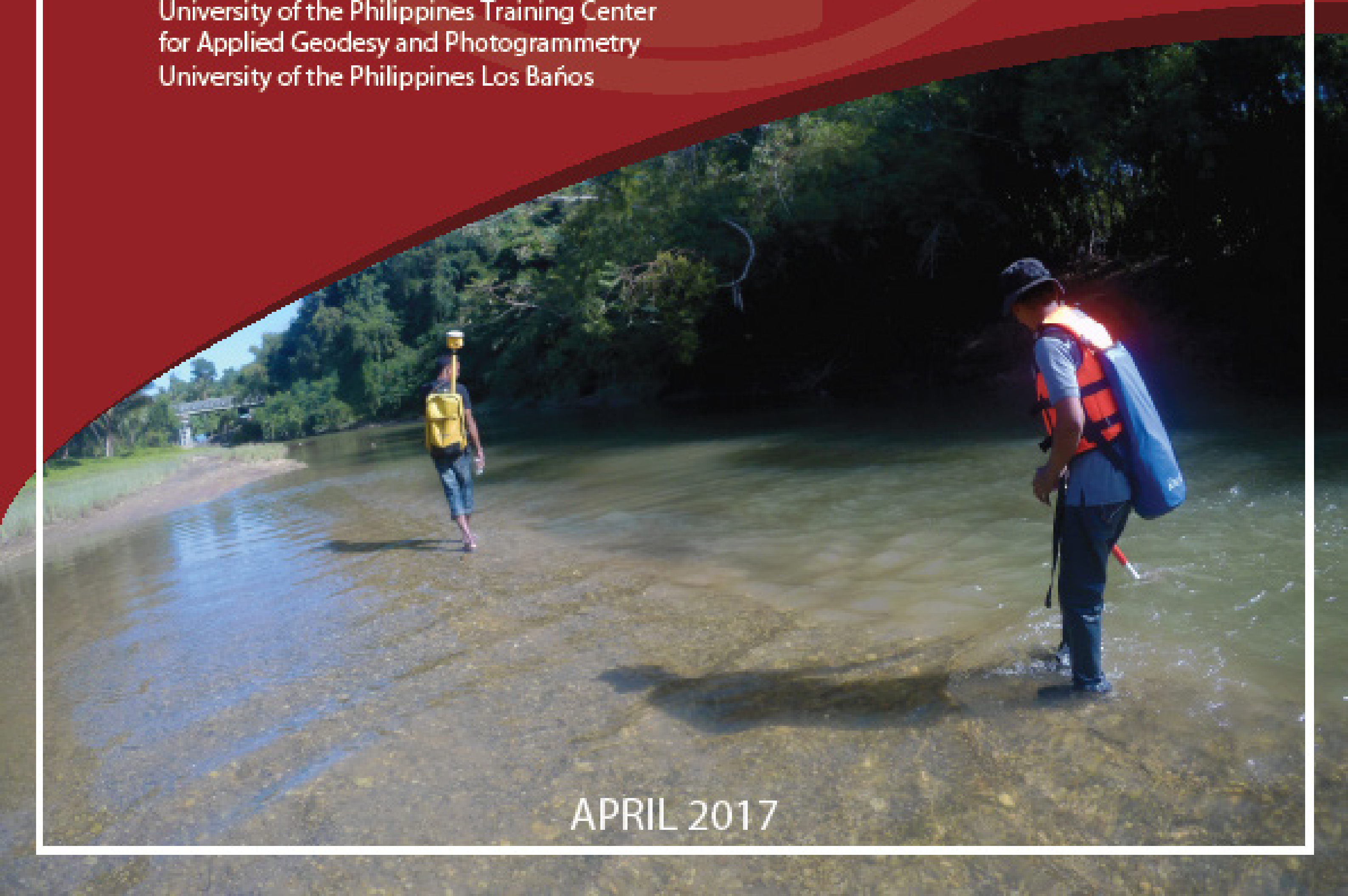
Hazard Mapping of the Philippines Using LIDAR (Phil-LI   AR 1D)

LiDAR Surveys and Flood Mapping of Caramay 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
UPLB	University of the Philippines Los Baños
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CARAMAY RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and Ms. Sandra S. Samantela

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 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 Southern Luzon region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Caramay River Basin

Caramay River Basin, a 15,633-ha watershed, covers the Municipality of Roxas, and a small portion of San Vicente in the province of Palawan. It encompasses barangay Caramay, Jolo, Nicanor Zabala, and Tinitian in the municipality of Roxas; and Caruray in San Vicente. The DENR River Basin Control Office identified the basin to have a drainage area of 69 km^2 and an estimated 110 million cubic meter (MCM) annual run-off (RBCO, 2015).

In terms of geology, the basin area is classified as having Basement Complex (Pre-Jurassic) and Recent. Generally, the slope in the area can be classified as undulating to very steep with elevation ranging from 50 to more than 300 meters above sea level (masl). The soil in the large extent of rough mountainous land is still unclassified. However, other area has San Manuel clay loam and Coron clay loam. Dense vegetation of closed forest (broadleaved) dominates the basin area along with other wooded land (wooded grassland) and built-up area.

Its main stem, Caramay River, is part of the 45 river systems in MIMAROPA. The Caramay river passes through Caramay, Jolo, Nicanor Zabala, Tinitian. According to the 2015 national census of NSO, a total of tributed in Brgy. Caramay, in the Municipality of Roxas (NSO, 2015).

Fishing is the primary source of livelihood in the Municipality of Roxas since most of the barangays are in coastal areas. Moreover, Brgy. Caramay has been identified as a Marine Protected Area (MPA) focal site by the Palawan Council for Sustainable Development Staff. The MPAs serve as habitats to many aquatic species such as the endangered dugong, green groupers, lobsters, and many more. The campaign aims to educate fishermen with the right fishing methods, and to increase the number of fish in MPAs (PCSD, 2015).

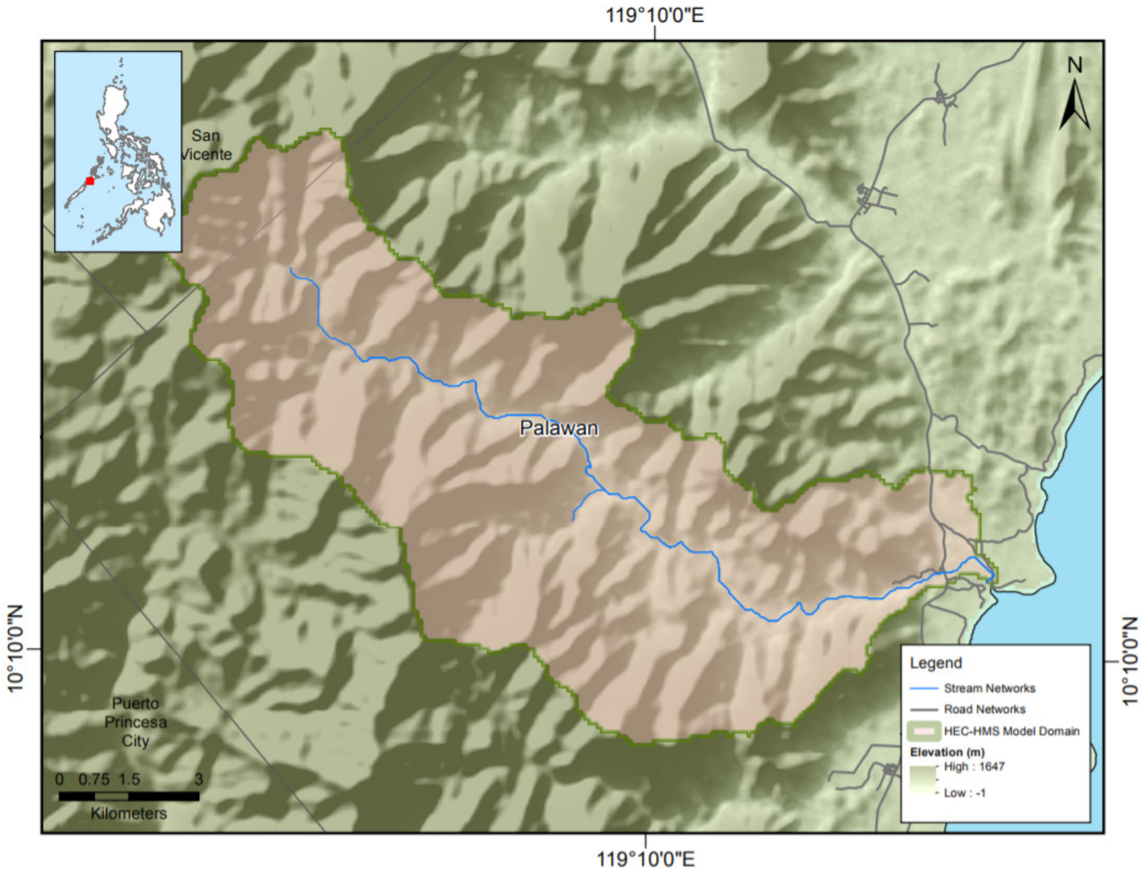

Figure 1. Map of Caramay River Basin (in brown)

In the Caramay River Basin area, Climate Type I and III prevails, similar to its larger environment 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.

During the wet or typhoon season, some communities are affected by flooding in the Caramay River Basin area. The study conducted by the Mines and Geosciences Bureau showed that generally the barangays in the basin area has no susceptibility to flooding except for those small areas near Caramay river that has moderate to high susceptibility. Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, there were two notable weather disturbances that caused flooding in 2005 (Quedan) and 2013 (Yolanda). Last November 2013, before exiting the country, super typhoon Yolanda, internationally known as *Haiyan*, made landfall on the region of Palawan. The Provincial Disaster Risk Reduction of Palawan released a report stating that fourteen (14) municipalities were placed under state of calamity, one of them was the Municipality of Roxas. At least 20,000 families from the municipalities placed under state of calamity were affected by the storm (Rappler.com, 2013). For landslides, all barangays located in the basin particularly the upper sloping areas have moderate to high susceptibility.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CARAMAY 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 Caramay Floodplain in Palawan. These missions were planned for 33 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plans and base stations for Caramay Floodplain.

Table 1. Parameters used in the Gemini LiDAR System during Flight Acquisition.

Block Name	Flying Height (m AGL)	Overlap (%)	Max. Field of View (θ)	Pulse Rate Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK40A	1200	30	30	125	50	130	5
BLK42A	1200	30	30	125	50	130	5
BLK42eA	1200	30	30	125	50	130	5
BLK42eB	1200	30	30	125	50	130	5

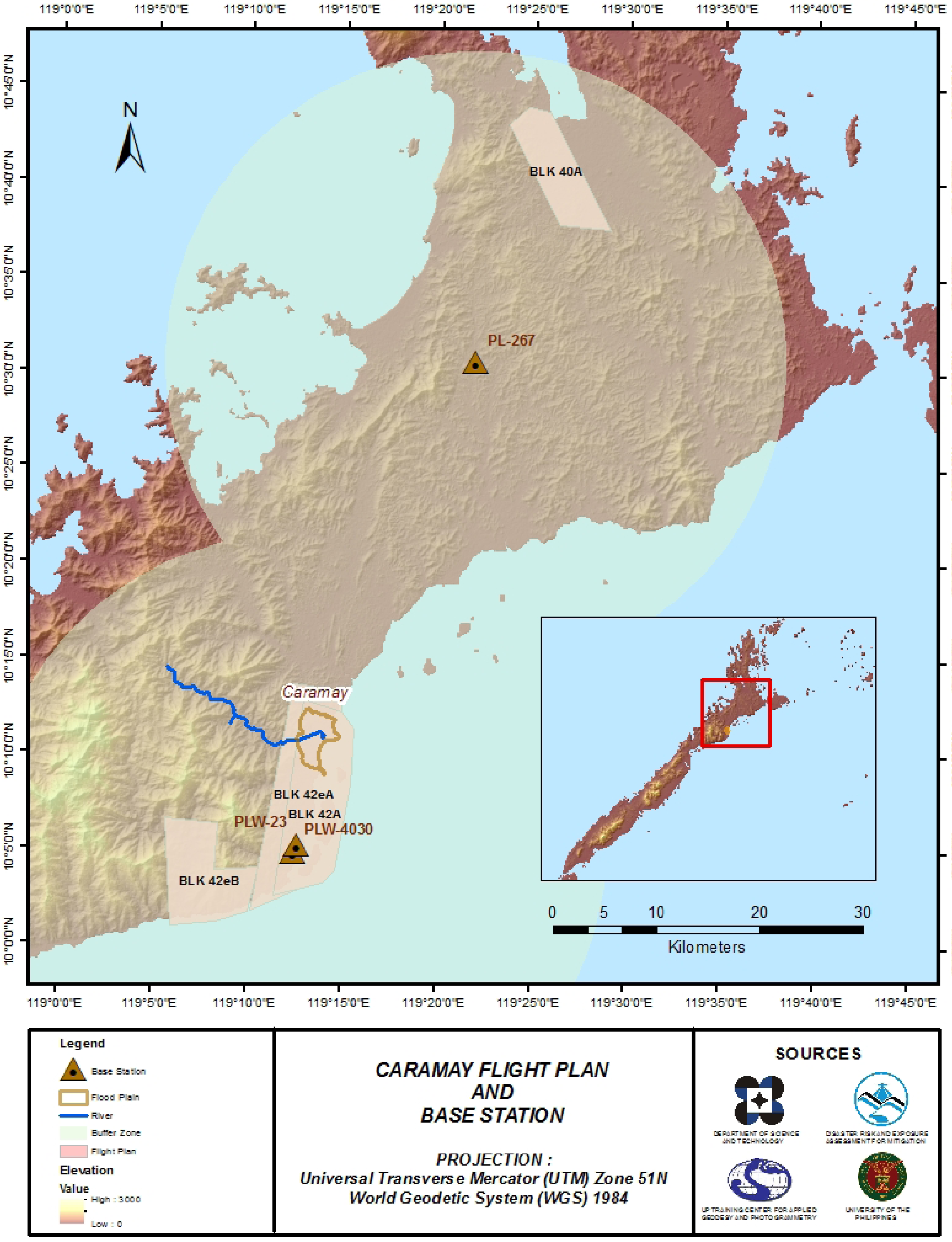


Figure 2. Flight plans and base stations used for Caramay Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: PLW-23 which is of first (1st) order accuracy, and PLW-4030 which is of fourth (4th) order accuracy. One (1) NAMRIA benchmark was recovered: PL-267. This benchmark was used as vertical reference point and was also established as ground control point. The certifications for the NAMRIA reference points are found in Annex 2, while the processing report NAMRIA benchmark is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (November 18-28, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS R8. Flight plans and location of base stations used during the aerial LiDAR acquisition in Caramay floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area, in addition Table 2 to Table 4 show the details about the following NAMRIA control stations and established points, Table 5 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

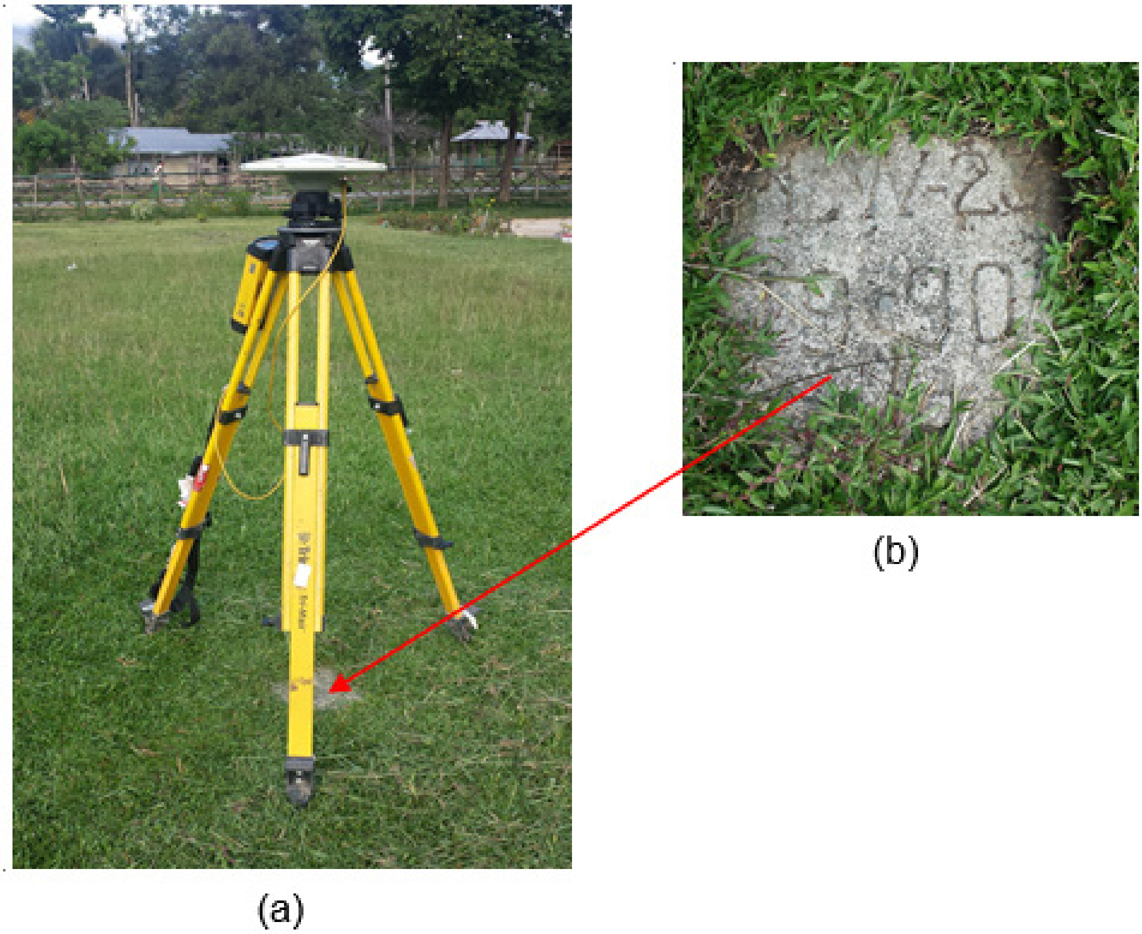


Figure 3. GPS set-up over PLW-23 as recovered at Jolo Elementary School, Puerto Princesa City (a) and NAMRIA reference point PLW-23 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point PLW-23 used as base station for the LiDAR Acquisition.

Station Name	PLW-23	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10°5’19.52517” North
	Longitude	119°12’33.72062” East
	Ellipsoidal Height	10.427 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting	577752.254 meters
	Northing	1115630.596 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	10° 5’15.04804” North
	Longitude	119° 12’ 39.01413” East
	Ellipsoidal Height	61.07260 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 51N PRS 92)	Easting	742130.31 meters
	Northing	1115973.89 meters

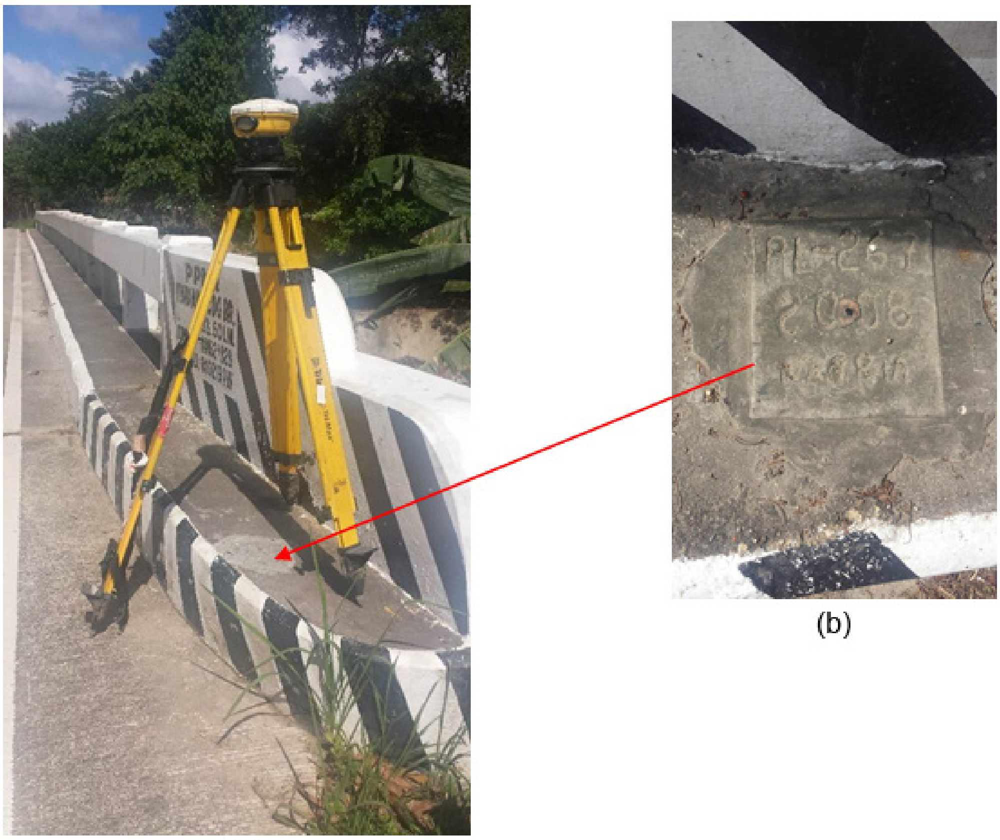
(b)

(a)

Figure 4. GPS set-up over PLW-4030 as recovered on the ground beside Jolo Bridge, Roxas, Palawan (a) and NAMRIA reference point PLW-4030 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point PLW-4030 used as base station for the LiDAR Acquisition.

Station Name	PLW-4030	
Order of Accuracy	**4th**	
Relative Error (horizontal positioning)	**1:10,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 4' 56.95146" North
	Longitude	119° 12' 22.75168" East
	Ellipsoidal Height	11.183 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting	84042.662 meters
	Northing	1116875.986 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	10° 4' 52.47562" North
	Longitude	119° 12' 28.04576" East
	Ellipsoidal Height	61.835 meters



(b)

(a)

Figure 5. GPS set-up over PL-267 as recovered on the ground beside Itabiak Bridge, Roxas, Palawan (a) and NAMRIA reference point PL-267 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA vertical control point PL-267 used as base station for the LiDAR Acquisition.

Station Name	PL-267	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 30' 40.21529" North
	Longitude	119° 21' 48.02348" East
	Ellipsoidal Height	34.545 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	101820.908 meters
	Longitude	1164164.984 meters
	Ellipsoidal Height	10° 30' 35.64621" North
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting	119° 21' 53.27911" East
	Northing	84.611 meters

Table 5. Ground Control Points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
18-Nov-15	3505G	2BLK42AES322A	PLW-23, PLW-4030
18-Nov-15	3507G	2BLK42ISLAS322B	PLW-23, PLW-4030
20-Nov-15	3513G	2BLK42islAs324A	PLW-23, PLW-4030
21-Nov-15	3517G	2BLK42B325A	PLW-23, PLW-4030
28-Nov-15	3545G	2BLK42B332A	PL-267, PLW-23, PLW-4030

2.3 Flight Missions

Five (5) missions were conducted to complete the LiDAR Data Acquisition in Caramay Floodplain, for a total of sixteen hours and forty-three minutes (16+43) of flying time for RP-C9022. All missions were acquired using the Gemini LiDAR system. Table 6 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for LiDAR data acquisition in Caramay Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
18-Nov-15	3505G	214.12	99.41	8.59	90.82	NA	3	35
18-Nov-15	3507G	117.39	169.79	13.65	156.14	NA	3	0
20-Nov-15	3513G	117.39	210.88	13.66	197.22	240	4	10
21-Nov-15	3517G	62.78	21.82	0.46	21.36	65	2	18
28-Nov-15	3545G	114.31	95.67	0.54	95.13	NA	3	40
TOTAL		625.99	597.57	36.9	560.67	305	16	43

Table 7. 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)
3505G	1000, 600	30	26, 40	100, 125	50, 40	120	5
3507G	600, 1100	30	50, 24	125, 100	40, 50	120	5
3513G	1100, 1200	30	24	100	50	120	5
3517G	1100, 900	30	24, 30	100	50	120	5
3545G	1100, 850	30	24, 40	100, 125	50	120	5

2.4. Survey Coverage

Caramay floodplain is located in the province of Palawan with majority of the floodplain situated within the municipality of Roxas. Municipality of Roxas is mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 8. The actual coverage of the LiDAR acquisition for Caramay floodplain is presented in Figure 6.

Table 8. List of municipalities and cities surveyed during Caramay Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Palawan	Puerto Princesa City	2186.36	28.94	1.32%
	Roxas	1007.73	109.3	10.85%
	San Vicente	870.45	2.89	0.33%
	Taytay	1325	38.52	2.91%
Total		5389.54	179.65	3.85%

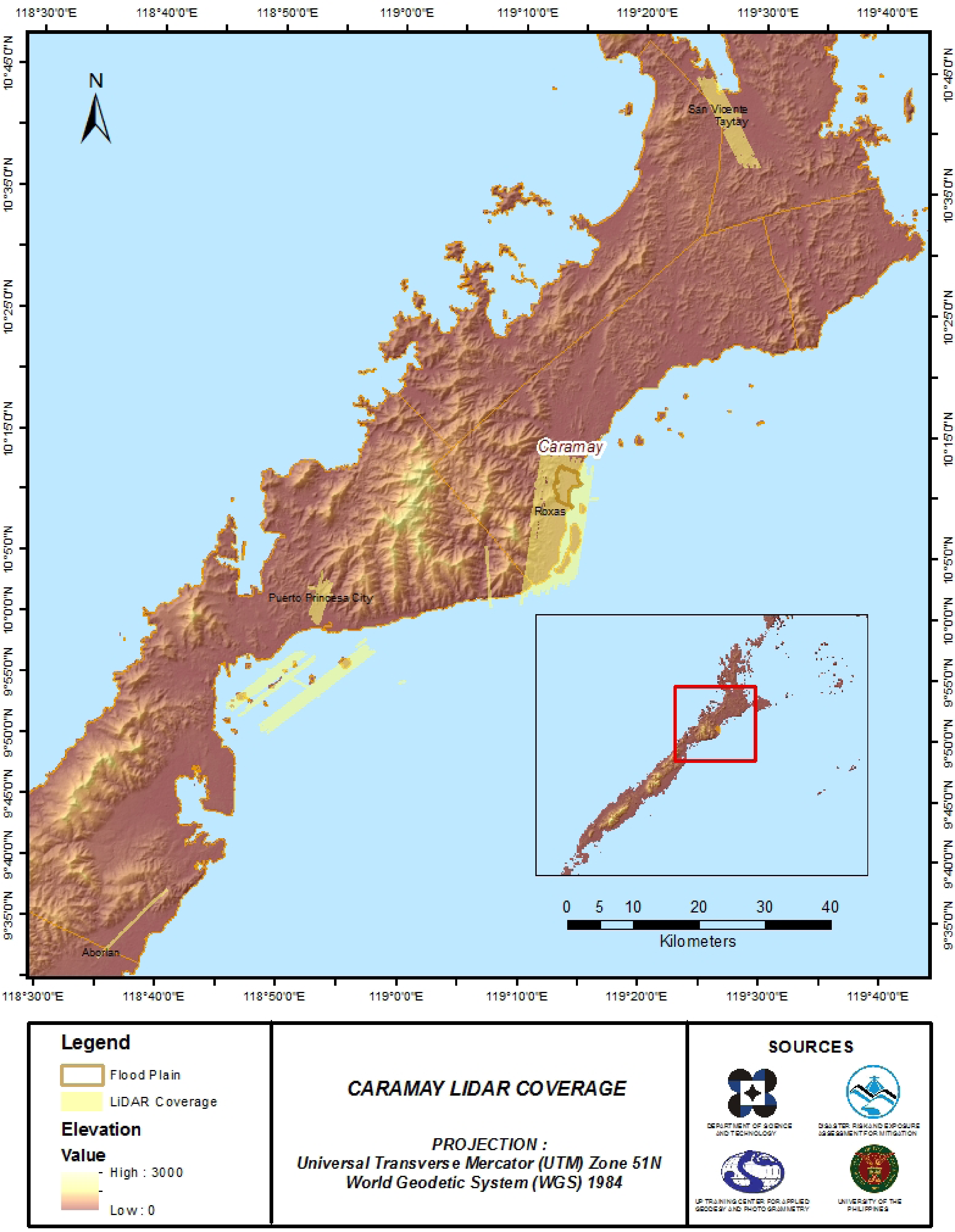


Figure 6. Actual LiDAR survey coverage for Caramay Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE CARAMAY 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.

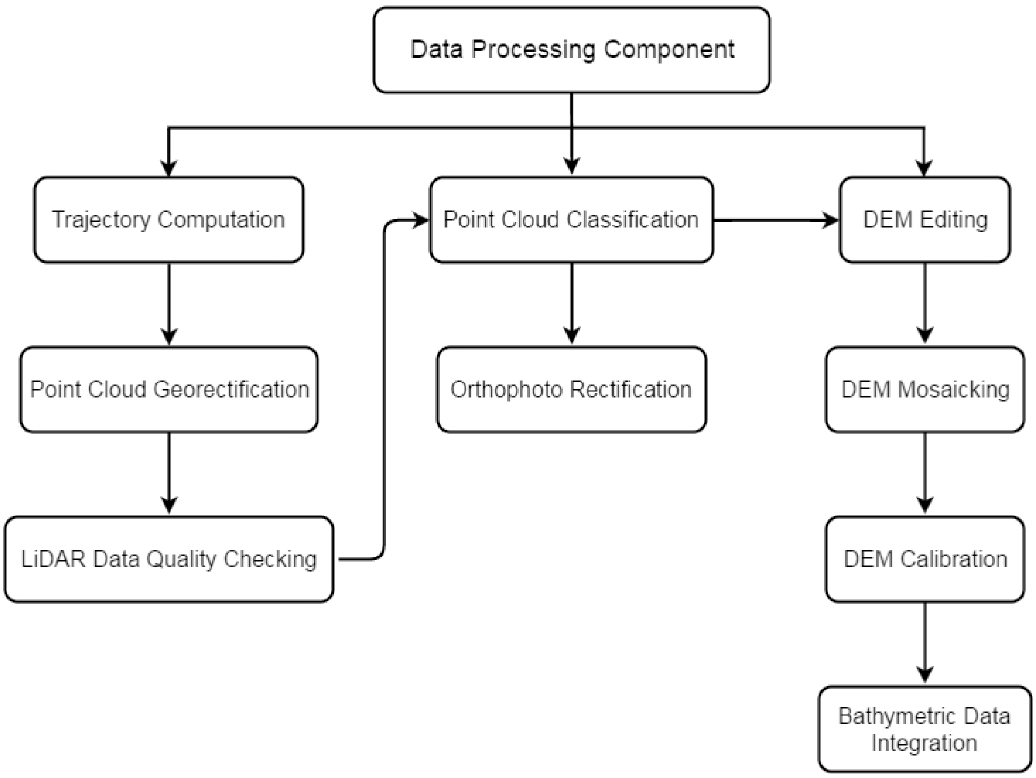

Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Caramay floodplain can be found in Annex 5. Missions flown during the survey conducted on November 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Roxas, Palawan.

The Data Acquisition Component (DAC) transferred a total of 57.17 Gigabytes of Range data, 1.46 Gigabytes of POS data, 34.39 Megabytes of GPS base station data, and 0 Gigabytes of raw image data to the data server on December 8, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Caramay was fully transferred on December 8, 2015, as indicated on the Data Transfer Sheets for Caramay floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3507G, one of the Caramay 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 November 15, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

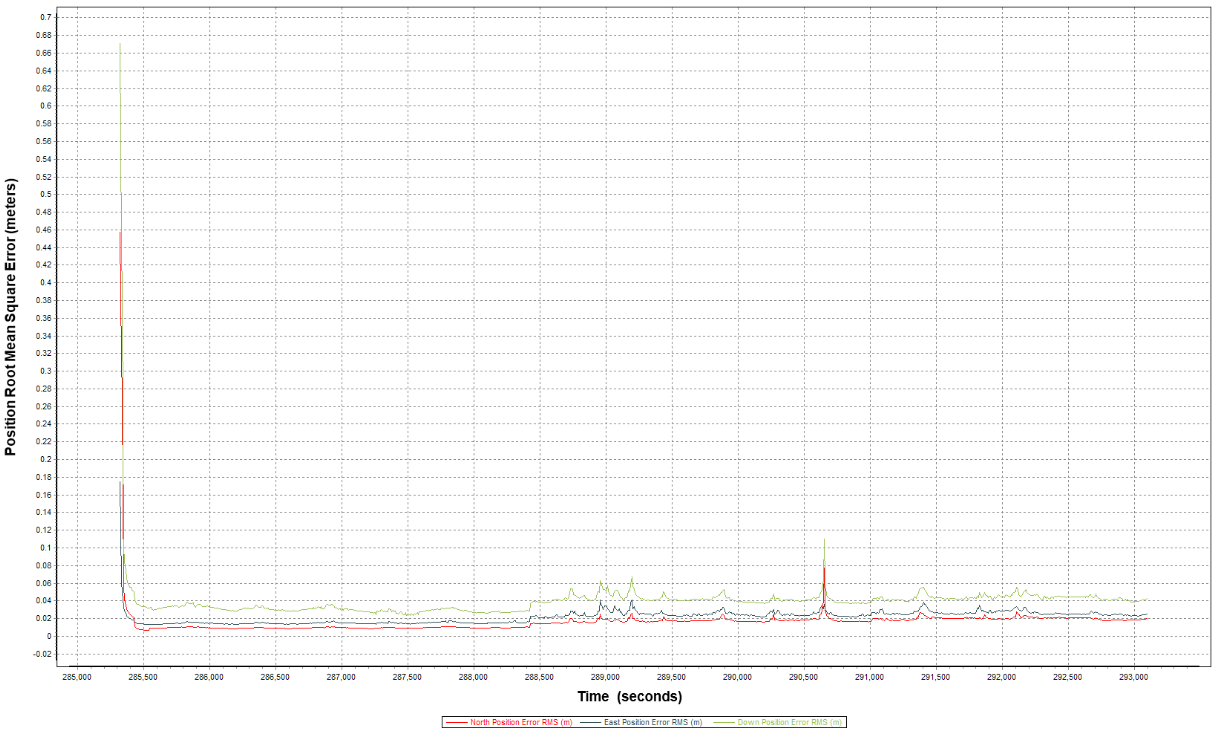

Figure 8. Smoothed Performance Metrics of Caramay Flight 3507G.

The time of flight was from 285000 seconds to 293000 seconds, which corresponds to morning of November 18, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the 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 0.80 centimeters, the East position RMSE peaks at 0.40 centimeters, and the Down position RMSE peaks at 1.20 centimeters, which are within the prescribed accuracies described in the methodology.

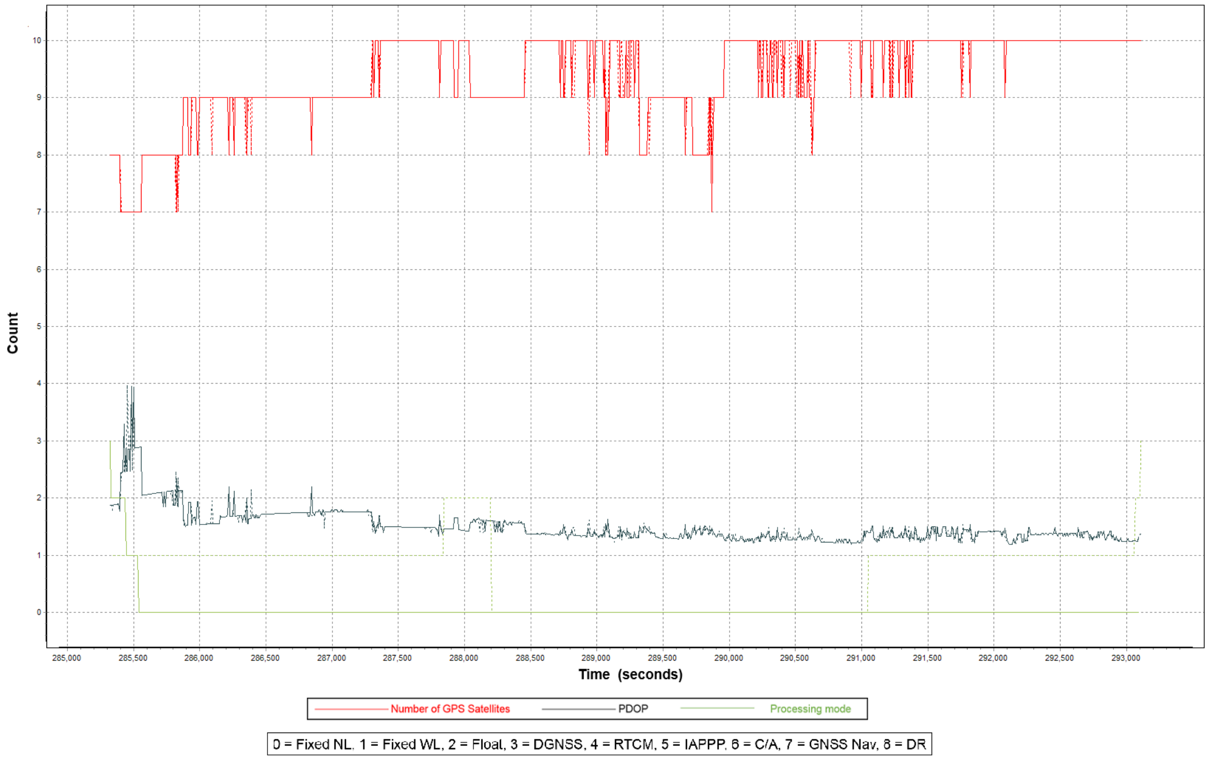

Figure 9. Solution Status Parameters of Caramay Flight 3507G.

The Solution Status parameters of flight 3507G, one of the Caramay flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 10. The PDOP value also did not go above the value of 4, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 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 Caramay flights is shown in Figure 10.

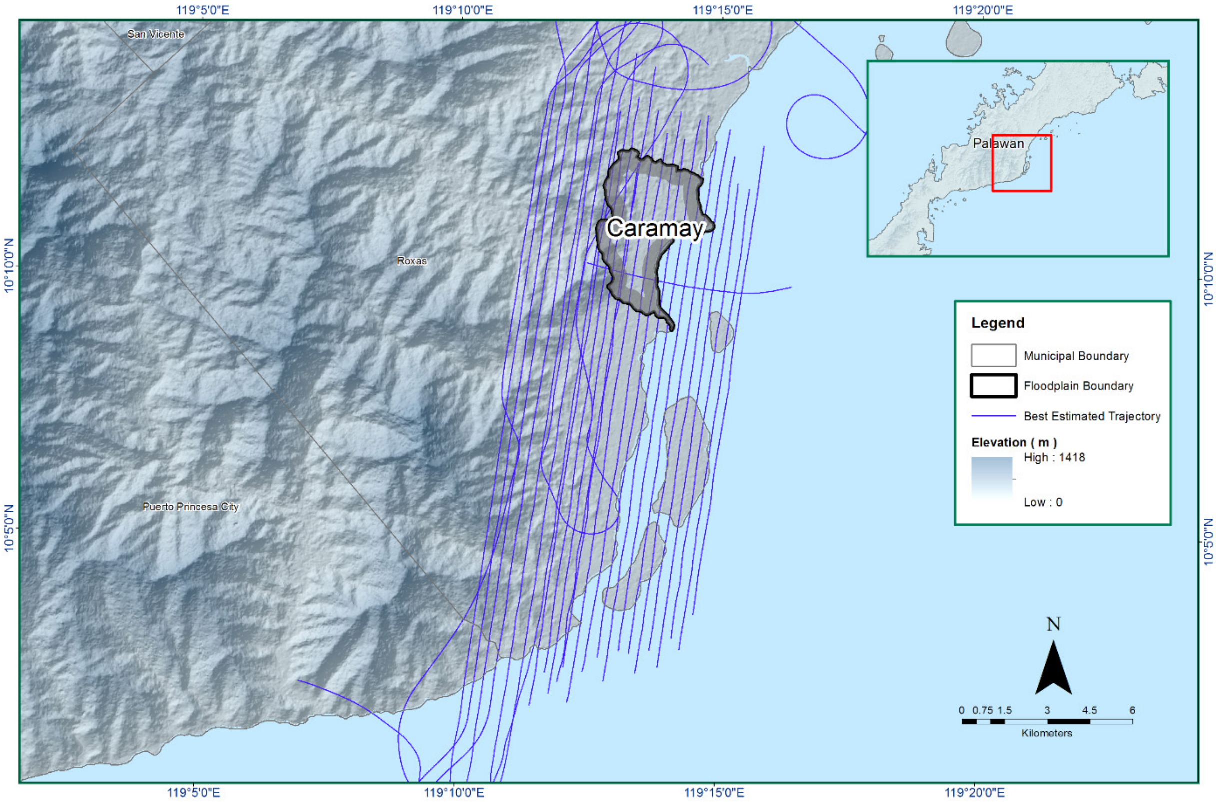

Figure 10. Best Estimated Trajectory for Caramay Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 24 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Caramay floodplain are given in Table 9.

