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

LiDAR Surveys and Flood Mapping of Labangan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mindanao State University-Iligan Institute of Technology

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
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
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 LABANGAN RIVER

Enrico C. Paringit, Dr. Eng. and Prof. Alan Milano

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the 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. The university is located in Iligan City in the province of Lanao del Norte.

1.2 Overview of Labangan River Basin

Labangan River Basin is located in the province of Zamboanga del Sur, Zamboanga Peninsula under Region IX, Philippines. Labangan River Basin covers portions of the municipalities of Labangan, Pagadian, Tigbao, Sominot, Tukuran and Lakewood in Zamboanga del Sur. Based on the DENR River Basin Control Office (RBCO), it has a drainage area of 591 km2 and an estimated 453 million cubic meter (MCM) annual run-off.

The main river used for the delineation of the basin is the Labangan River that passes through the Municipality of Labangan. The river is named after Labangan Municipality where it is situated. Labangan is one of the municipalities in the province where the outlet of the river basin is located, specifically in Barangay Bokong. The municipality is located on the eastern portion of Zamboanga del Sur, bounded on the west by Pagadian City, on the northeast by the Municipalities of Tukuran and Midsalip, and on the south by Illana Bay. Labangan's topography ranges from flat grounds to rolling and steep hills. Most of the north-western portions are hilly and mountainous, and are generally forested. The central portion, on the other hand are level to nearly-level, and are usually used to cultivate rice and corn. The whole municipality is crossed over by wide rivers and creeks. The most notable of this is the Labangan River that cuts through the wide Labangan Valley.

The river, according to the local government, is generally used as a quarrying site for the citizens within the community and serves as their main source of living. Labangan City has a total population of 39, 168 based on the 2010 NSO census.

The delineated catchment traverses through the municipalities of Labangan, Sominot, Midsalip, Tigbao and the city of Pagadian. The larger areas of the river basin are within Labangan, Tigbao and Pagadian City. Labangan River Basin is bounded on the North by the Municipality of Sominot, on the East by the Municipality of Tukuran, on the West by the Municipality of Lakewood, and on the South by Illana Bay. All of the barangays in the Municipality of Labangan are within the said river basin. The flood prone area includes the Municipality of Labangan and Tukuran and the City of Pagadian. For the Municipality of Labangan, nineteen (19) barangays are included, namely, Balimbingan, Bukong, Bulanit, Combo, Dalapang, Dimasangca, Lantian, Lower Campo Islam, Lower Pulacan, Lower Sang-an, New Labangan, Old Labangan, San Isidro, Santa Cruz, Tapodoc, Tawagan Norte, Upper Campo Islam, Upper Pulacan, and Upper Sang-an. For the Municipality of Tukuran there are twenty (20), namely, Alindahaw, Baclay, Balimbingan, Camanga, Curvada, Libertad, Lower Bacayo, Luy-a, Manilan, Manlayag, Militar, Navalan, Panduma Senior, San Carlos, Santo Niño, Santo Rosario, Sugad, Tabuan, Tinotungan, and Upper Bacayo. For Pagadian City there are twenty-one (21) barangays, namely, Balangasan, Bulatok, Gatas, Kalasan, Kawit, Lenienza, Lumbia, Manga, MuricaySan Francisco, San Jose, San Pedro, Santa Lucia, Santa Maria, Santiago, Santo Niño, Tawagan Sur, Tiguma, Tuburan, Tulawas, and White Beach. The main outlet of the river basin, where the flow measurement data were obtained, is located at Isidro Rey LL. Real III Hanging Bridge, that connects the two (2) barangays within the Municipality of Labangan namely Barangay Santa Cruz and Barangay Bokong.

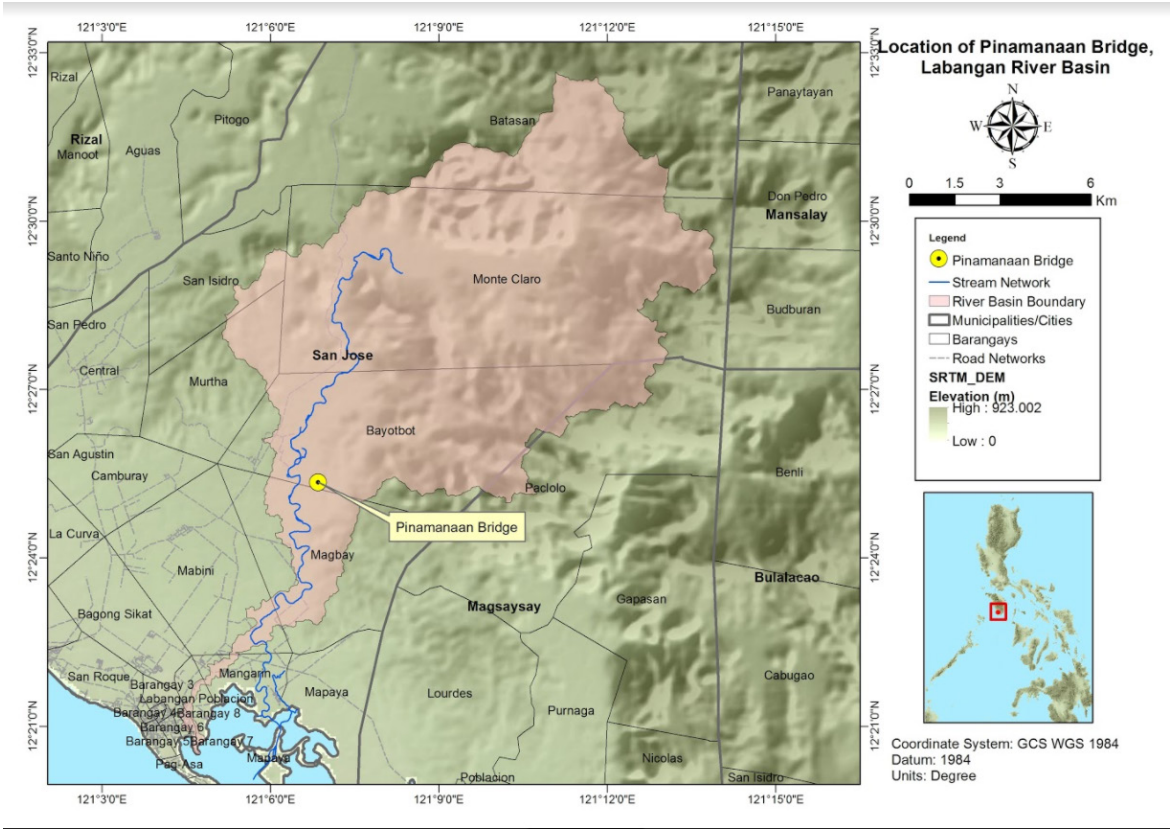

Figure 1. Map of the Labangan River Basin (in brown)

The Labangan river basin has an estimated drainage area of 446.2 square kilometers and travels 33.3 km from its source to its outlet and 39 km from its source to the mouth of Illana Bay. The flood plain area delineated within the basin has an area of 151.131671 square kilometers which is 33.87% of the whole area of the basin. The municipalities of Labangan and Tukuran including the City of Pagadian are found within the Labangan floodplain. A total of 44, 863 building features are extracted which belongs to the municipalities and city within the floodplain that corresponds to the area of Labangan floodplain with a 200-m buffer.

Flood incident occurred as Typhoon Jenny (international name: Dujuan) entered the Philippine Area of Responsibility (PAR) on the afternoon of September 23, 2015. According to National Disaster Risk Reduction Management Council (NDRRMC) Update Final Report re Effects of Southwest Monsoon Enhanced by Typhoon Jenny, around 8:00 PM, September 25, 2015, thunderstorms which brought heavy rains caused a flash flood in Barangay Bulanit, Municipality of Labangan, Zamboanga del Sur, which resulted to two (2) missing individuals namely, Paharodin Tinggalong, 20, and Lacmodin Tinggalong, 16. The victims were fishing near the boundary of the river when the strong current brought about by the flash flood destroyed their boat making them fall into the water (NDRRMC Update Sept. 23 – 29, 2015).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LABANGAN 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 Labangan Floodplain in Zamboanga Del Sur. The missions were planned for 20 lines that run for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plans and base stations for Labangan Floodplain.
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Table 1. Flight planning parameters for Pegasus LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Max Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK19A	1000	30	50	125	50	130	5
BLK19B	1000	30	50	125	50	130	5
BLK19C	1000	30	50	125	50	130	5
BLK19D	1000	30	50	125	50	130	5
BLK19E	1000	30	50	125	50	130	5
BLK19G	1000	30	50	125	50	130	5
BLK19I	1000	30	50	125	50	130	5
BLK19S	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5
BLK19Q	1000	30	50	125	50	130	5

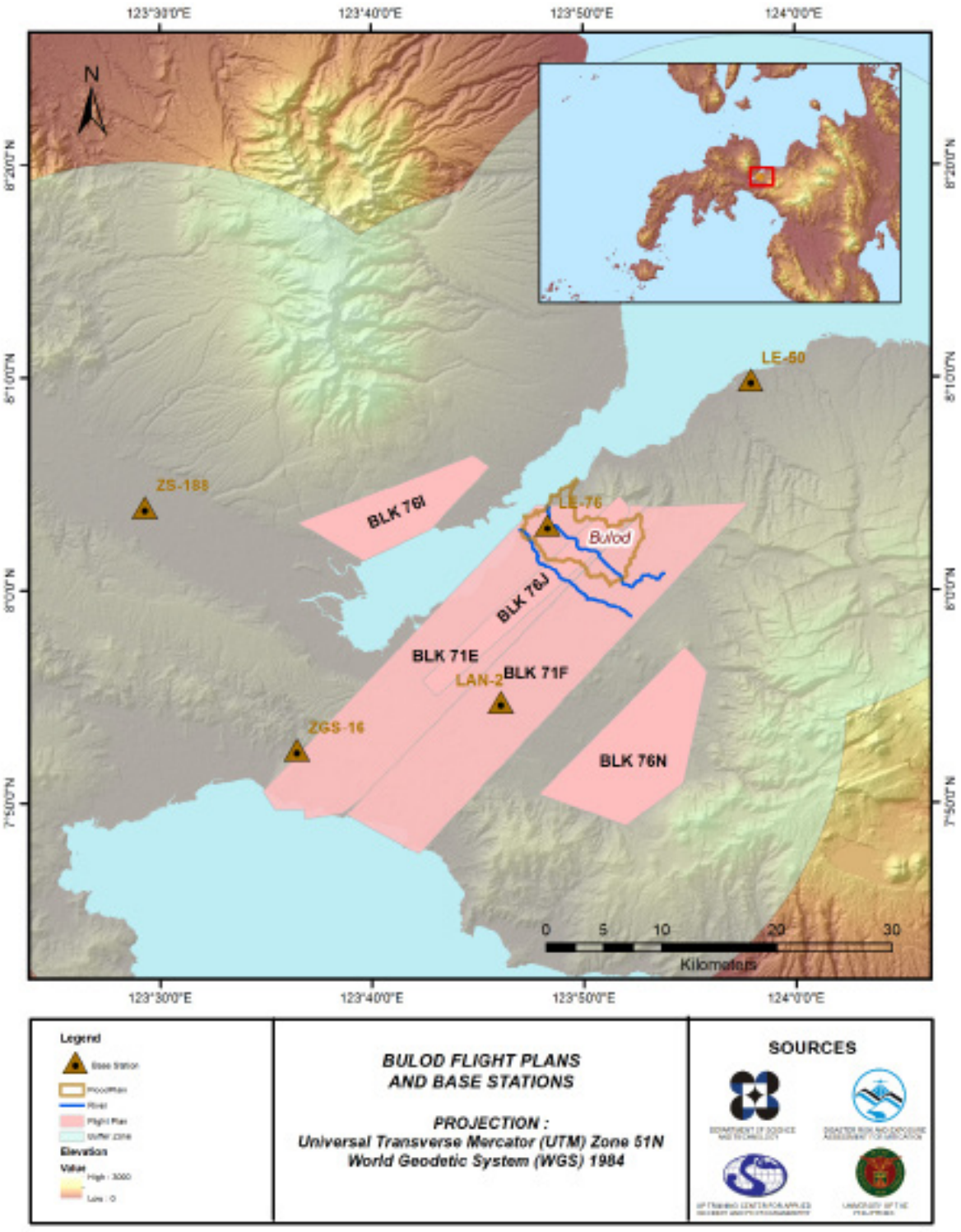


Figure 2. Flight plans and base stations used to cover Labangan Floodplain.

2.2 Ground Base Station

The project team was able to recover six (6) NAMRIA horizontal ground control points: LAN-2 and ZGS-1 which are of first (1st) order accuracy, and ZGS-16, ZGS-17, ZGS-68, and ZGS-89 which are of second (2nd) order accuracy. Four (4) NAMRIA benchmarks were recovered: LE-50, LE-76, ZS-188, and ZS-38. These benchmarks were used as vertical reference points and were also established as ground control points. The certifications for the NAMRIA reference points are found in Annex 2, while the processing reports for the NAMRIA benchmarks are found in Annex 3. These were used as base stations during the flight operation for the entire duration of the survey (June 4 – Oct 9, 2014, and February 7- March 3, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, TRIMBLESPS 985, and TOPCON-GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Labangan floodplain are shown in Figure 2.

Figure 3 to Figure 9 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 11 show the details about the NAMRIA control point and the established control point while Table 12 shows the list of all ground control points occupied during the acquisition together with corresponding dates of utilization.

(a)

(b)

Figure 3. GPS set-up over LAN-2 at Brgy. Pinoyak, Lala Lanao del Norte (a) and NAMRIA reference point LAN-2 (b) as recovered by the field team. .

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

Station Name	LAN-2	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°54'46.07859" North 123°46' 0.85333" East 17.35400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	364,025.74 meters 875,110.149 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°54'42.56546" North 123°46'6.31720" East 83.92120 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	584,533.45 meters 874,680.35 meters

(a)

(b)

Figure 4. GPS set-up of ZGS-1 at National Irrigation Administration (NIA) compound, Brgy. Dipolo, Molave, Zamboanga del Sur (a) and NAMRIA reference point ZGS-1 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-1 used as base station for the LiDAR data acquisition.

Station Name	ZGS-1	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	11:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°4'26.98334" North 123°29'14.53868" East 22.611 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	553,718.284 meters 892,784.790 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°04'23.40249" North 123°29'19.99013" East 88.163 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	553,699.48 meters 892,472.30 meters

(a) (b)

Figure 5. a) GPS set-up over ZGS-16 at Purok Nangka, Brgy. Baclay, Municipality of Tukuran, Zamboanga del Sur. b) NAMRIA reference point ZGS-16 as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point ZGS-16 used as base station for the LiDAR data acquisition.

Station Name	ZGS-16	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°52'35.53106" North 123°36'23.39905" East 18.178 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	566,881.259 meters 870,8554.959 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°52'29.01321" North 123°36'28.86762" East 84.42 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	566,857.85 meters 870,550.15 meters

(a)

(b)

Figure 6. GPS set-up over ZGS-68 at CENRO, Brgy. Poblacion, Municipality of Guipos, Zamboanga del Sur (a) and NAMRIA reference point ZGS-68 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ZGS-68 used as base station for the LiDAR data acquisition.

Station Name	ZGS-68	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°43'33.12722" North 123°18'488.96041" East 205.941 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	534,593.845 meters 854,250.138 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°43'29.62251" North 123°18'54.44472" East 271.748 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	534,581.74 meters 853,951.14 meters

(a)

(b)

Figure 7. GPS set-up over LE-50 at Barogohan Bridge and at the NE of the Covenant Baptist Church, Maigo, Lanao del Norte (a) and NAMRIA reference point LE-50 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA vertical control point LE-50 used as base station for the LiDAR Acquisition.

Station Name	LE-50	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°09'54.972" North 123°57'50.357" East 6.91 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°09'51.11024" North 123°57'55.36634" East 73.452 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	606,345.902 meters 902,577.426 meters

(a)

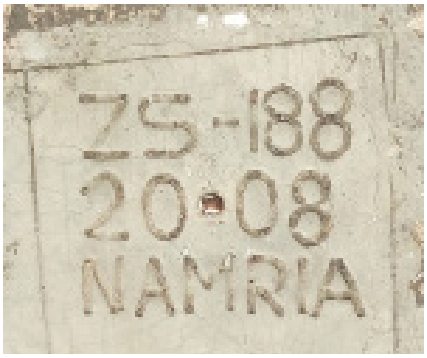
(b)

Figure 8. GPS set-up over LE-76 at Labangan Bridge footwalk of Brgy. Labangan, Tubud, Lanao del Norte (a) and NAMRIA reference point LE-76 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA vertical control point LE-76 used as base station for the LiDAR Acquisition.

Station Name	LE-76	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°03'05.36825" North 123°48'12.37307" East 9.355 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°03'01.82183" North 123°48'17.82405" East 75.717 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	588,530.790 meters 890,021.013 meters

(a)



(b)

Figure 9. GPS set-up over ZS-188 at Brgy. Licomo, Zamboanga City, Zamboanga del Sur (a) and NAMRIA reference point ZS-188 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA vertical control point ZS-188 used as base station for the LiDAR Acquisition.

Station Name	ZS-188	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°03'56.69408" North 123°29'12.15500" East 19.832 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°03'53.11537" North 123°29'17.60722" East 85.400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	553,627.634meters 891,542.089 meters

Table 9. Details of the recovered NAMRIA vertical control point LE-76 used as base station for the LiDAR Acquisition.

Station Name	ZGS-17	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°52'3342.71658" North 123°18'488.96041" East 29.684 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	567059.131 meters 871168.108 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°52'39.19831" North 123°36'34.68878" East 95.924 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	567035.66 meters 870863.18 meters

Table 10. Details of the recovered NAMRIA horizontal control point ZGS-89 used as base station for the LiDAR Acquisition.

Station Name	ZGS-89	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°57'04.32105" North 123°34'53.92221" East 254.447 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	564128.667 meters 879200.188 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°57'00.78119" North 123°34'59.38391" East 320.477 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	554106.22 meters 878892.45 meters

Table 11. Details of the recovered NAMRIA vertical control point ZS-38 used as base station for the LiDAR Acquisition.

Station Name	ZS-38	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°50'49.23365" North 123°28'40.92449" East 8.299 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°50'45.71176" North 123°28'46.38665" East 74.279 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	552,699.677 meters 867359.753 meters

Table 12. Ground Control points using LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
4-Jun-14	1549P	1BLK71D155A	LAN-2, LE-50
8-Jun-14	1565P	1BLK71B159A	LAN-2, LE-50
8-Jul-14	1685P	1BLK71S189A	LAN-2, LE-50
4-Jul-14	1689P	1BLK71S190A	LE-50, LE-76
29-Oct-14	2137P	1BLK70D302A	ZGS-89, ZS-38
7-Feb-16	23064P	1BLK76EF038A	ZGS-1, ZS-188
9-Feb-16	23072P	1BLK76EF040A	ZGS-1, ZS-188
9-Feb-16	23074P	1BLK76EFH040B	ZGS-1, ZS-188
10-Feb-16	23076P	1BLK76GH041A	ZGS-1, ZS-188
10-Feb-16	23078P	1BLK76DI041B	ZGS-1, ZS-188
11-Feb-16	23082P	1BLK76CDE042B	ZGS-68
12-Feb-16	23084P	1BLK76JKLM043A	ZGS-16, ZS-188
14-Feb-16	23092P	1BLK76GHI045A	ZGS-1, ZS-188
16-Feb-16	23100P	1BLK76EFG047A	ZGS-1, ZS-188
17-Feb-16	23104P	1BLK76DKLM048A	ZGS-16, ZS-188
23-Feb-16	23128P	1BLK70B054A	ZGS-17
1-Mar-16	23156P	1BLK76QR061A	ZGS-16, ZGS-17
2-Mar-16	23160P	1BLK76S062A	ZGS-16, ZGS-68
3-Mar-16	23164P	1BLK76T063A	ZGS-16, ZGS-68

2.3 Flight Missions

Nineteen (19) missions were conducted to complete the LiDAR Data Acquisition in Labangan Floodplain, for a total seventy-one hours and six minutes (71+6) of flying time for RP-C9022 and RP-C9122. The mission was acquired using the Pegasus LiDAR system. Table 13 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 14 presents the actual parameters used during the LiDAR data acquisition.

Table 13. Flight Missions for LiDAR Data Acquisition in Labangan 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
4-Jun-14	1549P	258.45	315.62	0.12	315.50	NA	4	24
8-Jun-14	1565P	258.45	117.70	0.00	117.70	324	2	53
8-Jul-14	1685P	258.45	238.03	0.00	238.03	569	4	5
4-Jul-14	1689P	247.57	299.01	25.69	273.32	NA	4	17
29-Oct-14	2137P	53.80	83.54	59.44	24.10	357	3	17
7-Feb-16	23064P	119.79	177.91	9.51	168.40	184	4	5
9-Feb-16	23072P	119.79	287.90	5.77	282.13	593	4	11
9-Feb-16	23074P	237.24	166.38	33.43	132.95	337	2	35
10-Feb-16	23076P	117.45	344.23	44.63	299.60	746	4	17
10-Feb-16	23078P	117.08	119.14	47.14	72.00	308	2	35
11-Feb-16	23082P	122.90	113.45	60.71	52.74	218	2	23
12-Feb-16	23084P	205.26	299.68	25.16	274.52	652	4	17
14-Feb-16	23092P	427.98	218.93	5.96	212.97	458	3	35
16-Feb-16	23100P	605.35	264.58	7.02	257.56	590	4	23
17-Feb-16	23104P	708.12	169.72	1.42	168.30	396	4	35
23-Feb-16	23128P	234.56	199.31	15.48	183.83	5	4	17
1-Mar-16	23156P	231.84	243.16	0.58	242.58	N/A	4	35
2-Mar-16	23160P	198.22	193.35	0.00	193.35	N/A	3	11
3-Mar-16	23164P	123.91	158.38	0.00	158.38	N/A	3	11
TOTAL		4646.21	4010.02	342.06	3667.96	3667.98	71	6

Table 14. Actual Parameters used during LiDAR Data Acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes
1549P	1000	30	50	200	32	130	5
1565P	1000	30	50	200	32	130	5
1685P	1000	30	50	200	32	130	5
1689P	1000	30	50	200	32	130	5
2137P	1000	30	50	200	32	130	5
23064P	1000	30	50	200	32	130	5
23072P	1000	30	50	200	32	130	5
23074P	1000	30	50	200	32	130	5
23076P	1000	30	50	200	32	130	5
23078P	1000	30	50	200	32	130	5
23082P	1000	30	50	200	32	130	5
23084P	1000	30	50	200	32	130	5
23092P	1000	30	50	200	32	130	5
23100P	1000	30	50	200	32	130	5
23104P	1000	30	50	200	32	130	5
23128P	1000	30	50	200	32	130	5
23156P	1000	30	50	200	32	130	5
23160P	1000	30	50	200	32	130	5
23164P	1000	30	50	200	32	130	5

2.4 Survey Coverage

Labangan floodplain is in the province of Zamboanga del Sur, with majority of the floodplain situated in the municipality of Labangan. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage is shown in Table 15. In Figure 9, the actual coverage of the LiDAR acquisition for Labangan floodplain is shown.

Table 15. List of municipalities and cities surveyed during Daraga Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City	Surveyed Area (km^2)	Percentage of Area Surveyed
Lanao del Norte	Lala	125.18	120.99	96.65%
	Kolambugan	70.7	63.48	89.79%
	Baroy	62.08	49.62	79.92%
	Kapatagan	184.77	138.33	74.87%
	Tubod	121.94	79.69	65.35%
	Baloi	65.18	40.74	62.50%
	Salvador	46.46	27.6	59.41%
	Magsaysay	83.06	42.03	50.61%
	Sapad	65.13	23.43	35.98%
	Sultan Naga Di-maporo	143.65	43.59	30.35%
	Pantar	50.19	9.7	19.32%
	Tagoloan	25.06	4.02	16.06%
	Linamon	22.21	2.99	13.45%
	Maigo	126.36	10.81	8.56%
	Pantao Ragat	71.36	4.94	6.92%
	Matungao	52.5	3.43	6.53%
	Poona Piagapo	88.11	5.26	5.97%
	Iligan City	650.87	23.63	3.63%
	Nunungan	418.22	9.91	2.37%
	Tangcal	118.94	2.32	1.95%
Misamis Occidental	Tangub City	141.82	48.21	34.00%
	Bonifacio	103.87	32.93	31.71%
	Ozamis City	149.44	2.75	1.84%
Zamboanga del Norte	Sergio Osmena Sr.	461.22	36.43	7.90%
Zamboanga del Sur	Tukuran	119.01	118.95	99.95%
	San Pablo	104.09	103.71	99.63%
	Aurora	162.22	161.42	99.51%
	Ramon Mag-saysay	92.84	83.99	90.47%
	Mahayag	175.97	153.93	87.47%
	Tambulig	142.93	120.79	84.51%
	Dumalinao	108.64	90.94	83.70%
	Dinas	168.43	131.7	78.20%
	Molave	61.24	42.56	69.50%
	Labangan	176.44	118.25	67.02%
	Sominot	97.75	64.41	65.89%
	Pagadian City	279.33	172.68	61.82%
	Guipos	96.96	36.78	37.93%
	Dumingag	318.87	105.29	33.02%
	San Miguel	93.38	26.53	28.41%
	Midsalip	285.12	2.67	0.94%
TOTAL		3329.64	1006.77	30.24%

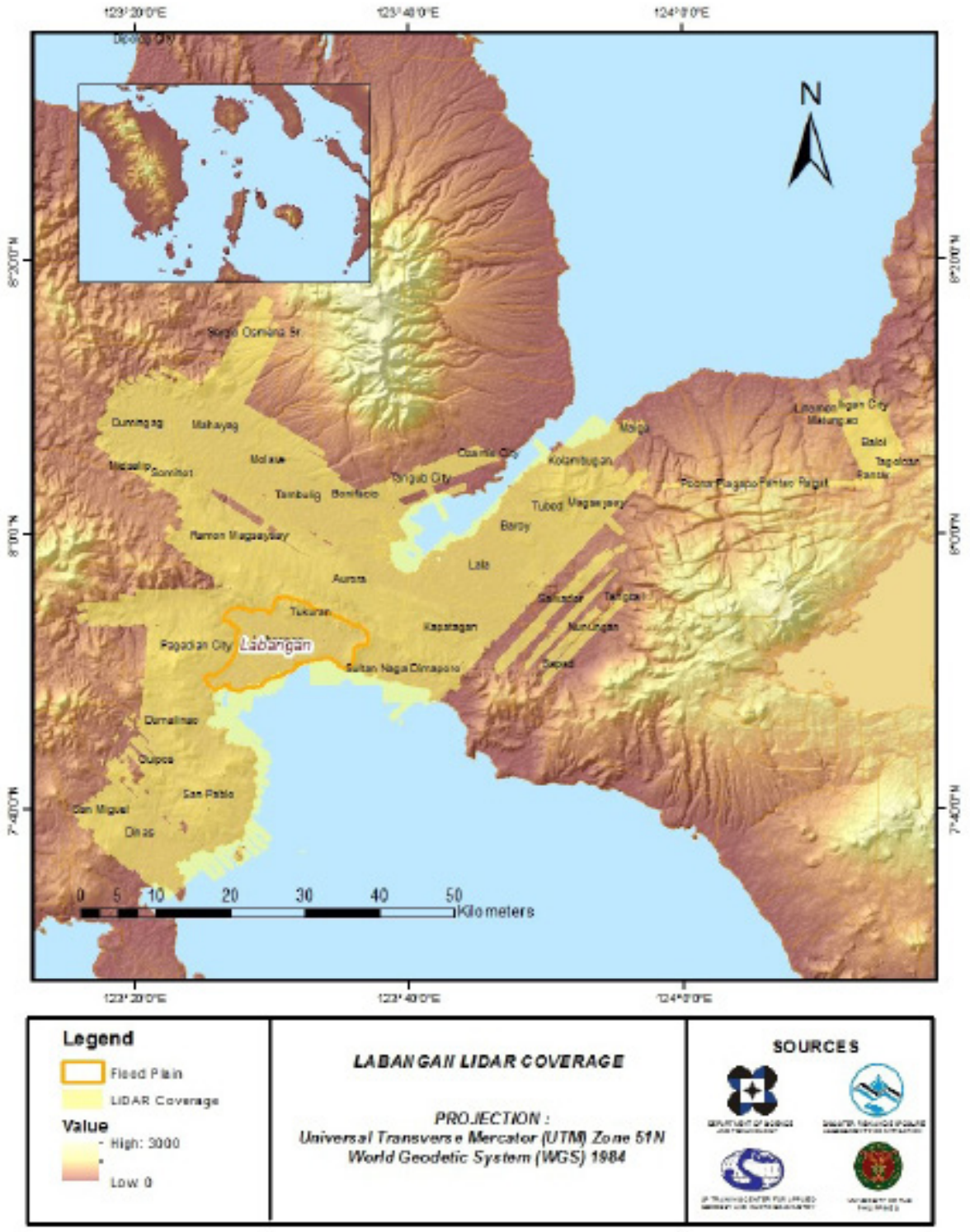


Figure 10. Actual LiDAR data acquisition for Labangan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LABANGAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models are calibrated. Portions of the river that are barely penetrated by the LiDAR system are replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 11.

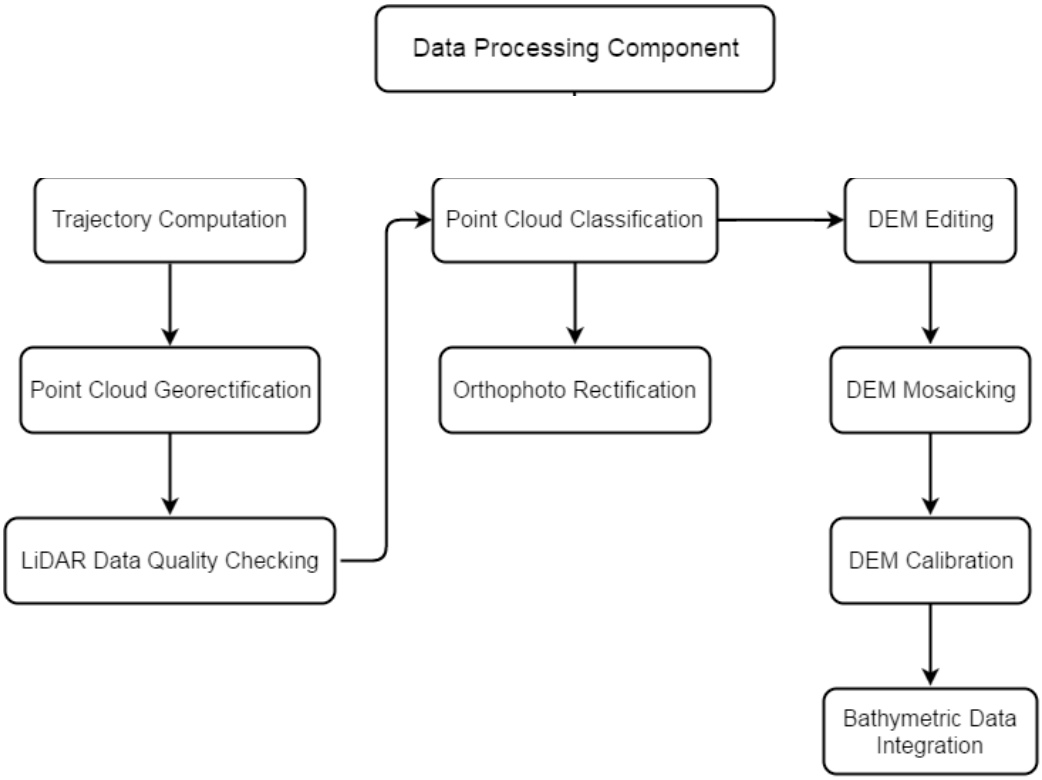


Figure 11. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Labangan floodplain can be found in Annex 5. Missions flown during the 5 surveys conducted on June 2014 and July 2014 over Northern Mindanao, October 2014 over Dipolog, February 2016 and March 2016 over Pagadian were flown using the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. The Data Acquisition Component (DAC) transferred a total of 407.26 Gigabytes of Range data, 4.42 Gigabytes of POS data, 1.49 Gigabytes of GPS base station data, and 376.81 Gigabytes of raw image data to the data server on June 23, 2014 for the first survey, August 6, 2014 for the second survey, November 19, 2014 for the third survey, February 26, 2016 for the fourth survey and March 16, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Labangan was fully transferred on March 16, 2016, as indicated on the Data Transfer Sheets for Labangan floodplain

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23064P, one of the Labangan flights, which is the North, East, and Down position RMSE values are shown in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 7, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

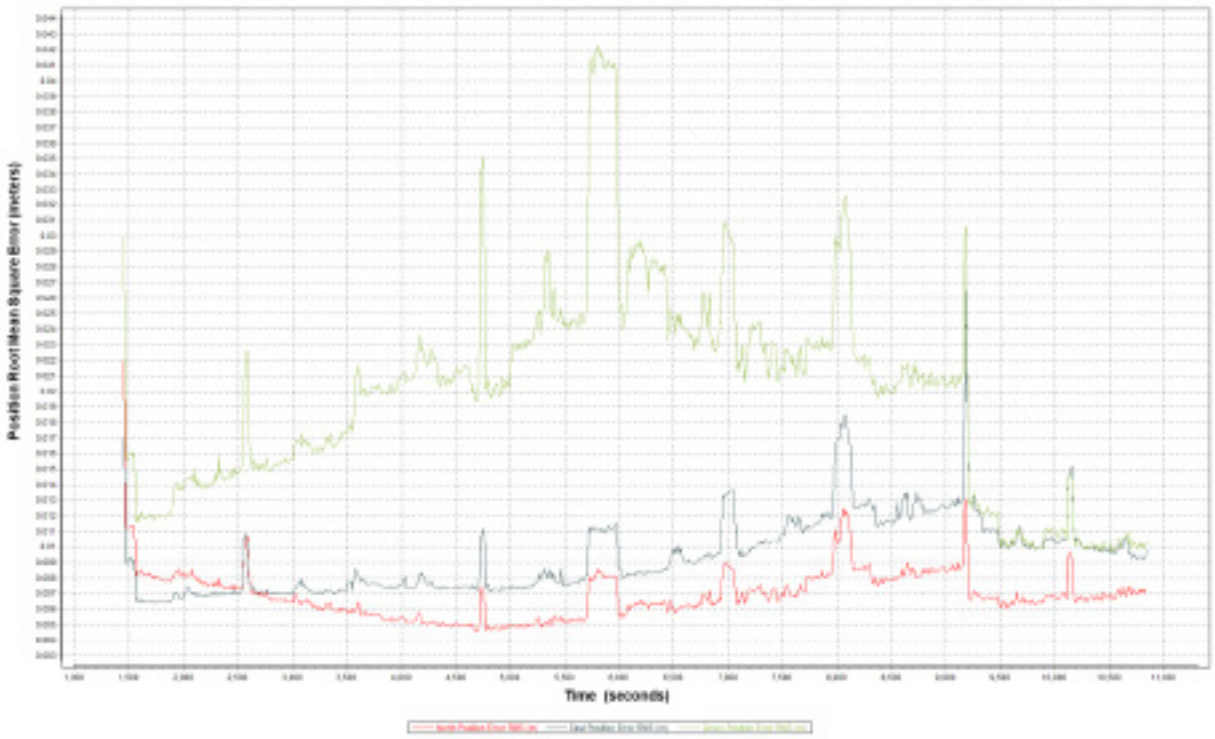


Figure 12. Smoothed Performance Metrics of Labangan Flight 23064P

The time of flight was from 1400 seconds to 10700 seconds, which corresponds to afternoon of February 7, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 12 shows that the North position RMSE peaks at 2.20 centimeters, the East position RMSE peaks at 1.80 centimeters, and the Down position RMSE peaks at 4.20 centimeters, which are within the prescribed accuracies described in the methodology.

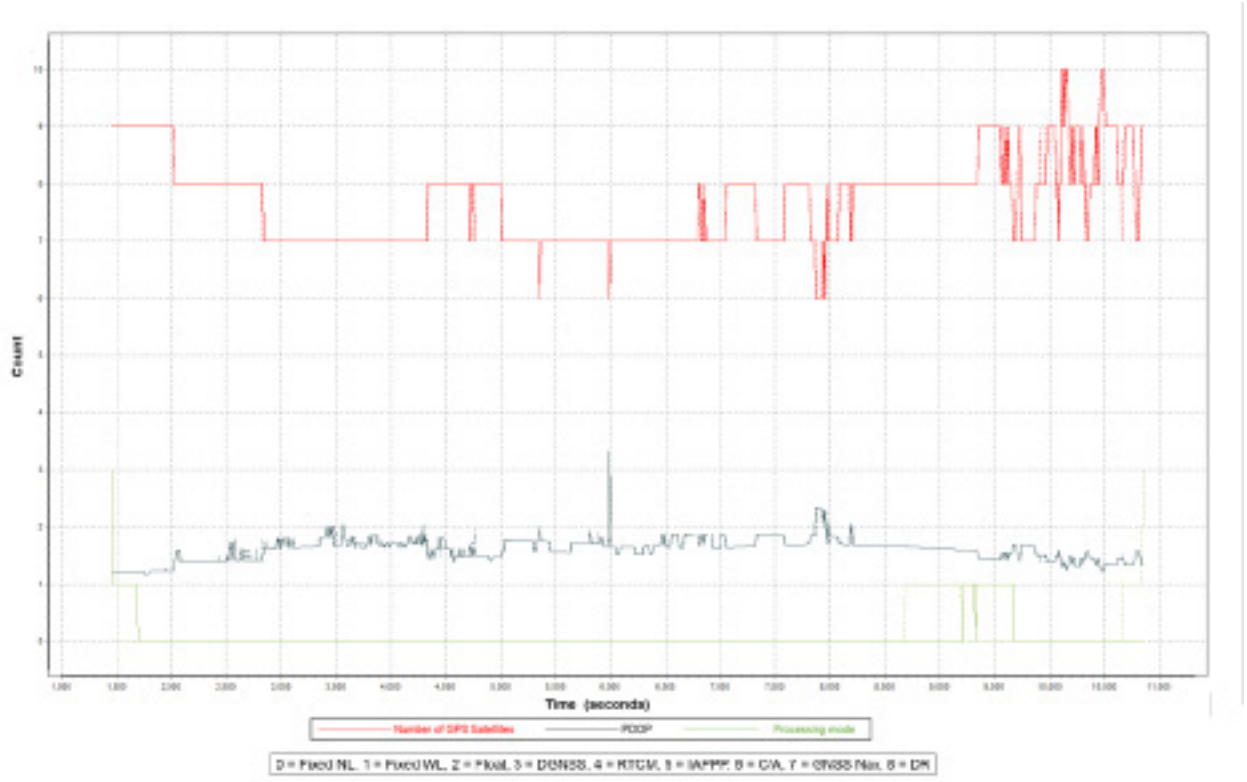


Figure 13. Solution Status Parameters of Labangan Flight 23064P.

The Solution Status parameters of flight 23064P, one of the Labangan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Labangan flights is shown in Figure 14.

