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

LiDAR Surveys and Flood Mapping of Dapitan River

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND DAPITAN RIVER

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Mindanao State University-Iligan Institute of Technology (MSU-IIT). MSU-IIT 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 16 river basins in the Northern Mindanao Region. The university is located in Iligan City in the province of Lanao Del Norte.

1.2 Overview of the Dapitan River Basin

Dapitan river basin is located in the Northwestern coast of the island of Mindanao, province of Zamboanga del Norte, Region IX. The city's topography is described as hilly and mountainous with level to rolling. There are some hilly terrains along the northern coastlines but the coastal areas are generally plain. The climate of Dapitan is characterized by rainfall more or less regularly distributed throughout the year. The delineated Dapitan river basin traverses through Dapitan and Oroquieta cities and the municipalities of Sibutad, Rizal, Sapang Dalaga, Concepcion, La Libertad and Don Victoriano Chiongban. The main river used in delineating the basin is Dapitan River which traverses mainly within Dapitan City. The outlet of the basin, where flow measurements were obtained, is located at Ilaya Bridge, Dapitan City.

Dapitan river basin has an estimated drainage area of 363.93 square kilometres. The floodplain area delineated within the basin has an area of 208.9 square kilometres, which is 50.20% of the whole area of the basin. The municipalities of Sibutad, La Libertad and Rizal; and Dapitan City are found within the floodplain. A total of 23,738 building features were extracted within the floodplain which belongs to the municipalities and cities within the flood prone area.

It was reported on February 9, 2012 by Minda News that 13 barangays in Dapitan City were affected Thursday with no sign of the flood water receding. According to the city's councilor Apple Marie Agolong the flood was caused by continuous heavy rains which started Wednesday night until 10:00am Thursday. The councilor also said that the roads were impassable except for the big vehicles, some areas were described as neck-deep while other areas were up to eight feet high. When flooding like this occurs to Dapitan City, local residents affected by the flood can't help but worry if the water would not recede quickly because it's going to be hightide at midnight, it will only worsen the current flood situation. The affected barangays are Barcelona, Ba-ao, Burgos, Dampalan, Diwa-an, Ilaya, Masidlakon, Oyan, Opao, Potungan, Polo, Sulangon and Tamion. As of the time the article was published in www.mindanews.com, casualties and extent of damage property were still unknown. Because of this heavy rains, not only Dapitan city was affected but also the neighboring municipality, Sapang Dalaga in Misamis Occidental, which experienced landslide that caused delay among those who were travelling. Lastly, vehicles bound for the cities of Dipolog and Dapitan were stranded as flood waters blocked the main roads and highways.

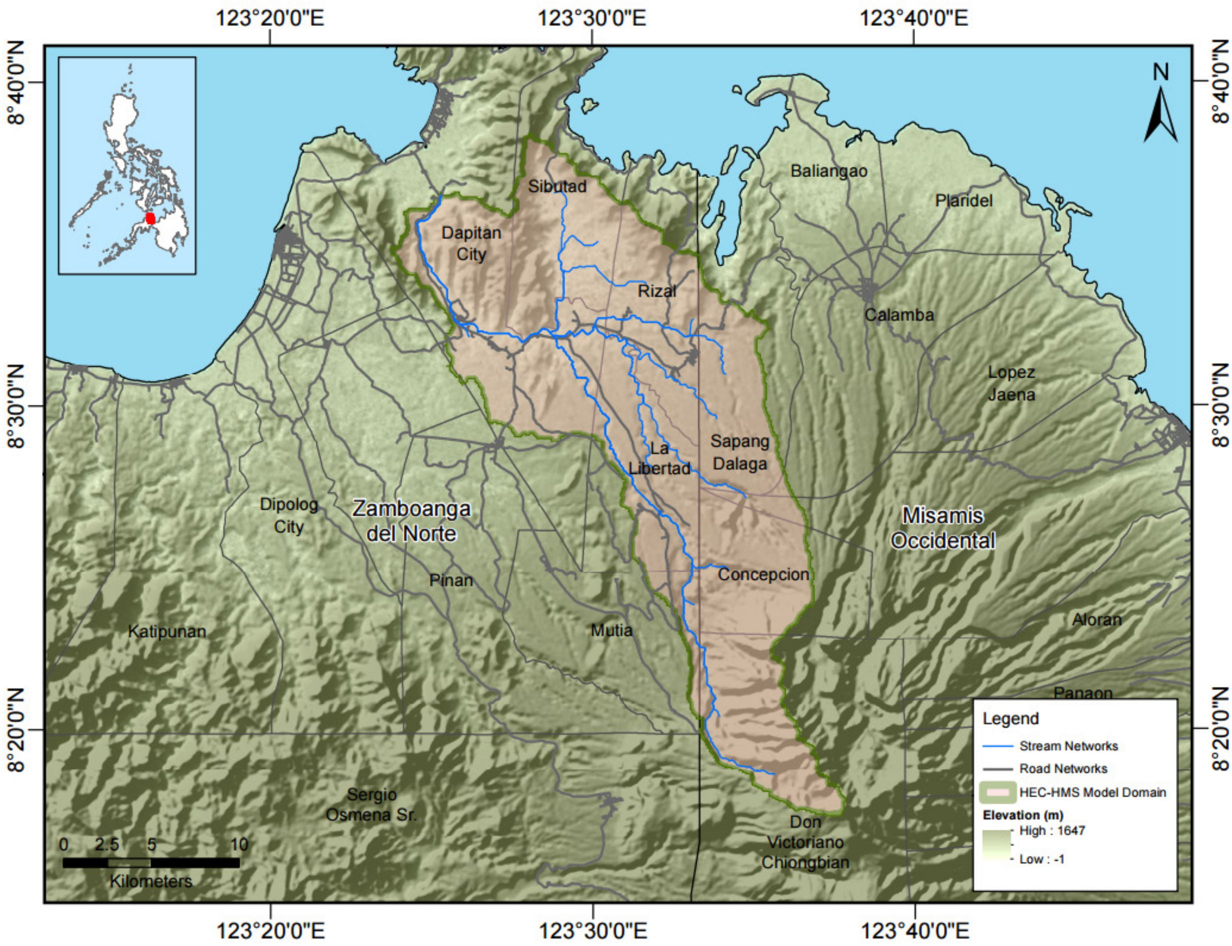

Figure 1. Map of the Dapitan River Basin (in brown)

Rappler also reported on the same flood incident that happened in Dapitan city. Moreover, Rappler released the partial reports: nearly 311 families or 780 persons were affected by the flooding incident and thus damaging about 120 houses. DOH's Health Emergency Managemnt Staff (HEMS) deployed a rescue team that saved at least 7 families from Barangay Sulangon. Evacuation centers were in San Pedro Elementary School, Dapitan Cultural Center and Department of Social Welfare and Development shelter in Brgy. Antipolo. It was also reported that the Philippine Red Cross (PRC) deployed 2 emergency response teams and ambulance and a rubber boat were directed to the affected areas. There were a total of 57 families or 228 persons that sought refuge in the evacuation centers.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE DAPITAN 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 Dapitan floodplain in Zamboanga del Norte. 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 is found in Table 1. Figure 2 shows the flight plans for Dapitan Floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR System.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK69A	700/1000	30	50	200	30	130	5
BLK69B	750/800/ 1000	30	50	200	30	130	5
BLK69C	750/800/ 1000	30	50	200	30	130	5
BLK69D	700/ 800/1000	30	50	200	30	130	5
BLK69BC	1000	30	50	200	30	130	5

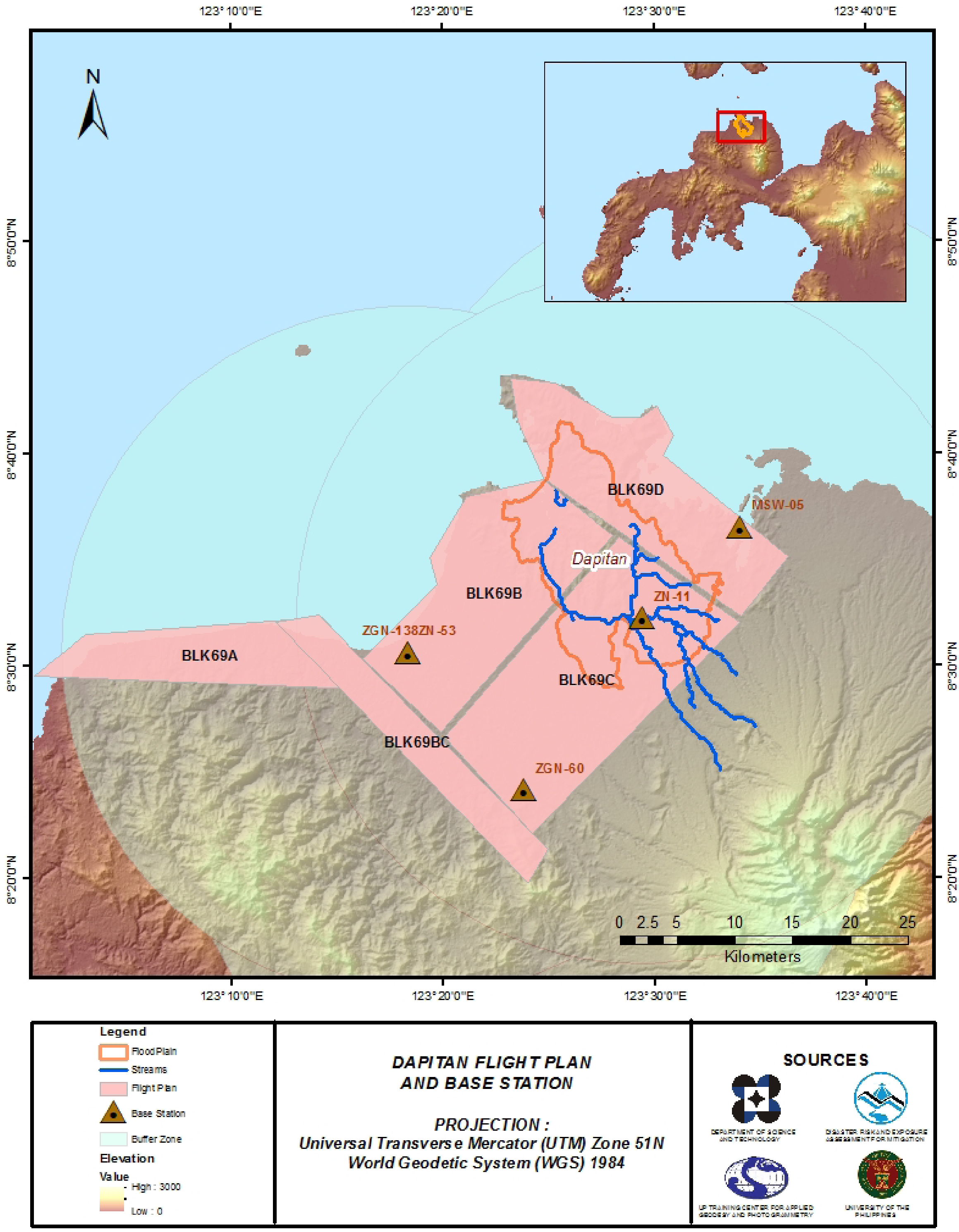


Figure 2. Flight plan and base stations used for Labason Floodplain.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: ZGN-138 , ZGN-60 and MSW-05 which are of second (2nd) order accuracy and two (2) bench markpoints: ZN-53 and ZN-11. The certifications for the NAMRIA reference points and processing report for the established points are found in Annex B. These were used as base stations during flight operations for the entire duration of the survey (October22-November 31, 2014; February 4-March 4, 2016; November 18- December 2, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 852, SPS 985 and Topcon GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Dapitan floodplain are also shown in Figure 1.

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

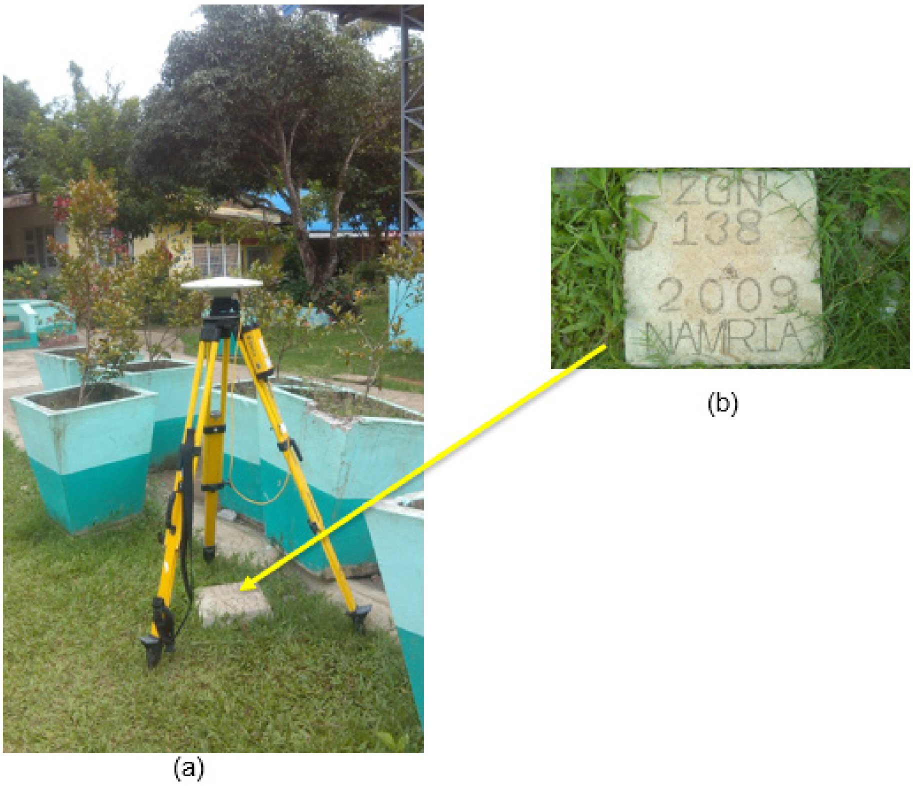


Figure 3. GPS set-up overZGN-138(a) in Katipinan Zamboanga del Norte and NAMRIA reference point ZGN-138 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGN-138 used as base station for the LiDAR Acquisition.

Station Name	ZGN-138	
Order of Accuracy	2^{rd}	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 30’ 40.65974”North
	Longitude	122° 18’ 14.44217”East
	Ellipsoidal Height	6.715 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	533471.036 meters
	Northing	941106.14 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 30’ 36.94779” North
	Longitude	123° 18’ 19.85548”East
	Ellipsoidal Height	70.925 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	533459.32 meters
	Northing	940776.74 meters

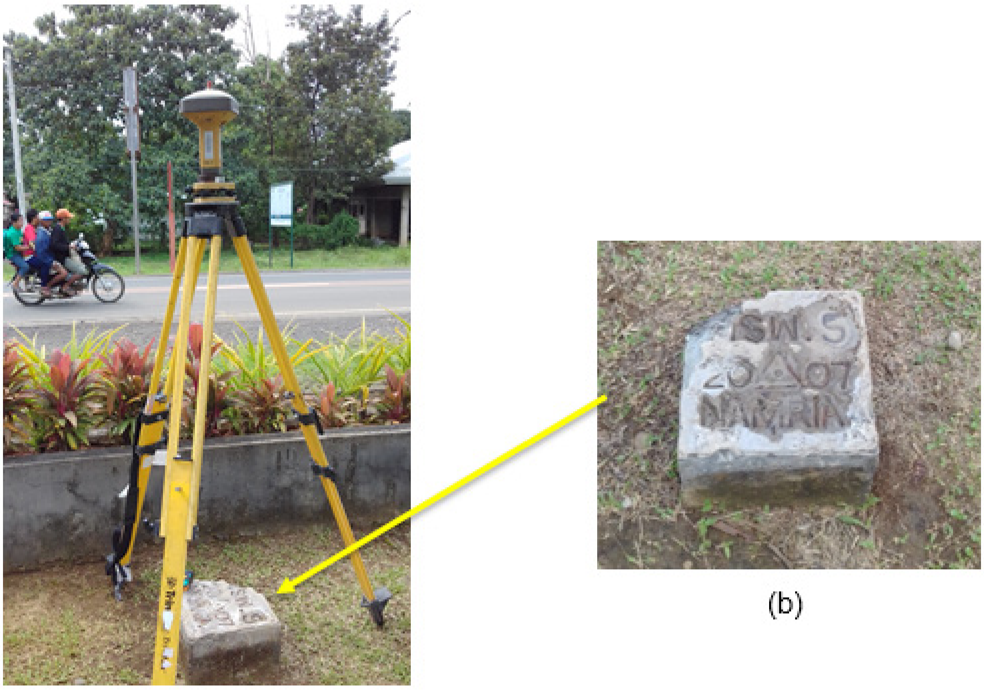
(a)

(b)

Figure 4. GPS set-up over ZGN-60(a) in Layawan Bridge, Brgy. San Pedro, Polanco, Zamboanga del Norte and NAMRIA reference point ZGN-60(b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGN-60 used as base station for the LiDAR Acquisition.

Station Name	ZGN-60	
Order of Accuracy	2^{rd}	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 24’ 13.24705”North
	Longitude	123° 23’ 43.64096”East
	Ellipsoidal Height	78.371meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting	543551.053 meters
	Northing	29214.294meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 24’ 9.57149” North
	Longitude	123° 23’ 49.06324”East
	Ellipsoidal Height	143.029meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	543535.81meters
	Northing	928889.05meters

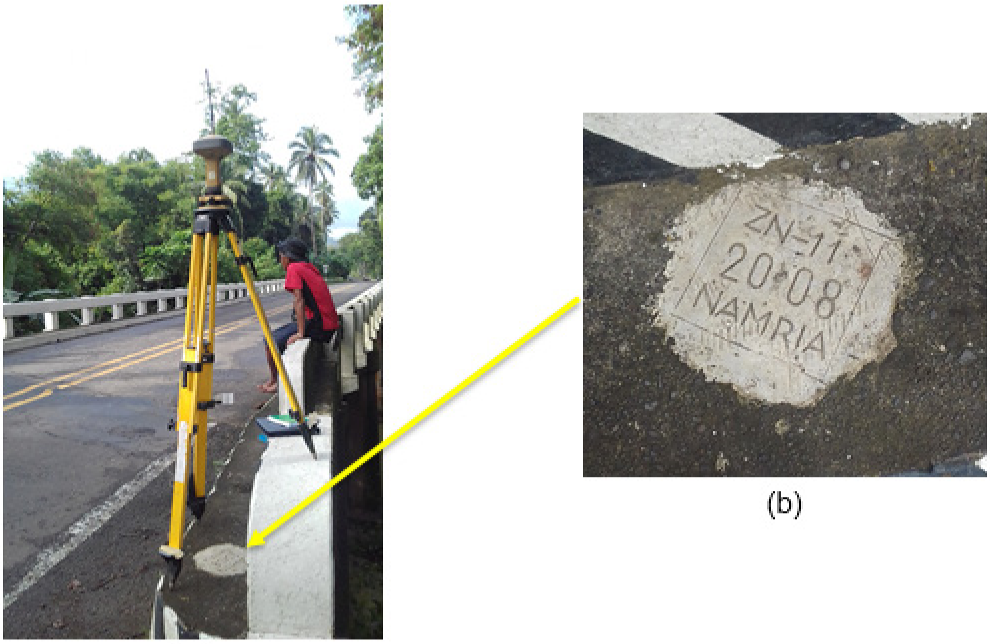


(a) (b)

Figure 5. GPS set-up overMSW-05 (a) in Sapang Dalaga, Misamis Occidental and NAMRIA reference point MSW-05 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MSW-05 used as base station for the LiDAR Acquisition.

Station Name	MSW-05	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	8° 32’ 35.68185”North
	Longitude	123° 33’ 56.01853”East
	Ellipsoidal Height	113.481meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting	562262.537 meters
	Northing	944671.948meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 32’ 31.98501” North
	Longitude	123° 34’ 1.42685”East
	Ellipsoidal Height	178.247meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	562240.75meters
	Northing	944341.30meters



(a) (b)

Figure 6. GPS set-up over ZN-11 at Potungan Bridge, Dapitan, Zamboanga del Norte (a) reference point ZN-11 (b) as established by the field team.

Table 5. Details of the established pointZN- 11 used as base station for the LiDAR Acquisition.

Station Name	ZN-11	
Order of Accuracy (benchmark)	2^{nd}	
Elevation (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°32’19.31150”North 123°29’19.41683”East 21.953meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°32’15.60892” North 123°29’24.82623”East 86.565meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	553,785.501meters 943,827.025meters

(a) (b)

Figure 7. GPS set-up over ZN-53 at Brgy. Daanglungsod, Katipunan, Zamboanga del Norte (a) reference point ZN-53 (b) as established by the field team.

Table 6. Details of the established point ZN- 53 used as base station for the LiDAR Acquisition.

Station Name	ZN-53	
Order of Accuracy (benchmark)	2nd	
Elevation (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°30'41.04428"North 123°18'14.33457"East 7.072 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°30'37.33230" North 123°18'19.74787"East 71.282 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	533456.022 meters 940788.542 meters

Table 7. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
October 22, 2014	2111P	1BLK69B295A	ZGN-138 and ZN-53
October 23, 2014	2113P	1BLK69B296A	ZGN-138 and ZN-53
October 23, 2014	2115P	1BLK69DBA296B	ZGN-138 and ZN-53
October 26, 2014	2125P	1BLK69C299A	ZGN-138 and ZN-53
October 31, 2014	2145P	1BLk69C304A	ZGN-138 and ZN-53
February 21, 2016	23120P	1BLK69D052A	ZGN-60
February 22, 2016	23124P	1BLK69AB053A	ZGN-60
November 20, 2016	23558P	1BLK69BC325A	MSW-05 and ZN-11
November 21, 2016	23562P	1BLK69BD326A	MSW-05 and ZN-11
November 24, 2016	23574P	1BLK69AD329A	MSW-05 and ZN-11

2.3 Flight Missions

Ten (10) missions were conducted to complete LiDAR data acquisition in Dapitan Floodplain, for a total of 37 hours and 15 minutes (37+15) of flying time for RP-C9022. All missions were acquired using the Pegasus system. Table 8 shows the total area of actual coverage per mission and the flying hours per mission and Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Dapitan floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
October 22, 2014	2111P	219.61	177.11	58.92	118.19	578	4	05
October 23, 2014	2113P	196.35	164.11	10.9	153.21	514	3	35
October 23, 2014	2115P	196.36	72.76	16.29	56.47	224	1	59
October 26, 2014	2125P	291.99	106.67	32.26	74.41	475	2	05
October 31, 2014	2145P	177.10	154.73	60.60	94.13	675	3	17
February 21, 2016	23120P	227.63	167.99	18.59	149.4	392	4	30
February 22, 2016	23124P	123.34	124.91	29.23	95.68	NA	4	35
November 20, 2016	23558P	163.59	142.50	45.84	96.66	NA	4	29
November 21, 2016	23562P	152.77	193.37	37.65	155.72	NA	4	29
November 24, 2016	23574P	316.13	149.32	77.37	71.95	NA	4	11
TOTAL		2064.87	1453.47	387.65	1065.82	2858	37	15

Table 9. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2111P	1000	30	50	200	30	130	5
2113P	1000	30	50	200	30	130	5
2115P	800/ 1000	30	50	200	30	130	5
2125P	800	30	50	200	30	130	5
2145P	750	30	50	200	30	130	5
23120P	1000	30	50	200	30	130	5
23124P	1000	30	50	200	30	130	5
23558P	800	30	50	200	30	130	5
23562P	800	30	50	200	30	130	5
23574P	700/ 1000	30	50	200	30	130	5

2.4 Survey Coverage

Dapitan Floodplain is located in the province of Zamboanga del Norte with the floodplain situated within the municipalities of Dapitan City, La Libertad, Pinan, Polanco, Rizal and Sibutad. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Dapitan floodplain is presented in Figure 8.

Table 10. List of municipalities and cities surveyed in Dapitan floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed =(Total Area covered/ Area of Municipality)*100
Misasmis Occidental	Baliangao	58.16	4.13	7%
	Sapang Dalaga	85.68	27.34	32%
Zamboanga del Norte	Dapitan City	222.95	217.66	98%
	Dipolog City	184.42	114.26	62%
	Katipunan	189.62	35.70	19%
	La Libertad	66.24	21.81	33%
	Pinan	135.87	55.07	41%
	Polanco	86.49	85.24	99%
	Pres. Manuel A. Roxas	163.60	2.68	2%
	Rizal	61.97	57.34	93%
	Sibutad	75.69	75.38	99%
Total		1330.69	696.61	52.35%

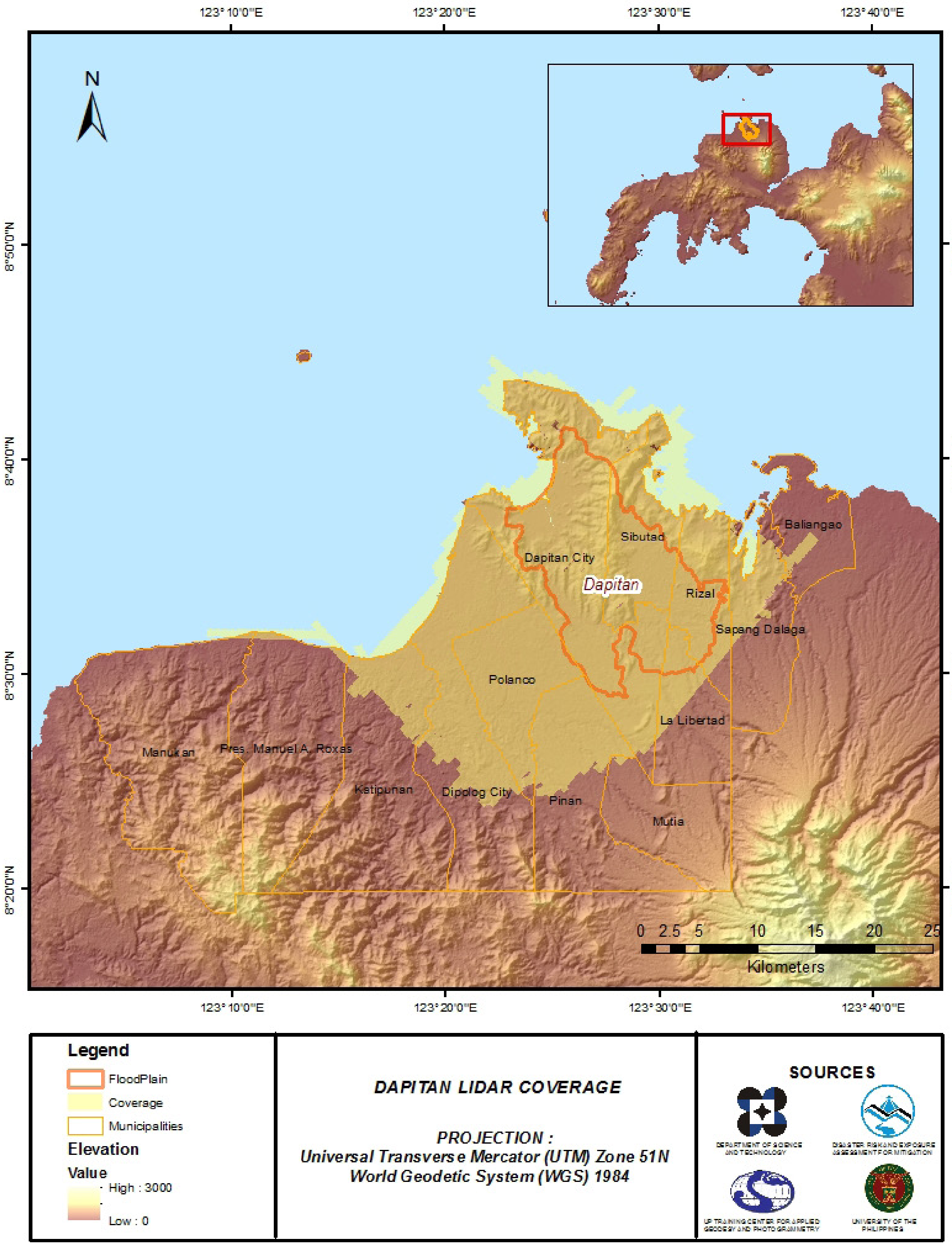


Figure 8. Actual LiDAR data acquisition for Dapitan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE DAPITAN 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

After the acquisition of LiDAR data, the latter is transmitted to the DPPC. Upon acceptance of the field data, the DPPC checks it for completeness and accuracy based on the list of raw files needed to proceed with its pre-processing. After which, the flight trajectory is georeferenced to obtain the exact location of the LiDAR sensor when the laser was shot.

Subsequently, the point cloud georectification is performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds are then subjected to a quality check to ensure that the required accuracies of the program, namely the minimum point density and vertical and horizontal accuracies, are met. These point clouds are then classified into various classes, which are integral in the generation of Digital Elevation Models (DEMs) such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

After this, the LiDAR-derived digital models are calibrated using the elevation of points gathered in the field. Parts of the river basin that were barely penetrated by the LiDAR system are then replaced by the actual river geometry measured from the field by the DVBC. Temporally acquired LiDAR data are then mosaicked to completely cover the target river systems in the Philippines. Images acquired from the field are orthorectified simultaneously with the LiDAR data through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 9.

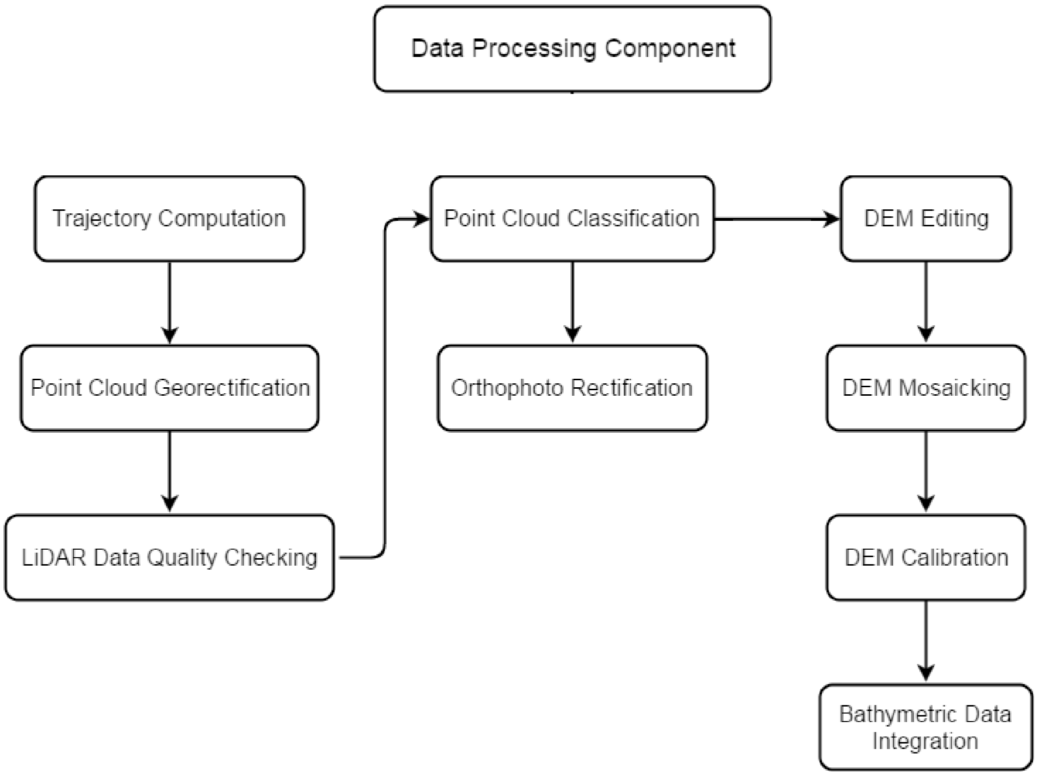


Figure 9. Schematic diagram for Data Pre-processing Component.

3.2 Transmittal of Acquired LIDAR Data

Data transfer sheets for all the LiDAR missions for Dapitan Floodplain can be found in Annex 5. Missions flown for all the surveys conducted used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Dipolog, Zamboanga del Norte and Pagadian, Zamboanga del Sur.

In total, the Data Acquisition Component (DAC) transferred 210.98 Gigabytes of Range data, 2.34 Gigabytes of POS data, 610.43 Megabytes of GPS base station data, and 182.60 Gigabytes of raw image data to the data server on October 22, 2014 for the first survey and November 24, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Dapitan was fully transferred on December 6, 2016, as indicated on the Data Transfer Sheets for Dapitan Floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 23124P, one of the Dapitan flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell onFebruary 22, 2016 00:00 AM. The y-axis, on the other hand is the RMSE value for that particular position.

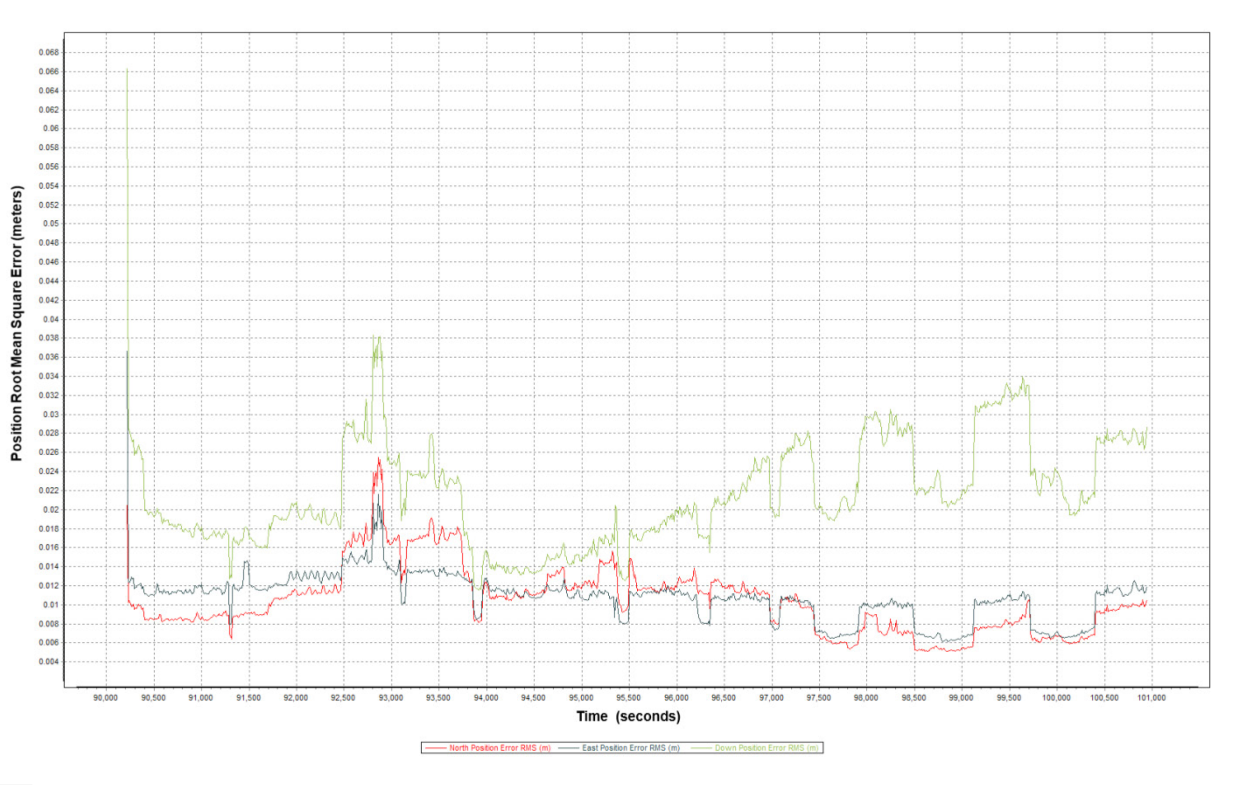


Figure 10. Smoothed Performance Metrics of Dapitan Flight 23124P.

The time of flight was from 90000 seconds to 101000 seconds, which corresponds to morning of February 22, 2016. The initial spike seen on the diagram above 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 11 shows that the North position RMSE peaks at 2.60 centimeters, the East position RMSE peaks at 2.20 centimeters, and the Down position RMSE peaks at 3.80 centimeters, which are within the prescribed accuracies described in the methodology.

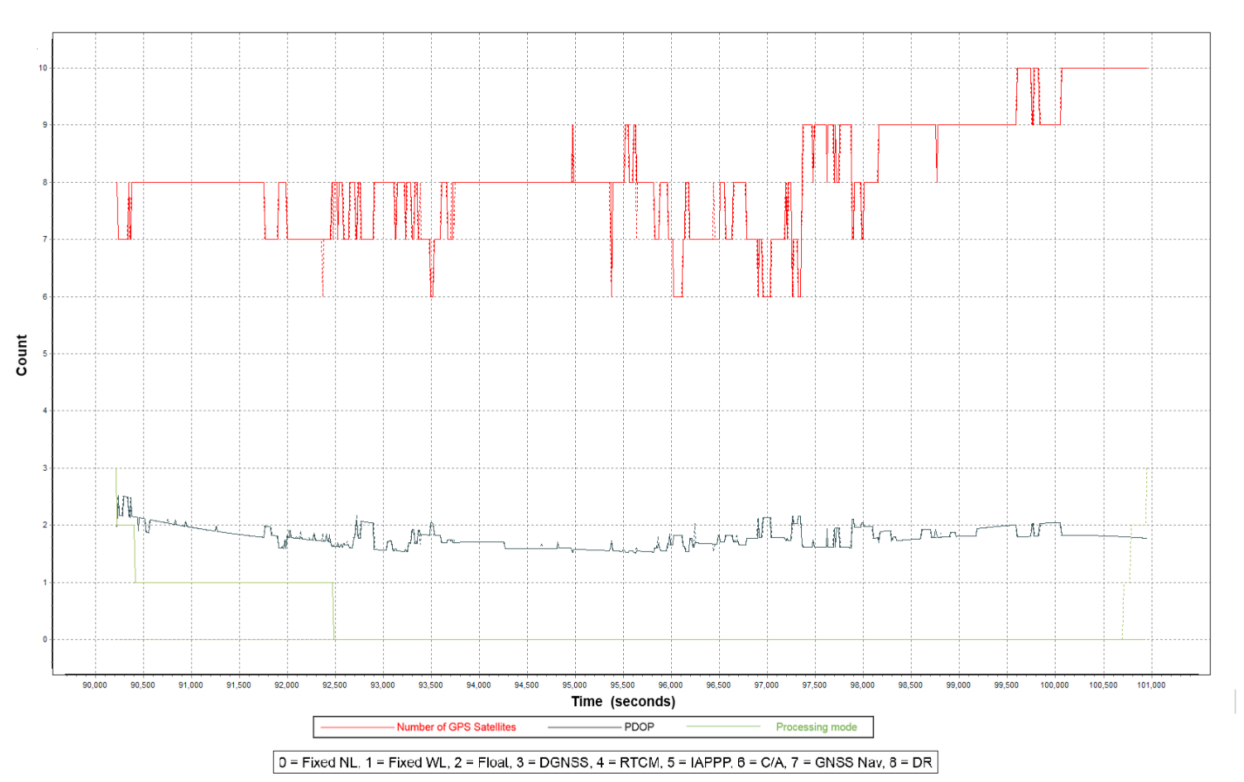


Figure 11. Solution Status Parameters of Dapitan Flight 23124P.

The S*olution Status* parameters of flight 23124P, indicating the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used, are presented in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down below 6. Most 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 remained at 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 Dapitan flights is shown in Figure 12.

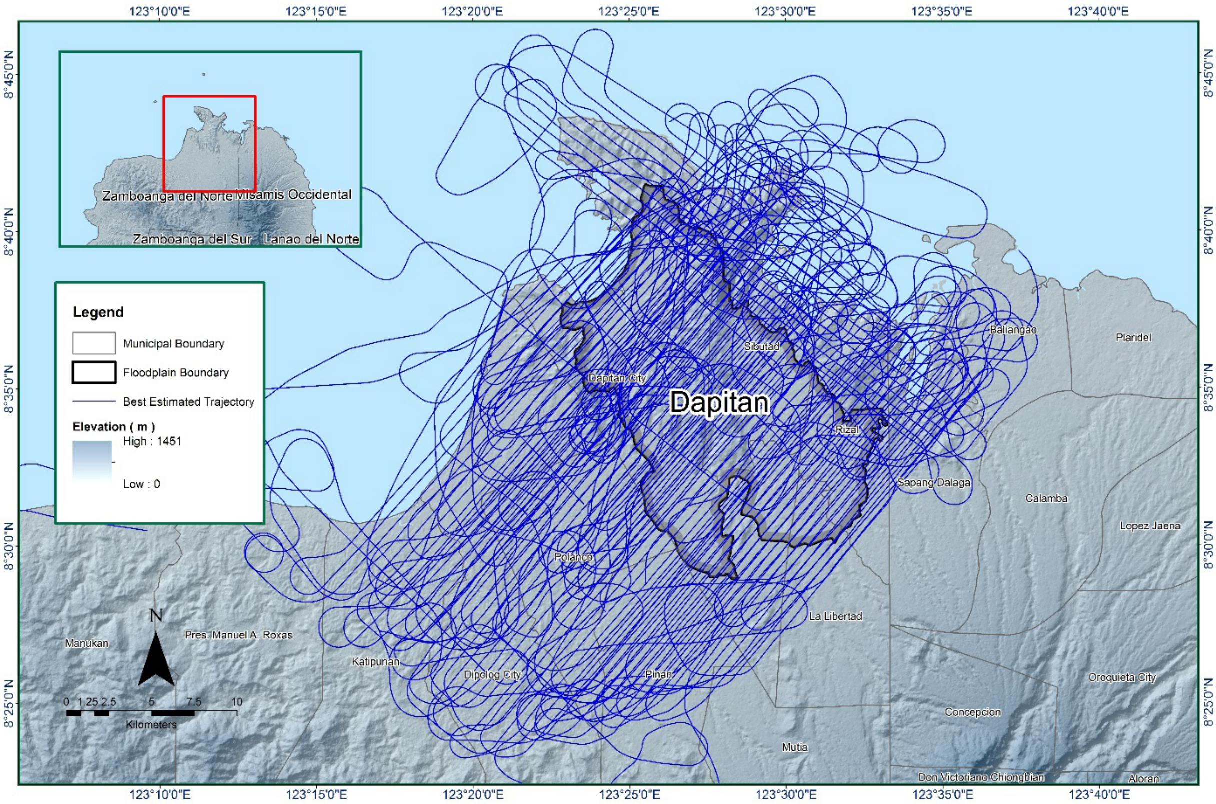


Figure 12. Best estimated trajectory for Dapitan floodplain.

3.4 LIDAR Point Cloud Computation

The data generated in LAS contains 194 flight lines, with each flight line comprised of two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Dapitan Floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Dapitan flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000371
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000999
GPS Position Z-correction stdev	(<0.01meters)	0.0067

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

3.5 LIDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

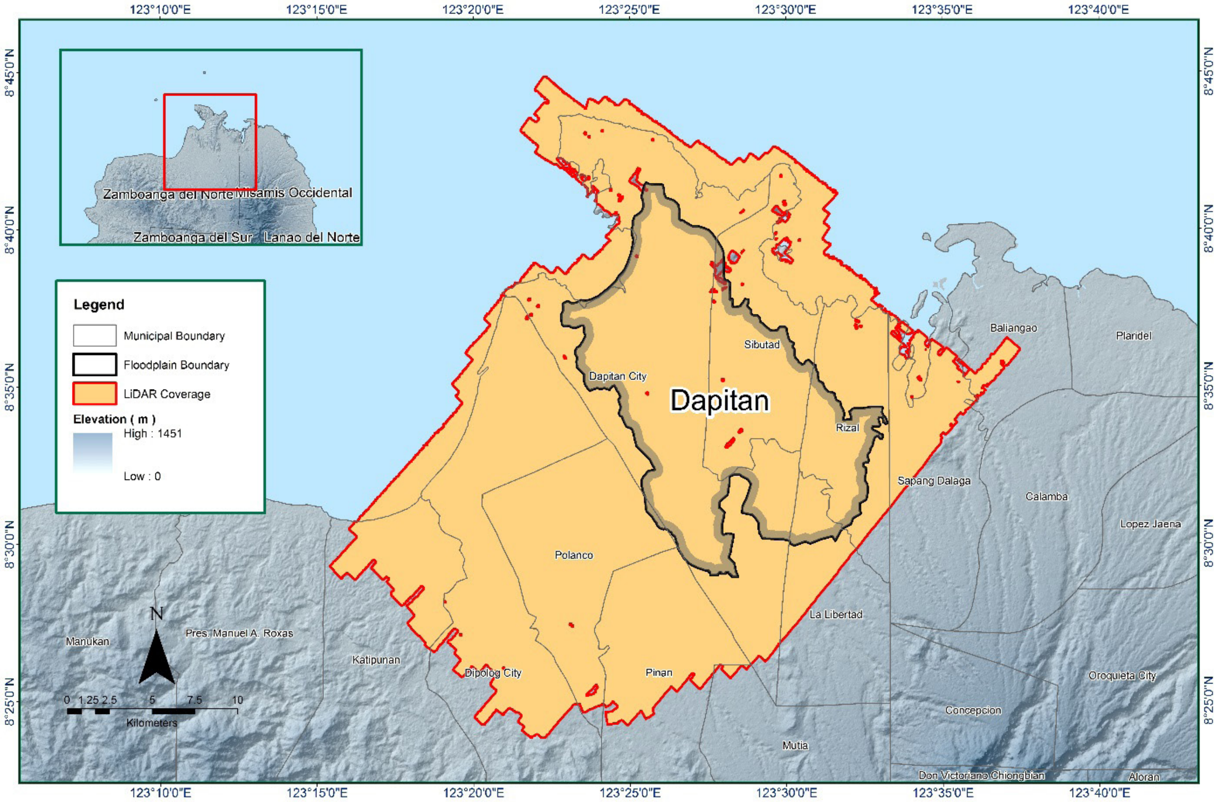


Figure 13. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Dapitan Floodplain.

The total area covered by the Dapitan missions is 1,328.95 square kilometers that is comprised of ten (10) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Dapitan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Pagadian_Blk69A	23124P	117.93
Pagadian_Blk69D	23120P	166.98
Dipolog_Blk69B	2111P	345.02
	2113P	
	2145P	
Dipolog_Blk69C	2125P	92.17
Dipolog_Blk69D	2113P	167.75
	2115P	
Dipolog_Reflights_Blk69B_supplement	23574P	57.73
Dipolog_Reflights_Blk69B	23558P	141.49
Dipolog_Reflights_Blk69D	23562P	155.81
Dipolog_Reflights_Blk69D_supplement	23574P	84.08
	TOTAL	**1,328.95 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Pegasus system employs two channels, an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

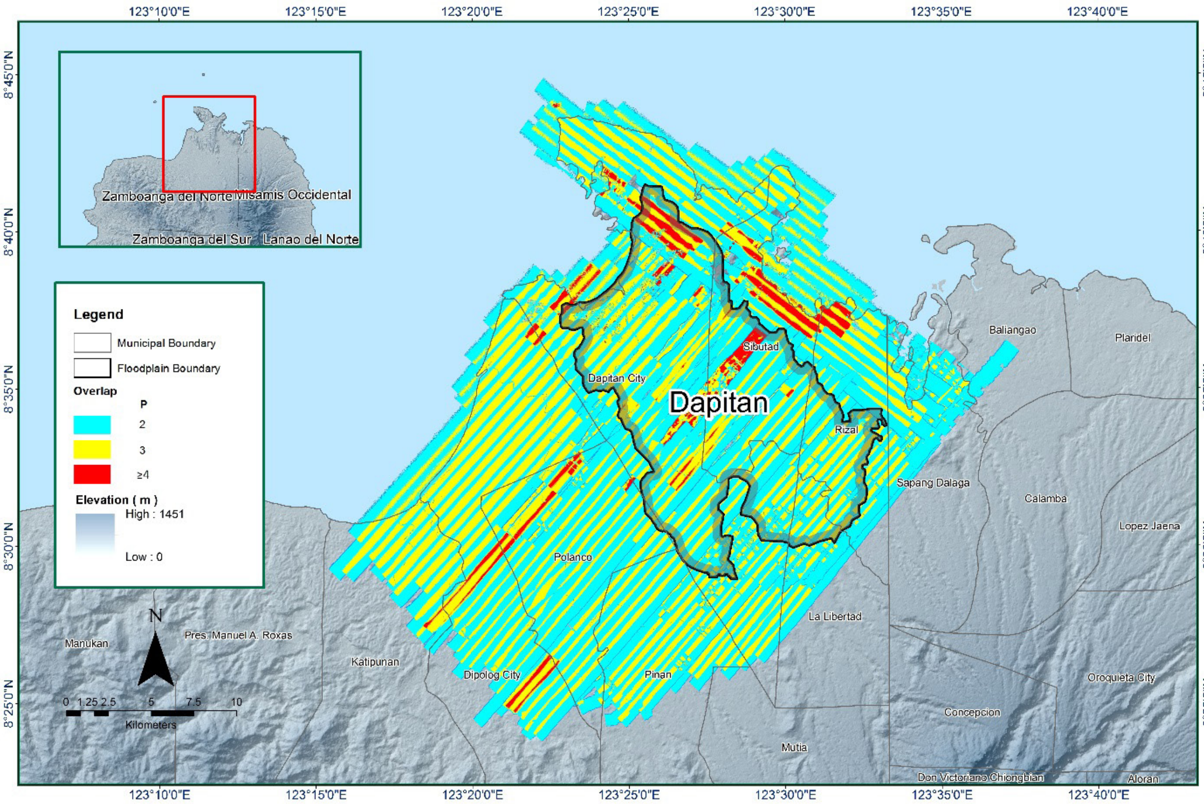


Figure 14. Image of data overlap for Dapitan Floodplain.

The overlap statistics per block for the Dapitan Floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.26% and 49.03% respectively, which passed the 25% requirement.

Figure 15 shows 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. It was determined that all LiDAR data for Dapitan Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.83 points per square meter.

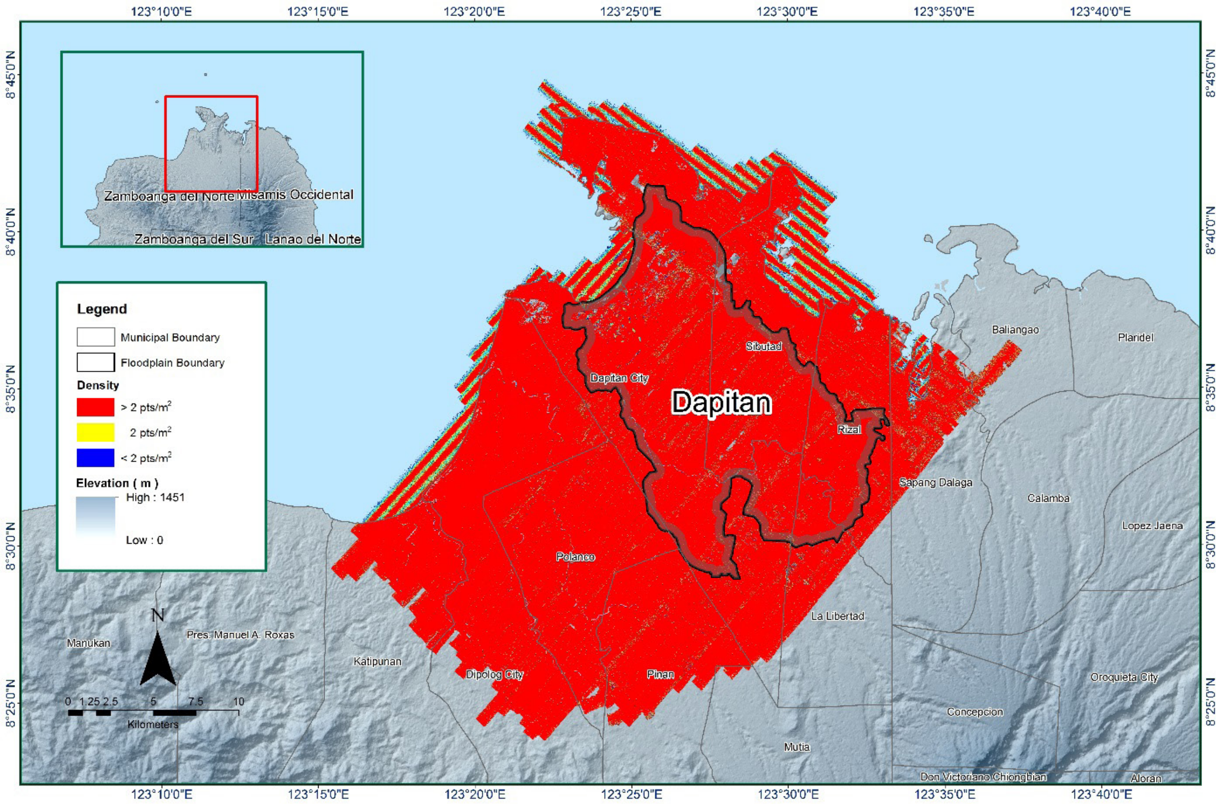


Figure 15. Pulse density map of merged LiDAR data for Dapitan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m 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.

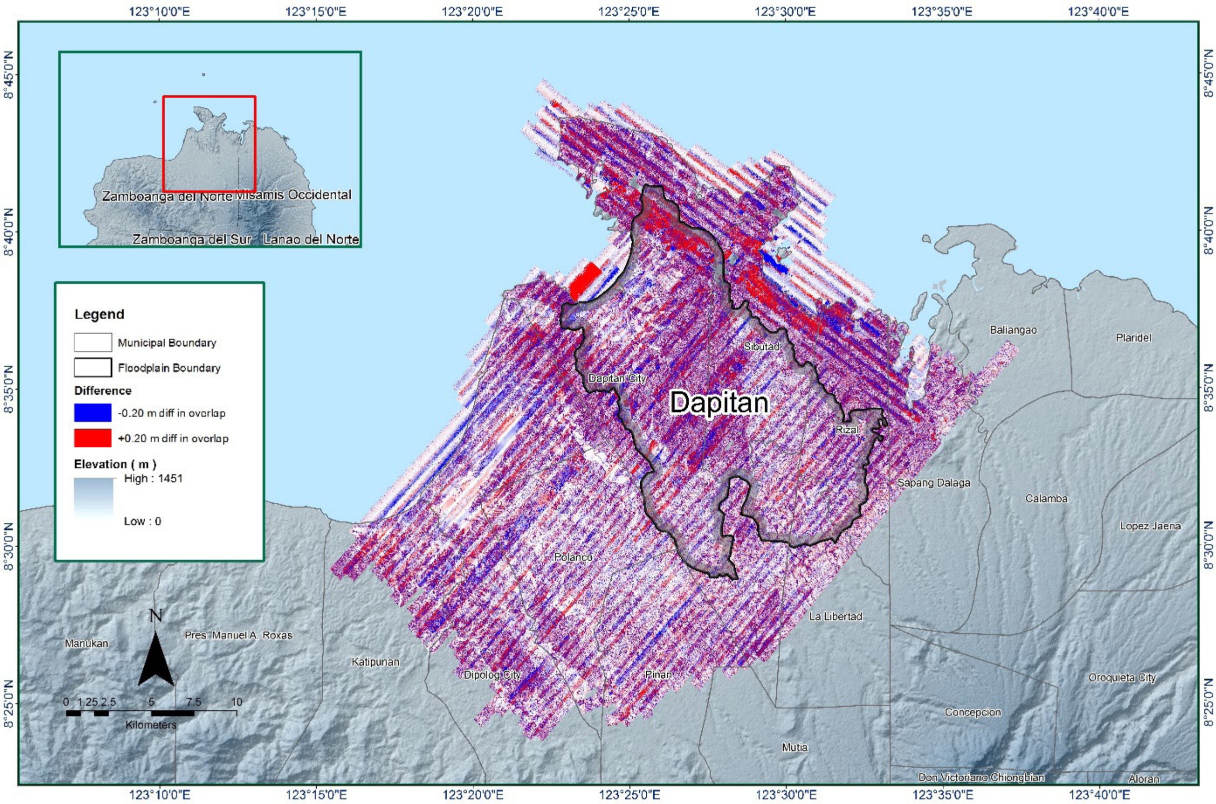


Figure 16. Elevation difference map between flight lines for Dapitan Floodplain.

Figure 17 presents a screen capture of the processed LAS data from a Dapitan flight 23124P loaded in QT Modeler. 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.

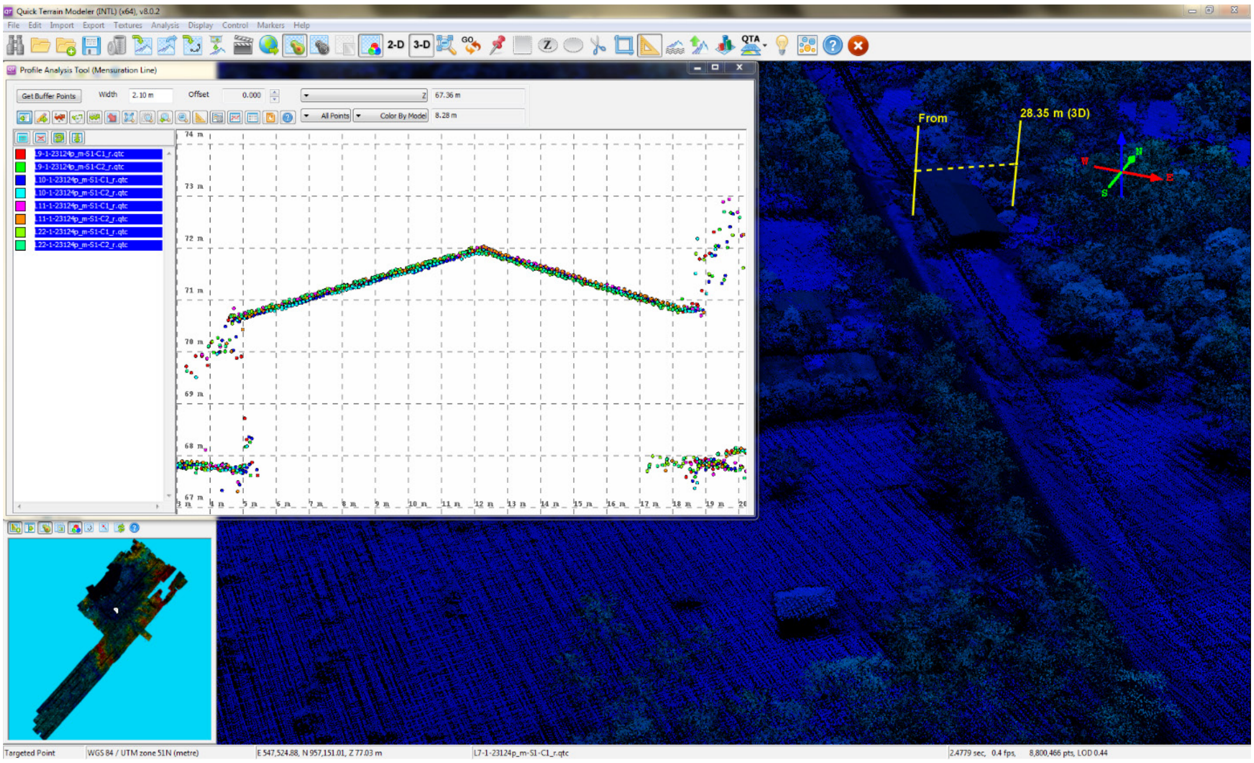


Figure 17. Quality checking for a Dapitan flight 23124P using the Profile Tool of QT Modeler.

3.6 LIDAR Point Cloud Classification and Rasterization

Table 13. Dapitan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	934,483,440
Low Vegetation	848,827,483
Medium Vegetation	1,473,853,858
High Vegetation	2,705,859,178
Building	56,476,014

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Dapitan Floodplain is shown in Figure 18. A total of 1,194 tiles with 1km X 1km were produced. Correspondingly, Table 13 shows the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 710.92 meters and 62.16 meters respectively.

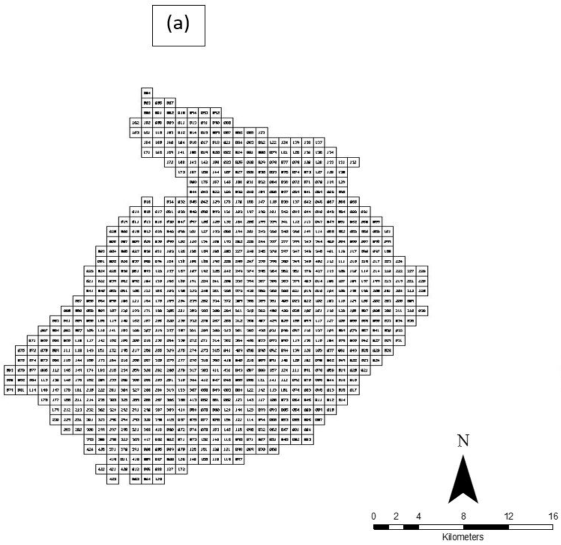


Figure 18. Tiles for Dapitan Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

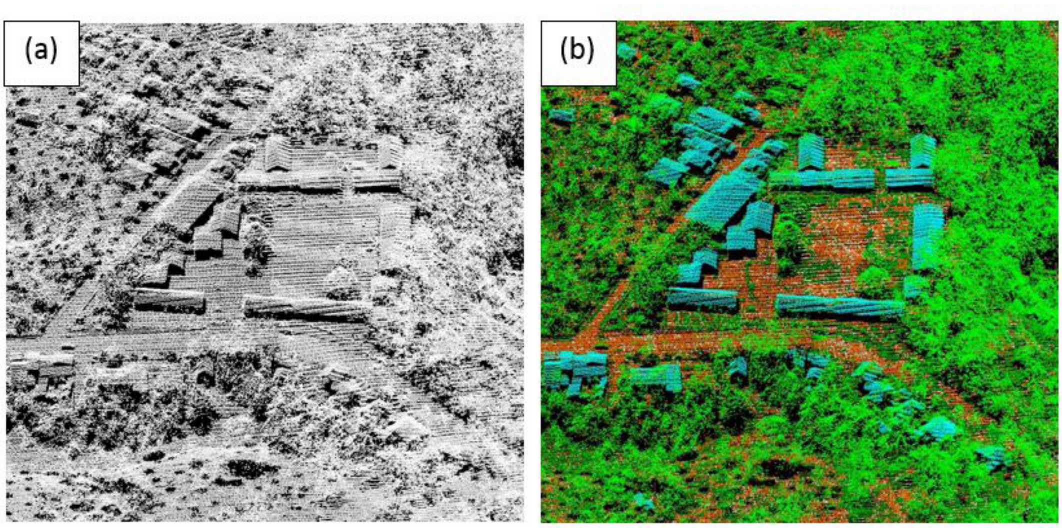


Figure 19. Point cloud before (a) and after (b) classification.

Correspondingly, Figure 20 shows the production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display. It suggests that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

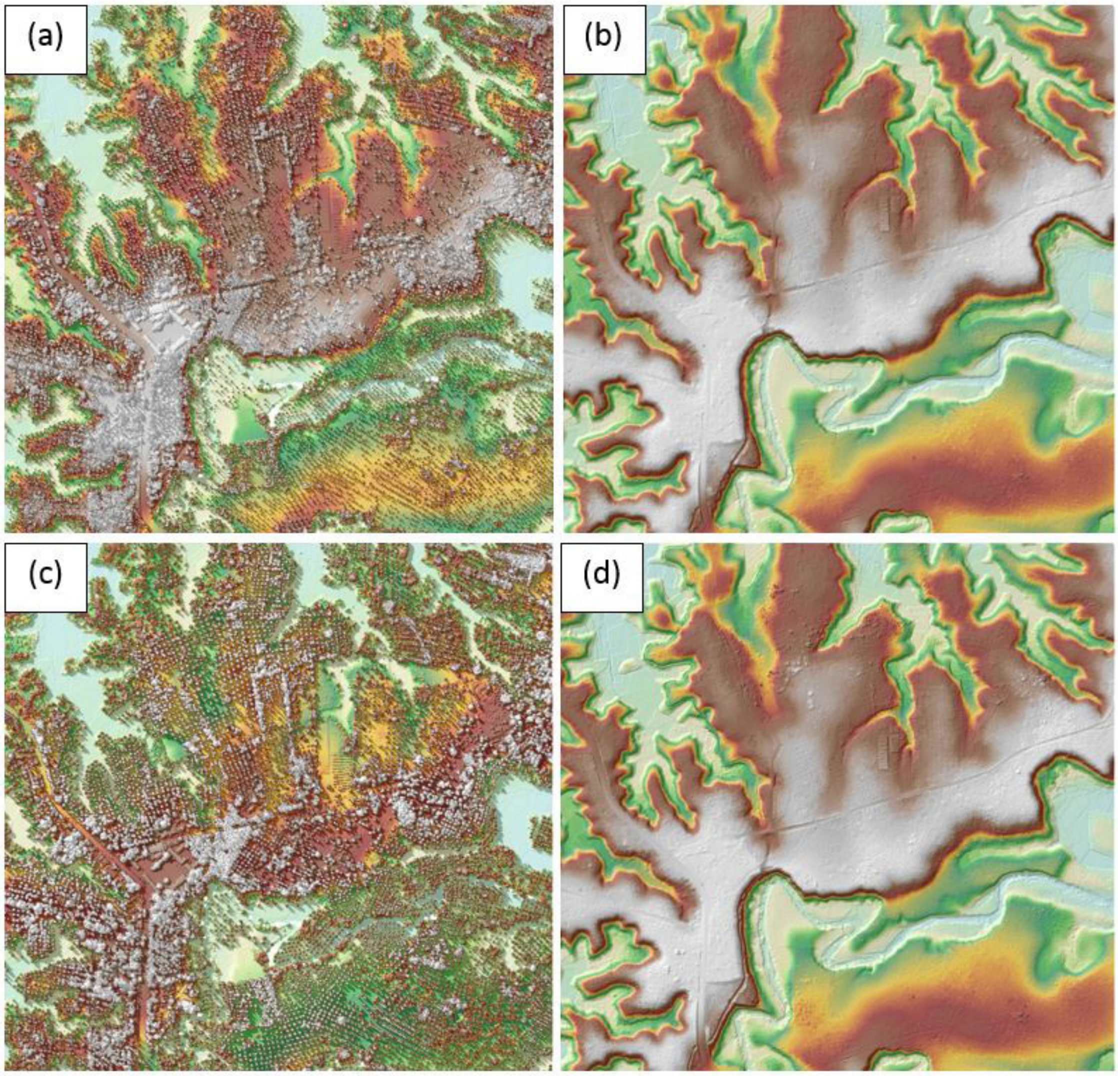


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Dapitan Floodplain.

3.7 LIDAR Image Processing and Orthophotograph Rectification

The 772 1km by 1km tiles area covered by Dapitan Floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Dapitan Floodplain has a total of 596.97 sq.km orthophotogaph coverage comprised of 2,369 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

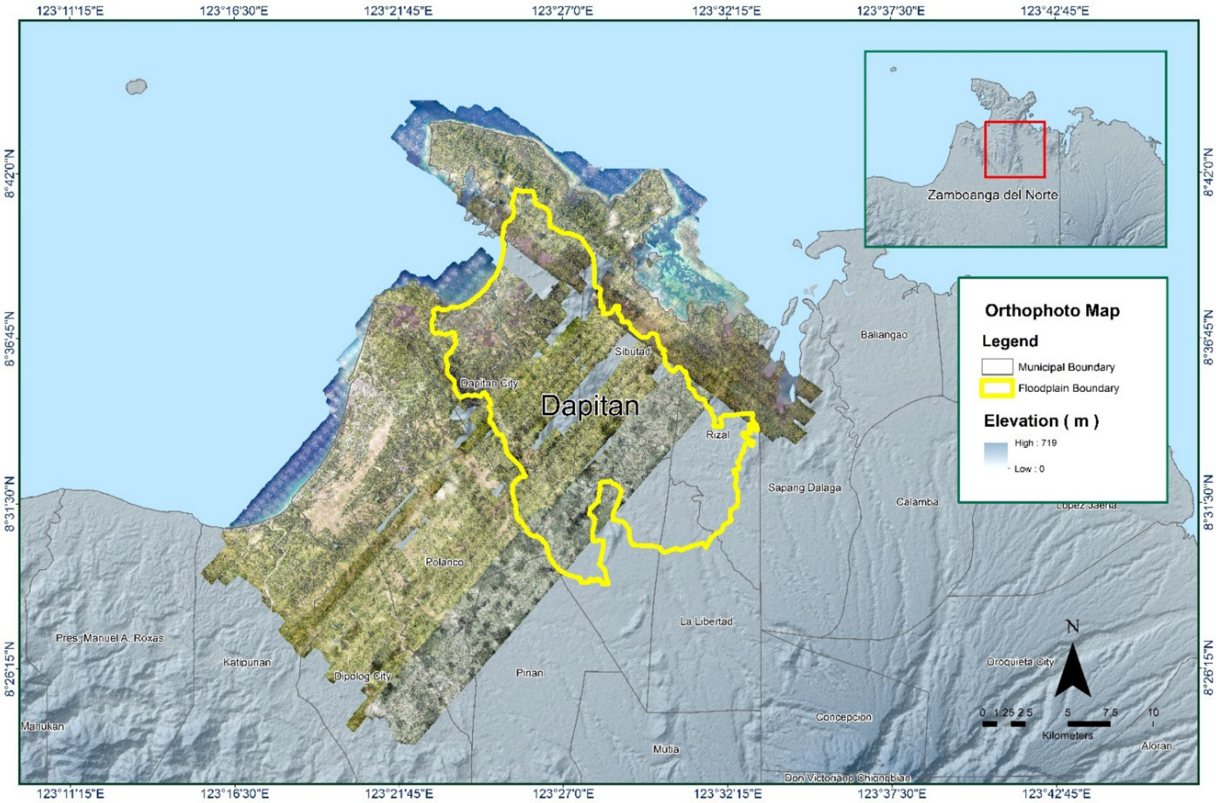


Figure 21. Dapitan floodplain with available orthophotographs.

Figure 22. Sample orthophotograph tiles for Dapitan floodplain.

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for Dapitan Floodplain. These blocks are composed of Pagadian, Dipolog and Dipolog_Reflights blocks with a total area of 1,328.95 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Pagadian_Blk69A	117.93
Pagadian_Blk69D	166.98
Dipolog_Blk69B	345.02
Dipolog_Blk69C	92.17
Dipolog_Blk69D	167.75
Dipolog_Reflights_Blk69B	141.49
Dipolog_Reflights_Blk69B_supplement	57.73
Dipolog_Reflights_Blk69D	155.81
Dipolog_Reflights_Blk69D_supplement	84.08
TOTAL	**1,328.95 sq.km**

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

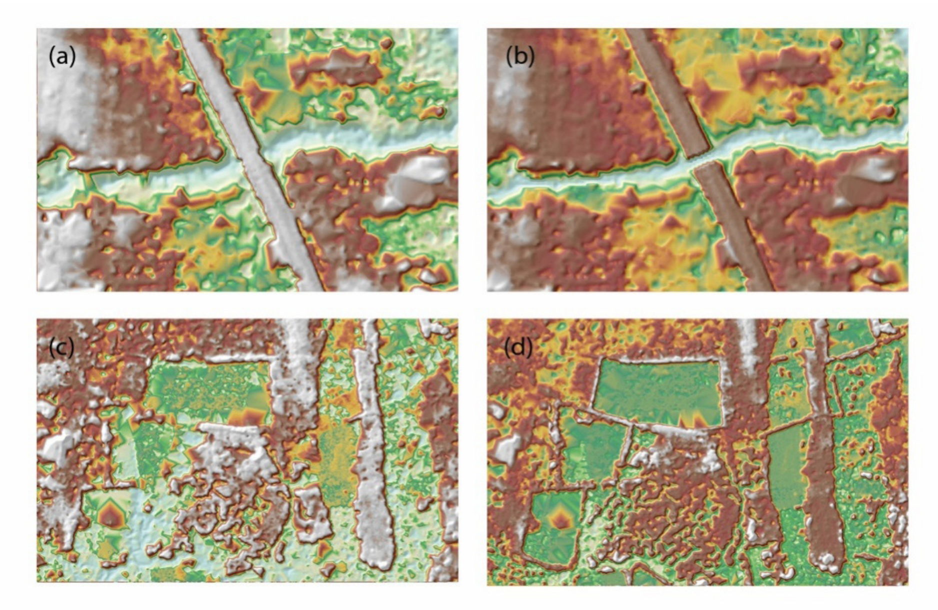


Figure 23. Portions in the DTM of Dapitan floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Dipolog_Blk69B was used as the reference block at the start of mosaicking because it comprises the largest area among the missions' blocks. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Dapitan Floodplain is shown in Figure 24. It can be seen that the entire Dapitan Floodplain is 99.58% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Dapitan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Pagadian_Blk69A	0.00	0.00	0.96
Pagadian_Blk69D	0.00	0.00	0.66
Dipolog_Blk69B	0.00	0.00	0.00
Dipolog_Blk69C	0.00	0.00	0.00
Dipolog_Blk69D	0.00	0.00	0.00
Dipolog_Reflights_Blk69B	-0.40	0.00	0.00
Dipolog_Reflights_Blk69B_supplement	-0.80	0.10	0.00
Dipolog_Reflights_Blk69D	-0.50	2.40	0.30
Dipolog_Reflights_Blk69D_supplement	0.50	-0.35	0.00

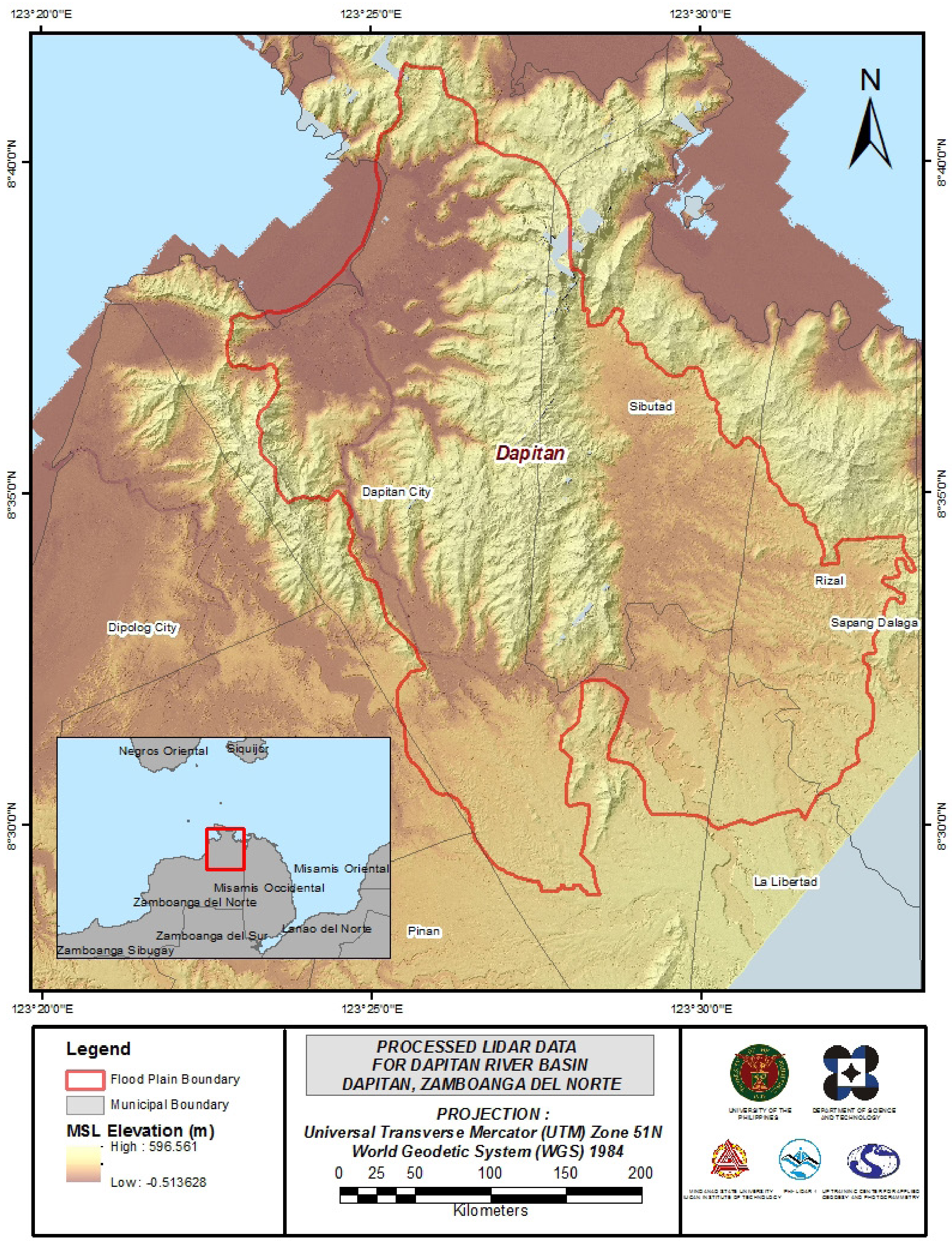


Figure 24. Map of Processed LiDAR Data for Dapitan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Dapitan to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 12,287 survey points were gathered for all the flood plains within the provinces of Zamboanga del Norte and Misamis Occidental wherein the Dapitan floodplain is located. Random selection of 80% of the survey points, resulting to 9,830 points, were used for calibration.

