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

LiDAR Surveys and Flood Mapping of Ocoy River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of San Carlos

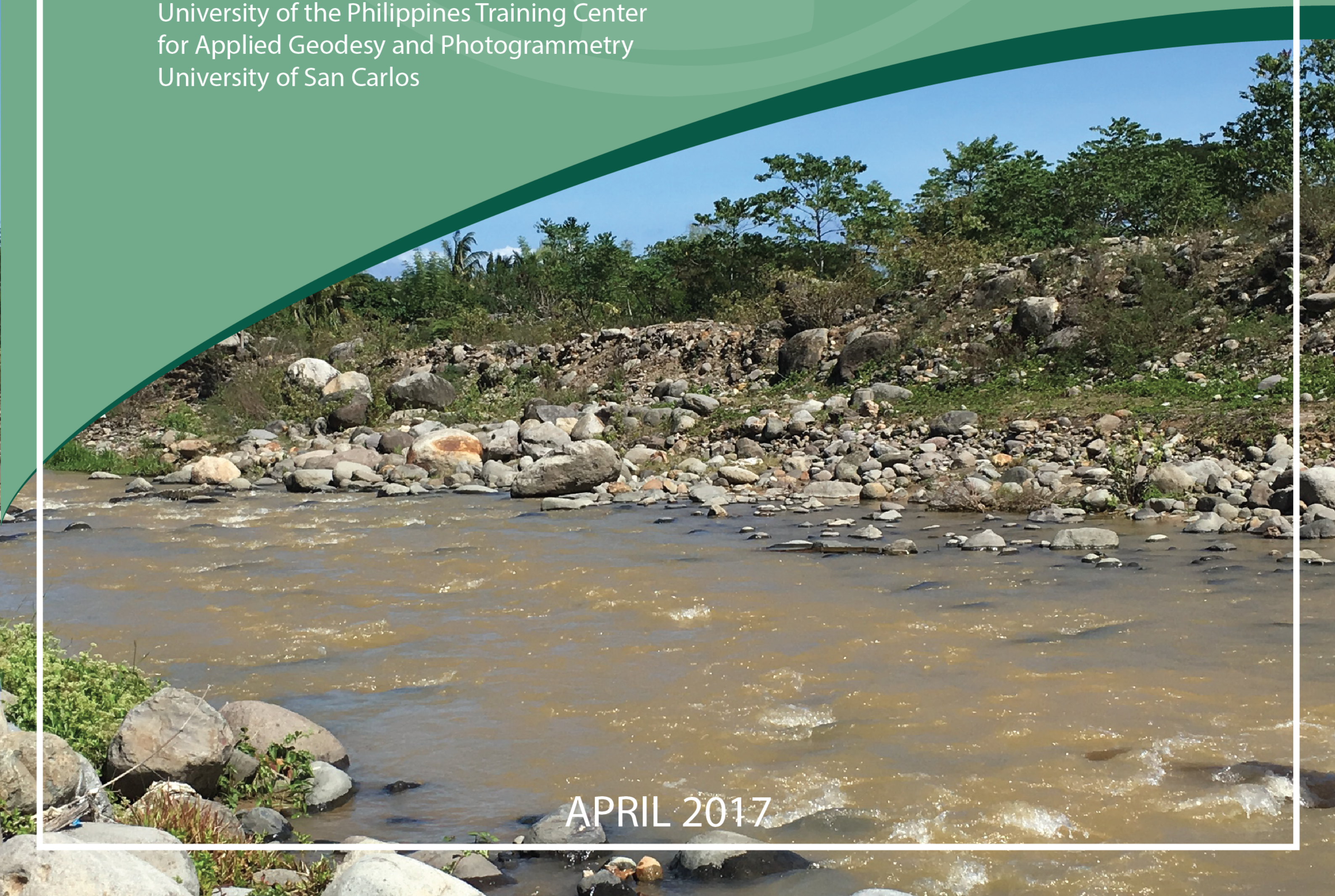

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA-BSWM	Department of Agriculture - Bureau of Soil and Water Management
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
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
USC	University of San Carlos
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND OCOY RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland S. Otadoy, and Engr. Aure Flo Oraya

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of San Carlos (USC). USC 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 17 river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Ocoy River Basin

Ocoy River Basin covers the municipalities of Santa Catalina and Sibulan and the city of Dumaguete in Negros Oriental. The DENR River Basin Control Office identified the basin to have a drainage area of 116 km2 and an estimated 70 million cubic meter annual run-off (RBCO, 2015).

Its main stem, Ocoy River, is part of the river systems in Central Visayas. The delineated basin and river name is "Candugay River" according to the RBCO, but the local Municipal government has indicated that the river is referred to as Ocoy River. There is a total of 12,120 people residing within the immediate vicinity of the river which is distributed among five (5) barangays, namely: Balili, Municipality of Valencia; Camanjac, Dumaguete City; Tubigon, Calabnugan, and Looc in the Municipality of Sibulan (NSO, 2015). Most of the livelihood of the population in Negros Oriental are involved in agriculture, where sugarcane, corn, and coconut are their principal produce. Whereas the population living in the coast cultivate extensive marine resources (Islands Web, 2015). Last October 2013, incessant rains, caused by the Southwestern Monsoon, brought about immense flooding to three (3) cities and four (4) municipalities in the southern area of Negros Oriental. Cities of Bayawan and Dumaguete were the most affected during the event (Philippine Daily Inquirer, 2013).

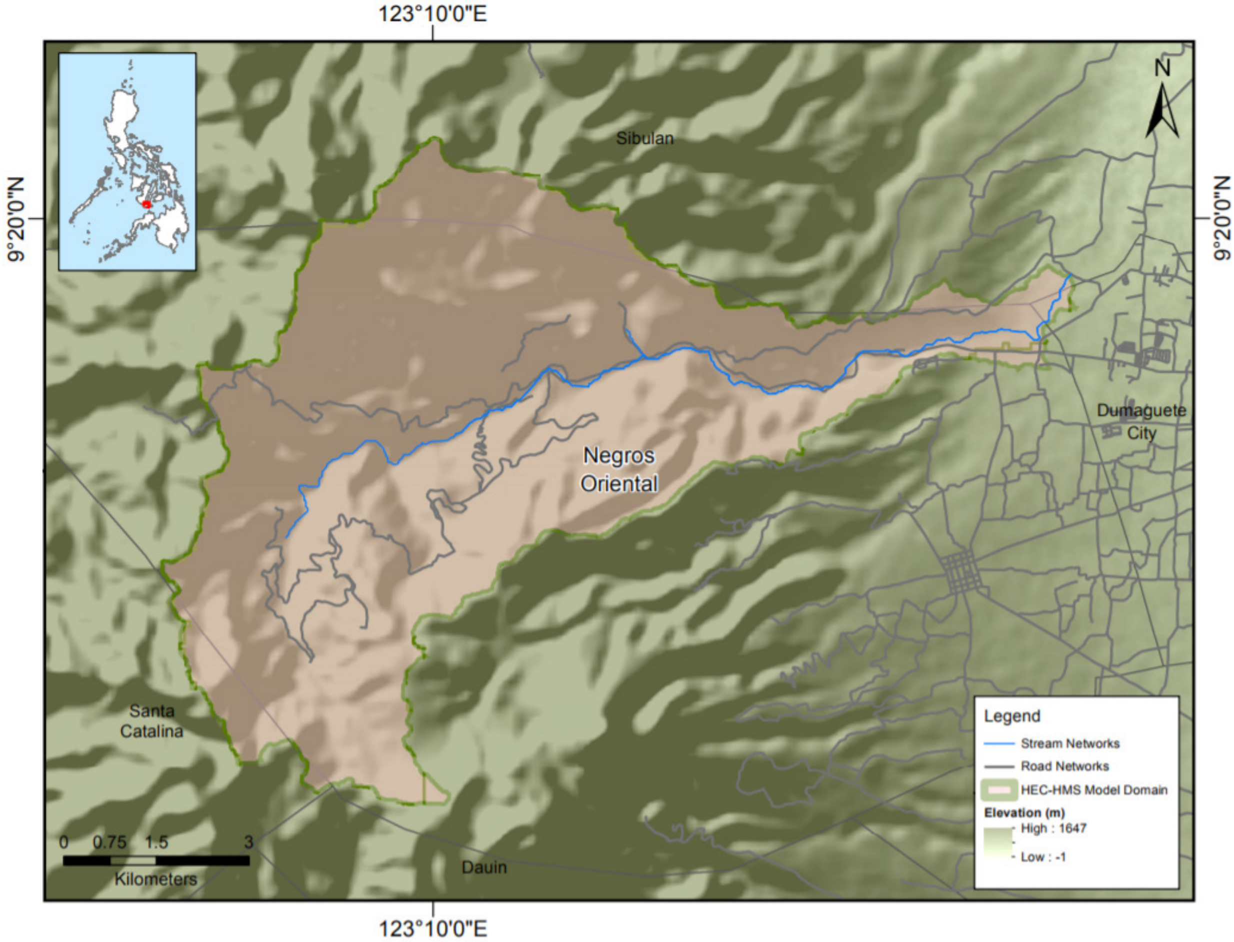

Figure 1. Map of Ocoy River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE OCOY 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 Ocoy floodplain in Samar. These missions were planned for 14 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 are found in Table 1 and Table 2. Figure 2 shows the flight plan for Ocoy floodplain.

Table 1. Flight planning parameters for the Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK56V	600	30	36	50	45	120	5

Table 2. Flight planning parameters for the Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK56B	1000	30	40	100	50	120	5
BLK56E	1000	30	40	100	50	120	5
BLK56F	1000	30	40	100	50	120	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

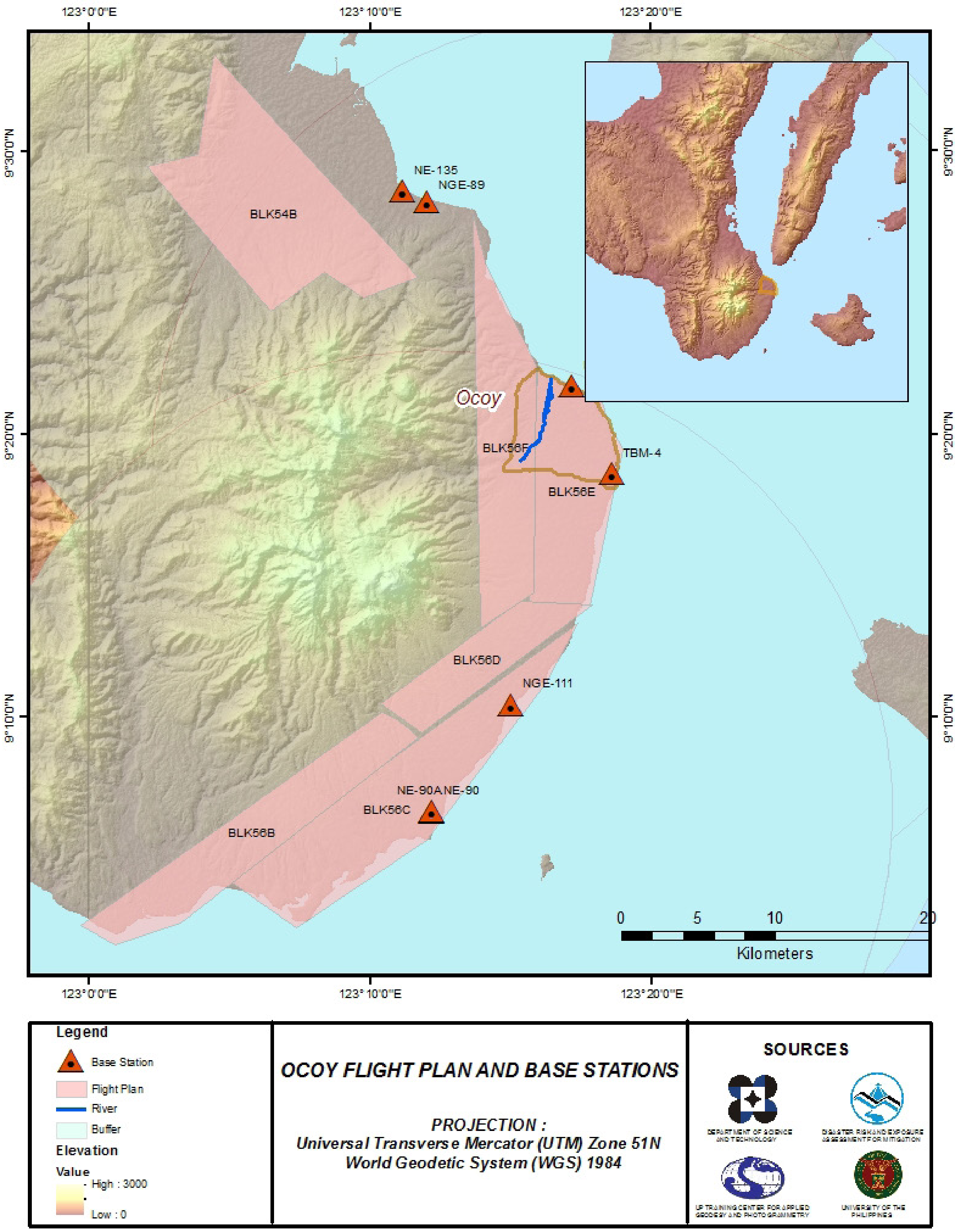


Figure 2. Flight Plan and base station used for the Ocoy Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points: NGE-89 and NGE-100, NGE-101, NGE-111, and NGW-126 which are of second (2nd) order accuracy. Four (4) NAMRIA benchmarks were recovered: NE-90, NE-90a, NE-135 and T-BM4 which are all of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (September 24-October 28, 2014 and January 30, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ocoy floodplain are shown in Figure 2.

Figure 3 to Figure 9 show the recovered NAMRIA reference points within the area. Table 3 to Table 10 show the details about the following NAMRIA control stations and established points, while Table 11 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

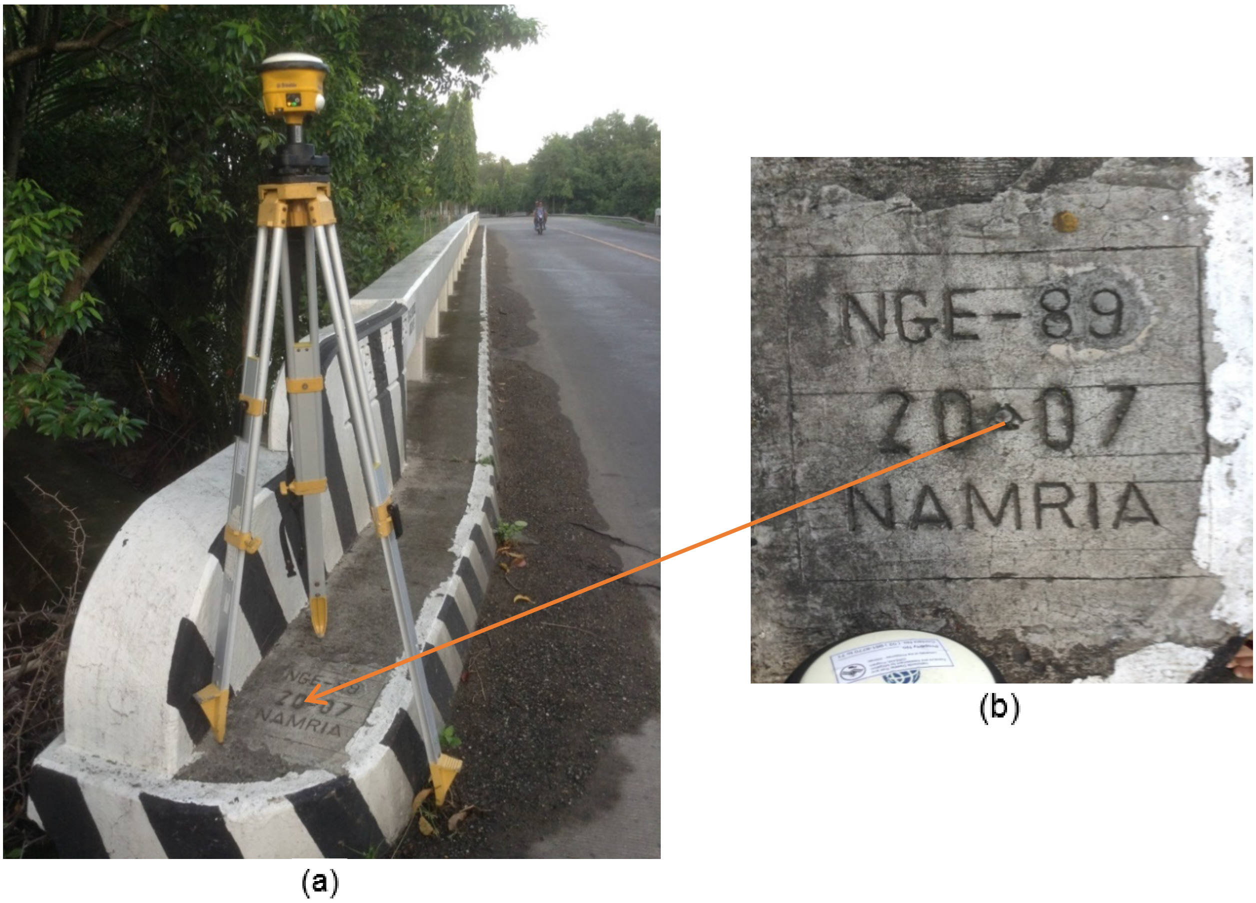


Figure 3. GPS set-up over NGE-89 as recovered on the SE corner of Bio-os Bridge in Brgy. Bio-os under the municipality of Amlan. (a) and NAMRIA reference point NGE-89 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGE-89 used as base station for the LiDAR acquisition.

Station Name	NGE-89	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 28' 17.93638" North 123o 11' 53.99321" East 5.92700 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	302131.943 m 1047809.850 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 28' 13.96567" North 123o 11' 59.32102" East 67.20400 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	521,895.196 m 1,046,874.129 m

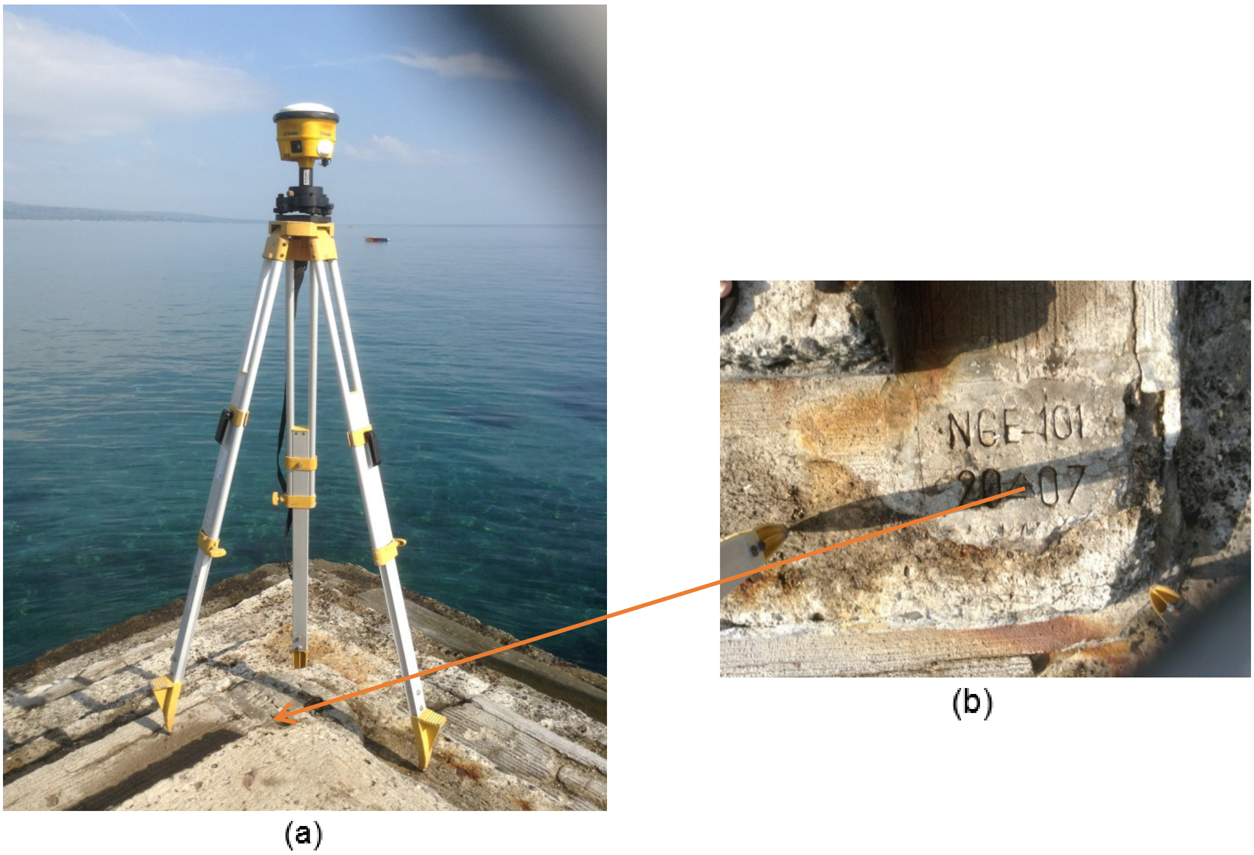


Figure 4. GPS set-up over NGE-101 as recovered on the third step from the top flooring of the pier NE corner in Brgy. Poblacion under the municipality of Sibulan (a) and NAMRIA reference point NGE-101 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point NGE-101 used as base station for the LiDAR acquisition.

Station Name	**NGE-101**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 21’ 46.05028” North 123o 17’ 3.45508” East 2.89700 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	311516.397 m 1035718.276 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 21’ 42.11526” North 123o 17’ 8.79199” East 65.25500 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	531,340.539 m 1,034,845.884 m

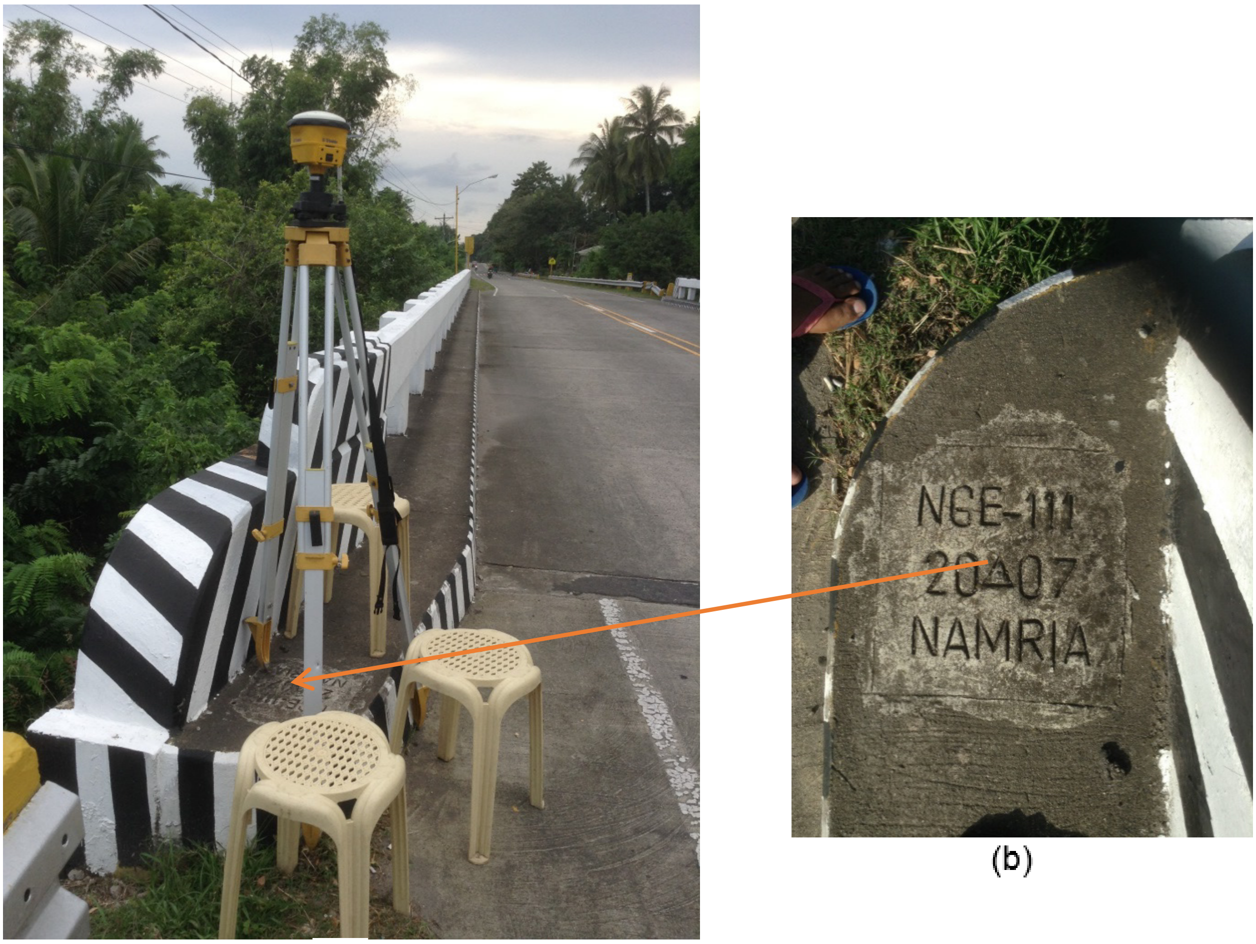


Figure 5. GPS set-up over NGE-111 as recovered on the concrete sidewalk on the NE approach of the 36 meter long Jagoba Bridge in barangay Jagoba under the municipality of Dauin (a) and NAMRIA reference point NGE-111 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point NGE-111 used as base station for the LiDAR acquisition.

Station Name	NGE-111	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 10’ 30.25228” North 123o 14’ 54.26711” East 13.11600 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	307470.632 m 1014968.138 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 10’ 26.36267” North 123o 14’ 59.62110” East 75.79100 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	527,414.069 m 1,014,090.031 m

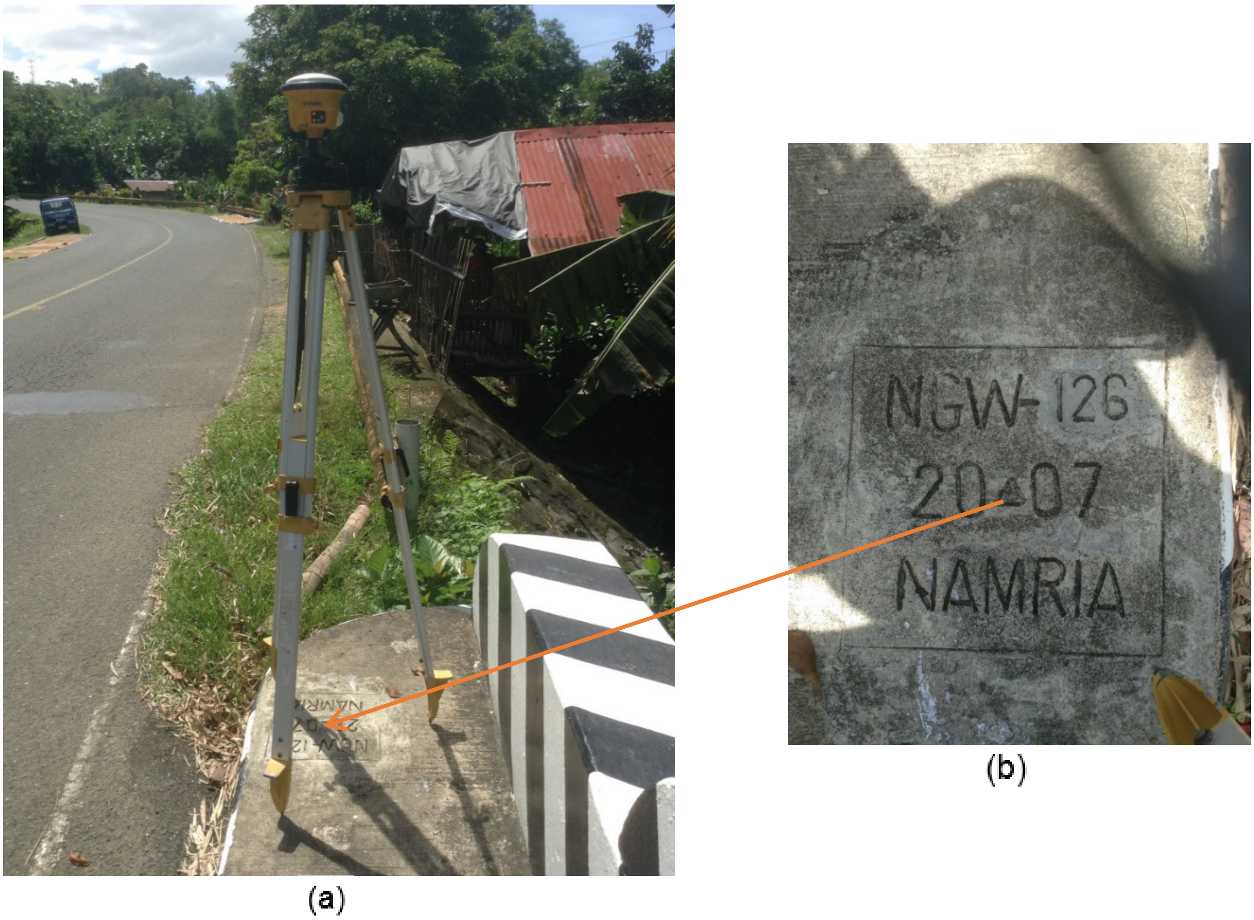
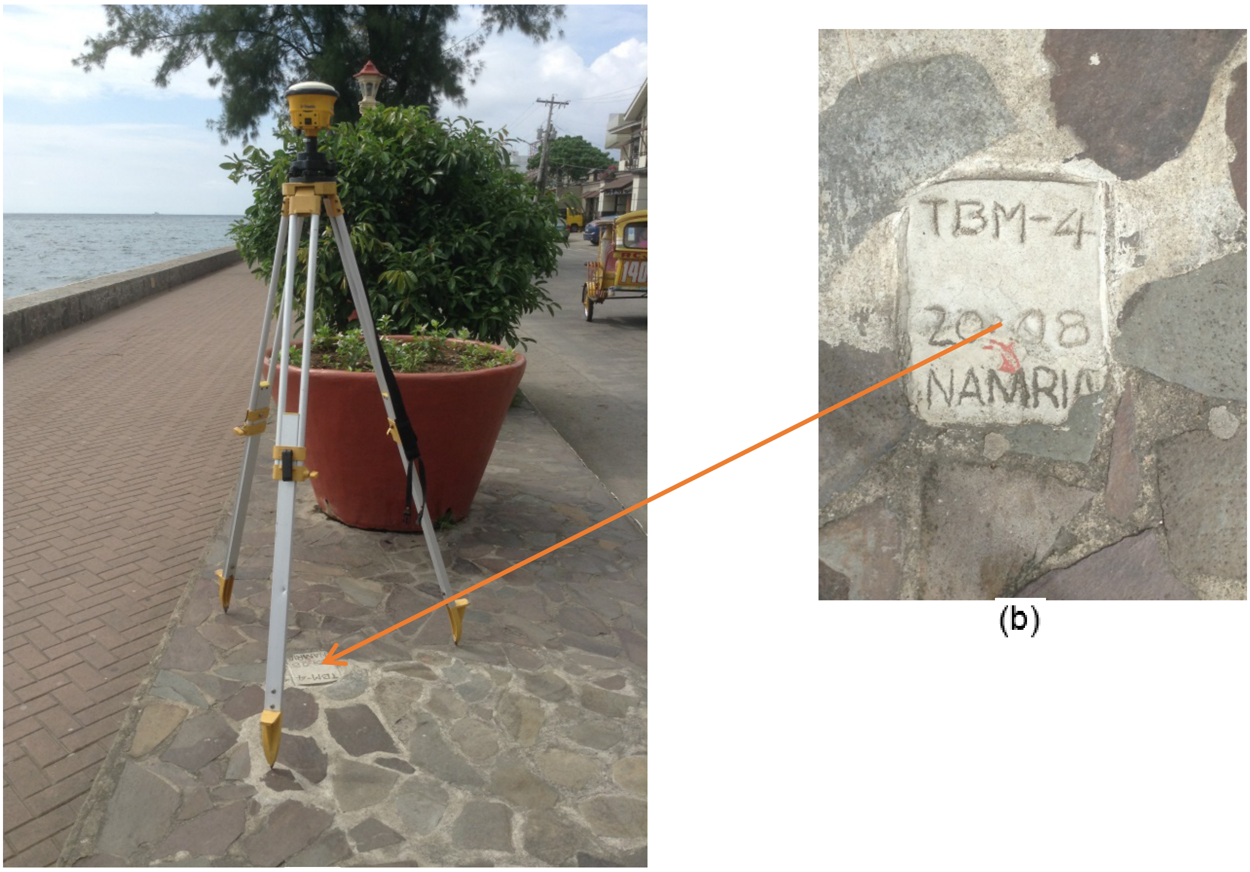


Figure 6. GPS set-up over NGW-126 as recovered on the SE corner of Maricalum Bridge which is at km 177+175 in Brgy. Maricalum under the municipality of Sipalay (a) and NAMRIA reference point NGW-126 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point NGW-126 used as base station for the LiDAR acquisition.

Station Name	**NGW-126**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 41’ 56.09927” North 122o 26’ 33.87232” East 20.29100 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	219291.805 m 1073487.816 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 41’ 52.00368” North 122o 26’ 39.18513” East 79.82600 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	438,996.109 m 1,072,045.486 m



(a) (b)

Figure 7. GPS set-up over TBM-4 as recovered on top of concrete pathway about five (5) meters from the seawall of Dumaguete City's boulevard.

Table 7. Details of the recovered NAMRIA vertical control point TBM-4 used as base station with established coordinates.

Station Name	TBM-4	
Order of Accuracy	**1st**	
Relative Error (Horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference Of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 18' 39.58660" North 123o 18' 28.47112" East 3.712 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	313960.450 m 1030039.396 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 18' 35.66706" North 123o 18' 33.81248" East 66.241 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	533,814.622 m 1,029,185.290 m

(a)

(b)

Figure 8. GPS set-up over NE-135 as recovered in Busuang Bridge on top of concrete sidewalk in Barangay Bio-os under the municipality of Amlan. (a) and NAMRIA reference point NE-135 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA vertical control point NE-135 used as base station with established coordinates.

Station Name	NE-135	
Order of Accuracy	1st	
Relative Error (Horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 28’ 39.60020” North 123o 11’ 03.44049” East 5.556 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	300468.479 m 1048547.710 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 28’ 35.62671” North 123o 11’ 08.76787” East 67.415 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	520,228.944 m 1,047,601.845 m

Figure 9. GPS set-up over NE-90 as recovered on the concrete sidewalk of Guinsan Bridge four (4) meters from the road centerline in Brgy. Poblacion under the municipality of Zamboangita. (a) and NAMRIA reference point NE-90 (b) as recovered by the field team.

Table 9. Details of the recovered NAMRIA vertical control point NE-90 used as base station with established coordinates.

Station Name	NE-90	
Order of Accuracy	1st	
Relative Error (Horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 6’ 42.32060” North 123o 12’ 4.93445” East 7.358 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	302140.874 m 1008052.054 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 6’ 38.44322” North 123o 12’ 10.29457” East 70.052 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	522,126.927 m 1,007,150.356 m

Table 10. Details of the recovered NAMRIA vertical control point NE-90A used as base station with established coordinates.

Station Name	**NE-90A**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9o 6’ 44.56134” North 123o 12’ 5.05054” East 6.617 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	522,130.430 meters 1,007,219.168 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9o 6’ 40.68380” North 123o 12’ 10.41051” East 69.311 meters

Table 11. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
September 24, 2014	7514G	2BLK56F267A	NGE 101 & TBM-4
October 2,2014	7530G	2BLK56B275A	NE-135 & NGE 101
October 28, 2014	7582G	2BLK56BS+53ES301A	NGE-111, NGE-89, NE-135 & NE-90
January 30, 2016	10077AC	3BLK56V030B	NGE-100, NGW-126, NE-90 & NE-90A

2.3 Flight Missions

Four (4) missions were conducted to complete LiDAR data acquisition in Ocoy Floodplain, for a total of twelve hours and fifty-five minutes (12+55) of flying time for RP-C9322 and RP-C9522. All missions were acquired using Aquarius and Gemini LiDAR systems. Table 12 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for the LiDAR data acquisition of the Ocoy 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
September 24, 2014	7514G	181.16	106.5	31.10	6.38	NA	3	47
October 2,2014	7530G	171	71.2	10.31	27.17	NA	2	23
October 28, 2014	7582G	151.95	117.6	4.61	32.87	NA	3	23
January 30, 2016	10077AC	25	24.53	2.61	34.87	NA	3	22
TOTAL		**529**	**319.83**	**48.63**	**101.29**	**NA**	**12**	**55**

Table 13. Actual parameters used during the LiDAR data acquisition of the Ocoy Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7514G	1000	30	40	100	50	120	5
7530G	1000	30	40	100	50	120	5
7582G	1000	30	40	100	50	120	5
10077AC	1000	30	40	100	50	120	5

2.4 Survey Coverage

Ocoy floodplain is located in the province of Negros Oriental with majority of the floodplain situated within Sibulan and Dumaguete City. Dumaguete City is completely covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Ocoy Floodplain is presented in Figure 10.

Table 14. List of municipalities and cities surveyed of the Ocoy Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Negros Oriental	Dumaguete City	30.42	30.42	100%
	Bacong	26.07	20.17	77.38%
	San Jose	47.09	19.96	42.38%
	Dauin	80.91	23.68	29.26%
	Sibulan	165.36	45.84	27.72%
	Valencia	144.43	33.09	22.91%
	Zamboanguita	152.83	25.09	16.42%
	Amlan	65.67	7.43	11.31%
	Siaton	312.75	25.28	8.08%
	Tanjay City	261.01	19.78	7.58%
Total		**1501.64**	**264.43**	**17.61%**

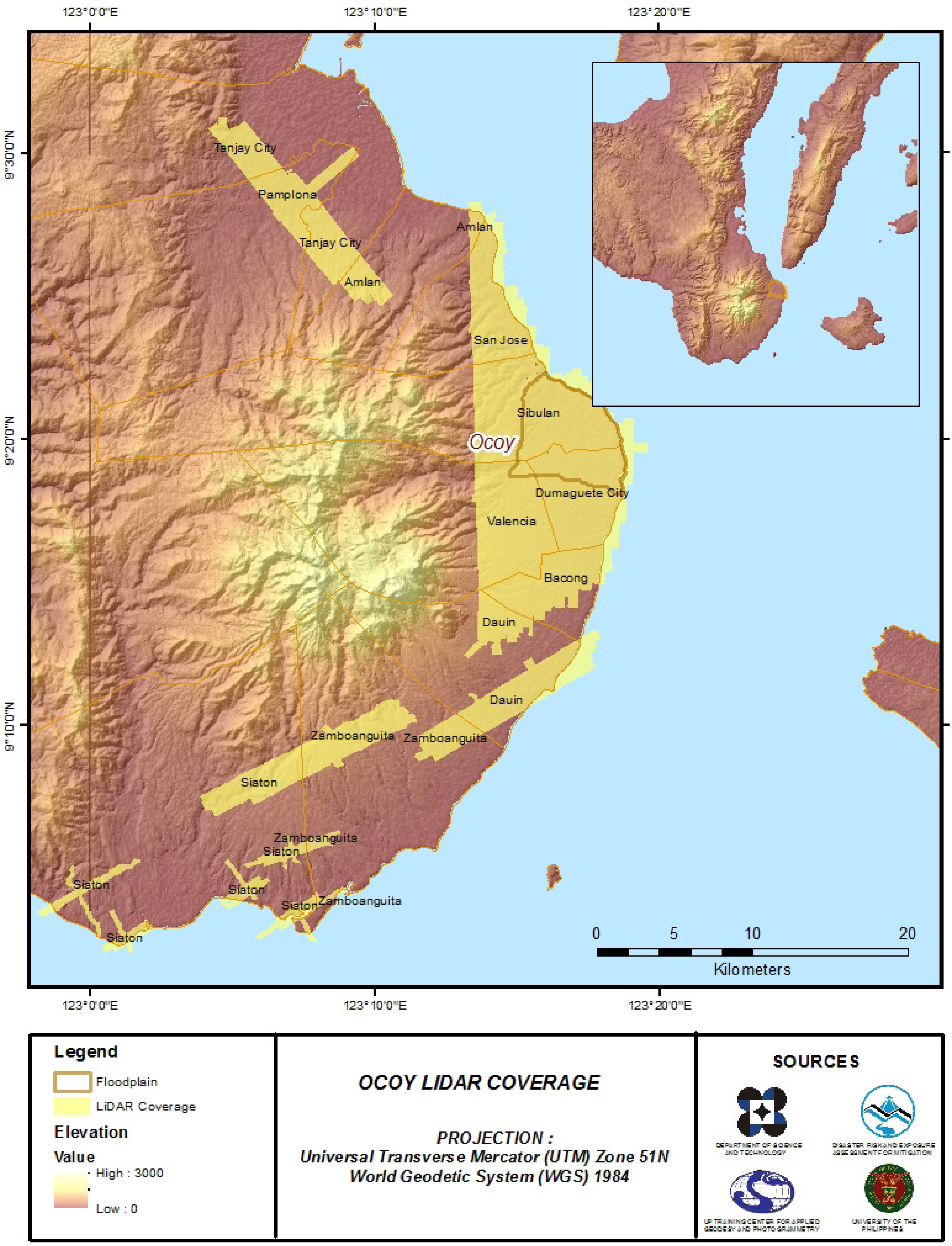


Figure 10. Actual LiDAR survey coverage of the Ocoy Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE OCOY 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 11.

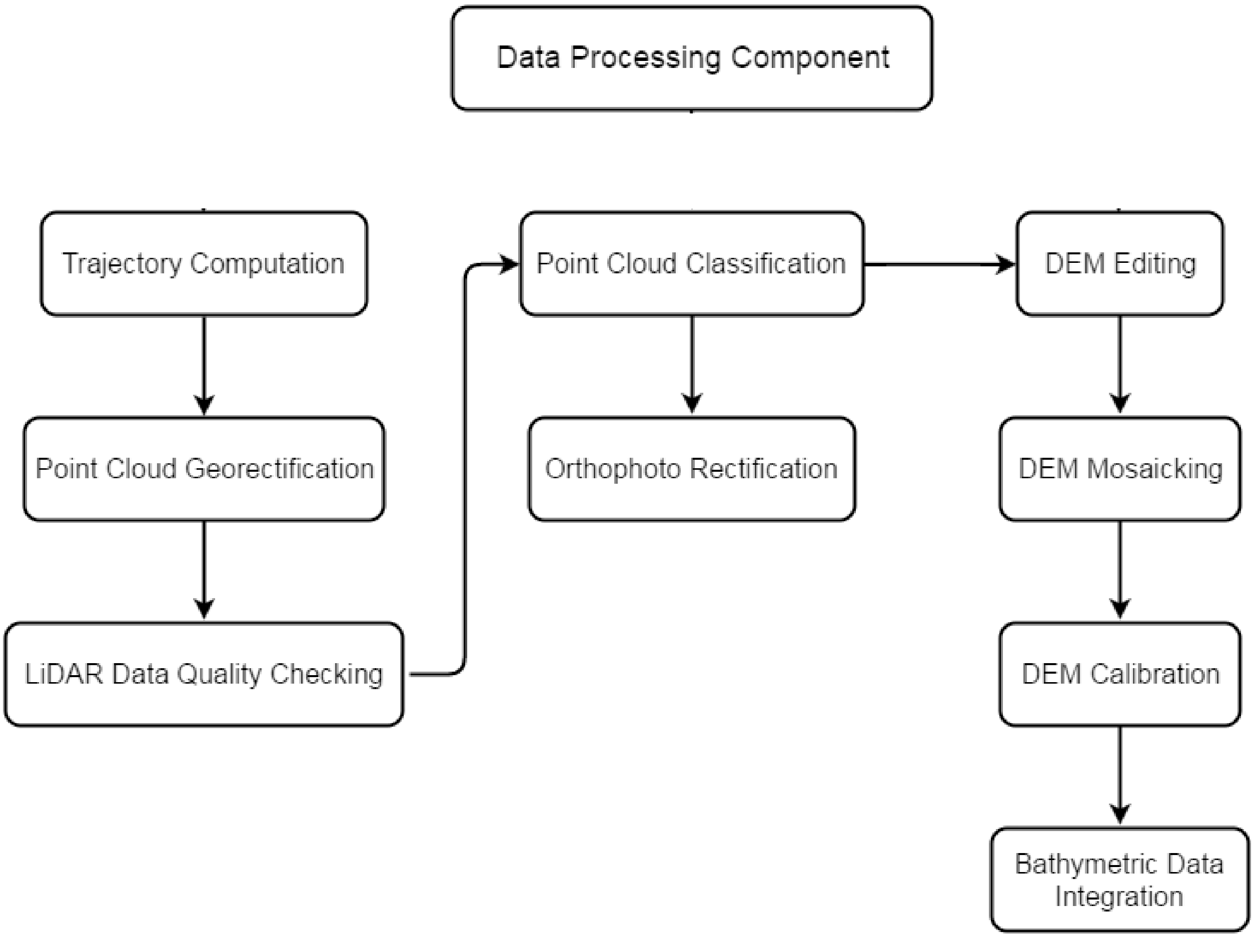

Figure 11. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ocoy floodplain can be found in Annex 5. Missions flown during the first survey conducted on September 2014 and the second survey on October 2014 both used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the third survey on January 2016 were flown using the Aquarius system over Sibulan, Negros Occidental.

The Data Acquisition Component (DAC) transferred a total of 50.9 Gigabytes of Range data, 723 Megabytes of POS data, 42.57 Megabytes of GPS base station data, and 34.62 Gigabytes of raw image data to the data server on October 20, 2014 for the first survey, November 6, 2014 for the second survey and February 9, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ocoy was fully transferred on February 9, 2016, as indicated on the Data Transfer Sheets for Ocoy floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7514G, one of the Ocoy flights, which is the North, East, and Down position RMSE values are shown in Figure 12. 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 September 24, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

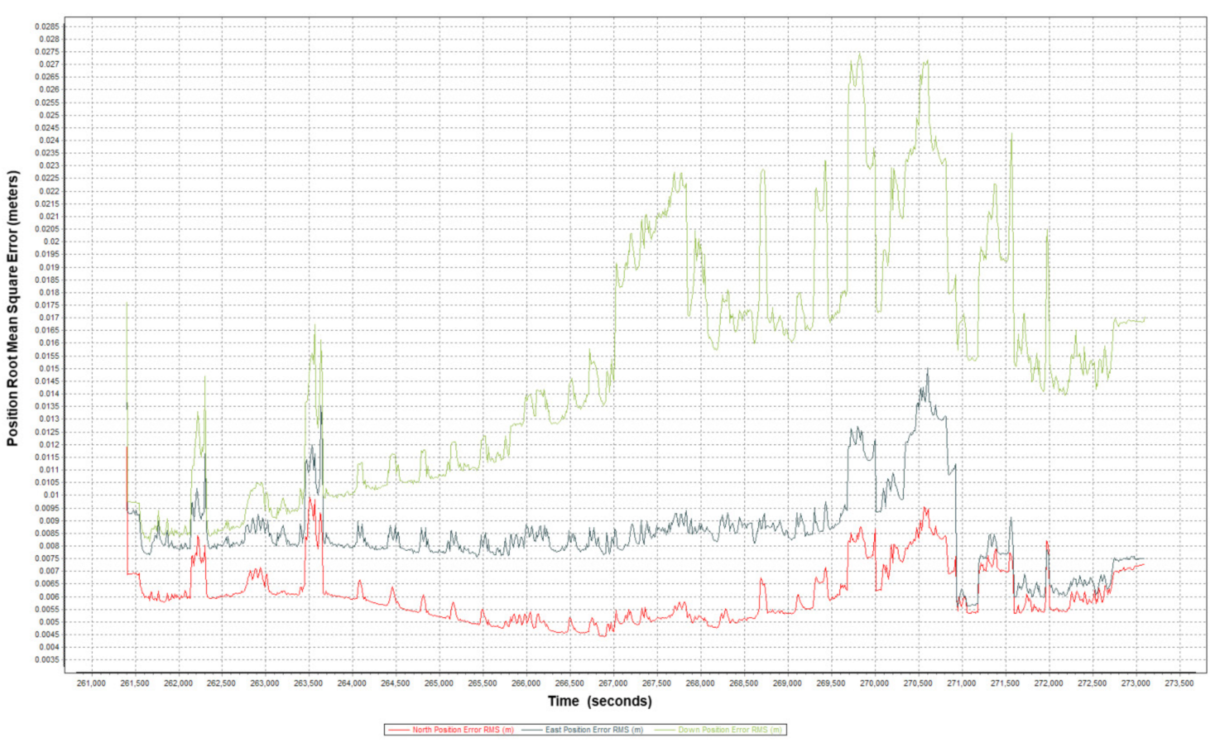

Figure 12. Smoothed Performance Metrics of Ocoy Flight 7514G.

The time of flight was from 261250 seconds to 273250 seconds, which corresponds to morning of September 24, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 shows that the North position RMSE peaks at 0.87 centimeters, the East position RMSE peaks at 1.25 centimeters, and the Down position RMSE peaks at 2.32 centimeters, which are within the prescribed accuracies described in the methodology.

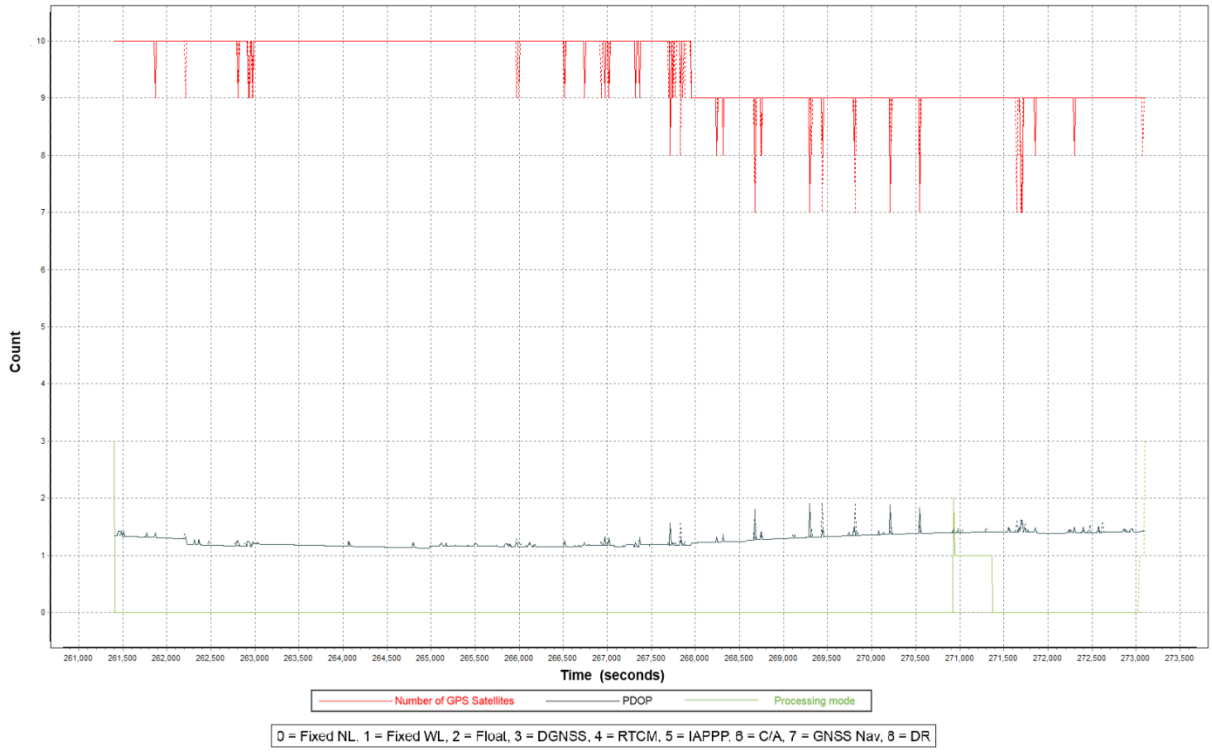

Figure 13. Solution Status Parameters of Ocoy Flight 7514G.

The Solution Status parameters of flight 7514G, one of the Ocoy flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Ocoy flights is shown in Figure 14.

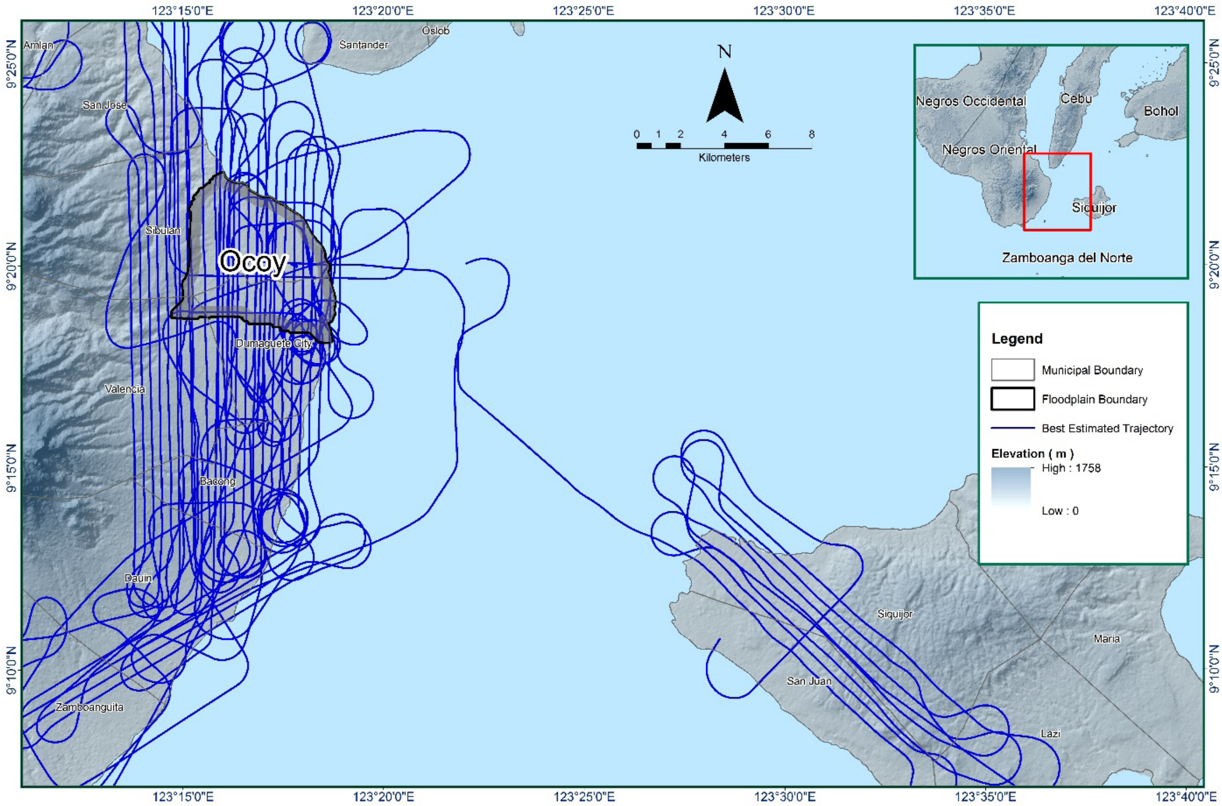

Figure 14. Best Estimated Trajectory of the LiDAR missions conducted over the Ocoy Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 50 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Ocoy floodplain are given in Table 15.