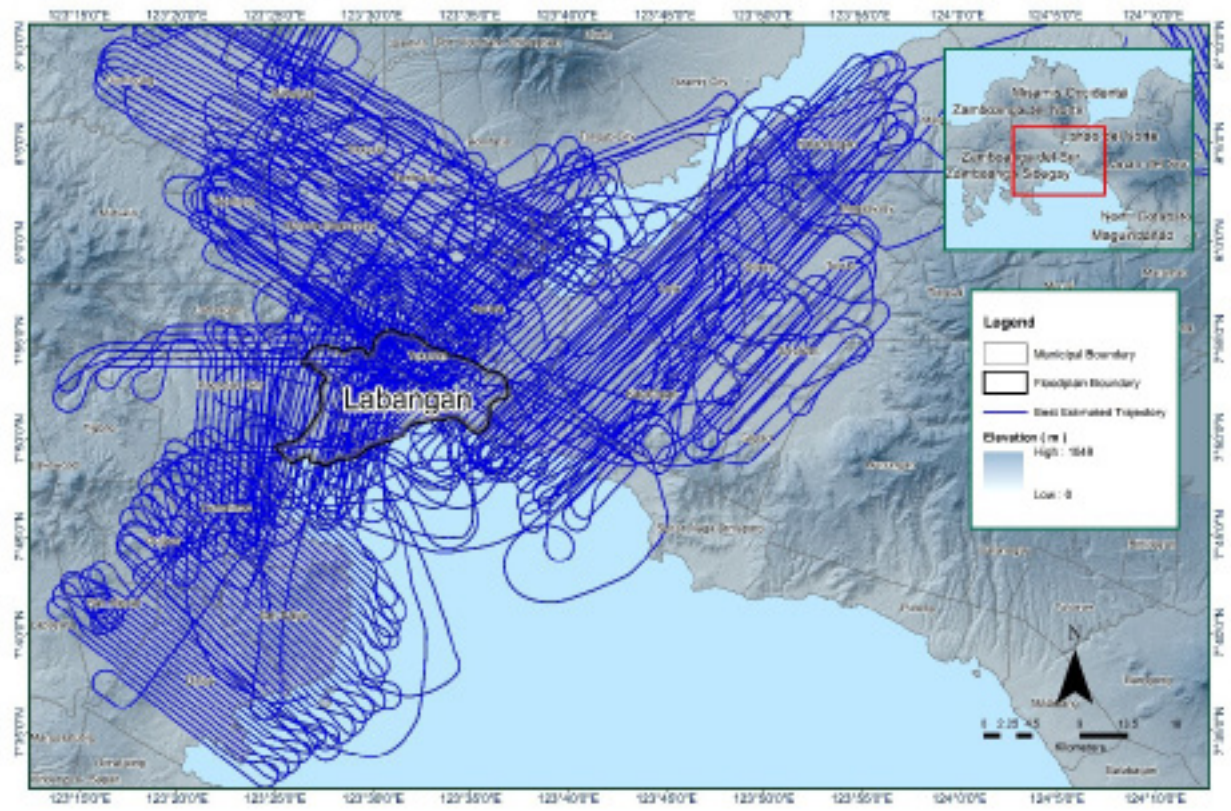


Figure 14. Best Estimated Trajectory for Labangan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 262 flight lines, with each flight line containing two channels, since the Pegasus system contain two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Labangan floodplain are given in Table 16.

Table 16. Self-Calibration Results values for Labangan flights.

Parameter		Value
Boresight Correction stdev	(<0.001degrees)	0.000176
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000599
GPS Position Z-correction stdev	(<0.01meters)	0.0014

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

3.5 LiDAR Data Quality Checking

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

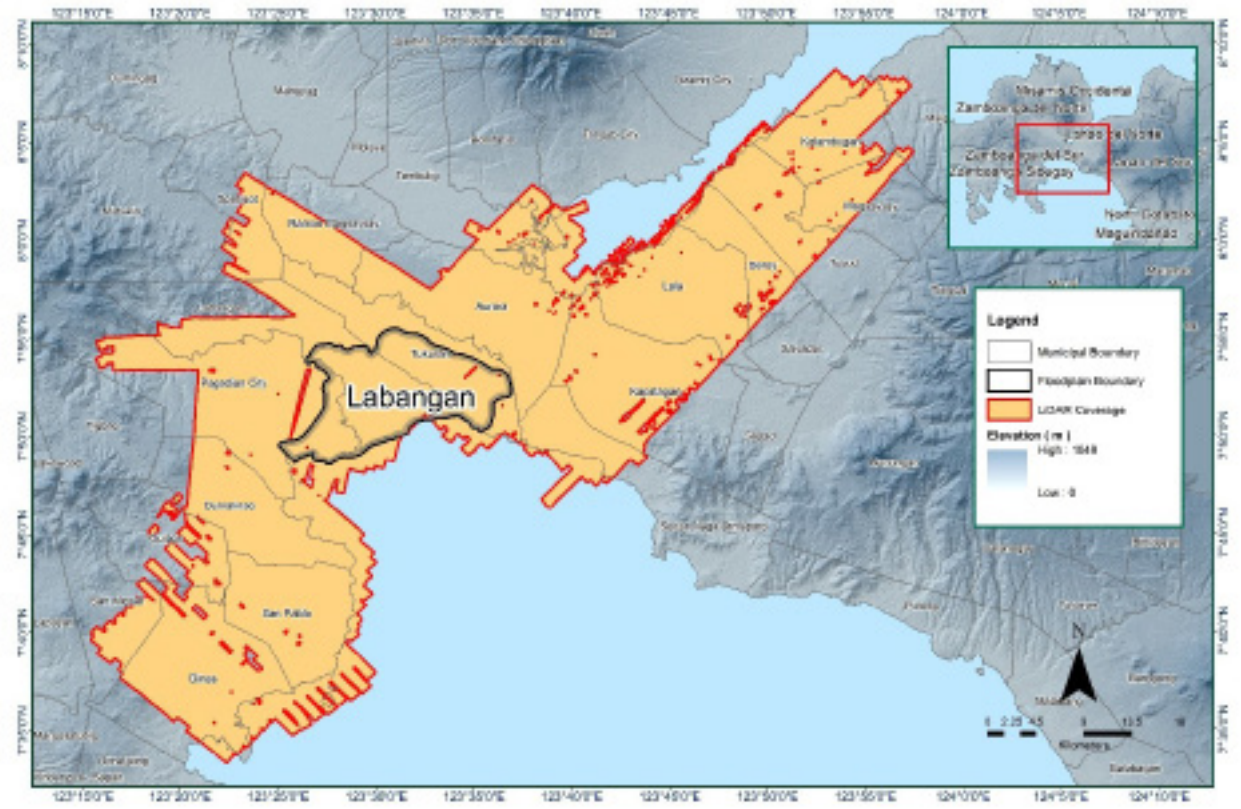


Figure 15. Boundary of the processed LiDAR data over Labangan Floodplain

The total area covered by the Labangan missions is 2380.38 sq.km that is comprised of nineteen (19) flight acquisitions grouped and merged into twelve (12) blocks as shown in Table 17.

Table 17. List of LiDAR blocks for Labangan floodplain.

LiDAR Blocks	Area (sq.km)	Area (sq.km)
Pagadian_Blk76C	23082P	122.87
	23084P	
Pagadian_Blk76D	23078P	82.06
Pagadian_Blk76D_additional	23104P	38.36
Pagadian_Blk76D_supplement	23082P	62.88
Pagadian_Blk76E	23074P	155.99
	23076P	
	23092P	
Pagadian_Blk76E_additional	23100P	54.34
Pagadian_Blk76H	23074P	197.53
	23076P	
	23092P	
Pagadian_Blk76H_supplement	23128P	128.15
Pagadian_Blk76K	23084P	182.99
Pagadian_Blk76T	23164P	138.76
Pagadian_Blk76S	23160P	189.82
Pagadian_Blk76R	23156P	156.56
Pagadian_Blk76Q	23156P	100.34
Dipolog_Blk70D	2137P	75.06
NorthernMindanao_Blk71E	1689P	194.58
NorthernMindanao_Blk71F	1565P	500.1
	1549P	
	1685P	
	TOTAL	**2380.39 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 16. Since the Pegasus system employ two channels, we would expect 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.

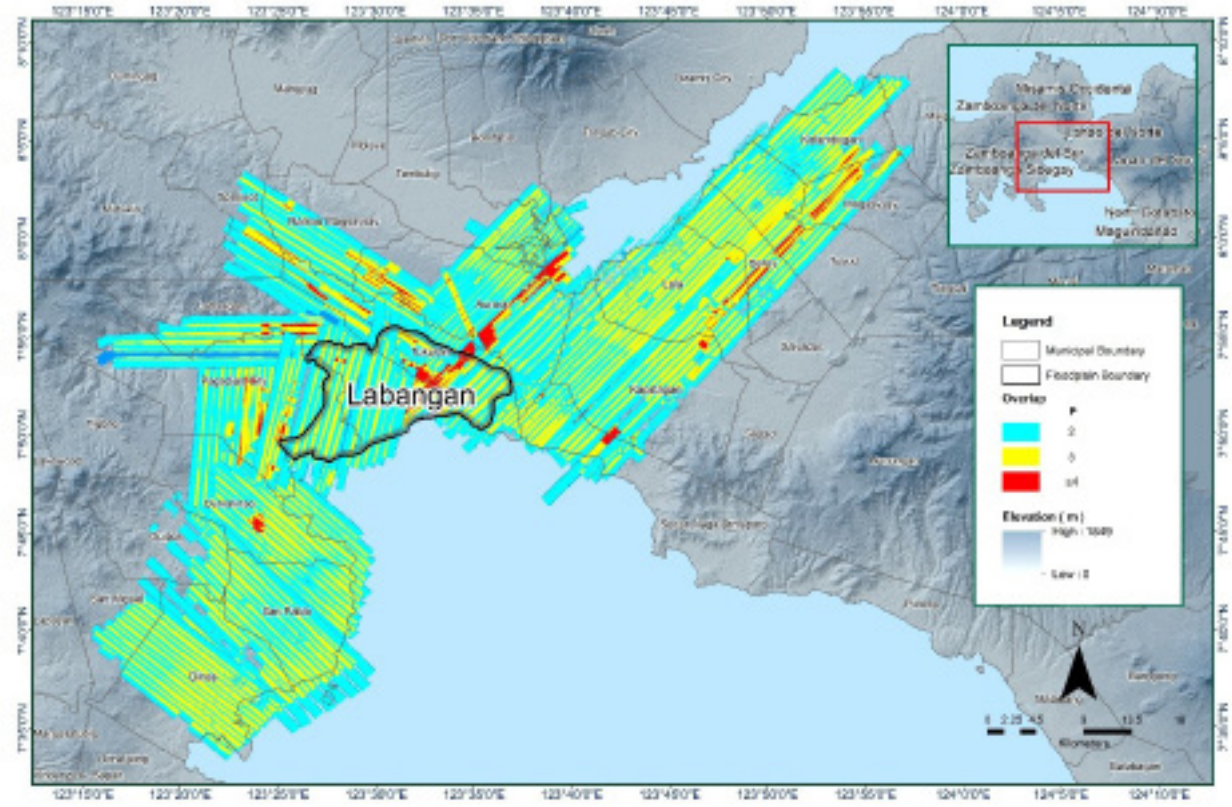


Figure 16. Image of data overlap for Labangan floodplain.

The overlap statistics per block for the Labangan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 32.91% and 51.29% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 17. It was determined that all LiDAR data for Labangan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.35 points per square meter.

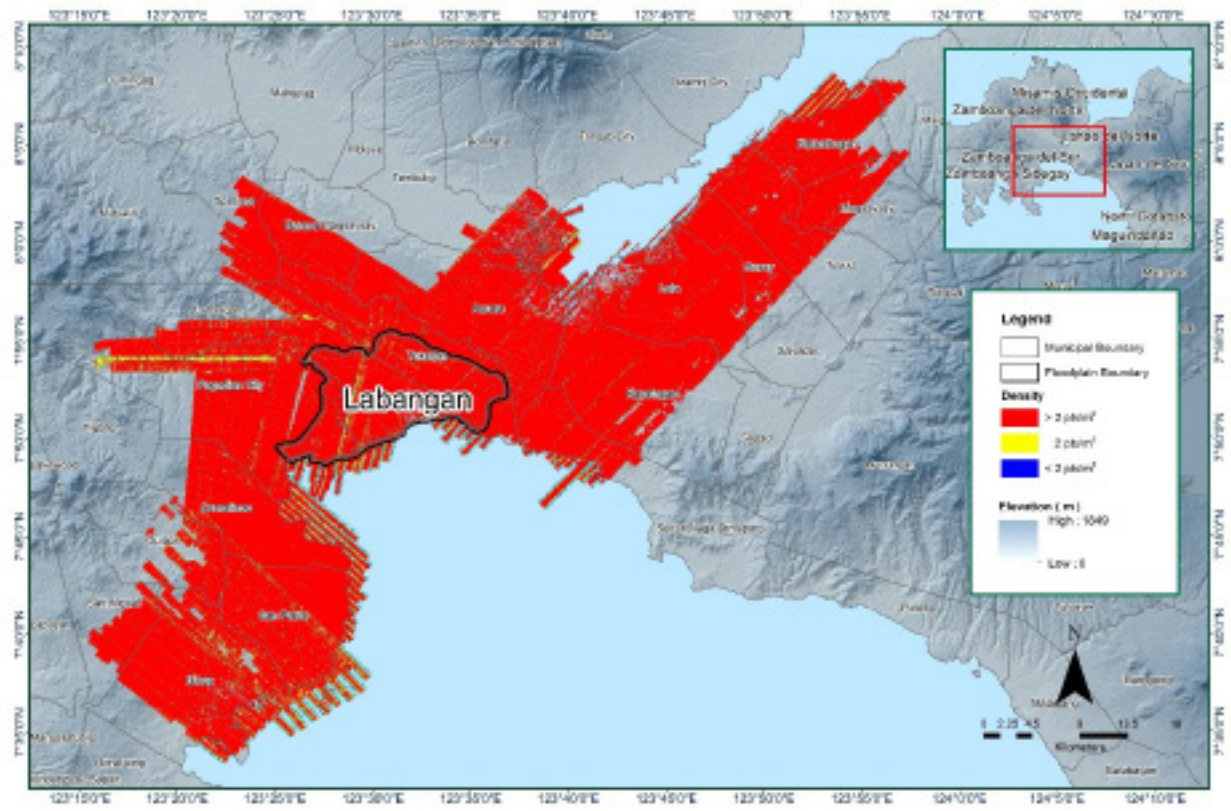


Figure 17. Pulse density map of merged LiDAR data for Labangan floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

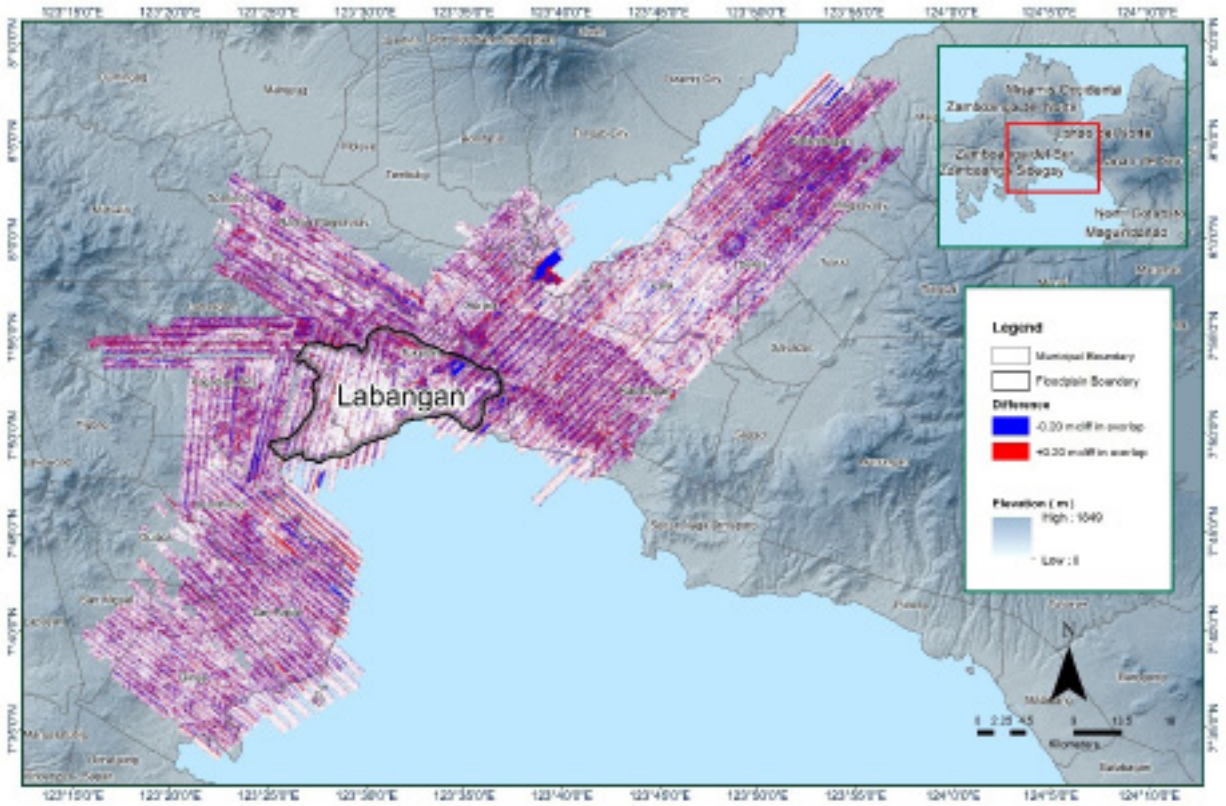


Figure 18. Elevation difference map between flight lines for Labangan floodplain.

A screen capture of the processed LAS data from a Labangan flight 23064P loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

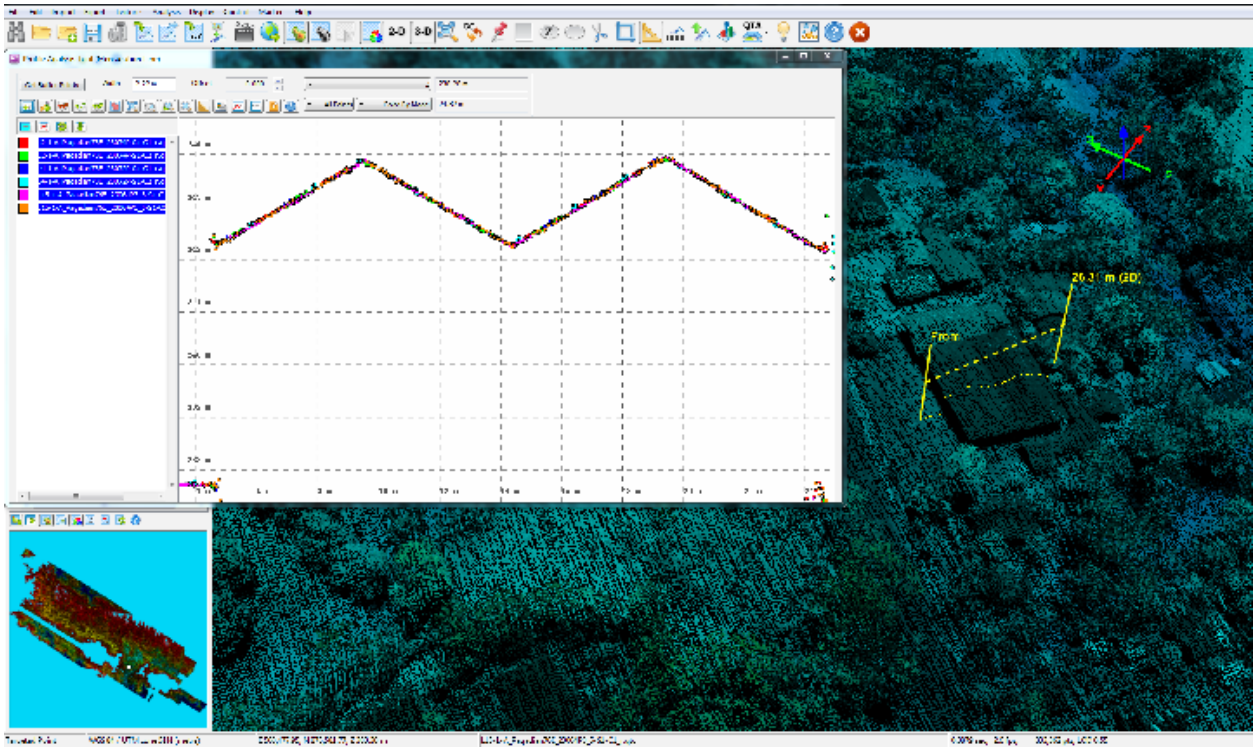


Figure 19. Quality checking for a Labangan flight 23064P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Computation

Table 18. Labangan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	3,106,188,193
Low Vegetation	2,223,738,984
Medium Vegetation	2,672,952,188
High Vegetation	5,367,660,599
Building	88,089,849

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Labangan floodplain is shown in Figure 20. A total of 3,142 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 18. The point cloud has a maximum and minimum height of 794.48 meters and 56.45 meters respectively.

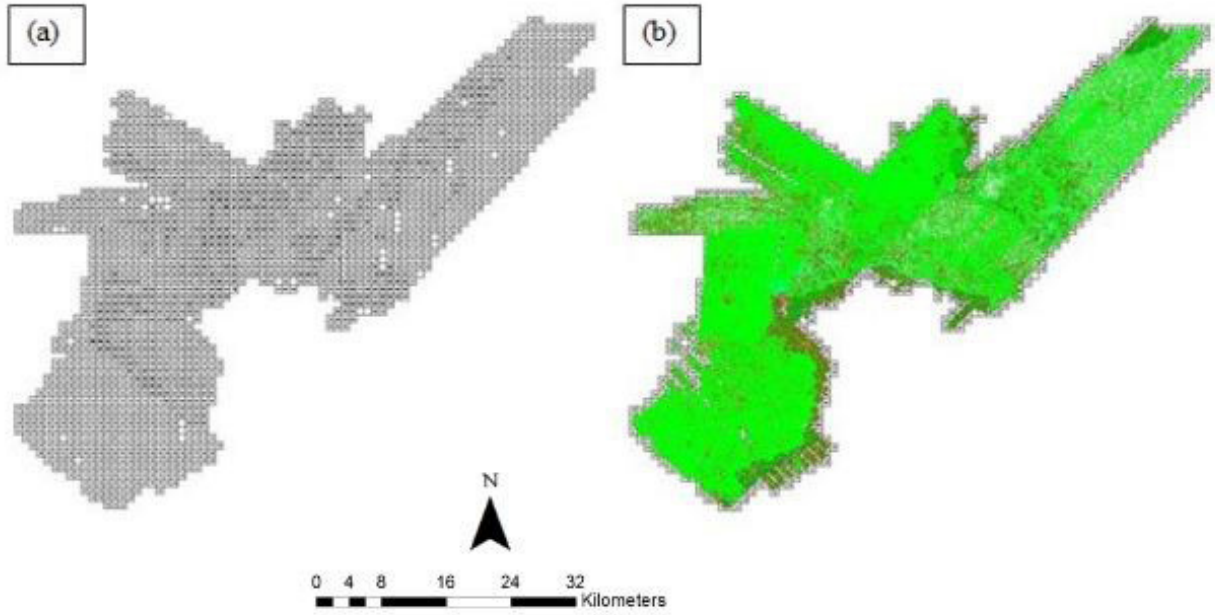


Figure 20. Tiles for Labangan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

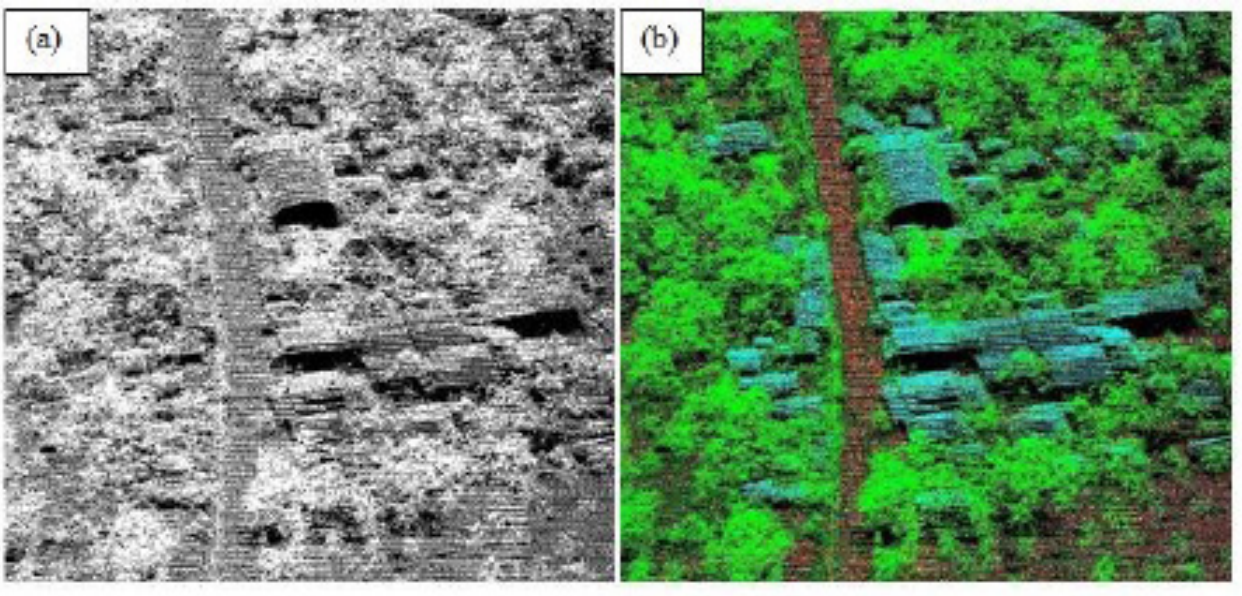


Figure 21. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 22. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

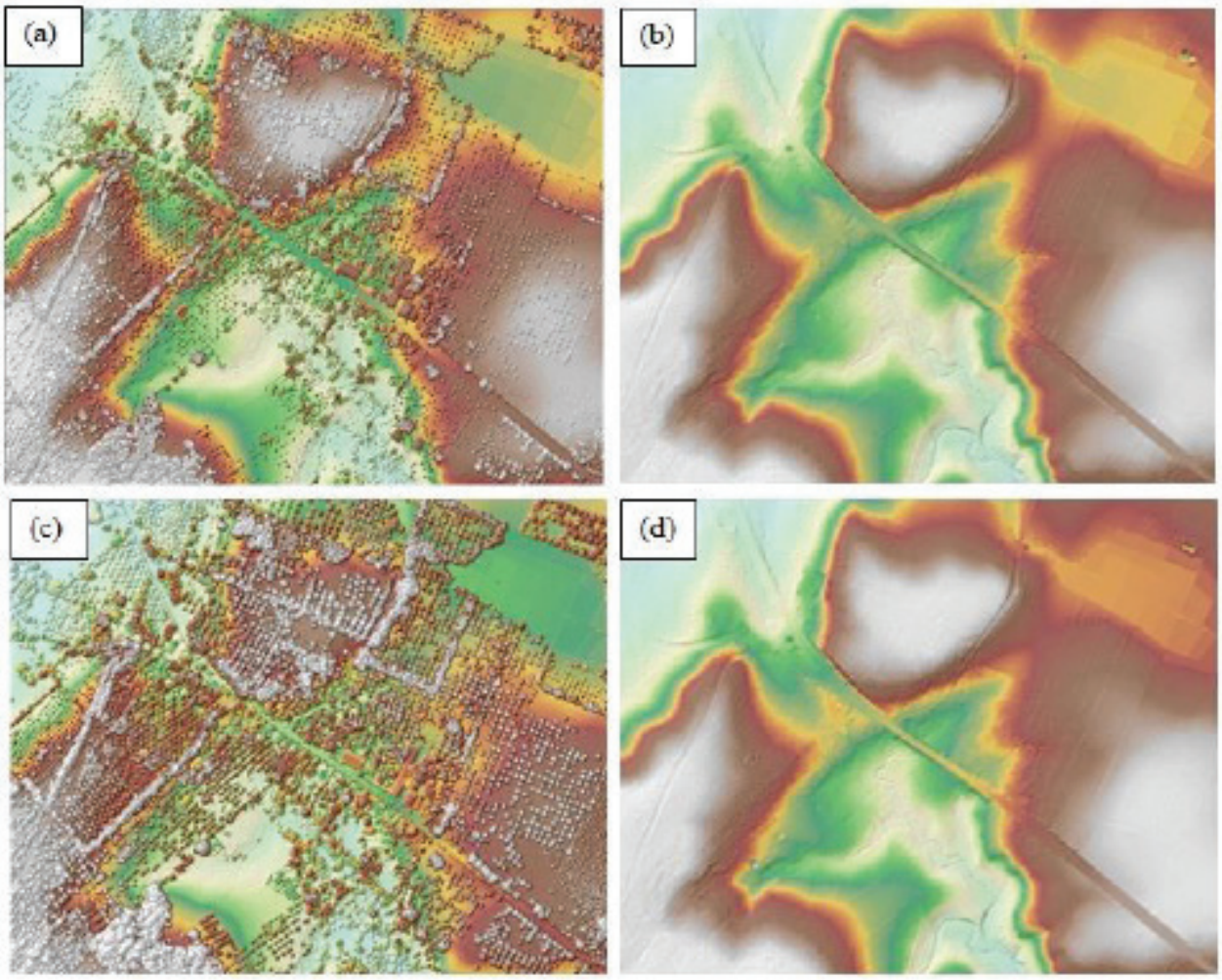


Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Labangan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,569 1km by 1km tiles area covered by Labangan floodplain is shown in Figure 23. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Labangan floodplain has a total of 797.22 sq.km orthophotogaph coverage comprised of 3,320 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 24.

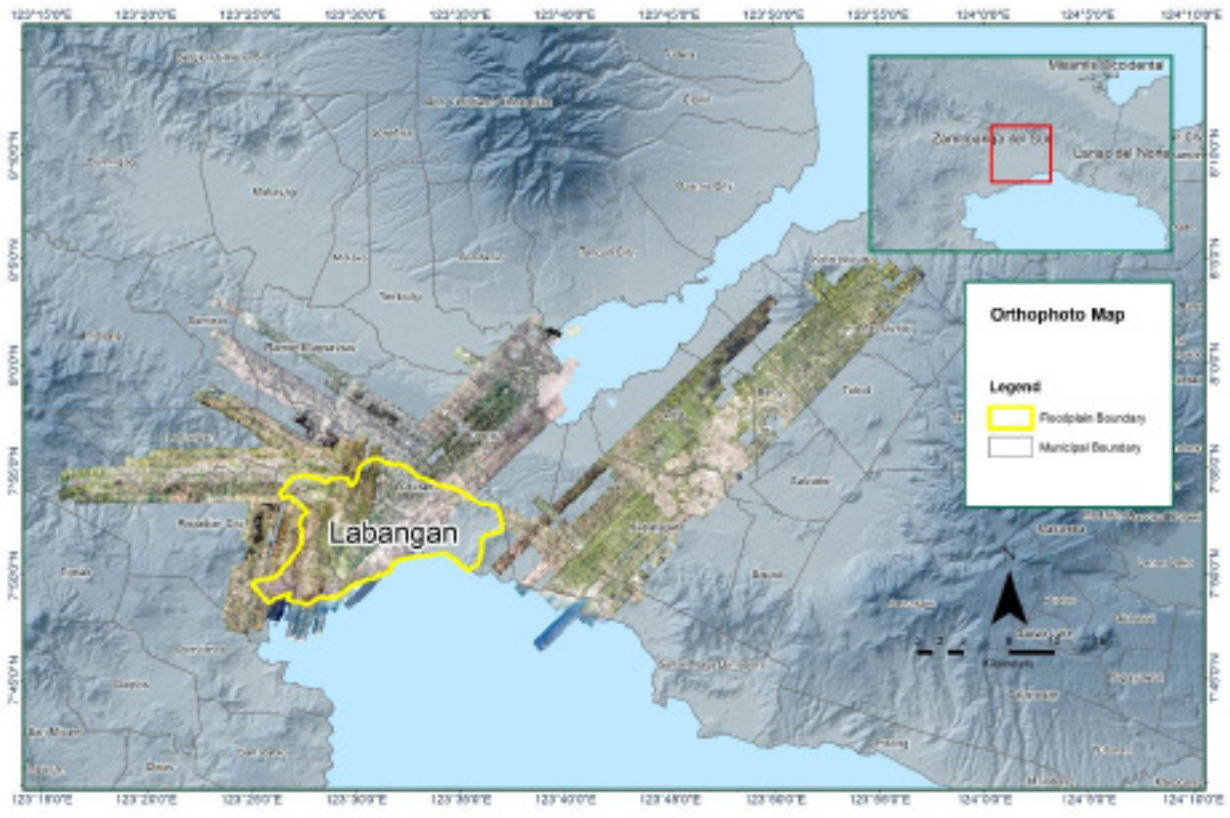


Figure 23. Labangan floodplain with available orthophotographs.

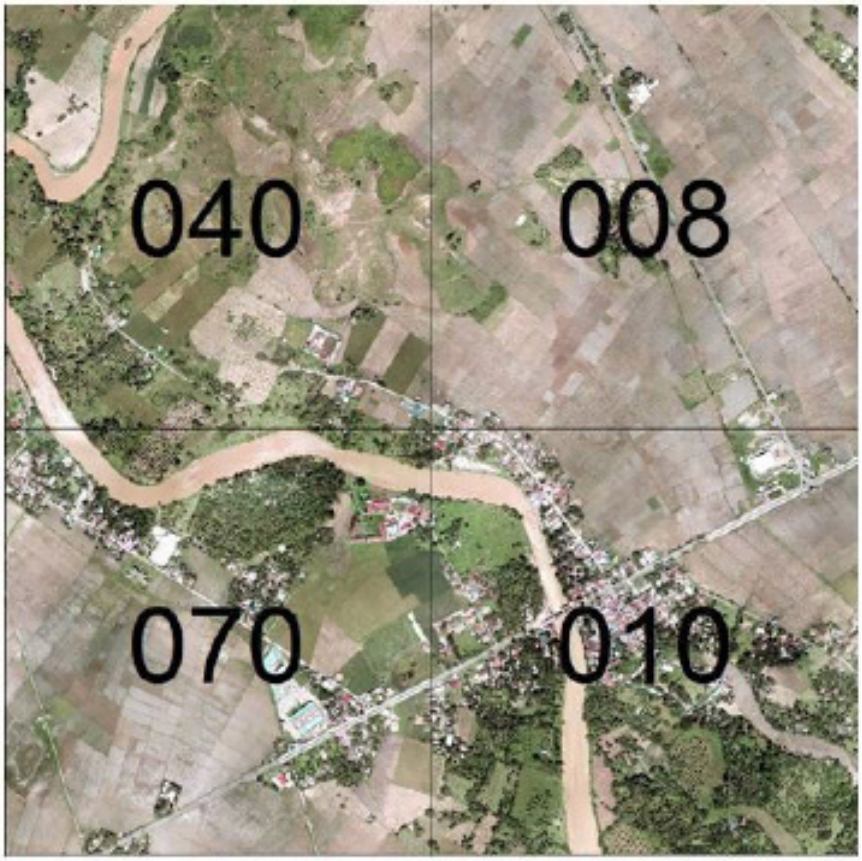


Figure 24. Sample orthophotograph tiles for Labangan floodplain.

3.8 DEM Editing and Hydro-Correction

Sixteen (16) mission blocks were processed for Labangan flood plain. These blocks are composed of Pagadian, Dipolog and NorthernMindanao blocks with a total area of 2380.39 square kilometers. Table 19 shows the name and corresponding area of each block in square kilometers.

Table 19. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Pagadian_Blk76C	122.87
Pagadian_Blk76D	82.06
Pagadian_Blk76D_additional	38.36
Pagadian_Blk76D_supplement	62.88
Pagadian_Blk76E	155.99
Pagadian_Blk76E_additional	54.34
Pagadian_Blk76H	197.53
Pagadian_Blk76H_supplement	128.15
Pagadian_Blk76K	182.99
Pagadian_Blk76T	138.76
Pagadian_Blk76S	189.82
Pagadian_Blk76R	156.56
Pagadian_Blk76Q	100.34
Dipolog_Blk70D	75.06
NothernMindanao_Blk71E	194.58
NothernMindanao_Blk71F	500.10
TOTAL	**2380.39 sq.km**

Portions of DTM before and after manual editing are shown in Figure 25. The bridge (Figure 25a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 25b) in order to hydrologically correct the river. The river embankment (Figure 25c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 25d) to allow the correct flow of water.

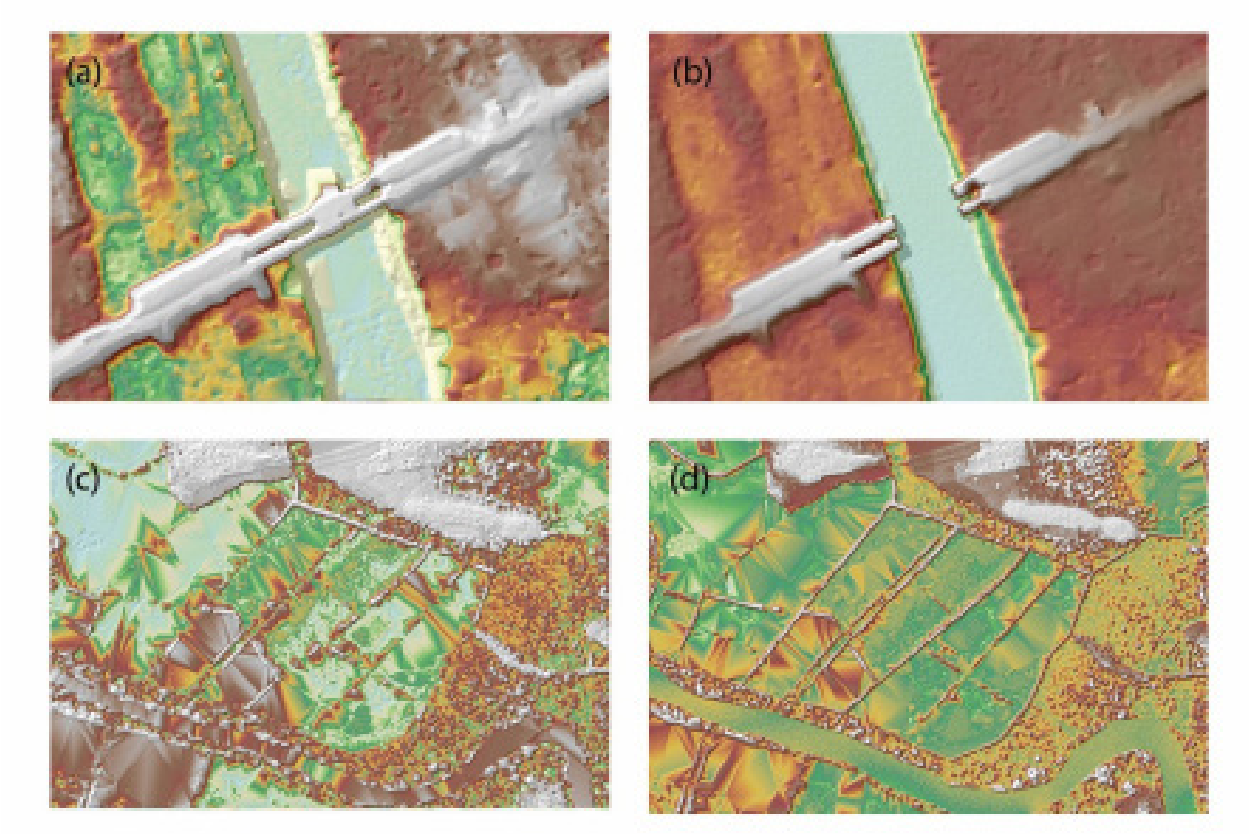


Figure 25. Portions in the DTM of Labangan floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

NorthernMindanao_Blk71E was used as the reference block at the start of mosaicking because it is already vertically calibrated to MSL and it overlaps Pagadian_Blk76H which is the largest DTM of Labangan river basin. Table 20 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Labangan floodplain is shown in Figure 26. It can be seen that the entire Labangan floodplain is 99.80% covered by LiDAR data.