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 4.25 meters with a standard deviation of 0.15 meters. Calibration of the LiDAR data was done by adding the height difference value, 4.25 meters, to the mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

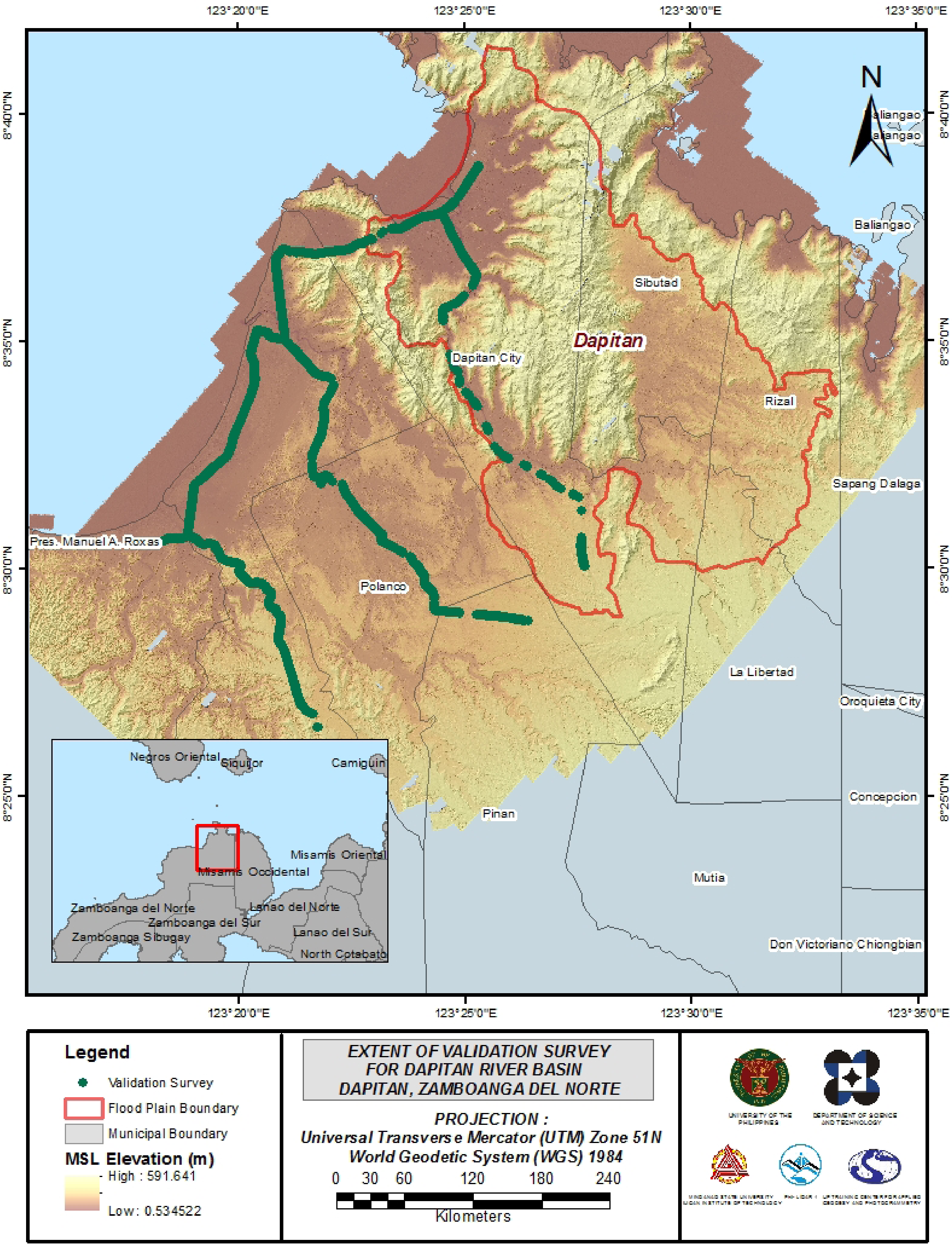


Figure 25. Map of Dapitan Floodplain with validation survey points in green.

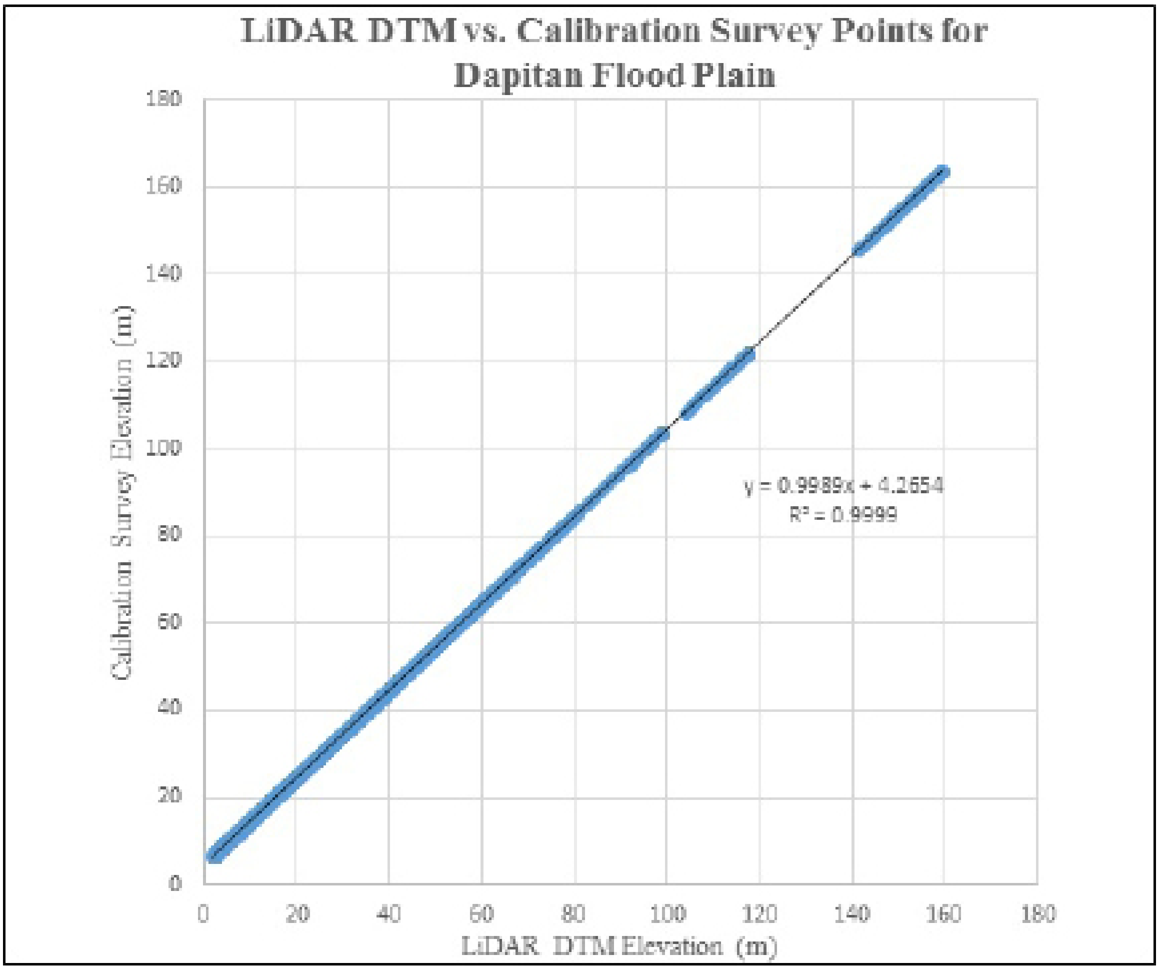


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	4.25
Standard Deviation	0.15
Average	4.25
Minimum	3.90
Maximum	4.60

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 210 points, were used for the validation of calibrated Dapitan 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 0.15 meters with a standard deviation of 0.06 meters, as shown in Table 17.

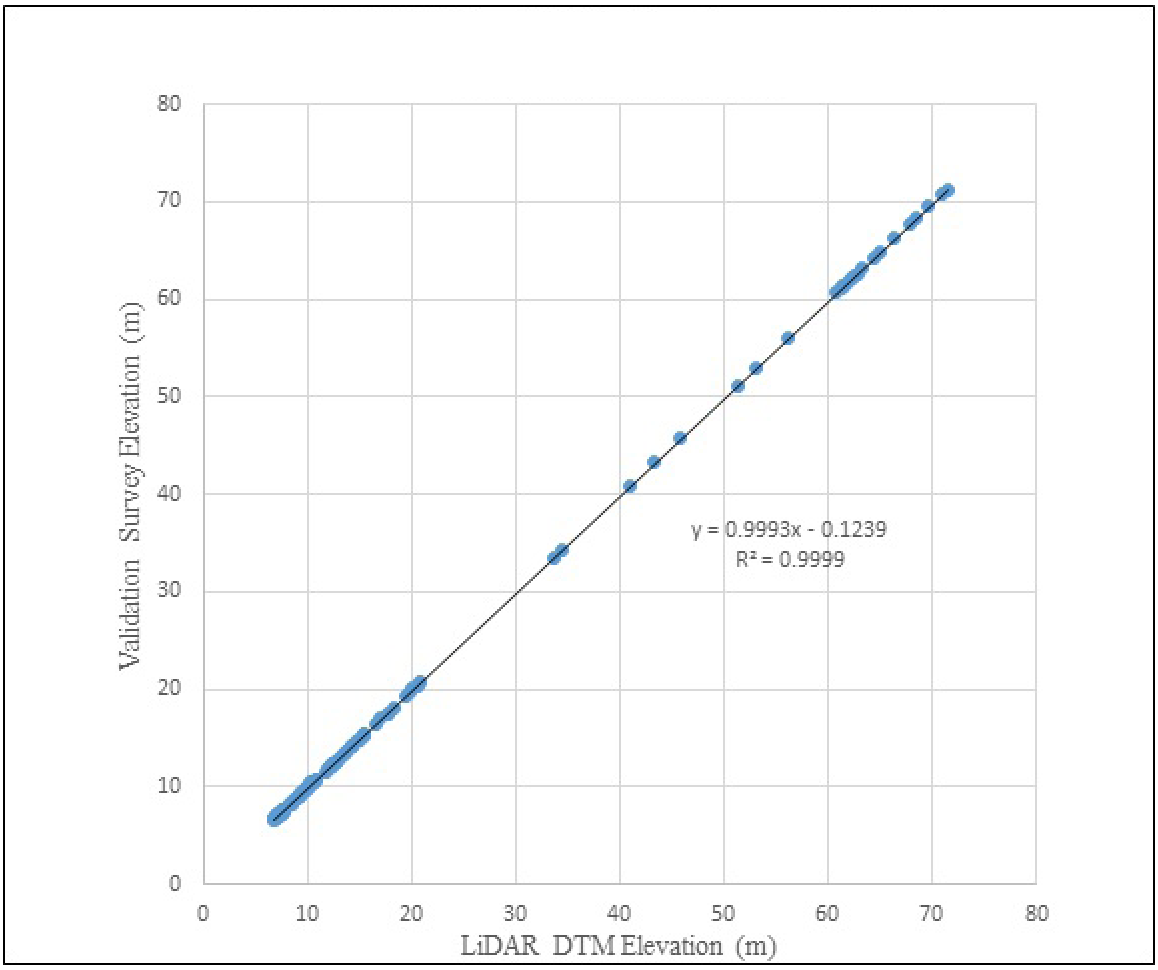


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.15
Standard Deviation	0.06
Average	-0.13
Minimum	-0.30
Maximum	0.23

3.11 Integration of Bathymetric Data into the LIDAR Digital Terrain Model

For bathy integration, only centerline and zigzag line data were available for Dapitan with 15,981 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.30 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Dapitan integrated with the processed LiDAR DEM is shown in Figure 28.

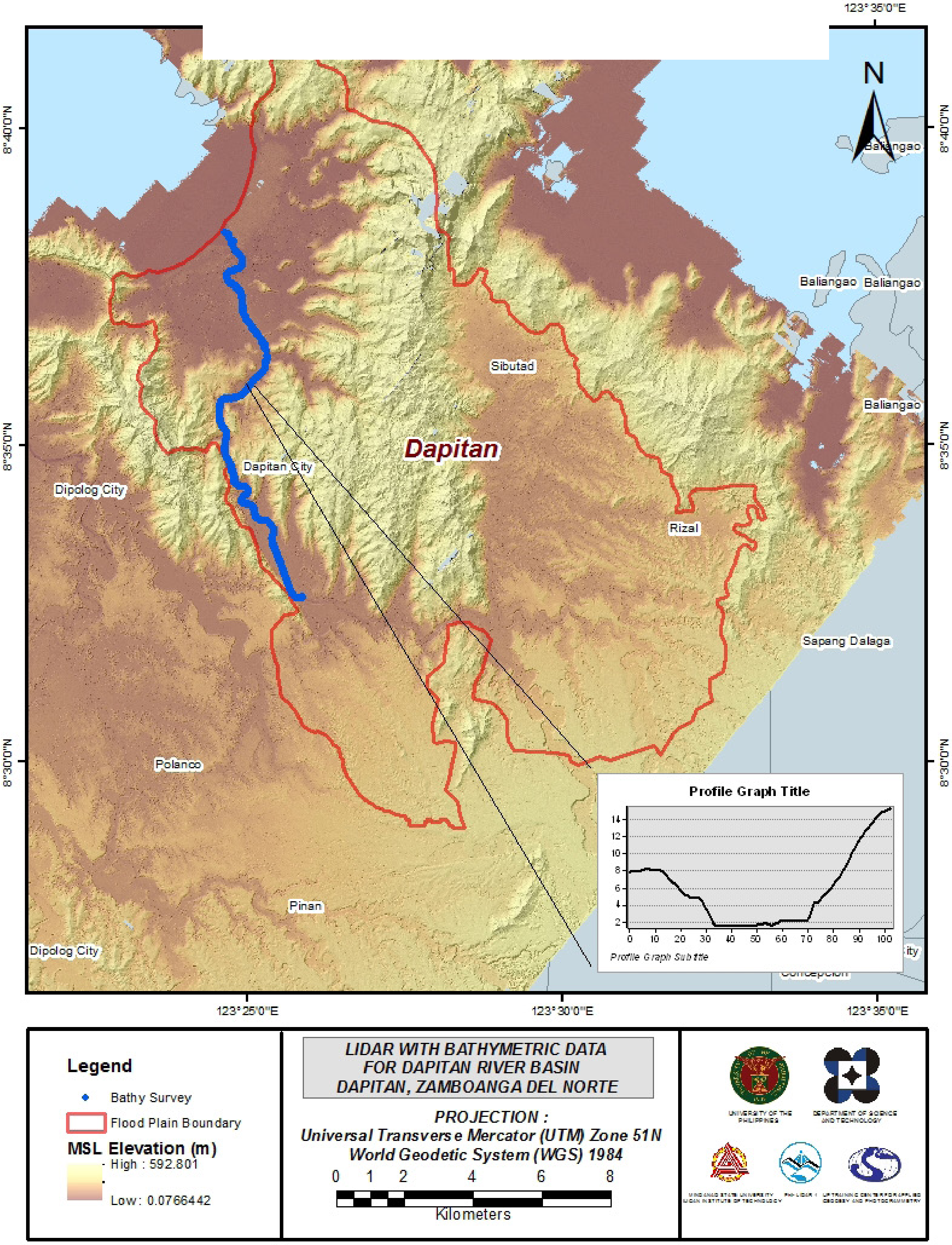


Figure 28. Map of Dapitan Floodplain with bathymetric survey points shown in blue.

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-meter 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

Dapitan Floodplain, including its 200-meter buffer, has a total area of 226.74 sq km. Of this area, a total of 7.0 sq km, which corresponds to a total of 2083 building features, were considered for QC. Figure 29 shows the QC blocks for Dapitan Floodplain.

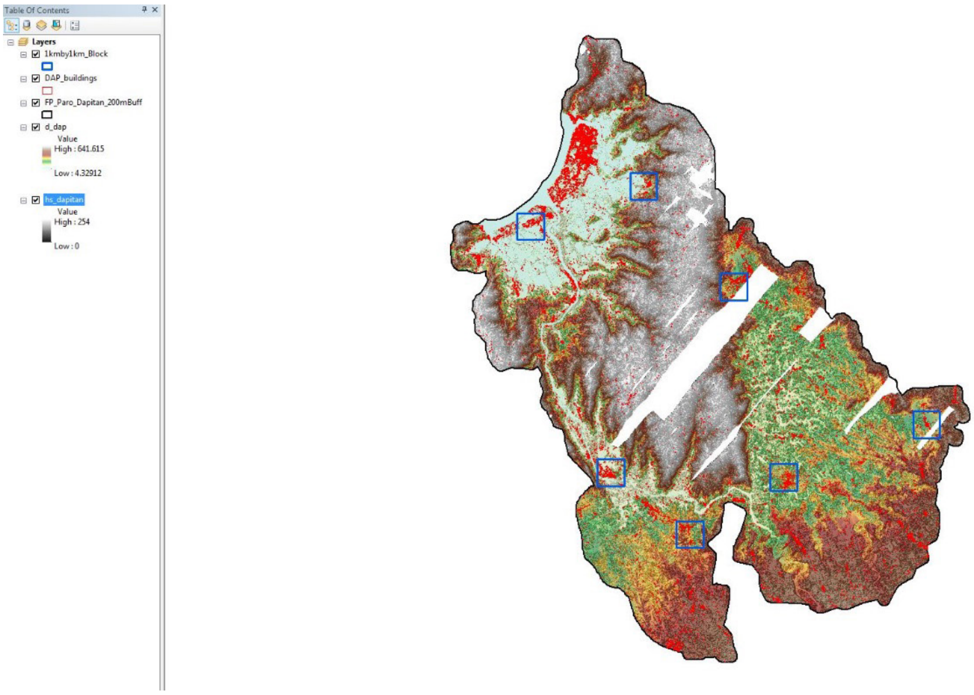


Figure 29. QC blocks for Dapitan building features.

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

Table 18. Quality Checking Ratings for Dapitan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Dapitan	97.38	99.57	80.09	PASSED

3.12.2 Height Extraction

A total of 23,738 building features in the Dapitan Floodplain underwent a height extraction. Of these building features, 211 were filtered out after height extraction, resulting to 23,527 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 22.69 meters.

3.12.3 Feature Attribution

Dapitan Floodplain is shared by two (2) municipalities and a city namely the City of Dapitan, Municipality of Rizal, and Municipality of Sibutad. The building attribution on the City of Dapitan and on the Municipalities of Rizal and Sibutad was done with the Google Earth approach. In Google Earth approach, aid from purok representatives were sought for participatory mapping over the Google Earth software. The attributions of road, bridge and water body features were done using NAMRIA maps, municipal and city records, and participatory mapping of municipals and cities.

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

Table 19. Building Features Extracted for Dapitan Floodplain.

Facility Type	No. of Features
Residential	22,038
School	338
Market	10
Agricultural/Agro-Industrial Facilities	192
Medical Institutions	37
Barangay Hall	37
Military Institution	0
Sports Center/Gymnasium/Covered Court	16
Telecommunication Facilities	2
Transport Terminal	1
Warehouse	154
Power Plant/Substation	1
NGO/CSO Offices	6
Police Station	6
Water Supply/Sewerage	30
Religious Institutions	91
Bank	4
Factory	1
Gas Station	9
Fire Station	0
Other Government Offices	81
Other Commercial Establishments	473

Table 20. Total Length of Extracted Roads for Dapitan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Dapitan	338.32	32.20	0.00	38.26	0.00	**408.78**

Table 21. Number of Extracted Water Bodies for Dapitan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Dapitan	98	3	0	0	485	**586**

A total of 73 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 Dapitan Floodplain overlaid with its ground features.

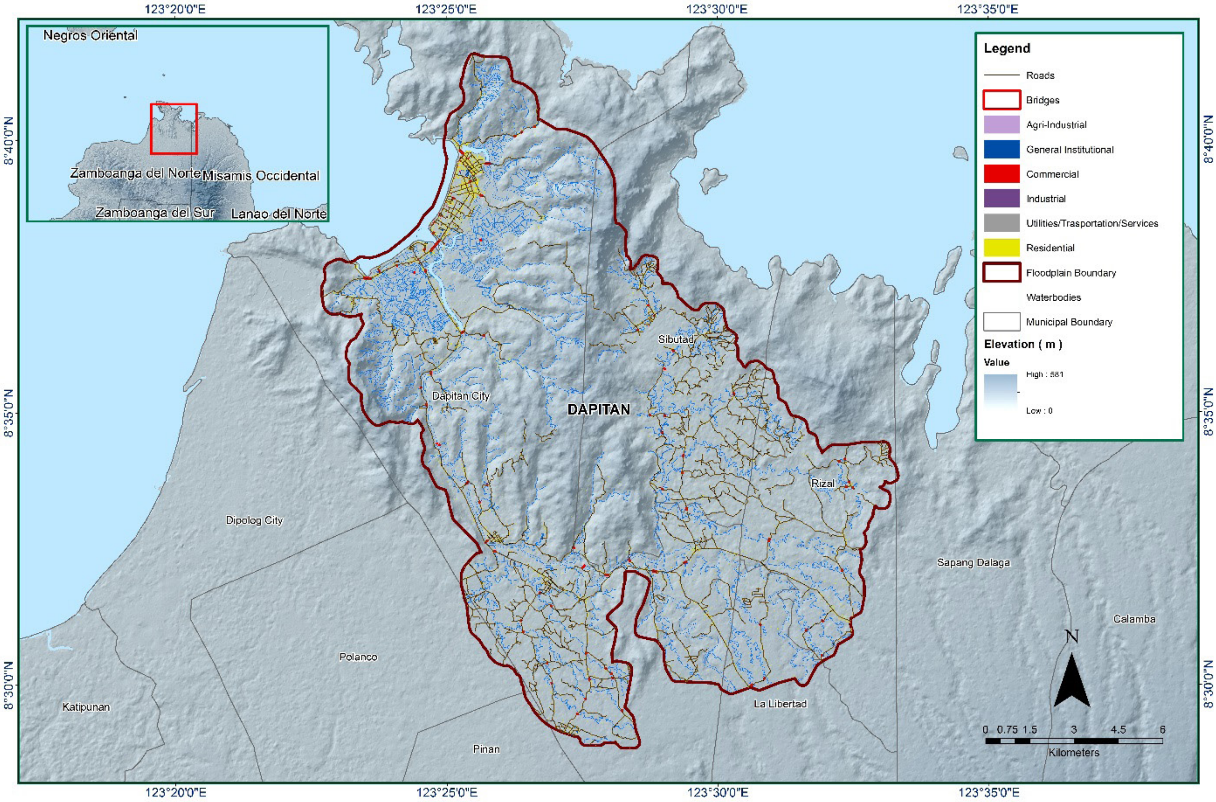


Figure 30. Extracted features for Dapitan Floodplain.

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

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

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

4.1 Summary of Activities

TheData Validation and Bathymetry Component (DVBC) field survey in Dapitan River was conducted on June 4 - 16, 2015 with the following scope of work: (i) site reconnaissance, (ii) courtesy calls to the LGUs, (iii) control survey for the establishment of control point in bridge's approach, (iv) cross-section survey, (v) bridge as-built features determination and water elevation marking in one of the bridge's pier, (vi) acquisition of validation points along concrete roads and bathymetric survey covering 12.0911 kilometers The general survey area is shown in Figure 31.

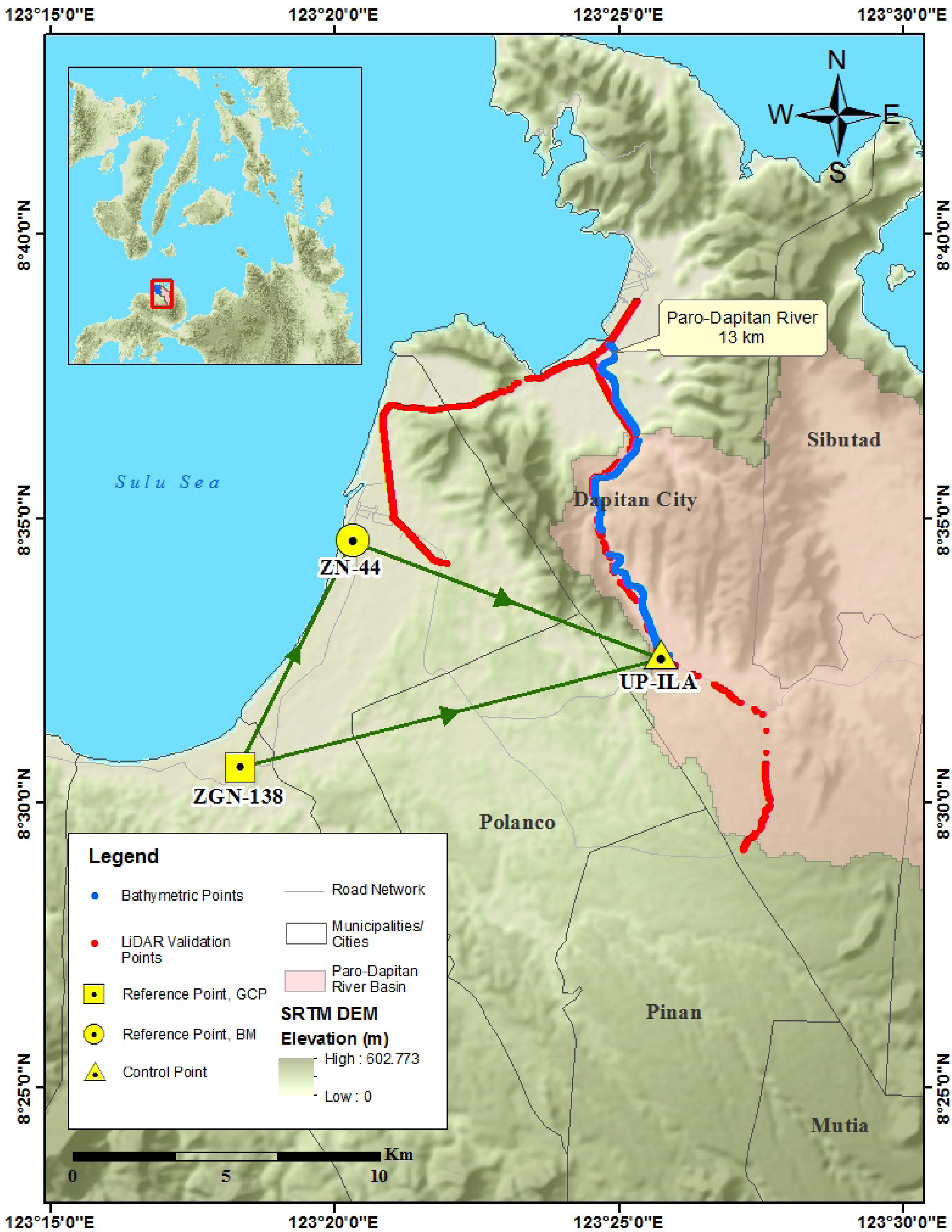


Figure 31. Extent of the Dapitan River Bathymetric Survey

4.2 Control Survey

The GNSS network used for Dapitan survey is composed of a single loop established on June 6, 2015 occupying the reference points: ZGN-138, a second order GCP located in Brgy. Daang Lugsod, Municipality of Katipunan, Zamboanga Del Norte; and ZN-44, a first order BM in Brgy. Miputak, Dipolog City, Zamboanga Del Norte; with values fixed from Dapitan Survey.

A control point was established along approach of Ilaya Bridge, Brgy. Ilaya, Dapitan City, Zamboanga Del Norte, to use as marker during the survey.

An elevation difference of 4.243 meters between geoid (EGM2008) and MSL values of ZN44 was applied to adjust the elevation of the included control points with reference to MSL. The list of control points occupied is shown in Table 22, while the GNSS network established is shown in Figure 32.

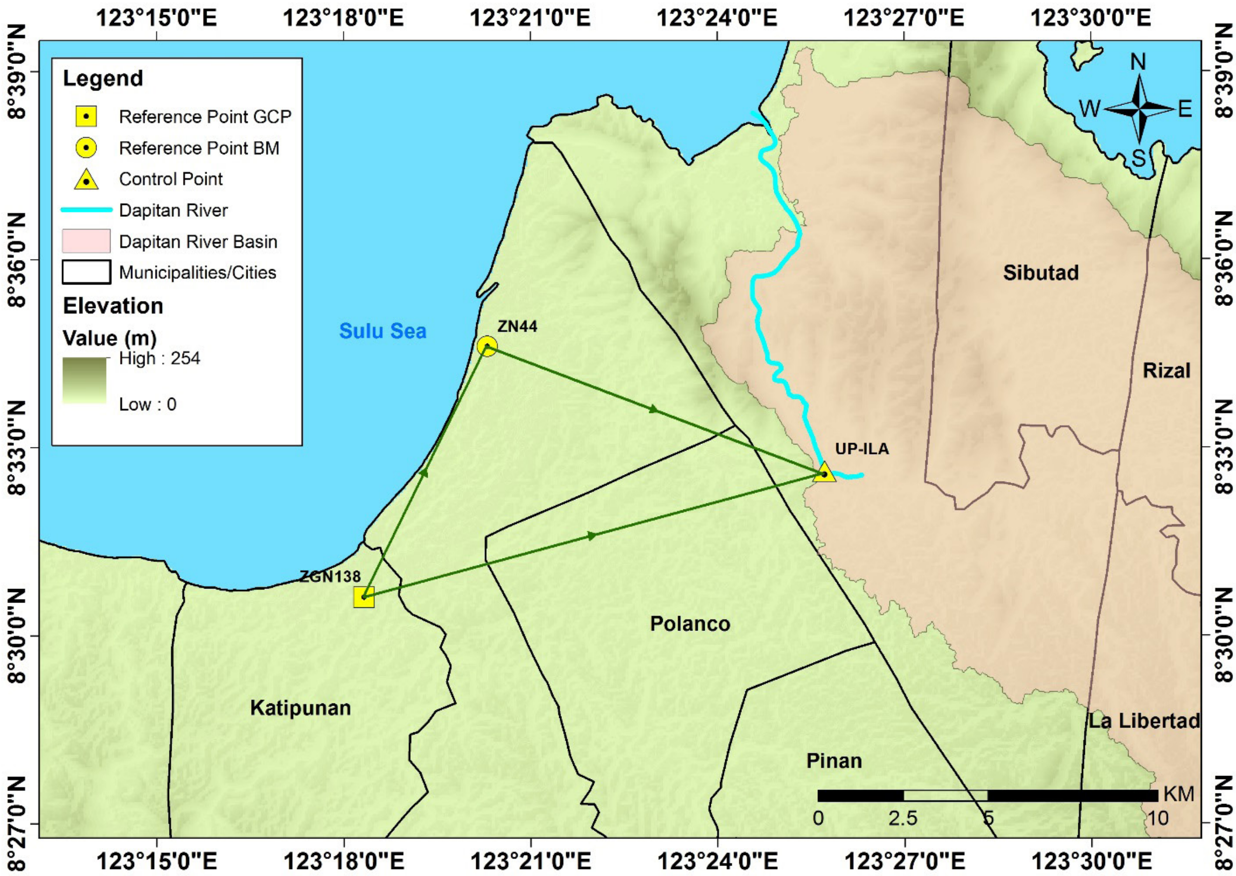


Figure 32. GNSS network for Dapitan River field survey

Table 22. List of References and Control Points used in Dapitan 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
ZGN-138	2nd Order, GCP	8d30’36.94779”E	123d18’19.85548”N	70.925	-	2009
ZN-44	1st Order BM	-	-	70.802	9.726	2007
UP-POL	UP Established	-	-	-	-	June 7, 2015

The GNSS set up for control points used in the Dapitan survey are shown in Figures 33 to 35.

Figure 33. GNSS receiver occupation, Trimble® SPS 882 at ZN-44, Miputak Bridge, in Brgy. Miputak, Dipolog City, Zamboanga del Norte

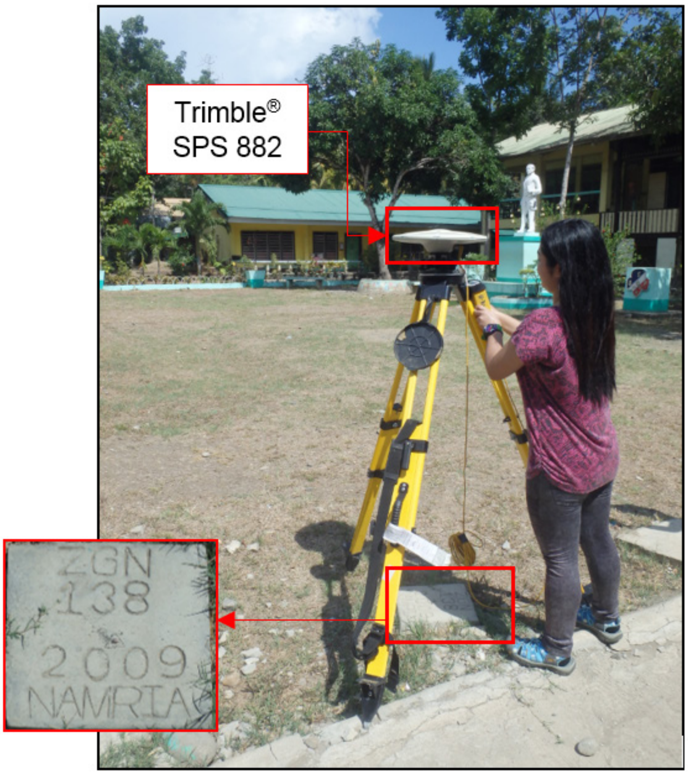


Figure 34. GNSS base receiver setup, Trimble® SPS 852 at ZGN-138 in TAGA Central School Brgy. Taga, Municipality of Katipunan, Zamboanga del Norte

Figure 35. GNSS base receiver, Trimble® SPS 882, setup at UP-ILA in Ilaya Bridge, Brgy. Ilaya, Dapitan City

4.3 Baseline Processing

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

Table 23. Baseline Processing for Dapitan River Survey

Observation	Date of Obser-vation	Solution Type	Horizontal Precision (m)	Vertical Precision (m)	Geodetic Azimuth	Ellipsoid Distance (m)	Δ Height (m)
ZGN138 --- ZN44	June 6, 2015	Fixed	0.005	0.021	26°13’36”	8210.379	-0.122
ZGN138 --- UP-ILA	June 6, 2015	Fixed	0.005	0.023	74°44’54”	14046.868	6.171
UP-ILA --- ZN44	June 6, 2015	Fixed	0.006	0.021	290°18’49”	10580.669	-6.279

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates Table 25 of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. The detailed Network Adjustment Report is discussed in Tables 24 and 25.

The three control points ZGN-138, ZN-44 and UP-ILA were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of ZGN-138 and ZN-44 were held fixed during the processing of the control point as presented in Table 24.

Table 24. Control points constraints

Point ID	Type	East σ (m)	North σ (m)	Height σ (m)	Elevation σ (m)
ZGN138	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (m)					

The coordinates of control point ZGN-138 were held fixed during the network adjustment as shown in Table 25. This control point was used to derive the geodetic coordinates for the rest of the network.

Table 25. Adjusted grid coordinates

Point ID	Easting (m)	Easting Error (m)	Northing (m)	Northing Error (m)	Elevation (m)	Elevation Error (m)	Constraint
UP-ILA	547168.592	0.004	944426.675	0.003	10.899	0.024	
ZGN138	533624.515	?	940722.222	?	5.484	?	LLh
ZN44	537245.631	0.005	948087.419	0.003	5.484	0.022	

The network is fixed at reference point ZGN138. Using the given equations for the horizontal accuracy and for the vertical accuracy, the computations are as follows:

a. ZN44

horizontal accuracy $= \sqrt{((0.5)^2 + (0.3)^2}$

$= \sqrt{(0.25 + 0.09)}$

$= 0.34$ cm < 20 cm

vertical accuracy = 2.2 cm < 10 cm

b. UP-ILA

horizontal accuracy $= \sqrt{((0.4)^2 + (0.3)^2}$

$= \sqrt{(0.16 + 0.09)}$

$= 0.25$ cm < 20 cm

vertical accuracy = 2.4< 10 cm

From the given formula, the resulting horizontal and vertical accuracies of the three occupied control points are within the required accuracy.

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
ZGN138	N8°30’36.94779”	E123°18’19.85548”	70.925	?	LLh
UP-ILA	N8°32’37.15488”	E123°25’43.00843”	77.088	0.024	
ZN44	N8°34’36.67923”	E123°20’18.51204”	70.802	0.022	

The adjusted geodetic coordinates is presented in Table 26. The height error for ZN-44 is 2.4 cm, which is less than the 10 cm accuracy requirement by the project. The established point UP-ILA has a height error of 2.2 cm also less than the 10 cm accuracy requirement. Both points complied with the vertical accuracy required by the program.

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

Table 27. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
ZGN-138	2nd order, GCP	8°30'36.94779"	123°18'19.85548"	70.925	940722.222	533624.515	9.727
ZN-44	1st order BM	8°34'36.67923"	123°20'18.51204"	70.802	948087.419	537245.631	9.726
UP-ILA	Used as Marker	8°32'37.15488"	123°25'43.00843"	77.088	944426.675	547168.592	15.142

4.5 Cross-section and Bridge as Built Survey and Water Level Marking

Cross-section and as-built survey were conducted along the downstream side of Ilaya Bridge, in Brgy. Ilaya, Dapitan City, Zamboanga Del Norte on June 6 and 8, 2015 using GNSS receiver, Trimble® SPS 882 in PPK survey technique as shown in Figure 36.

Figure 36. Cross-section survey at Ilaya Bridge

There are twenty-one (21) points acquired with an estimated length of 121.09 meters gathered using the control point UP-ILA as GNSS base station. The location map and cross-section diagram are shown in Figure 37 and Figure 38, while the bridge as-built form in shown in Figure 39.

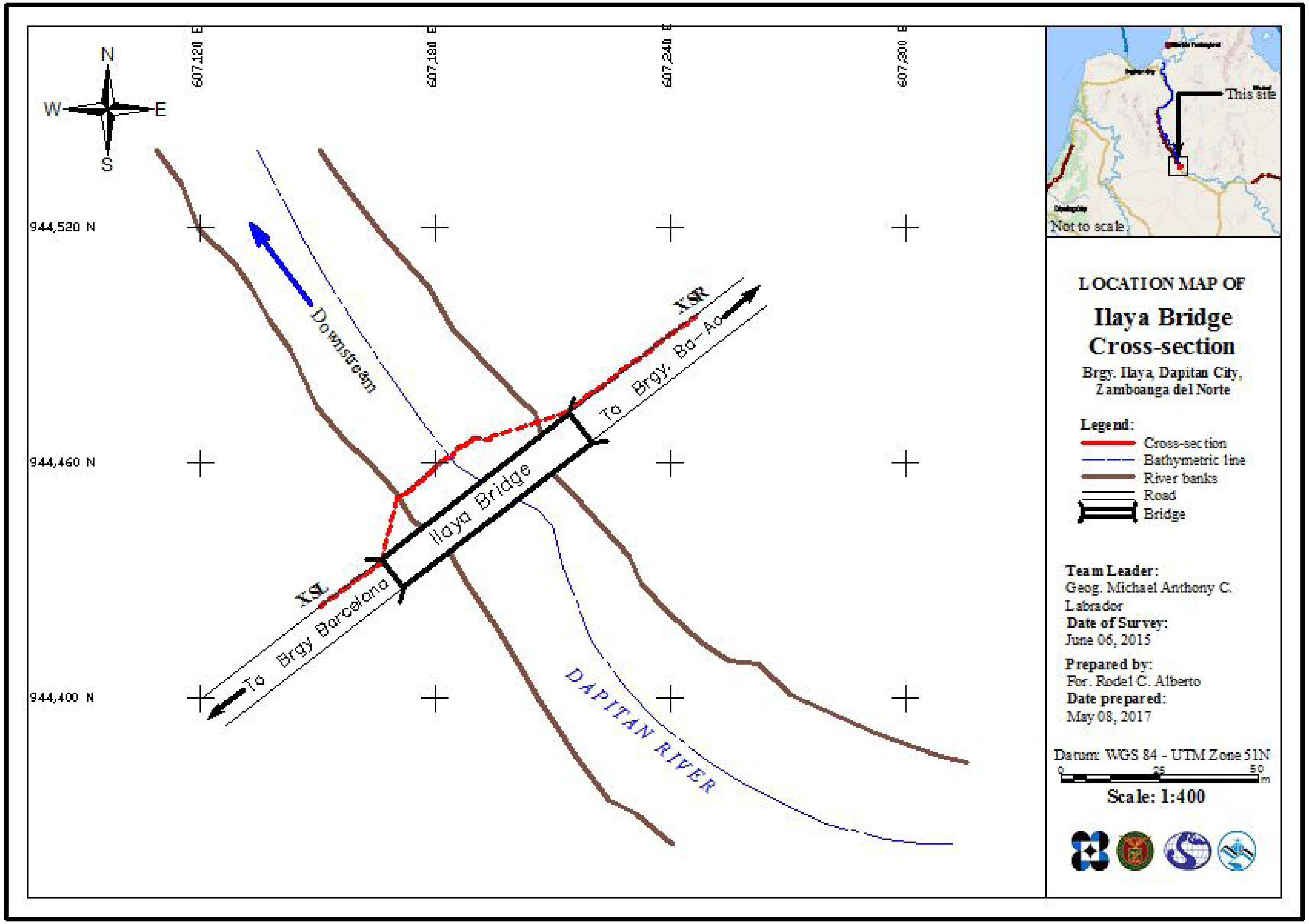


Figure 37. Ilaya bridge cross-section location map

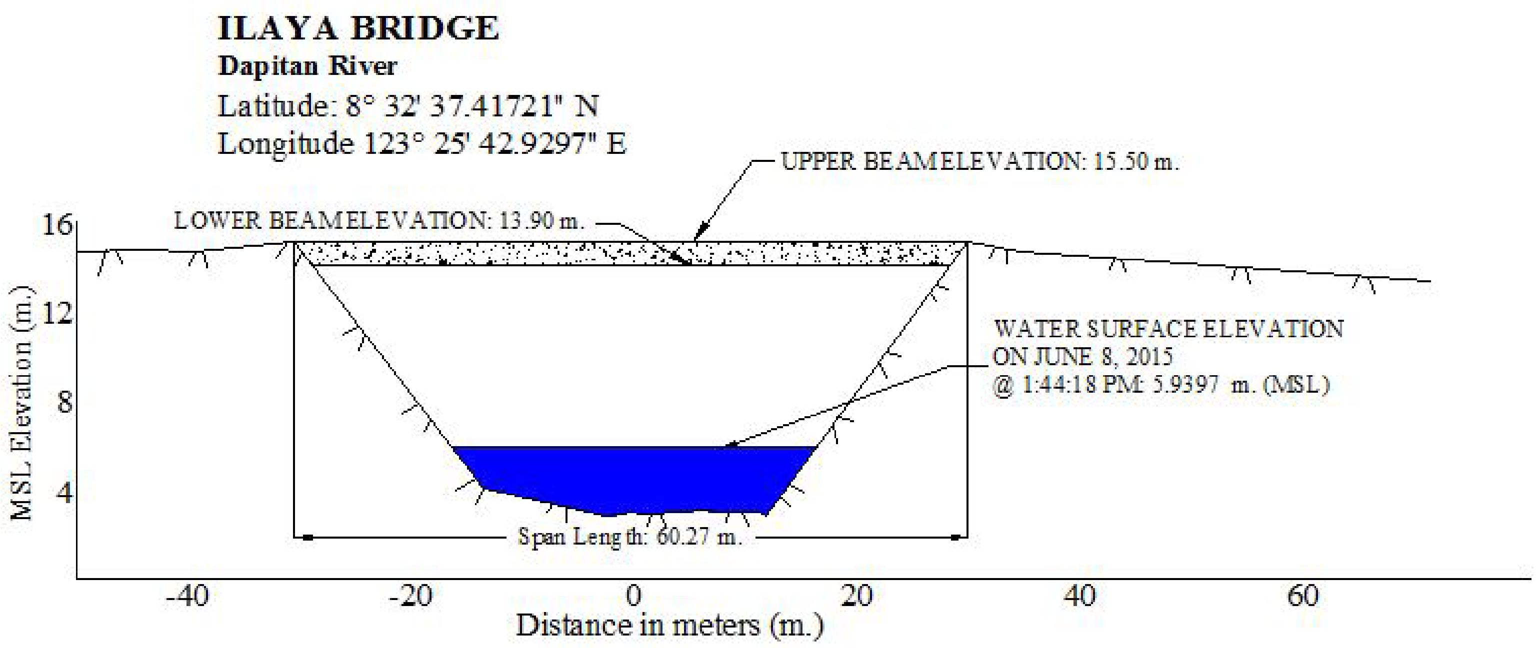


Figure 38. Cross-sectional diagram of Dapitan River along Ilaya Bridge with marked water-level

Bridge Data Form

Bridge Name: Ilaya Bridge Date: 06/06/15

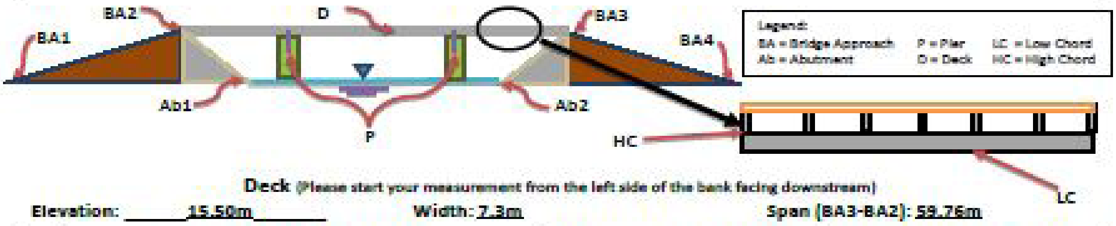
River Name: Dapitan River Time: 3:16 PM

Location: Barangay Ilaya, Dapitan City

Survey Team:

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 8d32'37.41721" Longitude: 123d25'42.9297"



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

Elevation: 15.50m Width: 7.3m Span (BA3-BA2): 59.76m

	Station (Distance from BA1)	High Chord Elevation, MSL	Low Chord Elevation, MSL
1	19.32 m	15.50m	14.44m
2	79.59 m	15.11m	14.05m
3			
4			
5			

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

	Station(Distance from BA1)	Elevation, MSL		Station(Distance from BA1)	Elevation, MSL
BA1	0	14.74m	BA3	79.59m	14.11m
BA2	19.32m	15.15m	BA4	121.09m	13.34m

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

	Station (Distance from BA1)	Elevation
Ab1	33.80m	5.93
Ab2		

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

Shape: Number of Piers: 0

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			

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

Figure 39. Data form for Ilaya Bridge

The water surface elevation of Dapitan River was acquired on June 8, 2015 at 1:44:18 PM using Trimble® SPS 882 in GNSS PPK survey technique with a value of 5.94 meter in MSL. This was translated into marking in the bridge's abutment to serve as reference for the flow measurement and depth gauge deployment of Phil-LiDAR 1 partner HEI, Mindanao State University-Iligan Institute of Technology.

Figure 40. Water-level marking at Ilaya Bridge

4.6 Validation Points Acquisition Survey

Validation Points Acquisition Survey was conducted on June 8, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 41. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced and stable. The antenna height was measured from the bottom of the notch of the GNSS receiver down to the ground with a measurement of 1.945 meters. The survey was conducted using PPK technique on a continuous topo mode.

The team covered the major roads running along Dipolog-Polanco-Oroquieta Road and Dipolog-Oroquieta National Road as shown in Figure 42.

Figure 41. LiDAR Ground Validation Setup

About three thousand eight hundred twenty (3,820) ground validation points were gathered with an approximate length of 37.342 km using UP-ILA as GNSS base station.

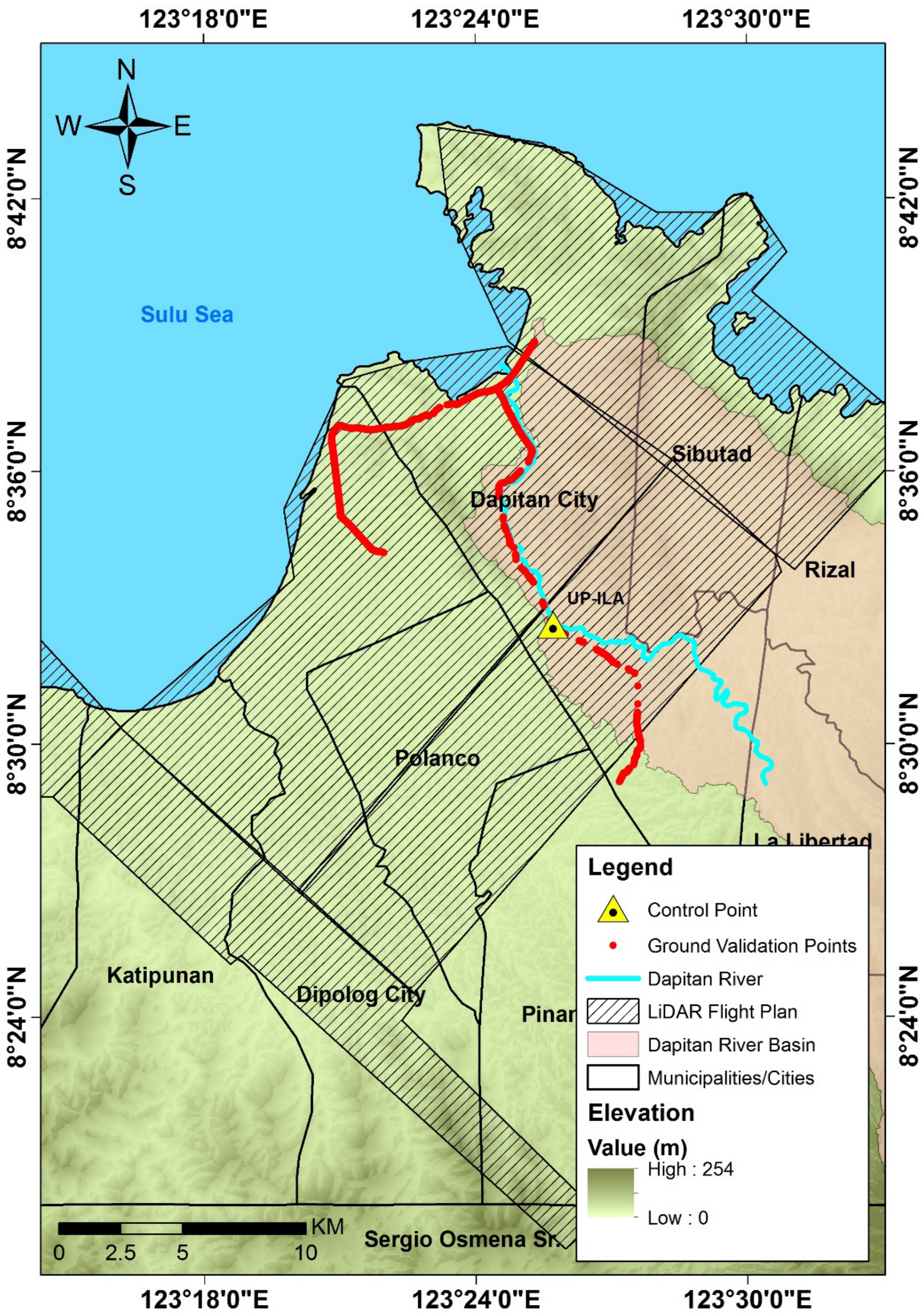


Figure 42. Obtained ground validation points in the vicinity of Dapitan River overlayed with river basin delineation.

4.7 River Bathymetric Survey

The bathymetric survey was conducted on June 8, 2015 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS receiver in PPK survey techniques as shown in Figure . The survey began in Ilaya Bridge in Brgy. Ilaya, Dapitan City with coordinates 8°32'35.19009" 123°25'50.01942", down to the mouth of the river in Brgy. Polo, also in Dapitan City with coordinates 8°38'04.02425" 123°24'49.54489". The established point, UP-ILA, at the approach of Ilaya Bridge used as the GNSS base station.

A total of seven thousand one hundred two (7,102) bathymetry points were gathered starting from Brgy. Ilaya down to the mouth of the river along Brgys. Polo and Maria Uray. The entire coverage of the bathymetric survey is shown in the map in Figure 43.

Figure 43. Trimble® SPS 882 Rover and OHMEX™ single beam echo sounder set up on a boat with "katig"for the Dapitan River bathymetric survey

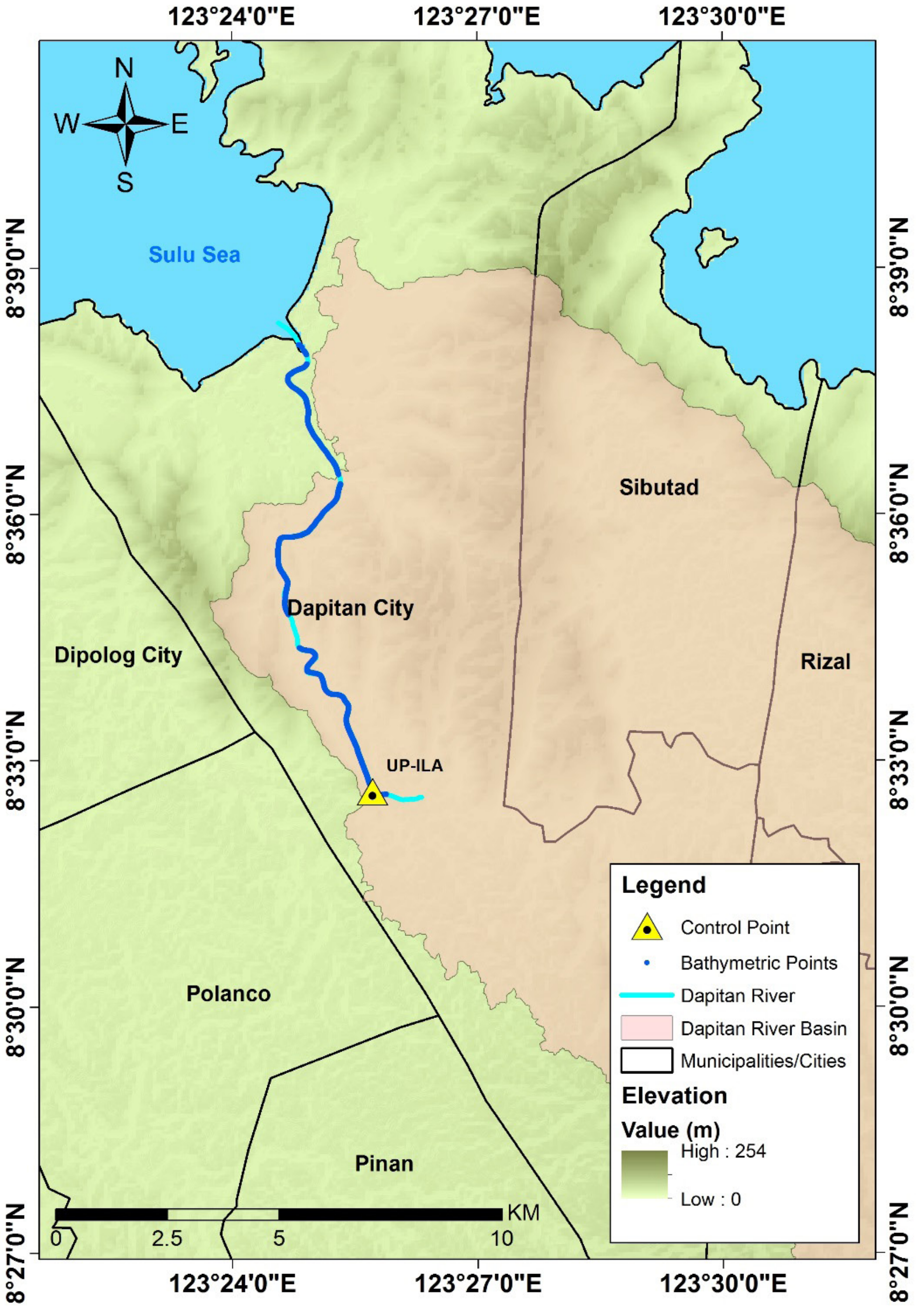


Figure 44.Bathymetric points gathered in Dapitan River

A CAD drawing was also produced illustrating the Dapitan riverbed profile. As shown in Figure 45, the difference in elevation from upstream in Brgy. Ilaya down to the last point in Brgy. Polo is 1.947 meters. The deepest portion or the lowest elevation recorded is about 2.427 meters below MSL in Brgy.Diwa-an, while the highest elevation was 4.866 meters in MSL located in Brgy.Burgos.

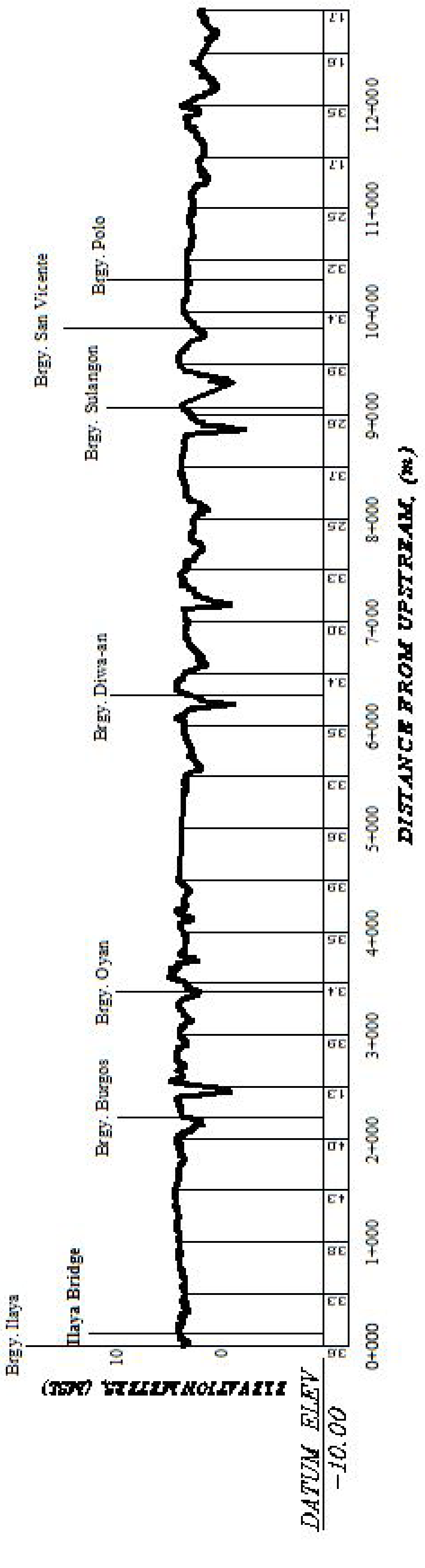


Figure 45. Riverbed profile of Dapitan River

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, and Neil Tingin

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 Dapitan 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 Dapitan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an Automatic Rain Gauge (ARG) installed upstream by the DOST. The ARG was specifically installed in the Municipality of Dapitan with coordinates 8°28’21.00”N Latitude and 123°31’27.84”E Longitude. The location of therain gauge is shown in Figure 46 below.

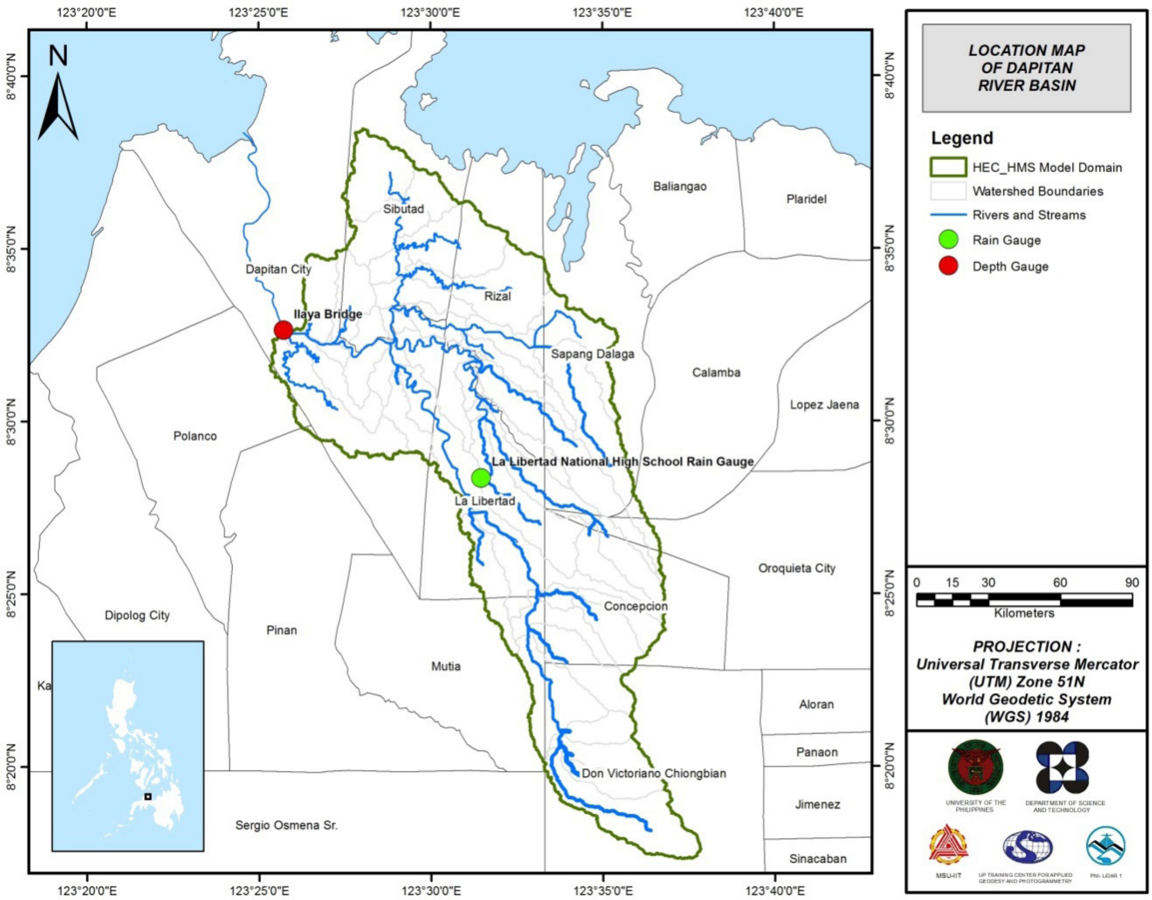


Figure 46. The location map of Dapitan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

HQ curve analysis is important in determining the equation to be used in establishing Q values with R-Squared values closer to 1. A trendline is more accurate if the R-Squared value is closer or at 1.

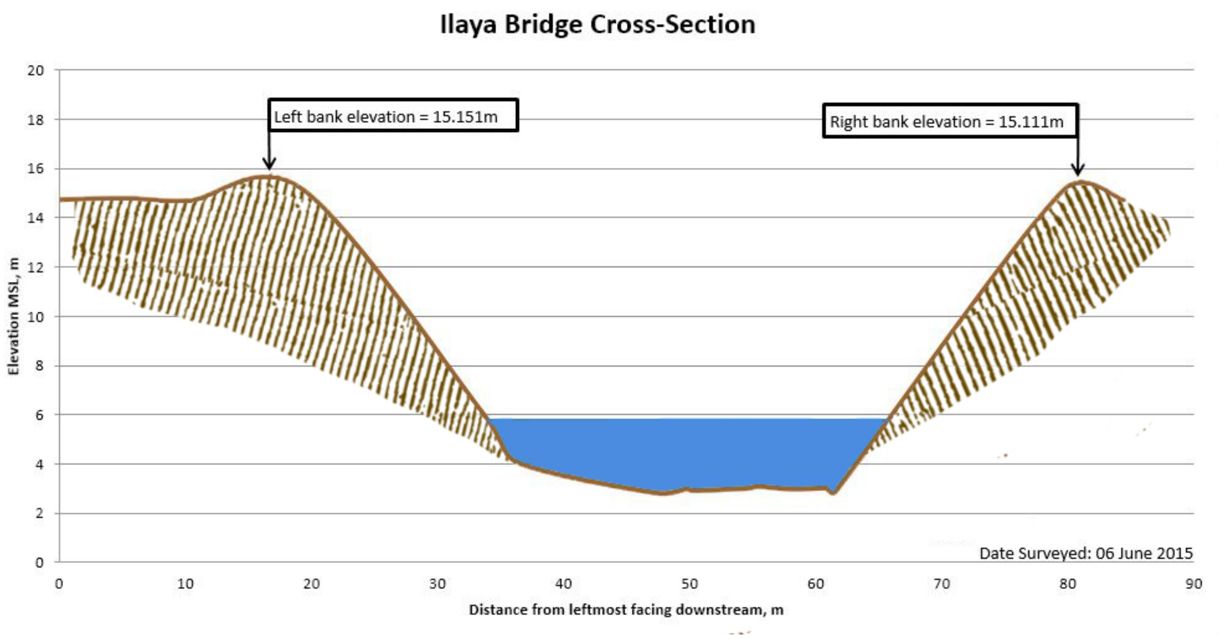


Figure 47. Cross-Section Plot of Ilaya Bridge

Figure 48 shows the highest R-Squared value of 0.9054. In this case, Q boxed values with Q at bank-full were plotted versus the stage.

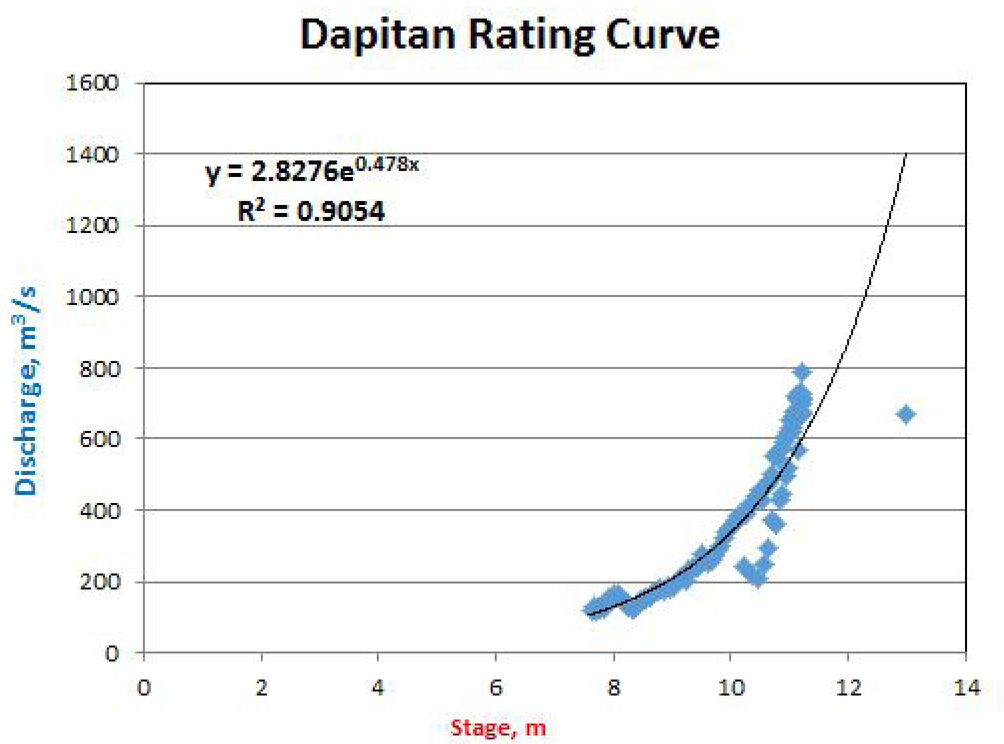


Figure 48. Rating Curve at Ilaya Bridge

This rating curve equation was used to compute the river outflow at Ilaya Bridge for the calibration of the HEC-HMS model.

Total rainfall taken from the ARG at La Libertad National High School, La Libertad was 285 mm. It peaked to 20 mm on 4 December 2016, 07:15. The lag time between the peak rainfall and discharge is 6 hours and 15 minutes.

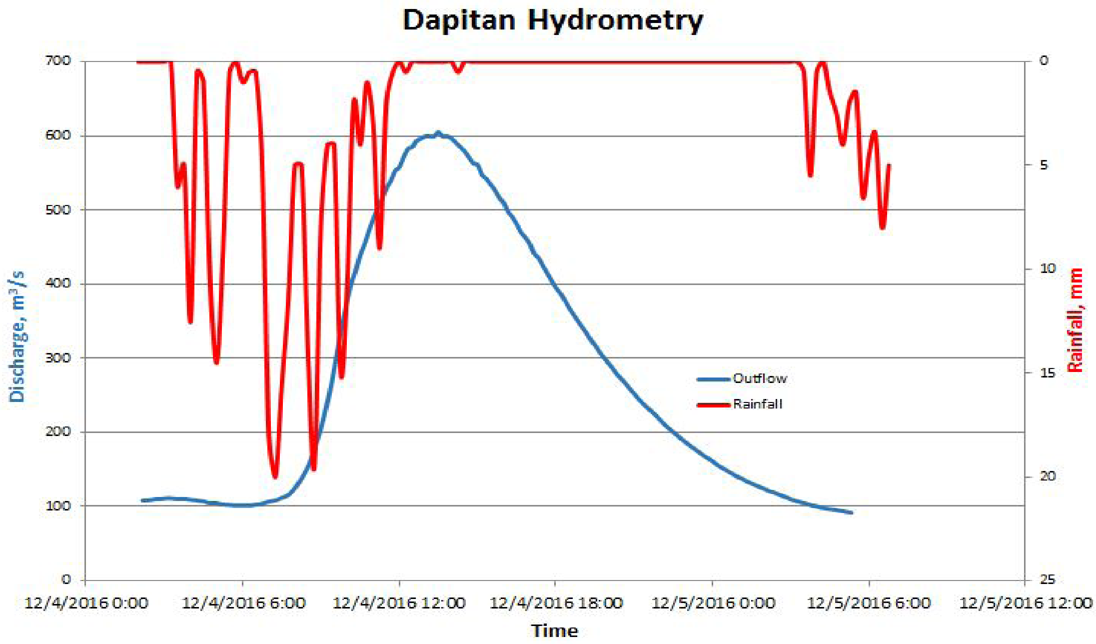


Figure 49. Rainfall and outflow data at Ilaya Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Dipolog Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Dapitan watershed. The extreme values for this watershed were computed based on a 51-year record.

Table 28. RIDF values for Dipolog 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	19.7	30.9	38.7	53.8	73.6	85.5	105.7	120.3	136.2
5	25.9	39.6	50.1	72.6	99.7	117.3	140.9	158.3	178.5
10	30	45.4	57.6	85.1	117	138.3	164.3	183.4	206.5
15	32.3	48.6	61.8	92.1	126.8	150.2	177.4	197.6	222.4
20	34	50.9	64.8	97.1	133.6	158.5	186.6	207.6	233.4
25	35.2	52.7	67.1	100.9	138.9	164.9	193.7	215.2	242
50	39	58.1	74.1	112.5	155.1	184.6	215.6	238.8	268.3
100	42.9	63.4	81.1	124.1	171.2	204.2	237.3	262.1	294.4

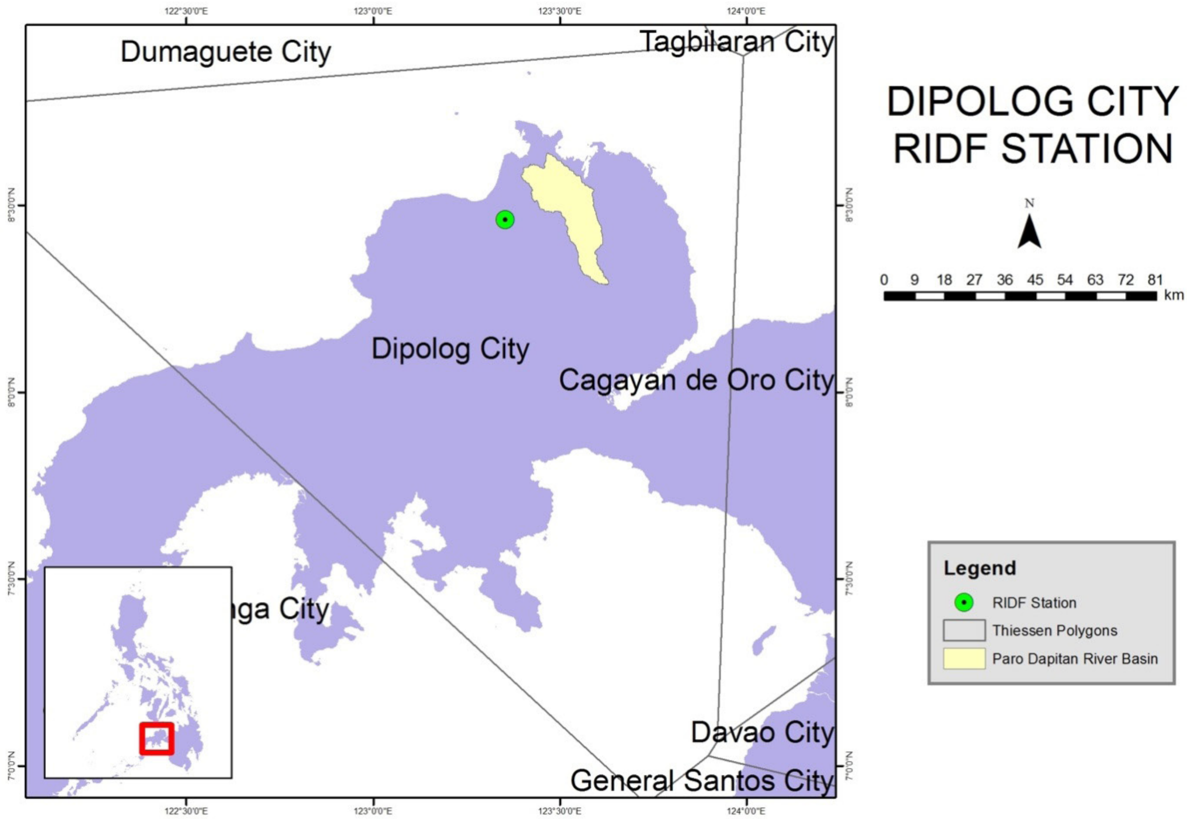


Figure 50. Location of Dipolog RIDF station relative to Dapitan River Basin

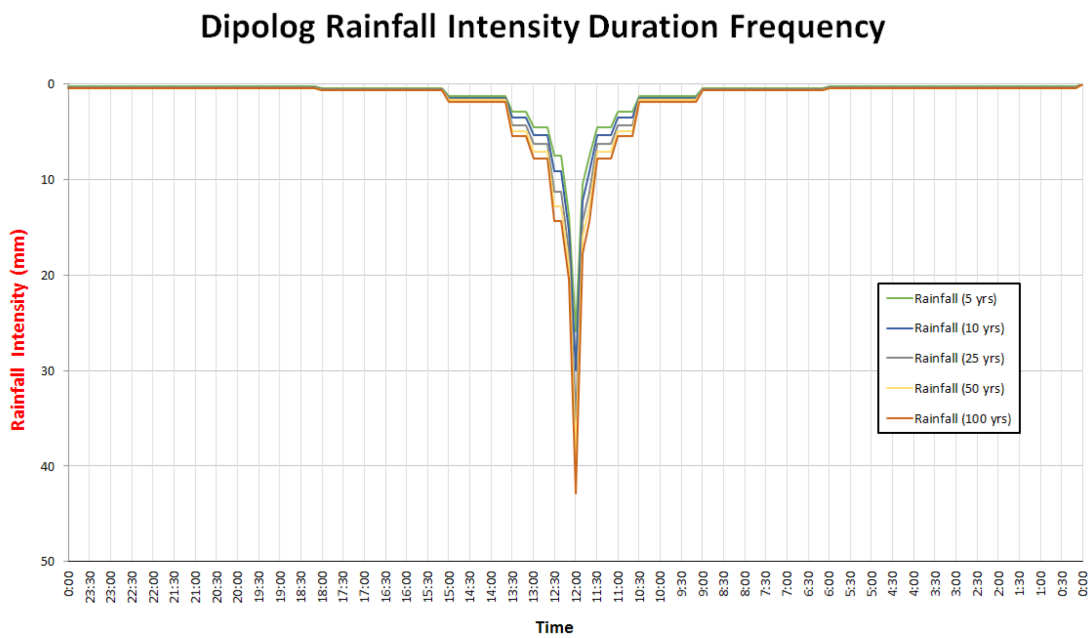


Figure 51. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource Information Authority (NAMRIA). The soil texture map of the Dapitan River basin was used as one of the factors for the estimation of the CN parameter.