Table 9. Self-Calibration Results values for Caramay flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000835
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000924
GPS Position Z-correction stdev	(<0.01meters)	0.0096

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

3.5 LiDAR Data Quality Checking

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

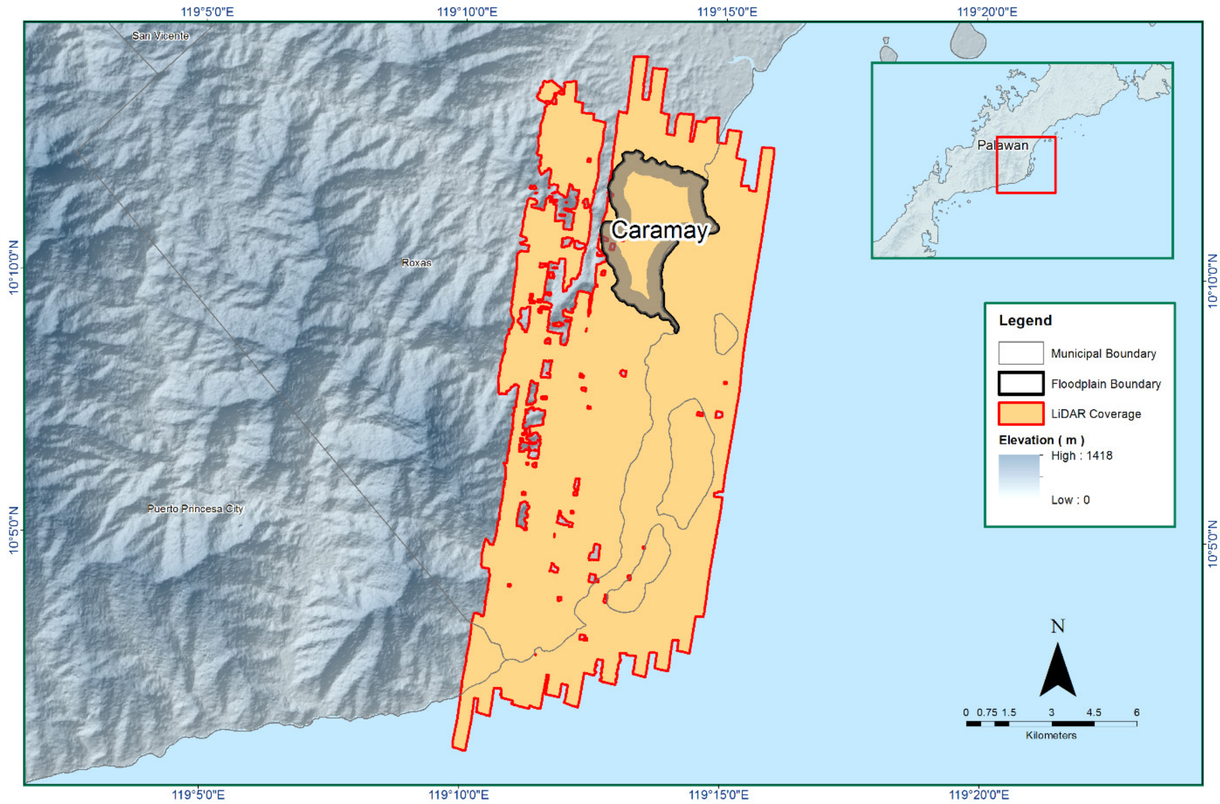

Figure 11. Boundary of the processed LiDAR data over Caramay Floodplain

The total area covered by the Caramay missions is 149.84 sq.km that is comprised of five (5) flight acquisitions grouped and merged into two (2) blocks as shown in Table 10.

Table 10. List of LiDAR blocks for Caramay floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_reflights_Blk42eA	3505G	106.01
	3507G	
	3513G	
Palawan_reflights_Blk42eB	3517G	43.83
	3545G	
TOTAL		149.84 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 system employs 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.

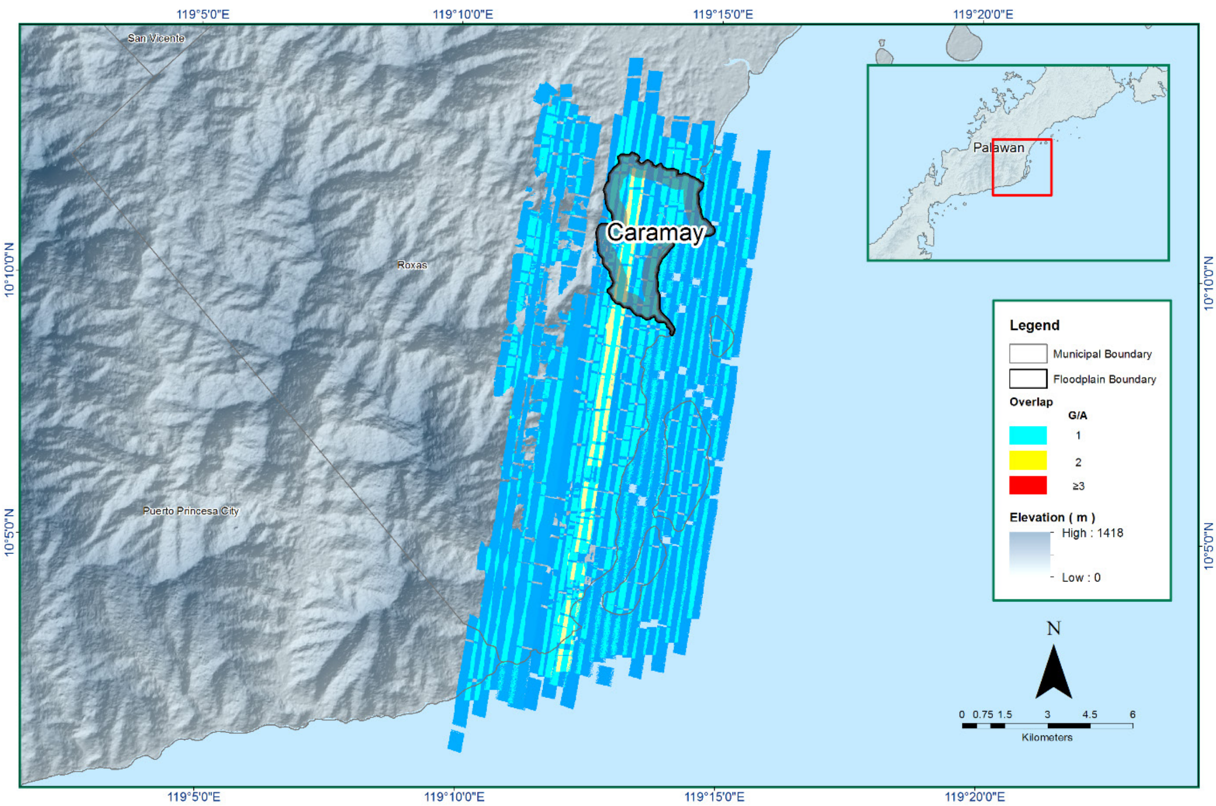

Figure 12. Image of data overlap for Caramay Floodplain.

The overlap statistics per block for the Caramay 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 36.93% and 70.34% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Caramay floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.82 points per square meter.

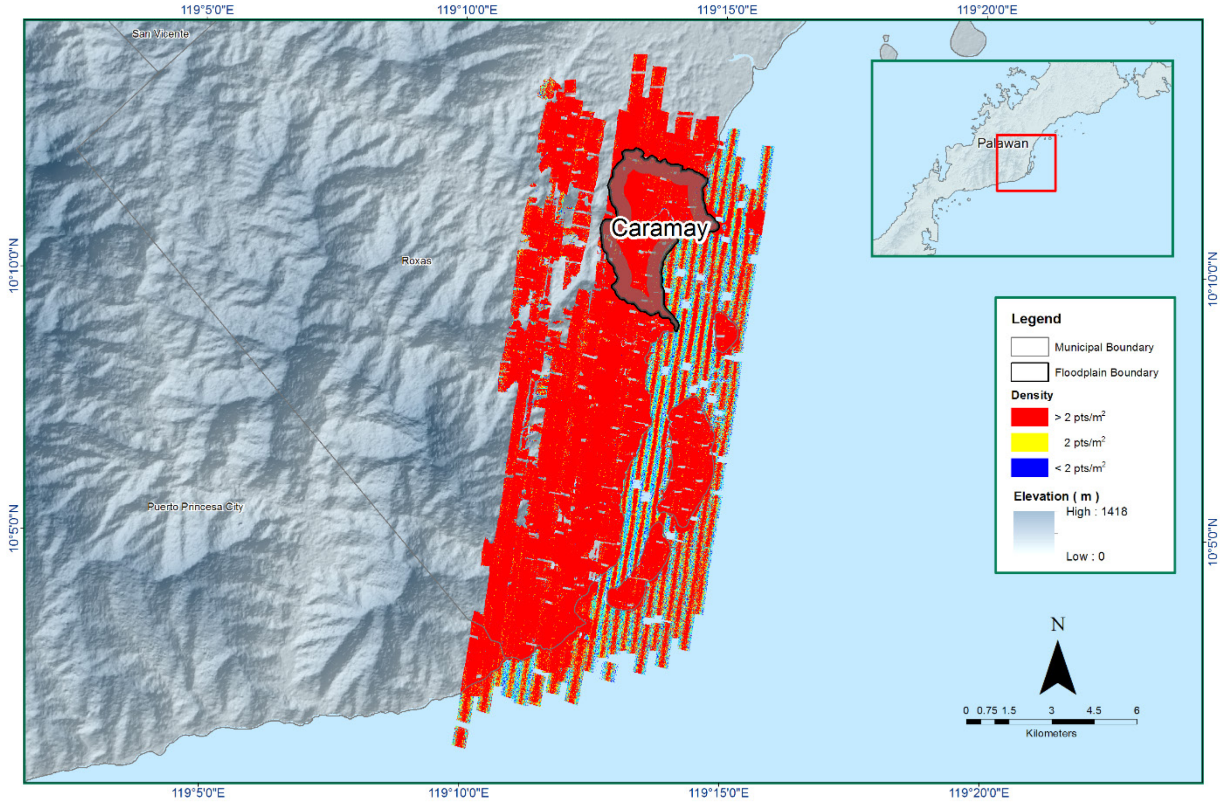

Figure 13. Pulse density map of merged LiDAR data for Caramay Floodplain.

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.

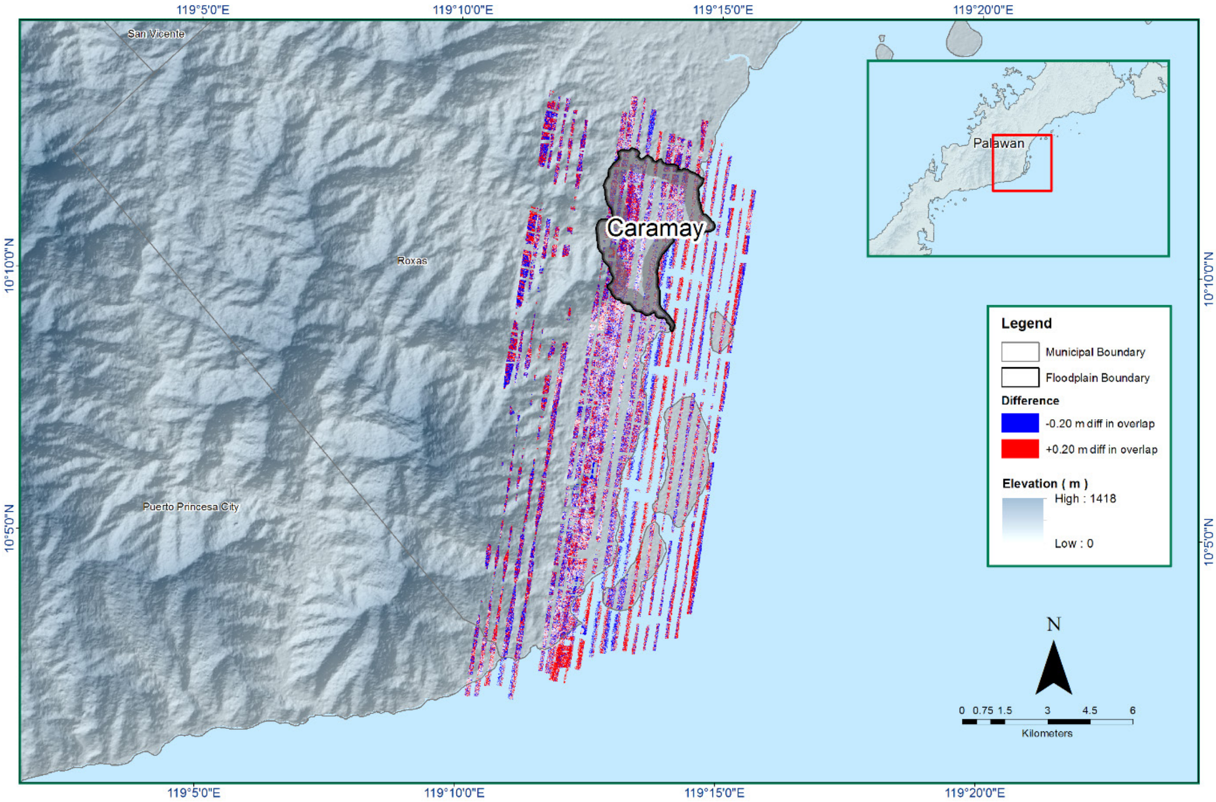

Figure 14. Elevation difference map between flight lines for Caramay Floodplain.

A screen capture of the processed LAS data from a Caramay flight 3507G 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.

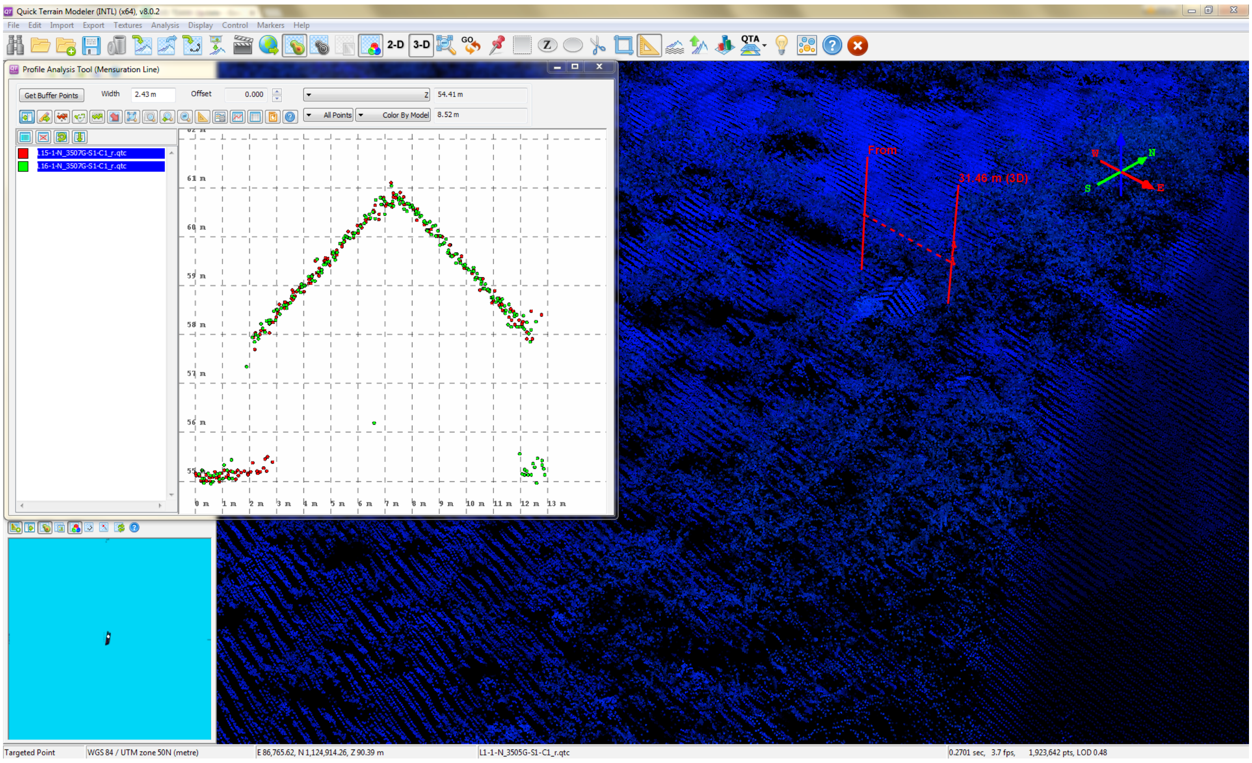

Figure 15. Quality checking for Caramay flight 3507G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Caramay classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	38,622,821
Low Vegetation	290,137,517
Medium Vegetation	206,214,236
High Vegetation	352,934,713
Building	5,722,416

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Caramay floodplain is shown in Figure 16. A total of 226 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 514.64 meters and 50.38 meters respectively.

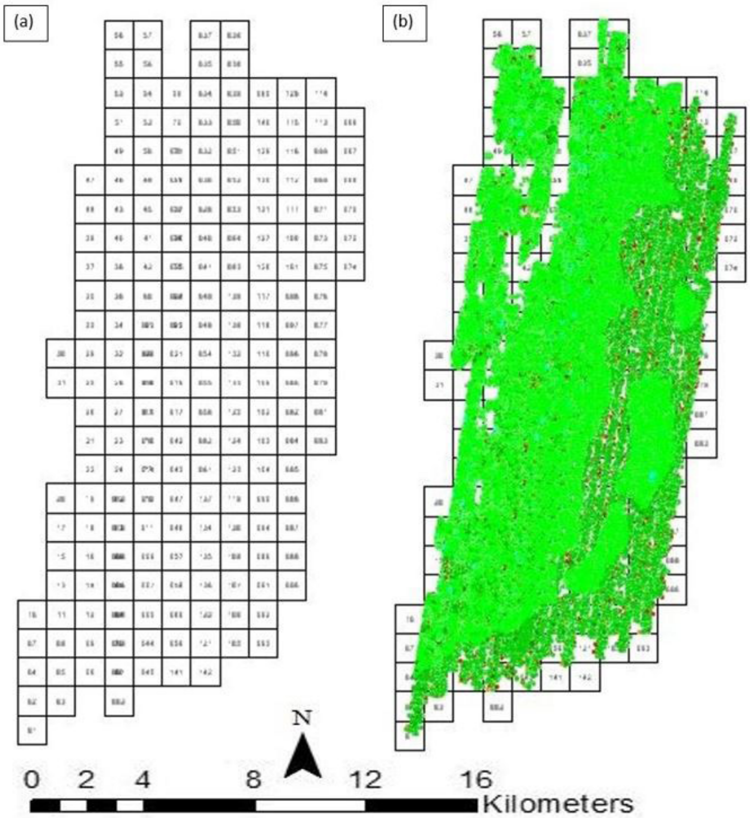

Figure 16. Tiles for Caramay Floodplain (a) and classification results (b) in TerraScan.

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.

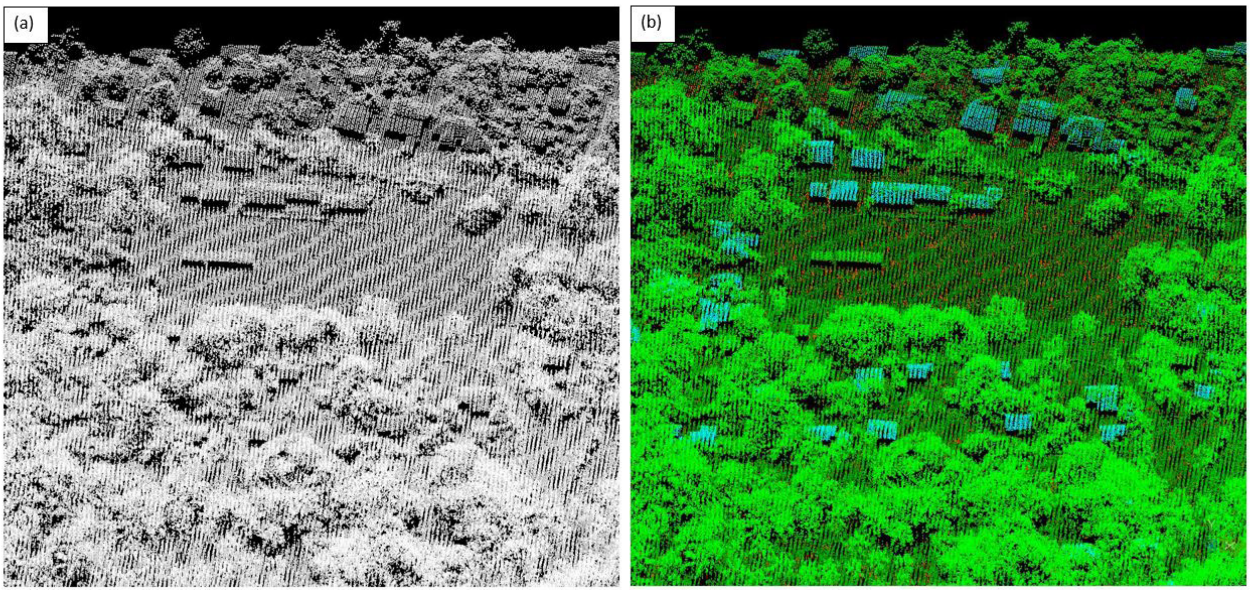

Figure 17. Point cloud before (a) and after (b) classification.

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.

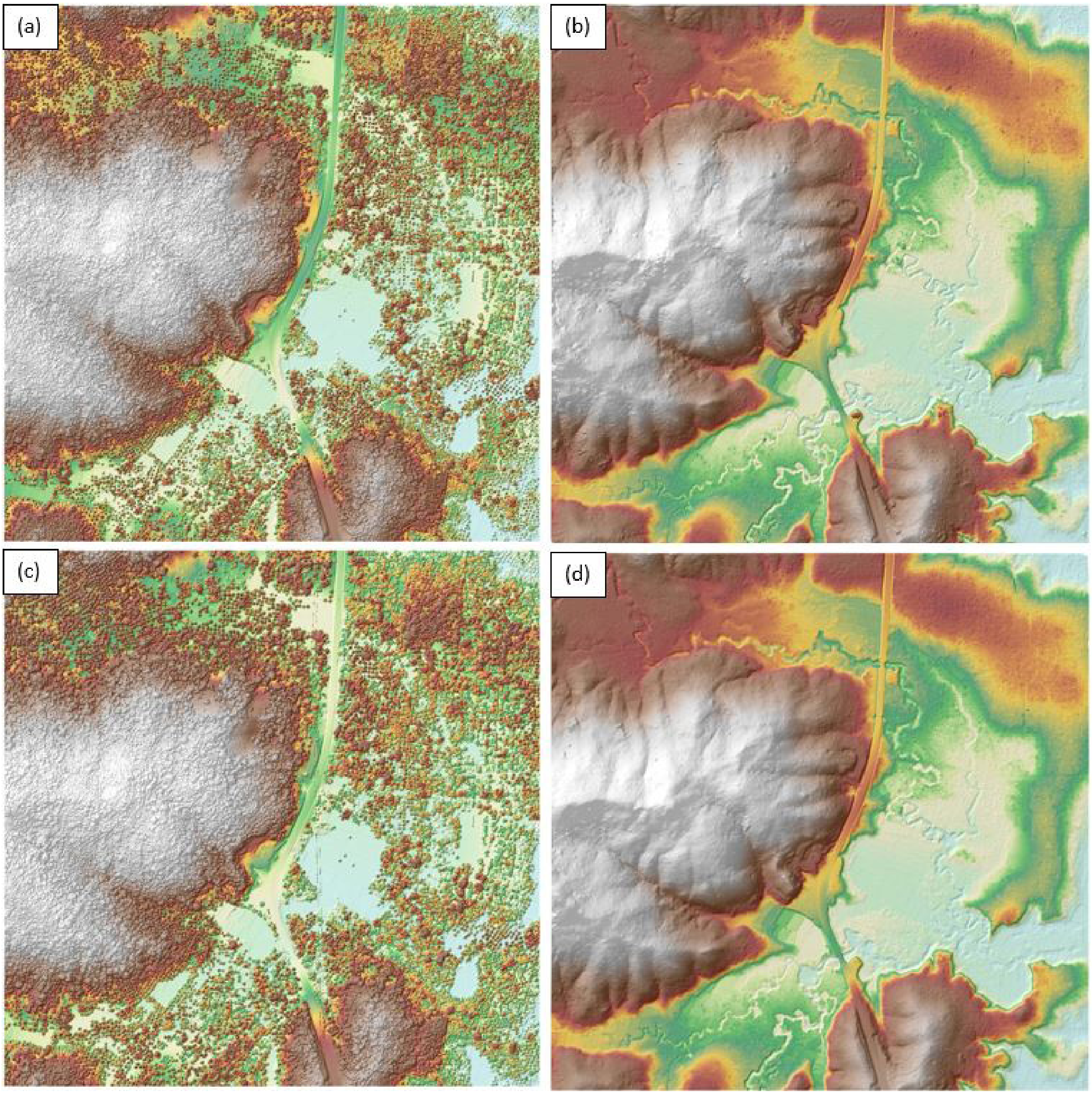

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Caramay floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Caramay floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Caramay flood plain. These blocks are composed of Palawan_reflights blocks with a total area of 149.84 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Palawan_reflights_Blk42eA	106.01
Palawan_reflights_Blk42eB	43.83
TOTAL	149.84 sq.km

Portions of DTM before and after manual editing are shown in Figure 19. The bridge (Figure 19a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 19b) in order to hydrologically correct the river. The paddy field (Figure 19c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19d) to allow the correct flow of water.

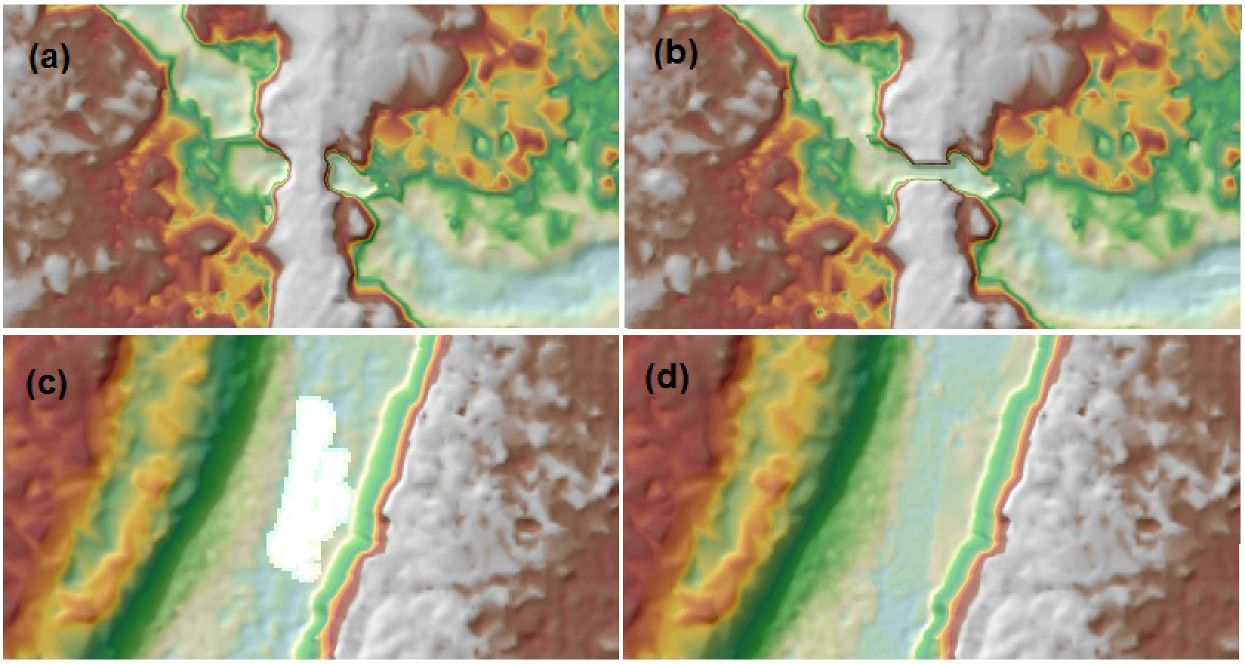

Figure 19. Portions in the DTM of Caramay floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Palawan_Blk42Aa was used as the reference block at the start of mosaicking because it was the first block mosaicked to the larger DTM of West Coast Palawan. Upon inspection of the blocks mosaicked for the Caramay floodplain, it was concluded that the elevation of both blocks needed adjustment. Table 13 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Caramay floodplain is shown in Figure 20. The entire Caramay flood plain is 99.18% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 13. Shift Values of each LiDAR Block of Caramay Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_reflights_Blk42eA	0.54	0.75	-12.81
Palawan_reflights_Blk42eB	0.54	0.75	-0.53

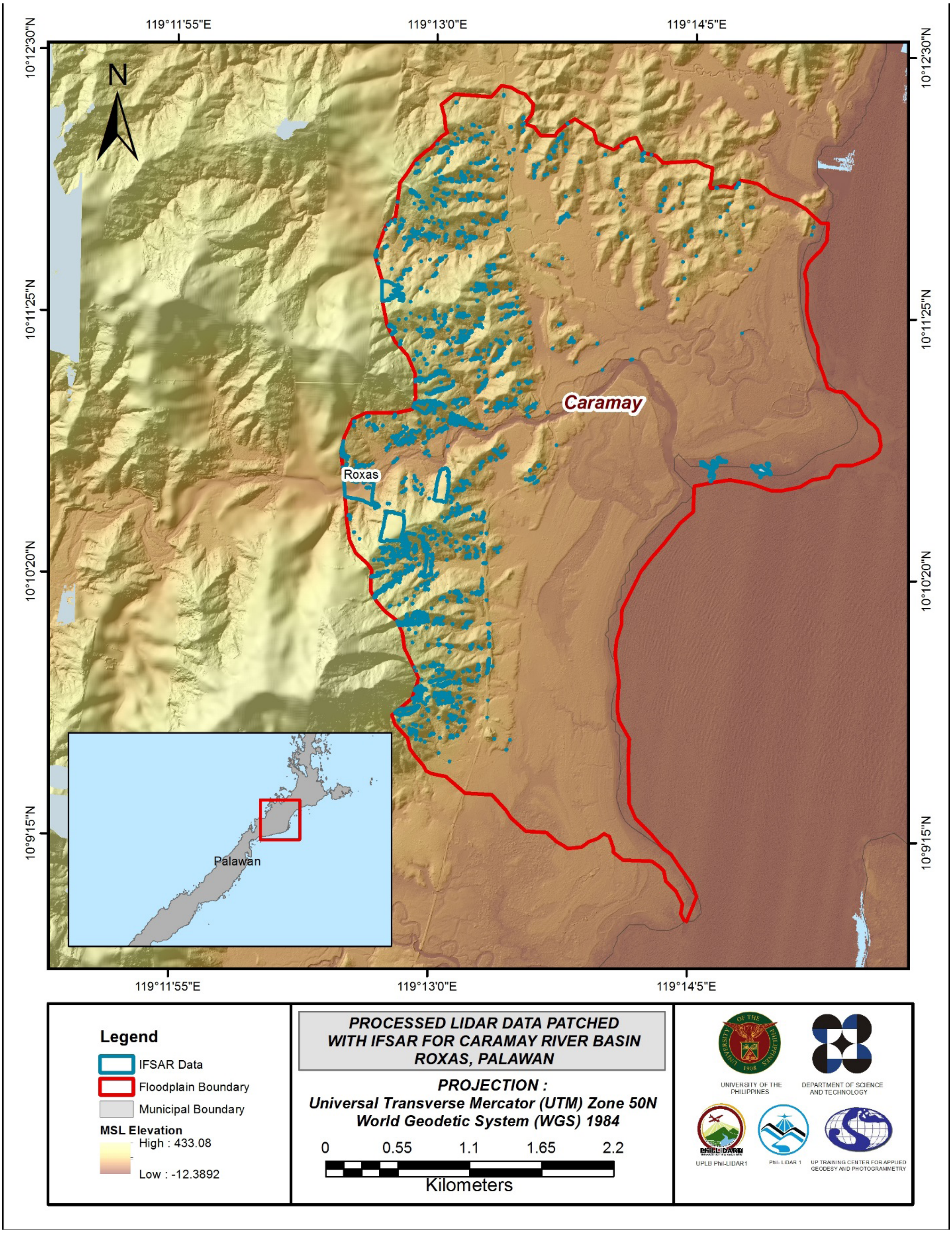

Figure 20. Map of Processed LiDAR Data for Caramay Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Caramay to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 990 survey points were used for calibration and validation of Caramay LiDAR data. Random selection of 80% of the survey points, resulting to 793 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 22. 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 11.18 meters with a standard deviation of 0.19 meters. Calibration of Caramay LiDAR data was done by adding the height difference value, 11.18 meters, to Caramay mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

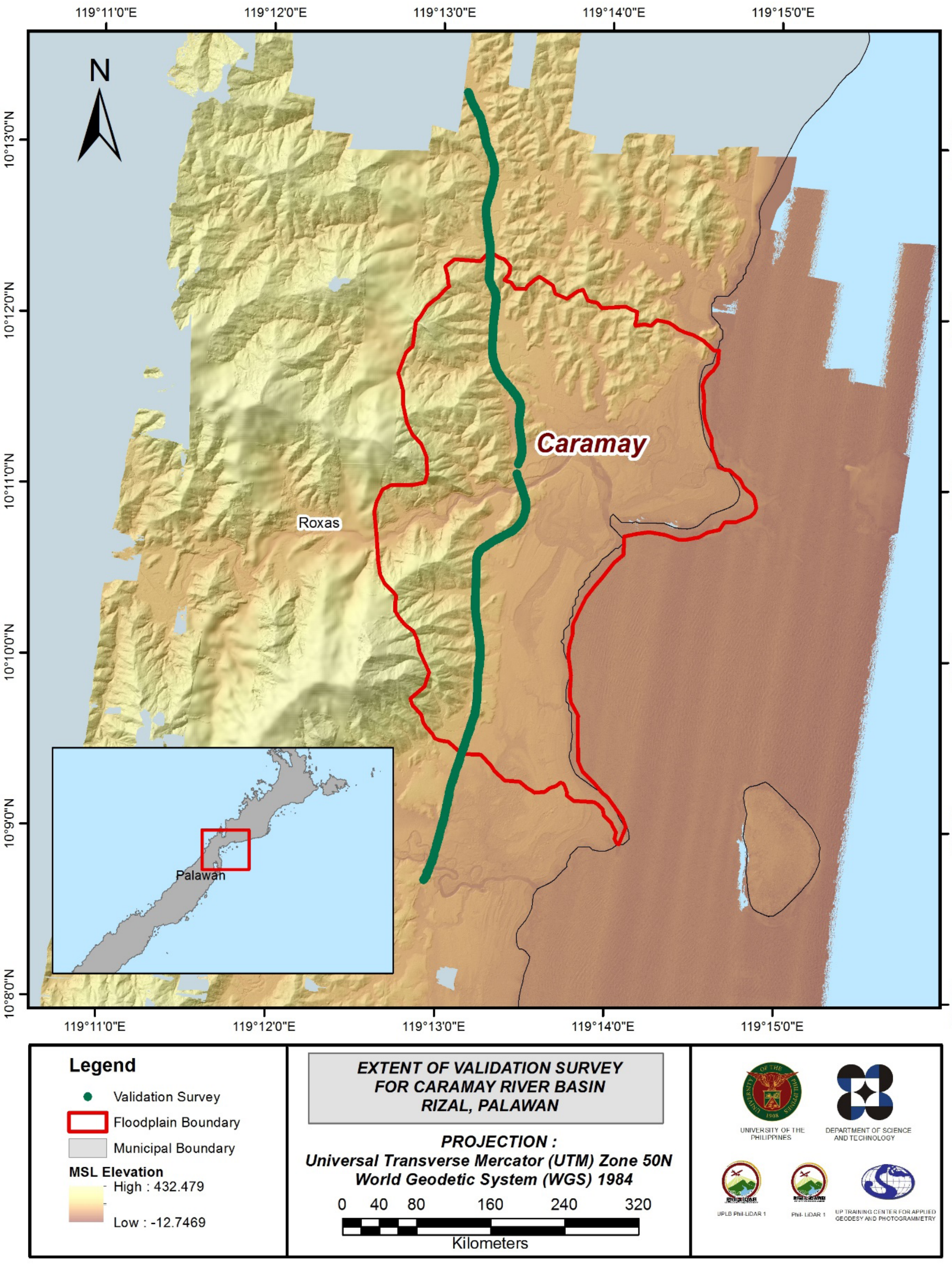

Figure 21. Map of Caramay Floodplain with validation survey points in green.

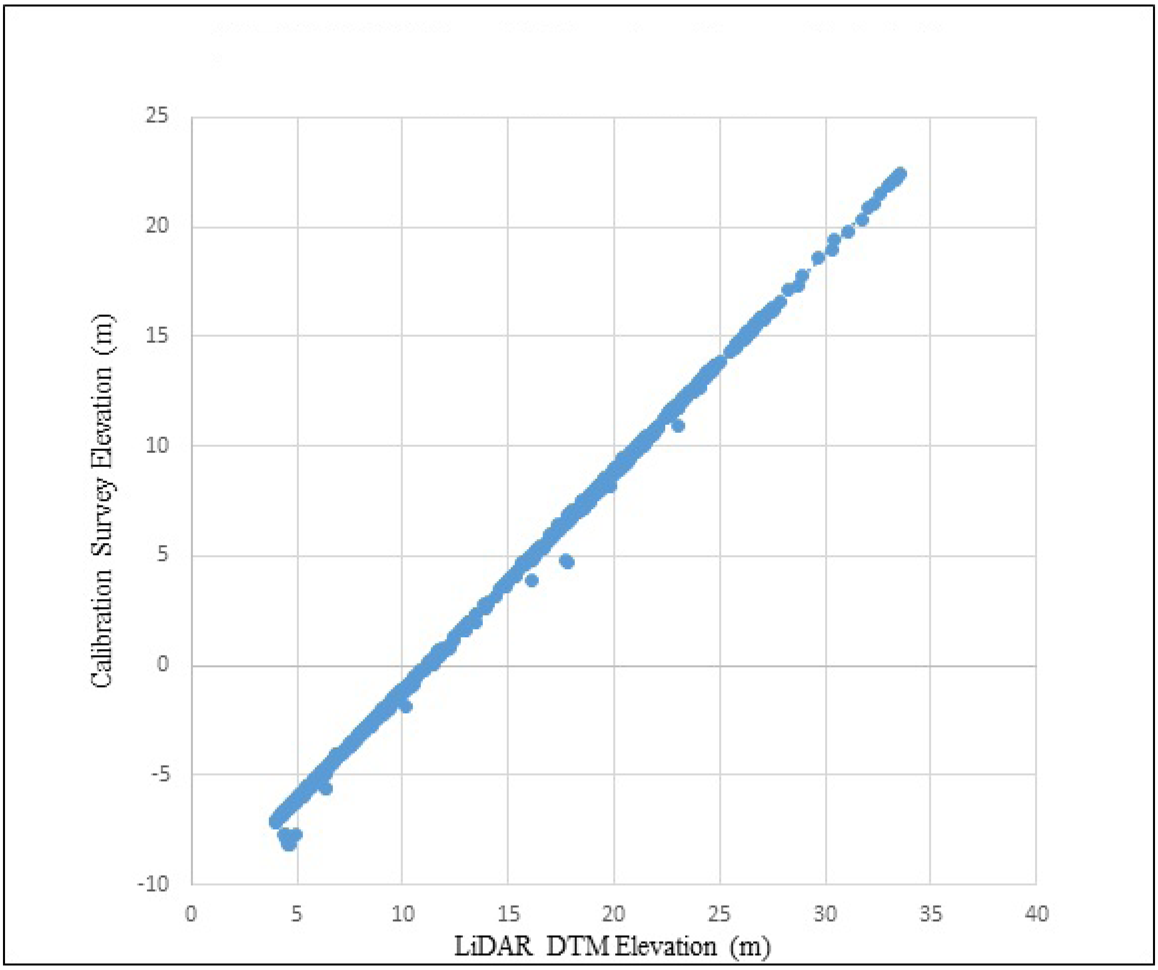

Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	11.18
Standard Deviation	0.19
Average	11.17
Minimum	10.80
Maximum	11.55

The remaining 20% of the total survey points, resulting to 197, were used for the validation of calibrated Caramay 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 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 11.16 meters with a standard deviation of 0.12 meters, as shown in Table 15.