Table 20. Shift Values of each LiDAR Block of Labangan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	Z
Pagadian_Blk76C	0.30	0.10	0.00
Pagadian_Blk76D	-0.10	0.00	0.56
Pagadian_Blk76D_additional	-0.30	0.10	0.00
Pagadian_Blk76D_supplement	0.70	0.15	0.41
Pagadian_Blk76E	0.20	0.50	0.41
Pagadian_Blk76E_additional	0.20	0.50	0.41
Pagadian_Blk76H	0.20	0.50	0.41
Pagadian_Blk76H_supplement	0.20	0.50	0.00
Pagadian_Blk76K	0.00	0.00	0.00
Pagadian_Blk76T	-0.80	-0.30	0.41
Pagadian_Blk76S	-0.90	0.10	0.41
Pagadian_Blk76R	-0.80	0.00	0.41
Pagadian_Blk76Q	-1.00	-0.10	0.41
Dipolog_Blk70D	-6.30	2.40	-6.90
NothernMindanao_Blk71E	0.00	0.00	-0.30
NothernMindanao_Blk71F	0.00	0.00	-0.30

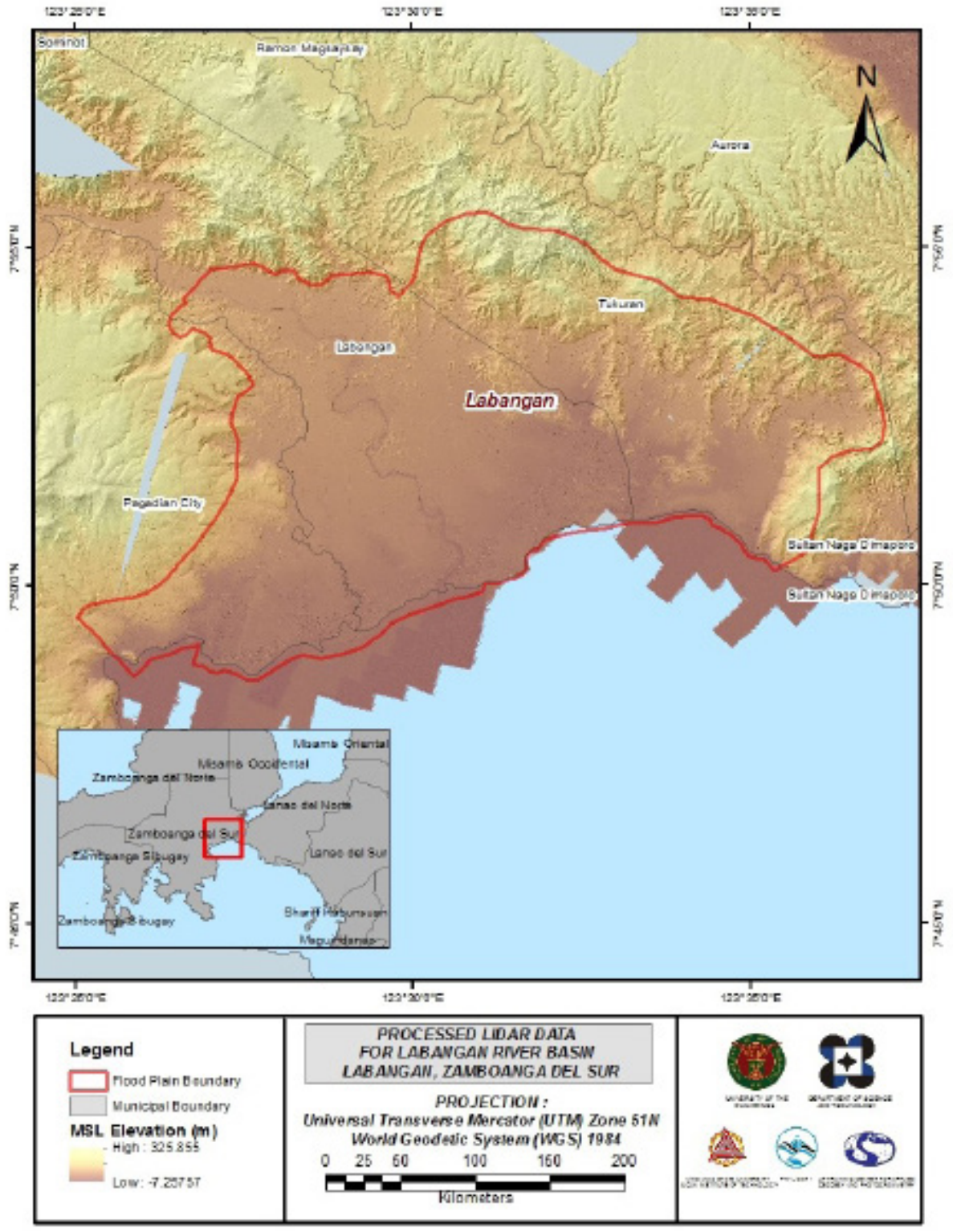


Figure 26. Map of Processed LiDAR Data for Labangan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Labangan to collect points with which the LiDAR dataset is validated is shown in Figure 27. A total of 28,494 survey points were used for calibration and validation of Labangan LiDAR data. Random selection of 80% of the survey points, resulting to 22,795 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 28. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.23 meters with a standard deviation of 0.20 meters. Calibration of Labangan LiDAR data was done by adding the height difference value, 0.23 meters, to Labangan mosaicked LiDAR data. Table 21 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

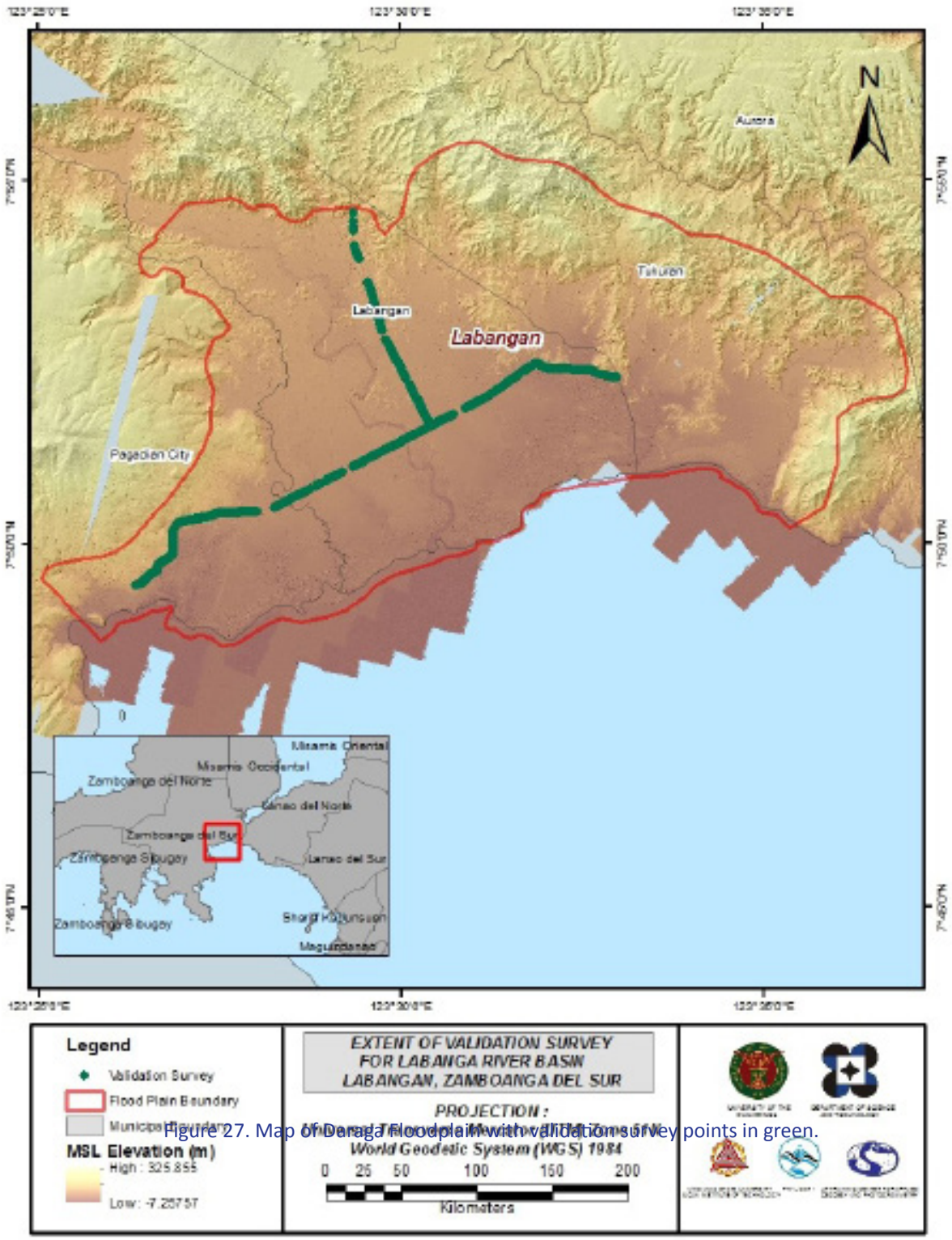


Figure 27. Map of Daraga Floodplain with validation survey points in green.

Figure 27. Map of Labangan Flood Plain with validation survey points in green.

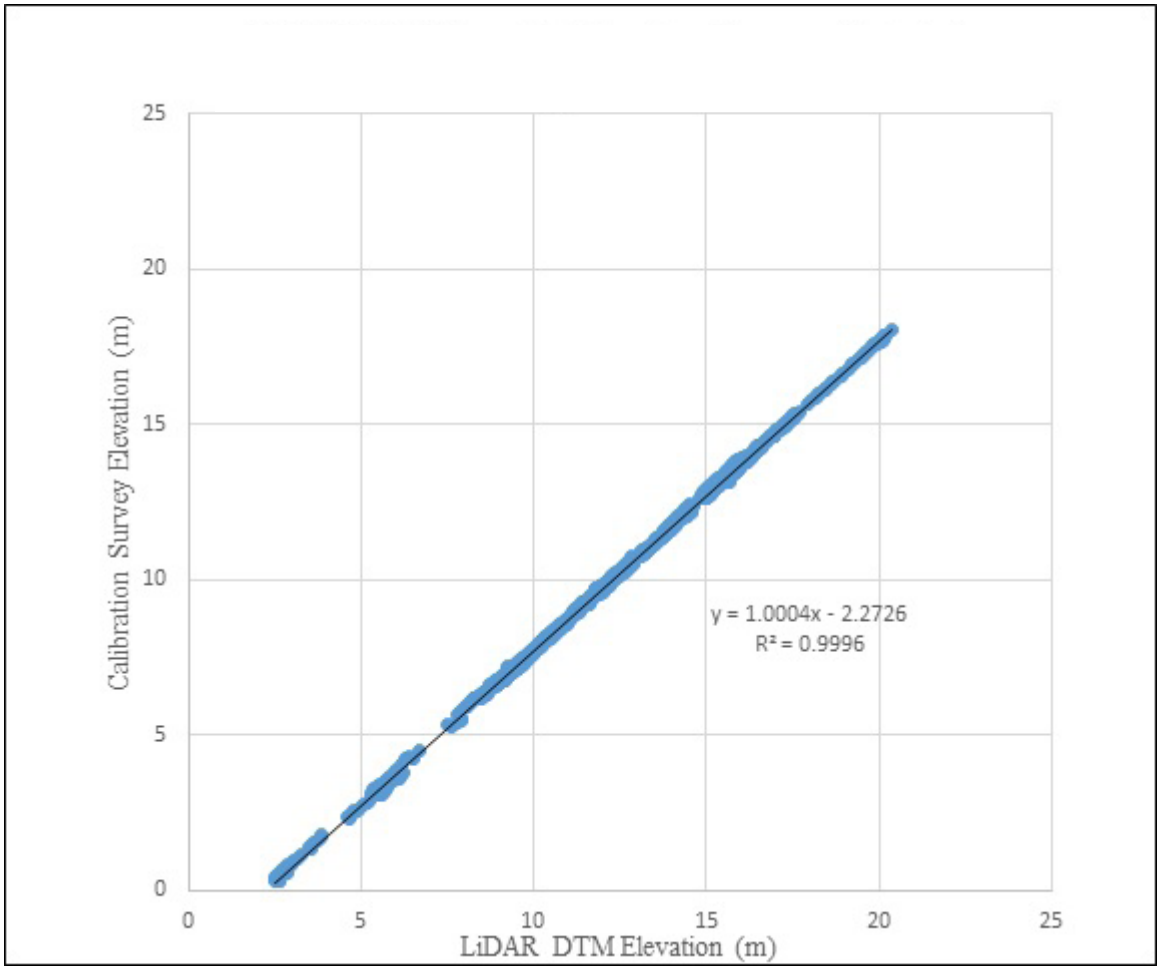


Figure 28. Correlation plot between calibration survey points and LiDAR data.

Table 21. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.23
Standard Deviation	0.20
Average	0.10
Minimum	-0.33
Maximum	0.53

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 195 points. These were used for the validation of calibrated Labangan 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 29. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.20 meters, as shown in Table 22.

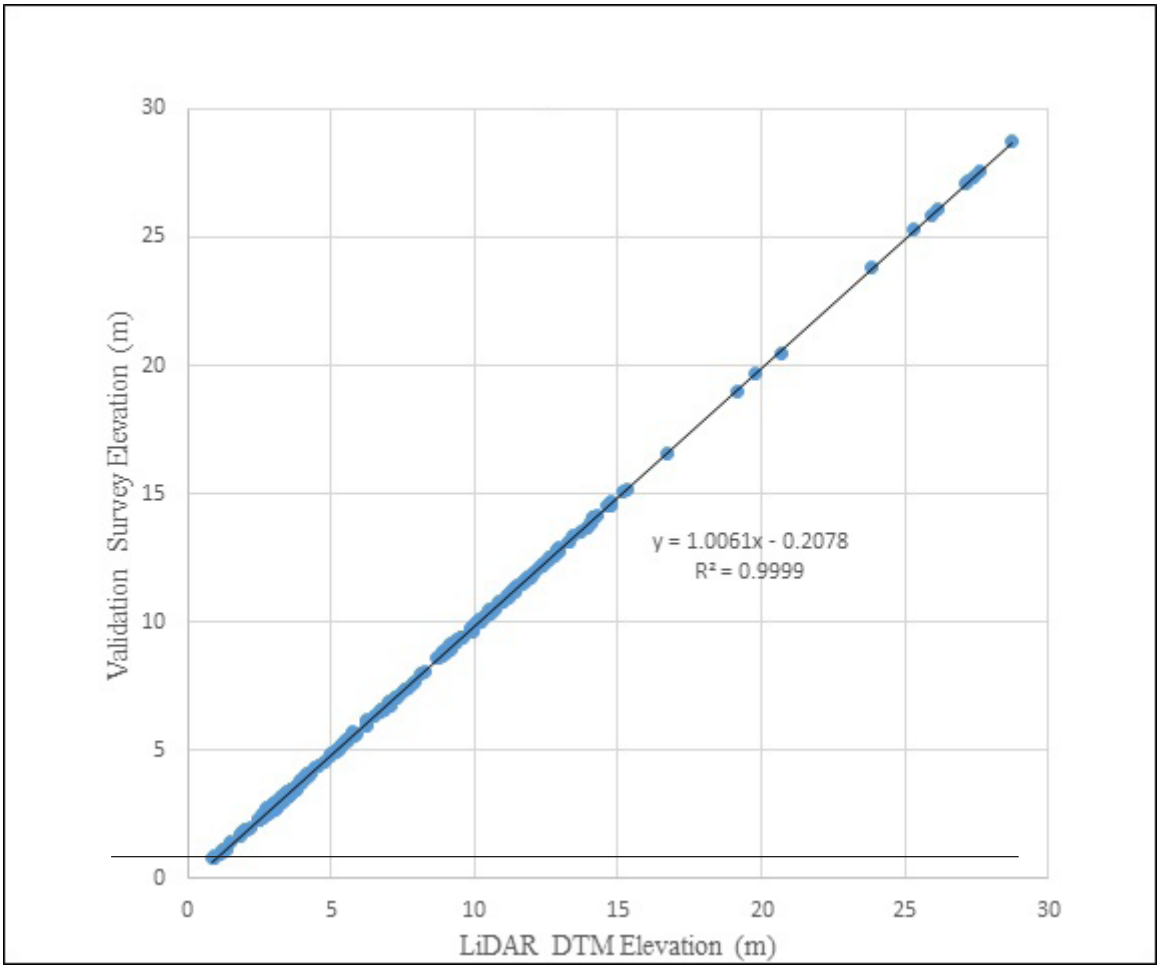


Figure 29. Correlation plot between validation survey points and LiDAR data

Table 22. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.20
Average	0.06
Minimum	-0.20
Maximum	0.35

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Labangan with 15,474 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.26 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Labangan integrated with the processed LiDAR DEM is shown in Figure 30.

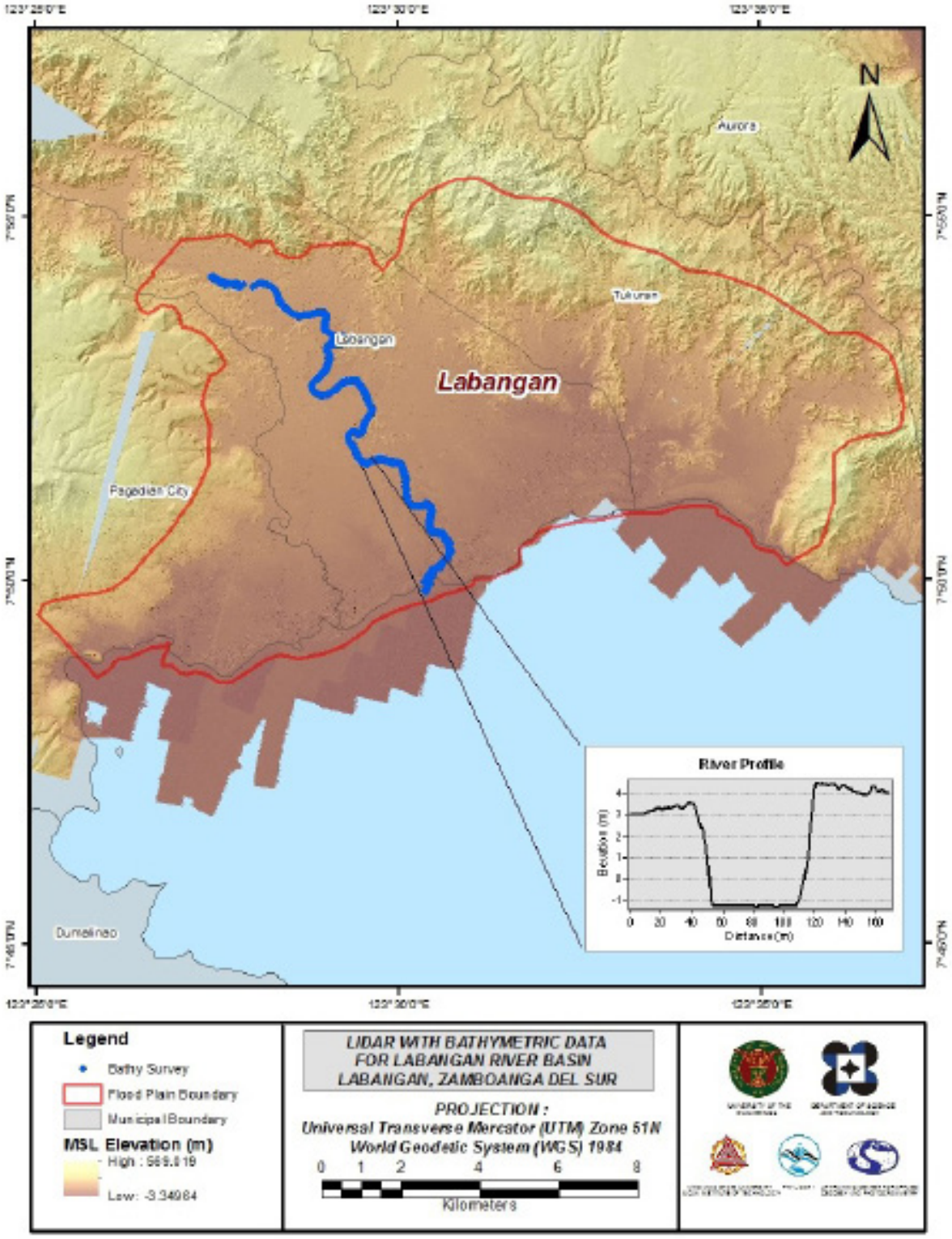


Figure 30. Map of Labangan Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Labangan floodplain, including its 200 m buffer, has a total area of 164.29 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 2488 building features, are considered for QC. Figure 31 shows the QC blocks for Labangan floodplain.

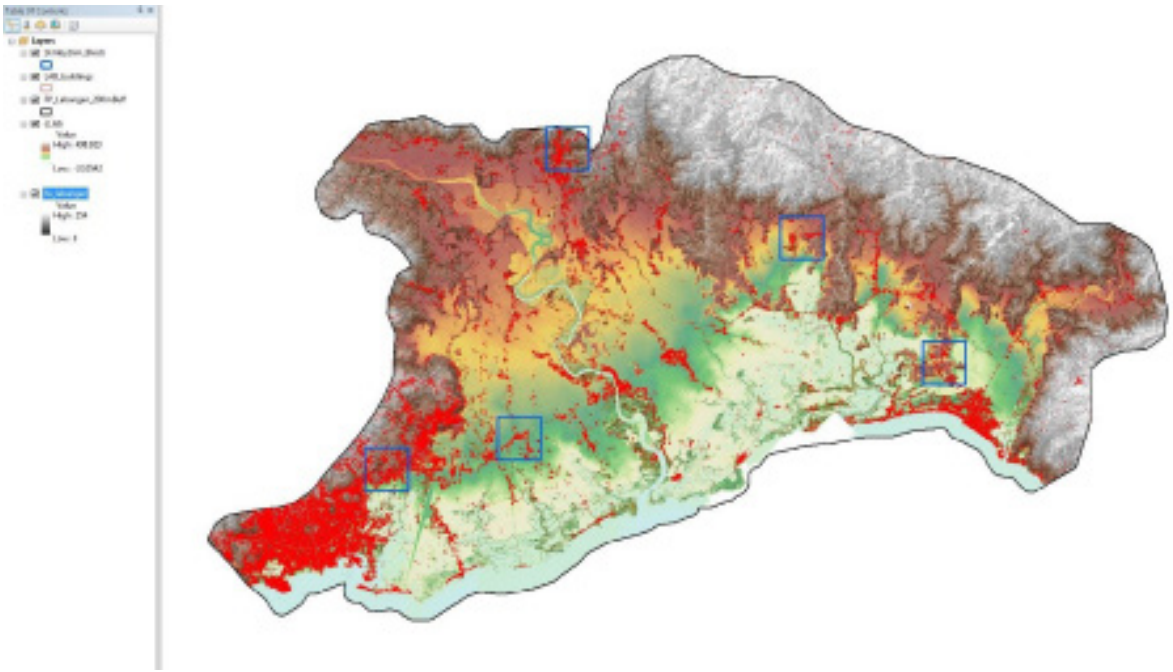


Figure 31. QC blocks for Labangan building features.

Quality checking of Labangan building features resulted in the ratings shown in Table 23.

Table 23. Quality Checking Ratings for Labangan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Labangan	97.60	98.19	82.64	PASSED

3.12.2 Height Extraction

Height extraction was done for 45,925 building features in Labangan floodplain. Of these building features, 1,062 was filtered out after height extraction, resulting to 44,863 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 21.01 m.

3.12.3 Feature Attribution

Labangan floodplain is shared by three (3) municipalities namely the municipality of Labangan, municipality of Tukuran and Pagadian City. The building attribution on Pagadian City and on the municipalities of Labangan and Tukuran 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 24 summarizes the number of building features per type. On the other hand, Table 25 shows the total length of each road type, while Table 26 shows the number of water features extracted per type.

Table 24. Building Features Extracted for Labangan Floodplain.

Facility Type	No. of Features
Residential	42629
School	552
Market	38
Agricultural/Agro-Industrial Facilities	82
Medical Institutions	57
Barangay Hall	61
Military Institution	5
Sports Center/Gymnasium/Covered Court	28
Telecommunication Facilities	3
Transport Terminal	11
Warehouse	109
Power Plant/Substation	0
NGO/CSO Offices	4
Police Station	4
Water Supply/Sewerage	5
Religious Institutions	275
Bank	25
Factory	8
Gas Station	17
Fire Station	1
Other Government Offices	293
Other Commercial Establishments	656
Total	**44,863**

Table 25. Total Length of Extracted Roads for Labangan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Labangan	80.05	74.25	15.81	29.73	0.00	**199.84**

Table 26. Number of Extracted Water Bodies for Labangan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Labangan	41	0	0	0	1	**42**

A total of 64 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 32 shows the Digital Surface Model (DSM) of Labangan floodplain overlaid with its ground features.

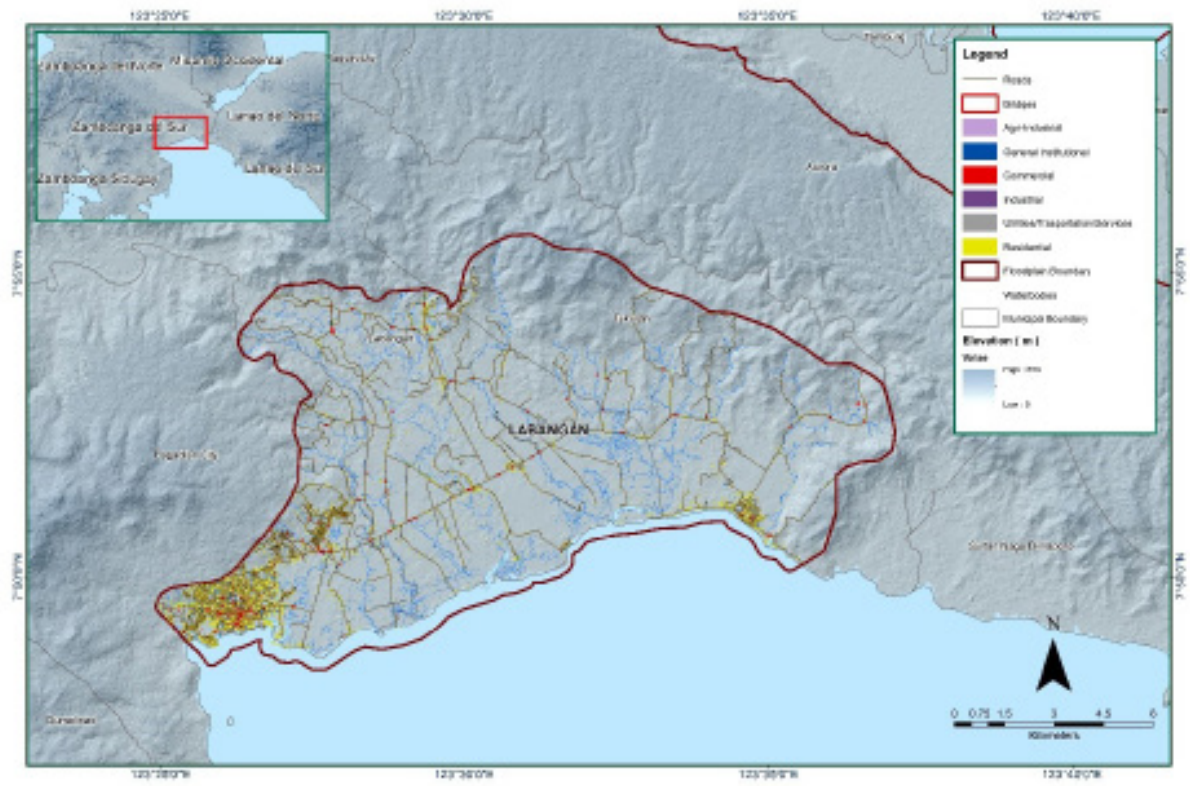


Figure 32. Extracted features for Labangan floodplain.

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

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

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

4.1 Summary of Activities

In line with this, the Data Validation and Bathymetry Component (DVBC) conducted survey in Labangan River on July 2-16, 2015 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section survey, bridge as-built determination and water level marking in MSL of Labangan Bridge and Hanging Bridge in Brgy. Sta Cruz; validation points acquisition of about 20.2 km; and bathymetric survey from Brgy. Bokong, Labangan, Zamboanga del Sur down to the mouth of the river in Brgy. Lower Sang-An, Labangan, Zamboanga del Sur with an estimated length of 15.73 km using an OHMEX™ Single Beam Echo Sounder and Trimble® GNSS PPK survey technique.

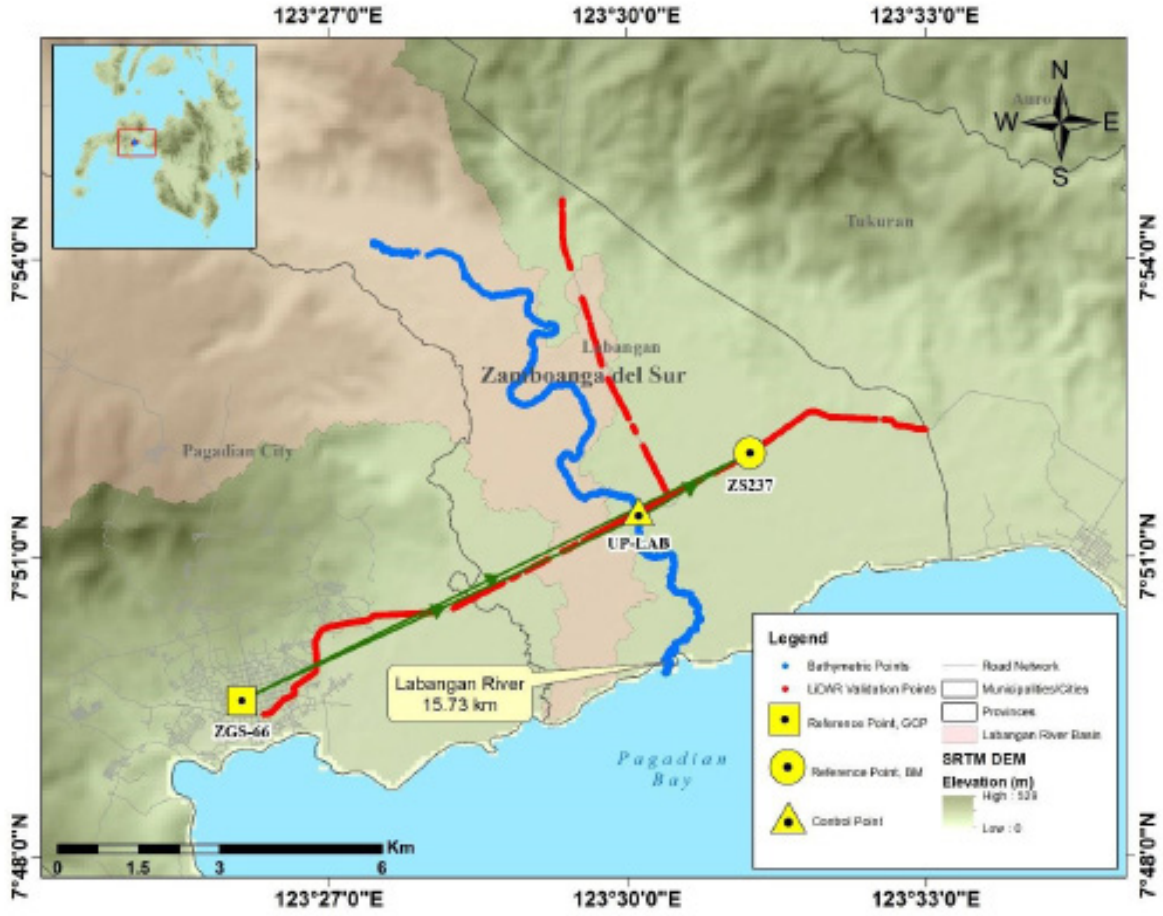


Figure 33. Labangan River survey extent

4.2 Control Survey

The GNSS network for this survey is composed of a single loop established on July 10, 2015 occupying the following reference points: ZGS-66, a second order GCP in Brgy. San Gatas, Pagadian City, Zamboanga Del Sur; and ZS-237, a first order BM in Brgy. Upper Campo Islam, Municipality of Labangan, Zamboanga Del Sur.

A control was also established namely UP-LAB, located at the approach of Labanga Bridge in Brgy. New Labangan, Municipality of Labangan, Zamboanga Del Sur.

The summary of reference and control points and its location is summarized in Table 27. While the GNSS network established is illustrated in Figure 34.

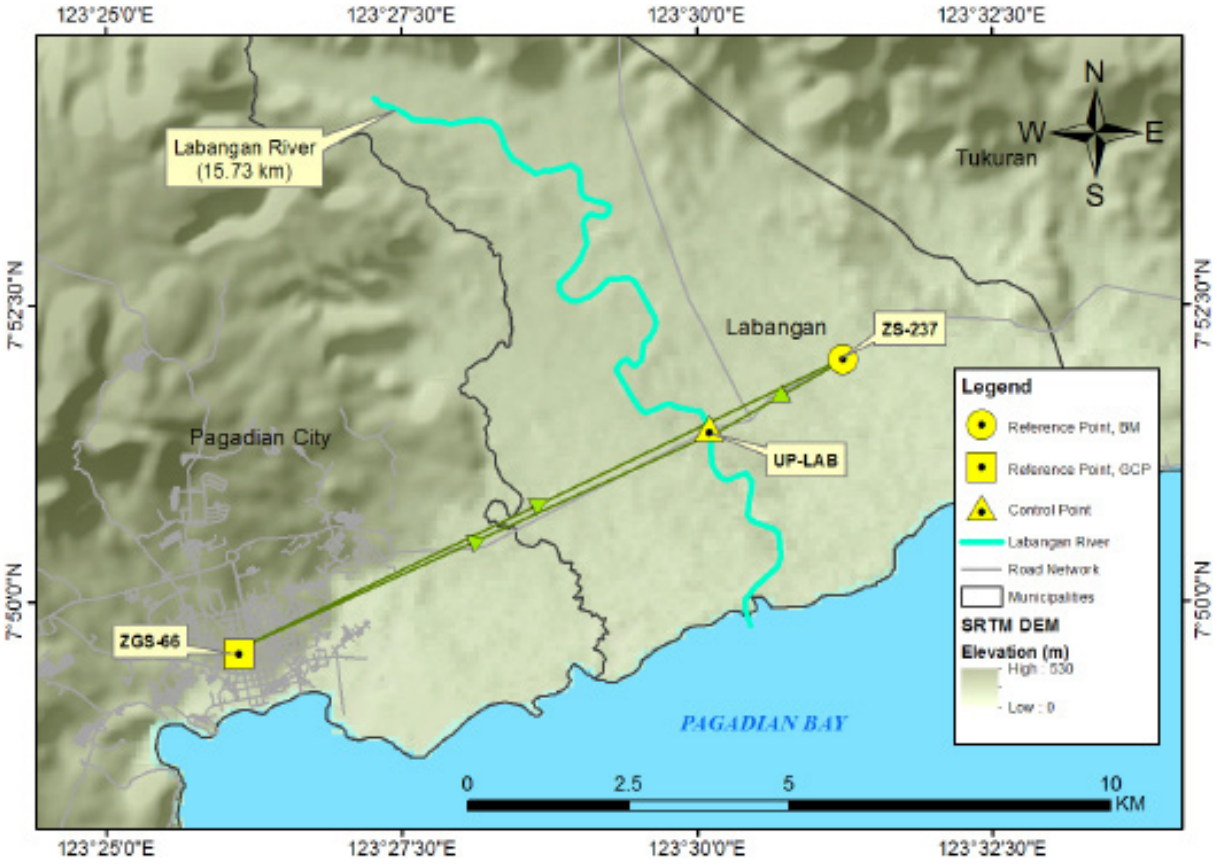


Figure 34. GNSS Network of Labangan Field Survey

Table 27. List of References and Control Points used in Labangan River survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
ZS-237	1st Order	-	-	75.009	6.322	2002
ZGS-66	2nd Order	7°49'33.63371"N	123°26'07.29814"E	106.854	-	2005
UP-LAB		-	-	-	-	7-10-2015

The GNSS set up and established control points in Labangan survey are shown in Figure 35 to Figure 37.

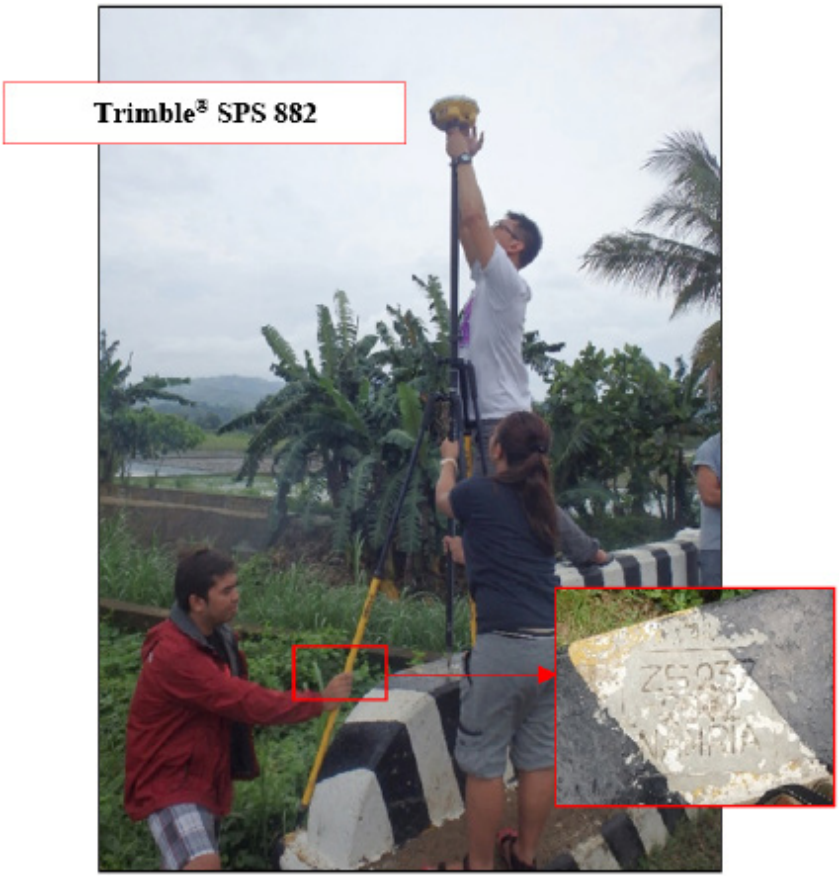


Figure 35. GNSS receiver occupation, Trimble® SPS 882, at ZS-237, Lantian Bridge, in Brgy. Upper Campo Islam, Labangan City, Zamboanga del Sur

Figure 36. GNSS base receiver setup, Trimble® SPS 852, at ZGS-66 in front of the Purok Carnation concrete marker, San Gatas, Pagadian City, Zamboanga del Sur

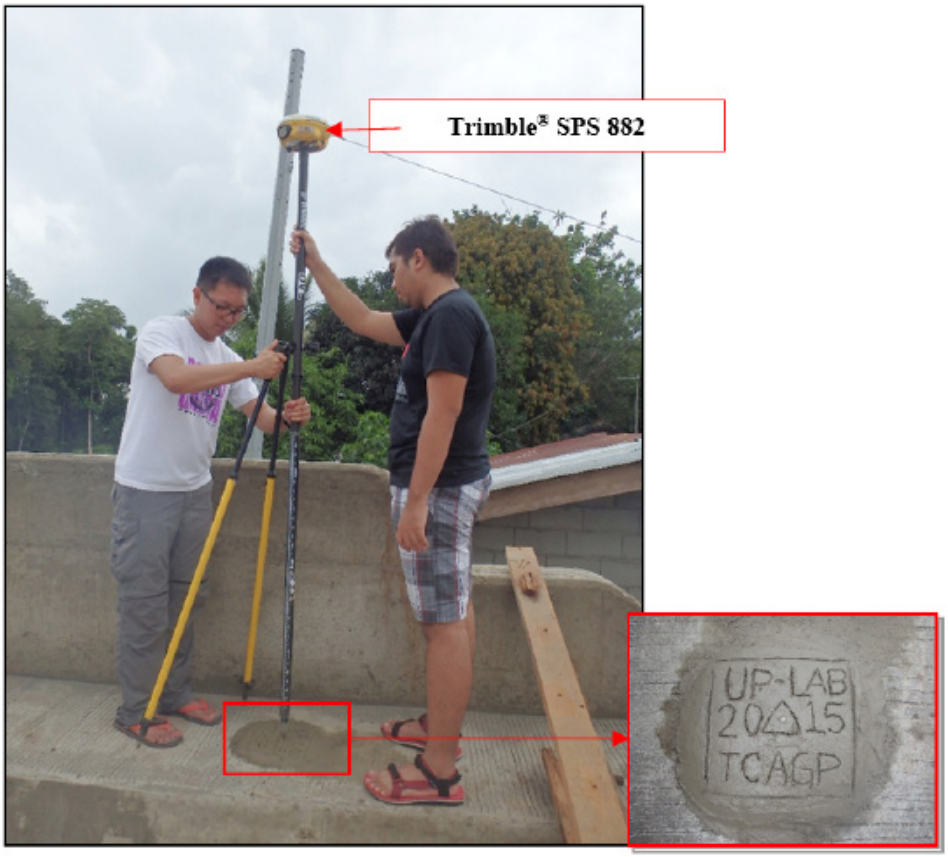


Figure 37. GNSS base occupation, Trimble® SPS 852, at control point UP-LAB, Labangan Bridge in Brgy. New Labangan, Labangan City, Zamboanga del Sur

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Labangan River Basin is summarized in Table 28 generated by TBC software.