Table 15. Self-calibration Results values for Ocoy flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000229
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000712
GPS Position Z-correction stdev	<0.01meters	0.0020

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Ocoy Floodplain is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

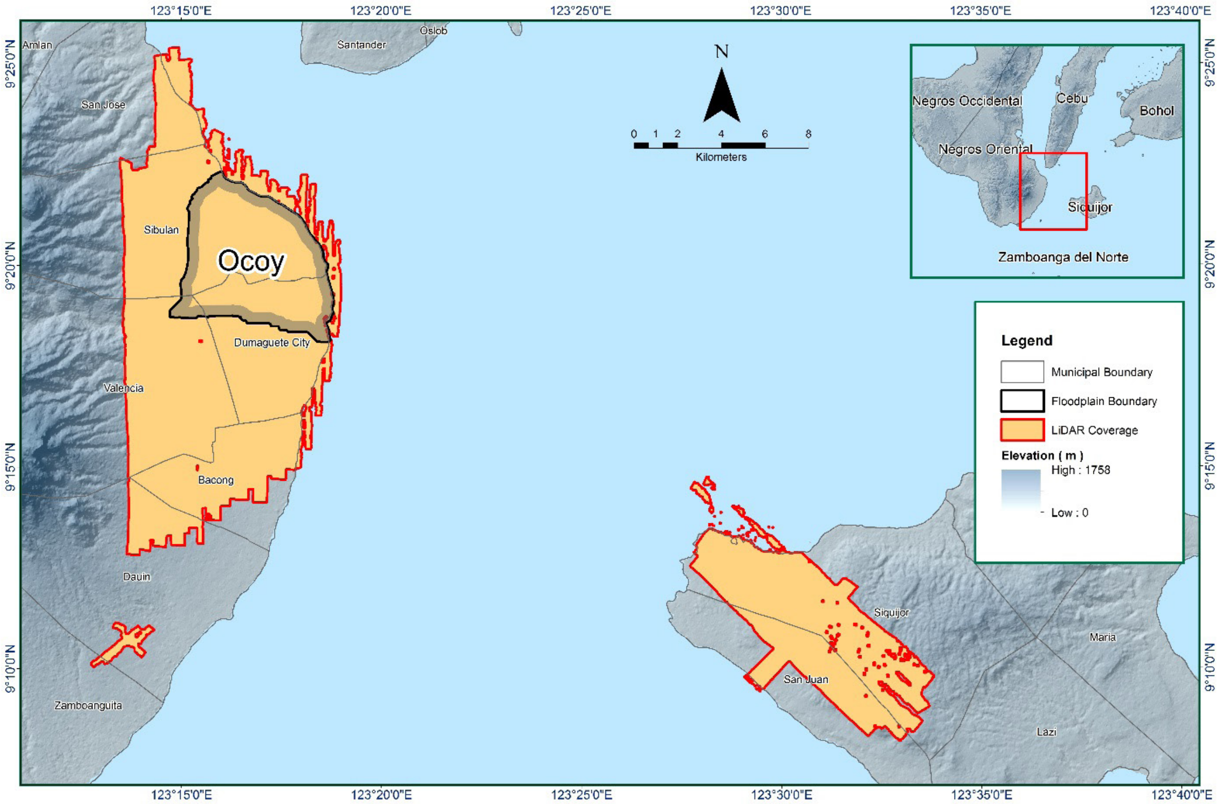

Figure 15. Boundary of the processed LiDAR data over Ocoy Floodplain

The total area covered by the Ocoy missions is 225.30 sq.km that is comprised of five (5) flight acquisitions grouped and merged into five (5) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for Ocoy Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Dumaguete_Blk56E_supplement	7582G	64.677
Dumaguete_Blk56EF	7514G	97.82
	7530G	
Dumaguete_Blk57C	7589GC	47.93
Dumaguete_reflights_Blk56D	10077AC	3.28
Dumaguete_reflights_Blk56E	10077AC	11.59
TOTAL		**225.30 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 16. Since the Gemini and Aquarius systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

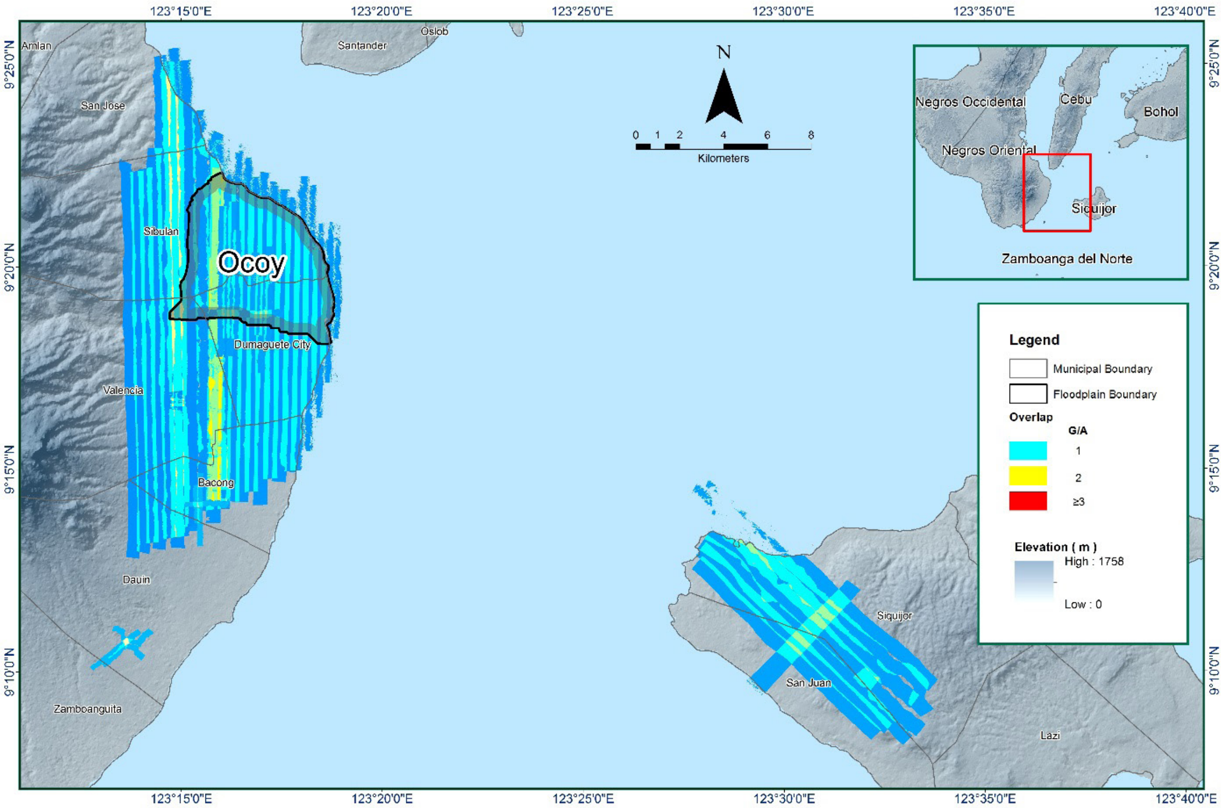

Figure 16. Image of data overlap for Ocoy Floodplain.

The overlap statistics per block for the Ocoy floodplain can be found in Annex 8: Mission Summary Reports. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 28.79% and 45.21% 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 17. It was determined that all LiDAR data for Ocoy floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.34 points per square meter.

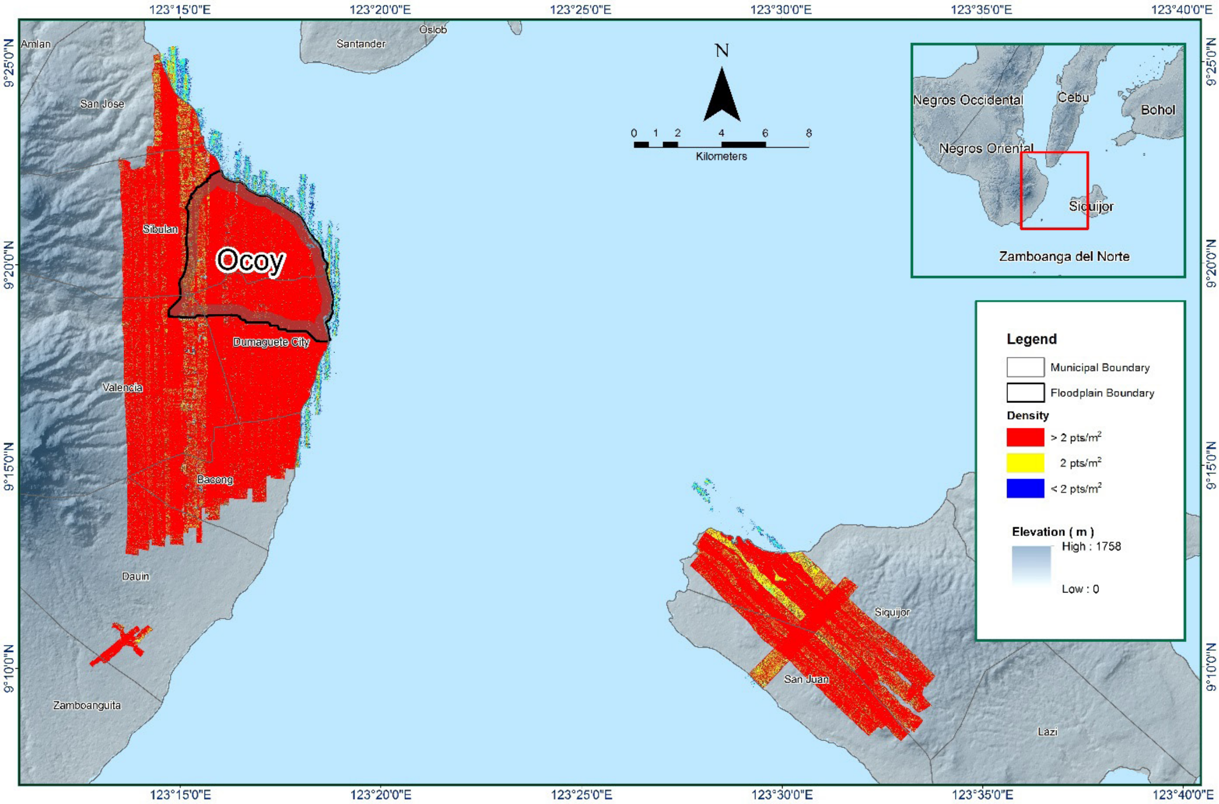

Figure 17. Pulse density map of merged LiDAR data for Ocoy Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. 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.

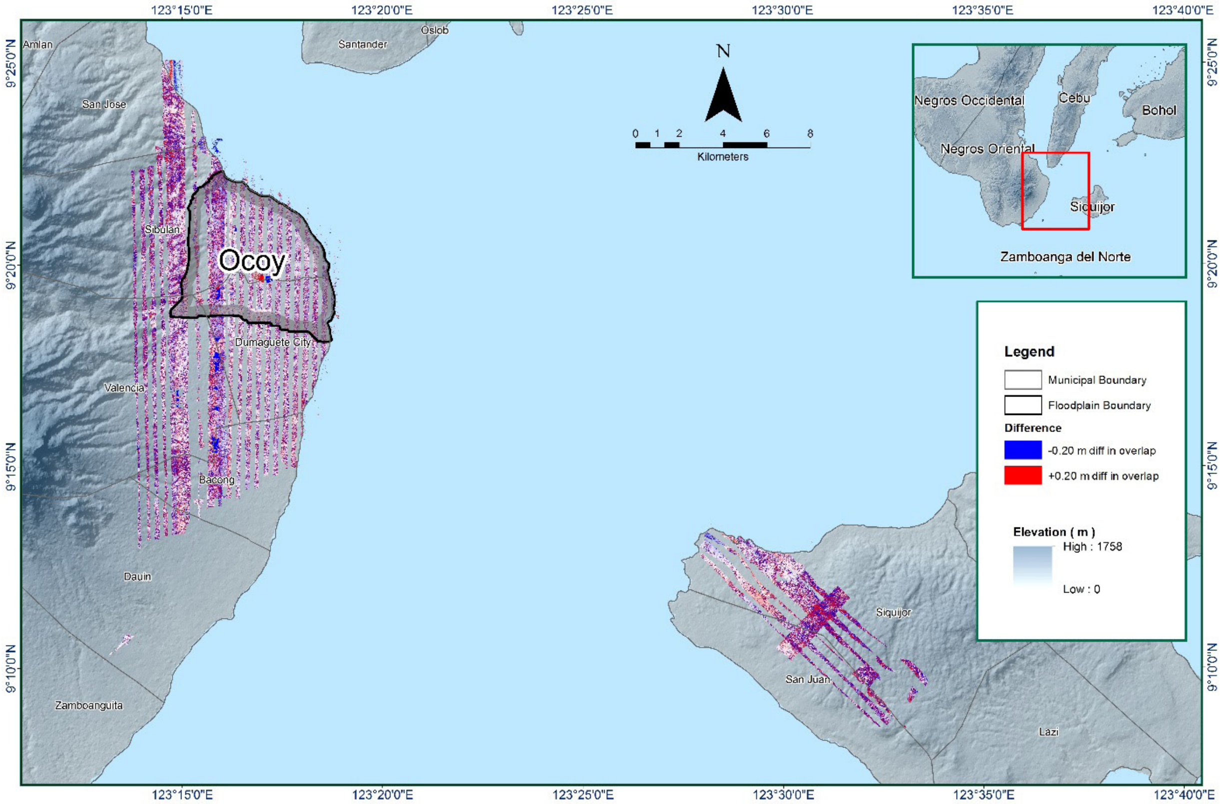

Figure 18. Elevation Difference Map between flight lines for Ocoy Floodplain Survey.

A screen capture of the processed LAS data from an Ocoy flight 7514G loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

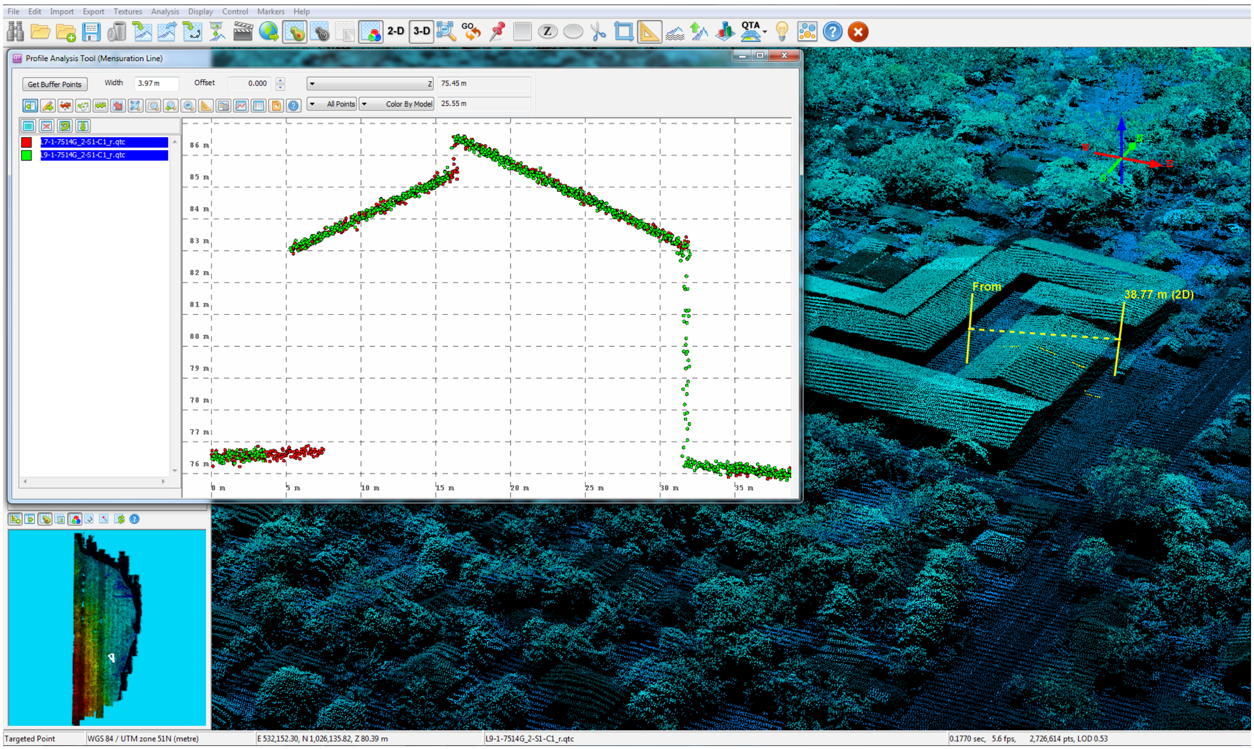

Figure 19. Quality checking for Ocoy Flight 7514G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Ocoy classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	92,707,751
Low Vegetation	117,264,788
Medium Vegetation	225,343,979
High Vegetation	434,597,151
Building	29,163,767

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ocoy floodplain is shown in Figure 20. A total of 364 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 543.76 meters and 2.76 meters respectively.

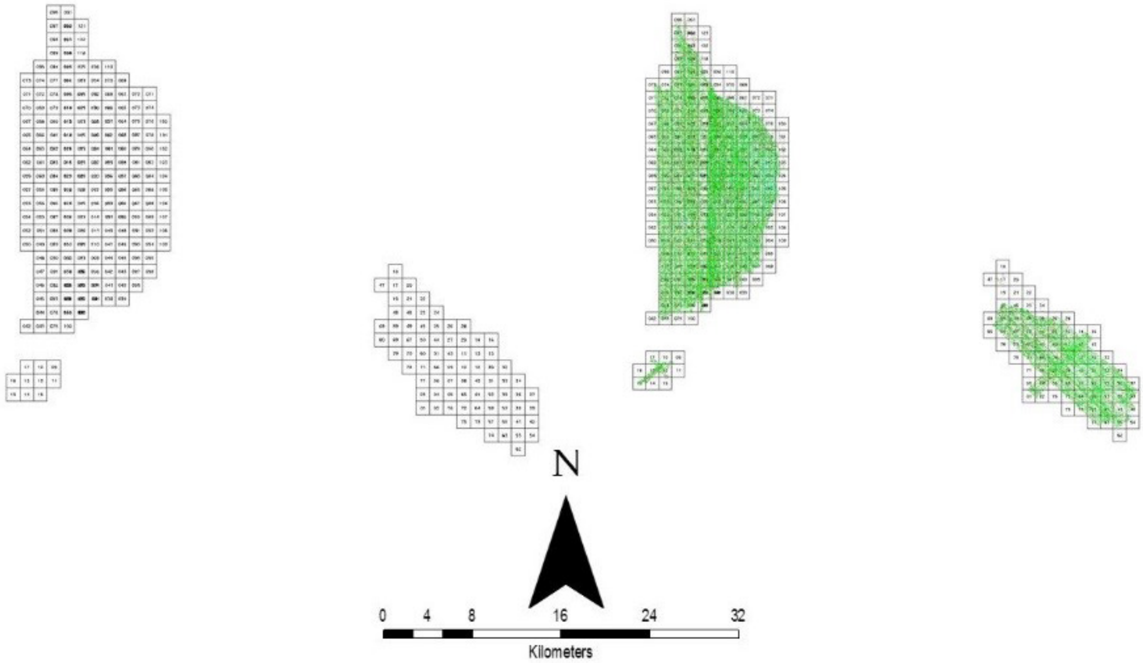

Figure 20. Tiles for Ocoy Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. 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.

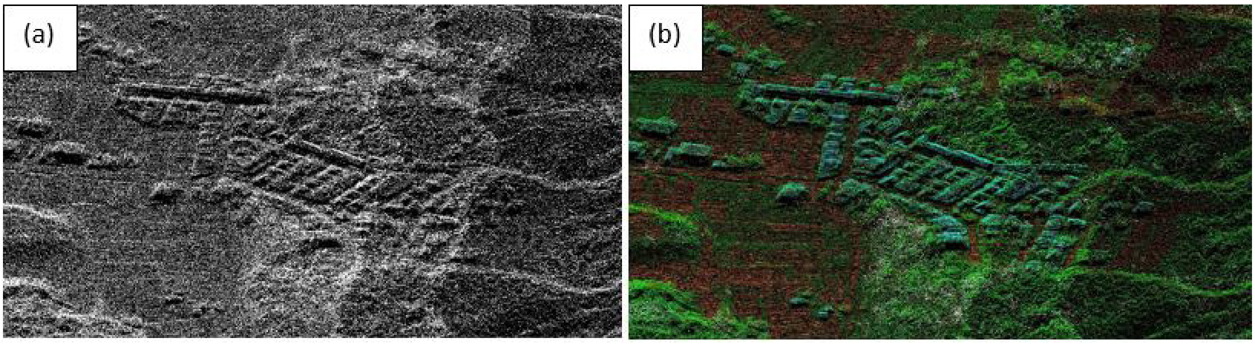

Figure 21. Point cloud before (a) and after (b) classification

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

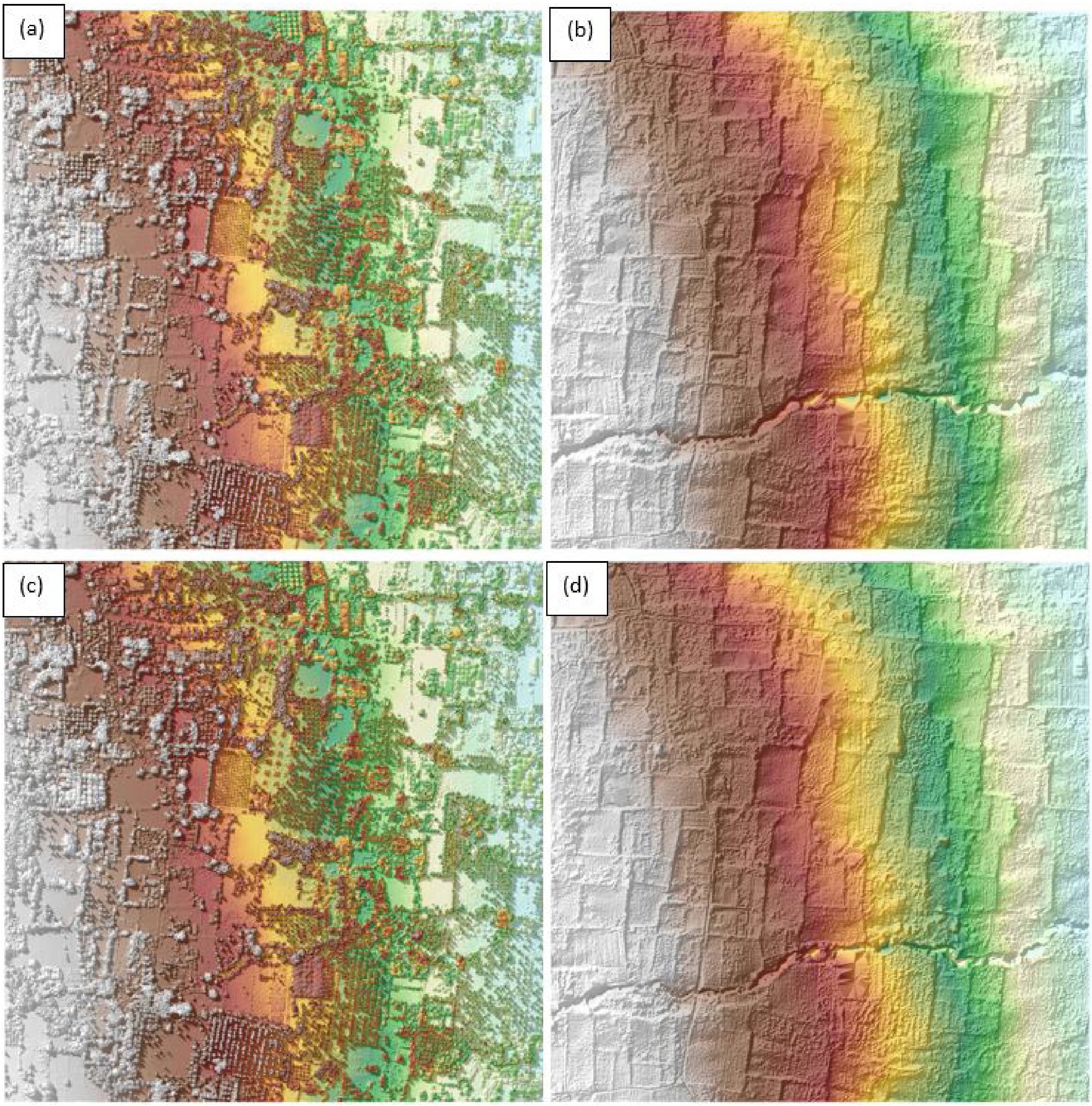

Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ocoy Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Ocoy floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Ocoy flood plain. These blocks are composed of Dumaguete and Dumaguete_reflight blocks with a total area of 225.30 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Dumaguete_Blk56EF	97.82
Dumaguete_Blk56E_supplement	64.677
Dumaguete_Blk57C	47.93
Dumaguete_reflights_Blk56E	11.59
Dumaguete_reflights_Blk56D	3.28
TOTAL	**225.30 sq.km**

Portions of DTM before and after manual editing are shown in Figure 23. Portions of the DTM of Ocoy with existing building features (Figure 23a) were edited (Figure 23b). Another is the bridge (Figure 23c) is also considered to be an impedance to the flow of water and has to be removed (Figure 23d) in order to hydrologically correct the river.

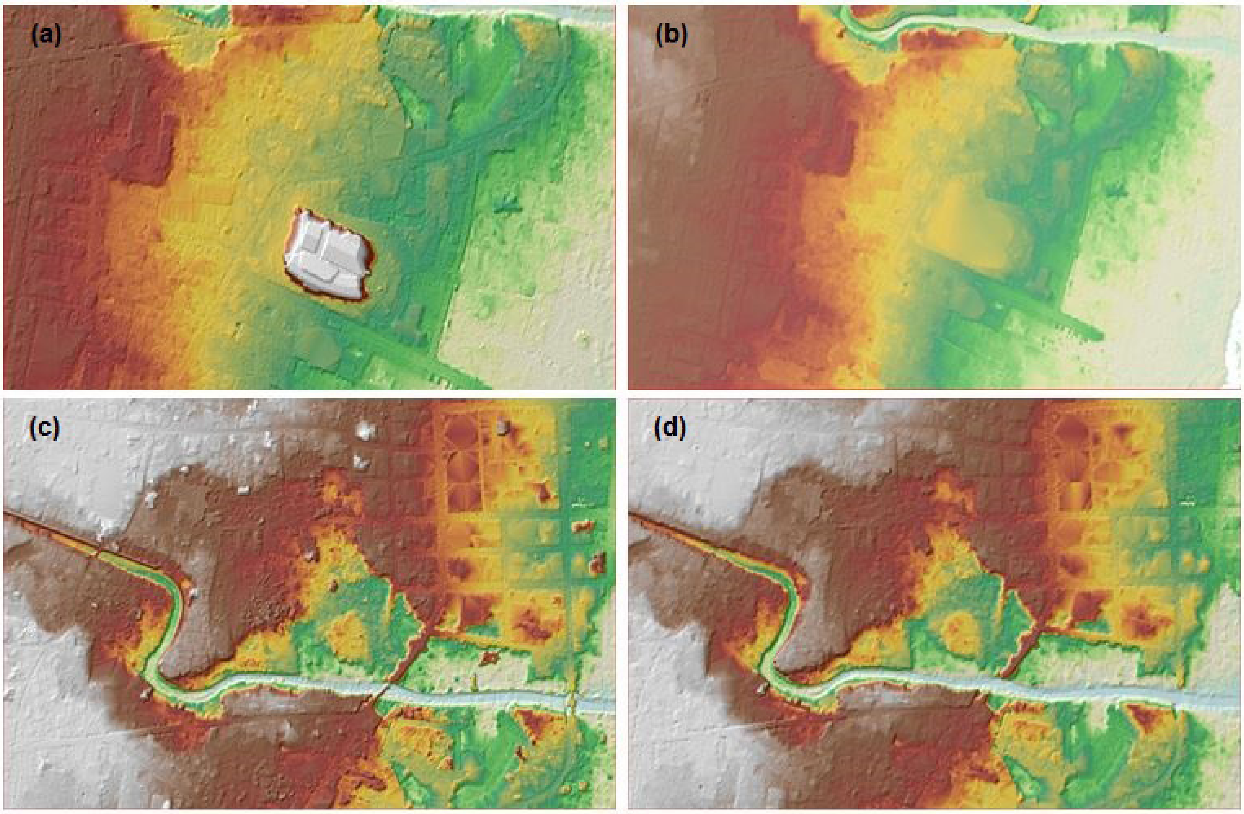

Figure 23. Portions in the DTM of Ocoy floodplain – (a) before and (b) after building removal; (c) before and (d) after bridge removal

3.9 Mosaicking of Blocks

Dumaguete_Blk54B_supplement was used as the reference block in mosaicking due to the presence of more built up areas Table 19 shows the shift values applied to each LiDAR block during mosaicking.

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

Table 19. Shift values of each LiDAR block of Ocoy Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Dumaguete_Blk56EF	0.00	0.00	-0.07
Dumaguete_Blk56Esupplement	0.00	0.00	-0.76
Dumaguete_Blk57C	0.00	0.00	0.00
Dumaguete_reflights_Blk56E	0.00	0.00	-0.04
Dumaguete_reflights_Blk56D	0.00	0.00	0.00

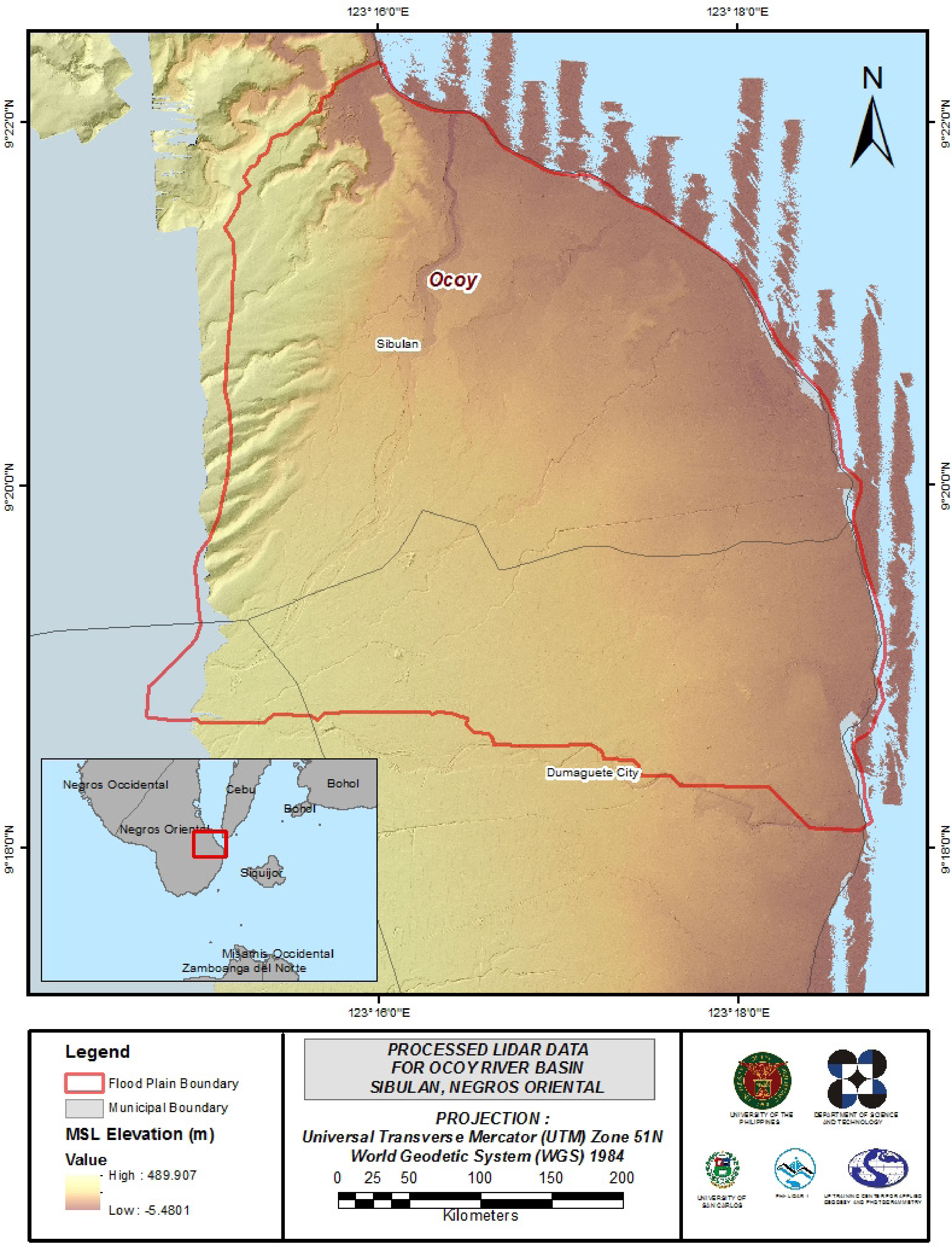

Figure 24. Map of Processed LiDAR Data for Ocoy Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ocoy to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 14,047 survey points were gathered for all the flood plains within the provinces of Negros Oriental and Negros Occidental wherein the Ocoy floodplain is located. Random selection of 80% of the survey points, resulting to 11,237 points, was used for calibration.

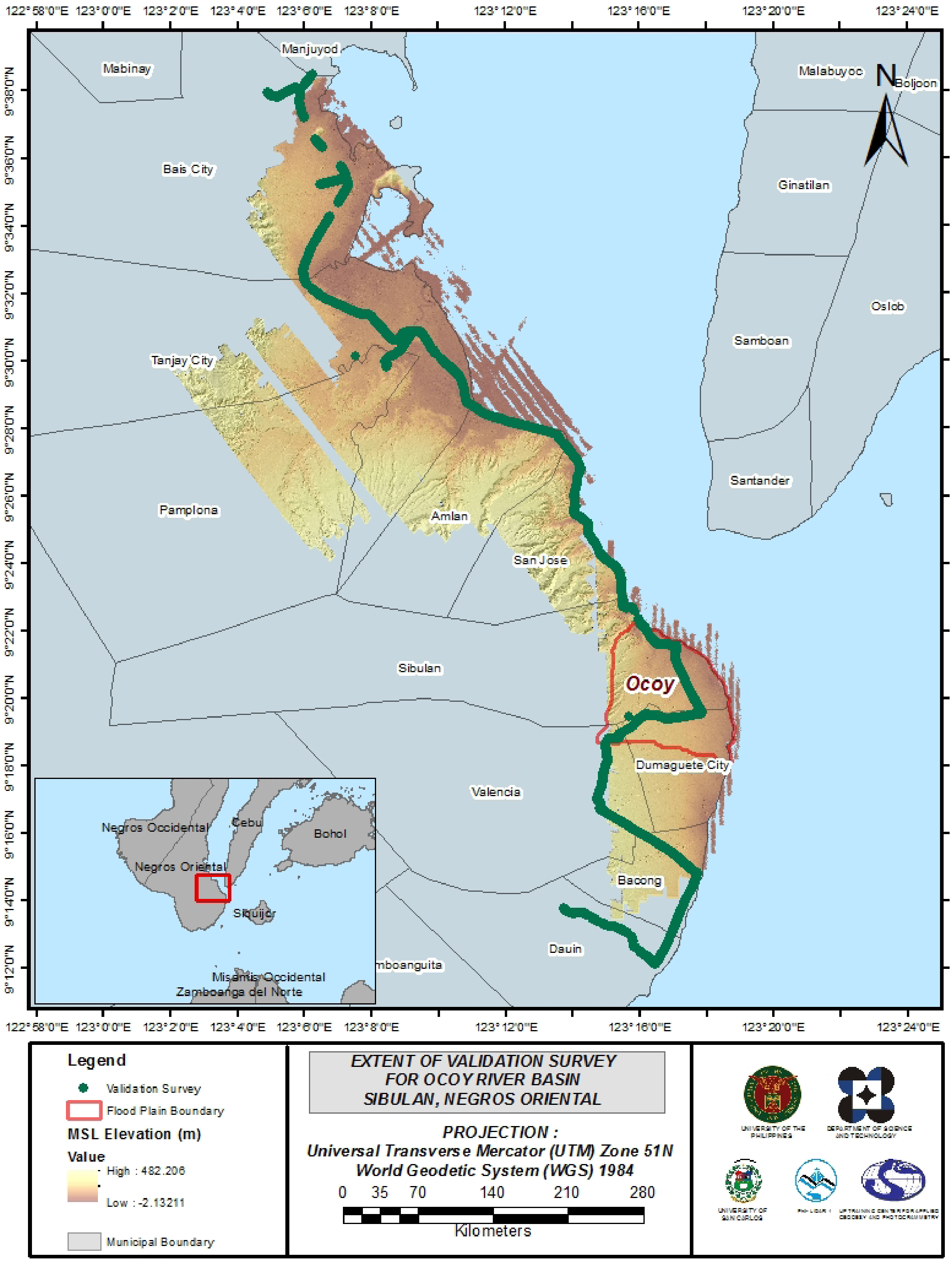

Figure 25. Map of Ocoy Floodplain with validation survey points in green.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.35 meters with a standard deviation of 0.18 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 0.35 meters, to the mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

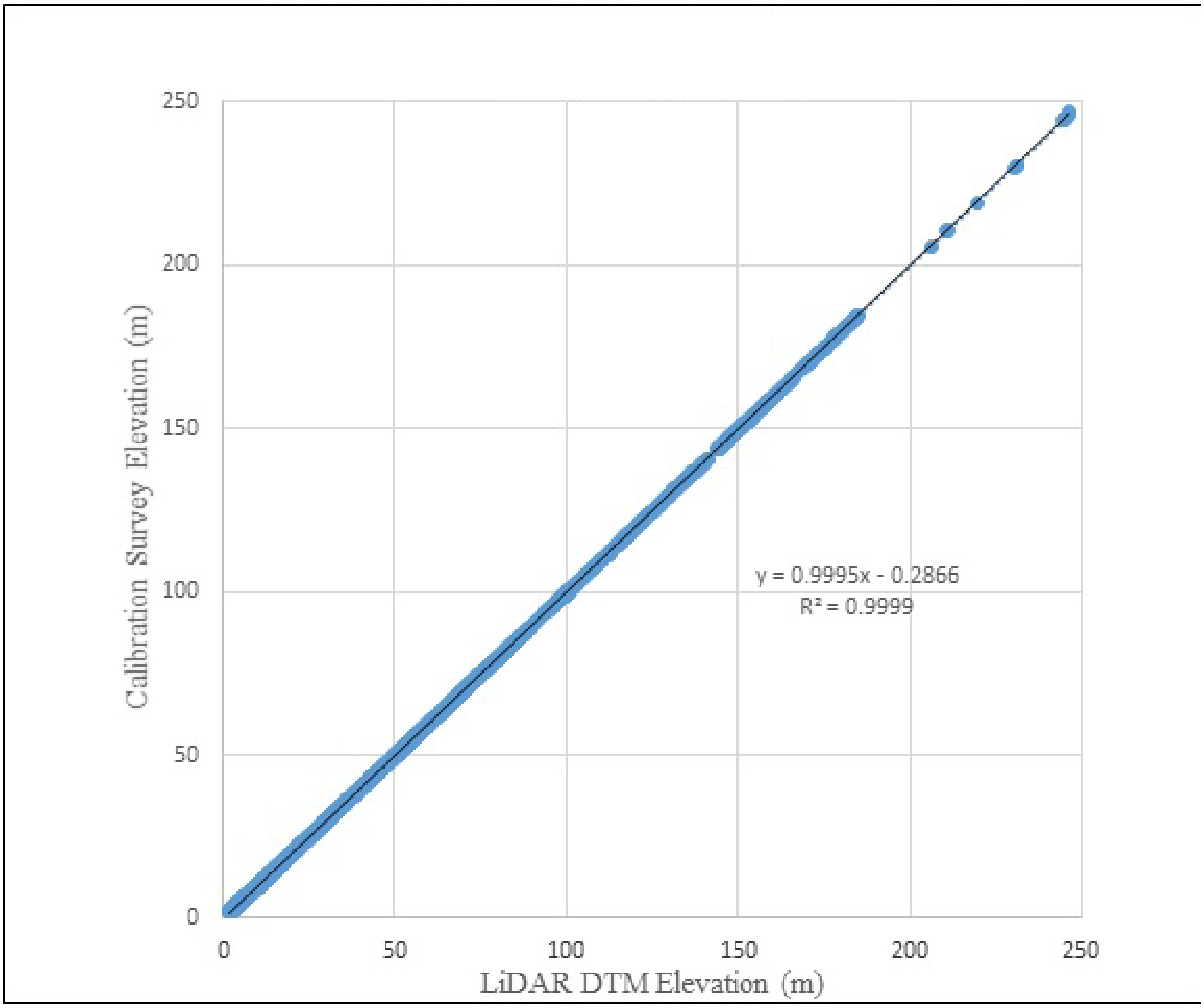

Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 20. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.35
Standard Deviation	0.18
Average	-2.30
Minimum	-0.57
Maximum	0.30

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 389 points, were used for the validation of calibrated Ocoy DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.18 meters with a standard deviation of 0.13 meters, as shown in Table 21.

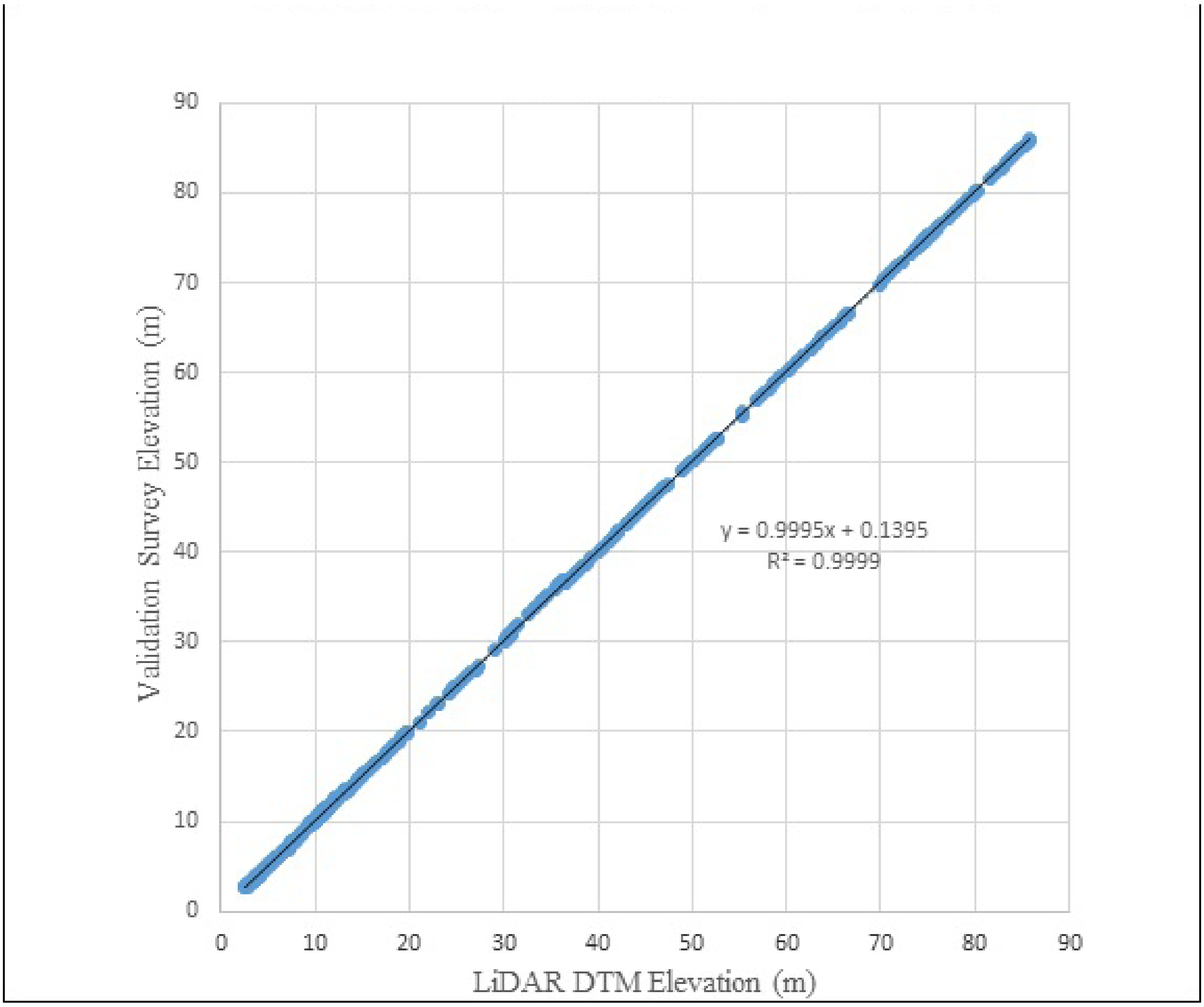

Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 21. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.09
Average	-0.09
Minimum	-0.33
Maximum	0.10

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Ocoy with 3,383 bathymetric 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 0.0776 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ocoy integrated with the processed LiDAR DEM is shown in Figure 28.

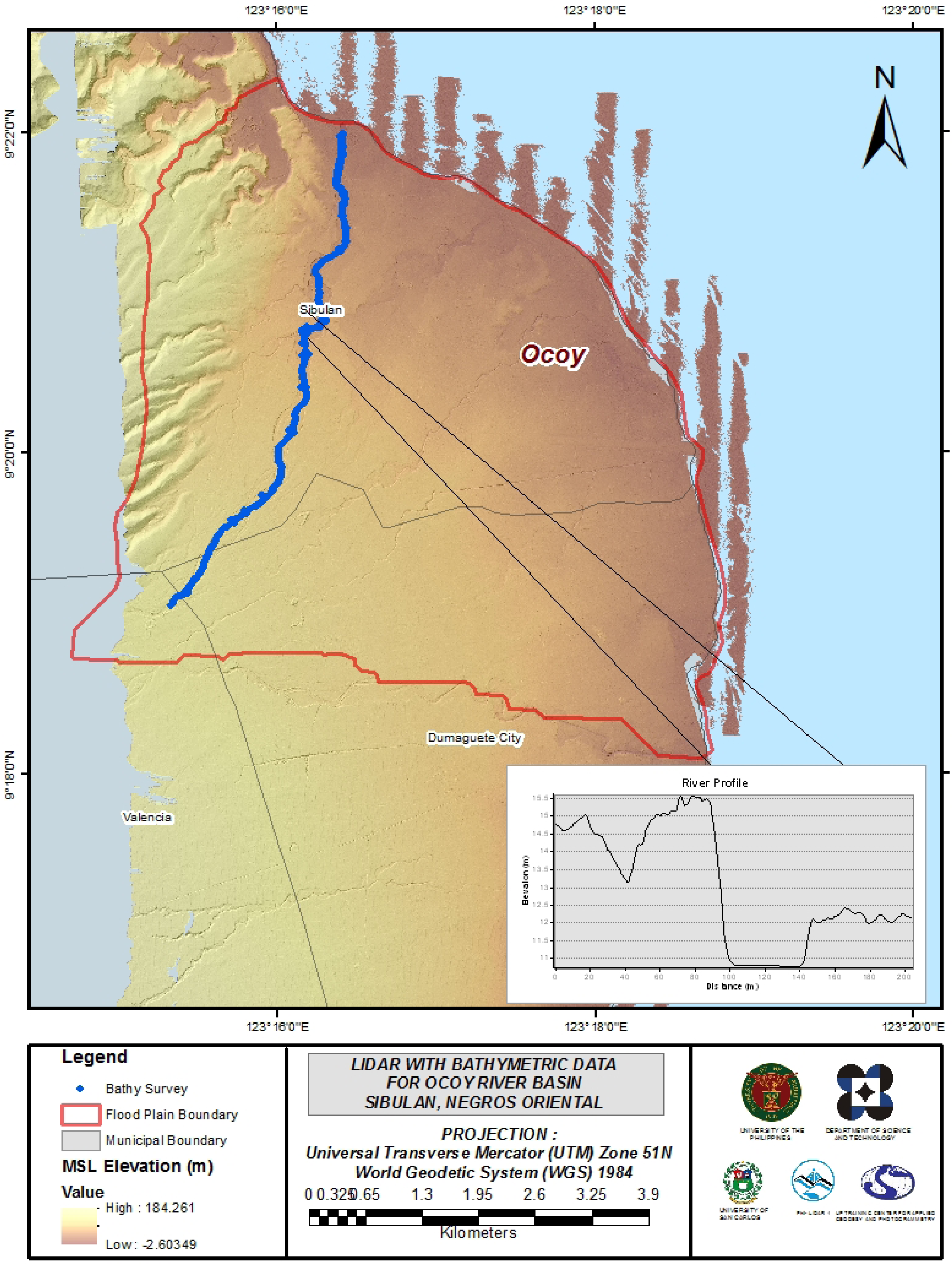

Figure 28. Map of Ocoy Floodplain with bathymetric survey points shown in blue.

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

Ocoy floodplain, including its 200 m buffer, has a total area of 42.88 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 4,617 building features, are considered for QC. Figure 29 shows the QC blocks for Ocoy floodplain.

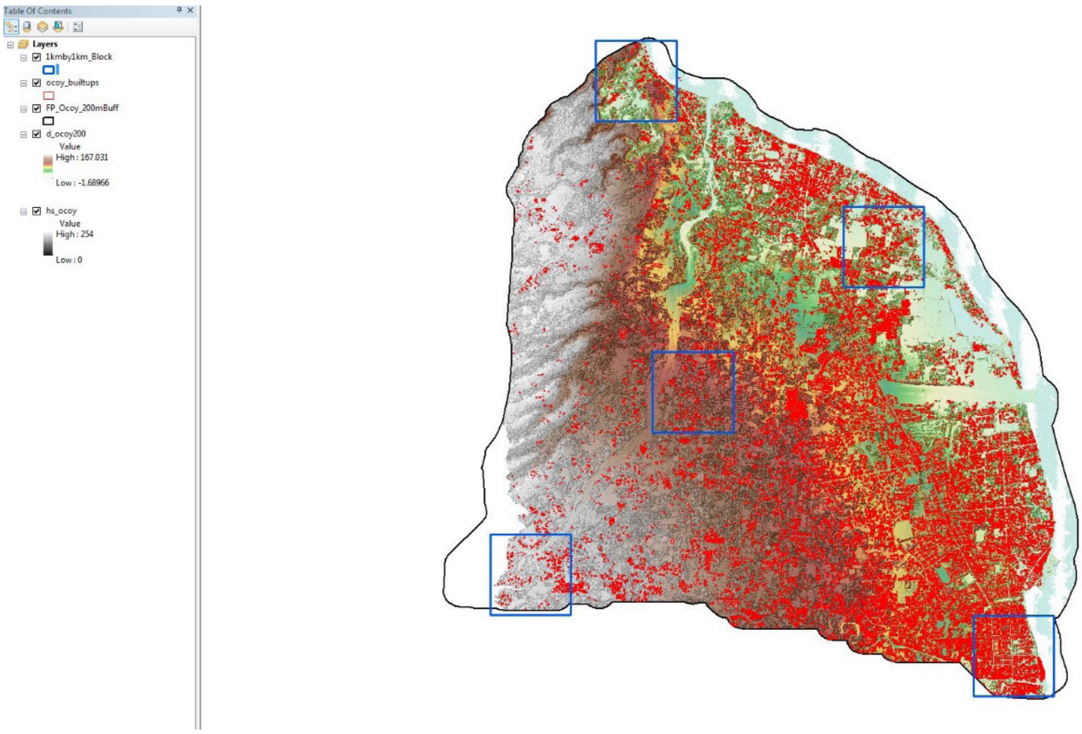

Figure29. Blocks (in blue) of Ocoy building features that were subjected to QC

Quality checking of Ocoy building features resulted in the ratings shown in Table 22.

Table 22. Quality Checking Ratings for Ocoy Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Ocoy	99.91	99.95	98.91	PASSED

3.12.2 Height Extraction

Height extraction was done for 31,203 building features in Ocoy floodplain. Of these building features, 480 were filtered out after height extraction, resulting to 30,723 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 20.71 m.

3.12.3 Feature Attribution

In attribution, combination of participatory mapping and actual field validation was done. Representatives from LGU were invited to assist in the determination of the features. The remaining unidentified features were then validated on the field.

Table 23 summarizes the number of building features per type. On the other hand, Table 24 shows the total length of each road type, while Table 25 shows the number of water features extracted per type.

Table 23. Building Features Extracted for Ocoy Floodplain.

Facility Type	No. of Features
Residential	28,972
School	509
Market	30
Agricultural/Agro-Industrial Facilities	82
Medical Institutions	40
Barangay Hall	11
Military Institution	1
Sports Center/Gymnasium/Covered Court	13
Telecommunication Facilities	2
Transport Terminal	19
Warehouse	24
Power Plant/Substation	0
NGO/CSO Offices	24
Police Station	0
Water Supply/Sewerage	3
Religious Institutions	60
Bank	11
Factory	0
Gas Station	25
Fire Station	0
Other Government Offices	108
Other Commercial Establishments	789
Total	**30,723**

Table 24. Total Length of Extracted Roads for Ocoy Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Ocoy	107.98	63.09	18.55	2.93	0.00	192.55

Table 25. Number of Extracted Water Bodies for Ocoy Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Ocoy	7	0	0	0	0	7

A total of 6 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

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

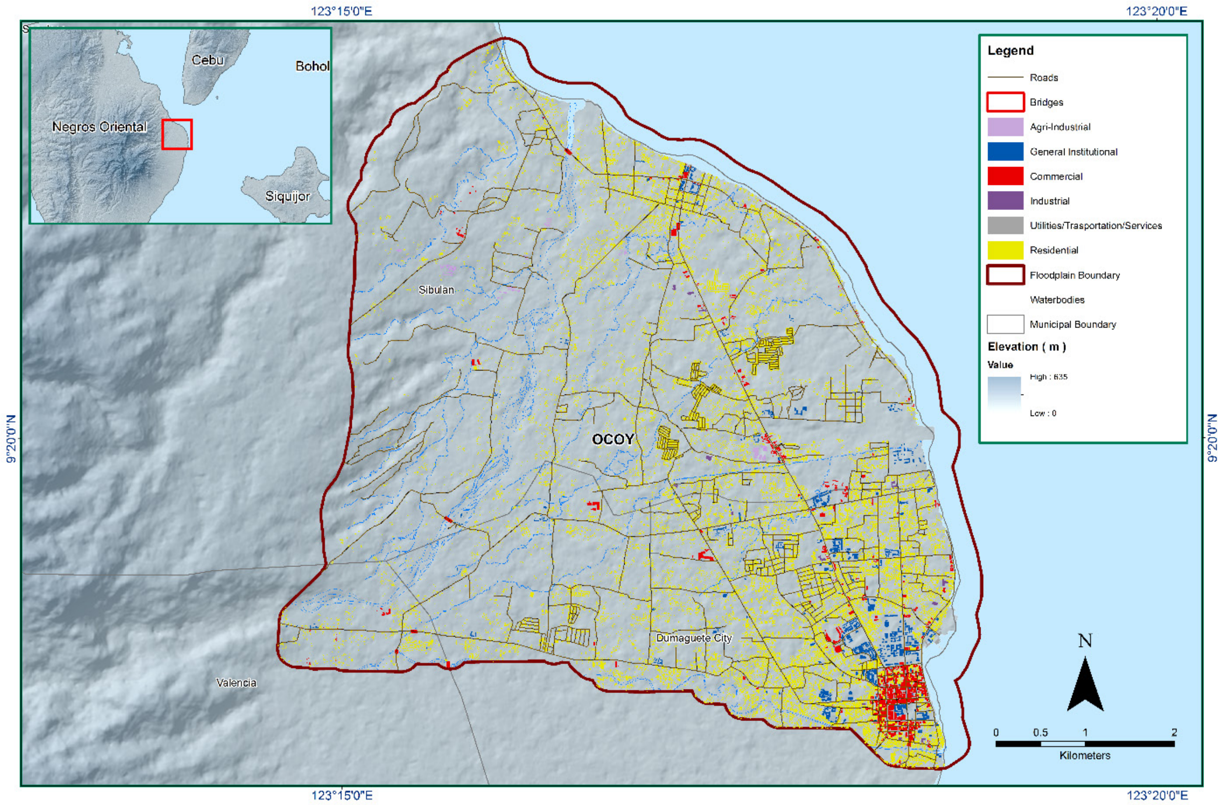

Figure 30. Extracted features for Ocoy Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE OCOY 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 Ocoy River on January 26 – February 10, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey in Ocoy Bridge in Brgy. Calabnugan, Municipality of Sibulan; validation points data acquisition of about 83.024 km for the areas traversing the Cities of Bais, Tanjay, and Dumaguete, and Municipalities of Asturias, Pamplona, Amlan, San Jose, Sibulan, Valencia, Bacong, and Dauin; and bathymetric survey from Brgy. Balili, Municipality of Valencia down to Brgy. Looc, Municipality of Sibulan, with an estimated length of 6.64 km using OHMEX™ Sonarmite echo sounder and Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 31.