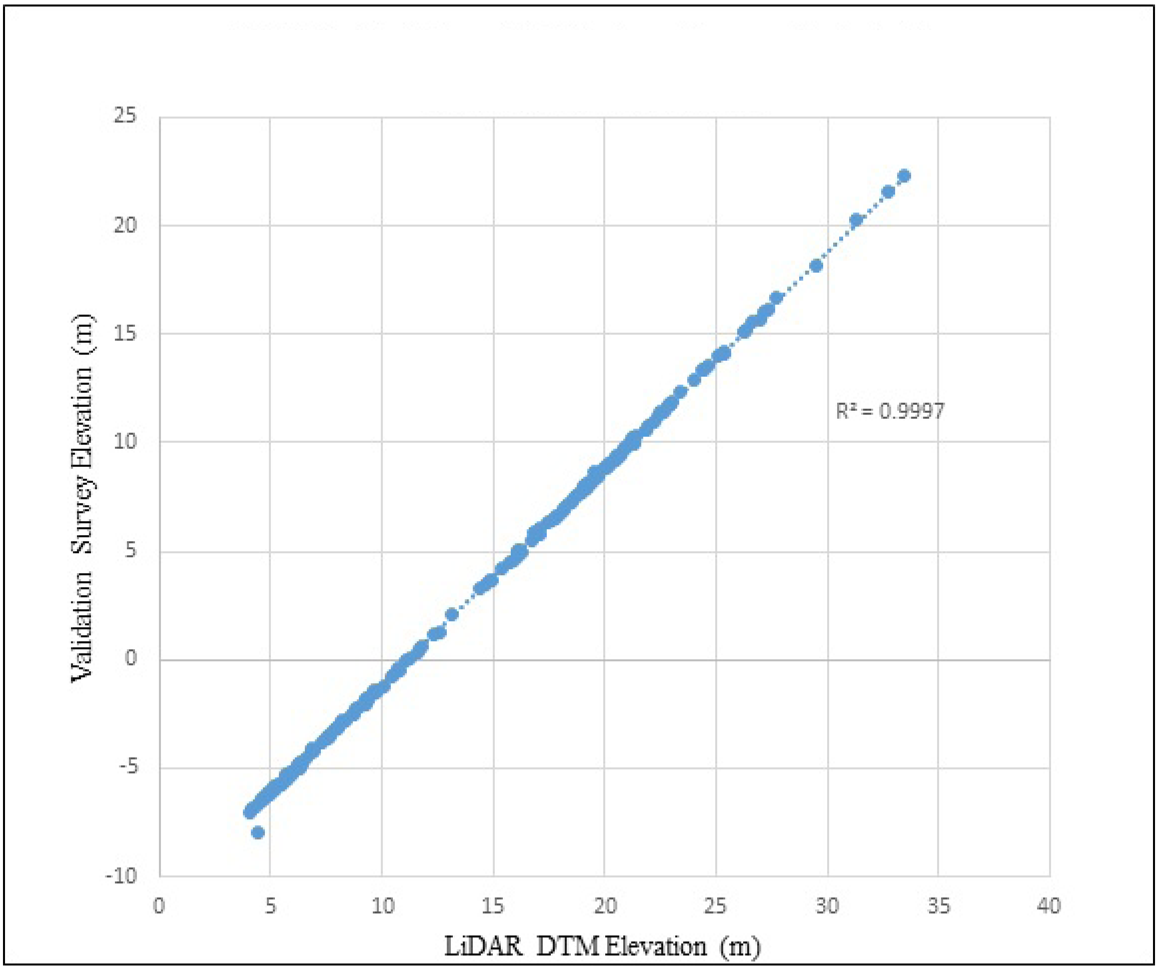

Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	11.16
Standard Deviation	0.12
Average	11.16
Minimum	10.92
Maximum	11.41

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathymetric data integration, centerline and cross section were available for Caramay with a total of 10,321 survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.29 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Caramay integrated with the processed LiDAR DEM is shown in Figure 24.

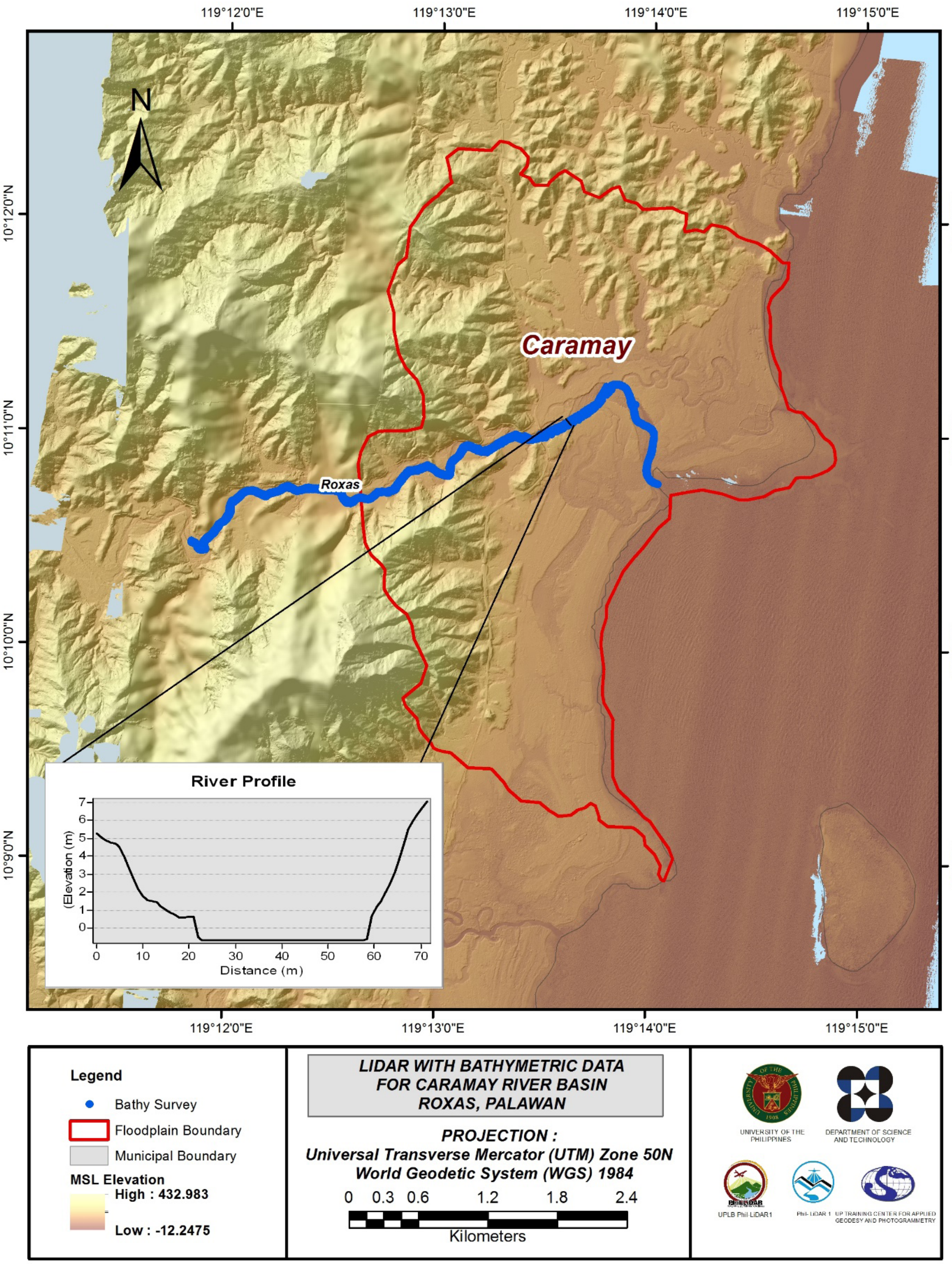

Figure 24. Map of Caramay Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Caramay floodplain, including its 200 m buffer, has a total area of 17.72 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 251 building features, are considered for QC. Figure 25 shows the QC blocks for Caramay floodplain.

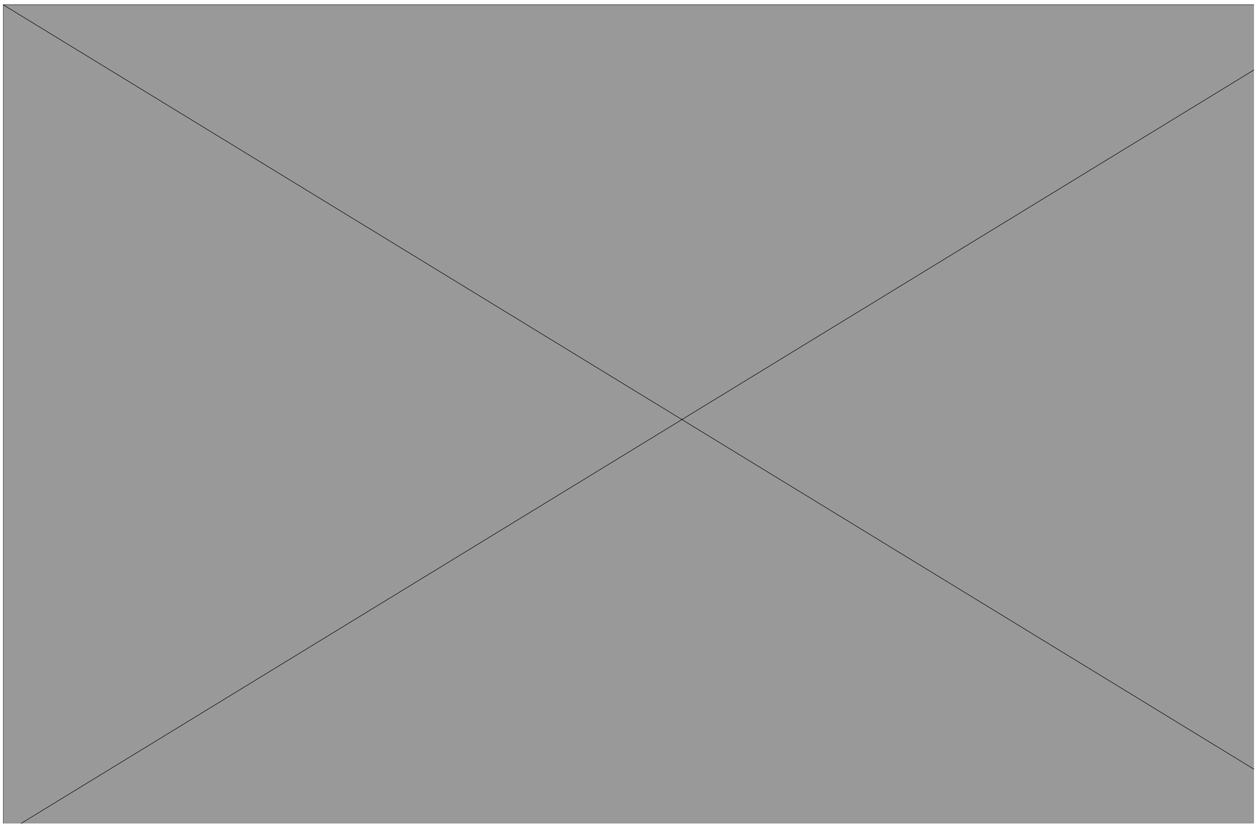

Figure 25. QC blocks for Caramay building features.

Quality checking of Caramay building features resulted in the ratings shown in Table 16.

Table 16. Quality Checking Ratings for Caramay Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Caramay	96.90	99.60	93.63	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,690 building features in Caramay floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,690 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

3.12.3 Feature Attribution

A field team was deployed to the floodplain areas to gather attribute data for the features. Point features in .gpx format were generated from the feature shapefiles. These were loaded into OsmAnd, a mobile mapping application that uses OpenStreetMap (OSM) data as base map. Attributes of feature points of interest (POIs) such as government institutions, social service facilities, agro-industrial facilities, commercial buildings, and transportation and utility offices were recorded. These attributes include building types and names. Names and types of roads were also noted. For water bodies and bridges, only the names were recorded.

Table 17 summarizes the number of building features per type. On the other hand, Table 18 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 17. Building Features Extracted for Caramay Floodplain.

Facility Type	No. of Features
Residential	758
School	14
Market	1
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	1
Barangay Hall	0
Military Institution	0
Sports Center/Gymnasium/Covered Court	9
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	2
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	6
Religious Institutions	8
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	10
Other Commercial Establishments	0
Total	807

Table 18. Total Length of Extracted Roads for Caramay Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Caramay	14.00	0.00	0.00	6.20	0.00	20.20

Table 19. Number of Extracted Water Bodies for Caramay Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Caramay	1	0	1	0	0	2

A total of 44 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 26 shows the Digital Surface Model (DSM) of Caramay floodplain overlaid with its ground features.

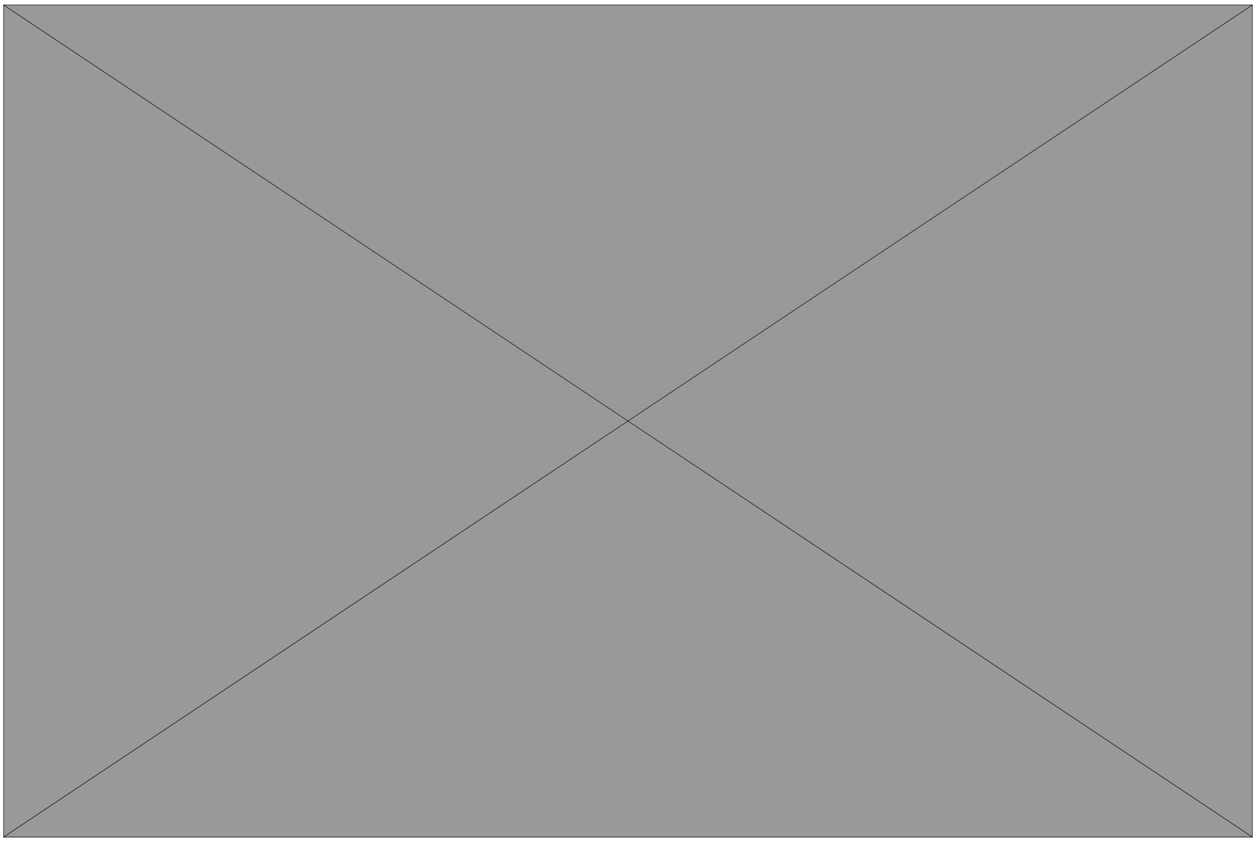

Figure 26. Extracted features for Caramay Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF CARAMAY 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 Data Validation and Bathymetry Component (DVBC) conducted a field survey in Caramay River on November 15 – 29, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built surveys at Caramay Bridge in Brgy. Caramay, Municipality of Roxas; validation points acquisition of about 14 km covering the Barangays: Tagumpay, Rizal, Salvacion, Caramay, and Nicanor Zabala in the Municipality of Roxas; and bathymetric survey from its upstream in Brgy. Caramay, in the Municipality of Roxas, to the mouth of the river in the same barangay, with an approximate length of 5.931 km using Trimble® SPS 985 GNSS PPK survey technique. The entire survey extent is illustrated in Figure 27.

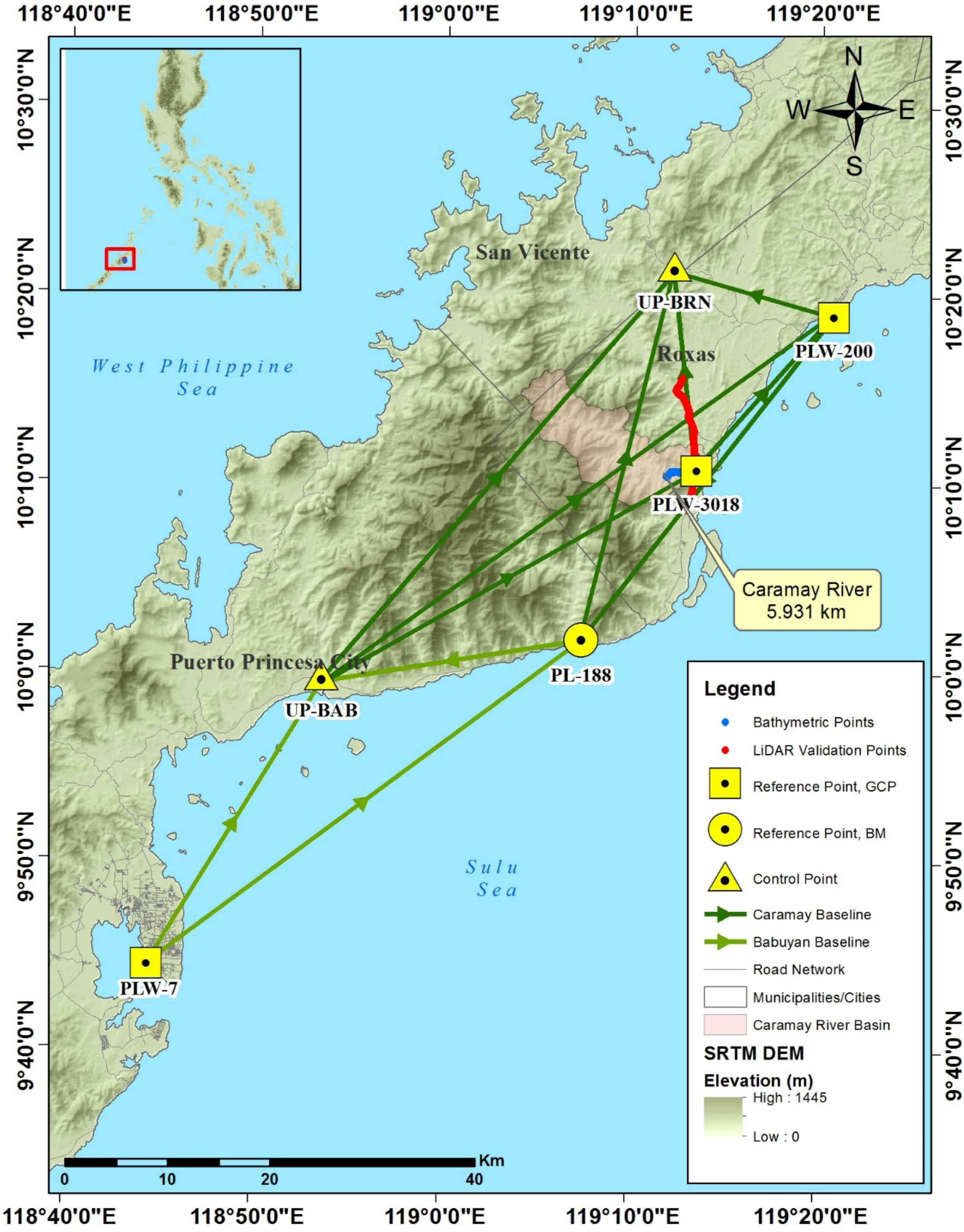


Figure 27. Caramay River Basin Survey Extent

4.2 Control Survey

A GNSS network was established for a previous PHIL-LIDAR 1 DVBC fieldwork in Babuyan River on November 6, 2015 occupying the control points PLW-7, a 2nd order GCP in Brgy. Maningning, Puerto Princesa City, Palawan; and PL-188, a 1st order Benchmark in Brgy. Langogan, Puerto Princesa City, Palawan.

The GNSS network used for Caramay River Basin is composed of four (4) loops established on November 16, 2016, occupying the reference points: PL-188, a 1st order BM in Brgy. Langogan, Puerto Princesa City; and UP-BAB, a UP established control point in Brgy. Babuyan, Puerto Princesa City in Palawan, both fixed from Babuyan Survey.

A control point was established namely UP-BRN located near Port Barton in Brgy. Port Barton, Municipality of San Vicente, Palawan. A NAMRIA established control point namely, PLW-200, in Brgy. 1 Poblacion, Municipality of Roxas, and PLW-3018, in Brgy. Caramay, Municipality of Roxas, Palawan; were also occupied to use as markers for the survey.

The summary of reference and control points and its location is summarized in Table 20 while the GNSS network established is illustrated in Figure 28.

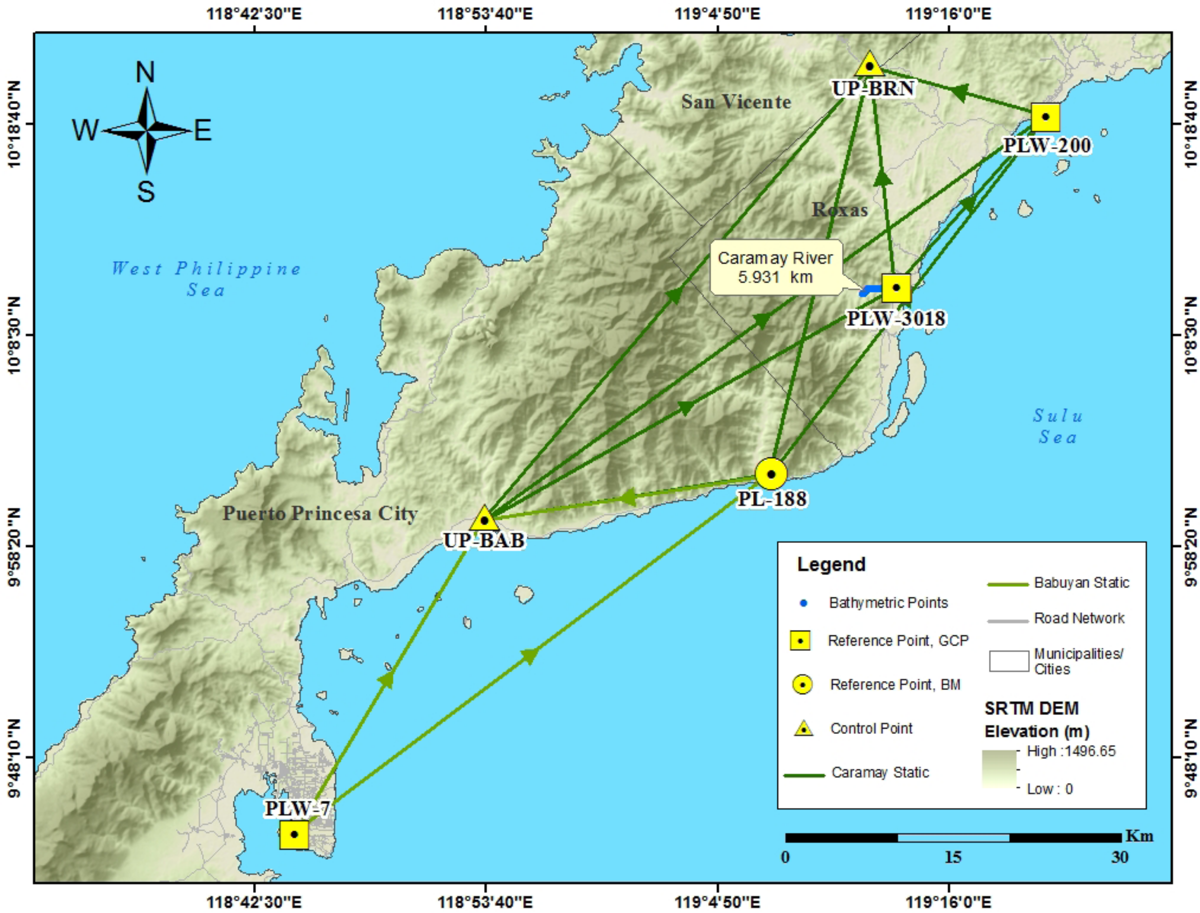


Figure 28. GNSS Network covering Caramay River

Table 20. List of reference and control points used during the survey in Caramay River
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Control Survey on November 16, 2016						
PL-188	Fixed	10°01’44.89299”	119°07’24.55685”	57.865	6.467	11-06-15
UP-BAB	Fixed	09°59’43.61060”	118°53’35.10633”	57.562	6.906	11-06-15
PLW-200	Used as marker	-	-		-	11-16-16
PLW-3018	Used as marker	-	-		-	11-16-16
UP-BRN	UP established	-	-		-	11-16-16
Control Survey on November 6, 2015						
PLW-7	2nd Order, GCP	09°44’25.33347”	118°44’25.60607”	87.116	36.677	11-06-15
PL-188	1st Order, BM	10°01’44.89299”	119°07’24.55685”	59.285	6.467	11-06-15

The GNSS set-ups on recovered reference points and established control points in Caramay River are shown in Figure 29 to Figure 34.

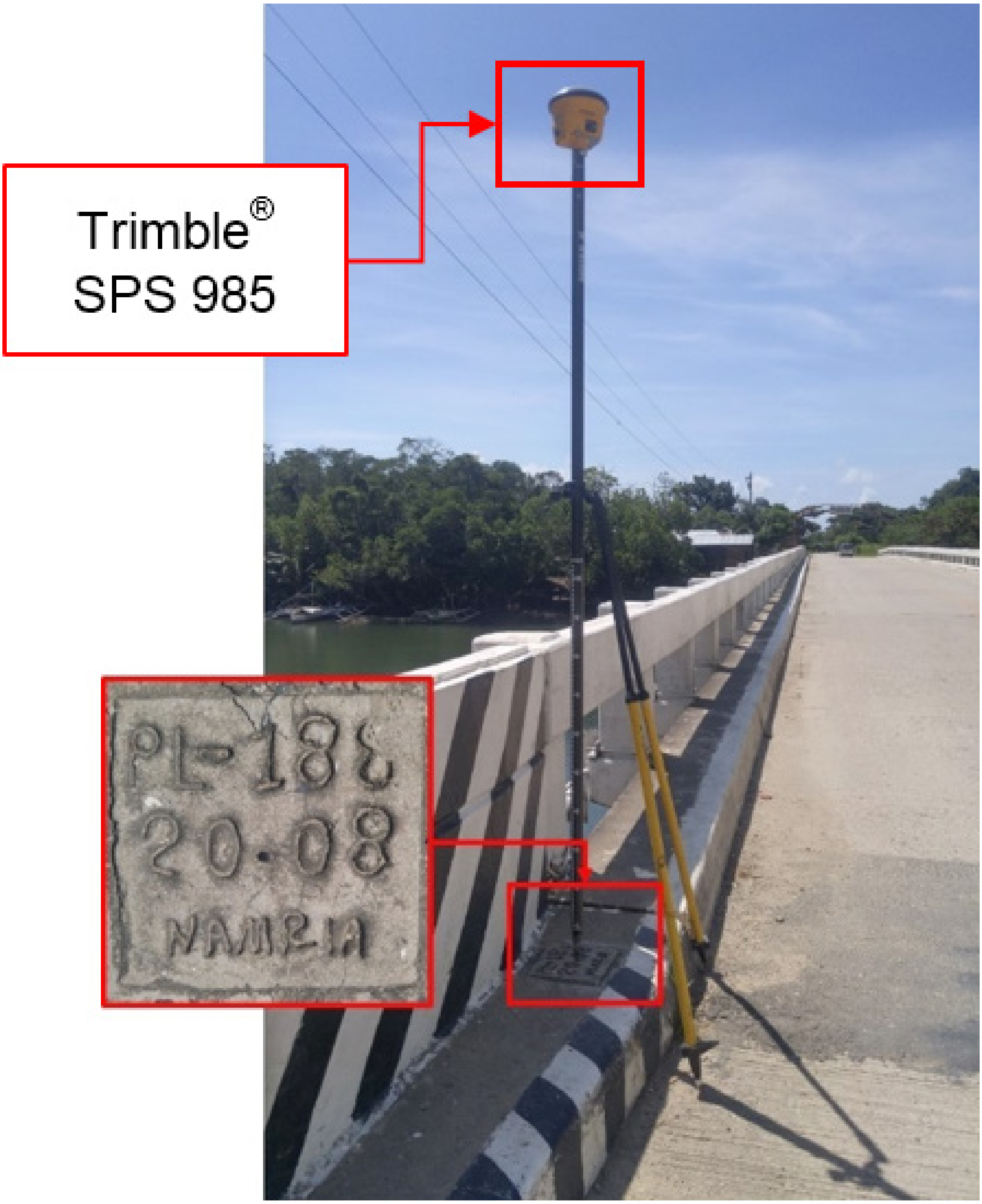


Figure 29. GNSS receiver setup, Trimble® SPS 985, at PL-188, located at the approach of Langogan Bridge in Brgy. Langogan, Puerto Princesa City, Palawan

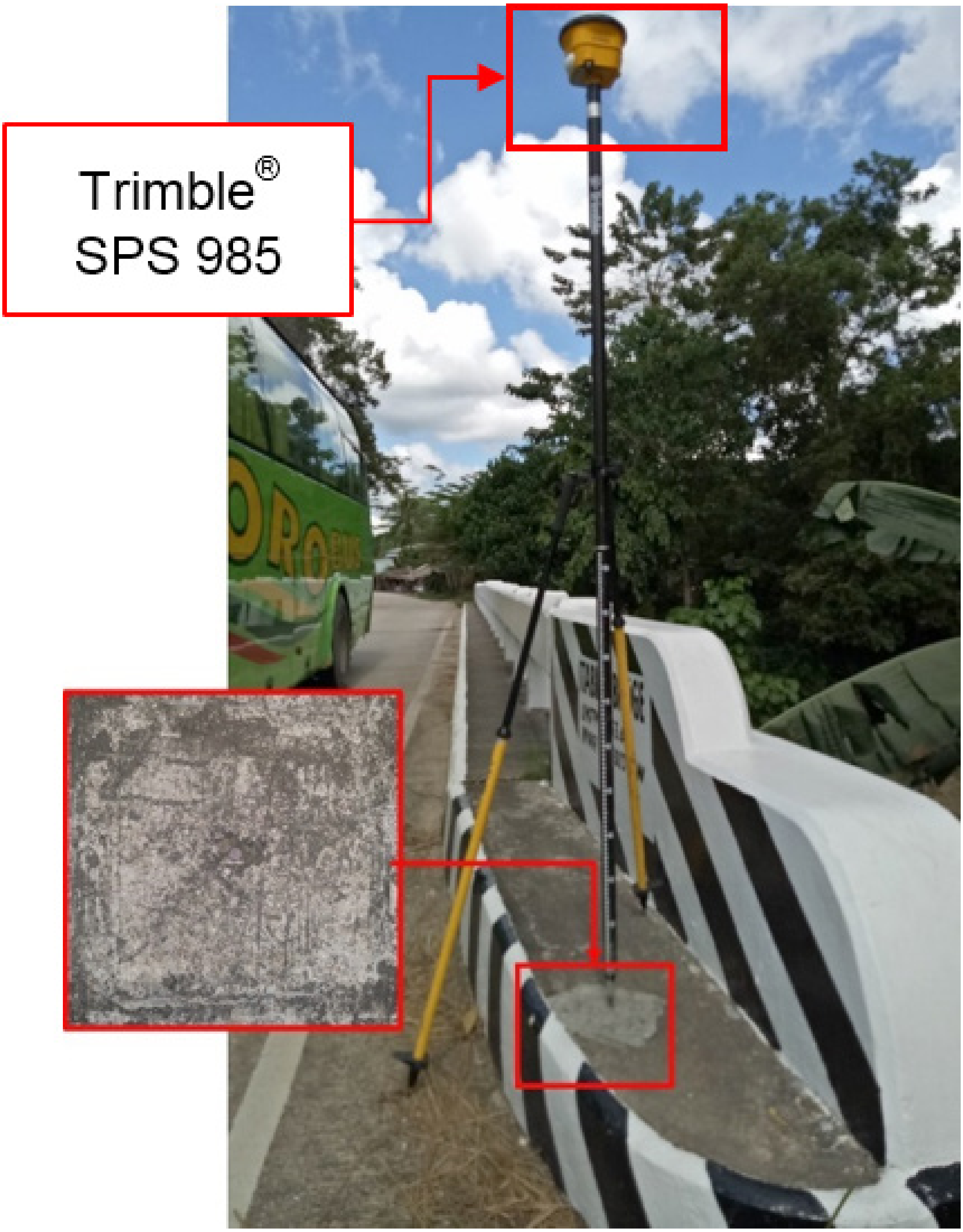


Figure 30. GNSS base set up, Trimble® SPS 985, at UP-BAB, located at the approach of Babuyan Bridge in Brgy. Babuyan, Puerto Princesa City, Palawan

Figure 31. GNSS receiver setup, Trimble® SPS 985 at PLW-200, located along the shoreline in Brgy. 1 Poblacion, Municipality of Roxas, Palawan

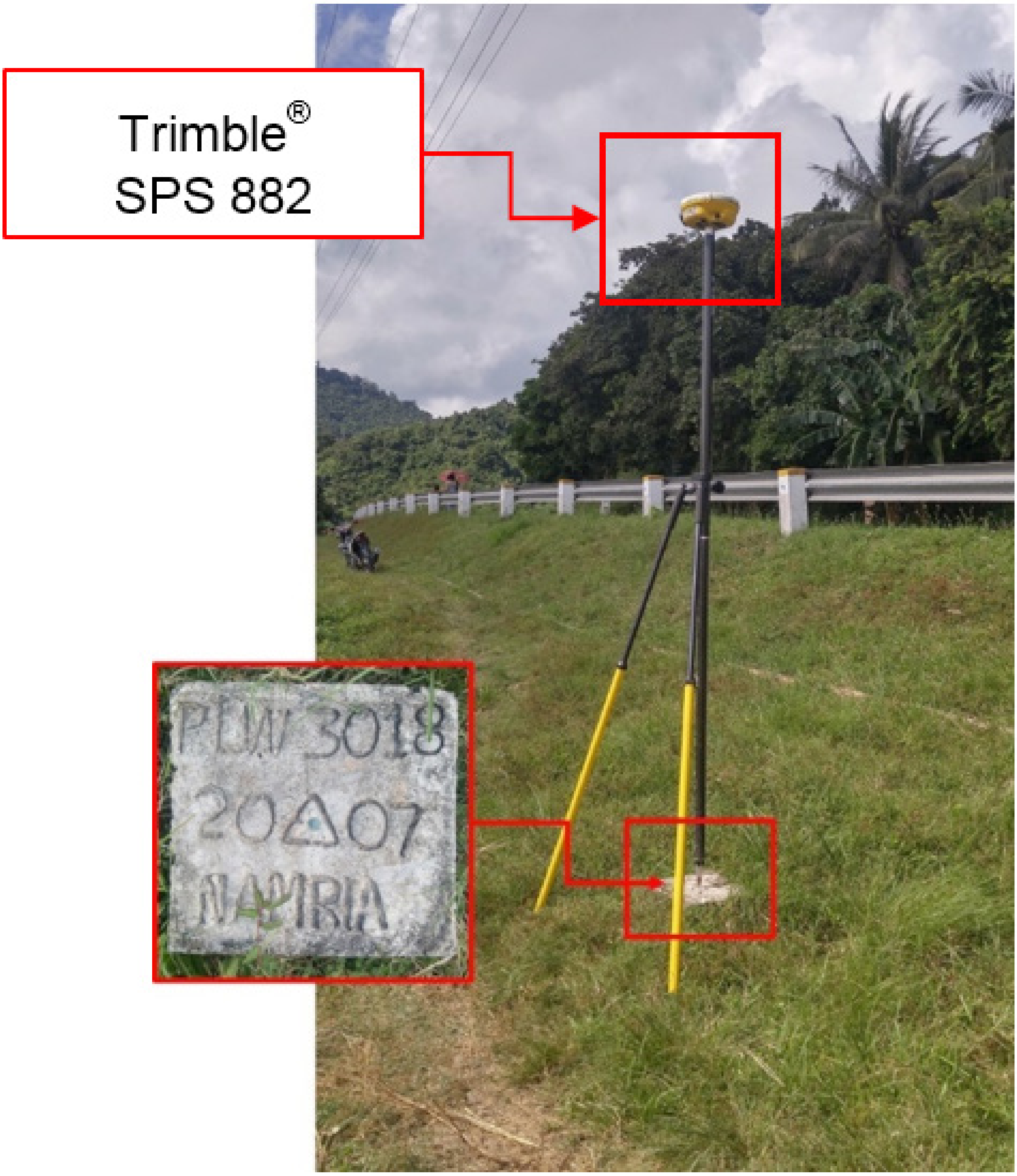


Figure 32. GNSS receiver setup, Trimble® SPS 882, at PLW-3018, located along Puerto Princesa North Road in Brgy. Caramay, Municipality of Roxas, Palawan

Figure 33. GNSS receiver setup, Trimble® SPS 852, at UP-BRN, located near Port Barton in Brgy. Port Barton, Municipality of San Vicente, Palawan

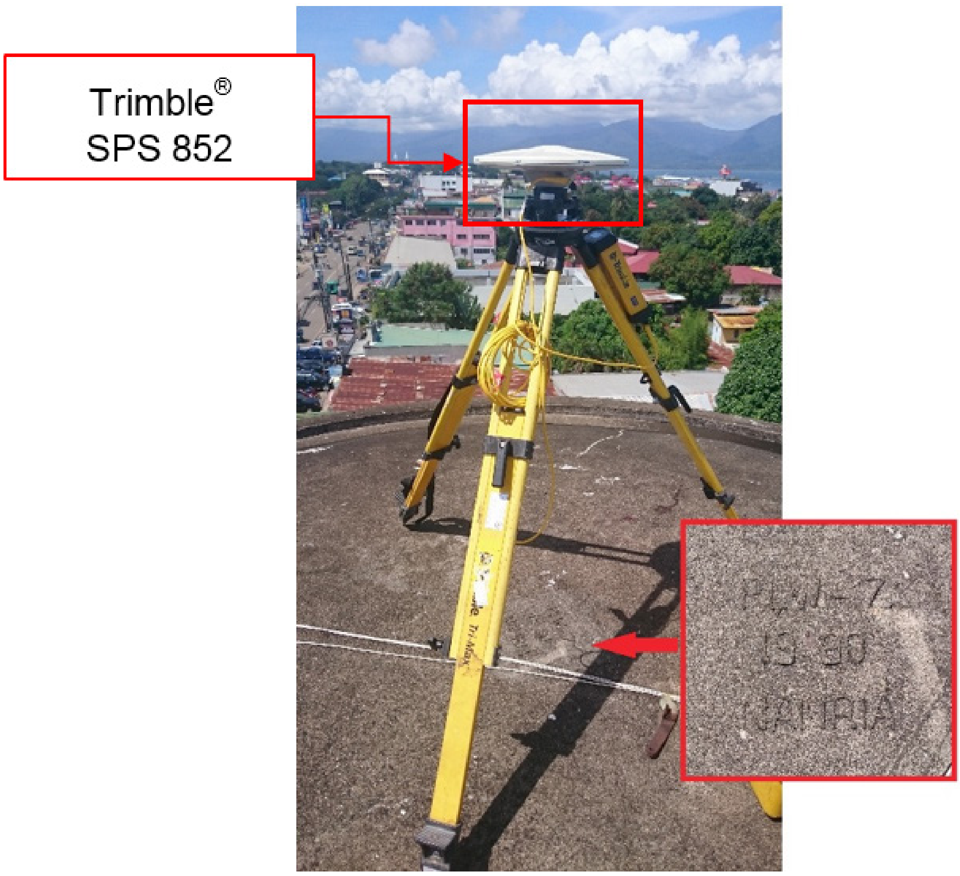


Figure 34. GNSS receiver setup, Trimble® SPS 852, at PLW-7, located at the top of a concrete water tank inside the Water District Compound in Brgy. Maningning, Puerto Princesa City, Palawan

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case 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 in Caramay River Basin is summarized in Table 21 generated by TBC software.
.