Table 28. Baseline Processing Report for Labangan River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (m)	V. Prec (m)	Geodetic Az.	Ellipsoid Dist. (m)
UP-LAB --- ZS-237 (B4791)	7-10-2015	Fixed	0.003	0.010	62°36'28"	2331.404
ZGS-66 --- ZS-237 (B4792)	7-10-2015	Fixed	0.005	0.017	64°02'49"	10458.352
ZGS-66 --- UP-LAB (B4793)	7-10-2015	Fixed	0.004	0.014	64°27'45"	8127.904

As shown in Table 28, a total of three (3) baselines were processed with reference elevation of point ZS-237 and coordinates of ZGS-66 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report in the next page for complete details.

The three control points, ZGS-66, ZS-237 and UP-LAB were occupied and observed simultaneously to form a GNSS loop. The latitude and longitude of control point ZGS-66, and elevation of control point ZS-237 were held fixed during the processing of the control point as presented in Table 29.

Table 29. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZGS-66	Local	Fixed	Fixed		
ZS-237	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 30. The fixed control point ZS-237 and ZGS-66, has no values for standard elevation and coordinates error, respectively.

Table 30. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
UP-LAB	555324.459	0.003	868598.102	0.002	7.859	0.009	
ZGS-66	547996.953	?	865087.828	?	38.057	0.012	LL
ZS-237	557392.428	0.003	869672.825	0.002	6.322	?	e

The network is fixed at reference point ZGS-66 and ZS-237. With the mentioned equation for the vertical; $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ and $z_e < 10\ cm$ the computation for the accuracy for:

a. UP-LAB

horizontal accuracy = $\sqrt{((0.3)^2 + (0.2)^2}$
= $\sqrt{(0.9 + 0.4)}$
= 0.13 cm < 20 cm
vertical accuracy = 0.9 < 10 cm

b. ZGS-66

horizontal accuracy = Fixed
vertical accuracy = 1.2 < 10 cm

c. ZS-237

horizontal accuracy = $\sqrt{((0.3)^2 + (0.2)^2}$
= $\sqrt{(0.9 + 0.4)}$
= 0.13 cm < 20 cm
vertical accuracy = Fixed

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

Table 31. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
UP-LAB	N7°51'27.67298"	E123°30'06.70252"	76.563	0.009	
ZGS-66	N7°49'33.63371"	E123°26'07.29814"	106.854	0.012	LL
ZS-237	N7°52'02.58691"	E123°31'14.27688"	75.009	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 31. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 32.

Table 32. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Point ID	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZS-237	1st order, BM	7°52'02.58691"N	123°31'14.27688"E	75.009	869672.825	557392.428	6.322
ZGS-66	1st order, GCP	7°49'33.63371"N	123°26'07.29814"E	106.854	865087.828	547996.953	38.057
UP-LAB	UP Established	7°51'27.67298" N	123°30'06.70252"E	76.563	868598.102	555324.459	7.859

4.5 Cross-section and Bridge-as-built survey and Water Level Marking

Cross section and as-built surveys were done simultaneously on July 6 and 7, 2015 along the downstream side of Labangan Bridge in Brgy. New Labangan, Labangan, Zamboanga del Sur and on the upstream side of Hanging Bridge in Brgy. Bokong, Labangan, Zamboanga del Sur. The survey was conducted using a Trimble® SPS 882 with base station at UP-LAB as shown in Figure 38, Figure 39 and Figure 40.

Figure 38. Cross-section survey at Labangan Bridge in Brgy. New Labangan, Labangan, Zamboanga del Sur

Figure 39. As-built survey at Labangan Bridge in Brgy. New Labangan, Labangan, Zamboanga del Sur

Figure 40. Cross-section survey at the Hanging Bridge in Brgy.Bokong, Labangan, Zamboanga del Sur

A total of seventy-two (72) points for Labangan Bridge and forty-eight (48) points for the Hanging Bridge were gathered with an approximate length of 345.5 meters and 79.5 meters at Labangan Bridge the Hanging Bridge, respectively. The location of the bridges and result of the cross-sectional diagrams and are shown in Figure 41 to Figure 44, and the bridge data form of Labangan Bridge is shown in Figure 45.

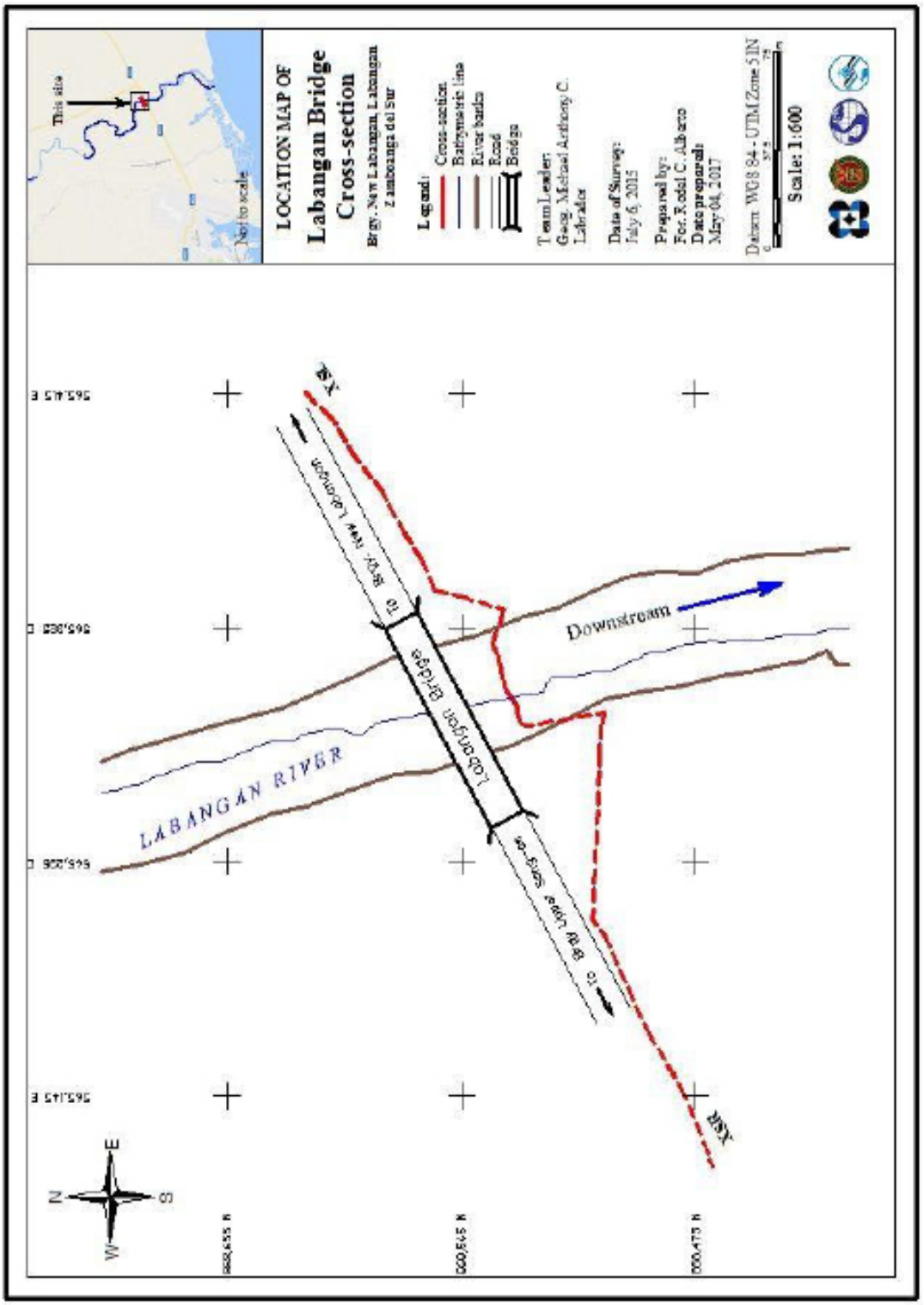


Figure 41. Labangan bridge cross-section location map

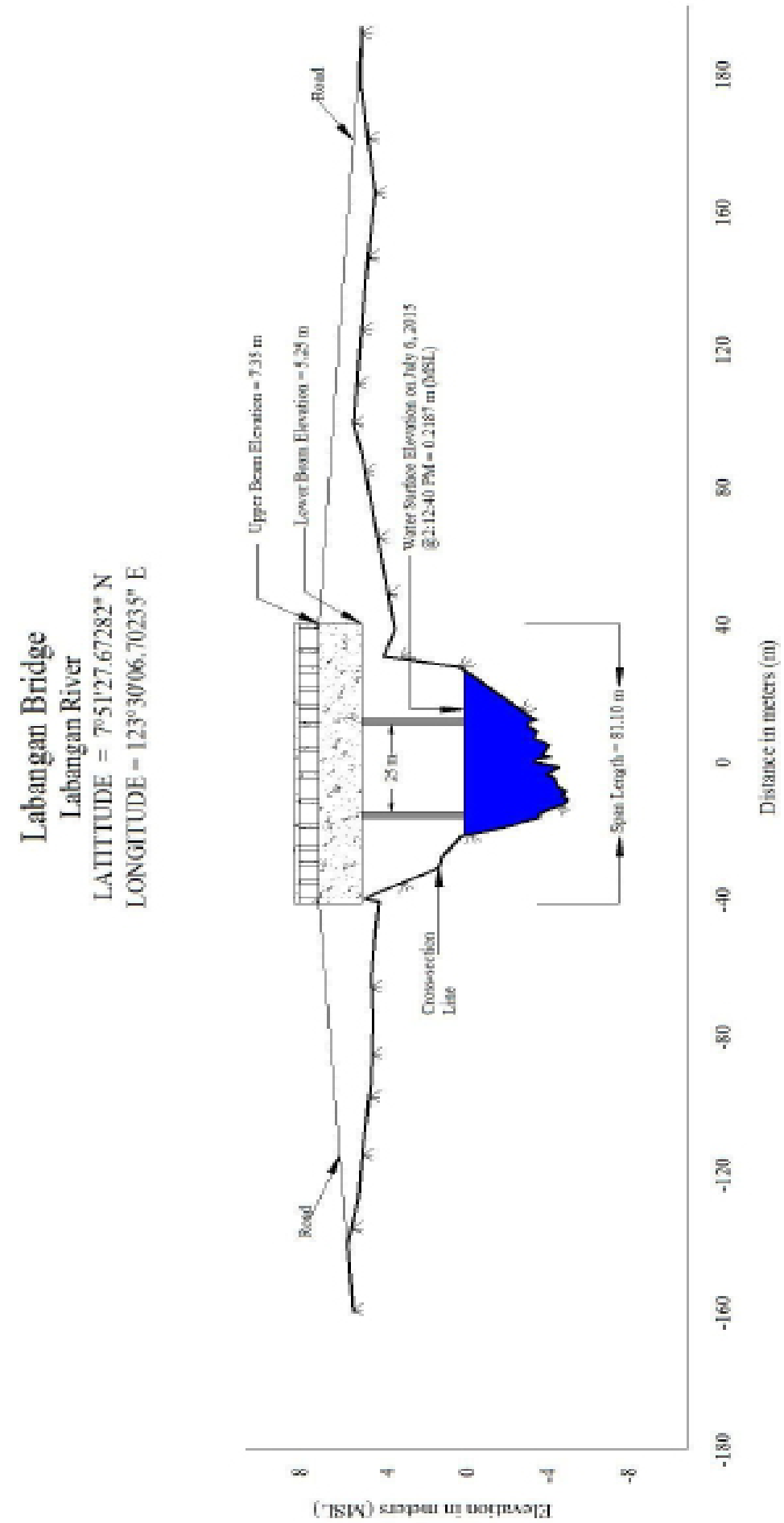


Figure 42. Labangan Bridge cross-section diagram

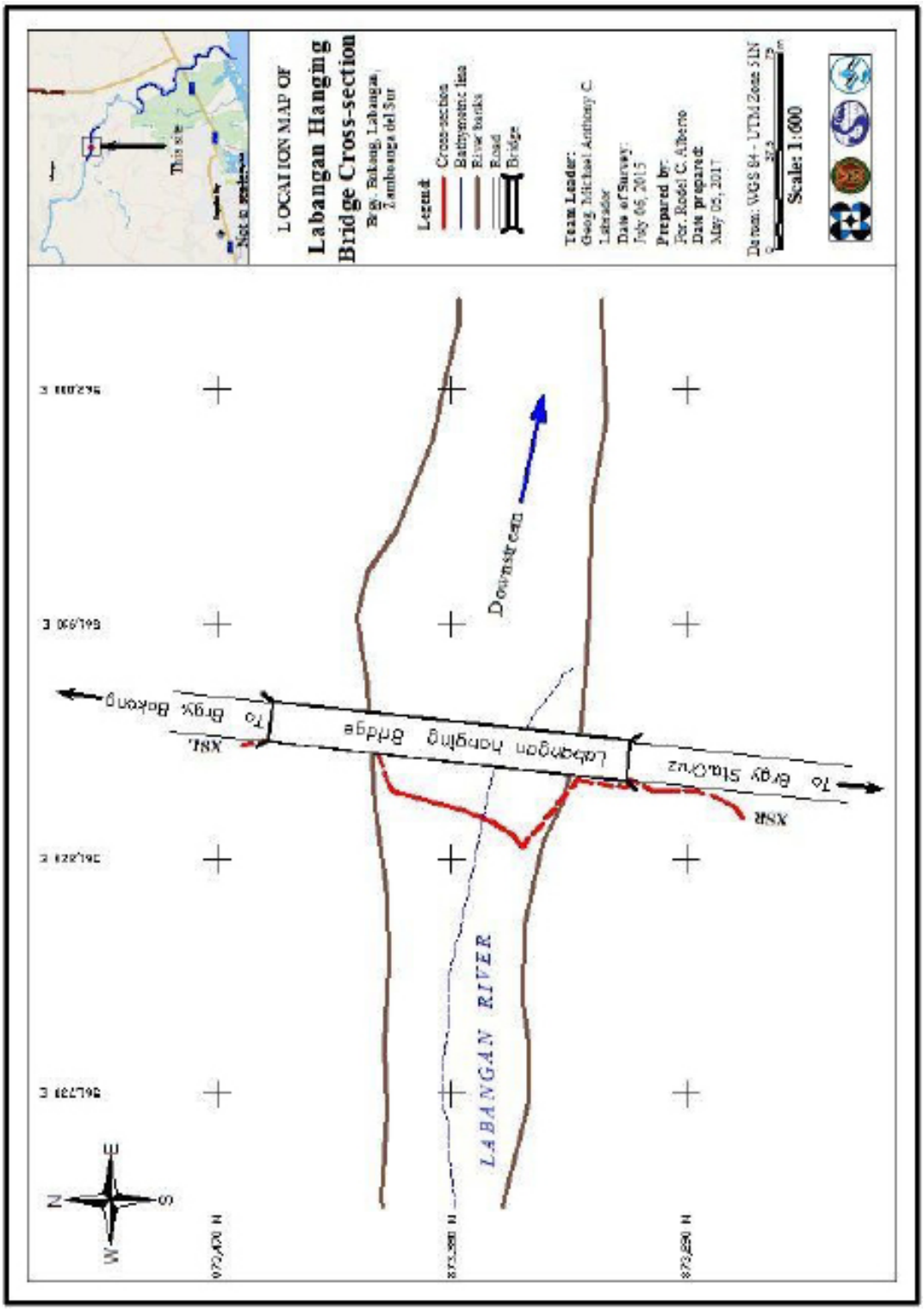


Figure 43. Labangan hanging bridge cross-section location map

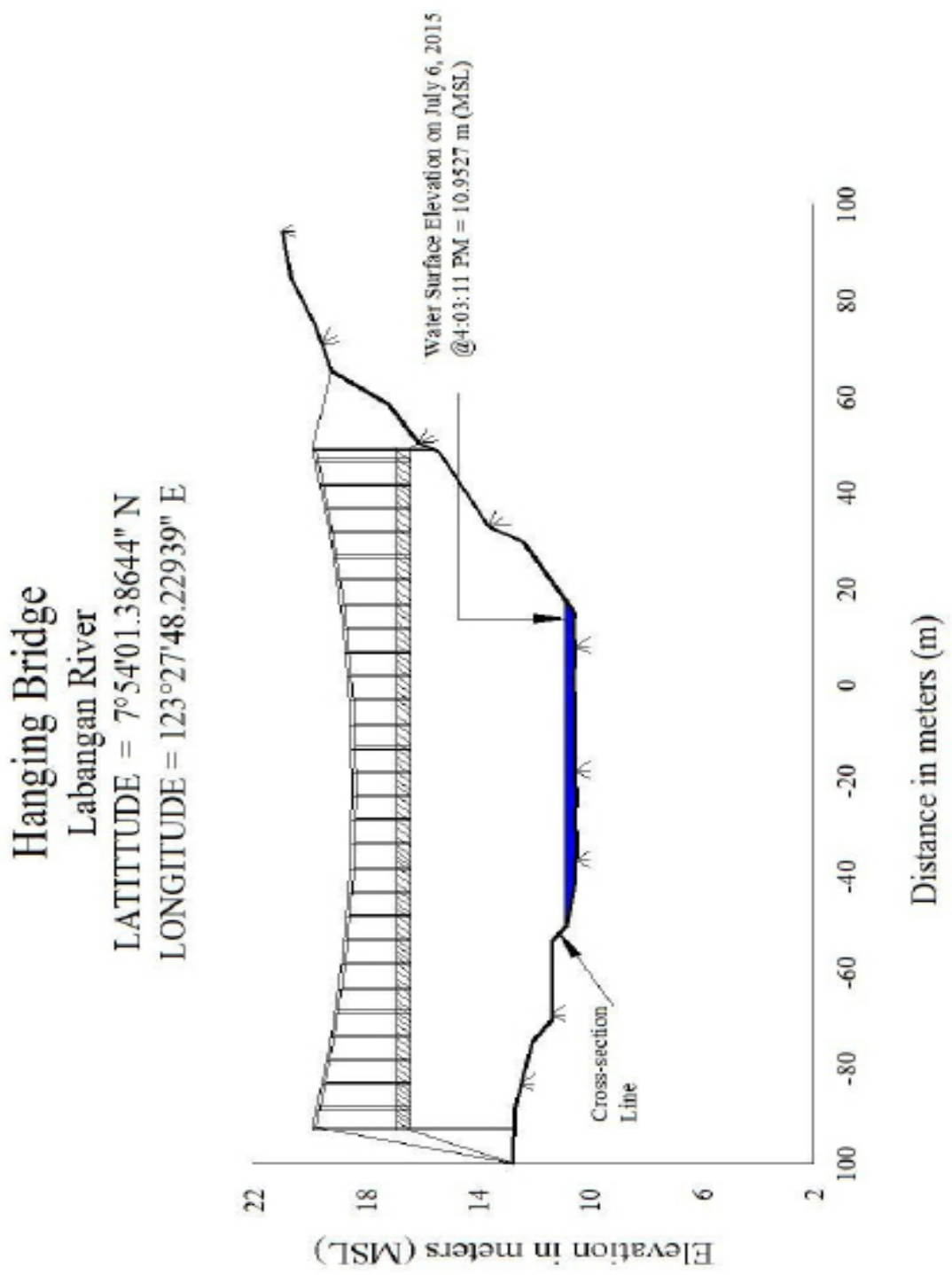
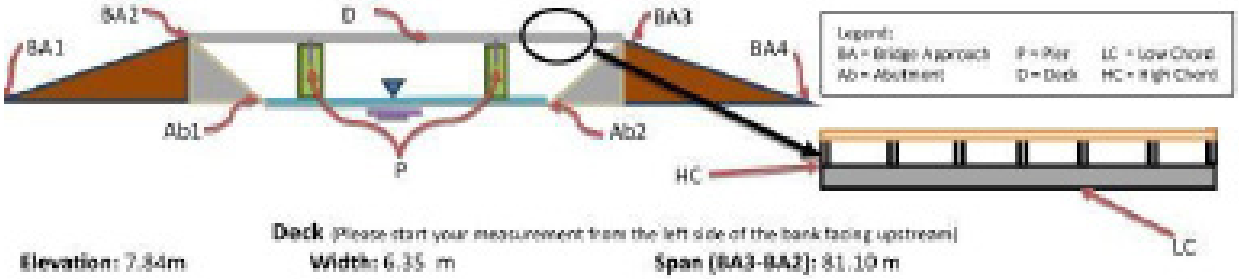


Figure 44. Hanging Bridge cross-section diagram

Bridge Data Form

Bridge Name: Labangan Bridge
Date: July 6, 2015
River Name: Labangan River
Time: 3:00 PM
Location (Brgy, City,Region): Barangay New Labangan, Labangan City
Survey Team: Michael Labrador, Romalyn Boado, Maridel Miras, Jonard Apilado
Flow condition: low normal high **Weather Condition:** fair rainy
Latitude: 7d51'27.67282"N **Longitude:** 123d30'06.70235"E



Deck (Please start your measurement from the left side of the bank facing upstream)
Elevation: 7.84m **Width:** 6.35 m **Span (BA3-BA2):** 81.10 m

	Station	High Chord Elevation	Low Chord Elevation
1	BA3 1	7.35	5.25
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.64 m	BA3	197.03	7.35 m
BA2	115.93	7.35 m	BA4	374.03 m	5.23 m

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

	Station (Distance from BA1)	Elevation
Ab1	129.33	1.37
Ab2	187.67	0.28

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

Shape: rectangle **Number of Piers:** 2 **Height of column footing:** _____

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	142.78	7.70	2.25 m
Pier 2	169.90	7.74	2.25 m
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 45. Labangan Bridge Data Form

The water surface elevation of Labangan River was acquired using PPK survey technique on July 6, 2015 at 2:12:40 PM at Labangan Bridge and at 4:03:11 PM at the Hanging Bridge. The resulting water surface elevation data at Labangan Bridge is 0.2187 m and at the Hanging Bridge is 10.9527 m above MSL. The markings on the bridge abutment and foot shall serve as a reference for flow data gathering and depth gauge deployment of Mindanao State University PHIL-LiDAR 1. Marking of the abutment (A) and the finished (B) water level marking for Labangan and Hanging Bridge are shown in Figure 46 and Figure 47 respectively.

Figure 46. MSL water level markings at Labangan Bridge's Abutment

Figure 47. MSL water level markings at Hanging Bridge's Foot

4.6 Validation Points Acquisition Survey

Validation Points Acquisition Survey was conducted on July 8 and 10, 2015 using a survey-grade GNSS Rover receiver mounted on a pole which was attached at the back of the vehicle as shown in Figure 48a. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.025m measured from the ground up to the bottom of notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topo mode. Measurement of antenna height and set-up of equipment for ground validation survey is illustrated in Figure 48b.

Figure 48. Validation points acquisition survey set-up

Within the two days ground validation, the team covered the major roads running along Rizal Avenue and the road from the intersection in Brgy. New Labangan to Brgy. Pulacan, Labangan City. The survey acquired 1,924 ground validation points with an approximate length of 20.056 km. shown in Figure 49.

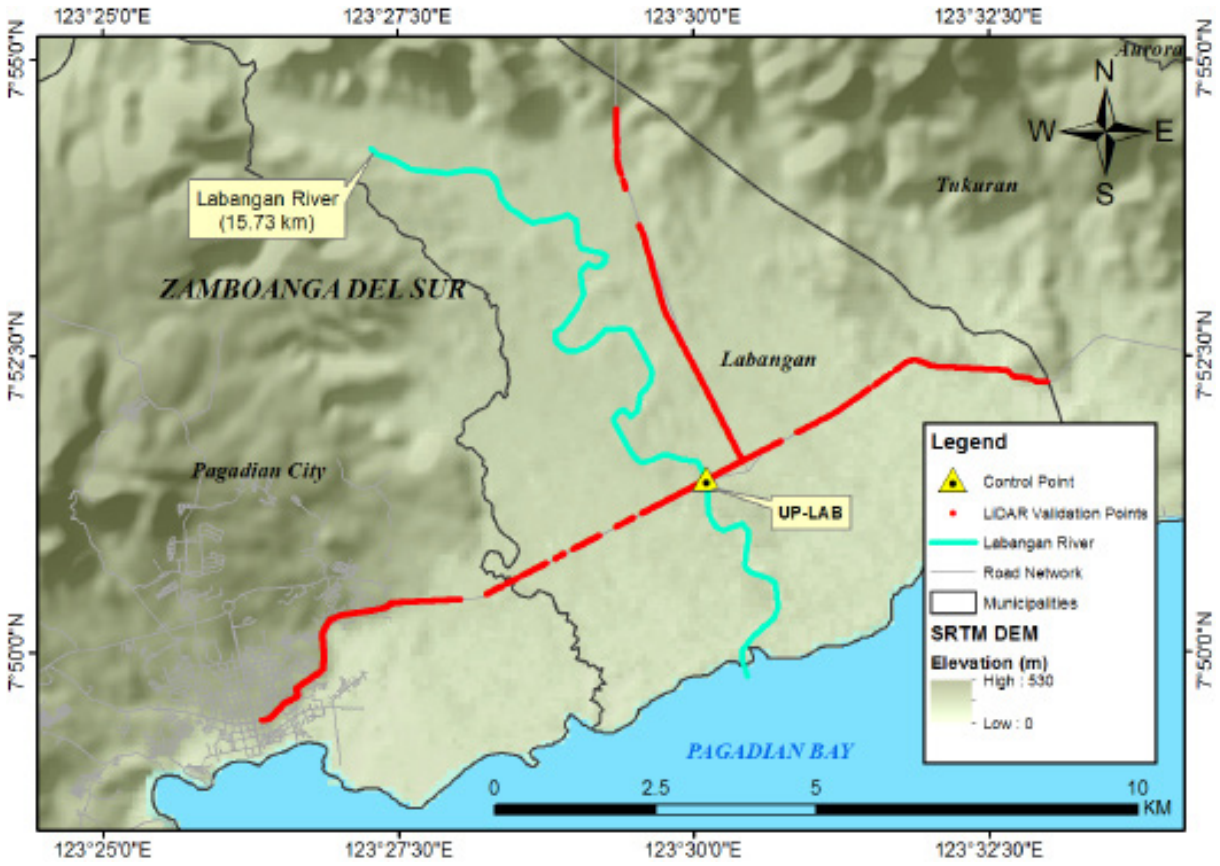


Figure 49. Ground validation points along Pagadian and Labangan City

4.7 Bathymetric Survey

Bathymetric survey was conducted on July 8-9 and 14, 2015 using an Ohmex™ single beam echo sounder. The set-up of the equipment is shown in Figure 50. The entire survey covered the centerline and zigzag of Labangan River from Brgy. Bokong, Municipality of Labangan with coordinates 7°54'08.52812" 123°27'26.75588", down to the mouth of the river in Brgy. Lower Sang-An, Labangan City, Zamboanga del Sur with coordinates 7°49'49.85167" 123°30'22.73699".

Figure 50. OHMEX™ single beam echo sounder set up on a boat for Labangan River bathymetric survey

Within the two days ground validation, the team covered the major roads running along Rizal Avenue and the road from the intersection in Brgy. New Labangan to Brgy. Pulacan, Labangan City. The survey acquired 1,924 ground validation points with an approximate length of 20.056 km. shown in Figure 49.

The bathymetric line started from Brgy. Bokong down to the mouth of the river with an estimated length of about 16.921 km with a total of 15, 442 points. The processed data were generated into a map using a GIS software as shown in Figure 51.

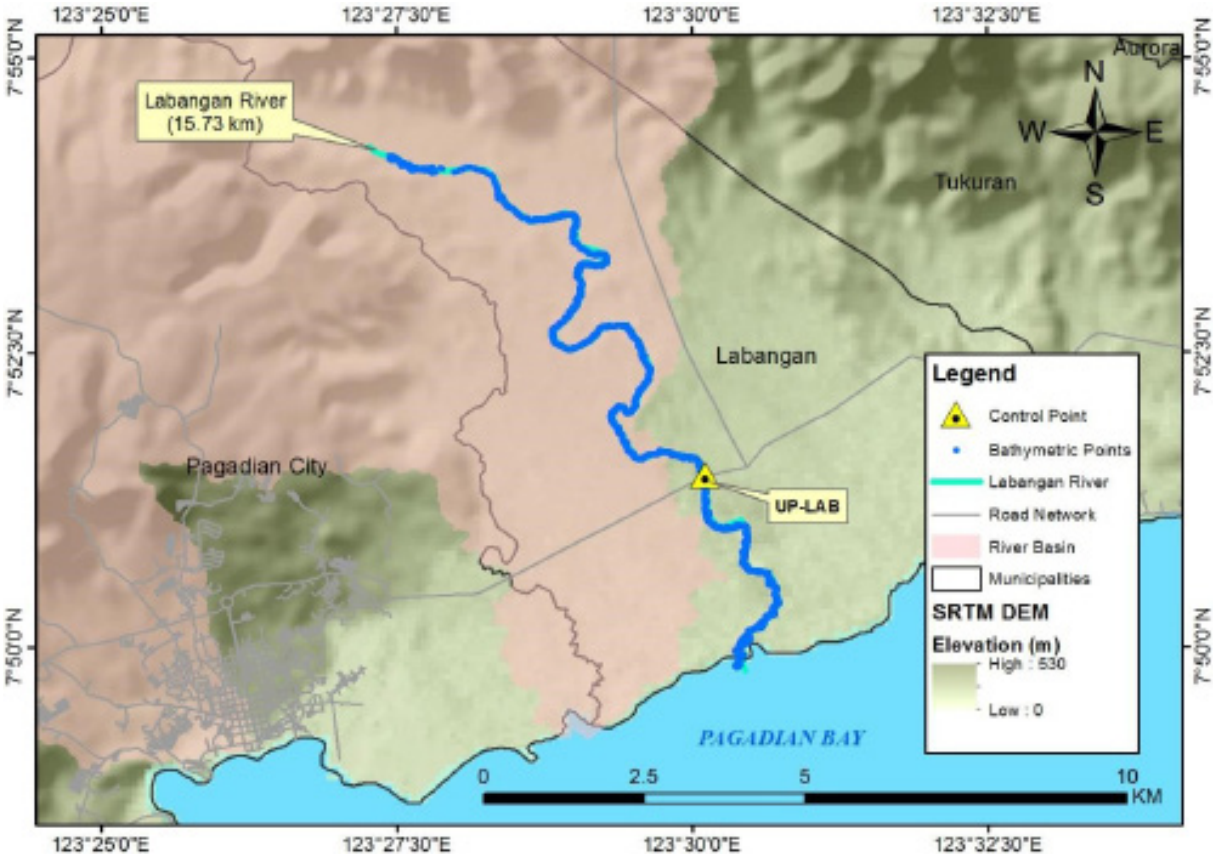


Figure 51. Bathymetric points gathered from Labangan River

A CAD drawing was also produced to illustrate the Labangan riverbed profile. As shown in Figure 52, it has 6 meters change in elevation from the Hanging Bridge in Brgy. Bokong to Brgy. Tawagan Norte, 5 meters change from Brgy. Tawagan Norte to Brgy. Dalapuang, There is a 1-meter change in elevation from Brgy. Dalapuang to Brgy. New Labangan, and from Brgy. New Labangan to the mouth of the river in Brgy. Lower Sang-An. Additionally, the deepest portion or the lowest elevation recorded is about four and three tenths (-4.3) meters (MSL) which is located in Brgy. New Labangan, Labangan City..

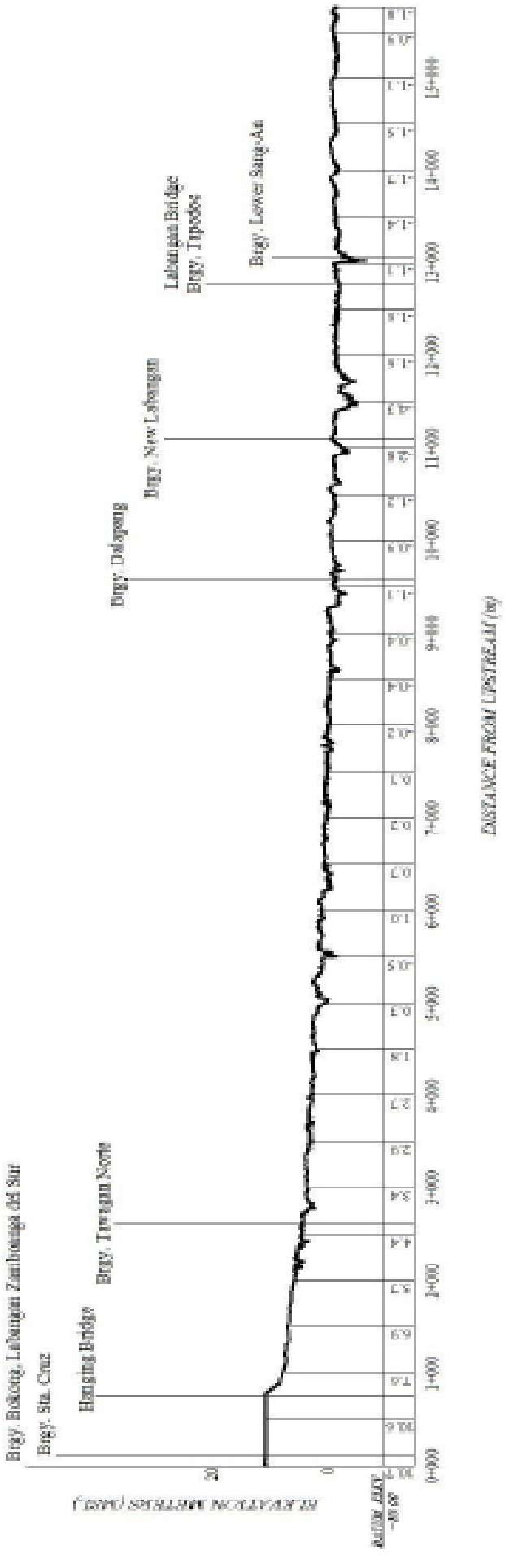


Figure 52. Labangan riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

Components and data that affect the hydrologic cycle of the Labangan 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 Labangan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from the Automatic Rain Gauge (ARG) installed upstream by the DOST. The ARG was specifically installed in the municipality of Labangan with coordinates 7°55'15.17"N Latitude and 123°23'54.82"E Longitude. The location of the rain gauge is shown in Figure 53 below.

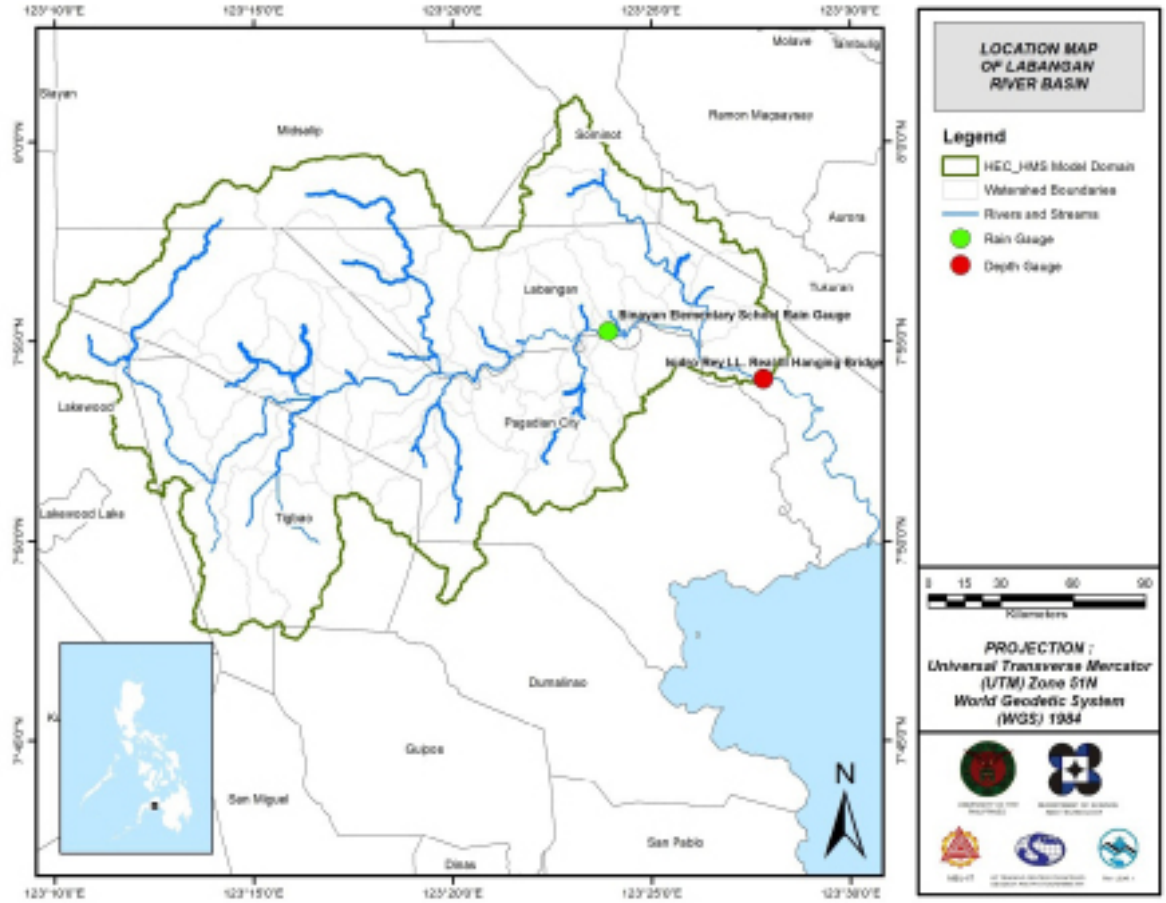


Figure 53. The location map of Labangan HEC-HMS model used for calibration

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 55 shows the highest R-Squared value of 0.9946 compared to the graphs using the original Q. In this case, Q boxed values with Q at bank-full were plotted versus the stage.