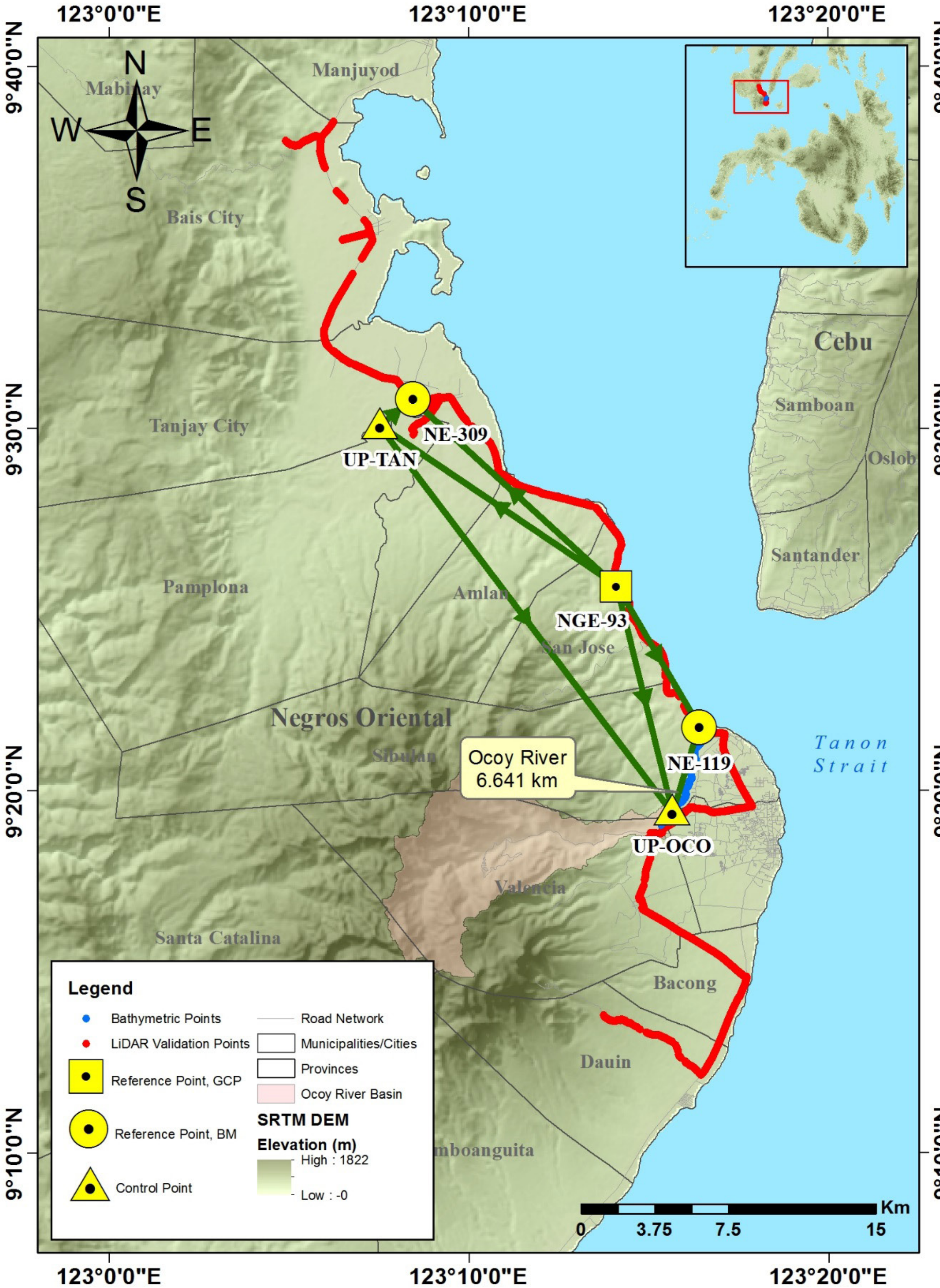


Figure 31. Extent of the bathymetric survey (in blue line) in Ocoy River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network for this survey is composed of seven (7) loops established on February 1, 2016 occupying the following reference points: NGE-93, a second order GCP located in Brgy. Jilocon, Municipality of San Jose; and, NE-119, a first order BM in Brgy. Calabnugan, Municipality of Sibulan.

Two (2) control points were established namely UP-OCO at Ocoy Bridge in Brgy. Calabnugan, Municipality of Sibulan, and UP-TAN in Brgy. Novallas, Tanjay City. The control point NE-309, in Brgy. San Jose, Tanjay City, established by NAMRIA, was also occupied to use as marker for the network.

The summary of reference and control points and its location is summarized in Table 26 while the GNSS network established is illustrated in Figure 32.

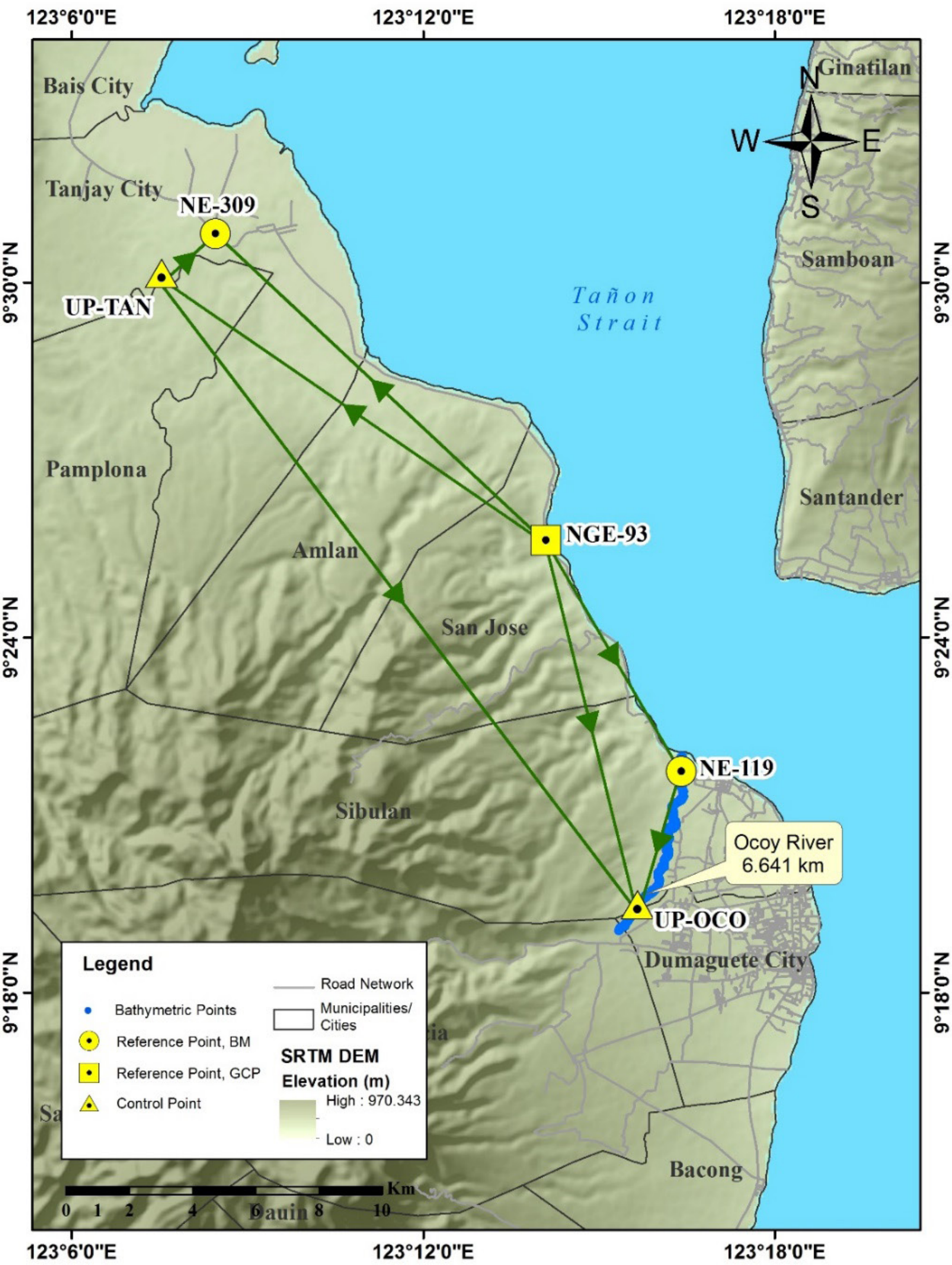


Figure 32. The GNSS Network established in the Ocoy River Survey.

Table 26. List of Reference and Control Points occupied for Ocoy River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
NGE-93	2nd order	9°25'38.283"N	123°14'05.681"E	66.238	-	2007
NE-119	1st order	-	-	71.085	7.414	2008
NE-309	Used as marker	-	-	-	-	2008
UP-OCO	UP Established	-	-	-	-	February 2016
UP-TAN	UP Established	-	-	-	-	February 2016

The GNSS set-ups on recovered reference points and established control points in Ocoy River are shown in Figure 33 to Figure 37.

Figure 33. GNSS receiver set-up, Trimble® SPS 852, at NGE-93 in Brgy. Jilocon, Municipality of San Jose, Negros Oriental

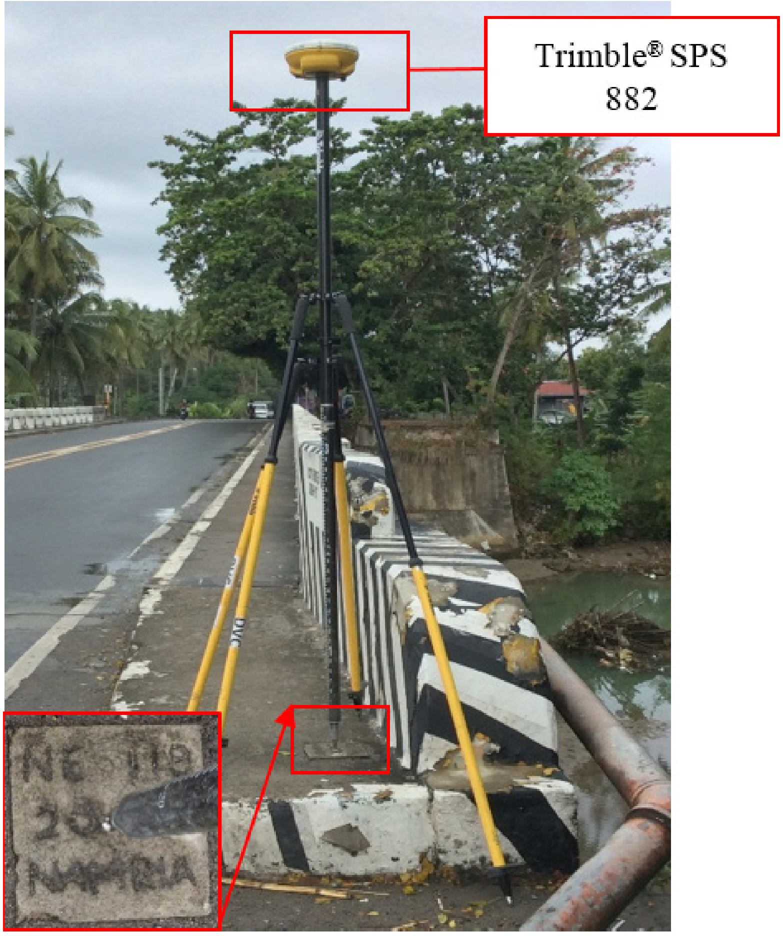


Figure 34. GNSS receiver setup, Trimble® SPS 882, at NE-119 at the approach of Ocoy Bridge in Brgy. Campaclan, Municipality of Sibulan, Negros Oriental

Figure 35. GNSS receiver set-up, Trimble® Zephyr ™ Model 2, at NE-309 in Brgy. San Jose, Tanjay City, Negros Oriental

Figure 36. GNSS receiver set-up, Trimble® Zephyr ™ Model 2, at UP-TAN in Brgy. Novallas, Tanjay City, Negros Oriental

Figure 37. GNSS receiver set-up, Trimble® SPS 882 at control point UP-OCO near the abutment of Sibulan Bridge Brgy. Calabnugan, Municipality of Sibulan, Negros Oriental

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 Ocoy River Basin is summarized in Table 27 generated by TBC software.

Table 27. Baseline Processing Summary Report for Ocoy River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NGE-93 --- NE-119 (B18)	02-01-2016	Fixed	0.006	0.016	149°32'32"	8342.974	4.857
NGE-93 --- UP-TAN (B20)	02-01-2016	Fixed	0.004	0.012	304°44'59"	14612.993	8.626
NGE-93 --- NE-309 (B19)	02-01-2016	Fixed	0.005	0.015	312°46'57"	14070.135	3.586
NGE-93 --- UP-OCO (B17)	02-01-2016	Fixed	0.004	0.014	165°50'22"	11697.257	50.653
NE-119 --- UP-OCO (B14)	02-01-2016	Fixed	0.008	0.022	198°14'36"	4369.643	45.844
UP-TAN --- NE-309 (B7)	02-01-2016	Fixed	0.004	0.015	53°50'00"	2080.683	-5.061
UP-TAN --- UPOCO (B16)	02-01-2016	Fixed	0.005	0.018	142°53'54"	24658.100	42.034

As shown in Table 27, a total of seven (7) baselines were processed and all of them passed the required accuracy set by the project..

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 28 to Table 30 for the complete details.

The five (5) control points, NGE-93, NE-119, NE-309, UP-OCO and UP-TAN were occupied and observed simultaneously to form a GNSS loop. Coordinates of point NGE-93 and elevation value of NE-119 were held fixed during the processing of the control points as presented in Table 28. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 28. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGE-93	Local	Fixed	Fixed	Fixed	
NE-119	Grid				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 29. The fixed control points NGE-93 and NE-119 have no values for grid errors and elevation error, respectively.

Table 29. Adjusted grid coordinates for the control points used in the Ocoy River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Cons-traint
NGE-93	525789.116	?	1042102.575	?	2.470	0.063	LLh
NE-119	530021.363	0.018	1034916.542	0.009	7.414	?	e
NE-309	515460.124	0.014	1051648.501	0.007	6.010	0.082	
UP-TAN	513781.484	0.011	1050420.498	0.006	11.014	0.075	
UP-OCO	528657.161	0.012	1030767.083	0.008	53.120	0.070	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in The network is fixed at reference point NGE-93 with known coordinates, and NE-119 with known elevation. As shown in Table 29, the standard errors (xe and ye) of NE-119 are 1.8 cm and 0.9 cm, NE-309 are 1.4 cm and 0.7, UP-TAN are 1.1 and 0.6, and UP-OCO are 1.2 and 0.8, respectively. With the mentioned equation, for horizontal and for the vertical; the computation for the accuracy are as follows:

a. NGE-93
horizontal accuracy = Fixed
vertical accuracy = 6.3 < 10 cm

b. NE-119
horizontal accuracy = $\sqrt{((1.8)^2 + (0.9)^2}$
= $\sqrt{(.3.24 + 0.81)}$
= 2.0 cm < 20 cm
vertical accuracy = Fixed

c. NE-309
horizontal accuracy = $\sqrt{((1.4)^2 + (0.7)^2}$
= $\sqrt{(1.96 +0.49)}$
= 1.6 cm < 20 cm
vertical accuracy = 0.08 < 10 cm

d. UP-TAN
horizontal accuracy = $\sqrt{((1.1)^2 + (0.6)^2}$
= $\sqrt{(.1.21 + 0.36)}$
= 1.3 cm < 20 cm
vertical accuracy = 0.08 < 10 cm

e. UP-OCO
horizontal accuracy = $\sqrt{((1.2)^2 + (0.8)^2}$
= $\sqrt{(1.44 + 0.64)}$
= 1.4 cm < 20 cm
vertical accuracy = 0.07 < 10 cm

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

Table 30. Adjusted geodetic coordinates for control points used in the Ocoy River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
NGE-93	N9°21'44.19651"	E123°16'24.28146"	70.612	0.063	LLh
NE-119	N9°30'49.29193"	E123°08'27.09880"	69.337	?	e
NE-309	N9°25'38.28279"	E123°14'05.68141"	65.765	0.082	
UP-TAN	N9°19'29.11814"	E123°15'39.45443"	116.436	0.075	
UP-OCO	N9°30'09.32754"	E123°07'32.02417"	74.388	0.070	

The corresponding geodetic coordinates of NAMRIA established reference points, NGE-93, NE-119, and NE-309 are within the required accuracy as shown in Table 30. 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 31.

Table 31. The reference and control points utilized in the Ocoy River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N			
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	EGM Ortho (m)	BM Ortho (m)
NGE-93	2nd order GCP	9°25'38.2828"N	123°14'05.6814"E	66.238	1042102.575	525789.116	2.943	2.470
NE-119	1st Order BM	9°21'44.1965"N	123°16'24.2814"E	71.085	1034916.543	530021.363	7.887	7.414
NE-309	Used as Marker	9°30'49.2919"N	123°08'27.0988"E	69.810	1051648.501	515460.125	6.483	6.010
UP-TAN	Used as Marker	9°30'09.3275"N	123°07'32.0242"E	74.861	1050420.498	513781.485	11.487	11.014
UP-OCO	Used as Marker	9°19'29.1182"N		116.909	1030767.084	528657.161	53.593	53.120

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

Bridge as-built and cross-section survey was conducted on February 5, 2016 at the downstream side of Ocoy Bridge in Brgy. Calabnugan, Municipality of Sibulan using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 38.

Figure 38. Cross-section survey conducted on Ocoy river in Brgy. Calabnugan, Municipality of Sibulan

The cross-sectional line length of Ocoy Bridge is about 160 m with 41 cross-sectional points acquired using UP-OCO as the GNSS base station. The cross-section diagram, location map, and bridge data form are shown in Figure 39 to Figure 41, respectively.

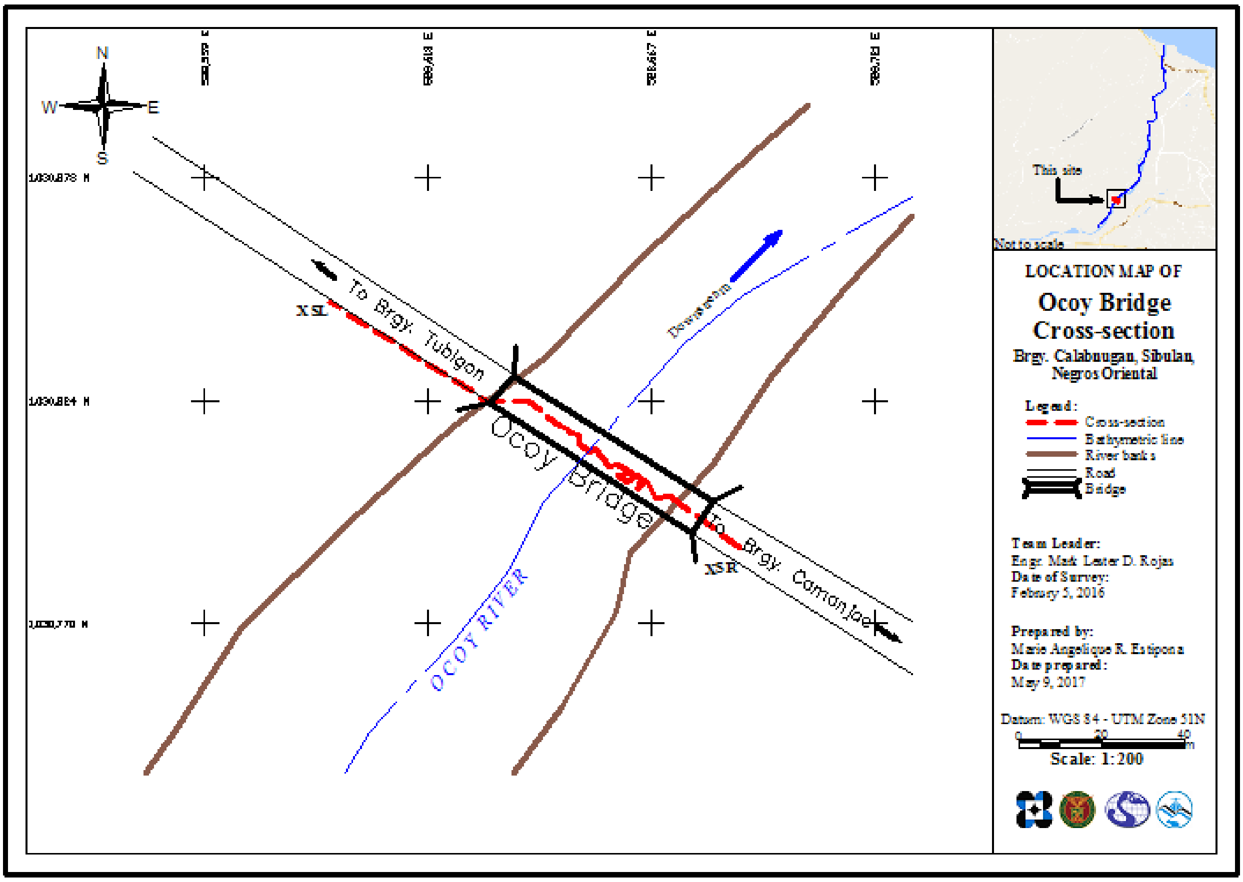


Figure 39. Location map of Ocoy River cross-section survey

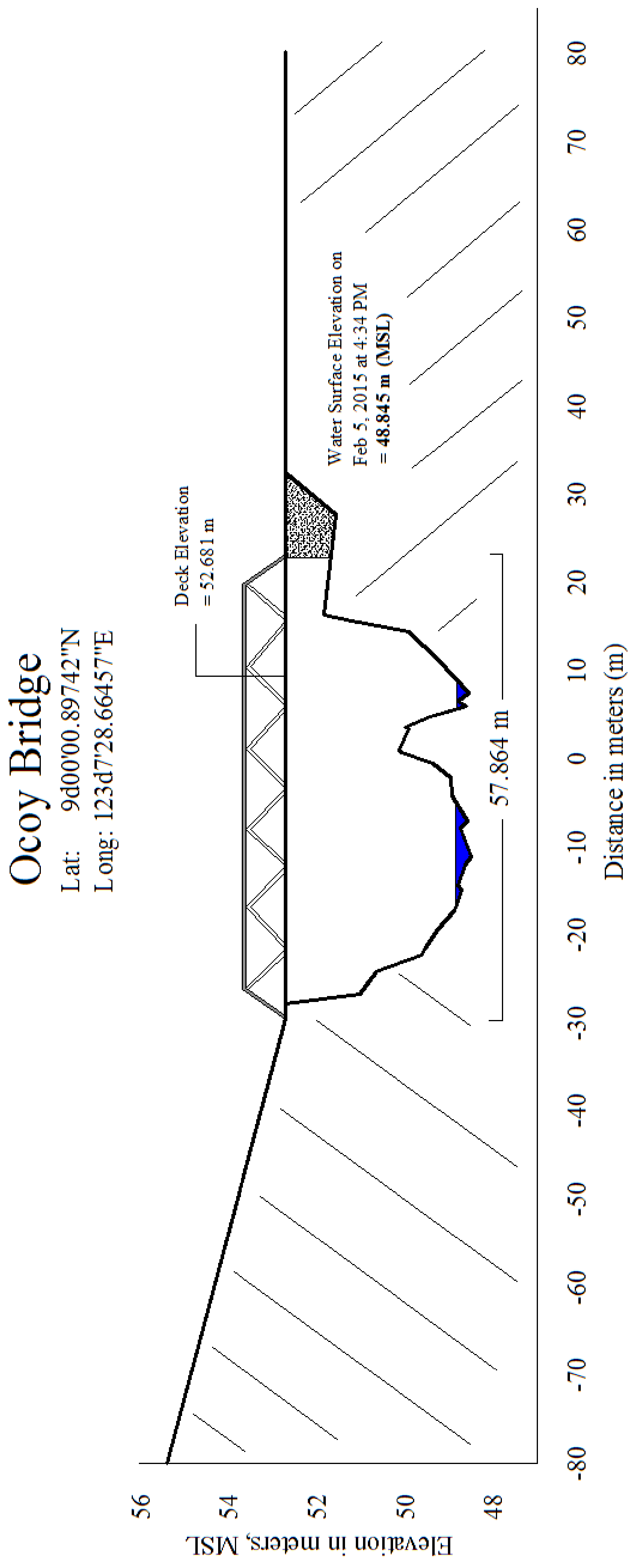
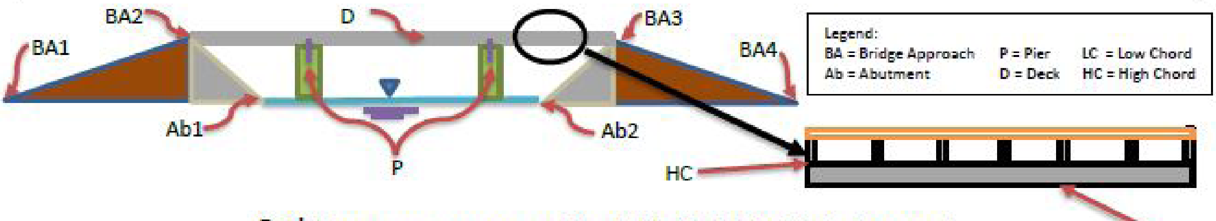


Figure 40. Ocoy Riverbed cross-section diagram

Bridge Data Form

Bridge Name: Ocoy Bridge	**Date:** February 5, 2016
River Name: Ocoy River	**Time:** 4:34 PM
Location: Brgy. Calabnugan, Municipality of Sibulan, Negros Oriental	
Survey Team: Mark Lester D. Rojas, Caren Joy Ordoña, Anthony Felix J. Abogado,	
Flow condition: low ✓ normal high	**Weather Condition:** ✓ fair rainy
Latitude: 9°30'9.32754"N	**Longitude:** 123°7'32.02417"E



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

Elevation: 55.386 m. Width: 8 m. Span (BA3-BA2): 57.864 m.

	Station	High Chord Elevation	Low Chord Elevation
1	1	57.912	57.538

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	55.386	BA3	103.147	57.538
BA2	45.283	57.690	BA4	160.134	54.211

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

	Station (Distance from BA1)	Elevation
Ab1	57.069	50.033
Ab2	94.898	50.449

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

Shape: Cylindrical Number of Piers: 0 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 41. Ocoy Bridge data form

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on February 4 and 5, 2016 using a survey-grade GNSS rover receiver, Trimble® SPS 882, mounted on a pole which was attached to the side of the vehicle as shown in Figure 42. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was 2.09 m 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 UP-OCO occupied as the GNSS base station all throughout the conduct of the survey.

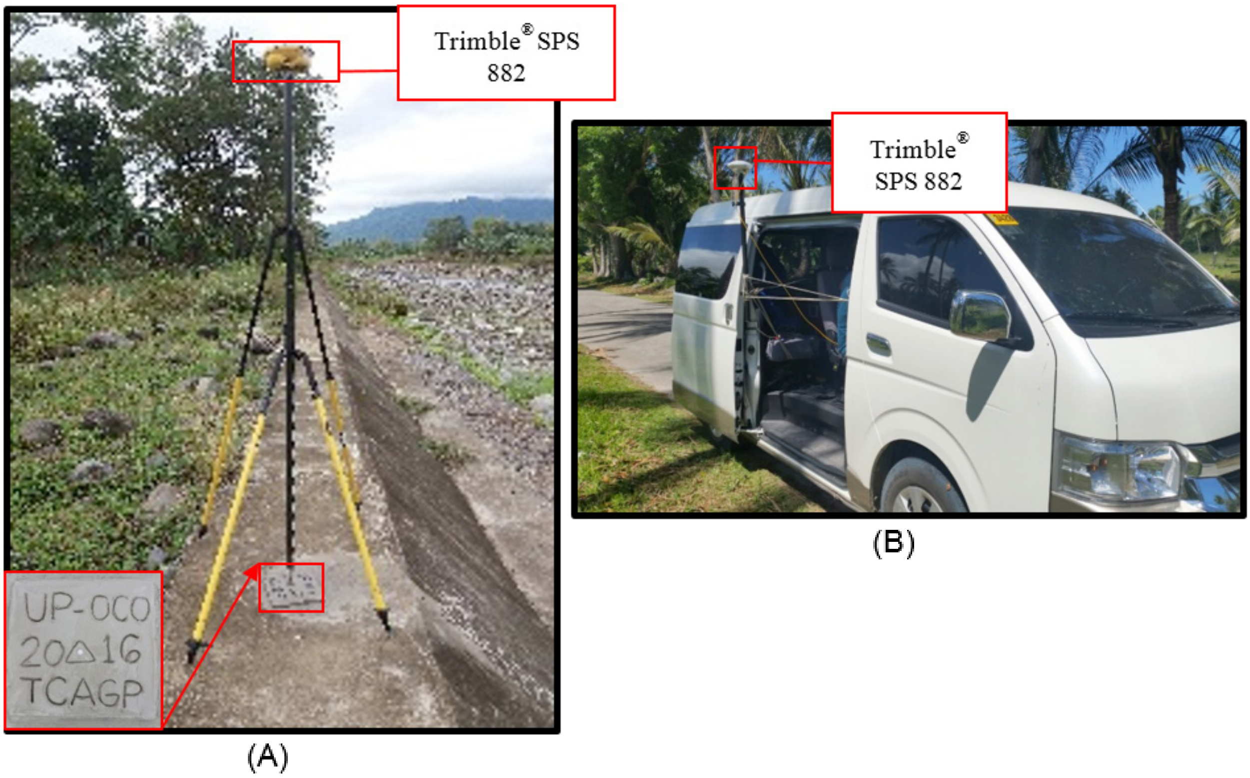


Figure 42. (A) Setup of GNSS base station at CU-552 and (B) Trimble® SPS 882 attached to a vehicle

The validation points acquisition survey for the Ocoy River Basin traversed the Cities of Bais, Tanjay, and Dumaguete, and the Municipalities of Pamplona, Amlan, San Jose, Sibulan, Valencia, Bacong, and Dauin. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. A total of 11,353 points with an approximate length of 83.024 km was acquired for the validation point acquisition survey as shown in the map in Figure 43.

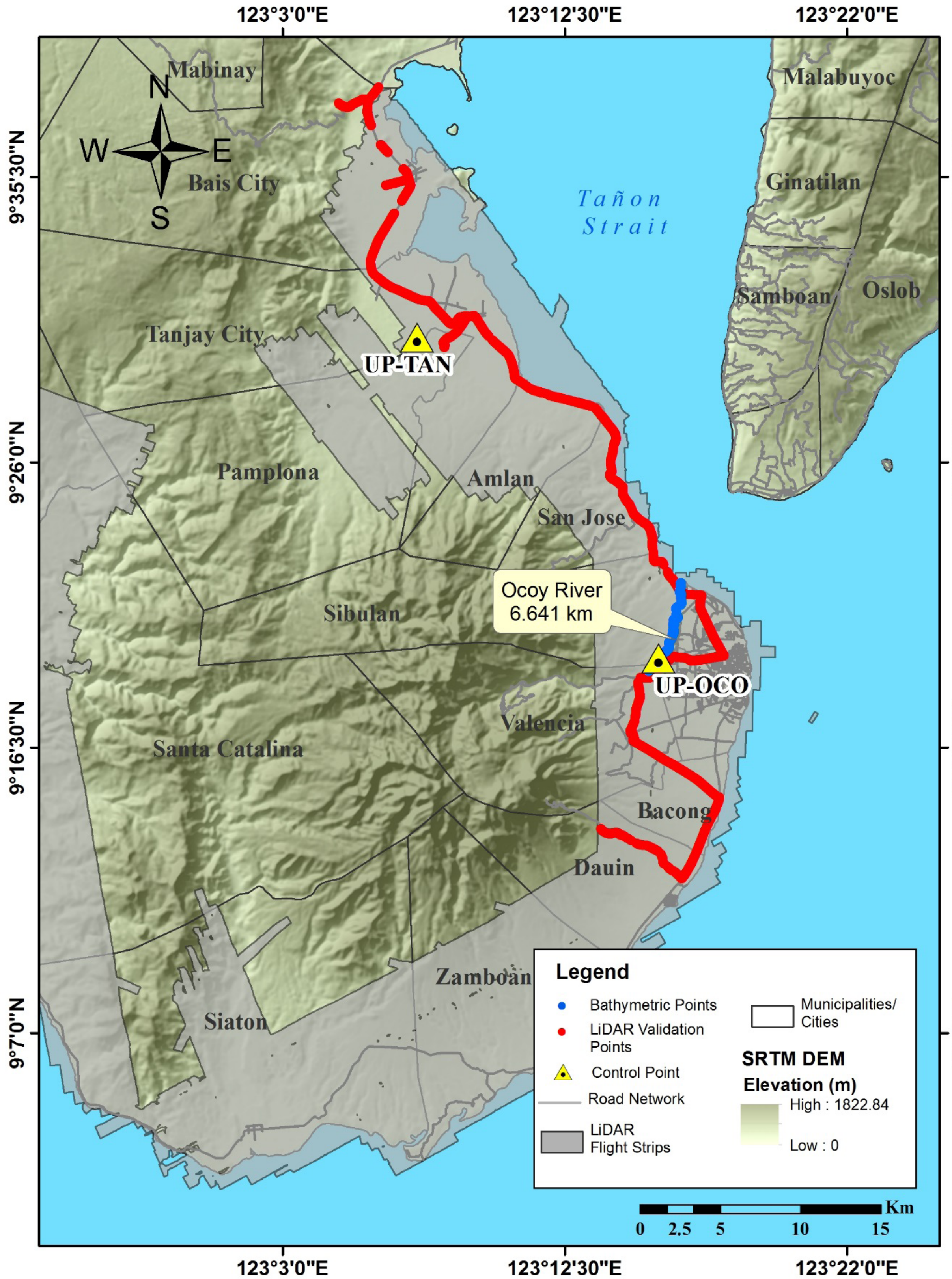


Figure 43. Validation point acquisition survey of Ocoy River basin

4.7 River Bathymetric Survey

Manual bathymetric survey using a Trimble® SPS 882 GNSS PPK technique was executed on February 3, 2016 as shown in Figure 44. The survey began by starting upstream in Brgy. Balili, Municipality of Valencia, with coordinates 9°19'02.83237"N 123°15'20.27855"E, until the deep portion of the river in of Brgy. Calabnugan, Municipality of Sibulan. Meanwhile, on the second day of Bathymetric Survey, February 5, 2016, the survey team utilized the OHMEX™ Sonarmite echo sounder and Trimble® SPS 882 GNSS PPK technique which was attached to a pole on a fishing boat for the remaining deep portions of the river. The survey started from Brgy. Calabnugan, Municipality of Sibulan with coordinates 9°20'31.94615"N 123°16'09.97772"E, going to the mouth of the river to Brgy. Looc. The survey was conducted with the assistance of personnel from the University of San Carlos. The control point UP-OCO was used as base station for the whole conduct of the survey.

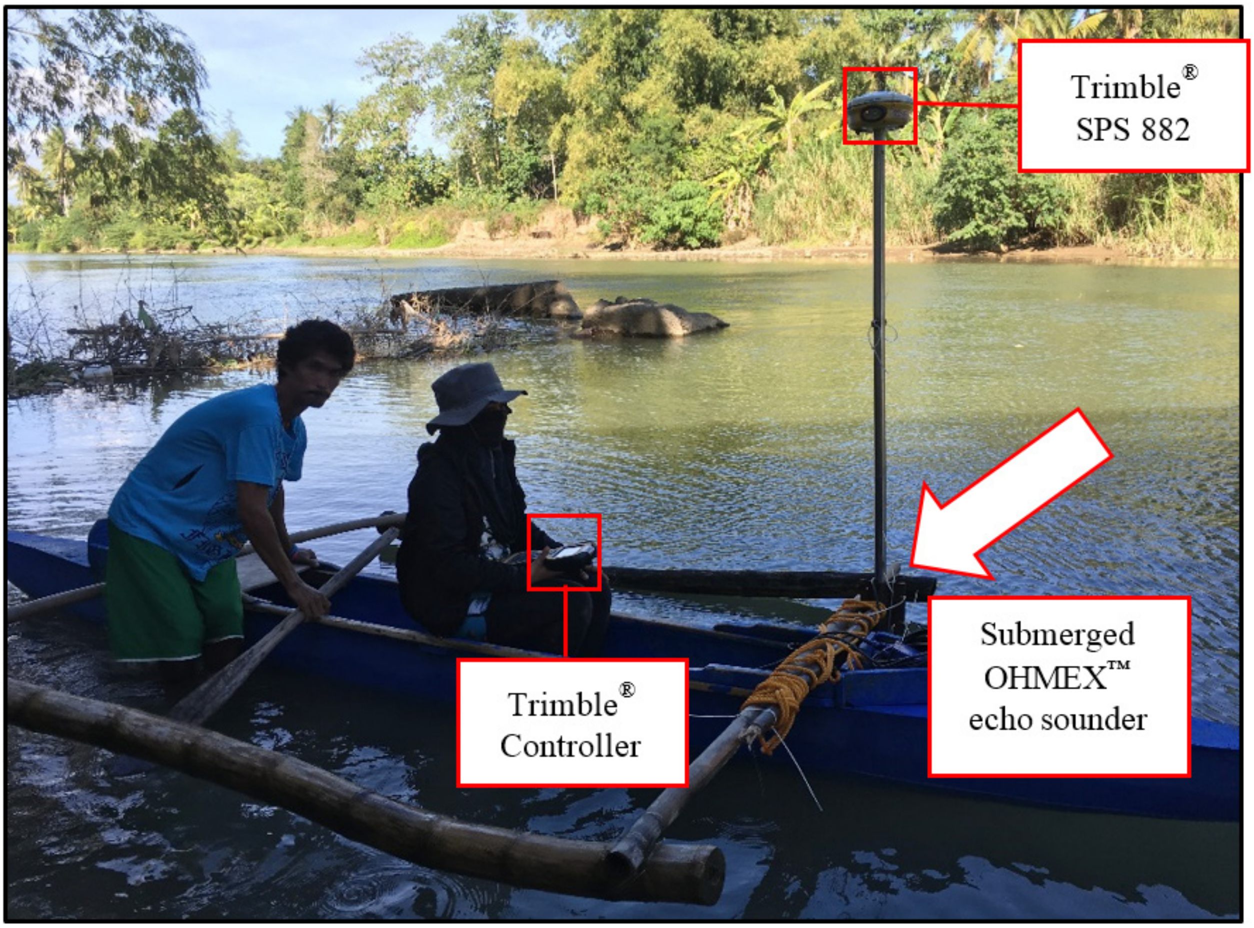


Figure 44. Bathymetric survey in Ocoy River

The bathymetric survey for Ocoy River gathered a total of 3,607 points with an estimated length of 6.641 km as illustrated in Figure 45. A CAD drawing was also produced to illustrate the Ocoy riverbed centerline profile as shown in Figure 46. There is about a 72.864-m change in elevation observed within the entire scope of the bathymetric data from its upstream in Brgy. Balili, Municipality of Valencia down to the mouth of the river in Brgy. Looc, Municipality of Sibulan. The highest elevation observed was 70.864 m above MSL while the lowest was -2.721 m MSL near the mouth of the river.

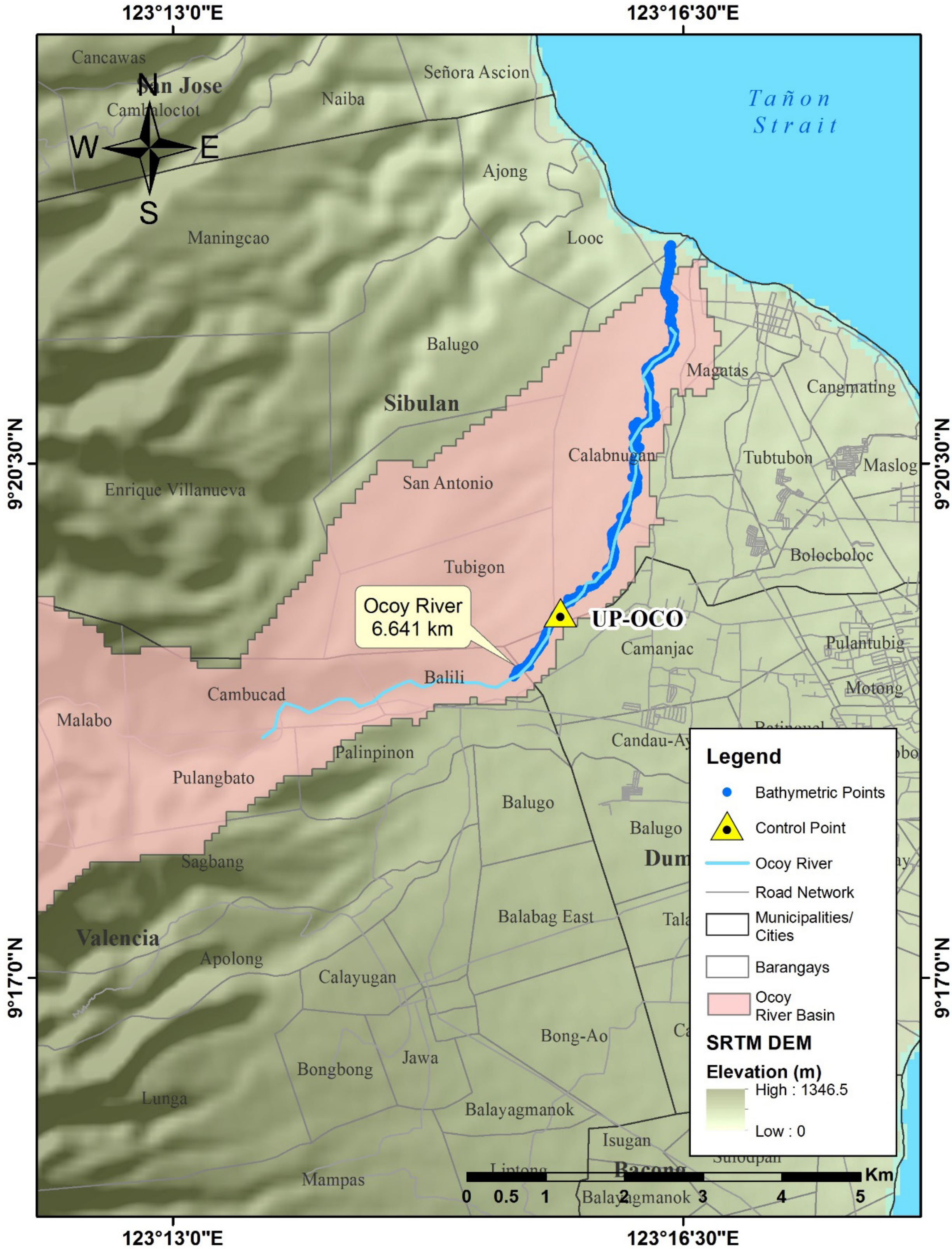


Figure 45. Extent of the Ocoy River Bathymetry Survey

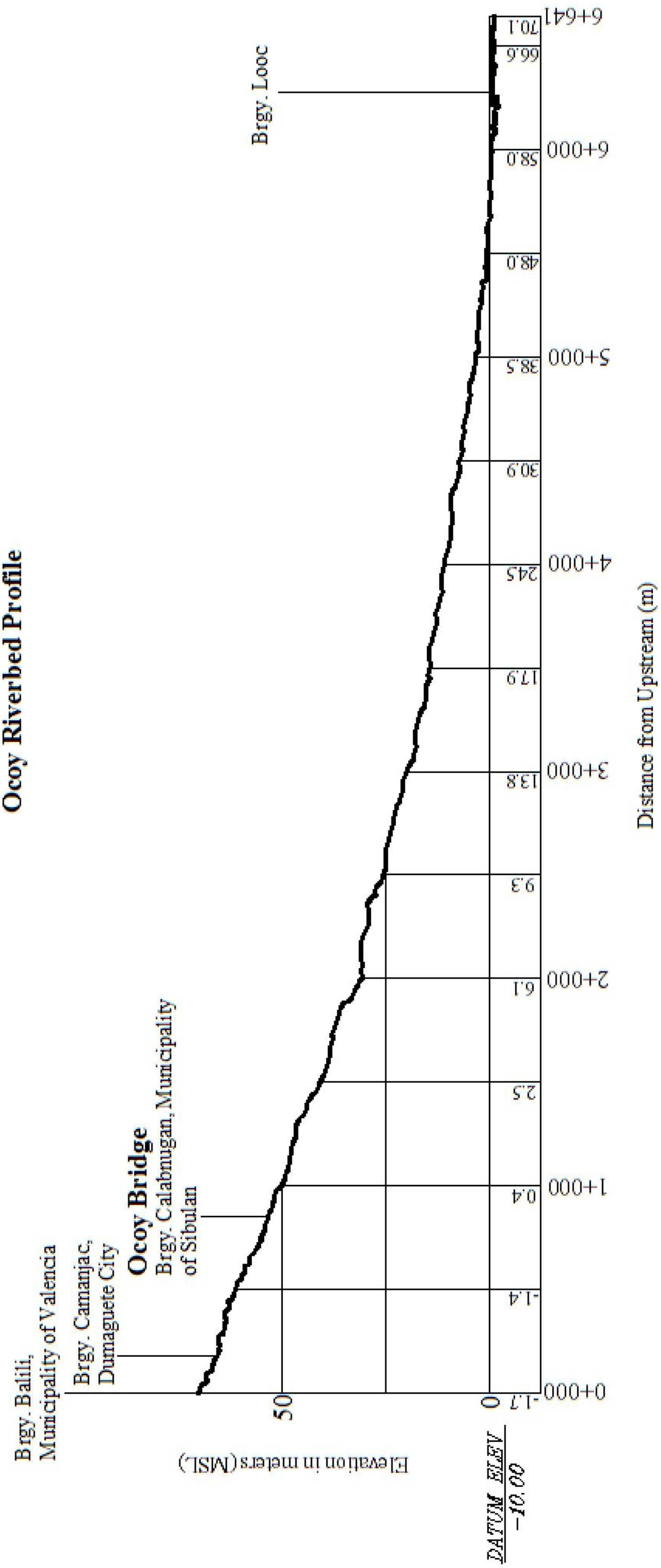


Figure 46. Ocoy riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Alfredo Mahar Francisco A. Lagmay, Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil R. Tingin, and Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from automatic rain gauges (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The locations of the ARG is Sitio Pancil, Sibulan. The location of the rain gauge is as shown in Figure 47. The total rain from the Sitio Pancil, Sibulan rain gauge is 78.5 mm. It peaked to 16 mm on January 16, 2017, 10:00. The lag time between the peak rainfall and discharge is 3 hours and 20 minutes, as shown in Figure 50.

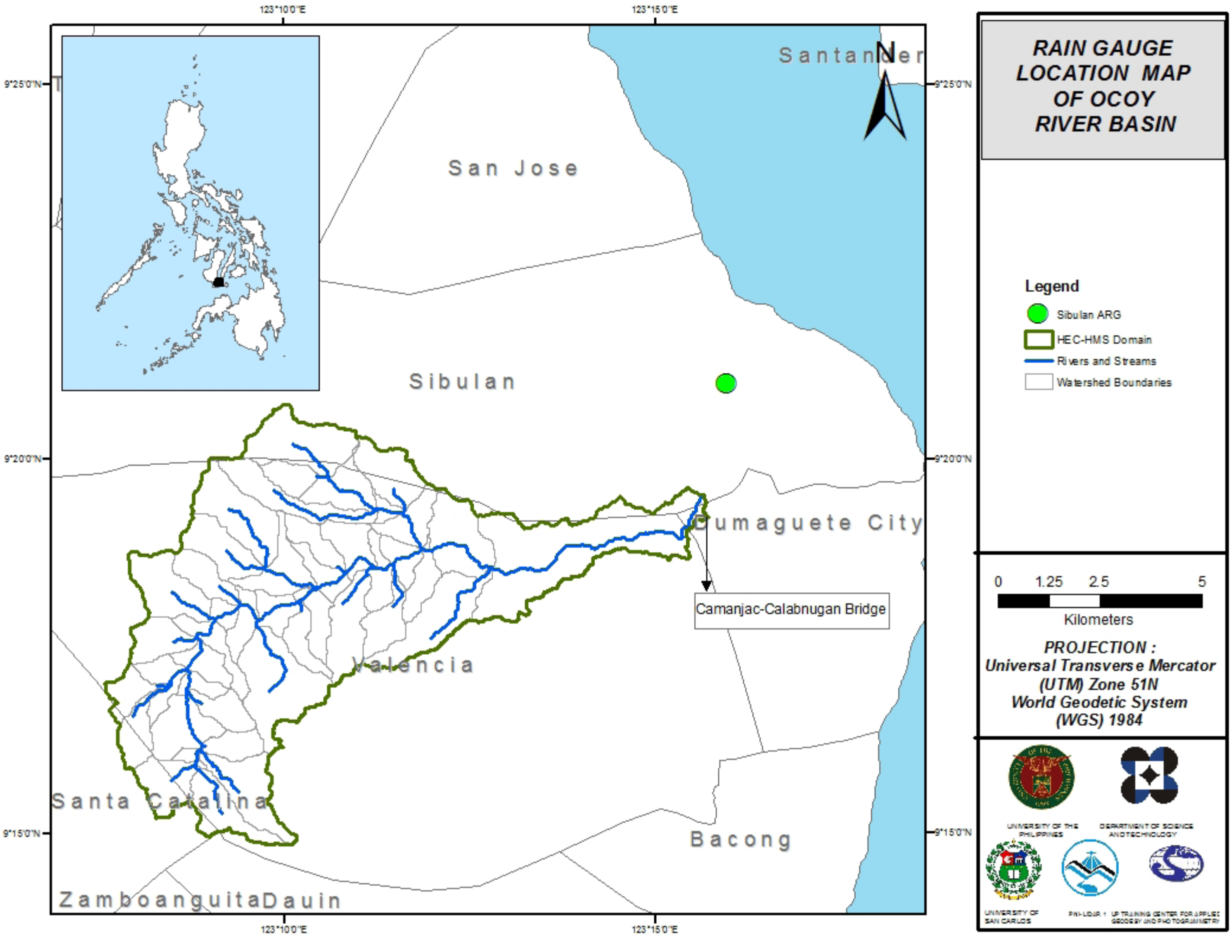


Figure 47. Location map of the Ocoy HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Camanjac-Calabnugan Bridge (9°19'30.58"N and 123°15'39.60"E). It gives the relationship between the observed water levels and outflow of the watershed at this location.

For Ocoy Bridge (also known as Camanjac-Calabnugan Bridge), the rating curve is expressed as shown in Figure 49

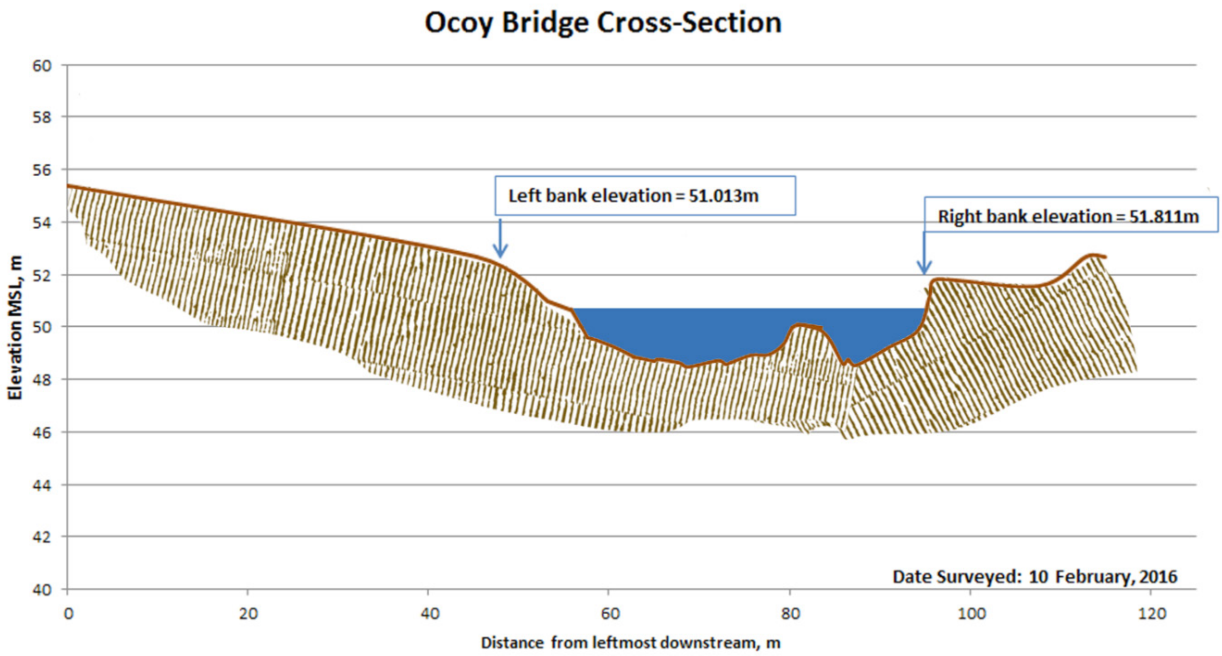


Figure 48. Cross-section plot of Ocoy Bridge

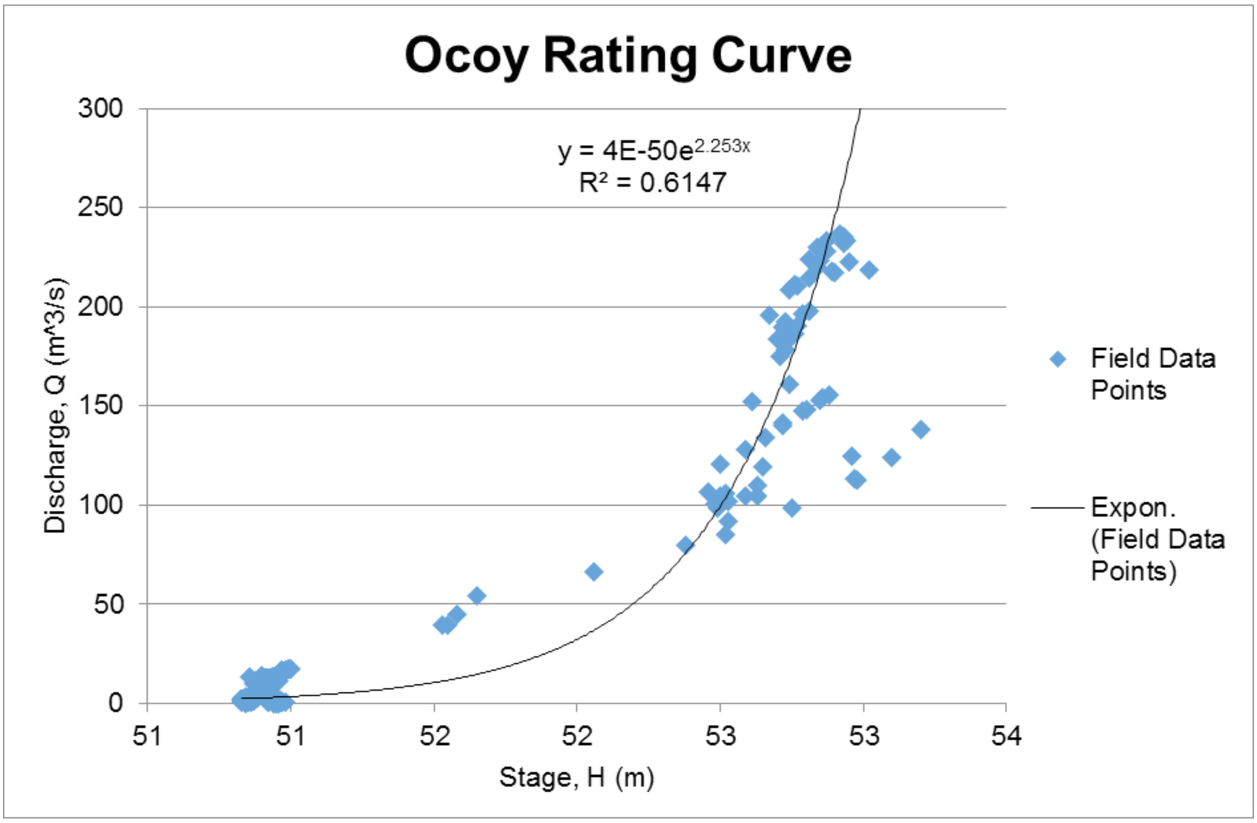


Figure 49. Rating curve at Ocoy Bridge in Ocoy River

This rating curve equation was used to compute the river outflow at Camanjac-Calabnugan Bridge for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge is 235.2 m3/s at 14:00, January 16, 2017.

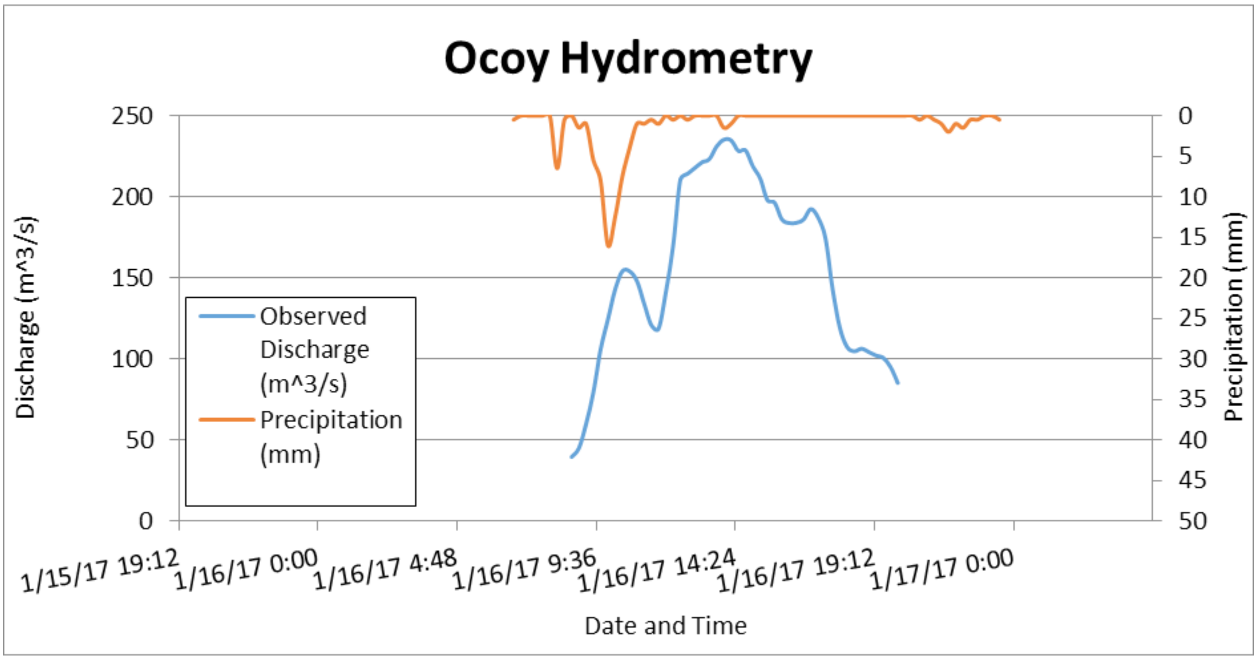


Figure 50. Rainfall and outflow data at Ocoy Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Dumaguete Point Gauge. This station chosen based on its proximity to the Ocoy watershed. The extreme values for this watershed were computed based on a 35-year record.