Table 21. Baseline Processing Report for Caramay River Static Survey (Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
UP-BAB --- PL-188 (B6)	PL-188	UP-BAB	Fixed	0.004	0.022	261°37’42”	25533.641
PLW-3018 --- PL-188 (B3)	PL-188	PLW-3018	Fixed	0.003	0.012	33°39’39”	19973.003
UP-BAB --- PLW-200 (B5)	UP-BAB	PLW-200	Fixed	0.009	0.036	54°21’18”	60909.606
UP-BAB --- UP-BRN (B7)	UP-BAB	UP-BRN	Fixed	0.011	0.040	40°06’28”	52687.150
UP-BAB --- PLW-3018 (B4)	UP-BAB	PLW-3018	Fixed	0.004	0.019	60°42’58”	41638.975
PLW-3018 --- PLW-200 (B2)	PLW-3018	PLW-200	Fixed	0.003	0.014	41°07’13”	20064.565
PLW-3018 --- UP-BRN (B8)	PLW-3018	UP-BRN	Fixed	0.004	0.028	353°15’43”	20070.679
PLW-200 --- UP-BRN (B9)	PLW-200	UP-BRN	Fixed	0.004	0.030	287°13’56”	16279.087
PL-188 --- PLW-200 (B1)	PL-188	PLW-200	Fixed	0.003	0.015	37°23’24”	39953.172
PL-188 --- UP-BRN (B10)	PL-188	UP-BRN	Fixed	0.005	0.053	13°24’03”	37578.719

As shown Table 21 a total of ten (10) baselines were processed with coordinate and elevation values of PL-188 and UP-BAB, both fixed from previous PHIL-LIDAR1 survey in Babuyan River; held fixed. All of them passed the required accuracy.

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:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 22 to Table 25 for complete details.

The five (5) control points, PL-188, PLW-200, PLW-3018, UP-BAB, and UP-BRN were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of PL-188 and UP-BAB were held fixed during the processing of the control points as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 22. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PL-188	Grid	Fixed	Fixed		Fixed
UP-BAB	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 23. All fixed control points have no values for grid and elevation errors.

Table 23. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PL-188	74882.789	?	1111141.315	?	6.467	?	ENe
PLW-200	99564.013	0.013	1142646.180	0.012	2.161	0.041	
PLW-3018	86170.148	0.008	1127662.105	0.008	17.691	0.036	
UP-BAB	49529.234	?	1107714.958	?	6.906	?	ENe
UP-BRN	84046.211	0.012	1147655.023	0.012	36.026	0.065	

With the mentioned equation $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for the horizontal and $z_e < 10\ cm\ z_e < 10\ cm$ for the vertical; the computation for the accuracy for:

PL-188
horizontal accuracy = Fixed
vertical accuracy = Fixed

UP-BAB
horizontal accuracy = Fixed
vertical accuracy = Fixed

PLW-200
horizontal accuracy = √((1.3)² + (1.2)²
= √ (1.69 + 1.44)
= 1.77 < 20 cm
vertical accuracy = 4.1 < 10 cm

PLW-3018
horizontal accuracy = √((0.8)² + (0.8)²
= √ (0.64 + 0.64)
= 1.13 < 20 cm
vertical accuracy = 3.6 < 10 cm

UP-BRN
horizontal accuracy = √((1.2)² + (1.2)²
= √ (1.44 + 1.44)
= 1.70 < 20 cm
vertical accuracy = 6.5 < 10 cm

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

Table 24. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
PL-188	N10°01’44.89299”	E119°07’24.55685”	57.865	?	ENe
PLW-200	N10°18’57.78651”	E119°20’41.94774”	53.650	0.041	
PLW-3018	N10°10’45.91002”	E119°13’28.25701”	69.163	0.036	
UP-BAB	N9°59’43.61060”	E118°53’35.10633”	57.562	?	ENe
UP-BRN	N10°21’34.63416”	E119°12’10.84685”	87.058	0.065	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 25.

Table 25. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on November 16, 2016							
PL-188	Fixed	10d01’44.89299”	119d07’24.55685”	57.865	1111141.315	74882.789	6.467
UP-BAB	Fixed	9d59’43.61060”	118d53’35.10633”	57.562	1107714.958	49529.234	6.906
PLW-200	Used as marker	10d18’57.78651”	119d20’41.94774”	53.65	1142646.18	99564.013	2.161
PLW-3018	Used as marker	10d10’45.91002”	119d13’28.25701”	69.163	1127662.105	86170.148	17.691
UP-BRN	UP established	10d21’34.63416”	119d12’10.84685”	87.058	1147655.023	84046.211	36.026
Control Survey on November 6, 2015							
PL-188	1st Order, BM	10d01’44.89298”	119d07’24.55686”	59.285	1111141.315	74882.789	6.467
PLW-7	2nd Order, GCP	9d44’25.33347”	118d44’25.60607”	87.116	1079651.883	32397.249	35.257

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

Cross-section and as-built surveys were conducted on November 18, 2016 at the downstream side of Caramay bridge in Brgy. Caramay, Municipality of Roxas, Palawan as shown in Figure 35. A survey grade GNSS receiver Trimble® SPS 985 in PPK survey technique was utilized for this survey as shown in Figure 36.

Figure 35. Caramay Bridge facing downstream

Figure 36. As-built survey of Caramay Bridge

The cross-sectional line of Caramay Bridge is about 172.856 m with ninety-four (94) cross-sectional points, using the control point PLW-3018 as the GNSS base station. The location map, cross-section diagram, and the bridge data form is shown in Figure 37 to Figure 39.

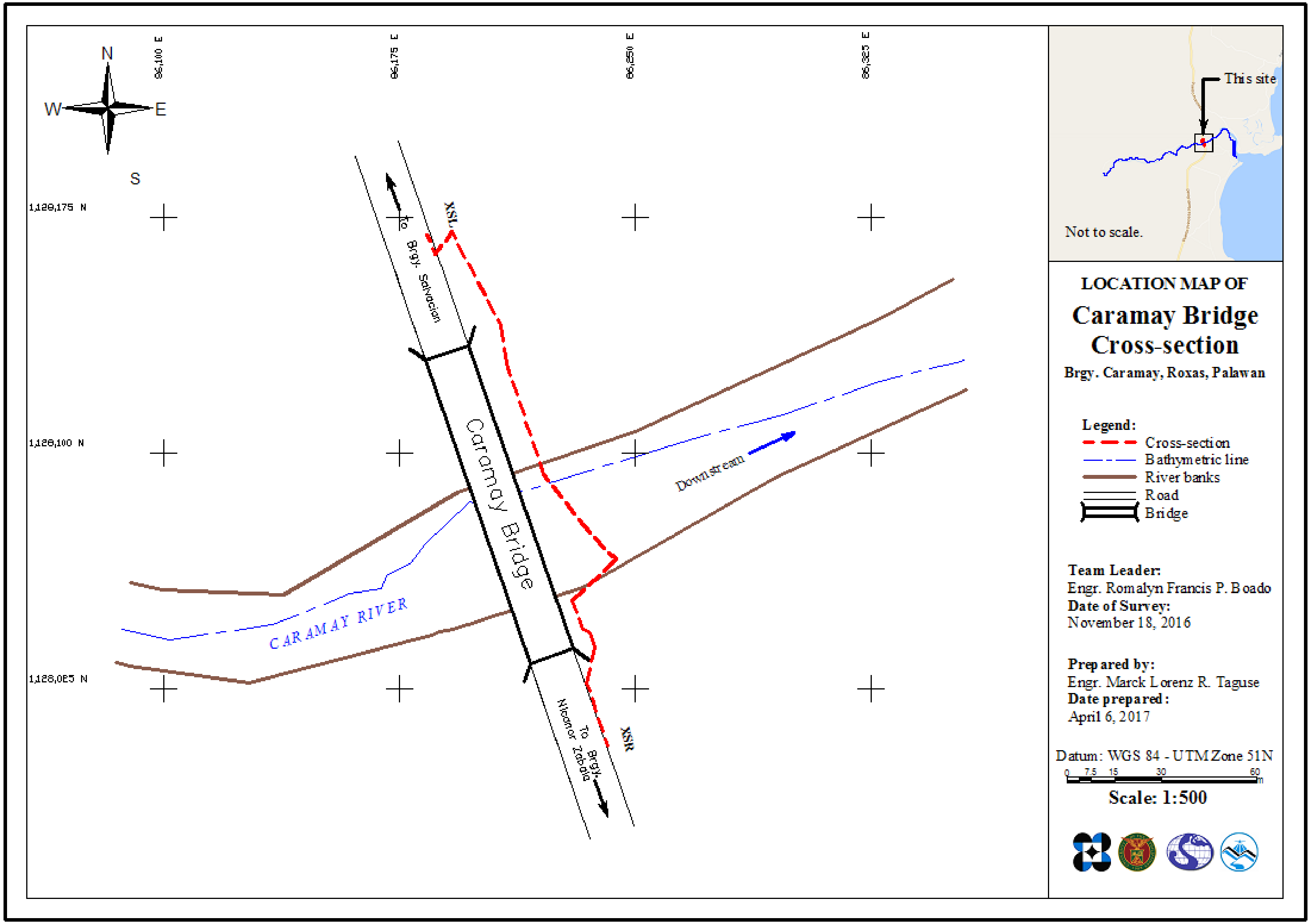


Figure 37. Location Map of Caramay Bridge River Cross-Section survey

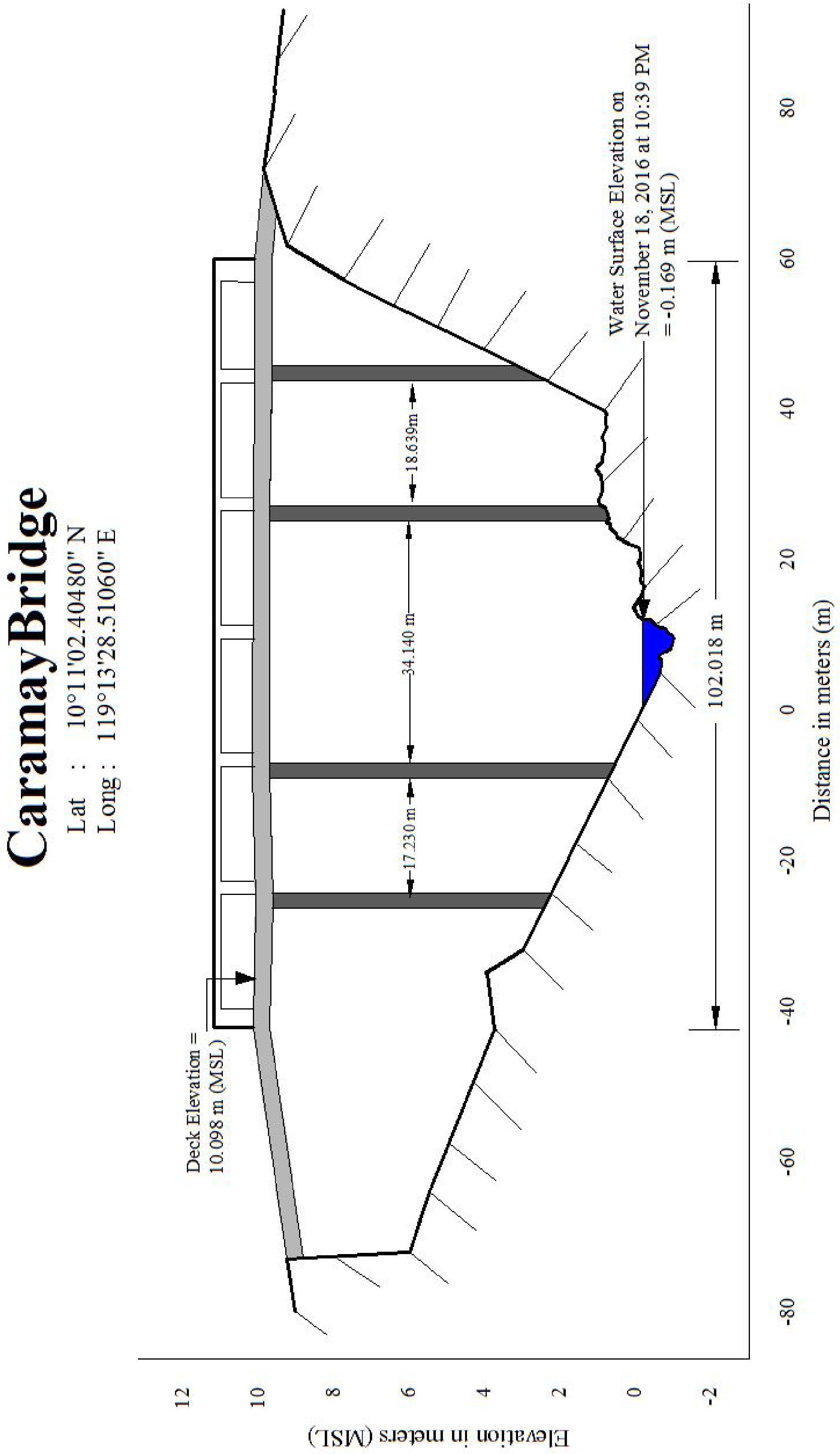


Figure 38. Caramay Bridge cross-section diagram

Bridge Data Form

Bridge Name: Caramay Bridge **Date:** November 18, 2016

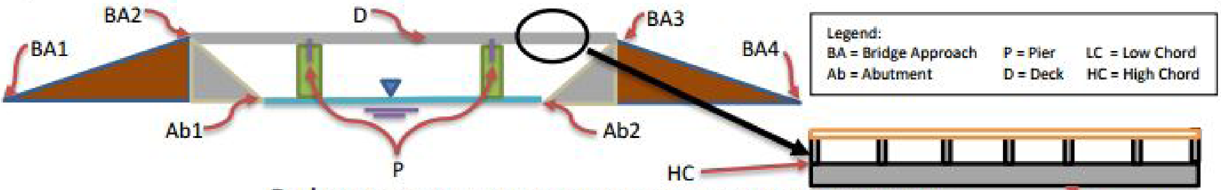
River Name: Caramay River **Time:** 10:39 AM

Location (Brgy, City,Region): Brgy. Caramay, Roxas, Palawan

Survey Team: Romalyn Francis Boado, Marck Lorenz Taguse, Cibyl Atacador

Flow condition: average **Weather Condition:** fair

Latitude: 10°11'02.40480"N **Longitude:** 119°13'28.51060"E



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

Elevation: 10.098 m **Width:** not available **Span (BA3-BA2):** 102.018 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	8.984 m	BA3	139.756 m	10.152 m
BA2	37.738 m	10.098 m	BA4	172.854 m	9.270 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: round Number of Piers: 4 Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	54.530 m	10.022 m	
Pier 2	71.760 m	10.112 m	
Pier 3	105.901 m	10.098 m	
Pier 4	124.541 m	10.039 m	

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

Figure 39. Bridge as-built form of Caramay Bridge

Water surface elevation of Caramay River was determined by a survey grade GNSS receiver Trimble® SPS 985 in PPK survey technique on November 18, 2016 at 10:39 AM at Caramay Bridge with a value of -0.169 m in MSL as shown in Figure 38. This was translated into marking on the bridge's abutment as shown in Figure 40. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Caramay River, the University of the Philippines Los Baños.

Figure 40. Water-level marking at Caramay Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on November 18, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 985, mounted in front of a vehicle as shown in Figure 41. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.23 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with PLW-3018 occupied as the GNSS base station in the conduct of the survey.

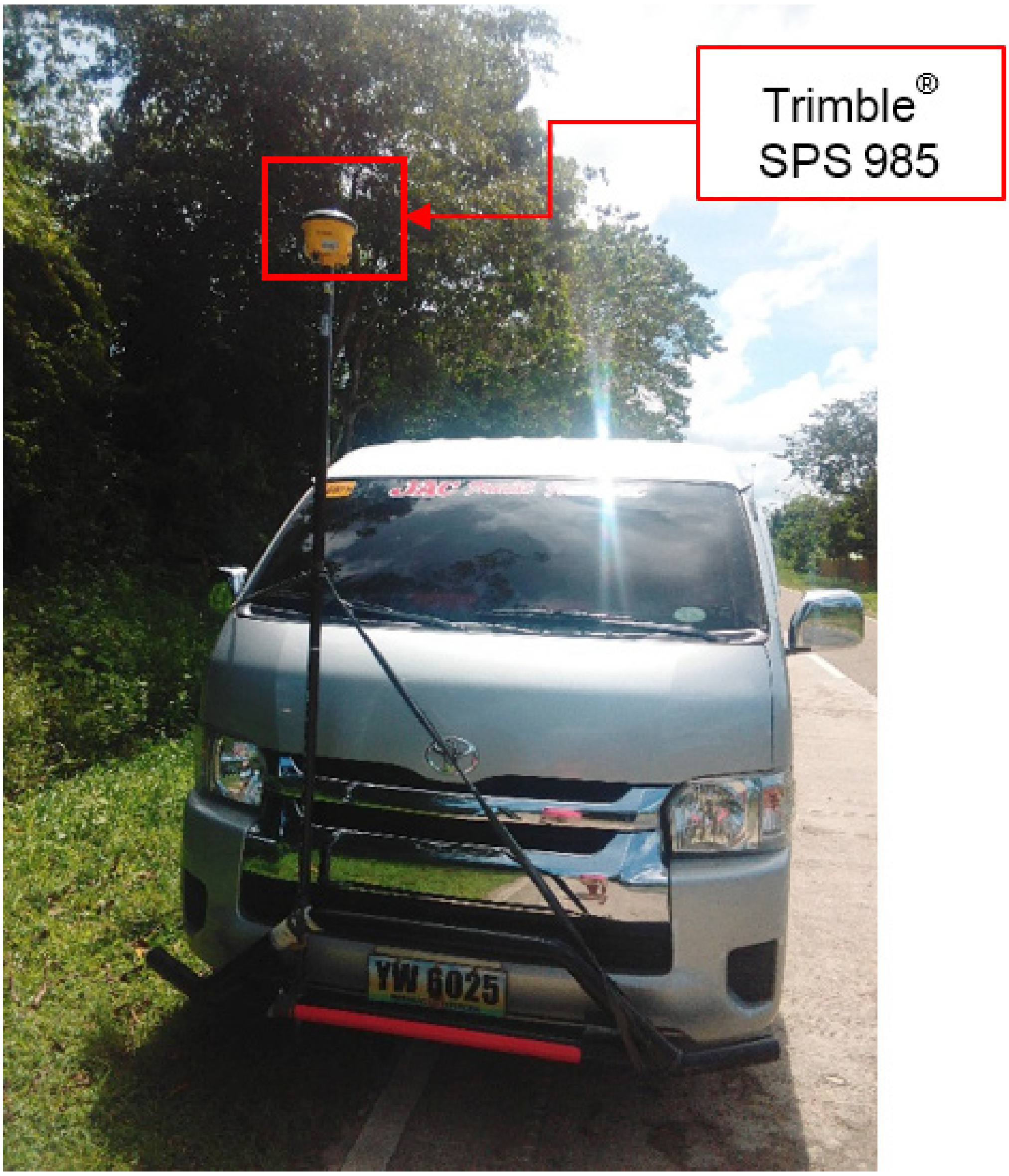


Figure 41. Validation points acquisition survey set-up for Caramay River

The survey started in Brgy. Tagumpay, Municipality of Roxas going south along national highway covering barangays Caramay, Rizal, Salvacion, and ended in Brgy. Nicanor Zabala, Municipality of Roxas, Plawan. A total of 1,635 points with approximate length of 14 km using PLW-3018 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 42.

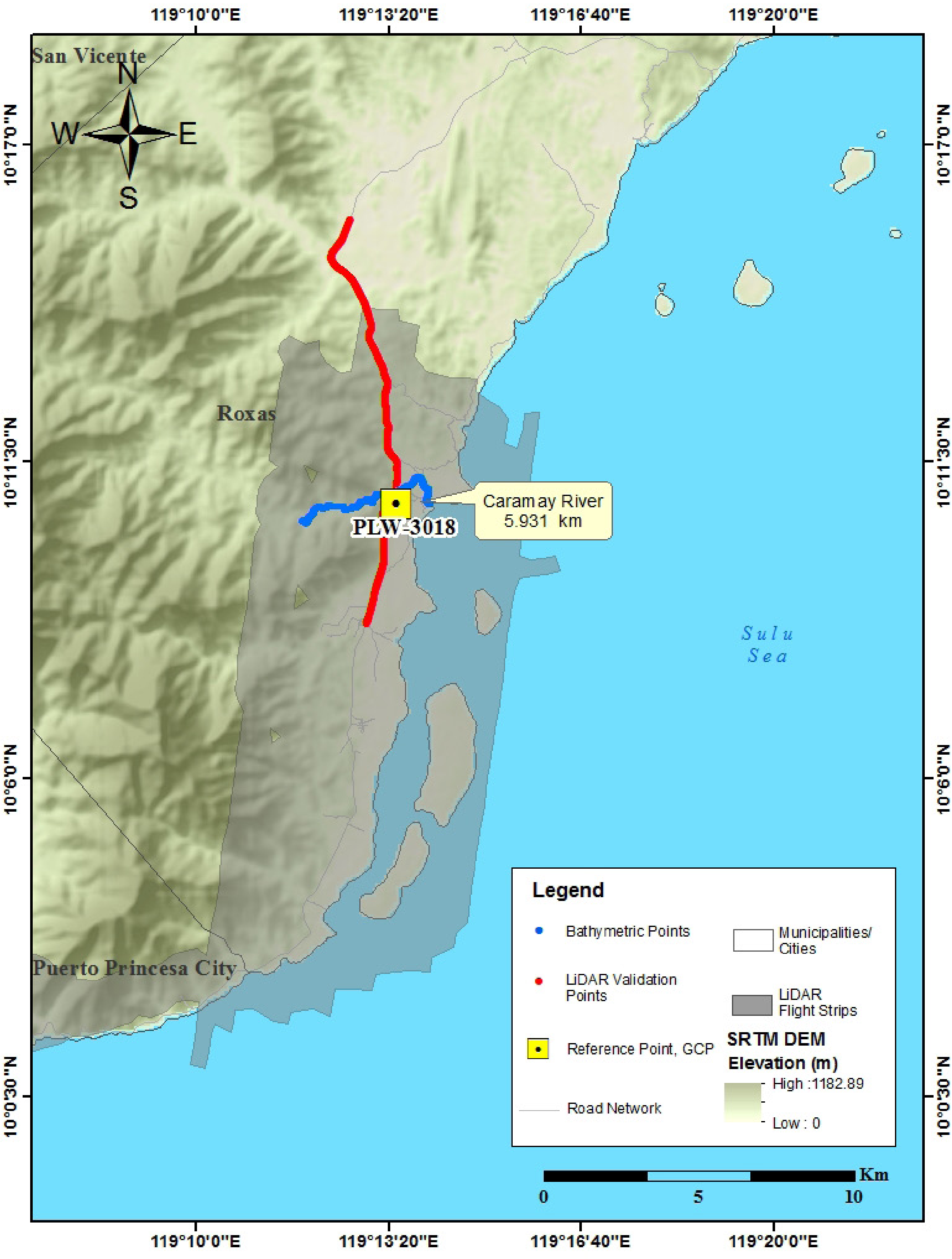


Figure 42. Validation point acquisition survey of Caramay River Basin

4.7 Bathymetric Survey

Manual Bathymetric survey was executed on November 18 and 20, 2016 using Trimble® SPS 985 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 43. It started in Brgy. Caramay, Municipality of Roxas with coordinates 10°10’28.56384”N, 119°11’50.39948”E, traversed down the river by foot and ended at the mouth of the river in the same barangay with coordinates 10°10’46.27159”N, 119°14’02.08970”E. The control points PLW-3018 was used as GNSS base stations all throughout the entire survey.

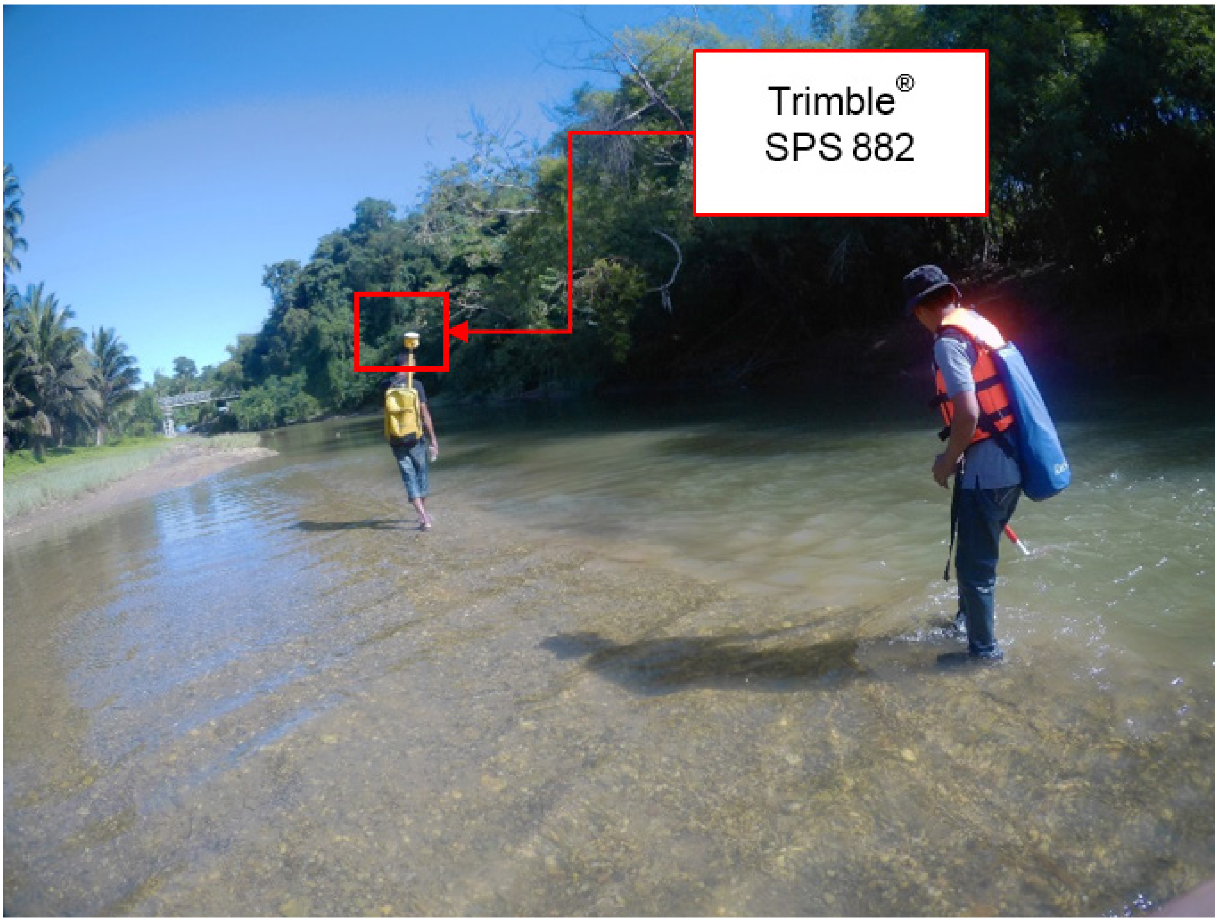


Figure 43. Manual Bathymetric survey using a Trimble® SPS 985 in GNSS PPK survey technique in Caramay River

The bathymetric survey for Caramay River gathered a total of 10,670 points covering 5.931 km of the river traversing Brgy. Caramay, Municipality of Roxas, Palawan (Figure 44).

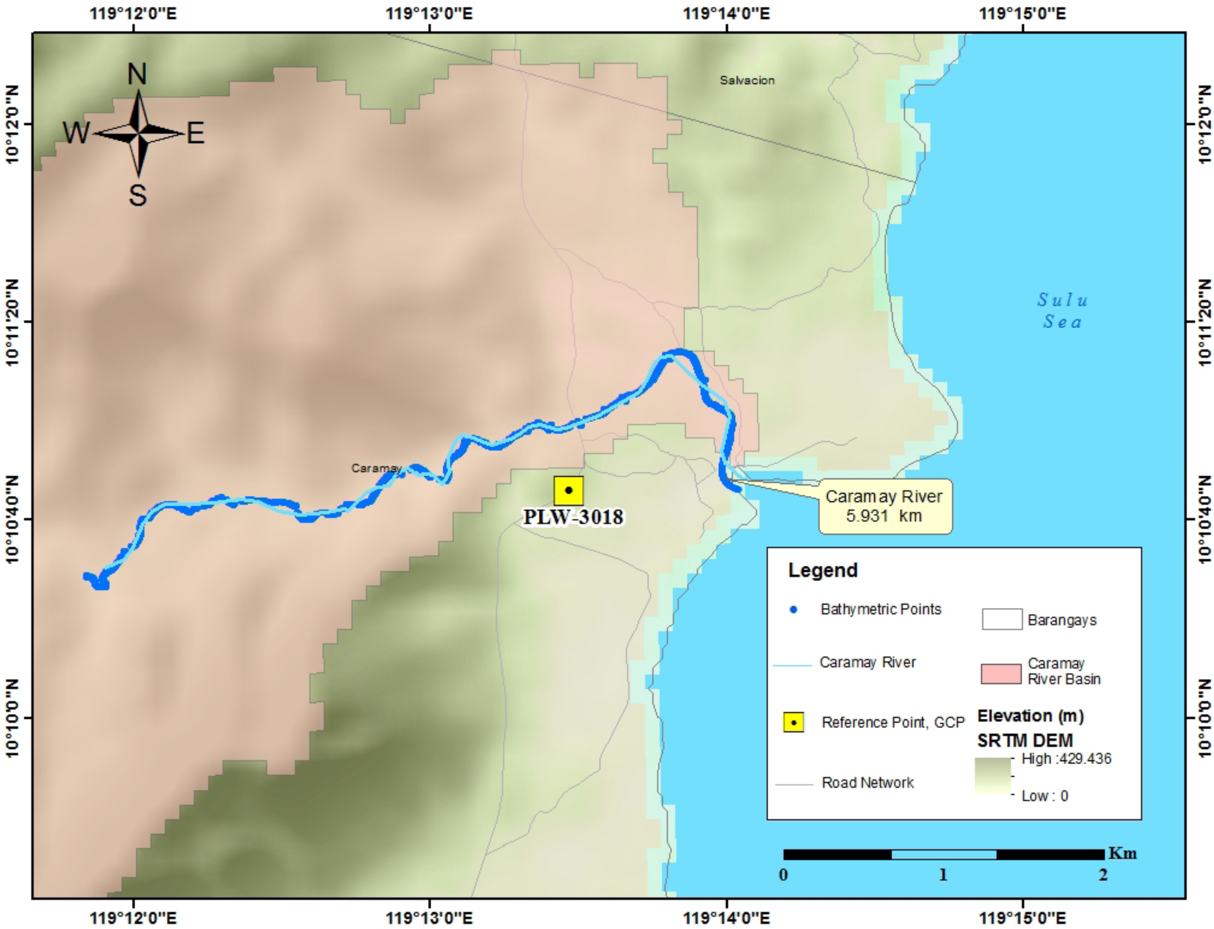


Figure 44. Bathymetric survey of Caramay River

A CAD drawing was also produced to illustrate the riverbed profile of Caramay River. As shown in Figure 45, the highest and lowest elevation has a 11-m difference. The highest elevation observed was 8.664 m above MSL located at the upstream part of the river; while the lowest was –2.465 m below MSL located a kilometer from the river's mouth.

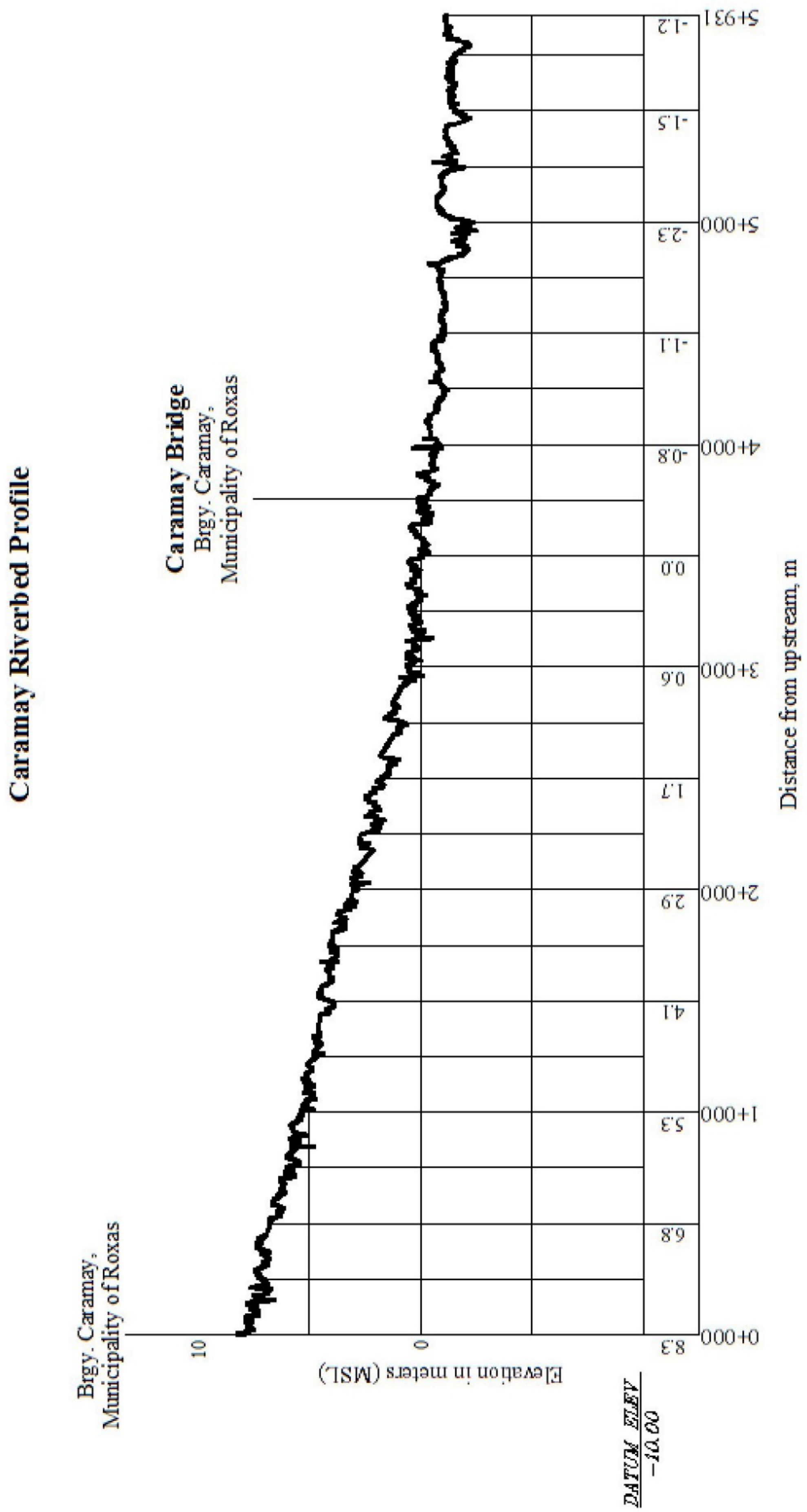


Figure 45. Caramay riverbed profile

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, and Kevin M. Manalo

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

5.1 Data used in Hydrologic Modeling

No gathered rainfall data for Caramay 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 Puerto Princesa 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 Caramay watershed. The extreme values for this watershed were computed based on a 58-year record, with the computed extreme values shown in Table 26.

Table 26. RIDF values for Puerto Princesa 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	14.8	22	27.3	36.2	49.8	58.8	75.1	88	104.1
5	21.3	31.9	39.7	52.3	73	86.9	112.8	135.4	156.4
10	25.6	38.5	48	63	88.4	105.5	137.8	166.8	191.1
15	28.1	42.2	52.6	69	97	116	151.9	184.5	210.6
20	29.8	44.7	55.9	73.3	103.1	123.4	161.7	196.8	224.3
25	31.1	46.7	58.4	76.5	107.8	129.1	169.3	206.4	234.9
50	35.2	52.9	66.1	86.5	122.2	146.5	192.7	235.8	267.3
100	39.2	59	73.7	96.4	136.5	163.8	216	265	299.6

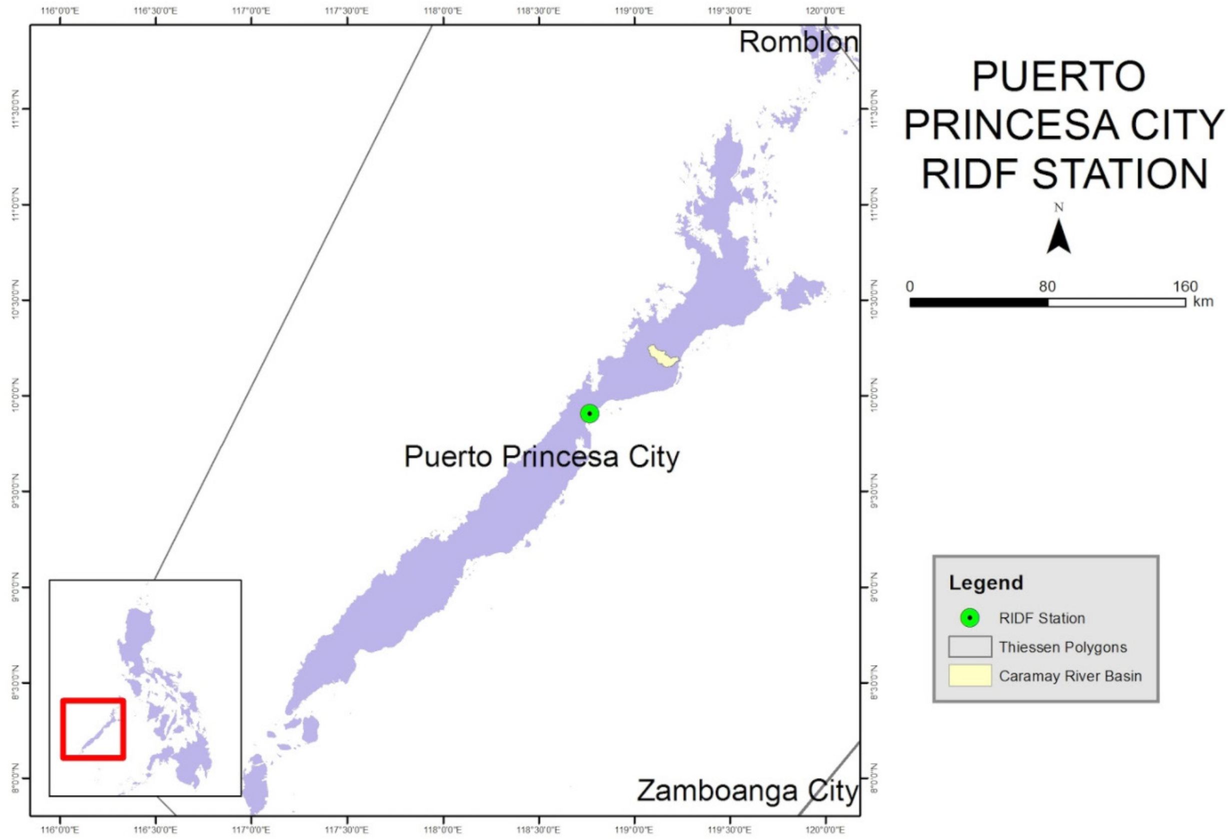


Figure 46.Location of Puerto Princesa RIDF relative to Caramay River Basin

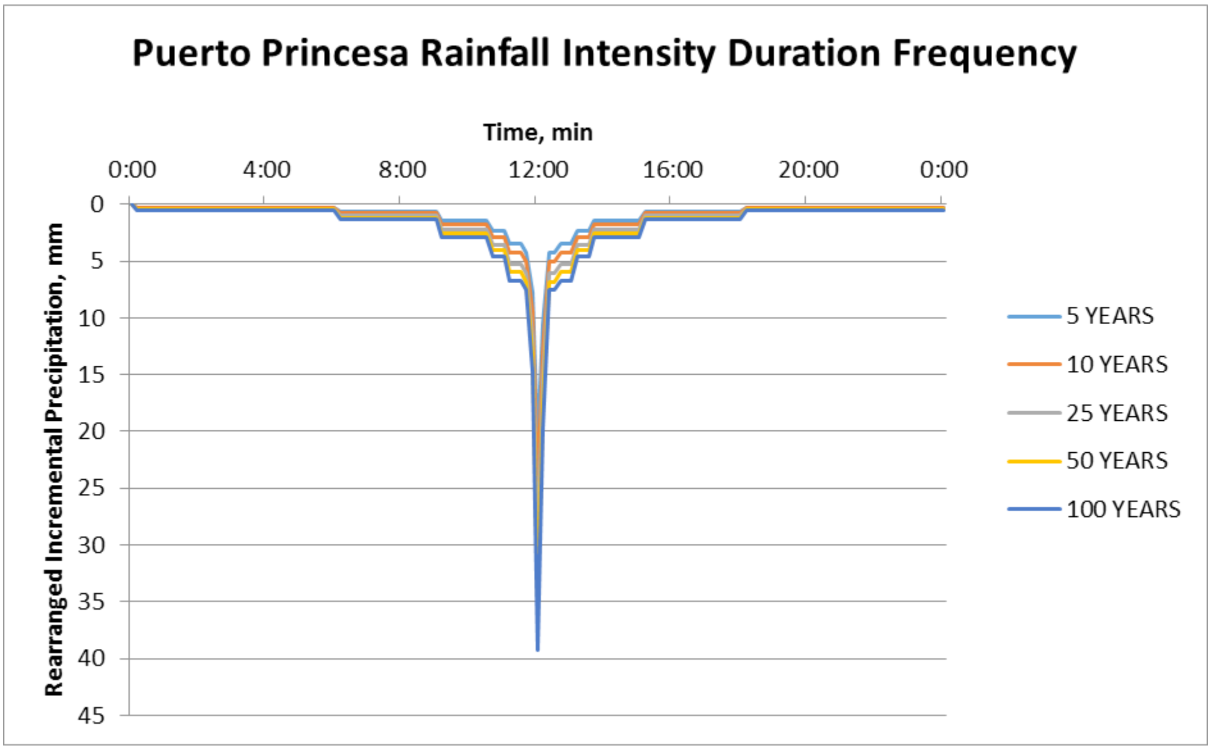


Figure 47. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Caramay River Basin are shown in Figure 48 and Figure 49, respectively.

