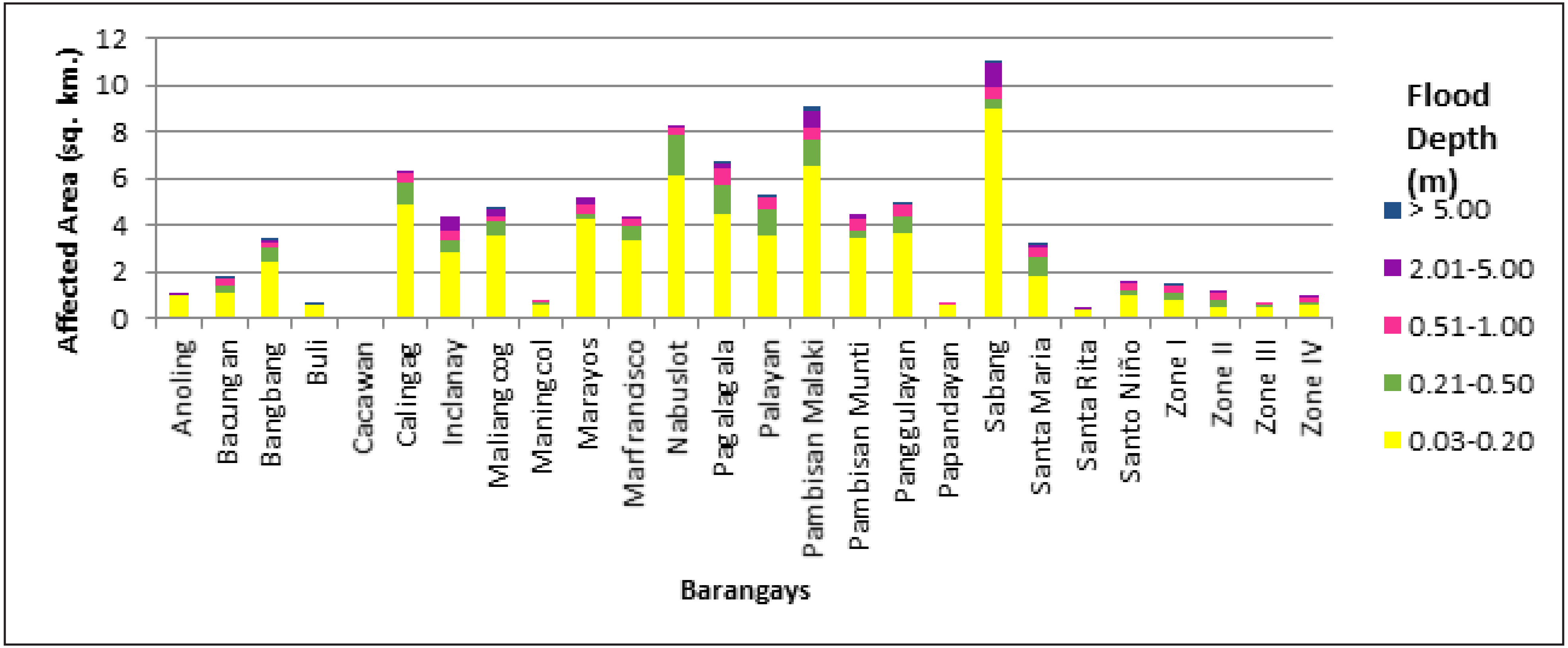


Figure 60. Affected Areas in Pinamalayan, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Pola, with an area of 127.4 sq. km., 29.47% will experience flood levels of less 0.20 meters. 4.20% of the area will experience flood levels of 0.21 to 0.50 meters while 5.69%, 2.76%, 0.47%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 31-32 are the affected areas in square kilometres by flood depth per barangay.

Table 31. Affected Areas in Pola, Oriental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pola (in sq. km.)							
	Bacungan	Batuhan	Bayanan	Calima	Calubasanhon	Casiligan	Malibago	Maluanluan
0.03-0.20	1.11	2.69	0.48	1.78	1.83	3.06	5.66	0.69
0.21-0.50	0.25	0.82	0.019	0.073	0.38	0.58	0.9	0.93
0.51-1.00	0.39	1.87	0.0031	0.043	0.58	1.14	0.72	0.75
1.01-2.00	0.19	0.26	0.000095	0.013	0.51	0.81	0.39	0.34
2.01-5.00	0.0015	0	0	0.0041	0.082	0.18	0.029	0.16
> 5.00	0.0014	0	0	0.0015	0	0	0	0

Table 32. Affected Areas in Pola, Oriental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pola (in sq. km.)							
	Matulatula	Pahilahan	Panikihan	Pula	Puting Cacao	Tagbakin	Zone I	Zone II
0.03-0.20	0.63	6.37	9.24	0.34	0.13	2.15	0.82	0.46
0.21-0.50	0.033	0.16	0.54	0.0021	0.0018	0.065	0.29	0.29
0.51-1.00	0.026	0.1	0.89	0.0005	0.0002	0.062	0.29	0.37
1.01-2.00	0.0034	0.08	0.79	0.001	0	0.048	0.032	0.033
2.01-5.00	0	0.017	0.094	0.0019	0	0.012	0.014	0.0046
> 5.00	0	0	0.0001	0.0023	0	0	0.0001	0

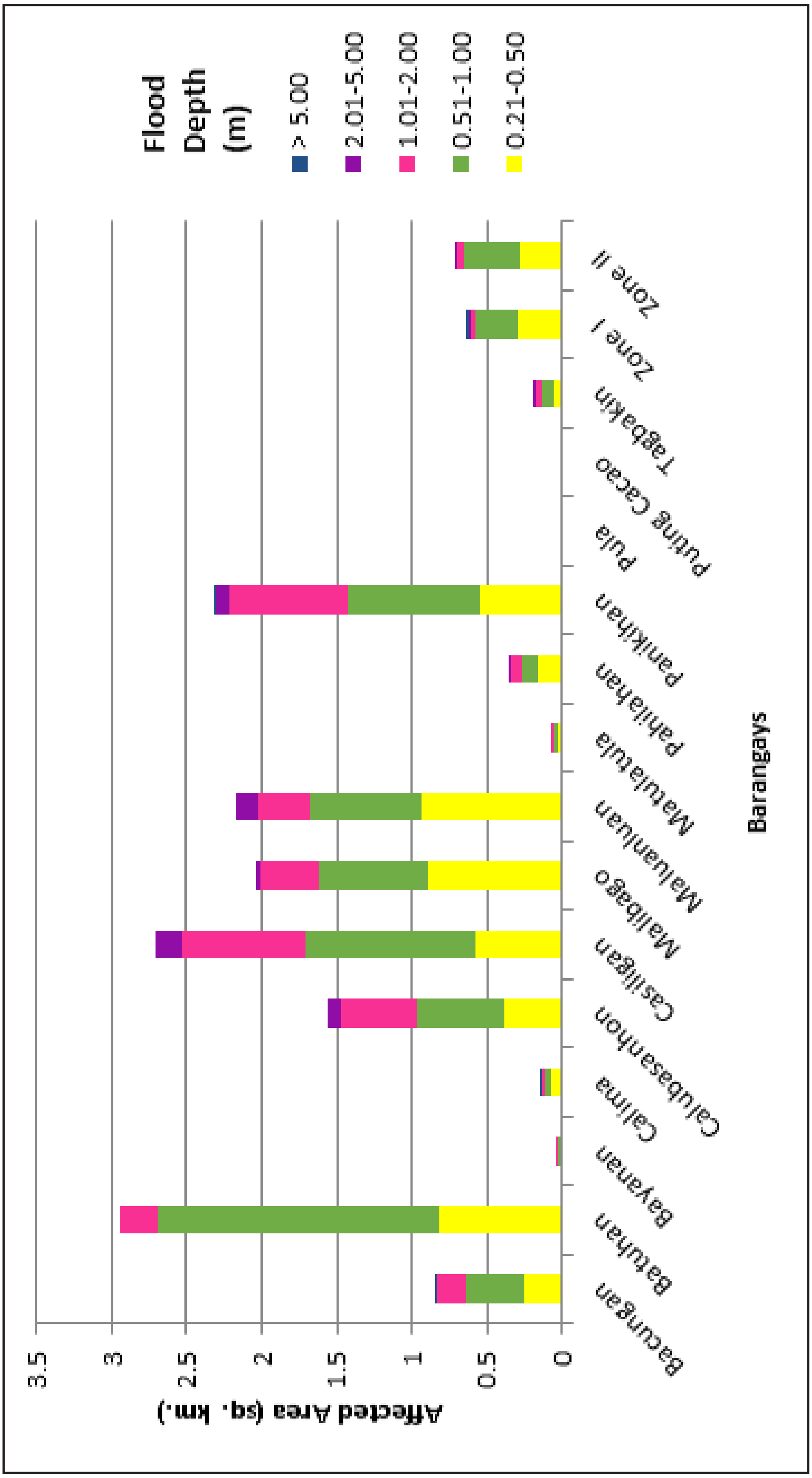


Figure 61. Affected Areas in Pola, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Socorro, with an area of 206.06 sq. km., 36.01% will experience flood levels of less 0.20 meters. 5.38% of the area will experience flood levels of 0.21 to 0.50 meters while 3.38%, 1.79%, 0.78%, and 0.30% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 33-34 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Socorro, Oriental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Socorro (in sq. km.)							
	Bagsok	Bayuin	Calocmoy	Calubayan	Catiningan	Fortuna	Leuteboro I	Leuteboro II
0.03-0.20	5.32	8.2	3.43	6.87	6.41	2.17	6.53	2.54
0.21-0.50	1.49	0.89	0.67	0.47	1.35	0.055	1.91	0.3
0.51-1.00	0.3	1.18	0.5	0.82	0.26	0.047	1.03	0.13
1.01-2.00	0.031	0.75	0.44	0.69	0.087	0.057	0.16	0.047
2.01-5.00	0.027	0.19	0.082	0.12	0.063	0.18	0.064	0.0061
> 5.00	0	0.039	0	0.0057	0.025	0.26	0	0

Table 34. Affected Areas in Socorro, Oriental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Socorro (in sq. km.)								
	Malugay	Matungao	Monteverde	Subaan	Villareal	Zone I	Zone II	Zone III	Zone IV
0.03-0.20	15.46	4.29	3.63	0.97	6.06	0.82	0.46	0.49	0.55
0.21-0.50	0.63	1.11	0.096	0.17	1.08	0.29	0.29	0.096	0.18
0.51-1.00	0.64	0.2	0.16	0.081	0.68	0.29	0.37	0.099	0.18
1.01-2.00	0.58	0.056	0.13	0.0094	0.52	0.032	0.033	0.041	0.024
2.01-5.00	0.6	0	0.03	0.0003	0.19	0.014	0.0046	0	0.037
> 5.00	0.24	0	0.0055	0	0.042	0.0001	0	0	0

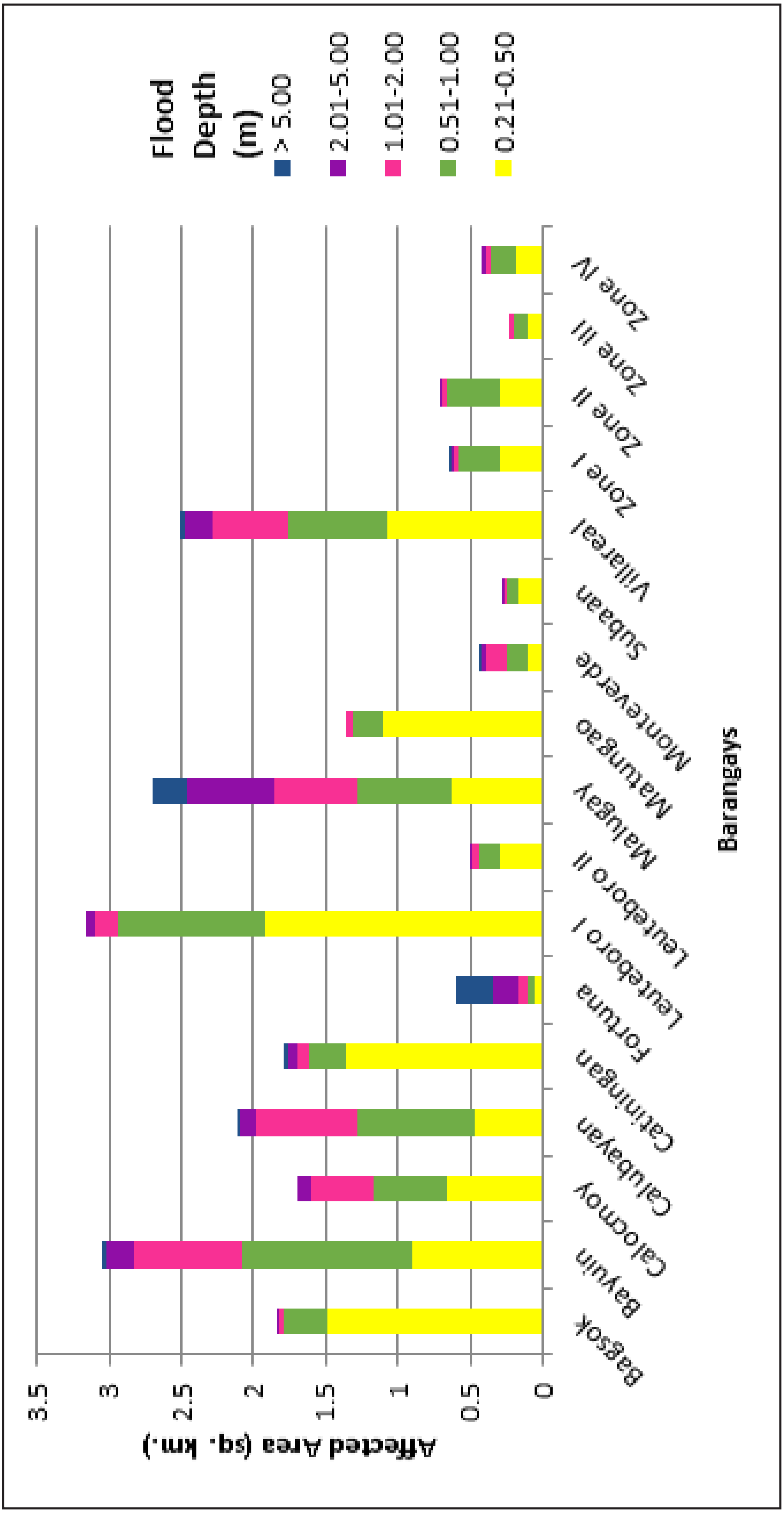


Figure 62. Affected Areas in Socorro, Oriental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 2.65% of the municipality of Gloria with an area of 327.28 sq. km. will experience flood levels of less 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.15%, 0.004%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Gloria, Oriental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq. km.)		
	Agos	Buong Lupa	Malamig
0.03-0.20	0.56	3.47	4.64
0.21-0.50	0.041	0.16	0.16
0.51-1.00	0.069	0.18	0.29
1.01-2.00	0.083	0.065	0.33
2.01-5.00	0.0069	0.021	0.11
> 5.00	0	0.0033	0.0004

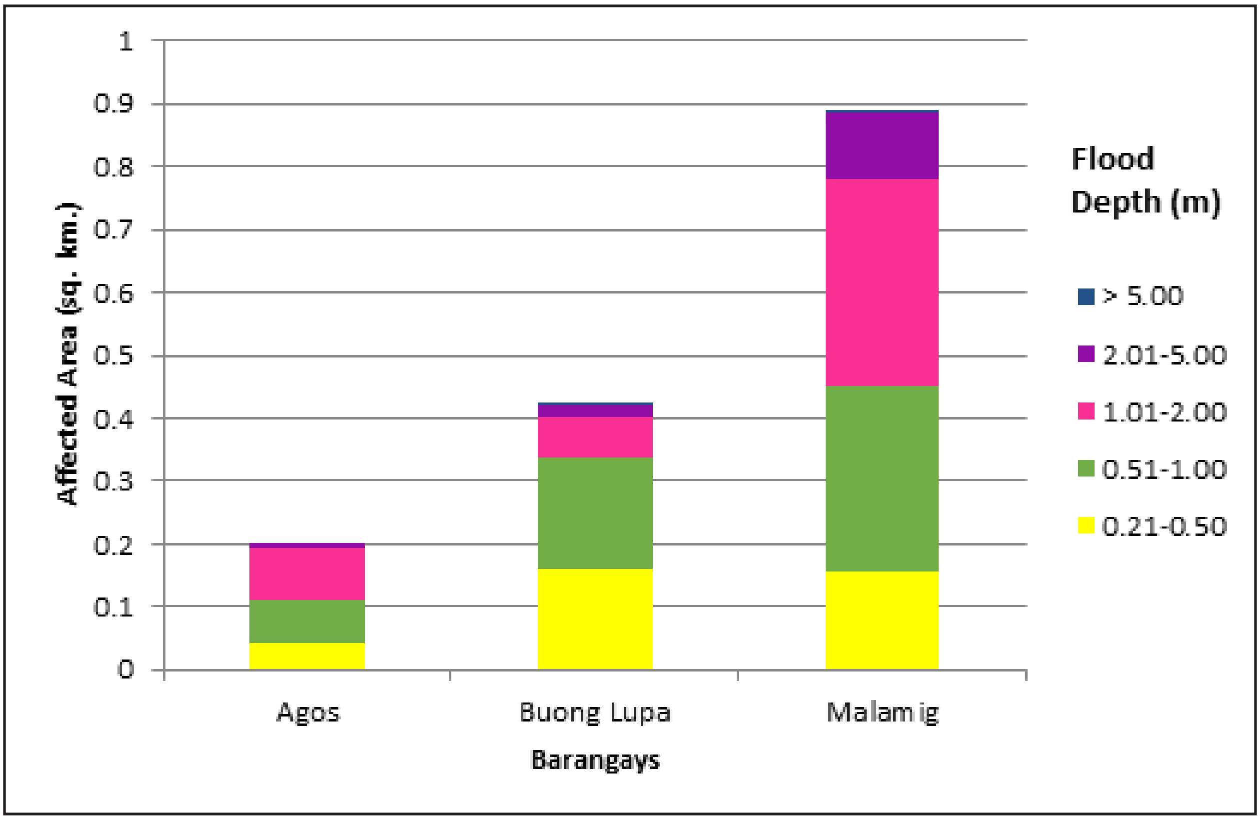


Figure 63. Affected Areas in Gloria, Oriental Mindoro during 25-Year Rainfall Return Period

For the municipality of Pinamalayan, with an area of 206.87 sq. km., 26.51% will experience flood levels of less 0.20 meters. 7.87% of the area will experience flood levels of 0.21 to 0.50 meters while 5.22%, 3.81%, 3.09%, and 0.34% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 36-37 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Pinamalayan, Oriental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinamalayan (in sq. km.)												
	Anoling	Bacungan	Bangbang	Buli	Cacawan	Calingag	Inclanay	Maliangcog	Maningcol	Marayos	Marfrancis-co	Nabuslot	Pagalagala
0.03-0.20	0.94	0.99	1.65	0.6	0.02	3.67	2.14	2.68	0.57	4.11	2.76	4.27	3.42
0.21-0.50	0.037	0.19	0.95	0.014	0	1.47	0.59	1.05	0.087	0.15	0.7	2.62	1.51
0.51-1.00	0.022	0.36	0.55	0.0047	0	0.69	0.63	0.45	0.047	0.22	0.6	1.14	1.29
1.01-2.00	0.017	0.39	0.2	0.0013	0	0.42	0.46	0.29	0.0031	0.43	0.31	0.21	0.42
2.01-5.00	0.0038	0.023	0.077	0.0012	0	0.12	1.12	0.41	0	0.77	0.022	0.051	0.24
> 5.00	0	0.0025	0.01	0.0022	0	0.0004	0.025	0.0085	0	0.012	0	0	0.0073

Table 37. Affected Areas in Pinamalayan, Oriental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinamalayan (in sq. km.)												
	Palayan	Pambisan Malaki	Pambisan Munti	Panggulayan	Papandayan	Sabang	Santa Maria	Santa Rita	Santo Niño	Zone I	Zone II	Zone III	Zone IV
0.03-0.20	2.88	4.86	2.92	3.17	0.47	8.64	1.19	0.39	0.75	0.64	0.29	0.36	0.47
0.21-0.50	1.18	2.06	0.29	0.83	0.15	0.3	0.98	0.017	0.24	0.29	0.28	0.16	0.14
0.51-1.00	0.87	0.84	0.43	0.57	0.0074	0.3	0.75	0.01	0.28	0.2	0.22	0.058	0.26
1.01-2.00	0.33	0.85	0.73	0.45	0	0.68	0.49	0.0092	0.35	0.29	0.36	0.13	0.067
2.01-5.00	0.031	0.89	0.69	0.021	0	1.6	0.16	0.0004	0.047	0.1	0.0019	0.0097	0.0021
> 5.00	0.0019	0.23	0	0.0059	0	0.32	0.081	0	0	0.0001	0	0	0

Figure 64. Affected Areas in Pinamalayan, Oriental Mindoro during 25-Year Rainfall Return Period

For the municipality of Pola, with an area of 127.4 sq. km., 25.34% will experience flood levels of less 0.20 meters. 2.51% of the area will experience flood levels of 0.21 to 0.50 meters while 4.22%, 7.04%, 3.51%, 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 Tables 38-39 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Pola, Oriental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pola (in sq. km.)							
	Bacungan	Batuhan	Bayanan	Calima	Calubasanhon	Casiligan	Malibago	Maluanluan
0.03-0.20	0.99	1.37	0.47	1.72	1.56	2.57	4.51	0.24
0.21-0.50	0.19	0.3	0.025	0.09	0.19	0.26	0.76	0.14
0.51-1.00	0.36	0.68	0.007	0.071	0.51	0.51	1.13	0.95
1.01-2.00	0.39	1.48	0.00074	0.021	0.86	1.87	0.98	1.21
2.01-5.00	0.023	1.81	0	0.0087	0.25	0.56	0.32	0.32
> 5.00	0.0025	0	0	0.0026	0	0	0	0

Table 39. Affected Areas in Pola, Oriental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pola (in sq. km.)							
	Matulatula	Pahilahan	Panikihan	Pula	Puting Cacao	Tagbakin	Zone I	Zone II
0.03-0.20	0.61	6.28	8.38	0.33	0.13	2.1	0.64	0.29
0.21-0.50	0.031	0.18	0.37	0.0032	0.002	0.078	0.29	0.28
0.51-1.00	0.032	0.12	0.51	0.0009	0.0011	0.061	0.2	0.22
1.01-2.00	0.014	0.1	1.3	0.0012	0	0.067	0.29	0.36
2.01-5.00	0	0.051	0.99	0.0021	0	0.028	0.1	0.0019
> 5.00	0	0	0.0002	0.0047	0	0	0.0001	0

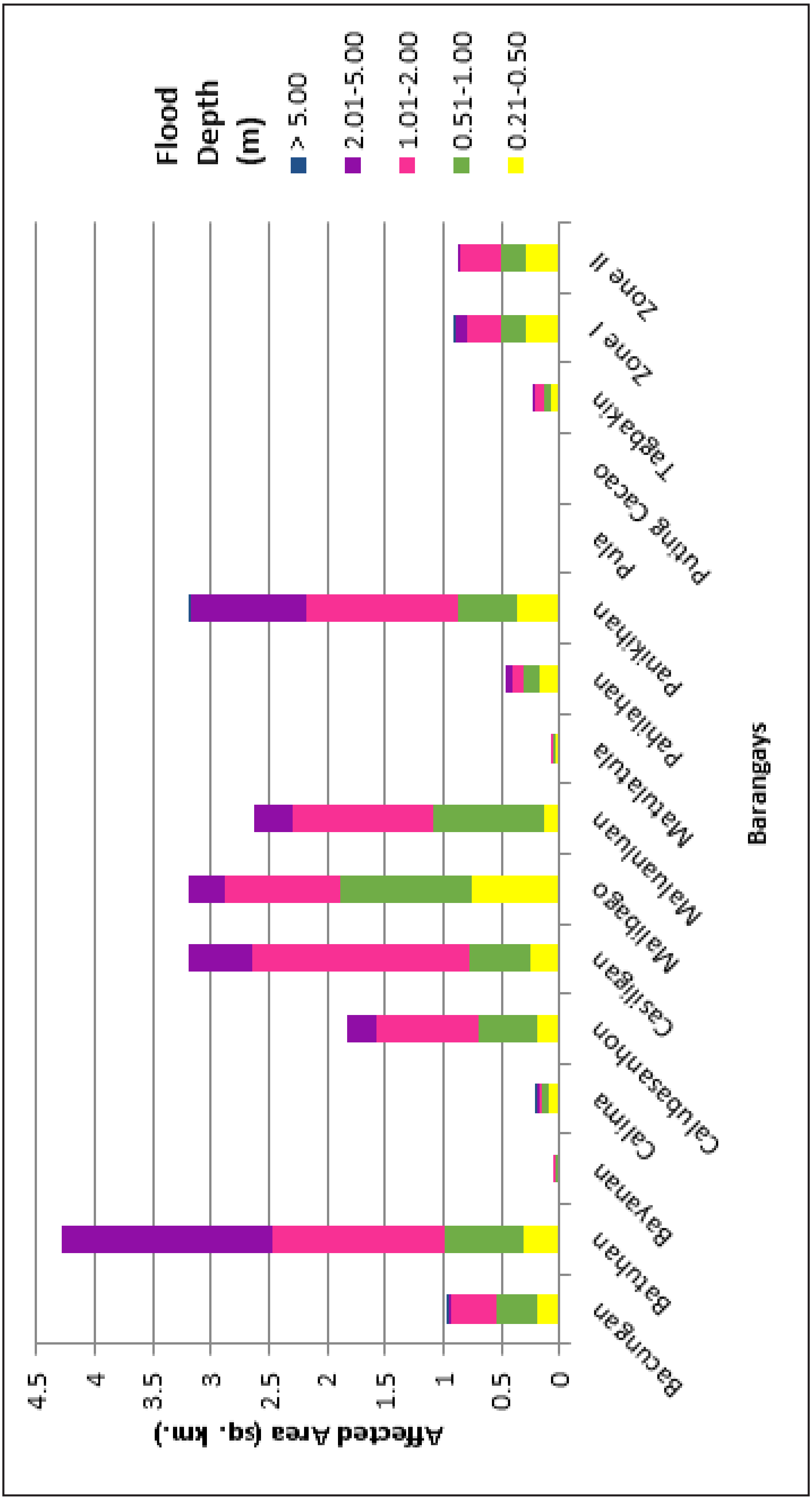


Figure 65. Affected Areas in Pola, Oriental Mindoro during 25-Year Rainfall Return Period