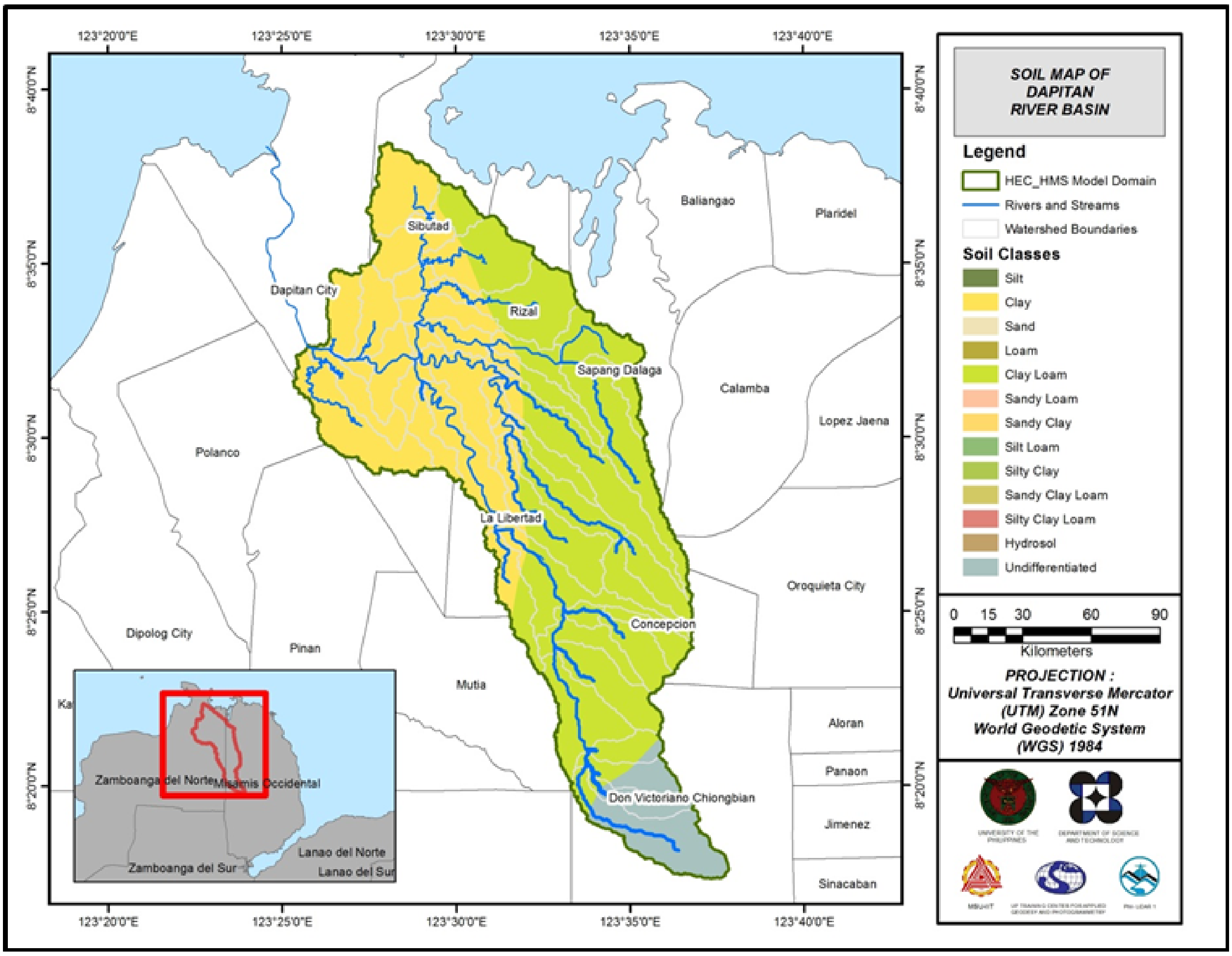


Figure 52. Soil Map of Dapitan River Basin

Figure 52 shows the Land Cover inside Dapitan River Basin. The land cover map of Palilan River Basin was used as another factor for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

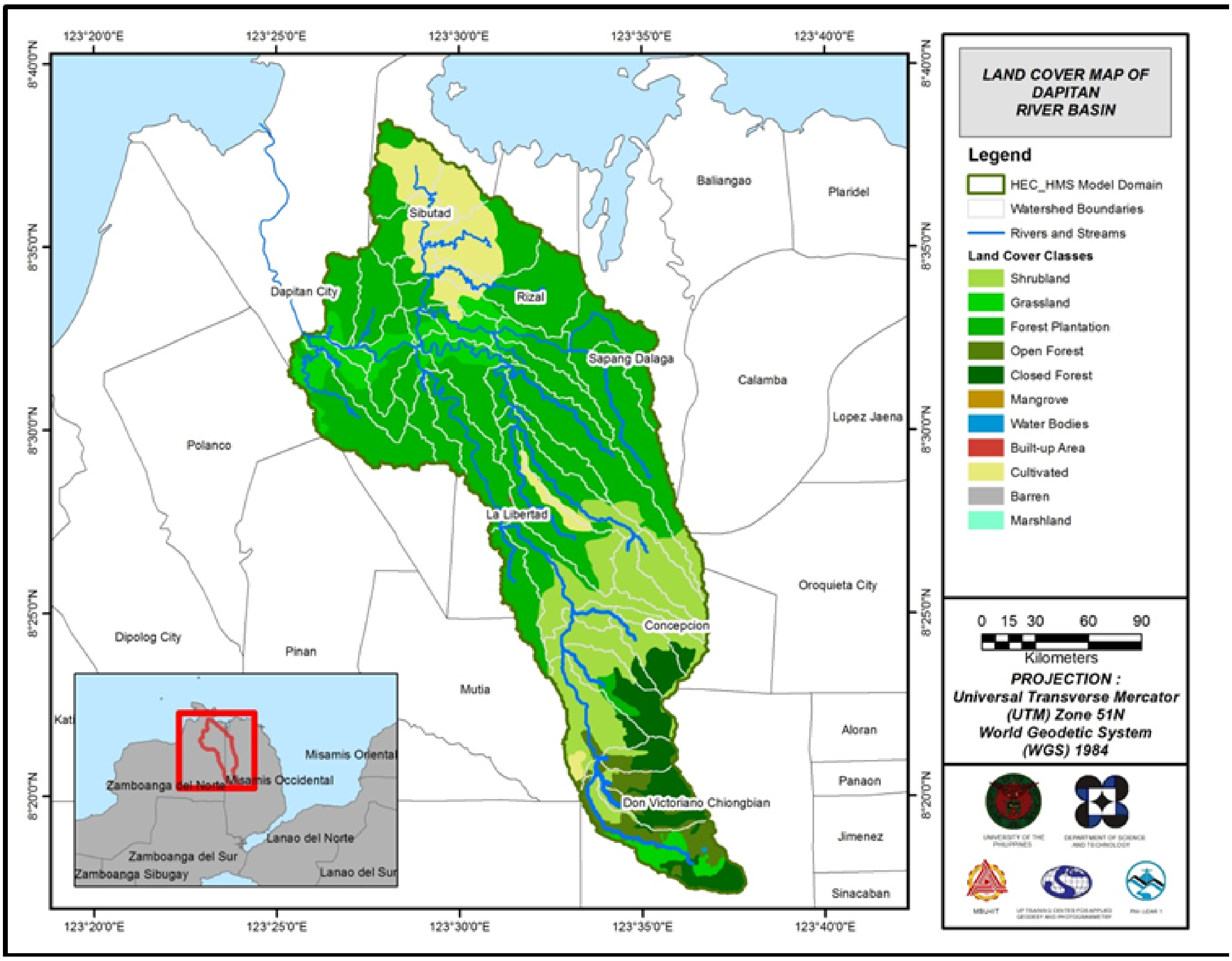


Figure 53. Land Cover Map of Dapitan River Basin

For Dapitan, the soil classes identified were clay loam, clay, and undifferentiated. The land cover types identified were shrubland, grassland, forest plantation, open forest, and closed forest.

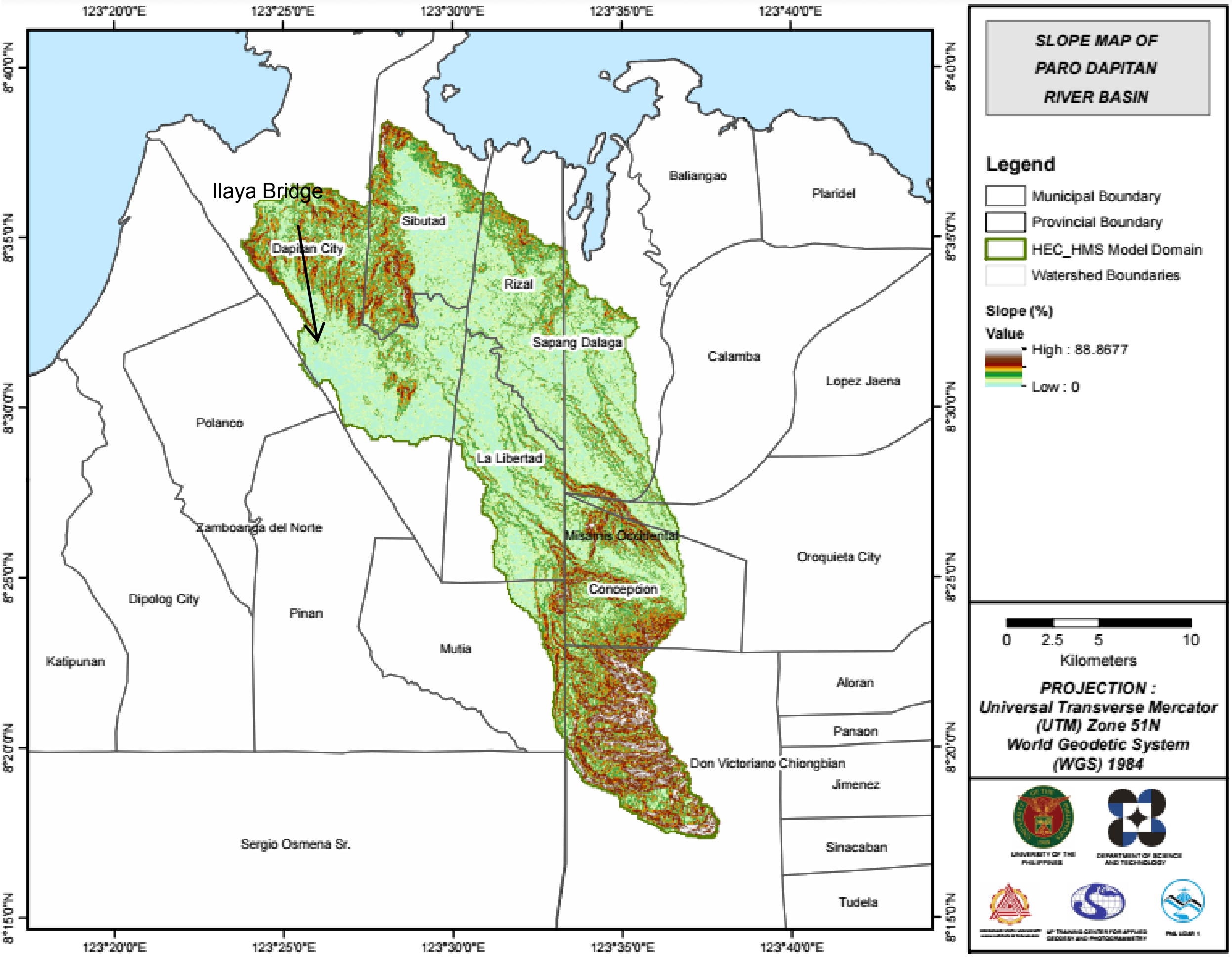


Figure 54. Slope Map of the Dapitan River Basin

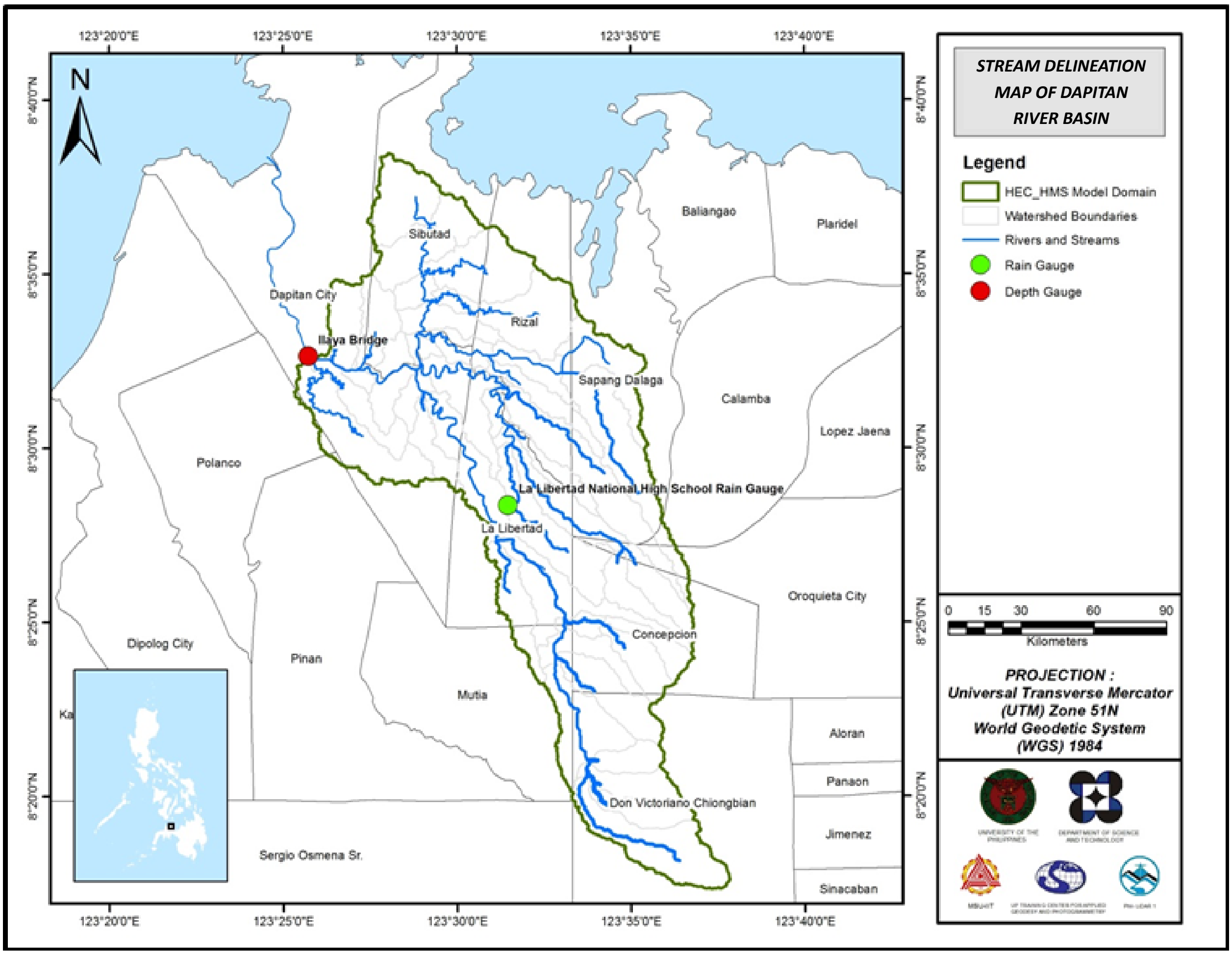


Figure 55. Stream Delineation Map of the Dapitan River Basin

Using the SAR-based DEM, the Dapitan basin was delineated and further subdivided into subbasins. The model consists of 42 sub basins, 24 reaches, and 24 junctions. The main outlet is located at Ilaya Bridge, Dapitan. This basin model is illustrated in Figure 56. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Ilaya Bridge.

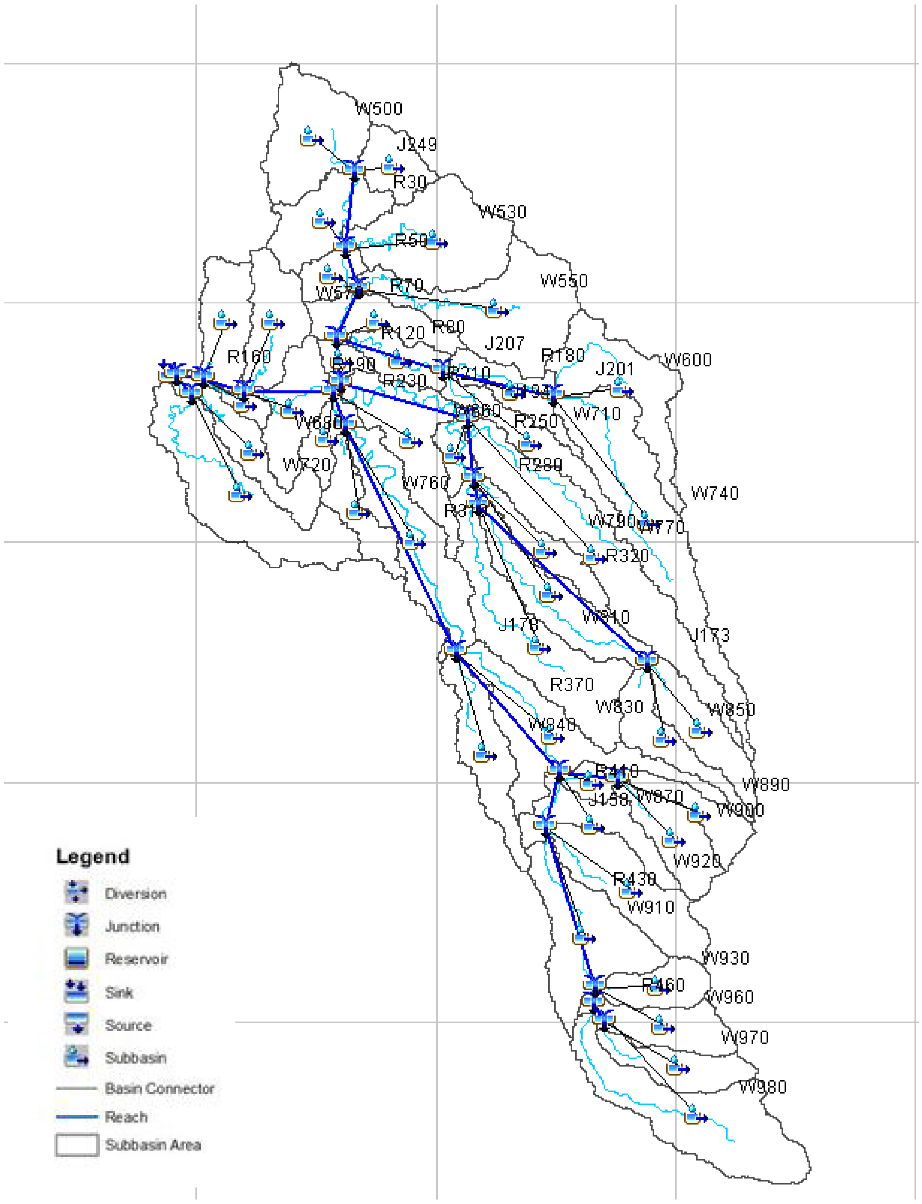


Figure 56. The Dapitan Hydrologic Model generated in HEC-GeoHMS

5.4 Cross-section Data

The 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 HEC GeoRAS tool and was post-processed in ArcGIS.

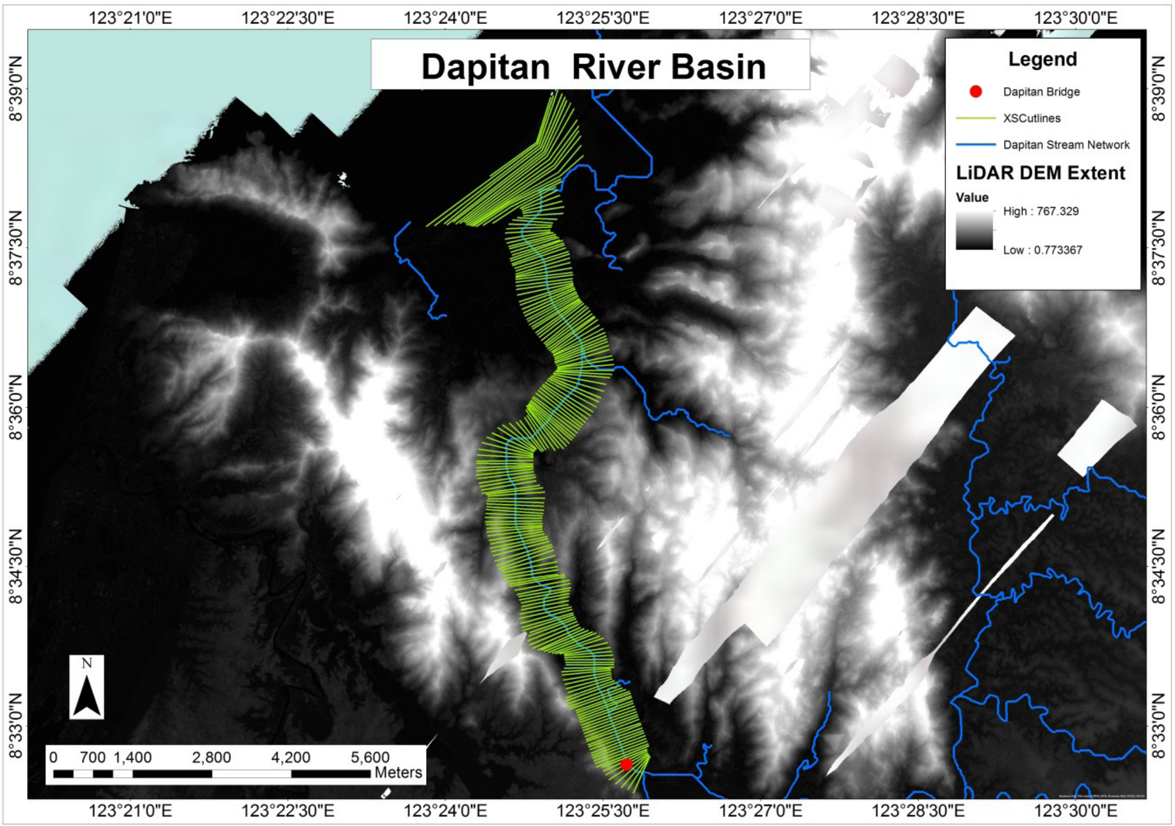


Figure 57. River cross-section of Dapitan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

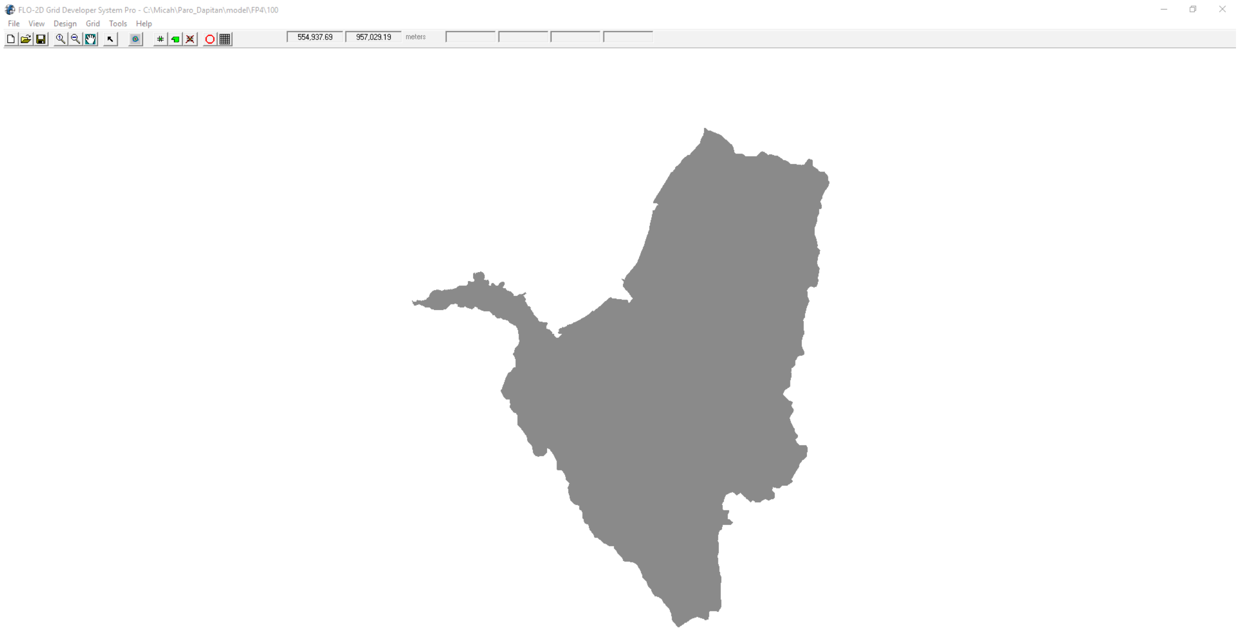


Figure 58. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 61.63855 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element.The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 90649200.00 m2.

There is a total of 32792322.84 m3 of water entering the model. Of this amount, 20658761.57 m3 is due to rainfall while 12133561.27 m3 is inflow from other areas outside the model. 7576481.50 m3 of this water is lost to infiltration and interception, while 20057923.59 m3 is stored by the flood plain. The rest, amounting up to 5157937.04 m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Dapitan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 shows the comparison between the two discharge data.

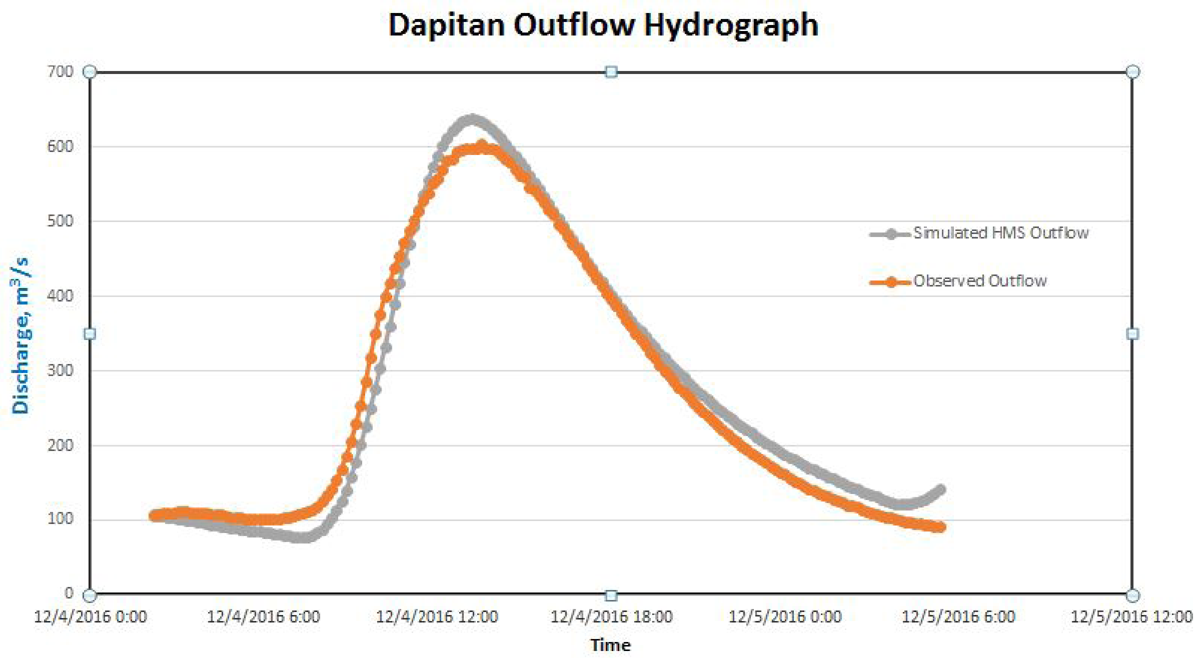


Figure 59. Outflow Hydrograph of Ilaya Bridge generated in HEC-HMS model compared with observed outflow

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

Table 29. Range of Calibrated Values for Dapitan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	62 - 147
			Curve Number	41 - 62
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1 - 10
			Storage Coefficient (hr)	2 - 14
	Baseflow	Recession	Recession Constant	0.2 – 0.3
			Ratio to Peak	0.005
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0005

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 62 to 147mm means that there is a high amount of infiltration or rainfall interception by vegetation per subbasin.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 41 to 62 for curve number is lower than the advisable value for Philippine watersheds depending on the soil and land cover of the area.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 1 to 14 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.2 to 0.3 indicates that the basin is likely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.005 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0005 corresponds lower than the common roughness of Philippine watersheds.

Table 30. Summary of the Efficiency Test of Dapitan HMS Model

Accuracy Measure	Value
RMSE	1.86
r^2	0.91
NSE	0.77
PBIAS	-1.53
RSR	0.48

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.86 (m3/s).

The Pearson correlation coefficient (r2) 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 0.91.

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 0.77.

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 -1.53.

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 0.48.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 60) shows the Dapitan outflow using the Dipolog Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, 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 range of durations and return periods.

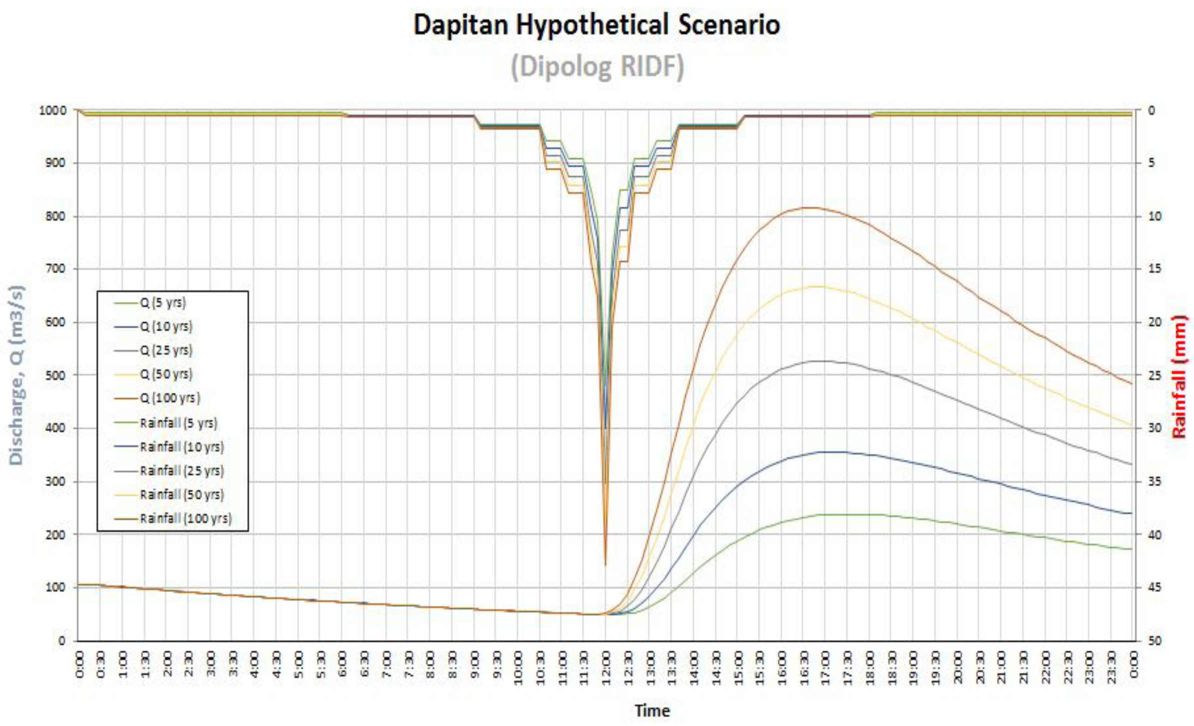


Figure 60. Outflow hydrograph at Dapitan Station generated using Dipolog RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Dapitan discharge using the Dipolog Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Peak values of the Dapitan HECHMS Model outflow using Dipolog RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	178.32	25.9	238.8	16 hours 30 mins
10-Year	206.37	30	355.4	17 hours 10 mins
25-Year	241.91	35.2	526.6	17 hours
50-Year	268.14	39	666.8	16 hours 50 mins
100-Year	294.55	42.9	816.4	16 hours 40 mins

5.7.2 Discharge Data using Dr. Horritts's Recommended Method

The river discharge values for the five rivers entering the floodplain are shown in Figure 61 to Figure 64, and the peak values are summarized in Table 32 to Table 35.

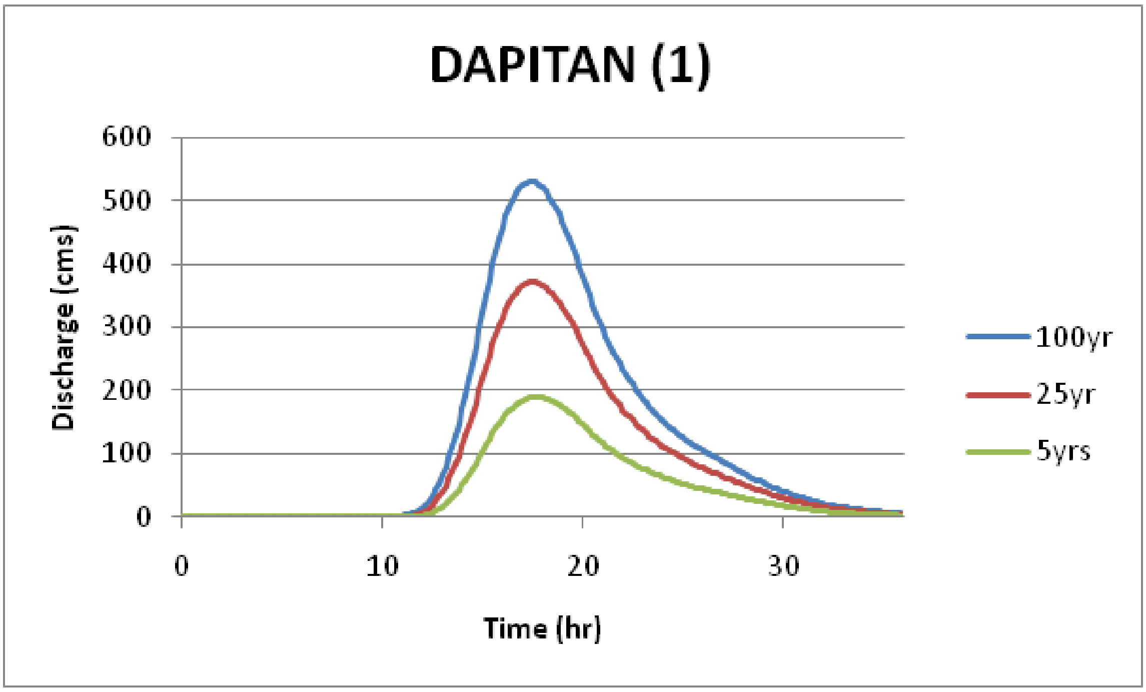


Figure 61. Dapitan river (1) generated discharge using 5-, 25-, and 100-year Dipolog rainfall intensity-duration-frequency (RIDF) in HEC-HMS

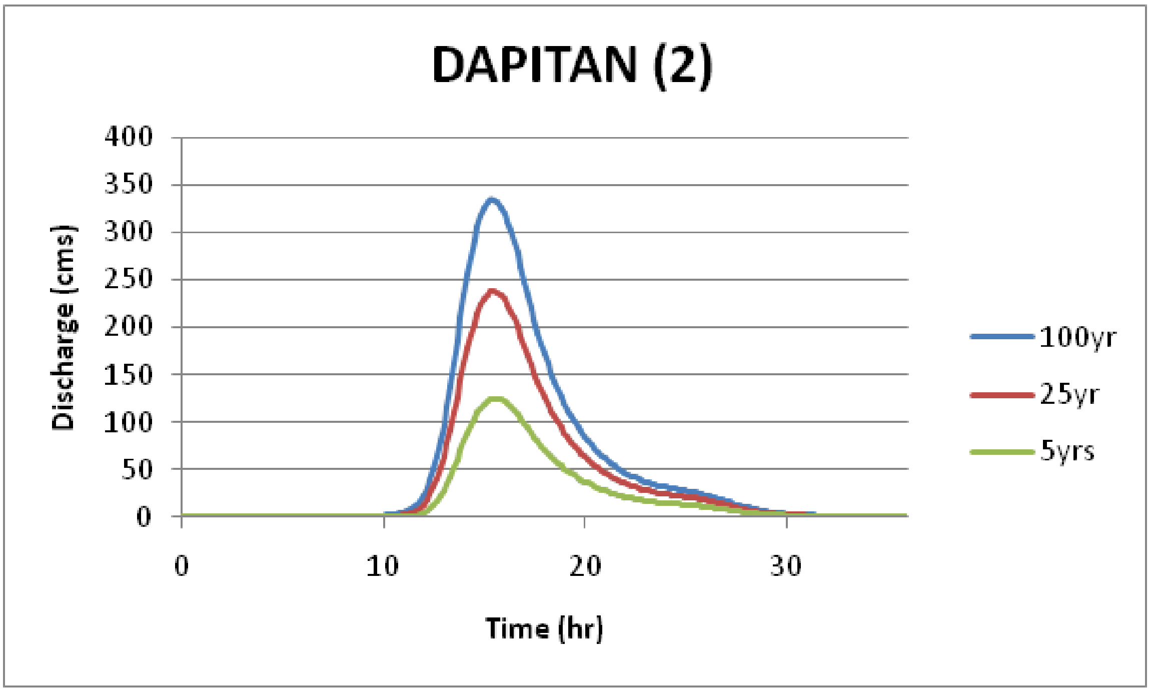


Figure 62. Dapitan river (2) generated discharge using 5-, 25-, and 100-year Dipolog rainfall intensity-duration-frequency (RIDF) in HEC-HMS

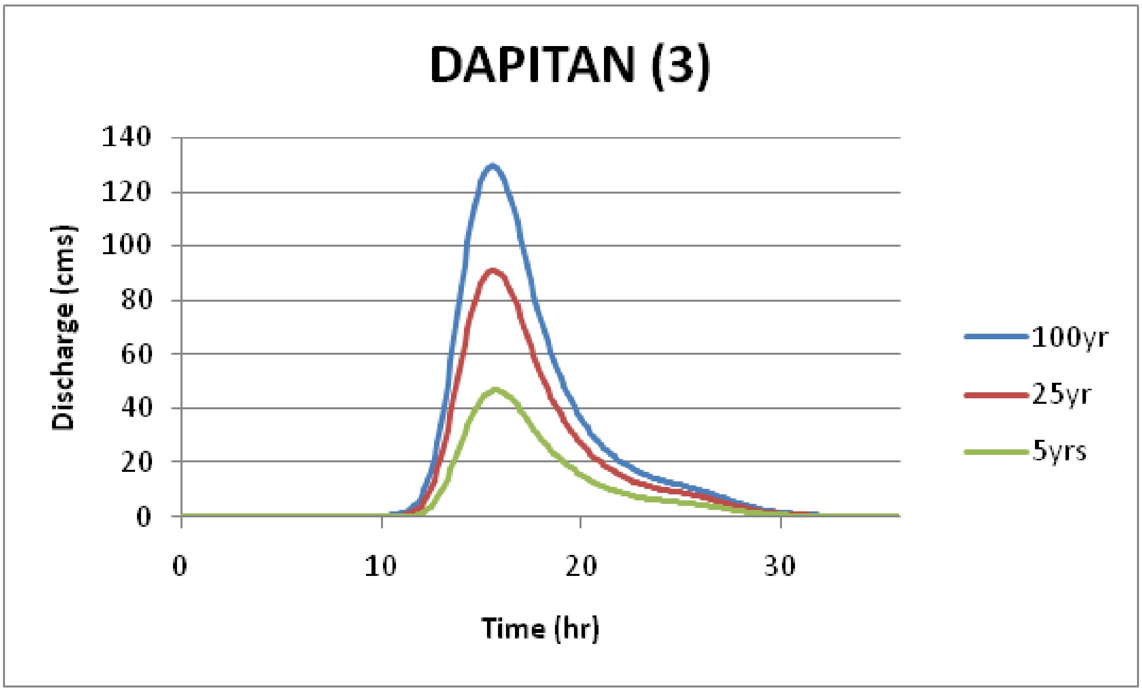


Figure 63. Dapitan river (3) generated discharge using 5-, 25-, and 100-year Dipolog rainfall intensity-duration-frequency (RIDF) in HEC-HMS

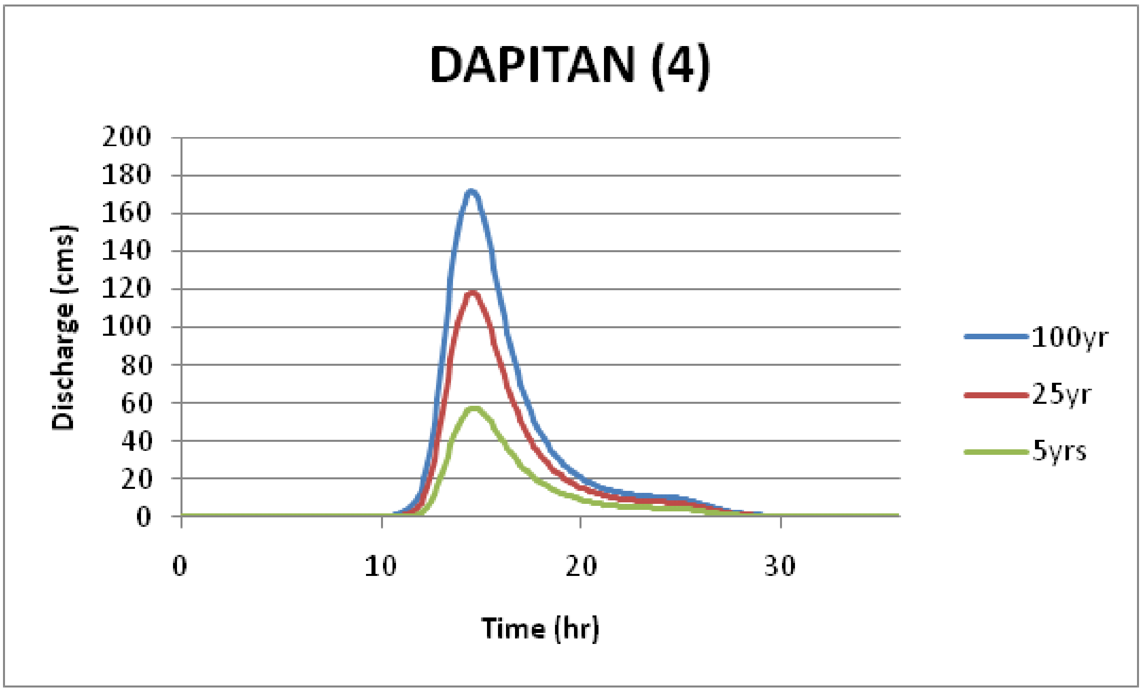


Figure 64. Dapitan river (4) generated discharge using 5-, 25-, and 100-year Dipolog rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 32. Summary of Dapitan river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	530.8	17 hours, 30 minutes
25-Year	372	17 hours, 30 minutes
5-Year	189.7	17 hours, 40 minutes

Table 33. Summary of Dapitan river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	334.3	15 hours, 50 minutes
25-Year	237.6	16 hours
5-Year	124.7	15 hours, 30 minutes

Table 34. Summary of Dapitan river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	129.5	15 hours, 30 minutes
25-Year	91.1	15 hours, 40 minutes
5-Year	46.7	15 hours, 40 minutes

Table 35. Summary of Dapitan river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	171.6	14 hours, 30 minutes
25-Year	118	14 hours, 30 minutes
5-Year	57.6	14 hours, 40 minutes

Table 36. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Dapitan (1)	166.936	112.780	333.804	PASS	PASS
Dapitan (2)	109.736	214.838	186.516	PASS	PASS
Dapitan (3)	41.096	36.873	99.306	PASS	FAIL
Dapitan (4)	50.688	59.325	105.981	PASS	FAIL

All four from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and two out of four were able to satisfy the conditions for validation using the specific discharge methods. The passing values are based on theory but are supported using other discharge computation methods so they were good to use for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Dapitan River using the calibrated HMS base flow is shown in Figure 65.

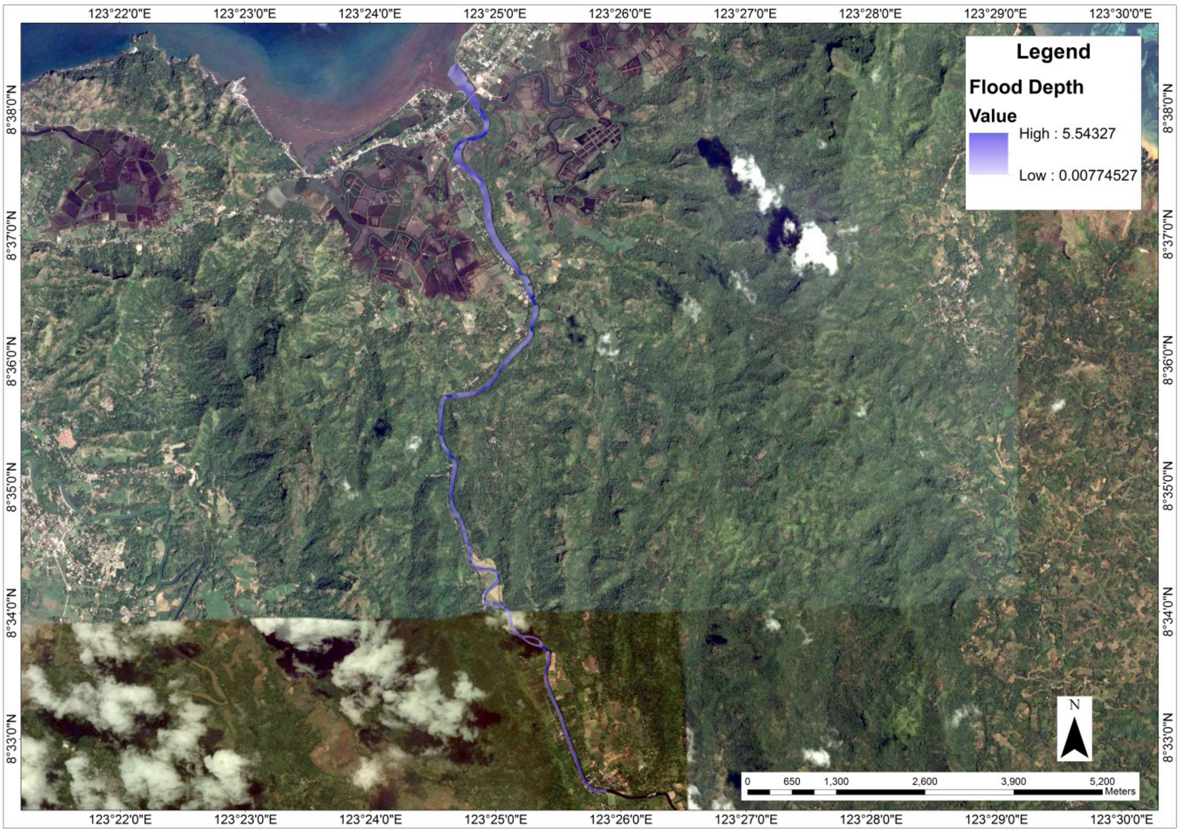


Figure 65. Sample output of Dapitan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Fgure 71 show the 5-, 25-, and 100-year rain return scenarios of the Dapitan Floodplain. The floodplain, with an area of 259.12 square kilometers covers Dapitan City and six municipalities namely Sapang Dalaga, La Libertad, Pinan, Polanco, Rizal, and Sibutad. Table 37 shows the percentage of area affected by flooding per municipality.

Table 37. Municipalities affected in Dapitan Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Sapang Dalaga	85.68	4.85	6%
Dapitan City	222.95	146.70	66%
La Libertad	66.24	12.37	19%
Pinan	135.87	0.24	0.2%
Polanco	86.49	1.02	1%
Rizal	61.97	38.61	62%
Sibutad	75.68	55.24	73%

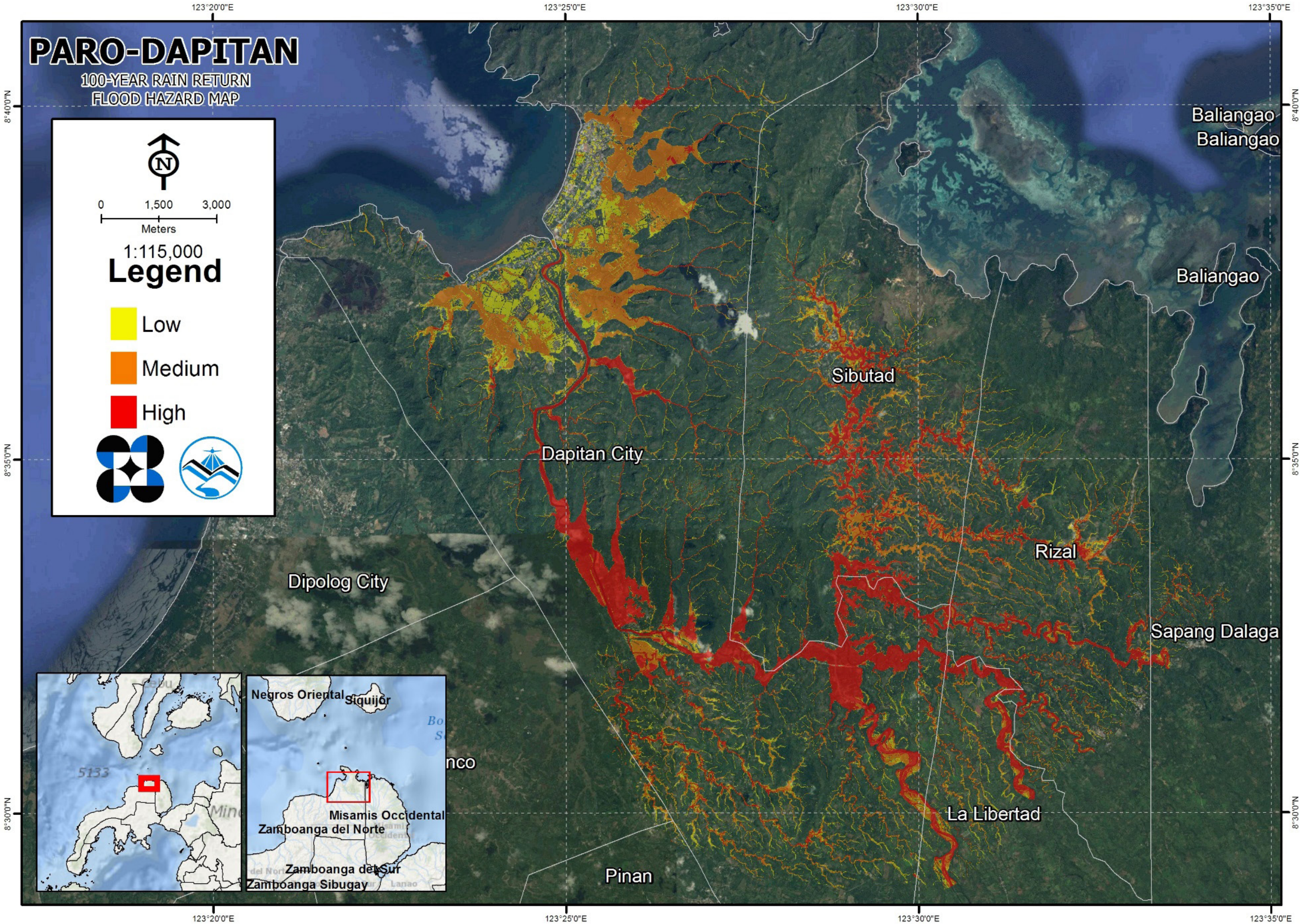


Figure 66. 100-year Hazard Map for Dapitan (Paro-Dapitan) Floodplain overlaid on Google Earth imagery

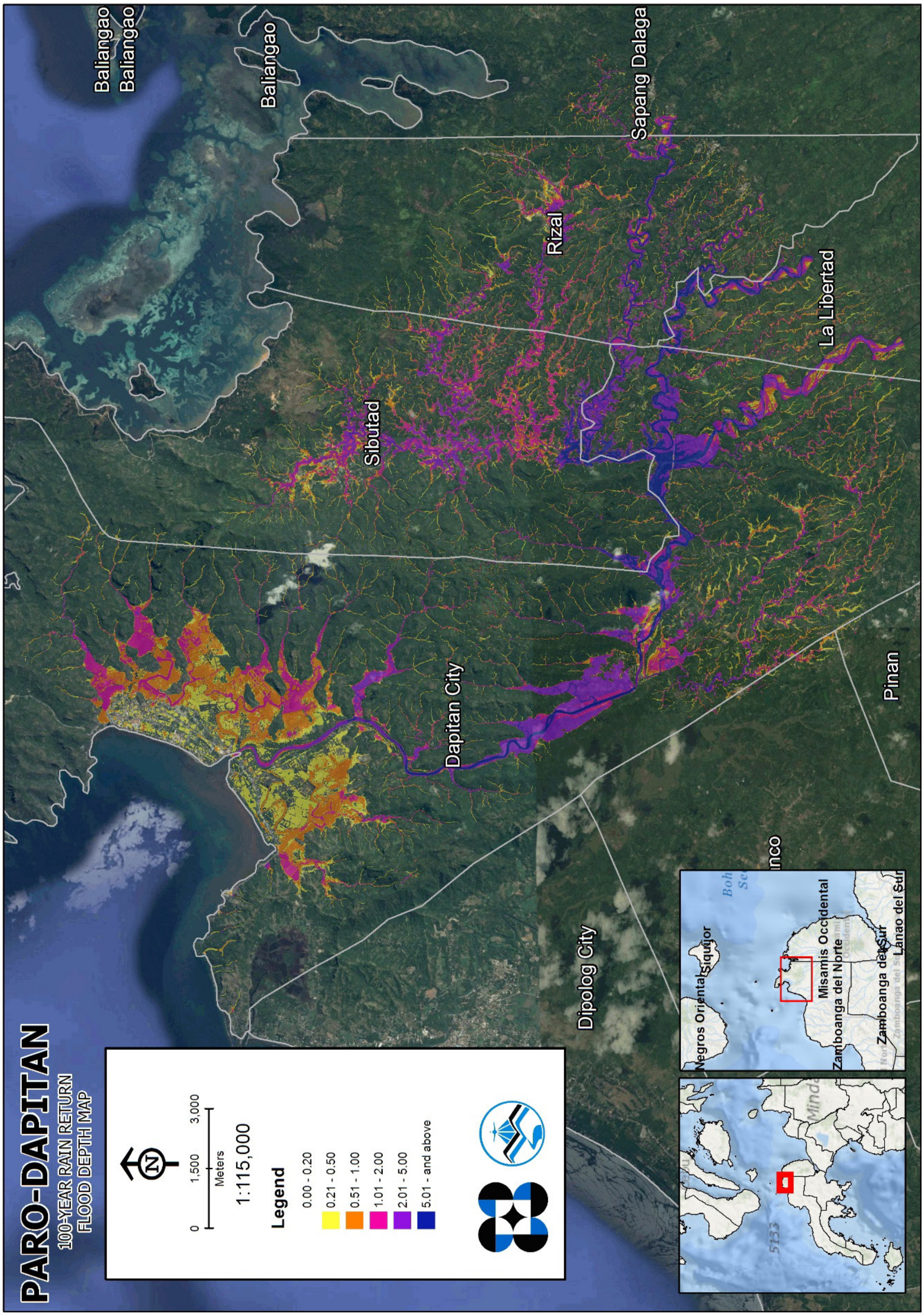


Figure 67. 100-year Flow Depth Map for Dapitan (Paro-Dapitan) Floodplain overlaid on Google Earth imagery

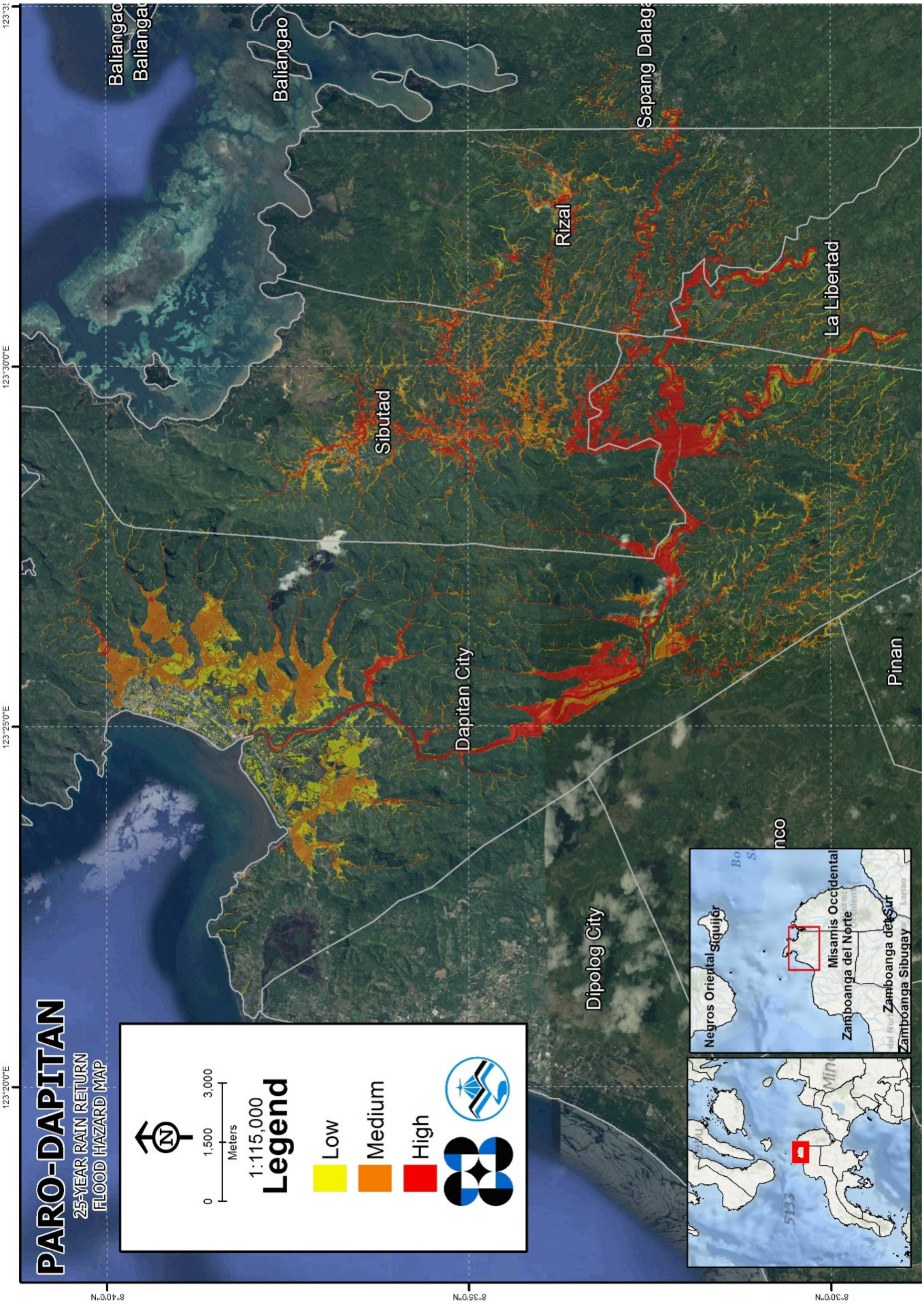


Figure 68. 25-year Hazard Map for Dapitan (Paro-Dapitan) Floodplain overlaid on Google Earth imagery

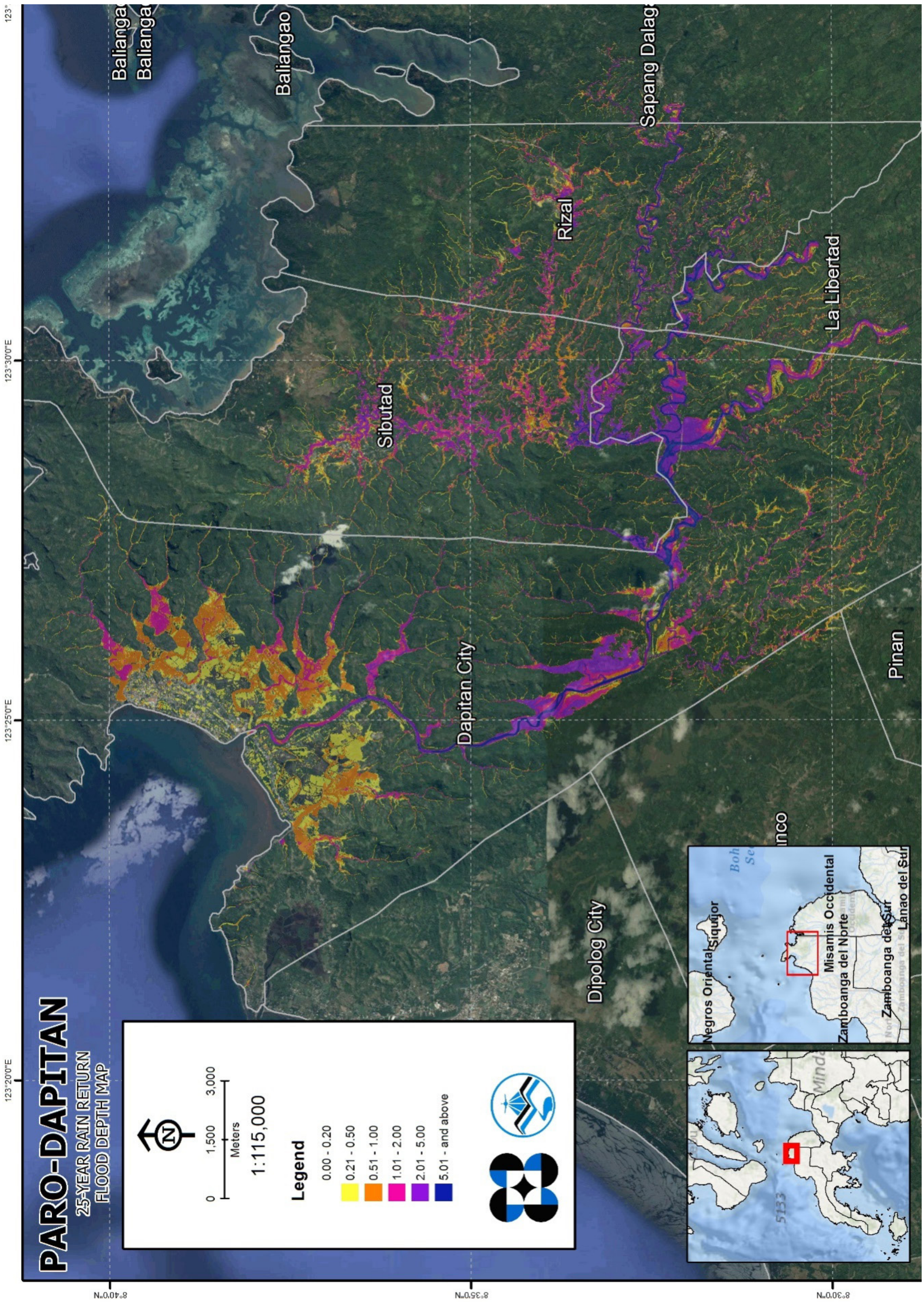


Figure 69. 25-year Flow Depth Map for Dapitan (Paro-Dapitan) Floodplain overlaid on Google Earth imagery

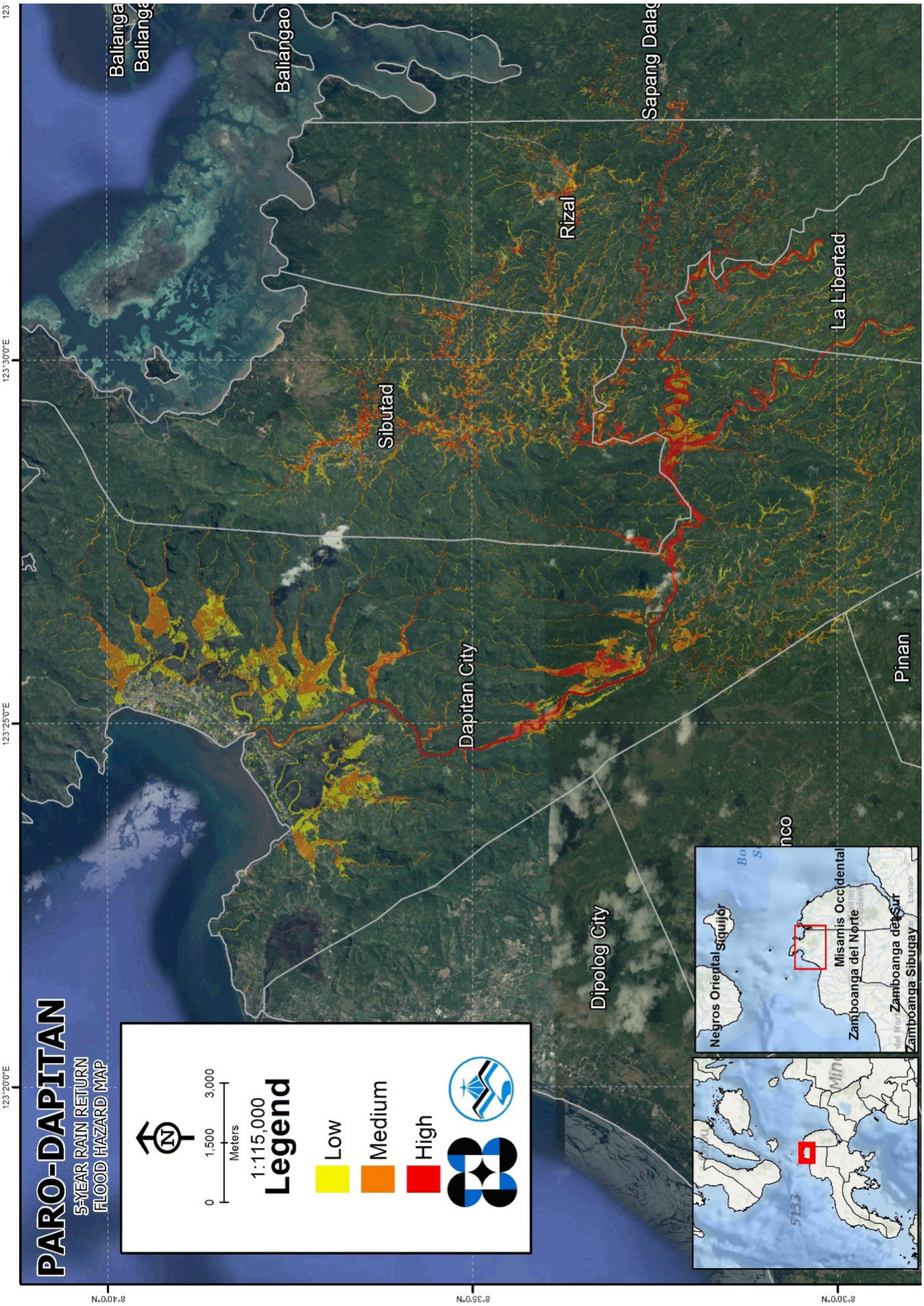


Figure 70. 5-year Hazard Map for Dapitan (Paro-Dapitan) Floodplain overlaid on Google Earth imagery

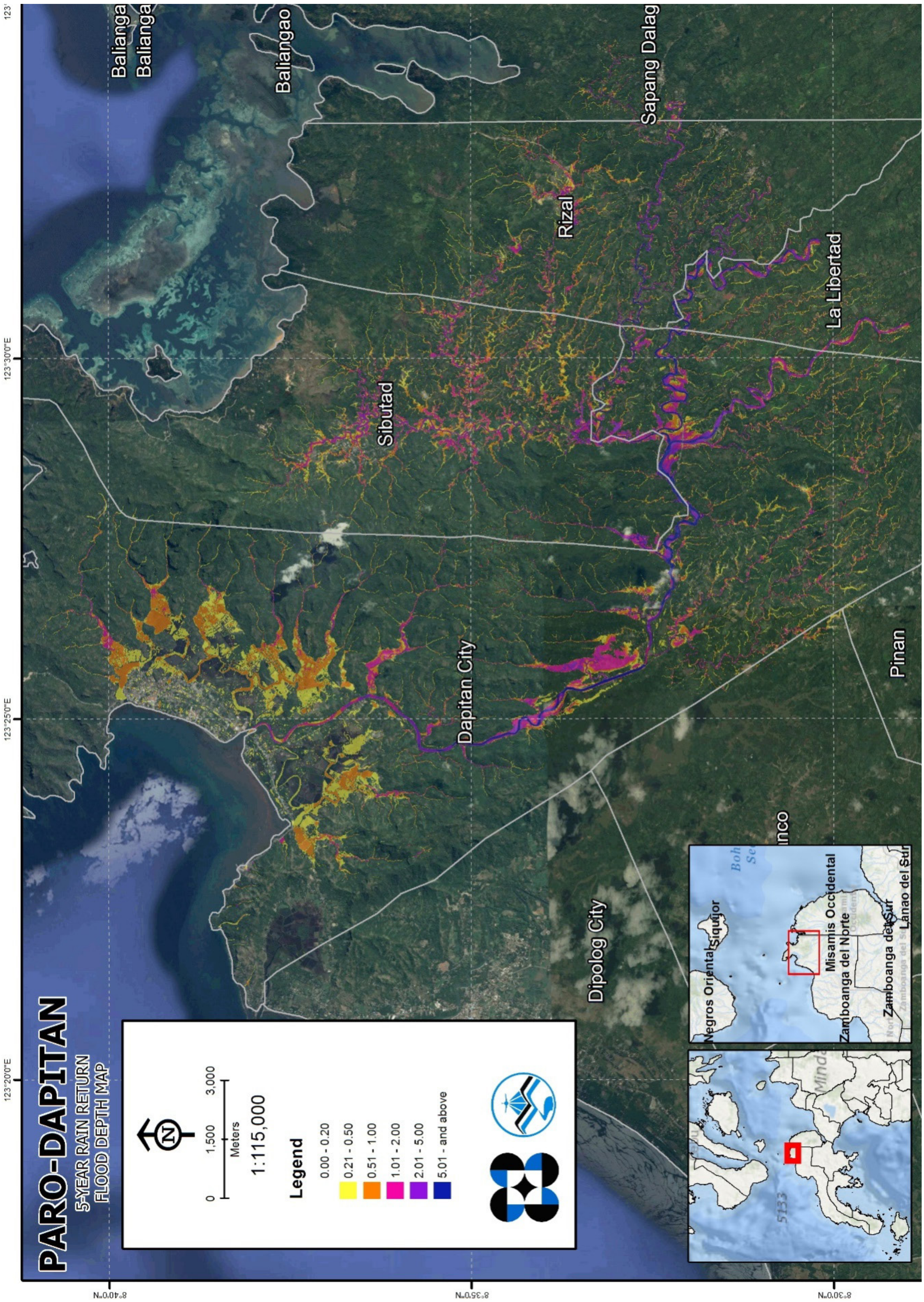


Figure 71. 5-year Flow Depth Map for Dapitan (Paro-Dapitan) Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Dapitan River Basin are listed below, grouped accordingly by municipality. For the said basin, seven (7) municipalities consisting of 81 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 55.44% of the city of Dapitan with an area of 222.95 square kilometers will experience flood levels of less 0.20 meters. 4.18% of the area will experience flood levels of 0.21 to 0.50 meters while 3.05%, 1.75%, 0.93%, and 0.46% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Dapitan City, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)												
	Antipolo	Aseniero	Ba-Ao	Bagting	Banonong	Barcelona	Baylimango	Burgos	Cawa-Cawa	Dampalan	Daro	Dawo	Diwa-An
0.03-0.20	6.02	5.75	3.28	0.17	1.32	11.32	0.64	0.83	0.15	4.6	1.06	1.1	11.22
0.21-0.50	0.37	0.3	0.14	0.027	0.14	0.72	0.011	0.071	0.057	0.36	0.029	0.11	0.47
0.51-1.00	0.31	0.2	0.11	0.0002	0.056	0.51	0.0051	0.076	0.1	0.37	0.012	0.0054	0.47
1.01-2.00	0.077	0.09	0.055	0	0	0.42	0.001	0.1	0	0.42	0.0034	0	0.44
2.01-5.00	0.018	0.02	0.031	0	0	0.32	0.0003	0.062	0	0.26	0.0007	0	0.19
> 5.00	0	0	0.0055	0	0	0.23	0	0.055	0	0.26	0	0	0.0071

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)												
	Hilltop	Ilaya	Kauswagan	Larayan	Linabo	Maria Cristina	Maria Uray	Masidla-kon	Matagobtob Poblacion	Opao	Oro	Owaon	Oyan
0.03-0.20	5.35	3.9	2	2.44	0.19	9.22	8.47	6.27	1.4	1.55	1.85	0.96	3.6
0.21-0.50	0.16	0.35	0.054	0.089	0.062	1.12	1.33	0.32	0.08	0.062	0.036	0.029	0.071
0.51-1.00	0.13	0.32	0.035	0.11	0.011	0.8	1.02	0.26	0.088	0.054	0.038	0.011	0.067
1.01-2.00	0.12	0.68	0.011	0.016	0	0.11	0.19	0.25	0.015	0.1	0.034	0.0052	0.11
2.01-5.00	0.028	0.17	0.0004	0.0031	0	0.0056	0.039	0.28	0	0.16	0.013	0.0003	0.13
> 5.00	0.0028	0.11	0	0.0002	0	0	0	0.028	0	0.14	0	0	0.078

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)											
	Polo	Potol	Potungan	San Nicolas	San Pedro	San Vicente	Santa Cruz	Santo Niño	Sicayab Bocana	Sinonoc	Sulangon	Tamion
0.03-0.20	1.57	0.34	3.14	8.81	2.16	1.09	0.26	0.0059	0.91	1.51	2.12	7.03
0.21-0.50	0.18	0.099	0.21	0.51	0.49	0.14	0.027	0	0.017	0.33	0.56	0.17
0.51-1.00	0.0028	0.022	0.2	0.28	0.25	0.036	0.0065	0	0.0043	0.58	0.14	0.12
1.01-2.00	0.0025	0	0.27	0.18	0.034	0.019	0.0004	0	0.0005	0.07	0.017	0.075
2.01-5.00	0.0065	0	0.23	0.051	0.0042	0.0025	0	0	0	0	0	0.036
> 5.00	0	0	0.096	0	0	0	0	0	0	0	0	0.01

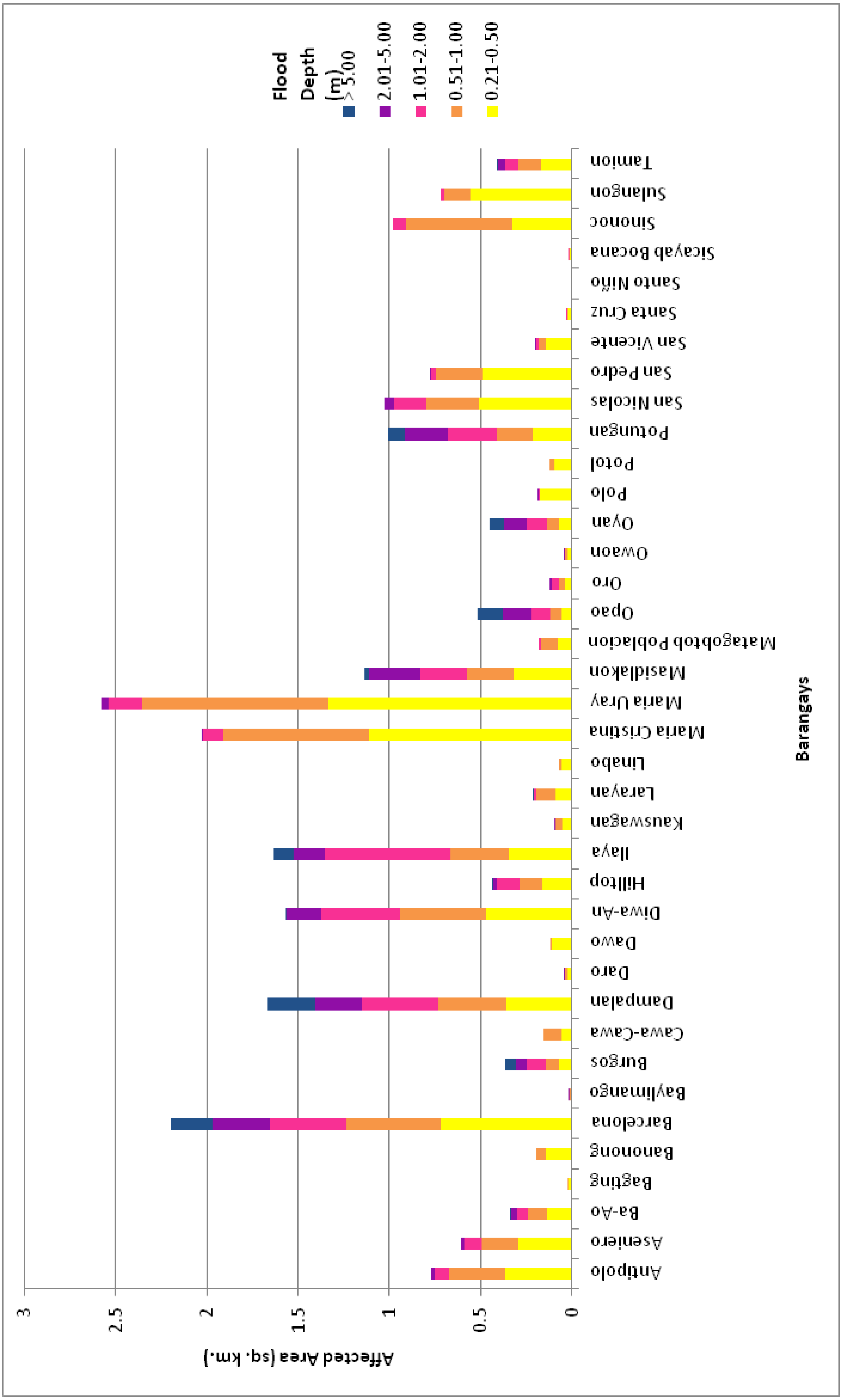


Figure 72. Affected Areas in Dapitan City, Zamboanga del Norte during 5-Year Rainfall Return Period