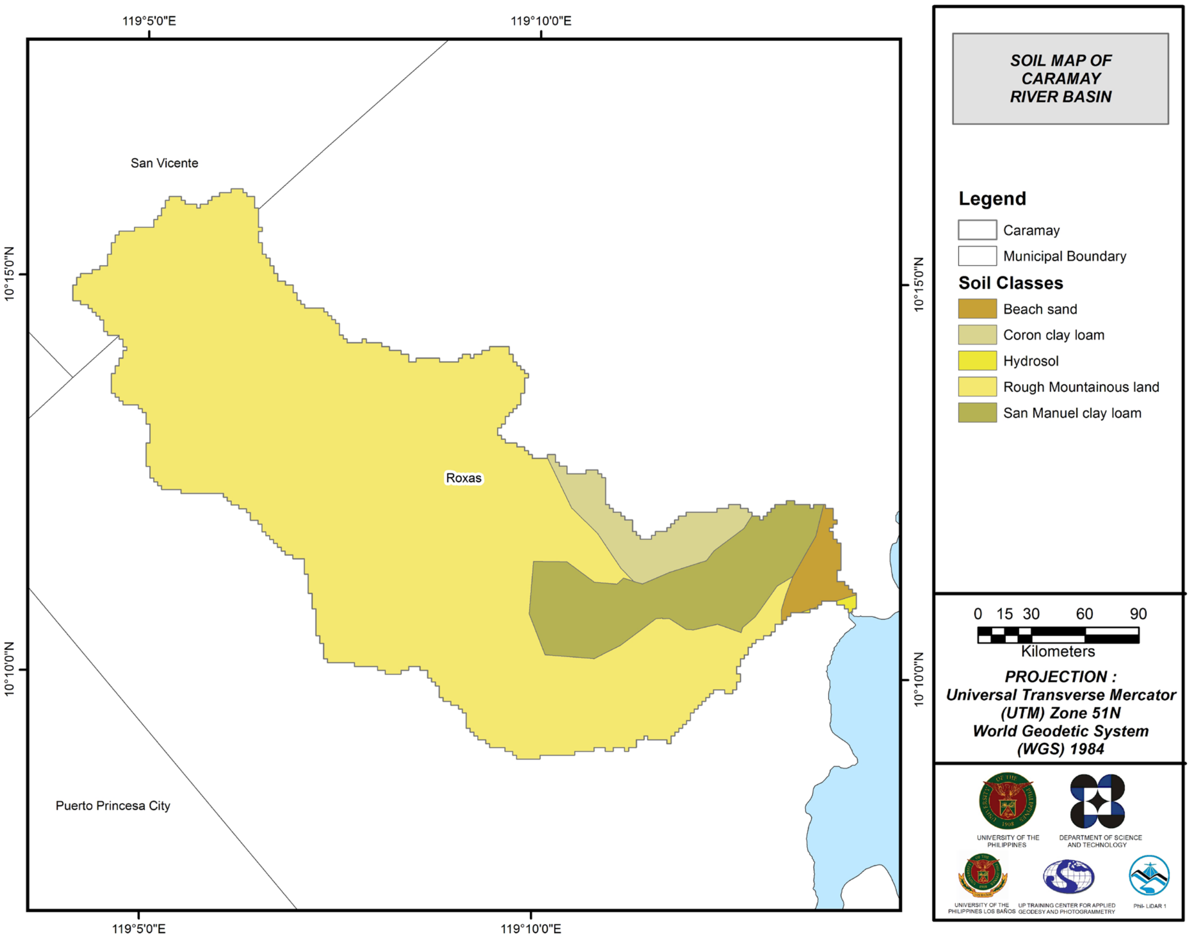


Figure 48. Soil map of Caramay River Basin used for the estimation of the CN parameter. (Source: DA)

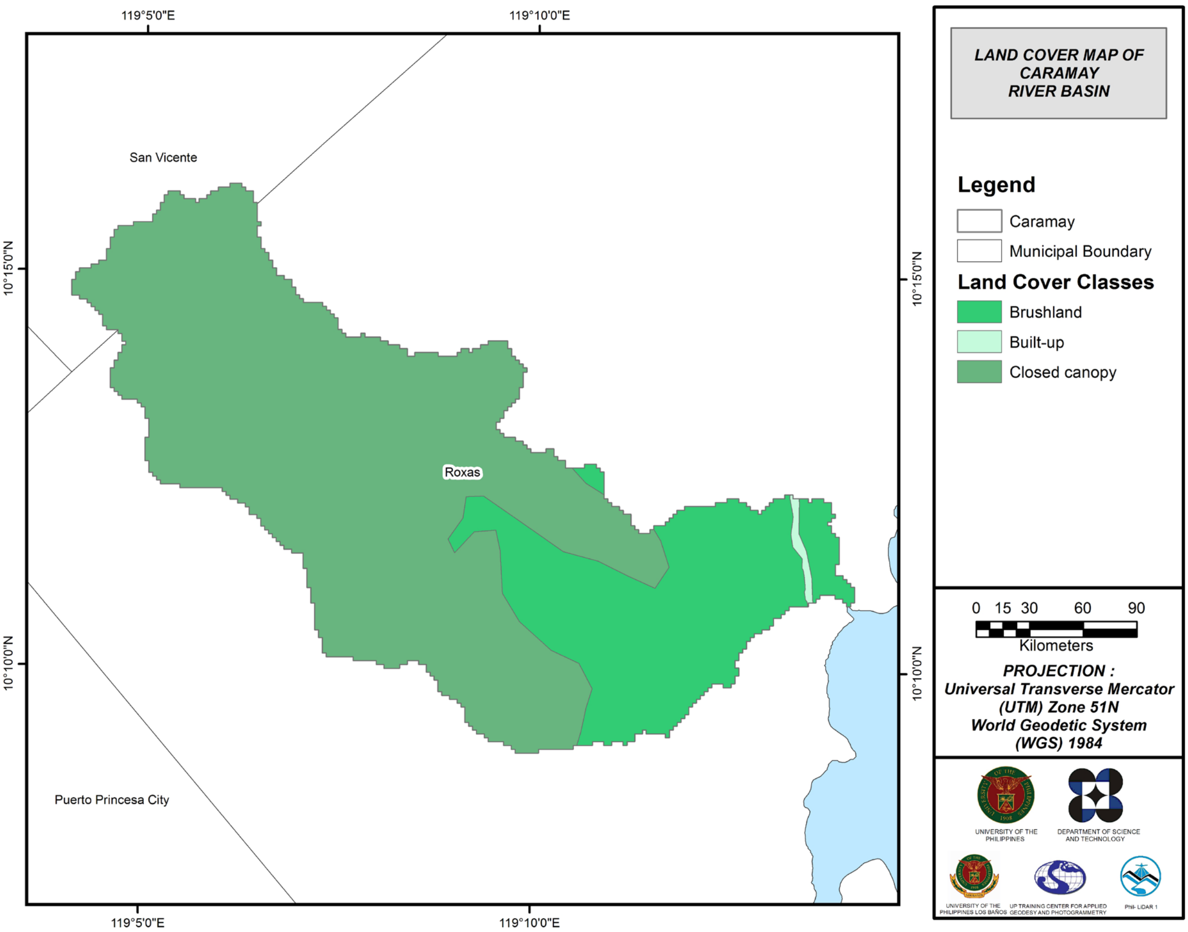


Figure 49. Land cover map of Caramay River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Caramay river basin, five (5) soil classes were identified. The river basin area is largely rough mountainous land, with portions of San Manuel clay loam, Coron clay loam, beach sand, and hydrosol. Moreover, the three (3) land cover types identified were closed canopy, brushland, and built-up area.

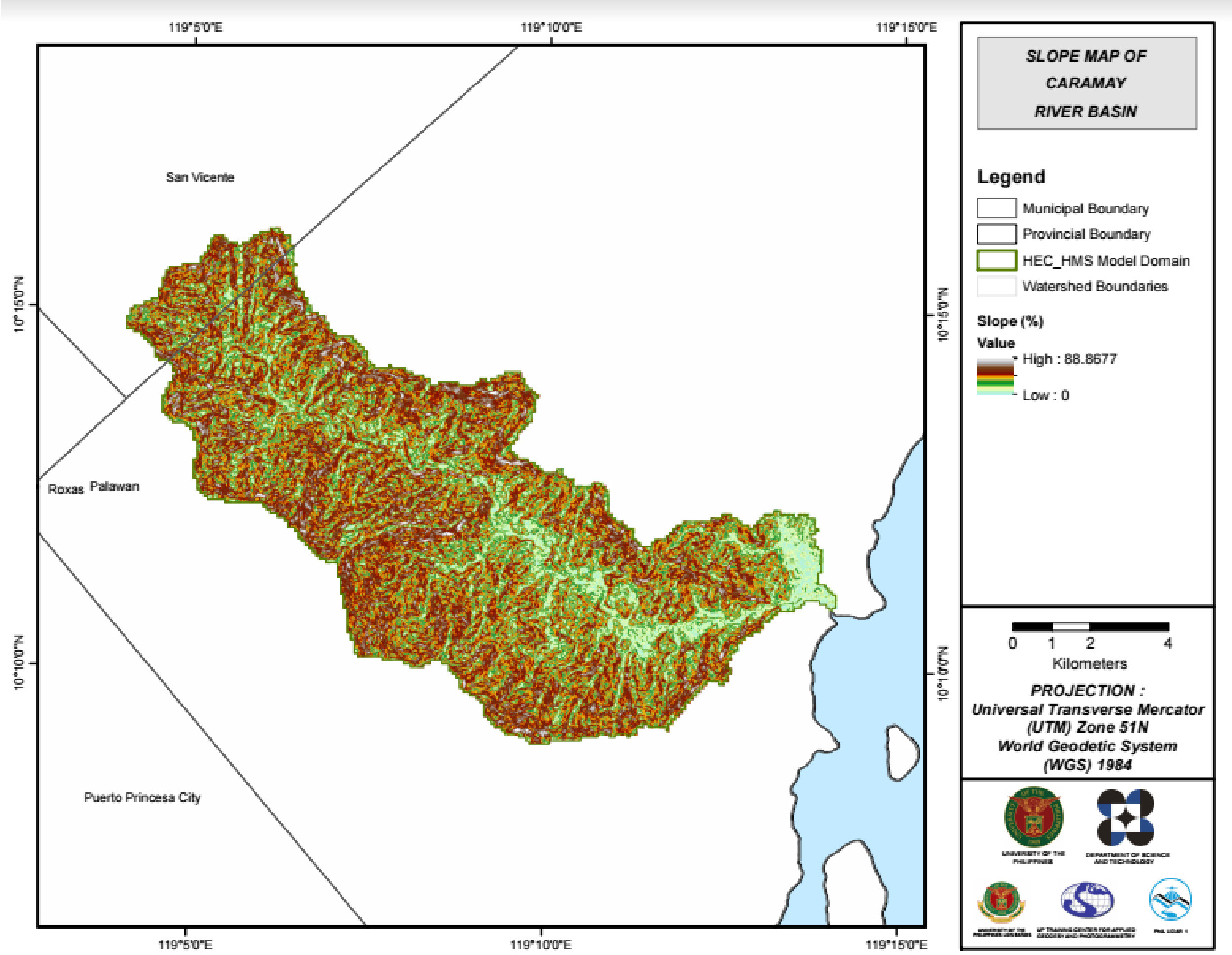


Figure 50. Slope map of Caramay River Basin

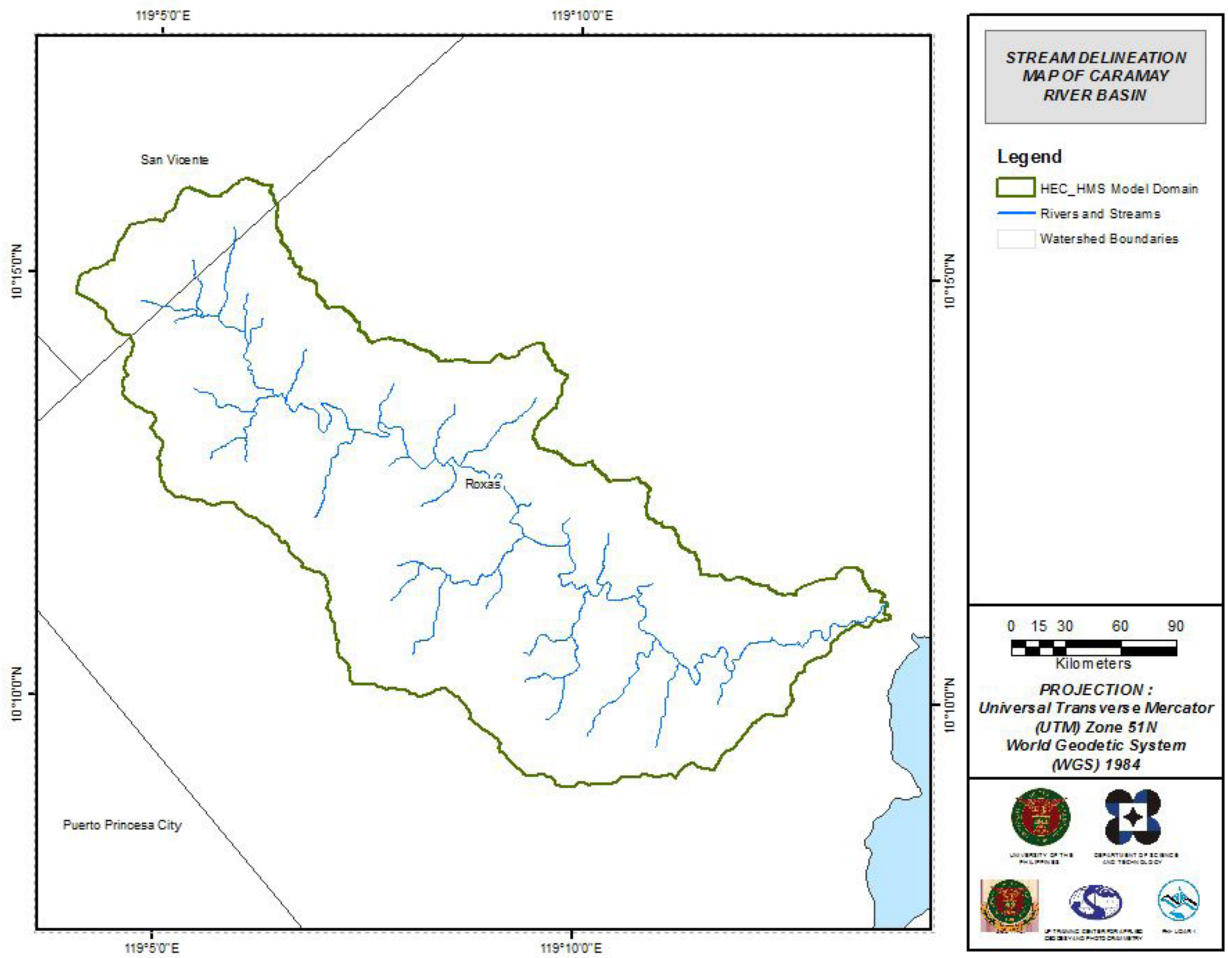


Figure 51. Stream delineation map of Caramay River Basin

Using SAR-based DEM, the Caramay basin was delineated and further subdivided into subbasins. The model consists of 64 sub basins, 31 reaches, and 30 junctions. The main outlet is labelled as 90. This basin model is illustrated in Figure 52. The basins were identified based on soil and land cover characteristics of the area.

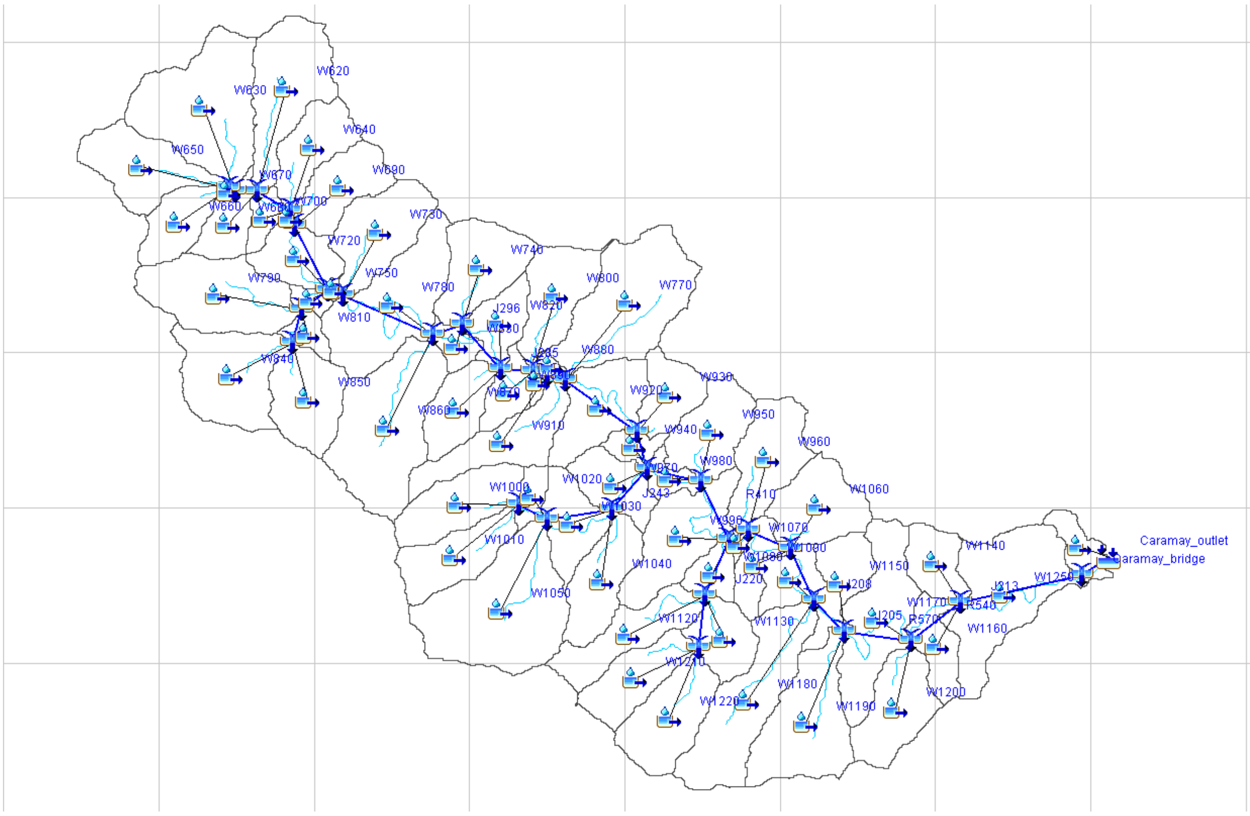


Figure 52. HEC-HMS generated Caramay River Basin Model.

5.4 Cross-section Data

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

[PLACEHOLDER FOR FIGURE 53]

Figure 53. River cross-section of Caramay River generated through Arcmap HEC GeoRAS tool

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 west of the model to the east, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

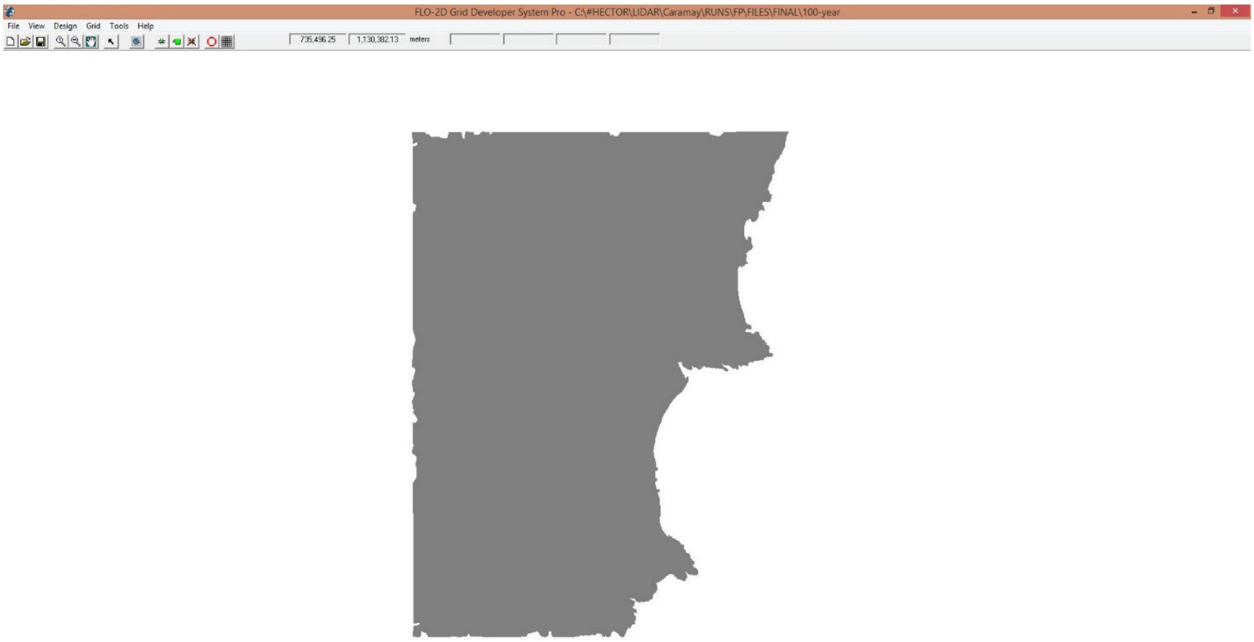


Figure 54. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 62.10889 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 m^2/s.

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 42 550 500.00 m^2.

There is a total of 44 398 597.41 m^3 of water entering the model. Of this amount, 13 786 789.76 m^3 is due to rainfall while 30 611 807.65 m^3 is inflow from other areas outside the model. 3 832 964.25 m^3 of this water is lost to infiltration and interception, while 4 748 953.07 m^3 is stored by the flood plain. The rest, amounting up to 35 816 663.38 m^3, is outflow.

5.6 HEC-HMS Model Values (Uncalibrated)

Enumerated in Table 27 are the range of values of the parameters in the model.

Table 27. Range of calibrated values for Caramay River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5 - 14
			Curve Number	48 - 73
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.2 - 2
			Storage Coefficient (hr)	0.3 - 4

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 5 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 48 to 73 for curve number is slightly lower than the range of advisable values 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 0.2 hours to 4 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 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Abongan River using the calibrated HMS base flow is shown in Figure 55.

Figure 55. Sample output of Caramay RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Caramay floodplain are shown in Figure 56 to Figure 61. The floodplain, with an area of 1007.73 sq. km., covers one municipality named Roxas. Table 28 shows the percentage of area affected by flooding per municipality.

Table 28. Municipalities affected in Caramay Floodplain

Municipality	Total Area (sq. km)	Area Flooded (sq. km.)	% Flooded
Roxas	1007.73	42.48	4.22

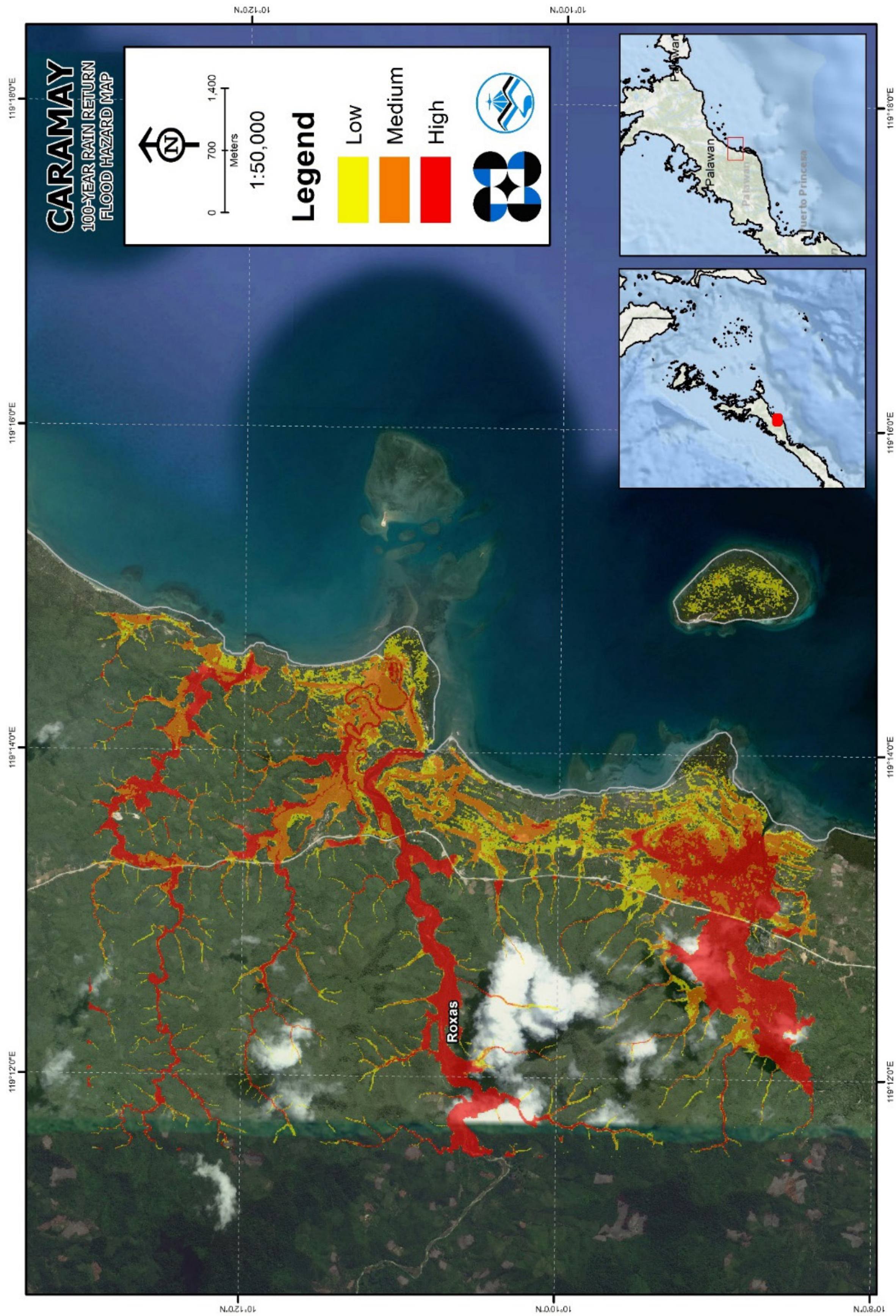


Figure 56. 100-year Flood Hazard Map for Caramay Floodplain overlaid on Google Earth imagery

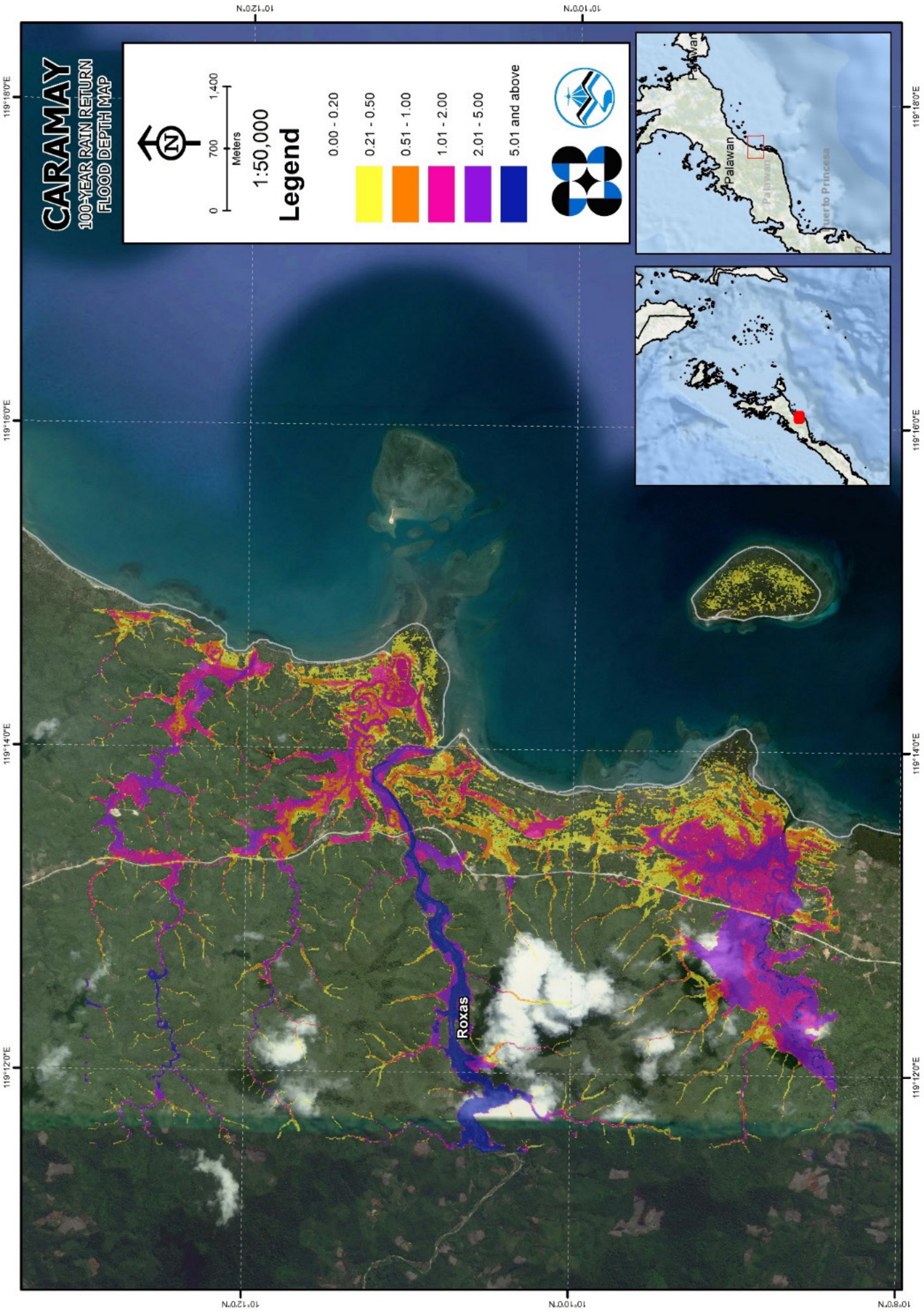


Figure 57. 100-year Flow Depth Map for Caramay Floodplain overlaid on Google Earth imagery

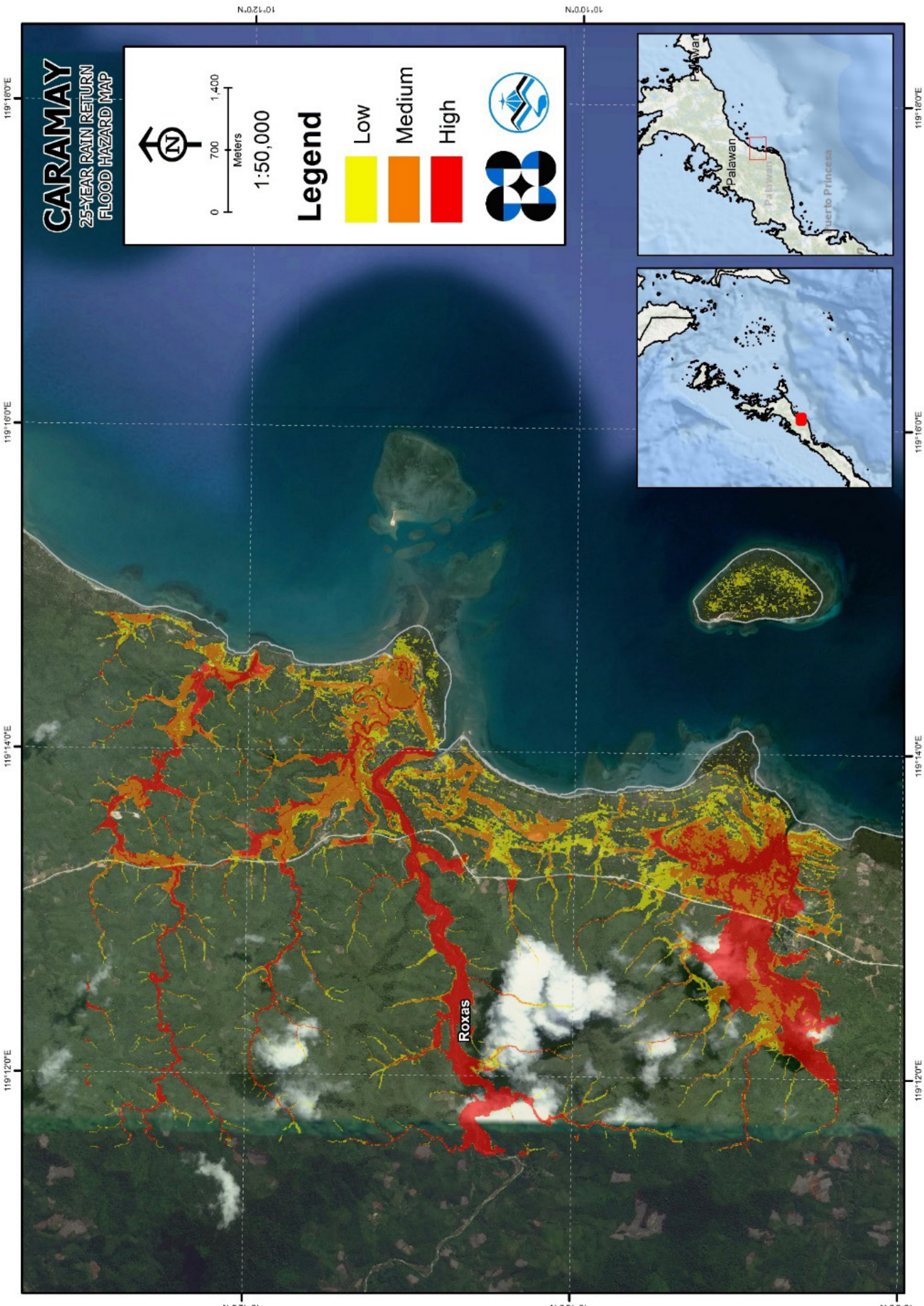


Figure 58. 25-year Flood Hazard Map for Caramay Floodplain overlaid on Google Earth imagery

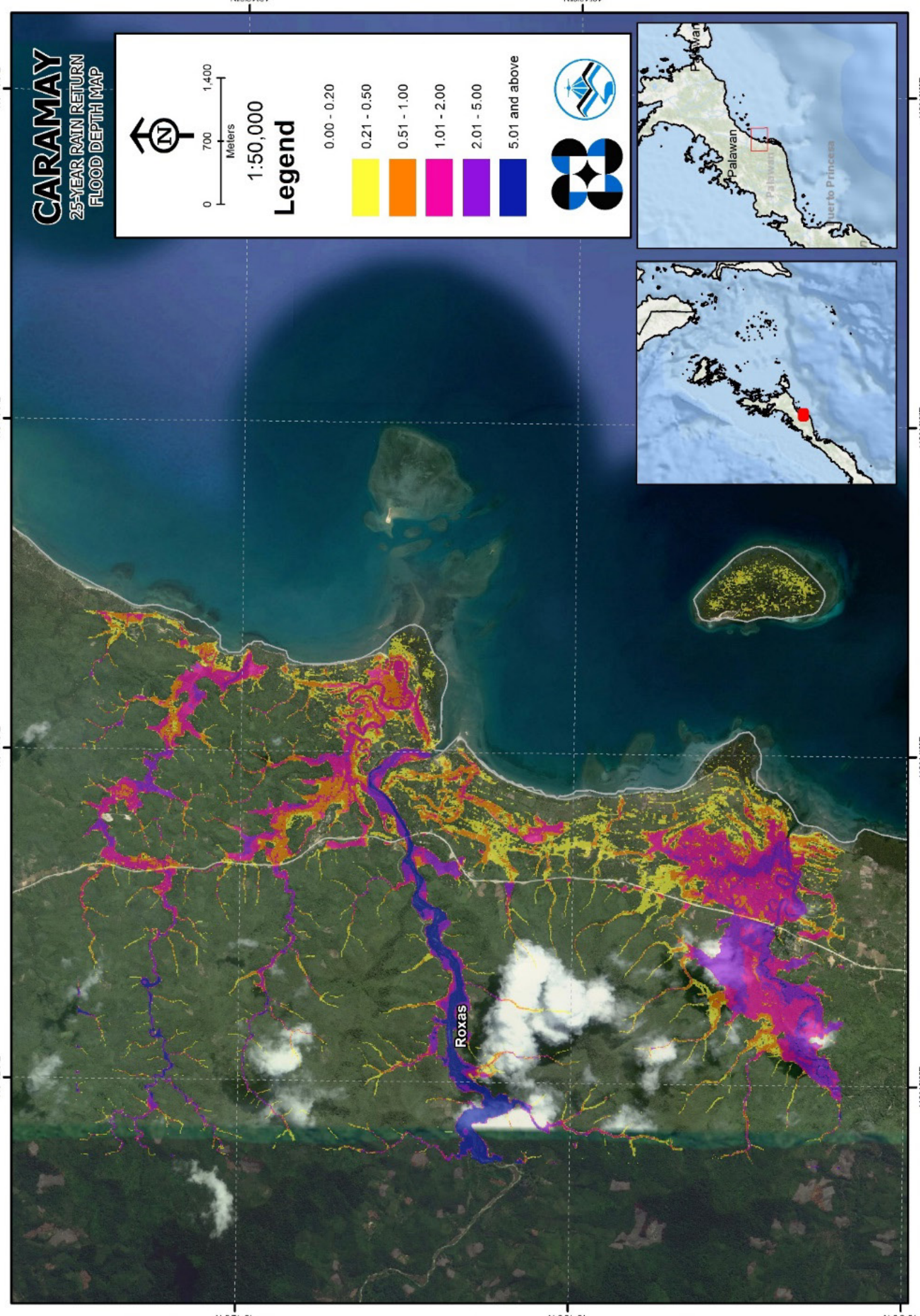


Figure 59. 25-year Flow Depth Map for Caramay Floodplain overlaid on Google Earth imagery