Table 32. RIDF values for Dumaguete Point 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	16.2	24.8	30.6	39.7	50	55.3	63.4	69.1	76
5	21.8	33.6	42.3	57.1	76.5	87.3	100	109.5	116.5
10	25.6	39.4	50	68.6	94	108.5	124.3	136.3	143.3
15	27.7	42.7	54.3	75.1	103.9	120.5	138	151.4	158.4
20	29.1	45	57.4	79.7	110.8	128.9	147.5	162	169
25	30.3	46.8	59.7	83.2	116.1	135.3	154.9	170.2	177.2
50	33.8	52.3	66.9	94	132.5	155.2	177.6	195.3	202.4
100	37.2	57.7	74.1	104.8	148.8	174.9	200.2	220.2	227.3

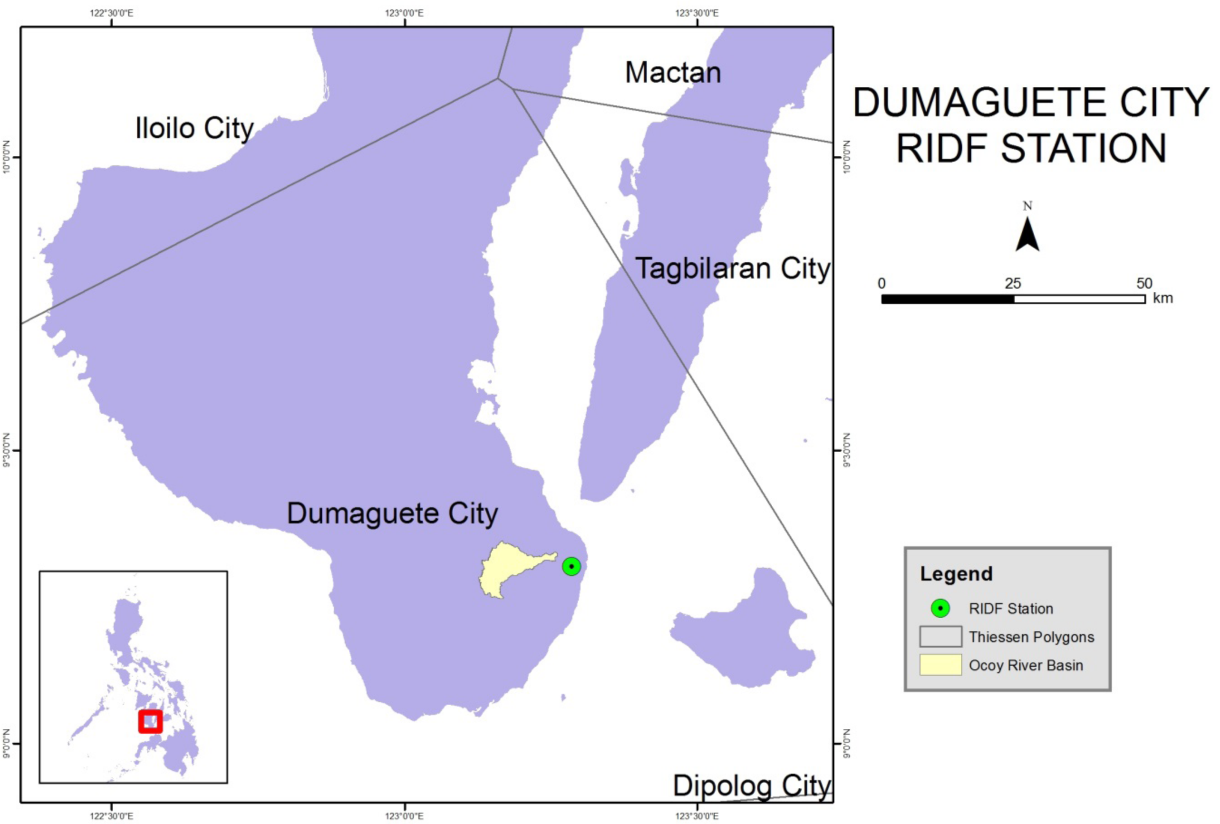


Figure 51. Location of Dumaguete RIDF Station relative to Ocoy River Basin

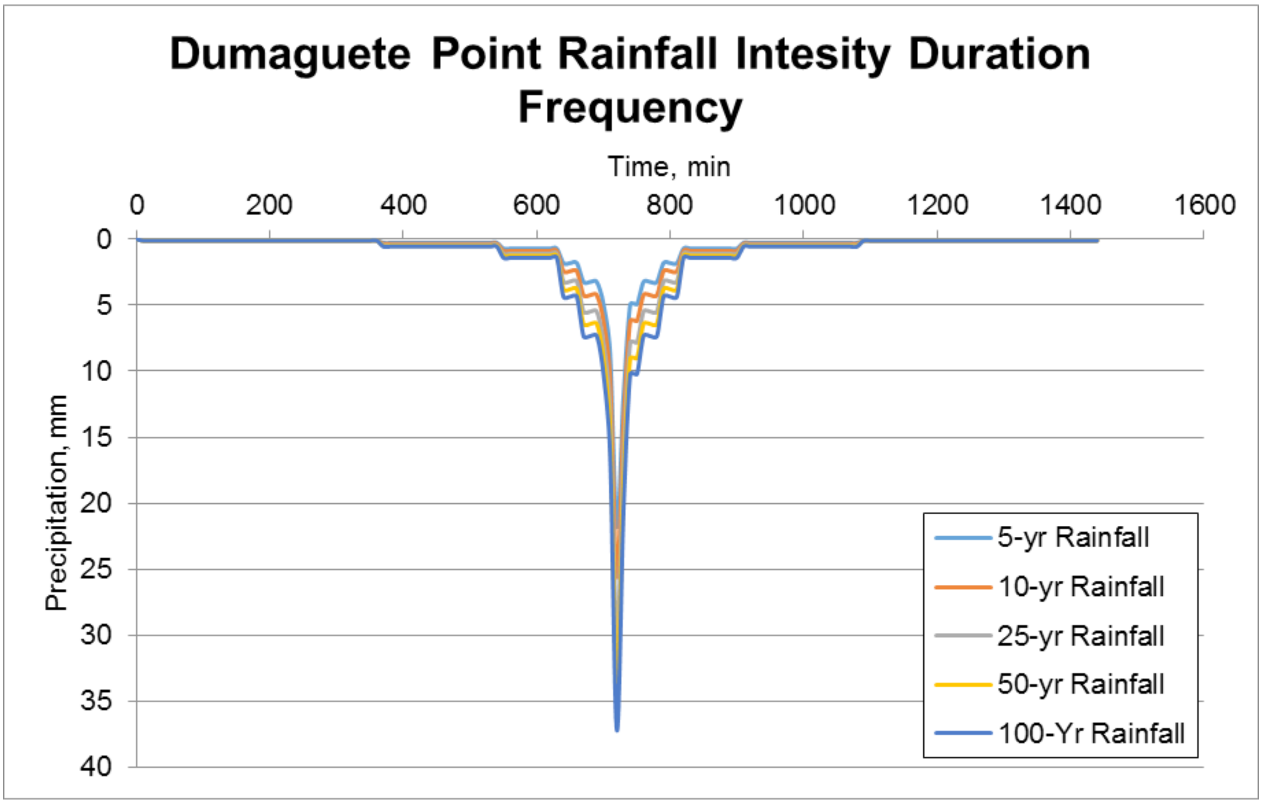


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

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 Ocoy River Basin are shown in Figure 53 and Figure 54, respectively.

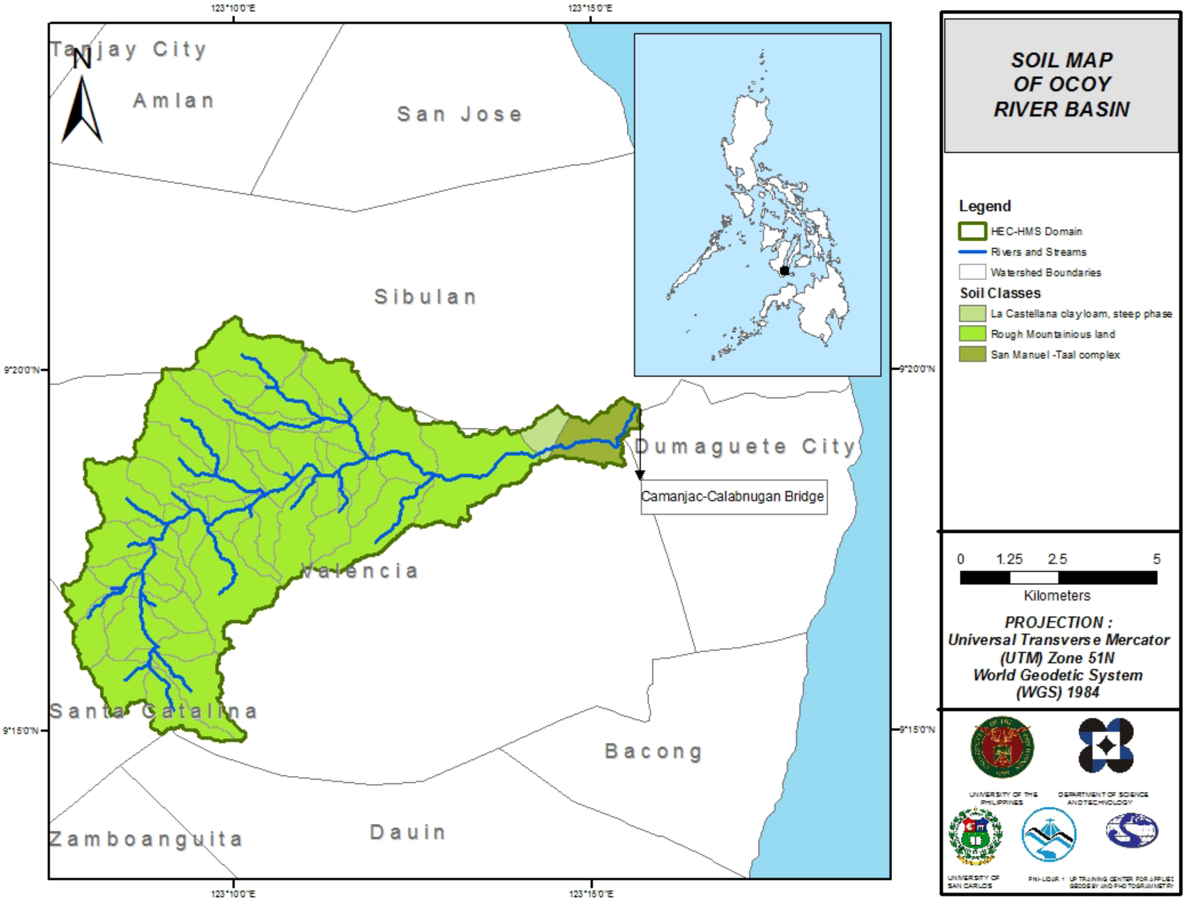


Figure 53. Soil Map of Ocoy River Basin used for the estimation of the CN parameter. (Source: DA)

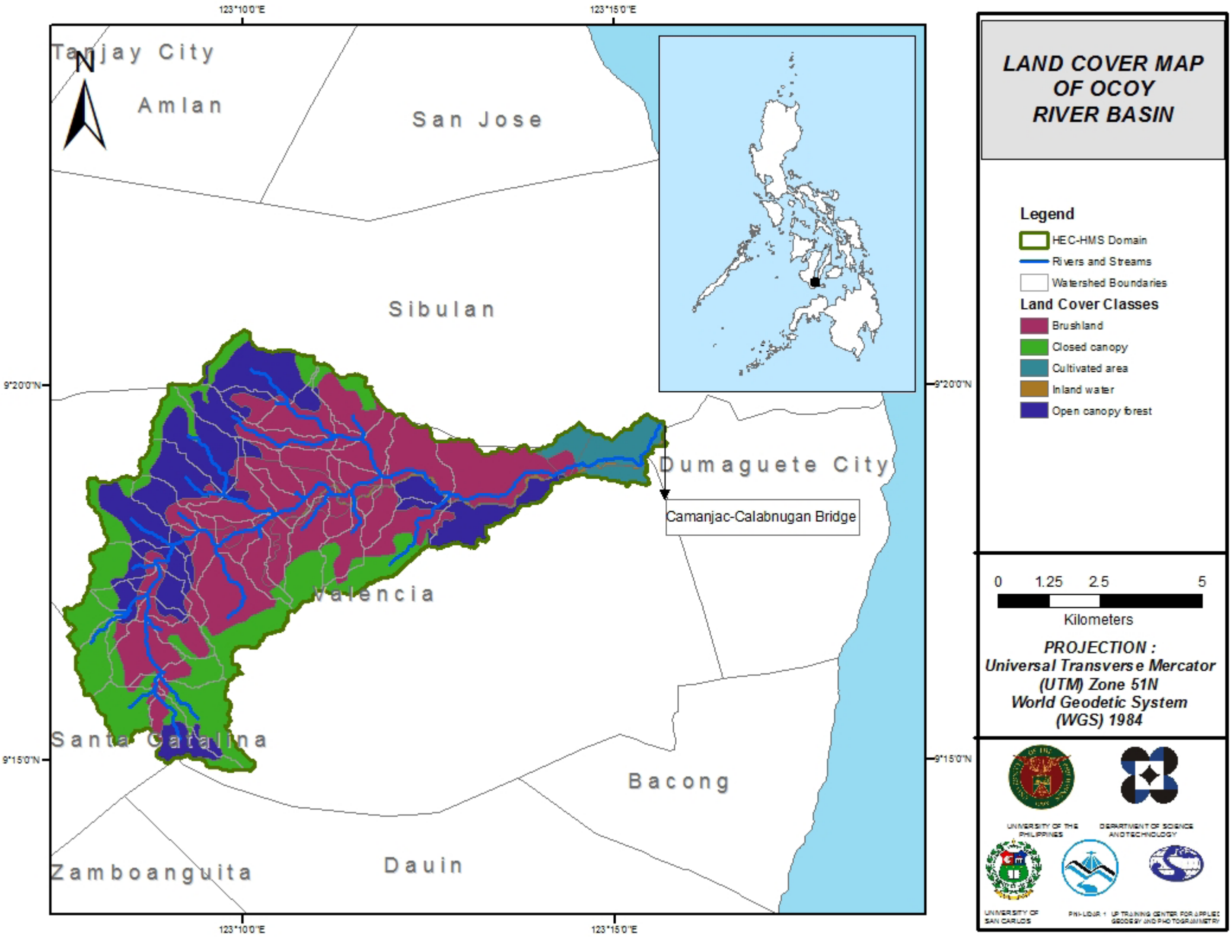


Figure 54. Land Cover Map of Ocoy River Basin used for the estimation of the Curve Number (CN) and the watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For the Ocoy river basin, three (3) soil classes were identified. The Ocoy river basin is mostly rough mountainous land, with portions of La Castellana clay loam (steep phase) and San Manuel-Taal complex. Moreover, five (5) land cover classes were identified. Most of the Ocoy river basin is brushland, closed canopy, and open canopy forest, while a small portion is inland water and cultivated area.

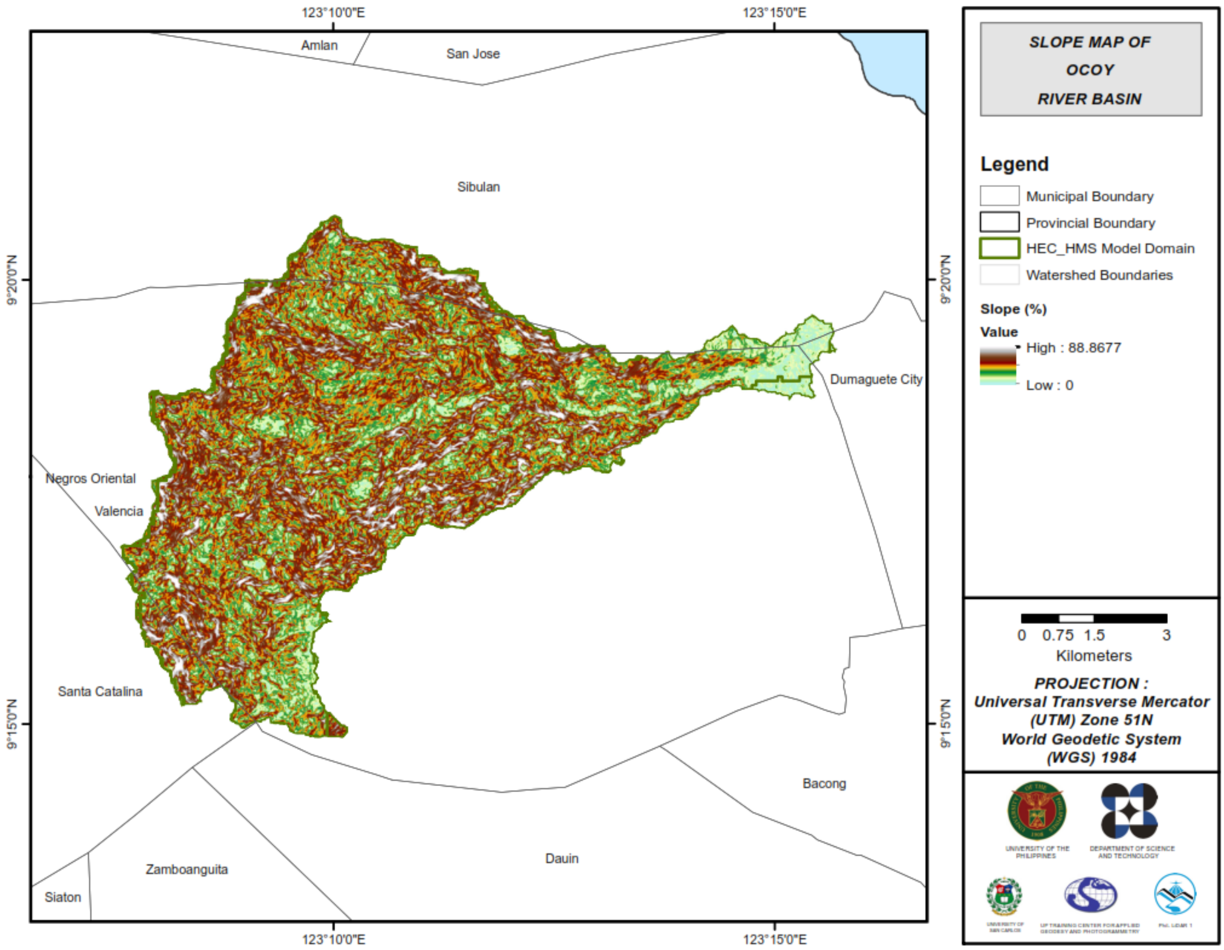


Figure 55. Slope Map of Ocoy River Basin

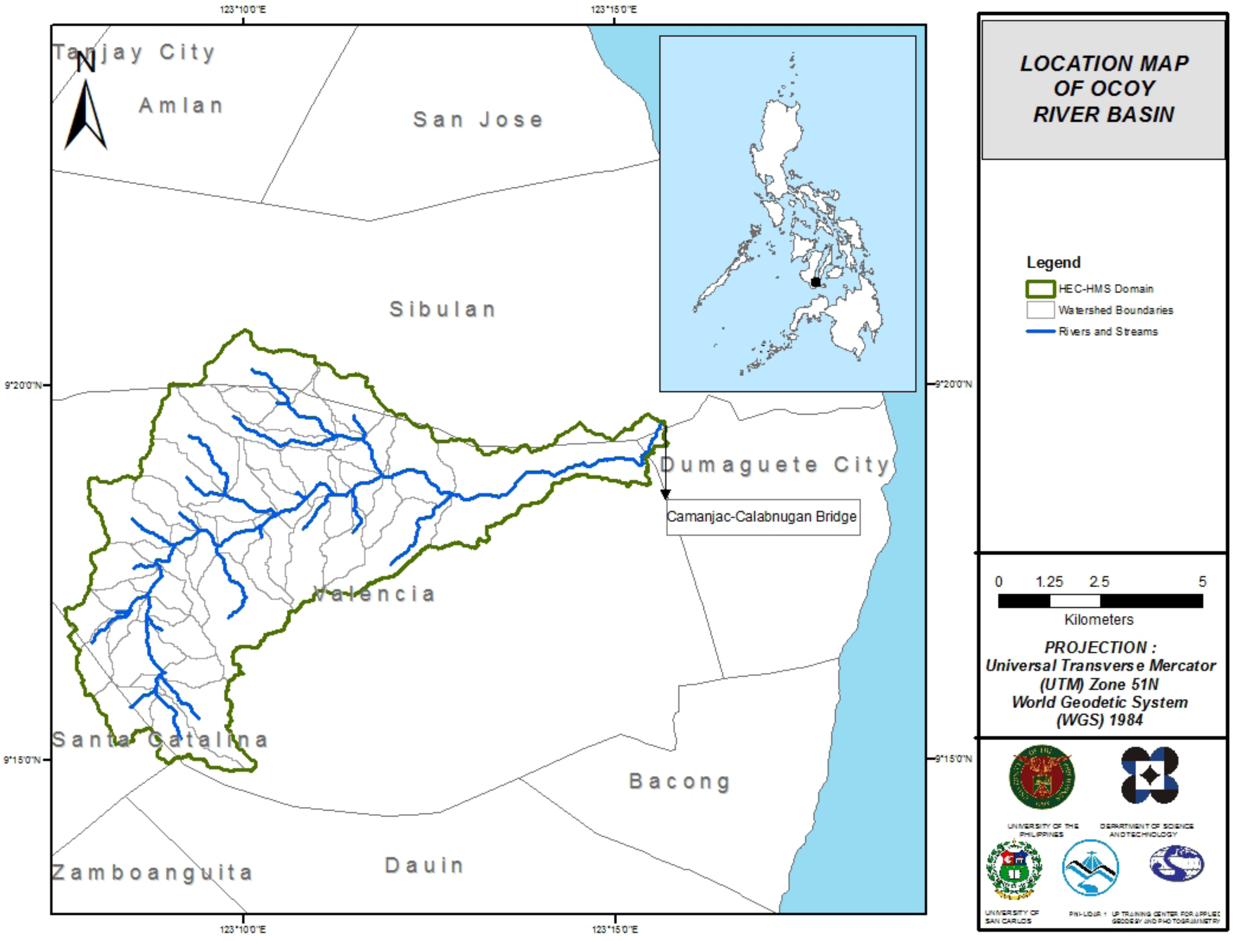


Figure 56. Stream Delineation Map of Ocoy River Basin

The Ocoy basin model comprises 45 sub basins, 22 reaches, and 22 junctions. The main outlet is outlet 1. This basin model is illustrated in Figure 57. The basins were identified based on soil and land cover characteristic of the area. Precipitation was taken from an installed Rain Gauge near and inside the river basin. Finally, it was calibrated using the data from actual discharge flow gathered in the Ocoy Bridge.

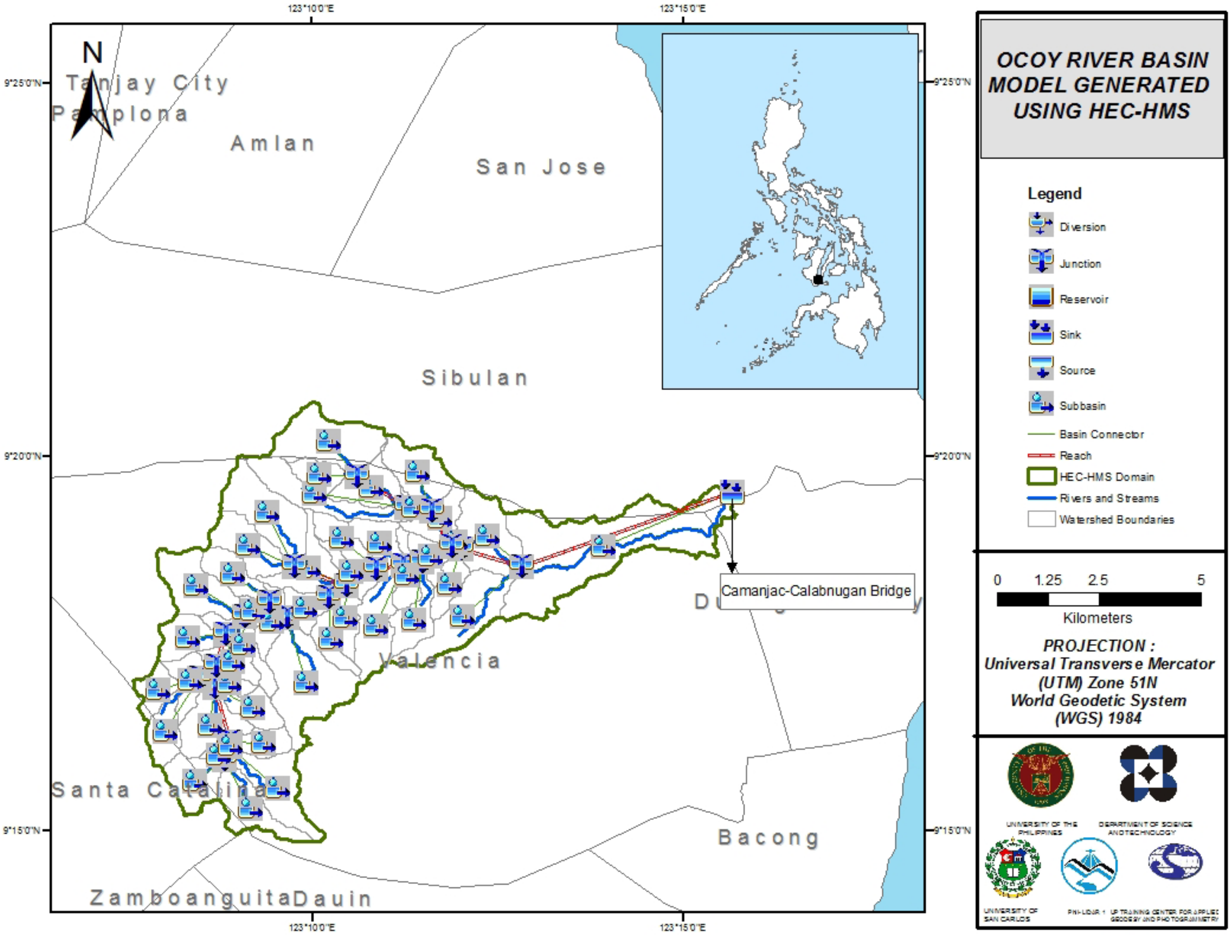


Figure 57. Ocoy River Basin model generated in HEC-HMS

5.4 Cross-section Data

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

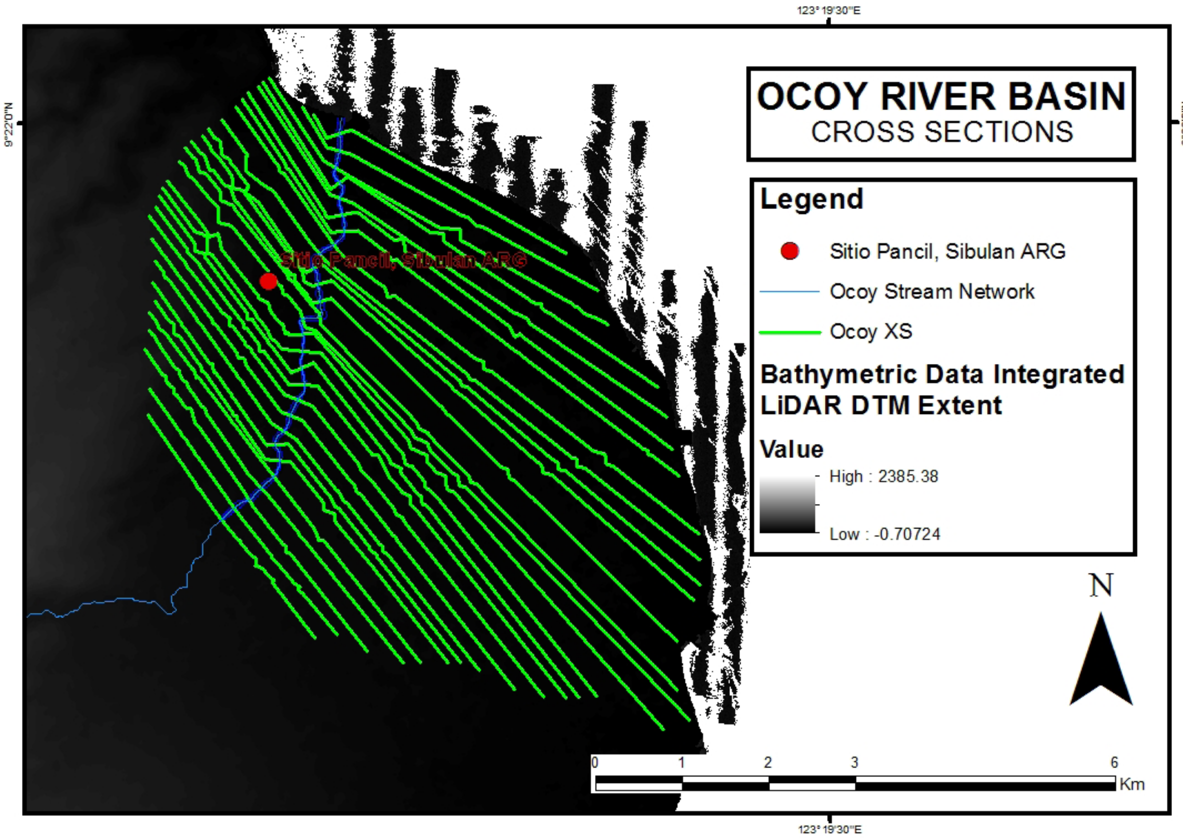


Figure 58. River cross-section of Ocoy River generated through Arcmap HEC GeoRAS tool

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).

This image is not available for this river basin.

Figure 59. Screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

5.6 Results of HMS Calibration

After calibrating the Ocoy HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

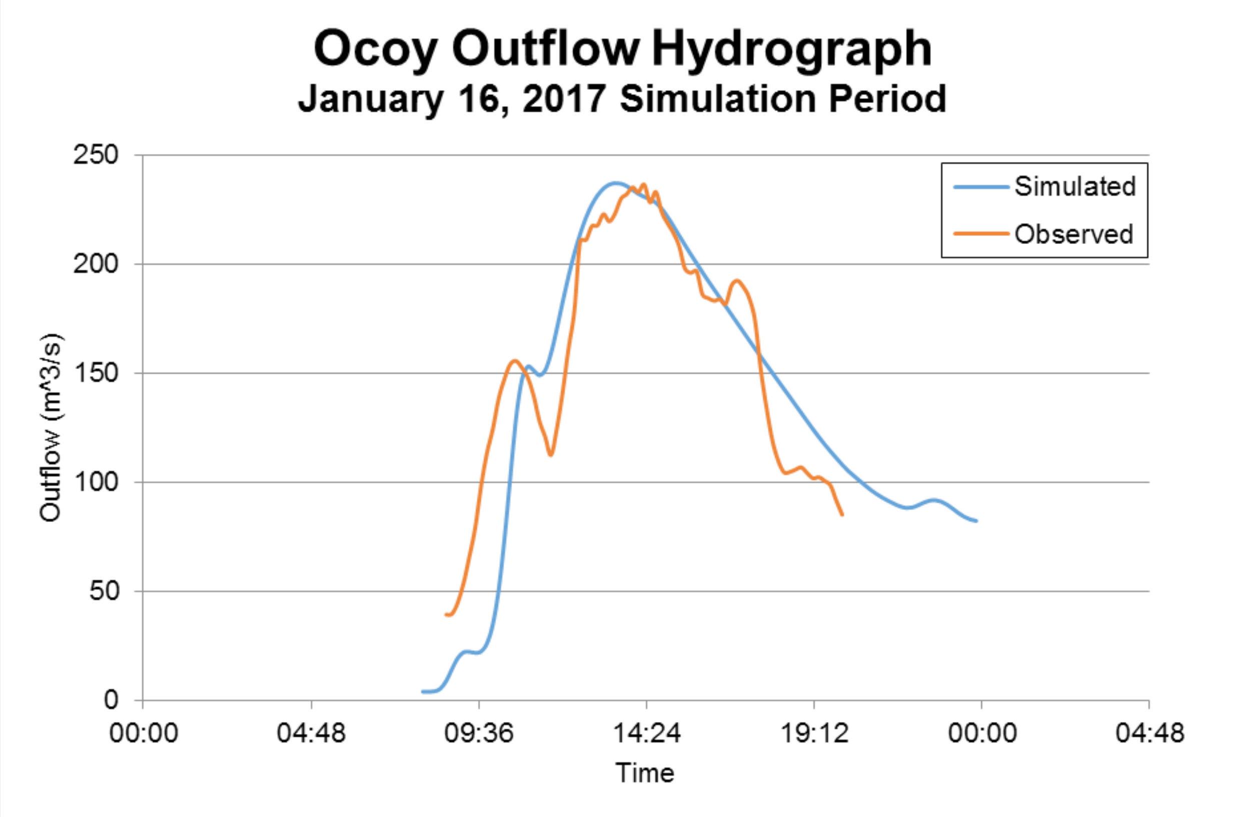


Figure 60. Outflow hydrograph of Ocoy produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 33 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of calibrated values for the Ocoy River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.08-6.29
			Curve Number	50.64-99
			Impervious (%)	25-100
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.15-9.86
			Storage Coefficient (hr)	0.04-1.06
	Baseflow	Recession	Recession Constant	0.03-0.07
			Ratio to Peak	0.31-1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.02-0.20

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 0.08 to 6.29 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Ocoy, the curve number is 50.64-99.

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 0.15 to 9.86 minutes determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.03 to 0.07 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.31 to 1 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.02 to 0.20 corresponds to the common roughness in Ocoy, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 34. Summary of the Efficiency Test of the Ocoy HMS Model

Accuracy measure	Value
RMSE	32.8999
r2	0.8775
NSE	0.6456
PBIAS	2.0105
RSR	0.5953

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 32.8999.

The Pearson correlation coefficient (assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8775.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.6456.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 2.0105.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.5953.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph shows the Ocoy outflow using the Dumaguete Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-, 10-, 25-, 50-, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a uniform duration of 24 hours and varying return periods.

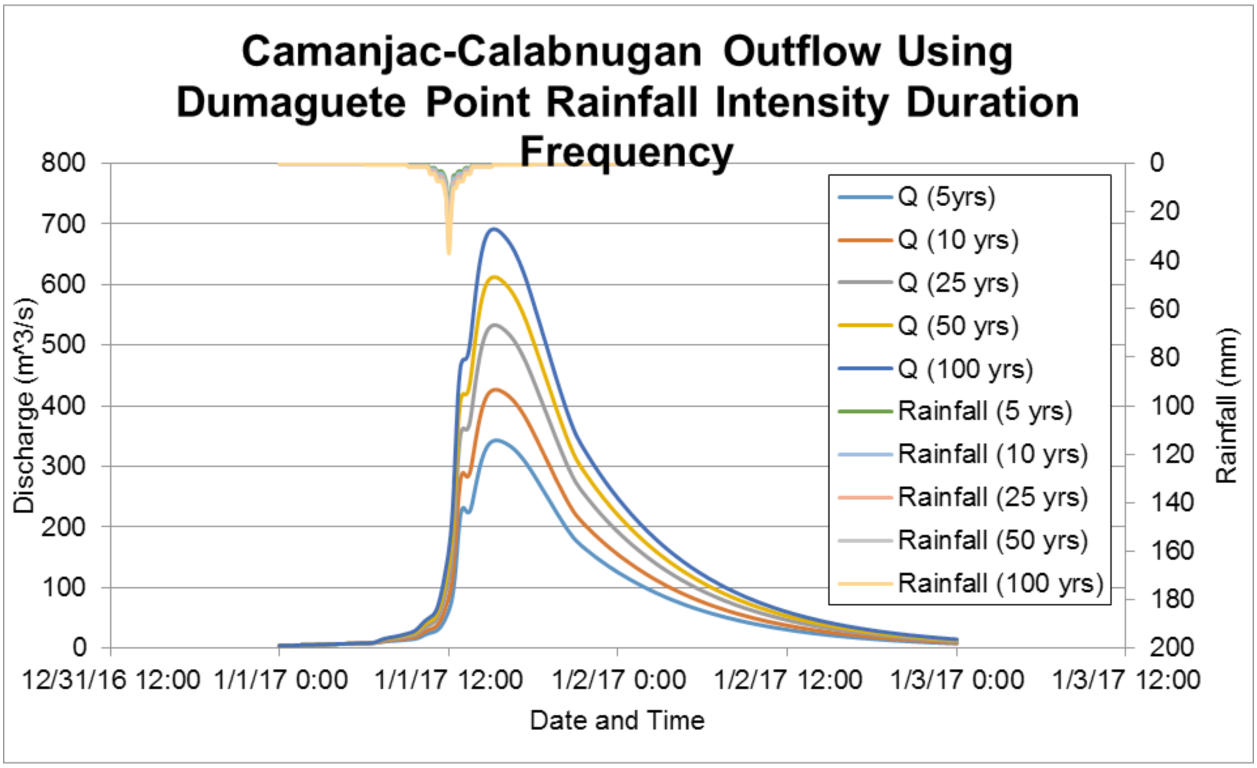


Figure 61. Outflow hydrograph at Ocoy Bridge (also known as Camanjac-Calabnugan Bridge), Sibulan generated using Dumaguete RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Ocoy River discharge using the Dumaguete Point Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 35.

Table 35. Peak values of the Ocoy HEC-HMS Model outflow using the Dumaguete RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	116.5	21.8	342.979	3 hours, 10 minutes
10-Year	143.3	25.6	426.773	3 hours, 20 minutes
25-Year	177.2	30.3	533.217	3 hours, 20 minutes
50-Year	202.4	33.8	612.636	3 hours, 10 minutes
100-Year	227.3	37.2	691.701	3 hours, 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Ocoy River using the calibrated event flow is shown in Figure 62.

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Figure 62. Sample output map of Ocoy RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 62 to Figure 67 shows the 5-, 25-, and 100-year rain return scenarios of the Ocoy floodplain.

The generated flood hazard maps for the Ocoy Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr). Figure 63 to Figure 68 shows the 5-, 25-, and 100-year rain return scenarios of the Ocoy floodplain. The floodplain, with an area of ________ sq. km., covers two municipalites namely Dumaguete and Sibulan. Table 36 shows the percentage of area affected by flooding per municipality or city.

Table 36. Municipalities affected in Ocoy Floodplain

Municipality/ City	Total Area	Area Flooded	% Flooded
Dumaguete City	34.3		
Sibulan	159.6		

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Figure 63. 100-year Flood Hazard Map for Ocoy Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 64. 100-year Flow Depth Map for Ocoy Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 65. 25-year Flood Hazard Map for Ocoy Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 66. 25-year Flow Depth Map for Ocoy Floodplain overlaid on Google Earth imagery

This image is not available for this river basin.

Figure 67. 5-year Flood Hazard Map for Ocoy Floodplain overlaid on Google Earth imagery

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Figure 68. 5-year Flood Depth Map for Ocoy Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Ocoy river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 36 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 36.41% of Dumaguete City with an area of 34.3 sq. km. will experience flood levels of less 0.20 meters. 4.13% of the area will experience flood levels of 0.21 to 0.50 meters while 1.4%, 0.84%, 0.44%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 and Table 38, and shown in Figure 69 and Figure 70 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected areas in Dumaguete City, Negros Oriental during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dumaguete City (in sq. km.)											
	Bagacay	Balugo	Bantayan	Batinguel	Bunao	Cadawinonan	Camanjac	Candau-Ay	Daro	Looc	Motong	Piapi
0.03-0.20	0.1	0.39	0.73	1.47	0.21	0.27	3.89	1.14	0.62	0.16	0.4	0.26
0.21-0.50	0.009	0.0019	0.059	0.16	0.06	0.048	0.29	0.24	0.068	0.079	0.028	0.02
0.51-1.00	0.0024	0.0002	0.00084	0.076	0.017	0.0021	0.039	0.18	0.021	0.0093	0.00018	0
1.01-2.00	0.0048	0	0	0.084	0.002	0.0033	0.02	0.08	0.0015	0	0	0
2.01-5.00	0.00071	0	0	0.045	0	0.0049	0.01	0.045	0	0	0	0
> 5.00	0	0	0	0.001	0	0.0003	0	0	0	0	0	0

Table 38. Affected areas in Dumaguete City, Negros Oriental during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dumaguete City (in sq. km.)										
	Poblacion No. 1	Poblacion No. 2	Poblacion No. 3	Poblacion No. 4	Poblacion No. 5	Poblacion No. 6	Poblacion No. 7	Poblacion No. 8	Pulantubig	Tabuctubig	Taclobo
0.03-0.20	0.026	0.014	0.12	0.1	0.13	0.061	0.063	0.033	1.16	0.026	1.11
0.21-0.50	0.016	0.0015	0.0071	0.022	0.011	0.0011	0.003	0.002	0.15	0.00056	0.14
0.51-1.00	0.033	0.0016	0.0025	0.011	0	0	0	0.0044	0.03	0.00052	0.049
1.01-2.00	0.013	0.0015	0.01	0.0004	0	0	0	0.013	0.0006	0.00029	0.052
2.01-5.00	0.0014	0.00014	0.0074	0.0001	0	0	0	0.0051	0	0	0.032
> 5.00	0	0	0	0	0	0	0	0	0	0	0

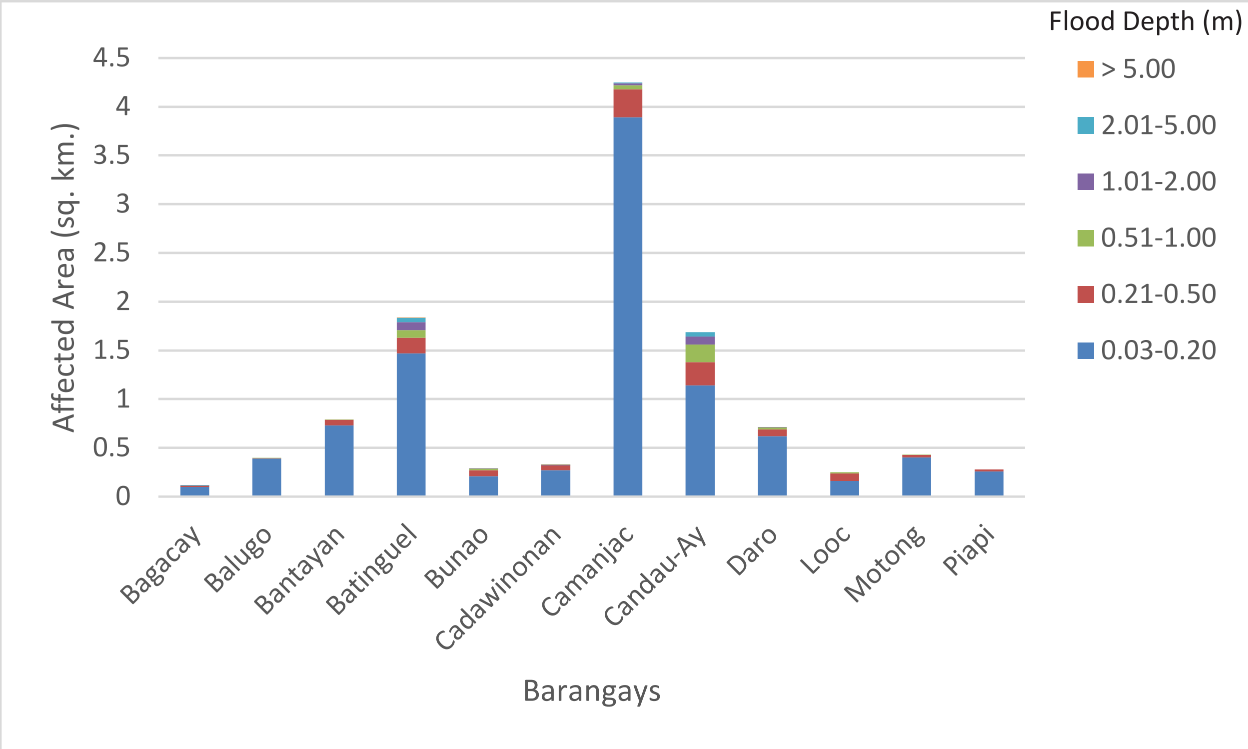

Figure 69. Affected Areas in Dumaguete City, Negros Oriental during 5-Year Rainfall Return Period

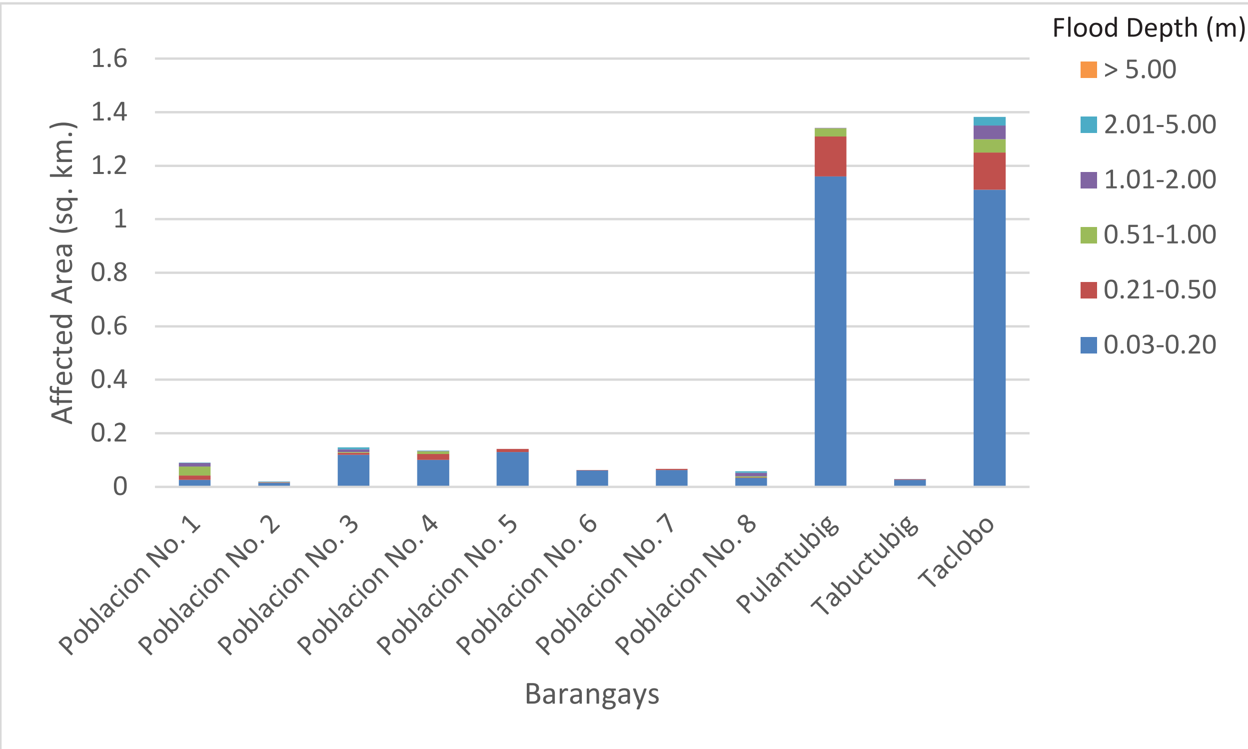

Figure 70. Affected Areas in Dumaguete City, Negros Oriental during 5-Year Rainfall Return Period

For the municipality of Sibulan, with an area of 159.6 sq. km., 11.62% will experience flood levels of less 0.20 meters. 1.5% of the area will experience flood levels of 0.21 to 0.50 meters while 0.52%, 0.22%, 0.16%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 and Table 40, and shown in Figure 71 and Figure 72 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected areas in Sibulan, Negros Oriental during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sibulan (in sq. km.)						
	Agan-An	Ajong	Balugo	Bolocboloc	Calabnugan	Cangmating	Looc
0.03-0.20	1.37	0.026	1.32	1.39	5.77	1.66	1.24
0.21-0.50	0.25	0.000022	0.039	0.16	0.67	0.31	0.15
0.51-1.00	0.036	0	0.015	0.027	0.28	0.09	0.11
1.01-2.00	0.0016	0	0.0054	0.0093	0.25	0.0061	0.018
2.01-5.00	0	0	0.0027	0.0013	0.24	0	0.0046
> 5.00	0	0	0	0	0.051	0	0

Table 40. Affected areas in Sibulan, Negros Oriental during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sibulan (in sq. km.)					
	Magatas	Maslog	Poblacion	San Antonio	Tubigon	Tubtubon
0.03-0.20	1.7	0.64	0.32	0.77	0.75	1.58
0.21-0.50	0.3	0.12	0.032	0.026	0.061	0.26
0.51-1.00	0.087	0.11	0.015	0.01	0.017	0.041
1.01-2.00	0.035	0.0013	0.0041	0.0019	0.0036	0.012
2.01-5.00	0.003	0	0	0	0.0043	0.0001
> 5.00	0	0	0	0	0	0

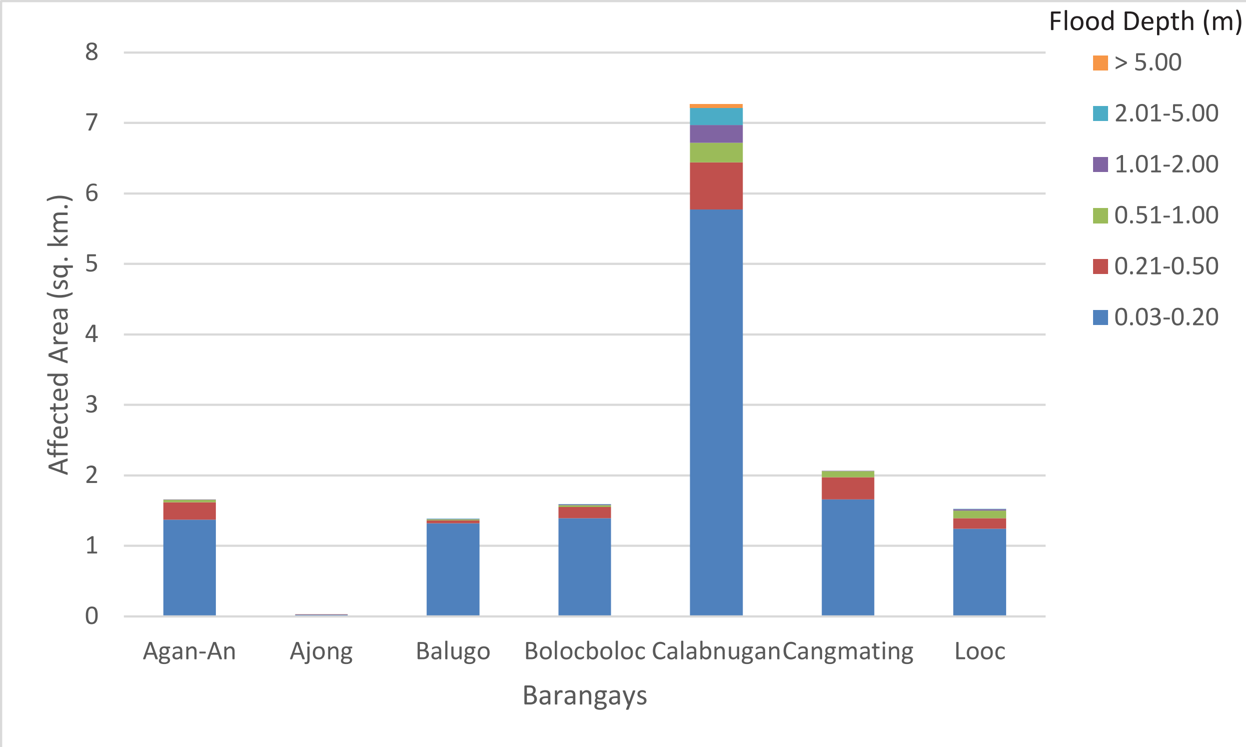

Figure 71. Affected Areas in Sibulan, Negros Oriental during 5-Year Rainfall Return Period

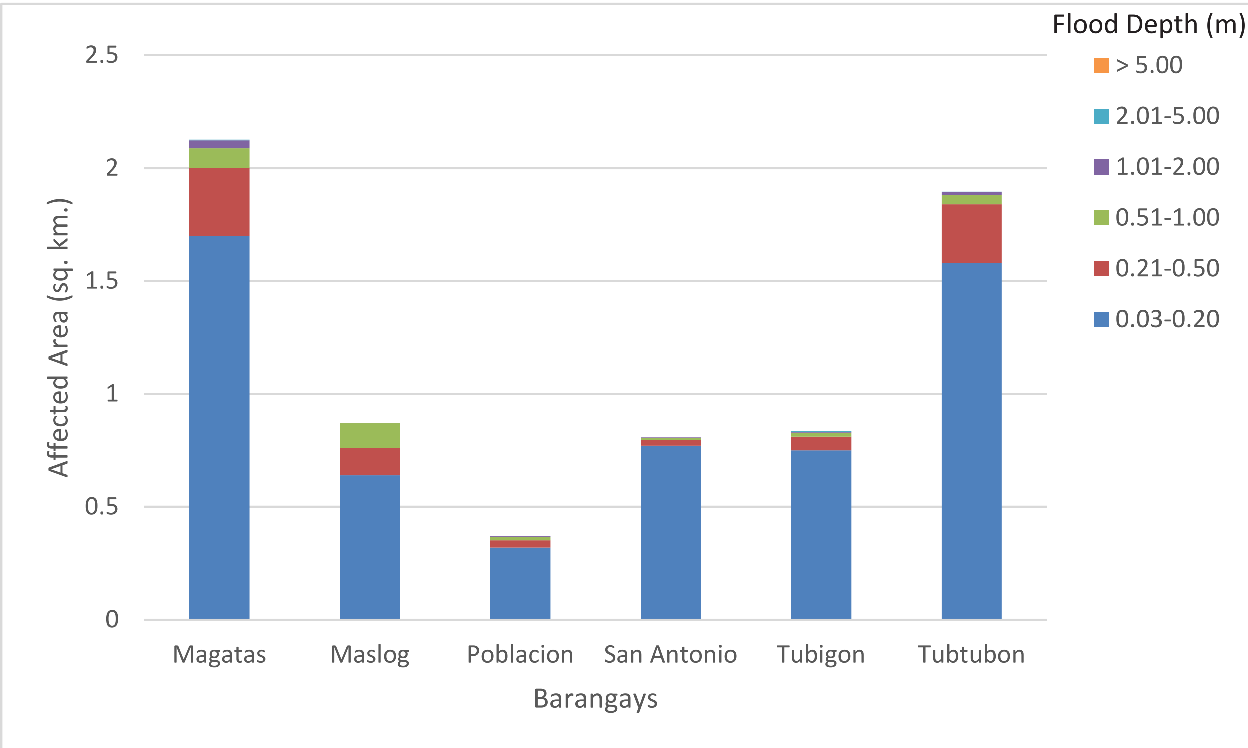

Figure 72. Affected Areas in Sibulan, Negros Oriental during 5-Year Rainfall Return Period

For the 25-year return period, 31.4% of Dumaguete City with an area of 34.3 sq. km. will experience flood levels of less 0.20 meters. 7.45% of the area will experience flood levels of 0.21 to 0.50 meters while 2.25%, 1.3%, 0.82%, and 0.013% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 and Table 42, and shown in Figure 73 and Figure 74 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected areas in Dumaguete City, Negros Oriental during a 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dumaguete City (in sq. km.)											
	Bagacay	Balugo	Bantayan	Batinguel	Bunao	Cadawinonan	Camanjac	Candau-Ay	Daro	Looc	Motong	Piapi
0.03-0.20	0.095	0.38	0.64	1.2	0.17	0.23	3.56	0.82	0.56	0.12	0.37	0.24
0.21-0.50	0.015	0.0045	0.15	0.34	0.082	0.084	0.57	0.33	0.11	0.098	0.049	0.04
0.51-1.00	0.0034	0.0003	0.0043	0.1	0.032	0.0044	0.071	0.29	0.04	0.029	0.0022	0.00011
1.01-2.00	0.0041	0	0	0.12	0.0027	0.0028	0.02	0.18	0.0049	0	0	0
2.01-5.00	0.0044	0	0	0.076	0	0.0065	0.023	0.073	0	0	0	0
> 5.00	0	0	0	0.0021	0	0.00075	0	0.0007	0	0	0	0