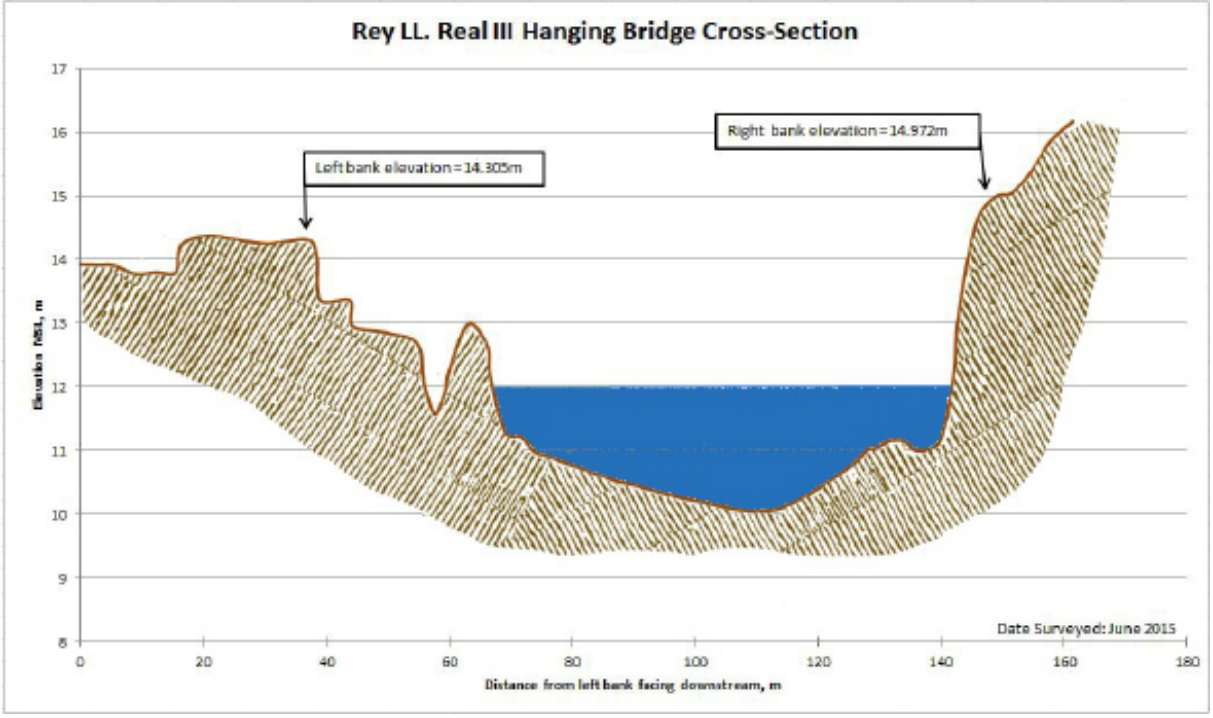


Figure 54. Cross-Section Plot of Isidro Rey LL. Real III Hanging Bridge

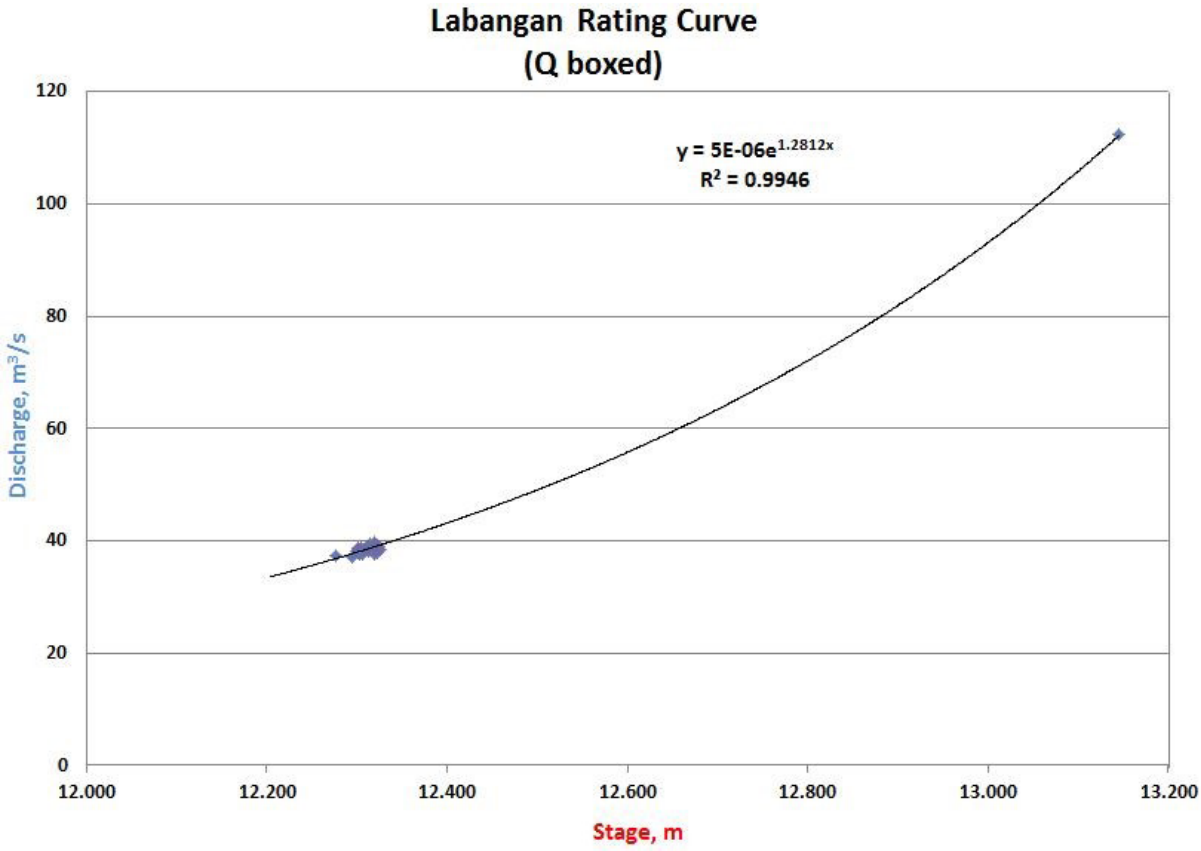


Figure 55. Rating Curve at Isidro Rey LL. Real III Hanging Bridge

This rating curve equation was used to compute the river outflow at Isidro Rey LL. Real III Hanging Bridge for the calibration of the HEC-HMS model.

Total rainfall taken from the ARG at Binayan Labangan was 74.5 mm. It peaked to 13.5 mm on 5 August2016, 14:15. The lag time between the peak rainfall and discharge is 3 hours and 55 minutes.

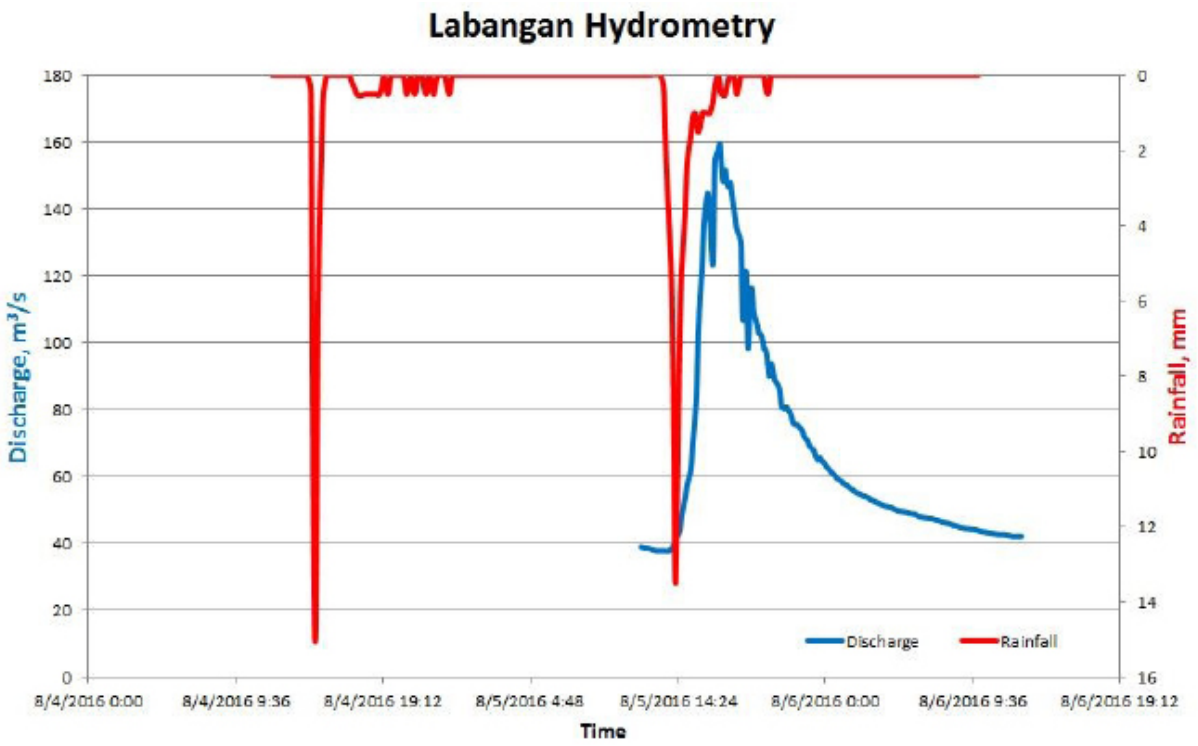


Figure 56. Rainfall and outflow data at Isidro Rey LL. Real III Hanging Bridge used for modeling

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 Labangan watershed. The extreme values for this watershed were computed based on a 51-year record.

Table 33. 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

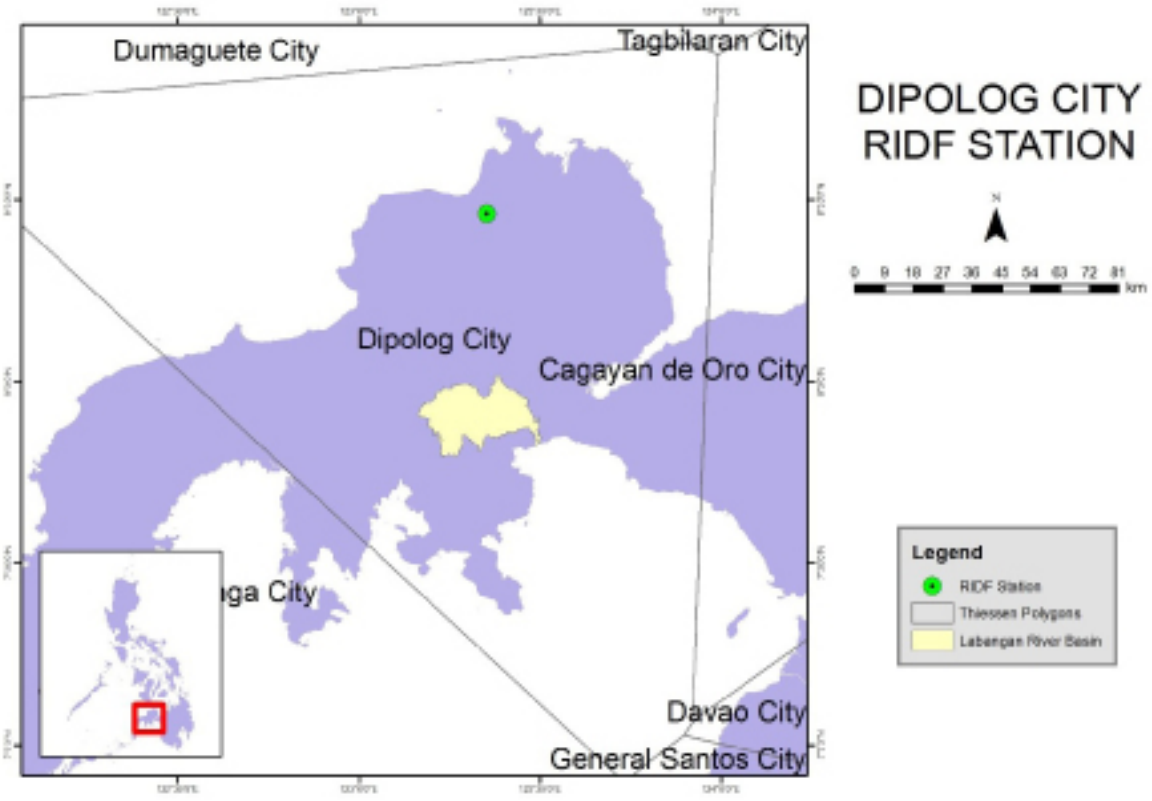


Figure 57. Location of Dipolog RIDF station relative to Labangan River Basin

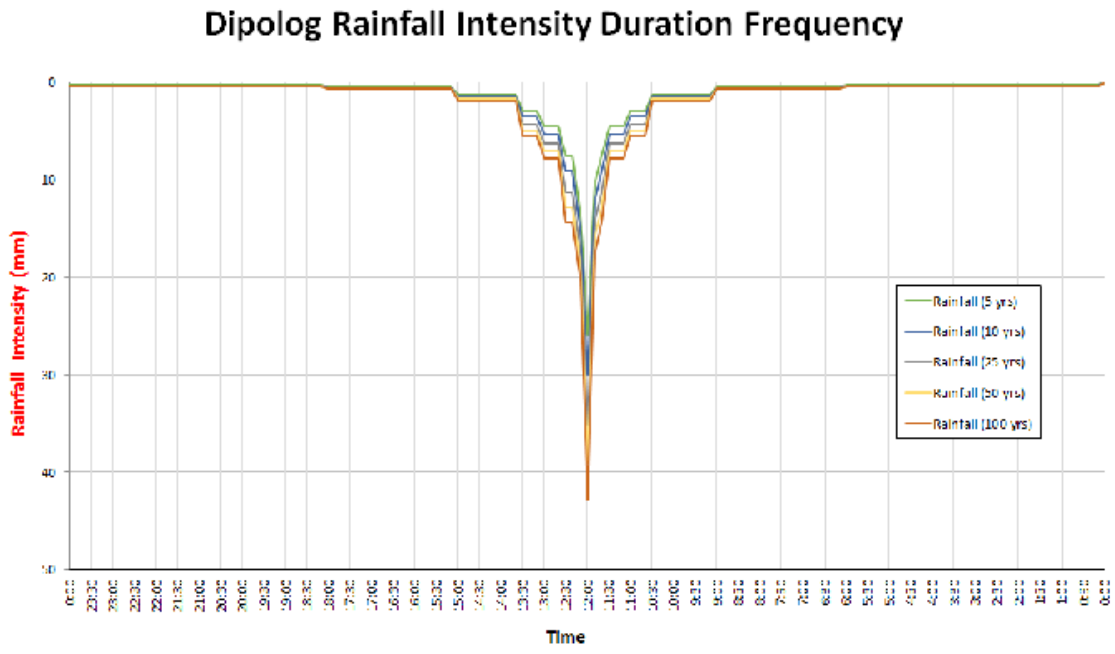


Figure 58. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil texture dataset was generated in 2004 from the Bureau of Soils and Water Management (BSWM); this is under the Department of Agriculture. The soil texture map (Figure 59) of the Labangan River basin was used as one of the factors for the estimation of the CN parameter.

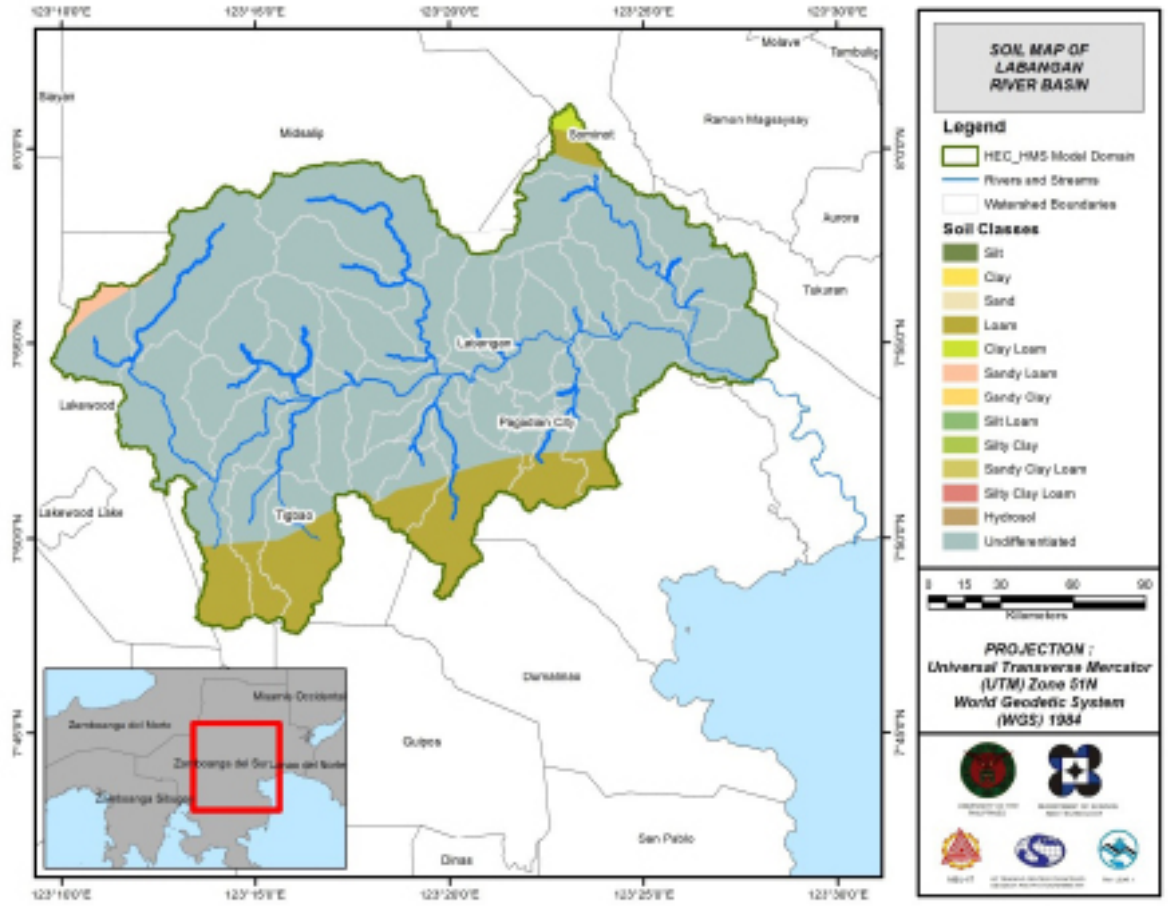


Figure 59. Soil Map of Labangan River Basin

The land cover data was generated in 2003 from the National Mapping and Resource information Authority (NAMRIA), DENR. Figure 60 shows the land cover inside Labangan river basin. The land cover map of Labangan river basin was used as another factor for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

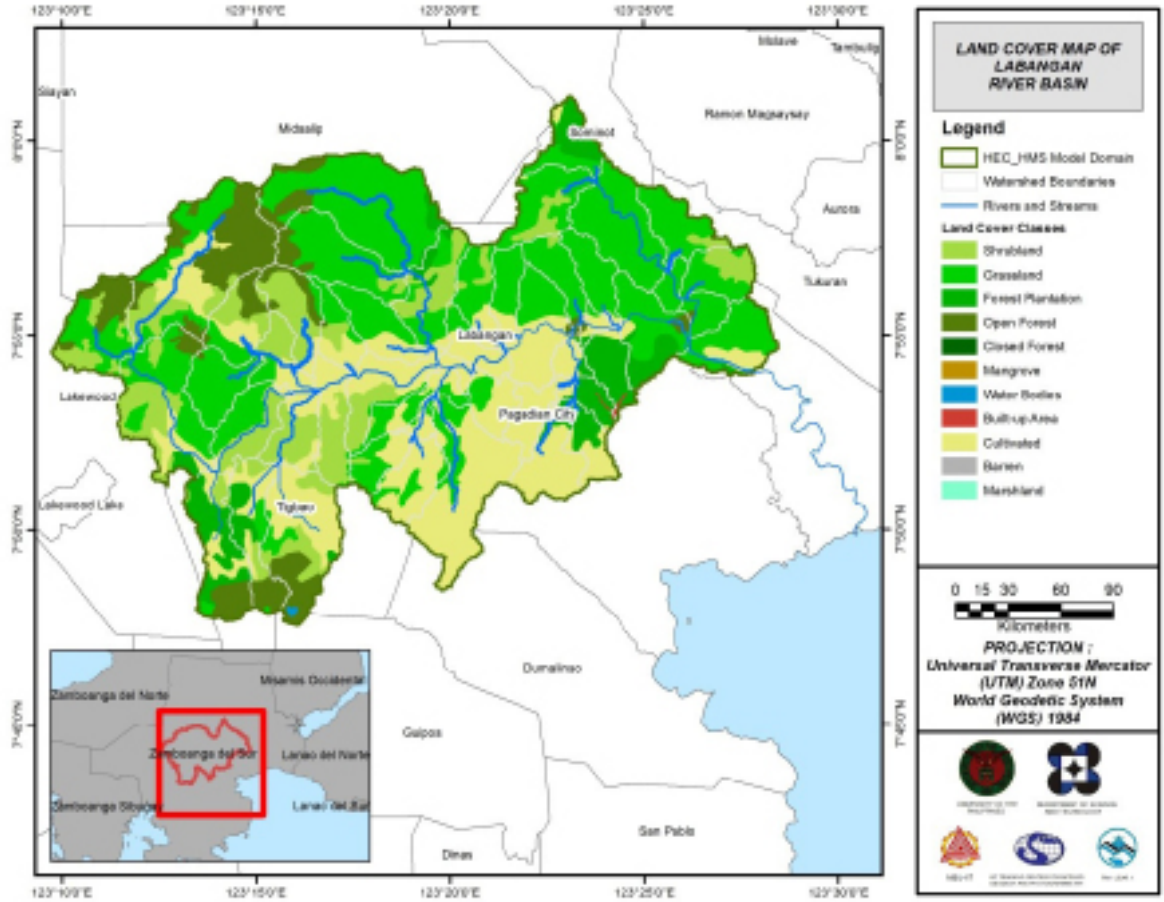


Figure 60. Land Cover Map of Labangan River Basin

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

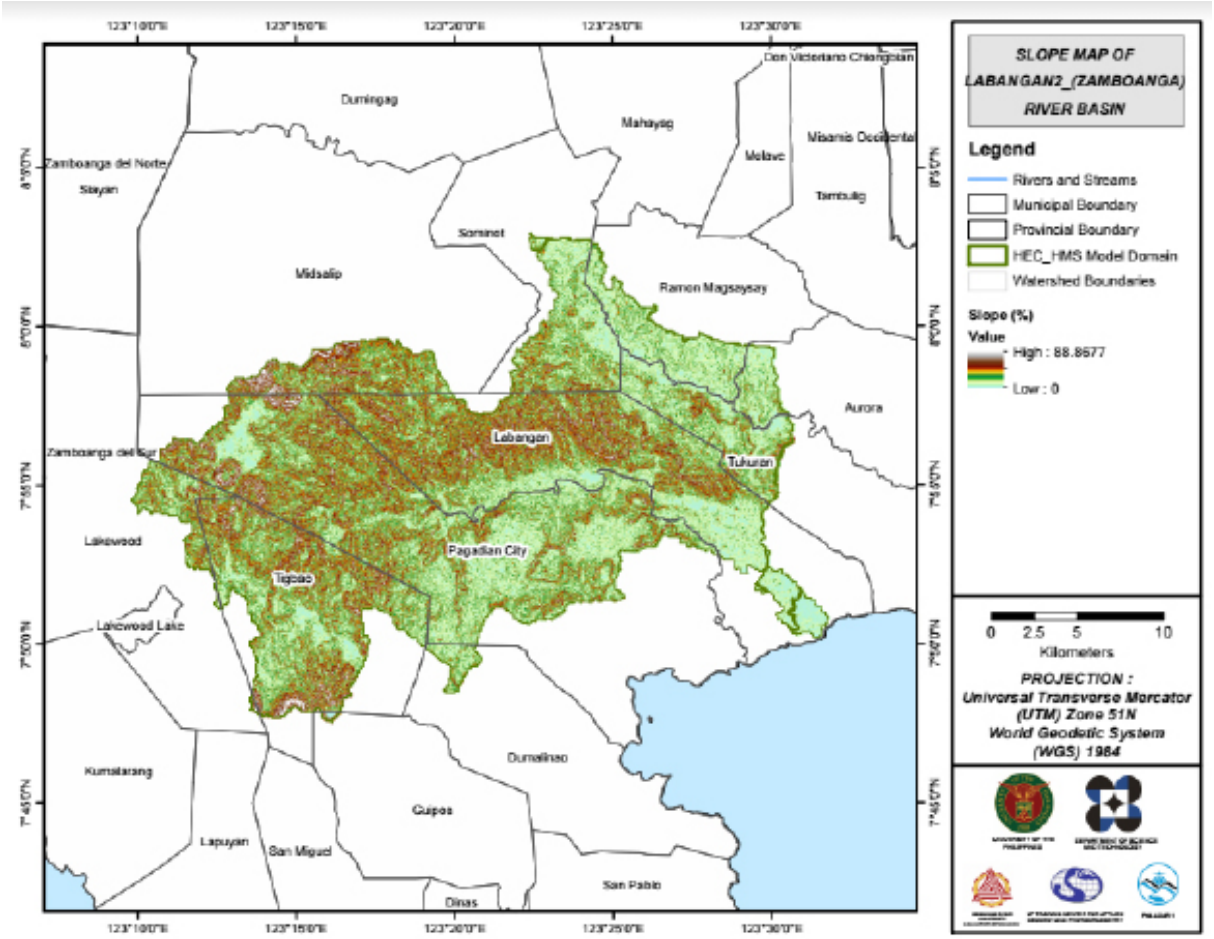


Figure 61. Slope Map of Labangan River Basin

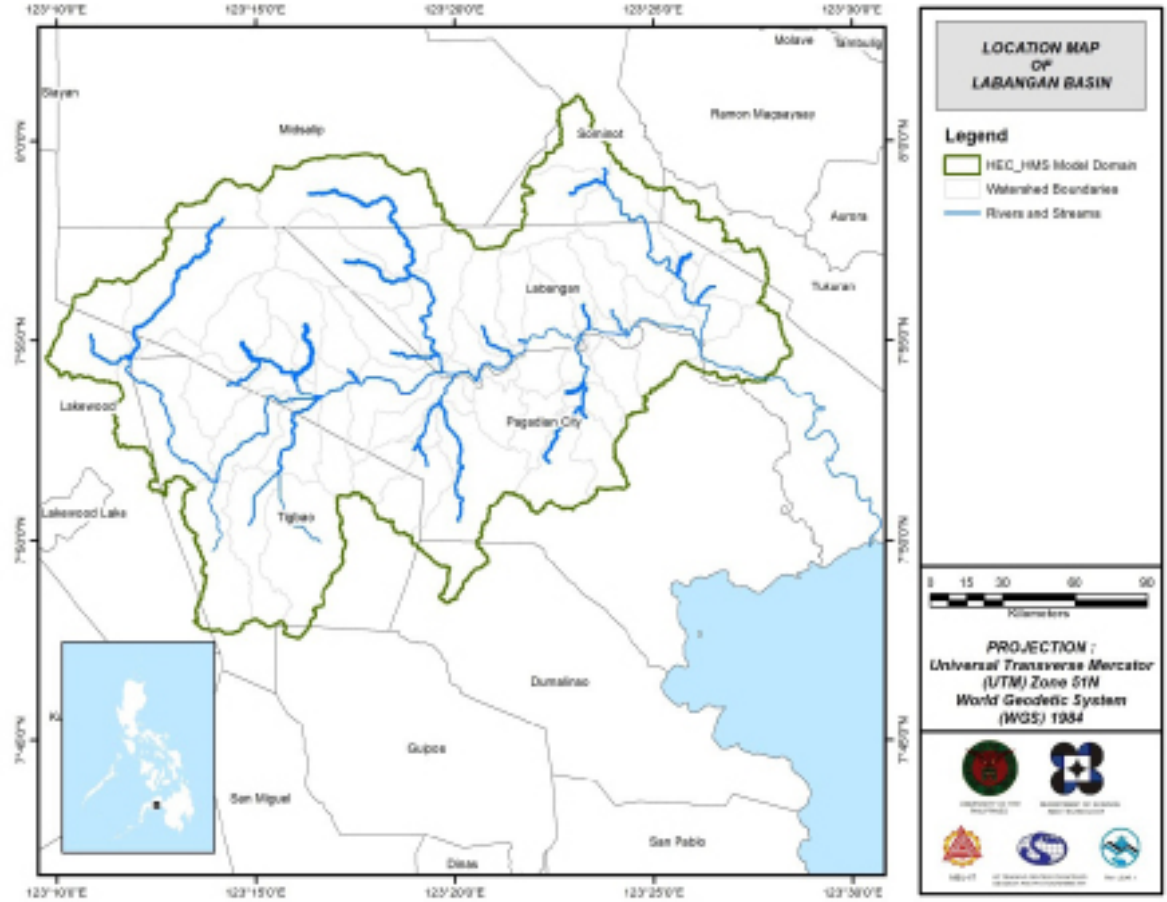


Figure 62. Stream Delineation Map of the Labangan River Basin

Using the SAR-based DEM, the Labangan basin was delineated and further subdivided into subbasins. The model consists of 48 sub basins, 27 reaches, and 27 junctions. The main outlet is located at Isidro Rey LL. Real III Bridge, Labangan. This basin model is illustrated in Figure 63. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Isidro Rey LL. Real III Bridge.

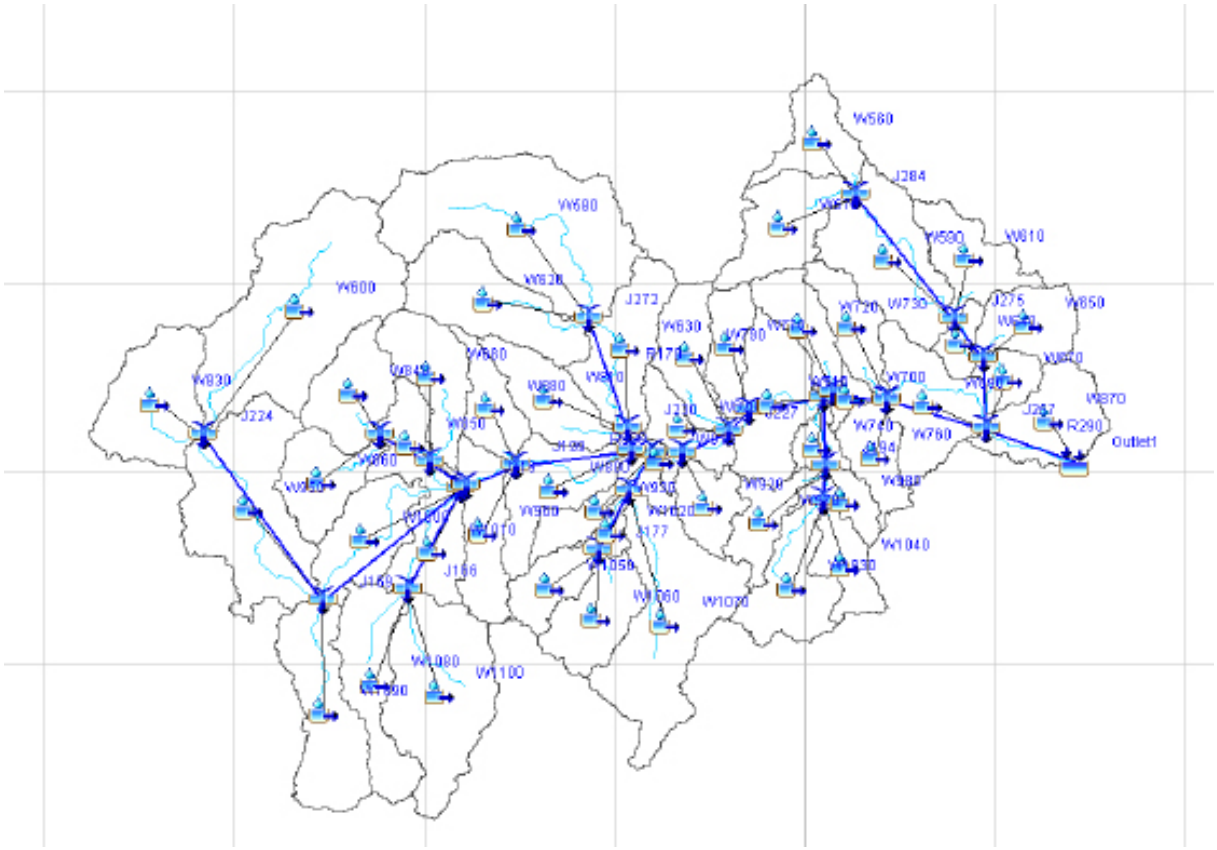


Figure 63. The Labangan Hydrologic Model generated in HEC-GeoHMS

5.4 Cross-section Data

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

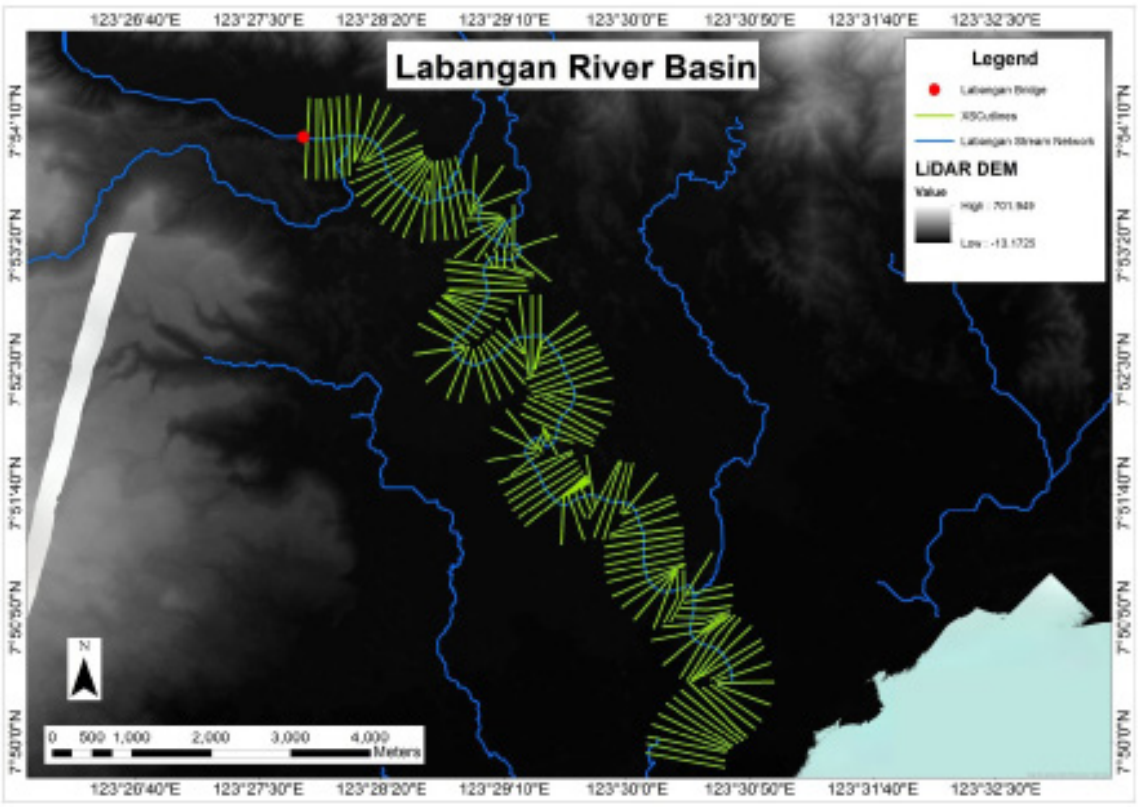


Figure 64. River cross-section of Labangan River generated through Arcmap HEC GeoRAS tool

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 north of the model to the south, following the main channel. As such, boundary elements northwest of the model are assigned as outflow elements.

Figure 65. 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 43.55 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 76,759,968.00 m2.

There is a total of 15,448,575.20m3 of water entering the model, of which 10,150,628.78 m3 is due to rainfall and 5,297,946.42 m3 is inflow from basins upstream. 4,896,492.50 m3 of this water is lost to infiltration and interception, while 5 592,738.71 m3 is stored by the flood plain. The rest, amounting up to 4,959,317.91 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Labangan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 66 shows the comparison between the two discharge data.

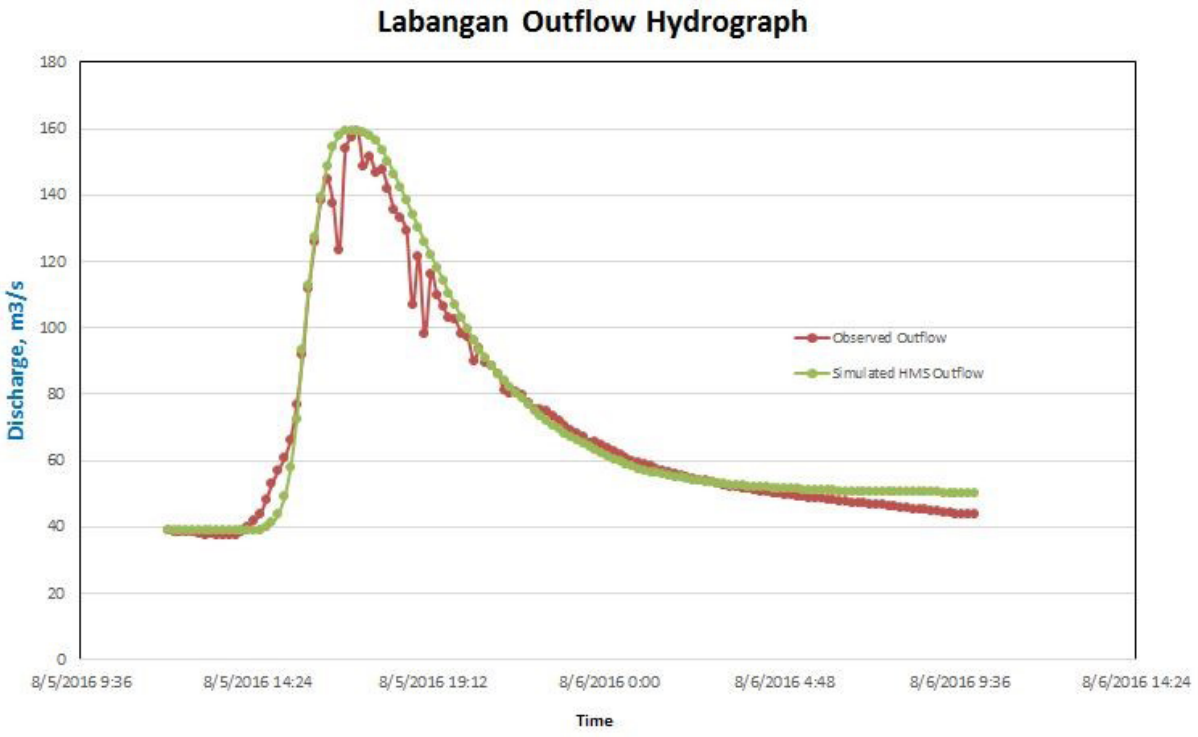


Figure 66. Outflow Hydrograph of Isidro Rey LL. Real III Bridge generated in HEC-HMS model compared with observed outflow

Enumerated in Table 34 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 34. Range of Calibrated Values for Labangan River

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	23 - 74
			Curve Number	52 - 78
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.25 – 1
			Storage Coefficient (hr)	0.7 - 3
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.155
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.019

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 23 to 74mm means that there is a average to high amount of infiltration or rainfall interception by vegetation per subbasin.

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 52 to 78 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Labangan, the soil mostly consists of loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.25 to 3 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 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.155 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.019 corresponds a lower value compared to the common roughness of Philippine watersheds.

Table 35. Summary of the Efficiency Test of Labangan HMS Model

Accuracy Measure	Value
RMSE	6.39
r2	0.98
NSE	0.96
PBIAS	-3.04
RSR	0.19

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 6.39 (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 0.98.

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 0.96.

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 -3.04.

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 0.19.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 67) shows the Labangan 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.