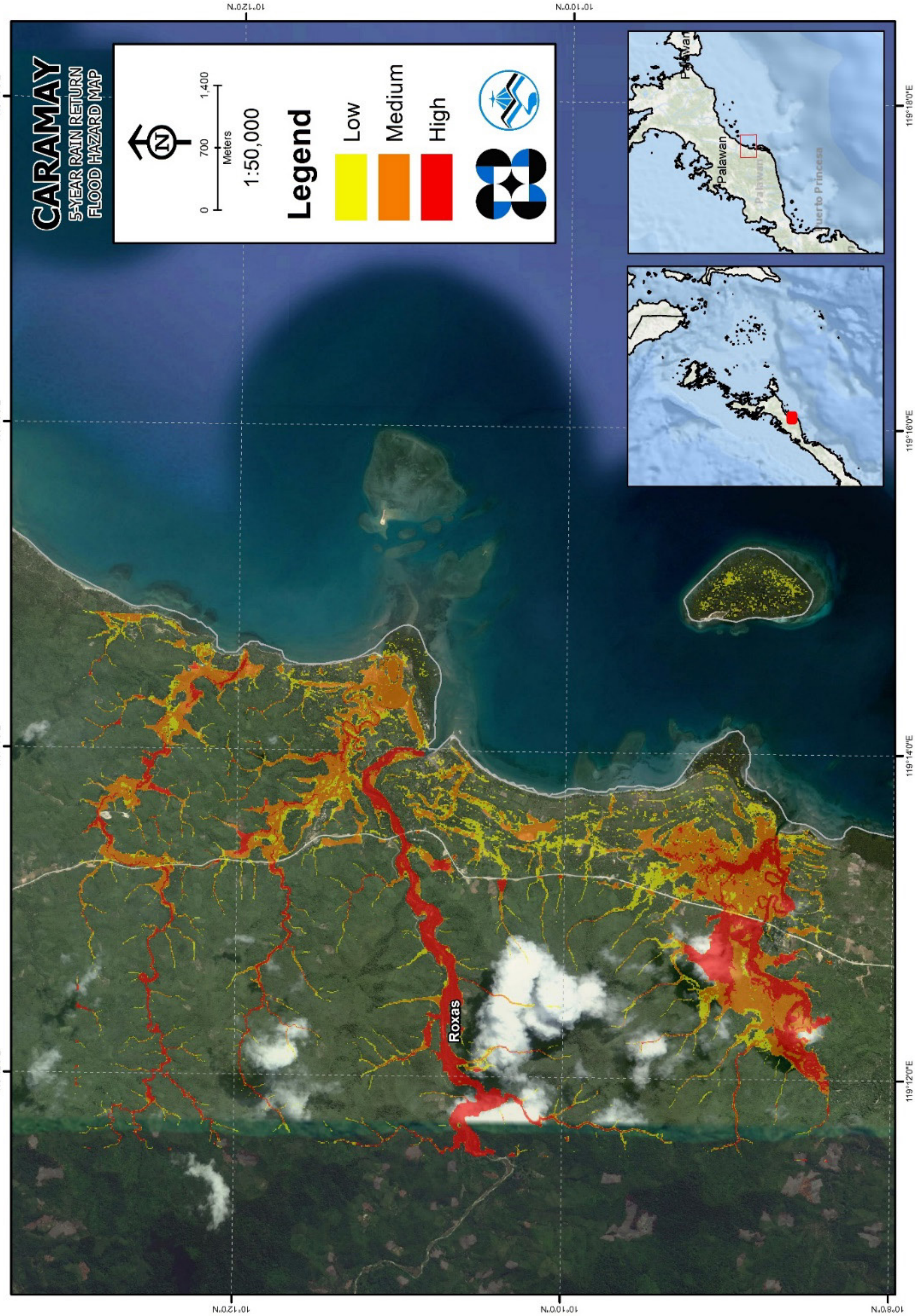


Figure 60. 5-year Flood Hazard Map for Caramay Floodplain overlaid on Google Earth imagery

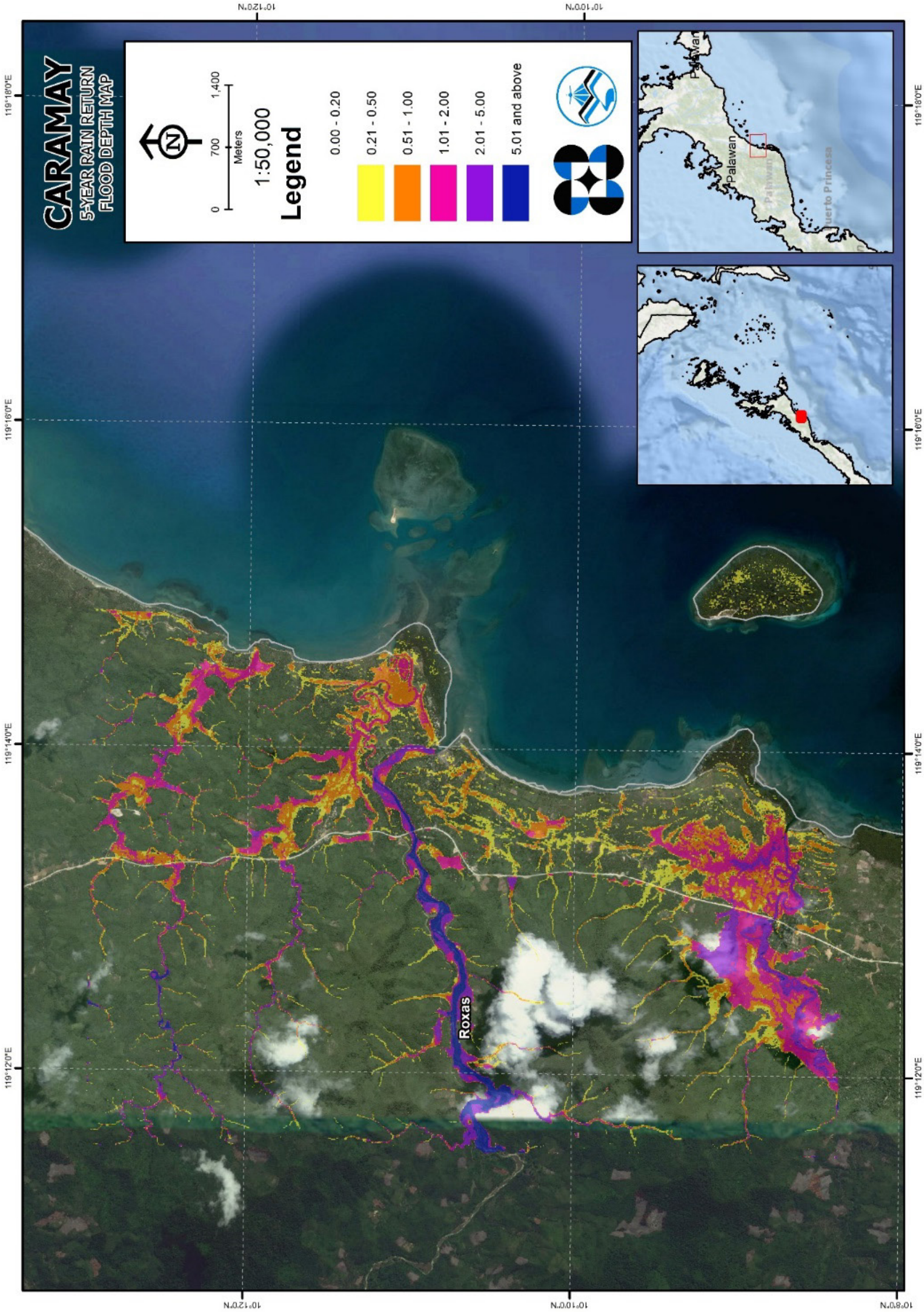


Figure 61. 5-year Flood Depth Map for Caramay Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Caramay River Basin, grouped accordingly by municipality. For the said basin, one (1) municipality consisting of 4 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 3.38% of the municipality of Roxas with an area of 1007.73 sq. km. will experience flood levels of less 0.20 meters, while 0.23% of the area will experience flood levels of 0.21 to 0.50 meters; 0.23%, 0.22%, 0.11%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 29 and Figure 62 depict the areas affected in Roxas in square kilometers by flood depth per barangay.

Table 29. Affected areas in Roxas, Palawan during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Roxas (in sq. km.)			
	Caramay	Magara	Nicanor Zabala	Salvacion
0.03-0.20	23.85	0.35	3.31	6.56
0.21-0.50	1.64	0.0077	0.31	0.31
0.51-1.00	1.38	0.004	0.53	0.44
1.01-2.00	0.96	0.006	0.85	0.41
2.01-5.00	0.6	0.0065	0.46	0.065
> 5.00	0.39	0	0.0093	0.023

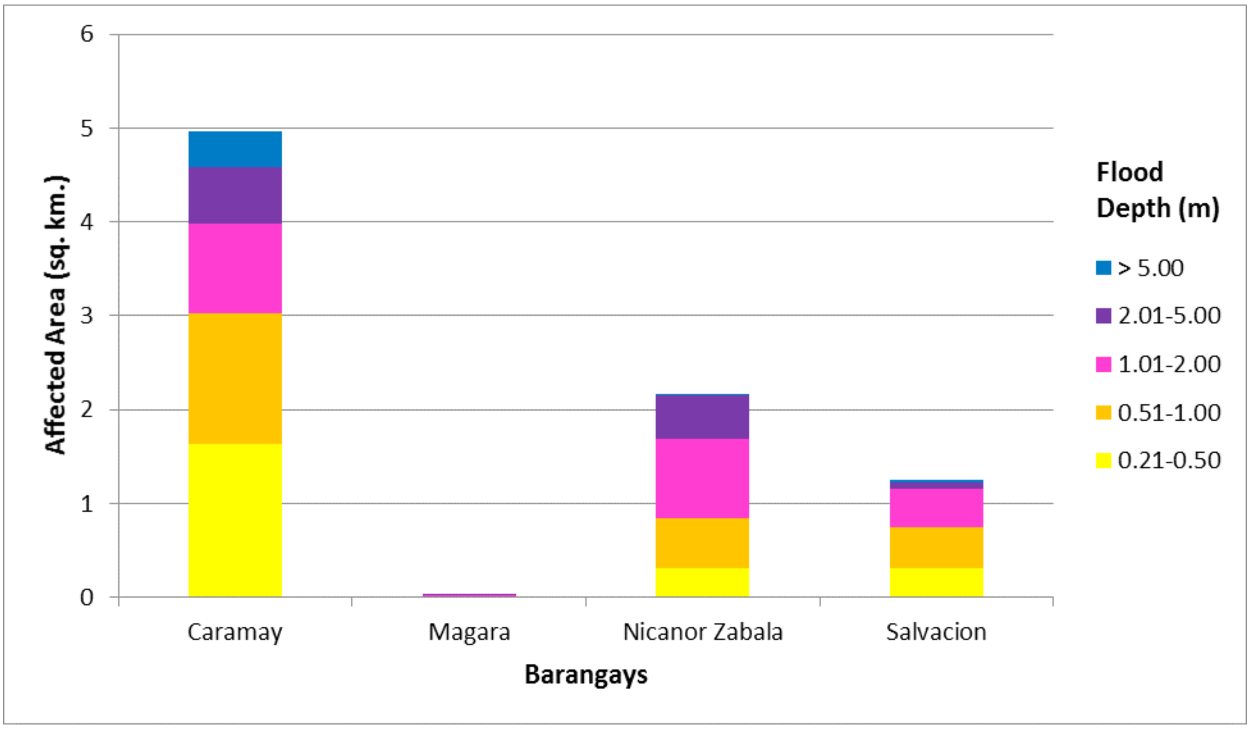


Figure 62. Affected areas in Roxas, Palawan during a 5-Year Rainfall Return Period.

For the 25-year return period, 3.21% of the municipality of Roxas with an area of 1007.73 sq. km. will experience flood levels of less 0.20 meters, while 0.25% of the area will experience flood levels of 0.21 to 0.50 meters; 0.22%, 0.29%, 0.18%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 30 and Figure 63 depict the areas affected in Roxas in square kilometers by flood depth per barangay.

Table 30. Affected areas in Roxas, Palawan during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Roxas (in sq. km.)			
	Caramay	Magara	Nicanor Zabala	Salvacion
0.03-0.20	22.57	0.35	3.08	6.38
0.21-0.50	1.98	0.0072	0.29	0.28
0.51-1.00	1.47	0.0048	0.34	0.36
1.01-2.00	1.44	0.0056	0.93	0.55
2.01-5.00	0.78	0.0083	0.81	0.19
> 5.00	0.58	0.0009	0.027	0.031

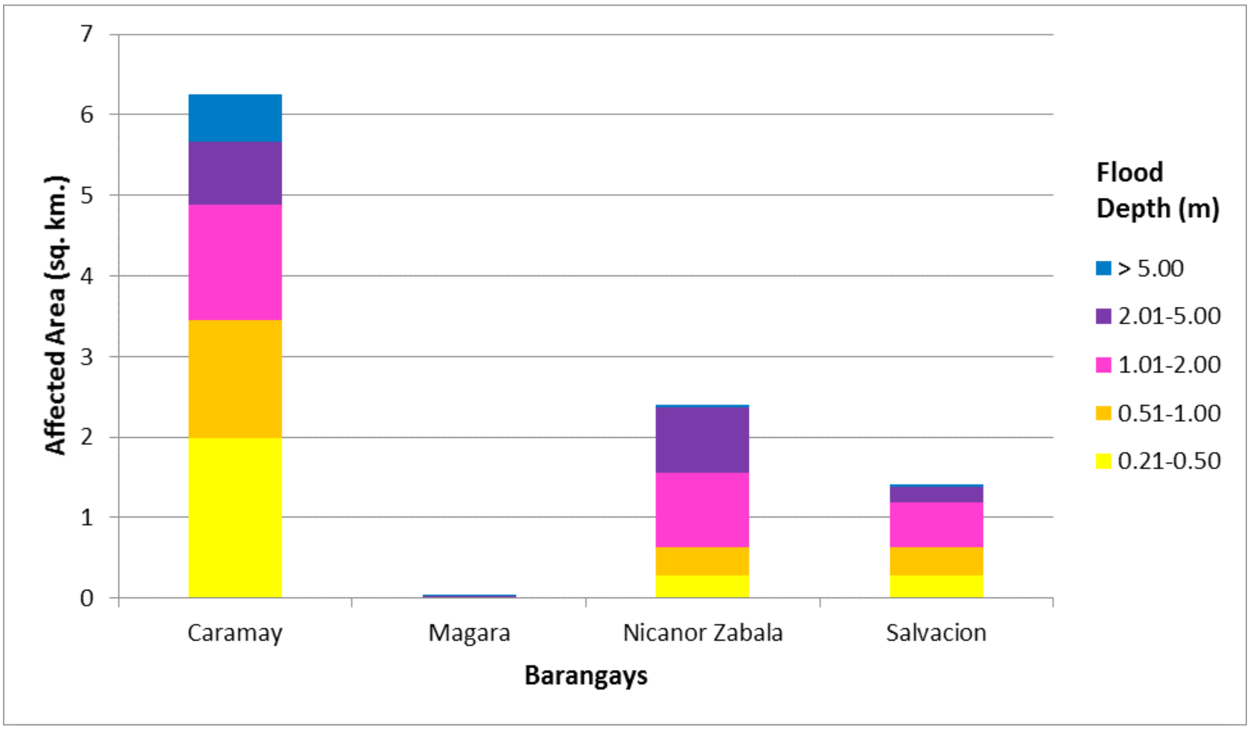


Figure 63. Affected areas in Roxas, Palawan during a 25-Year Rainfall Return Period.

For the 100-year return period, 3.1% of the municipality of Roxas with an area of 1007.73 sq. km. will experience flood levels of less 0.20 meters, while 0.28% of the area will experience flood levels of 0.21 to 0.50 meters; 0.22%, 0.31%, 0.23%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 31 and Figure 64 depict the areas affected in Roxas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Roxas, Palawan during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Roxas (in sq. km.)			
	Caramay	Magara	Nicanor Zabala	Salvacion
0.03-0.20	21.69	0.35	2.96	6.27
0.21-0.50	2.24	0.0062	0.28	0.27
0.51-1.00	1.56	0.0062	0.34	0.3
1.01-2.00	1.68	0.0052	0.81	0.6
2.01-5.00	0.96	0.01	1.05	0.32
> 5.00	0.69	0.0012	0.04	0.038

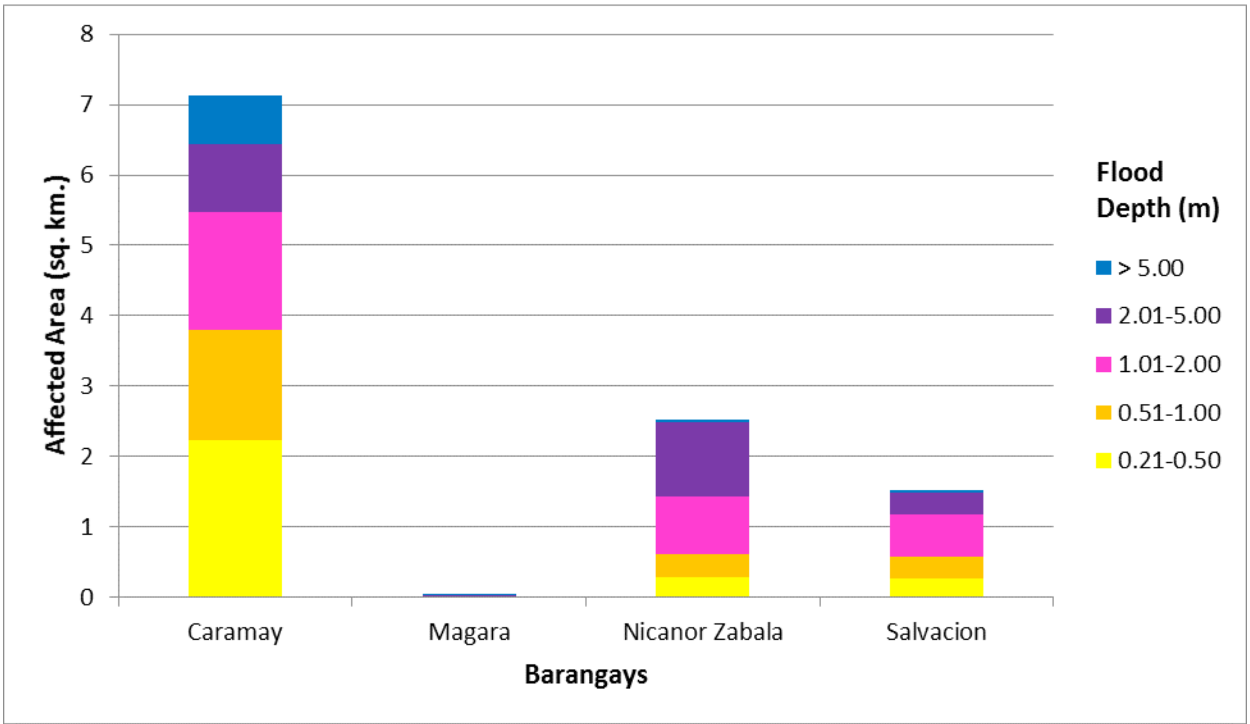


Figure 64. Affected areas in Roxas, Palawan during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Roxas, Caramay is projected to have the highest percentage of area that will experience flood levels of at 2.86%. On the other hand, Salvacion posted the percentage of area that may be affected by flood depths of at 0.77%.

5.11 Flood Validation

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

From the Flood Depth Maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios 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 a local DRRM office to obtain maps or situation reports about the past flooding events and through interviews with some residents who have knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field was 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 66.

The flood validation consisted of 49 points randomly selected all over the Caramay floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.67m. Table 32 shows a contingency matrix of the comparison.

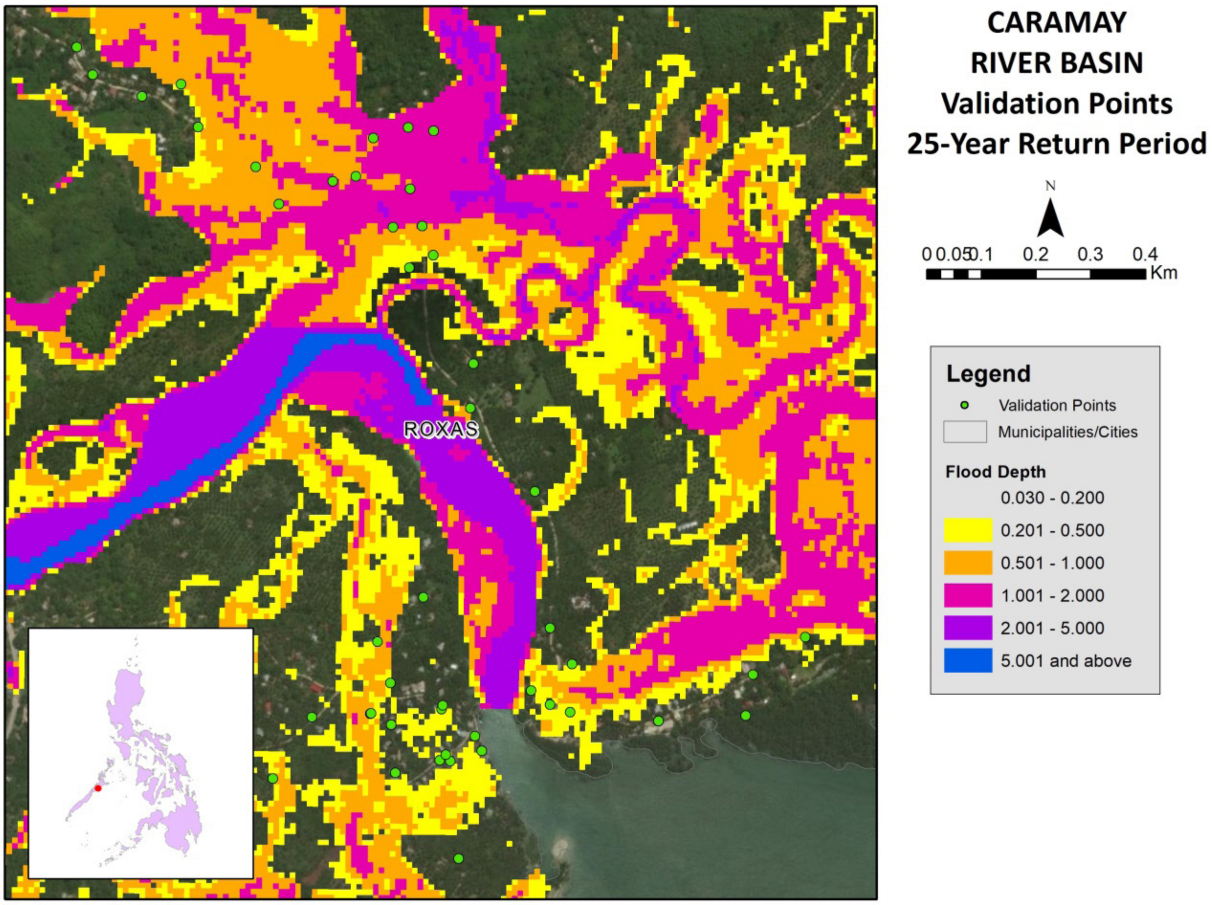


Figure 65. Validation points for 25-year Flood Depth Map of Caramay Floodplain

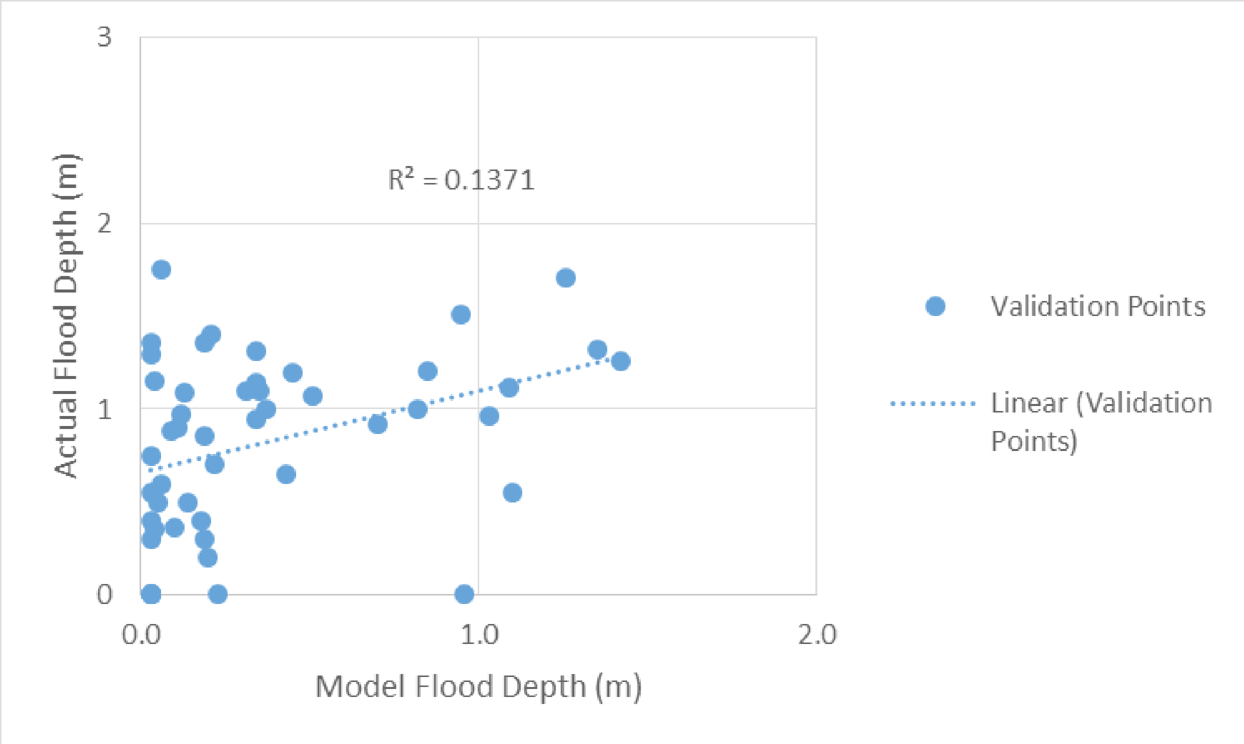


Figure 66. Flood map depth vs. actual flood depth

Table 32. Actual flood vs simulated flood depth at different levels in the Caramay 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	5	1	1	0	0	0	7
0.21-0.50	8	0	0	0	0	0	8
0.51-1.00	7	4	2	2	0	0	15
1.01-2.00	6	6	3	4	0	0	19
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	26	11	6	6	0	0	49

The overall accuracy generated by the flood model is estimated at 22.45% with 11 points correctly matching the actual flood depths. In addition, there were 14 points estimated one level above and below the correct flood depths while there were 14 points and 6 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 Caramay. Table 33 depicts the summary of the Accuracy Assessment in the Caramay River Basin Survey.

Table 33. Summary of the Accuracy Assessment in the Caramay River Basin Survey

	No. of Points	%
Correct	11	22.45
Overestimated	4	8.16
Underestimated	34	69.39
Total	49	**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

Palawan Council on Sustainable Development (PCSD), 2015, Our Palawan, retrieved from <http://pcsd.gov.ph/OurPalawanJournal/OUR%20PALAWAN.pdf>

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

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ANNEXES

Annex 1. Optech Technical Specification of the Gemini Sensor

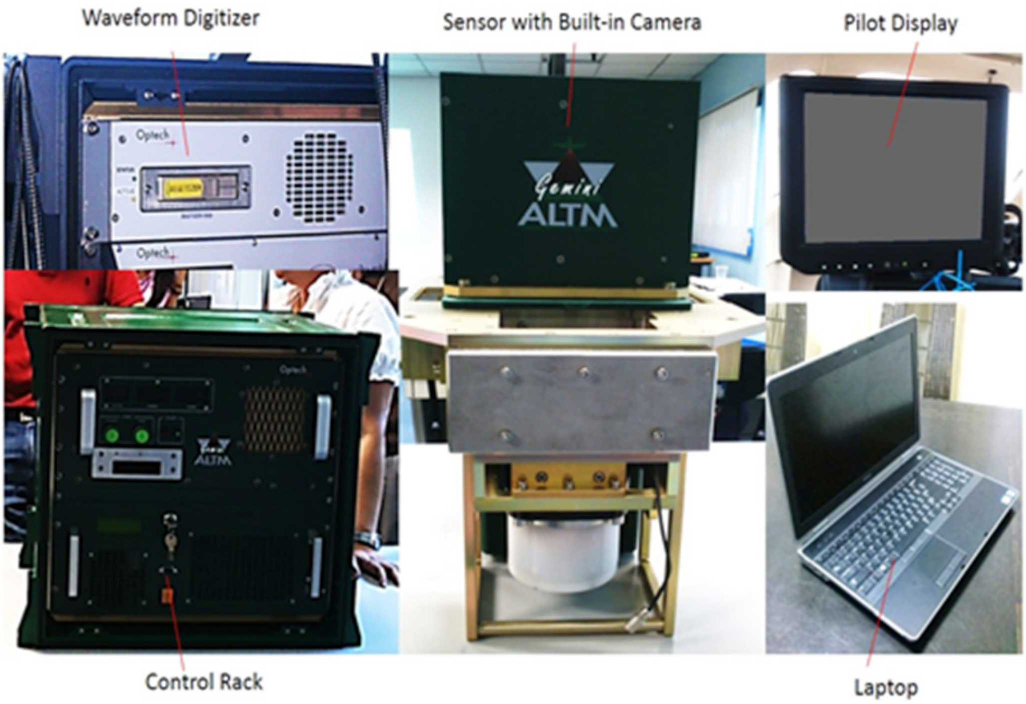


Figure A-1.1 Gemini Sensor

Table A-1.1 Parameters and Specifications of the Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)

Parameter	Specification
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

PLW-23

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

December 02, 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: **PALAWAN**
Station Name: **PLW-23**
Order: **1st**

Island: **LUZON**
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**
Barangay: **JOLO**
MSL Elevation:

PRS92 Coordinates

Latitude:	10° 5' 19.52517"	Longitude:	119° 12' 33.72062"	Ellipsoidal Hgt:	10.42700 m.

WGS84 Coordinates

Latitude:	10° 5' 15.04804"	Longitude:	119° 12' 39.01413"	Ellipsoidal Hgt:	61.07260 m.

PTM / PRS92 Coordinates

Northing:	1115630.596 m.	Easting:	577752.254 m.	Zone:	1A

UTM / PRS92 Coordinates

Northing:	1,115,973.89	Easting:	742,130.31	Zone:	50

Location Description

PLW-23
From the municipality of Roxas, on the intersection at Andres Soriano Memorial Elementary School, travel southwest along the provincial highway for 39.3 kilometers or 1 hour and 25 minutes drive to Jolo elementary School. The station is located inside the compound of Jolo elementary school. It is Norhtwest 10.00 meters of the school building. Station mark is a cross cut on top of a 0.15 m x 0.012 m in diameter brass rod centered in a 0.30 m x 0.30 m x 1.0 m concrete block, flush with the ground surface and inscribed with station name. Sub-surface mark is a bottle set on concrete block; 68 cm. below station. Reference mark nos. 1,2,3 and 4 are cross cut on top of 0.15 m x 0.01 m in diameter brass rod in a 0.30 m x 0.30 m x 1 meter concrete block, flush with the ground surface, and inscribed with the reference mark numbers and with arrows pointing to the station.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088735 I**
T.N.: **2015-3960**

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

9912022015105654

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. PLW-23

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

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
PLW-23 --- PLW-4030 (B1)	PLW-23	PLW-4030	Fixed	0.001	0.002	205°42'51"	769.753	0.756
PLW-23 --- PLW-4030 (B2)	PLW-23	PLW-4030	Fixed	0.001	0.002	205°42'52"	769.751	0.758
PLW-23 --- PL-267 (B3)	PLW-23	PL-267	Fixed	0.014	0.057	19°50'09"	49671.383	24.118
PLW-23 --- PLW-4030 (B4)	PLW-23	PLW-4030	Fixed	0.001	0.002	205°42'54"	769.752	0.745

Acceptance Summary

Processed	Passed	Flag	Fail
4	4	0	0

Figure A-3.1. Baseline Processing Report - A

PLW-23 - PLW-4030 (11:45:04 AM-3:31:34 PM) (S1)

Baseline observation:	PLW-23 --- PLW-4030 (B1)
Processed:	12/16/2015 2:07:32 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	2.098
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	11/20/2015 11:45:29 AM (Local: UTC+8hr)
Processing stop time:	11/20/2015 3:31:34 PM (Local: UTC+8hr)
Processing duration:	03:46:05
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	PLW-23				
Grid		Local		Global	
Easting	84385.264 m	Latitude	N10°05'19.52518"	Latitude	N10°05'15.04804"
Northing	1117566.788 m	Longitude	E119°12'33.72062"	Longitude	E119°12'39.01413"
Elevation	9.470 m	Height	10.427 m	Height	61.073 m

To:	PLW-4030				
Grid		Local		Global	
Easting	84042.662 m	Latitude	N10°04'56.95146"	Latitude	N10°04'52.47562"
Northing	1116875.986 m	Longitude	E119°12'22.75168"	Longitude	E119°12'28.04576"
Elevation	10.228 m	Height	11.183 m	Height	61.835 m

Vector					
ΔEasting	-342.602 m	NS Fwd Azimuth	205°42'51"	ΔX	231.869 m
ΔNorthing	-690.802 m	Ellipsoid Dist.	769.753 m	ΔY	269.625 m
ΔElevation	0.758 m	ΔHeight	0.756 m	ΔZ	-682.686 m

Standard Errors

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

2

Figure A-3.2. Baseline Processing Report - B

Vector Components (Mark to Mark)

From:	PLW-23				
Grid		Local		Global	
Easting	84385.264 m	Latitude	N10°05'19.52518"	Latitude	N10°05'15.04804"
Northing	1117566.788 m	Longitude	E119°12'33.72062"	Longitude	E119°12'39.01413"
Elevation	9.470 m	Height	10.427 m	Height	61.073 m

To:	PL-267				
Grid		Local		Global	
Easting	101820.908 m	Latitude	N10°30'40.21529"	Latitude	N10°30'35.64621"
Northing	1164164.984 m	Longitude	E119°21'48.02348"	Longitude	E119°21'53.27911"
Elevation	33.463 m	Height	34.545 m	Height	84.611 m

Vector					
ΔEasting	17435.644 m	NS Fwd Azimuth	19°50'09"	ΔX	-10634.211 m
ΔNorthing	46598.197 m	Ellipsoid Dist.	49671.383 m	ΔY	-15515.024 m
ΔElevation	23.993 m	ΔHeight	24.118 m	ΔZ	45972.210 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.013 m
σ ΔNorthing	0.005 m	σ Ellipsoid Dist.	0.006 m	σ ΔY	0.026 m
σ ΔElevation	0.029 m	σ ΔHeight	0.029 m	σ ΔZ	0.005 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0001625016		
Y	-0.0003217825	0.0006901336	
Z	-0.0000343902	0.0000615645	0.0000255690

Figure A-3.3. Baseline Processing Report – C

Annex 4. 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	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Research Associate (RA)	JASMINE ALVIAR	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ARIES TORNO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JUSTINE JOYA	AAC

Annex 5. Data Transfer Sheets

DATA TRANSFER SHEET
palawan 12/2/15

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	
15-Nov-15	3493P	2BLK42EF319A	GEMINI	NA	300	611	208	NA	NA	13.2	NA	5.16	0KB	1KB	8/67	NA	Z:\DAC\RAW DATA
16-Nov-15	3497P	2BLK42DisI320A	GEMINI	NA	384	616	220	NA	NA	17.4	NA	7.61	0KB	1KB	22	NA	Z:\DAC\RAW DATA
16-Nov-15	3499P	2BLK42isI320B	GEMINI	NA	593	517	112	NA	NA	9.16	NA	7.61	0KB	1KB	14/15/16	NA	Z:\DAC\RAW DATA
18-Nov-15	3505P	2BLK42AEs322A	GEMINI	NA	438	737	222	NA	NA	17.5	NA	8.09	0KB	1KB	22/21/16	NA	Z:\DAC\RAW DATA
18-Nov-15	3507P	2BLK42isIAs322B	GEMINI	NA	728	734	180	NA	NA	13.2	NA	8.09	0KB	1KB	16/22	NA	Z:\DAC\RAW DATA

Received from
Name [illegible]
Position
Signature

Received by
Name AC Bongat
Position SSRS
Signature 12/8/15

Figure A-5.1. Data Transfer Sheet for Caramay Floodplain - A

DATA TRANSFER SHEET
PALAWAN 12/08/15

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	
20-Nov-15	3513G	2BLK42islAs324A	GEMINI	NA	176/846	991	180	1.81/13.3	10/74/33	8.14	NA	3.97	1KB	1KB	21/22/16/16/22	NA	Z:\DAC\RAW DATA
21-Nov-15	3517G	2BLK42B325A	GEMINI	NA	32	410	65	4.34	34	2.53	NA	4.14	1KB	1KB	21/22/18/16/19	NA	Z:\DAC\RAW DATA
26-Nov-15	3537G	2BLK42HJ330A	GEMINI	NA	18/218	709	199	NA	NA	11.9	NA	8.03	1KB	1KB	13/13/15/13	NA	Z:\DAC\RAW DATA
27-Nov-15	3541G	2BLK42I331A	GEMINI	NA	265	619	229	NA	NA	24.7	NA	5.79	1KB	1KB	13/13	NA	Z:\DAC\RAW DATA
28-Nov-15	3545G	2BLK42B40A332A	GEMINI	NA	760	667	228	NA	NA	15.8	NA	10.1	1KB	NA	22/21/22/16/16/22	NA	Z:\DAC\RAW DATA
30-Nov-15	3553G	2BLK42HJ334A	GEMINI	NA	202	389	187	NA	NA	16	NA	8.36	1KB	1KB	13/13/13/15	NA	Z:\DAC\RAW DATA
30-Nov-15	3555G	2BLK42JK334B	GEMINI	NA	76	495	238	NA	NA	19.1	NA	8.36	1KB	1KB	13/15	NA	Z:\DAC\RAW DATA
1-Dec-15	3557G	2BLK42HsL335A	GEMINI	NA	226	447	195	NA	NA	19	NA	4.3	1KB	1KB	22/24/22	NA	Z:\DAC\RAW DATA
3-Dec-15	3565G	2BLK42PQR337A	GEMINI	NA	NA	535	202	NA	NA	25.4	NA	6.96	1KB	1KB	22/24/22/48/51	NA	Z:\DAC\RAW DATA

Received from

Name C Joaquin
Position
Signature

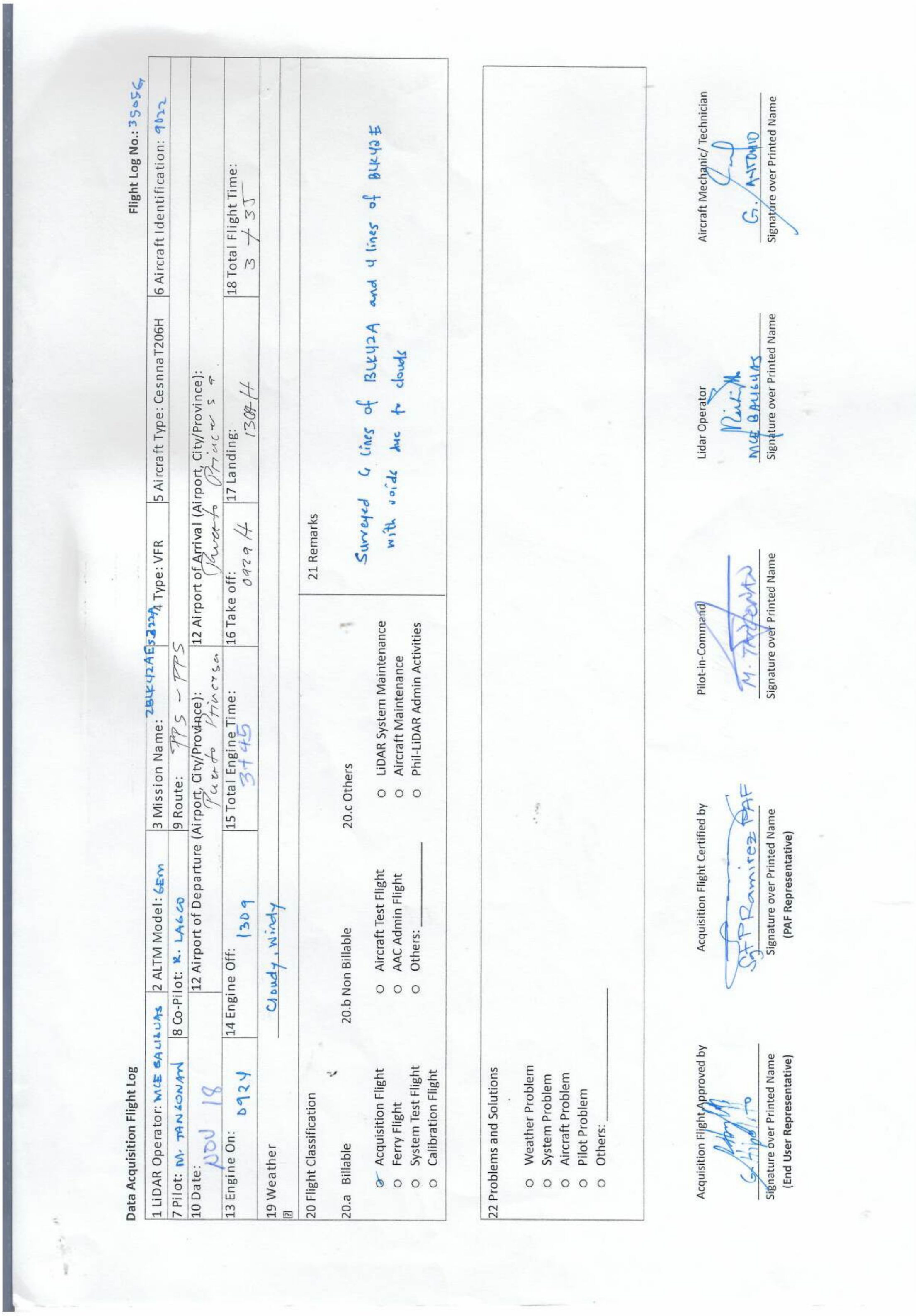
Received by

Name AC Bongat
Position SSRS
Signature 1/4/16

Figure A-5.2. Data Transfer Sheet for Caramay Floodplain - B

Annex 6. Flight Logs

1. Flight Log for **2BLK42AES322A** Mission



Data Acquisition Flight Log

Flight Log No.: 35056

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: GEM	3 Mission Name: 2BLK42AES322A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: R. LAGCO	9 Route: PPS - PPS			
10 Date: Nov 18	12 Airport of Departure (Airport, City/Province): Puerto Princesa		12 Airport of Arrival (Airport, City/Province): Puerto Princesa		
13 Engine On: 0924	14 Engine Off: 1309	15 Total Engine Time: 3+45	16 Take off: 0929 H	17 Landing: 1304 H	18 Total Flight Time: 3+35
19 Weather	Cloudy, Windy				

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

Surveyed 6 lines of BLK42A and 4 lines of BLK42E with voids due to clouds

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

Acquisition Flight Approved by: G. Lipdo, To — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: S/F Ramirez PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: MCE BALICUAS — Signature over Printed Name

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

Figure A-6.1. Flight Log for **2BLK42AES322A** Mission

Flight Log for **2BLK42ISLAS322B** Mission

Data Acquisition Flight Log — Flight Log No.: 35076

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEM	3 Mission Name: 2BLK42ISLAS322B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M. TANGONAN	8 Co-Pilot: R. LAGCO	9 Route:			
10 Date: NOV 18	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1432	14 Engine Off: 1742	15 Total Engine Time: 3+10	16 Take off: 1437H	17 Landing: 1737H	18 Total Flight Time: 3+0
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

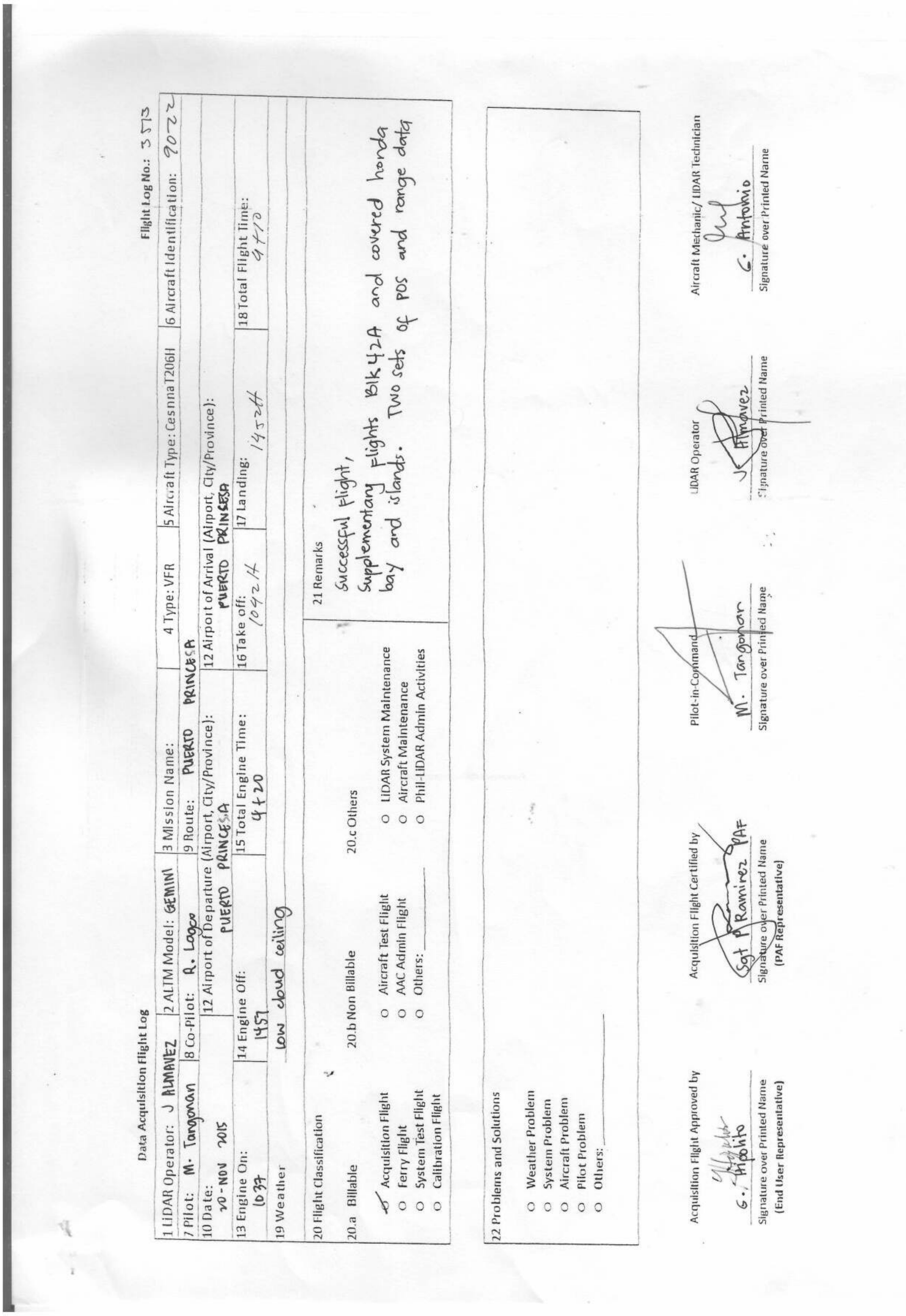
Covered voids over BLK42A & surveyed the islands. Camera shut off.