Table 42. Affected areas in Dumaguete City, Negros Oriental during a 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dumaguete City (in sq. km.)										
	Poblacion No. 1	Poblacion No. 2	Poblacion No. 3	Poblacion No. 4	Poblacion No. 5	Poblacion No. 6	Poblacion No. 7	Poblacion No. 8	Pulantubig	Tabuctubig	Taclobo
0.03-0.20	0.021	0.012	0.12	0.094	0.11	0.059	0.059	0.029	1.0	0.021	0.86
0.21-0.50	0.014	0.0014	0.013	0.027	0.027	0.0034	0.0063	0.0023	0.27	0.0042	0.31
0.51-1.00	0.035	0.0027	0.0032	0.016	0.00086	0	0.00037	0.0018	0.065	0.00073	0.073
1.01-2.00	0.017	0.0025	0.0053	0.00044	0	0	0	0.0076	0.0031	0.0011	0.076
2.01-5.00	0.0024	0.00043	0.014	0.0001	0	0	0	0.016	0	0	0.063
> 5.00	0	0	0	0	0	0	0	0.00036	0	0	0.00064

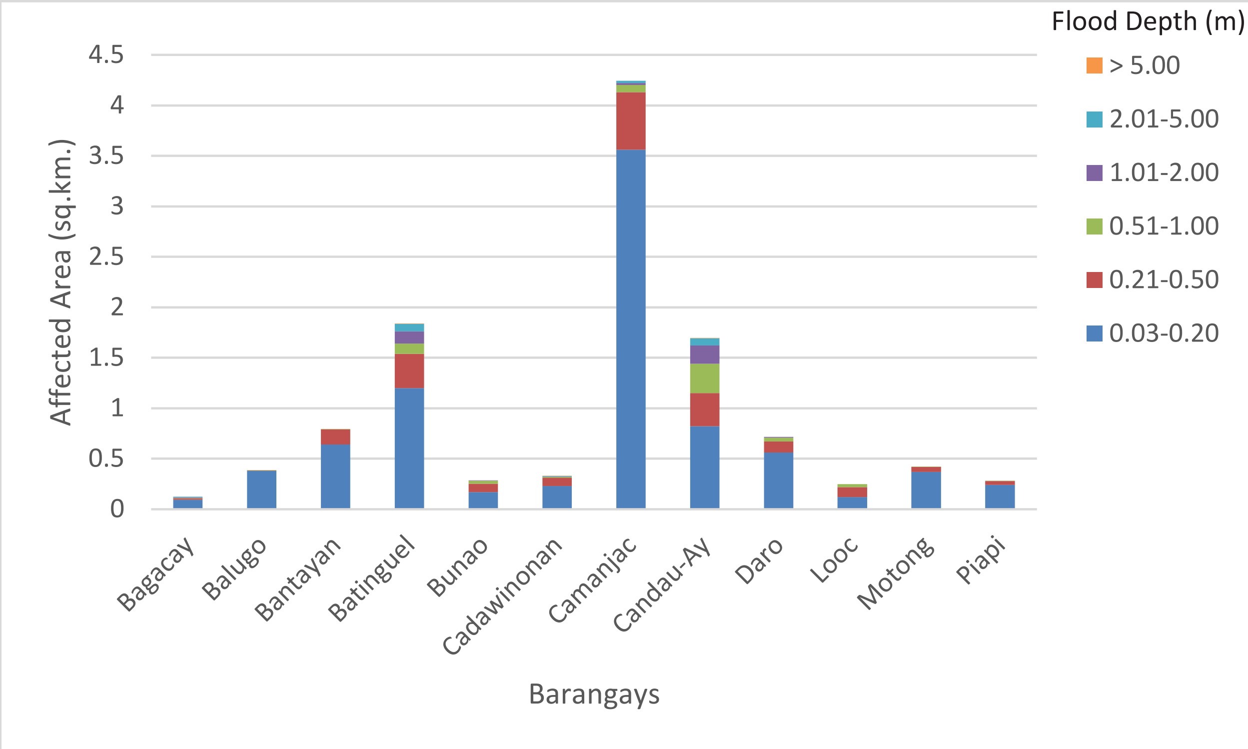

Figure 73. Affected Areas in Dumaguete City, Negros Oriental during 25-Year Rainfall Return Period

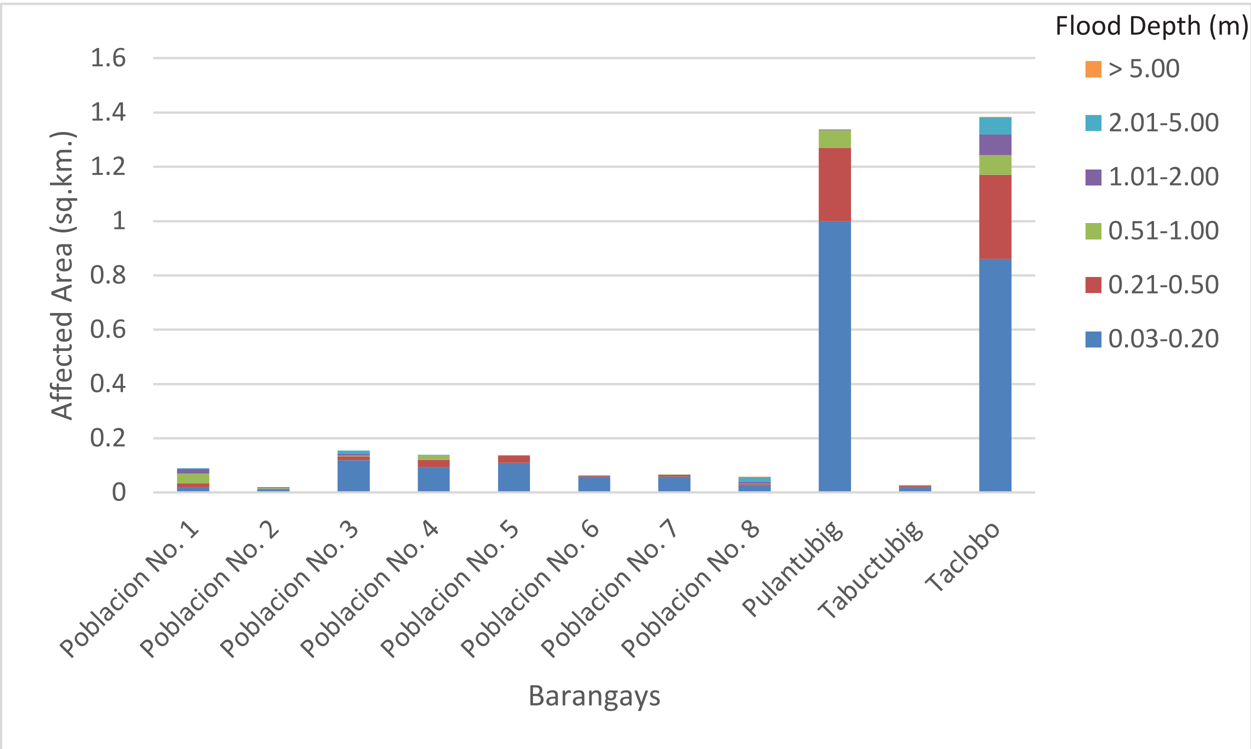

Figure 74. Affected Areas in Dumaguete City, Negros Oriental during 25-Year Rainfall Return Period

For the municipality of Sibulan, with an area of 159.6 sq. km., 10.16% will experience flood levels of less 0.20 meters. 2.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.94%, 0.47%, 0.27%, 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. Listed in Table 43 and Table 44, and shown in Figure 75 and Figure 76 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected areas in Sibulan, Negros Oriental during a 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sibulan (in sq. km.)						
	Agan-An	Ajong	Balugo	Bolocboloc	Calabnugan	Cangmating	Looc
0.03-0.20	1.37	0.026	1.32	1.39	5.77	1.66	1.24
0.21-0.50	0.25	0.000022	0.039	0.16	0.67	0.31	0.15
0.51-1.00	0.036	0	0.015	0.027	0.28	0.09	0.11
1.01-2.00	0.0016	0	0.0054	0.0093	0.25	0.0061	0.018
2.01-5.00	0	0	0.0027	0.0013	0.24	0	0.0046
> 5.00	0	0	0	0	0.051	0	0

Table 44. Affected areas in Sibulan, Negros Oriental during a 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sibulan (in sq. km.)					
	Magatas	Maslog	Poblacion	San Antonio	Tubigon	Tubtubon
0.03-0.20	1.7	0.64	0.32	0.77	0.75	1.58
0.21-0.50	0.3	0.12	0.032	0.026	0.061	0.26
0.51-1.00	0.087	0.11	0.015	0.01	0.017	0.041
1.01-2.00	0.035	0.0013	0.0041	0.0019	0.0036	0.012
2.01-5.00	0.003	0	0	0	0.0043	0.0001
> 5.00	0	0	0	0	0	0

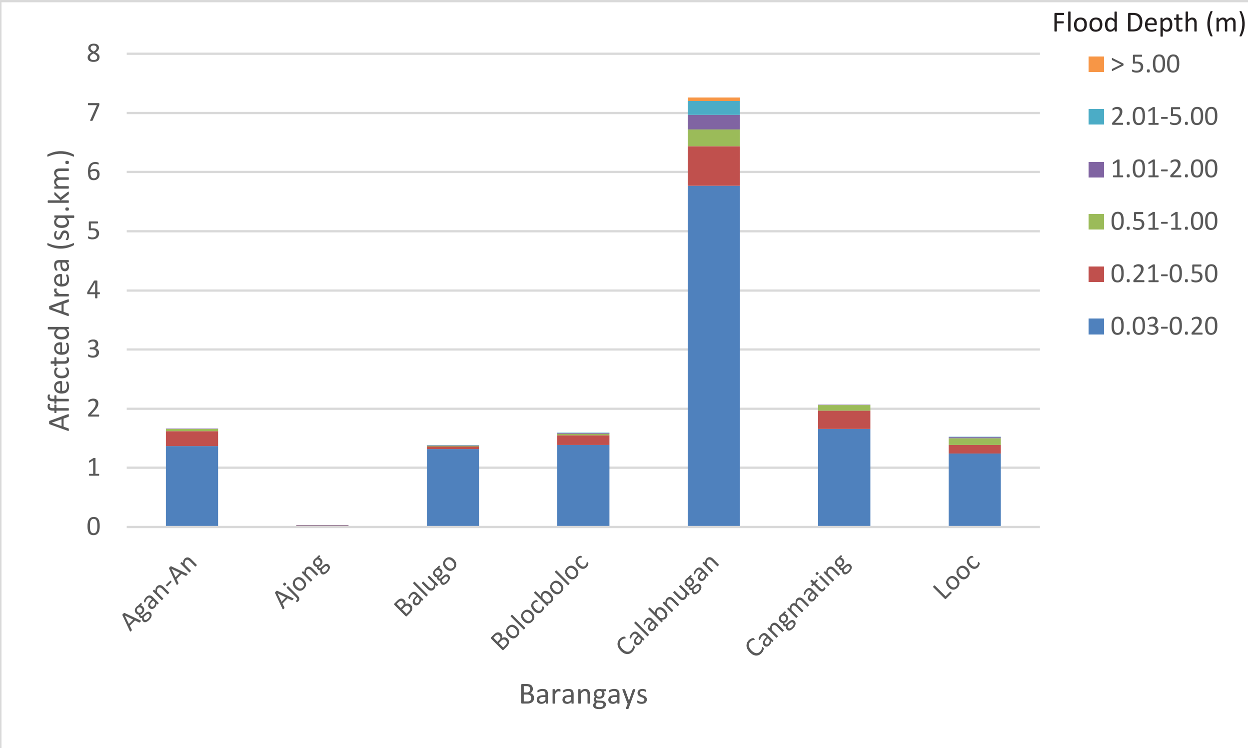

Figure 75. Affected Areas in Sibulan, Negros Oriental during 25-Year Rainfall Return Period

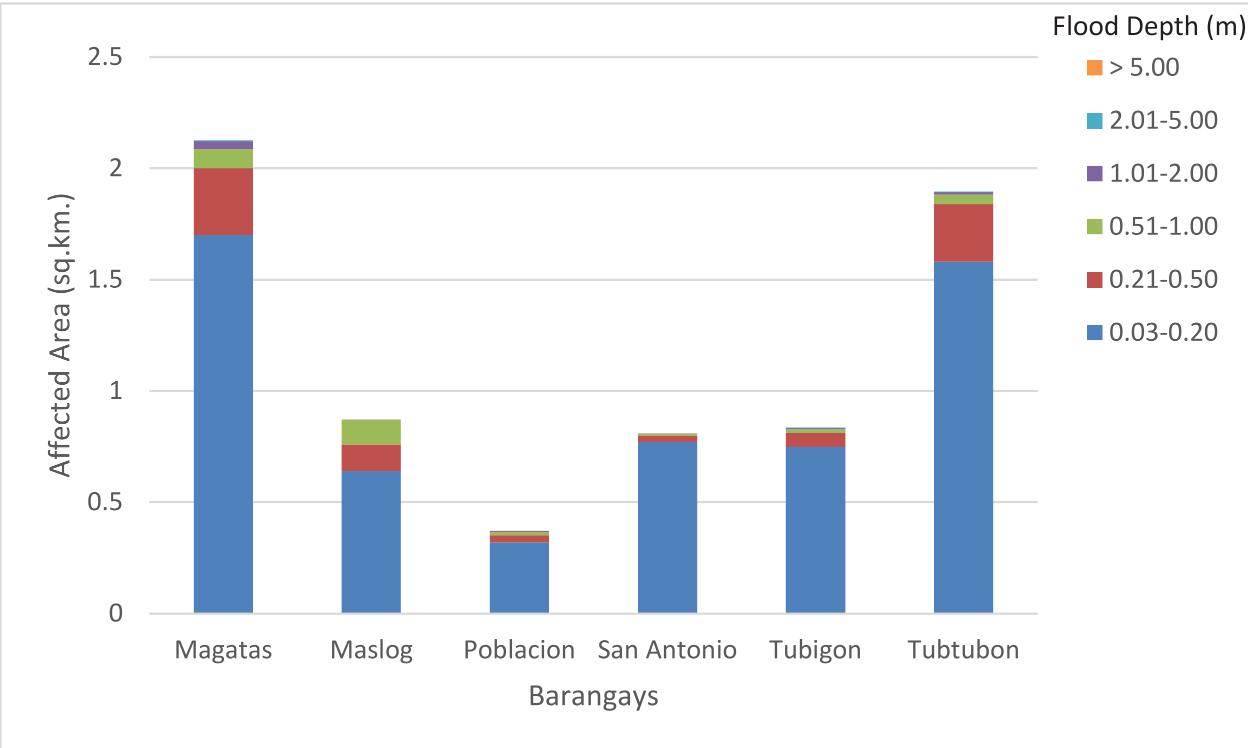

Figure 76. Affected Areas in Sibulan, Negros Oriental during 25-Year Rainfall Return Period

For the 100-year return period, 26.55% of Dumaguete City with an area of 34.3 sq. km. will experience flood levels of less 0.20 meters. 10.67% of the area will experience flood levels of 0.21 to 0.50 meters while 3.27%, 1.68%, 1.03%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 and Table 46, and shown in Figure 77 and Figure 78 are the affected areas in square kilometres by flood depth per barangay.

Table 45. Affected areas in Dumaguete City, Negros Oriental during a 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dumaguete City (in sq. km.)											
	Bagacay	Balugo	Bantayan	Batinguel	Bunao	Cadawinonan	Camanjac	Candau-Ay	Daro	Looc	Motong	Piapi
0.03-0.20	0.09	0.38	0.53	0.88	0.14	0.19	3.13	0.66	0.51	0.097	0.35	0.22
0.21-0.50	0.018	0.0088	0.25	0.54	0.093	0.12	0.92	0.33	0.14	0.098	0.064	0.058
0.51-1.00	0.003	0.0005	0.013	0.18	0.049	0.0093	0.14	0.33	0.05	0.05	0.011	0.0012
1.01-2.00	0.0046	0	0	0.12	0.0055	0.0023	0.028	0.27	0.0088	0	0	0
2.01-5.00	0.0055	0	0	0.1	0	0.0077	0.027	0.09	0	0	0	0
> 5.00	0	0	0	0.0037	0	0.00095	0.0015	0.0018	0	0	0	0

Table 46. Affected areas in Dumaguete City, Negros Oriental during a 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dumaguete City (in sq. km.)										
	Poblacion No. 1	Poblacion No. 2	Poblacion No. 3	Poblacion No. 4	Poblacion No. 5	Poblacion No. 6	Poblacion No. 7	Poblacion No. 8	Pulantubig	Tabuctubig	Taclobo
0.03-0.20	0.019	0.012	0.085	0.078	0.088	0.055	0.047	0.02	0.82	0.018	0.69
0.21-0.50	0.013	0.00096	0.04	0.035	0.05	0.0073	0.016	0.008	0.39	0.0067	0.44
0.51-1.00	0.035	0.0031	0.0058	0.023	0.0037	0.0001	0.0024	0.0036	0.12	0.0013	0.084
1.01-2.00	0.019	0.0025	0.005	0.00072	0	0	0	0.0049	0.0088	0.0012	0.089
2.01-5.00	0.0033	0.00089	0.016	0.0002	0	0	0	0.02	0.0001	0.00025	0.08
> 5.00	0	0	0	0	0	0	0	0.00076	0	0	0.0016

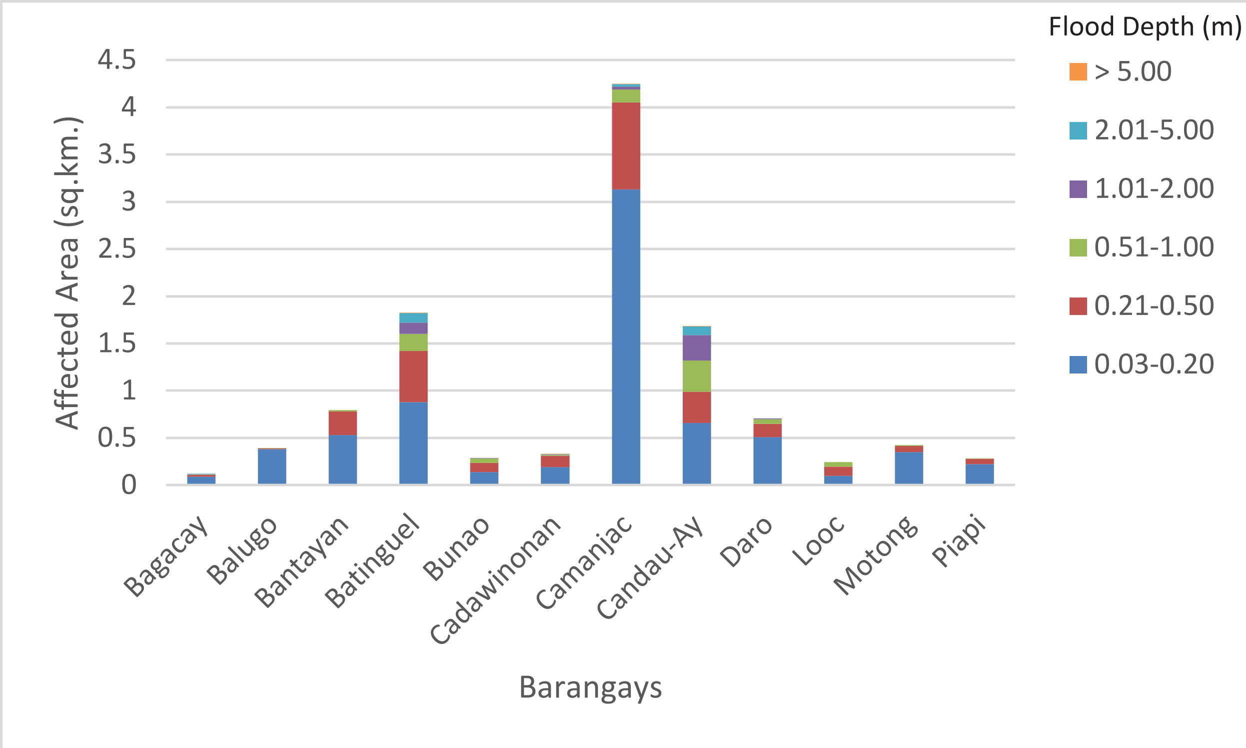

Figure 77. Affected Areas in Dumaguete City, Negros Oriental during 100-Year Rainfall Return Period

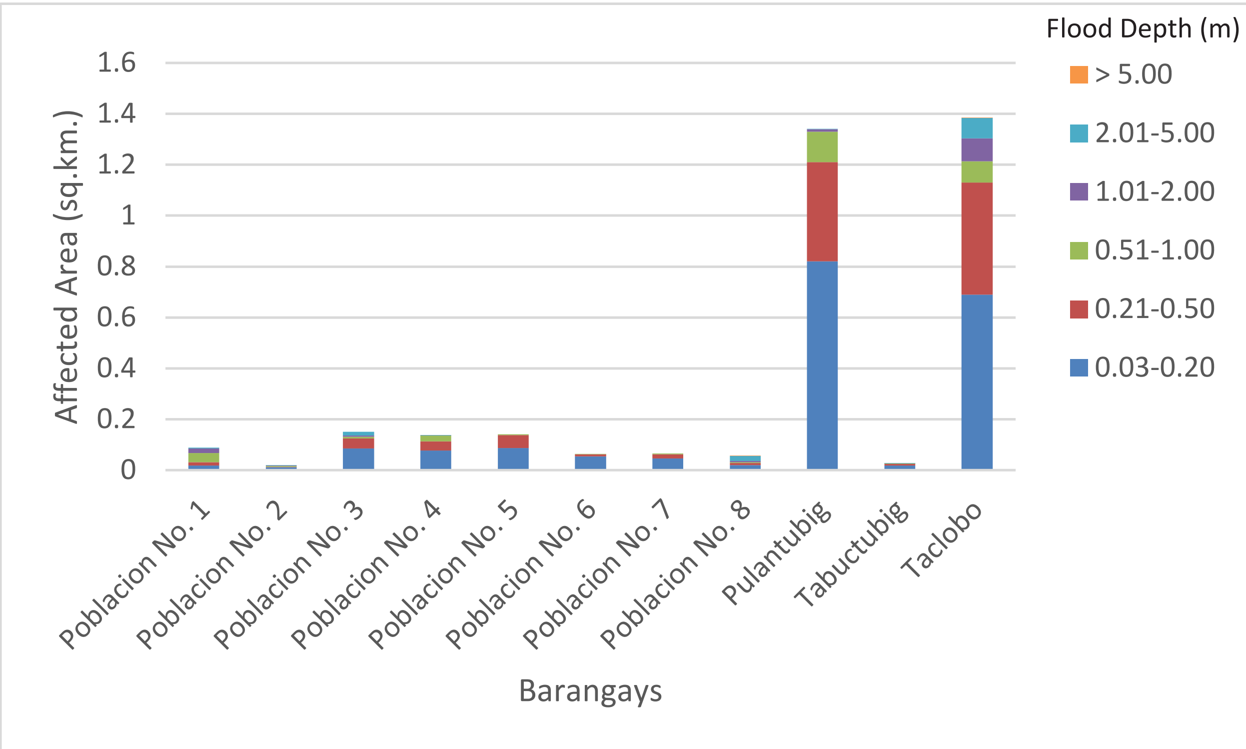

Figure 78. Affected Areas in Dumaguete City, Negros Oriental during 100-Year Rainfall Return Period

For the municipality of Sibulan, with an area of 159.6 sq. km., 9.12% will experience flood levels of less 0.20 meters. 2.61% of the area will experience flood levels of 0.21 to 0.50 meters while 1.29%, 0.62%, 0.33%, 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. Listed in Table 47 and Table 48, and shown in Figure 79 and Figure 80 are the affected areas in square kilometres by flood depth per barangay.

Table 47. Affected areas in Sibulan, Negros Oriental during a 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sibulan (in sq. km.)						
	Agan-An	Ajong	Balugo	Bolocboloc	Calabnugan	Cangmating	Looc
0.03-0.20	1.04	0.026	1.3	1.19	4.59	1.24	1.09
0.21-0.50	0.45	0.000022	0.047	0.29	1.06	0.53	0.15
0.51-1.00	0.16	0	0.022	0.094	0.55	0.27	0.17
1.01-2.00	0.013	0	0.0093	0.016	0.46	0.034	0.11
2.01-5.00	0	0	0.0045	0.0027	0.49	0	0.0077
> 5.00	0	0	0	0	0.13	0	0.0014

Table 48. Affected areas in Sibulan, Negros Oriental during a 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sibulan (in sq. km.)					
	Magatas	Maslog	Poblacion	San Antonio	Tubigon	Tubtubon
0.03-0.20	0.82	0.4	0.24	0.75	0.7	1.18
0.21-0.50	0.67	0.25	0.069	0.03	0.084	0.54
0.51-1.00	0.45	0.11	0.038	0.016	0.039	0.15
1.01-2.00	0.17	0.12	0.029	0.005	0.0033	0.024
2.01-5.00	0.012	0	0.0008	0	0.0089	0.0013
> 5.00	0	0	0	0	0.00033	0

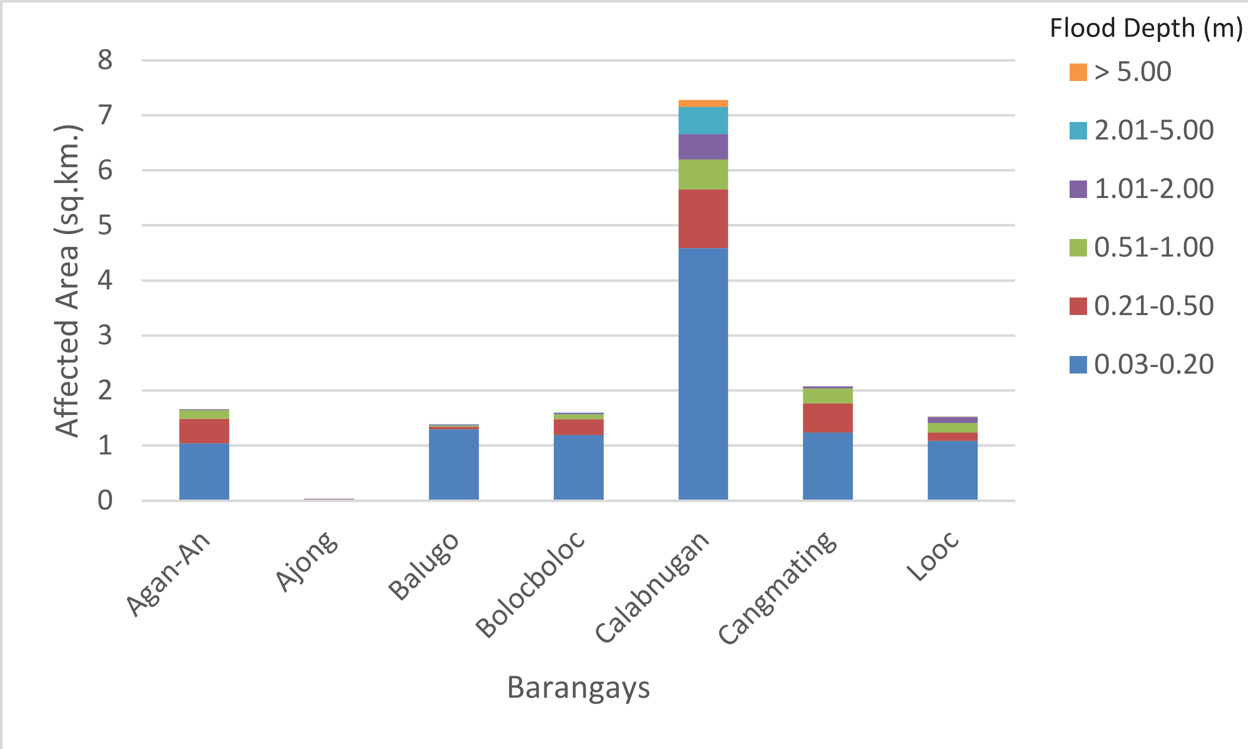

Figure 79. Affected Areas in Sibulan, Negros Oriental during 100-Year Rainfall Return Period

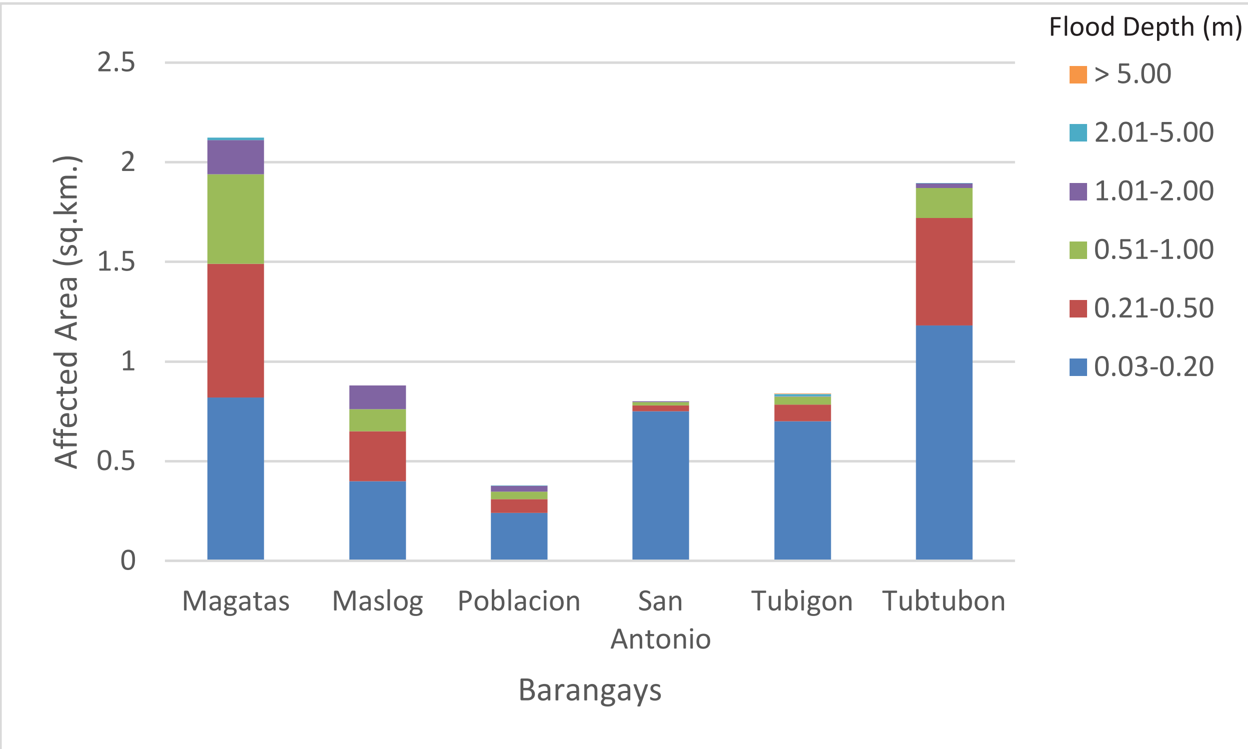

Figure 80. Affected Areas in Sibulan, Negros Oriental during 100-Year Rainfall Return Period

Among the barangays in the city of Dumaguete, Camanjac is projected to have the highest percentage of area that will experience flood levels at 12.4%. Meanwhile, Batinguel posted the second highest percentage of area that may be affected by flood depths at 5.36%.

Among the barangays in the municipality of Sibulan, Calabnugan is projected to have the highest percentage of area that will experience flood levels at 4.56%. Meanwhile, Cangmating posted the second highest percentage of area that may be affected by flood depths at 1.3%.

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

Table 49. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.81	5.99	7.83
Medium	1.64	3.08	4.24
High	0.78	1.21	1.54
TOTAL	**6.23**	**10.28**	**13.61**

Of the 65 identified Education Institutions in the Ocoy Flood plain, 11 schools were assessed to be exposed to Low level flooding during a 5 year scenario. In the 25 year scenario, 19 schools were assessed to be exposed to low level flooding, while 3 schools were assessed to be exposed to medium level flooding in the same scenario. In the 100 year scenario, 21 schools were assessed to be exposed to low level flooding, while 8 schools were assessed to be exposed to medium level flooding in the same scenario. The educational institutions exposed to flooding are shown in Annex 12.

Of the 7 identified Medical Institutions in the Ocoy Flood plain, no medical institutions were assessed to be exposed to any of the flooding levels during a 5 year scenario. In the 25 year scenario, 2 medical institutions were assessed to be exposed to low level flooding. In the 100 year scenario, 2 medical institutions were assessed to be exposed to low level flooding.The medical institutions exposed to flooding are shown in Annex 13.

5.11 Flood Validation

Survey was done along the floodplain of Ocoy River to validate the generated flood maps. The team gathered secondary data regarding flood occurrence in the area. Ground validation points were acquired as well as the other necessary details like date of occurrence, name of typhoon and actual flood depth. The flood validation points were obtained on November 16 to 17, 2016.

During validation, the team was assisted by the local Disaster Risk Reduction and Management representative from the Municipality of Sibulan and Dumaguete. Residents along the floodplain were interviewed of the historical flood events they experiences.

Actual flood depth acquired from the ground validation were then computed and compared to the flood depth simulated by the model. An RMSE value of 0.80 was obtained.

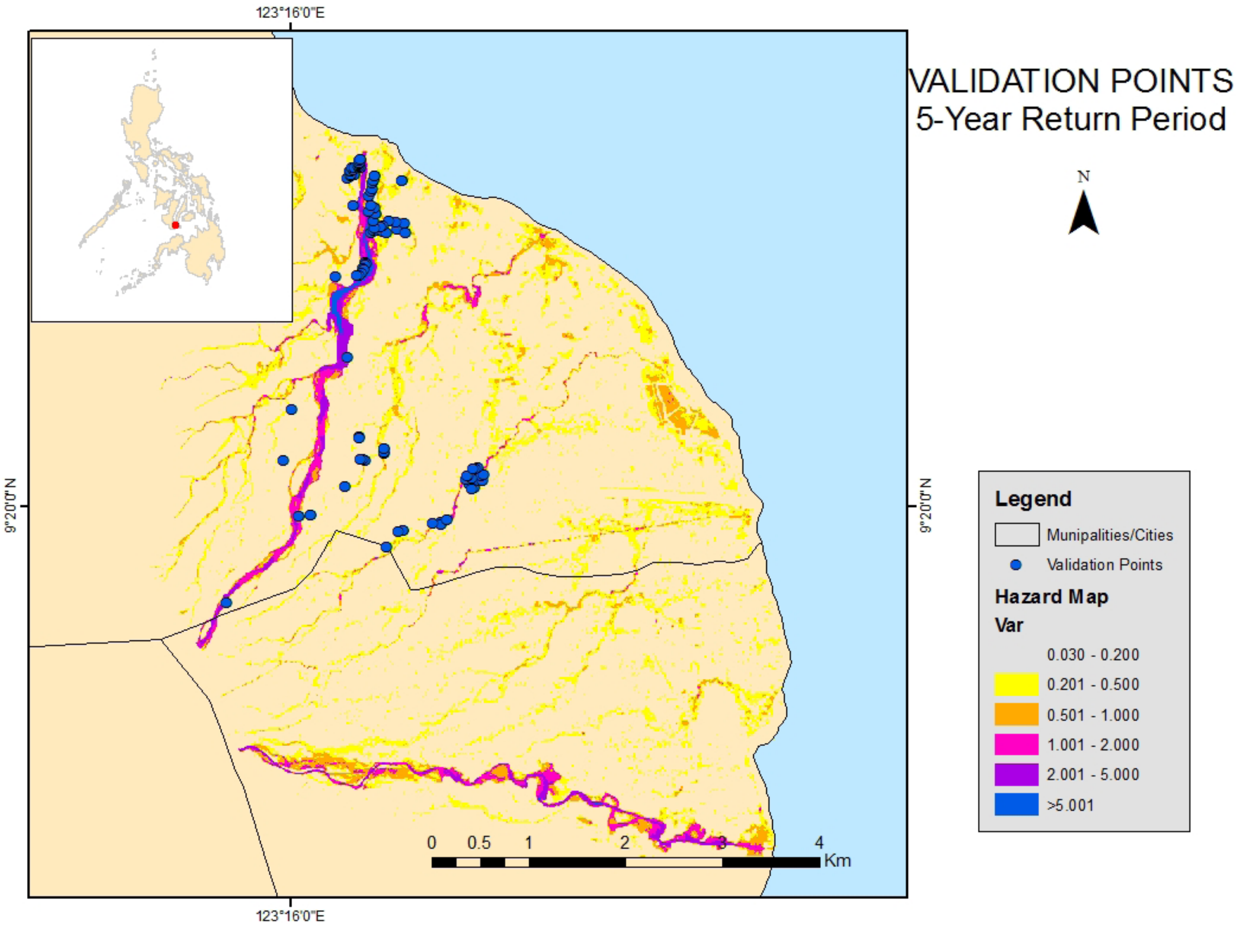

Figure 81. Ocoy Flood Validation Points

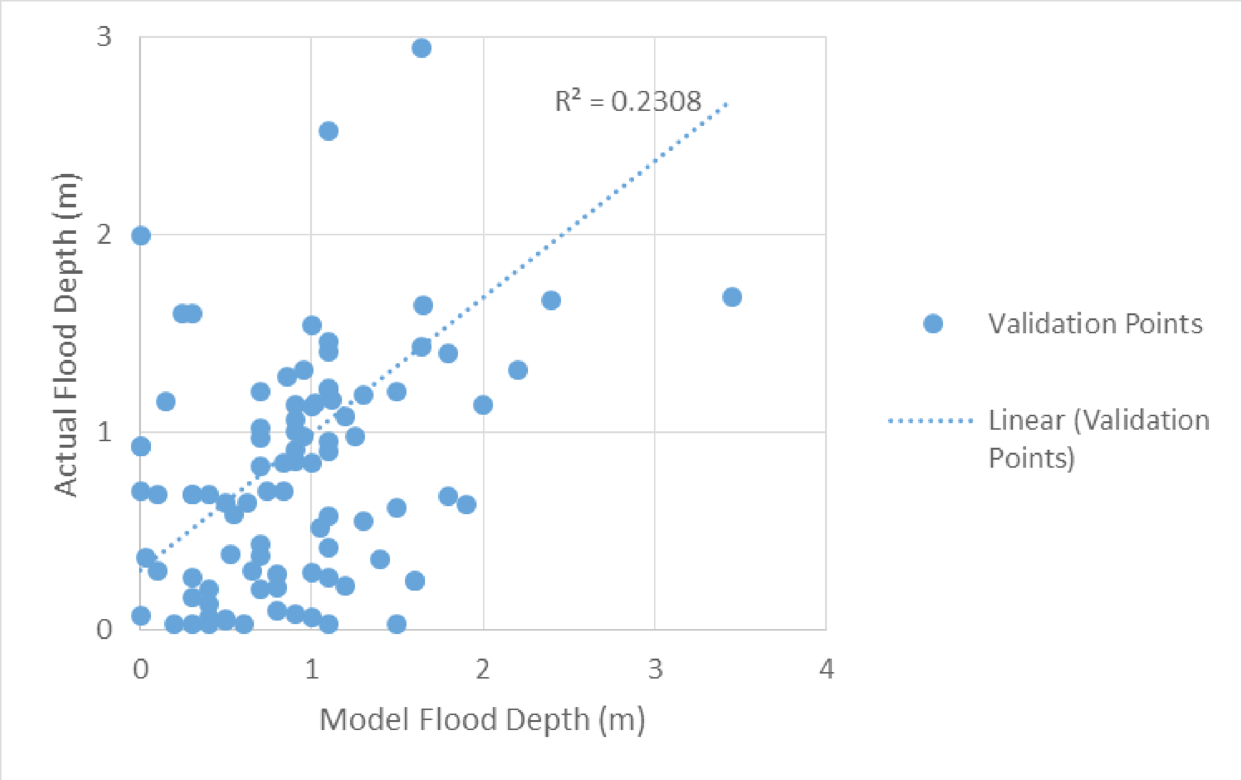

Figure 82. Flood map depth vs. actual flood depth

Table 50. Actual flood vs simulated flood depth at different levels in the Ocoy 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	2	7	4	2	0	0	15
0.21-0.50	2	2	2	6	0	0	18
0.51-1.00	4	4	11	9	0	0	28
1.01-2.00	2	2	9	13	3	0	29
2.01-5.00	0	0	0	7	2	0	9
> 5.00	0	0	0	0	0	0	0
Total	10	15	32	37	5	0	99

The overall accuracy generated by the flood model is estimated at 30.30% with 30 points correctly matching the actual flood depths. In addition, there were 45 points estimated one level above and below the correct flood depths while there were 16 points and 4 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 30 points were underestimated in the modelled flood depths of Ocoy. The summary of the accuracy assessment is presented in Table 51.

Table 51. Summary of the Accuracy Assessment in the Ocoy River Basin Survey

	No. of Points	%
Correct	30	30.30
Overestimated	39	39.39
Underestimated	30	30.30
Total	99	100.00

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Aquarius and Gemini Sensors

Table A-1.1. Parameters and Specification of Aquarius Sensor

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

Table A-1.2. Parameters and Specification of Gemini Sensor

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

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

1. NGE-89

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

October 15, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS ORIENTAL**
Station Name: **NGE-89**
Order: **2nd**

Island:	**VISAYAS**	Barangay:	**BIO-OS**		
Municipality:	**AMLAN (AYUQUITAN)**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**9° 28' 17.93638"**	Longitude:	**123° 11' 53.99321"**	Ellipsoidal Hgt:	**5.29700 m.**
		WGS84 Coordinates			
Latitude:	**9° 28' 13.96567"**	Longitude:	**123° 11' 59.32102"**	Ellipsoidal Hgt:	**67.20400 m.**
		PTM / PRS92 Coordinates			
Northing:	**1047303.984 m.**	Easting:	**521778.353 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,046,937.41**	Easting:	**521,770.73**	Zone:	**51**

Location Description

NGE-89
The station is on the SE corner of Bio-os Bridge, at km. 23+56. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on the concrete pavement of the bridge's sidewalk with inscriptions "NGE-89; 2007; NAMRIA".

The station is located along the Dumaguete-San Carlos national road, between the municipalities of Tanjay and Amlan.

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2467**

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. NGE-89

2. NGE-101

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

October 15, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS ORIENTAL**
Station Name: **NGE-101**
Order: **2nd**

Island: **VISAYAS**	Barangay: **POBLACION**	
Municipality: **SIBULAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 21' 46.05028"**	Longitude: **123° 17' 3.45508"**	Ellipsoidal Hgt: **2.89700 m.**
	WGS84 Coordinates	
Latitude: **9° 21' 42.11526"**	Longitude: **123° 17' 8.79199"**	Ellipsoidal Hgt: **65.25500 m.**
	PTM / PRS92 Coordinates	
Northing: **1035271.672 m.**	Easting: **531227.453 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,034,909.31**	Easting: **531,216.52**	Zone: **51**

Location Description

NGE-101
The station was established in coordination with the PPA Port manager. The station is on the 3rd step from the top flooring of the pier NE corner. It is on the east side of the Sibulan Town proper, along the shoreline of Tañon Strait, inside the Sibulan Ferry Terminal compound. Mark is the head of a 4" copper nail at the center of a 30 x 30 cm. cement putty embedded on the concrete stairs with inscriptions "NGE-101; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2466**

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

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. NGE-101

3. NGE-111

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

October 15, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **NEGROS ORIENTAL**	
	Station Name: **NGE-111**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **JAGOBA**	
Municipality: **DAUIN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 10' 30.25228"**	Longitude: **123° 14' 54.26711"**	Ellipsoidal Hgt: **13.11600 m.**
	WGS84 Coordinates	
Latitude: **9° 10' 26.36267"**	Longitude: **123° 14' 59.62110"**	Ellipsoidal Hgt: **75.79100 m.**
	PTM / PRS92 Coordinates	
Northing: **1014508.213 m.**	Easting: **527300.168 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,014,153.12**	Easting: **527,290.61**	Zone: **51**

Location Description

NGE-111

The station is located on the NE approach of the 36 m. long Jagoba bridge at Km.17+930. The station is about 40 m. SW of km.post # 18. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on the concrete sidewalk with inscriptions "NGE-111; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2465**

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

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CERTIFICATION INTERNATIONAL ISO 9001 2008
CIP/4701/12/09/614

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Figure A-2.3. NGE-111

4. NGW-126

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

October 30, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS OCCIDENTAL**
Station Name: **NGW-126**
Order: **2nd**

Island:	**VISAYAS**	Barangay:	**MARICALUM**		
Municipality:	**SIPALAY**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**9° 41' 56.09927"**	Longitude:	**122° 26' 33.87232"**	Ellipsoidal Hgt:	**20.29100 m.**
		WGS84 Coordinates			
Latitude:	**9° 41' 52.00368"**	Longitude:	**122° 26' 39.18513"**	Ellipsoidal Hgt:	**79.82600 m.**
		PTM / PRS92 Coordinates			
Northing:	**1072482.031 m.**	Easting:	**438848.628 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,072,106.64**	Easting:	**438,870.03**	Zone:	**51**

Location Description

NGW-126
The station is located on the SE corner of Maricalum bridge which is at the km 177+175. Mark is the head of a 4" copper nail flushed at the center of a 30 x 30 cm. cement putty embedded on the bridge sidewalk with inscriptions "NGW-126; 2007; NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2590**

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

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Figure A-2.4. NGW-126

3. NGE-100

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

January 27, 2016

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS ORIENTAL**
Station Name: **NGE-100**
Order: **2nd**

Island: **VISAYAS**		Barangay: **CAWITAN**			
Municipality: **STA CATALINA**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**9° 18' 11.02881"**	Longitude:	**122° 52' 26.45331"**	Ellipsoidal Hgt:	**8.14800 m.**
		WGS84 Coordinates			
Latitude:	**9° 18' 7.07298"**	Longitude:	**122° 52' 31.79856"**	Ellipsoidal Hgt:	**69.61900 m.**
		PTM / PRS92 Coordinates			
Northing:	**1028656.115 m.**	Easting:	**486159.164 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,028,296.07**	Easting:	**486,164.01**	Zone:	**51**

Location Description

NGE-100
The station is located on the SW corner of Cawitan Bridge, along the Dumaguete- Bayawan national highway. Mark is the head of a 4" copper nail drilled and grouted at the center of 30 x 30 cm. cement putty embedded on the concrete sidewalk with inscriptions "NGE-100; 2007; NAMRIA". The station is about 7 km. from Sta Catalina heading to Siaton.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0242**

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

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Figure A-2.5. NGE-100

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

1. TBM-4

Table A-3.1. TBM-4

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
T-BM4 --- NGE-101 (B1)	NGE-101	T-BM4	Fixed	0.005	0.017	155°37'59"	6288.490	0.815
T-BM4 --- NGE-101 (B2)	NGE-101	T-BM4	Fixed	0.004	0.009	155°37'59"	6288.479	0.804

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	NGE-101				
Grid		Local		Global	
Easting	531216.523 m	Latitude	N9°21'46.05028"	Latitude	N9°21'42.11526"
Northing	1034909.308 m	Longitude	E123°17'03.45508"	Longitude	E123°17'08.79199"
Elevation	2.110 m	Height	2.897 m	Height	65.255 m

To:	T-BM4				
Grid		Local		Global	
Easting	533814.622 m	Latitude	N9°18'39.58660"	Latitude	N9°18'35.66706"
Northing	1029185.290 m	Longitude	E123°18'28.47112"	Longitude	E123°18'33.81248"
Elevation	3.094 m	Height	3.712 m	Height	66.241 m

Vector					
ΔEasting	2598.099 m	NS Fwd Azimuth	155°37'59"	ΔX	-2679.198 m
ΔNorthing	-5724.018 m	Ellipsoid Dist.	6288.490 m	ΔY	-646.804 m
ΔElevation	0.985 m	ΔHeight	0.815 m	ΔZ	-5652.309 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

2. NE-90

Table A-3.2. NE-90

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NE-90 --- NGE-111 (B1)	NGE-111	NE-90	Fixed	0.003	0.011	216°26'37"	8704.123	-5.758
NGE-111 --- NE-90 (B2)	NGE-111	NE-90	Fixed	0.005	0.025	216°26'38"	8704.148	-5.719

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	NGE-111				
Grid		Local		Global	
Easting	527290.613 m	Latitude	N9°10'30.25228"	Latitude	N9°10'26.36267"
Northing	1014153.117 m	Longitude	E123°14'54.26711"	Longitude	E123°14'59.62110"
Elevation	12.583 m	Height	13.116 m	Height	75.791 m

To:	NE-90				
Grid		Local		Global	
Easting	522126.927 m	Latitude	N9°06'42.32060"	Latitude	N9°06'38.44322"
Northing	1007150.356 m	Longitude	E123°12'04.93455"	Longitude	E123°12'10.29457"
Elevation	7.044 m	Height	7.358 m	Height	70.052 m

Vector					
ΔEasting	-5163.685 m	NS Fwd Azimuth	216°26'37"	ΔX	3718.151 m
ΔNorthing	-7002.762 m	Ellipsoid Dist.	8704.123 m	ΔY	3758.805 m
ΔElevation	-5.538 m	ΔHeight	-5.758 m	ΔZ	-6914.376 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.001 m

3. NE-135

Table A-3.3. NE-135

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NE-135 --- NGE-89 (B1)	NGE-89	NE-135	Fixed	0.006	0.006	293°20'47"	1679.526	0.259
NGE-89 --- NE-135 (B3)	NGE-89	NE-135	Fixed	0.004	0.006	293°20'47"	1679.528	0.236

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	NGE-89				
Grid		Local		Global	
Easting	521770.730 m	Latitude	N9°28'17.93638"	Latitude	N9°28'13.96567"
Northing	1046937.409 m	Longitude	E123°11'53.99321"	Longitude	E123°11'59.32102"
Elevation	3.905 m	Height	5.297 m	Height	67.204 m

To:	NE-135				
Grid		Local		Global	
Easting	520228.944 m	Latitude	N9°28'39.60020"	Latitude	N9°28'35.62671"
Northing	1047601.845 m	Longitude	E123°11'03.44049"	Longitude	E123°11'08.76787"
Elevation	4.101 m	Height	5.556 m	Height	67.415 m

Vector					
ΔEasting	-1541.786 m	NS Fwd Azimuth	293°20'47"	ΔX	1350.288 m
ΔNorthing	664.437 m	Ellipsoid Dist.	1679.526 m	ΔY	752.714 m
ΔElevation	0.196 m	ΔHeight	0.259 m	ΔZ	656.467 m

Standard Errors

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

4. NE-90A

Table A-3.4. NE-90A

NE 90 - NE 90A1 (4:33:53 PM-6:08:49 PM) (S1)

Baseline observation:	NE 90 --- NE 90A1 (B1)
Processed:	2/23/2016 5:58:20 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.007 m
RMS:	0.001 m
Maximum PDOP:	2.945
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	1/30/2016 4:33:54 PM (Local: UTC+8hr)
Processing stop time:	1/30/2016 6:08:49 PM (Local: UTC+8hr)
Processing duration:	01:34:55
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	NE 90				
Grid		Local		Global	
Easting	522126.927 m	Latitude	N9°06'42.32060"	Latitude	N9°06'38.44322"
Northing	1007150.356 m	Longitude	E123°12'04.93454"	Longitude	E123°12'10.29457"
Elevation	7.044 m	Height	7.358 m	Height	70.052 m

To:	NE 90A1				
Grid		Local		Global	
Easting	522130.430 m	Latitude	N9°06'44.56131"	Latitude	N9°06'40.68377"
Northing	1007219.167 m	Longitude	E123°12'05.05055"	Longitude	E123°12'10.41052"
Elevation	6.278 m	Height	6.597 m	Height	69.290 m

Vector					
ΔEasting	3.502 m	NS Fwd Azimuth	2°56'44"	ΔX	3.419 m
ΔNorthing	68.812 m	Ellipsoid Dist.	68.928 m	ΔY	-11.689 m
ΔElevation	-0.766 m	ΔHeight	-0.761 m	ΔZ	67.848 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'05"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.002 m
σ ΔElevation	0.003 m	σ ΔHeight	0.003 m	σ ΔZ	0.001 m

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, DR.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016	AUBREY MATIRA PAGADOR	UP-TCAGP
	Research Associate (RA)	FOR. MA. VERLINA TONGA	UP-TCAGP
		MA. REMEDIOS VILLANUEVA	UP-TCAGP
		JONALYN GONZALES	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JONATHAN ALMALVEZ	UP-TCAGP
		ENGR. GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG ERWIN DELOS SANTOS	PHILIPPINE AIR FORCE (PAF)
		SSG RAYMUND DOMINE	PAF
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	AAC
		CAPT. MARK TANGONAN	AAC
		CAPT. NIEL AGAWIN	AAC
		CAPT. JEROME MOONEY	AAC

Annex 5. Data Transfer Sheet for Ocoy Floodplain

DATA TRANSFER SHEET
10/20/2014(Dumaguete ready)

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	
24-Sep-14	7514	2BLK56F267A	GEMINI	14.1	198	450	228	NA	NA	30	NA	12	1KB	1KB	3	7/8	Z:\DAC\RAW DATA
24-Sep-14	7515	2BLK54C267B	GEMINI	9.1	119	264	162	NA	NA	12.7	NA	12	1KB	1KB	NA	11	Z:\DAC\RAW DATA
25-Sep-14	7516	2BLK56DC268A	GEMINI	18.2	285	530	236	NA	NA	26.6	NA	7.82	1KB	1KB	3	7	Z:\DAC\RAW DATA
26-Sep-14	7518	2BLK56B269A	GEMINI	14.1	193	173	72.5	NA	NA	13.3	NA	5.54	1KB	1KB	3	8	Z:\DAC\RAW DATA
29-Sep-14	7524	2BLK54C272A	GEMINI	16.8	303	535	248	NA	NA	27	NA	6.07	1KB	1KB	4	8/9	Z:\DAC\RAW DATA
30-Sep-14	7526	2BLK53055A273A	GEMINI	5.37	91	173	144	NA	NA	7.8	NA	3.6	1KB	1KB	3/8	21	Z:\DAC\RAW DATA
1-Oct-14	7528	2BLK54B274A	GEMINI	7.91	115	219	122	NA	NA	9.25	NA	3.91	1KB	1KB	3/4	12	Z:\DAC\RAW DATA
2-Oct-14	7530	2BLK54BS56E275A	GEMINI	7.09	115	228	132	NA	NA	8.74	NA	3.7	1KB	1KB	3/4	12/7	Z:\DAC\RAW DATA

Received from

Name C. Joson
Position
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 10/20/2014

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

DATA TRANSFER SHEET
Dumaguete 2/5/16

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	
25-Jan	10068AC	3BLK54A025A	Aquarius	NA	114	342	157	27.6	211	5.25	na	3.97	1KB	1KB	10KB	15KB	Z:\DAC\RAW DATA
26-Jan	10072AC	3BLK53B026A	Aquarius	NA	231	530	227	43.3	44.3	18.5	140	9.99	1KB	1KB	3KB	6KB	Z:\DAC\RAW DATA
29-Jan	10074AC	3BLK53A029A	Aquarius	NA	45	375	247	36	190	7.74	na	10	1KB	NA	12KB	26KB	Z:\DAC\RAW DATA
29-Jan	10075AC	3BLK53S029B	Aquarius	NA	28	292	215	18	42.3/198	5.4	na	10	1KB	NA	12KB	20KB	Z:\DAC\RAW DATA
30-Jan	10076AC	3BLK53V030A	Aquarius	NA	56	332	190	53.1	193/42.9/198	6.06	68	18.4	1KB	NA	16KB	29KB	Z:\DAC\RAW DATA
30-Jan	10077AC	3BLK53V030B	Aquarius	NA	63	391	195	27	145/26.7/237	5.40	na	18.4	1KB	NA	24KB	37KB	Z:\DAC\RAW DATA