For the municipality of Socorro, with an area of 206.06 sq. km., 30.03% will experience flood levels of less 0.20 meters. 7.10% of the area will experience flood levels of 0.21 to 0.50 meters while 4.79%, 3.75%, 1.57%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 40-41 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Socorro (in sq. km.)							
	Bagsok	Bayuin	Calocmoy	Calubayan	Catiningan	Fortuna	Leuteboro I	Leuteboro II
0.03-0.20	3.01	7.4	2.43	6.64	4.48	2.1	4.4	2.17
0.21-0.50	2.56	0.58	0.95	0.25	2.43	0.063	2.41	0.57
0.51-1.00	1.3	0.87	0.63	0.72	1.08	0.036	1.89	0.17
1.01-2.00	0.26	1.84	0.87	0.91	0.11	0.042	0.9	0.086
2.01-5.00	0.034	0.53	0.23	0.44	0.078	0.13	0.11	0.03
> 5.00	0	0.048	0	0.013	0.026	0.39	0	0

Table 41. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Socorro (in sq. km.)								
	Malugay	Matungao	Monteverde	Subaan	Villareal	Zone I	Zone II	Zone III	Zone IV
0.03-0.20	15.07	2.83	3.55	0.78	5.26	0.64	0.29	0.36	0.47
0.21-0.50	0.59	1.84	0.11	0.29	1.11	0.29	0.28	0.16	0.14
0.51-1.00	0.57	0.81	0.1	0.13	0.82	0.2	0.22	0.058	0.26
1.01-2.00	0.7	0.17	0.19	0.03	0.78	0.29	0.36	0.13	0.067
2.01-5.00	0.89	0.0067	0.087	0.0035	0.55	0.1	0.0019	0.0097	0.0021
> 5.00	0.35	0	0.0077	0	0.067	0.0001	0	0	0

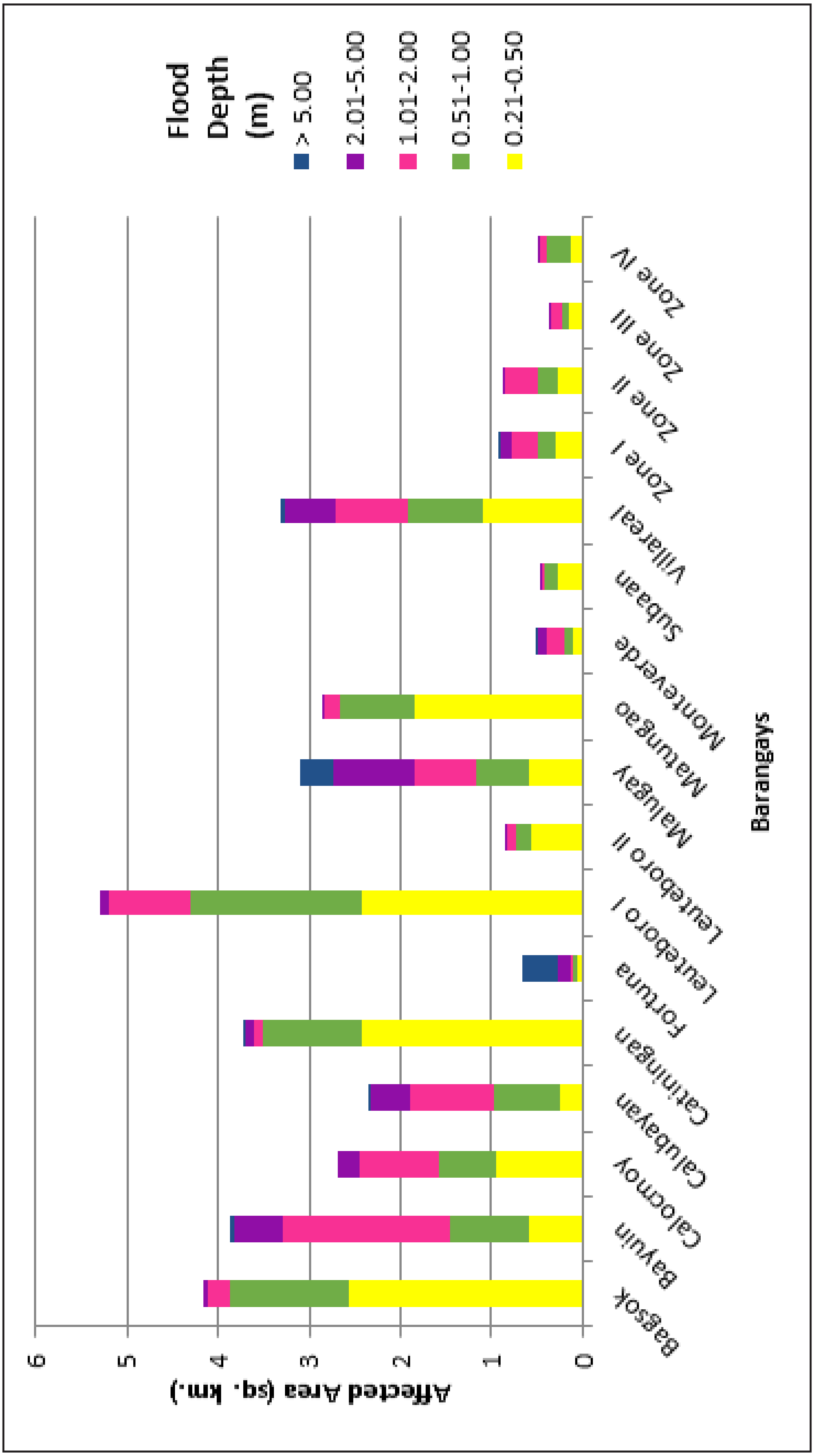


Figure 66. Affected Areas in Socorro, Oriental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 2.65% of the municipality of Gloria with an area of 327.28 sq. km. will experience flood levels of less 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.15%, 0.04%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table are the affected areas in square kilometres by flood depth per barangay. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Gloria, Oriental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq. km.)		
	Agos	Buong Lupa	Malamig
0.03-0.20	0.56	3.47	4.64
0.21-0.50	0.041	0.16	0.16
0.51-1.00	0.069	0.18	0.29
1.01-2.00	0.083	0.065	0.33
2.01-5.00	0.0069	0.021	0.11
> 5.00	0	0.0033	0.0004

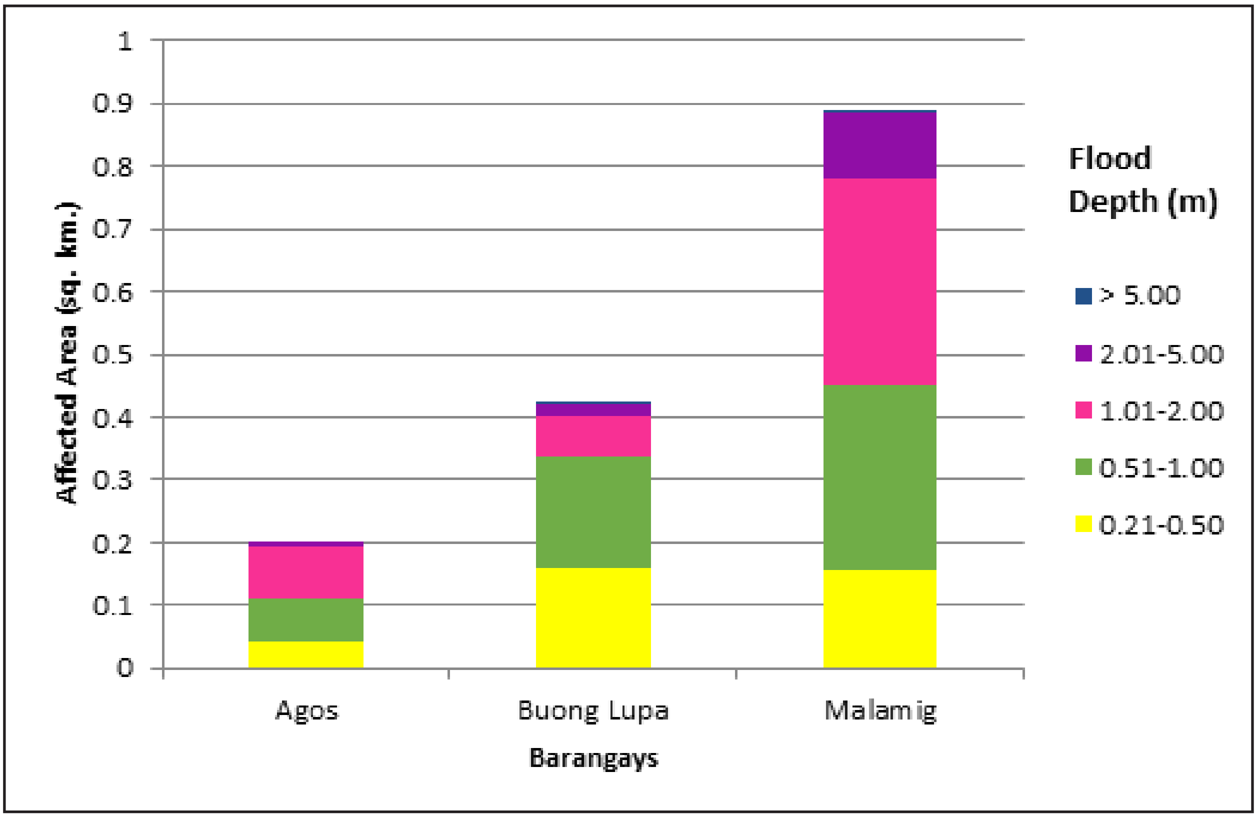


Figure 67. Affected Areas in Gloria, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Pinamalayan, with an area of 206.87 sq. km., 26.51% will experience flood levels of less 0.20 meters. 7.87% of the area will experience flood levels of 0.21 to 0.50 meters while 5.22%, 3.81%, 3.09%, and 0.34% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 43-44 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Pinamalayan, Oriental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinamalayan (in sq. km.)												
	Anoling	Bacungan	Bangbang	Buli	Cacawan	Calingag	Inclanay	Maliangcog	Maningcol	Marayos	Marfrancis-co	Nabuslot	Pagalagala
0.03-0.20	0.94	0.99	1.65	0.6	0.02	3.67	2.14	2.68	0.57	4.11	2.76	4.27	3.42
0.21-0.50	0.037	0.19	0.95	0.014	0	1.47	0.59	1.05	0.087	0.15	0.7	2.62	1.51
0.51-1.00	0.022	0.36	0.55	0.0047	0	0.69	0.63	0.45	0.047	0.22	0.6	1.14	1.29
1.01-2.00	0.017	0.39	0.2	0.0013	0	0.42	0.46	0.29	0.0031	0.43	0.31	0.21	0.42
2.01-5.00	0.0038	0.023	0.077	0.0012	0	0.12	1.12	0.41	0	0.77	0.022	0.051	0.24
> 5.00	0	0.0025	0.01	0.0022	0	0.0004	0.025	0.0085	0	0.012	0	0	0.0073

Table 44. Affected Areas in Pinamalayan, Oriental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinamalayan (in sq. km.)												
	Palayan	Pambisan Malaki	Pambisan Munti	Panggulayan	Papandayan	Sabang	Santa Maria	Santa Rita	Santo Niño	Zone I	Zone II	Zone III	Zone IV
0.03-0.20	2.88	4.86	2.92	3.17	0.47	8.64	1.19	0.39	0.75	0.64	0.29	0.36	0.47
0.21-0.50	1.18	2.06	0.29	0.83	0.15	0.3	0.98	0.017	0.24	0.29	0.28	0.16	0.14
0.51-1.00	0.87	0.84	0.43	0.57	0.0074	0.3	0.75	0.01	0.28	0.2	0.22	0.058	0.26
1.01-2.00	0.33	0.85	0.73	0.45	0	0.68	0.49	0.0092	0.35	0.29	0.36	0.13	0.067
2.01-5.00	0.031	0.89	0.69	0.021	0	1.6	0.16	0.0004	0.047	0.1	0.0019	0.0097	0.0021
> 5.00	0.0019	0.23	0	0.0059	0	0.32	0.081	0	0	0.0001	0	0	0

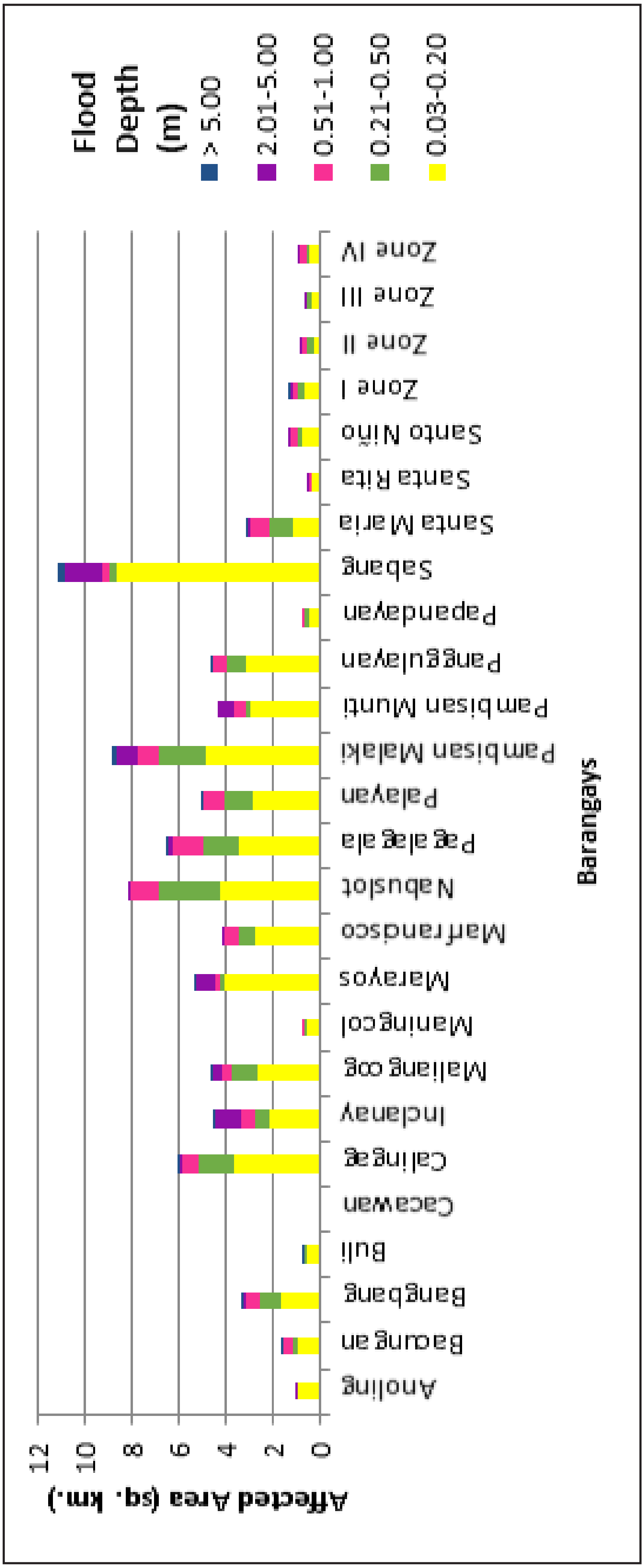


Figure 68. Affected Areas in Pinamalayan, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Pola, with an area of 127.4 sq. km., 25.34% will experience flood levels of less 0.20 meters. 2.51% of the area will experience flood levels of 0.21 to 0.50 meters while 4.22%, 7.04%, 3.51%, 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 Tables 45-46 are the affected areas in square kilometres by flood depth per barangay.

Table 45. Affected Areas in Pola, Oriental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pola (in sq. km.)							
	Bacungan	Batuhan	Bayanan	Calima	Calubasanhon	Casiligan	Malibago	Maluanluan
0.03-0.20	0.99	1.37	0.47	1.72	1.56	2.57	4.51	0.24
0.21-0.50	0.19	0.3	0.025	0.09	0.19	0.26	0.76	0.14
0.51-1.00	0.36	0.68	0.007	0.071	0.51	0.51	1.13	0.95
1.01-2.00	0.39	1.48	0.00074	0.021	0.86	1.87	0.98	1.21
2.01-5.00	0.023	1.81	0	0.0087	0.25	0.56	0.32	0.32
> 5.00	0.0025	0	0	0.0026	0	0	0	0

Table 46. Affected Areas in Pola, Oriental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pola (in sq. km.)							
	Matulatula	Pahilahan	Panikihan	Pula	Puting Cacao	Tagbakin	Zone I	Zone II
0.03-0.20	0.61	6.28	8.38	0.33	0.13	2.1	0.64	0.29
0.21-0.50	0.031	0.18	0.37	0.0032	0.002	0.078	0.29	0.28
0.51-1.00	0.032	0.12	0.51	0.0009	0.0011	0.061	0.2	0.22
1.01-2.00	0.014	0.1	1.3	0.0012	0	0.067	0.29	0.36
2.01-5.00	0	0.051	0.99	0.0021	0	0.028	0.1	0.0019
> 5.00	0	0	0.0002	0.0047	0	0	0.0001	0

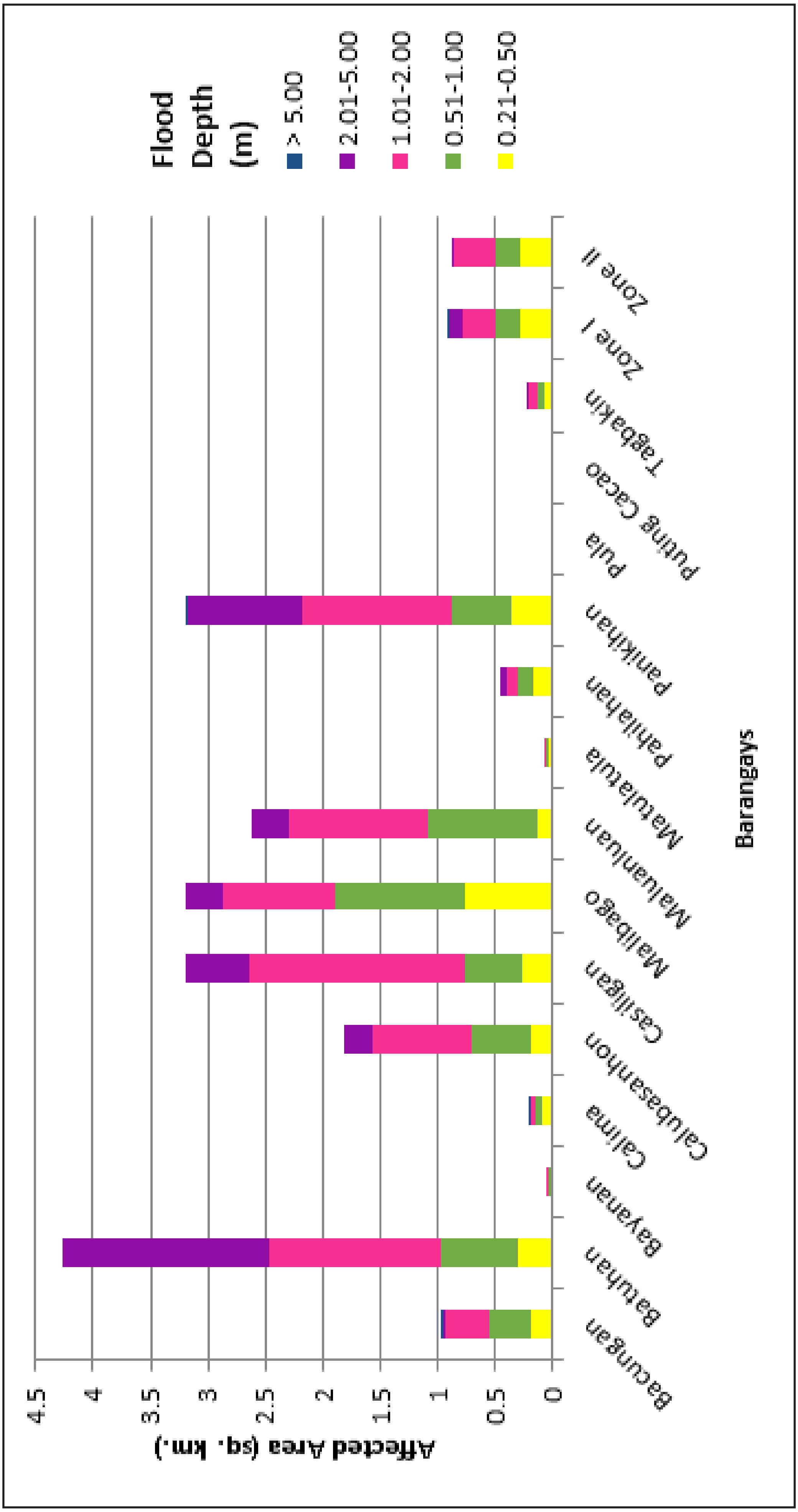


Figure 69. Affected Areas in Pola, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Socorro, with an area of 206.06 sq. km., 30.03% will experience flood levels of less 0.20 meters. 7.10% of the area will experience flood levels of 0.21 to 0.50 meters while 4.79%, 3.75%, 1.57%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 47-48 are the affected areas in square kilometres by flood depth per barangay.