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
C. Hipolito	SSgt P. Ramirez PAF	M. Tangonan	J. Almalvez	G. Antonio
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for **2BLK42ISLAS322B** Mission

Flight Log for **2BLK42islAs324A** Mission



Data Acquisition Flight Log

Flight Log No.: 3573

1 LiDAR Operator: J ALMAVEZ	2 ALTM Model: GEMINI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: R. Lago	9 Route: PUERTO PRINCESA			
10 Date: 20-NOV 2015	12 Airport of Departure (Airport, City/Province): PUERTO PRINCESA		12 Airport of Arrival (Airport, City/Province): PUERTO PRINSESA		
13 Engine On: 1037	14 Engine Off: 1457	15 Total Engine Time: 4+20	16 Take off: 1042H	17 Landing: 1452H	18 Total Flight Time: 4+10
19 Weather	low cloud ceiling				

20 Flight Classification

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

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

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

21 Remarks

Successful flight, Supplementary flights Blk42A and covered honda bay and islands. Two sets of POS and range data

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
G. Hipolito	Sgt R Ramirez PAF	M. Tangonan	J. Almavez	G. Antonio
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for **2BLK42islAs324A** Mission

Flight Log for **2BLK42B325A** Mission

Data Acquisition Flight Log | **Flight Log No.:** 35176

1 LiDAR Operator: MCE Baligwas	2 ALTM Model: GEM	3 Mission Name: 2BLK42B325A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: R. Labco	9 Route: PPS – PPS			
10 Date: Nov 21, 2015	12 Airport of Departure (Airport, City/Province): Puerto Princesa		12 Airport of Arrival (Airport, City/Province): Puerto Princesa		
13 Engine On: 0745	14 Engine Off: 1013	15 Total Engine Time: 2+28	16 Take off: 0750H	17 Landing: 1008H	18 Total Flight Time: 2+18
19 Weather	Cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed 3 lines over BLK42B with voids due to clouds. DiOps crashed & Task Dead Error was experienced. There is difference bet. swath & trajectory with range file. Last 2 lines has no POS data & are not processable. No tieline due to low cloud build up.

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
C. Hipolito	Sgt P Ramirez PAF	M. Tangonan	MCE Baligwas	G. Antonio
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for **2BLK42B325A** Mission

Flight Log for **2BLK42B332A** Mission

Data Acquisition Flight Log — **Flight Log No.:** 35456

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEM	3 Mission Name: 2BLK42B332A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: N. TANGONAN	8 Co-Pilot: R. LACGO	9 Route: PPS - PPS			
10 Date: NOV. 28, 2015	12 Airport of Departure (Airport, City/Province): Puerto		12 Airport of Arrival (Airport, City/Province): Puerto		
13 Engine On: 0637	14 Engine Off: 1029	15 Total Engine Time: 3+50	16 Take off: 0642 H	17 Landing: 1022 H	18 Total Flight Time: 3+40
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed 7 lines of BLK42C & 6 lines of BLK42B ; 40A

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

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

Acquisition Flight Certified by: SSgt P Ramirez PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: For: CAPT. N. TANGONAN — Signature over Printed Name

Lidar Operator: J. Almalvez — Signature over Printed Name

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

Figure A-6.5. Flight Log for **2BLK42B332A** Mission

Annex 7. Flight Status Report

CARAMAY FLOODPLAIN
(November 18-28, 2015)

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3505G	BLK42eA, 42A	2BLK42AEs322A	MCE Baliguas	18-Nov-15	Voids on mountainous part of 42eA; covered 42A voids
3507G	BLK42eA	2BLK42islAs322B	JM Almalvez	18-Nov-15	Covered 42eA
3513G	BLK42eA, islands	2BLK42islAs324A	JM Almalvez	20-Nov-15	Covered 42eA
3517G	BLK42eB	2BLK42B325A	MCE Baliguas	21-Nov-15	Covered 42eB
3545G	BLK42eB, BLK40A	2BLK42B40A332A	JM Almalvez	28-Nov-15	Surveyed BLK42eB and moved to BLK40A

LAS/SWATH BOUNDARIES PER MISSION FLIGHT
FLIGHT LOG NO. 3505G Scan Freq: 50 kHz
AREA: BLOCK 42eA & 42A Scan Angle: 15 deg
MISSION NAME: 2BLK42AES322A Alt: 1200 m

SURVEY COVERAGE:

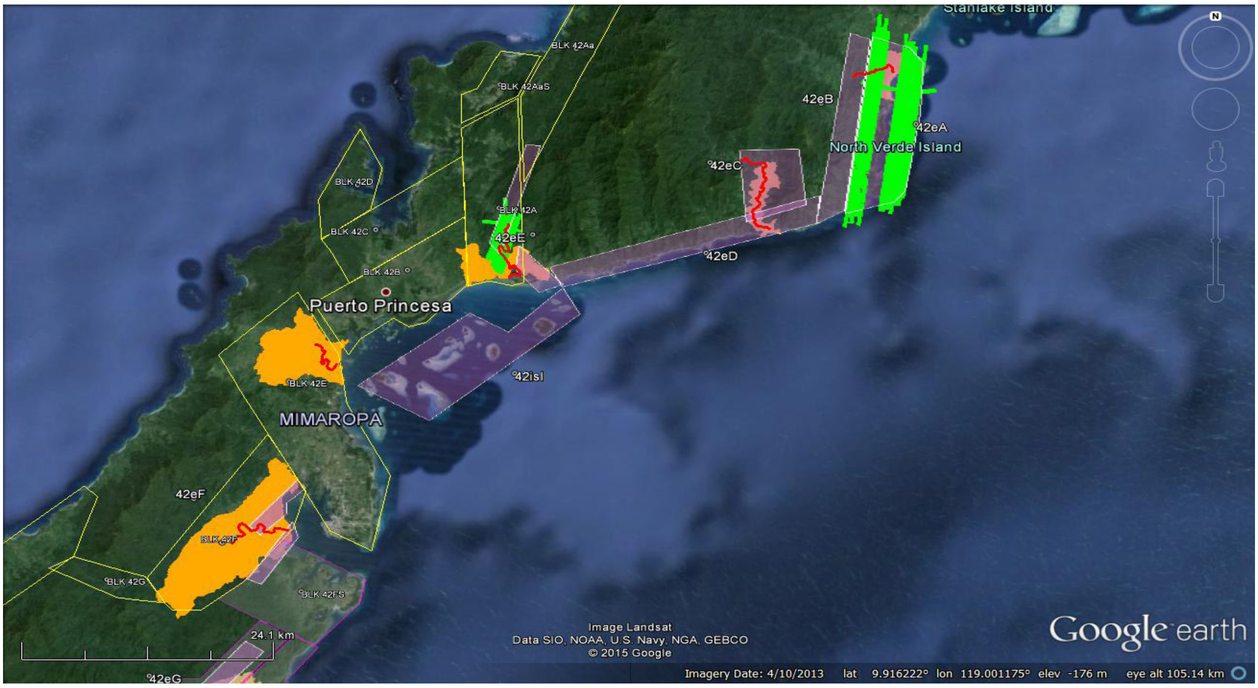


Figure A-7.1. Swath for Flight No. 3505G

FLIGHT LOG NO. 3507G
AREA: BLOCK 42eA
MISSION NAME: 2BLK42ISLAS322B

Scan Freq: 50 kHz
Scan Angle: 15 deg
Alt: 1200 m

SURVEY COVERAGE:

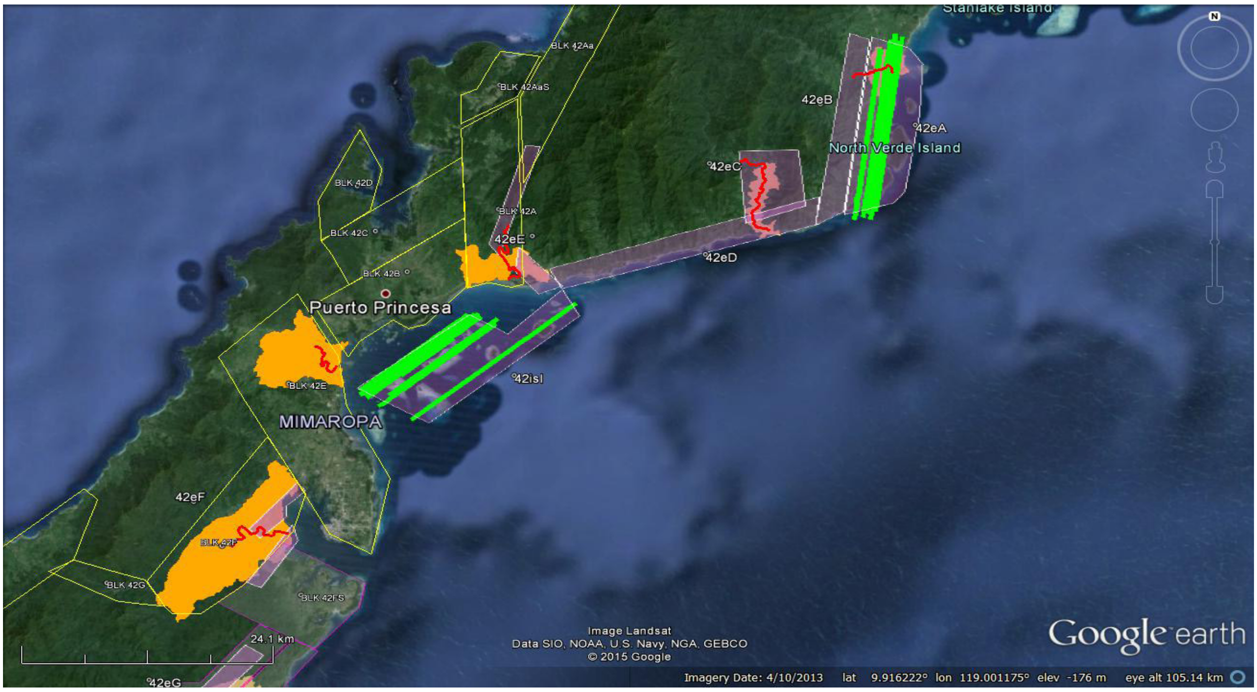


Figure A-7.2. Swath for Flight No. 3507G

FLIGHT LOG NO. 3513G
AREA: BLOCK 42eA
MISSION NAME: 2BLK42islAs324A

Scan Freq: 50 kHz
Scan Angle: 15 deg
Alt: 1200 m

SURVEY COVERAGE:

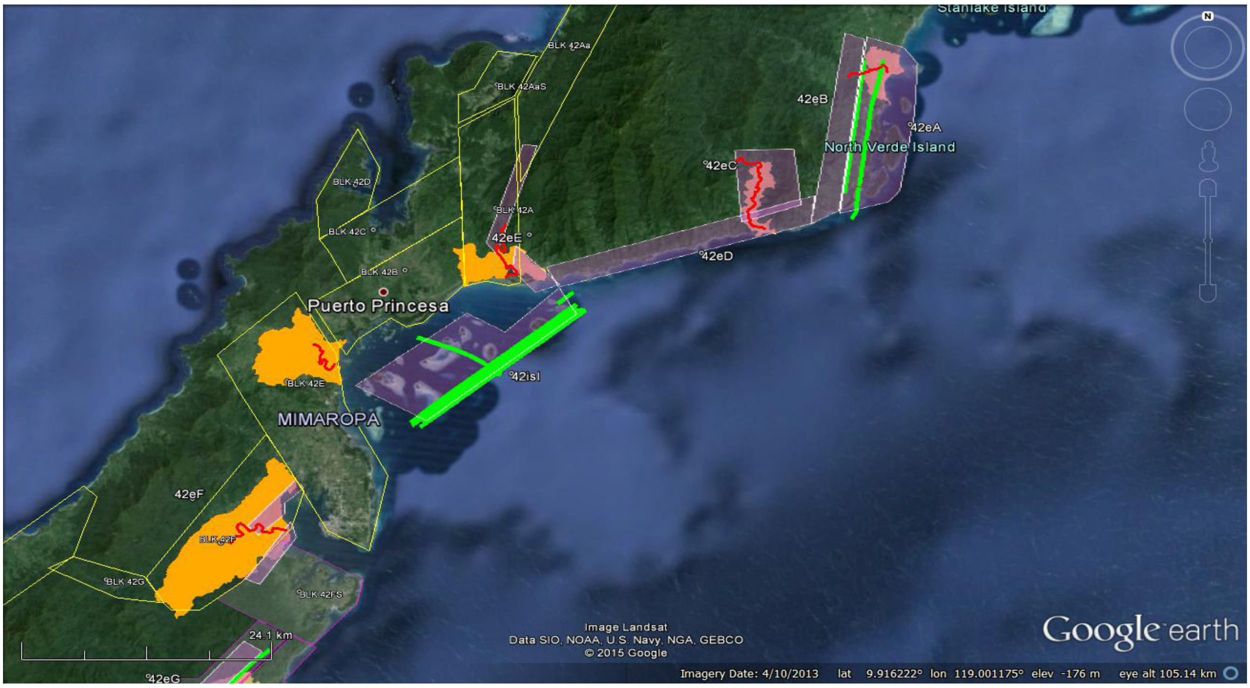


Figure A-7.4. Swath for Flight No. 3513G

FLIGHT LOG NO. 3517G
AREA: BLOCK 42eAB
MISSION NAME: 2BLK42B325A

Scan Freq: 50 kHz
Scan Angle: 15 deg
Alt: 1200 m

SURVEY COVERAGE:

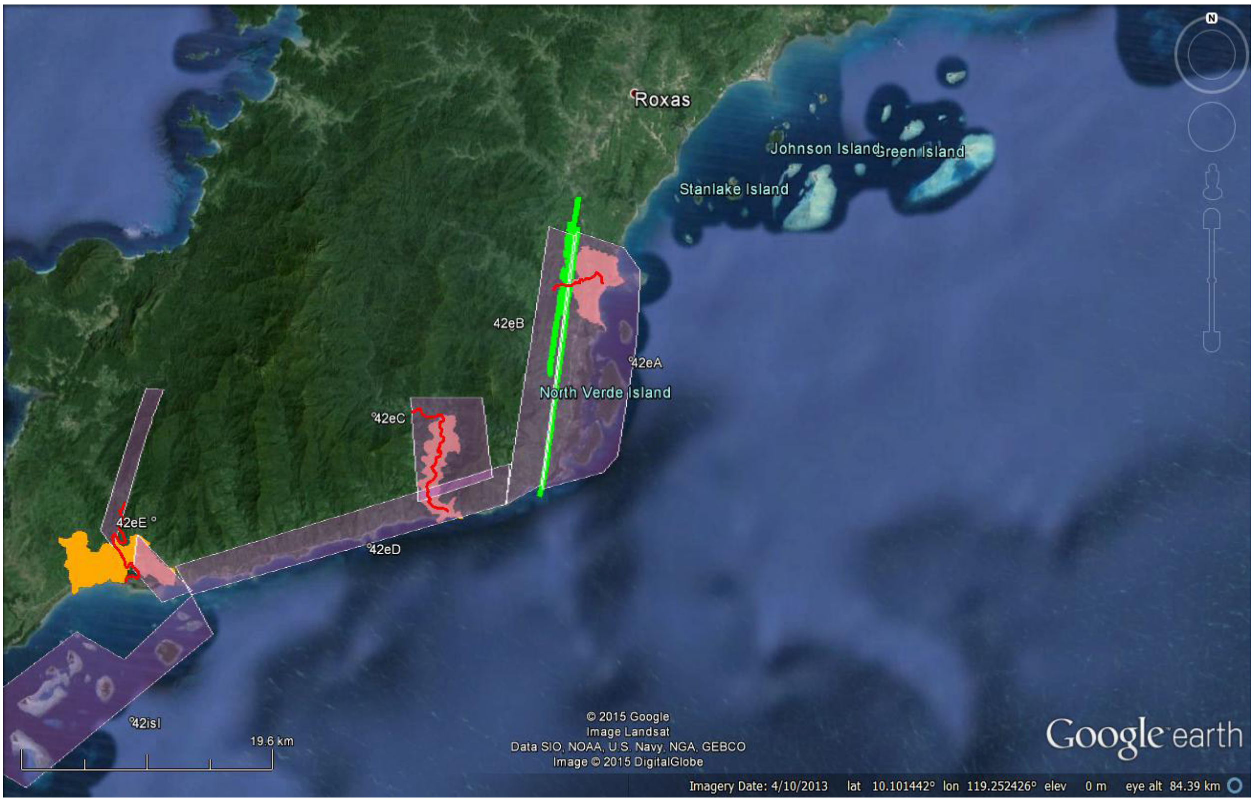


Figure A-7.5. Swath for Flight No. 3517G

FLIGHT LOG NO. 3545G
AREA: BLOCK 42eAB & 40A
MISSION NAME: 2BLK42B332A

Scan Freq: 50 kHz
Scan Angle: 15 deg
Alt: 1200 m

SURVEY COVERAGE:

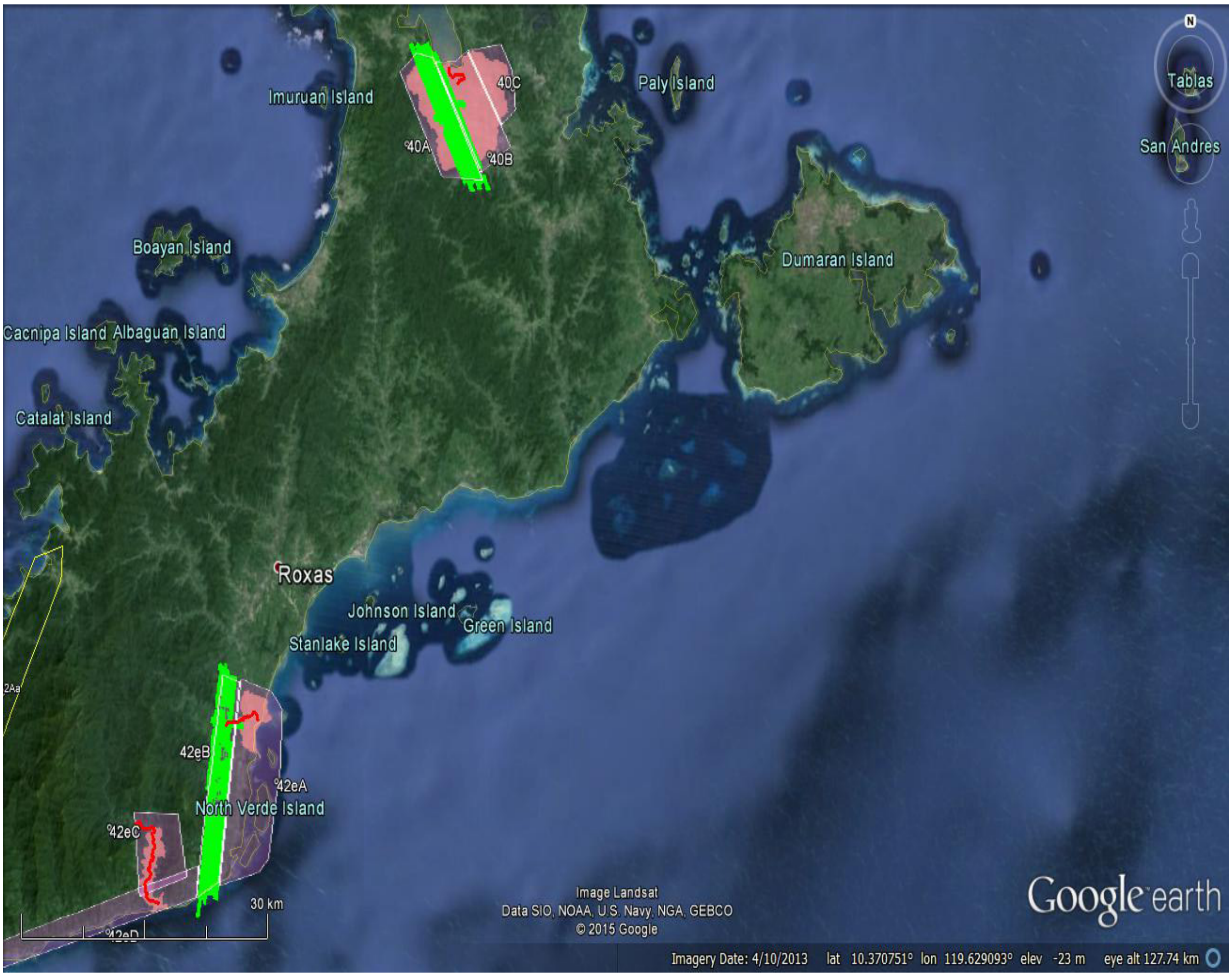


Figure A-7.6. Swath for Flight No. 3545G

Annex 8. Mission Summary Report

Table A-8.1. Mission Summary Report for Mission Blk42eA

Flight Area	Palawan Reflights
Mission Name	**Blk42eA**
Inclusive Flights	3505G, 3507G
Range data size	30.7 GB
Base data size	16.18 MB
POS	402 MB
Image	NA
Transfer date	December 8, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.52
RMSE for East Position (<4.0 cm)	1.72
RMSE for Down Position (<8.0 cm)	4.29
Boresight correction stdev (<0.001deg)	0.000835
IMU attitude correction stdev (<0.001deg)	0.090429
GPS position stdev (<0.01m)	0.0271
Minimum % overlap (>25)	36.93%
Ave point cloud density per sq.m. (>2.0)	4.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	142
Maximum Height	514.64 m
Minimum Height	50.90 m
Classification (# of points)	
Ground	30,345,934
Low vegetation	27,828,311
Medium vegetation	157,391,700
High vegetation	210,127,503
Building	3,839,873
Ortophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Analyn Naldo, Engr. Justine Francisco, Melissa