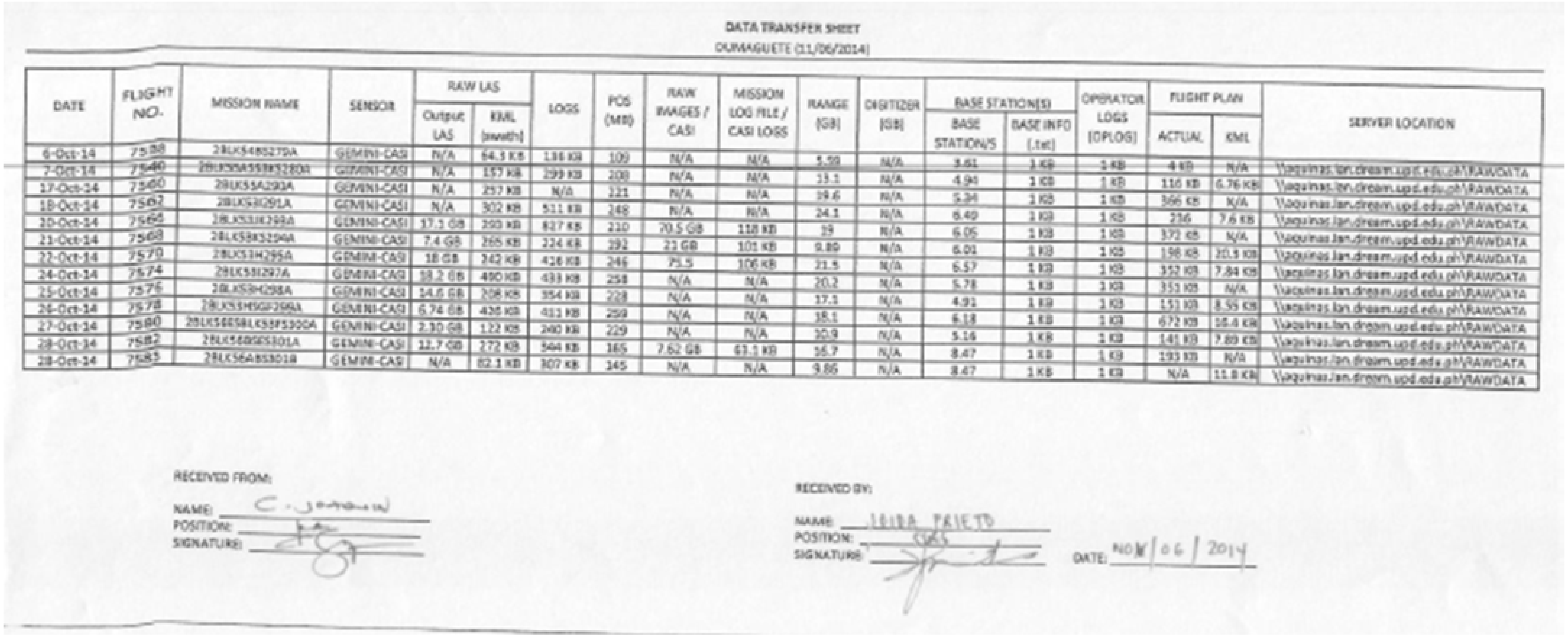
Received from

Name Jonalyn S. Gonzales
Position Research Associate
Signature

Received by

Name JC Bongat
Position
Signature

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



DATA TRANSFER SHEET
DUMAGUETE (11/06/2014)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS (MB)	RAW IMAGES / CASI	MISSION LOG FILE / CASI LOGS	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION/S	BASE INFO (.txt)		ACTUAL	KML	
6-Oct-14	7538	2BLK54BS279A	GEMINI-CASI	N/A	64.3 KB	138 KB	109	N/A	N/A	5.59	N/A	3.61	1 KB	1 KB	4 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
7-Oct-14	7540	2BLK55AS5BS280A	GEMINI-CASI	N/A	157 KB	299 KB	208	N/A	N/A	13.1	N/A	4.94	1 KB	1 KB	116 KB	6.76 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
17-Oct-14	7560	2BLK55A293A	GEMINI-CASI	N/A	257 KB	N/A	121	N/A	N/A	19.6	N/A	5.34	1 KB	1 KB	366 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
18-Oct-14	7562	2BLK53I291A	GEMINI-CASI	N/A	302 KB	511 KB	148	N/A	N/A	24.1	N/A	6.49	1 KB	1 KB	236	7.6 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
20-Oct-14	7566	2BLK53JK293A	GEMINI-CASI	17.1 GB	293 KB	827 KB	210	70.5 GB	118 KB	19	N/A	6.05	1 KB	1 KB	372 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
21-Oct-14	7568	2BLK53KS294A	GEMINI-CASI	7.4 GB	265 KB	224 KB	192	21 GB	101 KB	9.89	N/A	6.01	1 KB	1 KB	198 KB	20.5 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
22-Oct-14	7570	2BLK53H295A	GEMINI-CASI	18 GB	242 KB	416 KB	246	75.5	106 KB	21.5	N/A	6.57	1 KB	1 KB	352 KB	7.84 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
24-Oct-14	7574	2BLK53I297A	GEMINI-CASI	18.2 GB	490 KB	433 KB	258	N/A	N/A	20.2	N/A	5.78	1 KB	1 KB	353 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
25-Oct-14	7576	2BLK53H298A	GEMINI-CASI	14.6 GB	208 KB	354 KB	228	N/A	N/A	17.1	N/A	4.91	1 KB	1 KB	151 KB	8.55 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
26-Oct-14	7578	2BLK53MSGF299A	GEMINI-CASI	6.74 GB	426 KB	411 KB	259	N/A	N/A	18.1	N/A	6.18	1 KB	1 KB	672 KB	16.4 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
27-Oct-14	7580	2BLK56ES8LK53FS300A	GEMINI-CASI	2.30 GB	122 KB	240 KB	229	N/A	N/A	10.9	N/A	5.16	1 KB	1 KB	141 KB	7.89 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
28-Oct-14	7582	2BLK56BSES301A	GEMINI-CASI	12.7 GB	272 KB	544 KB	165	7.62 GB	63.1 KB	16.7	N/A	8.47	1 KB	1 KB	193 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
28-Oct-14	7583	2BLK56ABS301B	GEMINI-CASI	N/A	82.1 KB	307 KB	145	N/A	N/A	9.86	N/A	8.47	1 KB	1 KB	N/A	11.8 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA

RECEIVED FROM:

NAME: C. Joaquin
POSITION:
SIGNATURE:

RECEIVED BY:

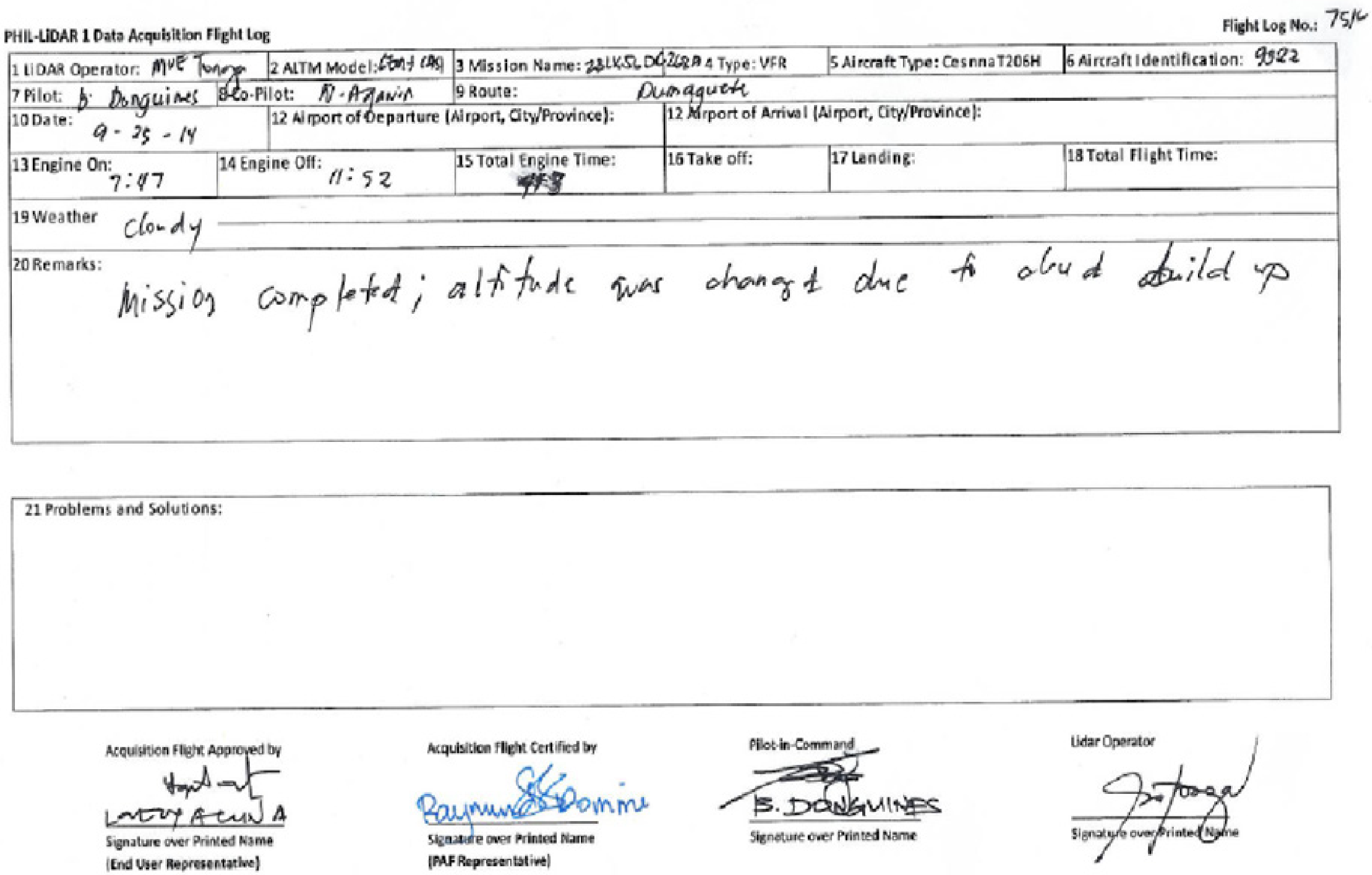
NAME: LEIDA PRIETO
POSITION:
SIGNATURE:

DATE: NOV/06/2014

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 7514G



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7514

1 LIDAR Operator: MVE Tongco	2 ALTM Model: Gemini	3 Mission Name: 2BLK5LD268A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: B. Donguines	8 Co-Pilot: N. Adanza	9 Route: Dumaguete			
10 Date: 9-25-14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:47	14 Engine Off: 11:52	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Mission completed; altitude was changed due to cloud build up

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuna	Raymund Dominic	B. Donguines	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 7514G

2. Flight Log for 7530G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log Flight Log No.: 7516

1 LiDAR Operator: MVE Tongga	2 ALTM Model: Gem 4 CAS	3 Mission Name: 23LK5LDG268A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: B. Donguines	8 Co-Pilot: N. Aganin	9 Route: Dumaguete			
10 Date: 9-25-14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:47	14 Engine Off: 11:52	15 Total Engine Time: [illegible]	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Mission completed; altitude was changed due to cloud build up					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuña	Raymund Dominic	B. Donguines	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 7530G

3. Flight Log for 7582G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 7582GC

1 LIDAR Operator: MVE Tongo	2 ALTM Model: Gem1CASI	3 Mission Name: 2BLK36BSES301A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route: Dumaguete			
10 Date: Oct 28, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province): Dumaguete		
13 Engine On: 0604	14 Engine Off: 0927	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Mission completed (without CASI due to intermittent grounding connection)

21 Problems and Solutions:

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

Figure A-6.3. Flight Log for Mission 7582G

4. Flight Log for 10077A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10077A

1 LiDAR Operator: MV TONGA	2 ALTM Model: AQUA+CASI	3 Mission Name: 3BLK56V030B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9522
7 Pilot: M. TANGONAN	8 Co-Pilot: J. MOONEY	9 Route: NEGROS ORIENTAL			
10 Date: 30 JAN 16	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1423	14 Engine Off: 1745	15 Total Engine Time: 3+22	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Fine				

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 BLK56A

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/ LiDAR Technician
LOVELY ALUNA	Raymund Domine	M. TANGONAN		
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 Mission 10077A

Annex 7. Flight Status Reports

Negros Mission
September 24 - October 28, 2014 and January 30, 2016

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7514GC	BLK56F	2BLK56F267A	MVE TONGA	Sep 24, 2014	Surveyed 18 lines; altitude changed to 750m AGL
7530GC	BLK56E	2BLK54BS56E275A	MVE TONGA	Oct 2, 2014	Surveyed 5 lines of BLK54B and 3 lines of BLK56E
7582GC	BLK56E	2BLK56BSES301A	MVE TONGA	Oct 28, 2014	Mission completed (without CASI due to intermittent grounding connection)
10077A	BLK56V	3BLK56V030B	MVE TONGA	January 30, 2016	COVERD VOIDS OVER BLK 56A

LAS BOUNDARIED PER FLIGHT

Flight No. : 7514G
Area: BLK56F
Mission Name: 2BLK56F267A
Total Area Surveyed: 106.5 sq km

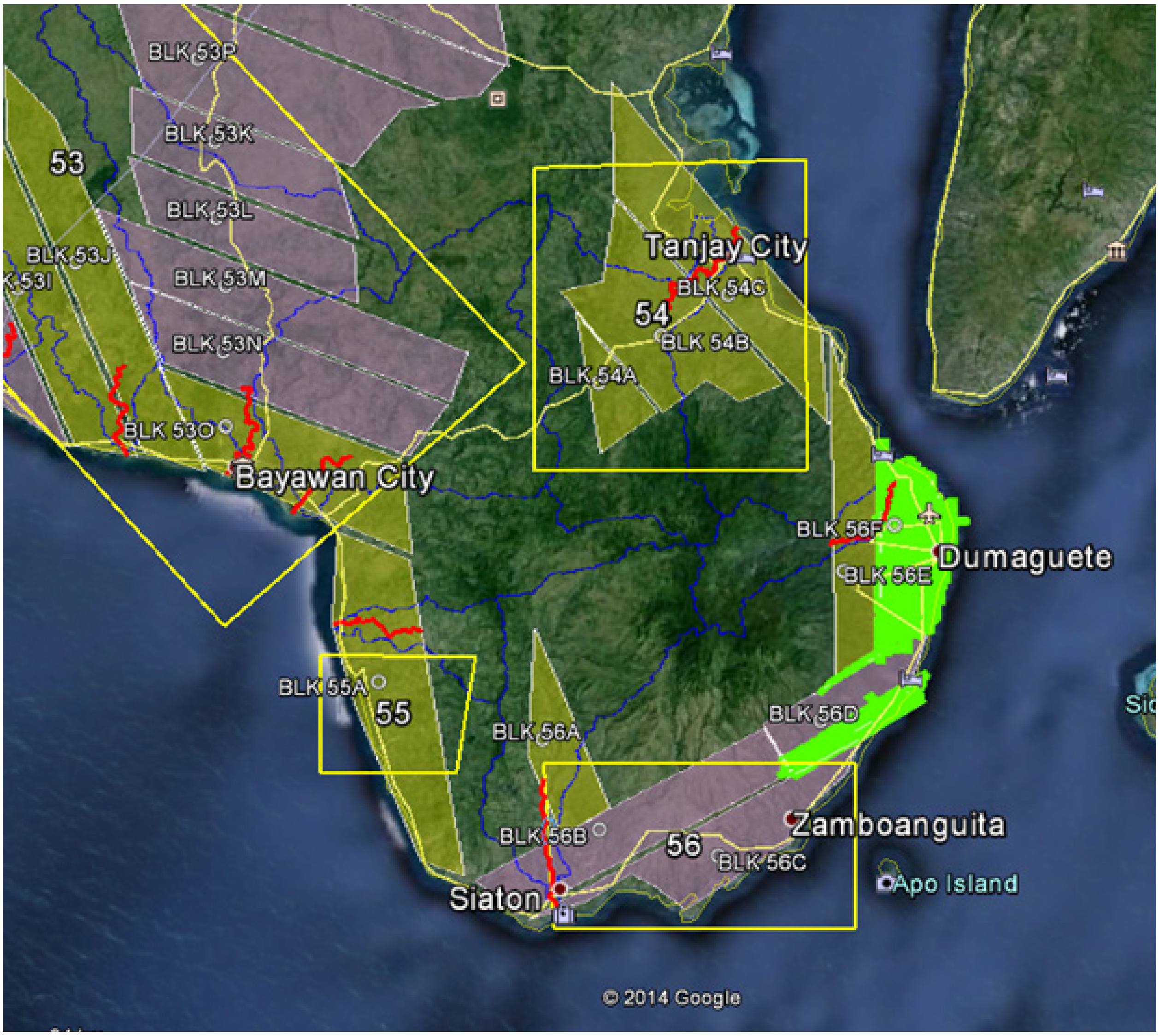


Figure A-7.1. Swath for Flight No. 7514G

Flight No. : 7530G
Area: BLK 54B & 56E
Mission Name: 2BLK54BS56E275A
Total Area Surveyed: 71.2 sq km

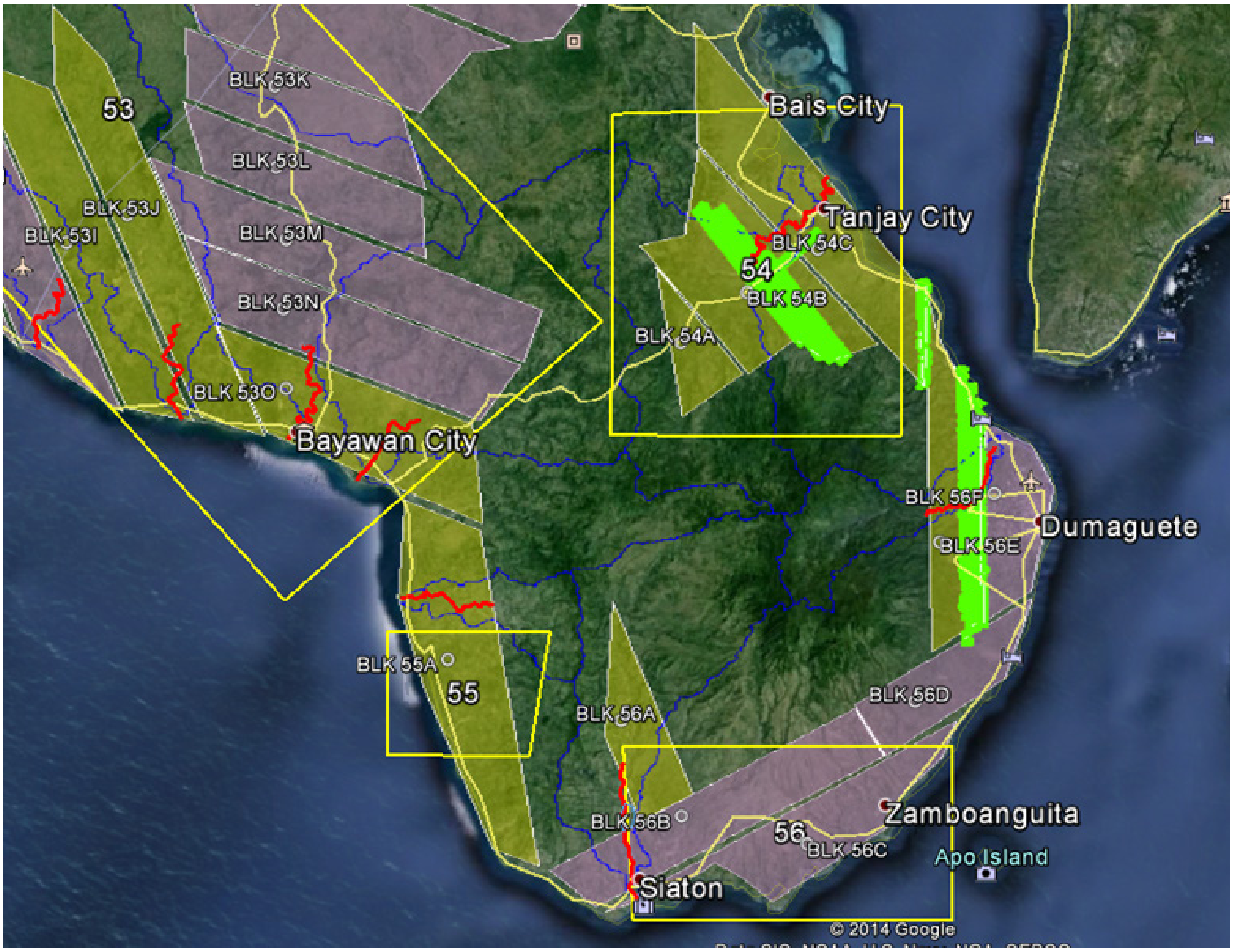


Figure A-7.2. Swath for Flight No. 7530G

Flight No. : 7582G
Area: BLK 56B & BLK 56E
Mission Name: 2BLK56BSES301A
Total Area Surveyed: 117.6 sq km

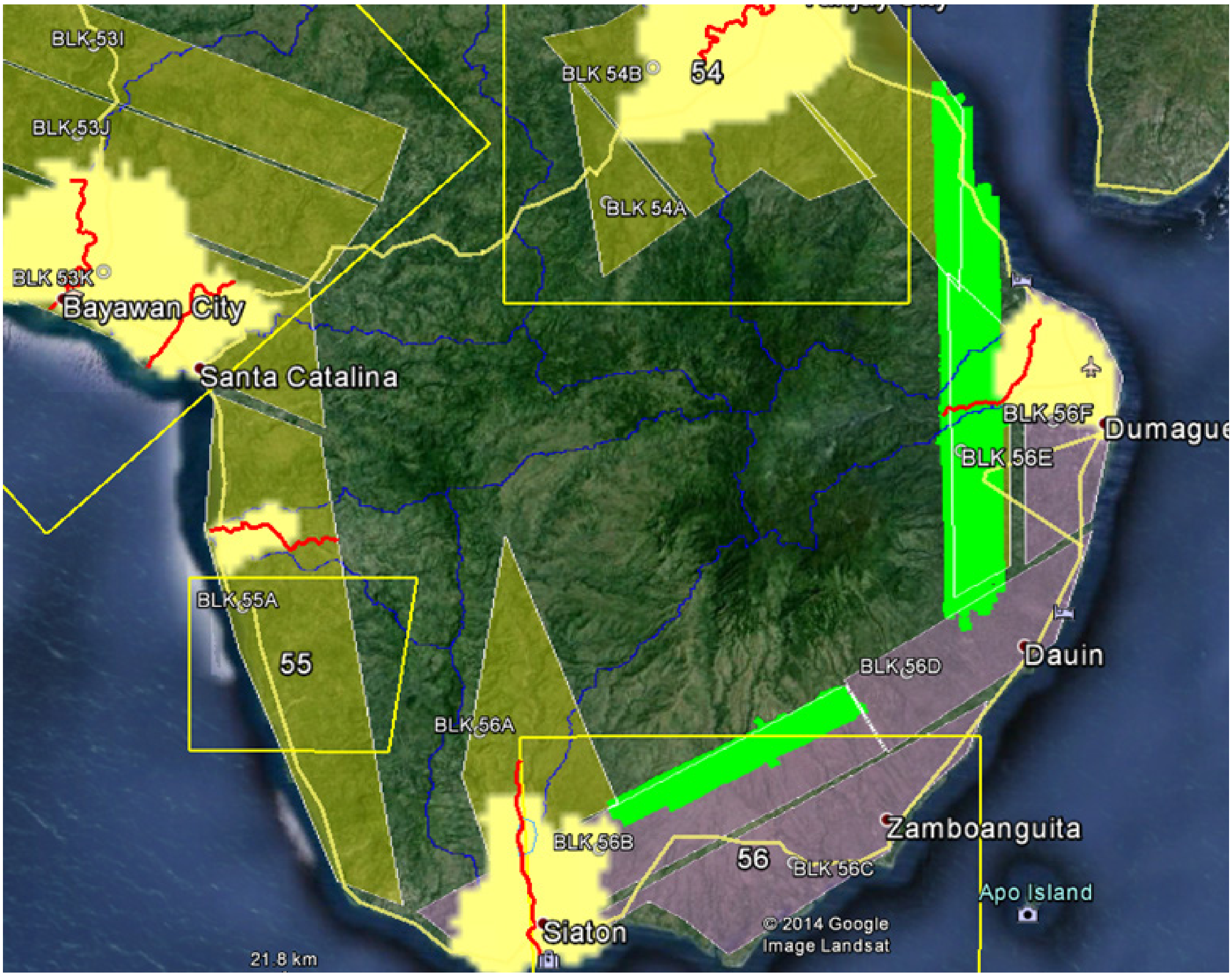


Figure A-7.3. Swath for Flight No. 7582G

Flight No.: 10077A
Area: BLK 56 VOIDS
Mission Name: 3BLK56V030B
Alt: 500 m Scan Freq: 45 Scan Angle: 18
Surveyed Area: 24.53 sq.km.

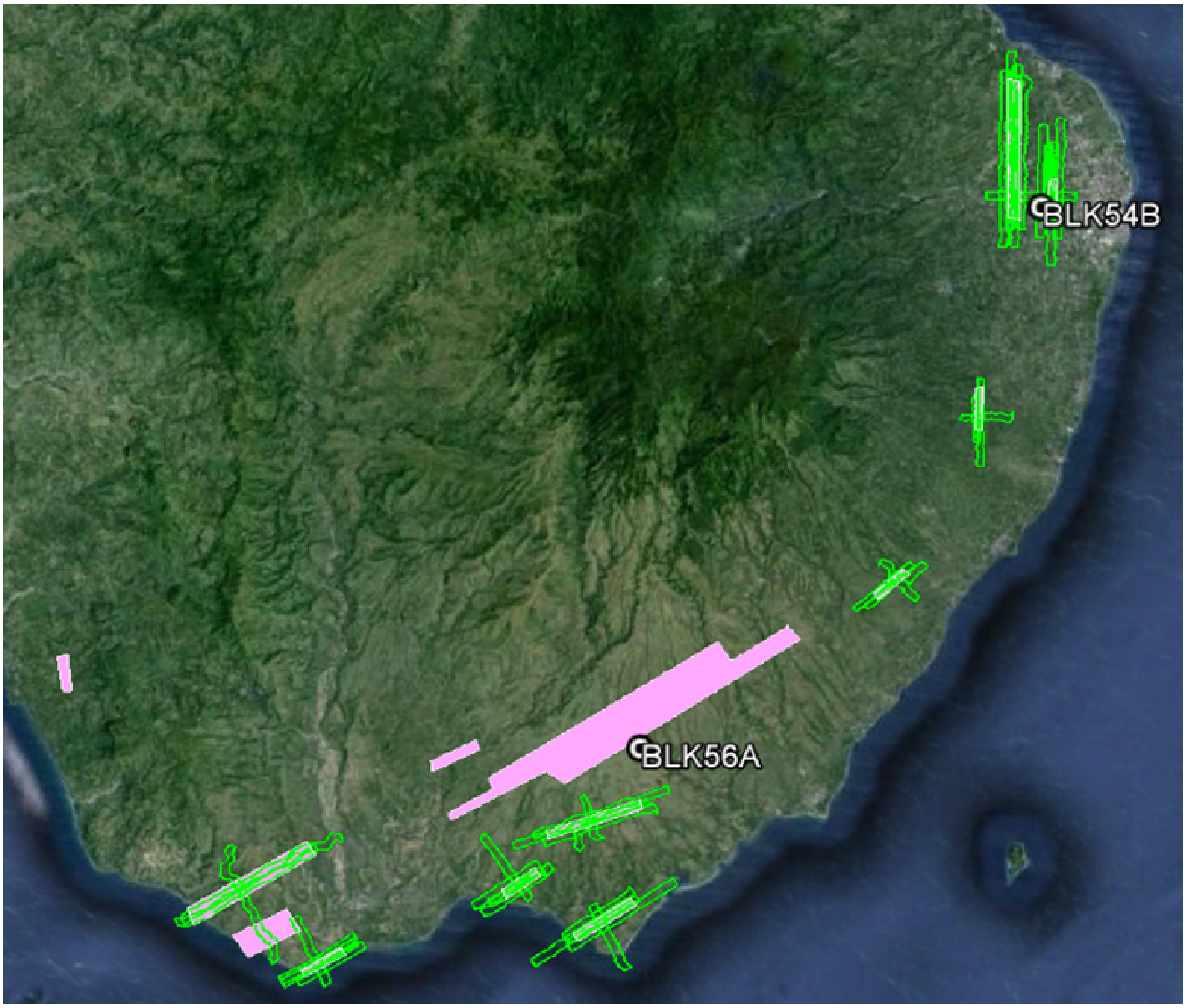


Figure A-7.4. Swath for Flight No. 10077A

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk56EF

Flight Area	Dumaguete
Mission Name	Blk56EF
Inclusive Flights	7514G,7530G
Range data size	44.24 GB
POS data size	360 MB
Base data size	15.7 MB
Image	NA
Transfer date	October 20, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	2.75
Boresight correction stdev (<0.001deg)	0.000229
IMU attitude correction stdev (<0.001deg)	0.000712
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	44.05%
Ave point cloud density per sq.m. (>2.0)	4.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	136
Maximum Height	298.38 m
Minimum Height	60.22 m
Classification (# of points)	
Ground	35397365
Low vegetation	56878245
Medium vegetation	123048930
High vegetation	173165124
Building	17709317
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Edgardo Gubatanga, Jr., Engr. John Dill Macapagal

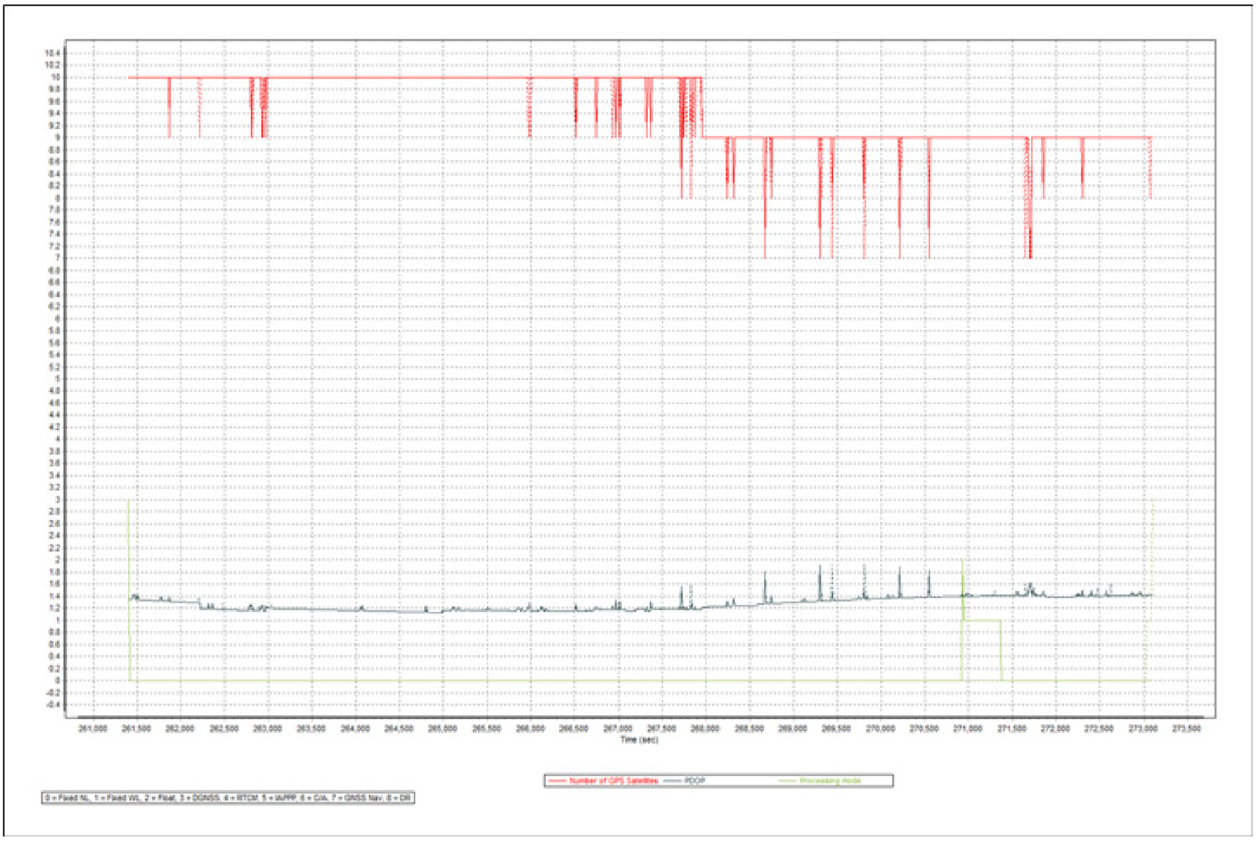


Figure A-8.1. Solution Status

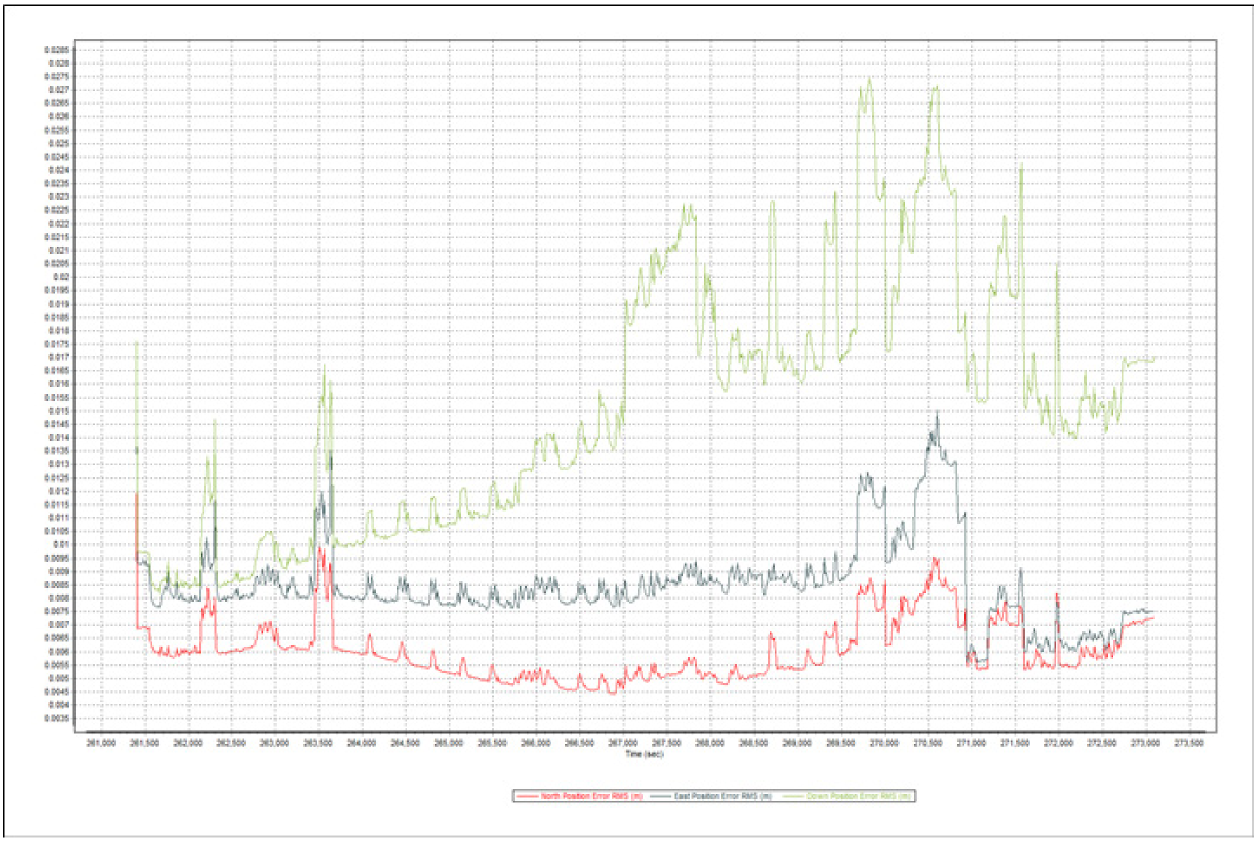


Figure A-8.2. Smoothed Performance Metrics Parameters

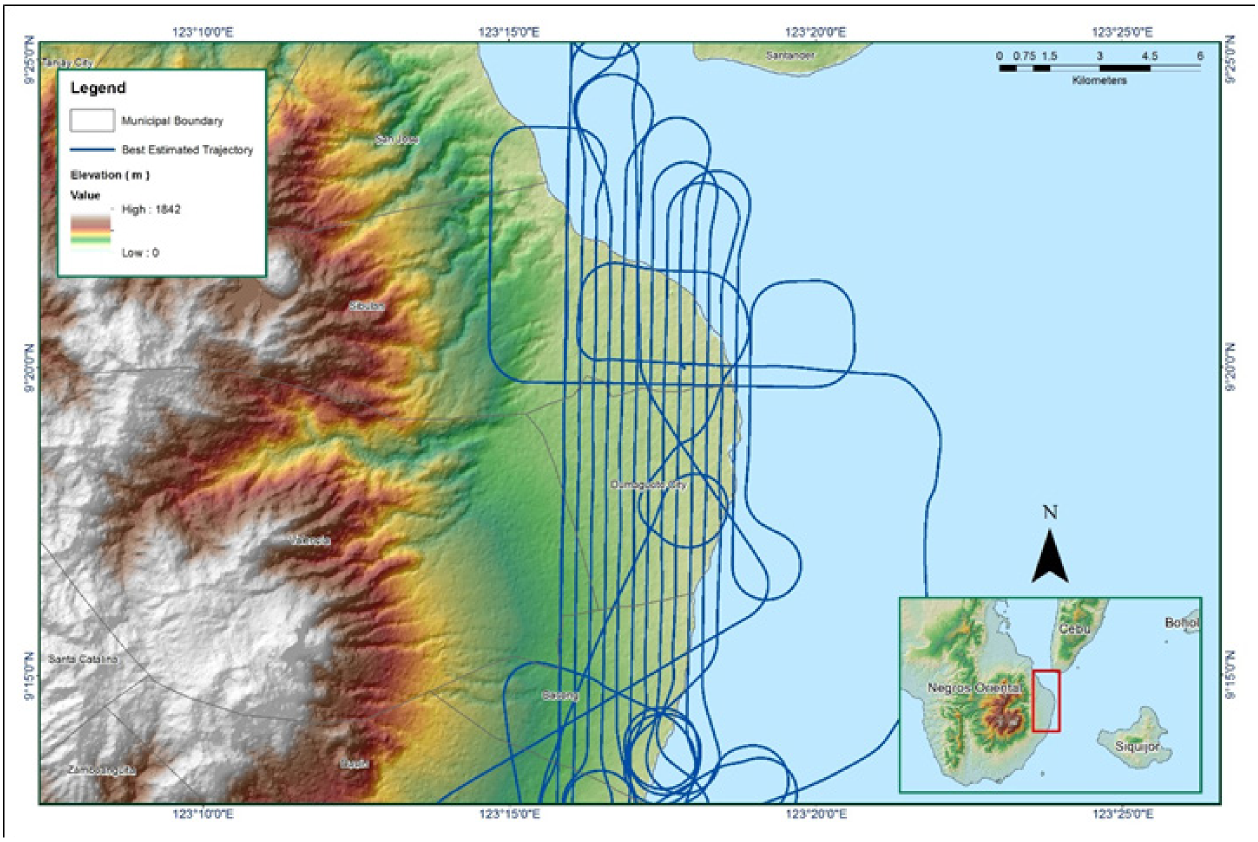


Figure A-8.3. Best Estimated Trajectory

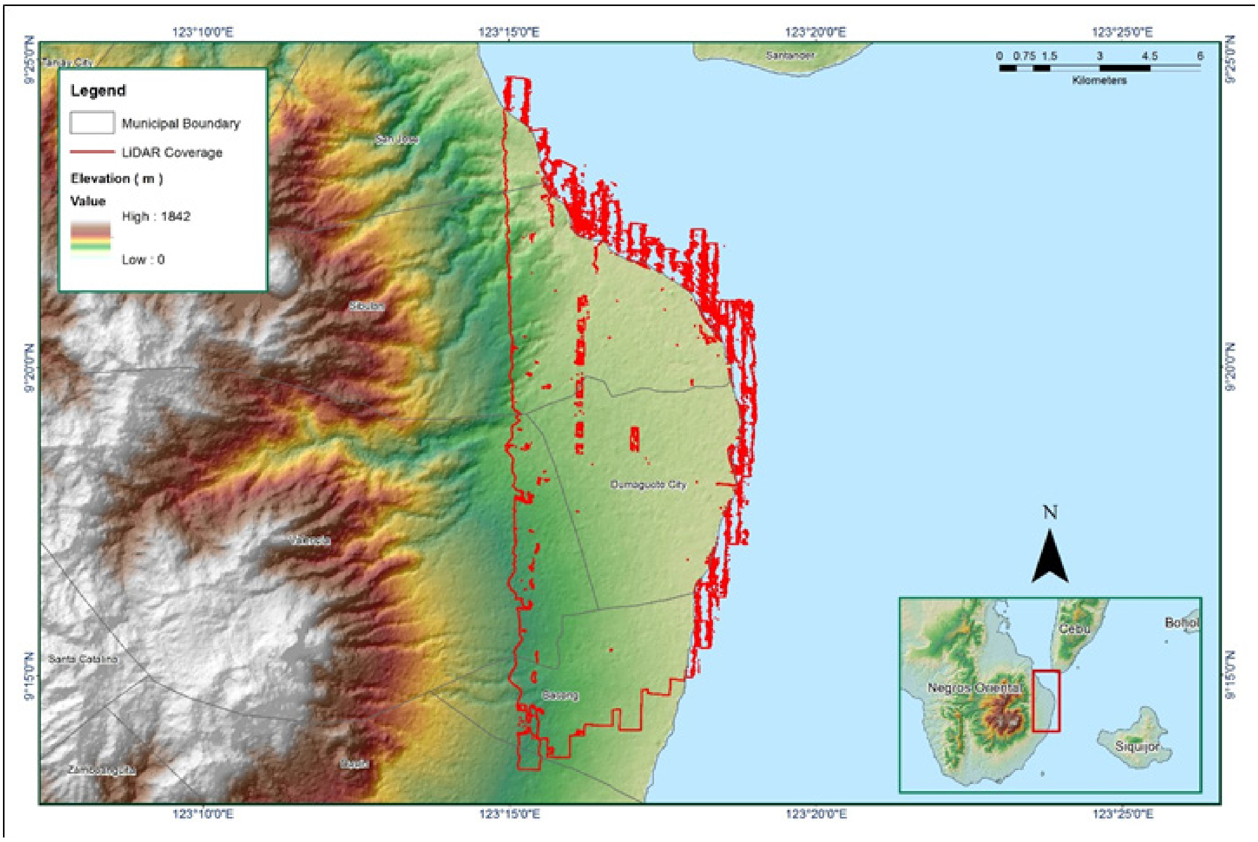


Figure A-8.4. Coverage of LiDAR data

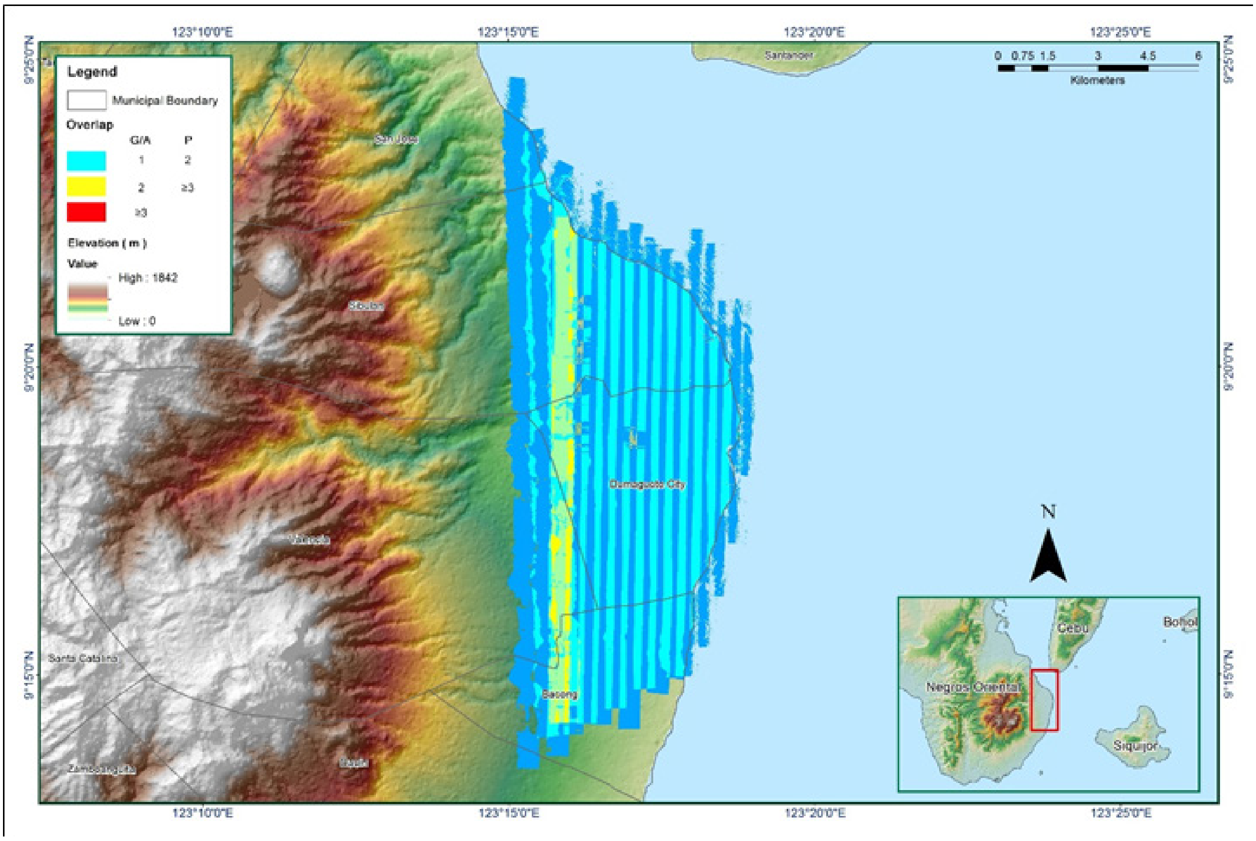


Figure A-8.5. Image of Data Overlap

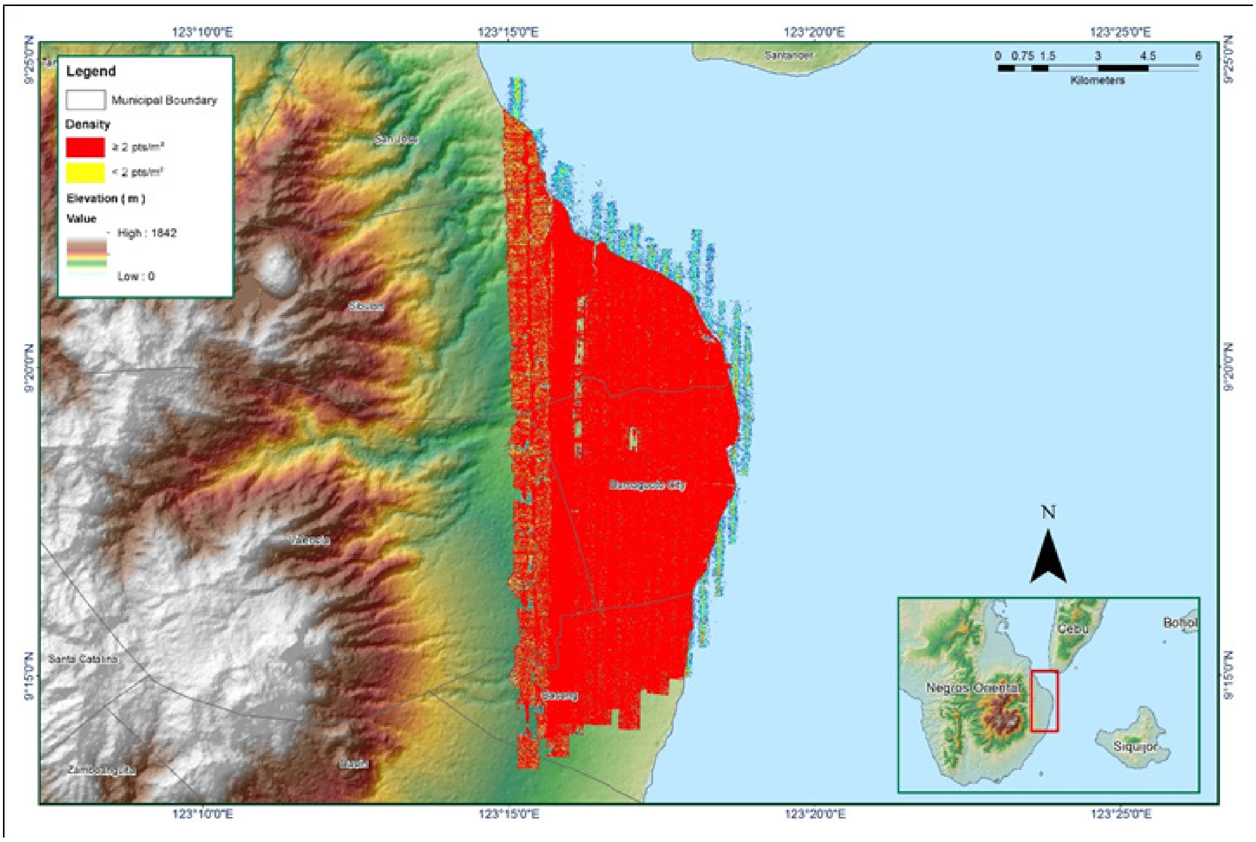


Figure A-8.6. Density map of merged LiDAR data

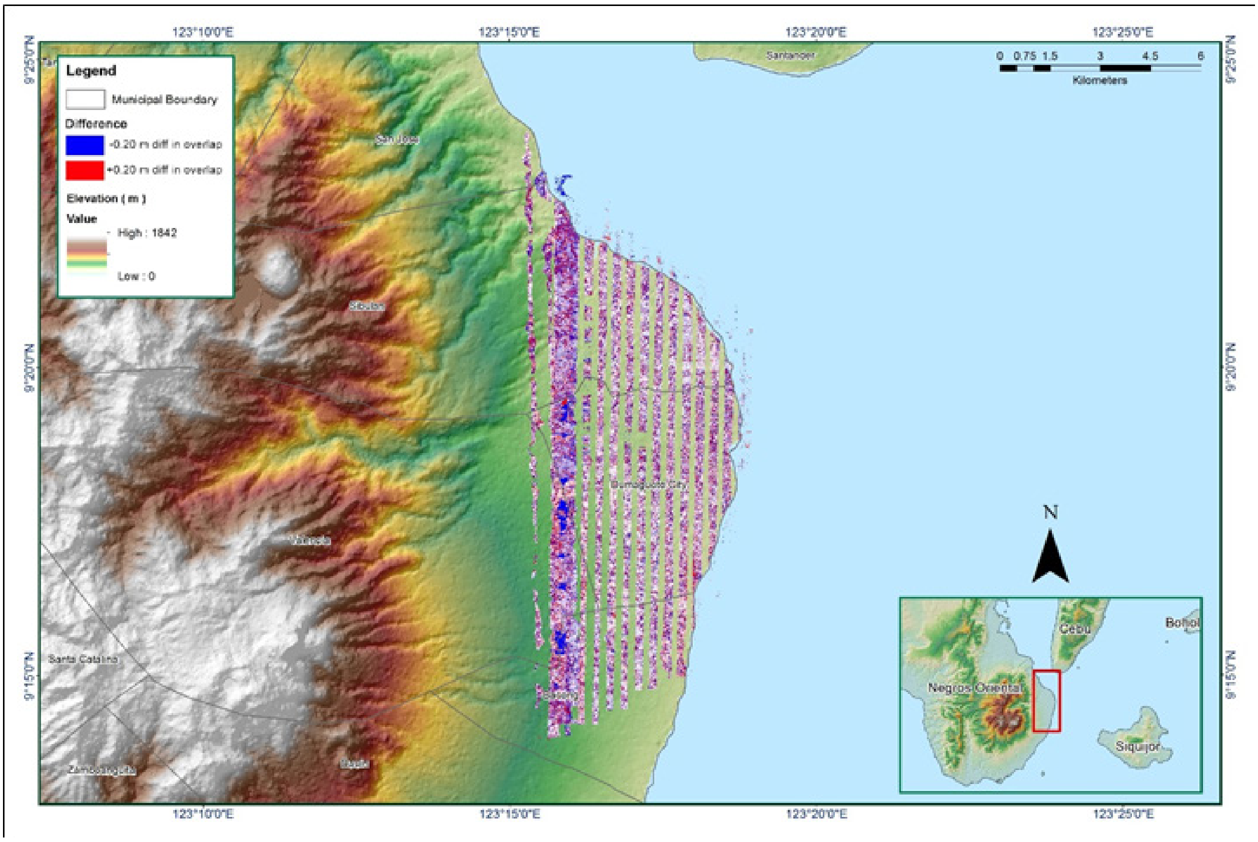


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk56E_supplement

Flight Area	Dumaguete
Mission Name	Blk56E_supplement
Inclusive Flights	7582G
Range data size	16.7 GB
POS data size	165 MB
Base data size	8.47 MB
Image	NA
Transfer date	November 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.08
RMSE for East Position (<4.0 cm)	1.75
RMSE for Down Position (<8.0 cm)	2.95
Boresight correction stdev (<0.001deg)	0.000217
IMU attitude correction stdev (<0.001deg)	0.000342
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	45.21%
Ave point cloud density per sq.m. (>2.0)	4.37
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	100
Maximum Height	543.76 m
Minimum Height	62.32 m
Classification (# of points)	
Ground	30655315
Low vegetation	30034017
Medium vegetation	54707994
High vegetation	136901911
Building	4774570
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Melanie Hingpit, Engr. Jeffrey Delica