For the municipality of La Libertad, with an area of 66.24 square kilometers, 15.47% will experience flood levels of less 0.20 meters. 0.84% of the area will experience flood levels of 0.21 to 0.50 meters while 0.63%, 0.65%, 0.59%, and 0.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in La Libertad, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in La Libertad (in sq. km.)				
	La Union	Mauswagon	New Carcar	Poblacion	Singaran
0.03-0.20	2.57	4.95	0.39	0.84	1.51
0.21-0.50	0.13	0.28	0.01	0.047	0.092
0.51-1.00	0.1	0.2	0.0092	0.037	0.071
1.01-2.00	0.095	0.17	0.0069	0.035	0.12
2.01-5.00	0.15	0.15	0.0016	0.037	0.054
> 5.00	0.13	0.048	0	0.0004	0

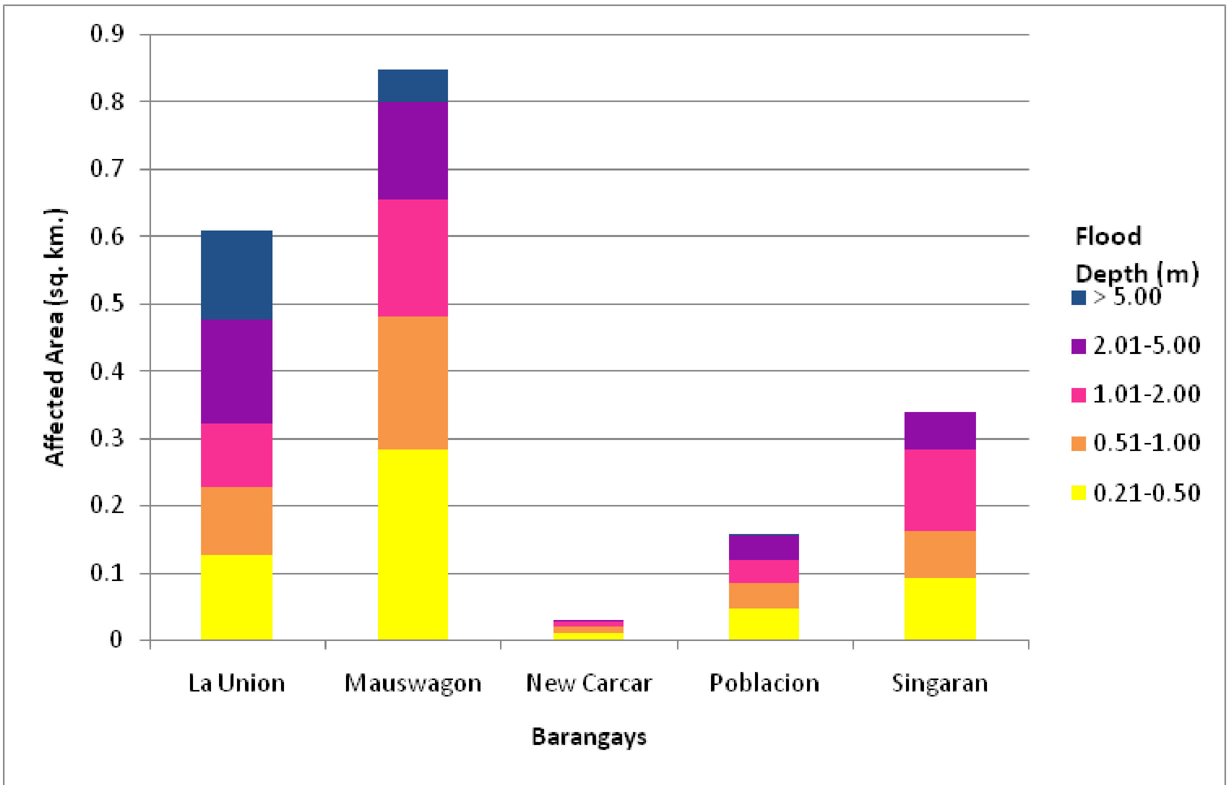


Figure73. Affected Areas in La Libertad, Zamboanga del Norte during 5-Year Rainfall Return Period

For the Municipality of Pinan, with an area of 135.87 square kilometers, 0.16% will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.003%, and 0.0005% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 40are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Pinan, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Pinan (in sq. km.)
	Adante
0.03-0.20	0.22
0.21-0.50	0.019039
0.51-1.00	0.004536
1.01-2.00	0.0007
2.01-5.00	0
> 5.00	0

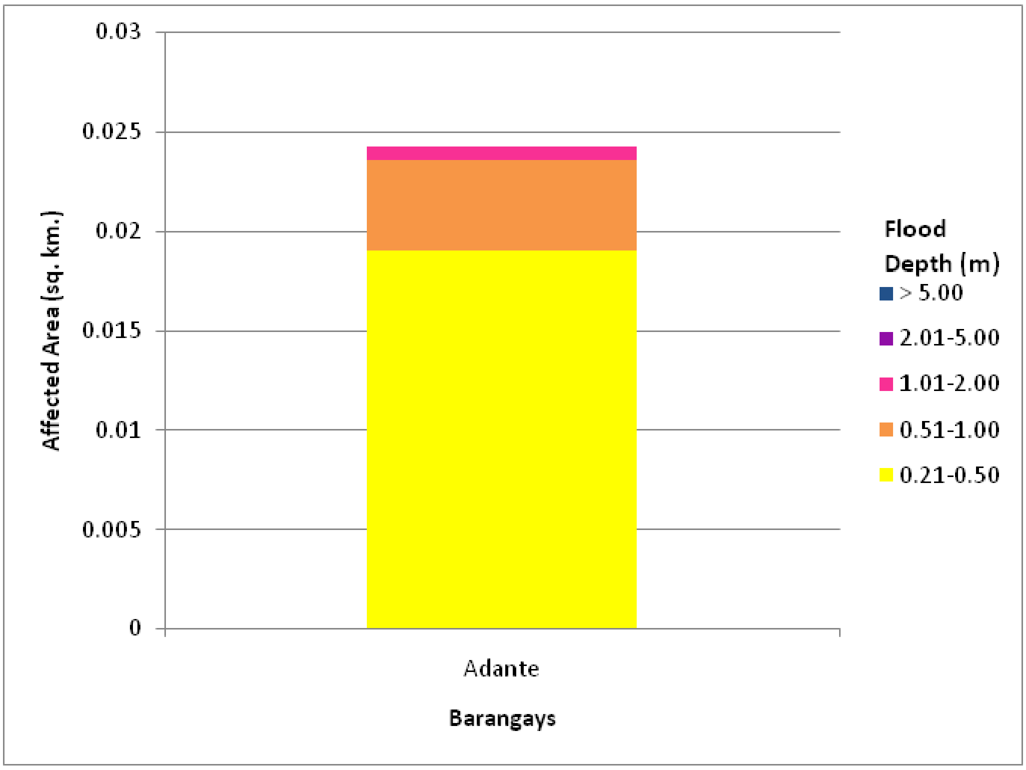


Figure74. Affected Areas in Pinan, Zamboanga del Norte during 5-Year Rainfall Return Period

For the Municipality of Polanco, with an area of 86.49 square kilometers, 0.65% will experience flood levels of less 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.01%, and 0.0007% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 41are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Polanco, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Polanco (in sq. km.)
	San Miguel
0.03-0.20	0.88
0.21-0.50	0.077
0.51-1.00	0.039
1.01-2.00	0.019
2.01-5.00	0.0009
> 5.00	0

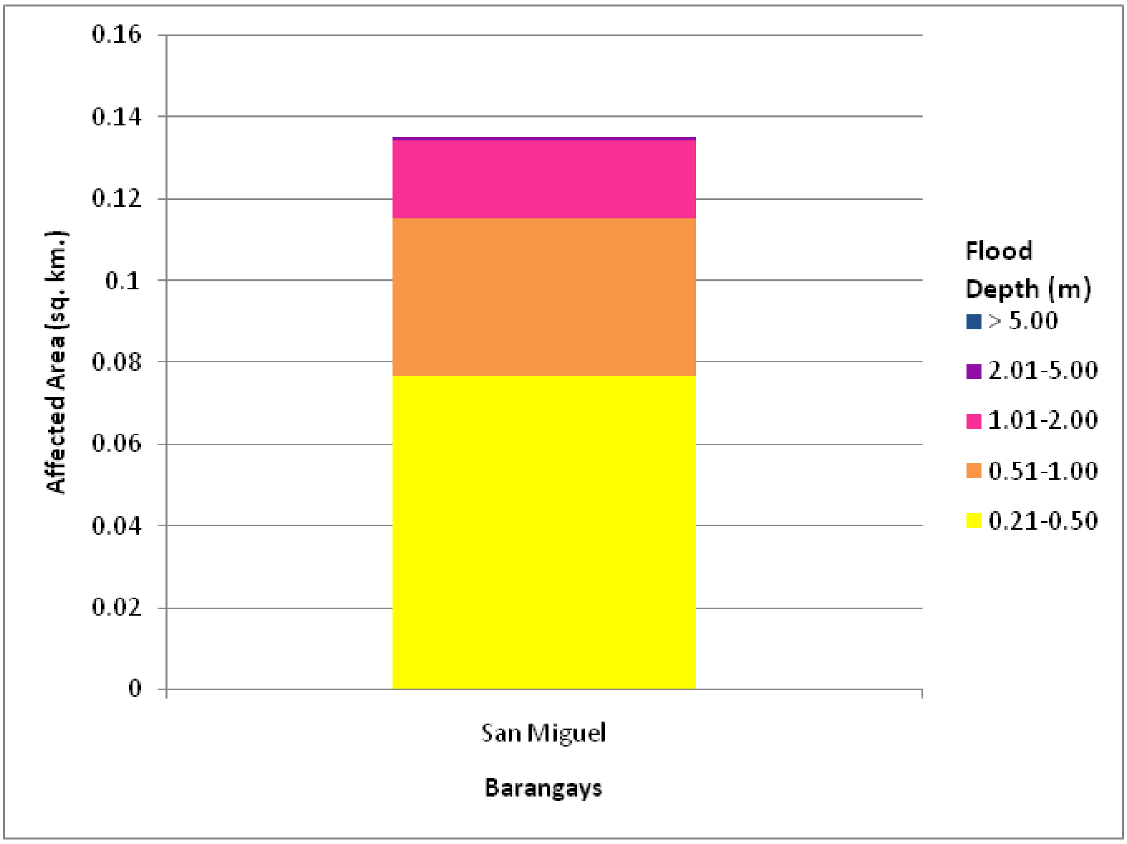


Figure 75. Affected Areas in Polanco, Zamboanga del Norte during 5-Year Rainfall Return Period

For the Municipality of Rizal, with an area of 61.97 sq. km., 31.08% will experience flood levels of less 0.20 meters. 1.31% of the area will experience flood levels of 0.21 to 0.50 meters while 1.02%, 0.70%, 0.42%, and 0.18% 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 42are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Rizal, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)								
	Balubohan	Birayan	Damasing	East Poblacion	La Esperanza	Mabuhay	Mitimos	Nangcaan	Napilan
0.03-0.20	0.17	2.08	0.11	0.88	2.72	0.22	1	1.92	1.2
0.21-0.50	0.00071	0.11	0.0015	0.041	0.16	0.0092	0.039	0.059	0.05
0.51-1.00	0.0001	0.1	0.0001	0.021	0.16	0.0022	0.037	0.05	0.036
1.01-2.00	0	0.057	0	0.028	0.15	0.0006	0.033	0.042	0.029
2.01-5.00	0	0.013	0	0.018	0.095	0	0.014	0.11	0.045
> 5.00	0	0	0	0	0.0065	0	0.000083	0.0015	0.0002

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)								
	Nasipang	New Dapitan	Nilabo	North Mapang	Rizalina	San Roque	South Mapang	Tolon	West Poblacion
0.03-0.20	0.72	0.95	3.09	0.043	7.52	5.98	2	2.74	1.02
0.21-0.50	0.021	0.032	0.14	0.0012	0.32	0.27	0.08	0.087	0.049
0.51-1.00	0.0078	0.023	0.082	0.0009	0.21	0.29	0.048	0.059	0.032
1.01-2.00	0.0011	0.035	0.047	0.0006	0.14	0.2	0.04	0.036	0.018
2.01-5.00	0.0001	0.077	0.0094	0	0.054	0.11	0.042	0.046	0.0044
> 5.00	0	0.017	0.0001	0	0	0.11	0.00069	0.0043	0

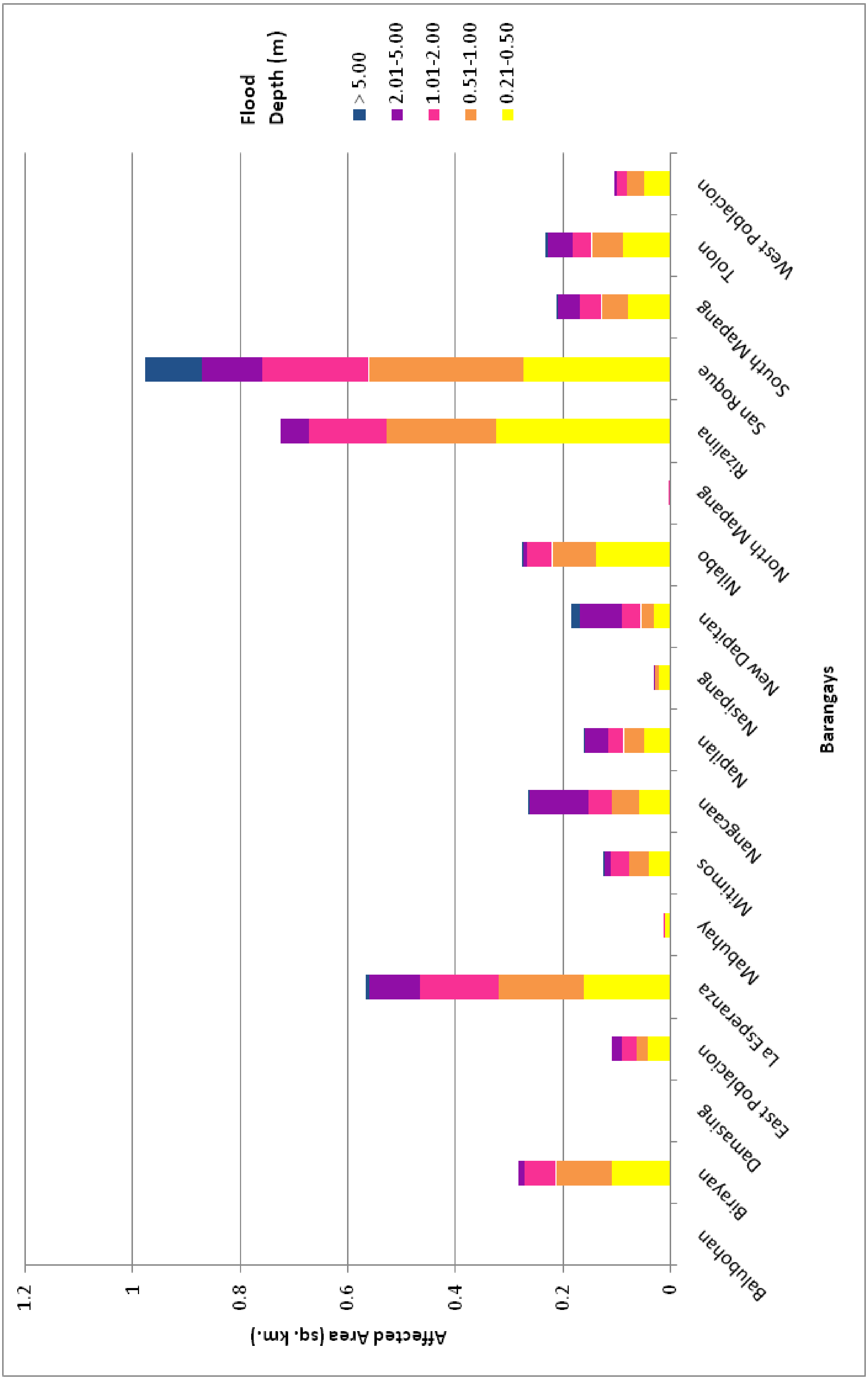


Figure 76. Affected Areas in Rizal, Zamboanga del Norte during 5-Year Rainfall Return Period

For the Municipality of Sapang Dalaga, with an area of 85.68 square kilometers, 5.15% will experience flood levels of less 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters while 0.13%, 0.11%, 0.09%, and 0.0005% 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 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Sapang Dalaga, Misamis Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Sapang Dalaga (in sq. km.)				
	Agapito Yap, Sr.	Boundary	Casul	El Paraiso	Poblacion
0.03-0.20	0.21	2.36	0.73	0.28	0.84
0.21-0.50	0.006	0.09	0.0091	0.0091	0.047
0.51-1.00	0.0027	0.063	0.0026	0.0073	0.037
1.01-2.00	0.0021	0.048	0.0012	0.0066	0.035
2.01-5.00	0.0054	0.03	0.0002	0.0011	0.037
> 5.00	0	0	0	0	0.0004

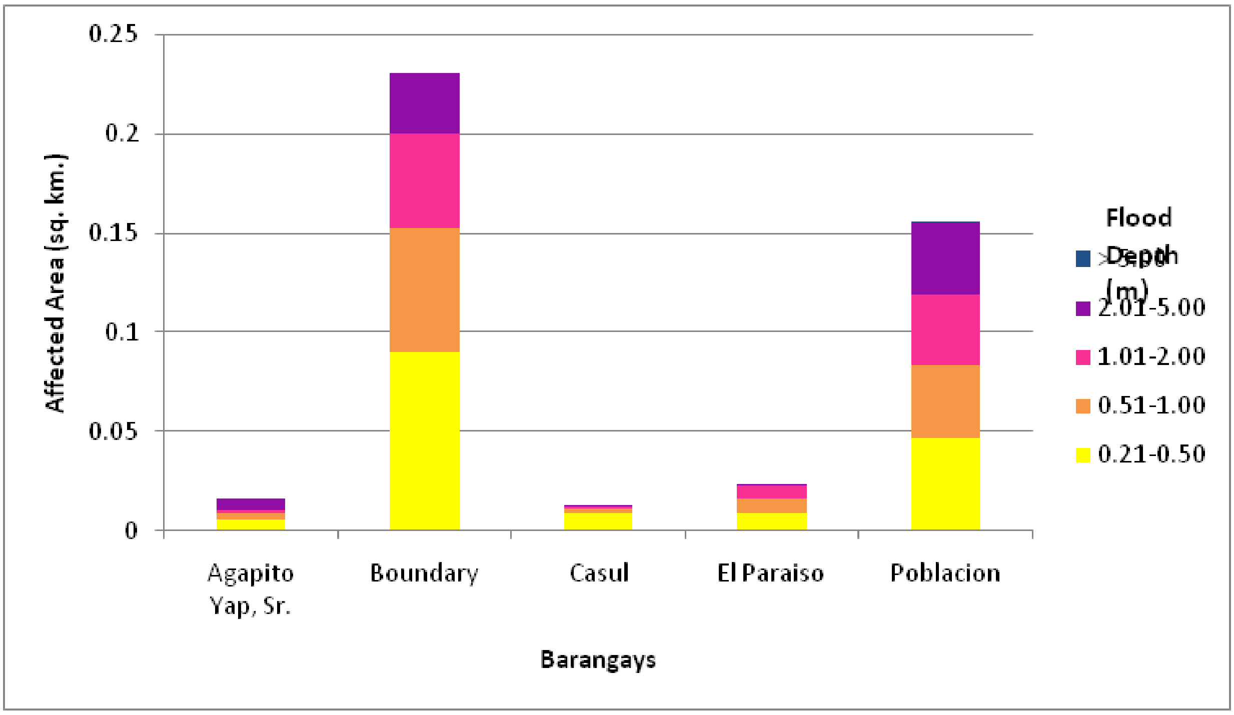


Figure 77. Affected Areas in Sapang Dalaga, Misamis Occidental during 5-Year Rainfall Return Period

For the Municipality of Sibutad, with an area of 75.68 square kilometers, 51.24% will experience flood levels of less 0.20 meters. 2.76% of the area will experience flood levels of 0.21 to 0.50 meters while 2.77%, 2.07%, 0.95%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Sibutad, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Sibutad (in sq. km.)												
	Bagacay	Calilic	Calube	Delapa	Kanim	Libay	Magsaysay	Marapong	Minlasag	Oyan	Poblacion	Sibuloc	Sipaloc
0.03-0.20	3.43	4.56	1.44	3.63	0.21	0.48	5.69	3.96	3.48	3.6	0.84	1.94	5.51
0.21-0.50	0.3	0.15	0.041	0.33	0.0027	0.0092	0.19	0.17	0.18	0.071	0.047	0.19	0.41
0.51-1.00	0.28	0.12	0.015	0.36	0.0005	0.0023	0.14	0.14	0.14	0.067	0.037	0.33	0.46
1.01-2.00	0.11	0.08	0.0012	0.25	0	0.0001	0.081	0.15	0.14	0.11	0.035	0.29	0.32
2.01-5.00	0.028	0.014	0	0.058	0	0	0.026	0.099	0.097	0.13	0.037	0.13	0.1
> 5.00	0.0033	0	0	0	0	0	0.0002	0.0054	0.0002	0.078	0.0004	0	0

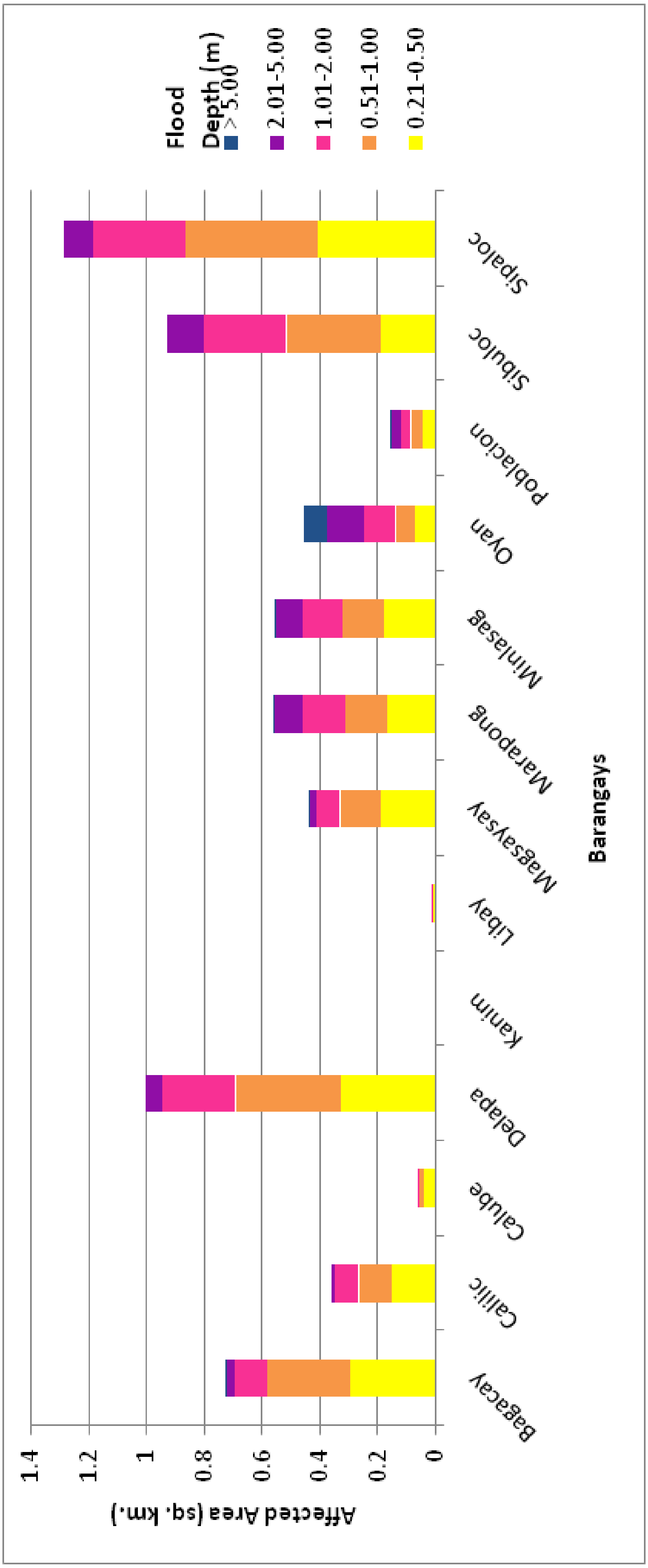


Figure 78. Affected Areas in Sibutad, Zamboanga del Norte during 5-Year Rainfall Return Period

For the 25-Year return period, 51.29% of the city of Dapitan with an area of 222.95 square kilometers. will experience flood levels of less 0.20 meters. 4.41% of the area will experience flood levels of 0.21 to 0.50 meters while 4.16%, 2.65%, 2.53%, and 0.77% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Dapitan City, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)												
	Antipolo	Aseniero	Ba-Ao	Bagting	Banonong	Barcelona	Baylimango	Burgos	Cawa-Cawa	Dampalan	Daro	Dawo	Diwa-An
0.03-0.20	5.84	5.57	3.18	0.15	0.97	10.29	0.64	0.67	0.12	4.06	1.05	0.97	10.86
0.21-0.50	0.38	0.34	0.12	0.029	0.45	0.75	0.012	0.028	0.029	0.27	0.037	0.23	0.53
0.51-1.00	0.42	0.25	0.13	0.011	0.094	0.71	0.0077	0.035	0.099	0.23	0.015	0.018	0.42
1.01-2.00	0.12	0.16	0.12	0	0.0079	0.75	0.0015	0.12	0.053	0.38	0.0057	0	0.57
2.01-5.00	0.029	0.036	0.065	0	0	0.66	0.0005	0.25	0	0.97	0.0011	0	0.39
> 5.00	0.00062	0	0.0072	0	0	0.38	0	0.084	0	0.35	0	0	0.022

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)												
	Hilltop	Ilaya	Kauswagan	Larayan	Linabo	Maria Cristina	Maria Uray	Masidla-kon	Matagobtob Poblacion	Opao	Oro	Owaon	Oyan
0.03-0.20	5.17	3.29	1.97	2.4	0.15	8.33	7.73	5.58	1.37	1.46	1.83	0.95	3.54
0.21-0.50	0.13	0.15	0.058	0.09	0.041	1.08	1.03	0.39	0.053	0.052	0.041	0.035	0.076
0.51-1.00	0.1	0.28	0.043	0.13	0.071	1.43	1.64	0.44	0.11	0.034	0.034	0.015	0.052
1.01-2.00	0.18	0.61	0.02	0.027	0	0.39	0.57	0.41	0.049	0.039	0.046	0.0076	0.061
2.01-5.00	0.21	1.07	0.0022	0.0088	0	0.014	0.081	0.45	0	0.24	0.026	0.001	0.2
> 5.00	0.0049	0.14	0	0.0006	0	0	0	0.14	0	0.25	0.0002	0	0.12

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)											
	Polo	Potol	Potungan	San Nicolas	San Pe-dro	San Vicente	Santa Cruz	Santo Niño	Sicayab Bocana	Sinonoc	Sulangon	Tamion
0.03-0.20	1.25	0.25	2.61	8.41	1.99	0.7	0.23	0.0059	0.9	1.36	1.6	6.91
0.21-0.50	0.44	0.088	0.13	0.62	0.38	0.44	0.053	0	0.026	0.15	0.89	0.19
0.51-1.00	0.066	0.12	0.14	0.43	0.51	0.11	0.011	0	0.006	0.6	0.32	0.15
1.01-2.00	0.0021	0.0011	0.33	0.27	0.059	0.031	0.0008	0	0.0011	0.37	0.023	0.11
2.01-5.00	0.008	0	0.74	0.12	0.0088	0.0093	0	0	0	0.0042	0.0056	0.046
> 5.00	0	0	0.2	0	0	0	0	0	0	0	0	0.032

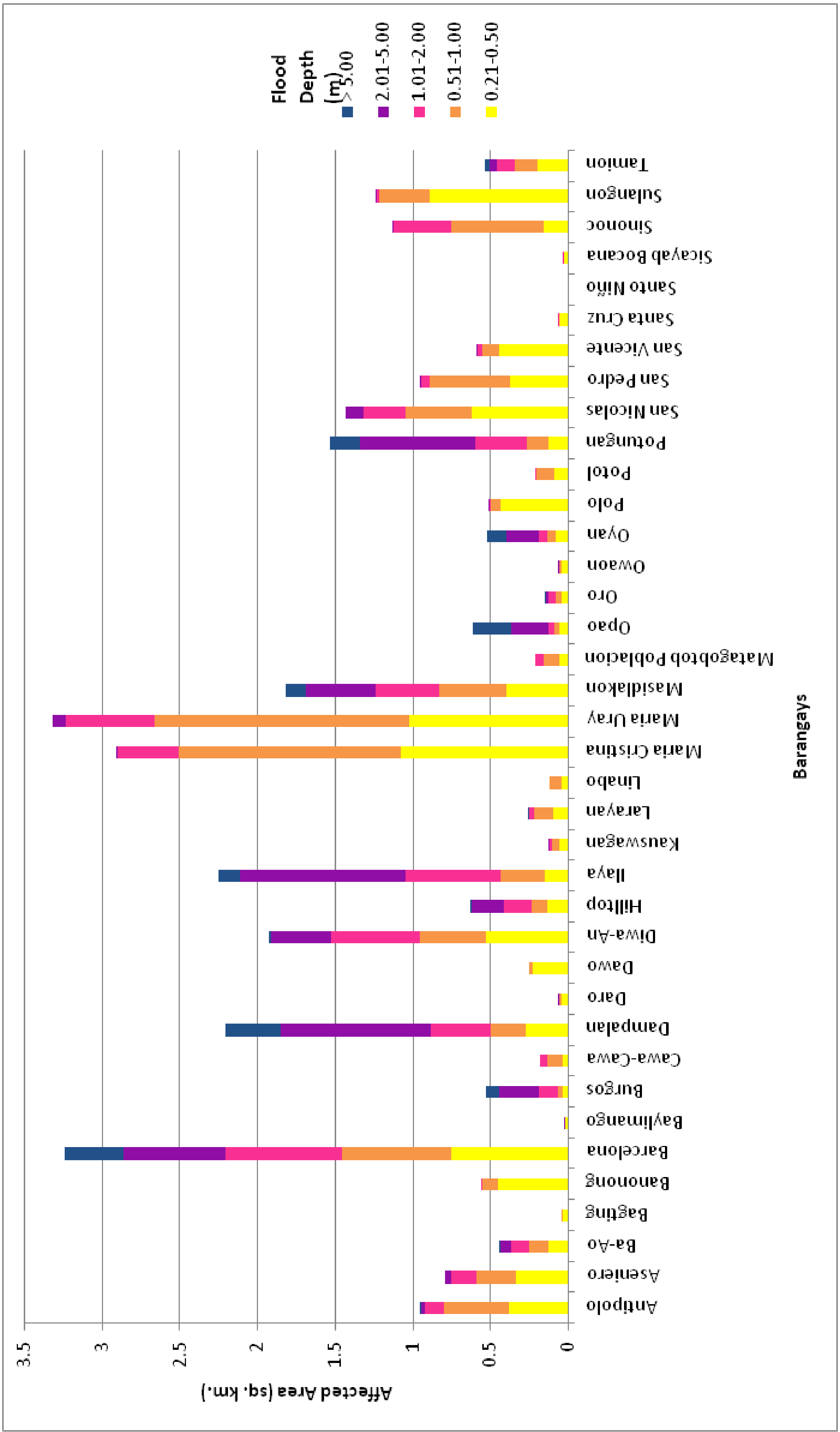


Figure 79. Affected Areas in Dapitan City, Zamboanga del Norte during 25-Year Rainfall Return Period

For the Municipality of La Libertad, with an area of 66.24 square kilometers, 14.28% will experience flood levels of less 0.20 meters. 0.95% of the area will experience flood levels of 0.21 to 0.50 meters while 0.77%, 0.84%, 1.07%, and 0.55% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected Areas in La Libertad, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in La Libertad (in sq. km.)				
	La Union	Mauswagon	New Carcar	Poblacion	Singaran
0.03-0.20	2.33	4.67	0.38	0.78	1.31
0.21-0.50	0.12	0.33	0.01	0.048	0.13
0.51-1.00	0.097	0.25	0.011	0.048	0.1
1.01-2.00	0.13	0.22	0.012	0.055	0.14
2.01-5.00	0.25	0.23	0.0035	0.061	0.17
> 5.00	0.25	0.11	0.000018	0.0039	0.0009

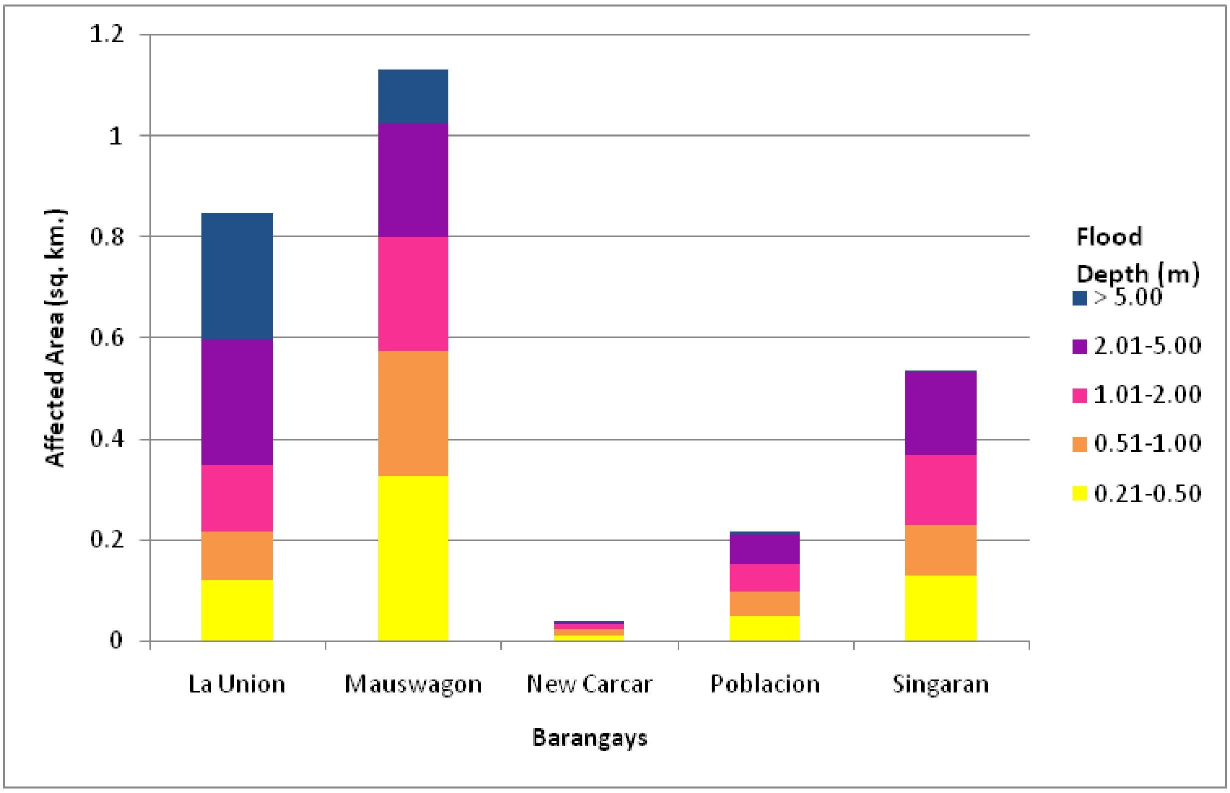


Figure 80. Affected Areas in La Libertad, Zamboanga del Norte during 25-Year Rainfall Return Period

For the Municipality of Pinan, with an area of 135.87 square kilometers, 0.15% will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.007%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 47 are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Pinan, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pinan (in sq. km.)
	Adante
0.03-0.20	0.21
0.21-0.50	0.019039
0.51-1.00	0.004536
1.01-2.00	0.0007
2.01-5.00	0
> 5.00	0

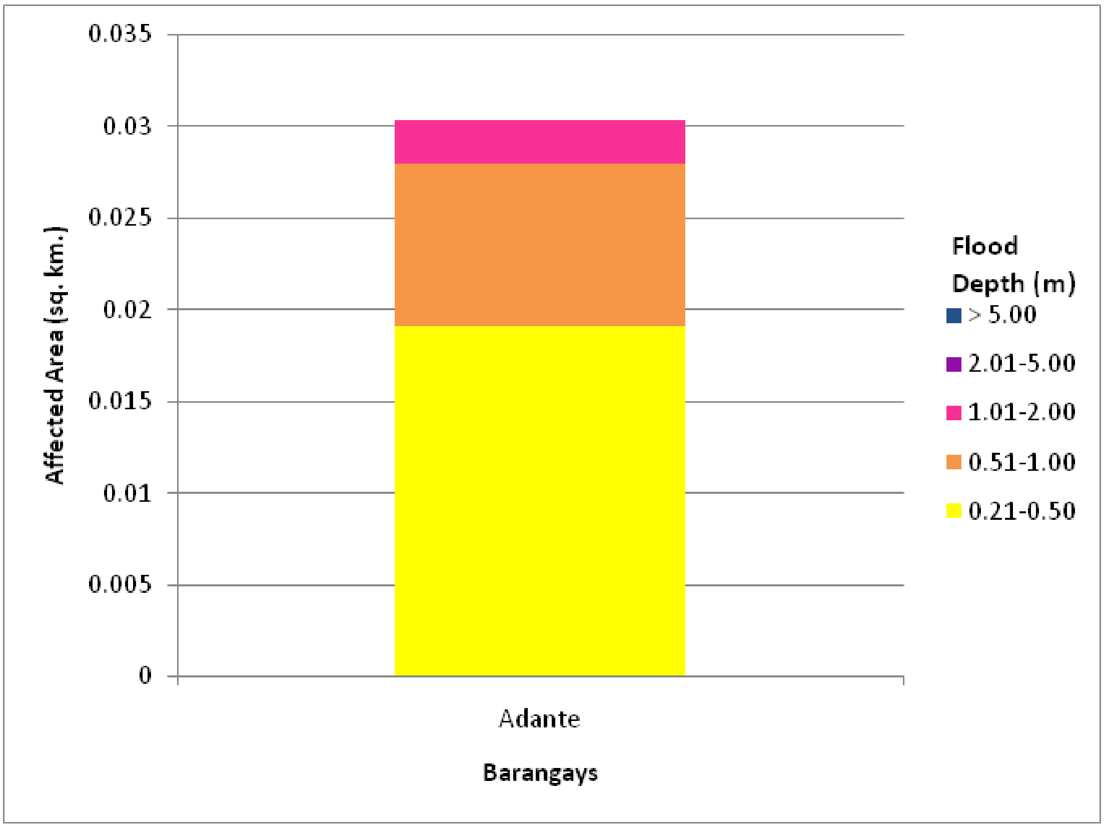


Figure 81. Affected Areas in Pinan, Zamboanga del Norte during 25-Year Rainfall Return Period

For the Municipality of Polanco, with an area of 86.49 square kilometers, 0.61% will experience flood levels of less 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.03%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 48are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Polanco, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Polanco (in sq. km.)
	San Miguel
0.03-0.20	0.83
0.21-0.50	0.086
0.51-1.00	0.065
1.01-2.00	0.036
2.01-5.00	0.0039
> 5.00	0

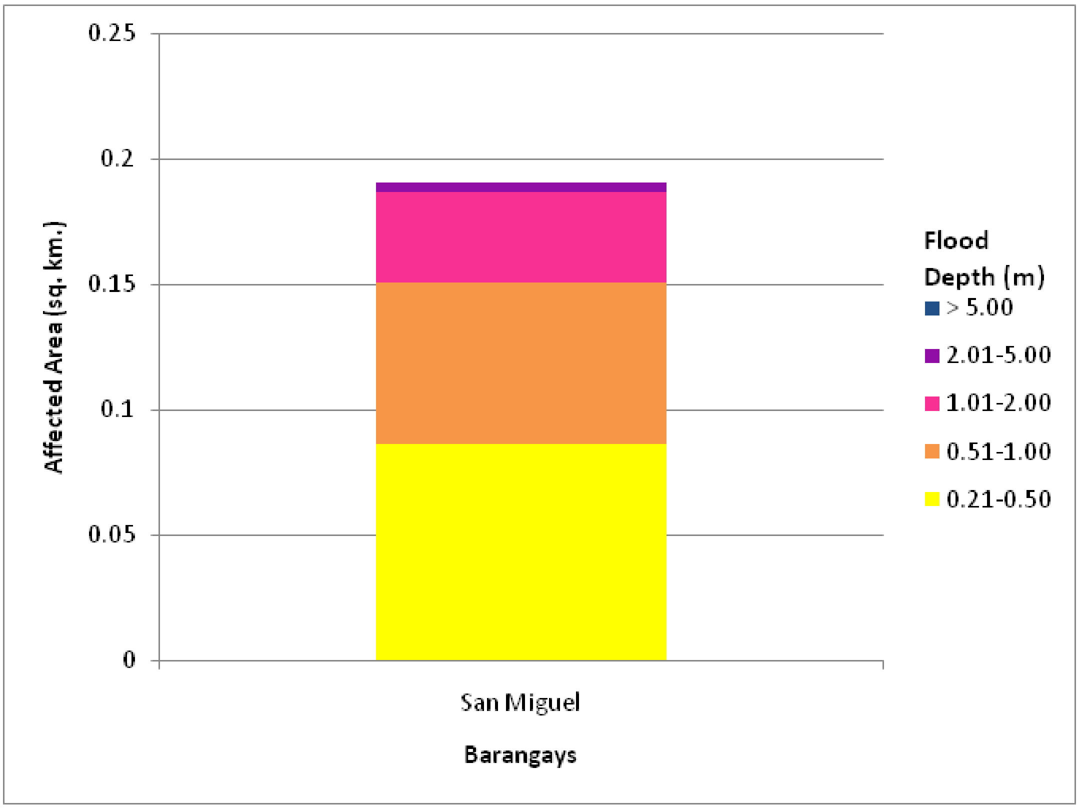


Figure 82. Affected Areas in Polanco, Zamboanga del Norte during 25-Year Rainfall Return Period

For the Municipality of Rizal, with an area of 61.97 square kilometers, 29.53% will experience flood levels of less 0.20 meters. 1.40% of the area will experience flood levels of 0.21 to 0.50 meters while 1.33%, 1.27%, 0.87%, and 0.32% 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 49are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Rizal, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)								
	Balubohan	Birayan	Damasing	East Poblacion	La Esperanza	Mabuhay	Mitimos	Nangcaan	Napilan
0.03-0.20	0.17	2	0.11	0.84	2.55	0.21	0.97	1.74	1.11
0.21-0.50	0.0022	0.11	0.0025	0.053	0.17	0.011	0.041	0.075	0.055
0.51-1.00	0	0.13	0.0002	0.039	0.17	0.0032	0.042	0.081	0.049
1.01-2.00	0.0001	0.1	0	0.024	0.21	0.00092	0.042	0.09	0.051
2.01-5.00	0	0.027	0	0.036	0.17	0	0.032	0.11	0.065
> 5.00	0	0	0	0	0.014	0	0.000083	0.089	0.029

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)								
	Nasipang	New Dapitan	Nilabo	North Mapang	Rizalina	San Roque	South Mapang	Tolon	West Poblacion
0.03-0.20	0.71	0.87	3.02	0.042	7.27	5.53	1.89	2.63	0.99
0.21-0.50	0.025	0.031	0.16	0.0016	0.36	0.25	0.1	0.098	0.059
0.51-1.00	0.011	0.026	0.099	0.0009	0.25	0.36	0.08	0.085	0.043
1.01-2.00	0.0031	0.04	0.069	0.001	0.22	0.4	0.073	0.065	0.027
2.01-5.00	0.0001	0.1	0.02	0.0001	0.14	0.27	0.06	0.061	0.0086
> 5.00	0	0.059	0.0001	0	0	0.15	0.01	0.032	0

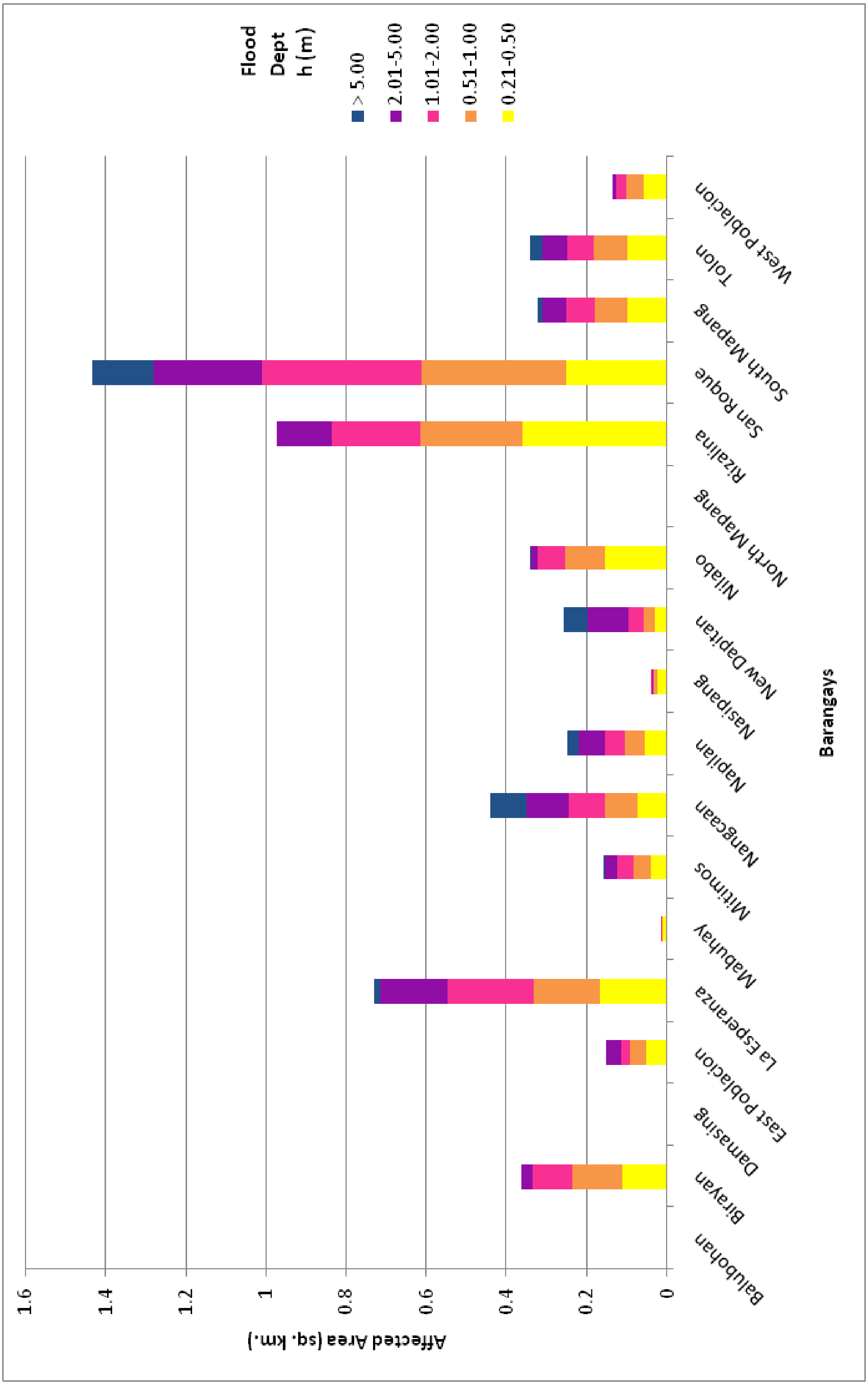


Figure 83. Affected Areas in Rizal, Zamboanga del Norte during 25-Year Rainfall Return Period

For the Municipality of Sapang Dalaga, with an area of 85.68 square kilometers, 4.98% will experience flood levels of less 0.20 meters. 0.21% of the area will experience flood levels of 0.21 to 0.50 meters while 0.17%, 0.16%, 0.15%, and 0.0006% 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 50 are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Sapang Dalaga, Misamis Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Sapang Dalaga (in sq. km.)				
	Agapito Yap, Sr.	Boundary	Casul	El Paraiso	Poblacion
0.03-0.20	0.2	2.28	0.73	0.27	0.78
0.21-0.50	0.0058	0.1	0.012	0.01	0.048
0.51-1.00	0.0038	0.078	0.0036	0.0089	0.048
1.01-2.00	0.0032	0.069	0.0015	0.0085	0.055
2.01-5.00	0.0059	0.056	0.0006	0.0025	0.061
> 5.00	0.00089	0	0	0	0.0039

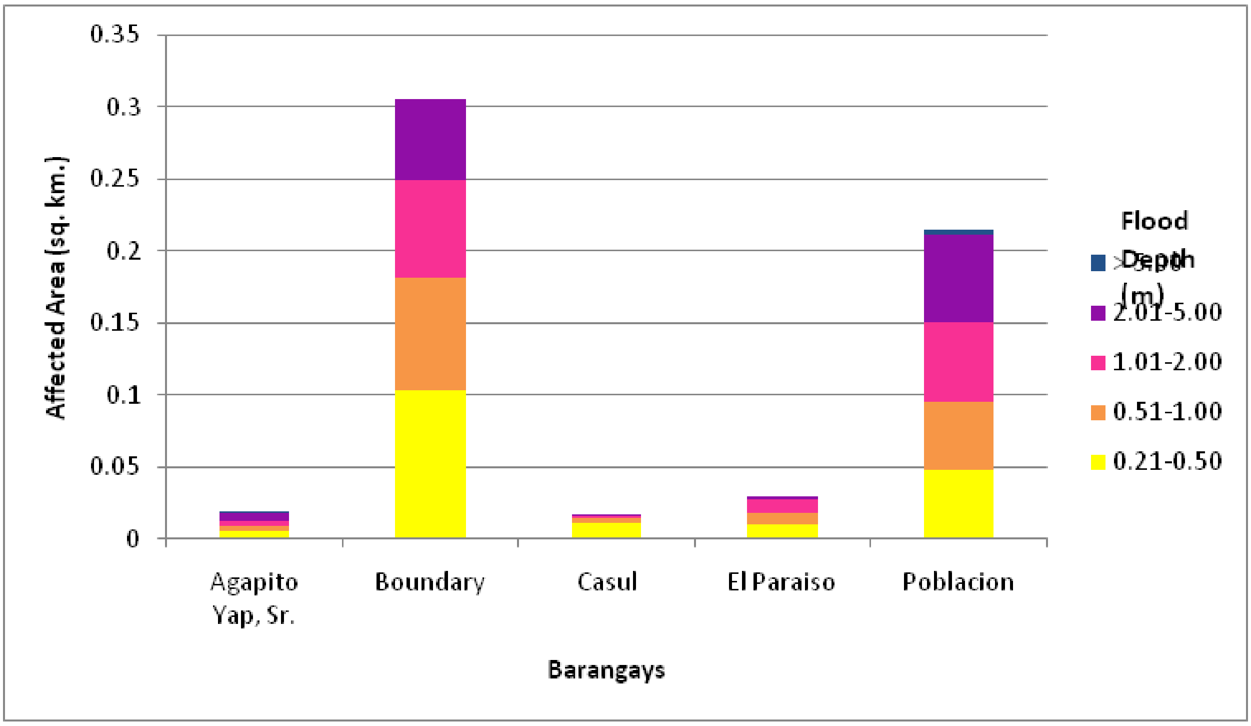


Figure 84. Affected Areas in Sapang Dalaga, Misamis Occidental during 25-Year Rainfall Return Period

For the Municipality of Sibutad, with an area of 75.68 square kilometers, 48.29% will experience flood levels of less 0.20 meters. 2.34% of the area will experience flood levels of 0.21 to 0.50 meters while 2.96%, 3.67%, 2.36%, and 0.28% 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 51 are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected Areas in Sibutad, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Sibutad (in sq. km.)												
	Bagacay	Calilic	Calube	Delapa	Kanim	Libay	Magsaysay	Marapong	Minlasag	Oyan	Poblacion	Sibuloc	Sipaloc
0.03-0.20	3.13	4.47	1.42	3.15	0.21	0.48	5.59	3.58	3.33	3.54	0.78	1.69	5.19
0.21-0.50	0.15	0.17	0.049	0.21	0.0036	0.014	0.22	0.2	0.18	0.076	0.048	0.11	0.34
0.51-1.00	0.33	0.12	0.023	0.43	0.0005	0.0033	0.14	0.26	0.16	0.052	0.048	0.21	0.45
1.01-2.00	0.28	0.12	0.0033	0.64	0.0002	0.0001	0.14	0.21	0.18	0.061	0.055	0.53	0.56
2.01-5.00	0.25	0.041	0	0.2	0	0	0.044	0.22	0.18	0.2	0.061	0.32	0.26
> 5.00	0.014	0	0	0	0	0	0.0004	0.067	0.0035	0.12	0.0039	0.004	0

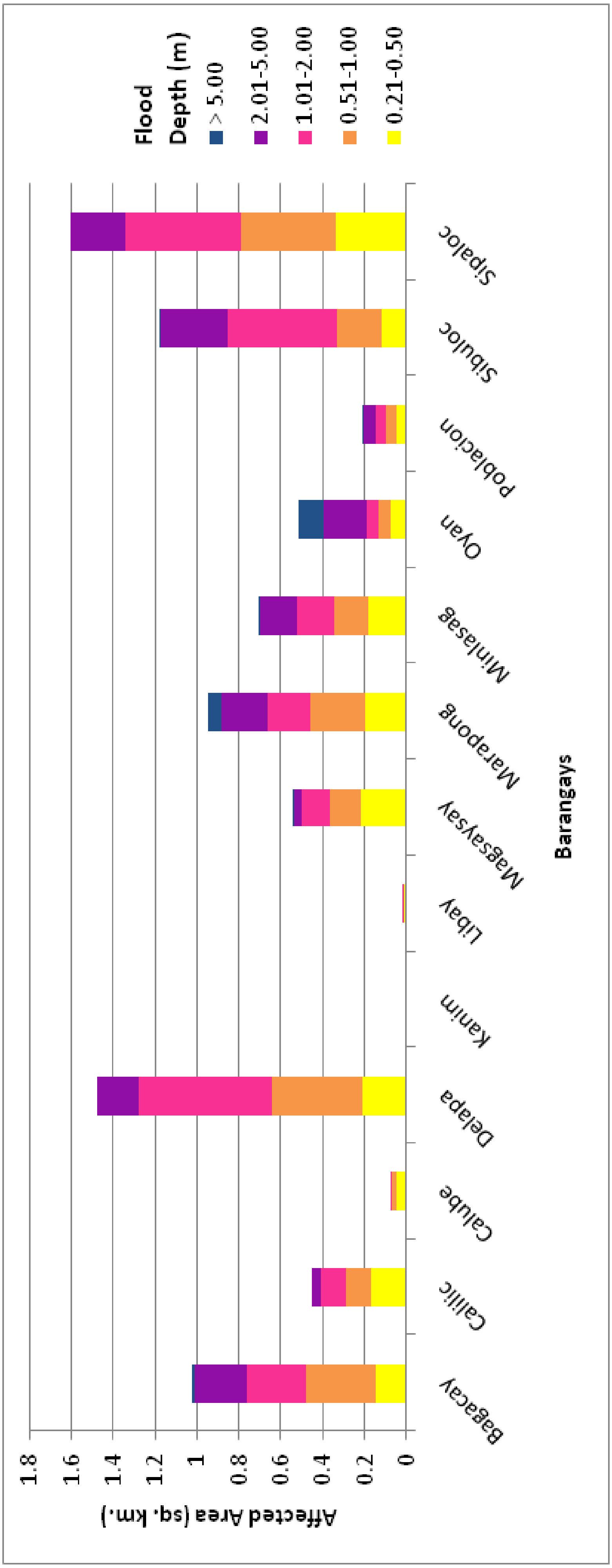


Figure 85. Affected Areas in Sibutad, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 100-year return period, 49.25% of the city of Dapitan with an area of 222.95 square kilometers will experience flood levels of less 0.20 meters. 4.22% of the area will experience flood levels of 0.21 to 0.50 meters while 4.45%, 3.21%, 3.43%, and 1.28% 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 52 are the affected areas in square kilometers by flood depth per barangay.

Table 52. Affected Areas in Dapitan City, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)												
	Antipolo	Aseniero	Ba-Ao	Bagting	Banonong	Barcelo-na	Baylimango	Burgos	Cawa-Cawa	Dampalan	Daro	Dawo	Diwa-An
0.03-0.20	5.76	5.47	3.03	0.14	0.7	9.68	0.64	0.65	0.11	3.84	1.04	0.88	10.65
0.21-0.50	0.36	0.35	0.12	0.034	0.56	0.74	0.014	0.019	0.032	0.27	0.043	0.3	0.52
0.51-1.00	0.42	0.28	0.11	0.014	0.22	0.73	0.0085	0.01	0.064	0.2	0.018	0.034	0.47
1.01-2.00	0.2	0.2	0.15	0	0.04	0.93	0.0023	0.043	0.099	0.27	0.008	0	0.48
2.01-5.00	0.042	0.059	0.19	0	0	0.98	0.0006	0.36	0	1.02	0.0012	0	0.6
> 5.00	0.0034	0	0.018	0	0	0.47	0	0.11	0	0.67	0	0	0.066

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)												
	Hilltop	Ilaya	Kauswagan	Larayan	Linabo	Maria Cristina	Maria Uray	Masidlakon	Matagobtob Poblacion	Opao	Oro	Owaon	Oyan
0.03-0.20	5.12	3.13	1.96	2.38	0.14	8.07	7.37	5.27	1.36	1.43	1.81	0.94	3.49
0.21-0.50	0.13	0.11	0.061	0.089	0.038	0.65	0.83	0.31	0.054	0.054	0.048	0.038	0.08
0.51-1.00	0.099	0.11	0.045	0.08	0.071	1.73	1.75	0.41	0.092	0.037	0.032	0.02	0.055
1.01-2.00	0.11	0.36	0.025	0.094	0.022	0.77	0.97	0.51	0.078	0.03	0.051	0.008	0.059
2.01-5.00	0.32	1.65	0.005	0.011	0	0.03	0.13	0.67	0	0.12	0.035	0.0024	0.21
> 5.00	0.017	0.19	0	0.0006	0	0	0	0.23	0	0.41	0.0004	0	0.15

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Dapitan City (in sq. km.)											
	Polo	Potol	Potungan	San Nicolas	San Pedro	San Vicente	Santa Cruz	Santo Niño	Sicayab Bocana	Sinonoc	Sulangon	Tamion
0.03-0.20	1.08	0.22	2.4	8.16	1.91	0.43	0.2	0.0059	0.89	1.31	1.28	6.85
0.21-0.50	0.53	0.057	0.12	0.66	0.27	0.65	0.07	0	0.031	0.098	0.87	0.19
0.51-1.00	0.13	0.11	0.11	0.51	0.56	0.15	0.016	0	0.0076	0.42	0.63	0.16
1.01-2.00	0.0014	0.07	0.17	0.35	0.19	0.043	0.0022	0	0.0015	0.65	0.04	0.13
2.01-5.00	0.0087	0	0.88	0.16	0.012	0.019	0	0	0	0.011	0.023	0.073
> 5.00	0.0003	0	0.48	0	0	0	0	0	0	0	0	0.036

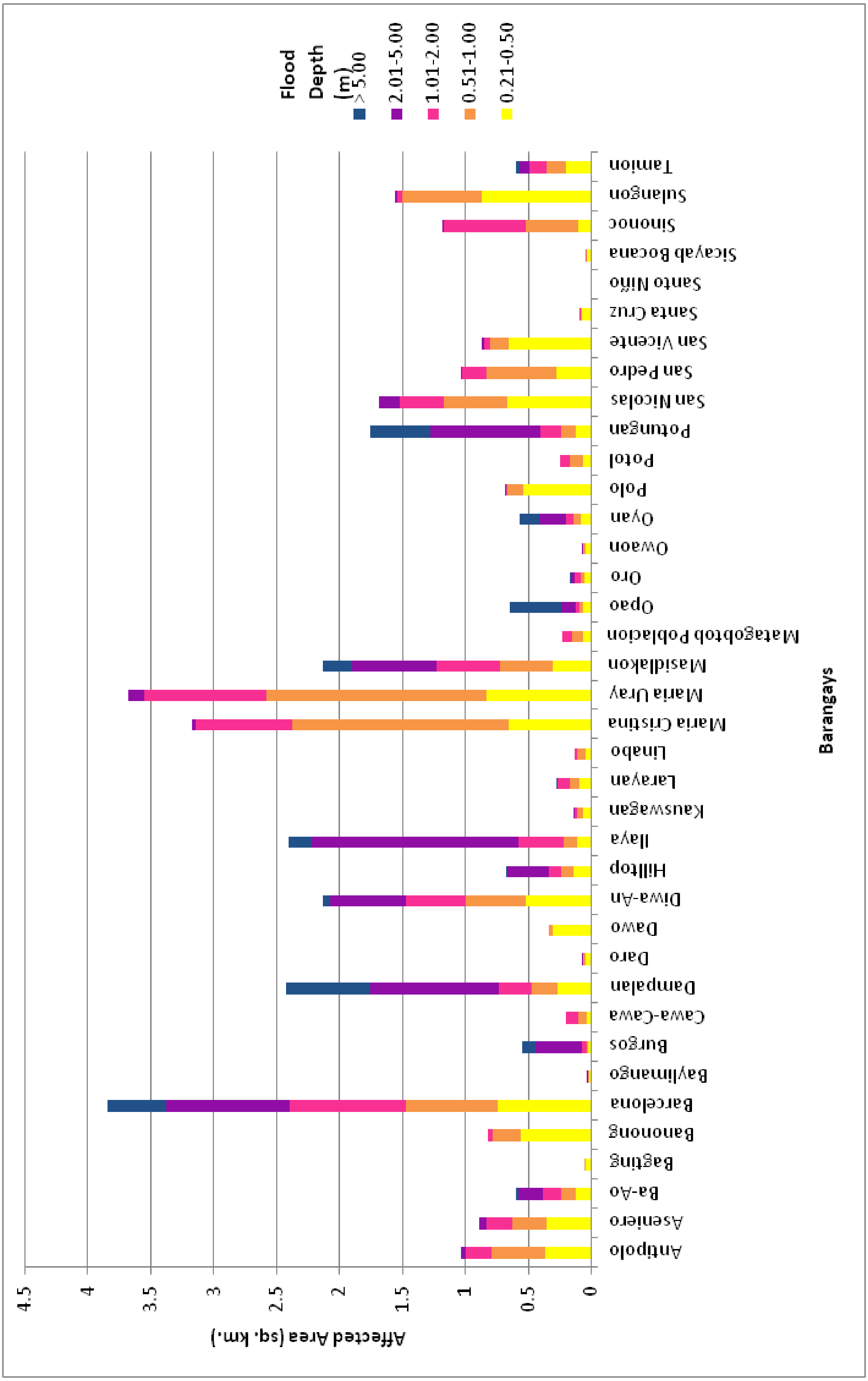


Figure 86. Affected Areas in Dapitan City, Zamboanga del Norte during 100-Year Rainfall Return Period

For the Municipality of La Libertad, with an area of 66.24 square kilometers, 13.57% will experience flood levels of less 0.20 meters. 0.97% of the area will experience flood levels of 0.21 to 0.50 meters while 0.86%, 0.96%, 1.30%, and 0.80% 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 53are the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected Areas in La Libertad, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in La Libertad (in sq. km.)				
	La Union	Mauswagon	New Carcar	Poblacion	Singaran
0.03-0.20	2.19	4.51	0.37	0.75	1.17
0.21-0.50	0.13	0.32	0.012	0.047	0.13
0.51-1.00	0.11	0.27	0.01	0.045	0.14
1.01-2.00	0.12	0.27	0.015	0.064	0.16
2.01-5.00	0.26	0.28	0.0063	0.075	0.24
> 5.00	0.36	0.15	0.00022	0.012	0.0027

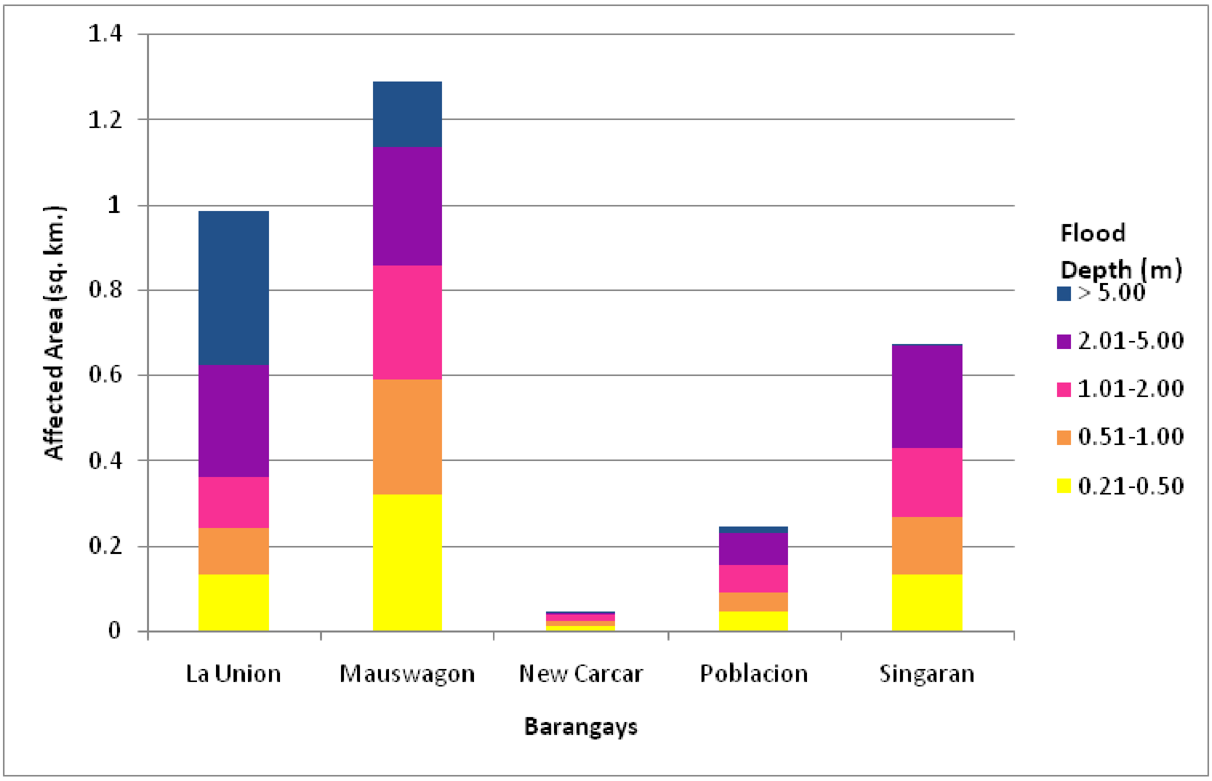


Figure 87. Affected Areas in La Libertad, Zamboanga del Norte during 100-Year Rainfall Return Period

For the Municipality of Pinan, with an area of 135.87 square kilometers, 0.15% will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.009%, 0.002%, and 0.0002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 54are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected Areas in Pinan, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Pinan (in sq. km.)
	Adante
0.03-0.20	0.21
0.21-0.50	0.019039
0.51-1.00	0.004536
1.01-2.00	0.0007
2.01-5.00	0
> 5.00	0

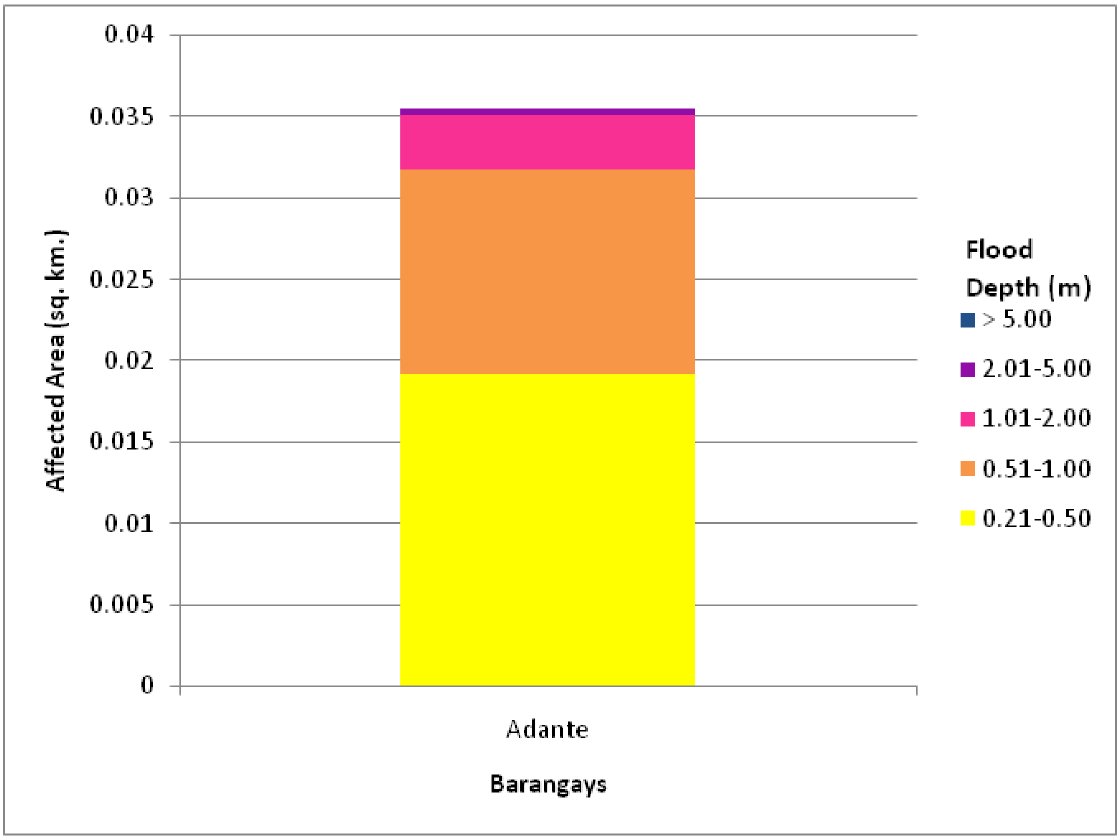


Figure 88. Affected Areas in Pinan, Zamboanga del Norte during 100-Year Rainfall Return Period

For the Municipality of Polanco, with an area of 86.49 square kilometers., 0.58% will experience flood levels of less 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.03%, and 0.006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 55 are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected Areas in Polanco, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Polanco (in sq. km.)
	San Miguel
0.03-0.20	0.79
0.21-0.50	0.091
0.51-1.00	0.078
1.01-2.00	0.047
2.01-5.00	0.0087
> 5.00	0

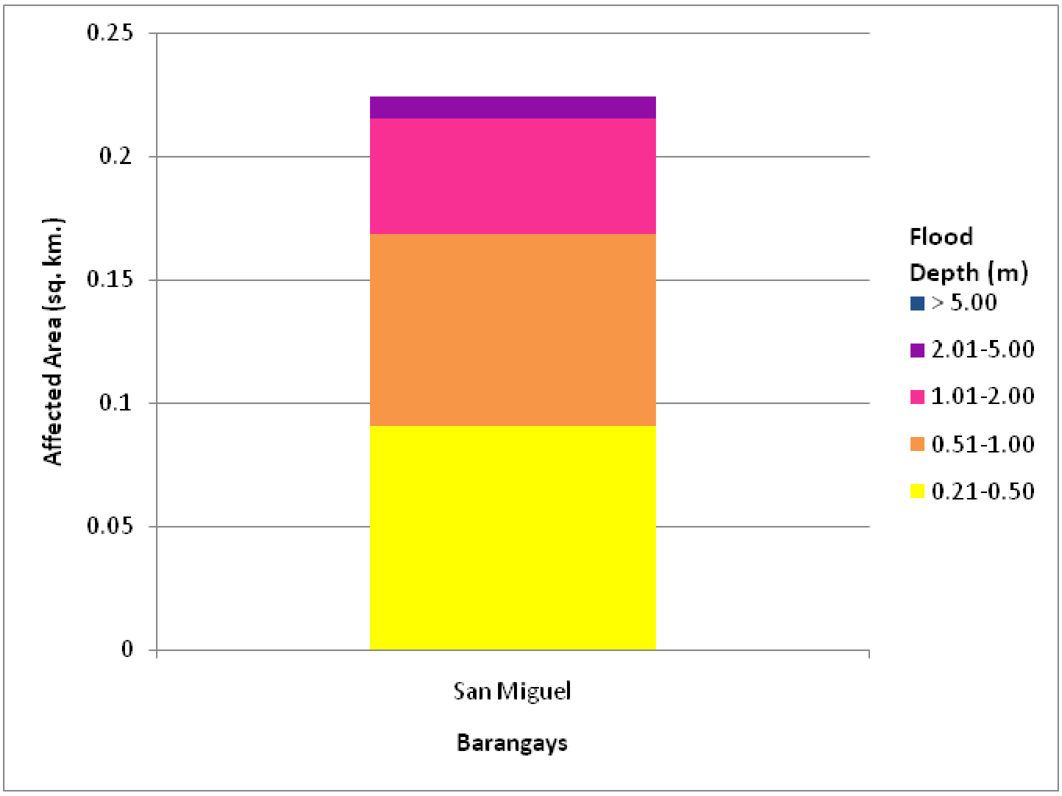


Figure 89. Affected Areas in Polanco, Zamboanga del Norte during 100-Year Rainfall Return Period

For the Municipality of Rizal, with an area of 61.97 square kilometers, 28.71% will experience flood levels of less 0.20 meters. 1.41% of the area will experience flood levels of 0.21 to 0.50 meters while 1.27%, 1.53%, 1.36%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 56 are the affected areas in square kilometers by flood depth per barangay.