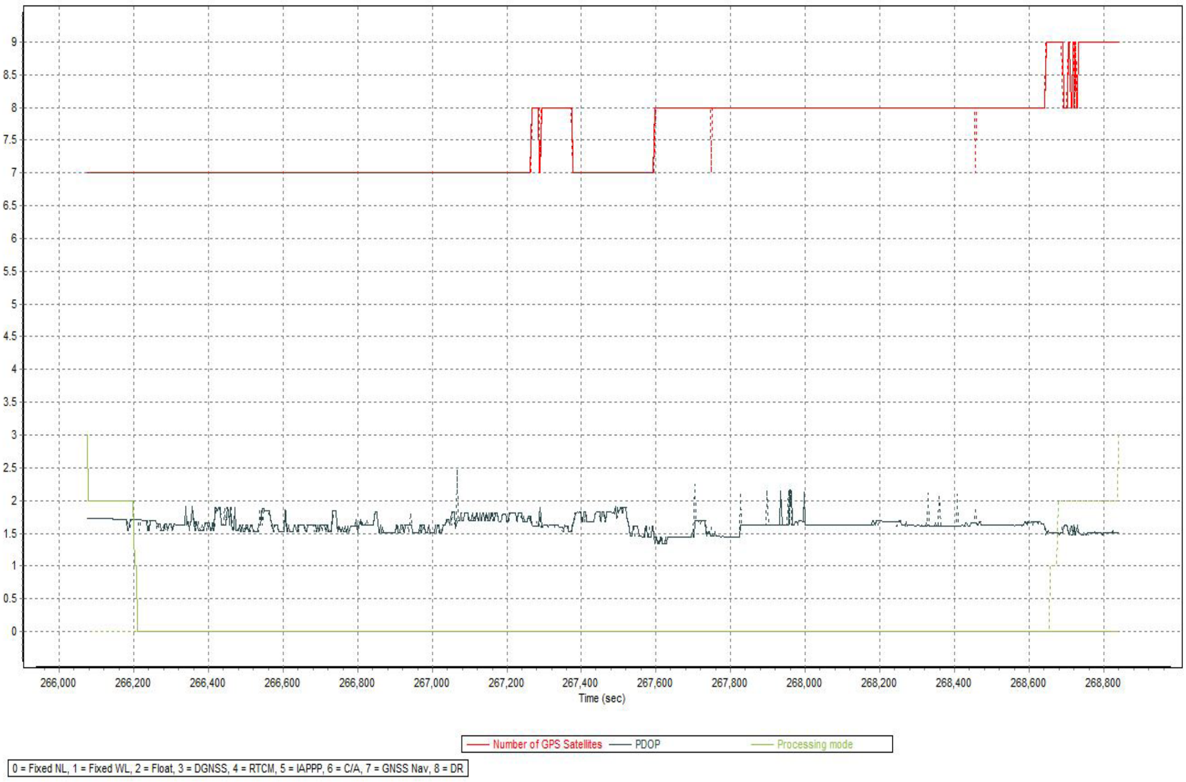


Figure A-8.1. Solution Status

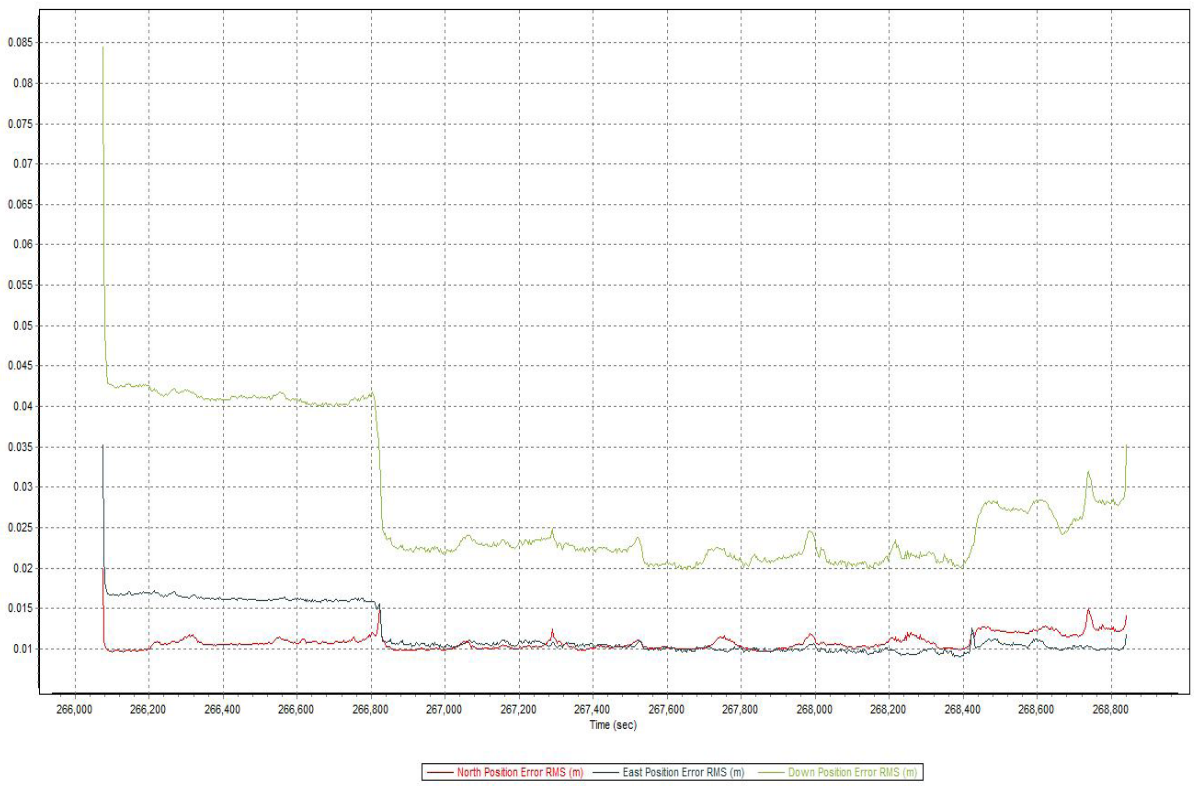


Figure A-8.2. Smoothed Performance Metrics Parameters

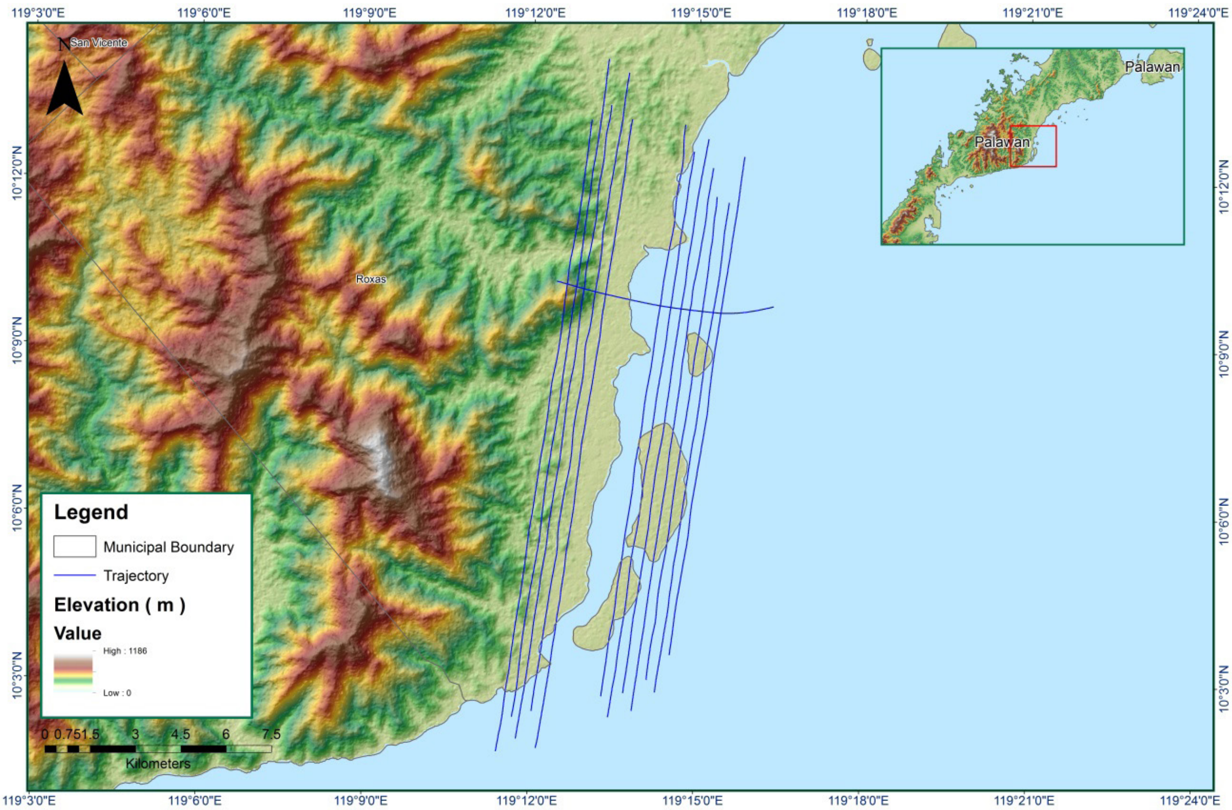


Figure A-8.3. Best Estimated Trajectory

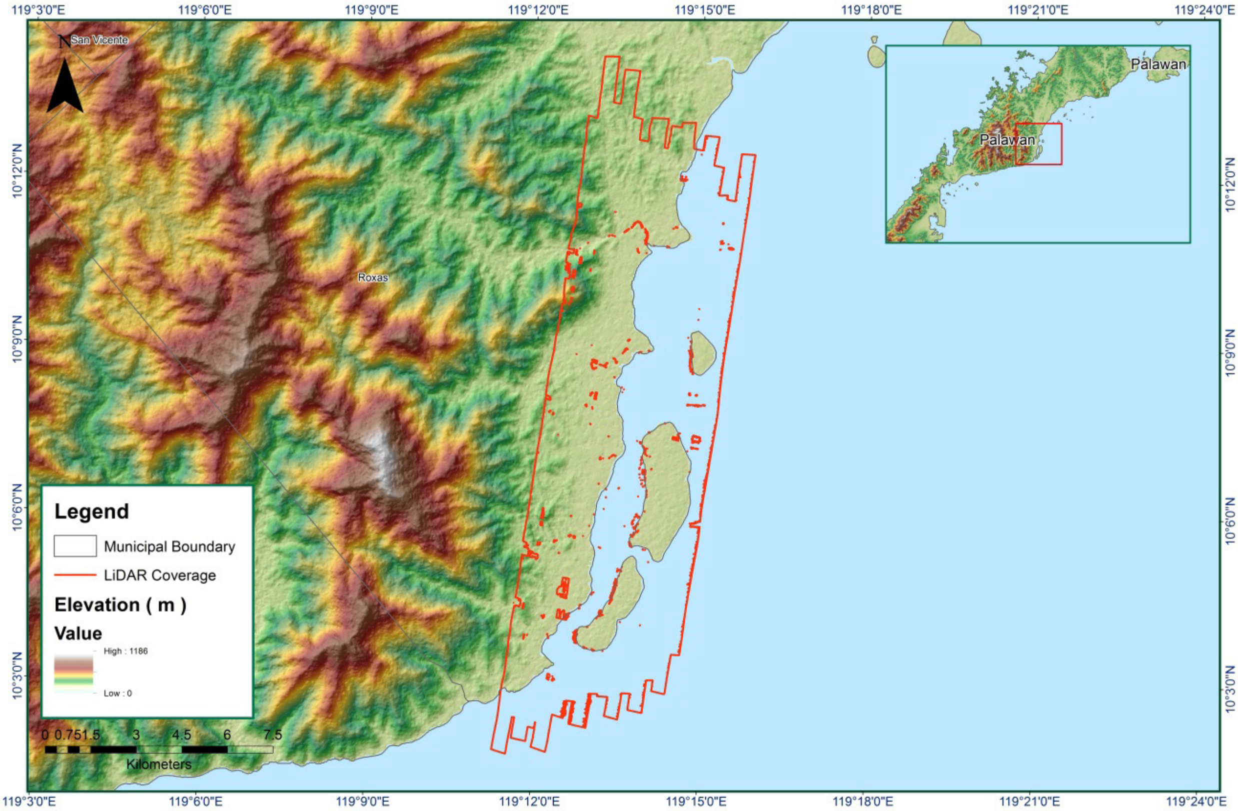


Figure A-8.4 Coverage of LiDAR data

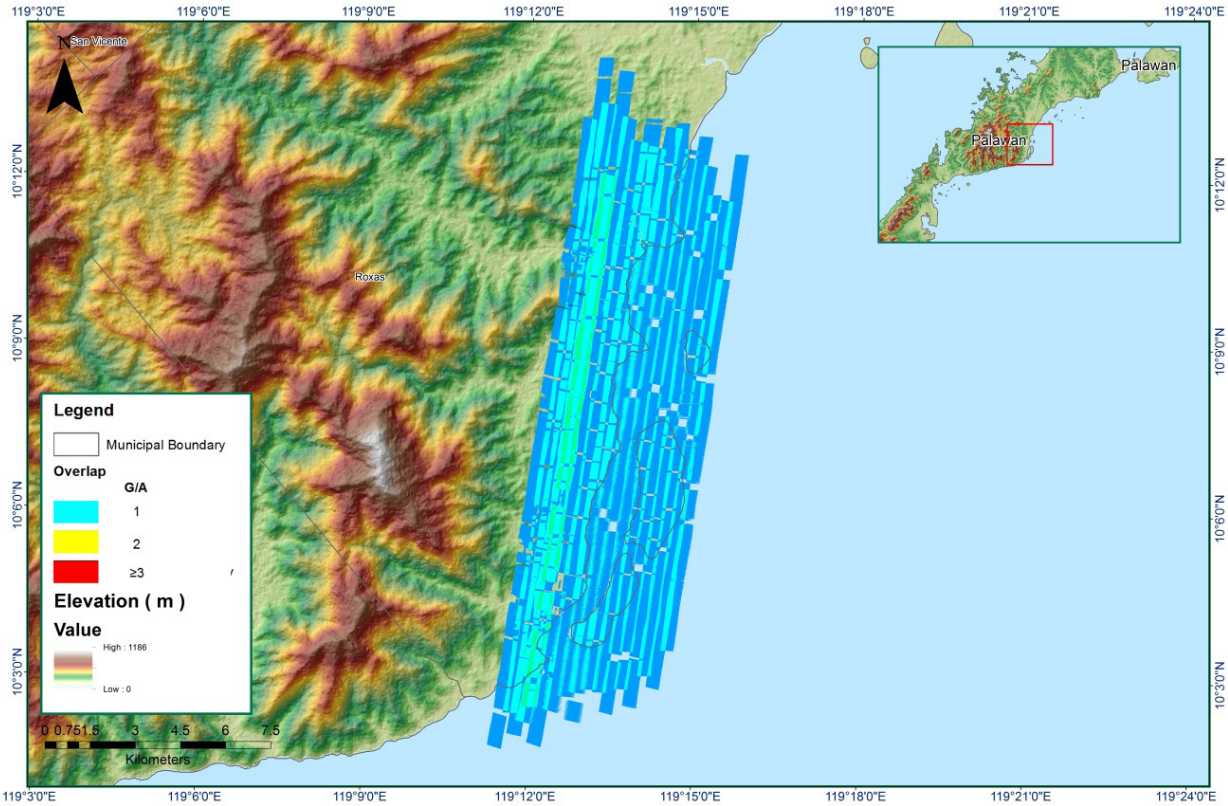


Figure A-8.5. Image of data overlap

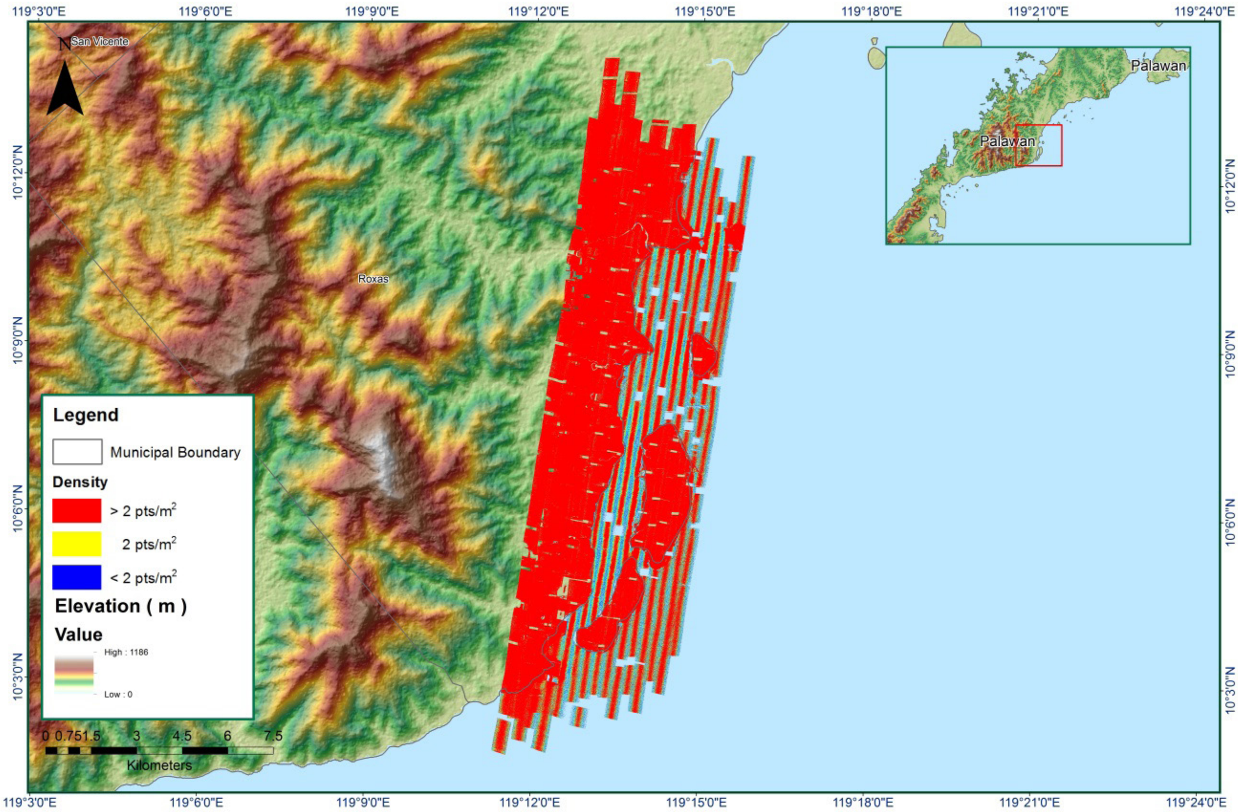


Figure A-8.6. Density map of merged LiDAR data

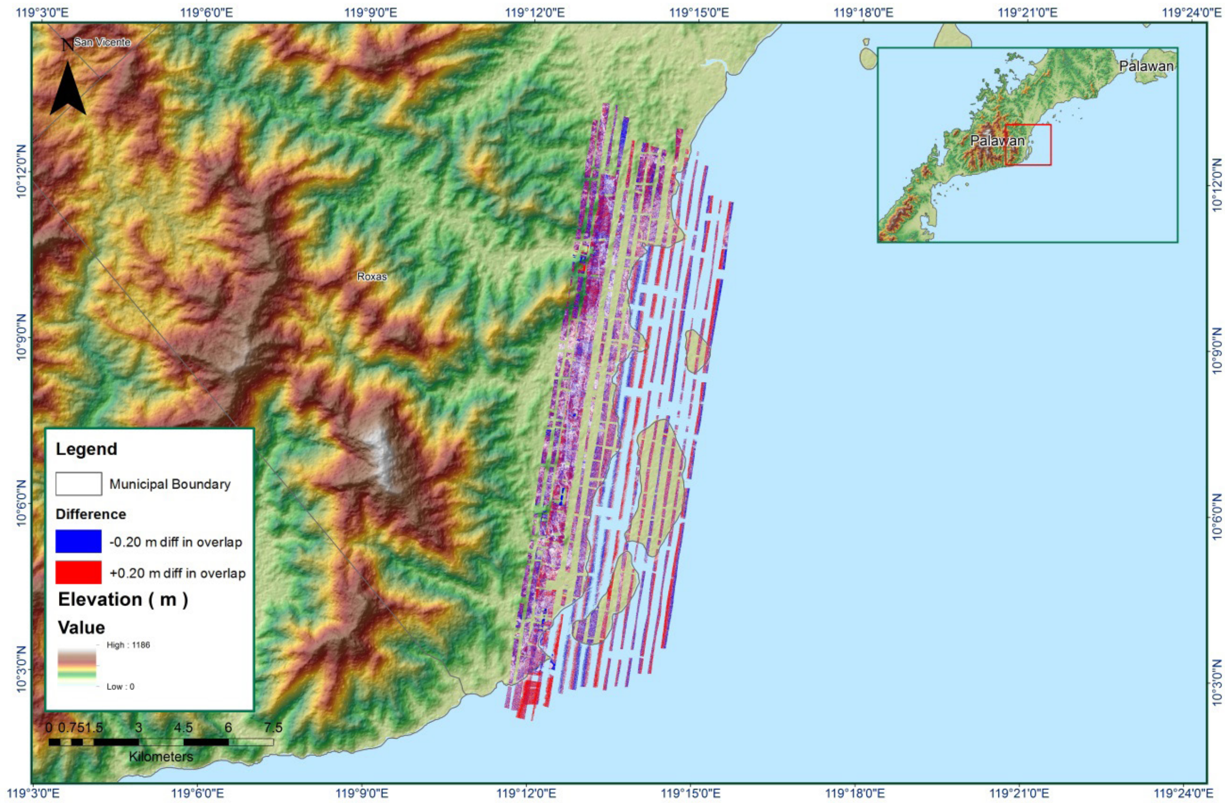


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk42eB

Flight Area	Palawan Reflights
Mission Name	**Blk42eB**
Inclusive Flights	3545G
Range data size	15.8 GB
Base data size	10.1 MB
POS	228 MB
Image	NA
Transfer date	January 4, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.26
RMSE for East Position (<4.0 cm)	1.12
RMSE for Down Position (<8.0 cm)	1.89
Boresight correction stdev (<0.001deg)	0.020777
IMU attitude correction stdev (<0.001deg)	0.017523
GPS position stdev (<0.01m)	0.0279
Minimum % overlap (>25)	21.10%
Ave point cloud density per sq.m. (>2.0)	4.94
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	84
Maximum Height	547.79 m
Minimum Height	50.86 m
Classification (# of points)	
Ground	8,276,887
Low vegetation	4,050,735
Medium vegetation	48,822,536
High vegetation	142,807,210
Building	1,882,543
Ortophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Merven Matthew Natino, Denise

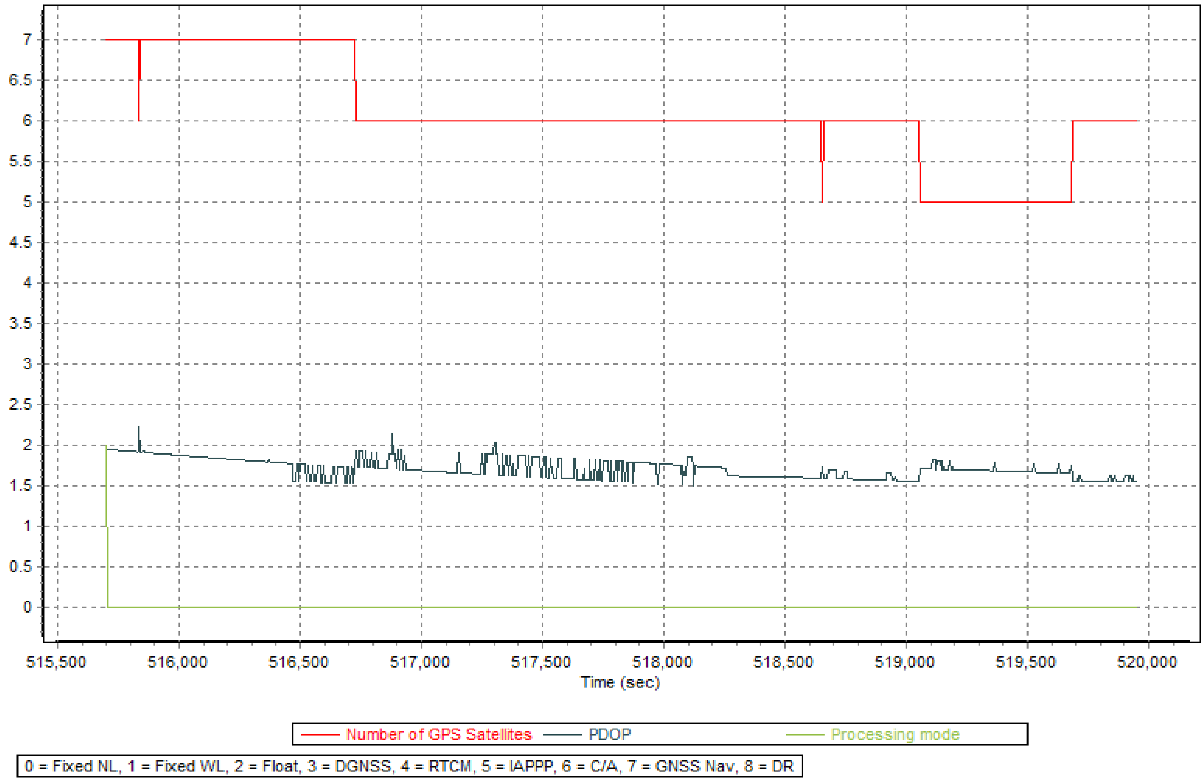


Figure A-8.8. Solution Status

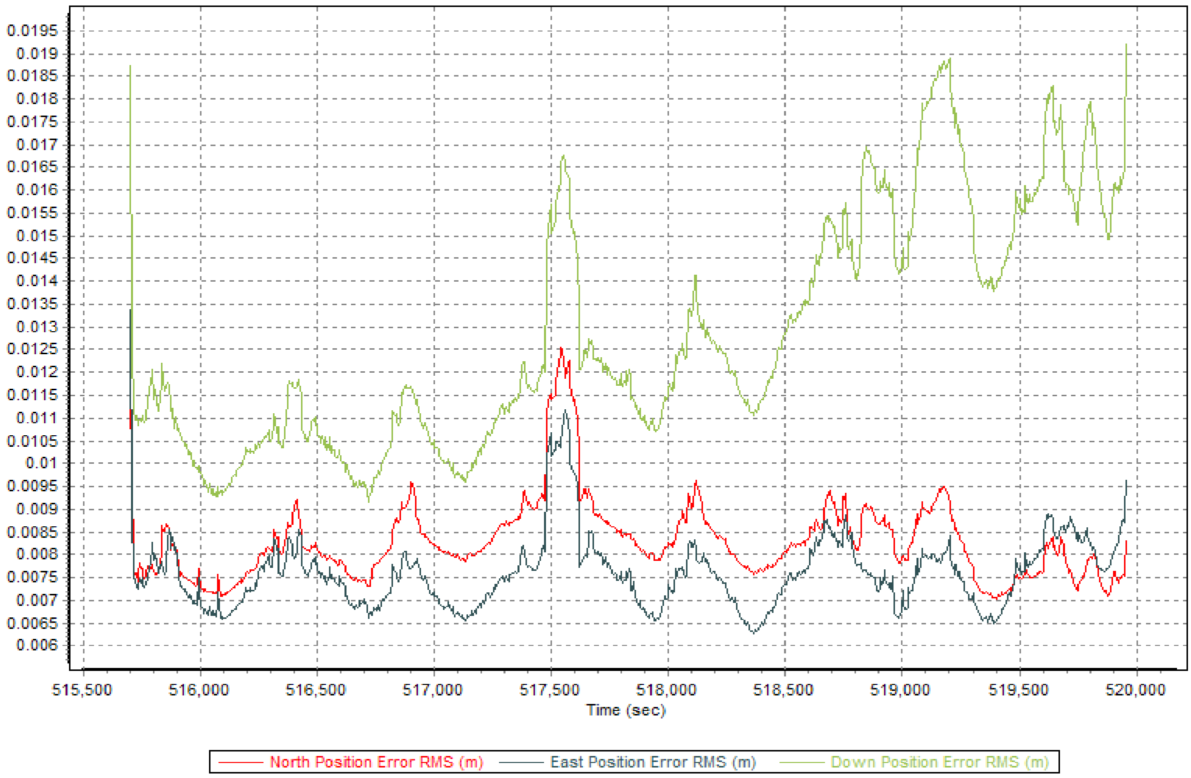


Figure A-8.9. Smoothed Performance Metrics Parameters

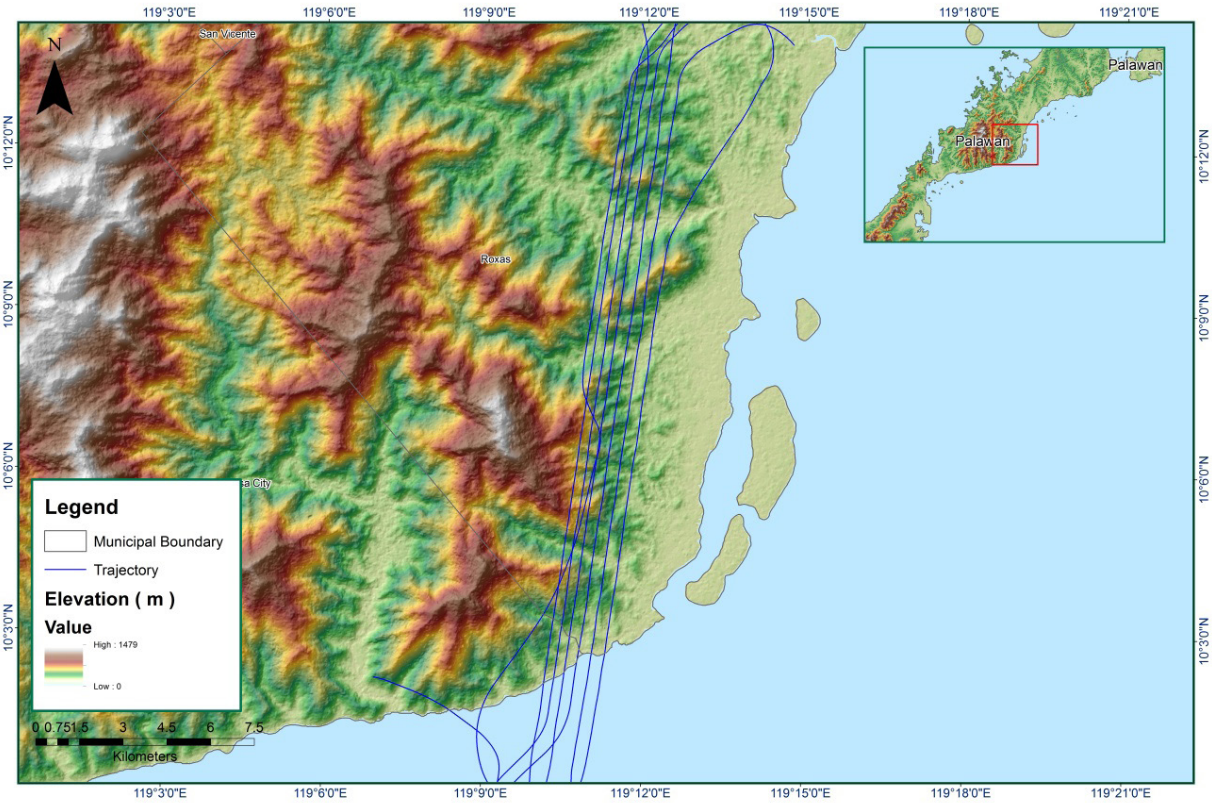


Figure A-8.10. Best Estimated Trajectory

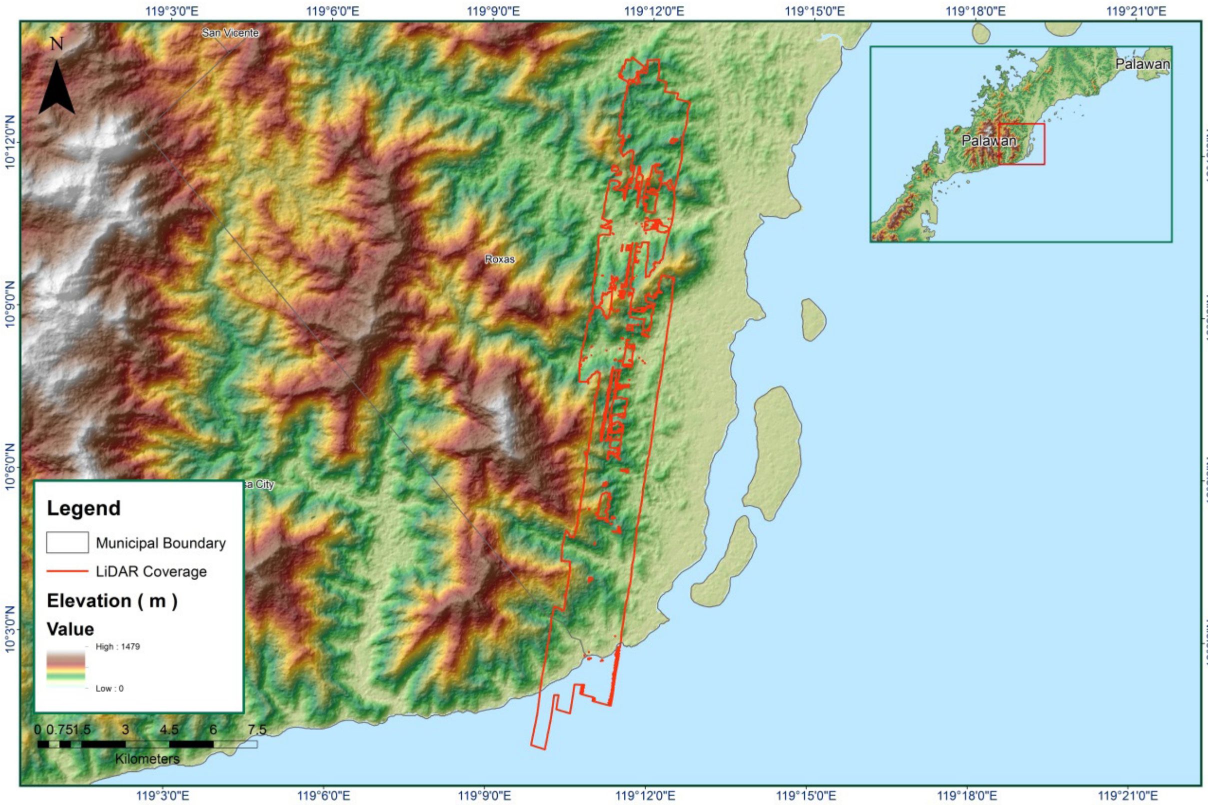


Figure A-8.11. Coverage of LiDAR data

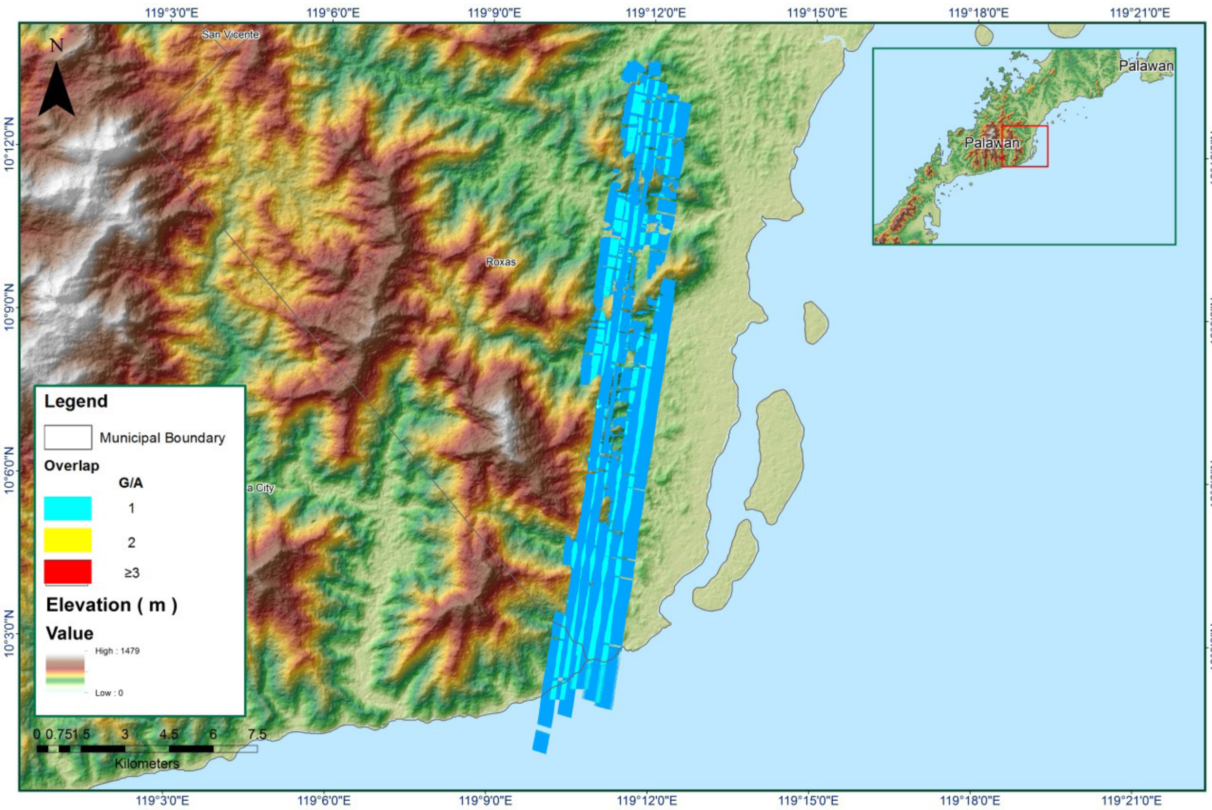


Figure A-8.12. Image of data overlap

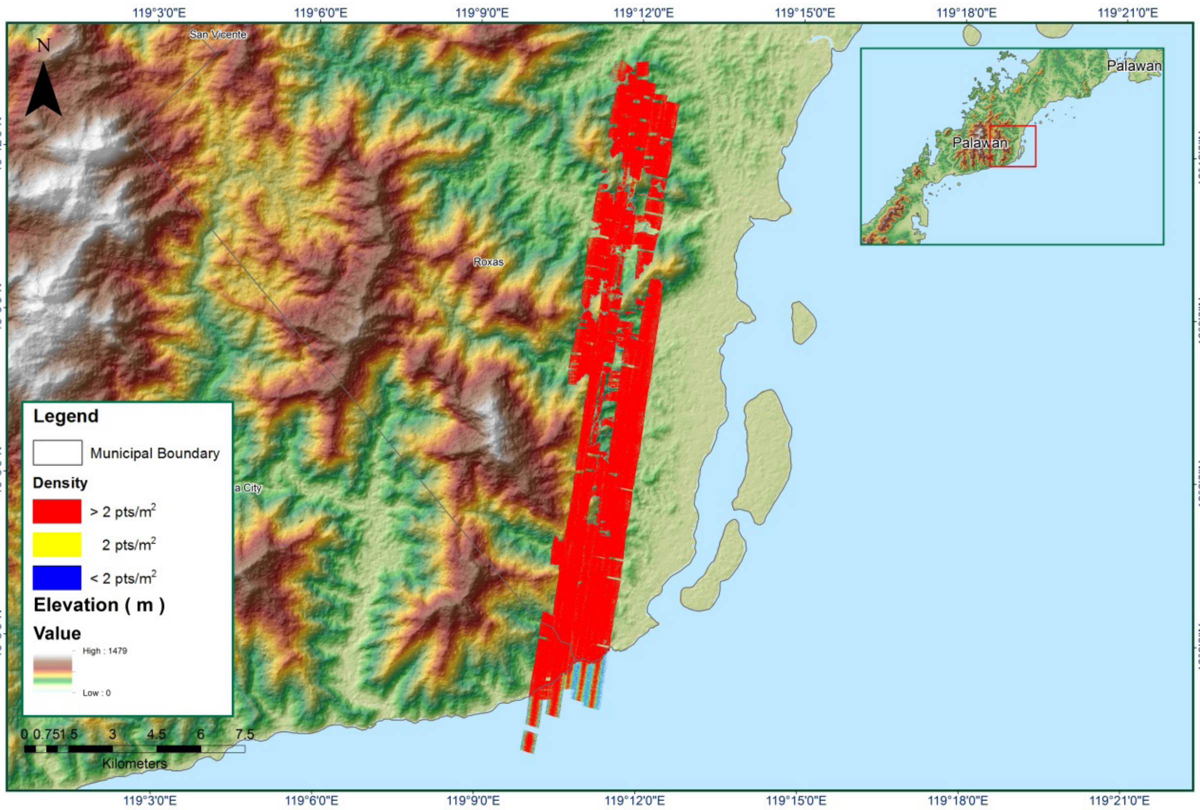


Figure A-8.13. Density map of merged LiDAR data

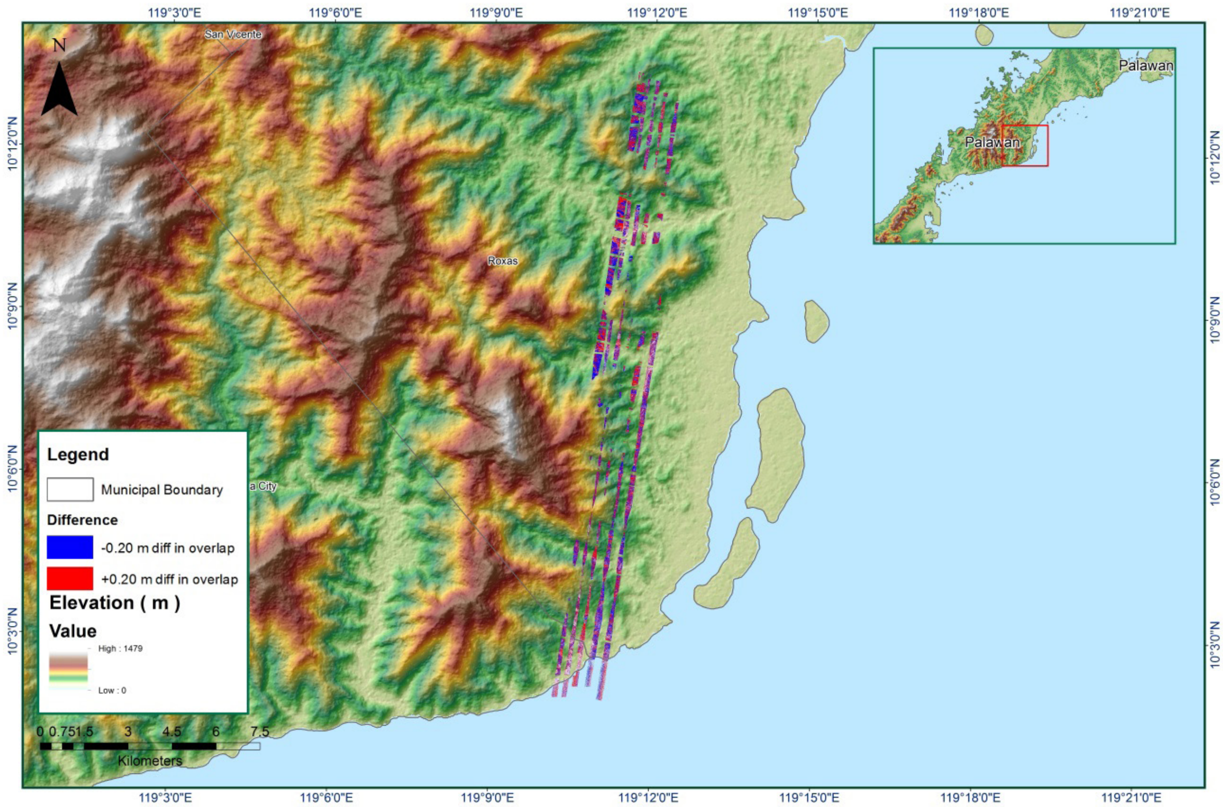


Figure A-8.14. Elevation difference between flight lines

Annex 9. Caramay Model Basin Parameters

Table A-9.1 Caramay Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM	
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W1000	10.35	55	0	0.86982	1.4195
W1010	10.35	55	0	1.0201	1.6649
W1020	10.35	55	0	0.52261	0.85289
W1030	10.35	55	0	1.1292	1.8428
W1040	10.52	54.694	0	1.2456	2.0327
W1050	10.35	55	0	1.417	2.3126
W1060	5.8914	68.311	0	0.70784	1.1552
W1070	4.65	73	0	0.41522	0.67764
W1080	6.5898	65.838	0	0.71641	1.1692
W1090	5.2937	70.58	0	0.81371	1.328
W1100	4.9577	71.923	0	1.0401	1.6975
W1120	10.481	54.786	0	1.4702	2.3993
W1130	7.6444	62.425	0	0.98729	1.6113
W1140	4.6665	73.129	0	0.53562	0.87413
W1150	4.9001	72.159	0	0.91066	1.4862
W1160	11.547	52.377	0	1.2148	1.9826
W1170	8.5542	59.753	0	1.6172	2.6393
W1180	8.9611	58.631	0	1.7314	2.8257
W1190	12.285	50.83	0	1.5935	2.6007
W1200	13.75	48	0	1.3606	2.2205
W1210	10.35	55	0	1.1233	1.8332
W1220	10.35	55	0	1.0601	1.7301
W1240	12.763	49.877	0	1.7552	2.8645
W1250	8.9285	58.719	0	1.9121	3.1205
W620	10.35	55	0	1.5402	2.5137
W630	10.35	55	0	1.4925	2.4358
W640	10.35	55	0	1.0837	1.7687
W650	10.35	55	0	1.355	2.2113
W660	10.35	55	0	0.91128	1.4872
W670	10.35	55	0	0.18442	0.30098

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM	
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W680	10.35	55	0	0.84209	1.3743
W690	10.35	55	0	1.1179	1.8244
W700	10.35	55	0	0.68189	1.1128
W710	10.35	55	0	0.29086	0.47469
W720	10.35	55	0	1.4927	2.4361
W730	10.35	55	0	1.2105	1.9756
W740	10.35	55	0	0.97445	1.5903
W750	10.35	55	0	0.48973	0.79925
W760	10.35	55	0	0.69128	1.1282
W770	10.35	55	0	1.5458	2.5227
W780	10.35	55	0	2.2271	3.6347
W790	10.35	55	0	1.4178	2.3139
W800	10.35	55	0	1.1838	1.932
W810	10.35	55	0	0.74586	1.2172
W820	10.35	55	0	0.87134	1.422
W830	10.35	55	0	1.2526	2.0442
W840	10.35	55	0	1.0851	1.7709
W850	10.35	55	0	0.83324	1.3599
W860	10.35	55	0	1.5167	2.4753
W870	10.35	55	0	0.94476	1.5418
W880	10.35	55	0	0.60293	0.98398
W890	10.35	55	0	0.62683	1.023
W900	10.35	55	0	0.42838	0.69912
W910	10.35	55	0	1.5868	2.5897
W920	10.35	55	0	1.259	2.0548
W930	10.35	55	0	0.92237	1.5053
W940	10.629	54.439	0	0.9038	1.475
W950	9.6175	56.906	0	1.1887	1.9399
W960	6.6292	65.704	0	1.2886	2.103
W970	11.145	53.262	0	0.8643	1.4105
W980	13.123	49.182	0	1.3161	2.1479
W990	10.873	53.876	0	1.473	2.4039

Annex 10. Caramay Model Reach Parameters

Table A-10.1 Caramay Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING			
	Length (M)	Slope(M/M)	Shape	Side Slope (xH:1V)
R110	1759.2	0.001206	Trapezoid	1
R120	339.71	0.001206	Trapezoid	1
R1270	3050.8	0.000697	Trapezoid	1
R140	729.41	0.011412	Trapezoid	1
R170	3530.9	0.016276	Trapezoid	1
R180	757.7	0.039189	Trapezoid	1
R190	1269.1	0.039189	Trapezoid	1
R200	1289.8	0.020226	Trapezoid	1
R250	348.7	0.022026	Trapezoid	1
R260	435.27	0.022026	Trapezoid	1
R280	764.68	0.020461	Trapezoid	1
R30	120.71	0.12382	Trapezoid	1
R300	2099.7	0.020461	Trapezoid	1
R330	947.4	0.000417	Trapezoid	1
R350	1015.3	0.007081	Trapezoid	1
R370	1048.1	0.014842	Trapezoid	1
R380	649.41	0.099429	Trapezoid	1
R400	1587.8	0.021124	Trapezoid	1
R410	2156.5	0.002115	Trapezoid	1
R420	537.7	0.012509	Trapezoid	1
R450	1239.1	0.012509	Trapezoid	1
R470	1177.4	0.021773	Trapezoid	1
R480	1311.2	0.008402	Trapezoid	1
R50	417.28	0.029308	Trapezoid	1
R500	664.77	0.002521	Trapezoid	1
R530	798.11	0.008402	Trapezoid	1
R540	1368.1	0.006722	Trapezoid	1
R550	1243	0.032333	Trapezoid	1
R570	2873.9	0.002521	Trapezoid	1
R70	755.98	0.030927	Trapezoid	1
R90	311.42	0.017823	Trapezoid	1

Annex 11. Caramay Flood Validation Data

Table A-11.1 Caramay Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
1	10.17856	119.2325	0.03	1.36	1.33	Quedan	Dec. 2005	25-Year
2	10.17987	119.2294	0.04	1.15	1.11		2005	25-Year
3	10.17997	119.2314	0.14	0.5	0.36	Quedan	2005	25-Year
4	10.18016	119.2323	0.22	0.7	0.48	Quedan	2005	25-Year
5	10.18017	119.2322	0.19	1.36	1.17	Quedan	2005	25-Year
6	10.18026	119.2323	0.19	0.86	0.67	Quedan	2005	25-Year
7	10.1803	119.2288	0.31	1.1	0.79		2005	25-Year
8	10.18033	119.2329	0.06	1.75	1.69	Quedan	2005	25-Year
9	10.18057	119.2328	0.11	0.9	0.79	Quedan		25-Year
10	10.18076	119.2314	0.09	0.88	0.79		2005	25-Year
11	10.18084	119.2289	0.03	0.3	0.27		2005	25-Year
12	10.18082	119.2358	0.05	0.5	0.45	Quedan	Dec. 18, 2005	25-Year
13	10.18088	119.2301	0.06	0.6	0.54	Quedan	2005	25-Year
14	10.18094	119.231	0.34	0.95	0.61	Quedan	2005	25-Year
15	10.18094	119.231	0.34	1.31	0.97	Quedan	2005	25-Year
16	10.18094	119.231	0.34	1.14	0.8	Quedan	Dec. 18, 2005	25-Year
17	10.18091	119.2372	0.03	0.75	0.72	Quedan	Dec. 2005	25-Year
18	10.18096	119.2343	0.43	0.65	0.22	Quedan	Dec. 18, 2005	25-Year
19	10.18102	119.2322	0.35	1.1	0.75	Quedan	2005	25-Year
20	10.18108	119.2322	0.19	0.3	0.11	Quedan	Dec. 2005	25-Year
21	10.18109	119.234	0.13	1.09	0.96	Quedan	Dec. 2005	25-Year
22	10.18132	119.2337	0.18	0.4	0.22	Quedan	Dec. 2005	25-Year
23	10.18144	119.2314	0.37	1	0.63		2005	25-Year
24	10.18158	119.2373	0.03	0	-0.03			25-Year
25	10.18175	119.2343	0.03	0.4	0.37	Quedan	Dec. 2005	25-Year
26	10.18212	119.2312	0.45	1.2	0.75		Dec. 2005	25-Year
27	10.18219	119.2382	0.2	0.2	0	Yolanda	Nov. 2013	25-Year
28	10.18235	119.234	0.03	0.55	0.52	Quedan	Dec. 2005	25-Year
29	10.18285	119.2319	0.03	1.3	1.27	Yolanda	Nov. 2013	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
30	10.18458	119.2337	0.04	0.35	0.31	Quedan	Dec. 2005	25-Year
31	10.18595	119.2327	0.1	0.36	0.26	Quedan	Dec. 2005	25-Year
32	10.18669	119.2327	0.21	1.4	1.19	Quedan	Dec. 2005	25-Year
33	10.18826	119.2317	0.12	0.97	0.85	Quedan	Dec. 2005	25-Year
34	10.18846	119.2321	0.51	1.07	0.56	Quedan	Dec. 2010	25-Year
35	10.18893	119.2314	1.09	1.12	0.03	Quedan	Dec. 2007	25-Year
36	10.18895	119.2319	1.03	0.96	-0.07	Quedan	Dec. 2008	25-Year
37	10.1893	119.2295	0.7	0.92	0.22	Quedan	Dec. 2006	25-Year
38	10.18955	119.2317	1.1	0.55	-0.55	Quedan	Dec. 2009	25-Year
39	10.18968	119.2304	1.26	1.71	0.45	Quedan	Dec. 2015	25-Year
40	10.18976	119.2308	0.85	1.21	0.36	Quedan	Dec. 2014	25-Year
41	10.18992	119.2292	0.82	1	0.18	Quedan	Dec. 2005	25-Year
42	10.19039	119.2311	0.95	1.51	0.56	Quedan	Dec. 2013	25-Year
43	10.1905	119.2321	1.35	1.32	-0.03	Quedan	Dec. 2011	25-Year
44	10.19057	119.2282	0.23	0	-0.23			25-Year
45	10.19056	119.2317	1.42	1.26	-0.16	Quedan	Dec. 2012	25-Year
46	10.19107	119.2273	0.03	0	-0.03			25-Year
47	10.19127	119.2279	0.96	0	-0.96			25-Year
48	10.19143	119.2265	0.03	0	-0.03			25-Year
49	10.19188	119.2262	0.03	0	-0.03			25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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