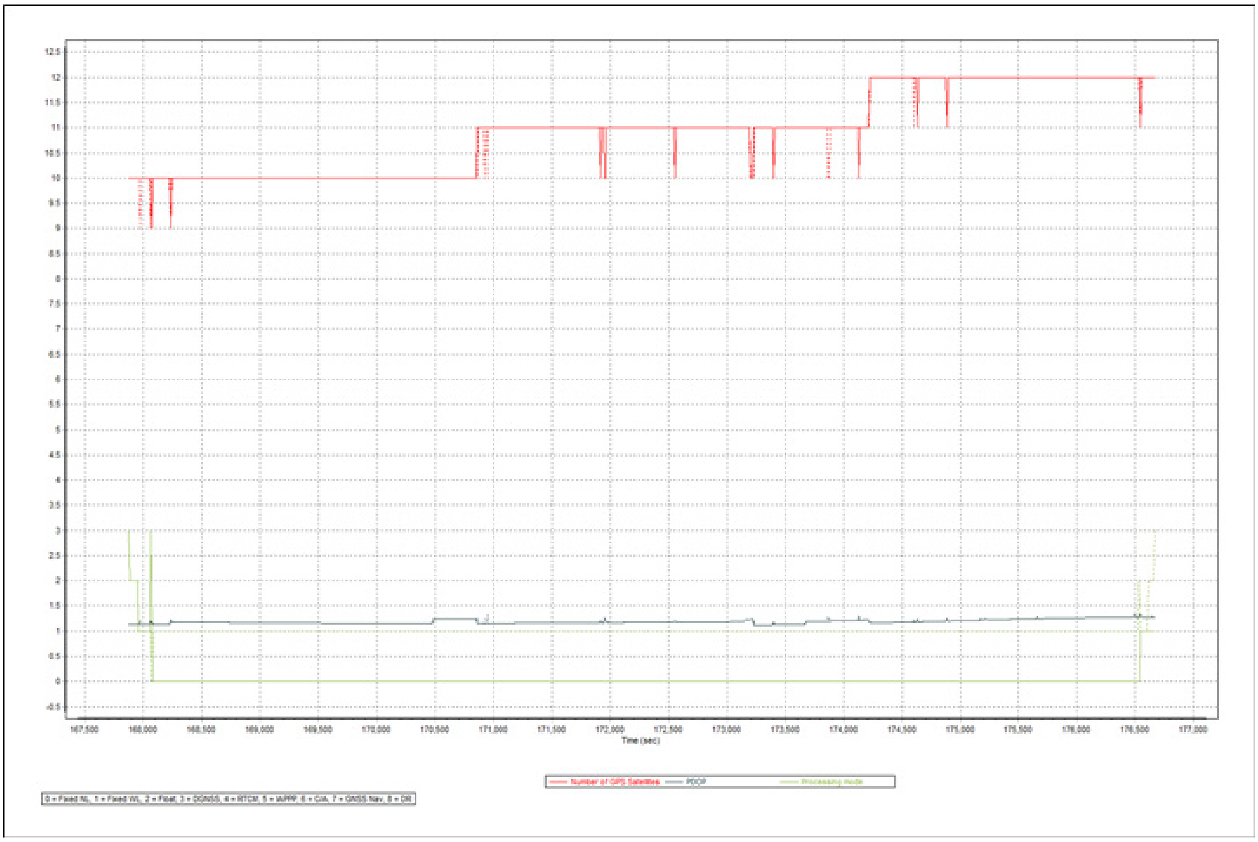


Figure A-8.8. Solution Status Parameters

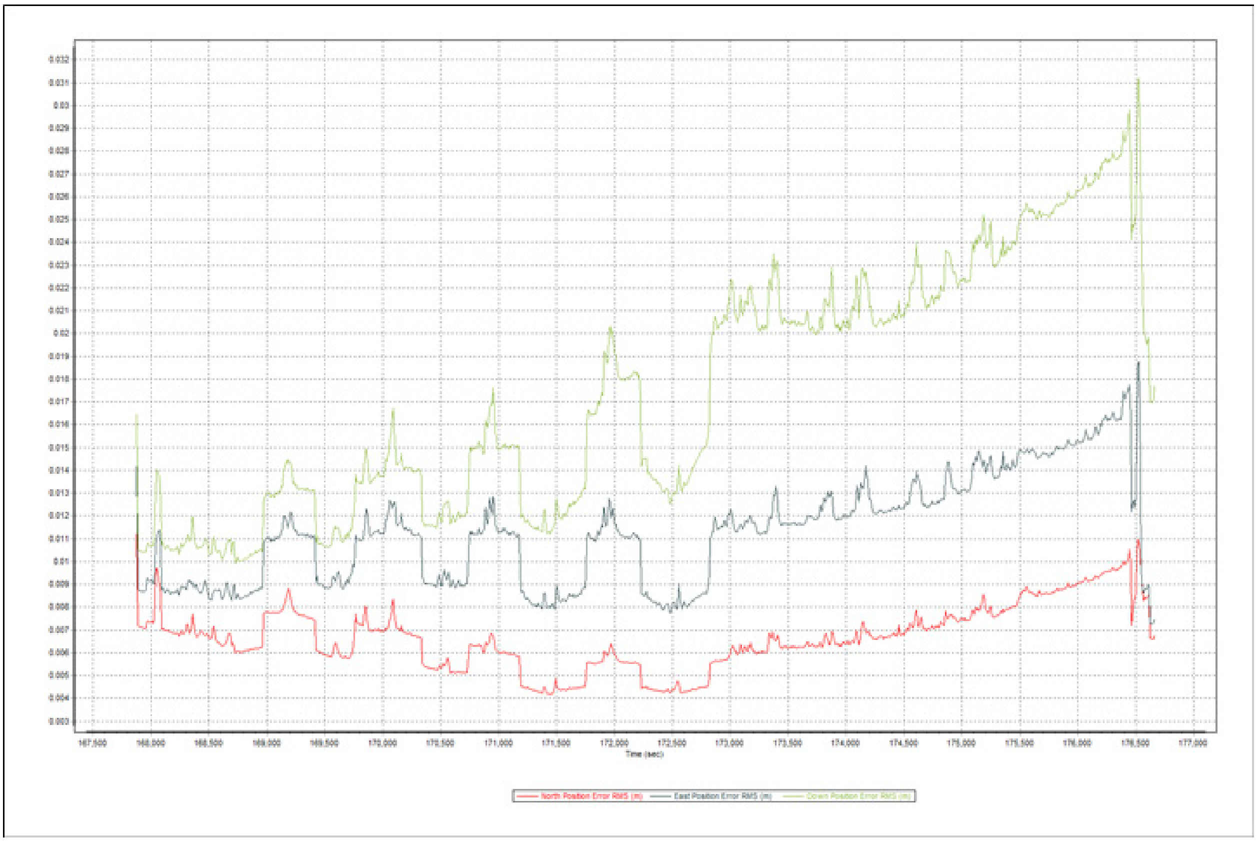


Figure A-8.9. Smoothed Performance Metrics Parameters

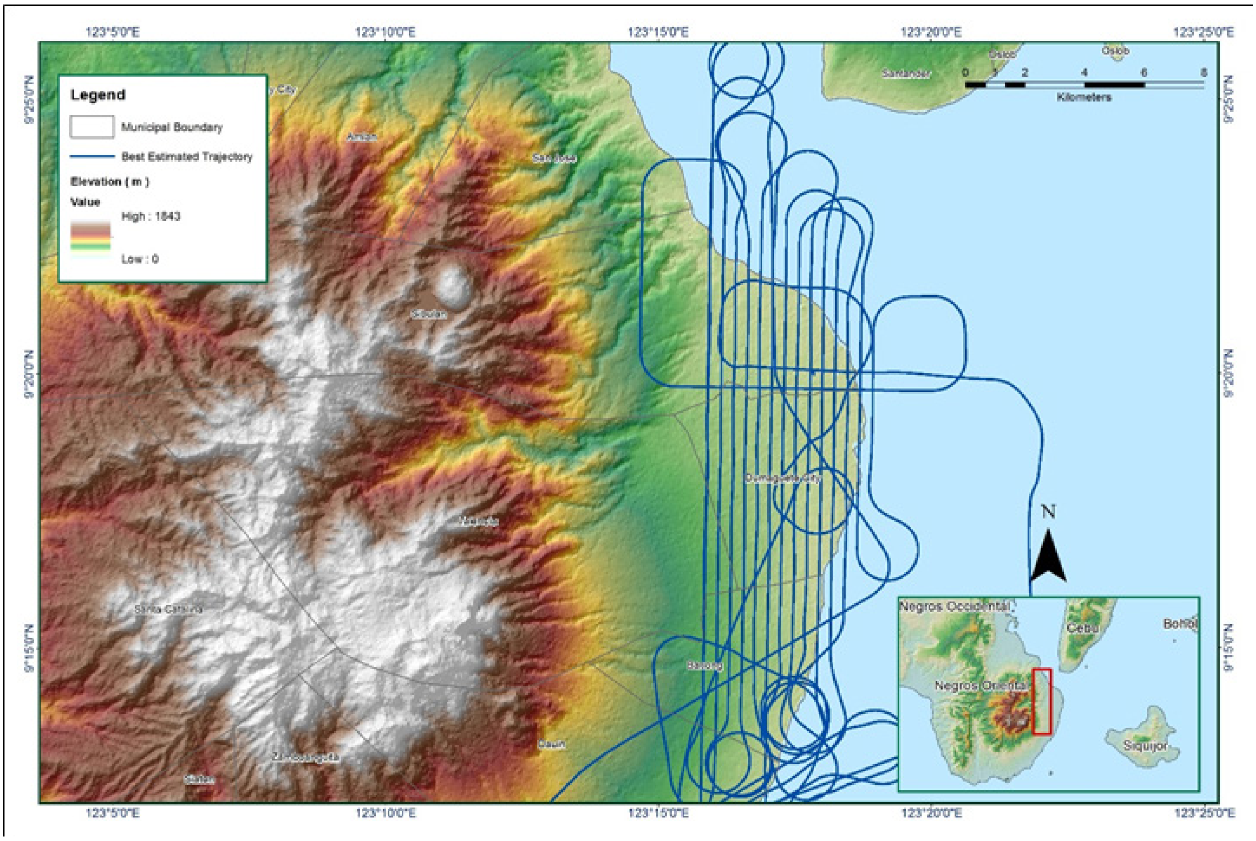


Figure A-8.10. Best Estimated Trajectory

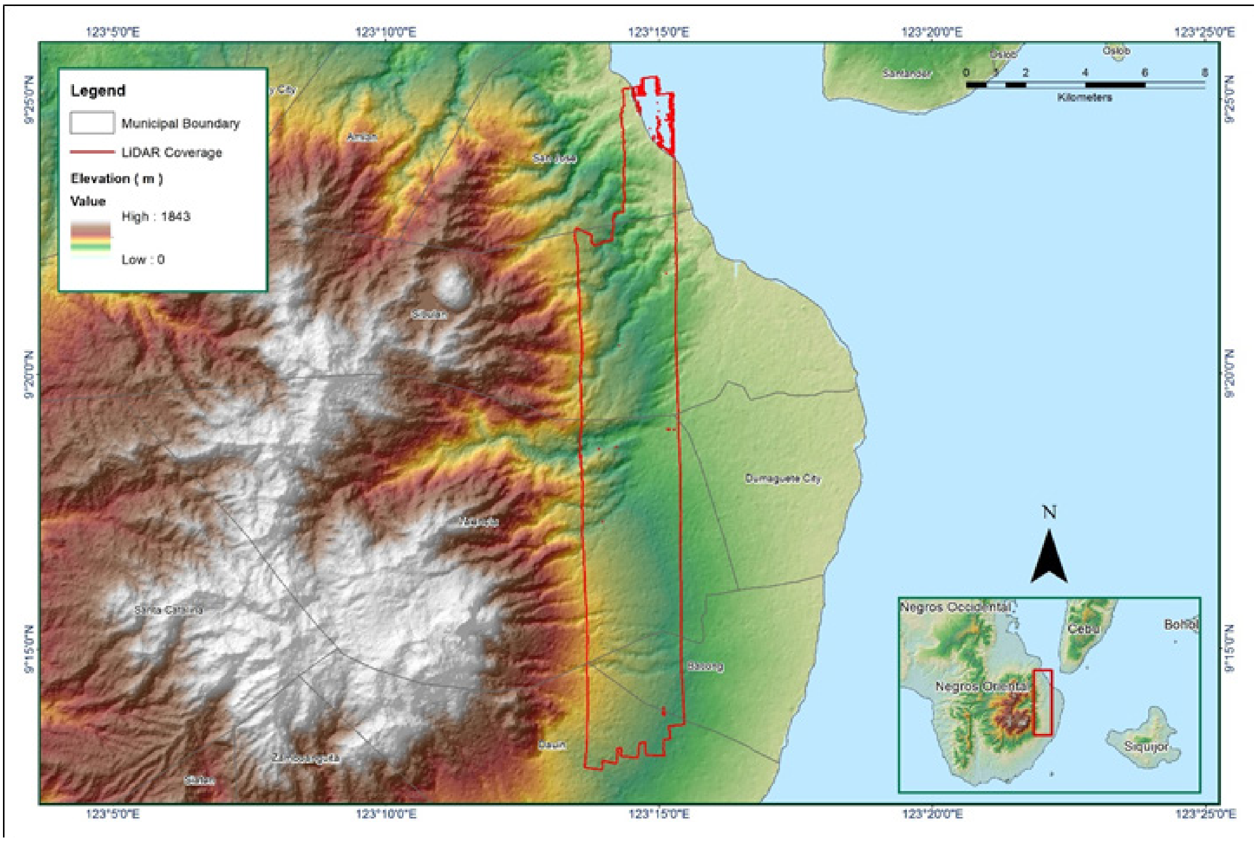


Figure A-8.11. Coverage of LiDAR data

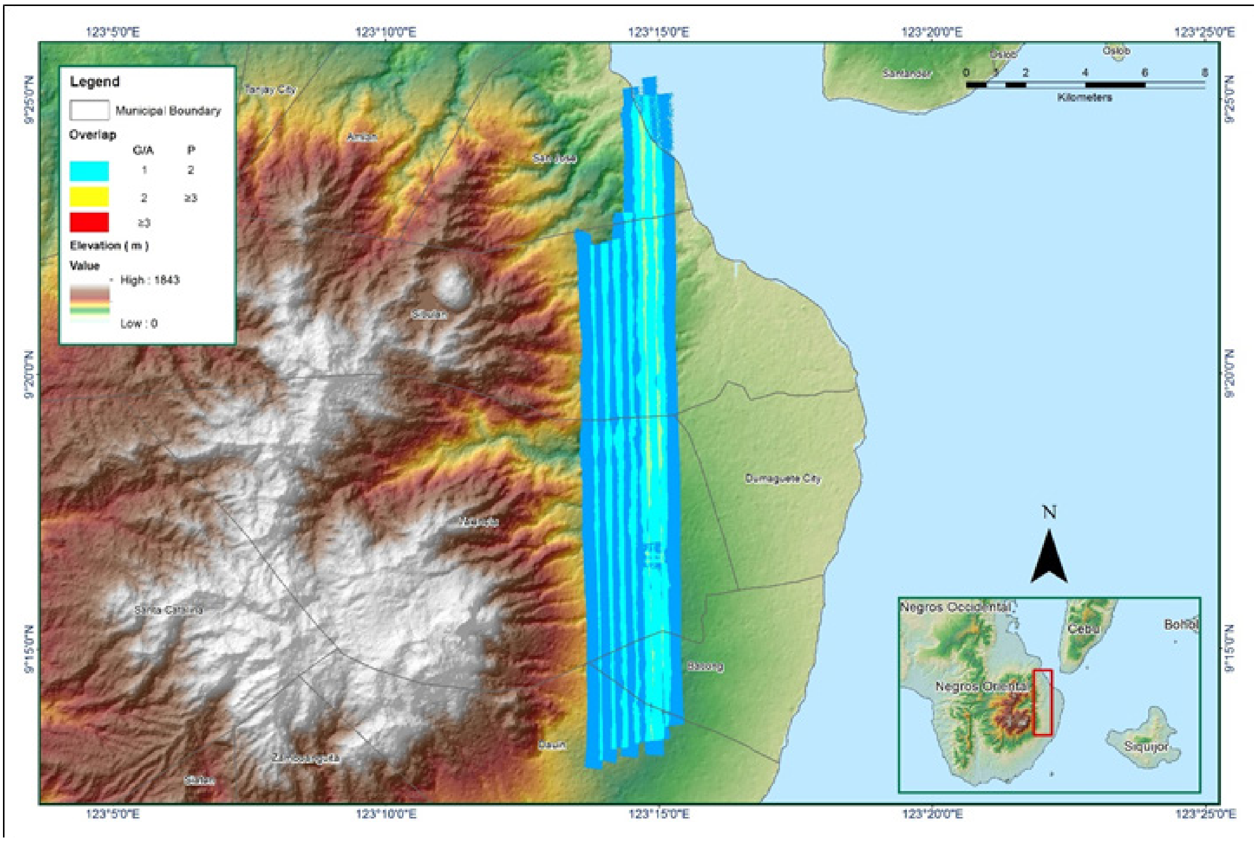


Figure A-8.12. Image of Data Overlap

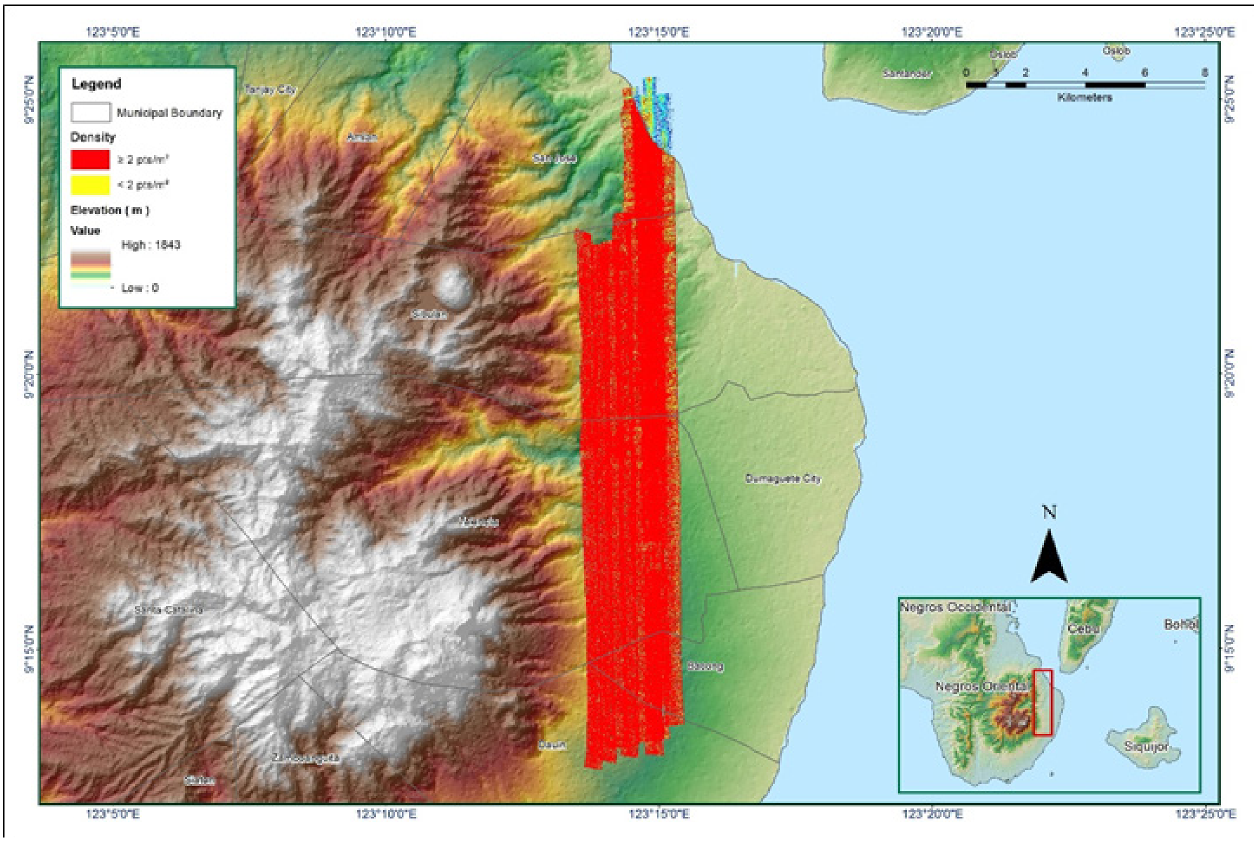


Figure A-8.13. Density map of merged LiDAR data

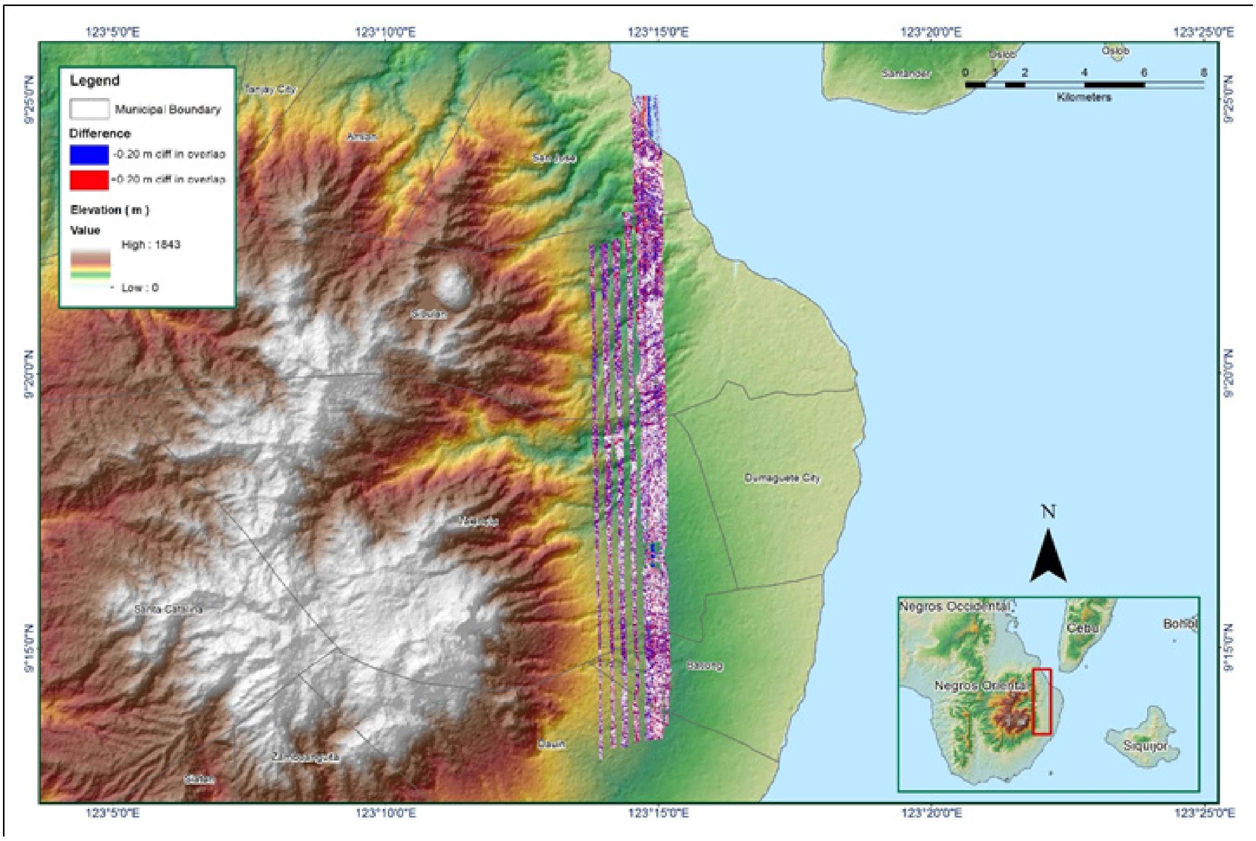


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk57C

Flight Area	Dumaguete
Mission Name	Blk57C
Inclusive Flights	7589G
Range data size	6.34 GB
Base data size	6.53 MB
POS	87.6 MB
Image	na
Transfer date	December 9, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	4.6
Boresight correction stdev (<0.001deg)	0.000208
IMU attitude correction stdev (<0.001deg)	0.000496
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	35.18%
Ave point cloud density per sq.m. (>2.0)	3.23
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	80
Maximum Height	441.7 m
Minimum Height	-0.44 m
Classification (# of points)	
Ground	16008746
Low vegetation	17343883
Medium vegetation	38375487
High vegetation	99950892
Building	3617019
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Gladys Mae Apat

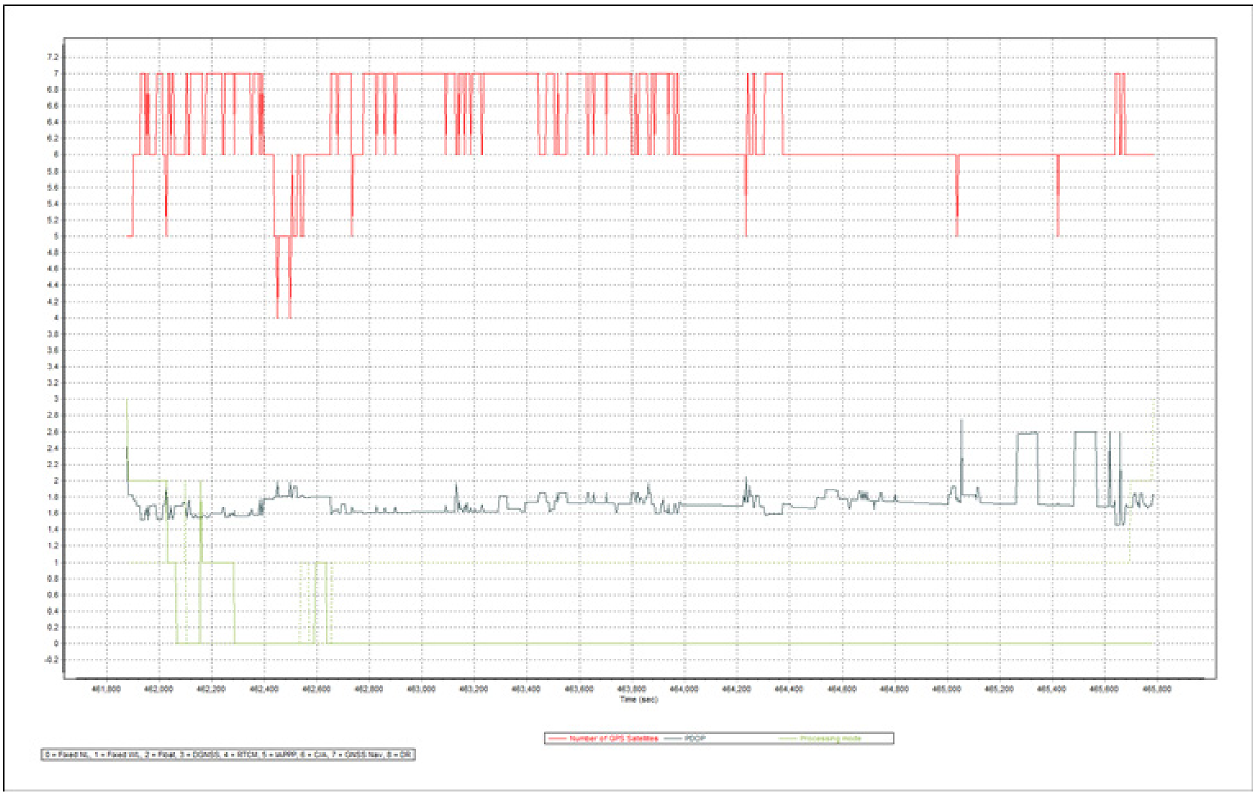


Figure A-8.15. Solution Status

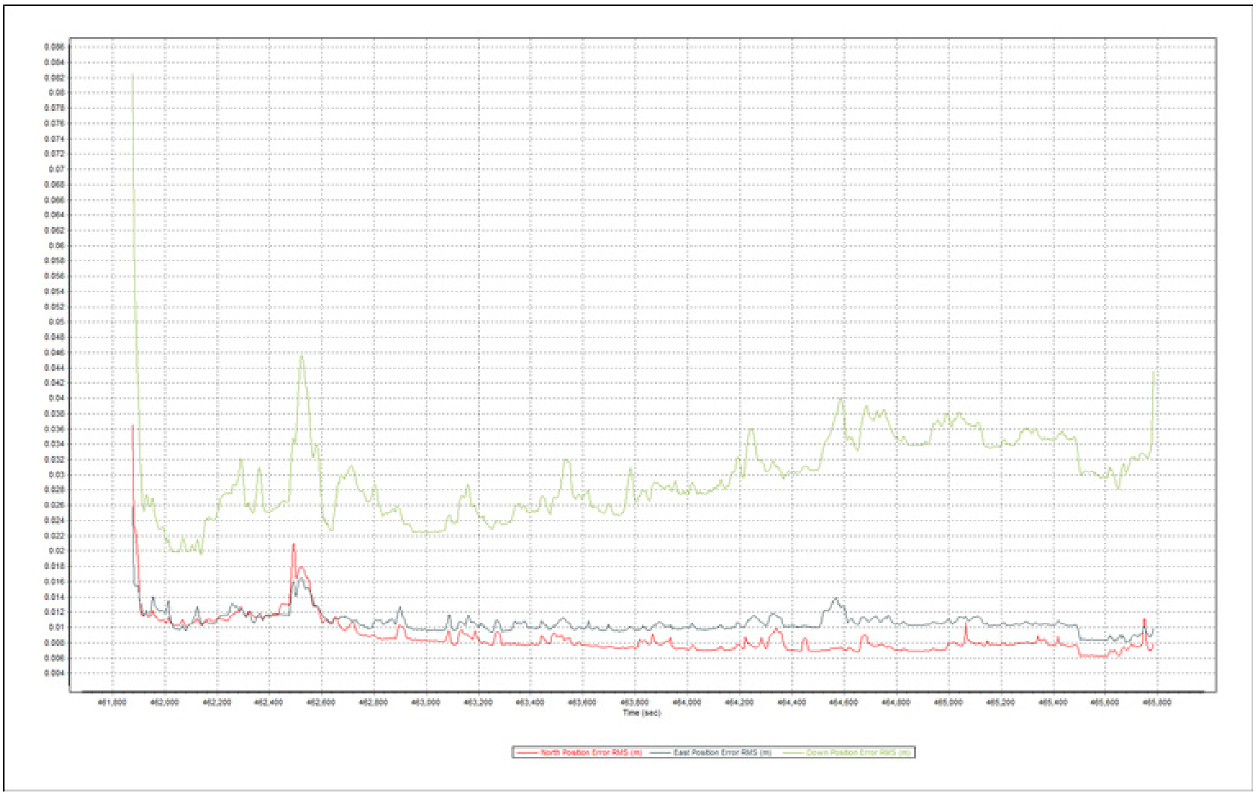


Figure A-8.16. Smoothed Performance Metric Parameters

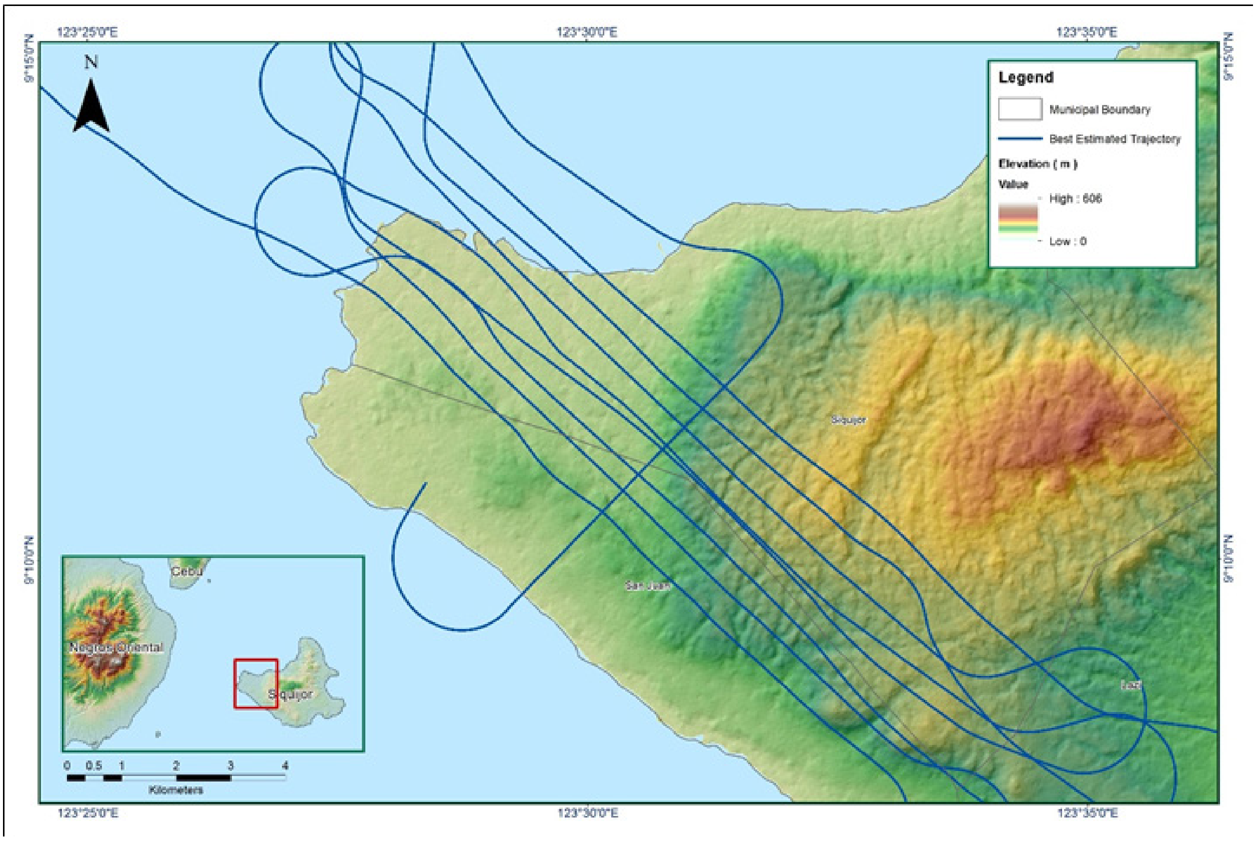


Figure A-8.17. Best Estimated Trajectory

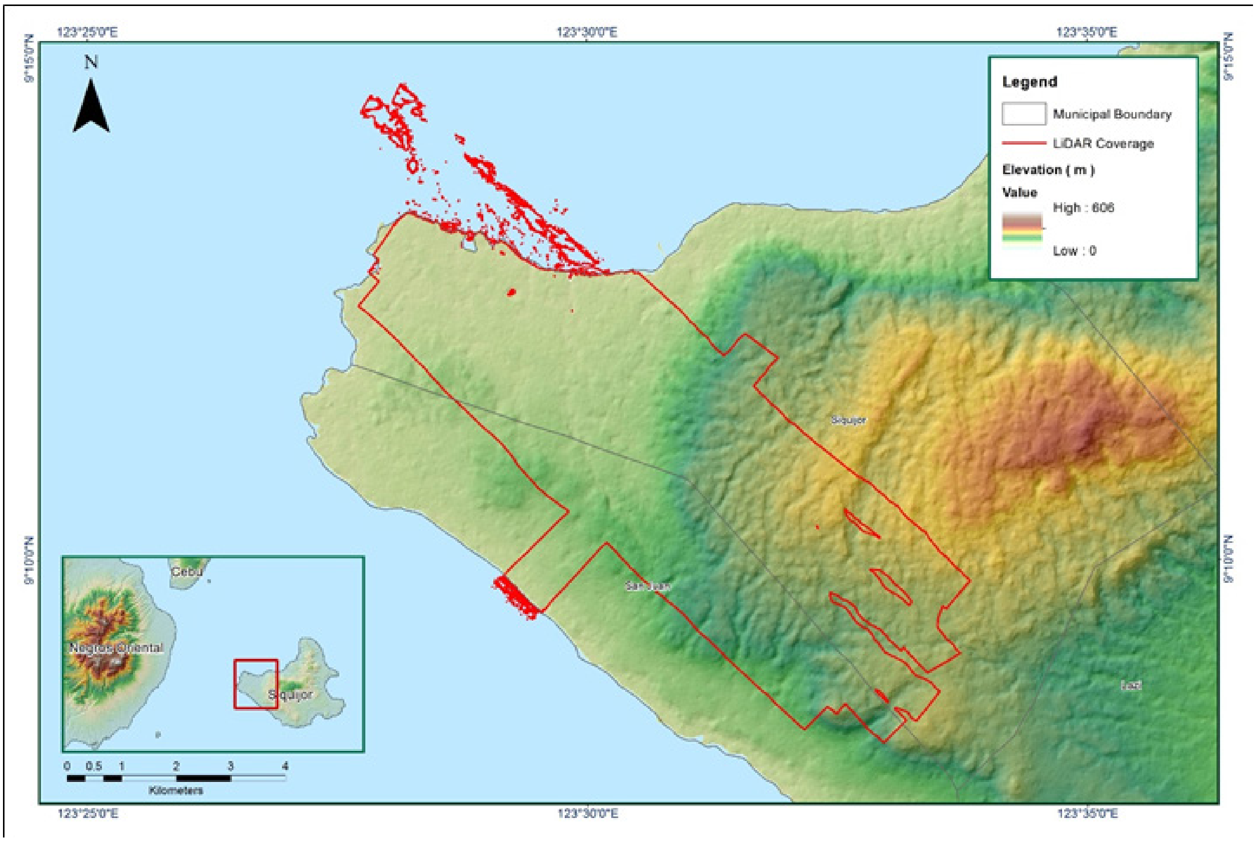


Figure A-8.18. Coverage of LiDAR data

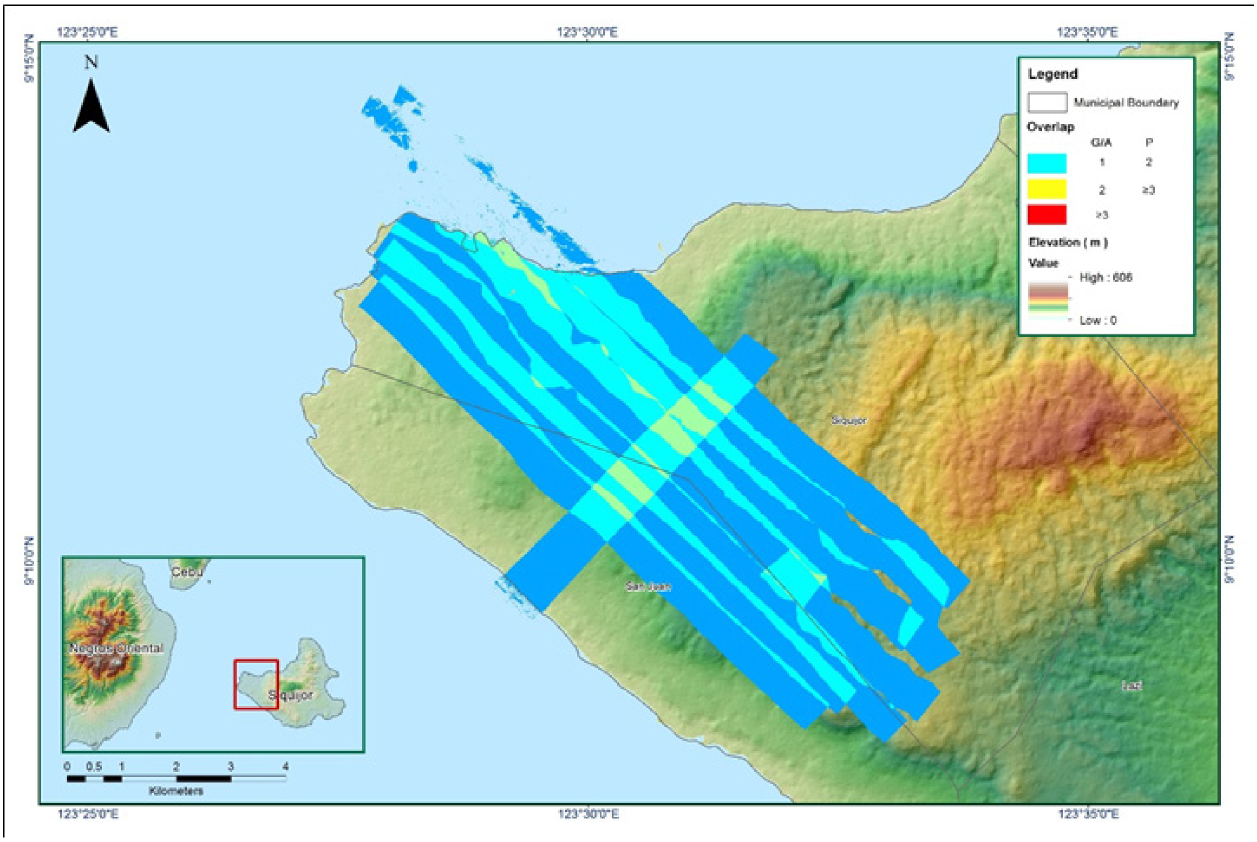


Figure A-8.19. Image of Data Overlap

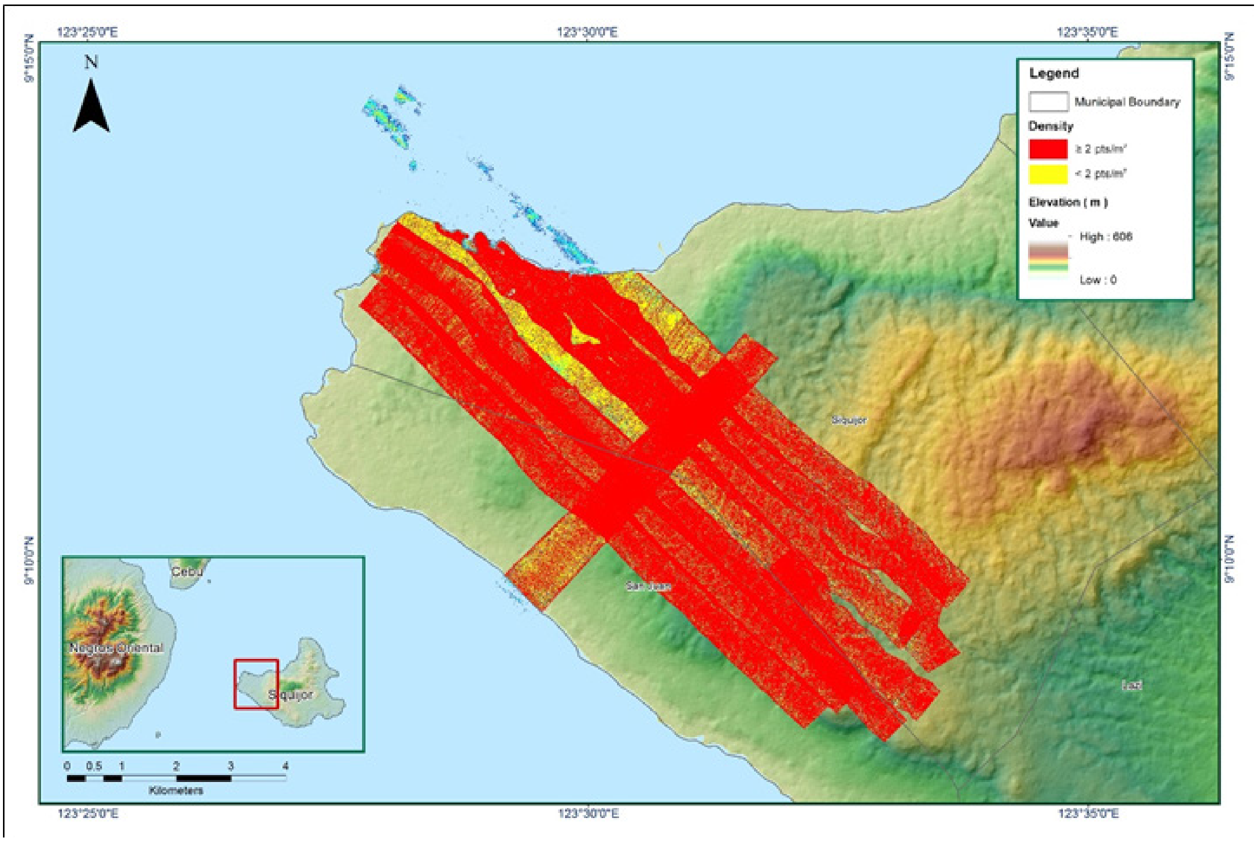


Figure A-8.20. Density map of merged LiDAR data

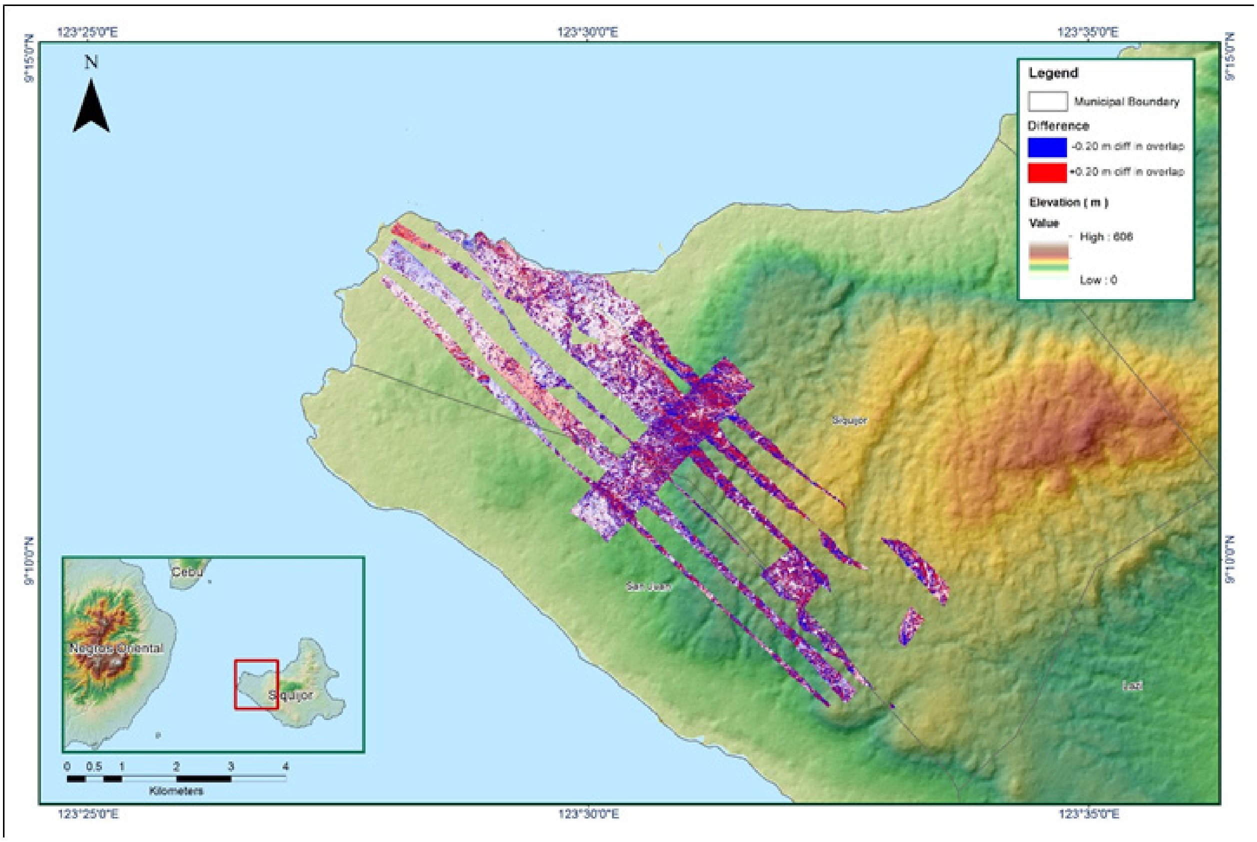


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk56D

Flight Area	Dumaguete Reflights
Mission Name	Blk56D
Inclusive Flights	10077AC
Range data size	5.46 GB
POS data size	198 MB
Base data size	18.4 MB
Image	27 MB
Transfer date	February 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.23
RMSE for Down Position (<8.0 cm)	2.32
Boresight correction stdev (<0.001deg)	0.002341
IMU attitude correction stdev (<0.001deg)	0.003698
GPS position stdev (<0.01m)	0.0245
Minimum % overlap (>25)	12.20%
Ave point cloud density per sq.m. (>2.0)	5.31
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	18
Maximum Height	293.38 m
Minimum Height	137.98 m
Classification (# of points)	
Ground	2,361,786
Low vegetation	3,190,255
Medium vegetation	3,044,366
High vegetation	7,507,156
Building	137,935
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Ma. Joanne Balaga, Alex John Escobido