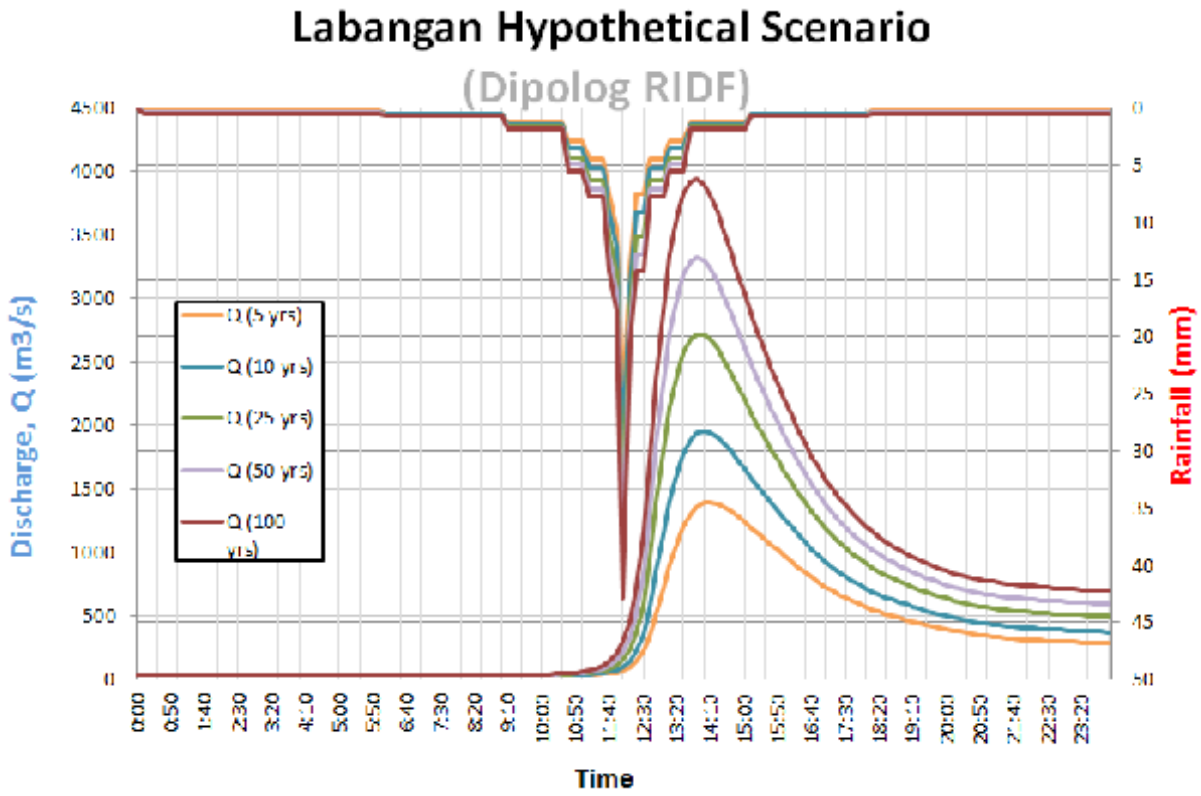


Figure 67. Outflow hydrograph at Labangan Station generated using Dipolog RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Labangan discharge using the Dipolog Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 37.

Table 36. Peak values of the Labangan HECHMS Model outflow using Dipolog RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow	Range of Calibrated Values
5-Year	178.32	25.9	1399.9	14 hours 10 mins
10-Year	206.37	30	1959	14 hours
25-Year	241.91	35.2	2720.7	13 hours 50 mins
50-Year	268.14	39	3324	13 hours 50 mins
100-Year	294.55	42.9	3940.5	13 hours 50 mins

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 Labangan River using the calibrated HMS base flow is shown in Figure 68.

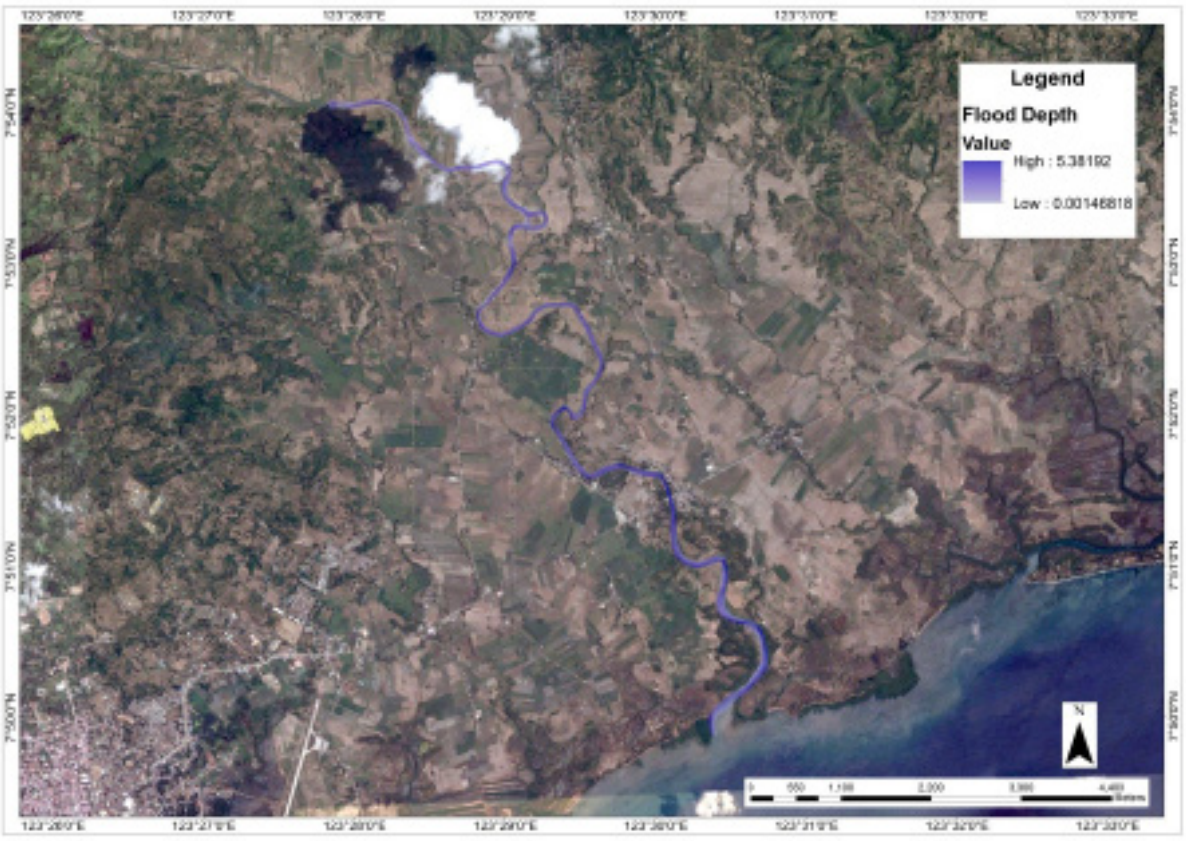


Figure 68. Sample output of Labangan RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 69 to Figure 74 shows the 5-, 25-, and 100-year rain return scenarios of the Labangan floodplain. The floodplain, with an area of 177.58 sq. km., covers Pagadian City and two municipalities namely Labangan and Tukuran. Table 37 shows the percentage of area affected by flooding per municipality.

Table 37. Municipalities affected in Labangan Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Labangan	176.44	68.76	39%
Pagadian City	279.34	48.29	17%
Tukuran	119.01	60.00	50%

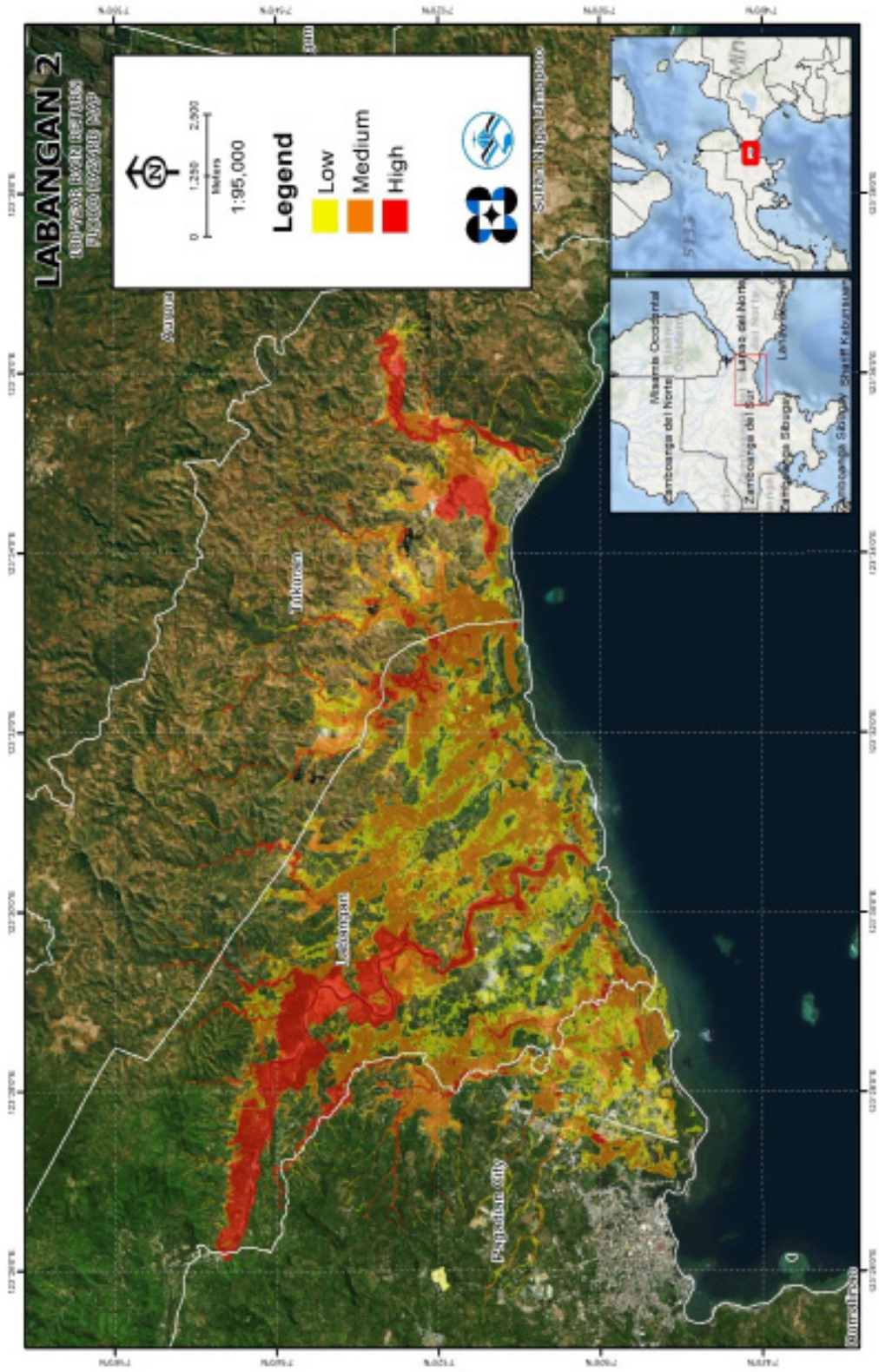


Figure 69. 100-year Flood Hazard Map for Labangan Floodplain overlaid on Google Earth imagery

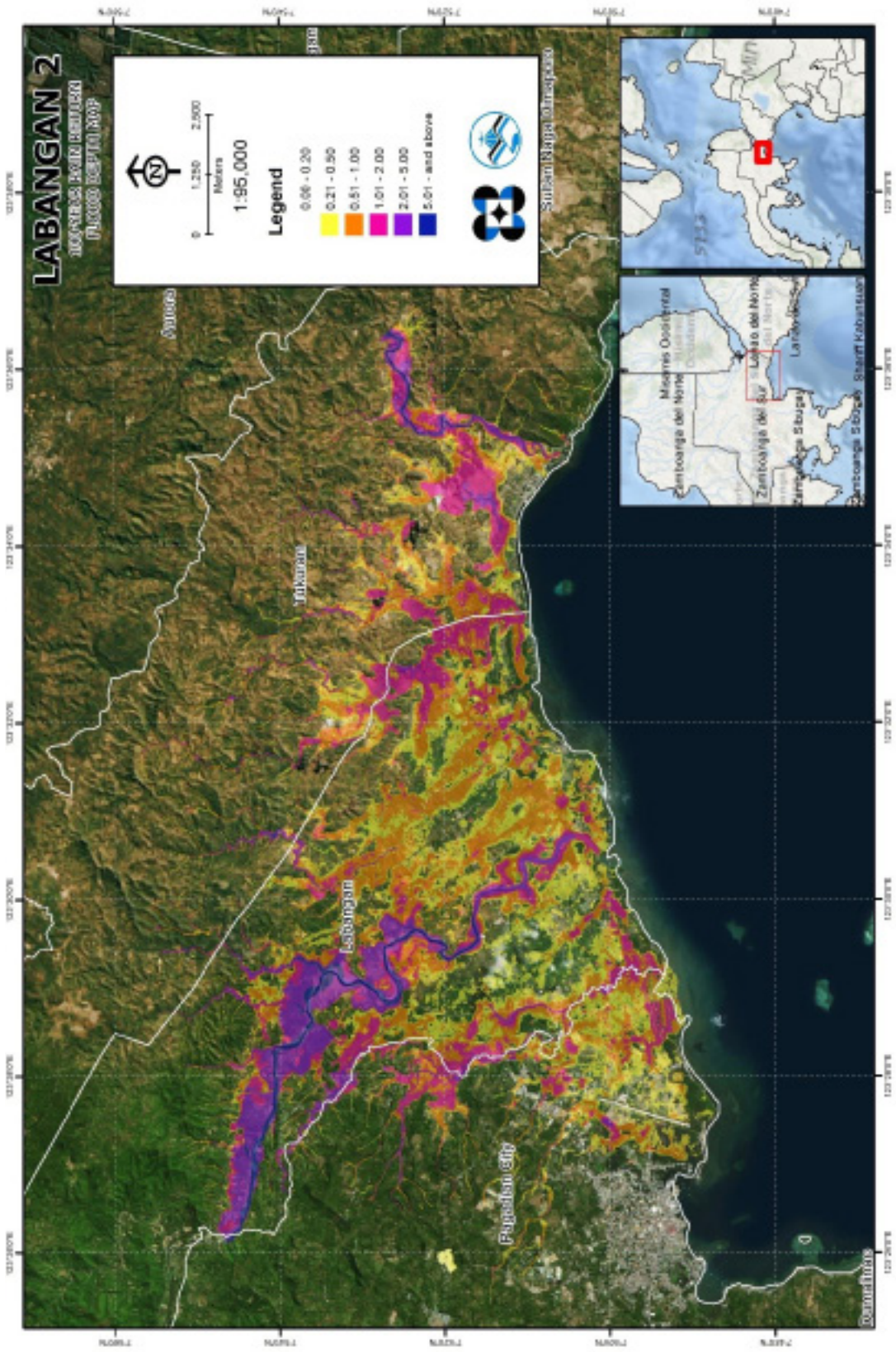


Figure 70. 100-year Flood Depth Map for Labangan Floodplain overlaid on Google Earth imagery

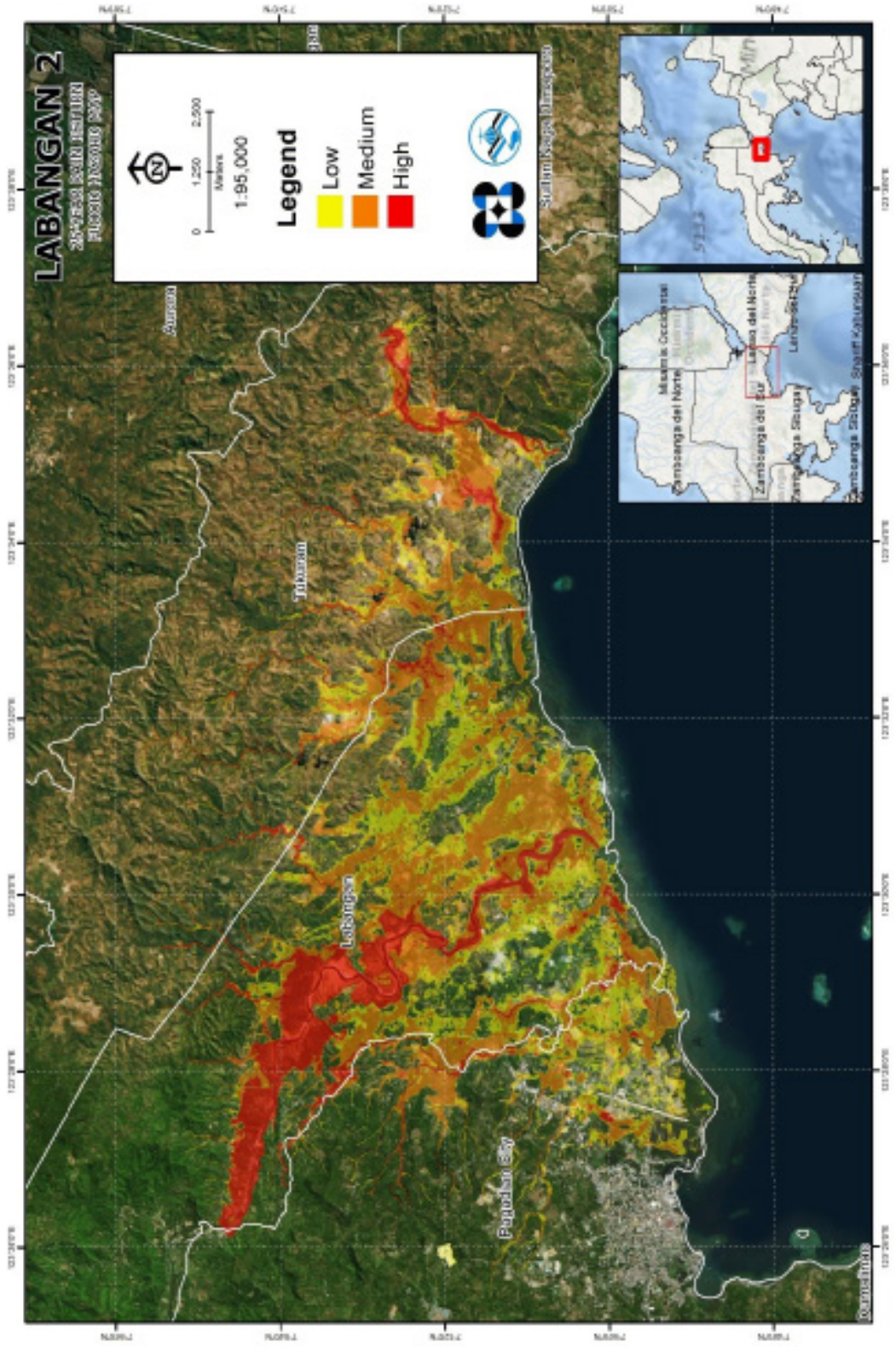


Figure 71. 25-year Flood Hazard Map for Labangan Floodplain overlaid on Google Earth imagery

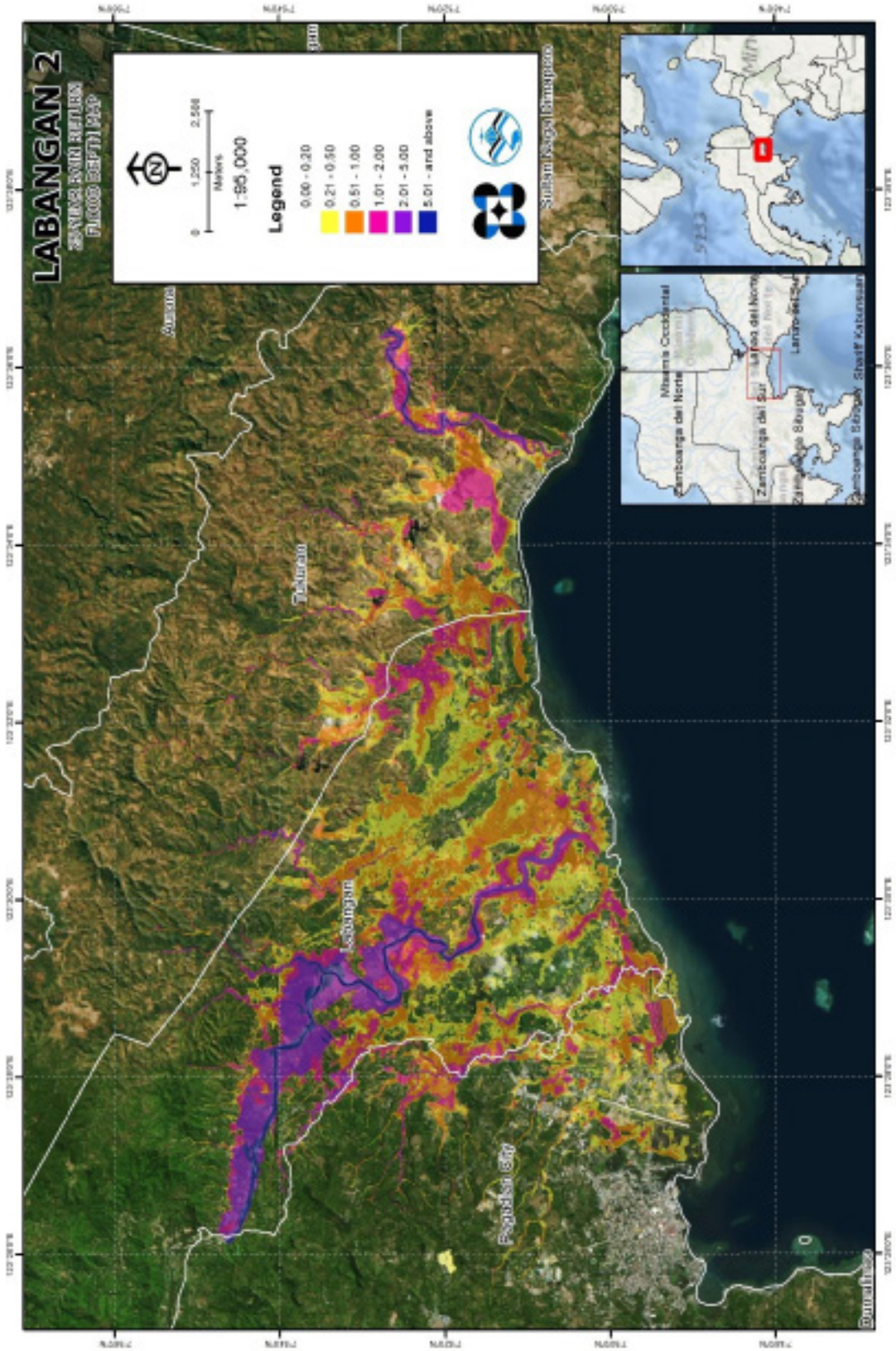


Figure 72. 25-year Flood Depth Map for Labangan Floodplain overlaid on Google Earth imagery

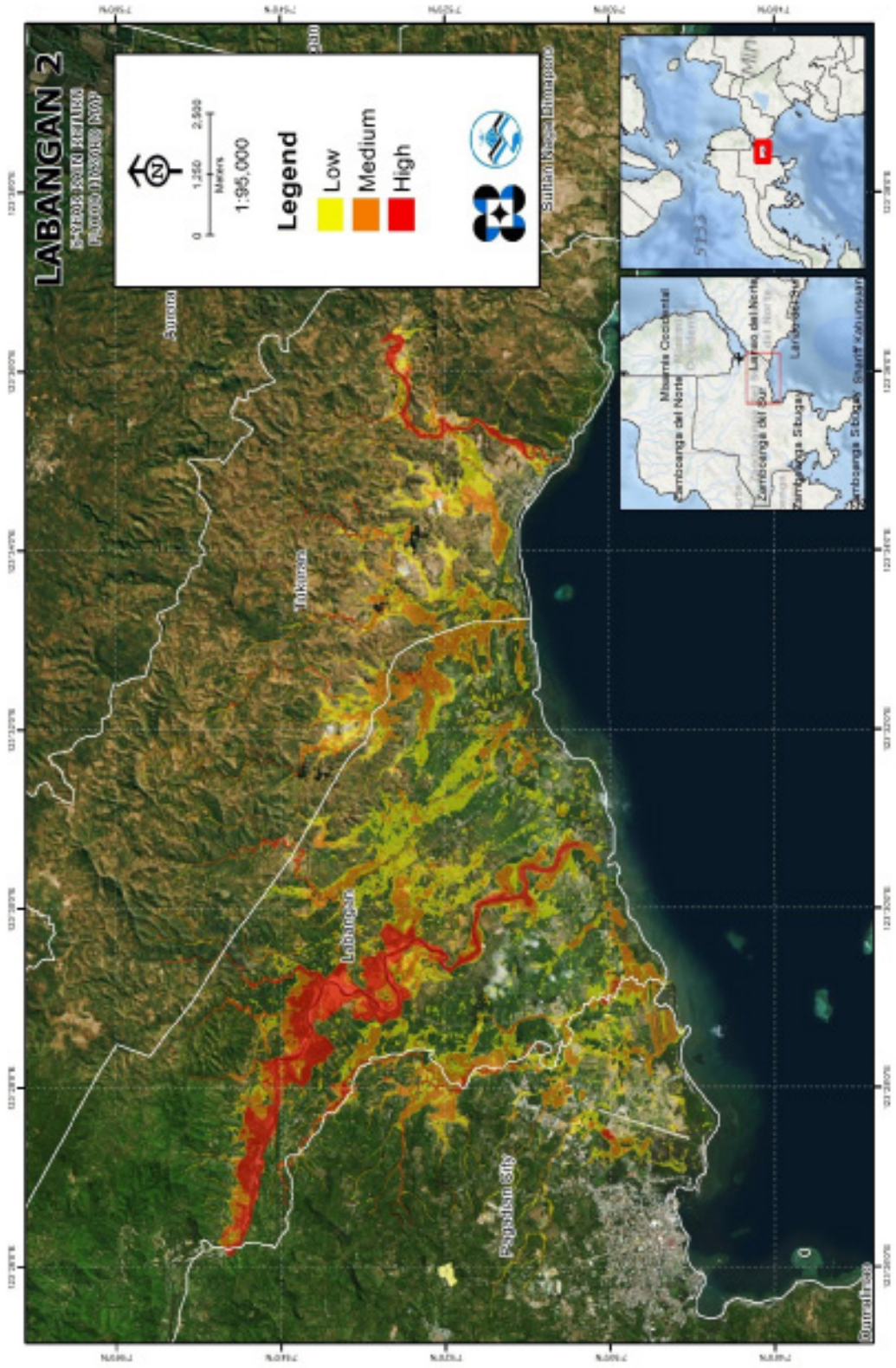


Figure 73. 5-year Flood Hazard Map for Labangan Floodplain overlaid on Google Earth imagery

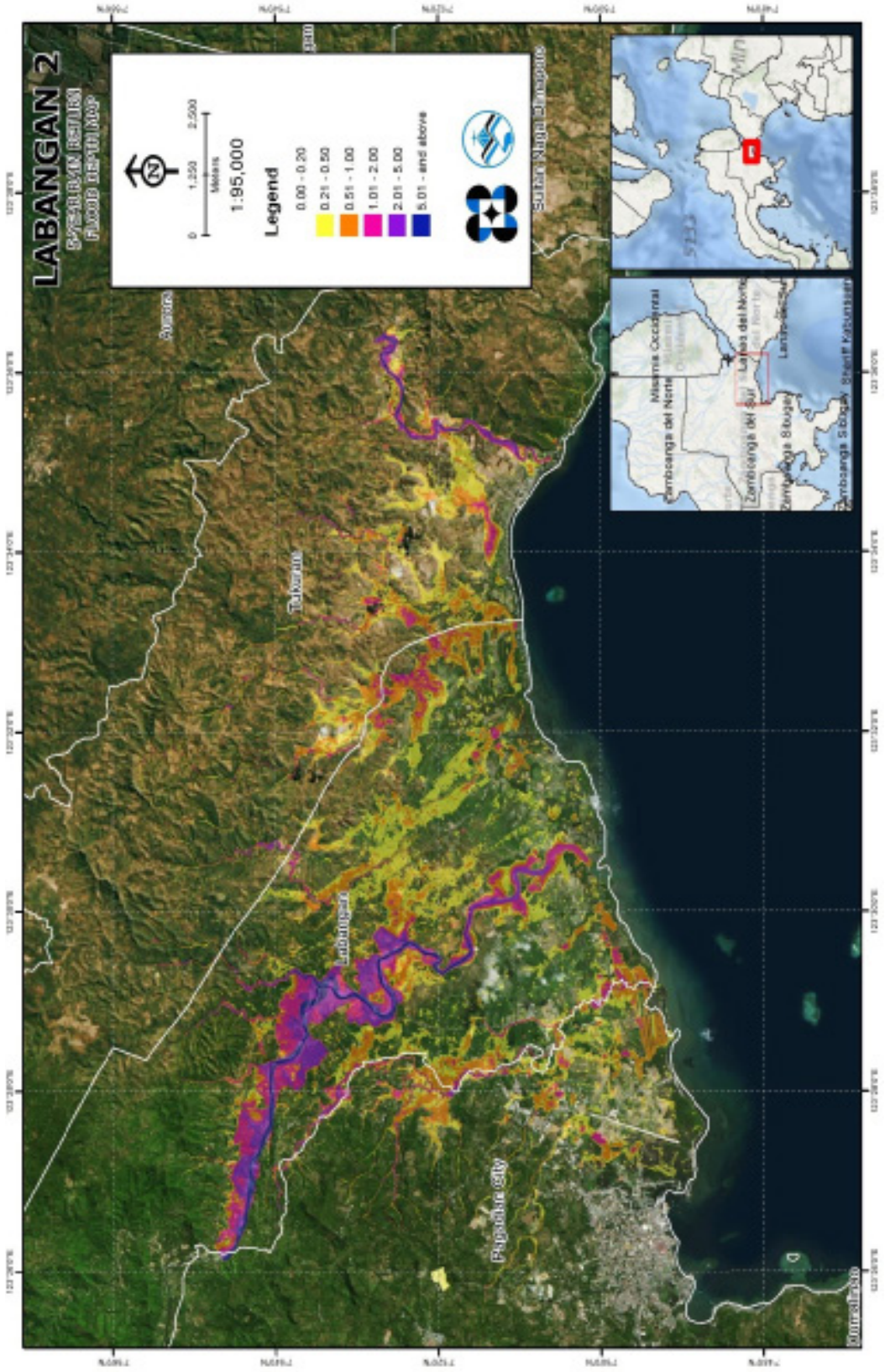


Figure 74. 5-year Flood Depth Map for Labangan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Labangan river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 73 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 24.16% of the municipality of Labangan with an area of 176.44 sq. km. will experience flood levels of less 0.20 meters. 6.25% of the area will experience flood levels of 0.21 to 0.50 meters while 3.65%, 2.45%, 1.89%, and 0.57% 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 Labangan, Zamboanga del Sur during 5-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Labangan									
	(Balimbingan	Bokong	Bulanit	Combo	Dalapang	Dimasangca	Dipaya	Lantian	Lower Campo Islam	Lower Pulacan
0.03-0.20	2.03	3.84	2.48	1.13	1.77	4.05	0.22	3.25	1.96	1.64
0.21-0.50	0.52	0.23	0.58	0.28	0.13	1.45	0.022	0.64	0.75	0.33
0.51-1.00	0.44	0.25	0.49	0.24	0.048	1.12	0.055	0.45	0.11	0.25
1.01-2.00	0.15	0.6	0.24	0.042	0.052	0.34	0.07	0.26	0.017	0.53
2.01-5.00	0.0014	0.51	0.0019	0	0.11	0.0041	0.023	0.45	0	0.36
> 5.00	0	0.17	0	0	0.049	0	0.018	0.12	0	0.13

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Labangan									
	Lower Sang-An	New Labangan	Old Labangan	San Isidro	Santa Cruz	Tapodoc	Tawagan Norte	Upper Campo Islam	Upper Pulacan	Upper Sang-An
0.03-0.20	1.71	1.26	2.38	2.74	1.43	0.43	4.52	1.09	3.41	1.3
0.21-0.50	0.35	0.82	0.5	1.35	0.17	0.18	1.66	0.56	0.097	0.42
0.51-1.00	0.23	0.31	0.057	0.5	0.24	0.14	1.2	0.11	0.065	0.13
1.01-2.00	0.29	0.12	0.0036	0.071	0.58	0.14	0.65	0.0003	0.073	0.095
2.01-5.00	0.064	0.095	0	0.01	0.43	0.097	1.07	0	0.048	0.047
> 5.00	0	0.025	0	0	0.15	0	0.35	0	0	0

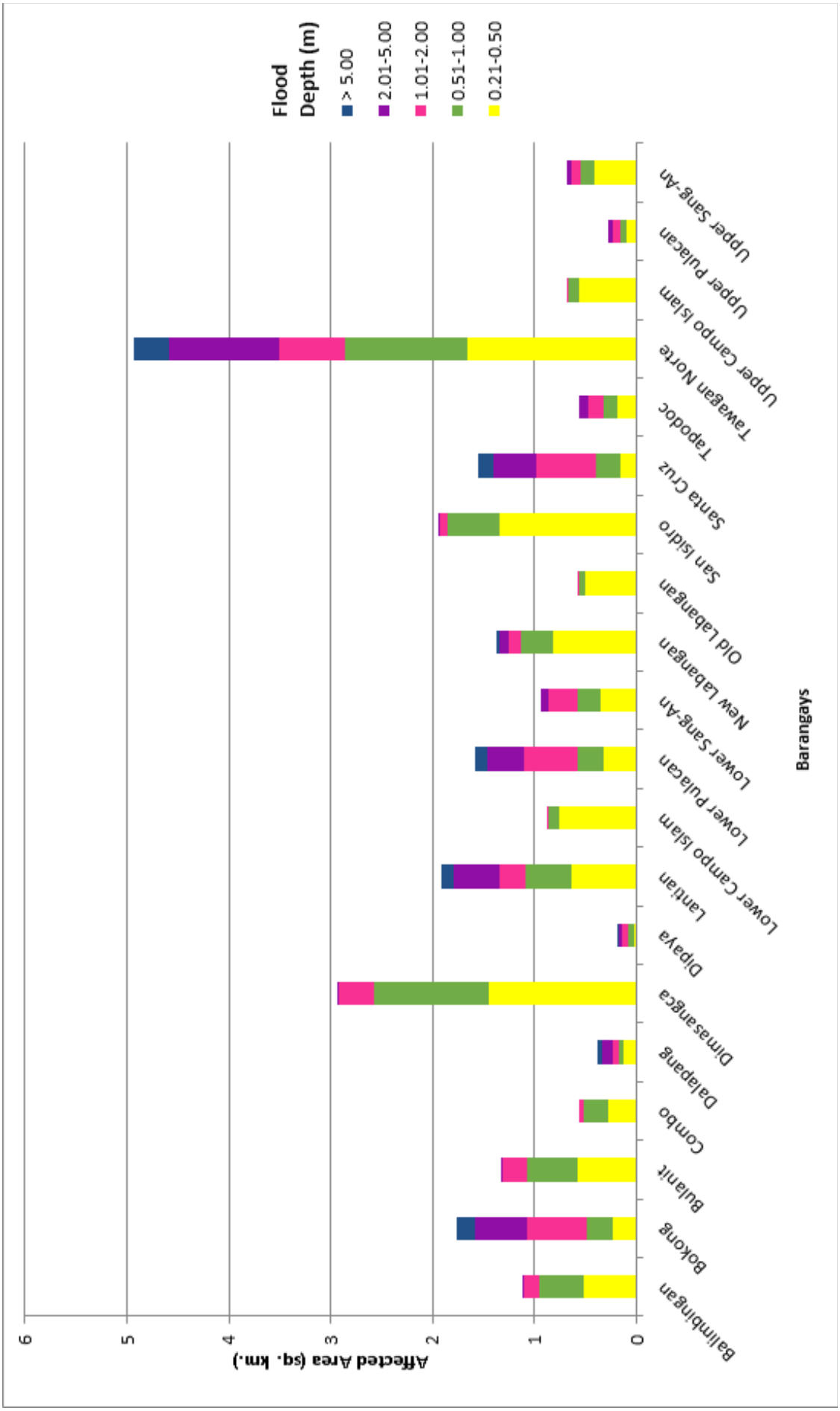


Figure 75. Affected Areas in Labangan, Zamboanga del Sur during 5-Year Rainfall Return Period

For the city of Pagadian, with an area of 279.34 sq. km., 14.34% will experience flood levels of less 0.20 meters. 1.57% of the area will experience flood levels of 0.21 to 0.50 meters while 1.01%, 0.31%, 0.05%, and 0.006% 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 kilometres by flood depth per barangay.

Table 39. Affected Areas in Pagadian City, Zamboanga del Sur during 5-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	Alegria	Balangasan	Balintawak	Banale	Bogo	Bulatok	Dao	Datagan	Gatas	Kagawasan
0.03-0.20	0.018	0.18	2.07	5.41	0.41	2.07	4.51	0.34	0.19	0.061
0.21-0.50	0.0006	0.022	0.1	0.24	0.011	0.11	0.18	0.0046	0.018	0
0.51-1.00	0.0003	0.072	0.023	0.12	0.0079	0.034	0.057	0.0008	0.013	0
1.01-2.00	0.000093	0.078	0.0053	0.069	0.0047	0.0027	0.0009	0.00098	0.007	0
2.01-5.00	0	0.0084	0	0.015	0	0	0	0.014	0	0
> 5.00	0	0	0	0	0	0	0	0.016	0	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	Kahayagan	Kalasan	Kawit	Lenienza	Lumbia	Manga	Muricay	Palpalan	San Francisco	San Jose
0.03-0.20	0.28	3.47	0.48	3.17	0.59	4.24	0.82	0.59	0.28	0.52
0.21-0.50	0.0034	0.11	0.11	0.23	0.054	0.33	0.42	0.0011	0.0052	0.015
0.51-1.00	0.0001	0.076	0.017	0.12	0.03	0.18	0.48	0	0	0.017
1.01-2.00	0	0.047	0	0.015	0.0019	0.049	0.08	0	0	0.0029
2.01-5.00	0	0.0094	0	0	0	0.037	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	San Pedro	Santa Lucia	Santa Maria	Santiago	Santo Niño	Tawagan Sur	Tiguma	Tuburan	Tulawas	White Beach
0.03-0.20	0.16	0.069	0.33	0.14	0.57	0.93	1.48	0.16	2.46	4.07
0.21-0.50	0.1	0.019	0.029	0.014	0.033	0.61	0.33	0.082	0.47	0.73
0.51-1.00	0.012	0.079	0.0092	0.026	0.014	0.26	0.13	0.092	0.69	0.28
1.01-2.00	0	0.011	0.0026	0.00013	0.016	0.072	0.038	0.012	0.24	0.1
2.01-5.00	0	0	0	0	0.012	0.0029	0.001	0	0.027	0
> 5.00	0	0	0	0	0	0	0	0	0	0

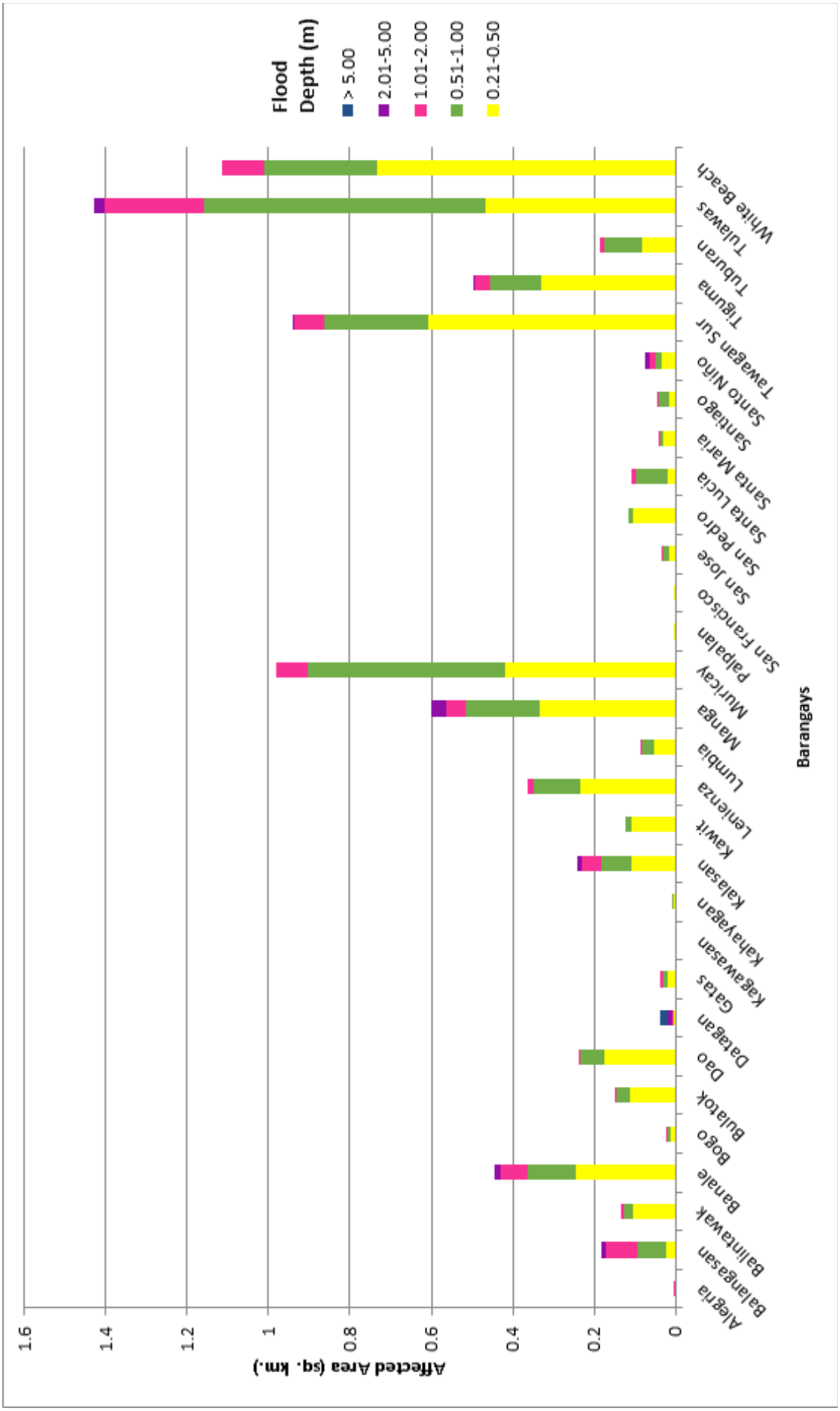


Figure 76. Affected Areas in Pagadian City, Zamboanga del Sur during 5-Year Rainfall Return Period

For the municipality of Tukuran, with an area of 119.01 sq. km., 42.32% will experience flood levels of less 0.20 meters. 4.68% of the area will experience flood levels of 0.21 to 0.50 meters while 2.80%, 1.02%, 0.38%, and 0.09% 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 40 are the affected areas in square kilometres by flood depth per barangay.