Table 47. Affected Areas in Socorro, Oriental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Socorro (in sq. km.)							
	Bagsok	Bayuin	Calocmoy	Calubayan	Catiningan	Fortuna	Leuteboro I	Leuteboro II
0.03-0.20	3.01	7.4	2.43	6.64	4.48	2.1	4.4	2.17
0.21-0.50	2.56	0.58	0.95	0.25	2.43	0.063	2.41	0.57
0.51-1.00	1.3	0.87	0.63	0.72	1.08	0.036	1.89	0.17
1.01-2.00	0.26	1.84	0.87	0.91	0.11	0.042	0.9	0.086
2.01-5.00	0.034	0.53	0.23	0.44	0.078	0.13	0.11	0.03
> 5.00	0	0.048	0	0.013	0.026	0.39	0	0

Table 48. Affected Areas in Socorro, Oriental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Socorro (in sq. km.)								
	Malugay	Matungao	Monteverde	Subaan	Villareal	Zone I	Zone II	Zone III	Zone IV
0.03-0.20	15.07	2.83	3.55	0.78	5.26	0.64	0.29	0.36	0.47
0.21-0.50	0.59	1.84	0.11	0.29	1.11	0.29	0.28	0.16	0.14
0.51-1.00	0.57	0.81	0.1	0.13	0.82	0.2	0.22	0.058	0.26
1.01-2.00	0.7	0.17	0.19	0.03	0.78	0.29	0.36	0.13	0.067
2.01-5.00	0.89	0.0067	0.087	0.0035	0.55	0.1	0.0019	0.0097	0.0021
> 5.00	0.35	0	0.0077	0	0.067	0.0001	0	0	0

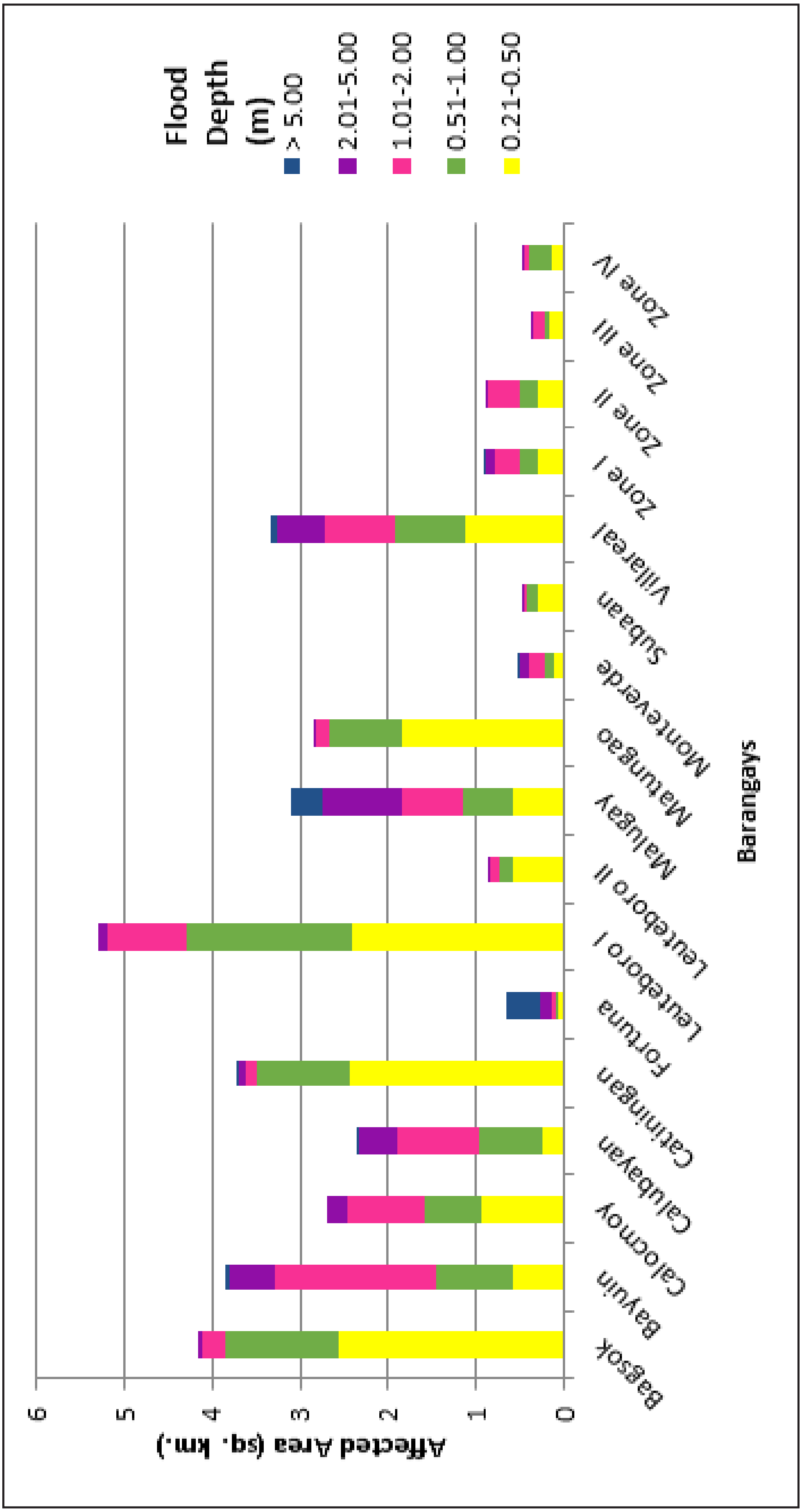


Figure 70. Affected Areas in Socorro, Oriental Mindoro during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Tineg Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

Table 39. Area covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	81.42	79.64	79.16
Medium	102.41	99.92	100.51
High	226.15	288.35	317.94
TOTAL	409.99	467.92	497.61

Of the 131 identified Educational Institutions in Tineg flood plain, 11 were assessed to be exposed to low, 17 to medium, and 16 to high level flooding during the 5-year scenario. In the 25-year scenario, 8 were assessed to be exposed to low, 12 to medium, and 42 to high level flooding. In the 100-year scenario, 7 were assessed to be exposed to low, 5 to medium, and 54 to high level flooding. See Annex 12 for a detailed enumeration of schools in the Tineg floodplain.

Of the 30 identified Medical Institutions in Tineg flood plain, 2 were assessed to be exposed to low, 1 to medium, and 1 to high level flooding in the 5-year scenario. In the 25-year scenario, 3 were assessed to be exposed to low, 3 to medium, and 1 to high level flooding. In the 100-year scenario, 5 were assessed to be exposed to low, 3 to medium, and 3 to high level flooding. See Annex 13 for a detailed enumeration of hospitals and clinics in the Tineg floodplain.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 71.
The flood validation consists of 99 points randomly selected all over the Casiligan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.924m. Table 49 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

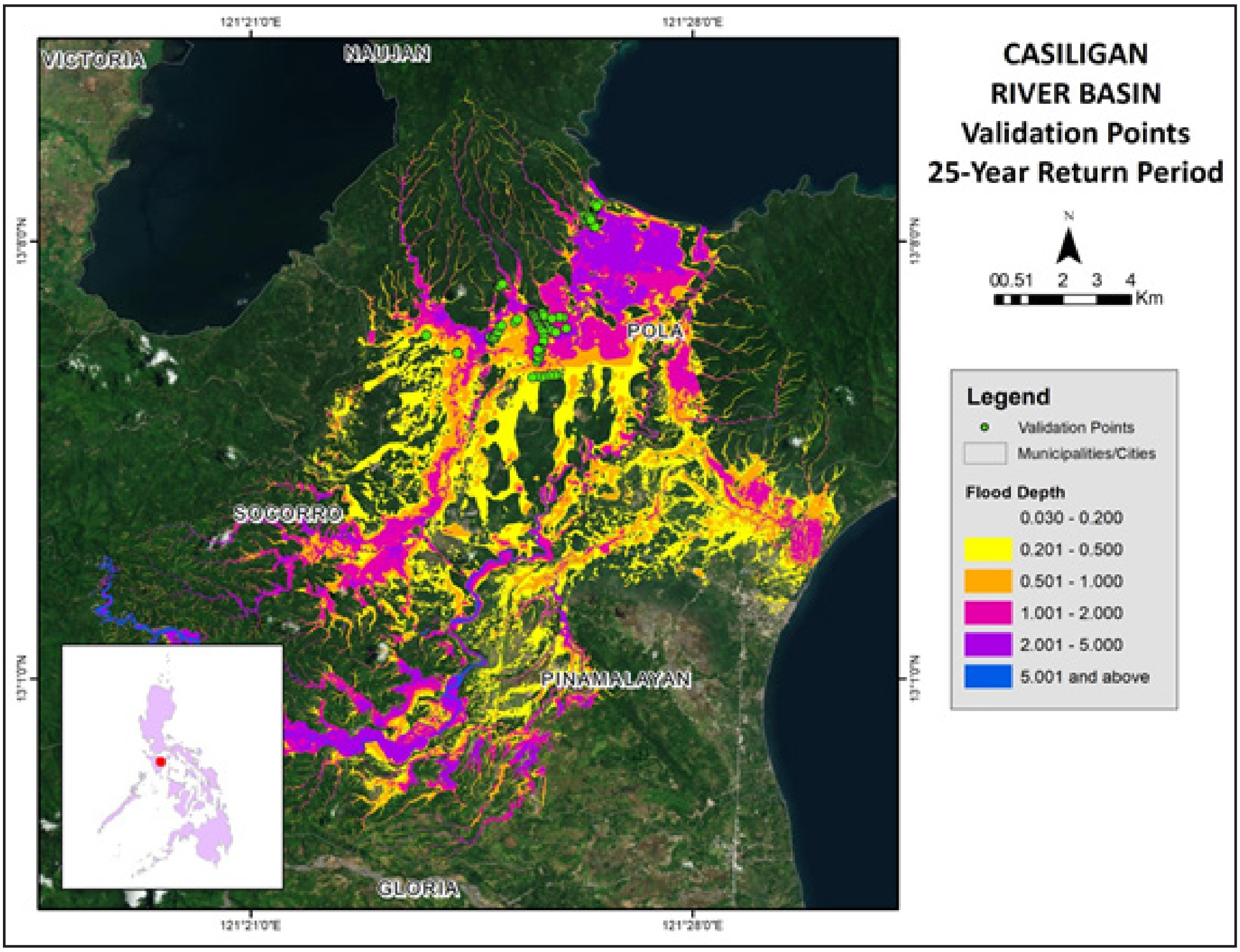


Figure 71. Validation points for 25-year Flood Depth Map of Casiligan Floodplain

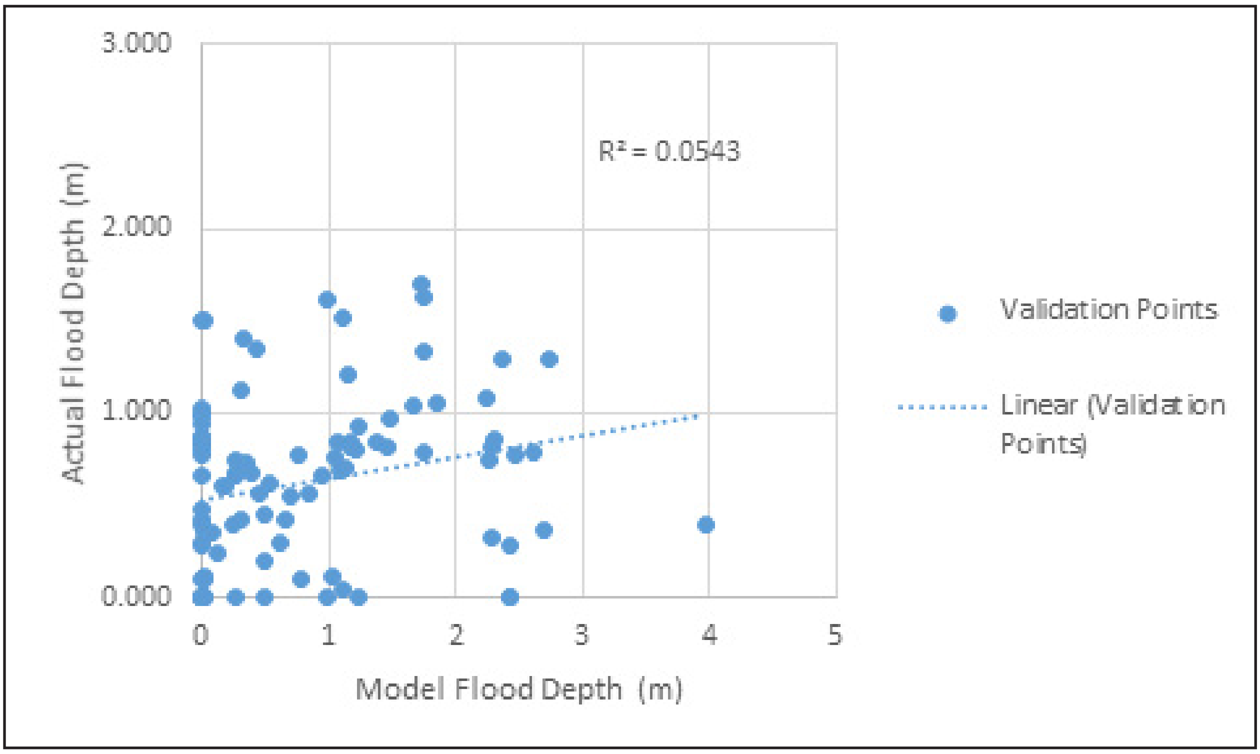


Figure 72. Flood map depth vs actual flood depth

Table 49. Actual Flood Depth vs Simulated Flood Depth at different levels in the Casiligan River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	14	3	2	3	2	0	24
0.21-0.50	8	3	2	0	4	0	17
0.51-1.00	13	6	5	12	5	0	41
1.01-2.00	3	3	1	7	3	0	17
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	38	15	10	22	14	0	99

The overall accuracy generated by the flood model is estimated at 29.29% with 29 points correctly matching the actual flood depths. In addition, there were 29 points estimated one level above and below the correct flood depths while there were 23 points and 12 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 34 points were underestimated in the modelled flood depths of Casiligan. Table 50 depicts the summary of the Accuracy Assessment in the Casiligan River Basin Survey.

Table 50. Summary of Accuracy Assessment in the Casiligan River Basin Survey

	No. of Points	%
Correct	29	29.29
Overestimated	36	36.36
Underestimated	34	34.34
Total	**99**	**100.00**

REFERENCES

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

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

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

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

ANNEXES

ANNEX 1. Technical Specifications of the LIDAR Sensors used in the Casiligan Floodplain Survey

1. AQUARIUS SENSOR

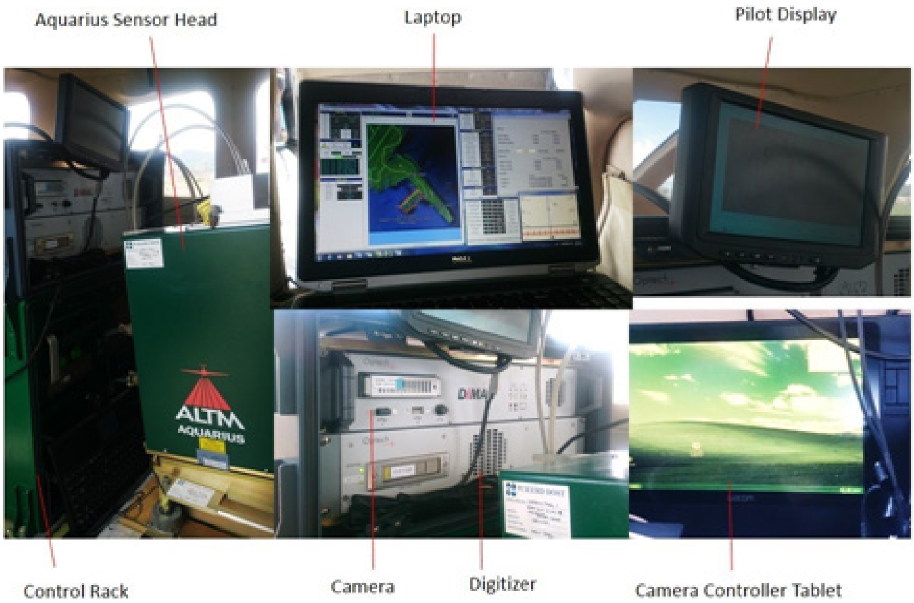


Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specification of Aquarius Sensor

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

2. GEMINI SENSOR

Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specification of Gemini Sensor

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

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

1. MRE-54

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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-54**
Order: **2nd**

Island: **LUZON**
Municipality: **PINAMALAYAN**
Barangay: **MALIANGCOG**

		PRS92 Coordinates			
Latitude:	**12° 59' 12.43671"**	Longitude:	**121° 24' 46.52637"**	Ellipsoidal Hgt:	**42.40800 m.**
		WGS84 Coordinates			
Latitude:	**12° 59' 7.43505"**	Longitude:	**121° 24' 51.55668"**	Ellipsoidal Hgt:	**91.39500 m.**
		PTM Coordinates			
Northing:	**1436124.562 m.**	Easting:	**544797.009 m.**	Zone:	**3**
		UTM Coordinates			
Northing:	**1,436,121.49**	Easting:	**327,864.09**	Zone:	**51**

Location Description

MRE-54

From Calapan City to Roxas, along Nat'l Road, approx. 100 m from Pula Bridge, along Brgy. Sto. Niño, right turn to Brgy. Road leading to Gloria Airport, passing through Brgy. Sto. Niño, Brgy. Sta. Maria, Brgy. Pambigan Malaki, all in Mun. of Pinamalayan. approx. 7.8 Km. from Nat'l Road, 1.1 Km. from Brgy. Chapel, 600 m from Maliangkog Elem. School, left side of road located Brgy. Hall of Maliangkog, Pinamalayan, Oriental Mindoro. Station is located beside of flagpole near gate of brgy. hall. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-54, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-196**

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

9902042014125855

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

CIP/4701/12/09/814

Figure A-2.1. MRE-54

2. MRE-44

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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-44**
Order: **2nd**

Island: **LUZON**
Municipality: **ROXAS**
Barangay: **HAPPY VALLEY**

PRS92 Coordinates

Latitude: **12° 38' 59.03778"**	Longitude: **121° 24' 32.60444"**	Ellipsoidal Hgt: **87.94200 m.**

WGS84 Coordinates

Latitude: **12° 38' 54.11733"**	Longitude: **121° 24' 37.66392"**	Ellipsoidal Hgt: **137.80400 m.**

PTM Coordinates

Northing: **1398838.995 m.**	Easting: **544436.519 m.**	Zone: **3**

UTM Coordinates

Northing: **1,398,840.08**	Easting: **327,214.81**	Zone: **51**

MRE-44

Location Description

From Calapan City to Bulalacao, approx. 4 Km. from Roxas Town Proper, along Nat'l Road is an intersection going to Roxas Proper, Mansalay, and Bongabong, Oriental Mindoro. Turn right to road leading to Bongabong Town Proper, approx. 6.9 Km., passing through Brgy. San Aquilino, Brgy. Libertad, Brgy. Little Tanauan, and Brgy. San Mariano, all in Mun. of Roxas. Along Brgy. San Rafael, left side of road located Km. post 130 about 50 m after RCBCulvert, turn left to Brgy. Road leading to Sitio Amawan, approx. 800 m passing through San Rafael Elem. School, and GK Village, left side of road located Brgy. Hall of Happy Valley, Roxas, Oriental Mindoro. Station is located beside of streetlight outside wall of brgy. hall. Mark is the head of a 4 in. copper nial flushed in a cement block embedded in the ground with inscriptions, "MRE-44, 2007, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795255 A**
T.N.:	**2014-198**

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

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

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

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

Figure A-2.2. MRE-44

3. MRE-32

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

April 05, 2013

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: **ORIENTAL MINDORO**	
	Station Name: **MRE-32**	
Island: **LUZON**	Order: **2nd**	
Municipality: **VICTORIA**		Barangay:
	PRS92 Coordinates	
Latitude: **13° 10' 28.85064"**	Longitude: **121° 16' 38.44761"**	Ellipsoidal Hgt: **19.49300 m.**
	WGS84 Coordinates	
Latitude: **13° 10' 23.79251"**	Longitude: **121° 16' 43.46244"**	Ellipsoidal Hgt: **67.64700 m.**
	PTM Coordinates	
Northing: **1456889.419 m.**	Easting: **530065.679 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,457,002.75**	Easting: **313,296.85**	Zone: **51**

MRE-32

Location Description

From Calapan City to Roxas, along Nat'l. Road approx. 34 Km. travel to Victoria Town Proper, 10 Km. from intersection of Naujan, left turn to Shell Gasoline Station, approx. 150 m, right side of road located Mun. Hall of Victoria, Oriental Mindoro. Station is located in Mun. Park in front of Former Mayor Statue, along corner of pathwalk. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-32, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943485 B**
T.N.: **2013-0270**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

9 9 0 4 0 5 2 0 1 3 1 5 5 2 5 7

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. MRE-32

4. MRE-11

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

October 28, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-11**
Order: **3rd**

Island: **LUZON**	Barangay:	
Municipality: **BONGABONG**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 44' 50.41380"**	Longitude: **121° 29' 7.80130"**	Ellipsoidal Hgt: **5.11500 m.**
	WGS84 Coordinates	
Latitude: **12° 44' 45.47630"**	Longitude: **121° 29' 12.85191"**	Ellipsoidal Hgt: **54.91100 m.**
	PTM / PRS92 Coordinates	
Northing: **1409650.153 m.**	Easting: **552720.766 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,409,587.05**	Easting: **335,581.55**	Zone: **51**

Location Description

MRE-11
To reach the station from Calapan town proper, travel SE to S ialong the nat'l. road for about 120 kms. leading to the town of iBongabong, passing by the towns of Victoria, Pinamalayan and iBansud. Station is located inside the school compound of iMagdalena Umali Suyon Elem. School on the SE corner of the ifooting of a concrete landmark bearing the school name. It is iabout 20 m. W of the main gate along Gov. Umali St. Mark is the ihead of a 4 in. copper nail embedded and centered on a 0.15 m. x i0.15 m. cement putty, with inscriptions "MRE-11 1997 NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3525**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 9 1 1

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. MRE-11

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

1. MRE-4563

Table A-3.1. MRE-4563

Vector Components (Mark to Mark)

From:	MRE-54				
Grid		Local		Global	
Easting	328016.924 m	Latitude	N12°59'07.43505"	Latitude	N12°59'07.43505"
Northing	1436055.870 m	Longitude	E121°24'51.55668"	Longitude	E121°24'51.55668"
Elevation	41.949 m	Height	91.395 m	Height	91.395 m

To:	MRE-4563				
Grid		Local		Global	
Easting	328034.015 m	Latitude	N13°00'53.01692"	Latitude	N13°00'53.01692"
Northing	1439300.319 m	Longitude	E121°24'51.45337"	Longitude	E121°24'51.45337"
Elevation	24.394 m	Height	73.715 m	Height	73.715 m

Vector					
ΔEasting	17.091 m	NS Fwd Azimuth	359°56'42"	ΔX	392.071 m
ΔNorthing	3244.450 m	Ellipsoid Dist.	3244.605 m	ΔY	-635.982 m
ΔElevation	-17.555 m	ΔHeight	-17.680 m	ΔZ	3157.508 m

2. MRE-11

Table A-3.2. MRE-11

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE54 - 22 --- MRE11 AM1 -22 (B3)	MRE54 - 22	MRE11 AM1 -22	Fixed	0.006	0.035	-9779.846	890.616	-25831.853	163°25'41"	27635.215	-36.405
MRE54 - 22 --- MRE11 PM2 - 22 (B2)	MRE54 - 22	MRE11 PM2 - 22	Fixed	0.004	0.023	-9779.877	890.724	-25831.856	163°25'41"	27635.232	-36.300

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

MRE54 - 22 - MRE11 AM1 -22 (7:40:13 AM-8:58:26 AM) (S3)

Baseline observation:	MRE54 - 22 --- MRE11 AM1 -22 (B3)
Processed:	11/5/2015 4:50:09 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.035 m
RMS:	0.005 m
Maximum PDOP:	3.705
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/22/2015 7:40:33 AM (Local: UTC+8hr)
Processing stop time:	10/22/2015 8:58:26 AM (Local: UTC+8hr)
Processing duration:	01:17:53
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE54 - 22				
Grid		Local		Global	
Easting	328016.924 m	Latitude	N12°59'07.43505"	Latitude	N12°59'07.43505"
Northing	1436055.870 m	Longitude	E121°24'51.55668"	Longitude	E121°24'51.55668"
Elevation	43.116 m	Height	91.395 m	Height	91.395 m

To:	MRE11 AM1 -22				
Grid		Local		Global	
Easting	335735.169 m	Latitude	N12°44'45.47242"	Latitude	N12°44'45.47242"
Northing	1409521.797 m	Longitude	E121°29'12.85426"	Longitude	E121°29'12.85426"
Elevation	5.611 m	Height	54.990 m	Height	54.990 m

Vector					
ΔEasting	7718.245 m	NS Fwd Azimuth	163°25'41"	ΔX	-9779.902 m
ΔNorthing	-26534.073 m	Ellipsoid Dist.	27635.215 m	ΔY	890.711 m
ΔElevation	-37.505 m	ΔHeight	-36.405 m	ΔZ	-25831.822 m

ANNEX 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		MILLIE SHANE REYES	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
Ground Survey, Data Download and Transfer	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
		GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	TSG ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
		TSG AWIC CHARISMA NAVARRO	
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	
		CAPT. MARK TANGONAN	
		CAPT. JEROME MOONEY	

ANNEX 5. Data Transfer Sheet for Casiligan Floodplain

DATA TRANSFER SHEET
~~Jan~~ Feb 6, 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	
Feb 1, 2014	1052A	3BLK28A033A	AQUARIUS	N/A	528KB	920KB	222MB	52.9GB	385KB	14.8GB	46.3GB	6.12MB	198	628B	888KB	N/A	X:\Airborne_Raw\1052A
Feb 1, 2014	1054A	3BLK28B033B	AQUARIUS	N/A	672KB	1.70MB	206MB	73.7GB	385KB	11.8GB	N/A	6.12MB	19B	625B	314KB	N/A	X:\Airborne_Raw\1054A
Feb 3, 2014	1056A	3BLK28C034A	AQUARIUS	N/A	700KB	1.06MB	210MB	77.2GB	558KB	12.2GB	172GB	6.29MB	19B	651B	239KB	N/A	X:\Airborne_Raw\1056A
Feb 3,2014	1058A	3BLK28CD034B	AQUARIUS	N/A	646KB	1.82MB	201MB	65.8GB	491KB	11.3GB	N/A	6.29MB	19B	328B	9.10KB	N/A	X:\Airborne_Raw\1058A

Received from
Name Faith Sible
Position RA
Signature

Received by
Name JOIDA F. PRIETO 02/06/14
Position SSRS
Signature

Verified by
Name JOIDA F. PRIETO 02/06/14
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Casiligan Floodplain - A