Table 56. Affected Areas in Rizal, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)								
	Balubohan	Birayan	Damasing	East Poblacion	La Esperanza	Mabuhay	Mitimos	Nangcaan	Napilan
0.03-0.20	0.17	1.94	0.11	0.82	2.47	0.21	0.95	1.67	1.04
0.21-0.50	0.003	0.13	0.003	0.05	0.14	0.012	0.041	0.066	0.059
0.51-1.00	0	0.13	0.0003	0.044	0.18	0.0042	0.044	0.077	0.05
1.01-2.00	0	0.13	0	0.033	0.23	0.0012	0.047	0.13	0.065
2.01-5.00	0.0001	0.042	0	0.046	0.24	0	0.043	0.14	0.096
> 5.00	0	0	0	0	0.022	0	0.000083	0.1	0.052

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)								
	Nasipang	New Dapitan	Nilabo	North Mapang	Rizalina	San Roque	South Mapang	Tolon	West Poblacion
0.03-0.20	0.7	0.82	2.98	0.042	7.13	5.29	1.83	2.56	0.97
0.21-0.50	0.026	0.039	0.16	0.0015	0.38	0.23	0.098	0.099	0.059
0.51-1.00	0.013	0.032	0.12	0.001	0.26	0.31	0.086	0.077	0.05
1.01-2.00	0.0044	0.043	0.082	0.0012	0.26	0.47	0.095	0.085	0.033
2.01-5.00	0.0002	0.11	0.027	0.0001	0.21	0.46	0.071	0.096	0.012
> 5.00	0	0.086	0.0002	0	0.0024	0.19	0.026	0.052	0.0001

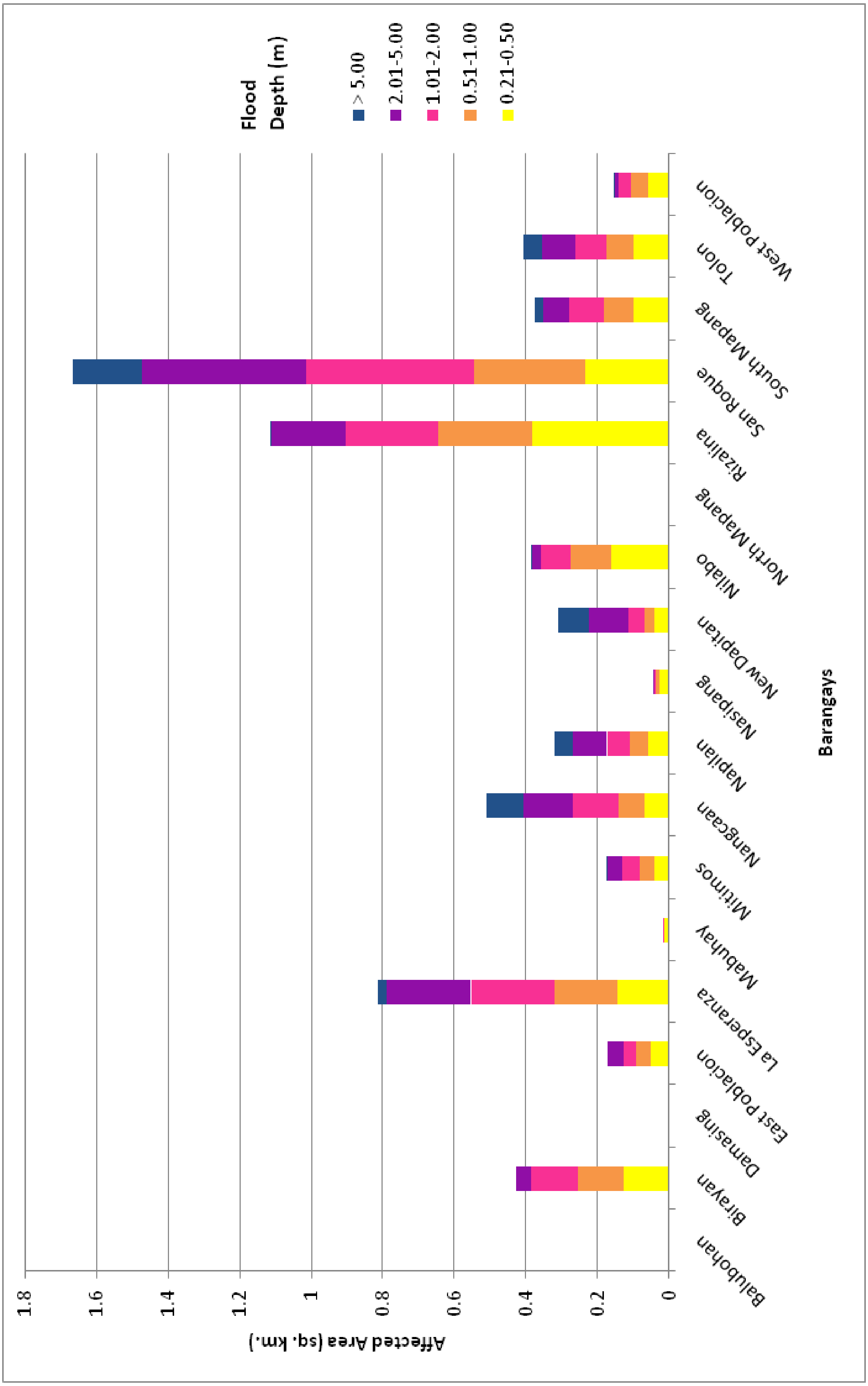


Figure 90. Affected Areas in Rizal, Zamboanga del Norte during 100-Year Rainfall Return Period

For the Municipality of Sapang Dalaga, with an area of 85.68 square kilometers, 4.88% will experience flood levels of less 0.20 meters. 0.21% of the area will experience flood levels of 0.21 to 0.50 meters while 0.18%, 0.19%, 0.18%, and 0.02% 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 57 are the affected areas in square kilometers by flood depth per barangay.

Table 57. Affected Areas in Sapang Dalaga, Misamis Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Sapang Dalaga (in sq. km.)				
	Agapito Yap, Sr.	Boundary	Casul	El Paraiso	Poblacion
0.03-0.20	0.2	2.24	0.72	0.27	0.75
0.21-0.50	0.007	0.1	0.012	0.01	0.047
0.51-1.00	0.0034	0.092	0.0052	0.0091	0.045
1.01-2.00	0.0053	0.082	0.002	0.01	0.064
2.01-5.00	0.006	0.071	0.0007	0.0037	0.075
> 5.00	0.0016	0	0	0	0.012

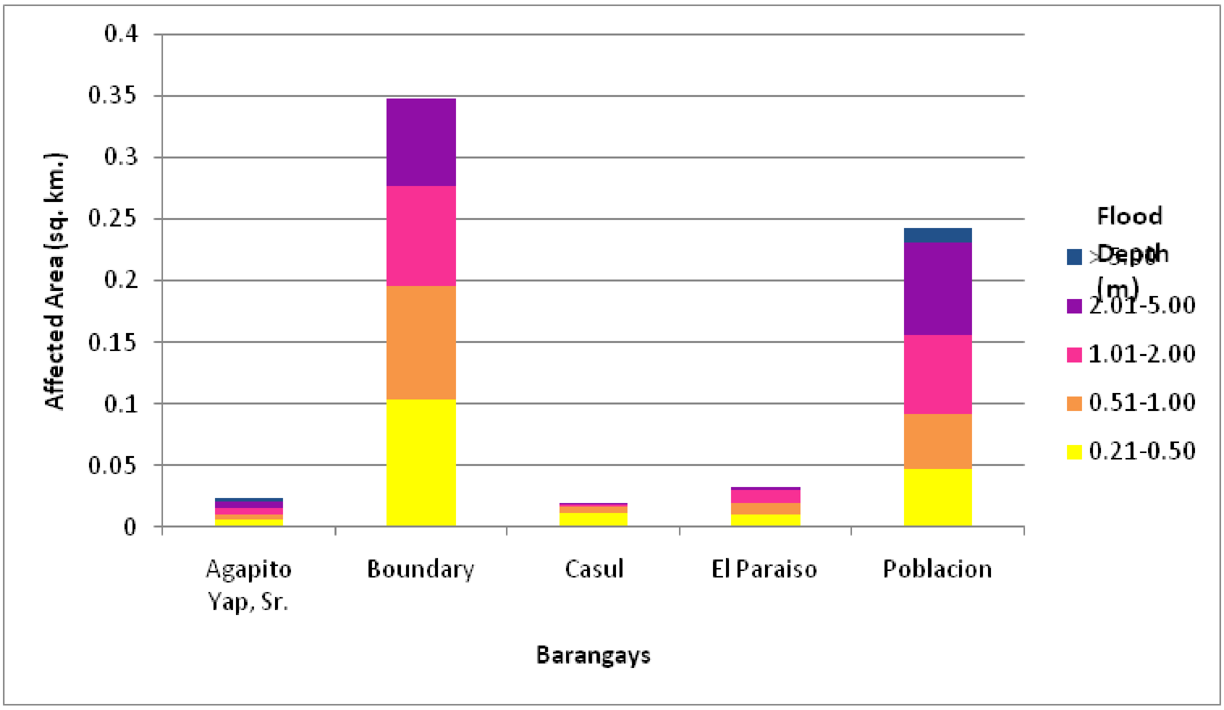


Figure 91. Affected Areas in Sapang Dalaga, Misamis Occidental during 100-Year Rainfall Return Period

For the Municipality of Sibutad, with an area of 75.68 square kilometers, 46.83% will experience flood levels of less 0.20 meters. 2.21% of the area will experience flood levels of 0.21 to 0.50 meters while 2.64%, 4.18%, 3.38%, and 0.66% 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 58are the affected areas in square kilometers by flood depth per barangay.

Table 58. Affected Areas in Sibutad, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Sibutad (in sq. km.)											
	Bagacay	Calilic	Calube	Delapa	Kanim	Libay	Magsaysay	Marapong	Minlasag	Oyan	Poblacion	Sibuloc	Sipaloc
0.03-0.20	2.97	4.39	1.41	3	0.21	0.47	5.52	3.44	3.24	3.49	0.75	1.53	5.02
0.21-0.50	0.13	0.18	0.053	0.15	0.0047	0.017	0.24	0.16	0.19	0.08	0.047	0.11	0.3
0.51-1.00	0.23	0.13	0.028	0.35	0.0007	0.0041	0.15	0.24	0.17	0.055	0.045	0.18	0.42
1.01-2.00	0.43	0.14	0.005	0.74	0.0002	0.0002	0.16	0.32	0.2	0.059	0.064	0.46	0.6
2.01-5.00	0.29	0.076	0	0.39	0	0	0.058	0.2	0.23	0.21	0.075	0.57	0.46
> 5.00	0.12	0	0	0.0009	0	0	0.0006	0.19	0.008	0.15	0.012	0.018	0.0036

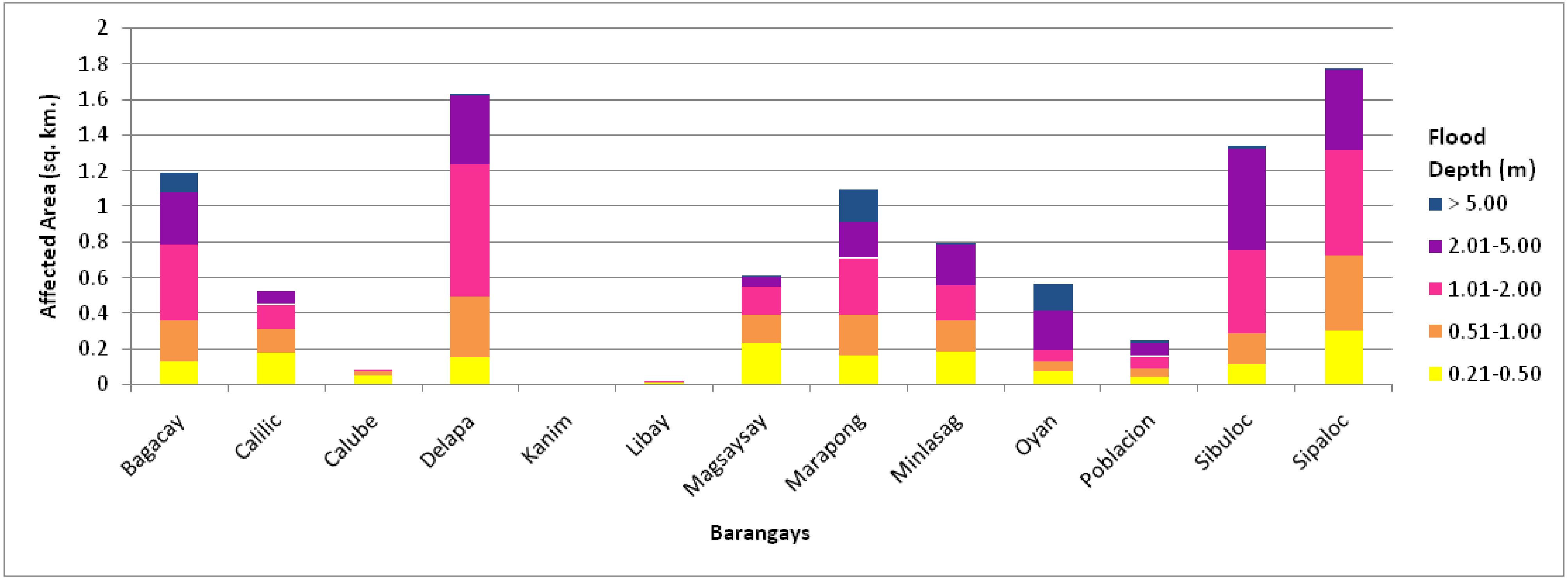


Figure 92. Affected Areas in Sibutad, Zamboanga del Norte during 100-Year Rainfall Return Period

Among the barangays in the City of Dapitan, Barcelona is projected to have the highest percentage of area that will experience flood levels at 6.07%. Meanwhile, Diwa-An posted the second highest percentage of area that may be affected by flood depths at 5.74%.

Among the barangays in the Municipality of La Libertad, Mauswagon is projected to have the highest percentage of area that will experience flood levels at 8.75%. Meanwhile, La Union posted the second highest percentage of area that may be affected by flood depths at 4.80%.

Among the barangays in the Municipality of Pinan, only Adante is projected to experience flood levels at a percentage of 0.18%.

Among the barangays in the Municipality of Polanco, only San Miguel is projected to experience flood levels at a percentage of 0.75%.

Among the barangays in the Municipality of Rizal, Rizalina is projected to have the highest percentage of area that will experience flood levels at 13.31%. Meanwhile, San Roque posted the second highest percentage of area that may be affected by flood depths at 11.23%.

Among the barangays in the Municipality of Sapang Dalaga, Boundary is projected to have the highest percentage of area that will experience flood levels at 3.02%. Meanwhile, Poblacion posted the second highest percentage of area that may be affected by flood depths at 1.16%.

Among the barangays in the Municipality of Sibutad, Sipaloc is projected to have the highest percentage of area that will experience flood levels at 8.98%. Meanwhile, Magsaysay posted the second highest percentage of area that may be affected by flood depths at 8.10%.

Moreover, the generated flood hazard maps for the Dapitan 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 59. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	13.93	14.31	13.77
Medium	15.25	20.66	22.75
High	8.31	17.03	22.85
Total	37.49	52.00	59.37

Of the 121 identified Education Institutions in Dapitan Floodplain, 11 schools were assessed to be exposed to the low-level flooding during a 5-year scenario while eight (8) schools were assessed to be exposed to medium-level flooding and three (3) schools were assessed to be exposed to high-level flooding in the same scenario. In the 25-year scenario, 18 schools were assessed to be exposed to the low-level flooding while nine (9) schools were assessed to be exposed to medium-level flooding and nine (9) schools were assessed to be exposed to high-level flooding in the same scenario. For the 100-year scenario, 17 schools were assessed for low-level flooding and 10 schools for medium-level flooding. In the same scenario, 14 schools were assessed to be exposed to high-level flooding. See Annex 12 for a detailed enumeration of schools inside Dapitan Floodplain.

Of the 28 identified Medical Institutions in Dapitan Floodplain, three were assessed to be exposed to the Low level flooding during a 5-year scenario while three were assessed to be exposed to Medium level flooding in the same scenario. In the 25-year scenario, three were assessed to be exposed to the Low level flooding while two were assessed to be exposed to Medium level flooding and one school was assessed to be exposed to High level flooding in the same scenario. For the 100-year scenario, three schools were assessed for Low level flooding and one for Medium level flooding. In the same scenario, two were assessed to be exposed to High level flooding. See Annex 13 for a detailed enumeration of medical institutions inside Dapitan Floodplain.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 94.

The flood validation consists of 168 points randomly selected all over the Dapitan Floodplain. It has an RMSE value of 0.44.

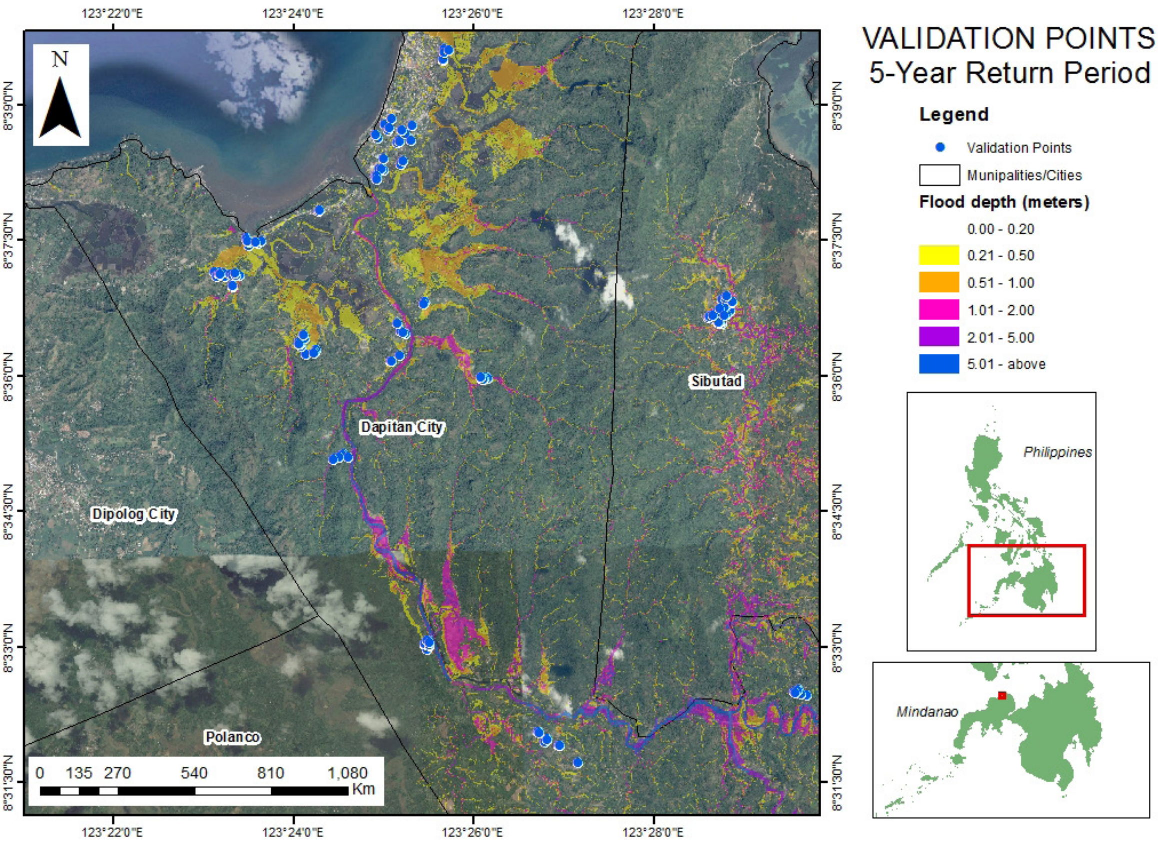


Figure 93. Validation points for 5-year Flood Depth Map of Dapitan Floodplain

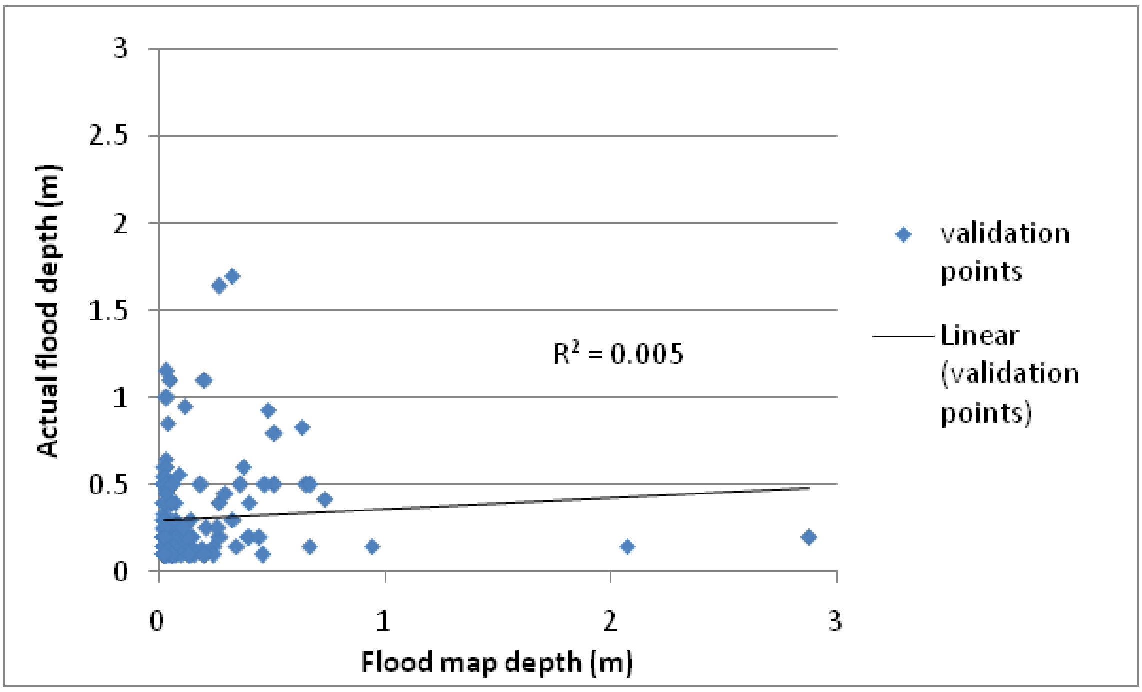


Figure 94 . Flood map depth vs actual flood depth

Table 60. Actual Flood Depth vs Simulated Flood Depth in Dapitan 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	83	10	2	0	2	0	97
0.21-0.50	41	8	4	0	0	0	53
0.51-1.00	9	2	2	0	0	0	13
1.01-2.00	2	3	0	0	0	0	5
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	135	23	8	0	2	0	168

The overall accuracy generated by the flood model is estimated at 55.36%, with 93 points correctly matching the actual flood depths. In addition, there were 57 points estimated one level above and below the correct flood depths while there were 14 points and 4 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 18 points were overestimated while a total of 57 points were underestimated in the modelled flood depths of Dapitan.

Table 61. Summary of Accuracy Assessment in Dapitan River Basin Survey

	No. of Points	%
Correct	93	**55.36**
Overestimated	18	10.71
Underestimated	57	33.93
Total	168	100

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Dapitan Floodplain Survey

1. Pegasus Sensor

Figure A-1.1. Pegasus Sensor.

Table A-1.1. Parameters and Specification of Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
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)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

1 Target reflectivity ≥20%
2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤20˚
4 Target size ≥ laser footprint5 Dependent on system configuration

Table A-1.2. Parameters and Specification of D-8900 Aerial Digital Camera

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

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

1. ZGN-138

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: **ZAMBOANGA DEL NORTE**
Station Name: **ZGN-138**
Order: **2nd**

Island: **MINDANAO**	Barangay:	
Municipality: **KATIPUNAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 30' 40.65974"**	Longitude: **123° 18' 14.44217"**	Ellipsoidal Hgt: **6.71500 m.**
	WGS84 Coordinates	
Latitude: **8° 30' 36.94779"**	Longitude: **123° 18' 19.85548"**	Ellipsoidal Hgt: **70.92500 m.**
	PTM / PRS92 Coordinates	
Northing: **941106.14 m.**	Easting: **533471.036 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **940,776.74**	Easting: **533,459.32**	Zone: **51**

Location Description

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a concrete open canal with inscription " ZGN-138, 2009 NAMRIA".Located at brgy. Taga katipunan zamboanga del norte. The monument is situated inside taga central school 10 meters from the main gate going north west 6 meters from the flag pole going south east.

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2584**

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

9 9 1 0 3 0 2 0 1 4 1 3 4 0 1 2

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. ZGN-138

2. ZGN-60

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

March 08, 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: **ZAMBOANGA DEL NORTE**
Station Name: **ZGN-60**
Order: **2nd**

Island: **MINDANAO**		Barangay: **SAN PEDRO**	
Municipality: **POLANCO**		MSL Elevation:	

PRS92 Coordinates

Latitude:	**8° 24' 13.24705"**	Longitude:	**123° 23' 43.64096"**	Ellipsoidal Hgt:	**78.37100 m.**

WGS84 Coordinates

Latitude:	**8° 24' 9.57149"**	Longitude:	**123° 23' 49.06324"**	Ellipsoidal Hgt:	**143.02900 m.**

PTM / PRS92 Coordinates

Northing:	**929214.294 m.**	Easting:	**543551.053 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**928,889.05**	Easting:	**543,535.81**	Zone:	**51**

Location Description

ZGN-60
Is situated on the sidewalk of Layawan Bridge. It is located near the SW edge of the bridge from its center. It is about 15 m. NNE of Barbaso Family residence and 300 m. SW of ZGN-61. Mark is the head of a 4 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGN-60 2005 NAMRIA LEP-9".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089979 I**
T.N.:	**2016-0567**

for

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. ZGN-60

3. MSW-05

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

December 01, 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: **MISAMIS OCCIDENTAL**	
	Station Name: **MSW-5**	
	Order: **2nd**	
Island: **MINDANAO**	Barangay: **POBLACION**	
Municipality: **SAPANG DALAGA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 32' 35.68185"**	Longitude: **123° 33' 56.01853"**	Ellipsoidal Hgt: **113.48100 m.**
	WGS84 Coordinates	
Latitude: **8° 32' 31.98501"**	Longitude: **123° 34' 1.42685"**	Ellipsoidal Hgt: **178.27400 m.**
	PTM / PRS92 Coordinates	
Northing: **944671.948 m.**	Easting: **562262.537 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **944,341.30**	Easting: **562,240.75**	Zone: **51**

Location Description

MSW-5
From Dipolog City, travel along the Nat'l. Highway going to Calamba until reaching Sapang Dalaga Proper. Station is located inside Sapang Dalaga Mun. Hall compound, beside the fence near the basketball court. It is about 50 m. from the DAR office and 100 m. from the mun. hall. Mark is the head of a 4 in. copper nail embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "MSW-5 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **FREE ISSUE**
T.N.: **2016-2168**

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

9 9 1 2 0 1 2 0 1 6 1 6 3 2 5 7

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. MSW-05

4. ZN-53

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: **ZAMBOANGA DEL NORTE** Station Name: **ZN-53**	
Island: **Mindanao**	Municipality: **KATIPUNAN**	Barangay: **DAANGLUNGSOD**
Elevation: **10.0561 +/- 0.00 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

ZN-53
Along Dipolog Liloy National Road. The station is located at the compound of Taga Central School, near the flagpole and about 50 meters northwest of the centerline of the road. Mark is the head of a 4" copper nail set on a dsrilled hole and cemented flushed on top of 15cm x 15cm cement putty with inscription " ZN-53 2008 NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8075910 I**
T.N.: **2014-2589**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. ZN-53

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
zgn 138 --- zn 53 am (B1)	zgn 138	zn 53 am	Fixed	0.001	0.002	344°25'59"	12.263	0.357
zgn 138 --- zn 53 pm (B2)	zgn 138	zn 53 pm	Fixed	0.003	0.004	344°25'44"	12.270	0.372

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MSW-5 --- ZN-11 (B1)	MSW-5	ZN-11	Float	0.020	0.073	266°35'44"	8470.799	-93.731

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	MSW-5				
Grid		Local		Global	
Easting	552405.518 m	Latitude	N8°32'31.98501"	Latitude	N8°32'31.98501"
Northing	944287.571 m	Longitude	E123°34'01.42685"	Longitude	E123°34'01.42685"
Elevation	111.479 m	Height	178.274 m	Height	178.274 m

To:	ZN-11				
Grid		Local		Global	
Easting	553953.442 m	Latitude	N8°32'15.58462"	Latitude	N8°32'15.58462"
Northing	943772.319 m	Longitude	E123°29'24.92624"	Longitude	E123°29'24.92624"
Elevation	18.000 m	Height	84.543 m	Height	84.543 m

Vector					
ΔEasting	-8452.076 m	NS Fwd Azimuth	266°35'44"	ΔX	7059.852 m
ΔNorthing	-515.252 m	Ellipsoid Dist.	8470.799 m	ΔY	4655.796 m
ΔElevation	-93.479 m	ΔHeight	-93.731 m	ΔZ	-512.194 m

Standard Errors

Vector errors:					
σ ΔEasting	0.008 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.023 m
σ ΔNorthing	0.006 m	σ Ellipsoid Dist.	0.008 m	σ ΔY	0.030 m
σ ΔElevation	0.037 m	σ ΔHeight	0.037 m	σ ΔZ	0.010 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0005116012		
Y	-0.0006225709	0.0009222780	
Z	-0.0001175407	0.0001737952	0.0000909524

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		ENGR. GEROME HIPOLITO	UP-TCAGP
	SSRS	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. RENAN PUNTO	UP-TCAGP
	RA	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	KRISTINE ANDAYA	UP-TCAGP
	RA	JERIEL PAUL ALAMBAN,GEOL	UP-TCAGP
	RA	ENGR. GEF SORIANO	UP-TCAGP
	RA	FRANK NICOLAS ILEJAY	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JASMIN DOMINGO	UP-TCAGP
	RA	MERLIN FERNANDO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. JAYCO MANZANO	PHILIPPINE AIR FORCE (PAF)
	Airborne Security	SSG. GERONIMO BALICOW III	PAF
	Airborne Security	TSG. JOSE RONALD MONTENEGRO	PAF
	Pilot	CAPT. BRYAN DONGUINES	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. SHERWIN CESAR ALFONSO	AAC
		CAPT. ERNESTO SAYSAY JR.	AAC
		CAPT. ANTON DAYO	AAC

Annex 5. Data Transfer Sheet for Dapitan Floodplain

DATA TRANSFER SHEET
11/17/2014(dipolog)

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	
19-Oct	2099P	1BLK89CALB292A	PEGASUS	106	na	3.84	113	9.11	83	3.84	na	4.08	1KB	1KB	47/23	na	Z:\DAC\RAW DATA
20-Oct	2111P	1BLK89B295A	PEGASUS	2.01	458	12.4	230	28.5	282	22.2	na	7.88	1KB	1KB	28/24/8/8	na	Z:\DAC\RAW DATA
20-Oct	2113P	1BLK89B298A	PEGASUS	1.82	394	16	216	30.4	280	18.4	na	18.1	1KB	1KB	48/51/44/81	na	Z:\DAC\RAW DATA
23-Oct	2115P	1BLK8970A296B	PEGASUS	754	171	6.36	195	13.6	115	8.18	na	18.1	1KB	1KB	48/81/25	na	Z:\DAC\RAW DATA
24-Oct	2117P	1BLK89B297A	PEGASUS	1.24	237	6.75	115	18.8	164	12.4	na	7.64	1KB	1KB	48/51/50	na	Z:\DAC\RAW DATA
26-Oct	2125P	1BLK89C299A	PEGASUS	1.8	267	8.41	211	32	239	15.4	na	37.4	1KB	1KB	48/51/50/411 554/523	na	Z:\DAC\RAW DATA
28-Oct	2127P	1BLK8970A299B	PEGASUS	2.54	na	5.91	114	16	1	12.8	na	37.4	1KB	1KB	27/1	na	Z:\DAC\RAW DATA
28-Oct	2133P	1BLK89FE301A	PEGASUS	2.06	344/464	10.2	225	37.8	343	na	na	37.3	1KB	1KB	75/51/01/38	na	Z:\DAC\RAW DATA
28-Oct	2135P	1BLK89F301B	PEGASUS	288	170/187	3.42	60.6	na	na	8.4	na	37.3	1KB	1KB	82	na	Z:\DAC\RAW DATA
29-Oct	2137P	1BLK70D302A	PEGASUS	1.05	453/350	7.37	190	28.5	181	11.2	na	19.4	1KB	1KB	108/80/82/75	na	Z:\DAC\RAW DATA
31-Oct	2145P	1BLK69C304A	PEGASUS	2.33	1118/804	9.11	182	49.6	342	22.8	na	8.52	1KB	1KB	74	na	Z:\DAC\RAW DATA
1-Nov	2149P	1BLK70B306A	PEGASUS	1.79	338	7.28	182	32.1	227	23.3	na	20.2	1KB	1KB	54/78	na	Z:\DAC\RAW DATA
3-Nov	2157P	1BLK70C307A	PEGASUS	2.28	108	11.3	340	40.6	298	28.1	na	28.8	1KB	1KB	30	na	Z:\DAC\RAW DATA
6-Nov	2169P	1BLK73AS310A	PEGASUS	3.01	320	12.1	246	52.8	na	26.9	na	21.3	1KB	1KB	80	na	Z:\DAC\RAW DATA
8-Nov	2177P	1BLK70C312A	PEGASUS	1.75	327	6.89	198	21.1	na	17.6	na	17.9	1KB	1KB	60/62/67	na	Z:\DAC\RAW DATA
9-Nov	2181P	1BLK69F313A	PEGASUS	1.48	208	8.11	192	22.4	182	18.2	na	17	1KB	1KB	65/82/51	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name Angelo Carlo Bongat
Position SSRS
Signature 11/19/2014

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

DATA TRANSFER SHEET
PAGADIAN 3/7/16

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	
02/20/2016	23116P	1BLK76NO051A	Pegasus	2.29 GB	NA	11.9 MB	294 MB	NA	NA	24.4 GB	0 B	63.8 MB	2KB	2KB	148/252/232	NA	Z:\DAC\RAW DATA
02/21/2016	23120P	1BLK69D052A	Pegasus	2.6 GB	NA	12 MB	298 MB	22.5 GB	NA	25.9 GB	0 B	59.6 MB	2KB	1KB	580/100/91/82	NA	Z:\DAC\RAW DATA
02/22/2016	23124P	1BLK69AB053A	Pegasus	1.89 GB	NA	11.4 MB	270 MB	NA	NA	21.1 GB	0 B	3.12 MB	1KB	NA	125/108/98/87/78/76	NA	Z:\DAC\RAW DATA
02/23/2016	23128P	1BLK70B054A	Pegasus	2.22 GB	NA	12.8 MB	273 MB	311 MB	NA	23.3	0 B	44.4 MB	1KB	NA	92/90/80/73	NA	Z:\DAC\RAW DATA
02/24/2016	23132P	1BLK73A055A	Pegasus	10.3 MB	NA	12.5 MB	266 MB	NA	NA	24.4 GB	0 B	49.7 MB	2KB	1KB	84/84/72/76/57	NA	Z:\DAC\RAW DATA
02/26/2016	23140P	1BLK73BS057A	Pegasus	2.47 GB	NA	13.5 MB	305 MB	NA	NA	26.5 GB	0 B	65.9 MB	2KB	1KB	85/83	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/10/16

16-17

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

DATA TRANSFER SHEET
DIPOLOG 12/8/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
November 28, 2016	23590P	1BLK73DEF333A	PEGASUS	1.56	NA	7.69	203	32.6	298	16.6	NA	42.3	1KB	1KB	1.19	NA	Z:\DAC\RAW DATA
November 30, 2016	23598P	1BLK76A335A	PEGASUS	600	NA	6.93	239	NA	NA	7.85	NA	48.2	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA
December 01, 2016	23602P	1BLK76AB336A	PEGASUS	1.56	NA	9.08	287	NA	NA	16.5	NA	53.9	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 12/8/16

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

DATA TRANSFER SHEET
DIPOLOG 12/6/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
November 20, 2016	23558P	1BLK69BC325A	PEGASUS	249	NA	11.2	274	NA	NA	24.8	NA	175	1KB	1KB	234	NA	Z:\DAC\RAW DATA
November 21, 2016	23562P	1BLK69BD326A	PEGASUS	2.64	NA	12.2	289	NA	NA	29.5	NA	165	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA
November 22, 2016	23566P	1BLK69E327A	PEGASUS	1.65	NA	9.58	267	NA	NA	18	NA	188	1KB	1KB	652	NA	Z:\DAC\RAW DATA
November 24, 2016	23574P	1BLK69AD329A	PEGASUS	1.92	NA	10	264	NA	NA	21.7	NA	126	1KB	1KB	421	NA	Z:\DAC\RAW DATA
November 26, 2016	23582P	1BLK73DE331A	PEGASUS	2.46	NA	11.6	281	25.1	274	25.5	NA	162	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC BongaT
Position SSRS
Signature 12/6/16

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 2111PMission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2111P

1 LiDAR Operator: G. SINADJAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK61B 295A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: B. DONGUINES	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: OCT. 22, 2014	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 11:17	14 Engine Off: 3:22	15 Total Engine Time: 4 HRS 5 MINS	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	CLOUDY				

20 Remarks:

SUCCESSFUL FLIGHT.

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

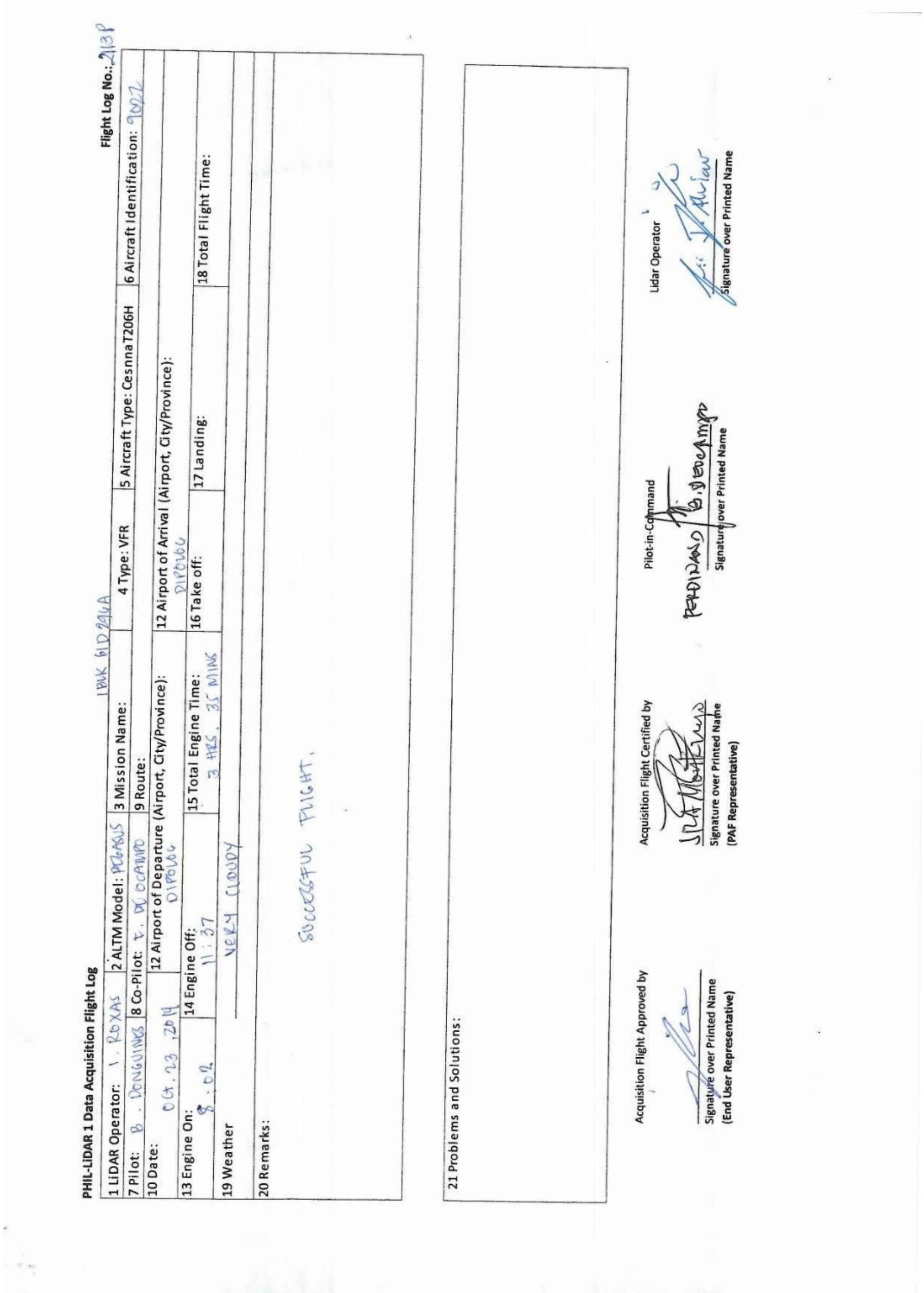
FERDINAND B. DE OCAMPO
Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2111P

2. Flight Log for 2113PMission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2113P

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK 61D296A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: B. DONGUINES	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: OCT. 23, 2014	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 8:02	14 Engine Off: 11:37	15 Total Engine Time: 3 HRS. 35 MINS	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	VERY CLOUDY				
20 Remarks:					

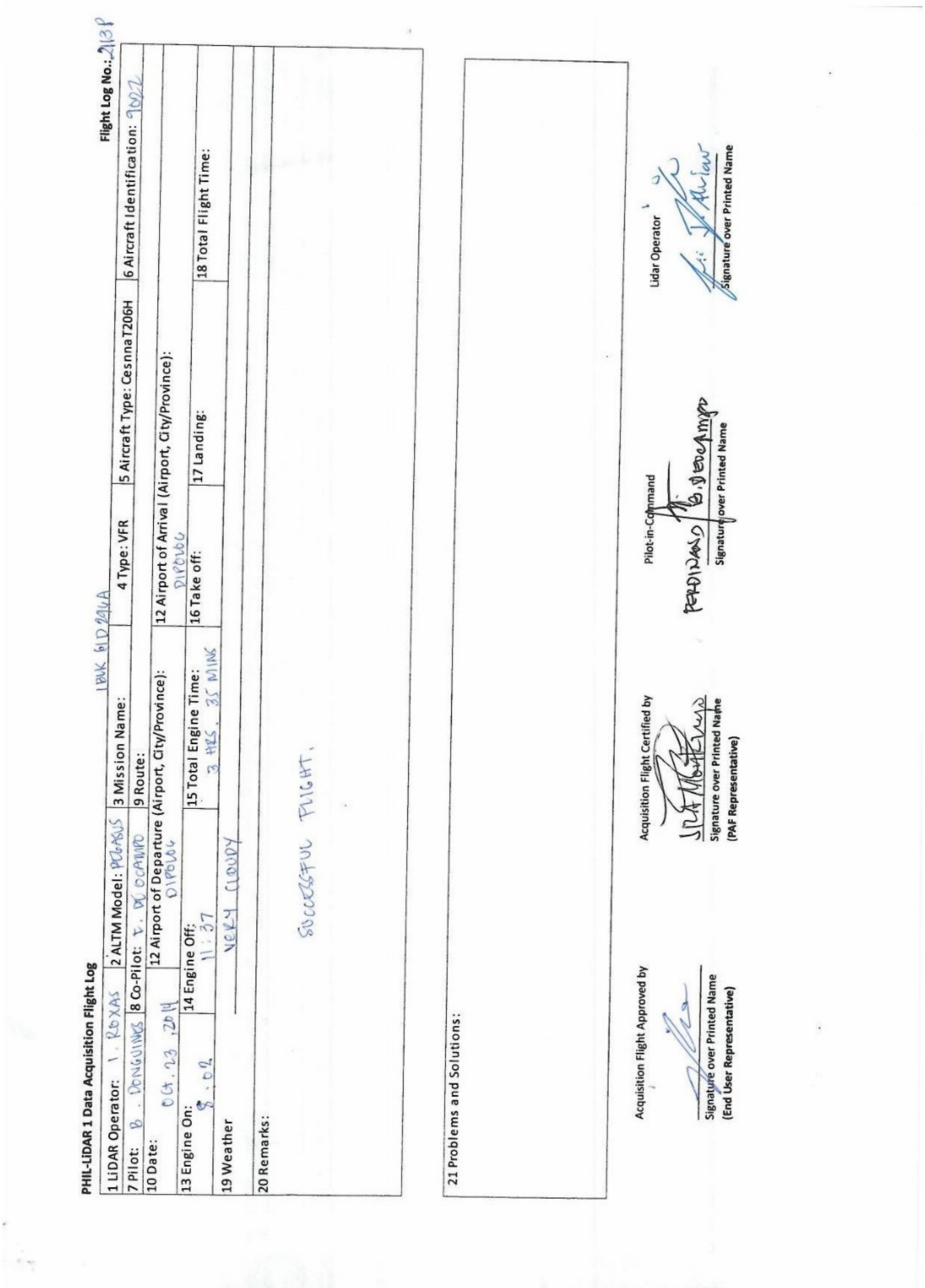
SUCCESSFUL FLIGHT.

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-6.2. Flight Log for Mission 2113P

3. Flight Log for 2115P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2113P

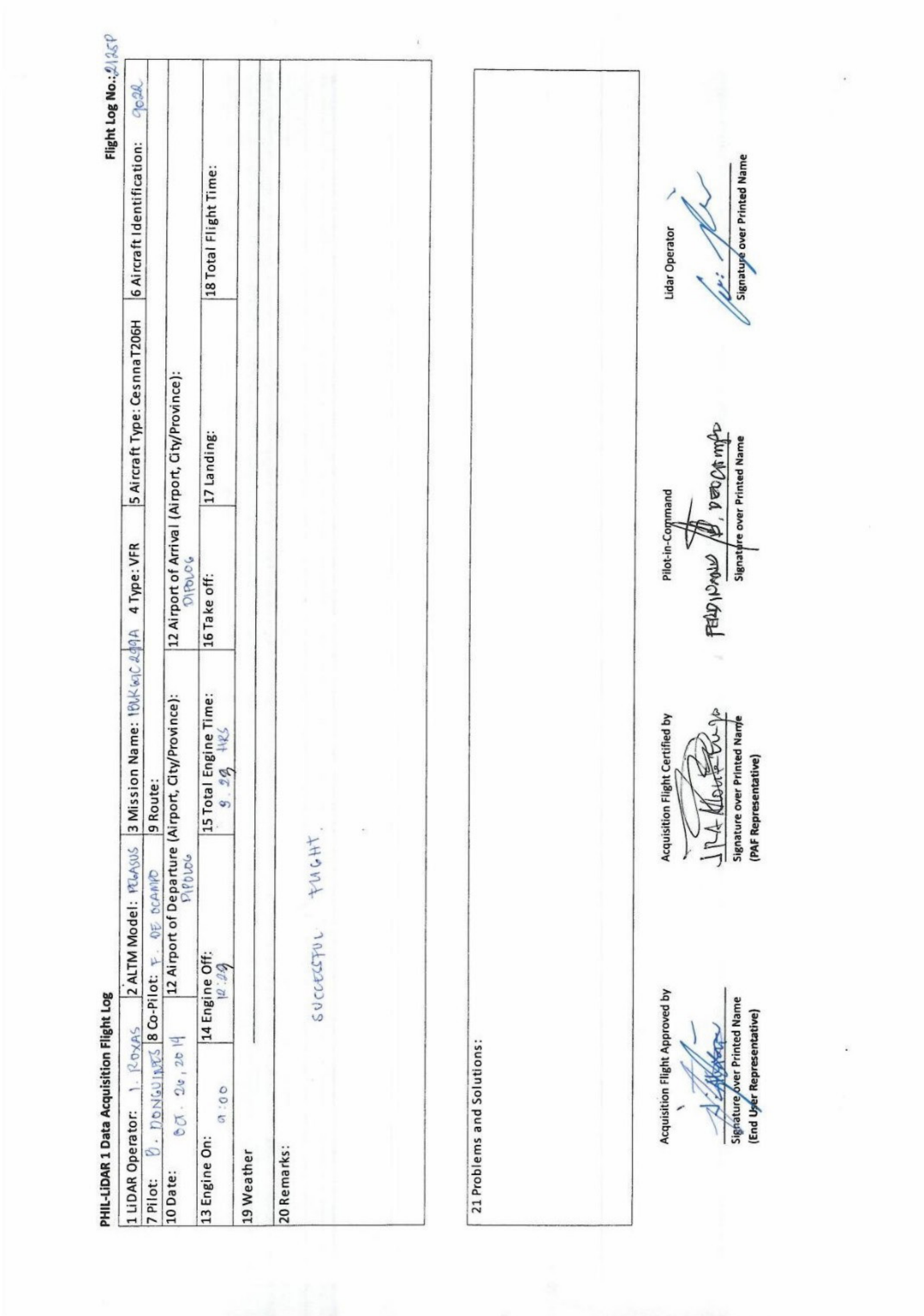
1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK 61D296A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: B. DONGUINES	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: OCT. 23, 2014	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 8:02	14 Engine Off: 11:37	15 Total Engine Time: 3 HRS, 35 MINS	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	VERY CLOUDY				
20 Remarks:					
SUCCESSFUL FLIGHT.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	SLT [signature] Signature over Printed Name (PAF Representative)	FERDINAND B. DONGUINES Signature over Printed Name	I. Roxas Signature over Printed Name

Figure A-6.3. Flight Log for Mission 2115P

4. Flight Log for 2125P Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2125P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK69C299A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: B. Donguines	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: Oct. 26, 2014	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 9:00	14 Engine Off: 12:29	15 Total Engine Time: 3.29 hrs	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Successful flight.					

21 Problems and Solutions:

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

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

Pilot-in-Command
Feadinand B. Deocampo
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2125P

5. Flight Log for 2145P Mission

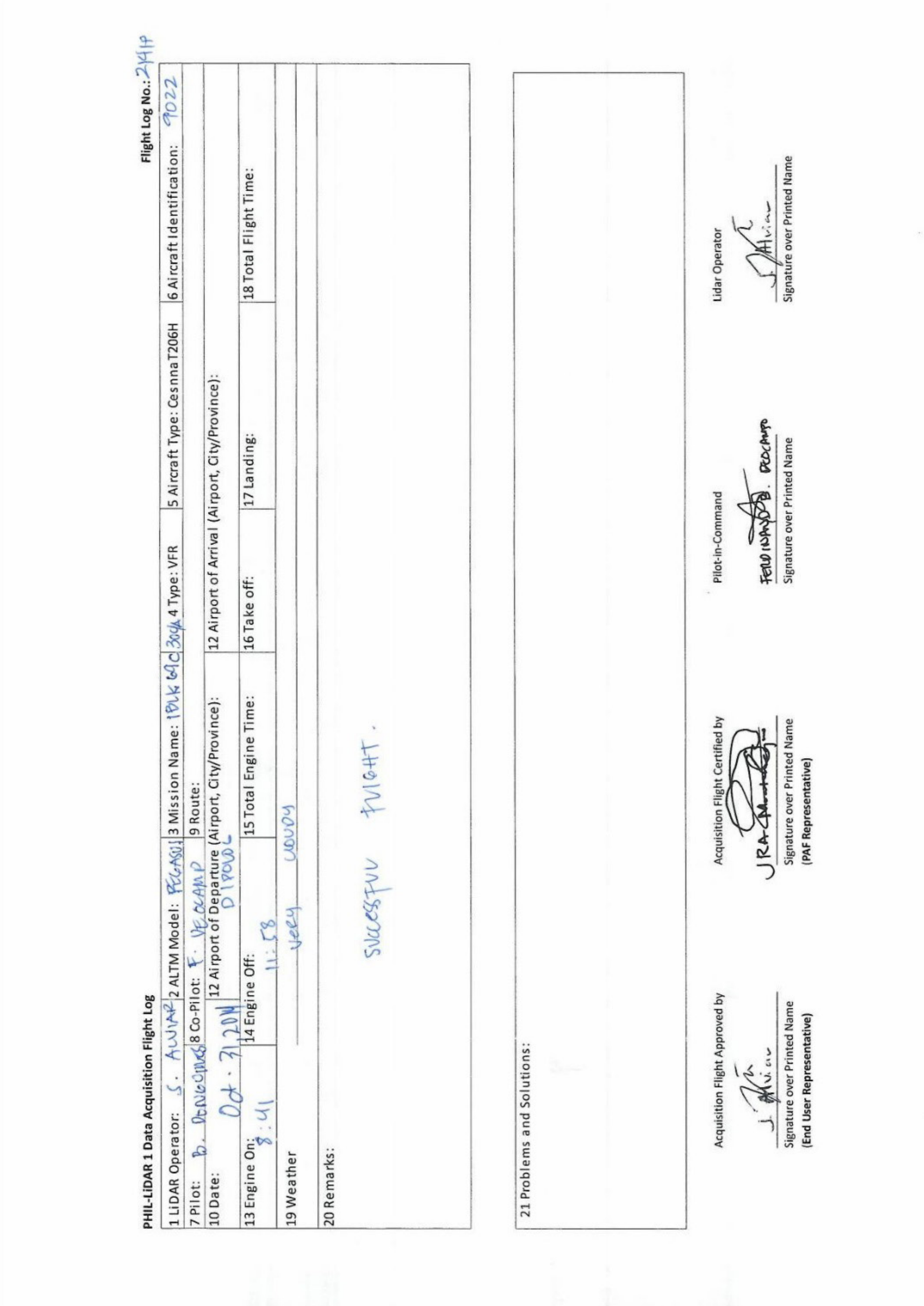


Figure A-6.5. Flight Log for Mission 2145P

6. Flight Log for 23120PMission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: Pau Arceo	2 ALTM Model: Pegasus	3 Mission Name: —	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/21/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 8:12	14 Engine Off: 12:47	15 Total Engine Time: 4+35	16 Take off: 8:17	17 Landing: 12:42	18 Total Flight Time: 4+25
19 Weather: Fair					

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

Successful flight

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
RJ Arceo	LEE JAY EPUNZALAN	C. Alfonso III	Pauline Joanne Arceo	NA
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-6.6. Flight Log for Mission 23120P

7. Flight Log for 23124PMission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: Kenneth Quisado	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/22/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian Zamboanga del Sur		
13 Engine On: 8:15	14 Engine Off: 12:50	15 Total Engine Time: 4+35	16 Take off: 8:20	17 Landing: 12:45	18 Total Flight Time: 4+25
19 Weather	Fair				

20 Flight Classification

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

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

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

21 Remarks

Successful flight

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
	LEE JAY E PUNZALAN	C. Alfonso III	Kenneth Quisado	NA
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-6.7. Flight Log for Mission 23124P

8. Flight Log for 23558PMission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LIDAR Operator: ARCEO / ALAMBAN	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A DAYO	8 Co-Pilot: E SAYSAY JR	9 Route:			
10 Date: 11/21/2016	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 0918 H	14 Engine Off: 1347 H	15 Total Engine Time: 4+29	16 Take off: 0923H	17 Landing: 1342 H	18 Total Flight Time: 04+19
19 Weather: CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

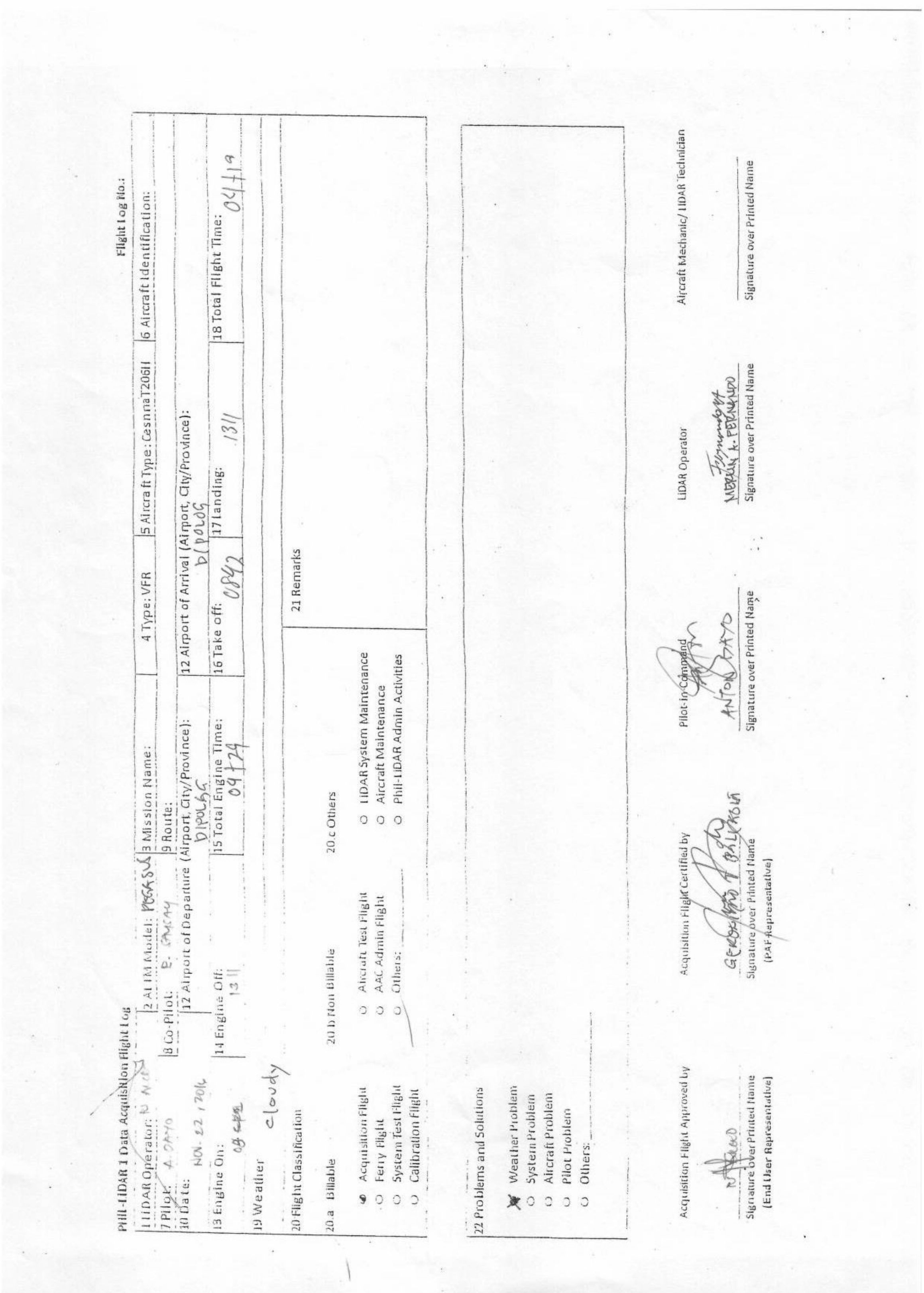
SURVEYED BLK 69 B AND D WITH VOIDS

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
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	ANTON DAYO Signature over Printed Name	JP ALAMBAN Signature over Printed Name	Signature over Printed Name

Figure A-6.8. Flight Log for Mission 23558P

9. Flight Log for 23562PMission



Phil-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: M. Nol	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: A. Dayo	8 Co-Pilot: E. Gacay	9 Route:			
10 Date: Nov. 22, 2016	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 0842	14 Engine Off: 1311	15 Total Engine Time: 04+29	16 Take off: 0852	17 Landing: 1311	18 Total Flight Time: 04+19
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

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

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

Acquisition Flight Certified by — Gerosimo T. Balanda — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Anton Dayo — Signature over Printed Name

LIDAR Operator — Merlin A. Fernando — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.9. Flight Log for Mission 23562P

10. Flight Log for 23574PMission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LIDAR Operator: G. Soriano	2 ALTM Model: Pegasus	3 Mission Name: 1BLK69BD329A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. Dayo	8 Co-Pilot: E. Saysay	9 Route:			
10 Date: Nov 29, 2016	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 09:55	14 Engine Off: 14:06	15 Total Engine Time: 4h 11m	16 Take off: 10:05	17 Landing: 13:55	18 Total Flight Time: 3h 50m
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successfol flight

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
Signature over Printed Name (End User Representative)	GERONIMO BALIDIO Signature over Printed Name (PAF Representative)	ANTON DAYO Signature over Printed Name	Gef Soriano Signature over Printed Name	Signature over Printed Name

Figure A-6.10. Flight Log for Mission 23574P

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT

Zamboanga del Norte

October22-November 31, 2014; February 21-22, 2016; November 21-22, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2111P	BLK 69B	1BLK69B295A	G. Sinadjan	Oct. 22, 2014	Surveyed BLK 69B, cloudy
2113P	BLK 69B	1BLK69B296A	I. Roxas	Oct. 23, 2014	Surveyed BLK 69 B, still cloudy
2115P	BLK 69ABD	1BLK6970A296B	G. Sinadjan	Oct. 23, 2014	Surveyed parts of BLK 69A, B, and D
2125P	BLK 69C	1BLK69C299A	I. Roxas	Oct. 26, 2014	Surveyed BLK 69C
2145P	BLK 69CB	1BLk69C304A	J. Alviar	Oct. 31, 2014	Surveyed BLk 69C, gaps in the middle due to clouds and terrain
23120P	BLK 69D	1BLK69D052A	PJ Arceo	Feb. 21, 2016	Encountered lost channel A. Completed BLK69D with voids due to cloud build up
23124P	BLK 69A, 69B	1BLK69AB053A	K Quisado	Feb. 22, 2016	Encountered lost channel A error several times. Surveyed fps over Dipolog, Zamboanga del Norte with voids due to cloud build up throughout the duration of the survey
23558P	DIPOLOG, PARO DAPITAN BLK 69B,69C	1BLK69BC325A	PJ Arceo, G Soriano	Nov. 20, 2016	Completed Dipolog and Paro Dapitan fp with voids due to build up and strong winds
23562P	DIPOLOG, PARO DAPITAN BLK 69B, 69D	1BLK69BD326A	PJ Arceo, JP Alamban	Nov. 21, 2016	Completed BLK69B and surveyed 69D with voids due to cloud build up
23574P	PARO DAPITAN BLK 69A, 69D	1BLK69AD329A	G SORIANO	Nov. 24, 2016	Surveyed BLK69A and voids over Paro Dapitan fp

SWATH PER FLIGHT MISSION

Flight No. :	2111P
Area:	BLK 69B
Mission Name:	1BLK69B295A
Parameters:	Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

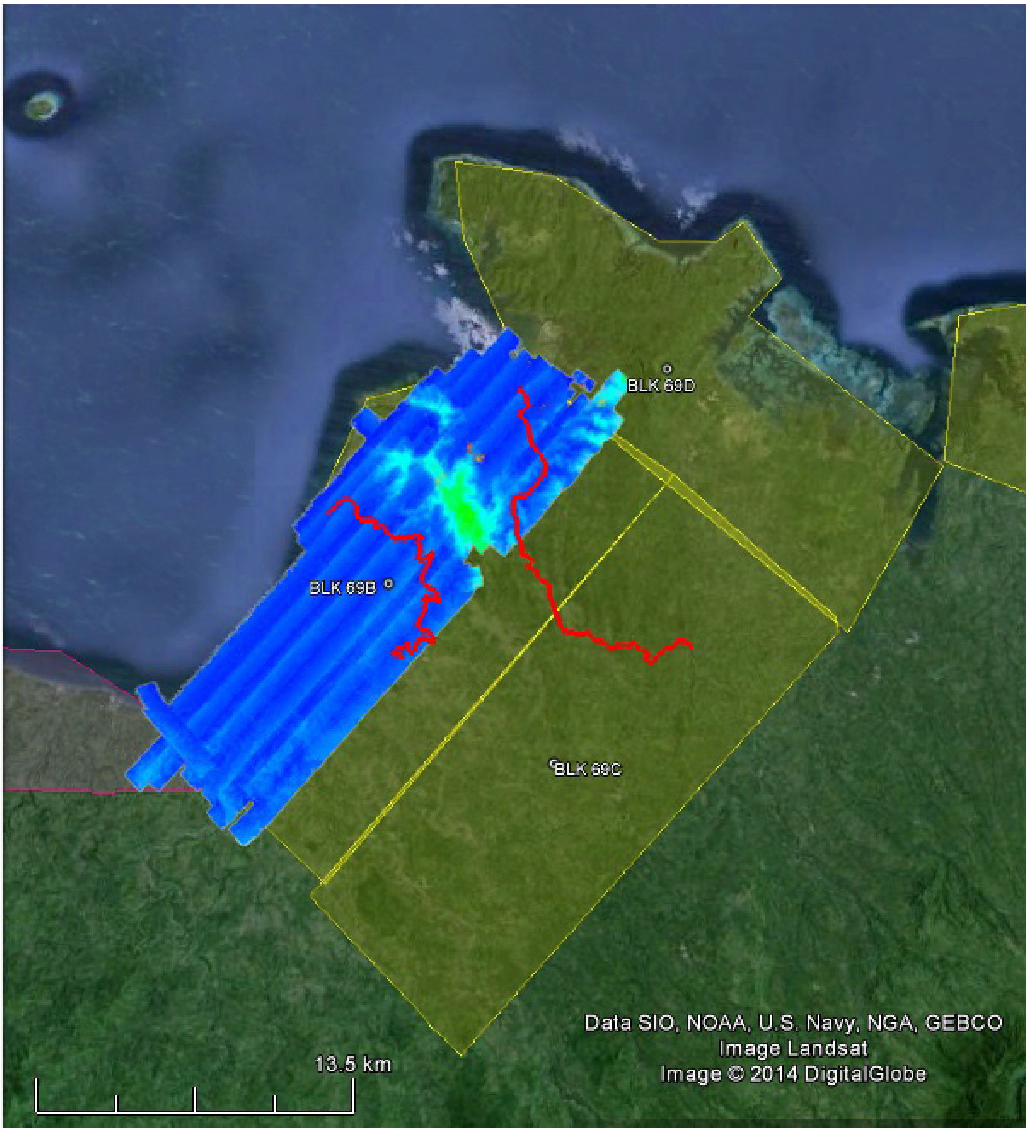


Figure A-7.1. Swath for Flight No. 2111P

Flight No. : 2113P
Area: BLK 69ABD
Mission Name: 1BLK69B296A
Parameters: Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

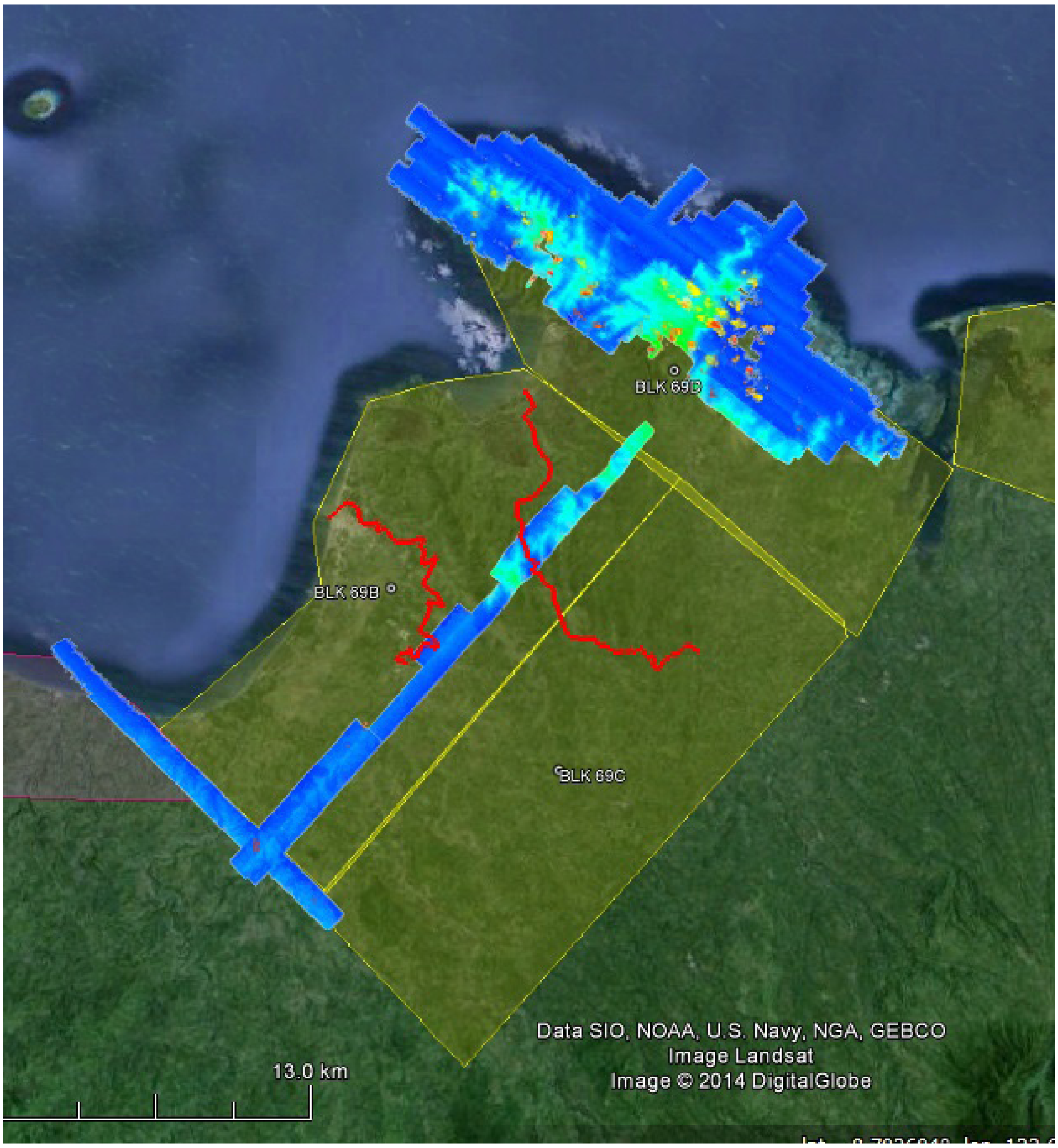


Figure A-7.2. Swath for Flight No. 2113P

Flight No. :	2115P
Area:	BLK 69D
Mission Name:	1BLK69DBA296B
Parameters:	Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

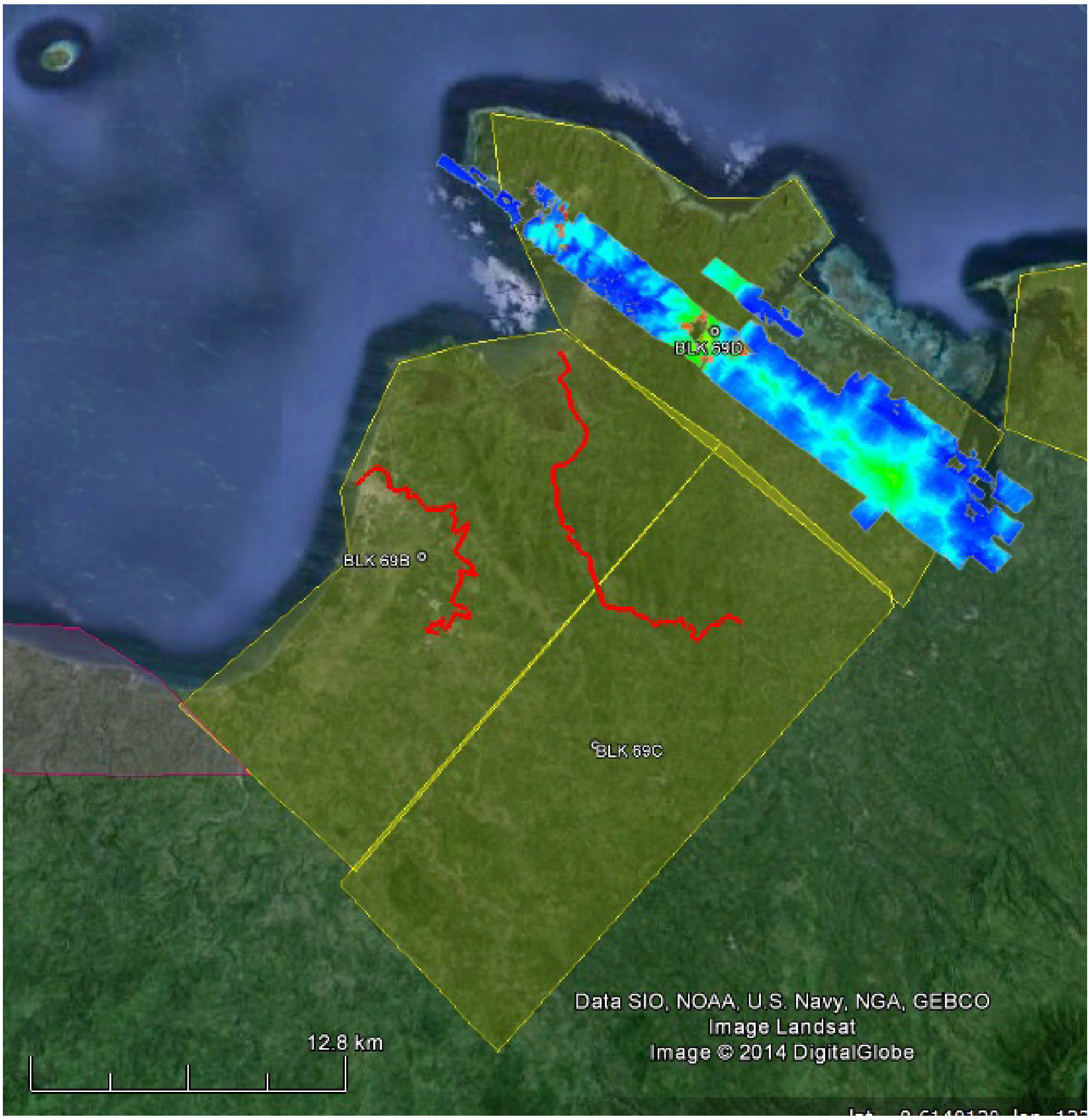


Figure A-7.3. Swath for Flight No. 2115P

Flight No. : 2125P
Area: BLK 69C
Mission Name: 1BLK69C299A
Parameters: Altitude: 800m; Scan Frequency: 30; Scan Angle: 50

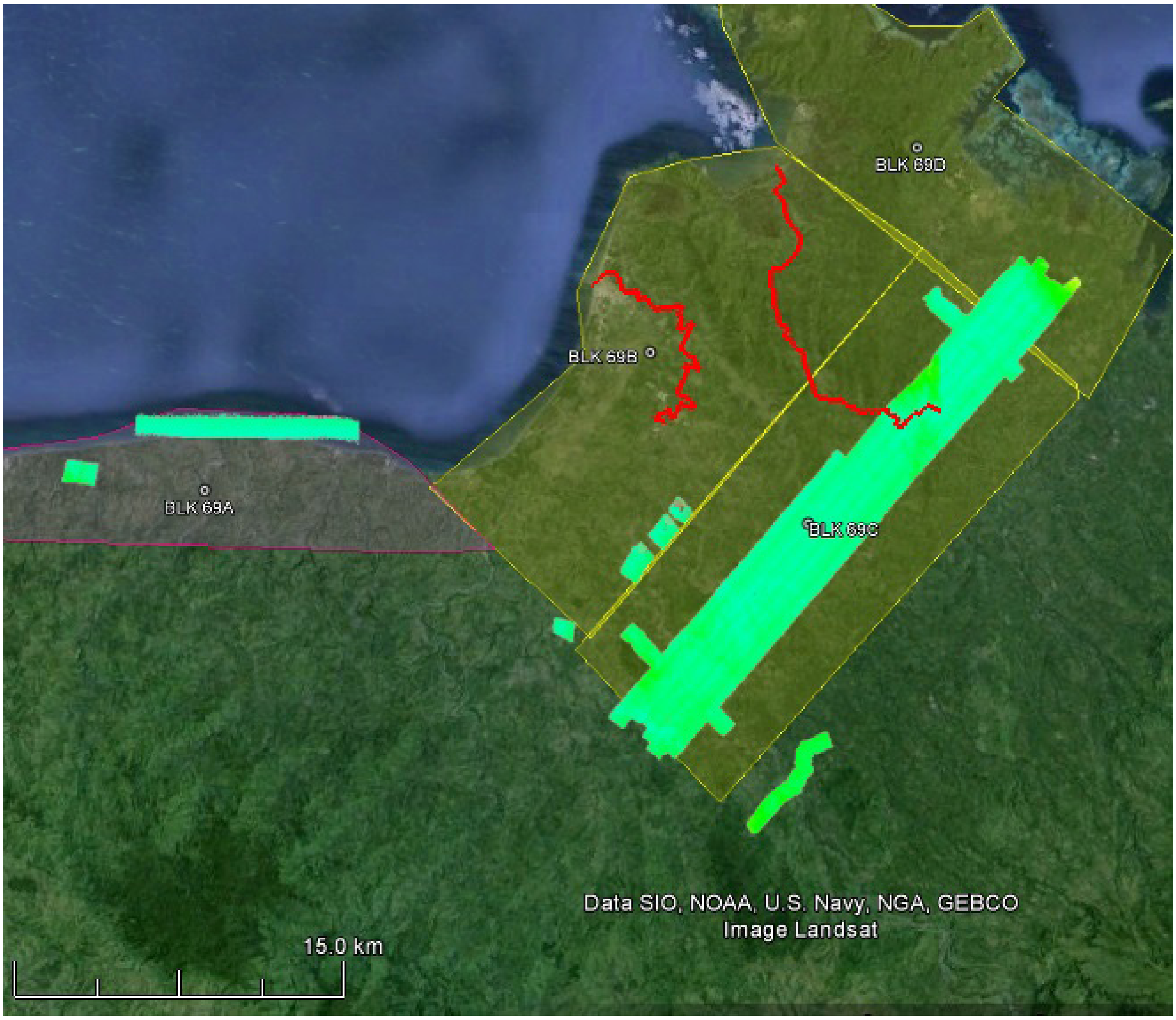


Figure A-7.4. Swath for Flight No. 2125P

Flight No. :	2145P
Area:	BLK 69CB
Mission Name:	1BLK69304A
Parameters:	Altitude: 750m; Scan Frequency: 30; Scan Angle: 50