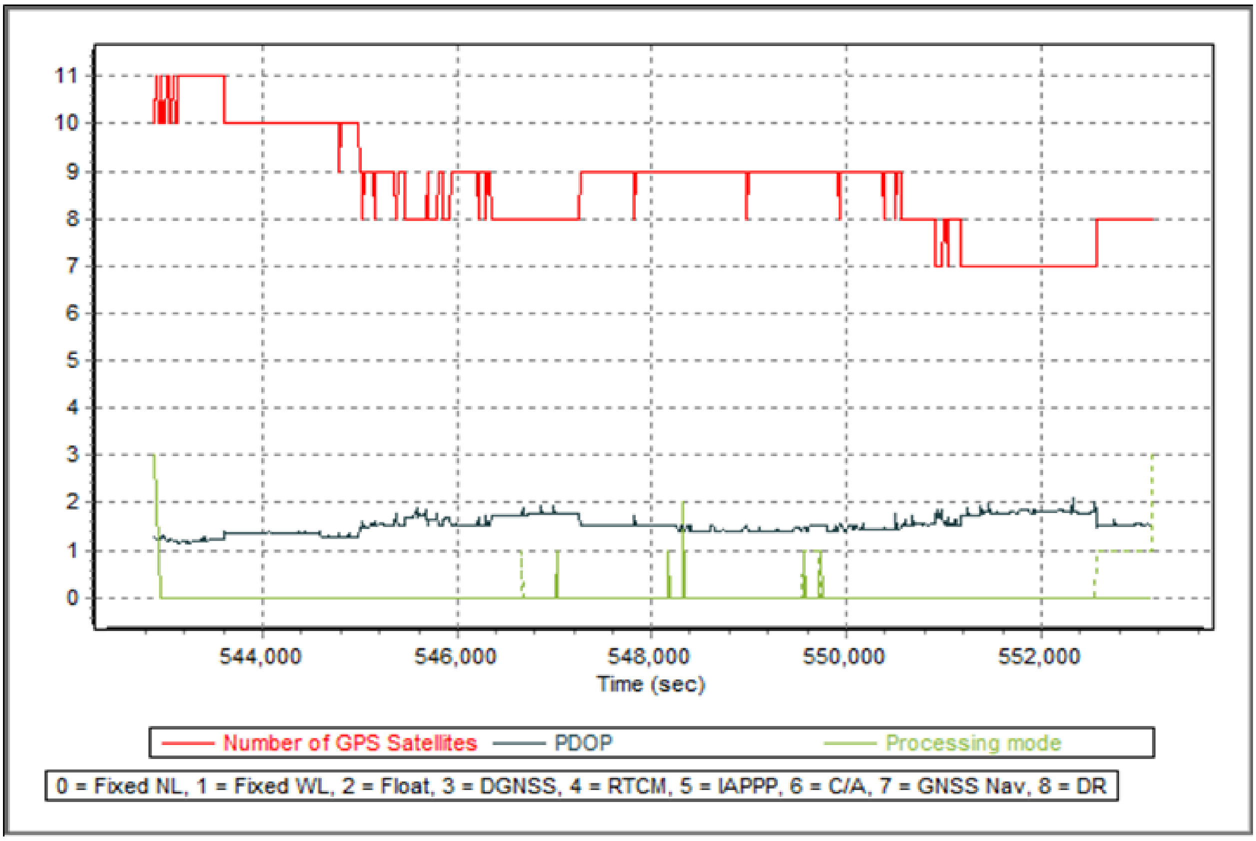


Figure A-8.22. Solution Status

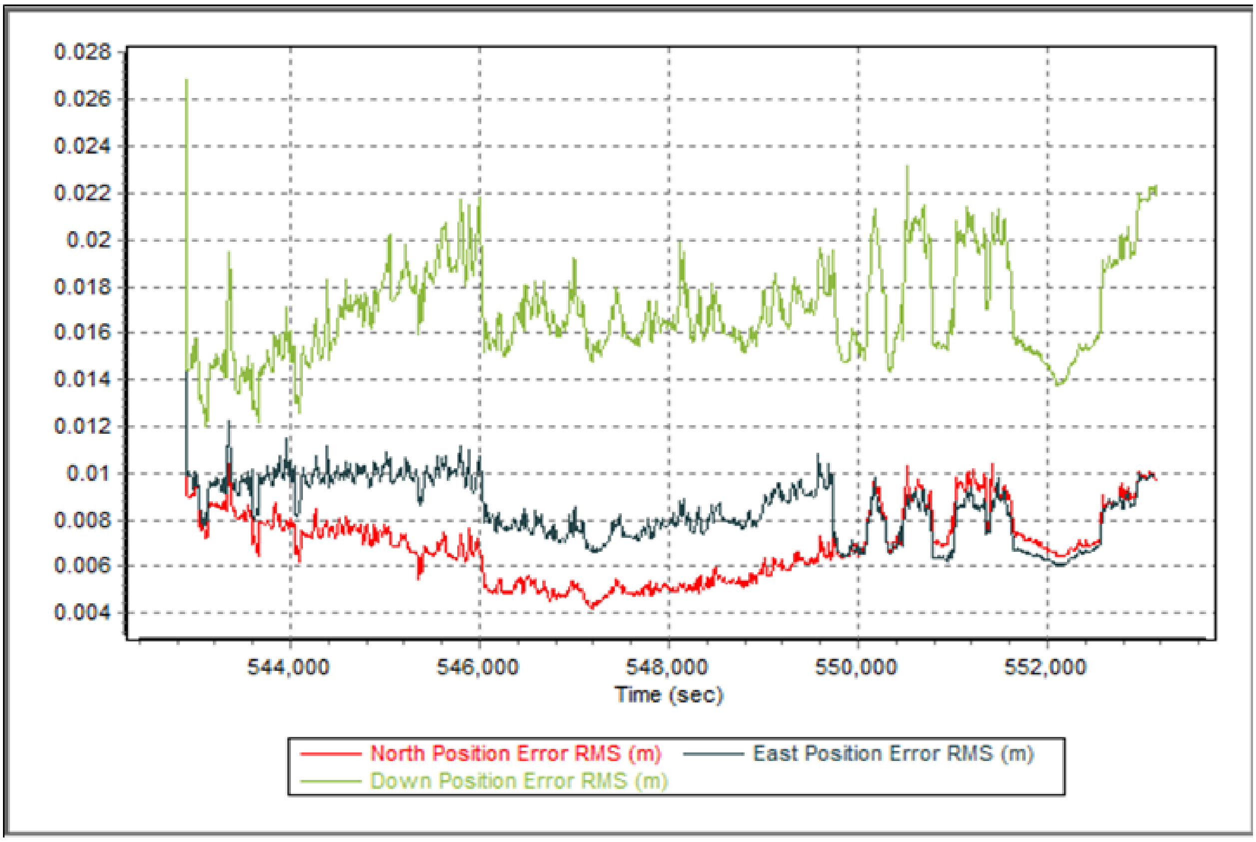


Figure A-8.23. Smoothed Performance Metric Parameters

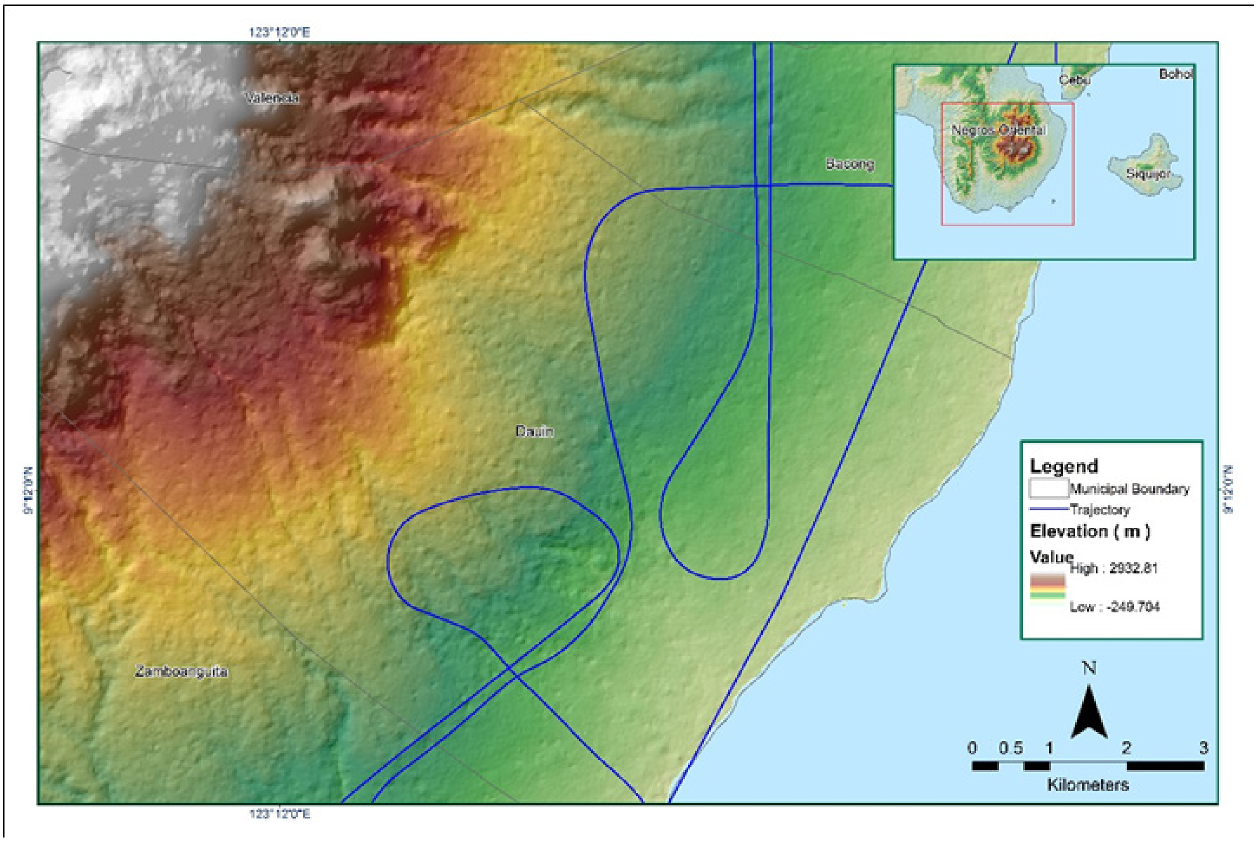


Figure A-8.24. Best Estimated Trajectory

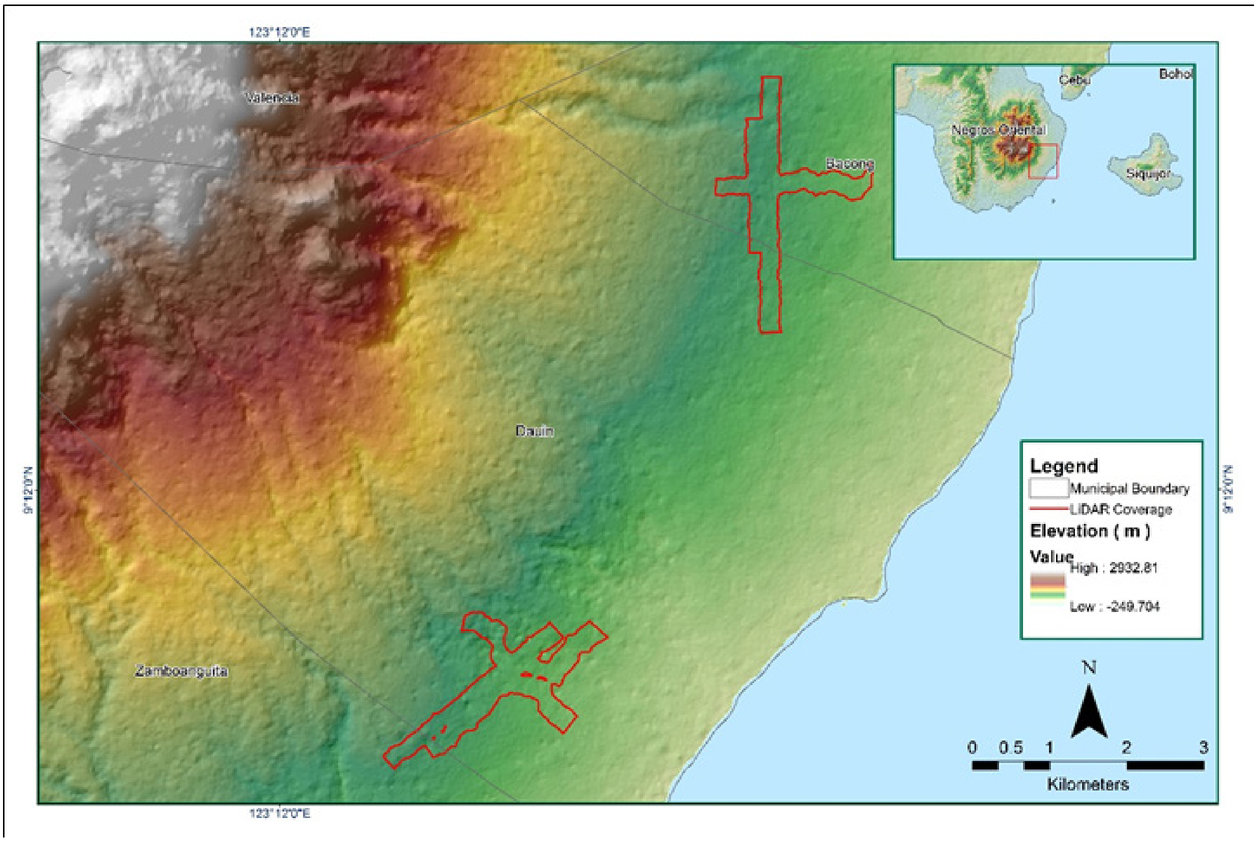


Figure A-8.25. Coverage of LiDAR data

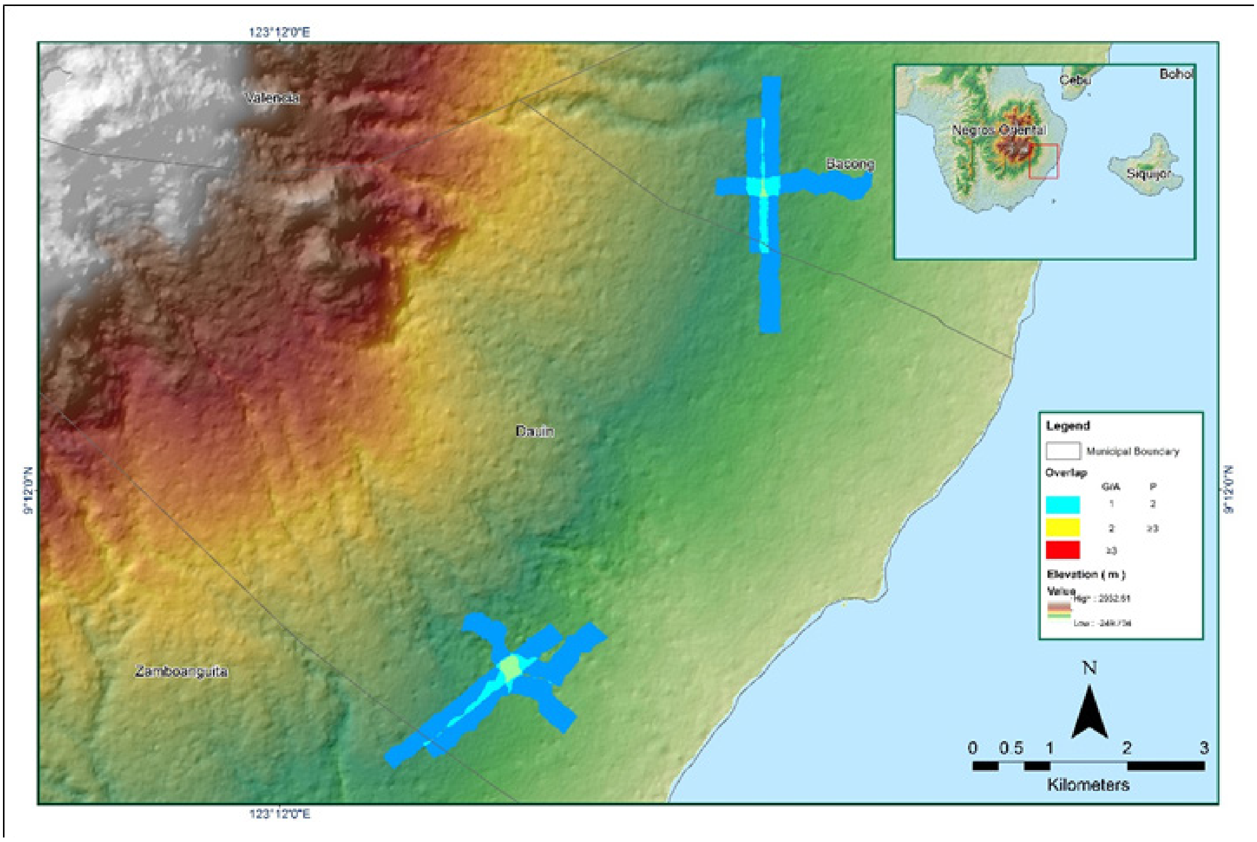


Figure A-8.26. Image of Data Overlap

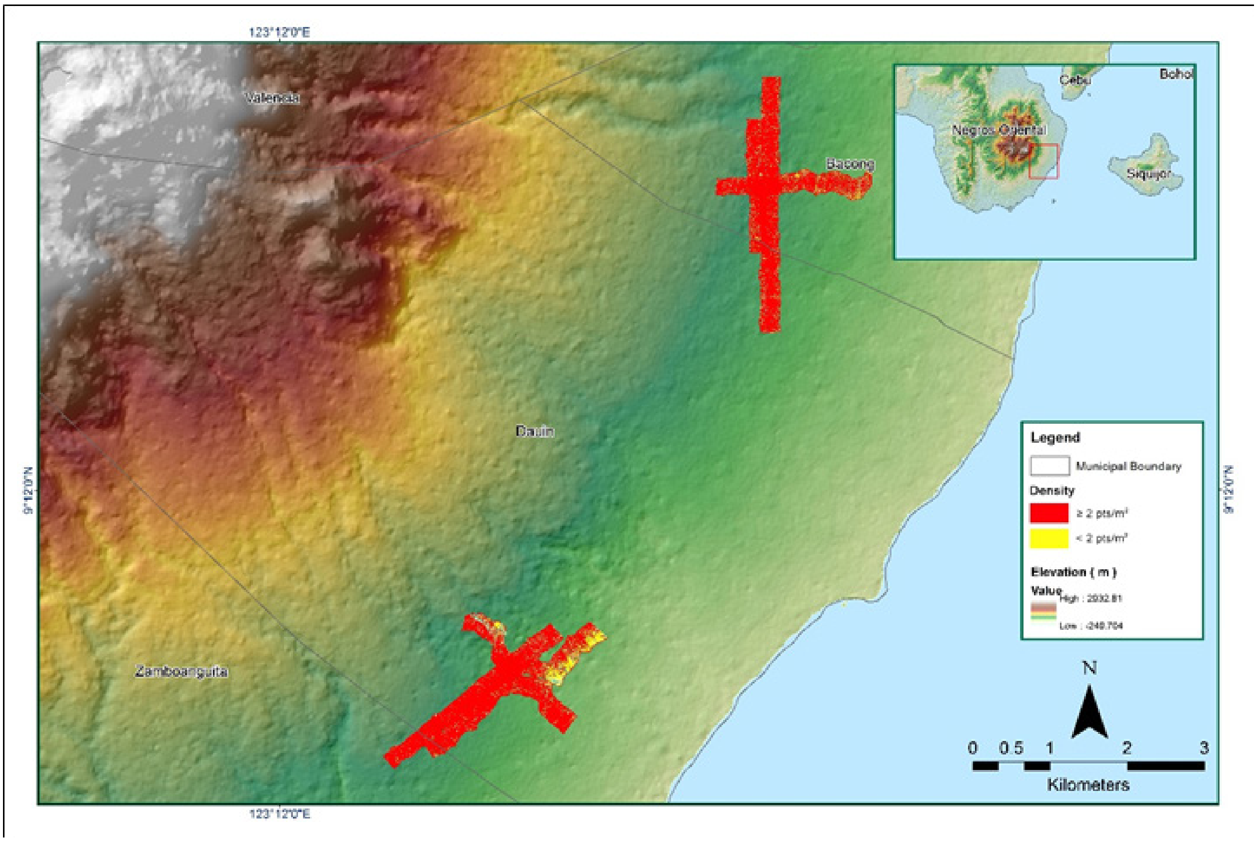


Figure A-8.27. Density map of merged LiDAR data

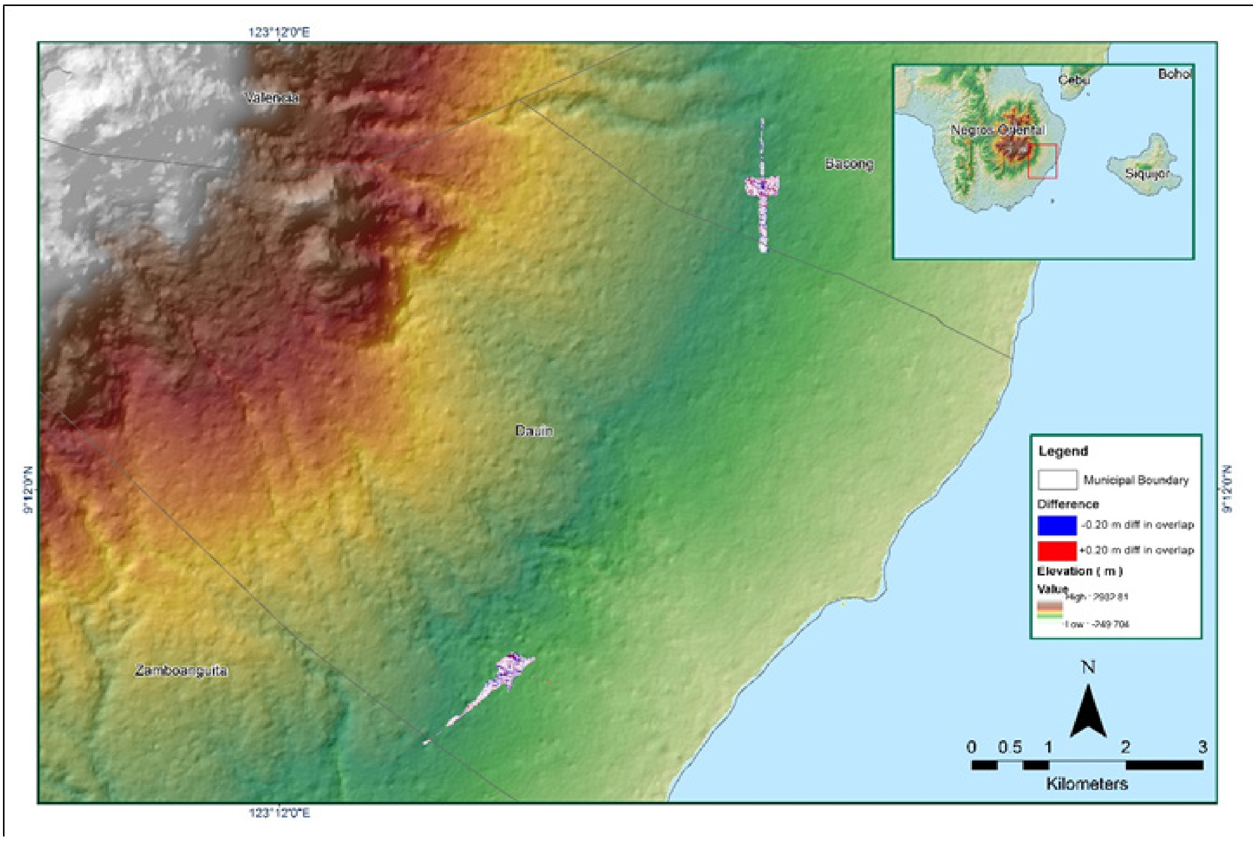


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk56E

Flight Area	Dumaguete Reflights
Mission Name	Blk56E
Inclusive Flights	10077AC
Range data size	5.46 GB
POS data size	198 MB
Base data size	18.4 MB
Image	27 MB
Transfer date	February 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.23
RMSE for Down Position (<8.0 cm)	2.32
Boresight correction stdev (<0.001deg)	0.000267
IMU attitude correction stdev (<0.001deg)	0.000335
GPS position stdev (<0.01m)	0.0126
Minimum % overlap (>25)	28.79%
Ave point cloud density per sq.m. (>2.0)	4.03
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	30
Maximum Height	170.09 m
Minimum Height	65.73 m
Classification (# of points)	
Ground	8,284,539
Low vegetation	9,818,388
Medium vegetation	6,167,202
High vegetation	17,072,068
Building	2,924,926
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Chelou Prado, Maria Tamsyn Malabanan

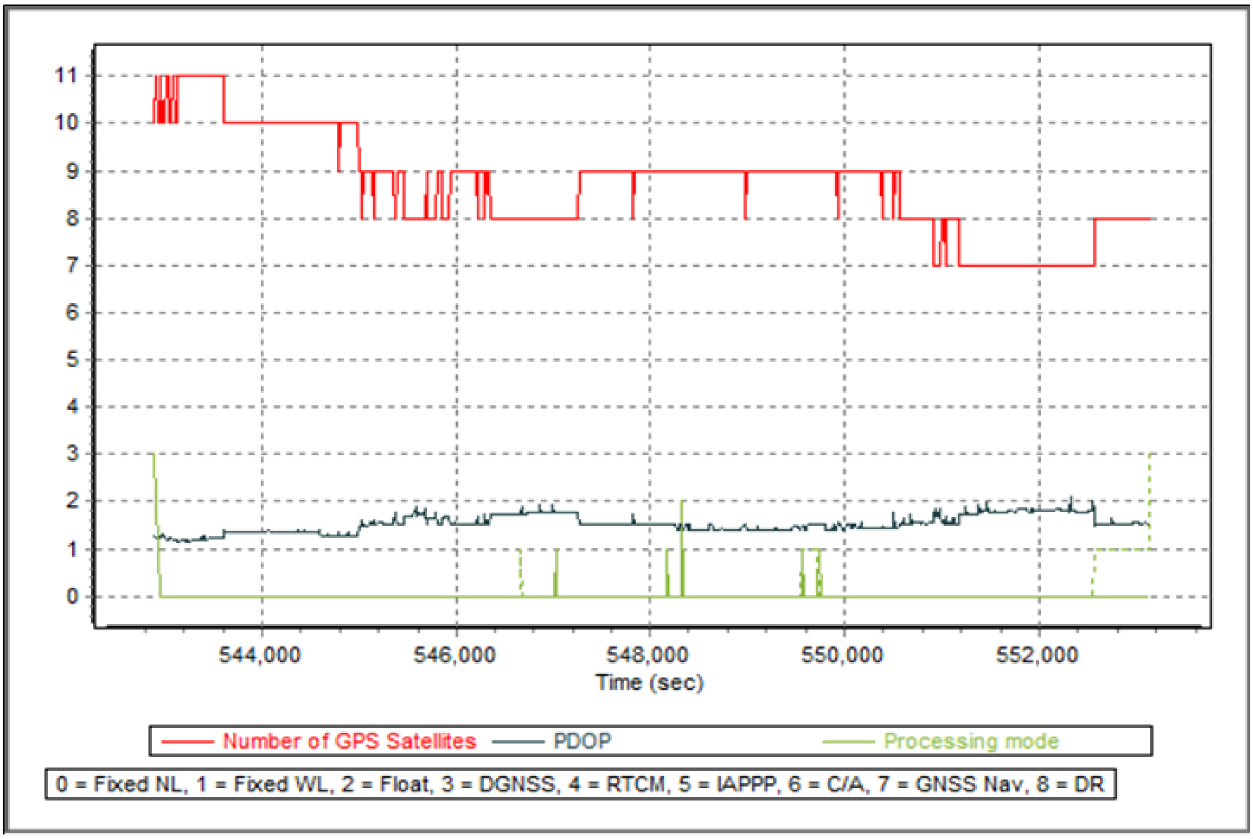


Figure A-8.29. Solution Status

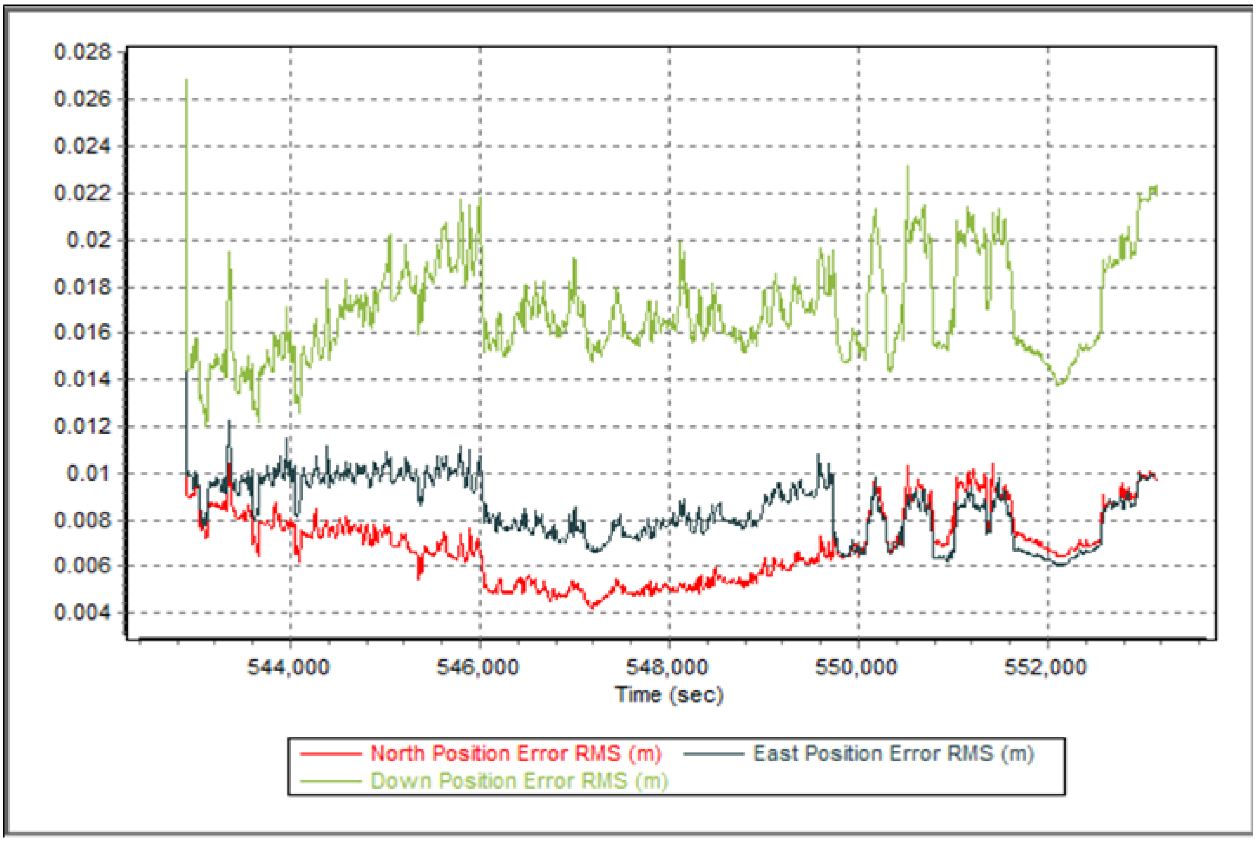


Figure A-8.30. Smoothed Performance Metric Parameters

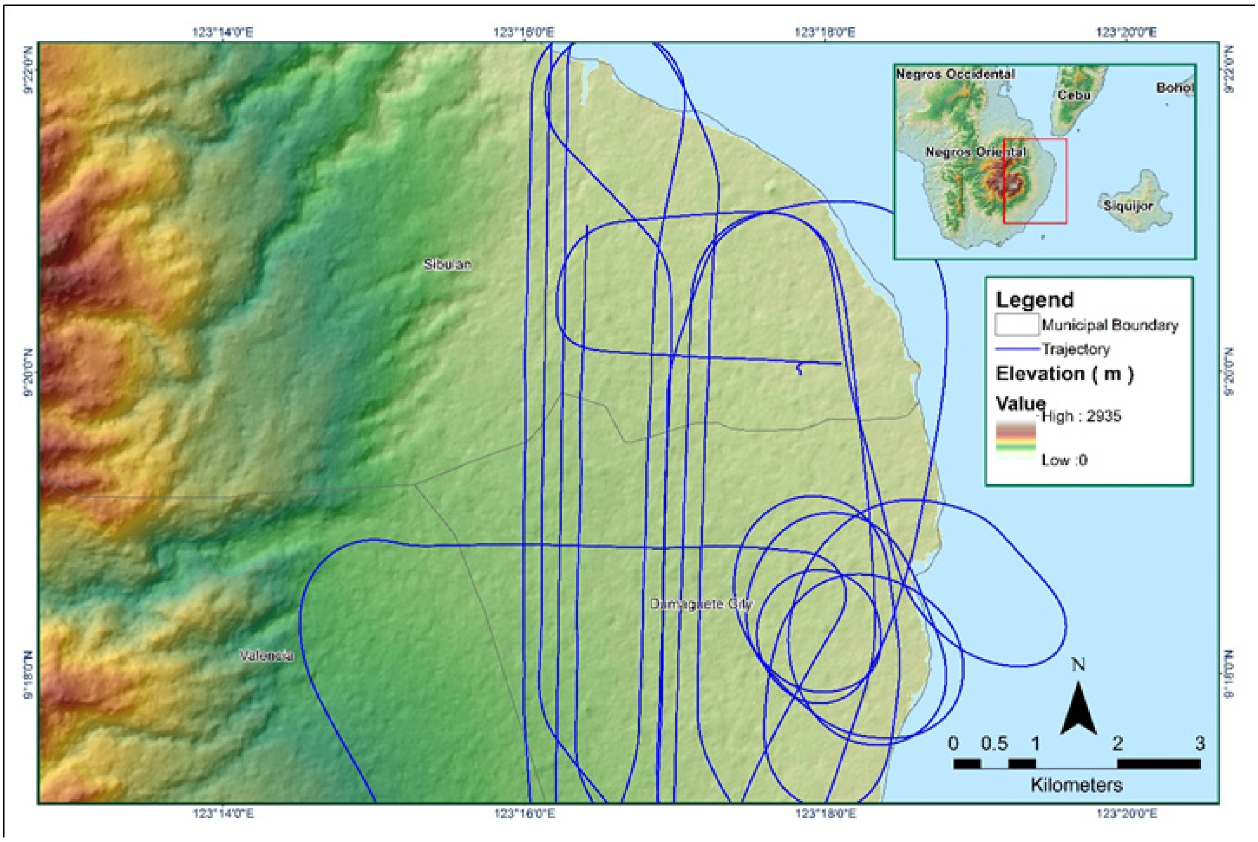


Figure A-8.31. Best Estimated Trajectory

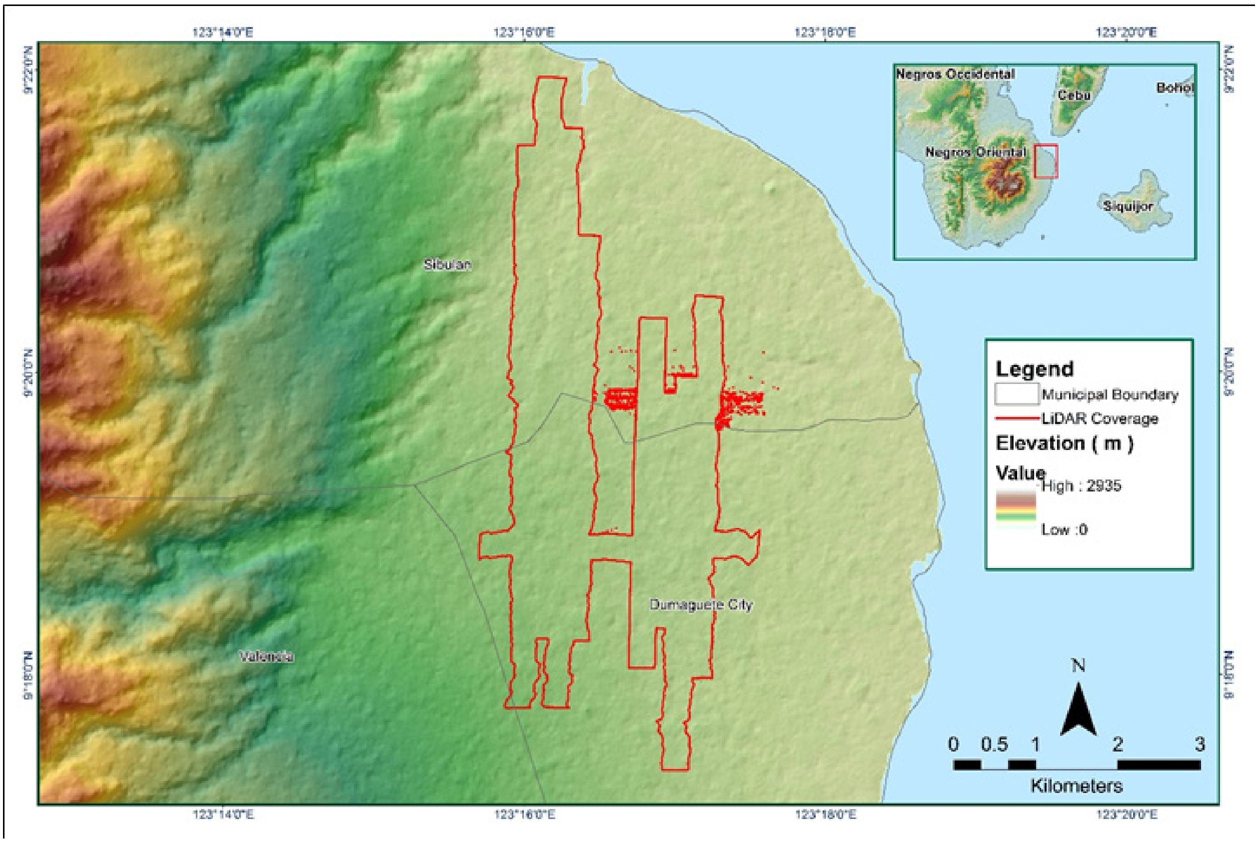


Figure A-8.32. Coverage of LiDAR data

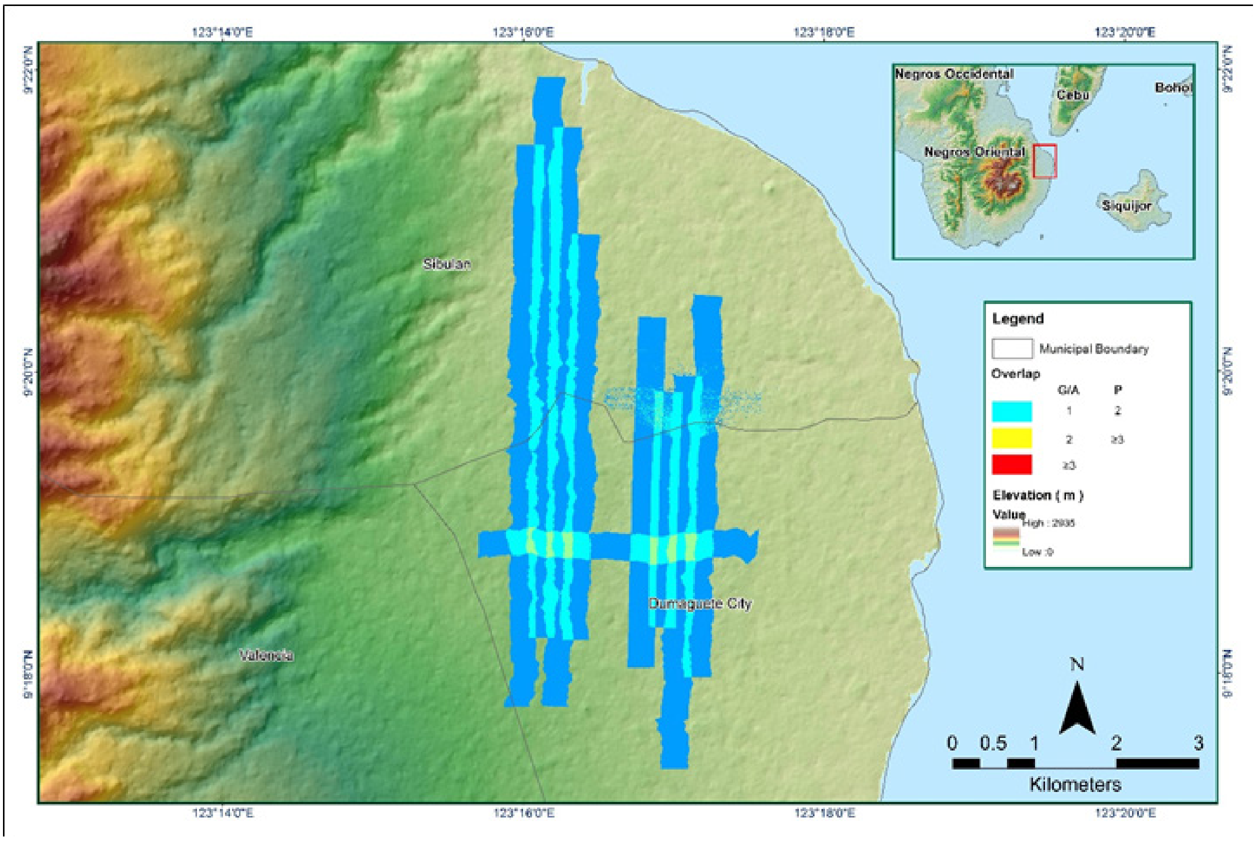


Figure A-8.33. Image of Data Overlap

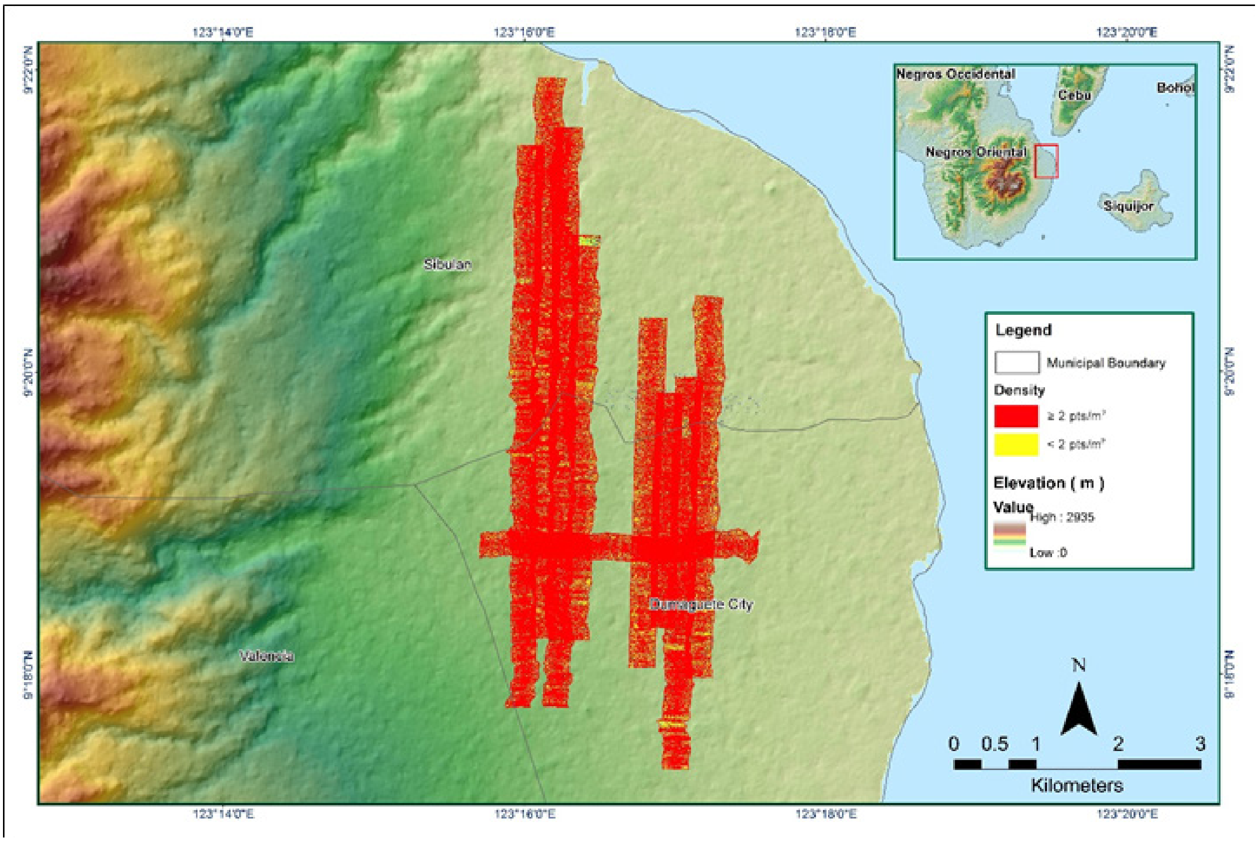


Figure A-8.34. Density map of merged LiDAR data

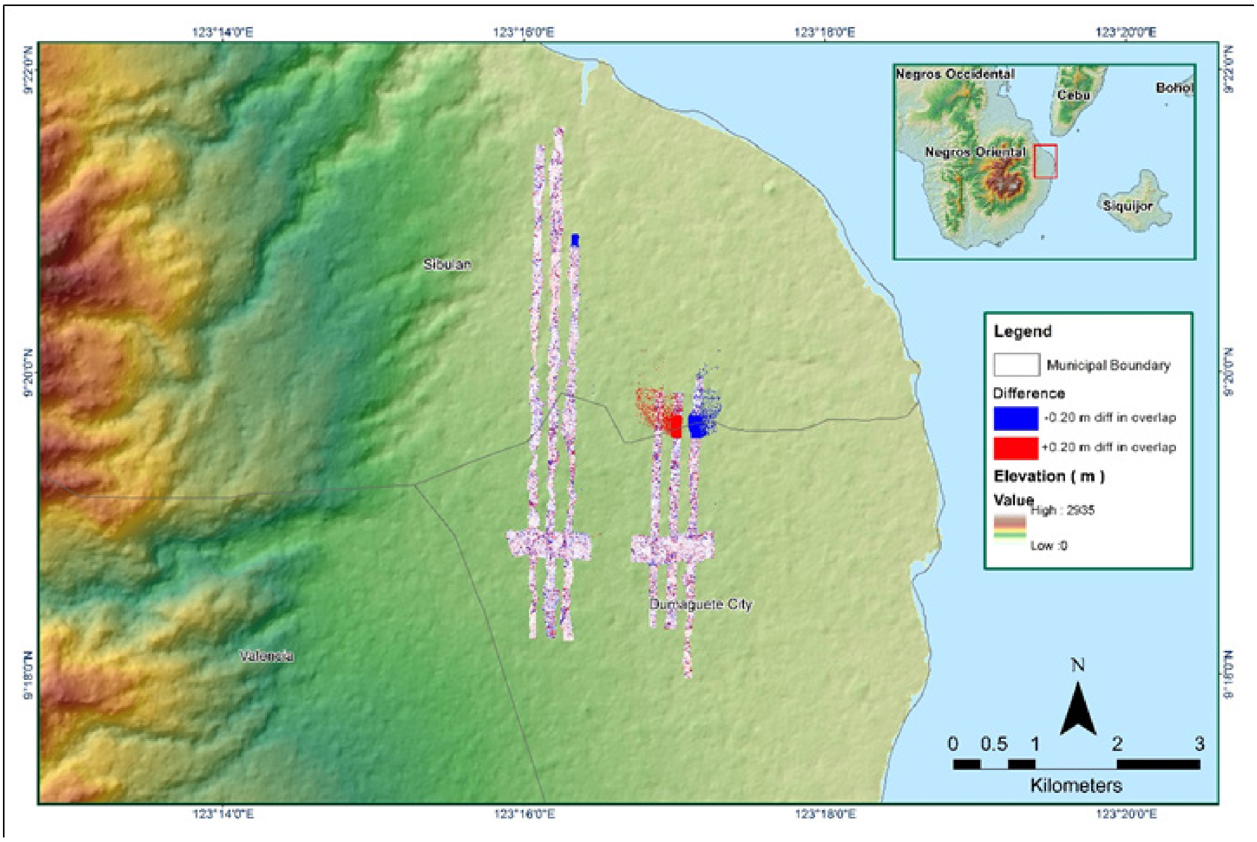


Figure A-8.35. Elevation difference between flight lines

Annex 9. Ocoy Model Basin Parameters

Table A-9.1. Ocoy Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threschold Type	Ratio to Peak
W460	0.16251	99	100	7.135119	0.6482	Discharge	0.17598	0.03	Ratio to Peak	0.47487
W470	0.48966	99	100	0.6145598	0.0981738	Discharge	0.0499821	0.0610466	Ratio to Peak	0.31498
W480	0.98314	99	100	1.037107	0.11271	Discharge	0.10952	0.0674827	Ratio to Peak	0.56011
W490	0.44188	99	100	0.7997744	0.12882	Discharge	0.0886813	0.0610461	Ratio to Peak	0.70906
W500	0.55243	99	100	0.7229364	0.078561	Discharge	0.0183102	0.0664736	Ratio to Peak	0.45177
W510	0.36153	89.835	50	6.690983	1.0477	Discharge	0.16276	0.045	Ratio to Peak	0.69811
W520	0.72341	86.274	100	6.701592	1.0527	Discharge	0.12176	0.045	Ratio to Peak	0.32299
W530	1.8272	99	100	0.754784	0.26594	Discharge	0.0710947	0.0678293	Ratio to Peak	0.46323
W540	0.082592	99	100	8.186337	0.85767	Discharge	0.50723	0.045225	Ratio to Peak	0.30733
W550	1.2943	81.399	100	8.330125	0.89103	Discharge	0.14941	0.045	Ratio to Peak	0.32156
W560	1.5631	99	100	0.9993884	0.0724034	Discharge	0.0469713	0.0678298	Ratio to Peak	0.45699
W570	1.243	99	100	0.1767995	0.0415163	Discharge	0.0021646	0.0678311	Ratio to Peak	0.31515
W580	1.5965	99	100	1.09695	0.0778775	Discharge	0.0522816	0.0678295	Ratio to Peak	0.45177
W590	1.1548	50.638	50	0.9961542	0.0707245	Discharge	0.0711192	0.0678296	Ratio to Peak	0.45177
W600	1.0525	99	50	0.5827225	0.0620576	Discharge	0.0526557	0.0678293	Ratio to Peak	0.45177
W610	2.2388	52.38	50	6.512381	1.0205	Discharge	0.0738786	0.06615	Ratio to Peak	0.6983
W620	0.95624	89.573	50	3.574821	0.56312	Discharge	0.10591	0.0678186	Ratio to Peak	0.70165
W630	2.3894	51.955	50	3.810279	0.59616	Discharge	0.0565618	0.0678236	Ratio to Peak	1
W640	0.88741	99	50	8.156673	0.38294	Discharge	0.12156	0.045	Ratio to Peak	0.47495
W650	1.2069	85.873	100	9.858954	1.0604	Discharge	0.17208	0.045	Ratio to Peak	1
W660	1.1259	76.453	50	2.37724	0.8528	Discharge	0.049326	0.0678297	Ratio to Peak	0.78786
W670	2.3363	80.187	50	6.692425	0.47179	Discharge	0.0901162	0.045	Ratio to Peak	0.79555

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threschold Type	Ratio to Peak
W680	1.0088	86.791	50	3.370366	0.35107	Discharge	0.0695923	0.0678269	Ratio to Peak	0.71231
W690	4.098	75.473	50	3.749097	0.5873	Discharge	0.0562981	0.0678242	Ratio to Peak	1
W700	4.195	76.141	50	5.470433	0.57624	Discharge	0.0505218	0.0447743	Ratio to Peak	0.48203
W710	3.8483	52.142	50	5.503599	0.39165	Discharge	0.053551	0.045	Ratio to Peak	0.71255
W720	0.72389	99	50	0.396447	0.0626997	Discharge	0.0243073	0.06783	Ratio to Peak	0.67766
W730	1.0686	76.264	50	0.4265539	0.84516	Discharge	0.0500864	0.06783	Ratio to Peak	0.47612
W740	0.86552	99	50	6.483026	0.30378	Discharge	0.13244	0.06615	Ratio to Peak	0.6699
W750	2.1157	85.931	50	4.344437	0.34775	Discharge	0.062099	0.0678285	Ratio to Peak	0.71587
W760	3.2186	84.715	50	6.683258	0.47999	Discharge	0.22797	0.045	Ratio to Peak	0.7312
W770	0.56645	87.173	50	2.813651	0.30156	Discharge	0.0773371	0.0678291	Ratio to Peak	0.72
W780	1.323	58.626	50	3.638681	0.44009	Discharge	0.0544033	0.0678272	Ratio to Peak	1
W790	1.7014	87.062	50	3.602734	0.32652	Discharge	0.0595297	0.0678226	Ratio to Peak	0.72992
W800	2.2189	81.035	50	1.848335	0.29001	Discharge	0.0290167	0.0678297	Ratio to Peak	0.48476
W810	2.0738	86.183	50	2.668421	0.9268	Discharge	0.0559547	0.0678276	Ratio to Peak	0.72898
W820	2.1062	89.599	50	4.516962	0.4839	Discharge	0.0684641	0.045	Ratio to Peak	1
W830	5.6888	69.898	50	3.833969	0.2673	Discharge	0.10849	0.0678285	Ratio to Peak	0.79556
W840	5.388	77.893	25	3.176417	0.28895	Discharge	0.0598608	0.0678273	Ratio to Peak	0.7338
W850	6.2926	72.056	25	0.1522134	0.0548895	Discharge	0.0003495	0.0664743	Ratio to Peak	0.45177
W860	4.0632	84.194	25	2.58839	0.27179	Discharge	0.0519812	0.0678282	Ratio to Peak	0.71555
W870	3.6783	81.404	25	3.53187	0.24695	Discharge	0.0132022	0.0678295	Ratio to Peak	0.66985
W880	2.0822	98.547	25	5.910552	0.42316	Discharge	0.13371	0.045	Ratio to Peak	1
W890	1.4727	85.438	25	2.293089	0.24028	Discharge	0.0937771	0.0678285	Ratio to Peak	0.71093
W900	1.8386	93.773	25	4.073753	0.42699	Discharge	0.10372	0.045	Ratio to Peak	0.71568

Annex 10. Ocoy Model Reach Parameters

Table A-10.1. Ocoy Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	922.55	0.0185	0.038845	Trapezoid	40	1
R110	Automatic Fixed Interval	2045.8	0.03597	0.026133	Trapezoid	40	1
R140	Automatic Fixed Interval	547.99	0.0404	0.13054	Trapezoid	40	1
R160	Automatic Fixed Interval	1007.1	0.05392	0.059371	Trapezoid	40	1
R170	Automatic Fixed Interval	6959.5	0.01729	0.038288	Trapezoid	40	1
R180	Automatic Fixed Interval	1554.4	0.13162	0.085286	Trapezoid	40	1
R190	Automatic Fixed Interval	949.83	0.03742	0.090413	Trapezoid	40	1
R200	Automatic Fixed Interval	555.98	0.06367	0.13578	Trapezoid	40	1
R260	Automatic Fixed Interval	760.83	0.11874	0.13578	Trapezoid	40	1
R270	Automatic Fixed Interval	685.27	0.08409	0.13576	Trapezoid	40	1
R280	Automatic Fixed Interval	1296.4	0.07814	0.20272	Trapezoid	40	1
R290	Automatic Fixed Interval	864.56	0.0836	0.090662	Trapezoid	40	1
R30	Automatic Fixed Interval	1656.1	0.11693	0.025525	Trapezoid	40	1
R320	Automatic Fixed Interval	976.4	0.05156	0.13573	Trapezoid	40	1
R330	Automatic Fixed Interval	591.84	0.15125	0.090774	Trapezoid	40	1
R350	Automatic Fixed Interval	604.56	0.09208	0.20263	Trapezoid	40	1
R390	Automatic Fixed Interval	1536.4	0.11515	0.13472	Trapezoid	40	1
R40	Automatic Fixed Interval	663.85	0.14538	0.037522	Trapezoid	40	1
R410	Automatic Fixed Interval	146.57	0.10934	0.091011	Trapezoid	40	1
R420	Automatic Fixed Interval	415.56	0.11214	0.09103	Trapezoid	40	1
R70	Automatic Fixed Interval	1124	0.07718	0.017364	Trapezoid	40	1
R80	Automatic Fixed Interval	236.57	0.03192	0.025525	Trapezoid	40	1

Annex 11. Ocoy Field Validation Points

Table A-11.1. Ocoy Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	123.27194	9.347203	0.0	0.927	0.859329	Sendong	100-Year
2	123.26744	9.332396	0.3	0.682	0.145924	Sendong	100-Year
3	123.26743	9.332418	0.4	0.682	0.079524	Sendong	100-Year
4	123.26848	9.33254	1.6	0.244	1.838736	Pablo	100-Year
5	123.26846	9.332558	1.6	0.244	1.838736	Sendong	100-Year
6	123.27173	9.335193	1.2	0.219	0.962361	Ruping	100-Year
7	123.27361	9.337609	0.0	0.699	0.488601	Sendong	100-Year
8	123.2734	9.33774	0.0	0.071	0.005041	Sendong	100-Year
9	123.27312	9.337712	0.4	0.208	0.036864	Sendong	100-Year
10	123.27536	9.338317	0.7	0.37	0.1089	Sendong	100-Year
11	123.27532	9.338361	0.7	0.436	0.069696	Ruping	100-Year
12	123.27534	9.338751	0.8	0.278	0.272484	Sendong	100-Year
13	123.27536	9.338734	0.8	0.211	0.346921	Ruping	100-Year
14	123.273	9.339782	1.1	0.03	1.1449	Sendong	100-Year
15	123.27299	9.339748	1.5	0.03	2.1609	Ruping	100-Year
16	123.28065	9.3319	1.1	0.418	0.465124	Sendong	100-Year
17	123.2806	9.331697	1.1	0.905	0.038025	Sendong	100-Year
18	123.27988	9.331778	1.0	0.29	0.5041	Sendong	100-Year
19	123.2771	9.331119	1.1	0.268	0.692224	Sendong	100-Year
20	123.27707	9.331059	0.3	0.268	0.001024	ITCZ	100-Year
21	123.27671	9.330955	1.0	0.06	0.8836	Sendong	100-Year
22	123.27552	9.329614	1.8	0.674	1.267876	Sendong	100-Year
23	123.28115	9.332149	2.2	1.315	0.783225	Sendong	100-Year
24	123.28332	9.335366	1.8	1.402	0.158404	Sendong	100-Year
25	123.2833	9.335509	1.9	0.632	1.607824	Sendong	100-Year
26	123.28332	9.335433	0	0.928	0.861184	Ruping	100-Year
27	123.28371	9.335104	0.7	0.205	0.245025	Sendong	100-Year
28	123.28419	9.335699	1.4	0.353	1.096209	Sendong	100-Year
29	123.2845	9.33578	0.65	0.296	0.125316	Sendong	100-Year
30	123.28438	9.336183	1.5	0.616	0.781456	Sendong	100-Year
31	123.28463	9.336303	1.3	0.55	0.5625	Sendong	100-Year
32	123.28354	9.334993	0.8	0.092	0.501264	Sendong	100-Year
33	123.28291	9.335876	0.5	0.044	0.207936	Sendong	100-Year
34	123.28349	9.335994	0.9	0.076	0.678976	Sendong	100-Year
35	123.28313	9.33616	0.4	0.03	0.1369	Sendong	100-Year
36	123.28311	9.336183	0.2	0.03	0.0289	Ruping	100-Year
37	123.28401	9.336956	0.3	0.03	0.0729	Sendong	100-Year
38	123.2838	9.336812	0.4	0.06	0.1156	Sendong	100-Year
39	123.28365	9.33686	0.4	0.13	0.0729	Sendong	100-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
40	123.26593	9.337568	0.3	0.166	0.017956	Sendong	100-Year
41	123.26669	9.342374	0.5	0.051	0.201601	Sendong	100-Year
42	123.26071	9.324433	0.0	1.995	3.980025	Sendong	100-Year
43	123.27418	9.358758	1.1	2.53	2.0449	Sendong	100-Year
44	123.27436	9.358977	1.1	1.412	0.097344	Sendong	100-Year
45	123.27478	9.358978	1.1	1.457	0.127449	Sendong	100-Year
46	123.2752	9.358842	1.1	1.213	0.012769	Sendong	100-Year
47	123.27561	9.358838	1.1	1.226	0.015876	Sendong	100-Year
48	123.27657	9.359095	1.2	1.078	0.014884	Sendong	100-Year
49	123.27729	9.358801	1.1	0.953	0.021609	Sendong	100-Year
50	123.27717	9.359659	0.1	0.682	0.399424	Sendong	100-Year
51	123.27643	9.359789	1.0	1.13	0.0169	Sendong	100-Year
52	123.27577	9.359873	0.86	1.281	0.177241	Sendong	100-Year
53	123.27527	9.359399	1.0	1.542	0.293764	Sendong	100-Year
54	123.275	9.359376	1.65	1.646	0.000016	ITCZ	100-Year
55	123.275	9.359365	0.25	1.602	1.827904	ITCZ	100-Year
56	123.27501	9.359358	0.3	1.602	1.695204	Sendong	100-Year
57	123.27444	9.359274	0.95	1.315	0.133225	Sendong	100-Year
58	123.27431	9.35993	1.64	1.436	0.041616	Sendong	100-Year
59	123.27459	9.360584	1.02	1.145	0.015625	Sendong	100-Year
60	123.27444	9.361067	1.12	1.161	0.001681	Sendong	100-Year
61	123.27394	9.360795	2.4	1.672	0.529984	Sendong	100-Year
62	123.2741	9.361342	3.45	1.685	3.115225	Sendong	100-Year
63	123.27396	9.362246	0.6	0.031	0.323761	Sendong	100-Year
64	123.27416	9.362679	0.53	0.38	0.0225	Sendong	100-Year
65	123.27428	9.362819	0.55	0.587	0.001369	Sendong	100-Year
66	123.27428	9.36346	0.9	0.914	0.000196	Sendong	100-Year
67	123.27432	9.363672	0.9	0.856	0.001936	Sendong	100-Year
68	123.27449	9.364107	1.25	0.977	0.074529	Sendong	100-Year
69	123.27449	9.364096	0.95	0.977	0.000729	Pablo	100-Year
70	123.27697	9.363633	1.3	1.187	0.012769	Sendong	100-Year
71	123.27701	9.363628	0.15	1.157	1.014049	Ondoy	100-Year
72	123.27193	9.36389	0.03	0.369	0.114921	Sendong	100-Year
73	123.27249	9.361329	1.05	0.514	0.287296	Sendong	100-Year
74	123.27353	9.356057	2.6	3.593	0.986049	Sendong	100-Year
75	123.27368	9.355928	2.1	3.609	2.277081	Sendong	100-Year
76	123.2736	9.355765	1.65	3.404	3.076516	Sendong	100-Year
77	123.2734	9.355507	1.64	2.949	1.713481	Sendong	100-Year
78	123.27342	9.355313	1.37	3.156	3.189796	Sendong	100-Year
79	123.27322	9.354991	1.68	3.623	3.775249	Sendong	100-Year
80	123.27302	9.35485	1.6	3.268	2.782224	Sendong	100-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
81	123.27283	9.354818	1.36	3.609	5.058001	Sendong	100-Year
82	123.27087	9.354657	0.1	0.298	0.039204	Sendong	100-Year
83	123.27257	9.364164	0.7	0.97	0.0729	Sendong	100-Year
84	123.2723	9.364041	0.7	1.024	0.104976	Sendong	100-Year
85	123.27222	9.364149	0.7	0.832	0.017424	Sendong	100-Year
86	123.27219	9.364535	0.9	1.065	0.027225	Sendong	100-Year
87	123.2722	9.364523	0.9	1.138	0.056644	Pablo	100-Year
88	123.27245	9.364635	0.5	0.644	0.020736	Sendong	100-Year
89	123.27238	9.364872	1.1	0.577	0.273529	Sendong	100-Year
90	123.27262	9.3648	0.3	0.685	0.148225	Sendong	100-Year
91	123.27302	9.36488	1.0	0.848	0.023104	Sendong	100-Year
92	123.27312	9.364846	1.5	1.209	0.084681	Sendong	100-Year
93	123.27311	9.364848	0.7	1.209	0.259081	ITCZ	100-Year
94	123.27302	9.364915	0.84	0.842	4E-06	Sendong	100-Year
95	123.27294	9.365068	0.62	0.643	0.000529	Sendong	100-Year
96	123.27298	9.365191	0.84	0.702	0.019044	Sendong	100-Year
97	123.27306	9.365325	0.74	0.698	0.001764	Sendong	100-Year
98	123.27302	9.365479	0.9	1.007	0.011449	Sendong	100-Year
99	123.27309	9.365668	2.0	1.141	0.737881	Sendong	100-Year

Annex 12. Educational Institutions affected by flooding in Ocoy Floodplain

Table A-12.1. Educational Institutions in Dumaguete City, Negros Oriental affected by flooding in Ocoy Floodplain

Negros Oriental				
Dumaguete City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ABC Learning Center	Bantayan		Low	Low
North City Elementary School	Bantayan		Low	Low
St. Paul University	Bantayan			
Batinguel Elementary School	Batinguel		Low	Medium
Global Tech Manpower Institute, Inc	Batinguel			
Taclobo National High School	Batinguel	Low	Low	Low
St. Paul University	Bunao	Low	Medium	Medium
Camanjac Elementary School	Camanjac		Low	Low
Camanjac High School	Camanjac		Low	Low
Candau-ay Elementary School	Camanjac			
Batinguel Elementary School	Candau-Ay			
Alpha Omega Academy	Daro	Low	Low	Low
Living Word Christian School	Daro	Low	Low	Medium
Negros Oriental High School	Daro		Low	Low
Negros Oriental State University	Daro		Low	Low
Silliman Early Childhood Department	Daro			Low
Silliman University Campus	Daro			
Silliman University Elementary School	Daro			
Silliman University High School	Daro			
Amador Dagudag Elementary School	Looc	Low	Medium	Medium
Silliman University Campus	Looc			
Silliman University Elementary School	Looc			
Silliman University High School	Looc			
World Maritime Academy	Looc	Low	Low	Medium
Negros Oriental High School	Motong			
Southdale Integrated School	Motong			
Collegio de Santa Catalina de Alejandria	Poblacion No. 3			
City Central Elementary School	Poblacion No. 4		Low	Low

Negros Oriental				
Dumaguete City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Dumaguete Chunghua School	Poblacion No. 5			
Silliman University Campus	Poblacion No. 5			
Collegio de Santa Catalina de Alejandria	Poblacion No. 6			
Learning Ladder	Pulantubig			
Metro Dumaguete College	Pulantubig			
North City Elementary School	Pulantubig		Low	Low
Ramon Magsaysay Elementary School	Pulantubig		Low	Low
Ramon Teves Pastor Memerial - Dumaguete Science High School	Pulantubig		Low	Low
Asian College of Science and Technology	Taclobo			
Chapel House	Taclobo	Low	Low	Low
Dumaguete Mission School	Taclobo	Low	Medium	Medium
Foundation University Main Campus	Taclobo			
Foundation University North Campus	Taclobo			Low
Negros Oriental High School	Taclobo			
Negros Oriental State University	Taclobo			
West City Elementary School	Taclobo			Low

Table A-12.2. Educational Institutions Sibulan, Negros Oriental affected by flooding in Ocoy Floodplain

Negros Oriental				
Sibulan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Silliman Univeristy Marine Mammal Museum	Agan-An			
Silliman University College of Agriculture	Agan-An			
Silliman University Marine Laboratory	Agan-An	Low	Low	Medium
St. Joseph Seminary College	Agan-An			
Boloc-Boloc Elementary School	Bolocboloc			
Boloc-Boloc High School	Bolocboloc			
Negros Maritime College Foundation	Bolocboloc	Low	Low	Medium
St. Paul University	Bolocboloc			Low

Negros Oriental				
Sibulan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Calabnugan Elementary School	Calabnugan			
Magatas Elementary School	Calabnugan			Low
Cangmating Elementary School	Cangmating			
Maslog High School	Cangmating			
Looc Elementary School	Looc			
Sibulan Science High School	Magatas			Low
Maschil Elementary School, Incorporated	Poblacion			
Sibulan Central Elementary School	Poblacion	Low	Low	Low
Sibulan High School	Poblacion			
Tubtubon Elementary School	Poblacion			Low
Maslog Elementary School	Tubtubon			

Table A-12.3. Educational Institutions in Valencia, Negros Oriental affected by flooding in Ocoy Floodplain

Negros Oriental				
Valencia				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Palinpinon Elementary School	Balili			
Palinpinon Elementary School	Palinpinon			

Annex 13. Health Institutions affected by flooding in Ocoy Floodplain

Table A-13.1. Health Institutions in Dumaguete City, Negros Oriental affected by flooding in Ocoy Floodplain

Negros Oriental				
Dumaguete City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Silliman University Medical Center	Daro		Low	Low
Holy Child Hospital	Poblacion No. 3			
City Medical Center	Poblacion No. 4			
Holy Child Hospital	Poblacion No. 6			
Negros Oriental Provincial Hospital	Pulantubig		Low	Low

Table A-13.2. Health Institutions in Sibulan, Negros Oriental affected by flooding in Ocoy Floodplain

Negros Oriental				
Sibulan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Cangmating Barangay Health Station	Cangmating			

Table A-13.3. Health Institutions in Valencia, Negros Oriental affected by flooding in Ocoy Floodplain

Negros Oriental				
Valencia				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Palinpinon Health Center	Balili			