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

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Tukuran											
	Alindahaw	Baclay	Balimbingan	Buenasuerte	Camanga	Curvada	Libertad	Lower Bayao	Luy-A	Manilan	Manlayag	Militar
0.03-0.20	0.72	0.5	2.03	0.3	2.47	2.74	0.78	0.59	5.01	3.97	8.18	2.63
0.21-0.50	0.1	0.0039	0.52	0.0017	0.78	0.61	0.01	0.31	0.9	0.11	0.29	0.085
0.51-1.00	0.048	0.0012	0.44	0.0028	0.29	0.23	0.01	0.29	0.56	0.061	0.21	0.039
1.01-2.00	0.014	0.0019	0.15	0.0026	0.036	0.11	0.0059	0.0048	0.16	0.031	0.083	0.022
2.01-5.00	0	0.001	0.0014	0	0.0005	0.1	0.0003	0	0.039	0.0051	0.019	0.015
> 5.00	0	0	0	0	0	0.033	0	0	0	0	0	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Tukuran										
	Navalan	Panduma Senior	Sambulawan	San Antonio	San Carlos	Santo Niño	Santo Rosario	Sugod	Tabuan	Tinotungan	Upper Bayao
0.03-0.20	4.58	0.59	2.24	1.41	0.43	0.57	5.5	0.52	0.92	2.67	1.01
0.21-0.50	0.13	0.069	0.087	0.12	0.18	0.033	0.21	0.019	0.27	0.23	0.5
0.51-1.00	0.062	0.11	0.066	0.035	0.14	0.014	0.13	0.0093	0.23	0.14	0.21
1.01-2.00	0.04	0.099	0.029	0.031	0.047	0.016	0.078	0.0009	0.086	0.12	0.054
2.01-5.00	0.026	0	0.006	0.096	0	0.012	0.025	0	0.0009	0.11	0
> 5.00	0.0003	0	0	0.03	0	0	0	0	0	0.049	0

Figure 77. Affected Areas in Tukuran, Zamboanga del Sur during 5-Year Rainfall Return Period

For the 25-year return period, 16.26% of the municipality of Labangan with an area of 176.44 sq. km. will experience flood levels of less 0.20 meters. 7.42% of the area will experience flood levels of 0.21 to 0.50 meters while 7.40%, 3.68%, 3.37%, and 0.84% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Labangan, Zamboanga del Sur during 25-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Labangan									
	Balimbingan	Bokong	Bulanit	Combo	Dalapang	Dimasangca	Dipaya	Lantian	Lower Campo Islam	Lower Pulacan
0.03-0.20	1.78	3.59	1.69	0.83	1.16	2.51	0.21	2.68	0.69	1.07
0.21-0.50	0.49	0.17	0.88	0.43	0.56	1.69	0.0063	0.66	0.89	0.38
0.51-1.00	0.5	0.17	0.69	0.33	0.15	1.74	0.0035	0.62	1.18	0.32
1.01-2.00	0.36	0.29	0.53	0.1	0.093	1	0.051	0.49	0.069	0.33
2.01-5.00	0.0052	1.1	0.0032	0	0.11	0.027	0.12	0.58	0	0.9
> 5.00	0	0.29	0	0	0.086	0	0.02	0.15	0	0.23

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Labangan									
	Lower Sang-An	New Labangan	Old Labangan	San Isidro	Santa Cruz	Tapodoc	Tawagan Norte	Upper Campo Islam	Upper Pulacan	Upper Sang-An
0.03-0.20	0.6	0.76	0.6	2.19	1.14	0.18	2.58	0.62	3.29	0.55
0.21-0.50	0.89	0.54	0.66	1.19	0.067	0.19	1.77	0.73	0.14	0.74
0.51-1.00	0.56	0.89	1.42	1.07	0.12	0.3	2.01	0.4	0.086	0.49
1.01-2.00	0.43	0.28	0.27	0.2	0.38	0.2	1.18	0.01	0.092	0.15
2.01-5.00	0.15	0.14	0	0.026	1.06	0.13	1.44	0	0.091	0.064
> 5.00	0	0.031	0	0	0.22	0	0.46	0	0.0017	0

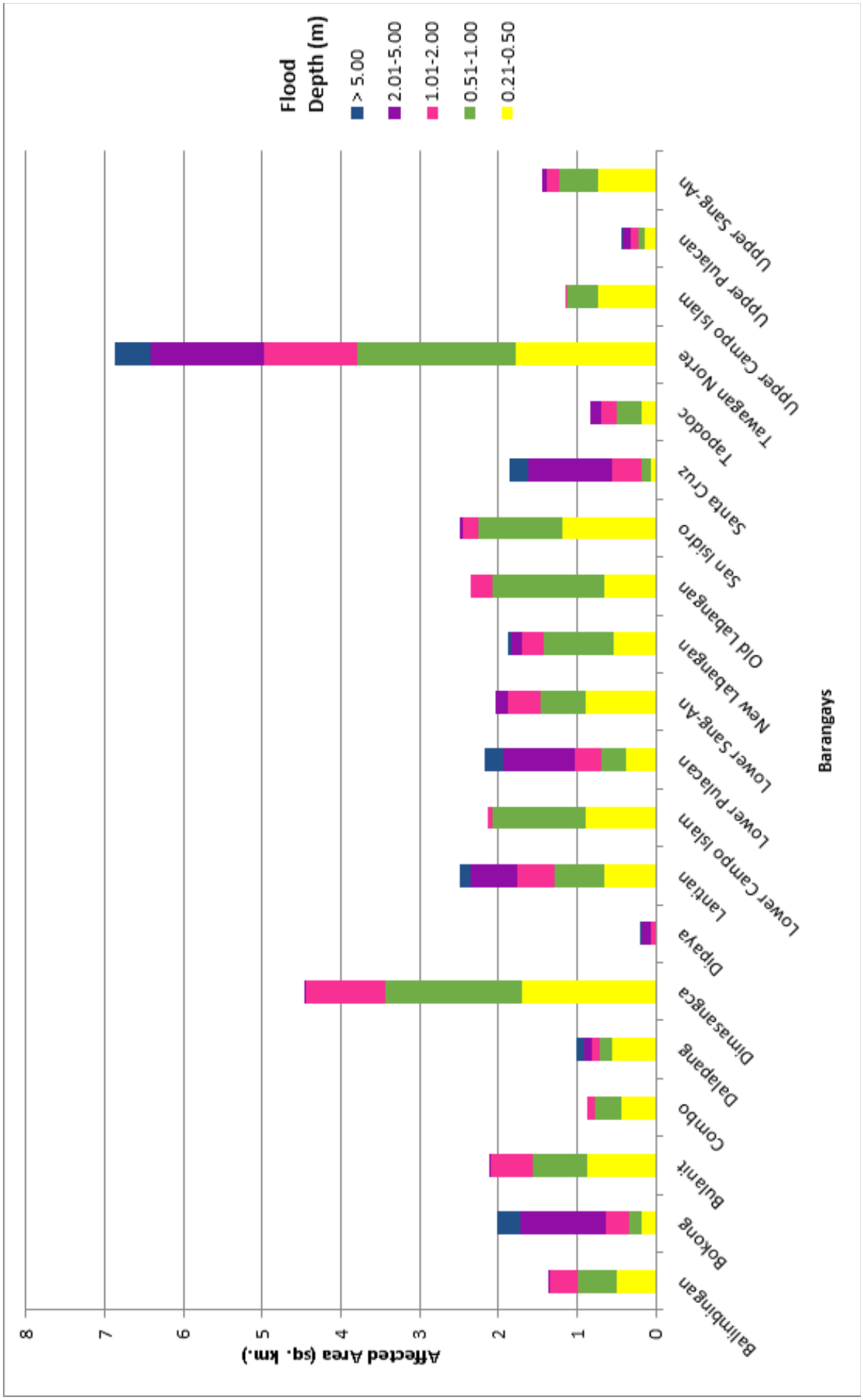


Figure 78. Affected Areas in Labangan, Zamboanga del Sur during 25-Year Rainfall Return Period

For the city of Pagadian, with an area of 279.34 sq. km., 13.28% will experience flood levels of less 0.20 meters. 1.87% of the area will experience flood levels of 0.21 to 0.50 meters while 1.39%, 0.65%, 0.09%, and 0.007% 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 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Pagadian City, Zamboanga del Sur during 25-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	Alegria	Balangasan	Balintawak	Banale	Bogo	Bulatok	Dao	Datagan	Gatas	Kagawasan
0.03-0.20	0.018	0.16	2.02	5.29	0.41	2.03	4.43	0.34	0.19	0.061
0.21-0.50	0.0007	0.02	0.13	0.28	0.011	0.14	0.22	0.0056	0.017	0
0.51-1.00	0.0004	0.037	0.04	0.15	0.012	0.05	0.089	0.0014	0.017	0
1.01-2.00	0.00029	0.13	0.0097	0.089	0.0057	0.0092	0.0057	0.0013	0.012	0
2.01-5.00	0	0.015	0.00089	0.043	0.0001	0	0	0.012	0	0
> 5.00	0	0	0	0	0	0	0	0.019	0	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	Kahayagan	Kalasan	Kawit	Lenienza	Lumbia	Manga	Muricay	Palpalan	San Francisco	San Jose
0.03-0.20	0.27	3.43	0.37	3.06	0.57	4.11	0.36	0.59	0.27	0.51
0.21-0.50	0.0039	0.11	0.17	0.28	0.053	0.28	0.58	0.0024	0.014	0.017
0.51-1.00	0.00067	0.073	0.06	0.16	0.043	0.32	0.61	0.00033	0	0.023
1.01-2.00	0	0.075	0	0.038	0.011	0.084	0.25	0	0	0.0054
2.01-5.00	0	0.031	0	0	0	0.046	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	San Pedro	Santa Lucia	Santa Maria	Santiago	Santo Niño	Tawagan Sur	Tiguma	Tuburan	Tulawas	White Beach
0.03-0.20	0.088	0.057	0.31	0.13	0.55	0.42	1.28	0.13	2.29	3.37
0.21-0.50	0.14	0.012	0.029	0.013	0.033	0.83	0.42	0.075	0.24	1.1
0.51-1.00	0.043	0.049	0.018	0.027	0.023	0.46	0.21	0.1	0.77	0.51
1.01-2.00	0	0.06	0.0044	0.012	0.017	0.15	0.076	0.048	0.52	0.2
2.01-5.00	0	0	0	0	0.024	0.0096	0.0018	0	0.068	0
> 5.00	0	0	0	0	0	0	0	0	0	0

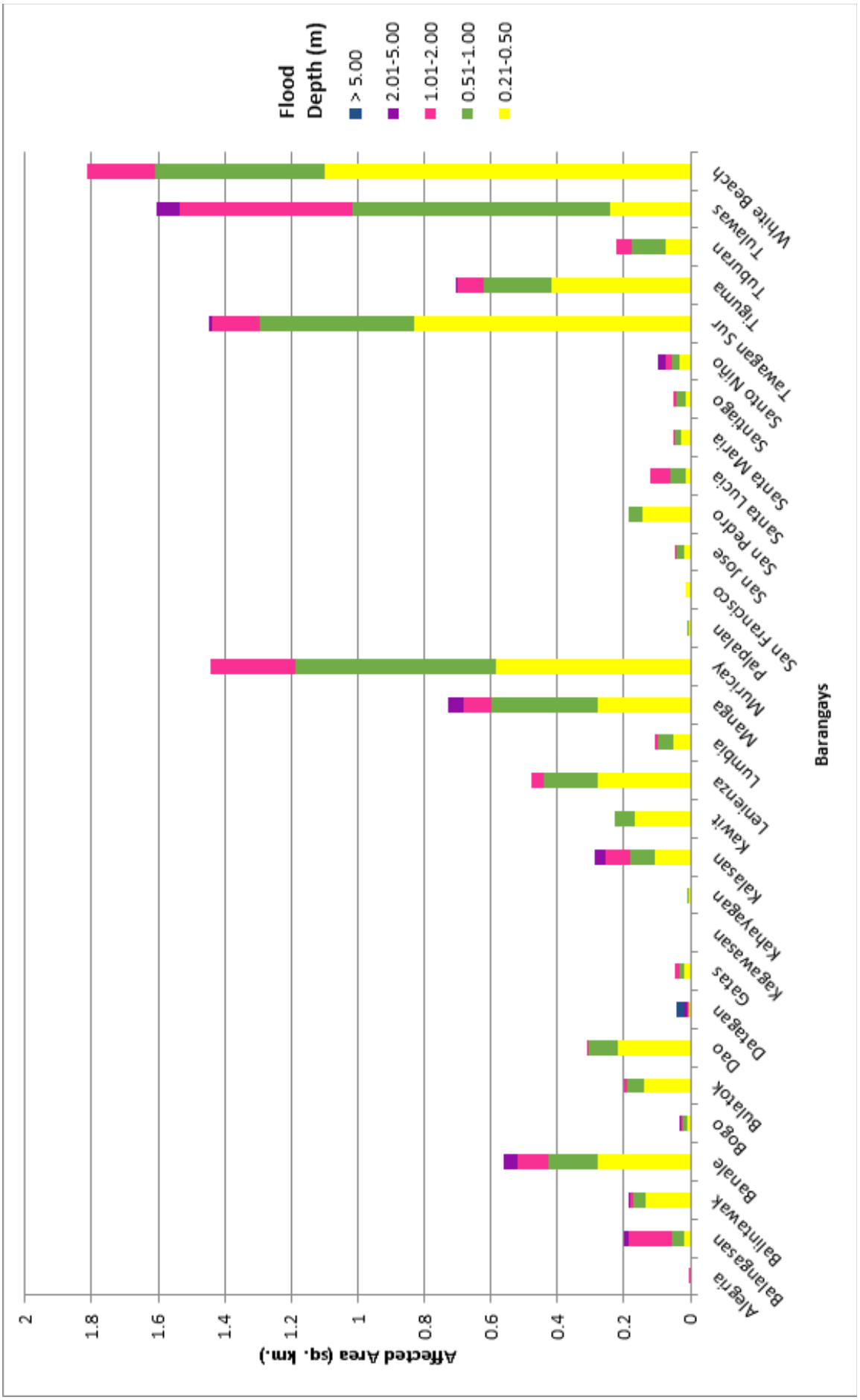


Figure 79. Affected Areas in Pagadian City, Zamboanga del Sur during 25-Year Rainfall Return Period

For the municipality of Tukuran, with an area of 119.01 sq. km., 39.55% will experience flood levels of less 0.20 meters. 4.05% of the area will experience flood levels of 0.21 to 0.50 meters while 4.17%, 2.76%, 0.60%, and 0.15% 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 Tukuran, Zamboanga del Sur during 25-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Tukuran											
	Alindahaw	Baclay	Balimbingan	Buenasuerte	Camanga	Curvada	Libertad	Lower Bayao	Luy-A	Manilan	Manlayag	Militar
0.03-0.20	0.55	0.5	1.78	0.3	2.18	2.26	0.78	0.34	4.55	3.91	8.05	2.59
0.21-0.50	0.14	0.0065	0.49	0.0028	0.56	0.35	0.01	0.26	0.89	0.14	0.3	0.11
0.51-1.00	0.13	0.0016	0.5	0.0016	0.48	0.65	0.01	0.49	0.82	0.075	0.24	0.05
1.01-2.00	0.075	0.0021	0.36	0.0047	0.35	0.38	0.0094	0.1	0.35	0.044	0.15	0.029
2.01-5.00	0.0003	0.0022	0.0052	0.0005	0.0027	0.14	0.0011	0	0.068	0.011	0.043	0.017
> 5.00	0	0.0002	0	0	0	0.053	0	0	0	0	0.00076	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Tukuran										
	Navalan	Panduma Senior	Sambulawan	San Antonio	San Carlos	Santo Niño	Santo Rosario	Sugod	Tabuan	Tinotungan	Upper Bayao
0.03-0.20	4.51	0.47	2.19	1.29	0.34	0.55	5.4	0.51	0.79	2.47	0.77
0.21-0.50	0.15	0.088	0.086	0.12	0.032	0.033	0.23	0.023	0.26	0.15	0.4
0.51-1.00	0.066	0.094	0.081	0.091	0.086	0.023	0.16	0.011	0.29	0.15	0.47
1.01-2.00	0.056	0.22	0.046	0.066	0.33	0.017	0.11	0.0027	0.17	0.28	0.13
2.01-5.00	0.041	0	0.016	0.11	0.0063	0.024	0.048	0	0.0022	0.18	0
> 5.00	0.0058	0	0.0001	0.043	0	0	0	0	0	0.07	0

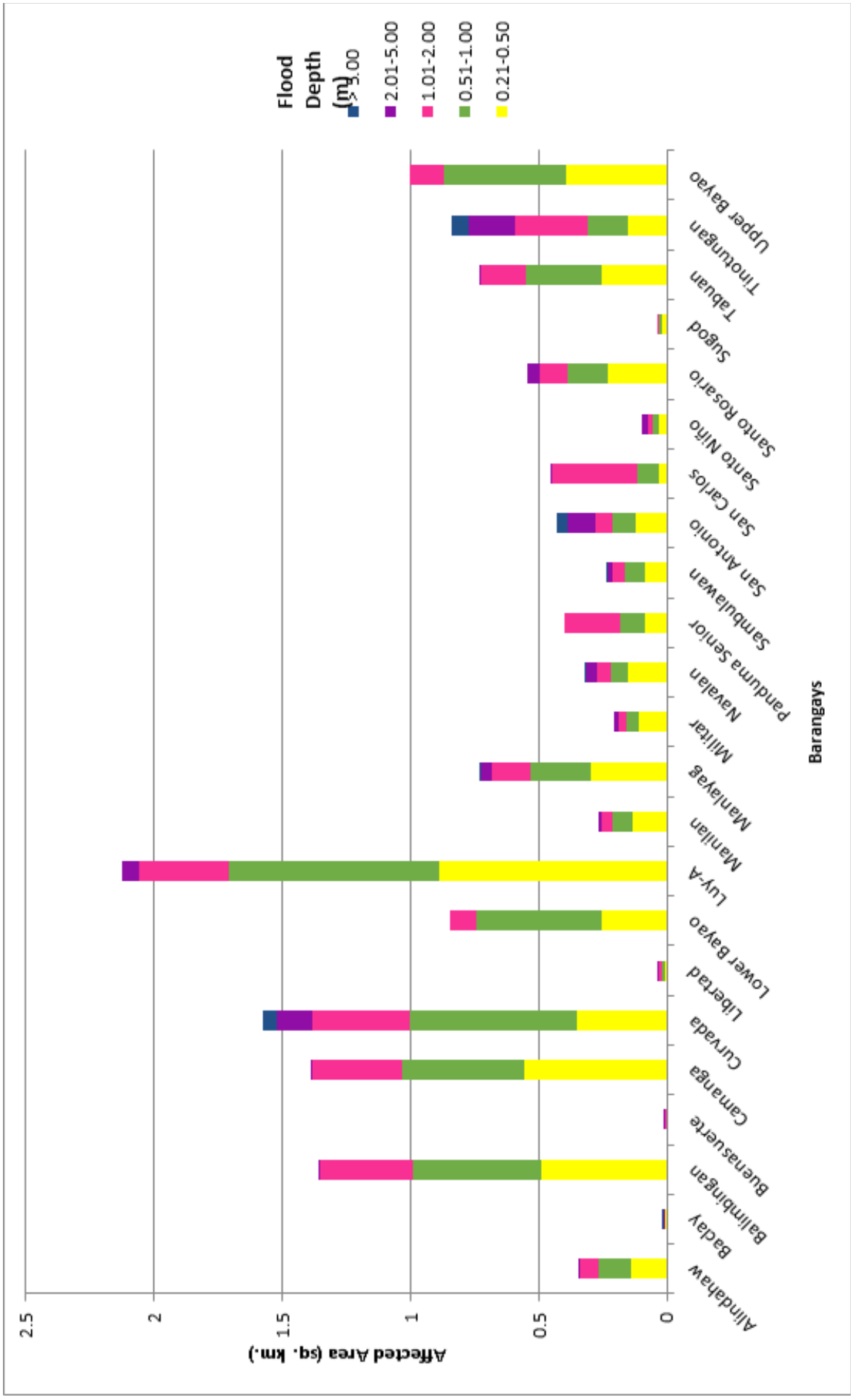


Figure 80. Affected Areas in Tukuran, Zamboanga del Sur during 25-Year Rainfall Return Period

For the 100-year return period, 15.81% of the municipality of Labangan with an area of 176.44 sq. km. will experience flood levels of less 0.20 meters. 7.26% of the area will experience flood levels of 0.21 to 0.50 meters while 7.85%, 4.07%, 3.25%, and 0.74% 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 kilometres by flood depth per barangay.

Table 44. Affected Areas in Labangan, Zamboanga del Sur during 100-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Labangan									
	Balimbingan	Bokong	Bulanit	Combo	Dalapang	Dimasangca	Dipaya	Lantian	Lower Campo Islam	Lower Pulacan
0.03-0.20	1.69	3.58	1.48	0.64	1.37	1.85	0.21	2.58	0.68	1
0.21-0.50	0.46	0.19	0.91	0.46	0.45	1.38	0.0067	0.7	0.96	0.41
0.51-1.00	0.54	0.2	0.79	0.41	0.088	2.16	0.006	0.75	1.14	0.48
1.01-2.00	0.43	0.31	0.6	0.18	0.071	1.53	0.065	0.45	0.049	0.37
2.01-5.00	0.025	1.08	0.015	0	0.1	0.055	0.1	0.55	0	0.79
> 5.00	0	0.25	0	0	0.076	0	0.019	0.13	0	0.19

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Labangan									
	Lower Sang-An	New Labangan	Old Labangan	San Isidro	Santa Cruz	Tapodoc	Tawagan Norte	Upper Campo Islam	Upper Pulacan	Upper Sang-An
0.03-0.20	0.86	0.88	0.77	2.08	1.16	0.24	2.21	0.61	3.22	0.81
0.21-0.50	0.87	0.7	0.81	0.88	0.099	0.22	1.76	0.71	0.14	0.67
0.51-1.00	0.4	0.71	1.21	1.49	0.19	0.24	2.19	0.43	0.11	0.34
1.01-2.00	0.38	0.18	0.16	0.19	0.33	0.18	1.46	0.013	0.099	0.11
2.01-5.00	0.13	0.12	0	0.034	1.01	0.12	1.42	0	0.12	0.057
> 5.00	0	0.029	0	0	0.21	0	0.4	0	0.0046	0

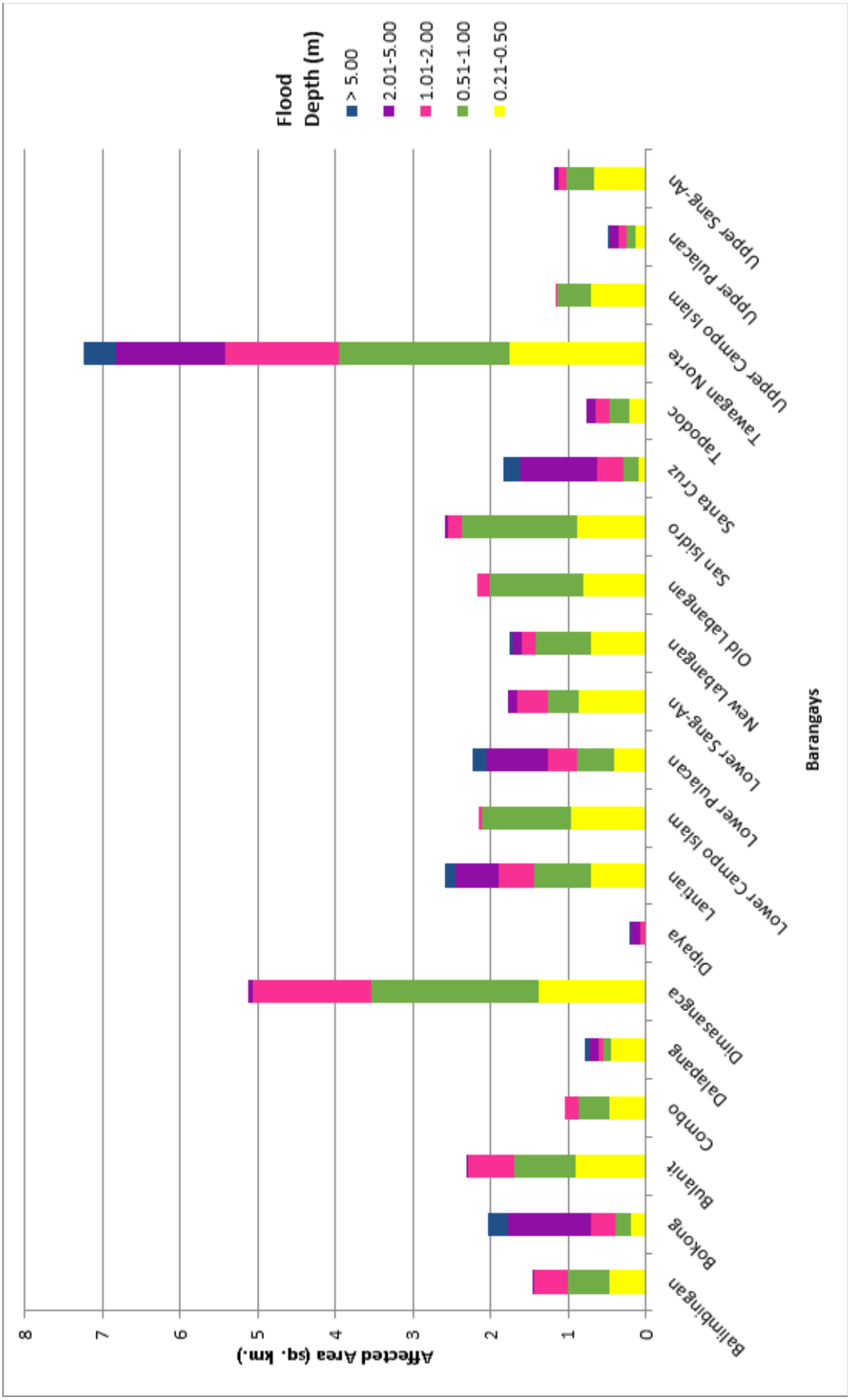


Figure 81. Affected Areas in Labangan, Zamboanga del Sur during 100-Year Rainfall Return Period

For the city of Pagadian, with an area of 279.34 sq. km., 12.64% will experience flood levels of less 0.20 meters. 2.00% of the area will experience flood levels of 0.21 to 0.50 meters while 1.56%, 0.93%, 0.15%, and 0.007% 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 kilometres by flood depth per barangay.

Table 45. Affected Areas in Pagadian City, Zamboanga del Sur during 100-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	Alegria	Balangasan	Balintawak	Banale	Bogo	Bulatok	Dao	Datagan	Gatas	Kagawasan
0.03-0.20	0.018	0.16	1.98	5.21	0.4	1.99	4.37	0.33	0.18	0.061
0.21-0.50	0.001	0.014	0.16	0.3	0.011	0.15	0.24	0.007	0.013	0
0.51-1.00	0.0003	0.032	0.051	0.17	0.012	0.062	0.11	0.0016	0.019	0
1.01-2.00	0.00039	0.14	0.014	0.098	0.0074	0.017	0.011	0.0014	0.017	0
2.01-5.00	0	0.023	0.0015	0.068	0.0004	0	0	0.012	0	0
> 5.00	0	0	0	0.0006	0	0	0	0.019	0	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	Kahayagan	Kalasan	Kawit	Lenienza	Lumbia	Manga	Muricay	Palpalan	San Francisco	San Jose
0.03-0.20	0.27	3.39	0.29	2.98	0.56	4.05	0.17	0.59	0.26	0.5
0.21-0.50	0.0039	0.12	0.2	0.3	0.051	0.26	0.58	0.0035	0.026	0.02
0.51-1.00	0.0019	0.073	0.1	0.18	0.054	0.34	0.62	0.00053	0	0.02
1.01-2.00	0	0.075	0.0018	0.066	0.017	0.14	0.44	0	0	0.014
2.01-5.00	0	0.06	0	0.0024	0	0.052	0.0004	0	0	0
> 5.00	0	0.00076	0	0	0	0	0	0	0	0

Area Affected (sq.m.) by flood depth (m.)	Affected Barangays in Pagadian City									
	San Pedro	Santa Lucia	Santa Maria	Santiago	Santo Niño	Tawagan Sur	Tiguma	Tuburan	Tulawas	White Beach
0.03-0.20	0.061	0.051	0.31	0.12	0.53	0.2	1.12	0.12	2.22	2.79
0.21-0.50	0.14	0.011	0.029	0.013	0.035	0.76	0.49	0.053	0.17	1.45
0.51-1.00	0.07	0.027	0.023	0.02	0.022	0.69	0.26	0.12	0.6	0.67
1.01-2.00	0.00075	0.089	0.0053	0.024	0.022	0.21	0.11	0.061	0.78	0.24
2.01-5.00	0	0	0	0	0.031	0.013	0.0026	0	0.12	0.032
> 5.00	0	0	0	0	0.0005	0	0	0	0	0

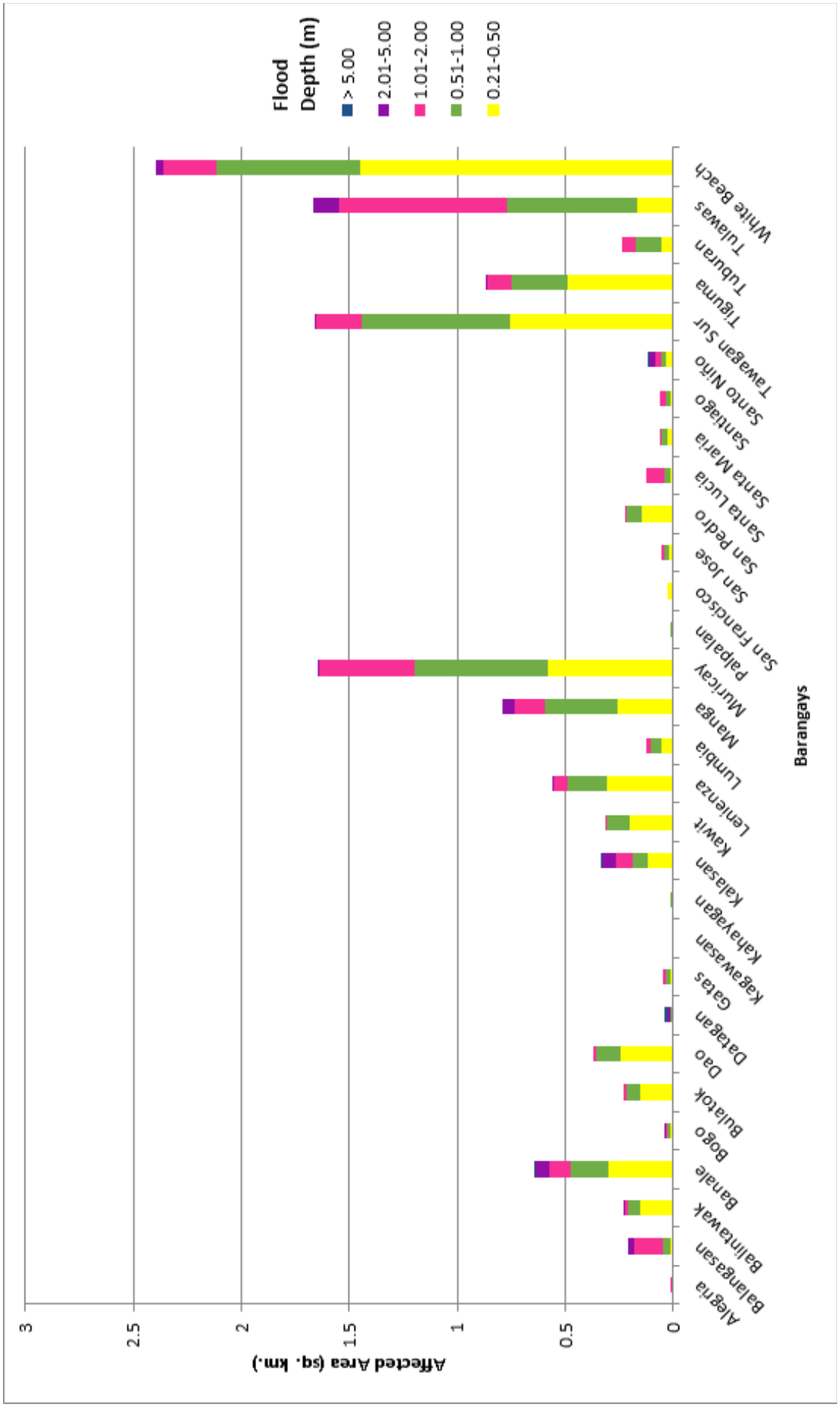


Figure 82. Affected Areas in Pagadian City, Zamboanga del Sur during 100-Year Rainfall Return Period

For the municipality of Tukuran, with an area of 119.01 sq. km., 38.36% will experience flood levels of less 0.20 meters. 3.73% of the area will experience flood levels of 0.21 to 0.50 meters while 4.20%, 3.82%, 0.99%, 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 46 are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected Areas in Tukuran, Zamboanga del Sur during 100-Year Rainfall Return Period

Area Affected (sq.m.) by flood depth (m.	Affected Barangays in Tukuran											
	Alindahaw	Baclay	Balimbingan	Buenasuerte	Camanga	Curvada	Libertad	Lower Bayao	Luy-A	Manilan	Manlayag	Militar
0.03-0.20	0.48	0.49	1.69	0.3	2.07	2.07	0.77	0.26	4.31	3.87	7.96	2.56
0.21-0.50	0.14	0.0092	0.46	0.0031	0.44	0.32	0.012	0.16	0.86	0.15	0.31	0.12
0.51-1.00	0.17	0.0021	0.54	0.002	0.49	0.48	0.0093	0.43	0.89	0.078	0.25	0.059
1.01-2.00	0.1	0.0021	0.43	0.0031	0.53	0.71	0.011	0.34	0.52	0.056	0.19	0.036
2.01-5.00	0.0009	0.0029	0.025	0.0029	0.033	0.19	0.0022	0	0.094	0.02	0.066	0.019
> 5.00	0	0.0003	0	0	0	0.064	0	0	0	0	0.0024	0

Area Affected (sq.m.) by flood depth (m.	Affected Barangays in Tukuran										
	Navalan	Panduma Senior	Sambulawan	San Antonio	San Carlos	Santo Niño	Santo Rosario	Sugod	Tabuan	Tinotungan	Upper Bayao
0.03-0.20	4.47	0.43	2.17	1.25	0.31	0.53	5.33	0.51	0.72	2.42	0.69
0.21-0.50	0.17	0.075	0.084	0.12	0.024	0.035	0.25	0.025	0.22	0.13	0.31
0.51-1.00	0.073	0.095	0.083	0.064	0.044	0.022	0.18	0.012	0.34	0.14	0.56
1.01-2.00	0.06	0.23	0.058	0.11	0.3	0.022	0.13	0.0038	0.22	0.27	0.22
2.01-5.00	0.056	0.035	0.027	0.12	0.12	0.031	0.065	0	0.0031	0.27	0
> 5.00	0.0083	0	0.0012	0.054	0	0.0005	0	0	0	0.083	0

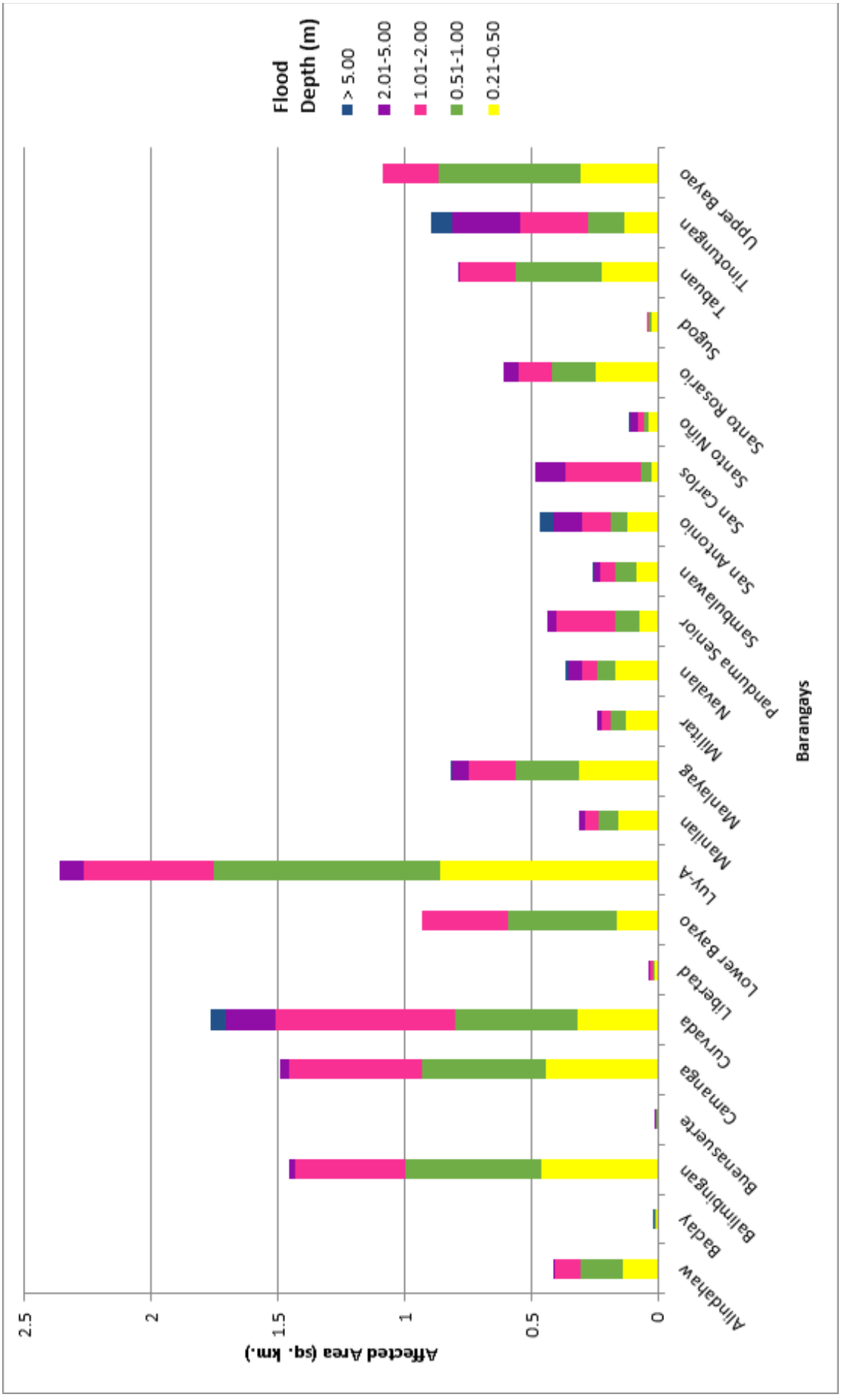


Figure 83. Affected Areas in Tukuran, Zamboanga del Sur during 100-Year Rainfall Return Period

Among the barangays in the municipality of Labangan, Tawagan Norte is projected to have the highest percentage of area that will experience flood levels at 5.36%. Meanwhile, Dimasangca posted the second highest percentage of area that may be affected by flood depths at 3.95%.