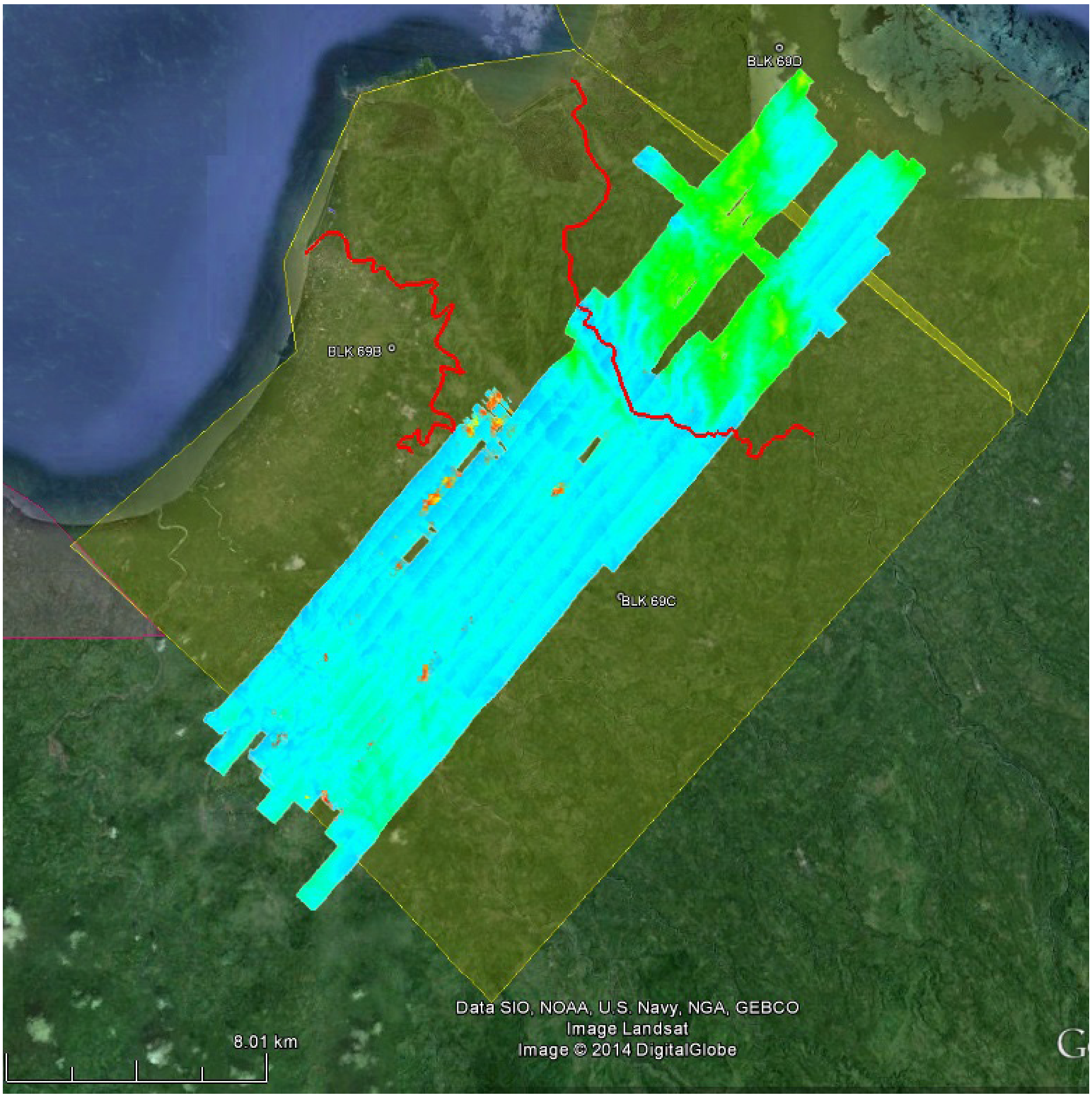


Figure A-7.5. Swath for Flight No. 2145P

Flight No. :	23120P
Area:	BLK69D
Mission Name:	1BLK69D052A
Parameters:	Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

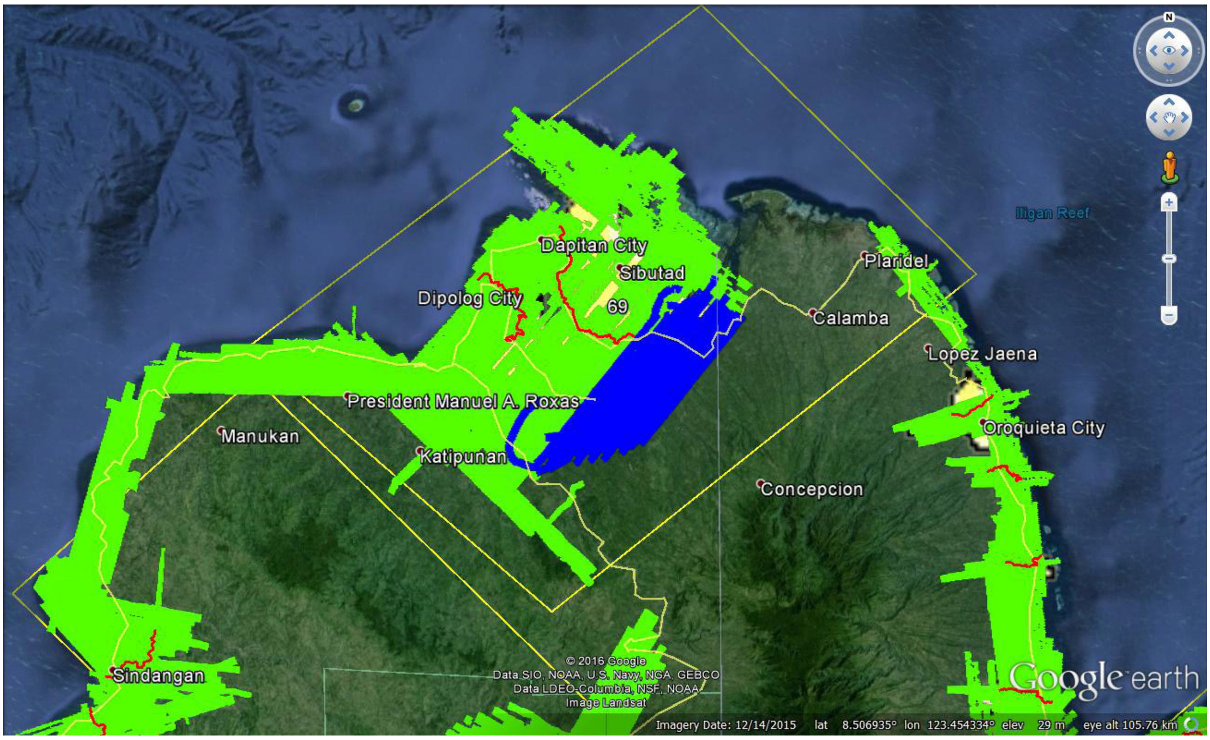


Figure A-7.6. Swath for Flight No. 23120P

Flight No. :	23124P
Area:	BLK69 A, B
Mission Name:	1BLK69AB053A
Parameters:	Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

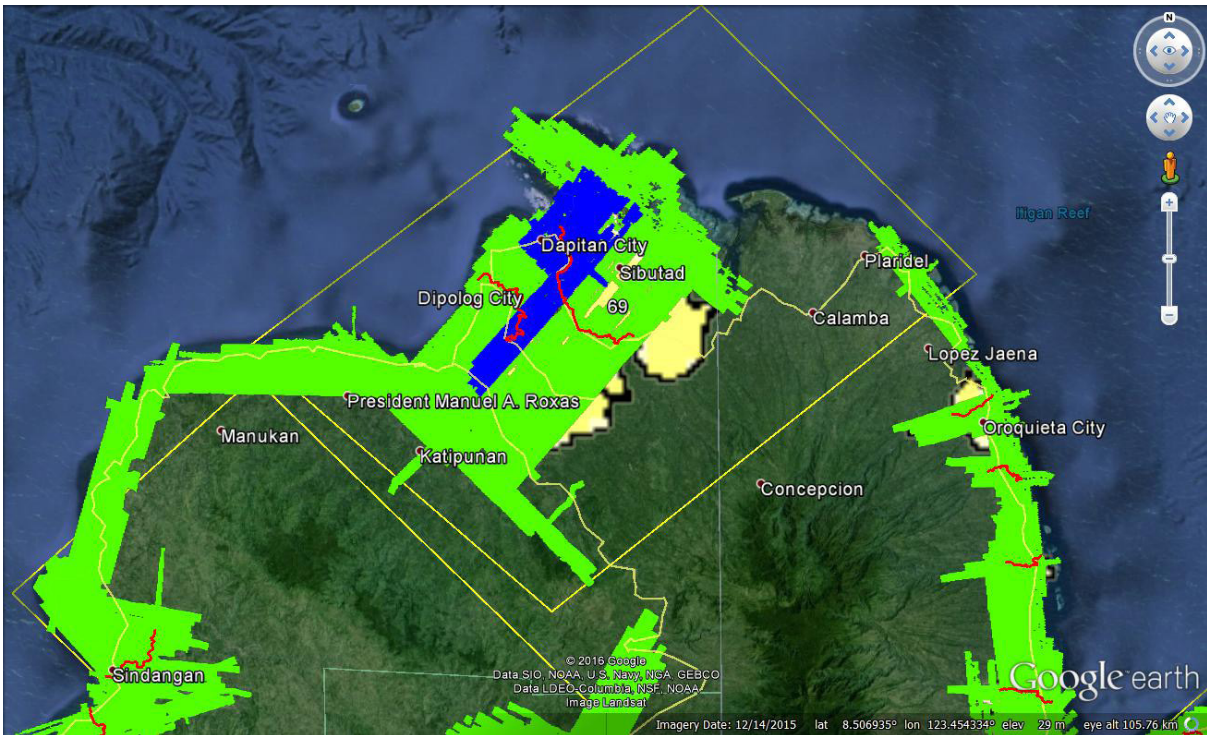


Figure A-7.7. Swath for Flight No. 23124P

Flight No. :	23558P
Area:	DIPOLOG AND PARO DAPITAN
Mission Name:	1BLK69BC325A
Parameters:	Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

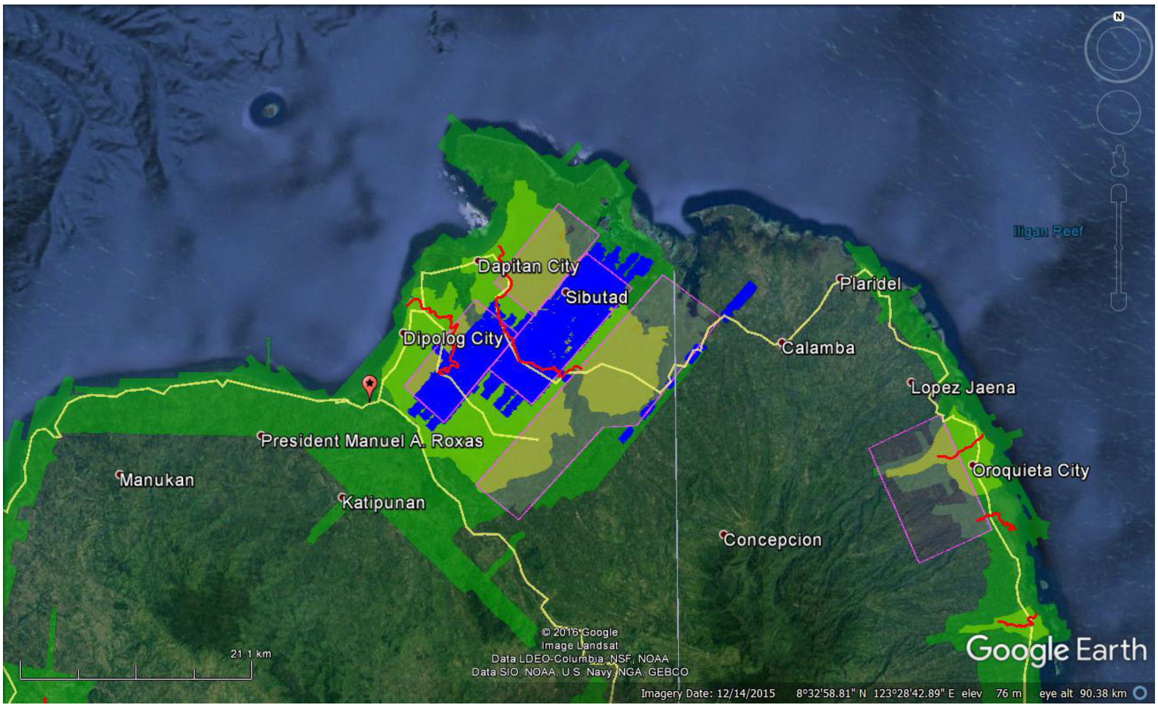


Figure A-7.8. Swath for Flight No. 23558P

Flight No. :	23562P
Area:	DIPOLOG AND PARO DAPITAN
Mission Name:	1BLK69BD326A
Parameters:	Altitude: 1000m; Scan Frequency: 30; Scan Angle: 50

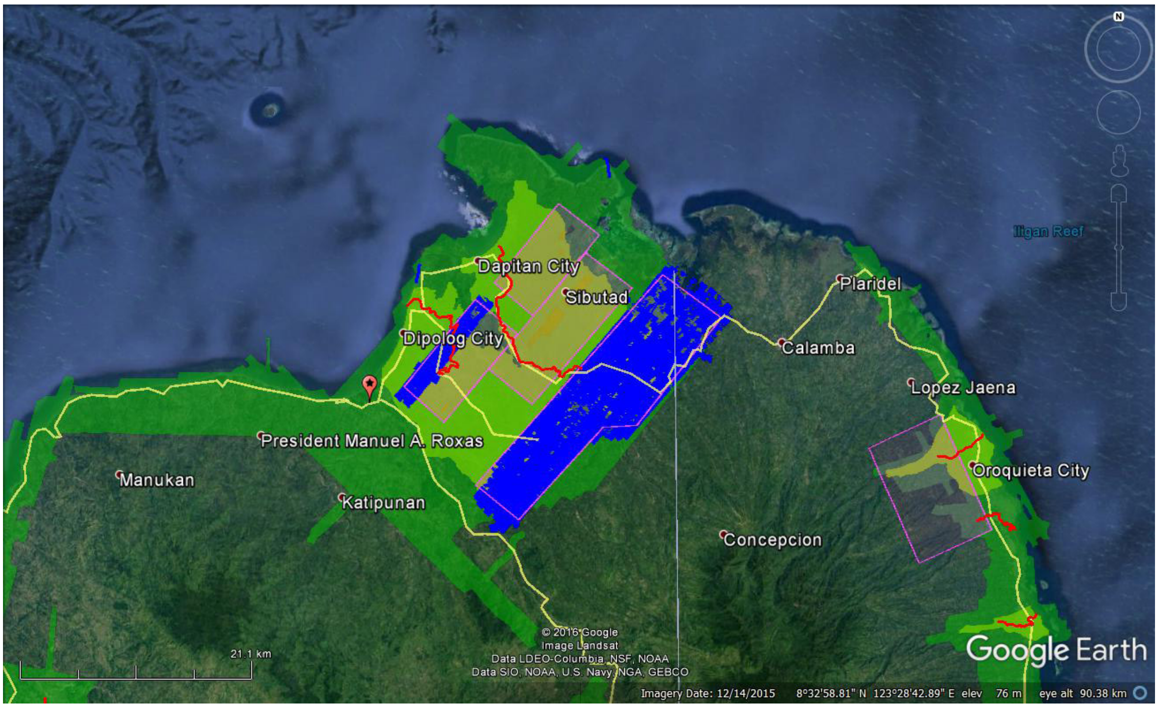


Figure A-7.9. Swath for Flight No. 23562P

Flight No. :	23574P
Area:	PARO DAPITAN
Mission Name:	1BLK69AD329A
Parameters:	Altitude: 700/1000m; Scan Frequency: 30; Scan Angle: 50

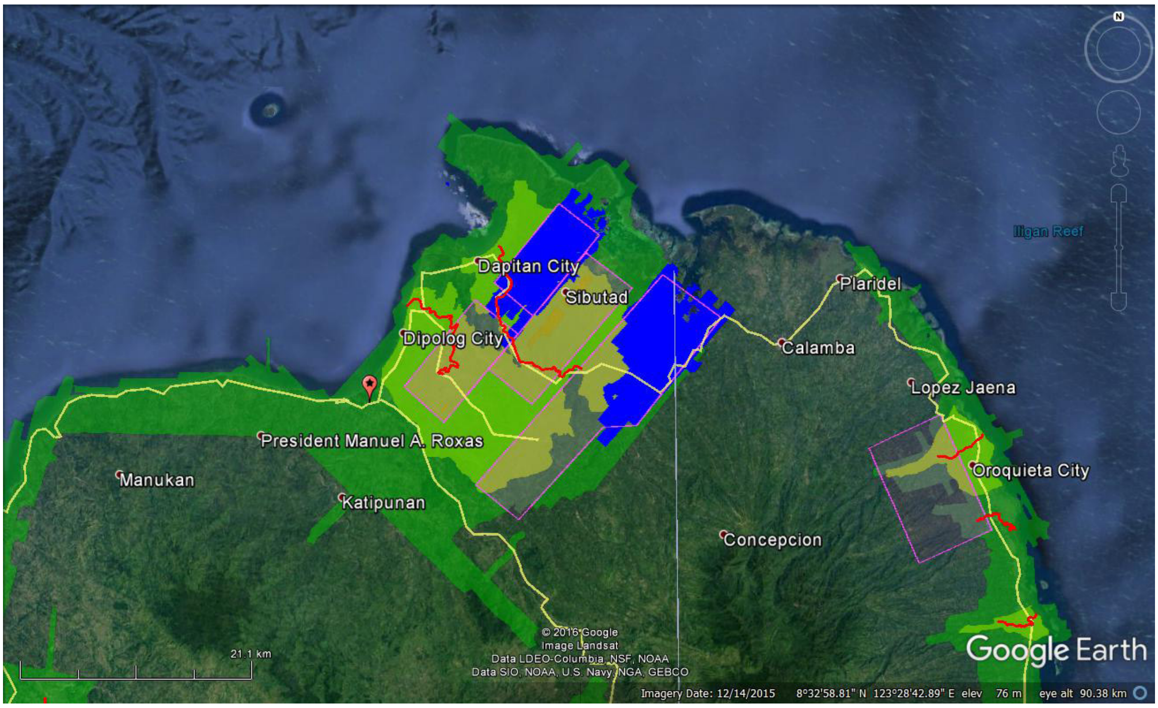


Figure A-7.10. Swath for Flight No. 23574P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission 69A

Flight Area	Pagadian
Mission Name	**69A**
Inclusive Flights	23124P
Range data size	21.1
POS data size	270
Base data size	3.12
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.6
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	3.9
Boresight correction stdev (<0.001deg)	0.000371
IMU attitude correction stdev (<0.001deg)	0.000999
GPS position stdev (<0.01m)	0.0067
Minimum % overlap (>25)	0.25
Ave point cloud density per sq.m. (>2.0)	5.88
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	170
Maximum Height	621.53 m
Minimum Height	62.16 m
Classification (# of points)	
Ground	171,617,535
Low vegetation	150,341,707
Medium vegetation	241,301,262
High vegetation	720,916,233
Building	12,197,633
Orthophoto	No

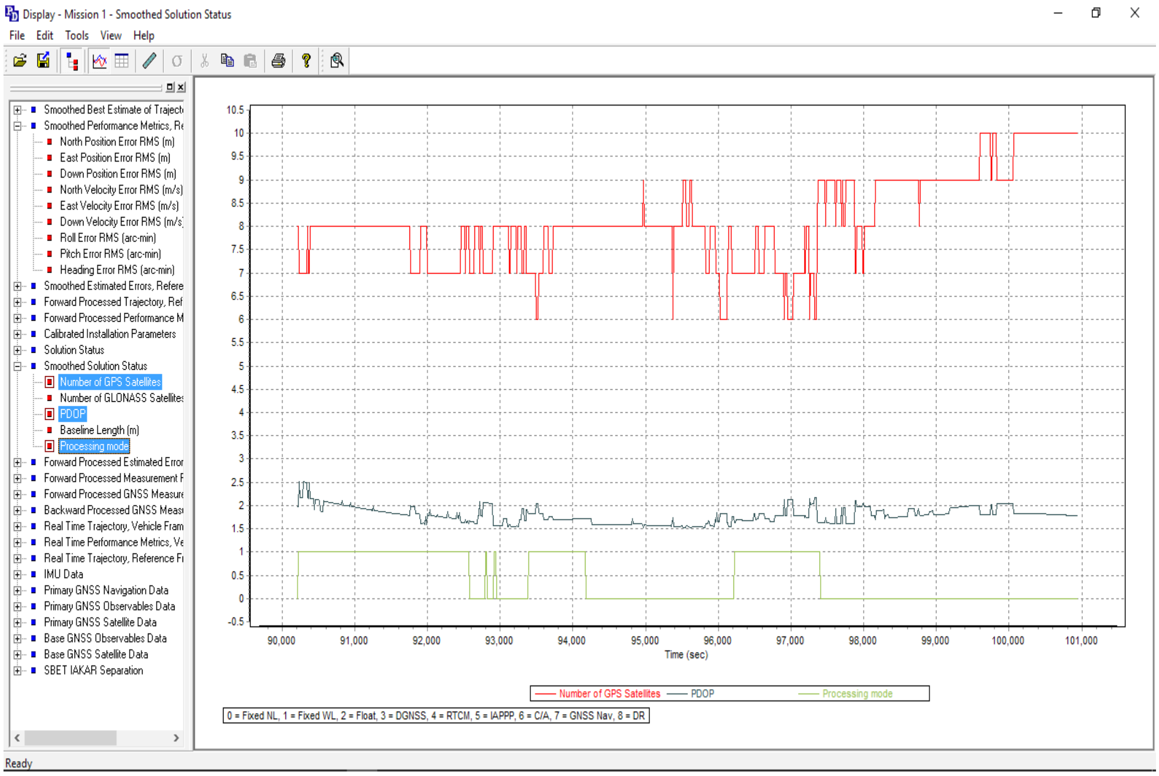


Figure A-8.1. Solution Status

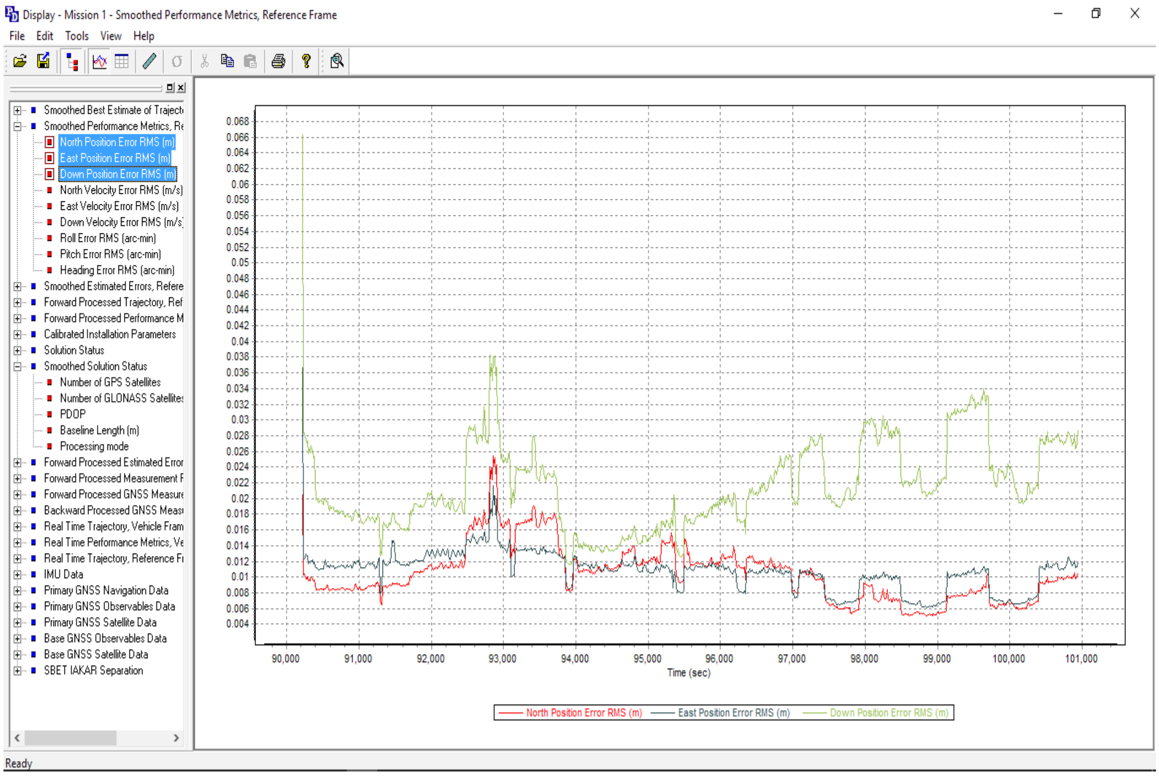


Figure A-8.2. Smoothed Performance Metric Parameters

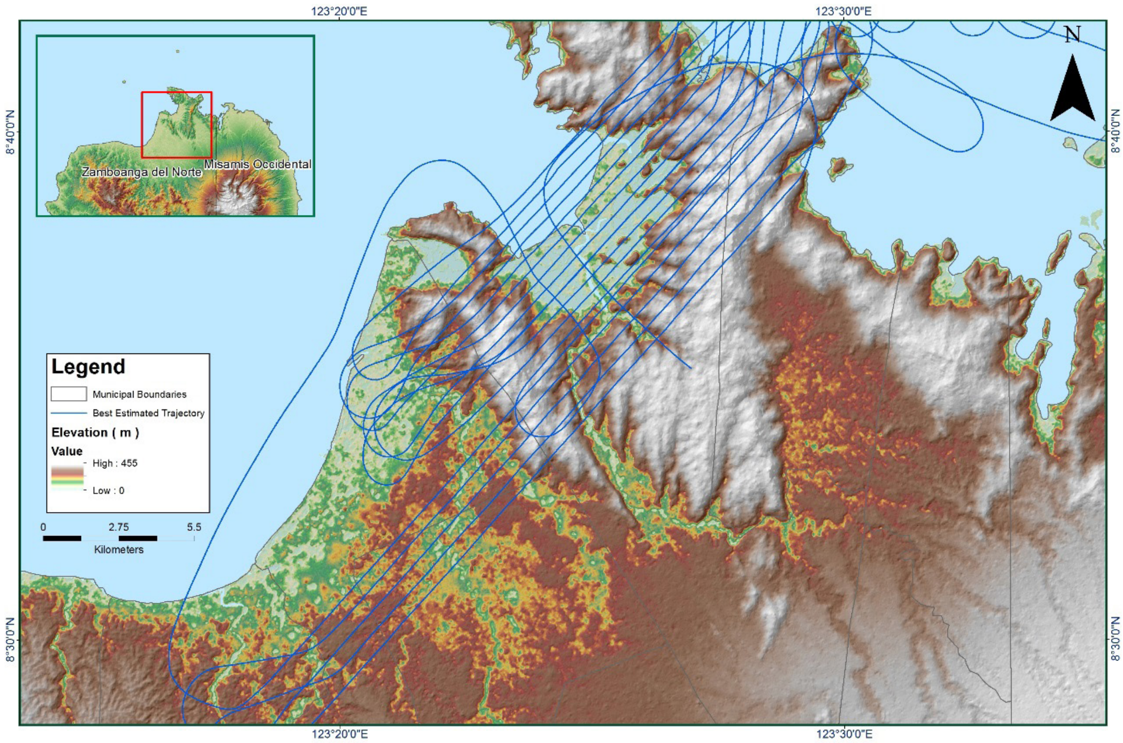


Figure A-8.3. Best Estimated Trajectory

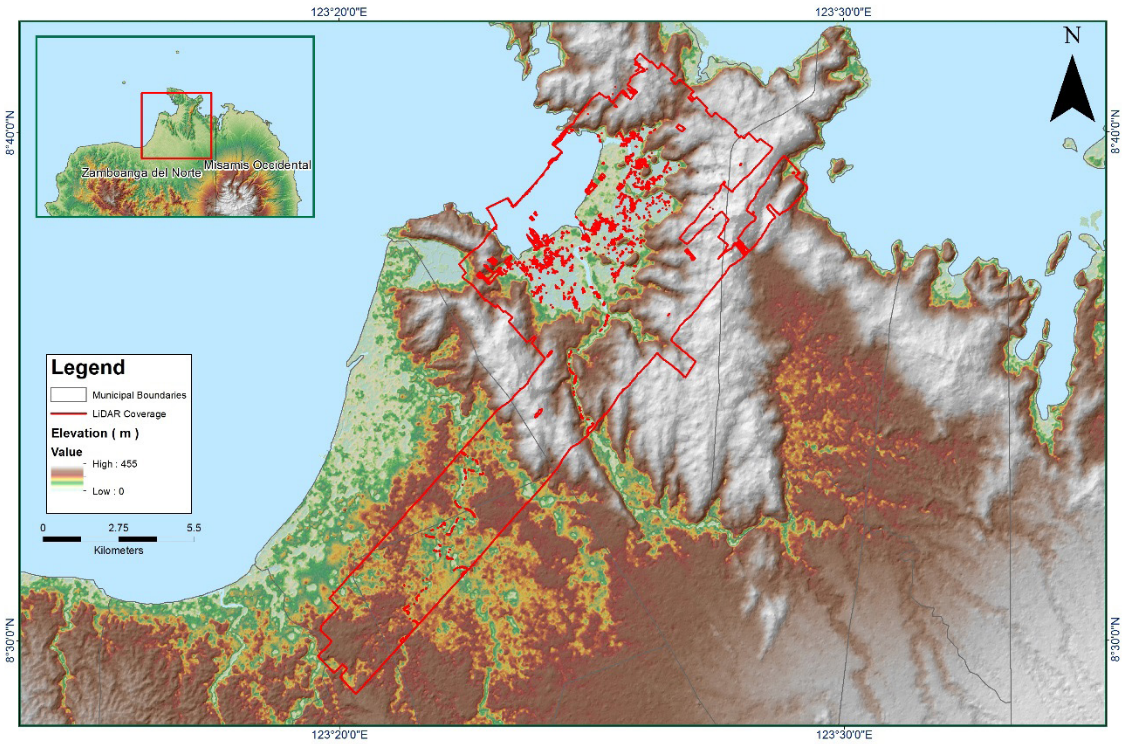


Figure A-8.4. Coverage of LiDAR Data

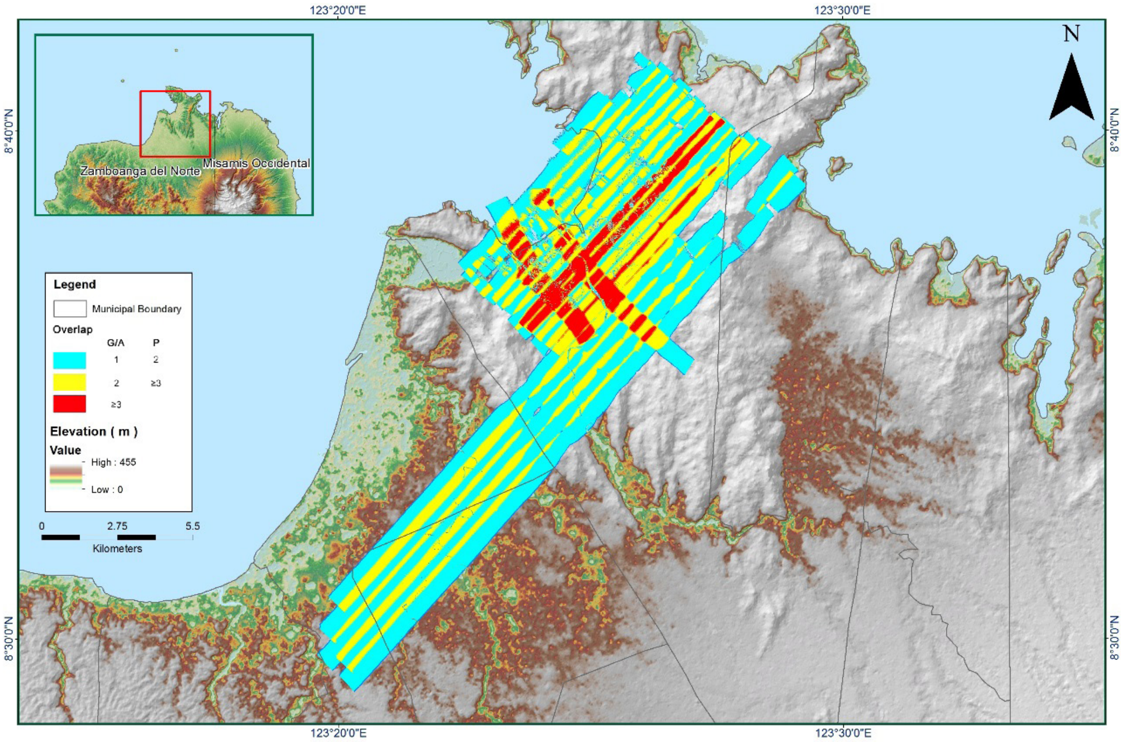


Figure A-8.5. Image of data overlap

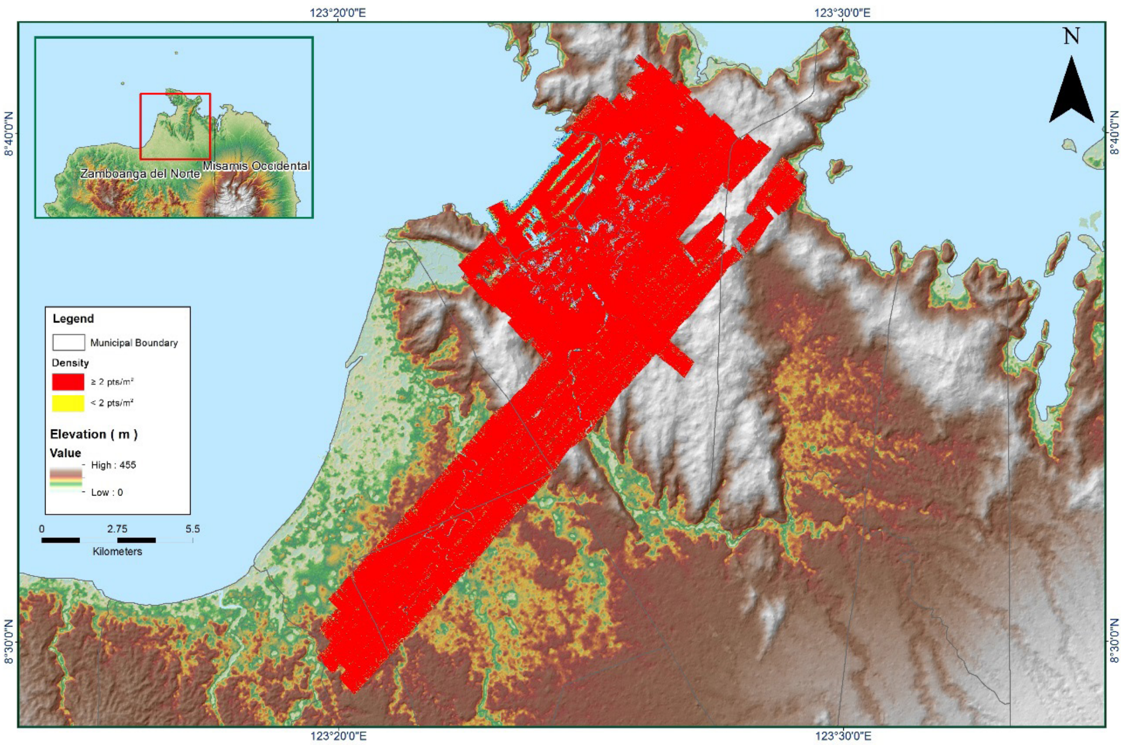


Figure A-8.6. Density map of merged LiDAR data

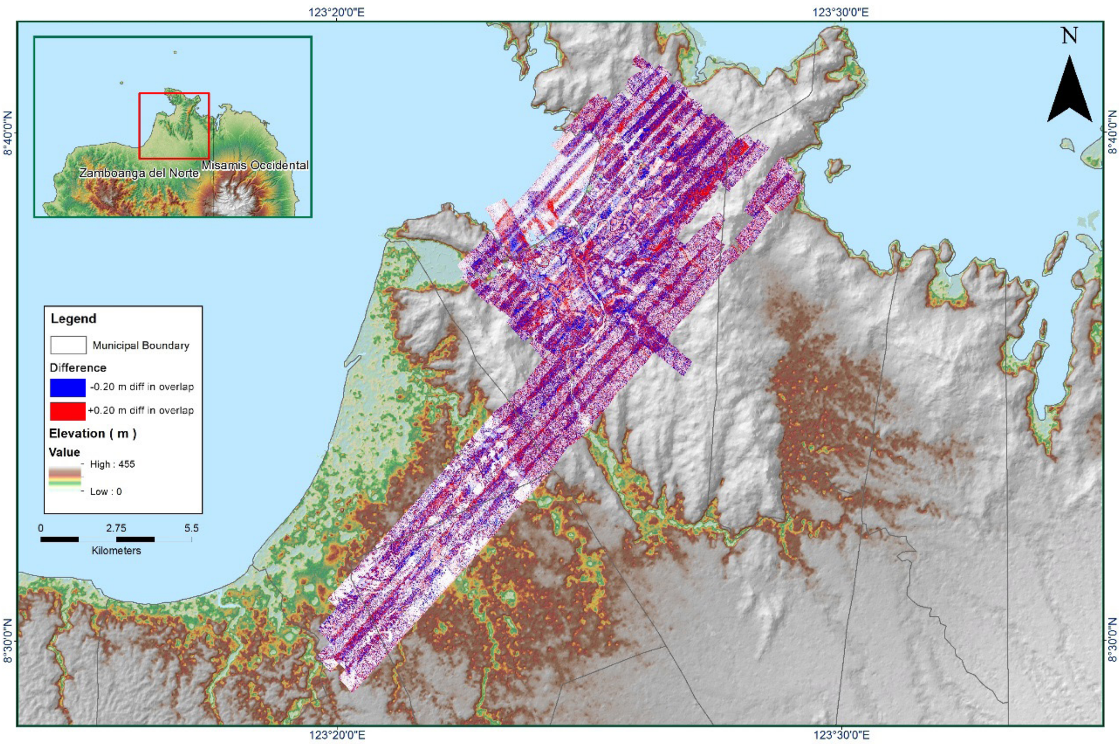


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission 69D

Flight Area	**Pagadian**
Mission Name	**69D**
Inclusive Flights	23120P
Range data size	25.9
POS data size	298
Base data size	59.6
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.5
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	6.3
Boresight correction stdev (<0.001deg)	0.000249
IMU attitude correction stdev (<0.001deg)	0.002107
GPS position stdev (<0.01m)	0.0096
Minimum % overlap (>25)	45.89
Ave point cloud density per sq.m. (>2.0)	5.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	229
Maximum Height	415.32 m
Minimum Height	66.20 m
Classification (# of points)	
Ground	236,562,708
Low vegetation	178,296,202
Medium vegetation	347,228,341
High vegetation	954,090,523
Building	9,130,143
Orthophoto	No

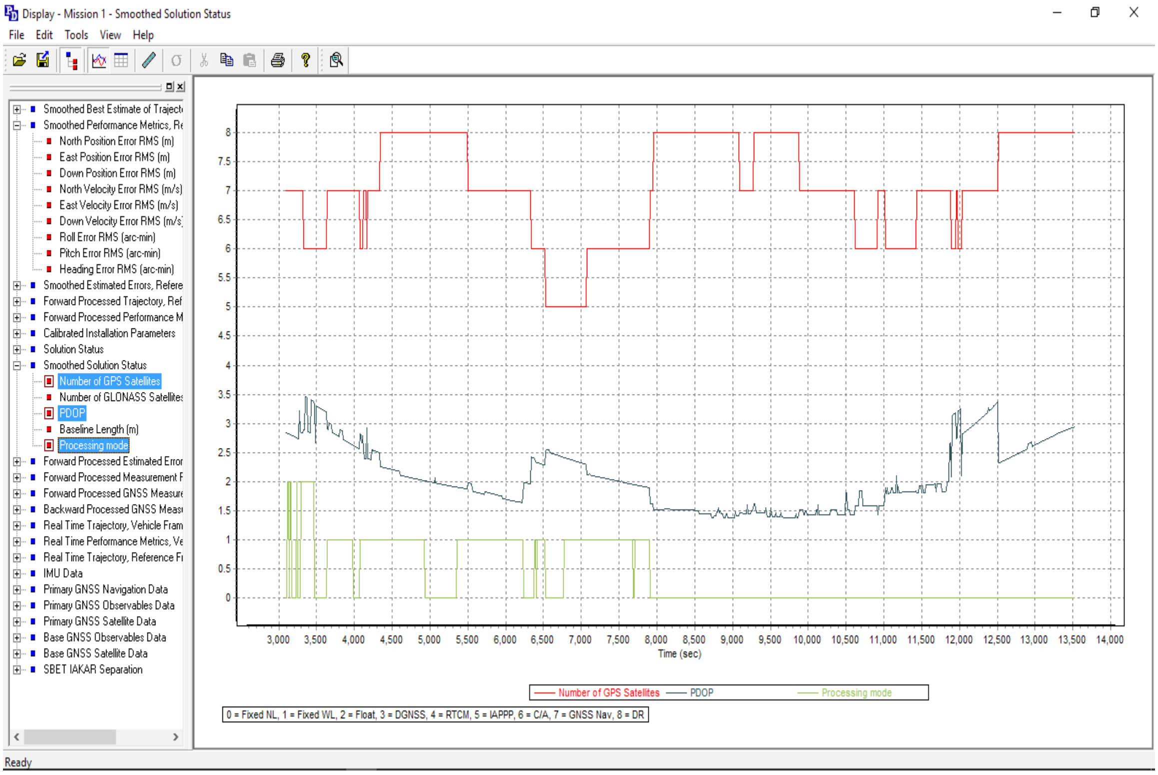


Figure A-8.8. Solution Status

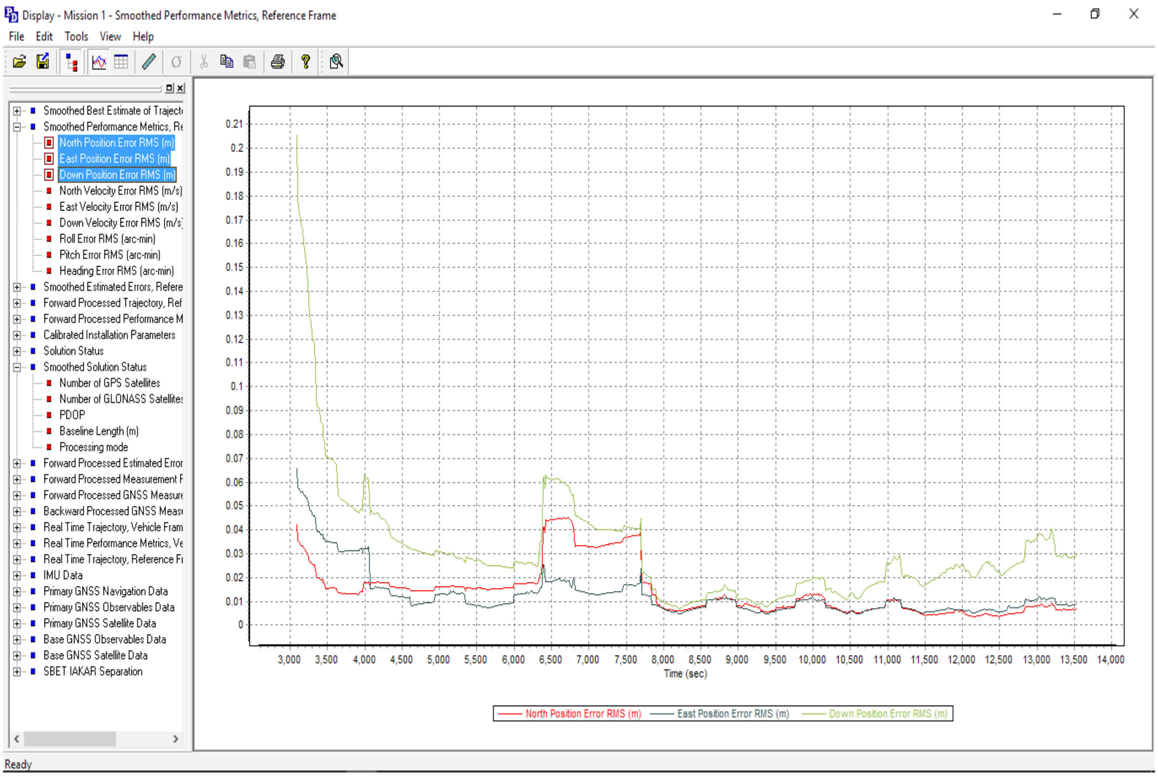


Figure A-8.9. Smoothed Performance Metric Parameters

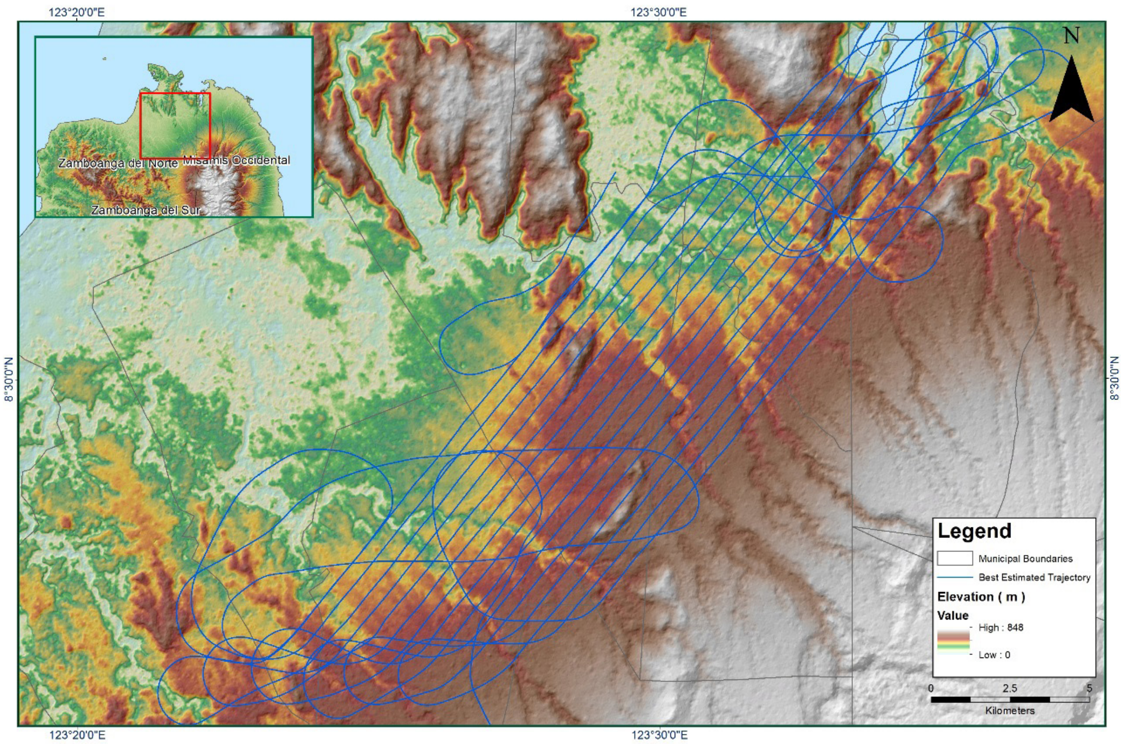


Figure A-8.10. Best Estimated Trajectory

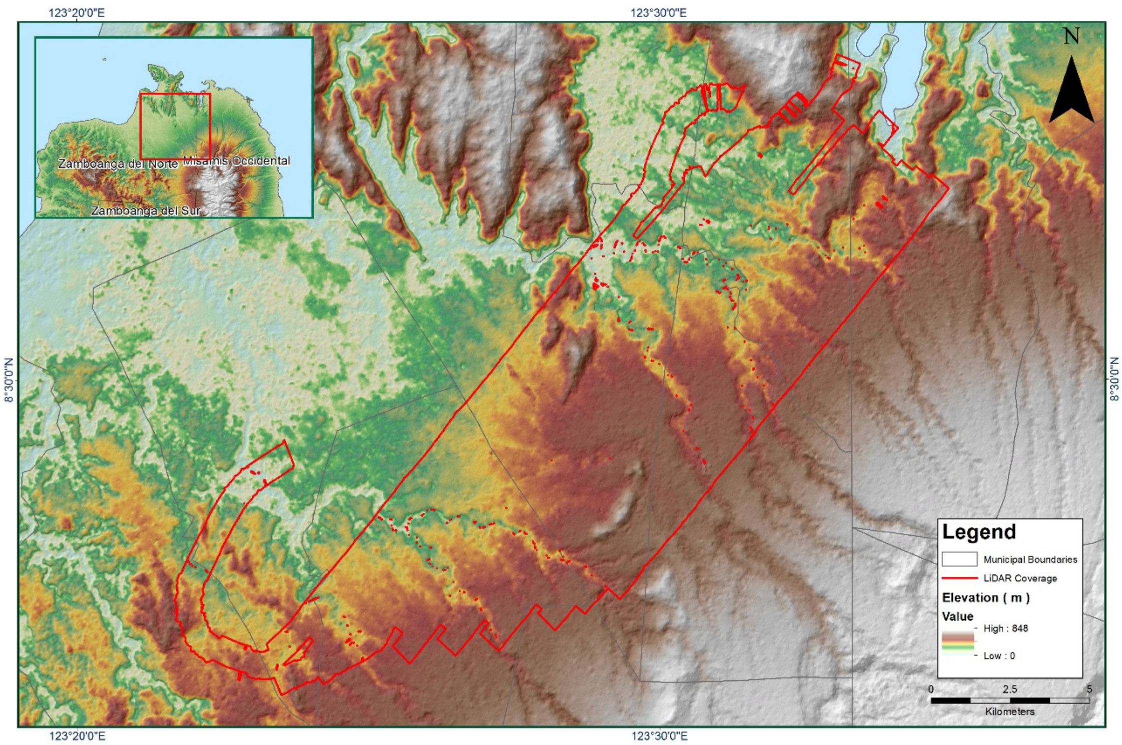


Figure A-8.11. Coverage of LiDAR Data

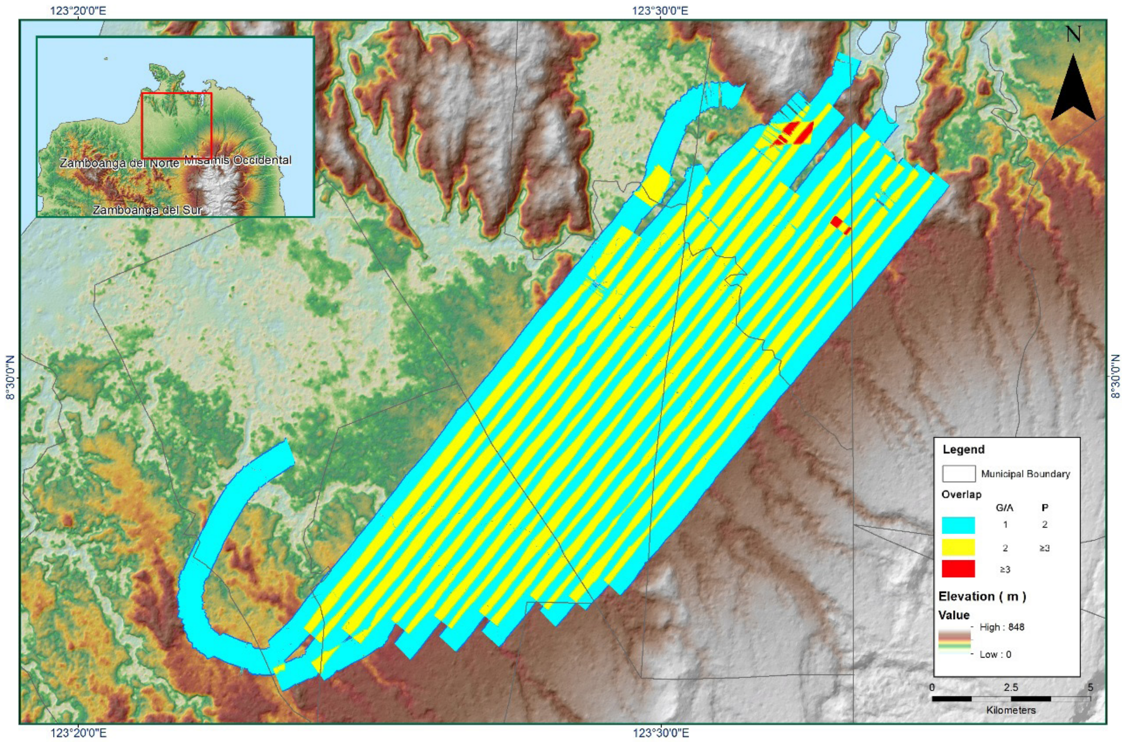


Figure A-8.12. Image of data overlap

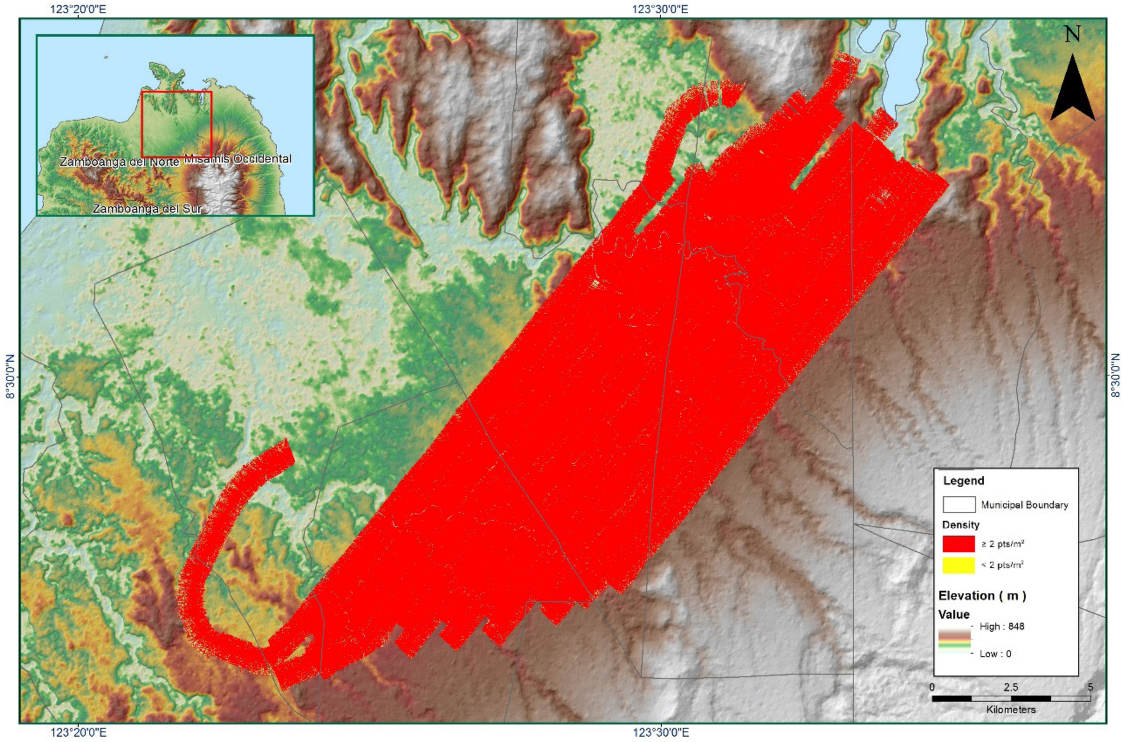


Figure A-8.13. Density map of merged LiDAR data

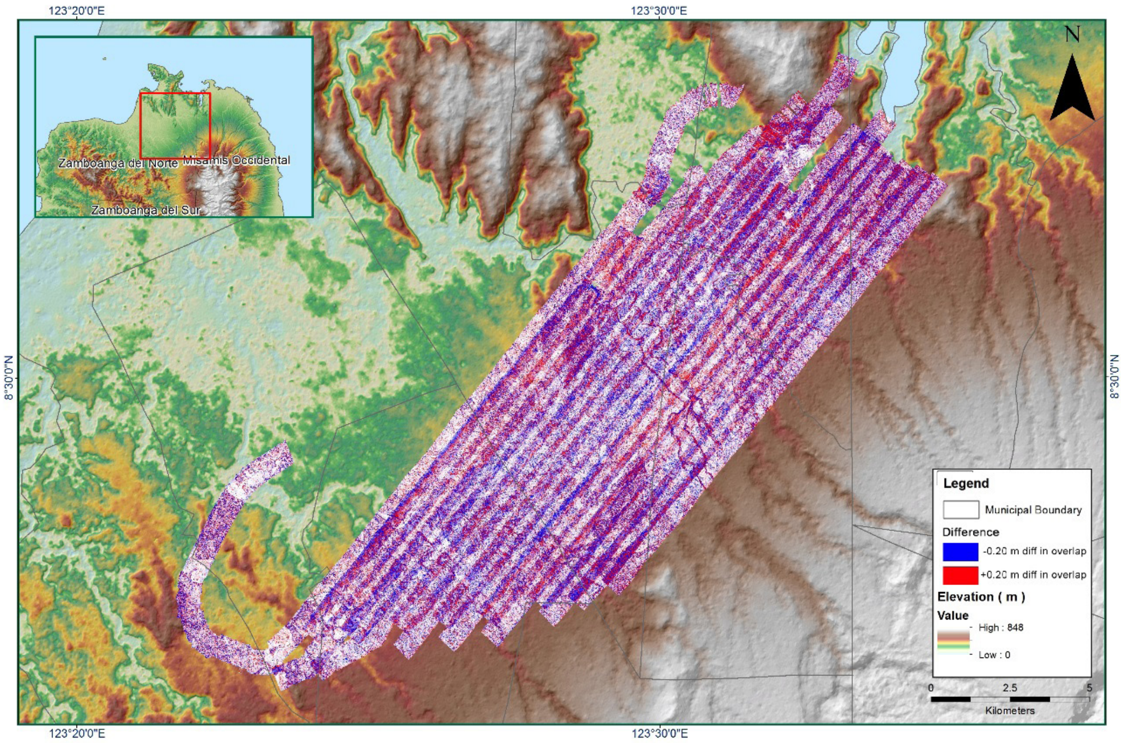


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk69B

Flight Area	Dipolog
Mission Name	Blk69B
Inclusive Flights	2111P,2113P,2117P,2145P
Range data size	76.8 GB
POS	747 MB
Image	145.3 GB
Transfer date	November 19, 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)	1.3
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000230
IMU attitude correction stdev (<0.001deg)	0.001892
GPS position stdev (<0.01m)	0.0055
Minimum % overlap (>25)	45.84%
Ave point cloud density per sq.m. (>2.0)	4.44
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	431
Maximum Height	583.31 m
Minimum Height	64.64 m
Classification (# of points)	
Ground	334,562,024
Low vegetation	335,327,811
Medium vegetation	532,124,060
High vegetation	552,692,726
Building	26,568,620
Orthophoto	Yes

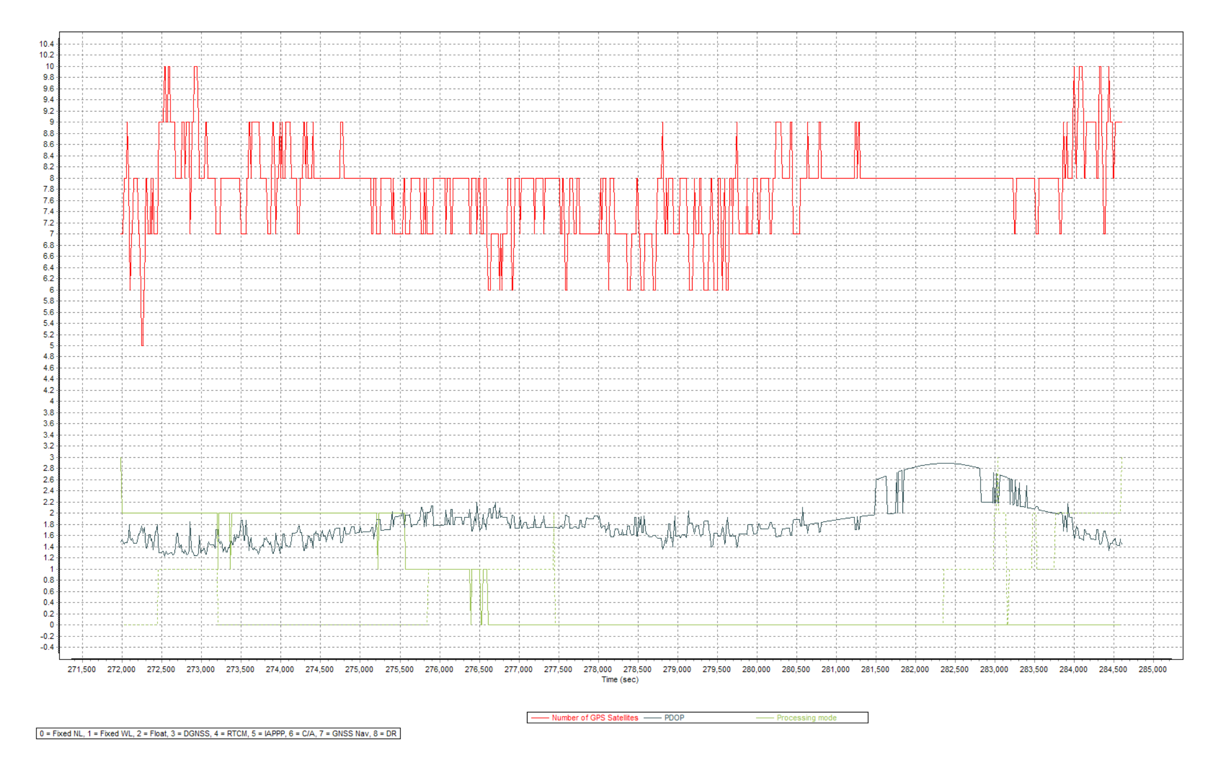


Figure A-8.15. Solution Status

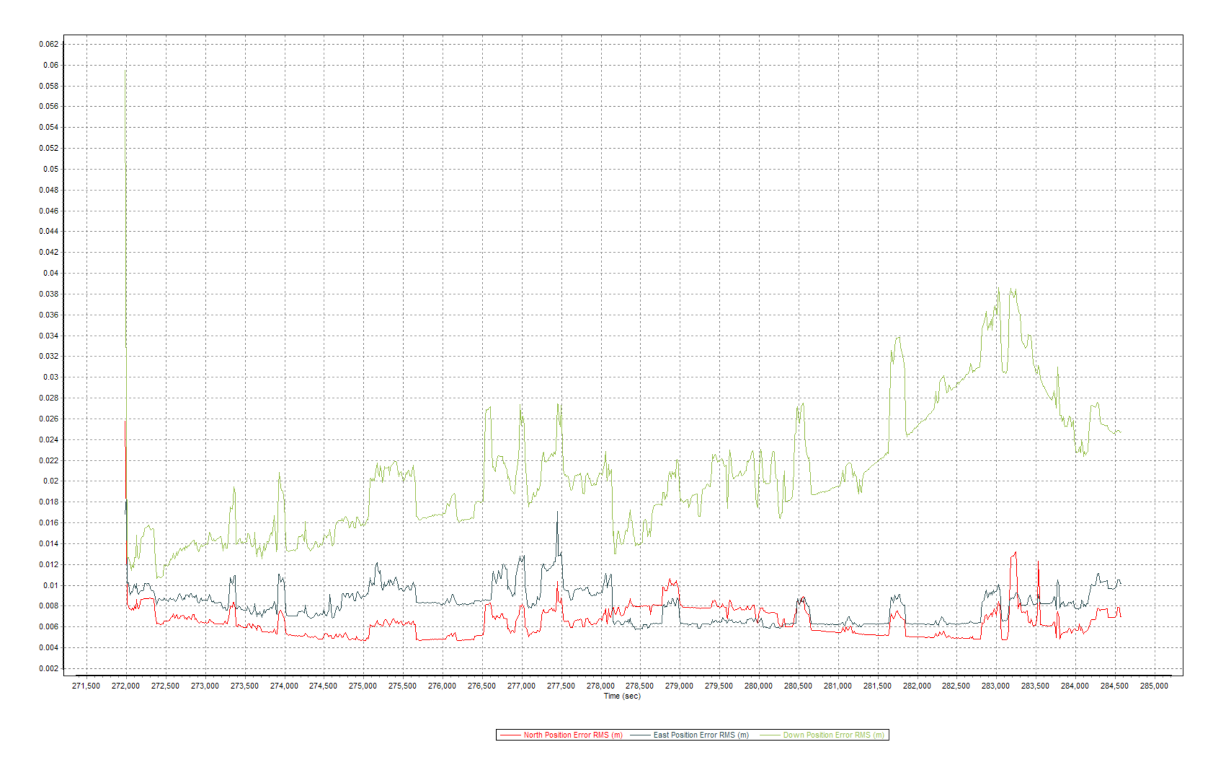


Figure A-8.16. Smoothed Performance Metric Parameters

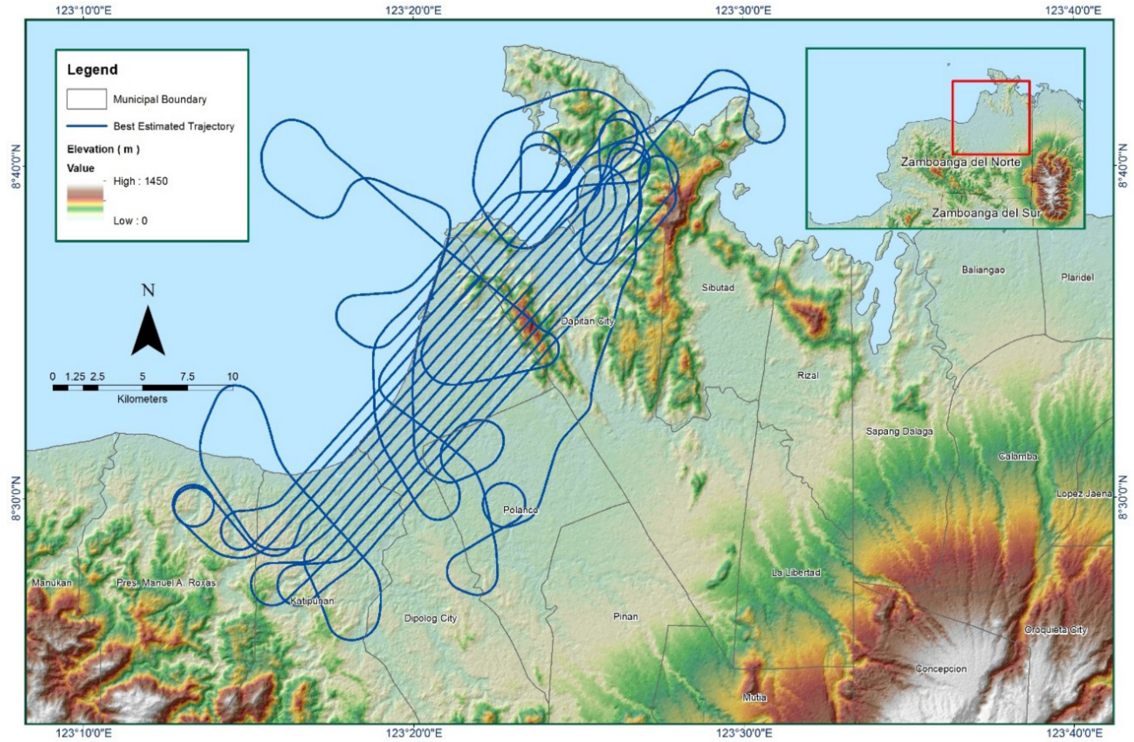


Figure A-8.17. Best Estimated Trajectory

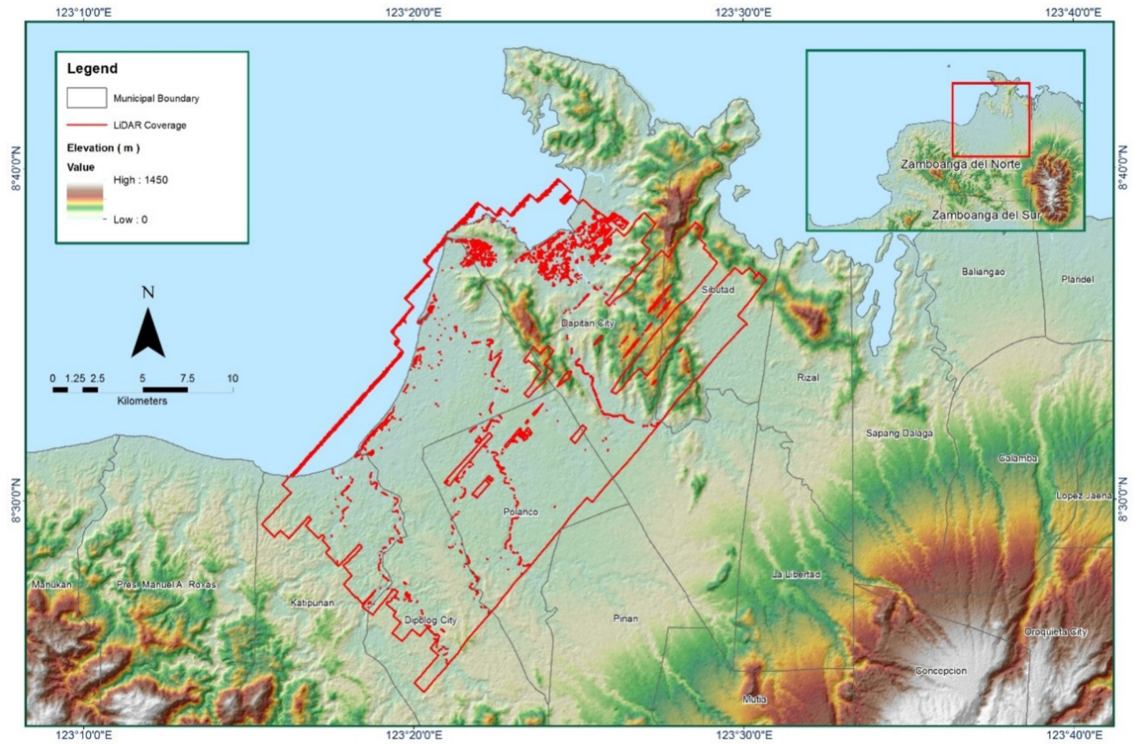


Figure A-8.18.Coverage of LiDAR data

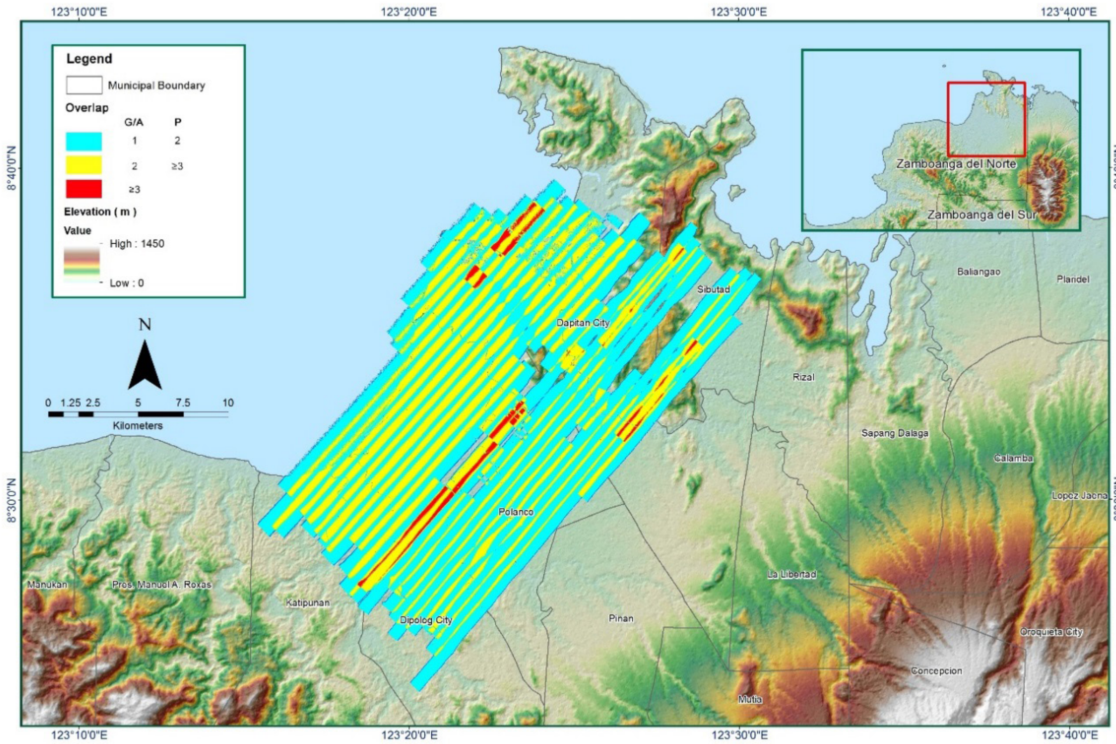


Figure A-8.19. Image of data overlap

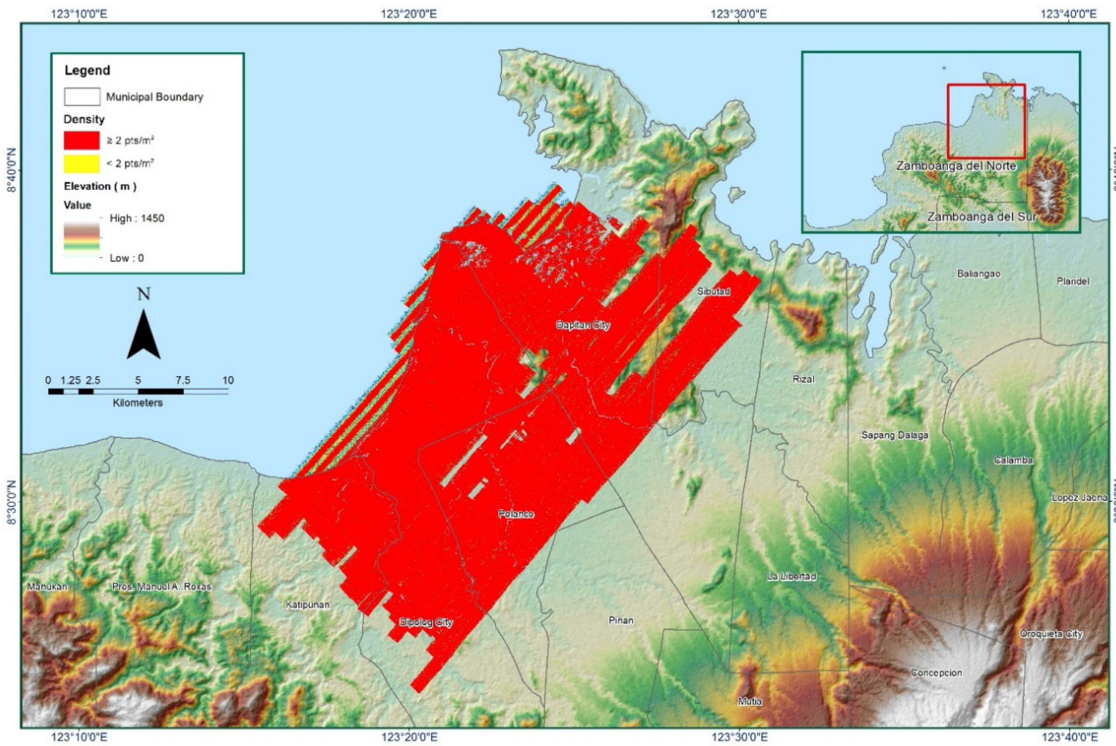


Figure A-8.20. Density map of merged LiDAR data

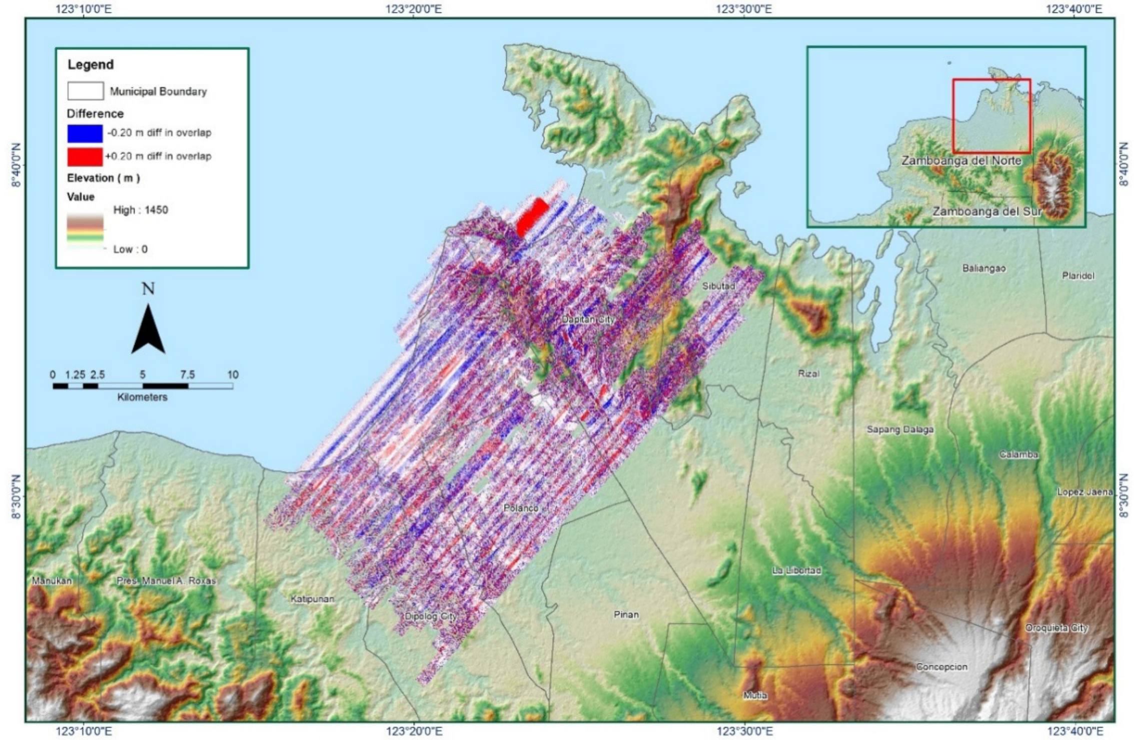


Figure A-8.21.Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk69C

Flight Area	Dipolog
Mission Name	Blk69C
Inclusive Flights	2125P
Range data size	15.4 GB
POS	211 MB
Image	32.0 GB
Transfer date	November 19, 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)	1.14
RMSE for East Position (<4.0 cm)	1.38
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000285
IMU attitude correction stdev (<0.001deg)	0.000756
GPS position stdev (<0.01m)	0.0074
Minimum % overlap (>25)	33.55%
Ave point cloud density per sq.m. (>2.0)	4.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	137
Maximum Height	578.40 m
Minimum Height	69.46 m
Classification (# of points)	
Ground	98,140,842
Low vegetation	88,616,617
Medium vegetation	171,027,483
High vegetation	145,166,407
Building	1,961,664
Orthophoto	Yes