DATA TRANSFER SHEET
Feb 18, 2014

DATE of Operation	FLIGHT NO.	SENSOR	MISSION NAME	RAW LAS (MB)	LOGS (KB)	POS (MB)	RAW IMAGES	MISSION LOG FILE	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S) (MB)	OPERATOR COMMENTS (DPC LOGS) (Bytes)	FLIGHT PLAN (KB)	SERVER LOCATION
2/7/2014	1072A	Aquarius	3BLK28F038A	703KB	1.16MB	256	81.4GB	563KB	12.5	174	14.1	767	13	\\FREENAS\geostorage3\Airborne_Raw\1072A
2/7/2014	1074A	Aquarius	3BLK28G038B	134 KB	968 KB	174	33.7GB	274KB	6.4	60.9	14.1	258	11 (28F)&12(28G)	\\FREENAS\geostorage3\Airborne_Raw\1074A
2/8/2014	1076A	Aquarius	3BLK28GS039A	643KB	1.21MB	233	76.8	308KB&218KB	11.5	101	14.3	357	12	\\FREENAS\geostorage3\Airborne_Raw\1076A
2/5/2014	1066A	Aquarius	3BLK28DS036A	360KB	1.38MB	203	73.9	311KB	11.7	N/A	14.5	414	11	\\FREENAS\geostorage3\Airborne_Raw\1066A
2/6/2014	1070A	Aquarius	3BLK28DSE037A	932KB	1.46MB	270	104	764KB	15.9	249	14.9	300	12	\\FREENAS\geostorage3\Airborne_Raw\1070A
2/8/2014	1078A	Aquarius	3BLK28GSH039B	530KB	892KB	197	56.6	442KB	9.71	N/A	14.3	738	12 (28G) & 12 (28H)	\\FREENAS\geostorage3\Airborne_Raw\1078A

Received from

Name/Signature Lovely Acuña
Position Supervising SRS
Date 02/19/2014

Received by

Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/2014

Verified by

Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/14

Figure A-5.2. Transfer Sheet for Casiligan Floodplain - B

DATA TRANSFER SHEET

Feb 21, 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	
2/11/2014	1088A	3BLK28HS042A	AQUARIUS	N/A	781	1.23MB	269	80.9GB 20.4	565	14	N/A	14.7	143	506	6	12	\\FREENAS\geostorage3\Airborne_Raw\1088A
2/11/2014	1090A	3BLK28JU042B	AQUARIUS	N/A	215	822KB	156	19.4	162	4.96	N/A	14.7	143	267	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1090A
2/12/2014	1092A	3BLK28ABES043A	AQUARIUS	N/A	1657	1.70MB	242	23.7	601	12.7	N/A	15.4	123	364	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1092A
2/12/2014	1094A	3BLK28BS043B	AQUARIUS	N/A	332	2.27MB	128	28.4GB 22.1	186	6.05	N/A	15.4	123	334	6	N/A	\\FREENAS\geostorage3\Airborne_Raw\1094A
2/13/2014	1096A	3BLK28NAJ044A	AQUARIUS	N/A	449	772KB	207	36.6	291	7.46	N/A	13.3	175	411	6	N/A	\\FREENAS\geostorage3\Airborne_Raw\1096A
2/13/2014	1098A	3BLK28JS044B	AQUARIUS	N/A	582	954KB	235	23.9	291	11	N/A	13.3	175	725	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1098A
2/15/2014	1104A	3BLK28JS046A	AQUARIUS	N/A	787	1.08MB	276	56.2	288KB&170KB	10.3	N/A	9.85	134	325	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1104A

Received from

Name Lovely Acuña / [signature]
Position Supervising SRS
Signature [signature] 02/21/2014

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature [signature]

Verified by

Name JOIDA F. PRIETO
Position SSRS
Signature [signature]

Figure A-5.3. Transfer Sheet for Casiligan Floodplain - C

DATA TRANSFER SHEET
Calapan 11/9/15

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Oct. 22, 2015	8300	2BLK28ABC295A	Gemini	na	400	675	236	28.5	214	18.2	247	15.6	1KB	1KB	24	na	Z:\DAC\RAW DATA
Oct. 22, 2015	8301	2BLK28CSD295B	Gemini	na	587	947	249	39.1/10.5	307/87	22.7	na	15.6	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 23, 2015	8302	2BLK28ASEHI296A	Gemini	na	343	593	228	28.2	223	14.5	na	11.5	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 24, 2015	8304	2BLK28FHS297A	Gemini	na	315	519	214	24.8	187	14.2	221	8.92	1KB	1KB	5/11/24/14/13	na	Z:\DAC\RAW DATA
Oct. 25, 2015	8306	2CALIBBLK28FSGS298A	Gemini	na	136	366	220	na	na	10.7	4.29	8.28	1KB	1KB	28/27	na	Z:\DAC\RAW DATA
Oct. 26, 2015	8308	2BLK28J299A	Gemini	na	312	356	235	na	na	14	153	8.39	1KB	1KB	7/5/2	na	Z:\DAC\RAW DATA
Oct. 28, 2015	8312	2BLK28JKLS301A	Gemini	na	40	292	215	na	na	11	427	7.5	1KB	1KB	7	270	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature [signature]

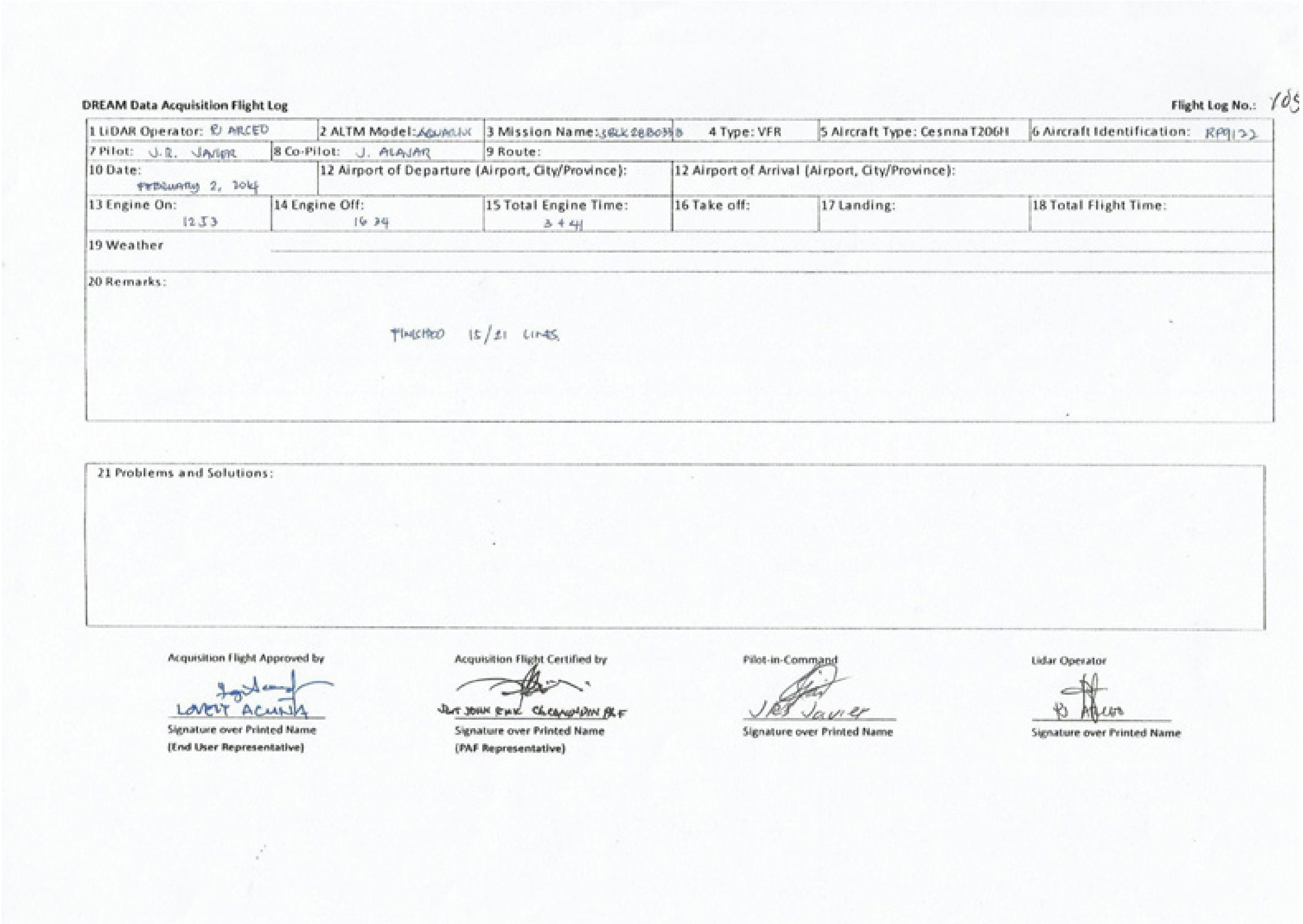
Received by

Name AC Bongat
Position SSRS
Signature [signature] 11/12/15

Figure A-5.4. Transfer Sheet for Casiligan Floodplain - D

ANNEX 6. Flight logs for the Flight Missions

1. Flight Log for Mission 1054A



DREAM Data Acquisition Flight Log

Flight Log No.: 108

1 LiDAR Operator: B. ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 1BLK28B033B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J.R. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEBRUARY 2, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1253	14 Engine Off: 1634	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

FINISHED 15/21 LINES

21 Problems and Solutions:

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

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

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

Lidar Operator
B. Arceo
Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1054A

2. Flight Log for Mission 1056A

DREAM Data Acquisition Flight Log — Flight Log No.: 105

1 LiDAR Operator: RJ Arceo	2 ALTM Model: Aquarius	3 Mission Name: 3BLK28CO049A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. Alajar	8 Co-Pilot: J. Javier	9 Route:			
10 Date: February 9, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 824	14 Engine Off: 1205	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Finished 11/21 lines.					

21 Problems and Solutions:

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

Acquisition Flight Certified by: SGT Jhan Eric Cabanlong, NPAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: JJ Alajar — Signature over Printed Name

Lidar Operator: RJ Arceo — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1056A

3. Flight Log for Mission 1058A

DREAM Data Acquisition Flight Log — Flight Log No.: 1058

1 LiDAR Operator: I. Roxas	2 ALTM Model: Aquarius	3 Mission Name: 2BLK28C 033B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. Alajar	8 Co-Pilot: J. Javier	9 Route:			
10 Date: February 2, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1617	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission 28C and finished some lines in D.					

21 Problems and Solutions:

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

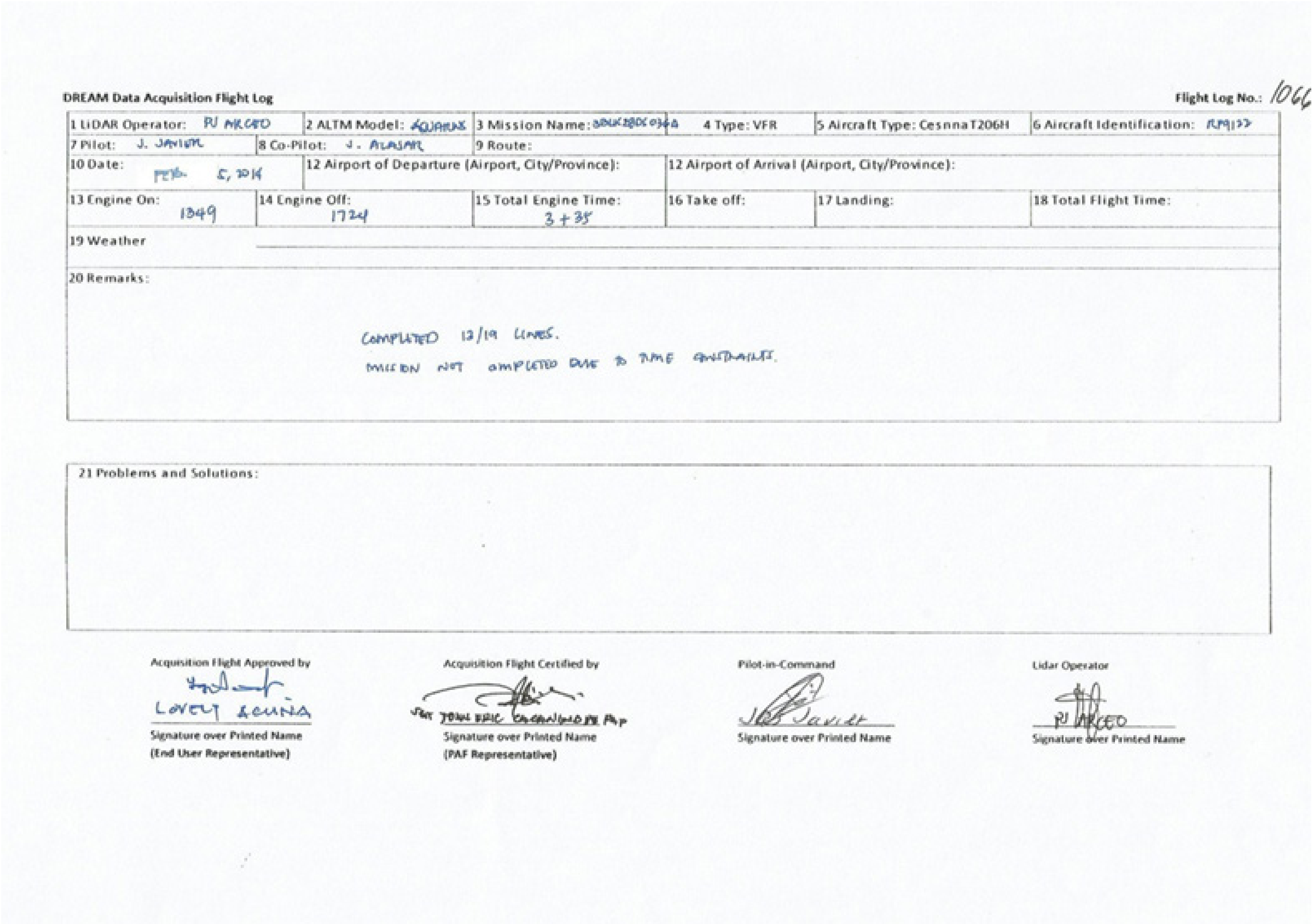
Acquisition Flight Certified by: SGT John Eric Cacananan PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: J. Alajar — Signature over Printed Name

Lidar Operator: I. Roxas — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1058A

4. Flight Log for Mission 1066A



DREAM Data Acquisition Flight Log

Flight Log No.: 1066

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 5, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1349	14 Engine Off: 1724	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

COMPLETED 12/19 LINES.
MISSION NOT COMPLETED DUE TO TIME CONSTRAINTS.

21 Problems and Solutions:

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

Acquisition Flight Certified by
SGT JOHN ERIC CACANINDIN PAF
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
PJ ARCEO
Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1066A

5. Flight Log for Mission 1070A

DREAM Data Acquisition Flight Log — Flight Log No.: 1070

1 LiDAR Operator: I.RO ROXAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK28DSE037A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J ALAJAR	8 Co-Pilot: J JAVIER	9 Route:			
10 Date: Feb 6, 14	12 Airport of Departure (Airport, City/Province): Catapan		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1723	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 3BLK29D

21 Problems and Solutions:

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

Acquisition Flight Certified by: SGT JOHN ERIC CACANINDIN PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: JJ ALAJAR — Signature over Printed Name

Lidar Operator: I ROXAS — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1070A

6. Flight Log for Mission 1092A

DREAM Data Acquisition Flight Log — Flight Log No.: 1092

1 LiDAR Operator: I. Roxas	2 ALTM Model: AQUA	3 Mission Name: 3BLKABES043A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. Javier	8 Co-Pilot: J. Alajar	9 Route:			
10 Date: FEB. 12, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 908	14 Engine Off: 1313	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed lines in Areas A & B.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
L. Acuna	SGT John Eric Pagaduan PAF	J. Javier	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.6. Flight Log for Mission 1092A

7. Flight Log for Mission 1094A

DREAM Data Acquisition Flight Log — Flight Log No.: 1094

1 LiDAR Operator: PJ Arceo	2 ALTM Model: AQUA	3 Mission Name: 1BLK28BC049A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. Javier	8 Co-Pilot: J. Alajar	9 Route:			
10 Date: Feb. 12, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1417	14 Engine Off: 1646	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

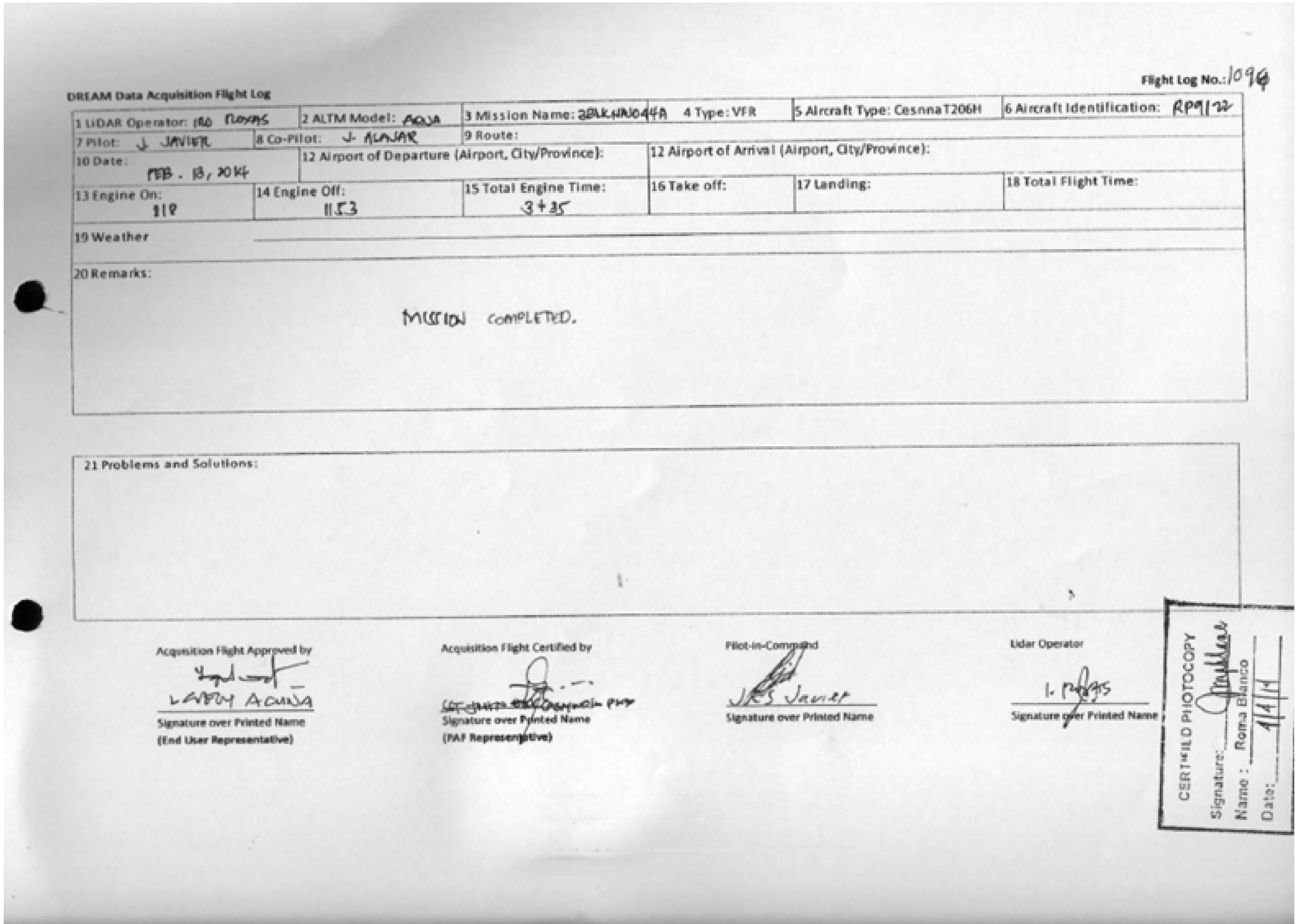
completed lines in area B.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuna	Capt. John Eric Casanova PAF	J R S Javier	PJ Arceo
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 1094A

8. Flight Log for Mission 1096A



DREAM Data Acquisition Flight Log

Flight Log No.: 1096

1 LiDAR Operator: I. ROXAS	2 ALTM Model: AQUA	3 Mission Name: 2BLKHA044A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 818	14 Engine Off: 1153	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

MISSION COMPLETED.

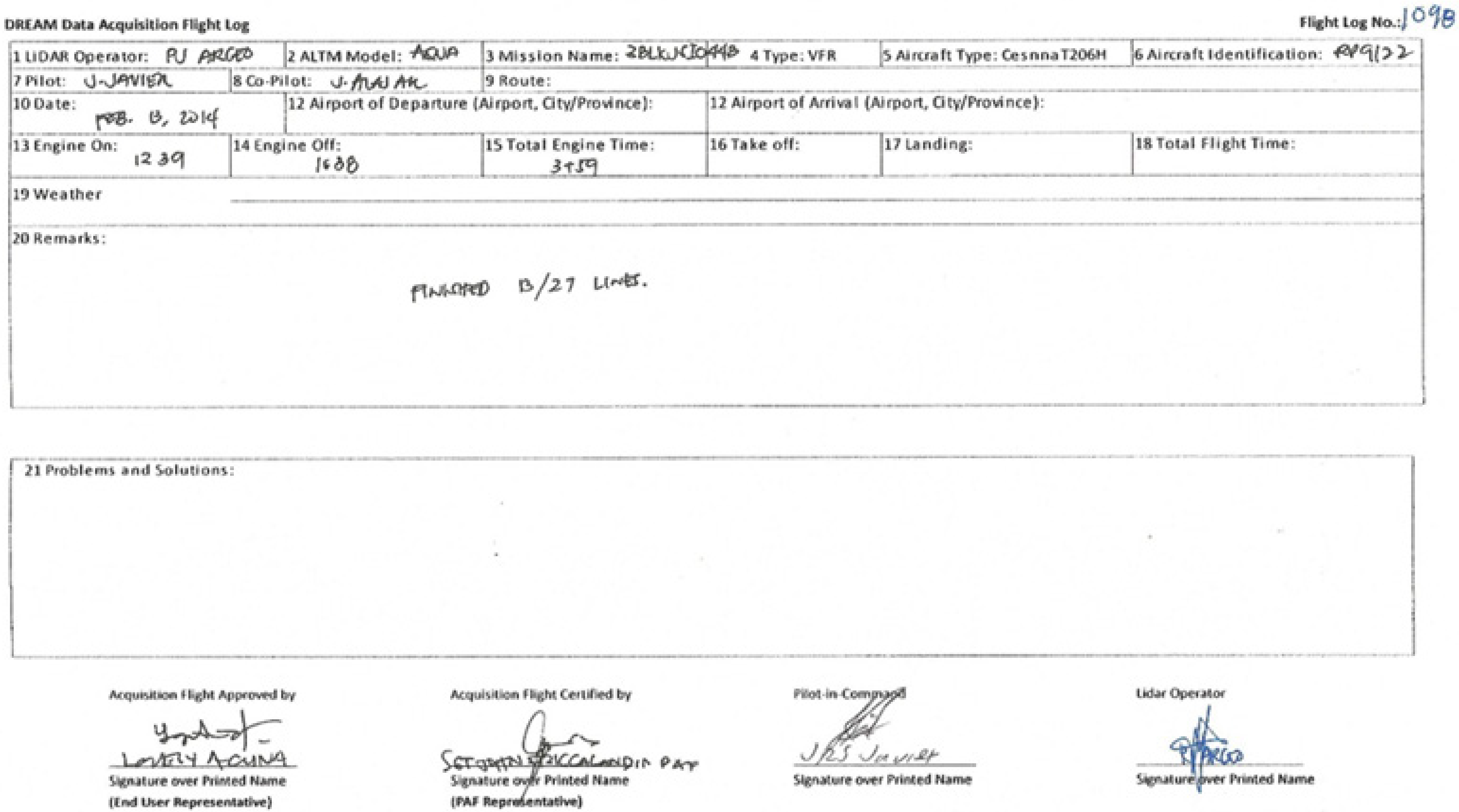
21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LARRY ACUNA		J. Javier	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name : Roma Blanco
Date: 4/4/14

Figure A-6.8. Flight Log for Mission 1096A

9. Flight Log for Mission 1098A


DREAM Data Acquisition Flight Log

Flight Log No.: 1098

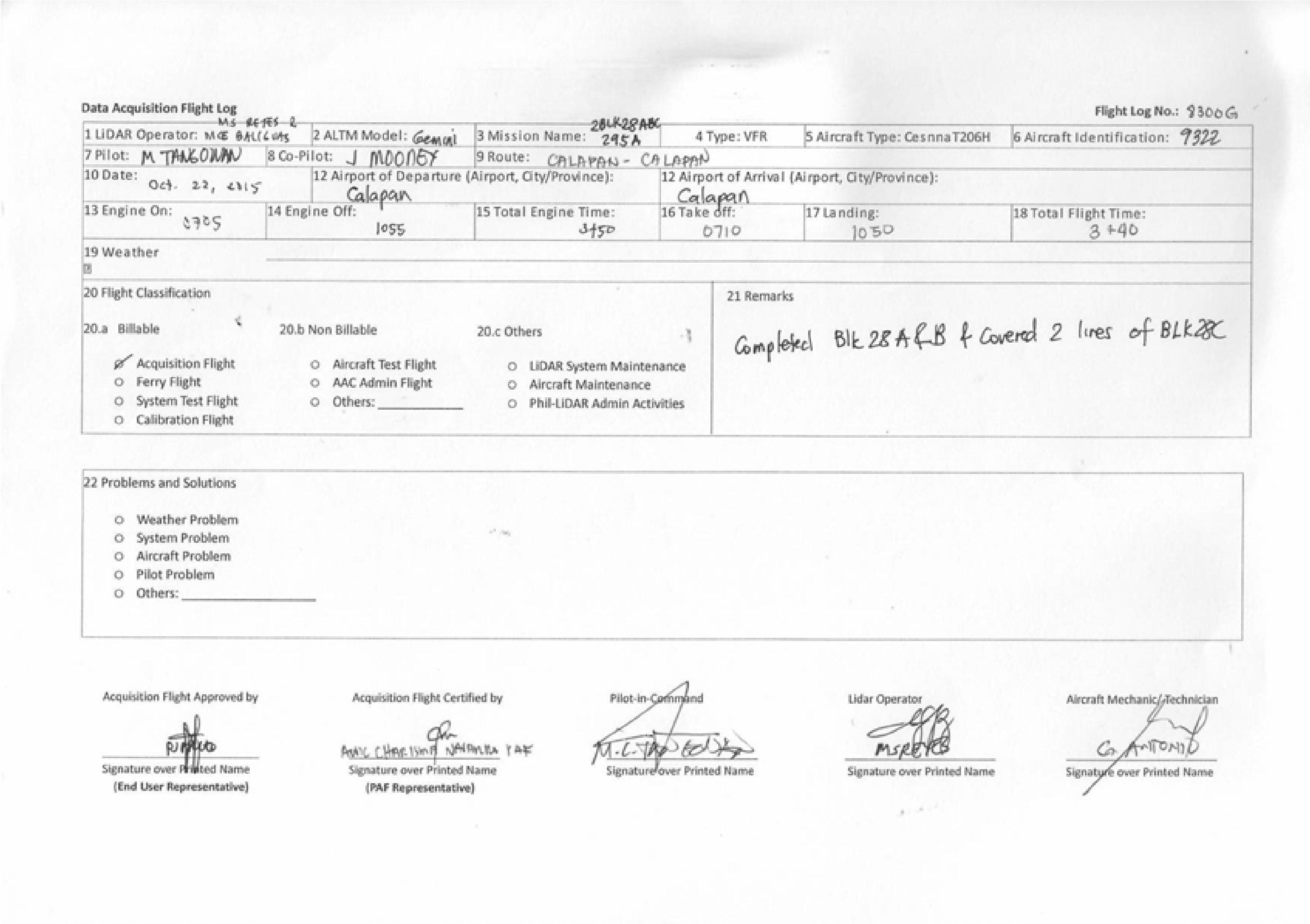
1 LiDAR Operator: PJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 2BLK3C10448	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1239	14 Engine Off: 1638	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 13/27 LINES.					

21 Problems and Solutions:

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

Figure A-6.9. Flight Log for Mission 1098A

10. Flight Log for Mission 8300G



Data Acquisition Flight Log

Flight Log No.: 8300G

1 LiDAR Operator: MS REYES & MCE BALICAS	2 ALTM Model: Gemini	3 Mission Name: 2BLK28ABC 295A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct. 22, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0705	14 Engine Off: 1055	15 Total Engine Time: 3+50	16 Take off: 0710	17 Landing: 1050	18 Total Flight Time: 3+40
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

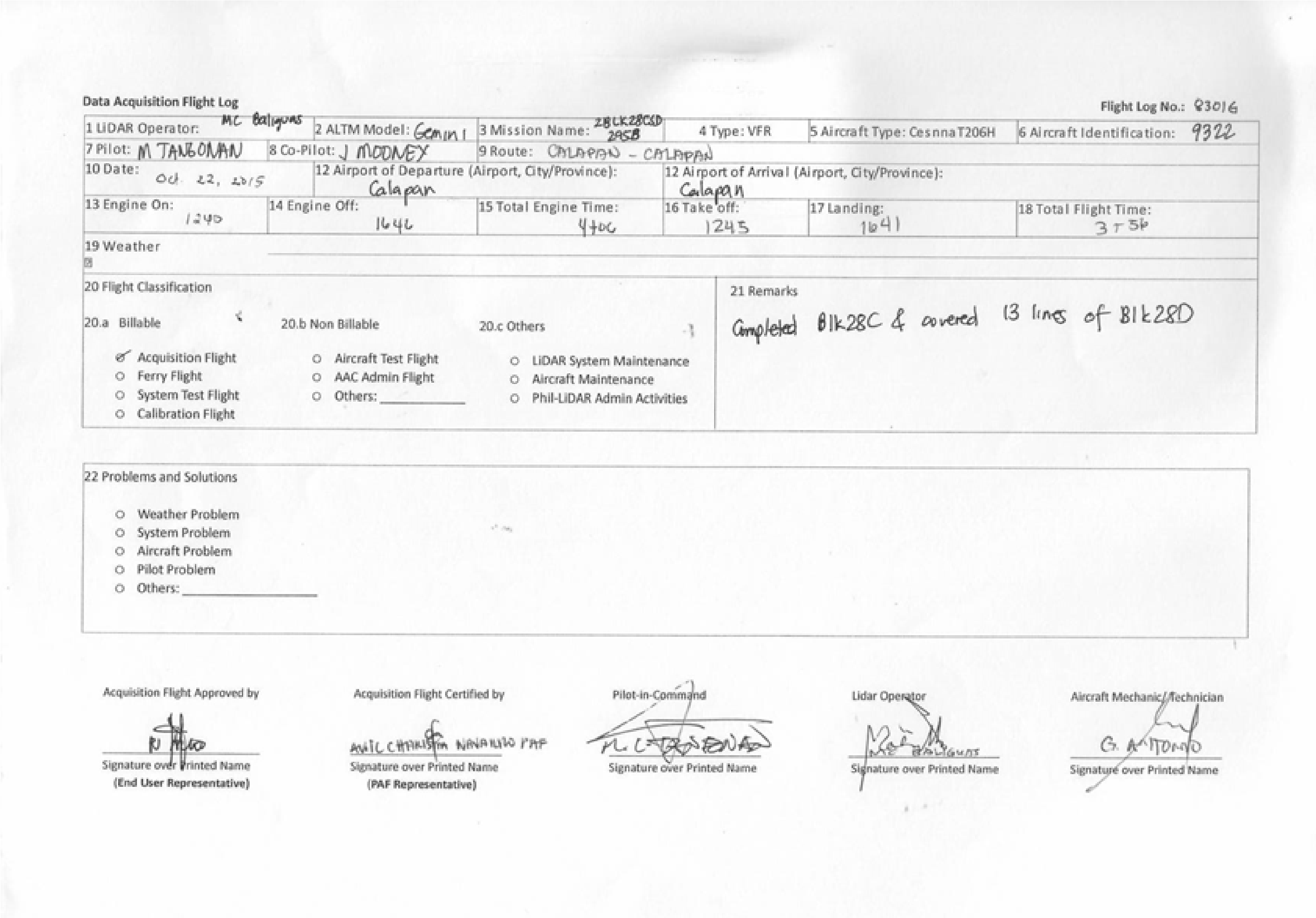
Completed Blk 28A & B & Covered 2 lines of BLK28C

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/Technician
Signature over Printed Name (End User Representative)	AMIC CHARISMA NAPALLA TAF Signature over Printed Name (PAF Representative)	M.C. TANGONAN Signature over Printed Name	MS REYES Signature over Printed Name	G. ANTONIO Signature over Printed Name

Figure A-6.10. Flight Log for Mission 8300G

11. Flight Log for Mission 8301G


Data Acquisition Flight Log

Flight Log No.: 83016

1 LiDAR Operator: MC Balguas	2 ALTM Model: Gemini	3 Mission Name: 2BLK28CSD 295B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct 22, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 1240	14 Engine Off: 1646	15 Total Engine Time: 4+06	16 Take off: 1245	17 Landing: 1641	18 Total Flight Time: 3+56
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Completed Blk28C & covered 13 lines of Blk28D

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

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

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

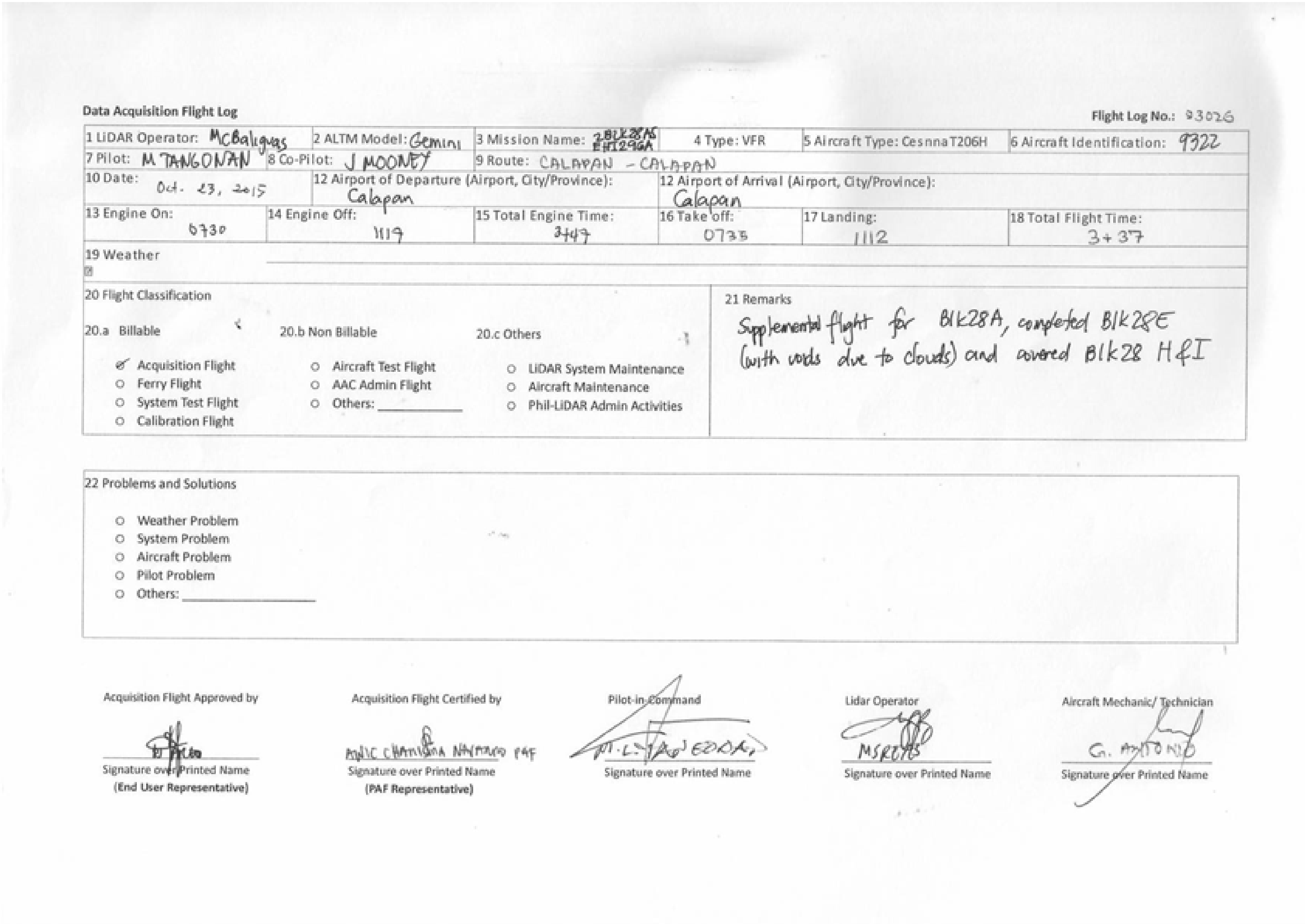
Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/Technician: G. ANTONIO — Signature over Printed Name

Figure A-6.11. Flight Log for Mission 8301G

12. Flight Log for Mission 8302G



Data Acquisition Flight Log

Flight Log No.: 8302G

1 LiDAR Operator: MCBalquas	2 ALTM Model: Gemini	3 Mission Name: 2BLK28AS EHI296A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct. 23, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0730	14 Engine Off: 1119	15 Total Engine Time: 3+49	16 Take off: 0735	17 Landing: 1112	18 Total Flight Time: 3+37
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Supplemental flight for BlK28A, completed BlK28E (with voids due to clouds) and covered BlK28 H&I

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	ANIC CHAMIANA NAVARRO PAF Signature over Printed Name (PAF Representative)	M. L. TANGONAN Signature over Printed Name	MSREYES Signature over Printed Name	G. ANTONIO Signature over Printed Name

Figure A-6.12. Flight Log for Mission 8302G

ANNEX 7. Flight status reports

CASILIGAN FLOODPLAIN
February 2-15, 2014; October 23-25, 2015

Table A-7.1. Flight Status Reports

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1054A	BLK 28B	3BLK28B033B	PAULINE ARCEO	FEB 2, 2014	Change parameters due to high dropouts (600agl, 50prf, 18degrees scan angle), not finished
1056A	BLK 28C	3BLK28C034A	PAULINE ARCEO	FEB 3, 2014	Finished lower half of BLK28C
1058A	BLK 28CD	3BLK28CD034B	IRO ROXAS	FEB 3, 2014	Finished the rest of BLK28C and some lines of BLK28D
1066A	BLK 28D	3BLK28DS036A	PAULINE ARCEO	FEB 5, 2014	Survey 8 lines BLK28D
1070A	BLOCK 28D & 28E	3BLK28DSE037A	IRO ROXAS	FEB 6, 2014	Finished Block 28D and some lines of Block 28E
1092A	BLK 28A, BLK 28D, BLK 28E	3BLK28ABES043A	IRO ROXAS	FEB 12, 2014	Survey lines in BLK28A, 28D and 28E
1094A	BLK 28B	3BLK28BS043B	PAU ARCEO	FEB 12, 2014	Mission Complete
1096A	BLK28A, AS	3BLK28NAJ044A	IRO ROXAS	FEB 13, 2014	Mission Completed
1098A	BLK28J,I	3BLK28JSI044B	PAU ARCEO	FEB 13, 2014	Mission Complete
8300G	BLK 28A, B, AS	2BLK28ABC295A	MCE BALIGUAS & MS REYES	Oct. 22, 2015	Completed BLK28 A & B and covered 2 lines of BLK28C.
8301G	BLK 28B,C,D,H	2BLK28CSD295B	MCE BALIGUAS & MS REYES	Oct. 22, 2015	Completed BLK28C and covered 13 lines of BLK28D.
8302G	BLK 28AS,C,D,F	2BLK28ASEHI296A	MCE BALIGUAS	Oct. 23, 2015	Supplemental flight for BLK28A, completed BLK28 E (with voids due to clouds) and covered BLK28 H & I.

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT LOG NO.	1054A	Scan Freq:	45 kHz
AREA:	BLOCK 28B	Scan Angle:	36 deg
MISSION NAME:	3BLK28B033B	Alt:	600m

SURVEY COVERAGE:

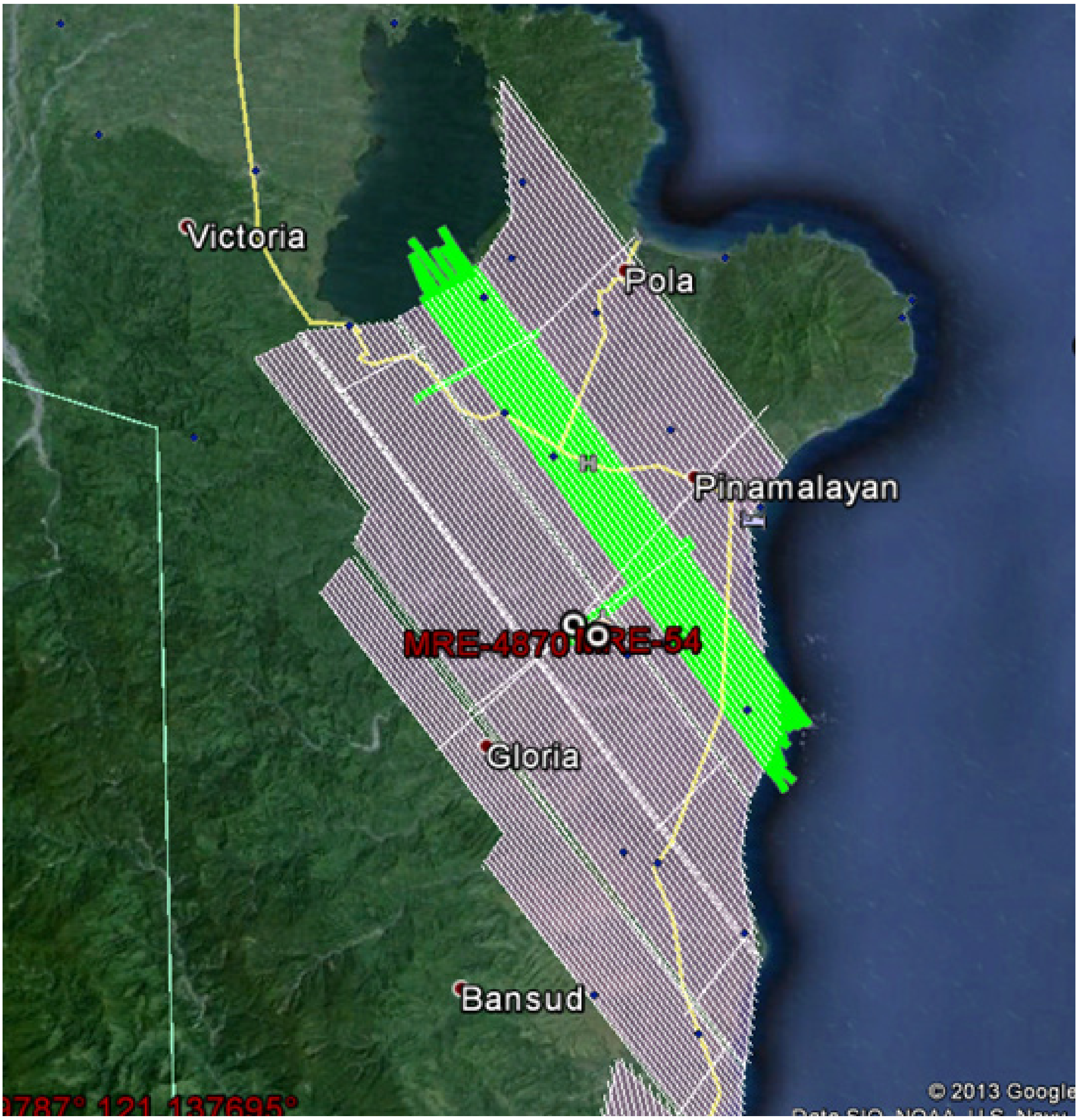


Figure A-7.1. Swath for Flight No. 1054A

FLIGHT LOG NO.	1054A	Scan Freq:	45 kHz
AREA:	BLOCK 28B	Scan Angle:	36 deg
MISSION NAME:	3BLK28B033B	Alt:	600m

SURVEY COVERAGE:

Figure A-7.2. Swath for Flight No. 1056A

FLIGHT LOG NO.	1058A	Scan Freq:	45 kHz
AREA:	BLOCK 28CD	Scan Angle:	36 deg
MISSION NAME:	3BLK28CD034B	Alt:	600 m

SURVEY COVERAGE:

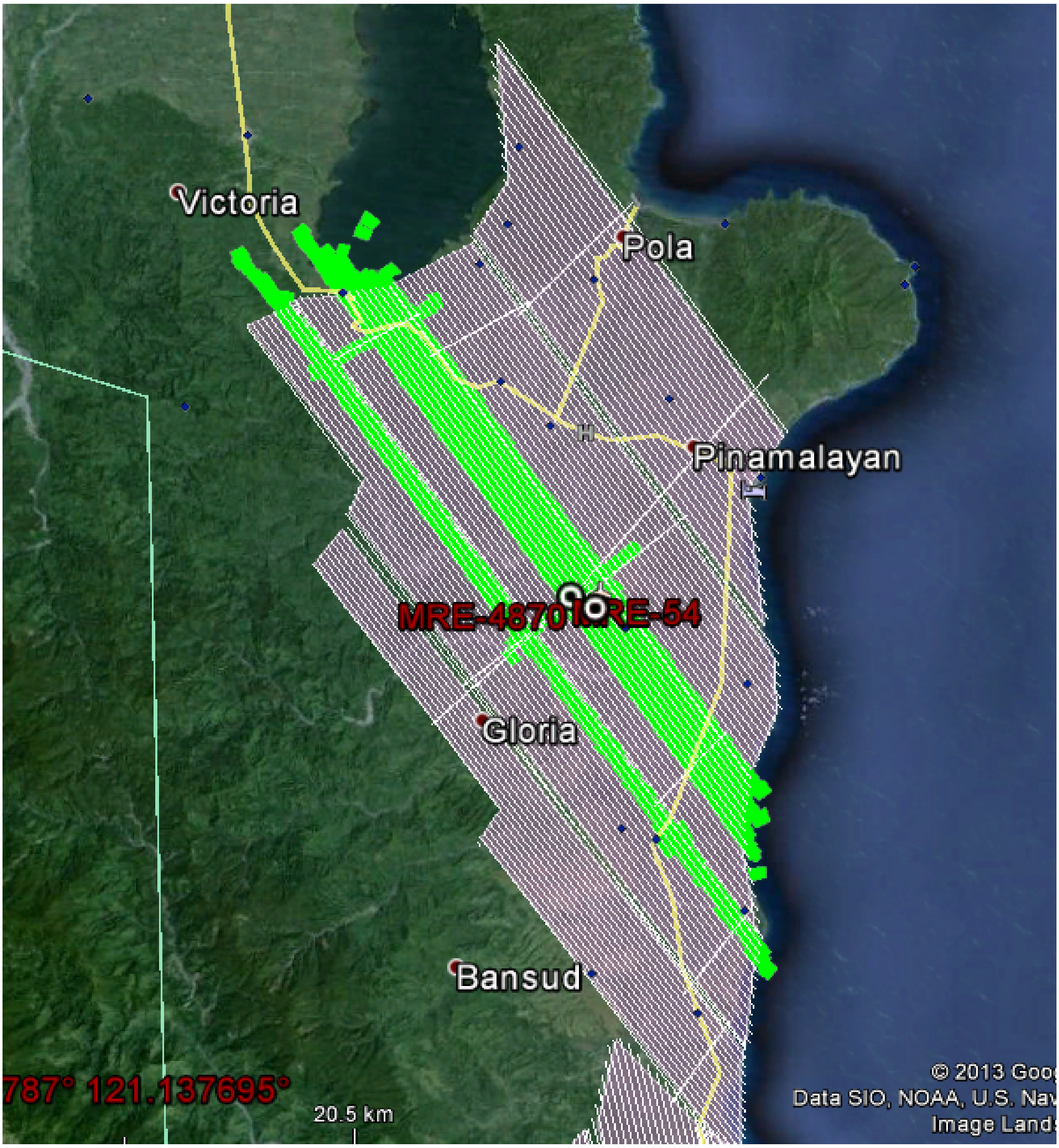


Figure A-7.3. Swath for Flight No. 1058A

FLIGHT LOG NO.	1066A	Scan Freq:	45 kHz
AREA:	BLOCK 28D	Scan Angle:	36 deg
MISSION NAME:	3BLK28DS036A	Alt:	600 m

SURVEY COVERAGE:

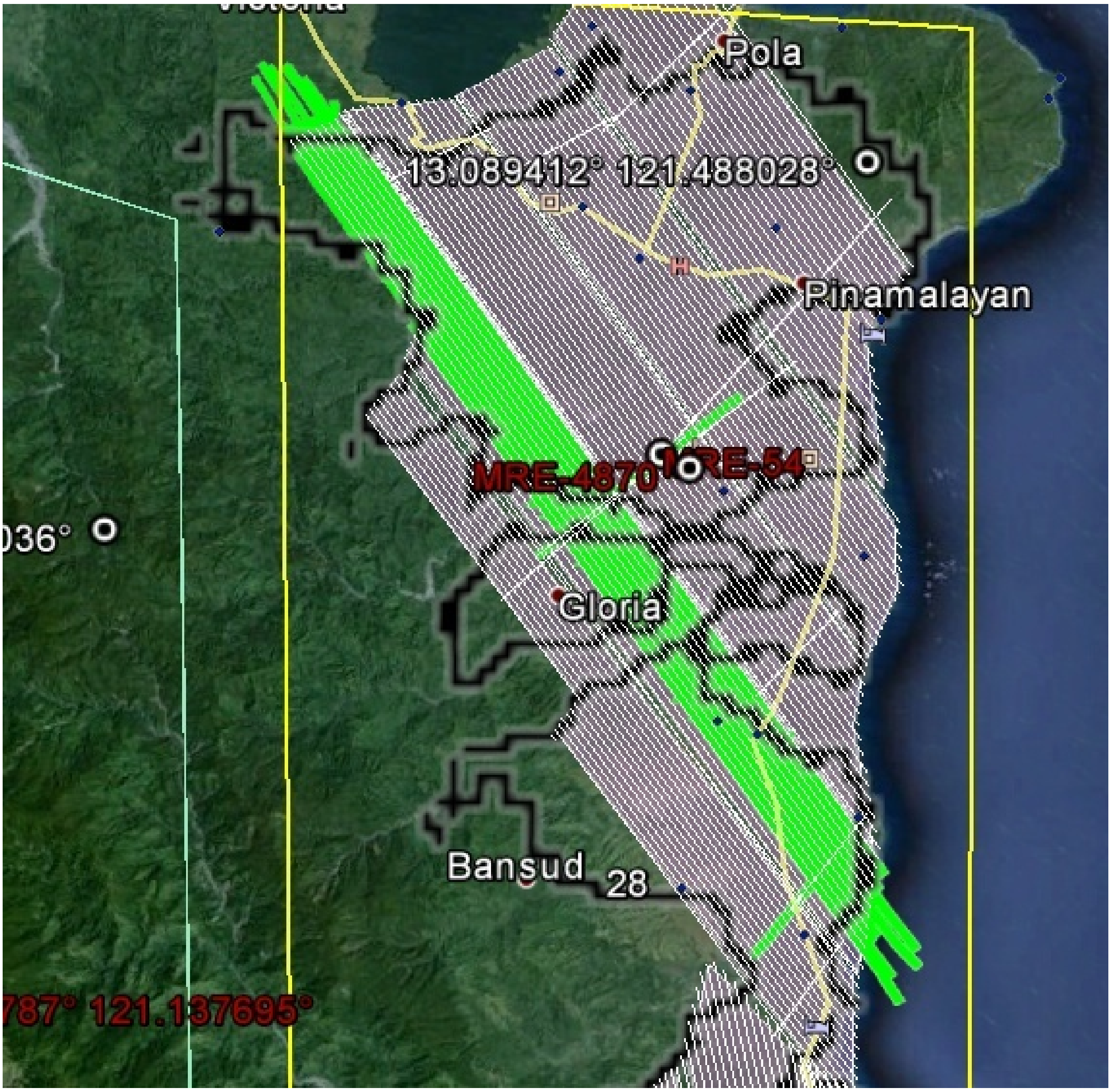


Figure A-7.4. Swath for Flight No. 1066A

FLIGHT LOG NO.	1070A	Scan Freq:	45 kHz
AREA:	28D & BLOCK 28E	Scan Angle:	36 deg
MISSION NAME:	3BLK28DSE037A	Alt:	600 m

SURVEY COVERAGE:

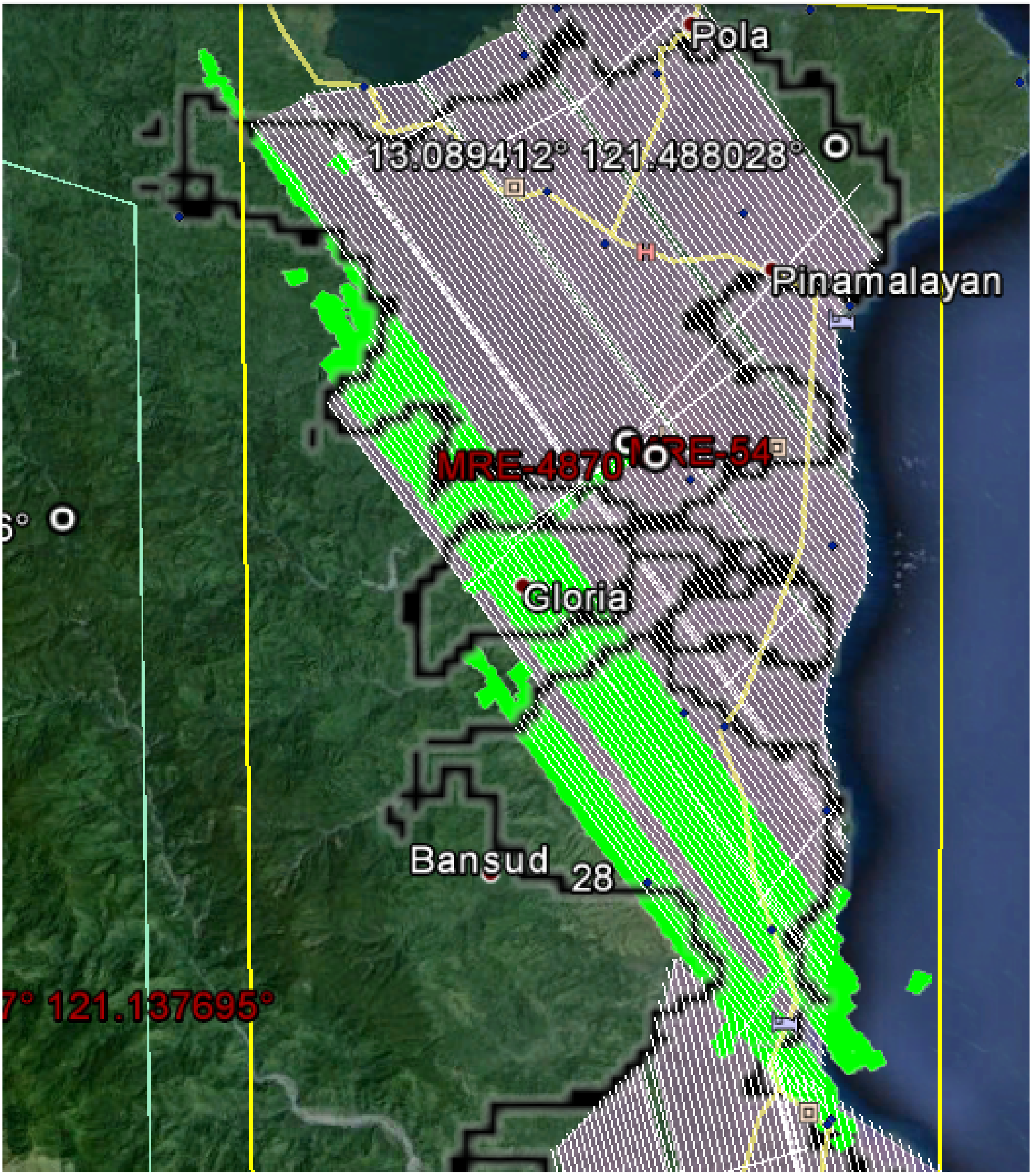


Figure A-7.5. Swath for Flight No. 1070A

FLIGHT LOG NO.	1092A	Scan Freq: 45 kHz
AREA:	BLK 28A,28D and 28E	Scan Angle: 36 deg
MISSION NAME:	3BLK28ABES043A	Alt: 600 m

SURVEY COVERAGE:

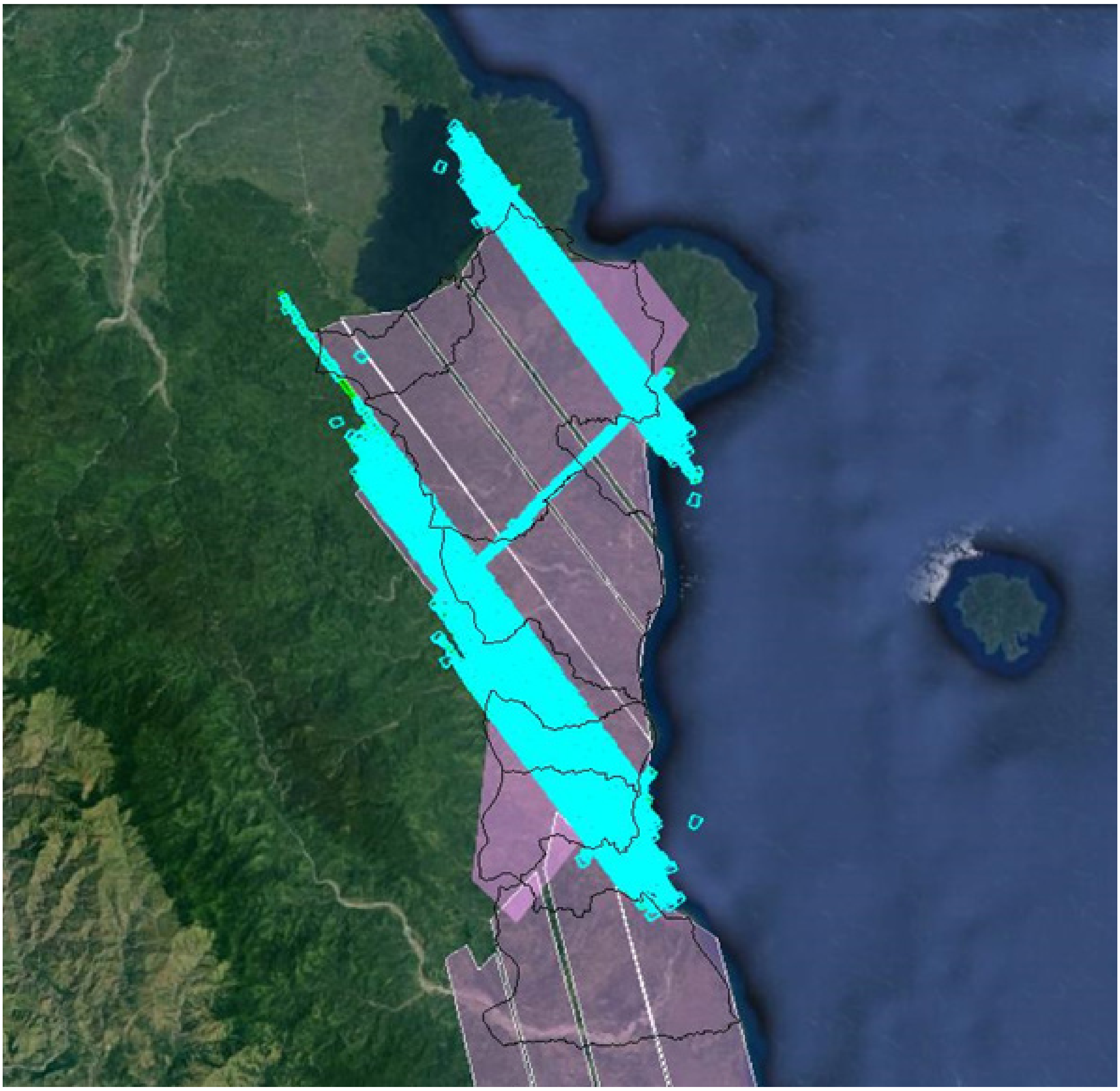


Figure A-7.6. Swath for Flight No. 1092A

FLIGHT LOG NO.	1094A	Scan Freq:	45 kHz
AREA:	BLOCK 28B	Scan Angle:	36 deg
MISSION NAME:	3BLK28BS043B	Alt:	600 m

SURVEY COVERAGE:

Figure A-7.7. Swath for Flight No. 1094A

FLIGHT LOG NO.	1096A	Scan Freq:	40 kHz
AREA:	BLOCK 28A, AS	Scan Angle:	30 deg
MISSION NAME:	3BLK28NAJ044A	Alt:	1100 m

SURVEY COVERAGE:

Figure A-7.8. Swath for Flight No. 1096A

FLIGHT LOG NO.	1098A	Scan Freq:	45 kHz
AREA:	BLOCK 28JI	Scan Angle:	36 deg
MISSION NAME:	3BLK28JSI044B	Alt:	600 m

SURVEY COVERAGE:

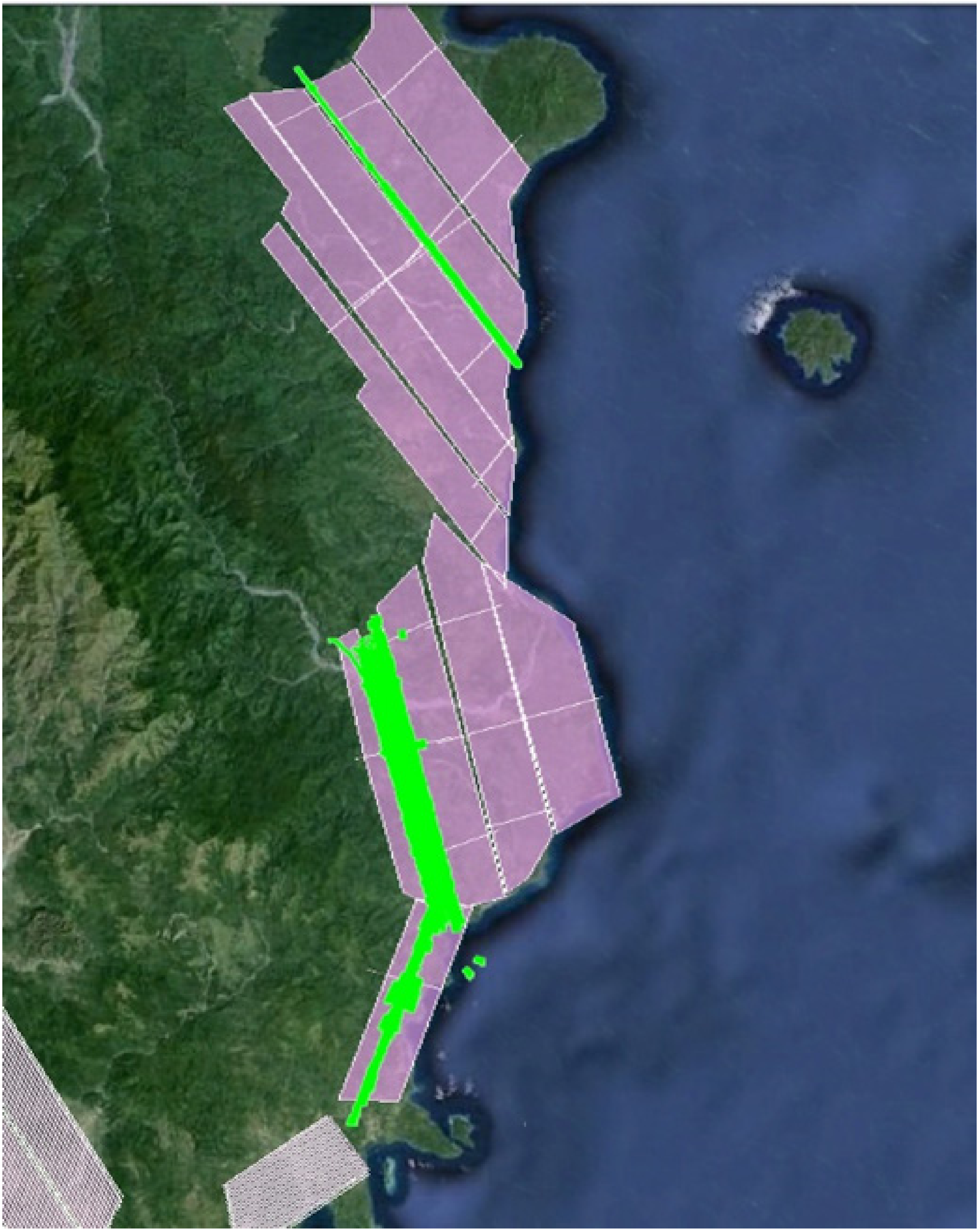


Figure A-7.9. Swath for Flight No. 1098A

FLIGHT NO.: 8300G
AREA: Oriental Mindoro
MISSION NAME: 2BLK28ABC295A
ALT: 1200 m SCAN FREQ: 50 SCAN ANGLE: 36

SURVEY COVERAGE:

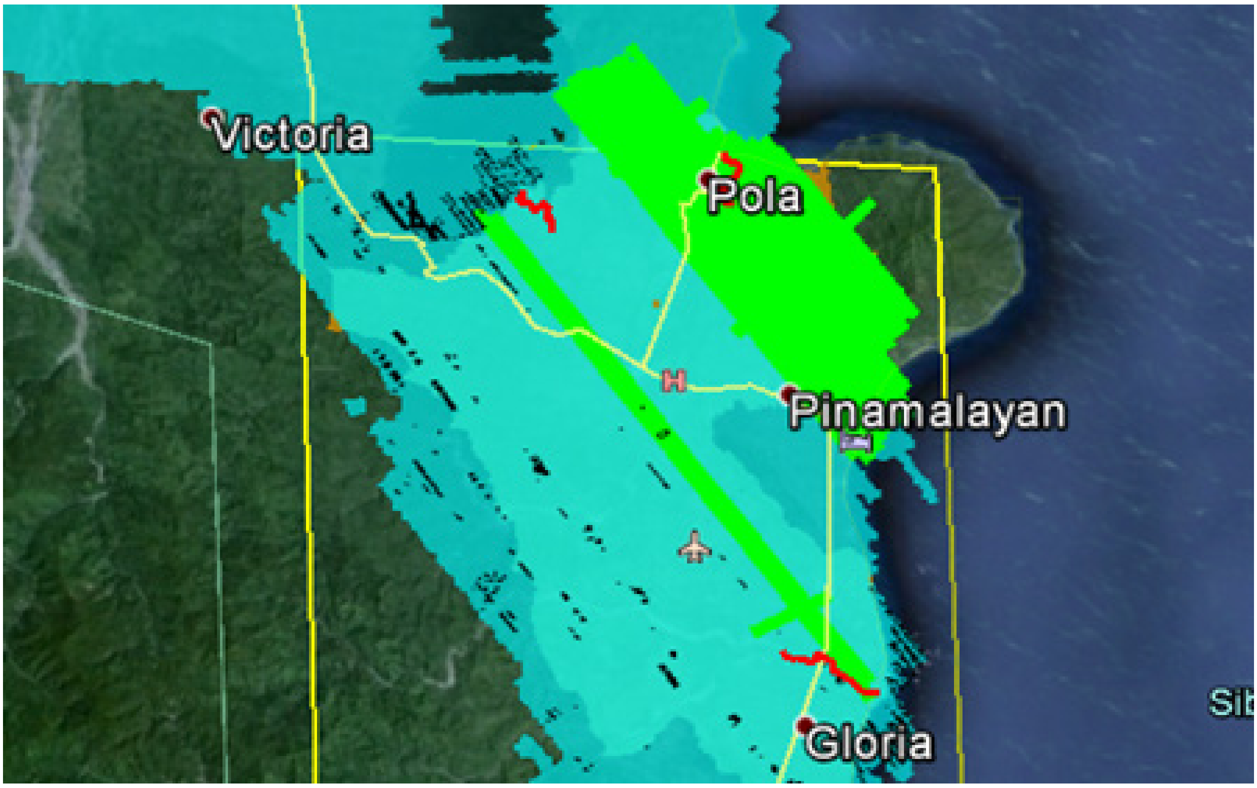


Figure A-7.10. Swath for Flight No. 8300G

FLIGHT NO.: 8301G
AREA: Oriental Mindoro
MISSION NAME: 2BLK28CSD295B
ALT: 1000 m SCAN FREQ: 50 SCAN ANGLE: 40

SURVEY COVERAGE:

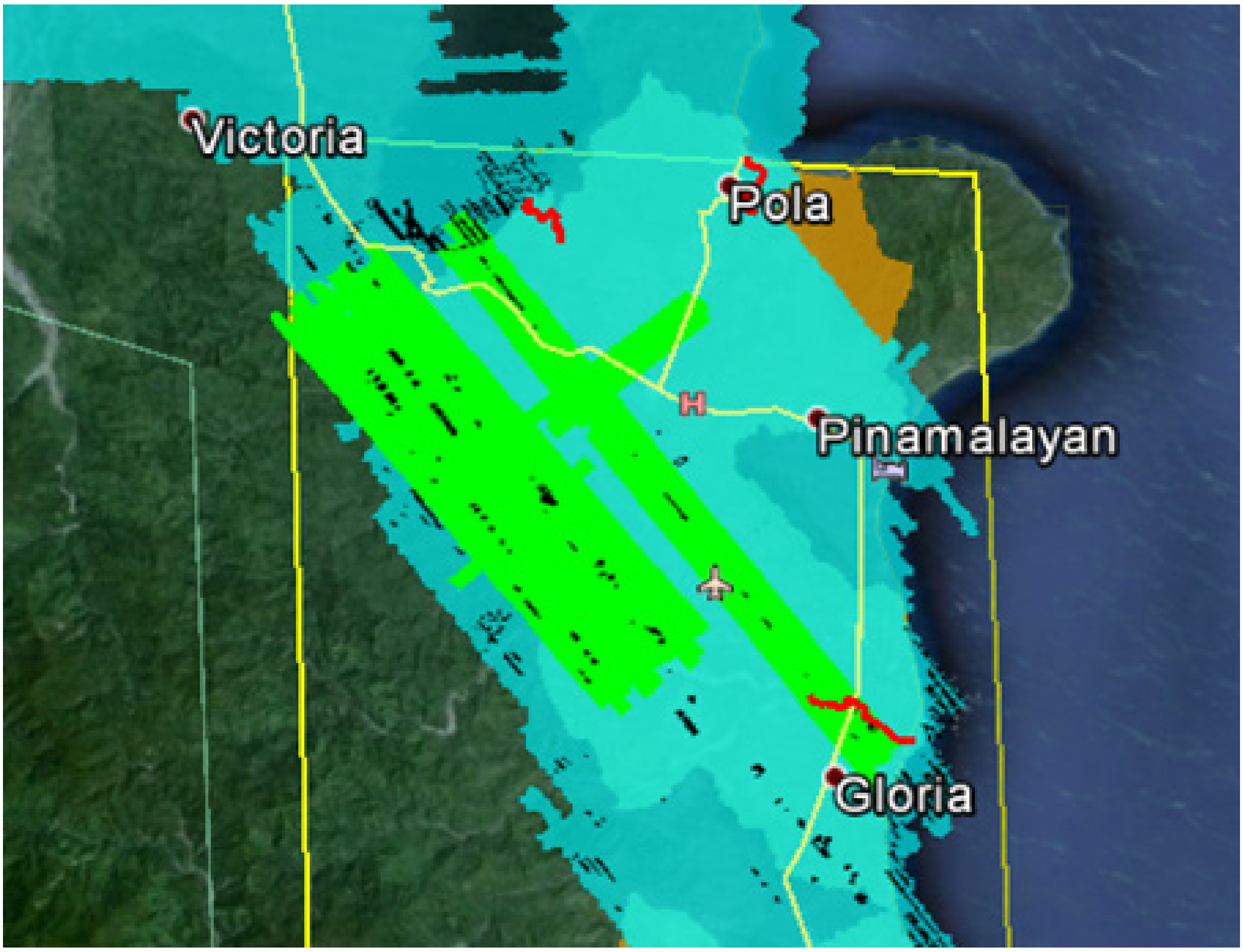


Figure A-7.11. Swath for Flight No. 8301G

FLIGHT NO.: 8302G
AREA: Oriental Mindoro
MISSION NAME: 2BLK28ASEHI296A
ALT: 1200 m SCAN FREQ: 50 SCAN ANGLE: 30

SURVEY COVERAGE:

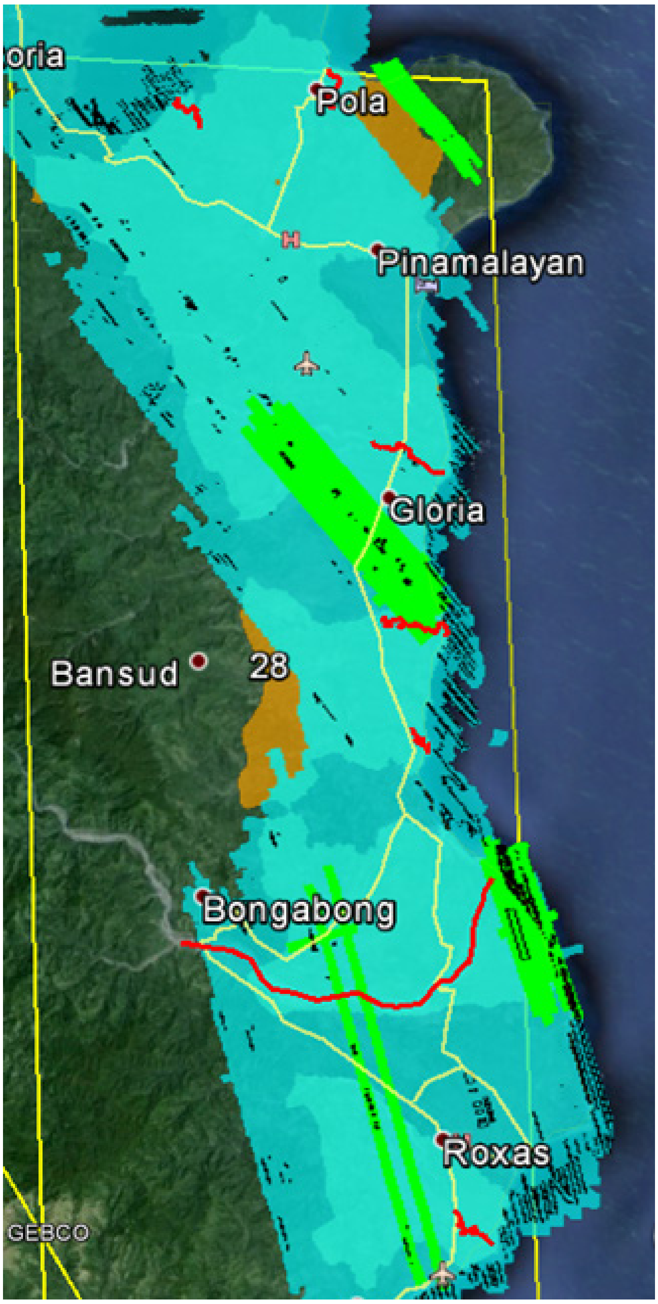


Figure A-7.12. Swath for Flight No. 8302G

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk06A

Flight Area	Ilocos
Mission Name	Blk06_A
Inclusive Flights	7104GC, 7105GC
Range data size	42.6GB
Base data size	24.9 MB
POS	460MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.7
RMSE for East Position (<4.0 cm)	3.3
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.000184
IMU attitude correction stdev (<0.001deg)	0.000642
GPS position stdev (<0.01m)	0.0064
Minimum % overlap (>25)	37.38%
Ave point cloud density per sq.m. (>2.0)	3.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	419
Maximum Height	614.2m
Minimum Height	39.17m
Classification (# of points)	
Ground	167,502,975
Low vegetation	193,929,105
Medium vegetation	261,271,939
High vegetation	401,795,646
Building	13,519,422
Orthophoto	NO
Processed by	Engr. Kenneth Solidum, Engr. Abigail Ching, Engr. Harmond Santos, Engr. Melissa Fernandez