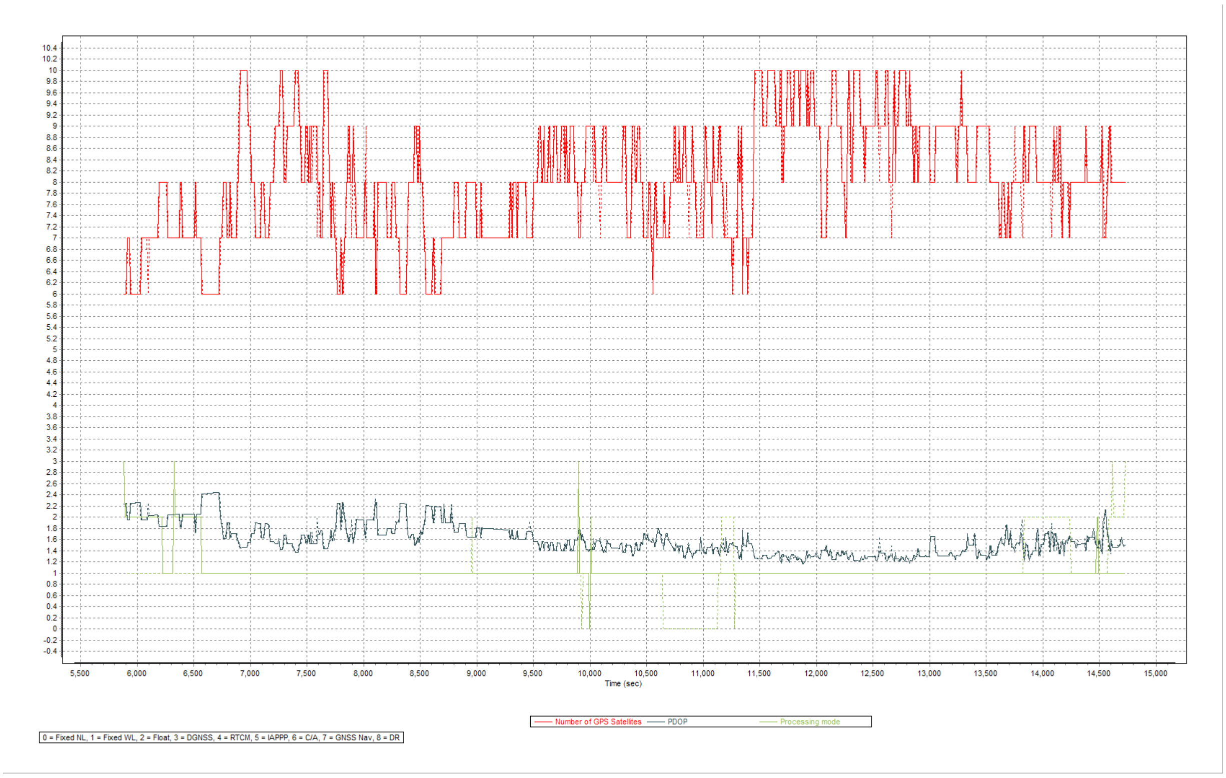


Figure A-8.22. Solution Status

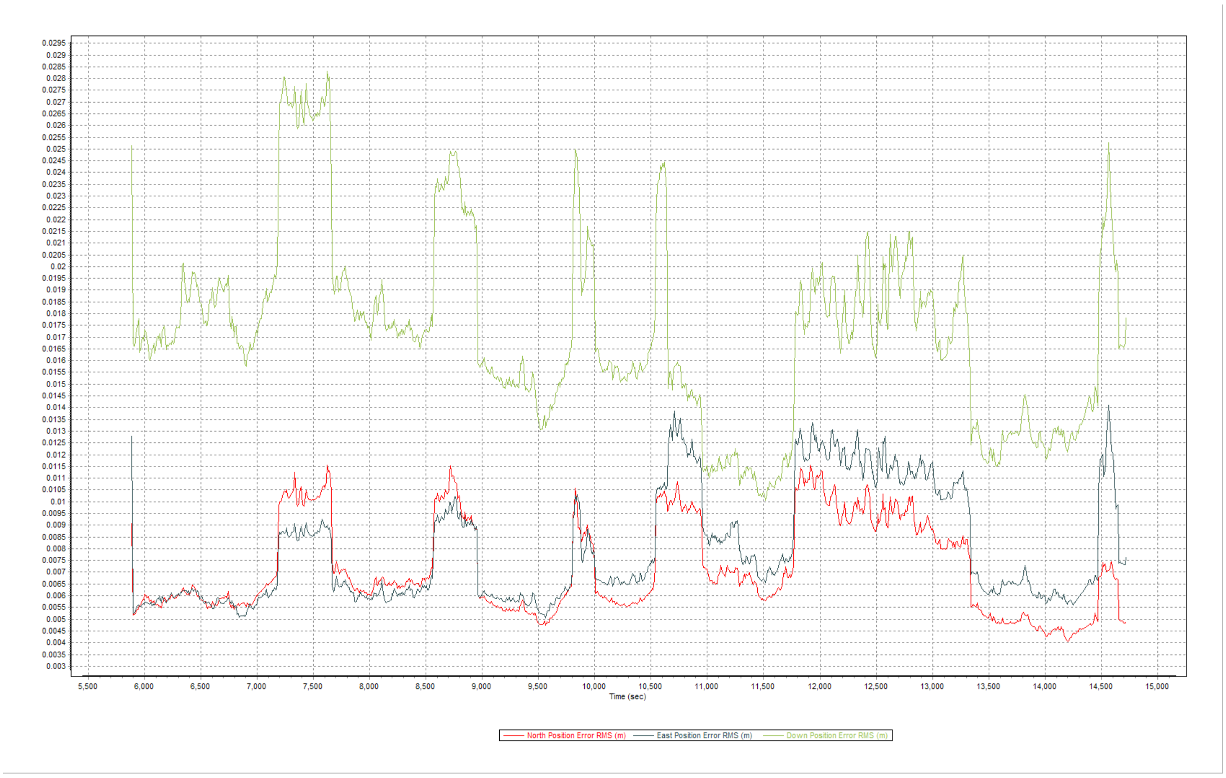


Figure A-8.23. Smoothed Performance Metric Parameters

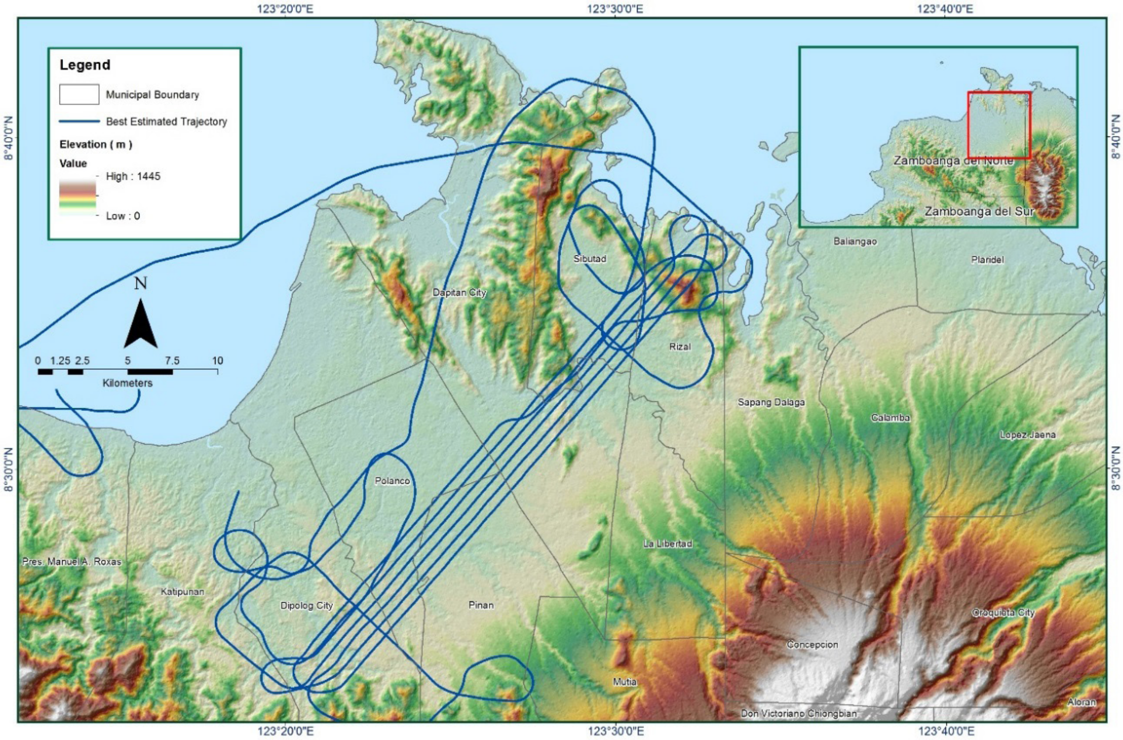


Figure A-8.24. Best Estimated Trajectory

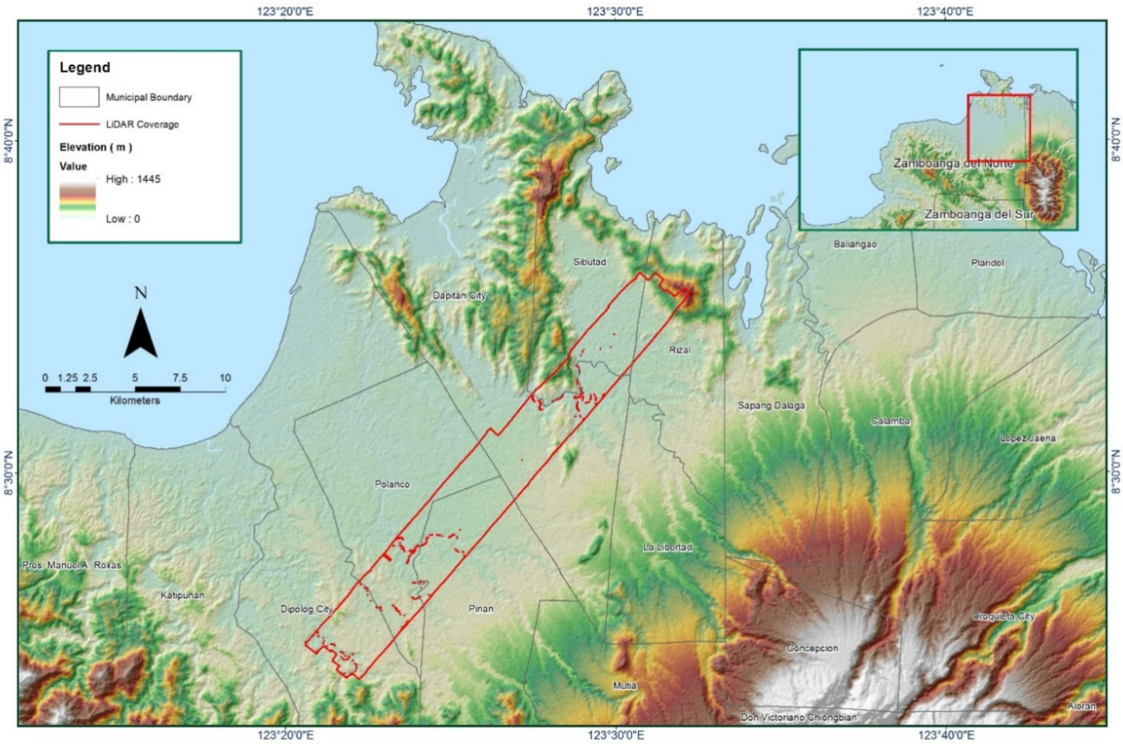


Figure A-8.25.Coverage of LiDAR data

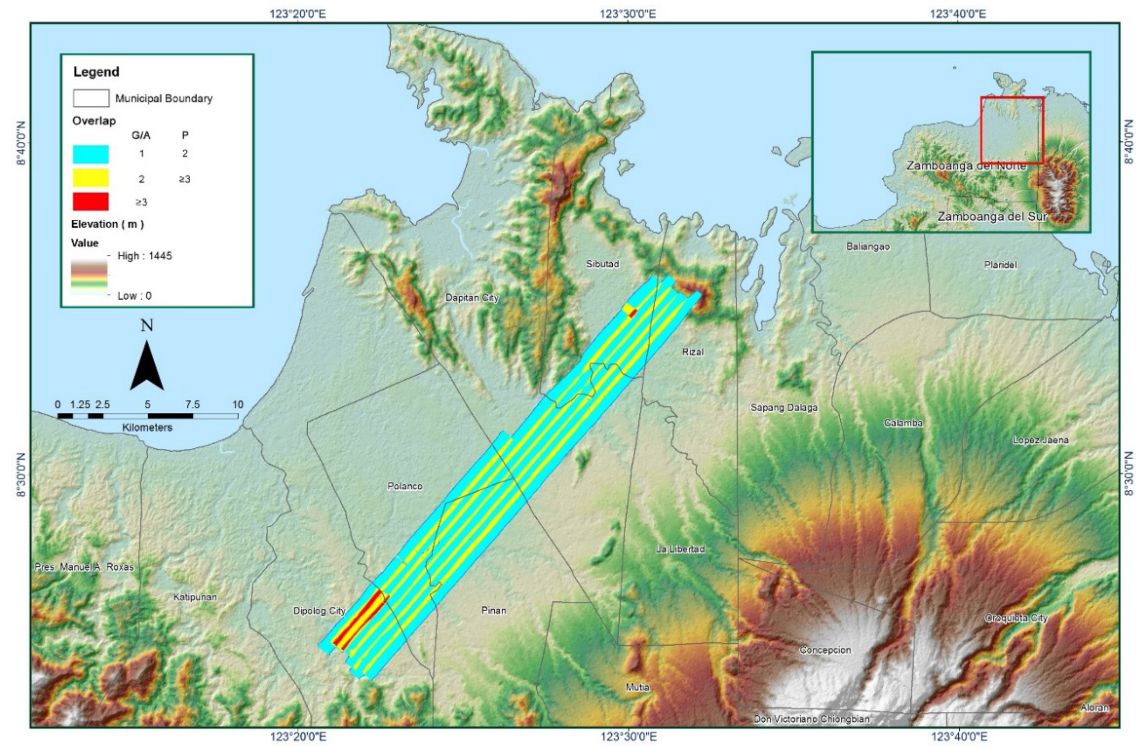


Figure A-8.26.Image of data overlap

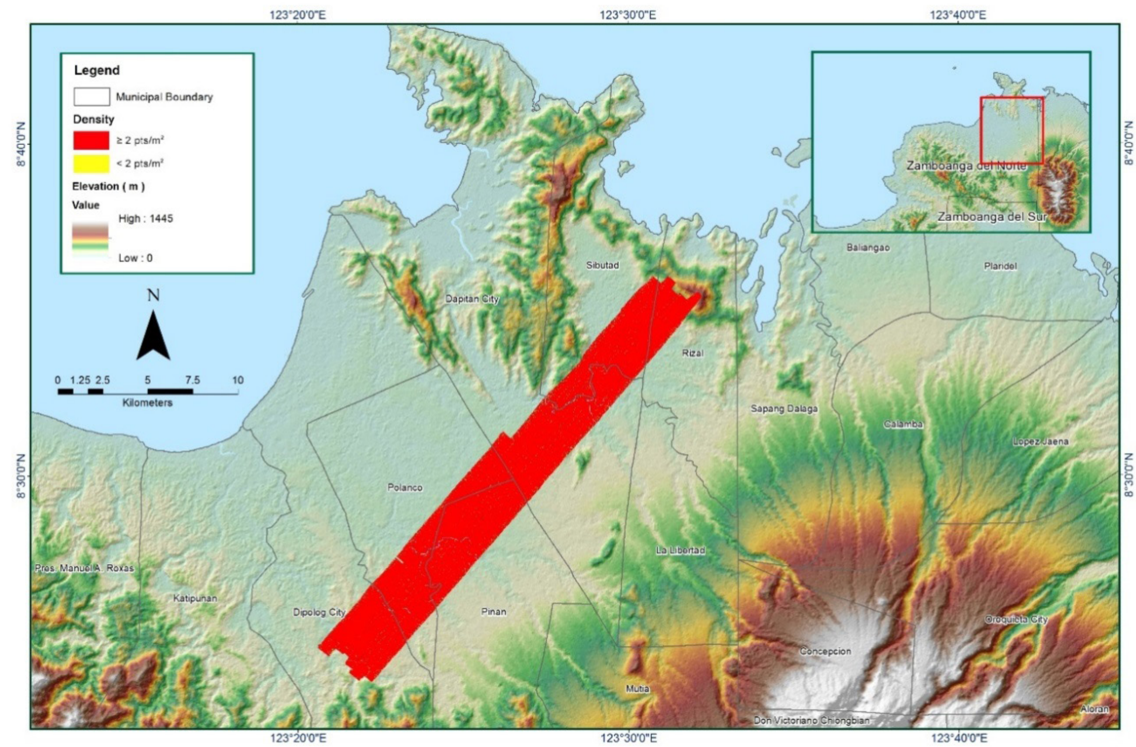


Figure A-8.27. Density map of merged LiDAR data

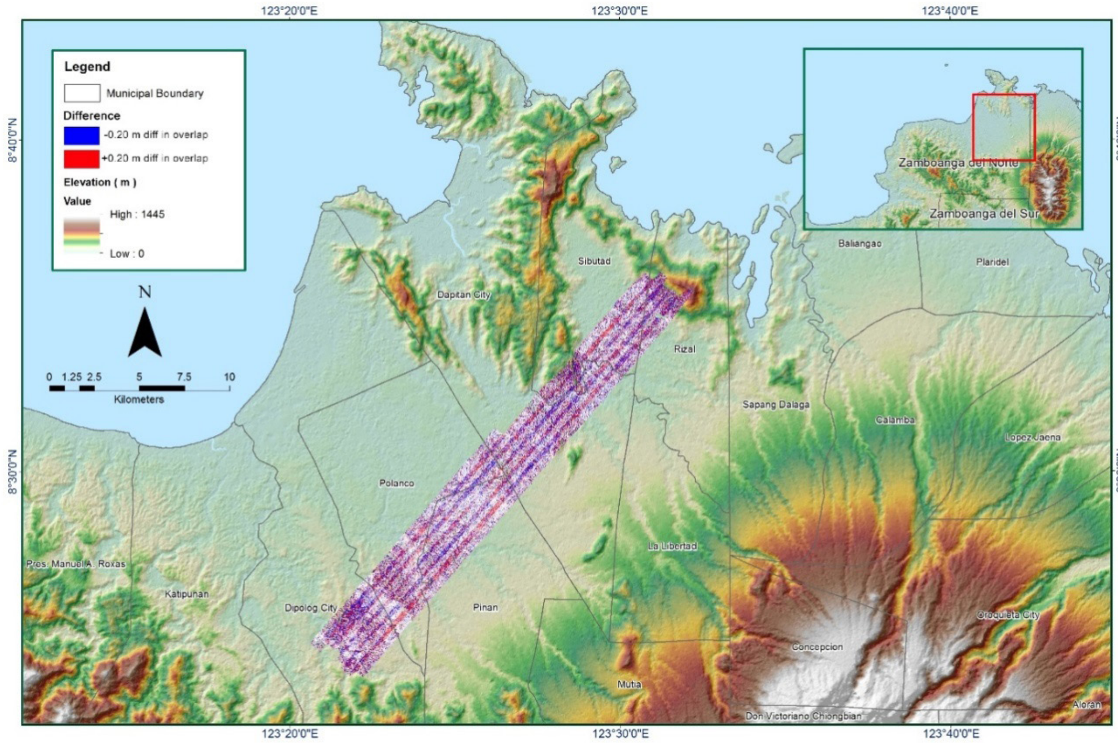


Figure A-8.28.Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Bl

Flight Area	Dipolog
Mission Name	Blk69D
Inclusive Flights	2113P,2115P
Range data size	19.4 GB
POS	216 MB
Image	36.4 GB
Transfer date	November 19, 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)	1.5
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	3.9
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.046864
GPS position stdev (<0.01m)	0.0133
Minimum % overlap (>25)	41.81%
Ave point cloud density per sq.m. (>2.0)	3.39
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	227
Maximum Height	710.92 m
Minimum Height	64.75 m
Classification (# of points)	
Ground	93,600,331
Low vegetation	96,245,146
Medium vegetation	182,172,712
High vegetation	332,993,289
Building	6,617,954
Orthophoto	yes

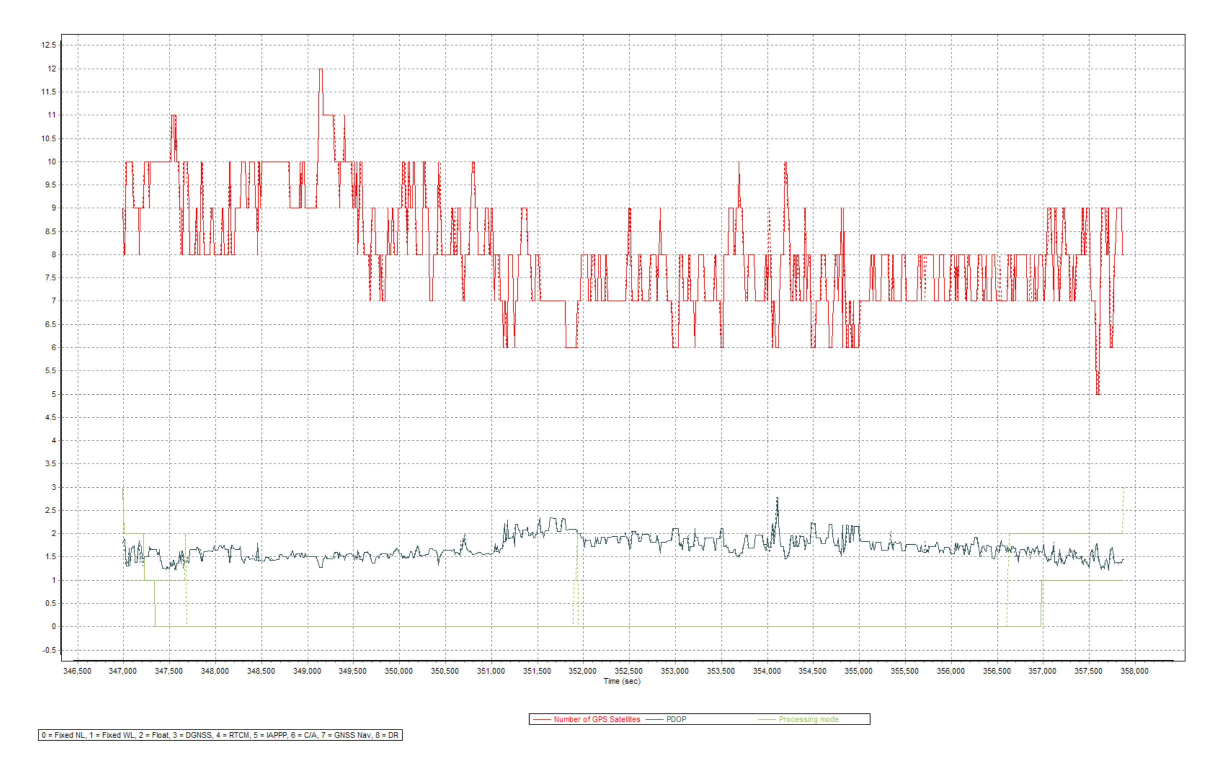


Figure A-8.29. Solution Status

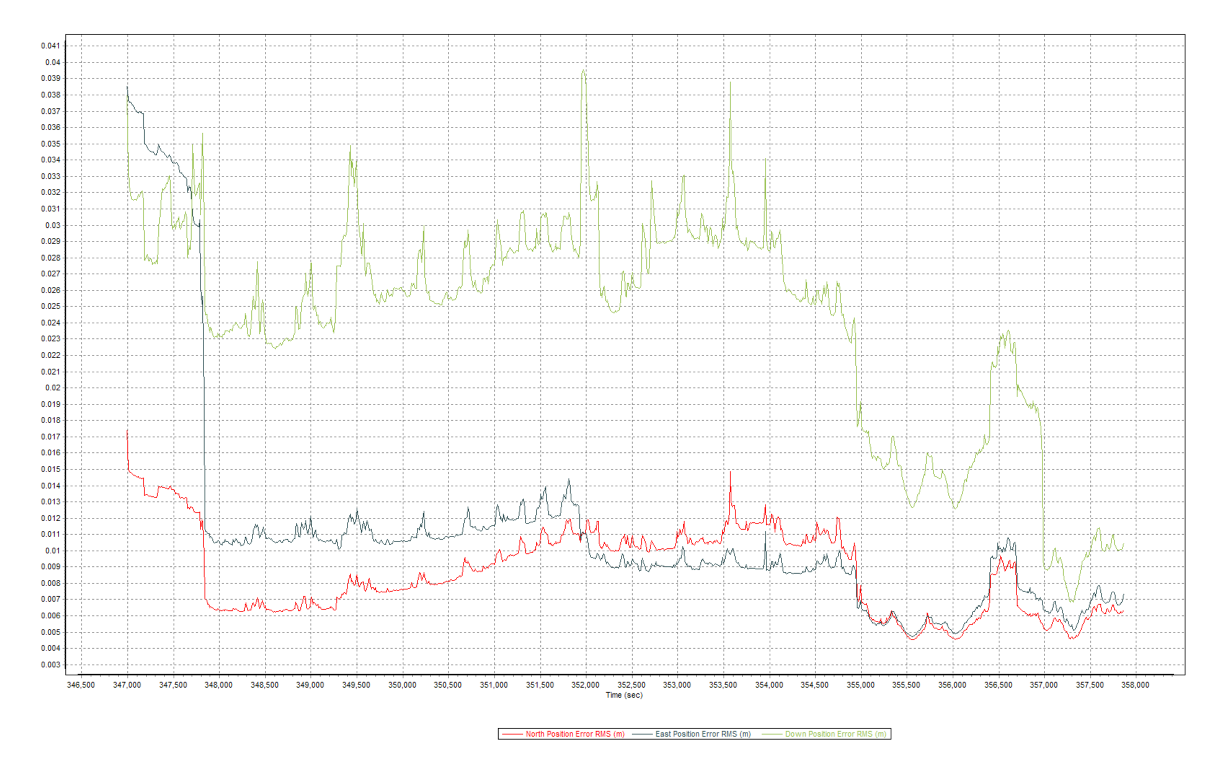


Figure A-8.30. Smoothed Performance Metric Parameters

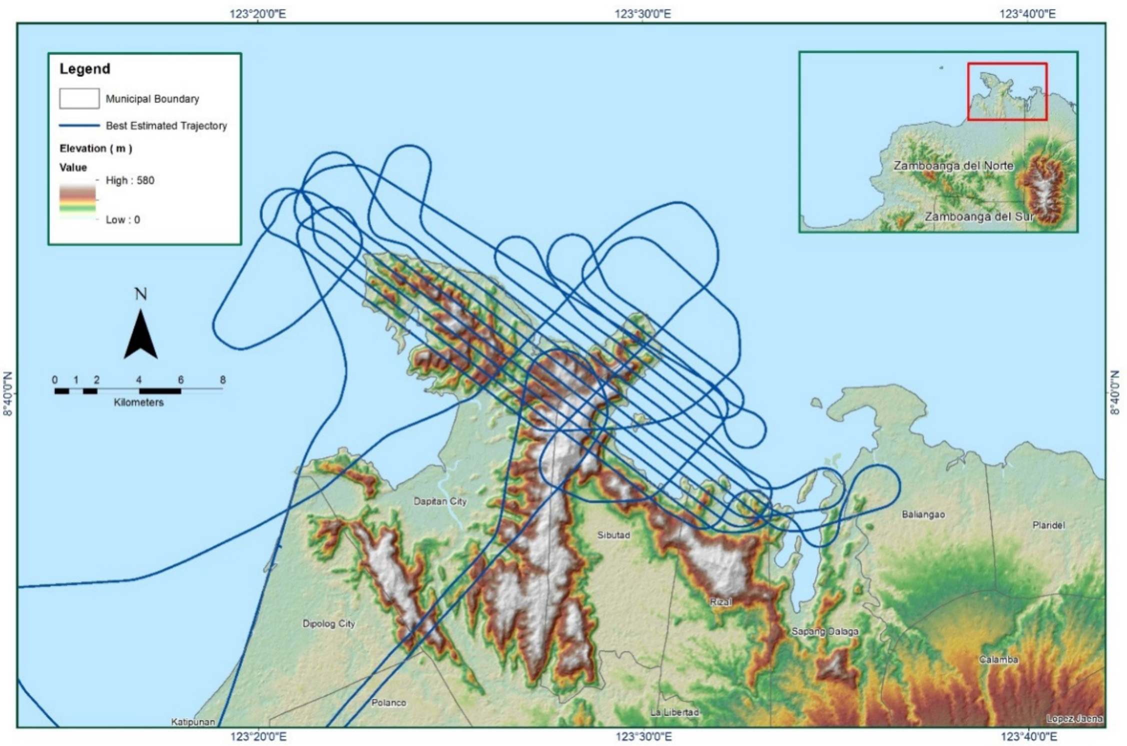


Figure A-8.31. Best Estimated Trajectory

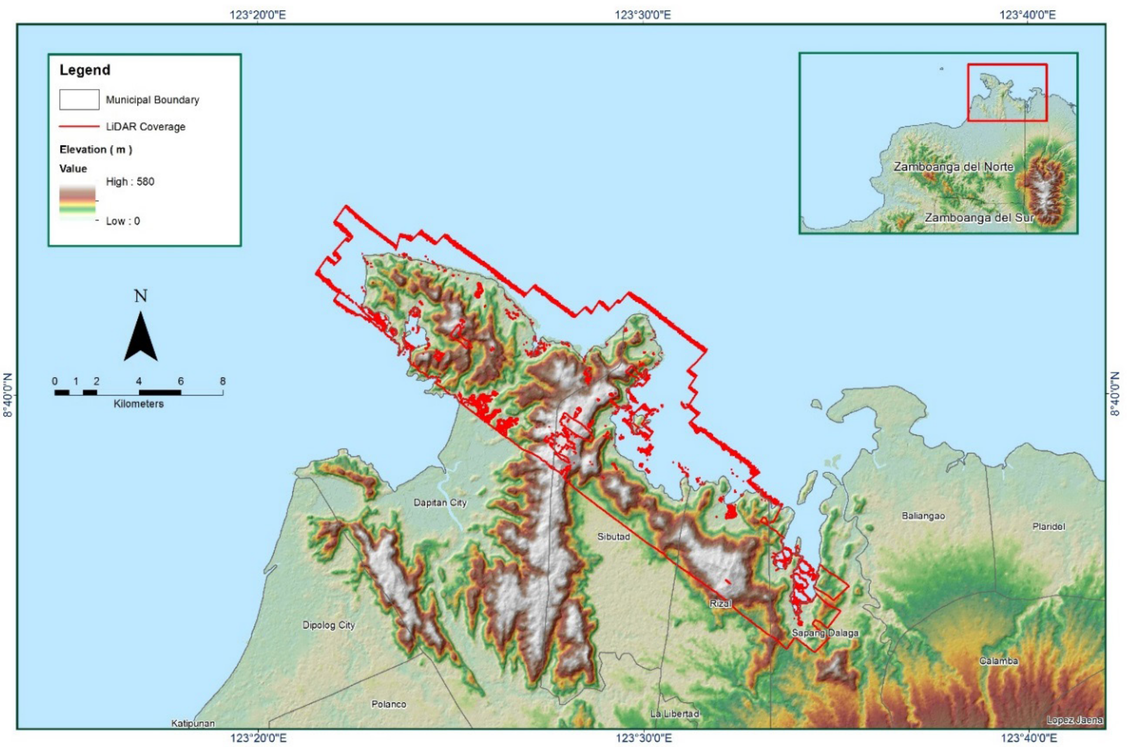


Figure A-8.32. Coverage of LiDAR data

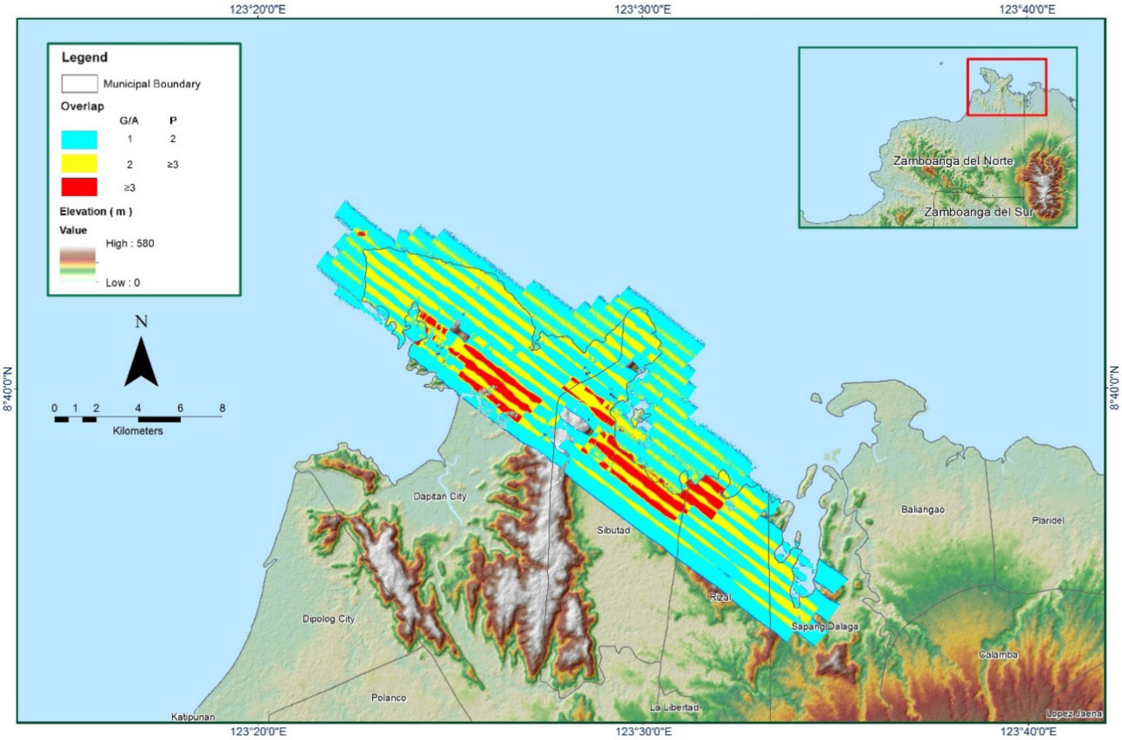


Figure A-8.33. Image of data overlap

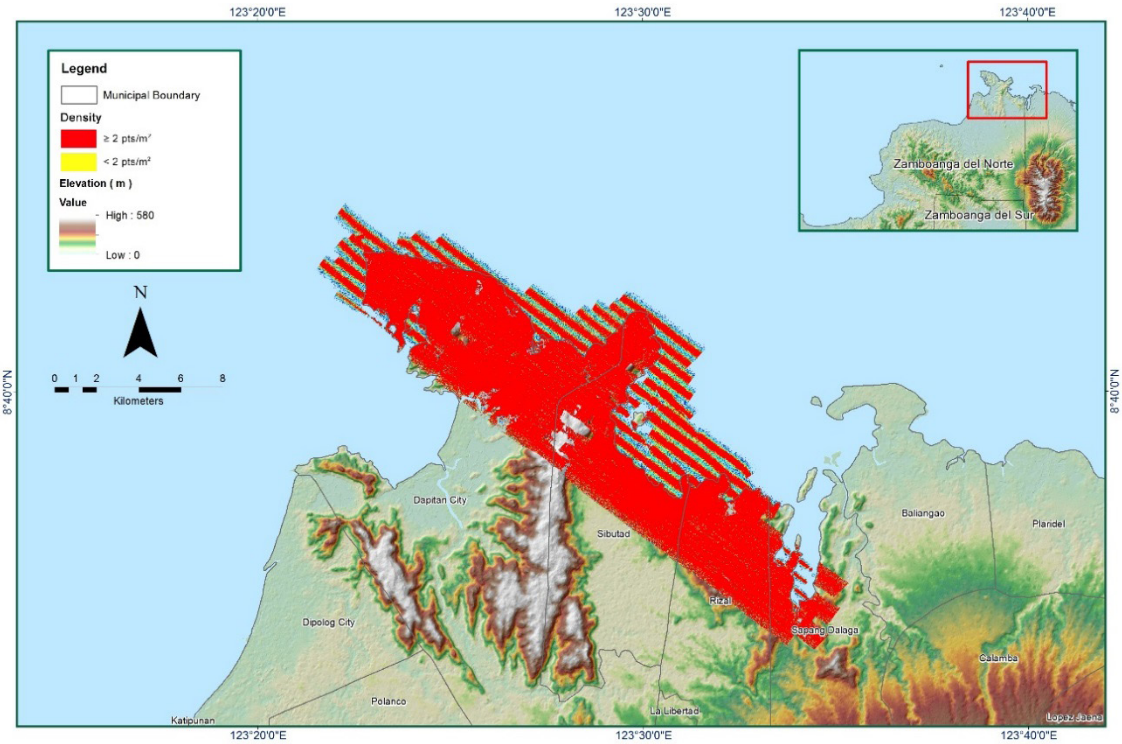


Figure A-8.34.Density map of merged LiDAR data

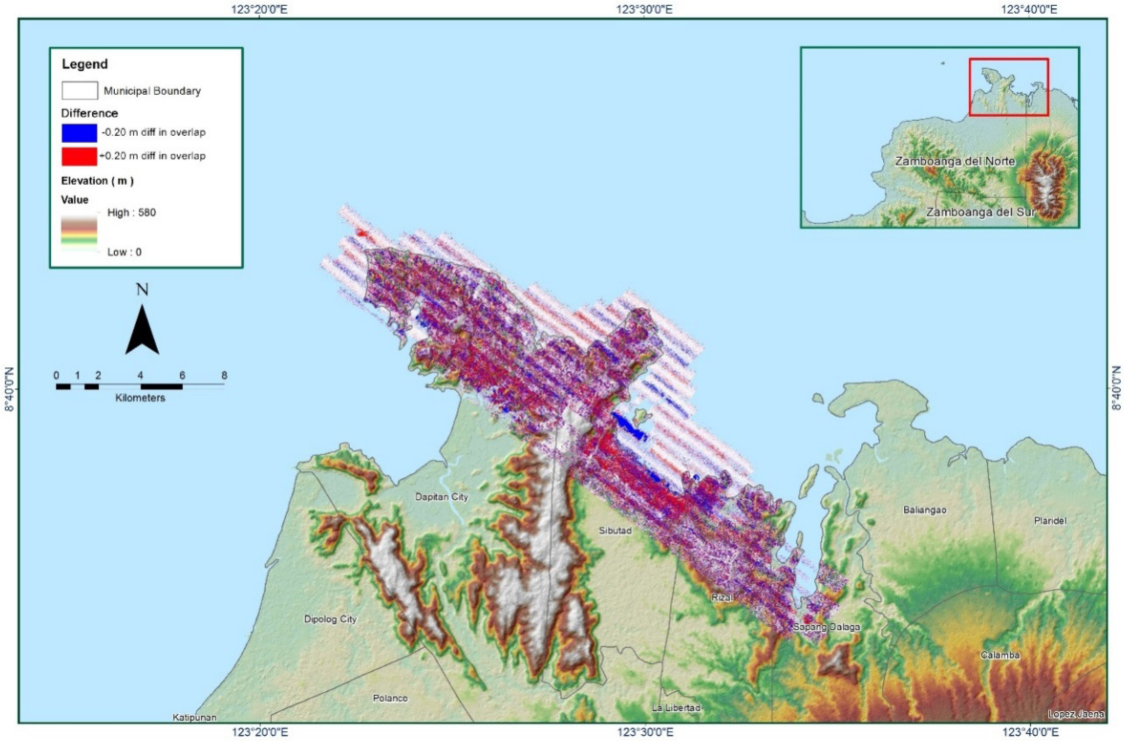


Figure A-8.35.Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk69B_supplement

Flight Area	Dipolog
Mission Name	**Blk69B_supplement**
Inclusive Flights	23574P
Range data size	21.7 GB
POS data size	264 MB
Base data size	126 MB
Image	n/a
Transfer date	December 6, 2016
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)	1.038
RMSE for East Position (<4.0 cm)	1.079
RMSE for Down Position (<8.0 cm)	1.83
Boresight correction stdev (<0.001deg)	0.000233
IMU attitude correction stdev (<0.001deg)	0.000405
GPS position stdev (<0.01m)	0.001
Minimum % overlap (>25)	37.16 %
Ave point cloud density per sq.m. (>2.0)	7.40
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	95
Maximum Height	613.93 m
Minimum Height	59.73 m
Classification (# of points)	
Ground	43,245,285
Low vegetation	30,492,688
Medium vegetation	101,922,114
High vegetation	380,153,983
Building	1,821,130
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Jovelle Anjeanette Canlas

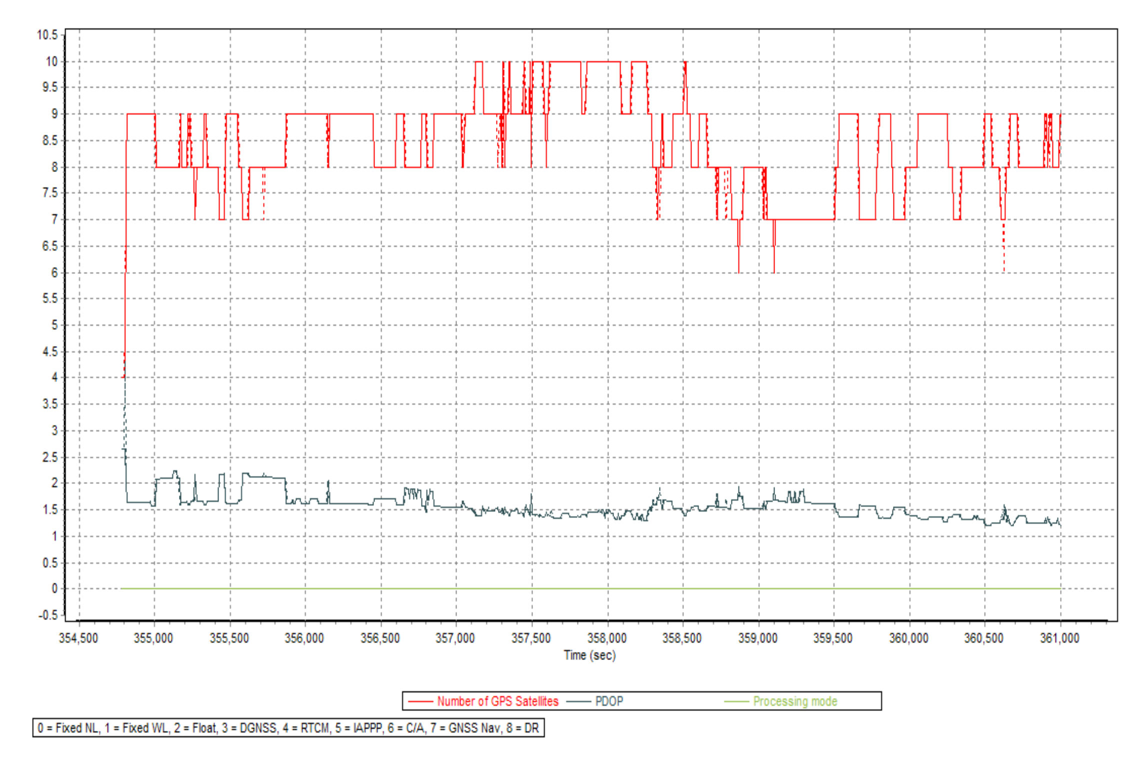


Figure A-8.36. Solution Status

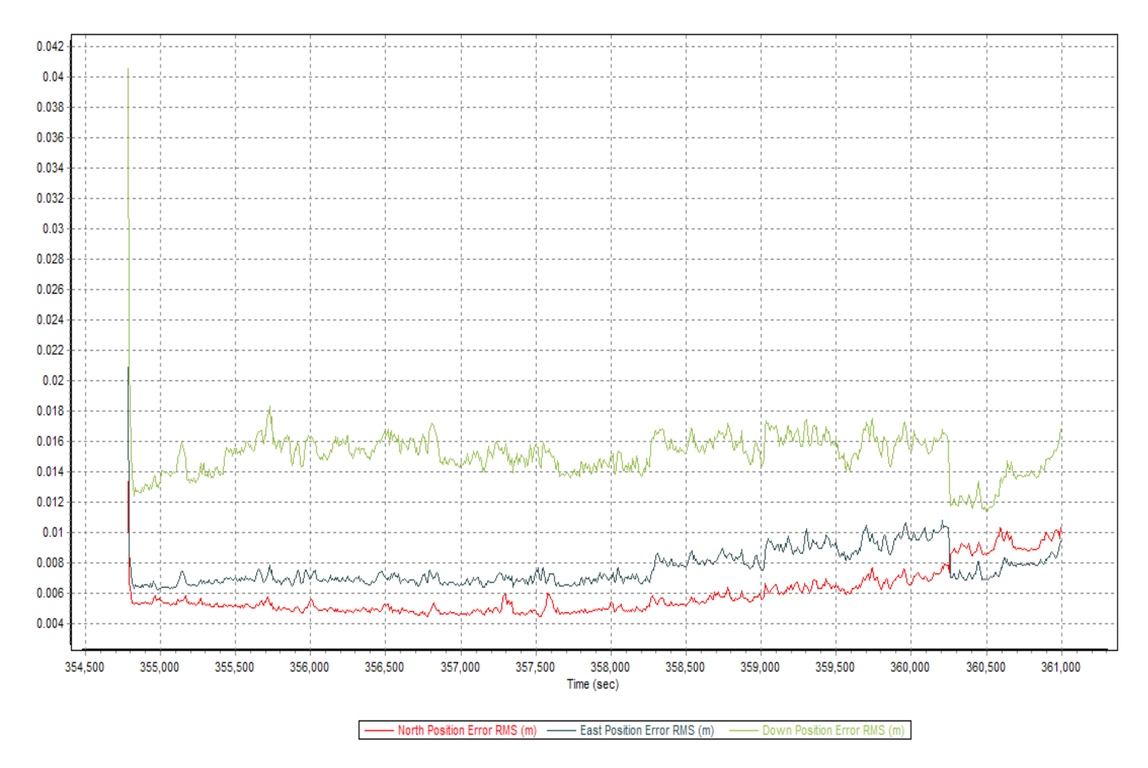


Figure A-8.37. Smoothed Performance Metric Parameters

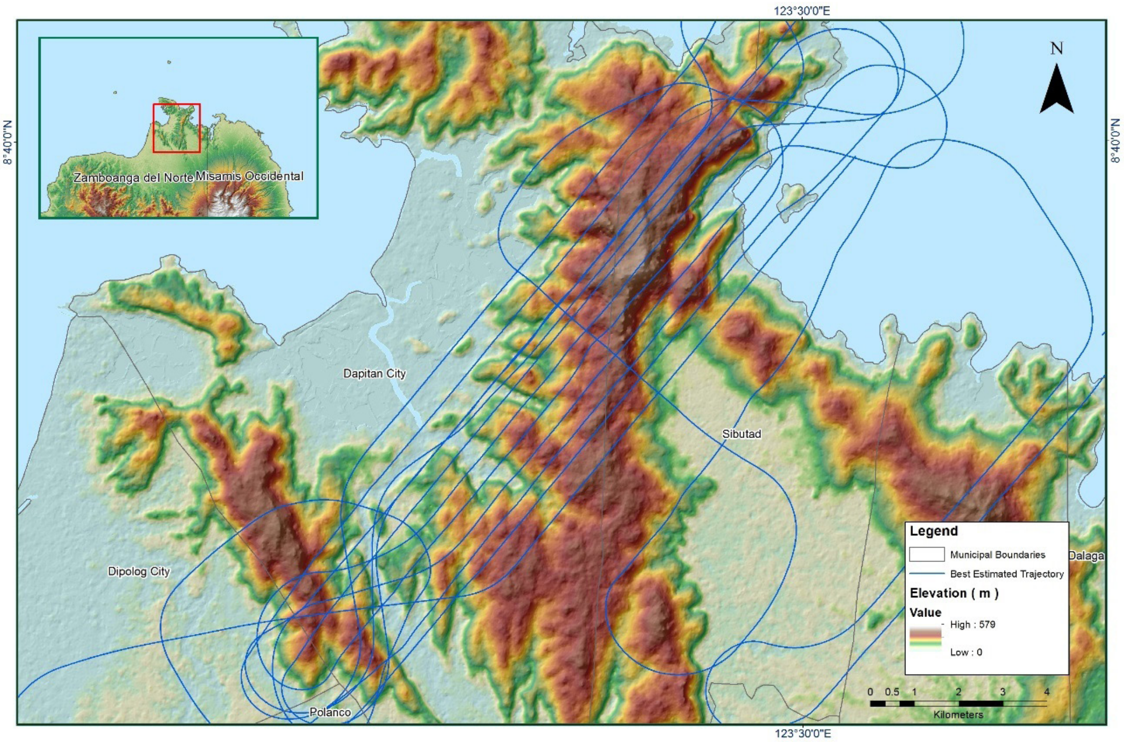


Figure A-8.38. Best Estimated Trajectory

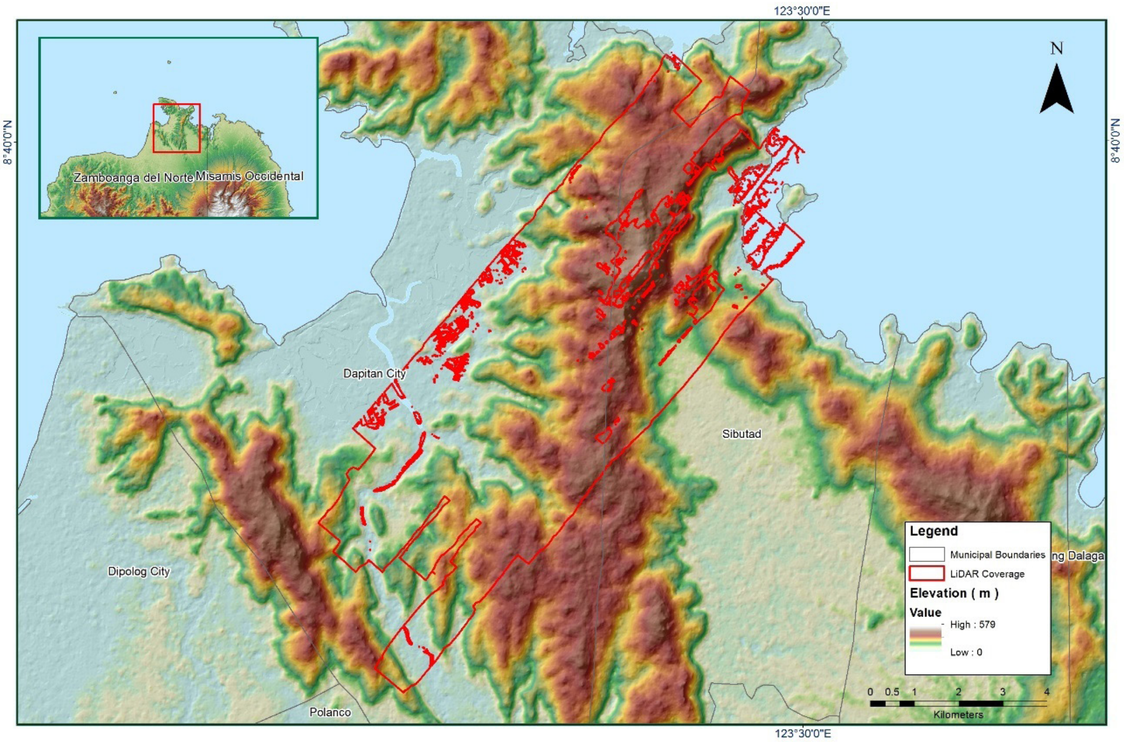


Figure A-8.39. Coverage of LiDAR Data

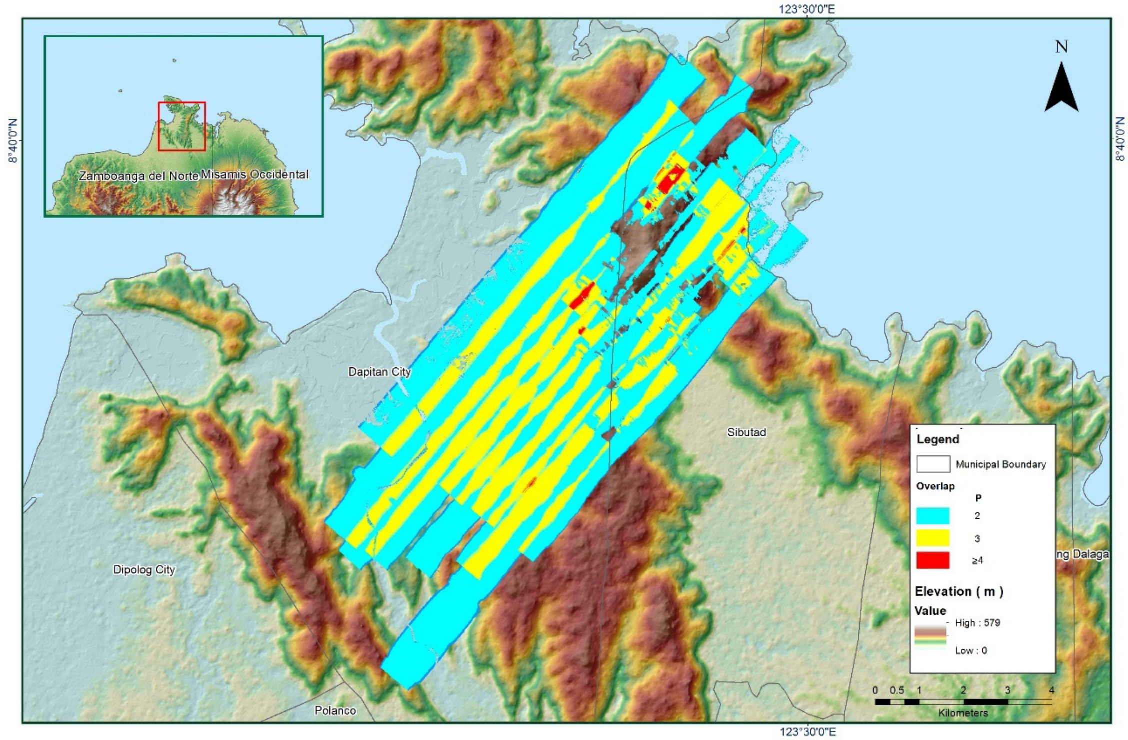


Figure A-8.40. Image of data overlap

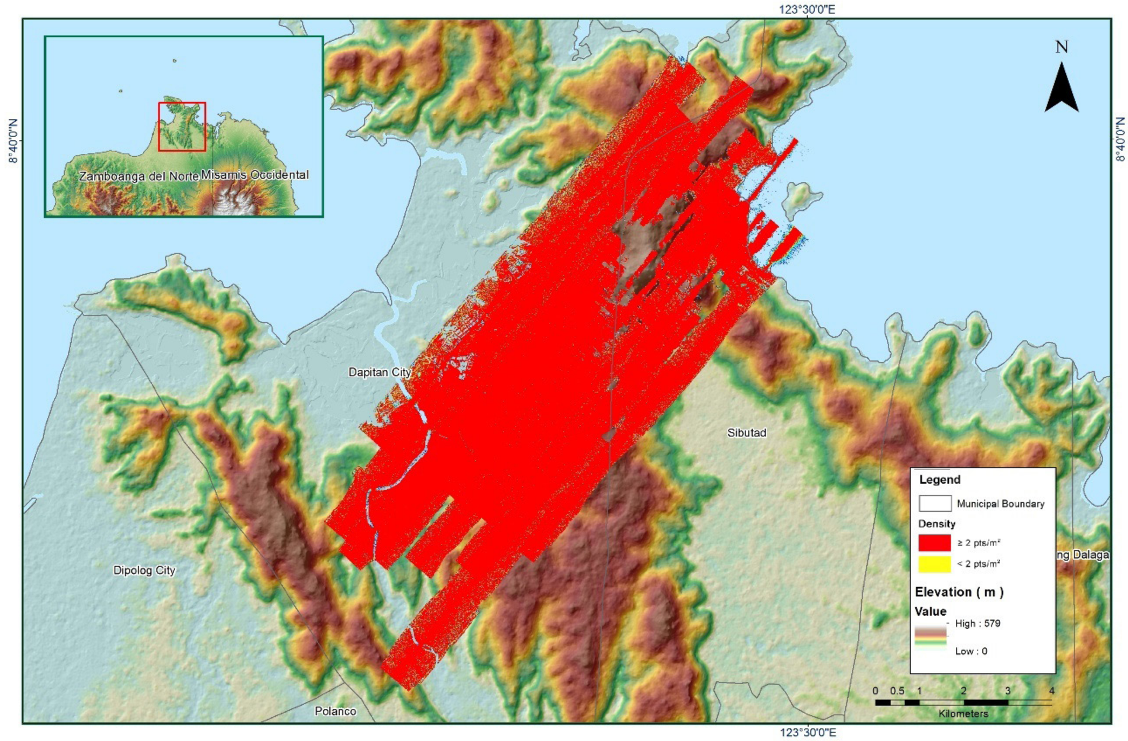


Figure A-8.41. Density map of merged LiDAR data

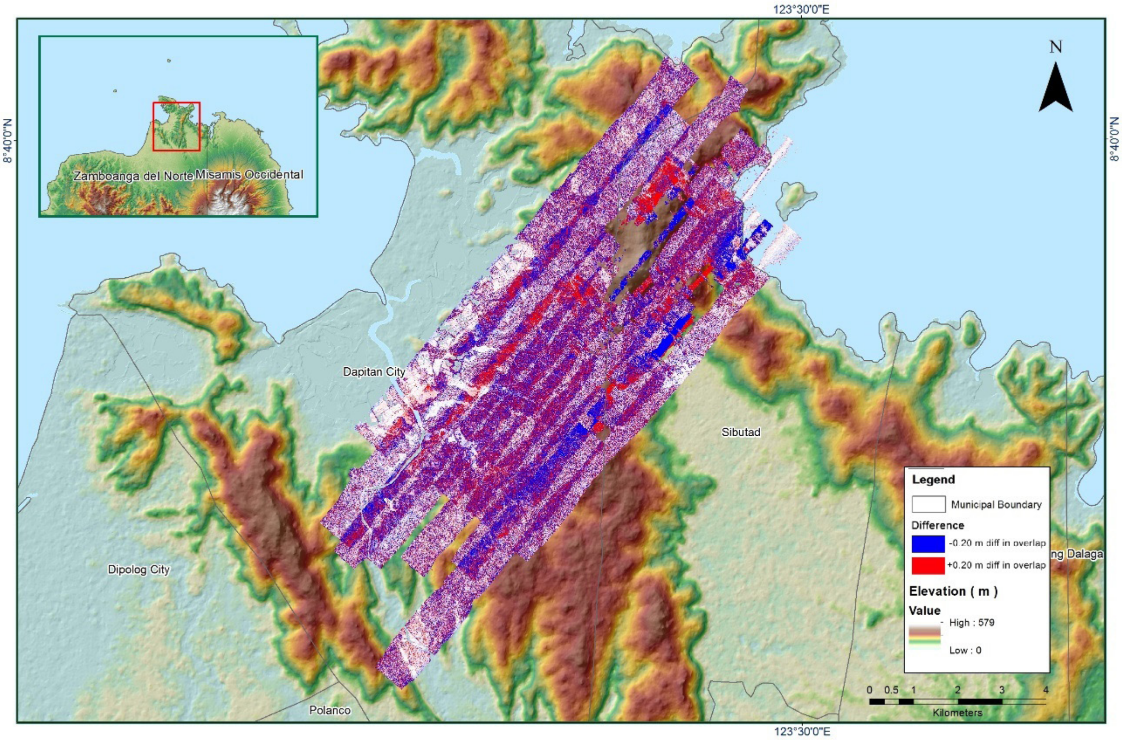


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk69B

Flight Area	Dipolog
Mission Name	**Blk69B**
Inclusive Flights	23558P
Range data size	24.8 GB
POS data size	274 MB
Base data size	175 MB
Image	n/a
Transfer date	December 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.329
RMSE for East Position (<4.0 cm)	1.723
RMSE for Down Position (<8.0 cm)	3.136
Boresight correction stdev (<0.001deg)	0.000167
IMU attitude correction stdev (<0.001deg)	0.000378
GPS position stdev (<0.01m)	0.0047
Minimum % overlap (>25)	49.03 %
Ave point cloud density per sq.m. (>2.0)	5.73
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	218
Maximum Height	471.64 m
Minimum Height	61.43 m
Classification (# of points)	
Ground	147,409,242
Low vegetation	138,606,637
Medium vegetation	306,863,820
High vegetation	915,242,697
Building	9,788,405
Orthophoto	No
Processed by	Engr. Analyn Naldo, Ma Joanne Balaga

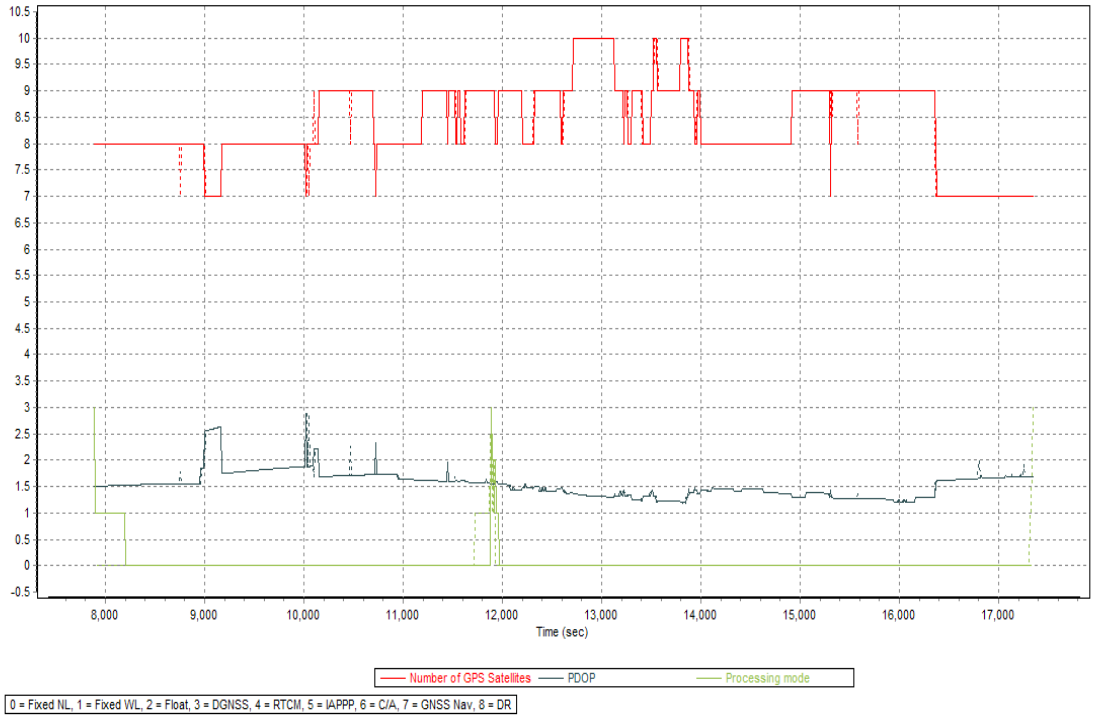


Figure A-8.43. Solution Status

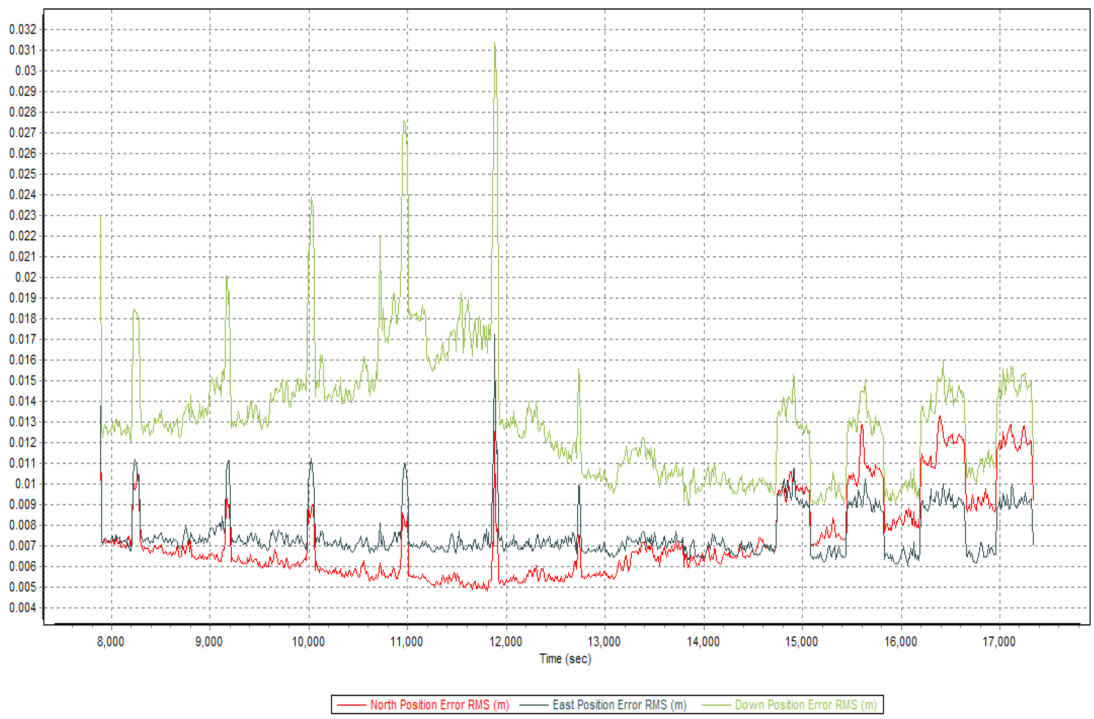


Figure A-8.44. Smoothed Performance Metric Parameters

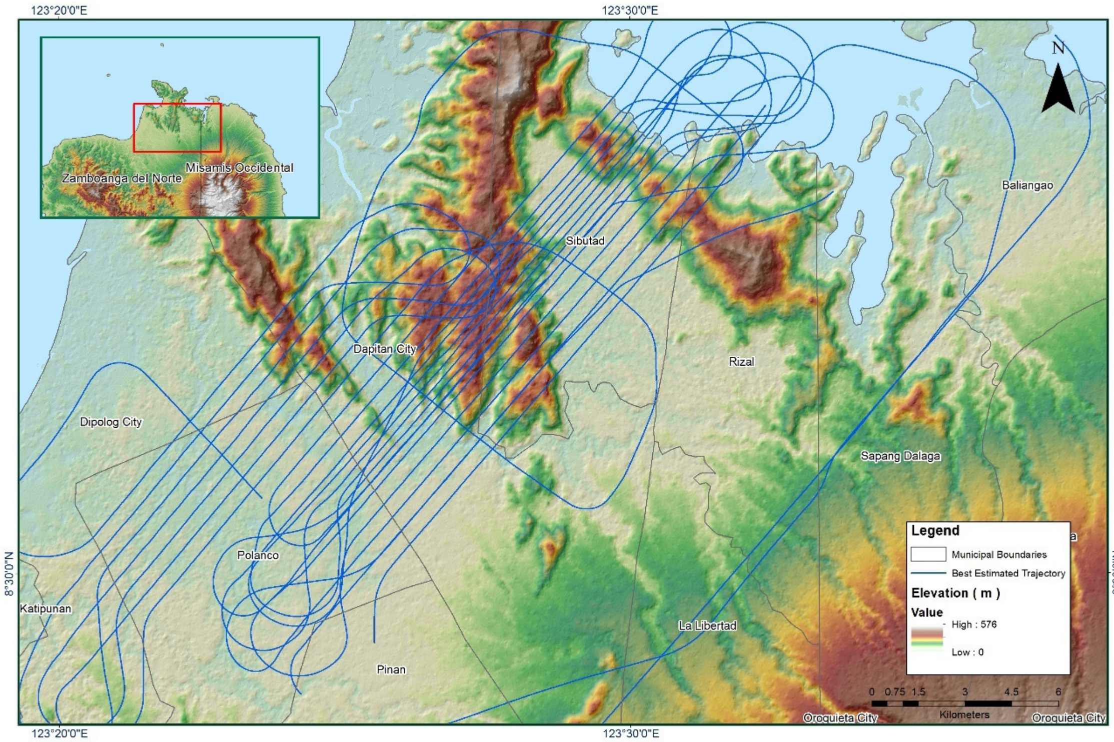


Figure A-8.45. Best Estimated Trajectory

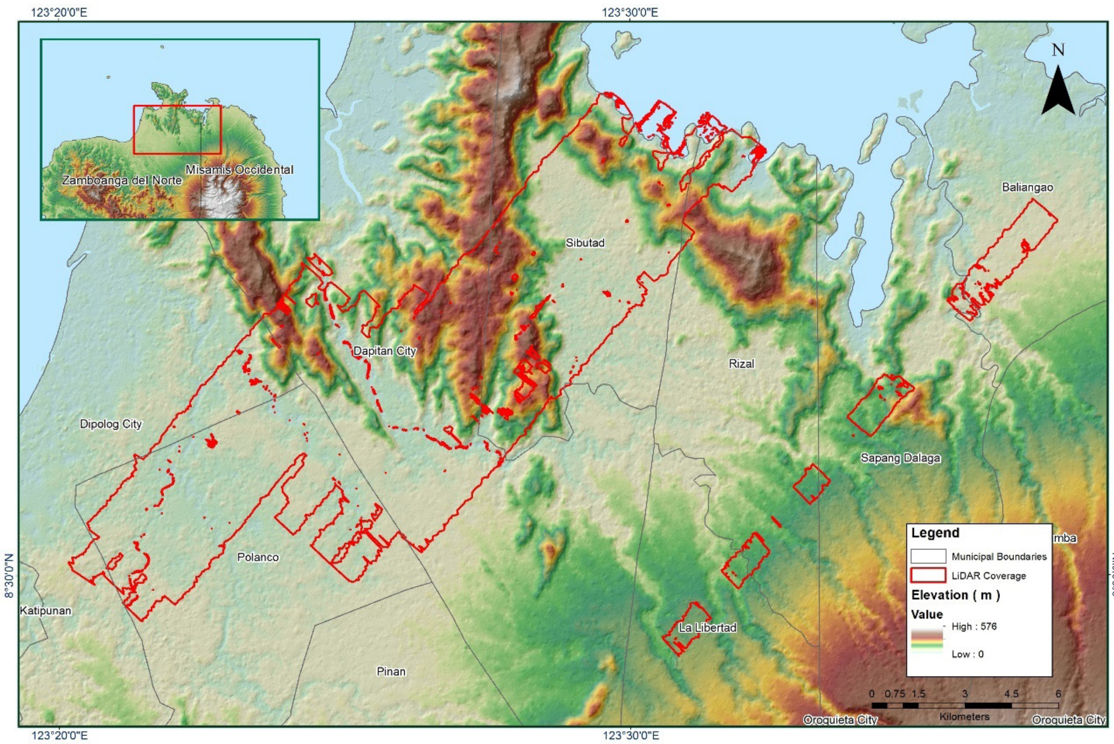


Figure A-8.46. Coverage of LiDAR Data

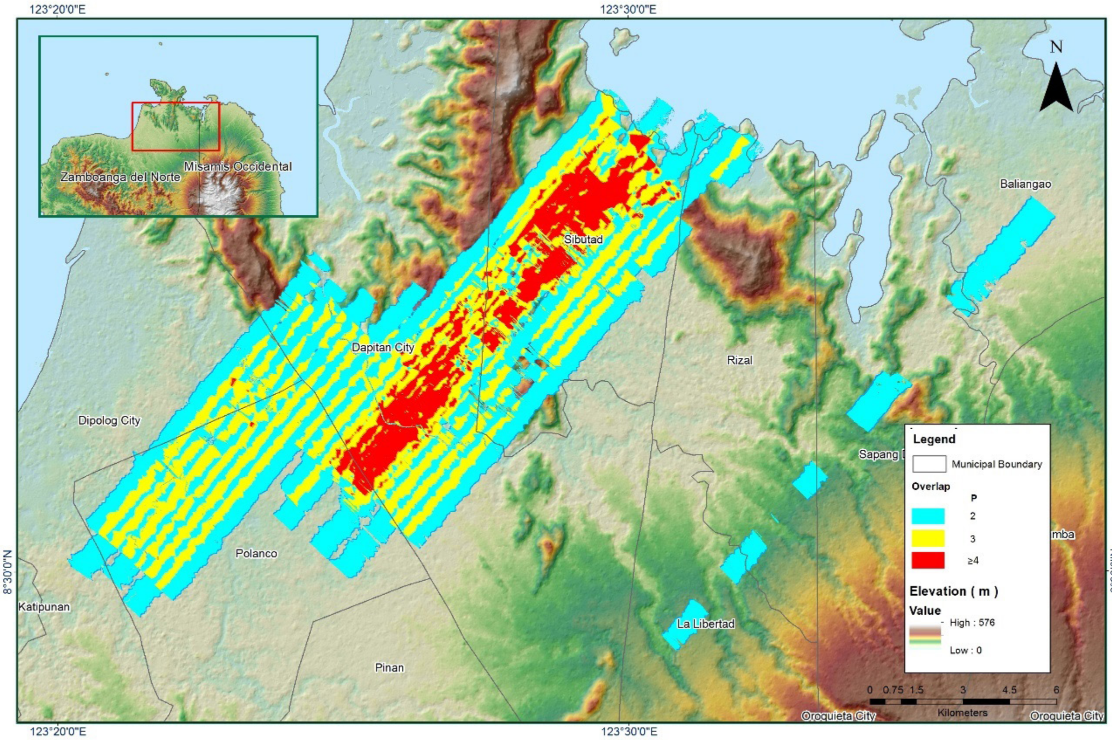


Figure A-8.47. Image of data overlap

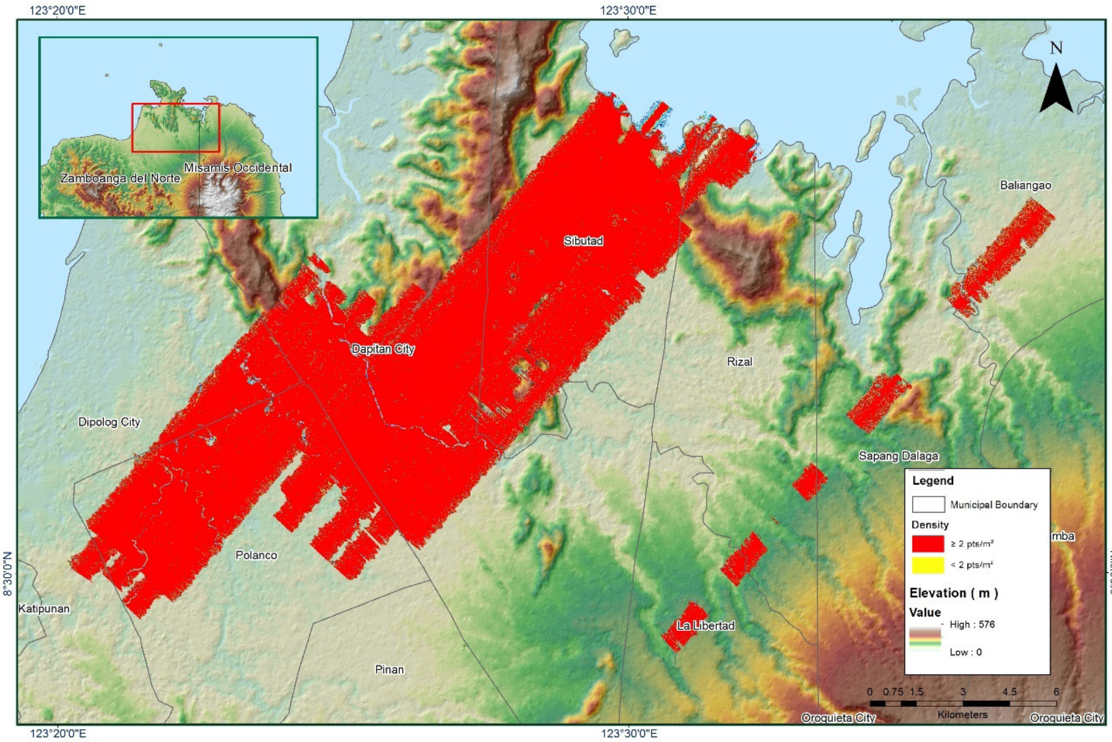


Figure A-8.48. Density map of merged LiDAR data

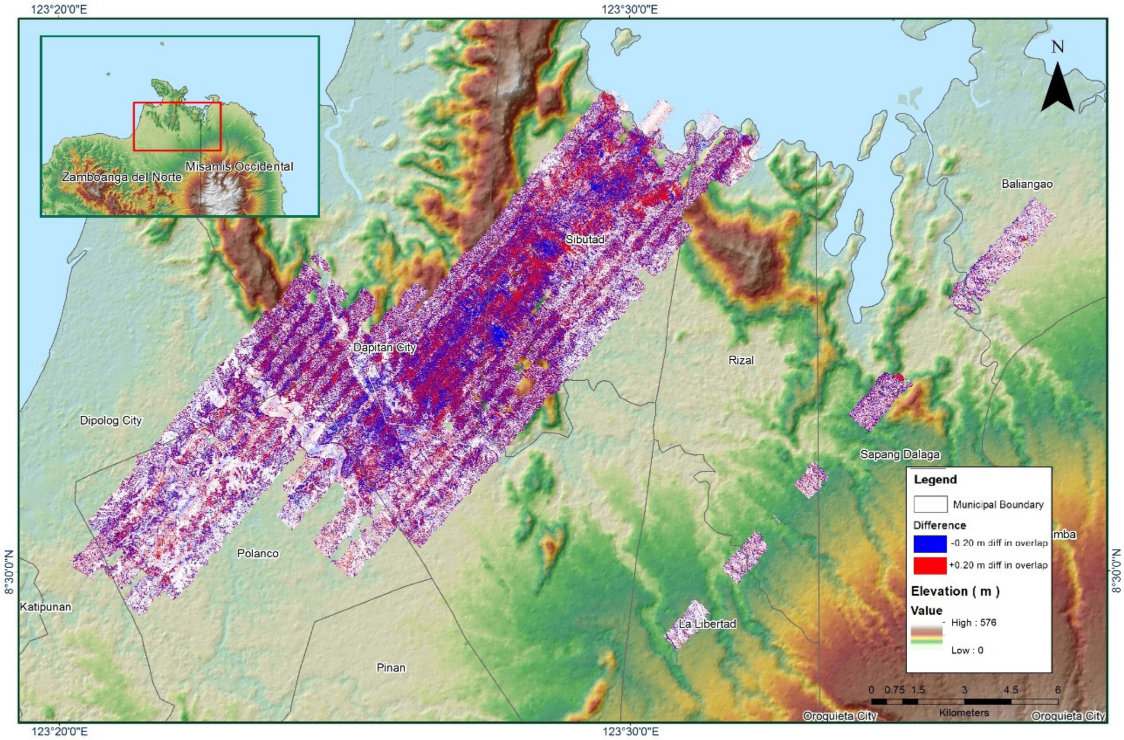


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk69D

Flight Area	Dipolog
Mission Name	**Blk69D**
Inclusive Flights	23562P
Range data size	29.5 GB
POS data size	289 MB
Base data size	165 MB
Image	n/a
Transfer date	December 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.774
RMSE for East Position (<4.0 cm)	3.583
RMSE for Down Position (<8.0 cm)	9.222
Boresight correction stdev (<0.001deg)	0.000156
IMU attitude correction stdev (<0.001deg)	0.001637
GPS position stdev (<0.01m)	0.0147
Minimum % overlap (>25)	35.05 %
Ave point cloud density per sq.m. (>2.0)	4.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	244
Maximum Height	576.58 m
Minimum Height	55.7 m
Classification (# of points)	
Ground	239,317,811
Low vegetation	120,242,691
Medium vegetation	259,977,867
High vegetation	779,460,724
Building	10,280,693
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Chelou Prado