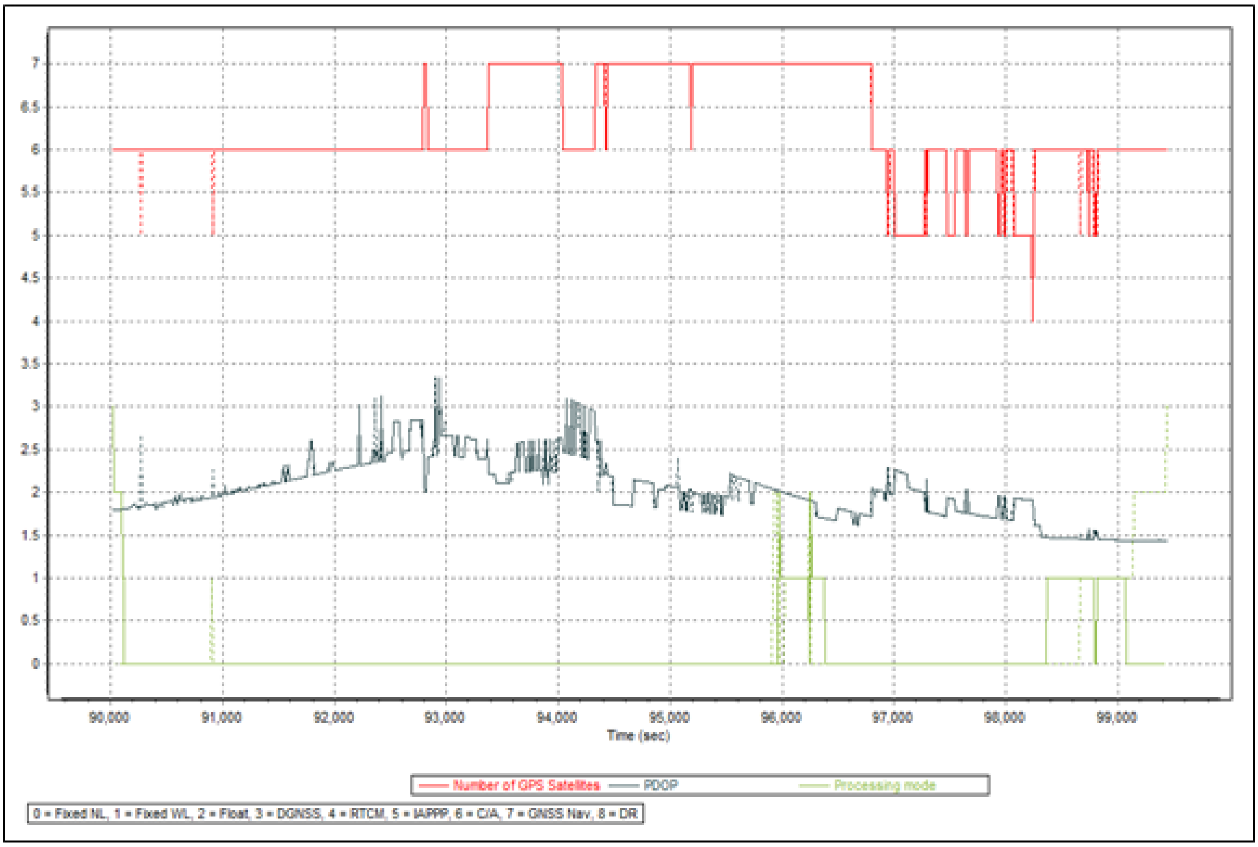


Figure A-8.1. Solution Status

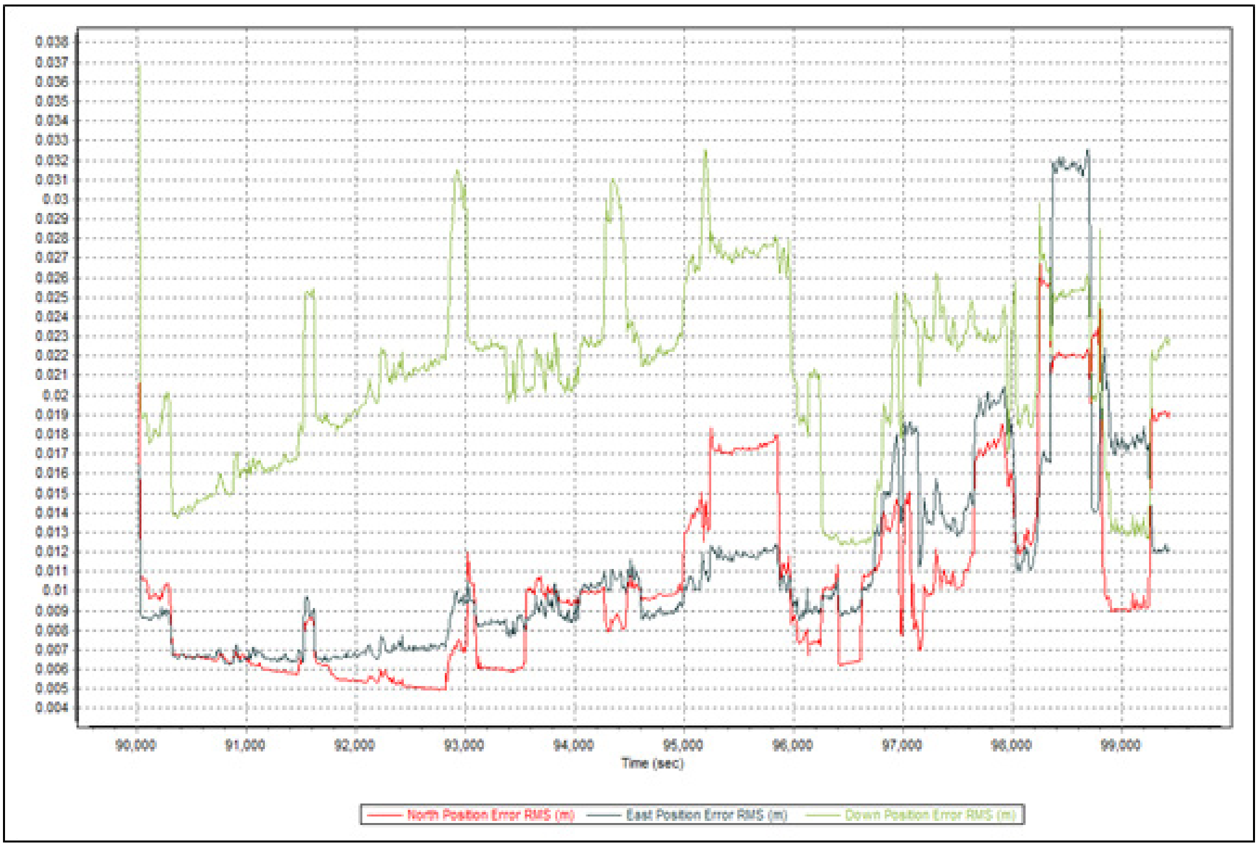


Figure A-8.2. Smoothed Performance Metrics Parameters

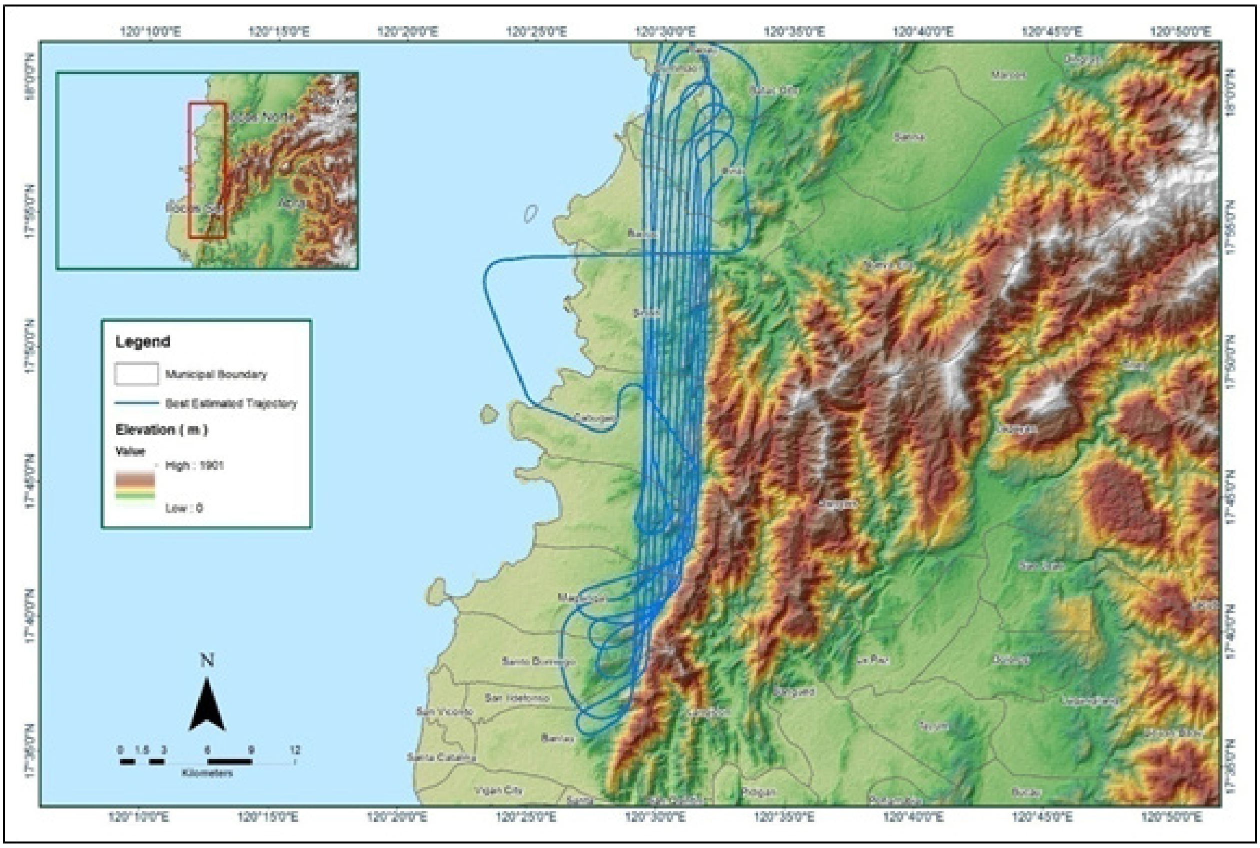


Figure A-8.3. Best Estimated Trajectory

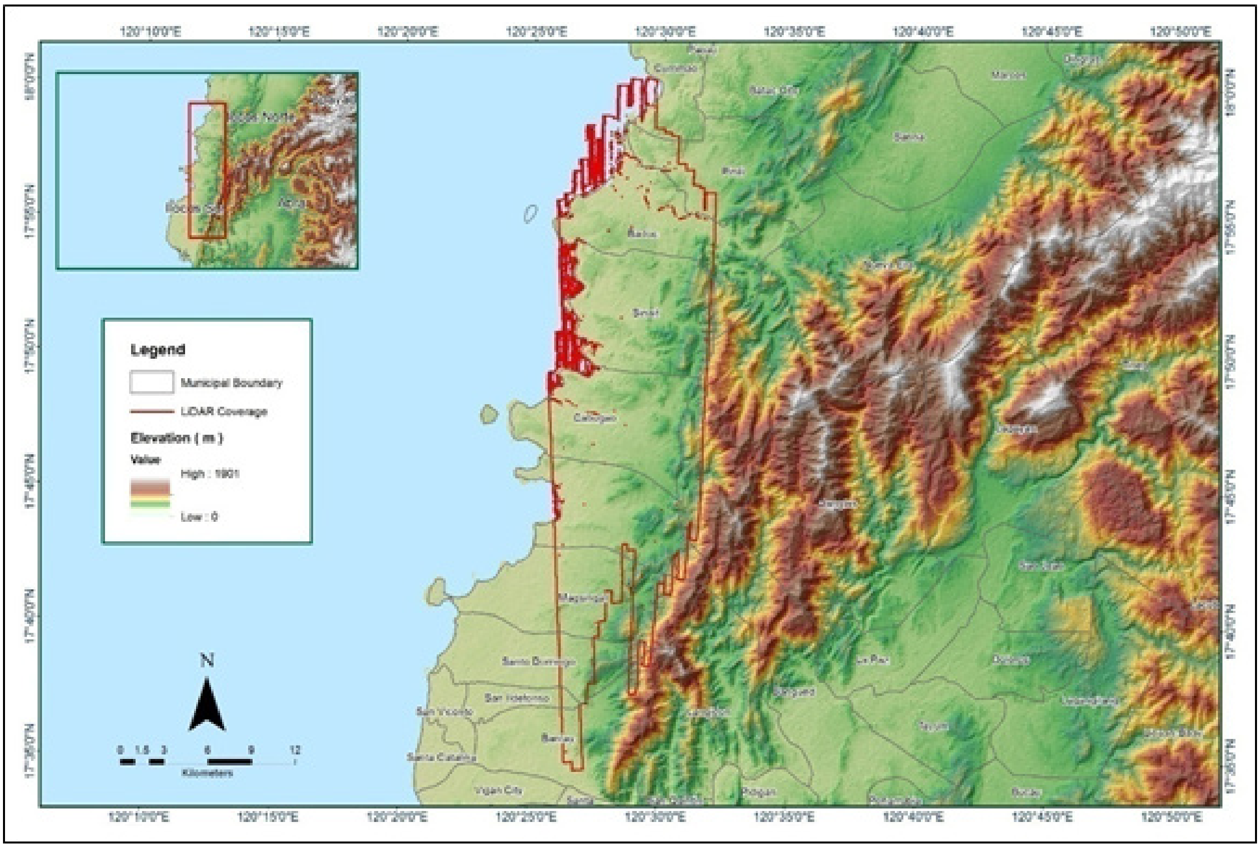


Figure A-8.4. Coverage of LiDAR data

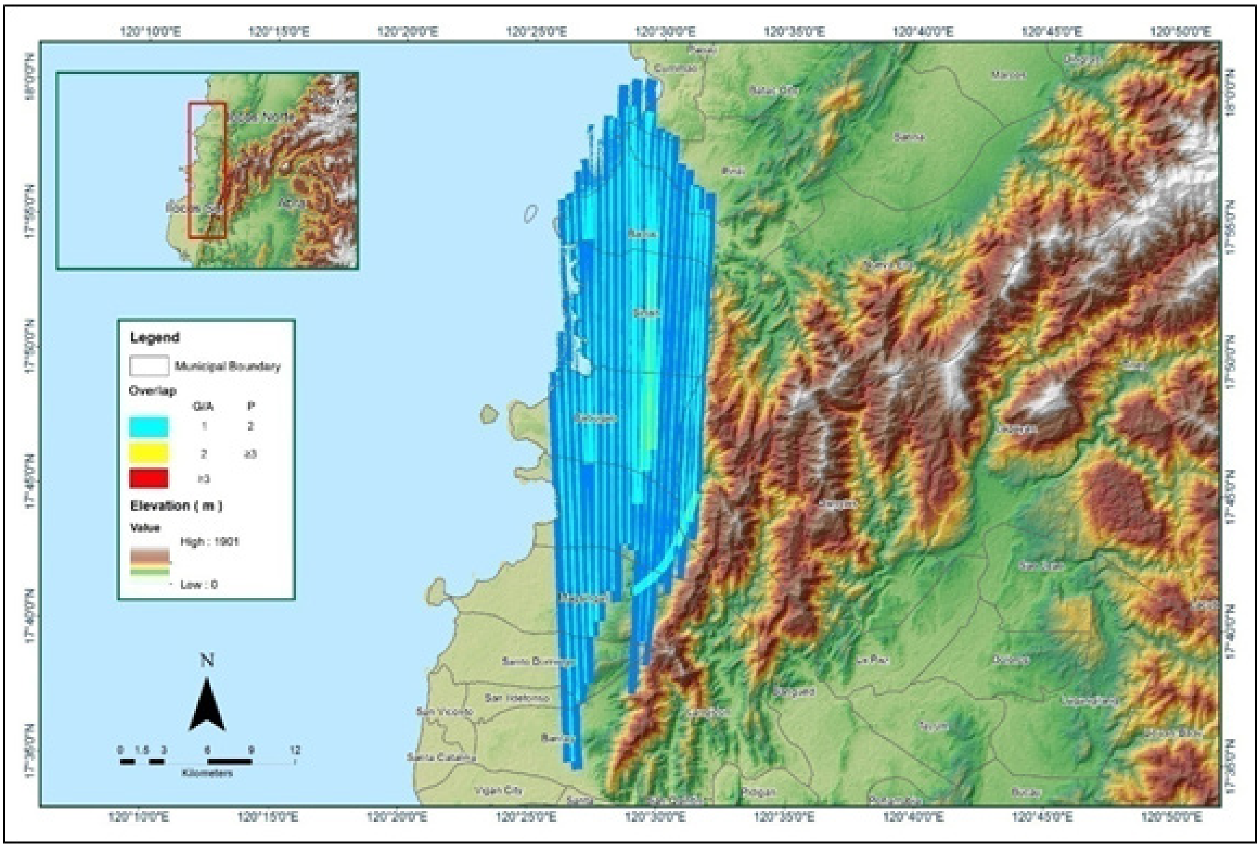


Figure A-8.5. Image of Data Overlap

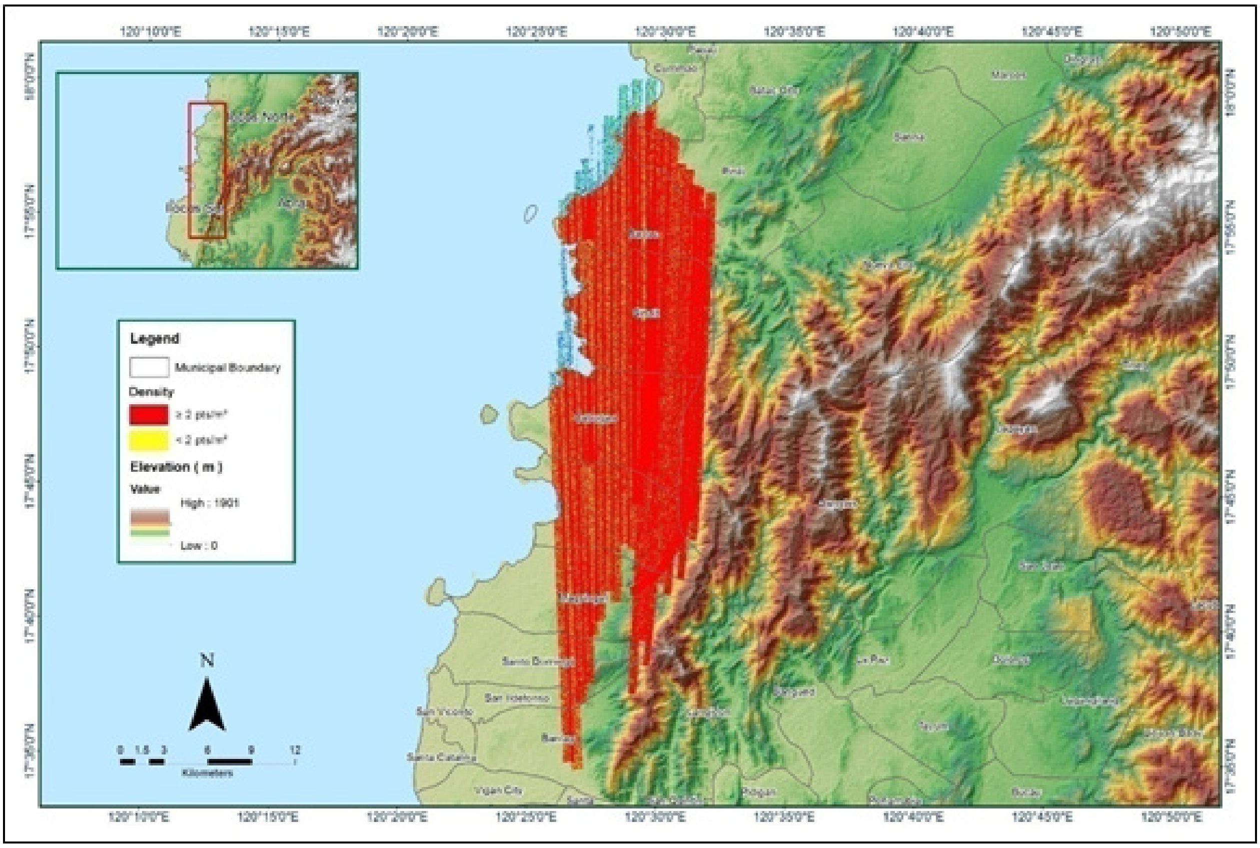


Figure A-8.6.Density map of merged LiDAR data

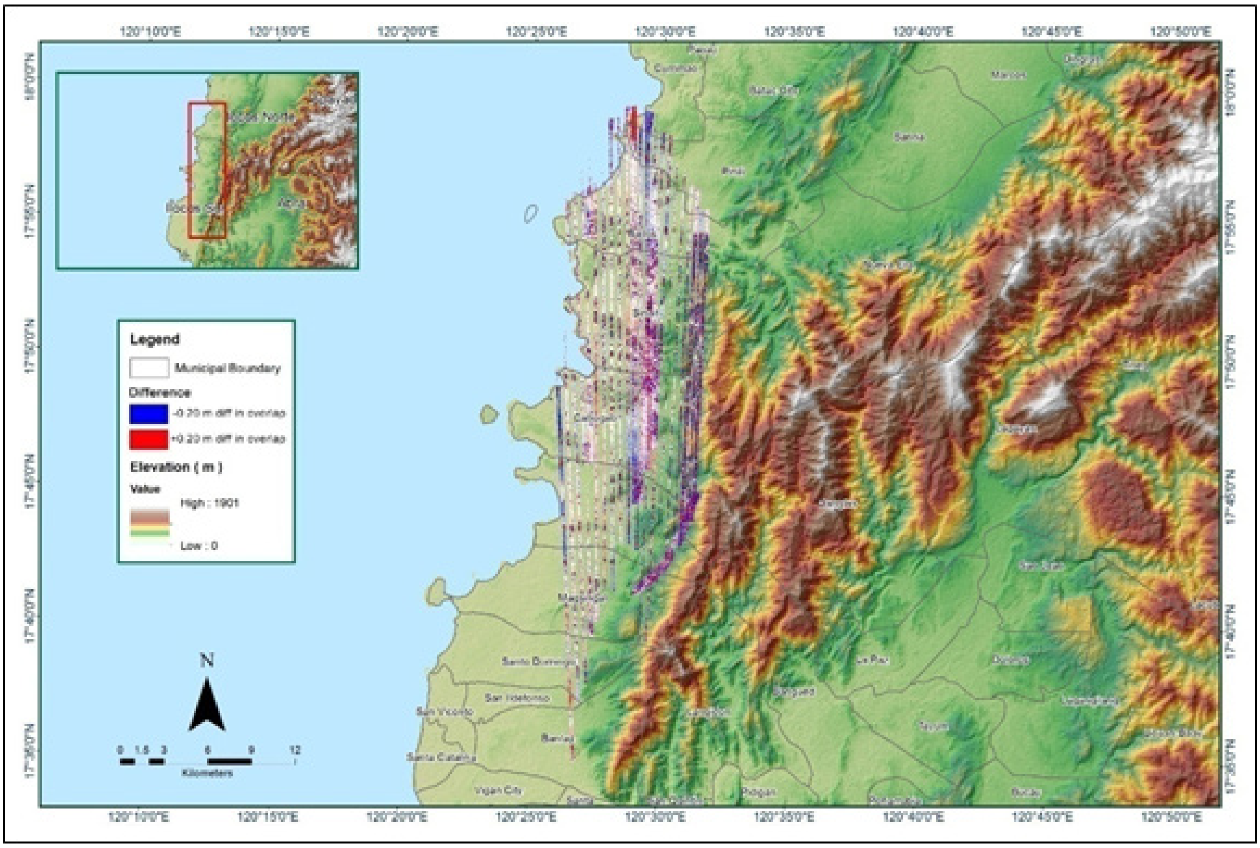


Figure A-8.7. Elevation difference between flight lines

ANNEX 9. Casiligan Model Basin Parameters

Table A-9.1. Casiligan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W1000	5.7659	54.296	0	7.7279	0.37742
W1010	4.491	58.27	0	15.522	0.83986
W1020	6.5083	63.068	0	8.8057	0.82658
W1040	2.5515	83.27	0	0.9169	1.4964
W1050	4.2114	53.204	0	5.122	0.087716
W520	7.1766	46.4	0	19.356	0.69432
W530	7.5598	37.936	0	2.6583	0.12323
W540	5.0653	37.177	0	1.8849	0.069751
W550	5.8734	74.903	0	1.9953	0.07384
W560	3.3924	78.919	0	3.6714	5.9917
W580	5.3872	49.773	0	21.162	1.7208
W590	13.712	35.996	0	10.55	0.6838
W630	6.7113	71.562	0	1.8568	0.10165
W640	5.5617	43.423	0	24.625	2.0018
W650	4.8958	51.158	0	10.98	0.39657
W660	9.3834	51.532	0	11.806	0.64289
W670	5.9889	54.195	0	12.743	0.45554
W680	8.8037	81.366	0	3.7561	0.33532
W690	2.067	60.834	0	3.0859	0.11709
W700	4.1714	53.328	0	21.323	1.1566
W710	4.6542	51.86	0	20.328	0.74046
W720	1.5733	62.825	0	2.7518	0.11268
W730	4.6573	59.26	0	0.32359	0.039273
W740	6.1491	53.483	0	8.3998	0.45769
W750	10.79	44.807	0	6.5256	0.34907
W760	7.894	41.482	0	7.1044	0.39607
W770	3.1306	60.71	0	10.733	0.38198
W780	2.9495	35.888	0	20.531	1.1136
W790	6.0353	35.415	0	11.663	0.64365
W800	13.475	52.92	0	2.7731	0.15177
W810	4.7431	53.414	0	7.7873	0.42254
W820	3.8671	54.293	0	9.5179	0.51878
W830	5.9889	54.234	0	4.6251	0.36986
W840	5.9889	35.419	0	5.222	0.97835
W850	6.1328	52.938	0	5.7722	0.50013
W860	4.7184	51.53	0	8.0385	0.29196
W870	4.7194	51.53	0	0.44175	0.036409

W880	4.7187	51.53	0	8.5481	0.31067
W890	0.73421	62.825	0	2.628	0.097192
W900	2.8205	57.916	0	11.453	2.0757
W910	2.9903	38.98	0	7.0086	1.2706
W920	3.2215	60.465	0	8.6809	0.70584
W930	1.7083	42.401	0	16.964	0.4144
W940	5.6218	77.597	0	10.952	0.89146
W950	2.3095	59.865	0	3.7508	0.061996
W960	2.4349	60.58	0	7.3555	0.2684
W970	0.99348	62.554	0	0.52604	0.028533
W980	1.6381	62.63	0	2.6091	0.2127
W990	7.2707	79.039	0	8.1609	0.44457

ANNEX 10. Casiligan Model Reach Parameters

Table A-10.1. Tineg Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing			
	Length (M)	Slope(M/M)	Shape	Side Slope (xH:1V)
R1060	1016.7	0.001074	Trapezoid	1
R110	3880.3	0.001074	Trapezoid	1
R120	2095	0.010999	Trapezoid	1
R140	902.67	0.010999	Trapezoid	1
R150	495.98	0.010999	Trapezoid	1
R180	573.55	0.010999	Trapezoid	1
R190	822.25	0.01057	Trapezoid	1
R200	2232.8	0.004224	Trapezoid	1
R230	5313.2	0.005154	Trapezoid	1
R240	740.12	0.040096	Trapezoid	1
R250	2478.1	0.00786	Trapezoid	1
R260	1886.5	0.009012	Trapezoid	1
R280	2952.2	0.008029	Trapezoid	1
R30	2501.4	0.01332	Trapezoid	1
R300	613.55	0.002773	Trapezoid	1
R310	2741.8	0.002773	Trapezoid	1
R360	1499.4	0.001272	Trapezoid	1
R390	1310.8	0.001272	Trapezoid	1
R420	956.27	0.000515	Trapezoid	1
R430	1722.1	5.15E-04	Trapezoid	1
R450	955.98	0.000515	Trapezoid	1
R460	521.13	0.005152	Trapezoid	1
R480	1501.5	0.012839	Trapezoid	1
R60	1270.5	0.001134	Trapezoid	1
R70	3035.8	0.000561	Trapezoid	1

ANNEX 11. Casiligan Field Validation Points

Table A-11.1. Casiligan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
1	13.10759	121.4135	0.43	1.35	0.92	Nona	Dec. 15, 2015	25-Year
2	13.10744	121.4133	0	1	1	Nona	Dec. 15, 2015	25-Year
3	13.10789	121.4132	1.24	0.93	-0.31	Nona	Dec. 15, 2015	25-Year
4	13.10783	121.414	1.39	0.84	-0.55	Nona	Dec. 15, 2015	25-Year
5	13.10752	121.4142	0.33	1.4	1.07	Nona	Dec. 15, 2015	25-Year
6	13.10806	121.4146	0.26	0.67	0.41	Nona	Dec. 15, 2015	25-Year
7	13.10898	121.4149	0.66	0.42	-0.24	Nona	Dec. 15, 2015	25-Year
8	13.10932	121.4154	0.7	0.55	-0.15	Nona	Dec. 15, 2015	25-Year
9	13.11065	121.4156	0.62	0.3	-0.32	Nona	Dec. 15, 2015	25-Year
10	13.11094	121.4163	0.12	0.24	0.12	Nona	Dec. 15, 2015	25-Year
11	13.11178	121.4197	0.39	0.68	0.29	Nona	Dec. 15, 2015	25-Year
12	13.11255	121.4203	0.46	0.57	0.11	Nona	Dec. 15, 2015	25-Year
13	13.11444	121.4238	2.29	0.82	-1.47	Nona	Dec. 15, 2015	25-Year
14	13.11428	121.4241	0	0.94	0.94	Nona	Dec. 15, 2015	25-Year
15	13.11425	121.424	0	0.77	0.77	Nona	Dec. 15, 2015	25-Year
16	13.11428	121.4243	2.7	0.37	-2.33	Nona	Dec. 15, 2015	25-Year
17	13.11431	121.427	1.06	0.76	-0.3	Nona	Dec. 15, 2015	25-Year
18	13.11351	121.4273	0.77	0.77	0	Yolanda/ Nona	Nov. 8, 2013; Dec. 15, 2016	25-Year
19	13.11061	121.428	0.5	0.45	-0.05	Nona	Dec. 15, 2015	25-Year
20	13.10986	121.4284	1.76	0.79	-0.97	Nona	Dec. 15, 2015	25-Year
21	13.10962	121.4295	2.36	1.3	-1.06	Nona	Dec. 15, 2015	25-Year
22	13.10917	121.4305	1.49	0.97	-0.52	Nona	Dec. 15, 2015	25-Year

23	13.11012	121.4332	1.74	1.7	-0.04	Nona	Dec. 15, 2015	25-Year
24	13.11304	121.4325	2.24	1.08	-1.16	Nona	Dec. 15, 2015	25-Year
25	13.11314	121.4314	1.46	0.82	-0.64	Nona	Dec. 15, 2015	25-Year
26	13.11281	121.4295	1.07	0.85	-0.22	Nona	Dec. 15, 2015	25-Year
27	13.12162	121.4155	0.03	0.12	0.09	Nona	Dec. 15, 2015	25-Year
28	13.12187	121.4158	0	0.8	0.8	Nona	Dec. 15, 2015	25-Year
29	13.11439	121.4245	0	0.3	0.3	Nona	Dec. 15, 2015	25-Year
30	13.11413	121.4244	0	0.84	0.84	Nona	Dec. 15, 2015	25-Year
31	13.11406	121.4247	0	0.42	0.42	Nona	Dec. 15, 2015	25-Year
32	13.11375	121.4246	0.84	0.57	-0.27	Nona	Dec. 15, 2015	25-Year
33	13.11339	121.425	3.97	0.4	-3.57	Nona	Dec. 15, 2015	25-Year
34	13.11296	121.4251	2.61	0.79	-1.82	Nona	Dec. 15, 2015	25-Year
35	13.11236	121.4254	1.17	0.82	-0.35	Nona	Dec. 15, 2015	25-Year
36	13.11181	121.4255	0	0.84	0.84	Nona	Dec. 15, 2015	25-Year
37	13.11116	121.426	1.76	1.33	-0.43	Nona	Dec. 15, 2015	25-Year
38	13.11092	121.426	0	0.48	0.48	Nona	Dec. 15, 2015	25-Year
39	13.11036	121.4264	2.47	0.78	-1.69	Nona	Dec. 15, 2015	25-Year
40	13.11039	121.4266	0	0.83	0.83	Nona	Dec. 15, 2015	25-Year
41	13.10984	121.4268	1.09	0.69	-0.4	Nona	Dec. 15, 2015	25-Year
42	13.10975	121.4267	0	1.03	1.03	Nona	Dec. 15, 2015	25-Year
43	13.10901	121.4272	1.66	1.04	-0.62	Nona	Dec. 15, 2015	25-Year
44	13.10767	121.4274	2.3	0.86	-1.44	Nona	Dec. 15, 2015	25-Year
45	13.10653	121.4272	2.74	1.3	-1.44	Nona	Dec. 15, 2015	25-Year
46	13.10481	121.4265	1.85	1.06	-0.79	Nona	Dec. 15, 2015	25-Year
47	13.10459	121.4266	0	0.87	0.87	Nona	Dec. 15, 2015	25-Year

48	13.12116	121.4156	0	1.5	1.5	Nona	Dec. 15, 2015	25-Year
49	13.12137	121.4159	0	0.98	0.98	Nona	Dec. 15, 2015	25-Year
50	13.12194	121.4164	0.03	1.5	1.47	Nona	Dec. 15, 2015	25-Year
51	13.14218	121.441	2.42	0	-2.42			25-Year
52	13.14259	121.441	0	0.4	0.4	Nona	December 2015	25-Year
53	13.14301	121.4409	0.03	0	-0.03			25-Year
54	13.14281	121.441	0.49	0	-0.49			25-Year
55	13.14291	121.4415	0	0	0			25-Year
56	13.14348	121.4416	0.26	0	-0.26			25-Year
57	13.14361	121.442	2.42	0	-2.42			25-Year
58	13.14016	121.4402	2.43	0.28	-2.15		June 24, 2013	25-Year
59	13.14035	121.4397	0.79	0.1	-0.69	Nona	December 2015	25-Year
60	13.14094	121.4391	0.03	0	-0.03			25-Year
61	13.14076	121.4387	0	0	0			25-Year
62	13.14027	121.4382	0.24	0.4	0.16	Nona	December 2015	25-Year
63	13.13886	121.4383	0.03	0.35	0.32	Nona	December 2015	25-Year
64	13.13882	121.4389	1.12	0.05	-1.07	Nona	December 2015	25-Year
65	13.13928	121.4394	1.04	0.11	-0.93	Nona	December 2015	25-Year
66	13.13905	121.4399	0.98	0	-0.98			25-Year
67	13.13834	121.4399	2.29	0.33	-1.96	Nona	December 2015	25-Year
68	13.13805	121.4404	1.24	0	-1.24			25-Year
69	13.13725	121.4405	0	0	0			25-Year
70	13.13724	121.4409	0	0	0			25-Year
71	13.10125	121.4255	0.95	0.66	-0.29	Nona	December 2015	25-Year
72	13.10205	121.4259	1.22	0.8	-0.42	Nona	December 2015	25-Year
73	13.10261	121.4258	1.17	0.84	-0.33	Nona	December 2015	25-Year
74	13.10371	121.4264	1.12	1.52	0.4	Nona	December 2015	25-Year
75	13.10443	121.4261	0.98	1.62	0.64	Nona	December 2015	25-Year
76	13.10451	121.4257	1.76	1.63	-0.13	Nona	December 2015	25-Year
77	13.0977	121.4309	0.26	0.66	0.4	Nona	December 2015	25-Year
78	13.09741	121.4297	0.09	0.35	0.26	Nona	December 2015	25-Year

79	13.09771	121.4301	0.32	1.13	0.81	Nona	December 2015	25-Year
80	13.09759	121.4287	0.54	0.62	0.08	Nona	December 2015	25-Year
81	13.09729	121.4275	0.19	0.6	0.41	Nona	December 2015	25-Year
82	13.09708	121.4267	0.27	0.75	0.48	Nona	December 2015	25-Year
83	13.09724	121.4255	0.31	0.42	0.11	Nona	December 2015	25-Year
84	13.09713	121.4243	0.35	0.73	0.38	Nona	December 2015	25-Year
85	13.10348	121.4045	1.15	1.21	0.06	Nona	December 2015	25-Year
86	13.10337	121.4047	0	0.87	0.87	Nona	December 2015	25-Year
87	13.1424	121.4408	0.03	0.1	0.07	Habagat		25-Year
88	13.14235	121.4408	0	0	0	Nona	Dec. 15, 2015	25-Year
89	13.1424	121.4409	0	0		Yolanda/ Nona	Nov. 8, 2013; Dec. 15, 2016	25-Year
90	13.14275	121.4407	0	0		Yolanda/ Nona	Nov. 8, 2013; Dec. 15, 2017	25-Year
91	13.1432	121.4405	0	0		Nona	Dec. 15, 2015	25-Year
92	13.14328	121.4406	0	0.1		Nona	Dec. 15, 2015	25-Year
93	13.14277	121.4414	0	0		Nona	Dec. 15, 2015	25-Year
94	13.14024	121.4391	1.14	0.7		Nona	Dec. 15, 2015	25-Year
95	13.13984	121.4394	2.27	0.74		Nona	Dec. 15, 2015	25-Year
96	13.13918	121.4397	0	0.29			2014	25-Year
97	13.1037	121.4045	0.16	0.6		Nona	Dec. 15, 2015	25-Year
98	13.1035	121.4045	0	0.66		Nona	Dec. 15, 2015	25-Year
99	13.1082	121.3963	0.49	0.2		Nona	Dec. 15, 2015	25-Year

ANNEX 12. Educational Institutions affected by flooding Tineg Flood Plain

Table A-12.1. Educational Institutions in Abra affected by flooding in Tineg Flood Plain

Abra				
Bangued				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BACSIL ES	Angad			
DANGDANGLA ES	Dangdangla			
ABRA VALLEY COLLEGES	Lingtan			
DATA CENTER COLLEGE	Lipcan			
DIVINE WORD COLLEGE OF BANGUED	Lipcan	Medium	Medium	Medium
MACARCARMAY ES	Macarcarmay			
COSILI WEST PS	Macray			
CALOT ES	Maoay			
SINALANG PILOT ELEMENTARY SCHOOL	Palao			
PATUCANNAY DAY CARE CENTER	Patucannay			High
PATUCANNAY ES	Patucannay		Low	High
STA. ROSA PS	Santa Rosa			Low
ABRA HIGH SCHOOL	Zone 2 Poblacion	Low	Low	Low
ABRA HS	Zone 2 Poblacion			
ABRA STATE INSTITUTE OF SCIENCE AND TECHNOLOGY	Zone 2 Poblacion	Medium	Medium	Medium
BANGUED WEST CENTRAL SCHOOL	Zone 2 Poblacion			
BANGBANGAR ES	Zone 3 Poblacion			
ABRA HIGH SCHOOL	Zone 4 Poblacion			
ABRA HIGH SCHOOL	Zone 4 Poblacion			
ABRA HIGH SCHOOL	Zone 4 Poblacion		Low	Low
BANGUED NORTH ES	Zone 4 Poblacion			
BANGUED WEST CENTRAL SCHOOL	Zone 4 Poblacion			
ABRA VALLEY COLLEGES	Zone 5 Poblacion			
HOLY SPIRIT ACADEMY OF BANGUED	Zone 5 Poblacion			
Bucay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BANGBANGCAG PRIMARY SCHOOL	Bangbangcag		Medium	High
PANGTOD NHS	Bangbangcag			

BANGCAGAN PS	Bangcagan			
BANGCAGAN PRIMARY SCHOOL	Bugbog			
PAGALA WEST ELEMENTARY SCHOOL	Bugbog			
BUCAY CS	North Poblacion			
CRISTINA B. GONZALES MHS	North Poblacion	Low	Medium	Medium
OUR LADY OF FATIMA SCHOOL	North Poblacion			
PAGALA EAST PRIMARY SCHOOL	Pagala	Low	High	High
PANGTOD NHS	Palaquio			
BUCAY NORTH ELEMENTARY SCHOOL	San Miguel	Low	High	High
LUBLUBNAC PRIMARY SCHOOL	Tabiog			
TABIOG ES	Tabiog			
Danglas				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
WESTERN ABRA NHS	Padangitan			
Dolores				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
MUDIIT ELEMENTARY SCHOOL	Mudiit			
MUDIIT ES	Mudiit			
DOLORES CS	Poblacion			
DON ROSALIO EDUARTE ES	Talogtog			
La Paz				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
CANAN ES	Canan			
Lagangilang				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
METODIO ES	Laguiben			
PRESENTAR ES	Presentar			
TAGODTOD ES	Tagodtod			
TAGODTOD NHS	Tagodtod			
TAPING PS	Taping			

Lagayan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
LAGAYAN CS	Poblacion			
PULOT NHS	Pulot			
Langiden				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
LANGIDEN NHS	Poblacion			
Peñarrubia				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
PEÑARRUBIA CS	Dumayco			
PEÑARRUBIA CS	Poblacion			
SAN QUINTIN NHS	Tattawa			
Pidigan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
CASILAGAN PS	Alinaya	High	High	High
GARRETA ES	Garreta	Low	Medium	High
BANAY PS	Monggoc	High	High	High
PANGTUD PS	Pangtud		High	High
PIDIGAN CS	Poblacion West		High	High
POBLACION WEST PS	Poblacion West		High	High
SUYO NATIONAL HIGH SCHOOL	Suyo			
SUYO PILOT ES	Suyo	High	High	High
San Juan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
NORTHERN ABRA NHS	Lam-Ag		Low	High
NANGOBONGAN PS	Nangobongan			
QUIDAOEN NHS	Quidaoen			

San Quintin				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
PALANG PS	Palang	Low	High	High
PANTOC ES	Pantoc			
SAN QUINTIN CS	Poblacion	High	High	High
SAN QUINTIN NHS	Poblacion		High	High
VILLA MERCEDES ES	Villa Mercedes			
Tayum				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BAGALAY ES	Bagalay			
BASBASA ES	Basbasa			
BUMAGCAT ES	Bumagcat			
DON MARCOS ROSALES ES	Cabaroan		High	High
GADDANI NATIONAL HIGH SCHOOL(G.N.H.S.)	Gaddani	Medium	Medium	Medium
DON MARCOS ROSALES ES	Patucannay		Medium	High
HOLY SPIRIT CONVENT	Poblacion			High
TAYUM CS	Poblacion			

Table A-12.2. Educational Institutions affected by flooding in the Tineg Floodplain

Ilocos Sur				
Bantay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BANAOANG ELEMENTARY SCHOOL	Banaoang			
BANTAY EAST CS	Barangay 5		Medium	Medium
ILOCOS SUR COMMUNITY COLLEGE	Barangay 6	High	High	High
BANTAY NHS	Cabalanggan	Low	High	High
BULAG ES	Cabalanggan	Low	High	High
ORA EAST ES	Ora			
ORA WEST ES	Ora			
PAING ES	Paing		Low	High
SILANG ES	Puspus		Medium	High
SAN JULIAN ES	San Julian	High	High	High
SALLACONG ELEMENTARY SCHOOL	San Mariano			

Caoayan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
ANONANG NAGUILIAN COMM. SCHOOL	Anonang Mayor	High	High	High
BAGGOC P. QUITIQUIT ES	Baggoc	High	High	High
BAGGOC P. QUITIQUIT ES	Callaguip	High	High	High
FUERTE ES	Manangat			
PANDAN ES	Manangat	High	High	High
NANSUAGAO PS	Nansuagao	Medium	High	High
PURO NHS CAOAYAN	Nansuagao	High	High	High
PANTAY QUITIQUIT PS	Pantay-Quitiquit	High	High	High
NAGPANAOAN ES	PantayTamurong	High	High	High
PANTAY TAMURONG ES	PantayTamurong	High	High	High
PANTAY TAMURONG NHS	PantayTamurong	Medium	High	High
VILLAMAR ES	Villamar	High	High	High
Santa				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BANAOANG COMM. SCH.	Dammay			Low
BASUG COMM. SCH.	Dammay			
BASUG NHS	Dammay			
MABILBILA IS	Dammay			
SACUYYA COMM. SCH.	Dammay			
MABILBILA IS	Labut Norte			
Vigan City				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BURGOS EAST MES	Ayusan Norte			
CORINTHIAN MONTESSORI	Ayusan Norte			
DIVINE WORLD COLLEGE OF VIGAN	Ayusan Norte		High	High
NATURALES TRAINING INSTITUTE	Ayusan Norte		Medium	High
PATER NOSTER LEARNING CENTER	Ayusan Norte	Low	Low	Low
TESDA	Ayusan Norte		Medium	High
VIGAN CS	Ayusan Norte	Low	Medium	High
CAPANGPANGAN ES	Barangay I	High	High	High

DIVINE WORLD COLLEGE OF VIGAN	Barangay I		High	High
PATER NOSTER LEARNING CENTER	Barangay III		Low	Low
SALINDEG ES	Barraca	Medium	High	High
SALINDEG ES (SPBES)	Barraca	Medium	High	High
CAMANGGAAN ES	Beddeng Laud	Medium	High	High
CABAROAN ES	Cabalangegan	Medium	High	High
SAN JULIAN ES	Capangpangan	Medium	High	High
NAGSANGALAN ES	Nagsangalan	Medium	High	High
VIGAN EAST NHS	Nagsangalan	Medium	High	High
UNIVERSITY OF NORTHERN PHILIPPINES	Paoa	Low	Low	Low
RUGSUNGAN-PUROC ES	Purok-A-Bassit	Medium	High	High
RAOIS ES	Raois	Medium	High	High
CAL-LAQUIP ES	Salindeg	Medium	High	High
CAOAYAN CS	Salindeg	Medium	High	High
CAOAYAN CS	Tamag	Medium	High	High
TAMAG ES	Tamag			

ANNEX 13. Medical Institutions affected by flooding in Tineg Flood Plain

Table A-13.1. Medical Institutions in Abra affected by flooding in Tineg Flood Plain

Abra				
Bangued				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DICKSON POLYCLINIC	Dangdangla			
PALOS CLINIC	Dangdangla			
ABRA PROVINCIAL HOSPITAL	Zone 1 Poblacion			
BARBADILLO CLINIC	Zone 4 Poblacion			
ABRA MEDICAL CENTER	Zone 5 Poblacion			Low
CASIA CLINIC	Zone 5 Poblacion			
DR. PETRONLO SEARES SR.	Zone 5 Poblacion			
HEALTH CHECK	Zone 5 Poblacion	Medium	Medium	High
MARIBEL MEDICAL CLINIC	Zone 5 Poblacion			
BANEZ CLINIC	Zone 5 Poblacion		Low	Low
DICKSON POLYCLINIC	Zone 7 Poblacion			
MAGALA BAUTISTA CLINIC	Zone 7 Poblacion			
MARIBEL MEDICAL CLINIC	Zone 7 Poblacion			Low
ASSUMPTA CLINIC	Zone 7 Poblacion			
BANGUED CHRISTIAN HOSPITAL	Zone 7 Poblacion			
Bucay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BUCAY HOSPITAL	North Poblacion			

Table A-13.2. Medical Institutions in Abra affected by flooding in Tineg Flood Plain

Ilocos Sur				
Bantay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
PATAO CLINIC	Aggay		Medium	High
NORTHEAST CARE CENTER	Sinabaan	High	High	High

Vigan City				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
DENTIST JOEY DE VERZOSA	Ayusan Norte			
LAHOZ CLINIC AND HOSPITAL	Ayusan Norte		Low	Medium
MERCURY DRUG	Ayusan Norte	Low	Medium	Medium
RABARA CLINIC AND HOSPITAL	Ayusan Norte			
RABE DENTAL CLINIC	Ayusan Norte			Low
REODIQUE OPTICAL - DENTAL CLINIC	Ayusan Norte	Low	Low	Low
S. M. AMORES VETERINARY CLINIC	Ayusan Norte			
YADAO OPTICAL CLINIC	Ayusan Norte			
VIGAN POLYCLINIC	Barangay VII			Medium
GABRIELA SILANG GENERAL HOSPITAL	Tamag			
PHARMACY	Tamag			
SABI NI DOC PHARMACY	Tamag			

Annex 14. Phil-LiDAR 1 UPLB Team Composition

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