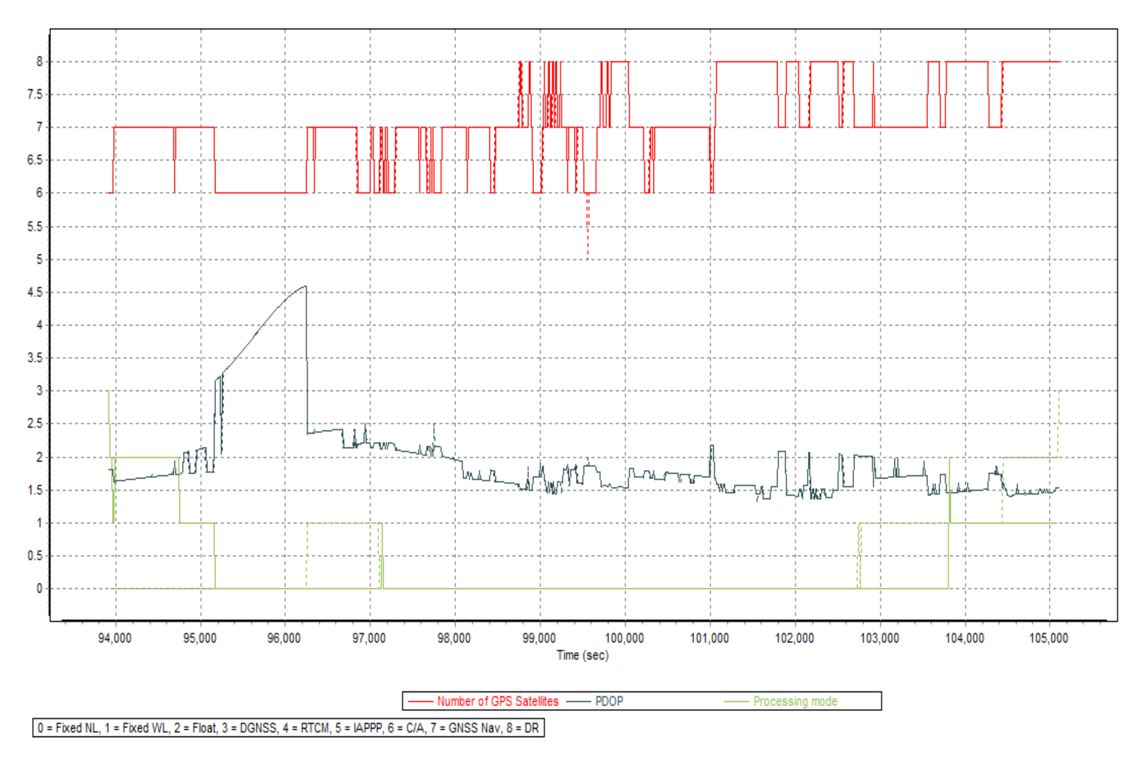


Figure A-8.50. Solution Status

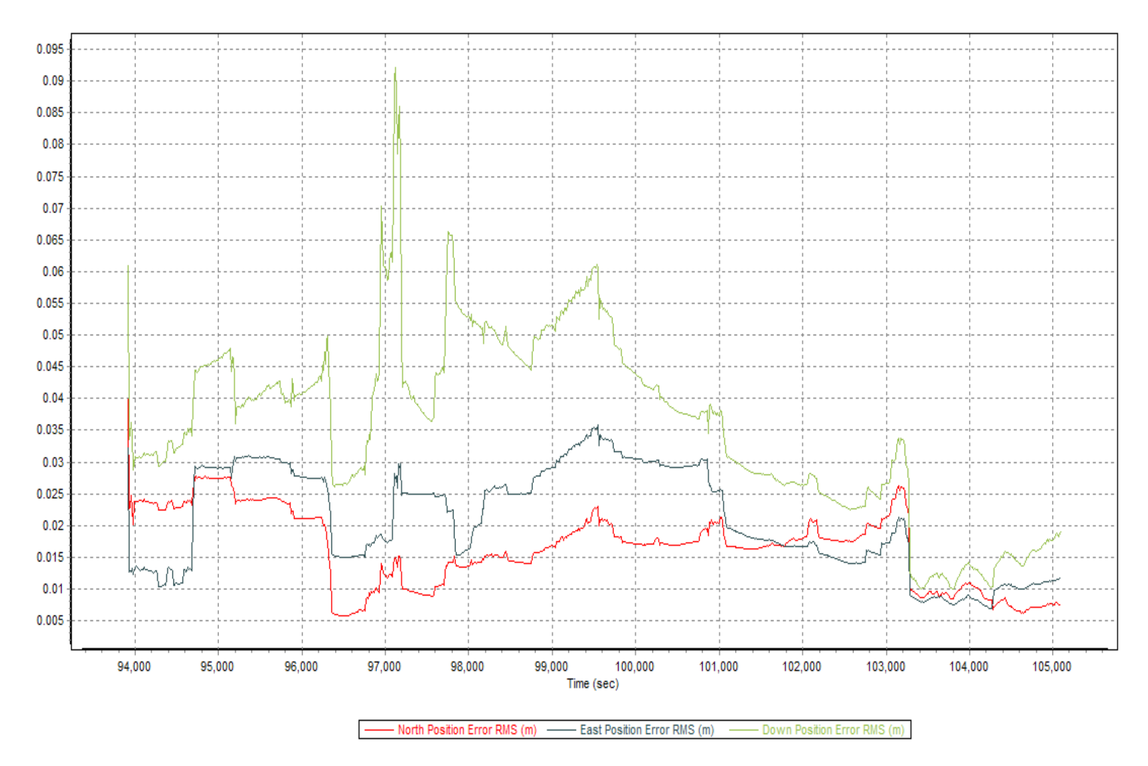


Figure A-8.51. Smoothed Performance Metric Parameters

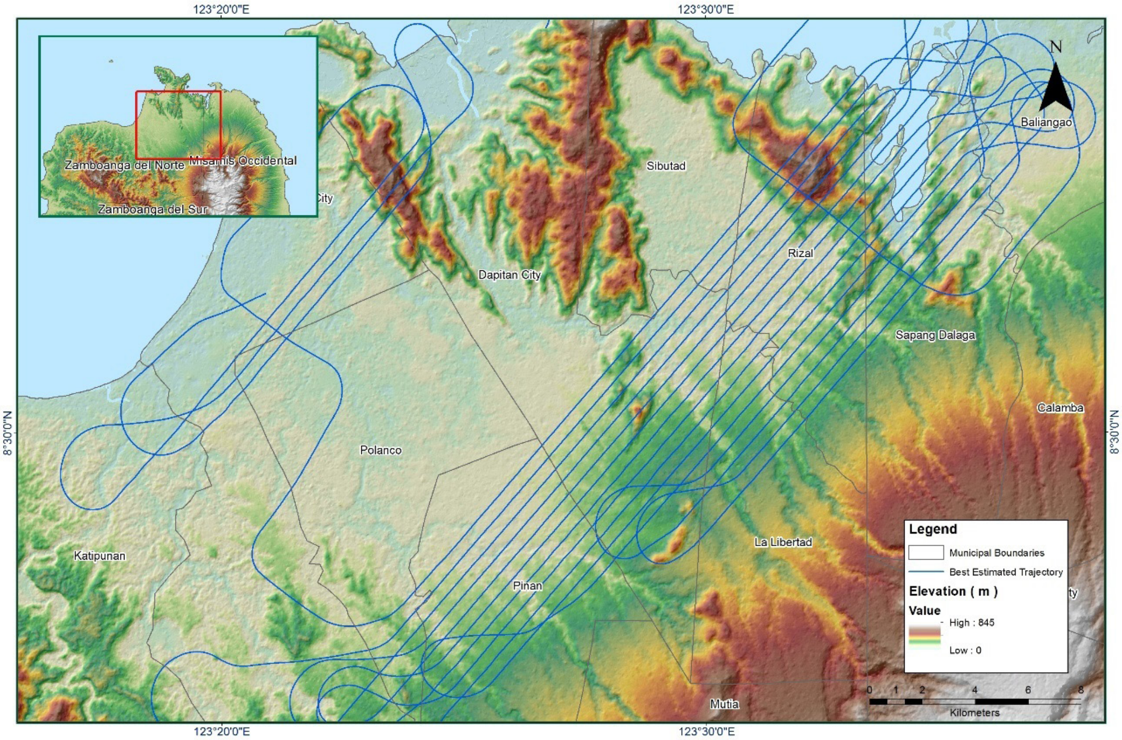


Figure A-8.52. Best Estimated Trajectory

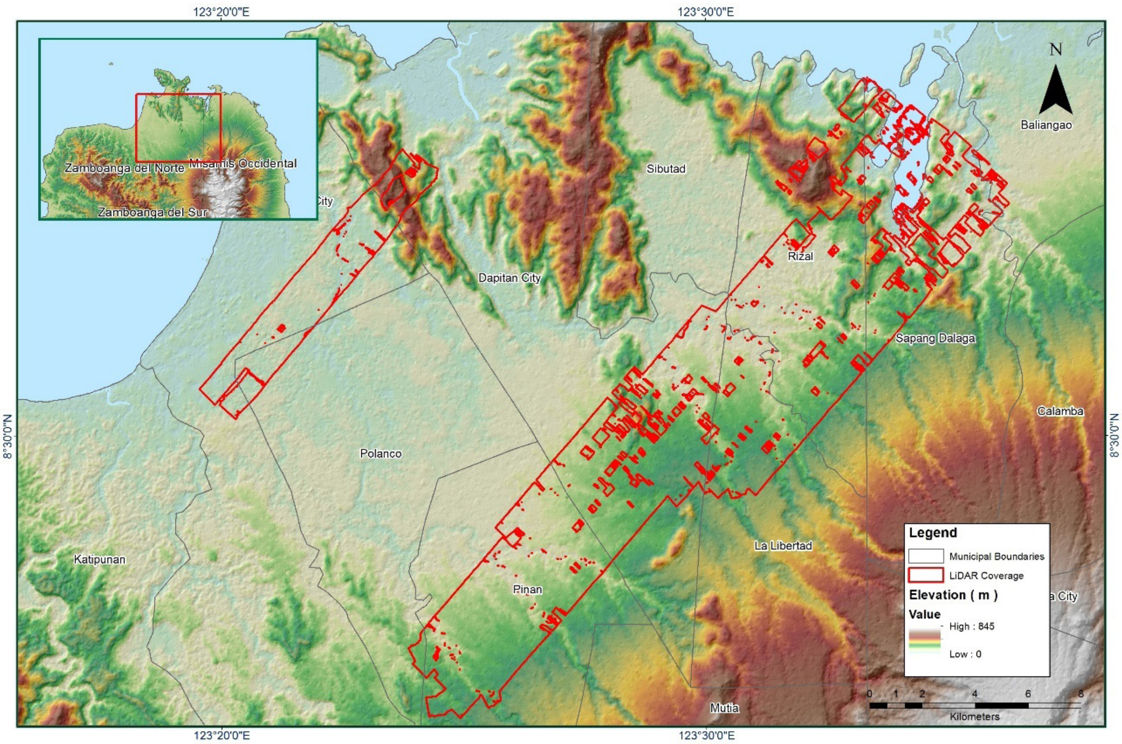


Figure A-8.53. Coverage of LiDAR Data

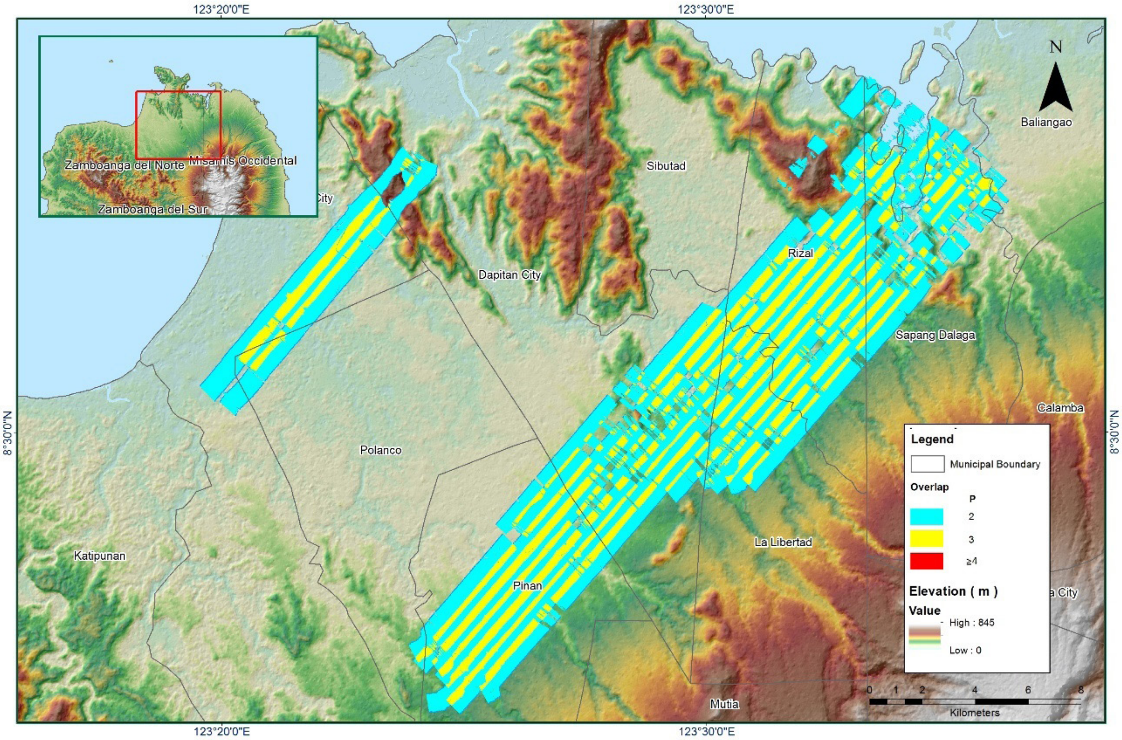


Figure A-8.54. Image of data overlap

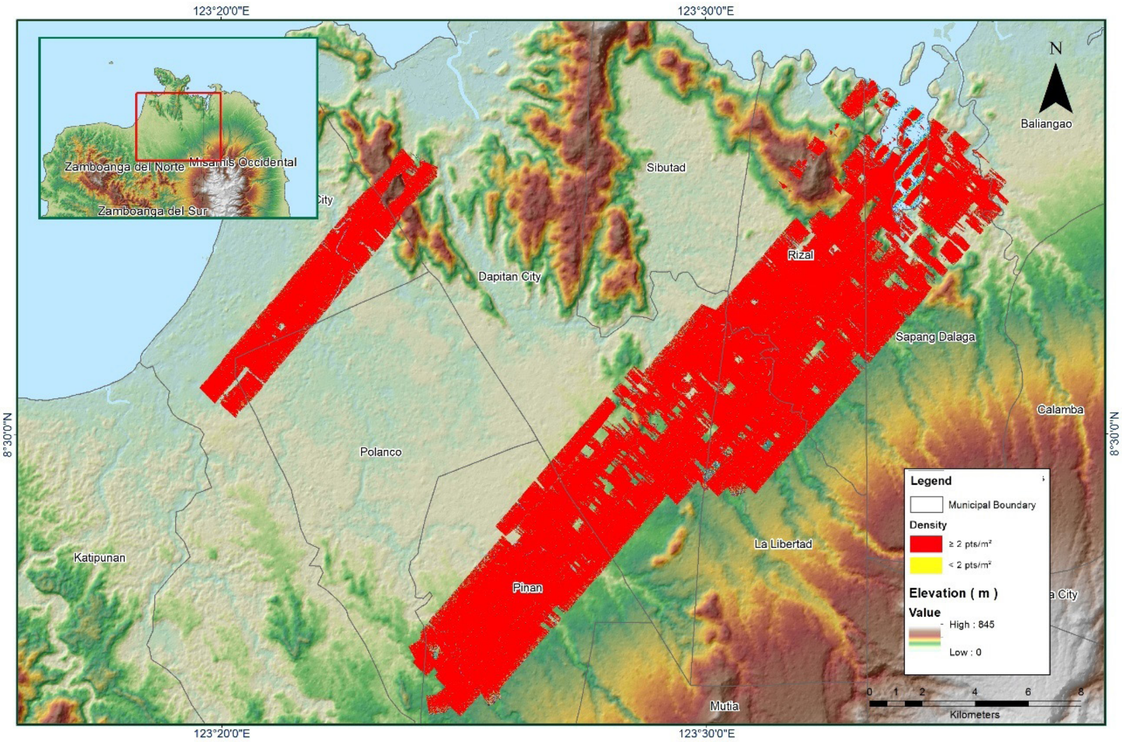


Figure A-8.55. Density map of merged LiDAR data

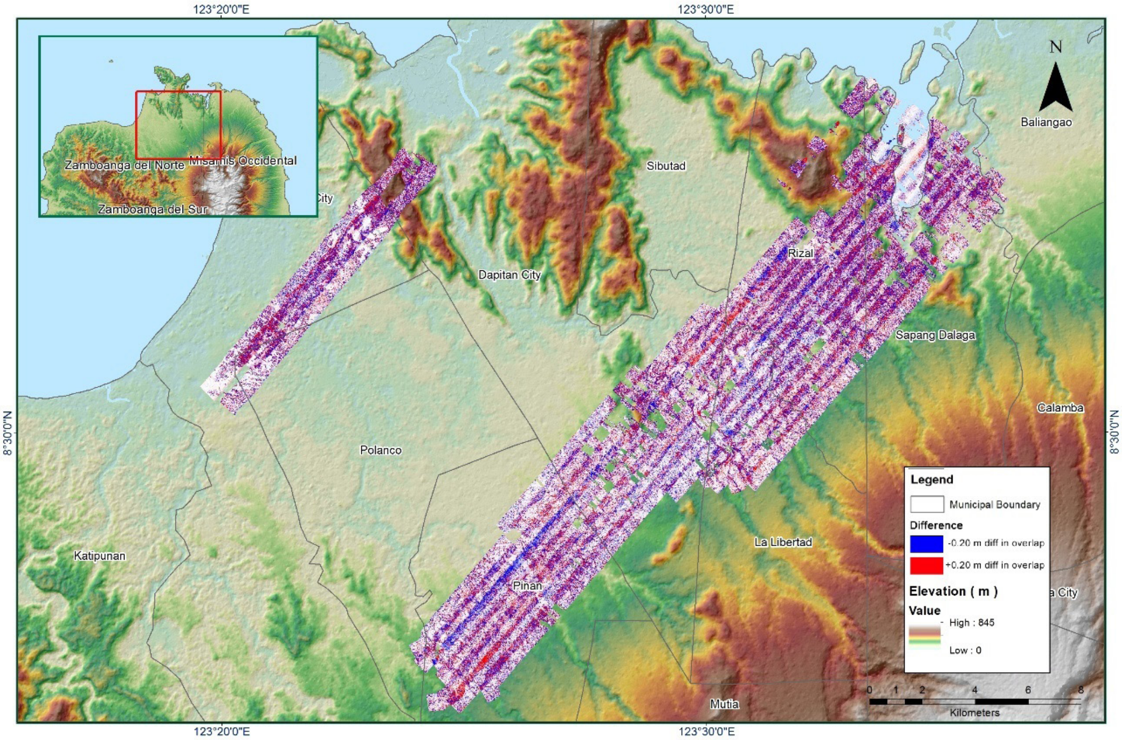


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk69D_supplement

Flight Area	Dipolog
Mission Name	**Blk69D_supplement**
Inclusive Flights	23574P
Range data size	21.7 GB
POS data size	264 MB
Base data size	126 MB
Image	n/a
Transfer date	December 6, 2016
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)	0.927
RMSE for East Position (<4.0 cm)	0.723
RMSE for Down Position (<8.0 cm)	1.389
Boresight correction stdev (<0.001deg)	0.000164
IMU attitude correction stdev (<0.001deg)	0.000238
GPS position stdev (<0.01m)	0.0009
Minimum % overlap (>25)	25.26 %
Ave point cloud density per sq.m. (>2.0)	2.96
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	122
Maximum Height	578.14 m
Minimum Height	66.32 m
Classification (# of points)	
Ground	62,007,878
Low vegetation	29,234,786
Medium vegetation	81,573,500
High vegetation	271,914,940
Building	2,886,312
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Aljon Rie Araneta

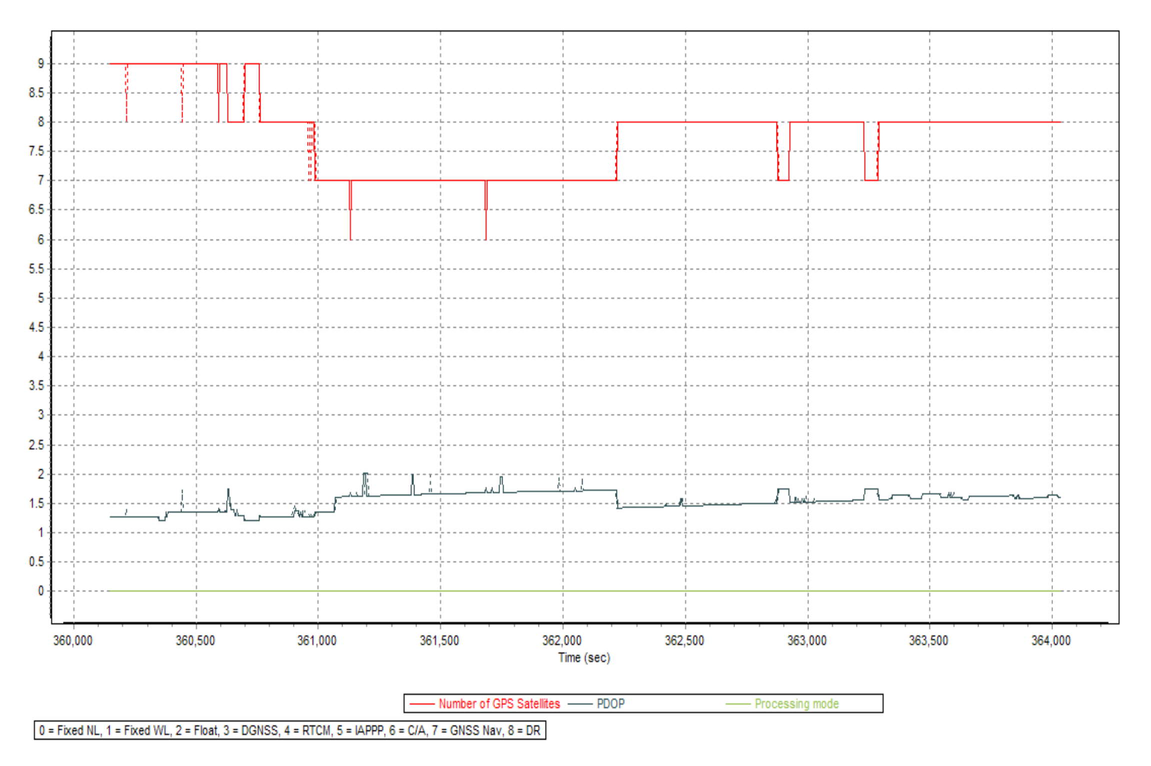


Figure A-8.57. Solution Status

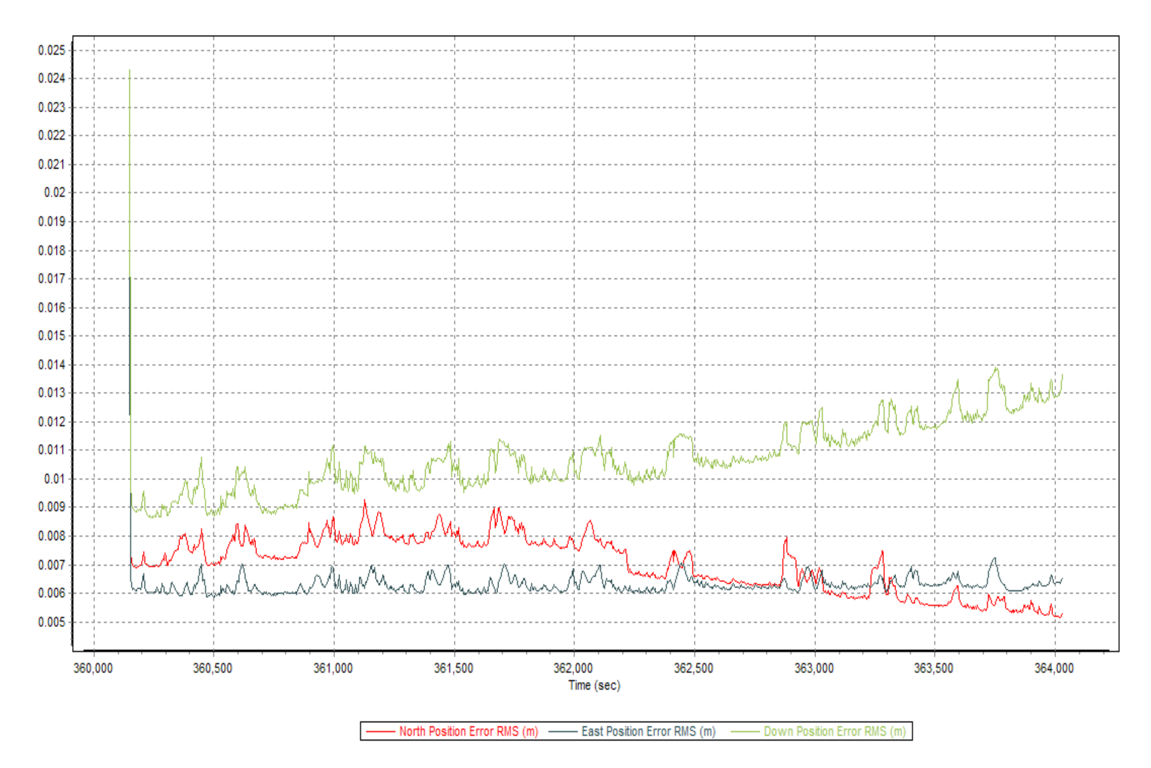


Figure A-8.58. Smoothed Performance Metric Parameters

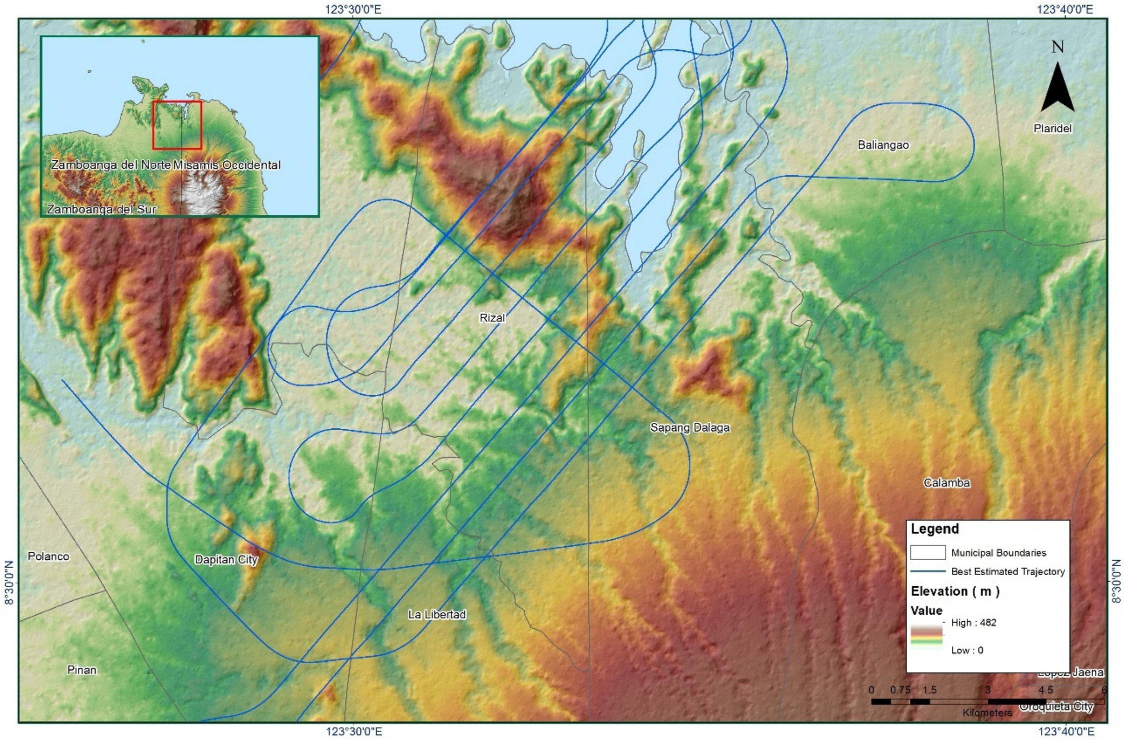


Figure A-8.59. Best Estimated Trajectory

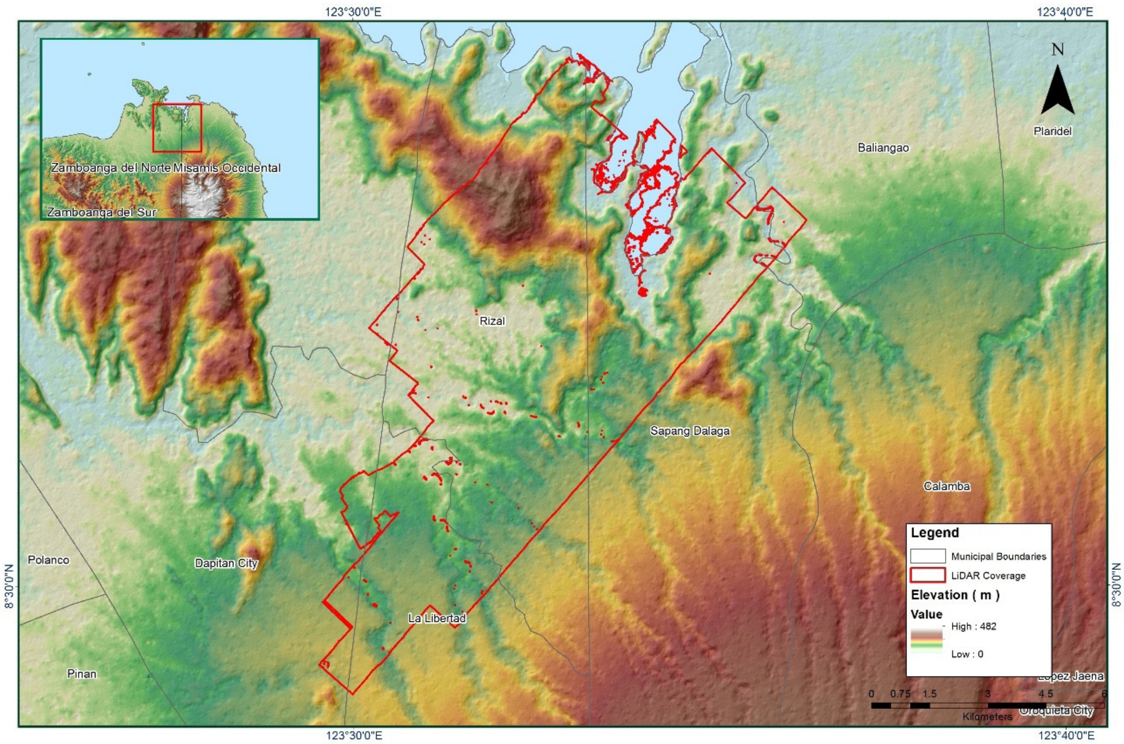


Figure A-8.60. Coverage of LiDAR Data

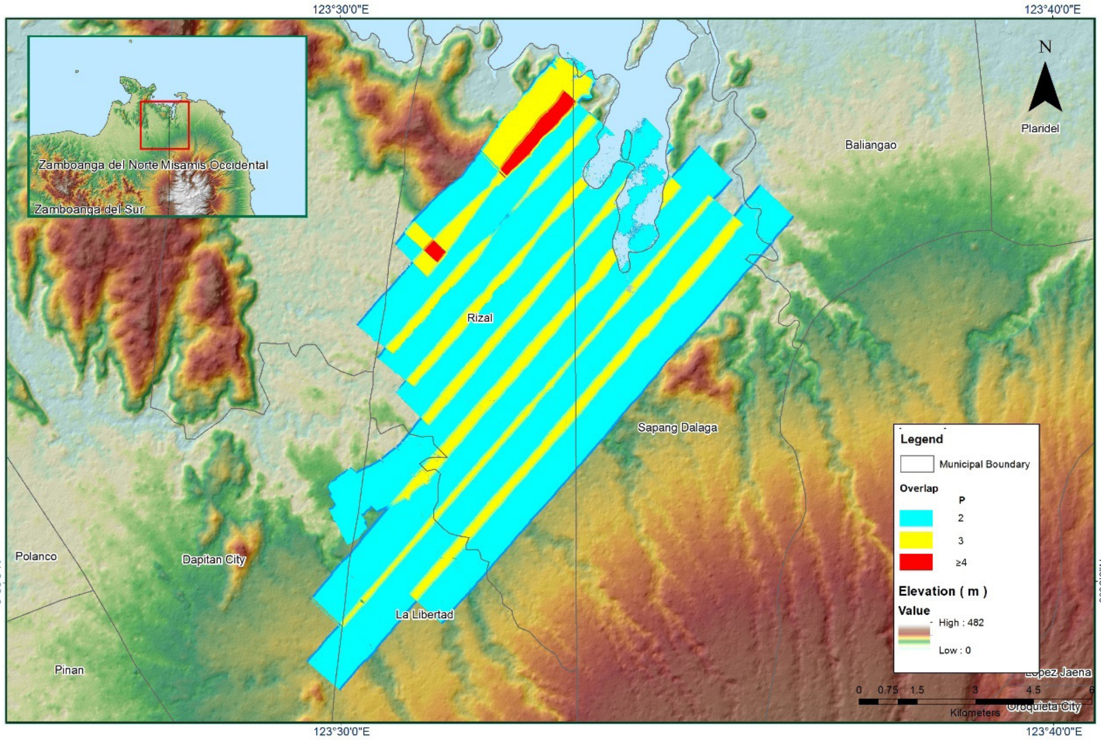


Figure A-8.61. Image of data overlap

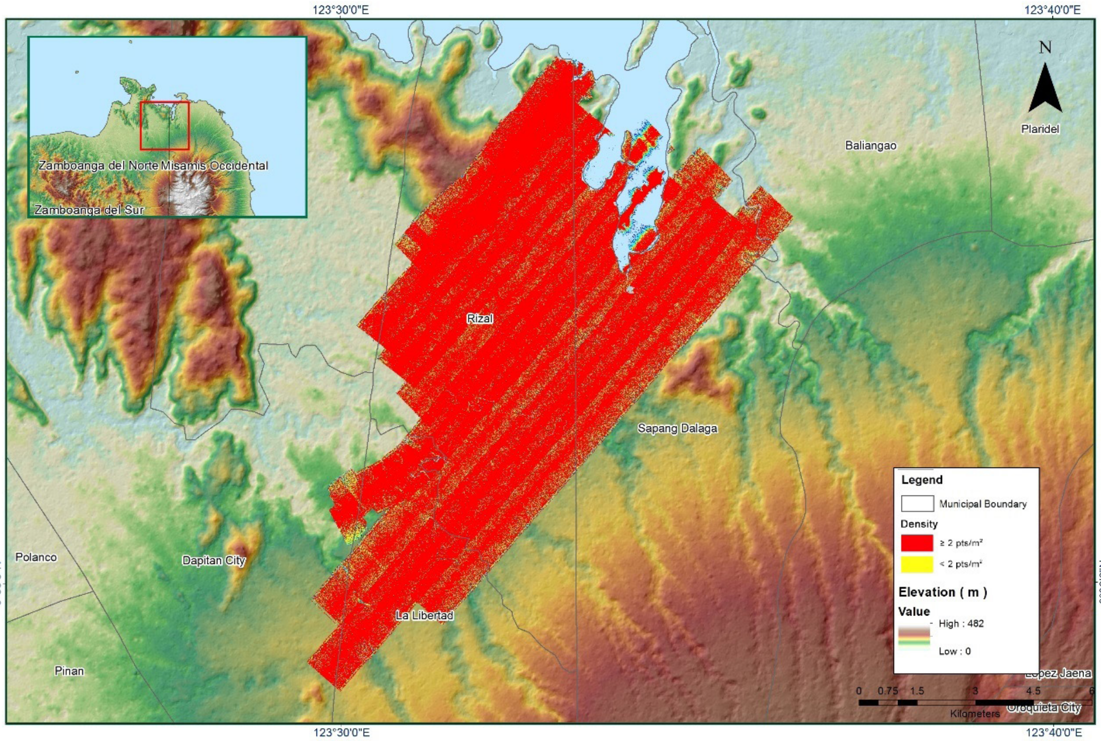


Figure A-8.62. Density map of merged LiDAR data

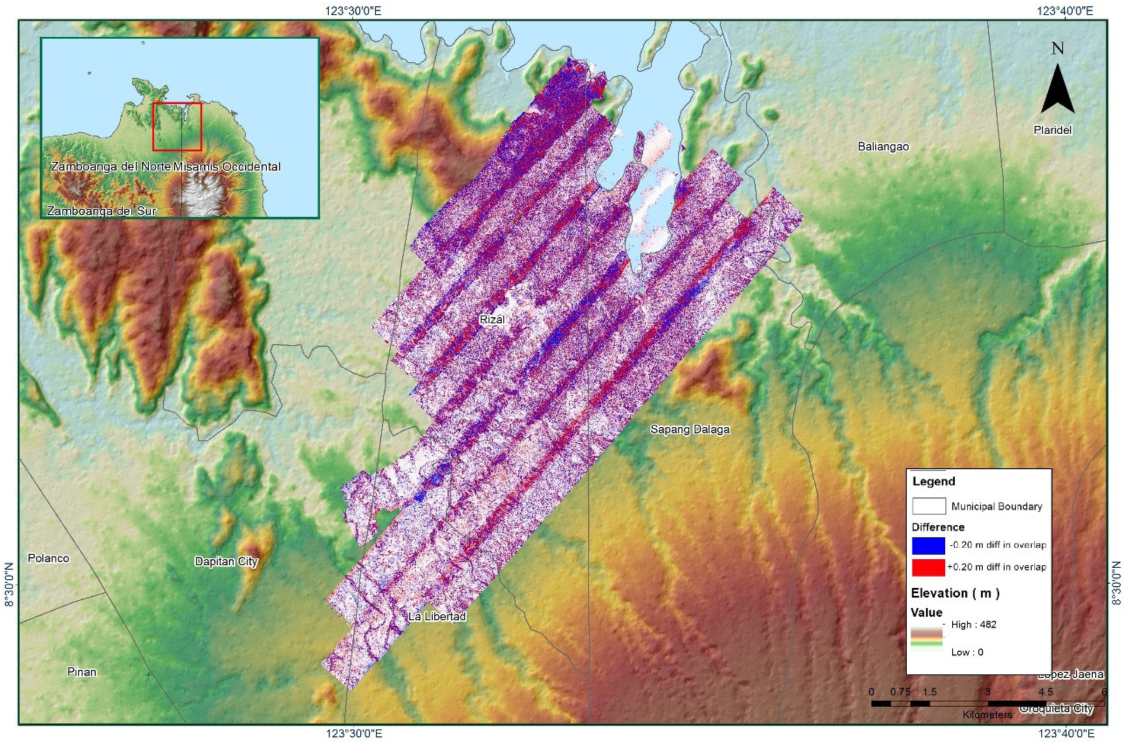


Figure A-8.63. Elevation difference between flight lines

Annex 9. Dapitan Model Basin Parameters

Table A-9.1. Dapitan 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	Threshold Type	Ratio to Peak
W500	68.477	60.0362	0.0	2.0639	2.8069	Discharge	3.4425	0.2	Ratio to Peak	0.005
W510	62.332	62.2692	0.0	2.3624	3.2128	Discharge	1.3620	0.20099	Ratio to Peak	0.005
W520	68.3532	60.0796	0.0	2.3875	3.2470	Discharge	2.4406	0.20099	Ratio to Peak	0.005
W530	66.114	60.8755	0.0	5.0719	6.8978	Discharge	4.3525	0.20098	Ratio to Peak	0.005
W540	68.2308	60.1223	0.0	1.5149	2.0603	Discharge	0.91997	0.20099	Ratio to Peak	0.005
W550	71.8542	58.8756	0.0	9.0265	12.276	Discharge	4.8945	0.20098	Ratio to Peak	0.005
W560	72	58.8266	0.0	7.8977	10.741	Discharge	1.8275	0.20098	Ratio to Peak	0.005
W570	74.1933	58.0979	0.0	3.3122	4.5046	Discharge	2.2336	0.20099	Ratio to Peak	0.005
W580	78.57	56.6965	0.0	5.7984	7.8859	Discharge	1.3399	0.20099	Ratio to Peak	0.005
W590	76.8258	57.2467	0.0	3.2689	4.4457	Discharge	0.53311	0.20099	Ratio to Peak	0.005
W600	74.187	58.1	0.0	5.8343	7.9347	Discharge	3.3259	0.20098	Ratio to Peak	0.005
W610	75.8754	57.5512	0.0	2.4686	3.3574	Discharge	2.0461	0.20099	Ratio to Peak	0.005
W620	77.1255	57.1515	0.0	4.5845	6.2349	Discharge	1.6113	0.20099	Ratio to Peak	0.005
W660	79.2018	56.4998	0.0	10.311	14.023	Discharge	3.3175	0.20099	Ratio to Peak	0.005
W670	78.7851	56.6293	0.0	4.1650	5.6644	Discharge	2.1872	0.20099	Ratio to Peak	0.005
W680	79.2333	56.49	0.0	5.8790	7.9954	Discharge	2.0477	0.20099	Ratio to Peak	0.005
W690	84.456	54.915	0.0	3.2028	4.3558	Discharge	0.42882	0.20099	Ratio to Peak	0.005
W700	75.4587	57.6856	0.0	1.9593	2.6646	Discharge	0.94127	0.20099	Ratio to Peak	0.005
W710	76.0797	57.4854	0.0	5.7583	7.8313	Discharge	1.8290	0.20099	Ratio to Peak	0.005
W720	76.7646	57.2663	0.0	10.630	14.457	Discharge	5.0304	0.20099	Ratio to Peak	0.005
W740	75.9816	57.5169	0.0	6.5419	8.8969	Discharge	5.7574	0.20098	Ratio to Peak	0.005

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	Threshold Type	Ratio to Peak
W750	75.8232	57.568	0.0	4.0960	5.5706	Discharge	0.72669	0.20099	Ratio to Peak	0.005
W760	74.3553	58.0447	0.0	4.8131	6.5458	Discharge	1.4664	0.20099	Ratio to Peak	0.005
W770	77.2335	57.1172	0.0	7.2432	9.8508	Discharge	5.8425	0.20098	Ratio to Peak	0.005
W780	74.2869	58.0671	0.0	9.8842	13.443	Discharge	3.7911	0.20096	Ratio to Peak	0.005
W790	74.187	58.1	0.0	3.6872	5.0146	Discharge	1.4783	0.20099	Ratio to Peak	0.005
W800	78.1542	56.8267	0.0	5.2991	7.2068	Discharge	3.1629	0.20099	Ratio to Peak	0.005
W810	75.6576	57.6212	0.0	5.4714	7.4411	Discharge	4.7771	0.20098	Ratio to Peak	0.005
W830	85.8411	54.5118	0.0	5.3391	7.2612	Discharge	3.9801	0.20099	Ratio to Peak	0.005
W840	74.187	58.1	0.0	4.1799	5.6846	Discharge	2.4562	0.20099	Ratio to Peak	0.005
W850	98.441	51.1	0.0	3.8989	5.3026	Discharge	1.7930	0.3	Ratio to Peak	0.005
W860	98.394	51.1119	0.0	3.3693	4.5823	Discharge	2.0551	0.20099	Ratio to Peak	0.005
W870	96.418	51.6187	0.0	2.5320	3.4435	Discharge	1.9391	0.20099	Ratio to Peak	0.005
W880	98.441	51.1	0.0	1.4841	2.0184171	Discharge	0.60333	0.20099	Ratio to Peak	0.005
W890	95.796	51.7804	0.0	2.1934	2.9830	Discharge	1.3373	0.20099	Ratio to Peak	0.005
W900	93.899	52.2795	0.0	1.9901	2.7065	Discharge	1.9580	0.20098	Ratio to Peak	0.005
W910	92.557	52.6386	0.0	3.7322	5.0759	Discharge	3.9640	0.20099	Ratio to Peak	0.005
W920	90.251	53.2672	0.0	2.6227	3.5668	Discharge	3.2489	0.20099	Ratio to Peak	0.005
W930	99.364	50.8669	0.0	1.6112	2.1913	Discharge	1.4294	0.3	Ratio to Peak	0.005
W960	128.4820613	44.4647	0.0	2.7535	3.7447	Discharge	1.9931	0.20097	Ratio to Peak	0.005
W970	147.4615609	41.0935	0.0	3.4257	4.6589	Discharge	1.7173	0.20097	Ratio to Peak	0.005
W980	142.3119261	41.9566	0.0	5.7934	7.8790	Discharge	5.1409	0.20099	Ratio to Peak	0.005

Annex 10. Dapitan Model Reach Parameters

Table A-10.1. Dapitan 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	1001.4	.00022603572271566347	0.0005	Trapezoid	49.6275	1
R120	Automatic Fixed Interval	1925.1	1.6086984265801785E-5	0.0005	Trapezoid	47.671	1
R140	Automatic Fixed Interval	524.56	.0007591661265966557	0.0005	Trapezoid	45.715	1
R150	Automatic Fixed Interval	1646.8	.000587511968518998	0.0005	Trapezoid	41.803	1
R160	Automatic Fixed Interval	1126.0	.0002059335349729642	0.0005	Trapezoid	42.104	1
R180	Automatic Fixed Interval	4698.9	0.0063699	0.0005	Trapezoid	42.405	1
R190	Automatic Fixed Interval	4301.7	0.0017650	0.0005	Trapezoid	43.006	1
R210	Automatic Fixed Interval	10339	0.0018118	0.0005	Trapezoid	45.813	1
R230	Automatic Fixed Interval	1634.1	0.0021374	0.0005	Trapezoid	48.62	1
R250	Automatic Fixed Interval	4950.1	0.0051758	0.0005	Trapezoid	46.2165	1
R280	Automatic Fixed Interval	1836.6	0.0013739	0.0005	Trapezoid	43.813	1
R30	Automatic Fixed Interval	3998.3	0.0012601	0.0005	Trapezoid	41.4095	1
R310	Automatic Fixed Interval	15591	0.0065334	0.0005	Trapezoid	39.006	1
R320	Automatic Fixed Interval	9879.5	0.0223901	0.0005	Trapezoid	35.56	1
R370	Automatic Fixed Interval	7343.7	0.0174664	0.0005	Trapezoid	32.114	1
R380	Automatic Fixed Interval	2472.1	0.0497789	0.0005	Trapezoid	34.902	1
R410	Automatic Fixed Interval	2299.2	0.0248703	0.0005	Trapezoid	37.69	1
R430	Automatic Fixed Interval	6780.0	0.0361135	0.0005	Trapezoid	37.8665625	1
R450	Automatic Fixed Interval	708.41	0.0875928	0.0005	Trapezoid	38.043125	1
R460	Automatic Fixed Interval	784.26	0.11485	0.0005	Trapezoid	38.2196875	1
R50	Automatic Fixed Interval	2312.4	0.0010828	0.0005	Trapezoid	38.39625	1
R70	Automatic Fixed Interval	2467.4	.0003161889457559702	0.0005	Trapezoid	38.39625	1
R80	Automatic Fixed Interval	5850.1	0.0019498	0.0005	Trapezoid	38.749375	1
R90	Automatic Fixed Interval	282.99	0.0214530	0.0005	Trapezoid	39.1025	1

Annex 11. Dapitan Field Validation Points

Table A-11.1 Dapitan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	8.541557	123.492311	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
2	8.637848	123.416679	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
3	8.638057	123.415761	0.03	0.25	-0.22	Typhoon Zoraida / Nov. 11. 2013	5 - Year
4	8.607775	123.420659	0.03	0.60	-0.57	Typhoon Zoraida / Nov. 11. 2013	5 - Year
5	8.624531	123.391932	0.03	0.30	-0.27	Typhoon Zoraida / Nov. 11. 2013	5 - Year
6	8.630296	123.404479	0.03	0.40	-0.37	Typhoon Zoraida / Nov. 11. 2013	5 - Year
7	8.630454	123.404696	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
8	8.639056	123.419692	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
9	8.610377	123.477774	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
10	8.610710	123.476553	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
11	8.611912	123.480602	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
12	8.613095	123.479903	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
13	8.613334	123.480789	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
14	8.613269	123.480170	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
15	8.623994	123.391664	0.03	0.50	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
16	8.624504	123.393308	0.03	0.40	-0.37	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
17	8.610391	123.478871	0.03	0.30	-0.27	Typhoon Zoraida / Nov. 11. 2013	5 - Year
18	8.658156	123.427593	0.03	0.50	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
19	8.658102	123.427580	0.03	0.55	-0.52	Typhoon Zoraida / Nov. 11. 2013	5 - Year
20	8.658405	123.427498	0.03	0.50	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
21	8.658467	123.427504	0.03	0.50	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
22	8.609621	123.478506	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
23	8.610347	123.478593	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
24	8.643386	123.419428	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
25	8.610540	123.477501	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
26	8.613339	123.479927	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
27	8.624588	123.391716	0.03	0.40	-0.37	Typhoon Zoraida / Nov. 11. 2013	5 - Year
28	8.612386	123.479201	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
29	8.609663	123.479100	0.03	0.24	-0.21	Typhoon Zoraida / Nov. 11. 2013	5 - Year
30	8.541052	123.494703	0.03	0.30	-0.27	Typhoon Zoraida / Nov. 11. 2013	5 - Year
31	8.624750	123.394038	0.03	0.30	-0.27	Typhoon Zoraida / Nov. 11. 2013	5 - Year
32	8.636860	123.415176	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
33	8.531701	123.448990	0.03	0.14	-0.11	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
34	8.531665	123.449197	0.03	0.12	-0.09	Typhoon Zoraida / Nov. 11. 2013	5 - Year
35	8.604777	123.404260	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
36	8.625373	123.391228	0.03	0.45	-0.42	Typhoon Zoraida / Nov. 11. 2013	5 - Year
37	8.604777	123.404260	0.03	0.25	-0.22	Typhoon Zoraida / Nov. 11. 2013	5 - Year
38	8.611170	123.477259	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
39	8.625310	123.391276	0.03	0.50	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
40	8.584699	123.407491	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
41	8.636693	123.415082	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
42	8.646417	123.416878	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
43	8.613580	123.424207	0.03	0.50	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
44	8.585478	123.409215	0.03	0.25	-0.22	Typhoon Zoraida / Nov. 11. 2013	5 - Year
45	8.602580	123.417872	0.03	0.65	-0.62	Typhoon Zoraida / Nov. 11. 2013	5 - Year
46	8.610796	123.476863	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
47	8.585370	123.408802	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
48	8.604026	123.402323	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
49	8.602575	123.418022	0.03	0.60	-0.57	Typhoon Zoraida / Nov. 11. 2013	5 - Year
50	8.585370	123.408987	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
51	8.603787	123.419610	0.03	0.55	-0.52	Typhoon Zoraida / Nov. 11. 2013	5 - Year
52	8.612106	123.478770	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
53	8.610435	123.478084	0.03	0.33	-0.30	Typhoon Zoraida / Nov. 11. 2013	5 - Year
54	8.604407	123.404027	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
55	8.645354	123.417383	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
56	8.541943	123.493299	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
57	8.542021	123.493327	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
58	8.611938	123.478838	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
59	8.610758	123.478423	0.03	0.25	-0.22	Typhoon Zoraida / Nov. 11. 2013	5 - Year
60	8.642908	123.419245	0.04	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
61	8.624827	123.391532	0.04	0.50	-0.46	Typhoon Zoraida / Nov. 11. 2013	5 - Year
62	8.611563	123.479135	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
63	8.532285	123.446434	0.04	0.15	-0.11	Typhoon Zoraida / Nov. 11. 2013	5 - Year
64	8.607771	123.420574	0.03	0.50	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
65	8.630506	123.404744	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
66	8.619131	123.386111	0.05	0.10	-0.05	Typhoon Zoraida / Nov. 11. 2013	5 - Year
67	8.611929	123.478677	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
68	8.604229	123.403825	0.05	0.25	-0.20	Typhoon Zoraida / Nov. 11. 2013	5 - Year
69	8.541799	123.493168	0.05	0.10	-0.06	Typhoon Zoraida / Nov. 11. 2013	5 - Year
70	8.608256	123.419714	0.05	0.40	-0.35	Typhoon Zoraida / Nov. 11. 2013	5 - Year
71	8.607880	123.420215	0.06	0.40	-0.34	Typhoon Zoraida / Nov. 11. 2013	5 - Year
72	8.541253	123.493682	0.03	0.30	-0.27	Typhoon Zoraida / Nov. 11. 2013	5 - Year
73	8.619228	123.385369	0.07	0.15	-0.08	Typhoon Zoraida / Nov. 11. 2013	5 - Year
74	8.610021	123.478629	0.06	0.10	-0.04	Typhoon Zoraida / Nov. 11. 2013	5 - Year
75	8.639622	123.420262	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
76	8.618731	123.387023	0.06	0.10	-0.04	Typhoon Zoraida / Nov. 11. 2013	5 - Year
77	8.618857	123.386666	0.06	0.15	-0.09	Typhoon Zoraida / Nov. 11. 2013	5 - Year
78	8.610111	123.479062	0.07	0.10	-0.03	Typhoon Zoraida / Nov. 11. 2013	5 - Year
79	8.599537	123.435783	0.03	0.47	-0.44	Typhoon Zoraida / Nov. 11. 2013	5 - Year
80	8.609854	123.478687	0.07	0.22	-0.15	Typhoon Zoraida / Nov. 11. 2013	5 - Year
81	8.618896	123.386965	0.06	0.20	-0.14	Typhoon Zoraida / Nov. 11. 2013	5 - Year
82	8.610137	123.478641	0.08	0.10	-0.03	Typhoon Zoraida / Nov. 11. 2013	5 - Year
83	8.643861	123.415512	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
84	8.614134	123.479009	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
85	8.532945	123.446874	0.06	0.10	-0.04	Typhoon Zoraida / Nov. 11. 2013	5 - Year
86	8.618489	123.385888	0.07	0.20	-0.13	Typhoon Zoraida / Nov. 11. 2013	5 - Year
87	8.618384	123.385793	0.08	0.20	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
88	8.528624	123.452542	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
89	8.528644	123.452469	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
90	8.528648	123.452509	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
91	8.638204	123.416091	0.10	0.20	-0.10	Typhoon Zoraida / Nov. 11. 2013	5 - Year
92	8.643102	123.419499	0.11	0.15	-0.04	Typhoon Zoraida / Nov. 11. 2013	5 - Year
93	8.534170	123.445153	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
94	8.611303	123.479888	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
95	8.611696	123.478336	0.03	0.25	-0.22	Typhoon Zoraida / Nov. 11. 2013	5 - Year
96	8.616455	123.388734	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
97	8.612617	123.479450	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
98	8.647333	123.418092	0.15	0.10	0.05	Typhoon Zoraida / Nov. 11. 2013	5 - Year
99	8.644618	123.420622	0.15	0.20	-0.05	Typhoon Zoraida / Nov. 11. 2013	5 - Year
100	8.645725	123.417571	0.14	0.10	0.04	Typhoon Zoraida / Nov. 11. 2013	5 - Year
101	8.609660	123.419066	0.07	0.30	-0.23	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
102	8.541795	123.492933	0.15	0.15	0.00	Typhoon Zoraida / Nov. 11. 2013	5 - Year
103	8.609831	123.478534	0.19	0.14	0.05	Typhoon Zoraida / Nov. 11. 2013	5 - Year
104	8.644429	123.415195	0.06	0.50	-0.44	Typhoon Zoraida / Nov. 11. 2013	5 - Year
105	8.618646	123.386143	0.14	0.15	-0.01	Typhoon Zoraida / Nov. 11. 2013	5 - Year
106	8.541525	123.492666	0.14	0.20	-0.06	Typhoon Zoraida / Nov. 11. 2013	5 - Year
107	8.643387	123.421767	0.21	0.10	0.11	Typhoon Zoraida / Nov. 11. 2013	5 - Year
108	8.541501	123.492511	0.14	0.20	-0.06	Typhoon Zoraida / Nov. 11. 2013	5 - Year
109	8.660265	123.427823	0.06	0.40	-0.34	Typhoon Zoraida / Nov. 11. 2013	5 - Year
110	8.614327	123.479800	0.03	0.45	-0.42	Typhoon Zoraida / Nov. 11. 2013	5 - Year
111	8.613653	123.480987	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
112	8.645304	123.419968	0.10	0.10	0.00	Typhoon Zoraida / Nov. 11. 2013	5 - Year
113	8.616555	123.388800	0.07	0.15	-0.08	Typhoon Zoraida / Nov. 11. 2013	5 - Year
114	8.611202	123.477505	0.03	0.15	-0.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
115	8.606947	123.401951	0.16	0.10	0.06	Typhoon Zoraida / Nov. 11. 2013	5 - Year
116	8.605848	123.401067	0.13	0.10	0.03	Typhoon Zoraida / Nov. 11. 2013	5 - Year
117	8.640063	123.416516	0.19	0.50	-0.31	Typhoon Zoraida / Nov. 11. 2013	5 - Year
118	8.636907	123.415337	0.06	0.10	-0.04	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
119	8.618210	123.387257	0.25	0.15	0.10	Typhoon Zoraida / Nov. 11. 2013	5 - Year
120	8.606167	123.400934	0.14	0.30	-0.16	Typhoon Zoraida / Nov. 11. 2013	5 - Year
121	8.646209	123.421875	0.21	0.25	-0.04	Typhoon Zoraida / Nov. 11. 2013	5 - Year
122	8.532767	123.446699	0.24	0.10	0.14	Typhoon Zoraida / Nov. 11. 2013	5 - Year
123	8.618801	123.386441	0.35	0.15	0.20	Typhoon Zoraida / Nov. 11. 2013	5 - Year
124	8.605390	123.401387	0.27	0.20	0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
125	8.659676	123.427831	0.07	0.40	-0.33	Typhoon Zoraida / Nov. 11. 2013	5 - Year
126	8.605859	123.401265	0.26	0.25	0.01	Typhoon Zoraida / Nov. 11. 2013	5 - Year
127	8.618722	123.388340	0.21	0.10	0.11	Typhoon Zoraida / Nov. 11. 2013	5 - Year
128	8.611143	123.479415	0.03	0.10	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
129	8.660021	123.428572	0.03	0.40	-0.37	Typhoon Zoraida / Nov. 11. 2013	5 - Year
130	8.605748	123.400970	0.33	0.30	0.03	Typhoon Zoraida / Nov. 11. 2013	5 - Year
131	8.534232	123.445320	0.13	0.20	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
132	8.534291	123.445207	0.13	0.20	-0.07	Typhoon Zoraida / Nov. 11. 2013	5 - Year
133	8.607590	123.401744	0.46	0.10	0.36	Typhoon Zoraida / Nov. 11. 2013	5 - Year
134	8.618488	123.389958	0.39	0.20	0.19	Typhoon Zoraida / Nov. 11. 2013	5 - Year
135	8.612299	123.478739	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
136	8.599689	123.435616	0.06	0.40	-0.34	Typhoon Zoraida / Nov. 11. 2013	5 - Year
137	8.624514	123.393076	0.27	0.40	-0.13	Typhoon Zoraida / Nov. 11. 2013	5 - Year
138	8.614725	123.479958	0.09	0.56	-0.47	Typhoon Zoraida / Nov. 11. 2013	5 - Year
139	8.636330	123.415443	0.40	0.20	0.20	Typhoon Zoraida / Nov. 11. 2013	5 - Year
140	8.636330	123.415443	0.40	0.40	0.00	Typhoon Zoraida / Nov. 11. 2013	5 - Year
141	8.534131	123.445256	0.11	0.25	-0.14	Typhoon Zoraida / Nov. 11. 2013	5 - Year
142	8.624514	123.392889	0.30	0.45	-0.15	Typhoon Zoraida / Nov. 11. 2013	5 - Year
143	8.611011	123.479453	0.03	0.20	-0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
144	8.618544	123.388833	0.45	0.20	0.25	Typhoon Zoraida / Nov. 11. 2013	5 - Year
145	8.599778	123.435337	0.06	0.50	-0.44	Typhoon Zoraida / Nov. 11. 2013	5 - Year
146	8.599511	123.435796	0.03	0.45	-0.42	Typhoon Zoraida / Nov. 11. 2013	5 - Year
147	8.618478	123.389279	0.67	0.15	0.52	Typhoon Zoraida / Nov. 11. 2013	5 - Year
148	8.613194	123.424060	0.66	0.50	0.16	Typhoon Zoraida / Nov. 11. 2013	5 - Year
149	8.550266	123.424277	0.03	1.15	-1.12	Typhoon Zoraida / Nov. 11. 2013	5 - Year
150	8.618822	123.389265	0.94	0.15	0.79	Typhoon Zoraida / Nov. 11. 2013	5 - Year
151	8.599588	123.435273	0.37	0.60	-0.23	Typhoon Zoraida / Nov. 11. 2013	5 - Year
152	8.599266	123.434698	0.48	0.93	-0.45	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
153	8.599350	123.434817	0.51	0.80	-0.29	Typhoon Zoraida / Nov. 11. 2013	5 - Year
154	8.599513	123.434675	0.51	0.50	0.01	Typhoon Zoraida / Nov. 11. 2013	5 - Year
155	8.549559	123.424615	0.04	1	-0.96	Typhoon Zoraida / Nov. 11. 2013	5 - Year
156	8.599550	123.434935	0.64	0.83	-0.20	Typhoon Zoraida / Nov. 11. 2013	5 - Year
157	8.599360	123.434957	0.67	0.50	0.17	Typhoon Zoraida / Nov. 11. 2013	5 - Year
158	8.599771	123.434639	0.74	0.42	0.32	Typhoon Zoraida / Nov. 11. 2013	5 - Year
159	8.550355	123.424391	0.05	1.10	-1.05	Typhoon Zoraida / Nov. 11. 2013	5 - Year
160	8.550125	123.425126	0.20	1.10	-0.90	Typhoon Zoraida / Nov. 11. 2013	5 - Year
161	8.550558	123.424228	0.12	0.95	-0.83	Typhoon Zoraida / Nov. 11. 2013	5 - Year
162	8.550337	123.424967	0.27	1.64	-1.37	Typhoon Zoraida / Nov. 11. 2013	5 - Year
163	8.551105	123.424612	0.04	0.85	-0.81	Typhoon Zoraida / Nov. 11. 2013	5 - Year
164	8.550652	123.424989	0.33	1.70	-1.37	Typhoon Zoraida / Nov. 11. 2013	5 - Year
165	8.584854	123.410102	0.36	0.50	-0.14	Typhoon Zoraida / Nov. 11. 2013	5 - Year
166	8.584840	123.410003	0.47	0.50	-0.03	Typhoon Zoraida / Nov. 11. 2013	5 - Year
167	8.585036	123.408352	2.07	0.15	1.92	Typhoon Zoraida / Nov. 11. 2013	5 - Year
168	8.584430	123.407383	2.87	0.20	2.67	Typhoon Zoraida / Nov. 11. 2013	5 - Year

Annex 12. Educational Institutions affected by flooding in Dapitan Floodplain

Table A-12.1. Educational Institutions in Dapitan City affected by flooding in Dapitan Floodplain

ZAMBOANGA DEL NORTE				
DAPITAN CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Antipolo Elementary School	Antipolo	Low	Low	Medium
Day Care Center	Antipolo			Low
Stage	Antipolo	Low	Low	Low
Day Care Center	Ba-Ao			Low
Elem. School	Ba-Ao			
Dapitan City Central School	Bagting	Low	Low	Low
Dapitan City Experimental School	Bagting	Low	Low	Low
Classroom	Banonong			
Stage	Banonong			Low
Barcelona Central School	Barcelona			
Barcelona National High School	Barcelona	Low	Low	Low
Day Care Center	Barcelona			
HE	Barcelona			
School Stage	Barcelona		Low	Low
Supervisors Office	Barcelona			
Brgy. Cawa-cawa Day Care Center	Cawa-Cawa			
La Libertad Elementary School	Dampalan			
Purok 3 Day Care Center	Dampalan		Medium	High
Classroom	Diwa-An			
Day Care Center	Diwa-An			
Classroom	Hilltop			
Day Care Center	Ilaya	High	High	High
HE	Ilaya	Medium	High	High
Ilaya Elem. School	Ilaya	Medium	High	High
Ilaya Elem. SchoolV	Ilaya	Medium	High	High
Ilaya High School	Ilaya	Medium	High	High
Principals Office	Ilaya	Medium	High	High
School CR	Ilaya			
School Stage	Ilaya	Medium	High	High
San Pedro Elementary School	Larayan			
Classroom	Maria Cristina	Low	Medium	Medium
Day Care Center	Maria Cristina	Low	Low	Medium
Classroom	Maria Uray			
CLASSROOM	Maria Uray			
Day Care Center	Maria Uray	High	High	High
Old School Building	Maria Uray		Low	Low
Stage	Maria Uray	Medium	Medium	Medium
Dampalan Elementary School	Masidlakon			

ZAMBOANGA DEL NORTE				
DAPITAN CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Opao Elementary School	Opao			
Purok 2 Day Care Center	Opao			
Canteen	Oyan		Medium	Medium
Classroom	Oyan	Medium	Medium	High
Day Care center	Oyan		Low	Medium
Dirty Kitchen	Oyan			
School Building	Oyan	Low	Medium	High
Classroom	Polo			
Principal's Office	Polo			
Stage	Polo			
RMIDCI Elementary	Potol			
Day Care Center	Potungan			
Faculty Room	Potungan			
Potungan Elementary Central School	Potungan			
Potungan National High School	Potungan			
School Canteen	Potungan			
School CR	Potungan			
Stage	Potungan			
San Nicolas Elem School	San Nicolas			
San Nicolas Multi Purpose Building	San Nicolas			
Classroom	San Pedro		Low	Low
Stage	San Pedro			
Dapitan City Central School	Santa Cruz		Low	Low
Dapitan City Experimental School	Santa Cruz	Low	Low	Low
JRMSU Grandstand	Santa Cruz			
JRMSU Main Campus	Santa Cruz			
JRMSU Maritime Building	Santa Cruz	Low	Low	Low
Classroom	Sulangon			

Table A-12.2. Educational Institutions in La Libertad affected by flooding in Dapitan Floodplain

ZAMBOANGA DEL NORTE				
LA LIBERTAD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Elementary School	La Union	Low	Low	Low
Elementary School	Mauswagon			

Table A-12.3. Educational Institutions in Rizal affected by flooding in Dapitan Floodplain

ZAMBOANGA DEL NORTE				
RIZAL				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
San Roque Elementary School	San Roque			
Grace Primitive Baptist Church	South Mapang			

Table A-12.4. Educational Institutions in Sibutad affected by flooding in Dapitan Floodplain

ZAMBOANGA DEL NORTE				
SIBUTAD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Grade 1 Room	Bagacay			
Grade 3 Room	Bagacay			
T.L.E Room	Bagacay			
Calilic Elementary Stage	Calilic			
Calilic Grade 1 Room	Calilic			
Calilic Grade 3 Room	Calilic		Medium	Medium
Calilic Grade 5 Room	Calilic			
Calilic Princepal's Office	Calilic		Low	Medium
Elemtary Library	Delapa			
Grade 2 Room	Delapa			
Grade 4 Room	Delapa			
Grade 5 Room	Delapa			
Grade 6 Room	Delapa			
Marapong Daycare Center	Delapa			
Marapong Elementary Guard Houses	Delapa			
Principal's Office Room	Delapa			
Canteen Elem. School	Magsaysay			
Grade 2 Room	Magsaysay			
Grade 5 Room	Magsaysay			
Grade 6 Room	Magsaysay			
Magsaysay Elem. Stage	Magsaysay			
Magsaysay Principal's Office	Magsaysay			
Payag	Magsaysay			
Staff Office	Magsaysay			
Daycare Center	Marapong	High	High	High
Grade 1 Room	Marapong			
Grade 5 Room	Marapong			
Oyan Elementary Stage	Marapong			
Princepal's Office	Marapong			
Staff Room	Marapong			

ZAMBOANGA DEL NORTE				
SIBUTAD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Grade 1 Room	Minlasag			
Grade 3 Room	Minlasag			Low
Grade 5 Room	Minlasag		Low	Low
Minlasag Daycare Center	Minlasag			
Minlasag Principal's Office Room	Minlasag			
Minlasag Stage Elem.	Minlasag			
Waitng Shed 2	Minlasag			
Ba-ao Elementary School	Oyan		Medium	High
Canteen	Oyan		Medium	High
Day Care Center	Oyan			
Old School	Oyan			
Calilic Daycare Center	Sibuloc		Low	Medium
Grade 1 Room	Sibuloc			Low
Grade 3 Room	Sibuloc			
Grade 5 Room	Sibuloc		Low	Medium
Covered Stage	Sipaloc			
Grade 1 Room	Sipaloc			
Grade 3 Room	Sipaloc			
Grade 5 Room	Sipaloc			
Sipaloc Library Elem.	Sipaloc			
Sipaloc Principal's Office	Sipaloc			

Annex 13. Health Institutions affected by flooding in Dapitan Floodplain

Table A-13.1. Health Institutions in Dapitan City affected by flooding in Dapitan Floodplain

ZAMBOANGA DEL NORTE				
DAPITAN CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Antipolo	Low	Low	Low
Botique	Bagting			
Pharmacy	Bagting			
Botika Cara	Banonong			
Botique	Banonong	Low	Low	Low
Birthing home	Barcelona			
Botika Cara	Dawo			
Clinic	Dawo			
Dapitan Drug Store	Dawo			
Public Hospital	Dawo			
Health Center	Diwa-An	Medium	Medium	High
Health Center	Ilaya	Medium	High	High
Health Center	Maria Cristina	Medium	Medium	Medium
Health Center	Oyan			
Clinica Dapitan	Polo			
Pharmacy	Potol			
Barangay Health Center	Potungan	Low	Low	Low
Health Center	San Pedro			
Botique	Santa Cruz			
City Health Office	Santa Cruz			
Health Center	Sulangon			

Table A-13.2. Health Institutions in Sibutad affected by flooding in Dapitan Floodplain

ZAMBOANGA DEL NORTE				
RIZAL				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Heatlh Center	San Roque			

Table A-13.3. Health Institutions in Sibutad affected by flooding in Dapitan Floodplain

ZAMBOANGA DEL NORTE				
SIBUTAD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Marapong Health Center	Delapa			
Sibutad Hospital	Magsaysay			
Barangay Health Center	Minlasag			
Botika ng Barangay	Oyan			
Health Center	Poblacion			
Barangay Health Center 1	Sipaloc			