Among the barangays in the city of Pagadian, Banale is projected to have the highest percentage of area that will experience flood levels at 2.10%. Meanwhile, White Beach posted the second highest percentage of area that may be affected by flood depths at 1.86%.

Among the barangays in the municipality of Tukuran, Manlayag is projected to have the highest percentage of area that will experience flood levels at 7.38%. Meanwhile, Luy-A posted the second highest percentage of area that may be affected by flood depths at 5.61%.

Moreover, the generated flood hazard maps for the Labangan 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 47. 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	21.04	23.11	22.97
Medium	16.4	29.87	32.69
High	7.89	12.57	14.12
TOTAL	**45.33**	**65.55**	**69.78**

Of the 211 identified Education Institutions in Labangan Flood plain, 16 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while 16 schools were assessed to be exposed to Medium level flooding and 3 schools were assessed to be exposed to High level flooding in the same scenario. In the 25-year scenario, 20 schools were assessed to be exposed to the Low level flooding while 21 schools were assessed to be exposed to Medium level flooding and 7 schools were assessed to be exposed to High level flooding. For the 100-year scenario, 22 schools were assessed for Low level flooding and 26 schools for Medium level flooding. In the same scenario, 6 schools were assessed to be exposed to High level flooding. See Annex 12 for a detailed enumeration of schools inside Labangan floodplain.

Of the 51 identified Medical Institutions in Labangan Flood plain, 3 were assessed to be exposed to the Low level flooding during a 5 year scenario while 5 were assessed to be exposed to Medium level flooding and 1 was assessed to be exposed to High level flooding in the same scenario. In the 25 year scenario, 5 were assessed to be exposed to the Low level flooding while 6 were assessed to be exposed to Medium level flooding and 1 was assessed to be exposed to High level flooding. For the 100 year scenario, 8 school was assessed for Low level flooding and 6 for Medium level flooding. In the same scenario, 1 was assessed to be exposed to High level flooding. See Annex 13 for a detailed enumeration of medical institutions inside Labangan 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 survey work. Field personnel gathered secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

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

After which, 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.

The flood validation consists of 277 points randomly selected all over the Labangan flood plain. It has an RMSE value of 0.64.

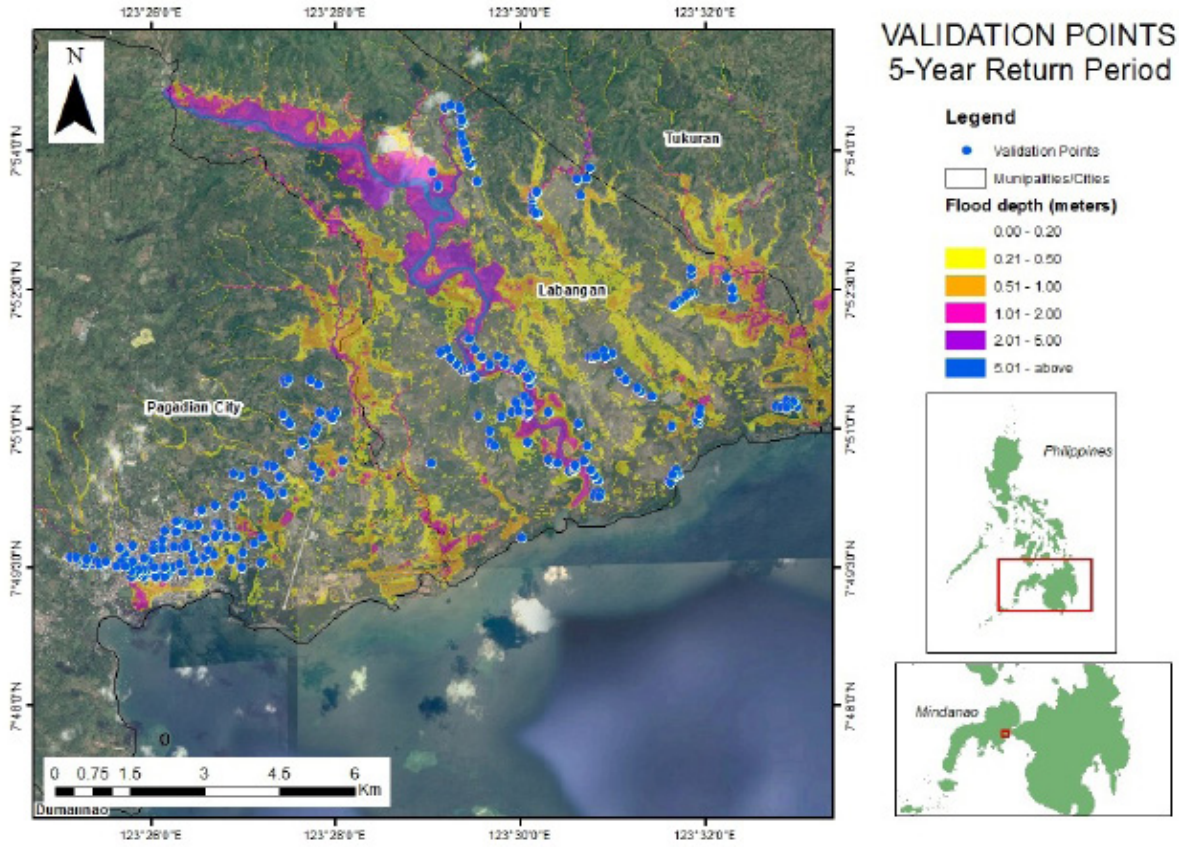


Figure 83. Validation points for 5-year Flood Depth Map of Labangan Floodplain

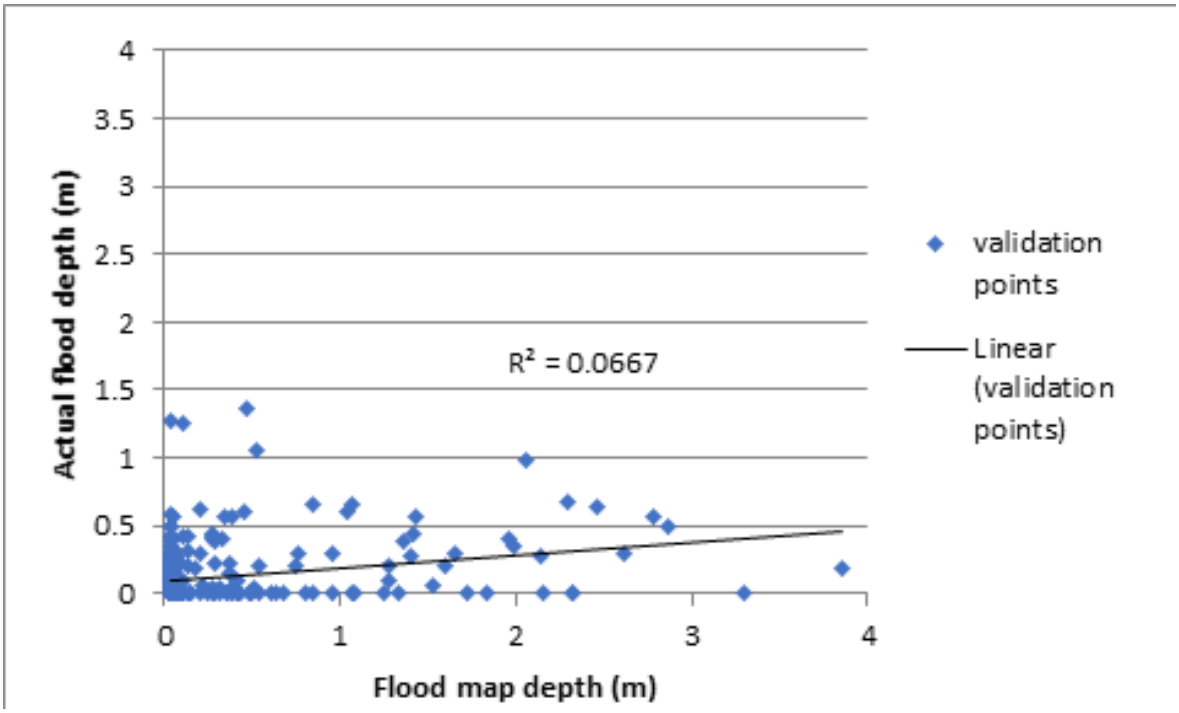


Figure 84. Flood map depth vs actual flood depth

Table 48. Actual Flood Depth vs Simulated Flood Depth in Labangan

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	161	22	10	9	5	0	207
0.21-0.50	32	8	2	7	3	0	52
0.51-1.00	3	3	1	3	4	0	14
1.01-2.00	2	1	1	0	0	0	4
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	198	34	14	19	12	0	277

The overall accuracy generated by the flood model is estimated at 61.37%, with 170 points correctly matching the actual flood depths. In addition, there were 63 points estimated one level above and below the correct flood depths while there were 25 points and 19 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 65 points were overestimated while a total of 42 points were underestimated in the modelled flood depths of Labangan.

Table 49. Summary of Accuracy Assessment in Labangan River Basin Survey

	No. of Points	%
Correct	170	**61.37**
Overestimated	65	**23.47**
Underestimated	42	**15.16**
Total	277	**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 Labangan Floodplain Survey

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
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;
Power requirements	28 V; 900 W;35 A(peak)
	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

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

1. LAN-2

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

June 24, 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: **LANAO DEL NORTE**
Station Name: **LAN-2**
Order: **1st**

Island: **MINDANAO**
Municipality: **LALA**
Barangay: **PINOYAK**

PRS92 Coordinates

Latitude: **7° 54' 46.07859"** Longitude: **123° 46' 0.85333"** Ellipsoidal Hgt: **17.35400 m.**

WGS84 Coordinates

Latitude: **7° 54' 42.56546"** Longitude: **123° 46' 6.31720"** Ellipsoidal Hgt: **83.92120 m.**

PTM Coordinates

Northing: **875110.149 m.** Easting: **364025.74 m.** Zone: **5**

UTM Coordinates

Northing: **874,680.35** Easting: **584,533.45** Zone: **51**

Location Description

LAN-2
From Iligan City, travel southwest along the National highway for 74.5 kilometers to the municipality of Lala. Travel farther along the national highway for 1.4 kilometers up to Maranding junction. Thence from the junction travel southeast along the national highway for another 1.3 kilometers to a dirt road going to Pinoyak barangay proper. Turn right on the dirt road and national highway intersection and continue travelling westward for 400 meters up to the irrigation canal. Station is located on top of the concrete irrigation canal water gate. Station mark is 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in a drill hole on top of the concrete irrigation canal water gate; centered in cement petty and inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in drill holes on top of the concrete irrigation canal water gate; centered in cement petty and inscribed with the reference mark numbers and arrow pointing to the station.

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1441**

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) 241-3484 to 88
www.namria.gov.ph
ISO 9001:2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. ZGS-1

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

February 10, 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 SUR**
Station Name: **ZGS-1**
Order: **1st**

Island: **MINDANAO** Barangay: **DIPOLO**
Municipality: **MOLAVE** MSL Elevation:

PRS92 Coordinates

Latitude: **8° 4' 26.98334"** Longitude: **123° 29' 14.53868"** Ellipsoidal Hgt: **22.61100 m.**

WGS84 Coordinates

Latitude: **8° 4' 23.40249"** Longitude: **123° 29' 19.99013"** Ellipsoidal Hgt: **88.16300 m.**

PTM / PRS92 Coordinates

Northing: **892784.79 m.** Easting: **553718.284 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **892,472.30** Easting: **553,699.48** Zone: **51**

Location Description

ZGS-1
From Iligan City, travel SW along the national highway for 138 km., about 2 hrs. and 5 min., passing through the towns of Kolambugan, Tubod, and Salvador, Lanao del Norte. Then turn right, travel NW direction passing by Aurora town, 138 km. about 2 hrs. and 52 min. drive. About 5.4 km. going W direction before the junction to Molave proper proceed to the junction going E direction to Pagadian City, 3.2 km. to National Irrigation Administration (NIA) compound. Station is located at the top S corner of the concrete water tank 6 m. high beside the NIA building. Station mark is a cross cut on top of a 0.15 m. x 0.01 m. in dia. brass rod, set in a drill hole, centered in a 0.30 m. x 0.30 m. cement patty with inscription of the station name.

*Note: Reported EXISTING by FNSP-DENR Region IX (By: Engr. Fermin Enero - 06 August 2003)

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0332**

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
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3. ZGS-16

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

February 10, 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 SUR**
Station Name: **ZGS-16**
Order: **2nd**

Island: **MINDANAO** Barangay: **BACLAY**
Municipality: **TUKURAN** MSL Elevation:

PRS92 Coordinates

Latitude: **7° 52' 32.53106"** Longitude: **123° 36' 23.39905"** Ellipsoidal Hgt: **18.17800 m.**

WGS84 Coordinates

Latitude: **7° 52' 29.01321"** Longitude: **123° 36' 28.86762"** Ellipsoidal Hgt: **84.42000 m.**

PTM / PRS92 Coordinates

Northing: **870854.959 m.** Easting: **566881.259 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **870,550.15** Easting: **566,857.85** Zone: **51**

Location Description

ZGS-16
Is located at Purok Nangka, Brgy. Baclay. It is situated 1 m. NE of Km. Post # 1644 and about 50 m. SW of the chapel, approx. 3 km. from the road junction leading to Aurora town. Mark is the head of a 3 in. concrete nail embedded and centered on a 30 cm. x 30 cm. x 68 cm. concrete monument, with inscriptions "ZGS-16 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0334**

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

P 9021020161222213

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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4. ZGS-68

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

February 10, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-68**
Order: **2nd**

Island: **MINDANAO**	Barangay: **POBLACION**		
Municipality: **GUIPOS**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **7° 43' 33.12722"**	Longitude: **123° 18' 48.98041"**	Ellipsoidal Hgt:	**285.94100 m.**
	WGS84 Coordinates		
Latitude: **7° 43' 29.62251"**	Longitude: **123° 18' 54.44472"**	Ellipsoidal Hgt:	**271.74800 m.**
	PTM / PRS92 Coordinates		
Northing: **854280.138 m.**	Easting: **534593.845 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **853,951.14**	Easting: **534,581.74**	Zone:	**51**

Location Description

ZGS-68
Is located on the lot of the CENRO of Guipos. It is on the E end of the S sidewalk along the entrance way of CENRO from the national road, 15 m. E of the said office and 2.5 m. from the centerline of the driveway. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-68 2006 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0335**

RUEL DM. BELEM MNSA
Director, Mapping and Geodesy Branch

NAMRIA Office
Main: Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. Nos. (632) 810-4831 to 41
Branch: 421 Barraca St., San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3481 to 89
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

5. LE-50

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

June 24, 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: **LANAO DEL NORTE**
Station Name: **LE-50**

Island: **Mindanao**	Municipality: **MAIGO**	Barangay: **CLARO M. RECTO**
Elevation: **5.3895 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LE-50 is in the Province of Lanao Del Norte, Town of Maigo, Brgy. C.M. Recto, along the Butuan - Zamboanga National Road, and about 50 meters North East of the Covenant Baptist Church. The station is located at the South West end of the Barogohan Bridge footwalk and about 70 meters South West of KM post 1561.

A brass rod is set on a drilled hole and cemented flushed on top of a 15cm x 15cm cement putty with inscription "LE-50, 2007, NAMRIA".

Requesting Party: **Engr. Cruz**
Pupose: **Reference**
OR Number: **8796376 A**
T.N.: **2014-1440**

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
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

6. LE-76

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

August 08, 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: **LANAO DEL NORTE**
Station Name: **BM LE-76**

Island: **Mindanao**	Municipality: **TUBOD (CAPITAL)**	Barangay: **BULOD**
Elevation: **5.0250 m.**	Order: **2nd Order**	Datum: **Mean Sea Level**

Location Description

BM LE-76 is in the Province of Lanao del Norte, Municipality of Tubug, Bgry. Bulod, along the Butuan-Zamboanga National Road. The station is located at the south west end of Bulod Bridge footwalk, about 2 meters north west of KM Post 1587, and about 4 meters north west of the centerline of the road

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Pupose: **Reference**
OR Number: **8799570 A**
T.N.: **2014-1787**

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

MAIN/A OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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7. ZS-188

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

February 10, 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 SUR**
Station Name: **ZS-188**

Island: **Mindanao**	Municipality: **ZAMBOANGA CITY**	Barangay: **LICOMO**
Elevation: **22.1396 +/- 0.16 m.**	Accuracy Class at 95% C.L: **2 CM**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

ZS-188 is located in Sitio Simoropan Purok 1 Brgy. Licomo Vital District Zamboanga City The BM established in hedawall of Pipe Culvert, about 4 m from the cneterline of the road leftside going to Maria Clara lobgegat Hi-way.

Mark is the head of a 4" copper nail on a drilled hole and cemented flushed on top of a 15x15cm cement putty with inscription "ZS-188, 2008, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0337**

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. Nos.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 95
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

8. ZGS-17

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

February 10, 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 SUR**
Station Name: **ZGS-17**
Order: **2nd**

Island: **MINDANAO** Barangay: **BACLAY**
Municipality: **TUKURAN** MSL Elevation:

PRS92 Coordinates

Latitude: **7° 52' 42.71658"** Longitude: **123° 36' 29.22049"** Ellipsoidal Hgt: **29.68400 m.**

WGS84 Coordinates

Latitude: **7° 52' 39.19813"** Longitude: **123° 36' 34.68878"** Ellipsoidal Hgt: **96.92400 m.**

PTM / PRS92 Coordinates

Northing: **871168.108 m.** Easting: **567059.131 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **870,863.18** Easting: **567,035.66** Zone: **51**

Location Description

ZGS-17
Is located at Purok Kasoy, Brgy. Baclay, Tukuran. It is situated on the slope of a cultivated hill. It is about 100 m. NW of UCCP chapel and about 200 m. NNE of the roman catholic chapel. Mark is the head of a 4 in. copper nail embedded and centered on a 30 cm. x 30 cm. x 38 cm., with inscriptions "ZGS-17 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0333**

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

9902102016122148

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 96
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

9. ZGS-89

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

July 11, 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 SUR**
Station Name: **ZGS-89**
Order: **2nd**

Island: **MINDANAO**
Municipality: **AURORA**
Barangay: **POBLACION**
MSL Elevation:

PRS92 Coordinates

Latitude: **7° 57' 4.32105"** Longitude: **123° 34' 53.92221"** Ellipsoidal Hgt: **254.44700 m.**

WGS84 Coordinates

Latitude: **7° 57' 0.78119"** Longitude: **123° 34' 59.38391"** Ellipsoidal Hgt: **320.47700 m.**

PTM / PRS92 Coordinates

Northing: **879200.188 m.** Easting: **564128.667 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **878,892.45** Easting: **564,106.22** Zone: **51**

Location Description

ZGS-89
Is located on the sidewalk of the national road. It is about 20 m. NE of the Salug Valley Rural Bank, which is located on the corner of the national road and the road going to the church and St. Teresita Academy, and 7 m. S of Norma Dimpos' house. mark is the head of a 4 in. concrete nail embedded and centered on a 20 cm. x 20 cm. cement putty, with inscriptions "ZGS-89 2005 NAMRIA LEP-IX".

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1602**

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 95
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Annex 3. Baseline Processing Reports of Control Points used in the LIDAR Survey

1. LE-50

LE50 - LAN2 (10:05:34 AM-2:59:59 PM) (S1)

Baseline observation:	LE50 --- LAN2 (B1)
Processed:	7/27/2014 10:28:26 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.012 m
Vertical precision:	0.024 m
RMS:	0.005 m
Maximum PDOP:	3.688
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	6/20/2014 10:05:34 AM (Local: UTC+8hr)
Processing stop time:	6/20/2014 2:59:59 PM (Local: UTC+8hr)
Processing duration:	04:54:25
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	LAN2				
Grid		Local		Global	
Easting	584699.973 m	Latitude	N7°54'42.56546"	Latitude	N7°54'42.56546"
Northing	874628.035 m	Longitude	E123°46'06.31720"	Longitude	E123°46'06.31720"
Elevation	15.242 m	Height	83.921 m	Height	83.921 m

To:	LE50				
Grid		Local		Global	
Easting	606345.902 m	Latitude	N8°09'51.11024"	Latitude	N8°09'51.11024"
Northing	902577.426 m	Longitude	E123°57'55.36634"	Longitude	E123°57'55.36634"
Elevation	4.394 m	Height	73.452 m	Height	73.452 m

Vector					
ΔEasting	21645.929 m	NS Fwd Azimuth	37°51'51"	ΔX	-15847.070 m
ΔNorthing	27949.392 m	Ellipsoid Dist.	35361.439 m	ΔY	-15348.392 m
ΔElevation	-10.847 m	ΔHeight	-10.469 m	ΔZ	27636.144 m

2

2. LE-76

Vector Components (Mark to Mark)

From:	LE-50				
Grid		Local		Global	
Easting	606180.417 m	Latitude	N8°09'54.67217"	Latitude	N8°09'51.11024"
Northing	902629.434 m	Longitude	E123°57'49.92699"	Longitude	E123°57'55.36834"
Elevation	4.394 m	Height	6.900 m	Height	73.452 m

To:	LE-76				
Grid		Local		Global	
Easting	588530.790 m	Latitude	N8°03'05.36825"	Latitude	N8°03'01.82183"
Northing	890021.013 m	Longitude	E123°48'12.37307"	Longitude	E123°48'17.82405"
Elevation	7.017 m	Height	9.335 m	Height	75.717 m

Vector					
ΔEasting	-17649.627 m	NS Fwd Azimuth	234°35'42"	ΔX	13688.663 m
ΔNorthing	-12608.421 m	Ellipsoid Dist.	21696.715 m	ΔY	11332.042 m
ΔElevation	2.623 m	ΔHeight	2.435 m	ΔZ	-12447.993 m

Standard Errors

Vector errors:					
σ ΔEasting	0.021 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.024 m
σ ΔNorthing	0.006 m	σ Ellipsoid Dist.	0.015 m	σ ΔY	0.034 m
σ ΔElevation	0.036 m	σ ΔHeight	0.036 m	σ ΔZ	0.009 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0005606089		
Y	-0.0003223999	0.0011623638	
Z	-0.0000556148	0.0002703935	0.0000791896

2

3. ZS-188

Vector Components (Mark to Mark)

From:	ZGS-1				
Grid		Local		Global	
Easting	553699.482 m	Latitude	N8°04'28.98335"	Latitude	N8°04'23.40249"
Northing	892472.300 m	Longitude	E123°29'14.53868"	Longitude	E123°29'19.99013"
Elevation	20.051 m	Height	22.611 m	Height	88.163 m

To:	ZS-188A				
Grid		Local		Global	
Easting	553627.634 m	Latitude	N8°03'56.69408"	Latitude	N8°03'53.11537"
Northing	891542.089 m	Longitude	E123°29'12.15500"	Longitude	E123°29'17.60722"
Elevation	17.277 m	Height	19.832 m	Height	85.400 m

Vector					
ΔEasting	-71.848 m	NS Fwd Azimuth	184°29'06"	ΔX	-9.705 m
ΔNorthing	-930.211 m	Ellipsoid Dist.	933.322 m	ΔY	146.900 m
ΔElevation	-2.773 m	ΔHeight	-2.778 m	ΔZ	-921.644 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.004 m	σ ΔHeight	0.004 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000013603		
Y	0.0000026352	0.0000296273	
Z	0.0000004069	0.0000057486	0.0000013978

2

4. ZS-38

Vector Components (Mark to Mark)

From:	zgs 89				
Grid		**Local**		**Global**	
Easting	564106.221 m	**Latitude**	N7°57'04.32105"	**Latitude**	N7°57'00.78119"
Northing	878892.452 m	**Longitude**	E123°34'53.92221"	**Longitude**	E123°34'59.38391"
Elevation	251.930 m	**Height**	254.446 m	**Height**	320.477 m

To:	zs 38 am				
Grid		**Local**		**Global**	
Easting	552699.677 m	**Latitude**	N7°50'49.23365"	**Latitude**	N7°50'45.71176"
Northing	867359.753 m	**Longitude**	E123°28'40.92449"	**Longitude**	E123°28'46.39665"
Elevation	5.545 m	**Height**	8.299 m	**Height**	74.279 m

Vector					
ΔEasting	-11406.544 m	**NS Fwd Azimuth**	224°45'54"	**ΔX**	8783.925 m
ΔNorthing	-11532.699 m	**Ellipsoid Dist.**	16226.543 m	**ΔY**	7427.802 m
ΔElevation	-246.385 m	**ΔHeight**	-246.147 m	**ΔZ**	-11447.353 m

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation, Ground Survey, Data Download and Transfer	Supervising Science Research Specialist (Supervising SRS)	GEROME HIPOLITO	UP-TCAGP
	Senior Science Research Specialist (Senior SRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	GEF SORIANO	UP-TCAGP
		JONATHAN ALMALVEZ	
		IRO ROXAS	
		GRACE SINADJAN	
		LANCE CINCO	
LiDAR Operation	Airborne Security	SSG. JAYCO S. MANZANO	PHILIPPINE AIR FORCE (PAF)
		SSG. LEE JAY PUNZALAN	
	Pilot	CAPT. JERICHO JECIEL	ASIAN AEROSPACE CORPORATION (AAC)
	Pilot	CAPT. C. ALFONSO	
	Pilot	CAPT. J. LIM	

Annex 5. Data Transfer Sheet for Labangan Floodplain

DATA TRANSFER SHEET
06/20/2014(Northern Mindanao)

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	
29-May-14	1525P	1RXB149A	PEGASUS	1.6	457	9.27	265	na	na	26.5	NA	9.63	1KB	1KB	40	NA	Z:\Airborne_Raw\1525P
31-May-14	1533P	1BLK67151A	PEGASUS	3.32	270	14.4	224	43.2	438	33.3	NA	8.87	1KB	1KB	47/38	NA	Z:\Airborne_Raw\1533P
2-Jun-14	1541P	1BLK71B153A	PEGASUS	4	242	0	285	19.7	139	39	674MB	12.6	1KB	1KB	47/45/40/34	NA	Z:\Airborne_Raw\1541P
3-Jun-14	1545P	1BLK71C154A	PEGASUS	4.13	2259	13	253	69.7	533	40.1	272MB	9.96	1KB	1KB	141	NA	Z:\Airborne_Raw\1545P
4-Jun-14	1549P	1BLK71D155A	PEGASUS	3.48	150	14.3	264	NA	NA	34.6	NA	11.2	1KB	1KB	54/50/46	NA	Z:\Airborne_Raw\1549P
7-Jun-14	1561P	1RXE158A	PEGASUS	NA	44	NA	187	NA	NA	22	NA	8.1	1KB	1KB	71	NA	Z:\Airborne_Raw\1561P
8-Jun-14	1565P	1BLK71B159A	PEGASUS	NA	16	5.35	168	22.1	193	13.3	NA	7.75	1KB	1KB	36	NA	Z:\Airborne_Raw\1565P

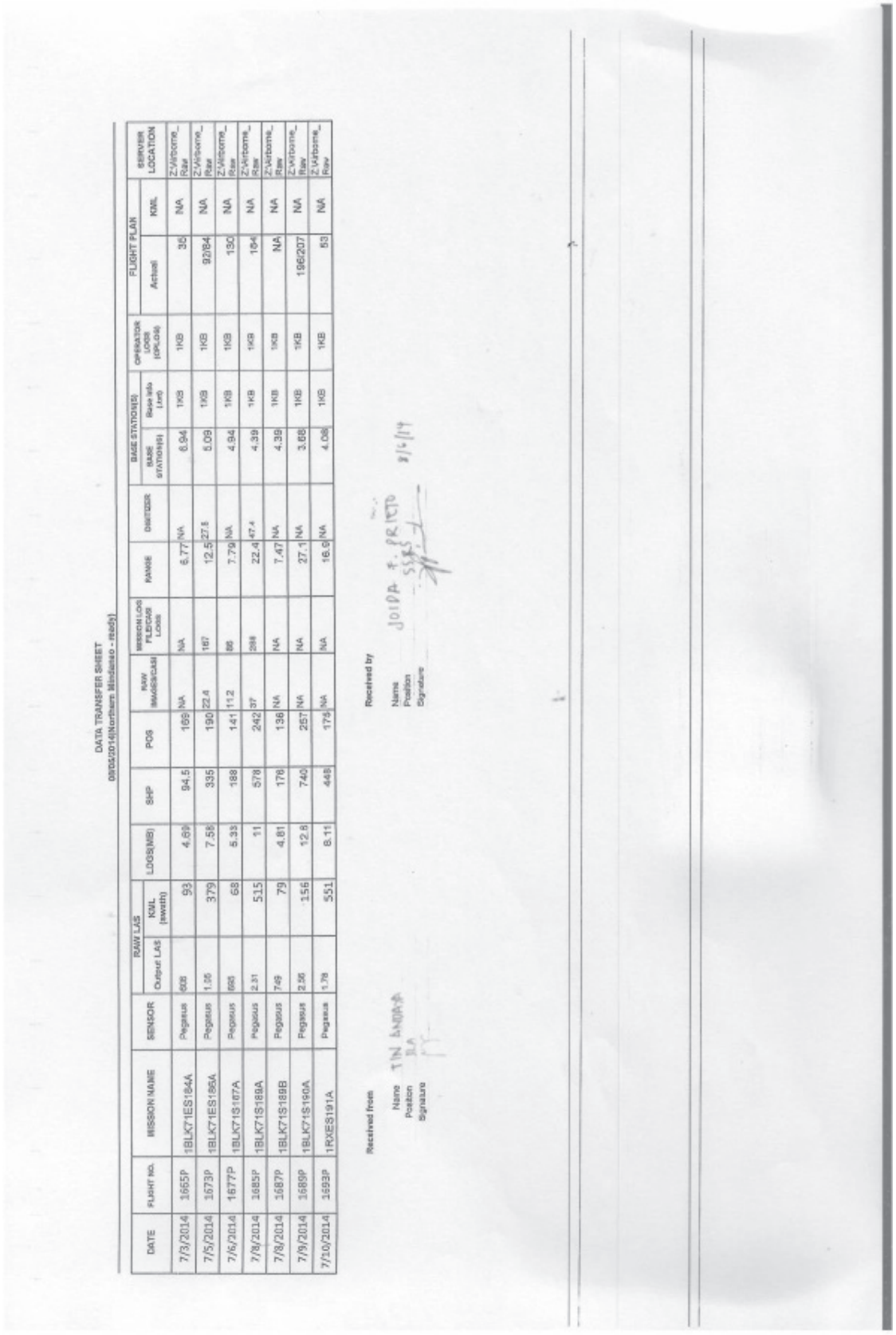
Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 6/23/2014

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



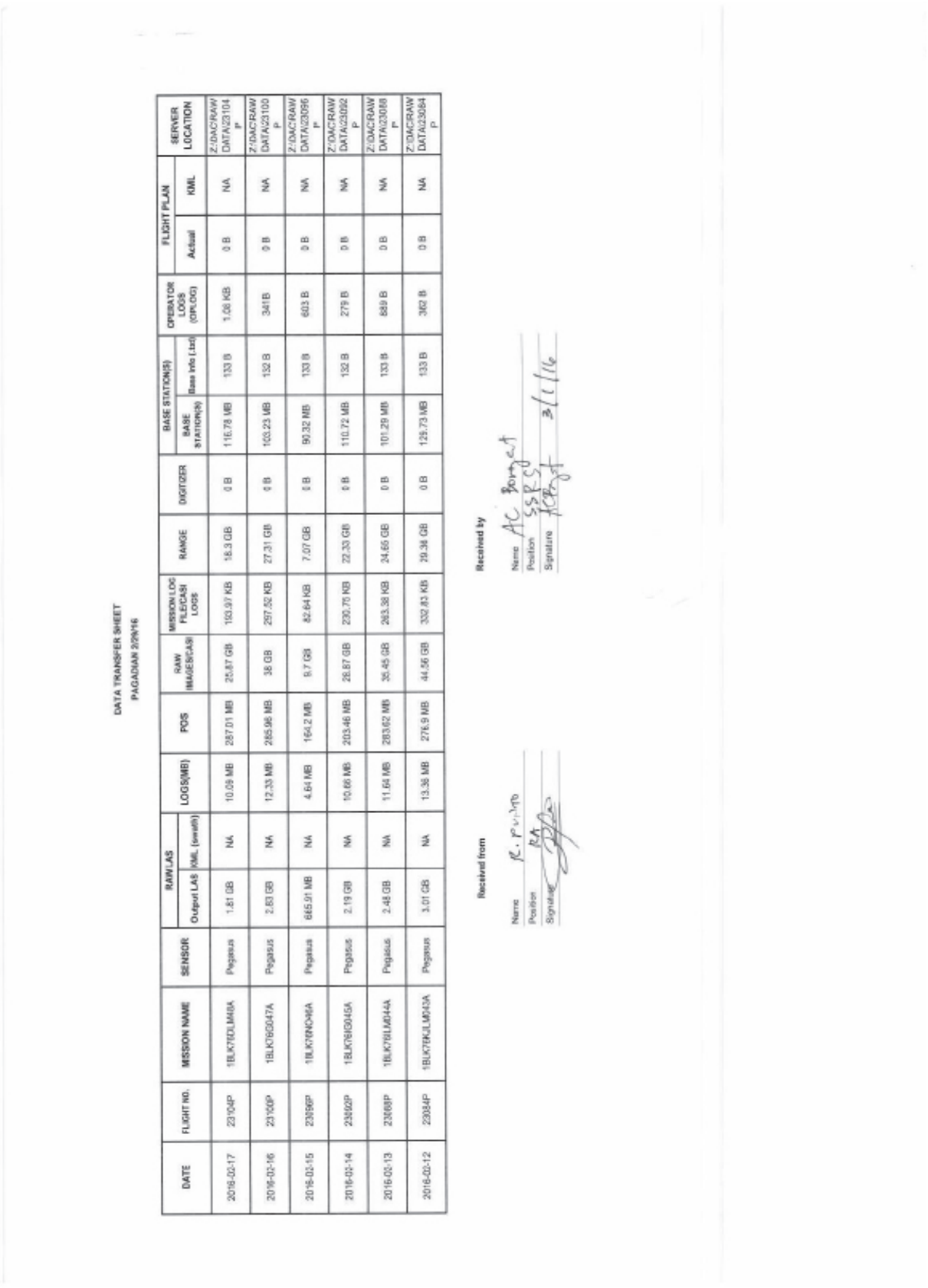
DATA TRANSFER SHEET
08/04/2014(Northern Mindanao - Iligan)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LDRS(MB)	SHP	POS	RAW IMAGES(GB)	MISSION LOG/ FLIGHT LOG	RANGE	DISTDIR	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)								BASE STATION(S)	Base w/o (.txt)		Actual	KML	
7/3/2014	1665P	1BLK71ES184A	Pegasus	628	93	4.69	94.5	166	NA	NA	6.77	NA	6.94	1KB	1KB	36	NA	Z:\Airborne_Raw
7/5/2014	1673P	1BLK71ES186A	Pegasus	1.35	379	7.58	335	190	22.4	167	12.5	27.5	5.09	1KB	1KB	92/84	NA	Z:\Airborne_Raw
7/6/2014	1677P	1BLK71S187A	Pegasus	695	68	5.33	188	141	11.2	85	7.79	NA	4.94	1KB	1KB	130	NA	Z:\Airborne_Raw
7/8/2014	1685P	1BLK71S188A	Pegasus	2.31	515	11	578	242	37	288	22.4	47.4	4.39	1KB	1KB	184	NA	Z:\Airborne_Raw
7/8/2014	1687P	1BLK71S188B	Pegasus	749	79	4.81	176	136	NA	NA	7.47	NA	4.39	1KB	1KB	NA	NA	Z:\Airborne_Raw
7/9/2014	1689P	1BLK71S190A	Pegasus	2.56	156	12.8	740	257	NA	NA	27.1	NA	3.68	1KB	1KB	196/207	NA	Z:\Airborne_Raw
7/10/2014	1693P	1RXES191A	Pegasus	1.78	551	8.11	448	179	NA	NA	16.6	NA	4.08	1KB	1KB	53	NA	Z:\Airborne_Raw

Received from
Name TIN BANDA
Position BA
Signature

Received by
Name JOIDA F. PRIETO
Position SSES
Signature 8/6/14

Figure A-5.1. Transfer Sheet for Labangan Floodplain - B



DATA TRANSFER SHEET
PAGADIAN 2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	PQS	RAW IMAGE/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (overlay)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2016-02-17	23104P	1BLK76DLM48A	Pegasus	1.61 GB	NA	10.09 MB	287.01 MB	25.87 GB	193.97 KB	18.3 GB	0 B	116.78 MB	133 B	1.06 KB	0 B	NA	Z:\DAC\RAW DATA\23104 P
2016-02-16	23100P	1BLK76G047A	Pegasus	2.83 GB	NA	12.33 MB	285.96 MB	36 GB	297.52 KB	27.31 GB	0 B	103.23 MB	132 B	341 B	0 B	NA	Z:\DAC\RAW DATA\23100 P
2016-02-15	23096P	1BLK76N0H6A	Pegasus	685.91 MB	NA	4.84 MB	164.2 MB	6.7 GB	82.64 KB	7.07 GB	0 B	90.32 MB	133 B	603 B	0 B	NA	Z:\DAC\RAW DATA\23096 P
2016-02-14	23092P	1BLK76H0045A	Pegasus	2.19 GB	NA	10.66 MB	203.46 MB	28.87 GB	230.76 KB	22.33 GB	0 B	110.72 MB	132 B	279 B	0 B	NA	Z:\DAC\RAW DATA\23092 P
2016-02-13	23088P	1BLK76LM044A	Pegasus	2.48 GB	NA	11.64 MB	283.62 MB	35.45 GB	283.38 KB	24.65 GB	0 B	101.29 MB	133 B	689 B	0 B	NA	Z:\DAC\RAW DATA\23088 P
2016-02-12	23084P	1BLK76KJLM043A	Pegasus	3.01 GB	NA	13.36 MB	276.9 MB	44.56 GB	332.83 KB	29.36 GB	0 B	125.73 MB	133 B	362 B	0 B	NA	Z:\DAC\RAW DATA\23084 P

Received from

Name
Position
Signature

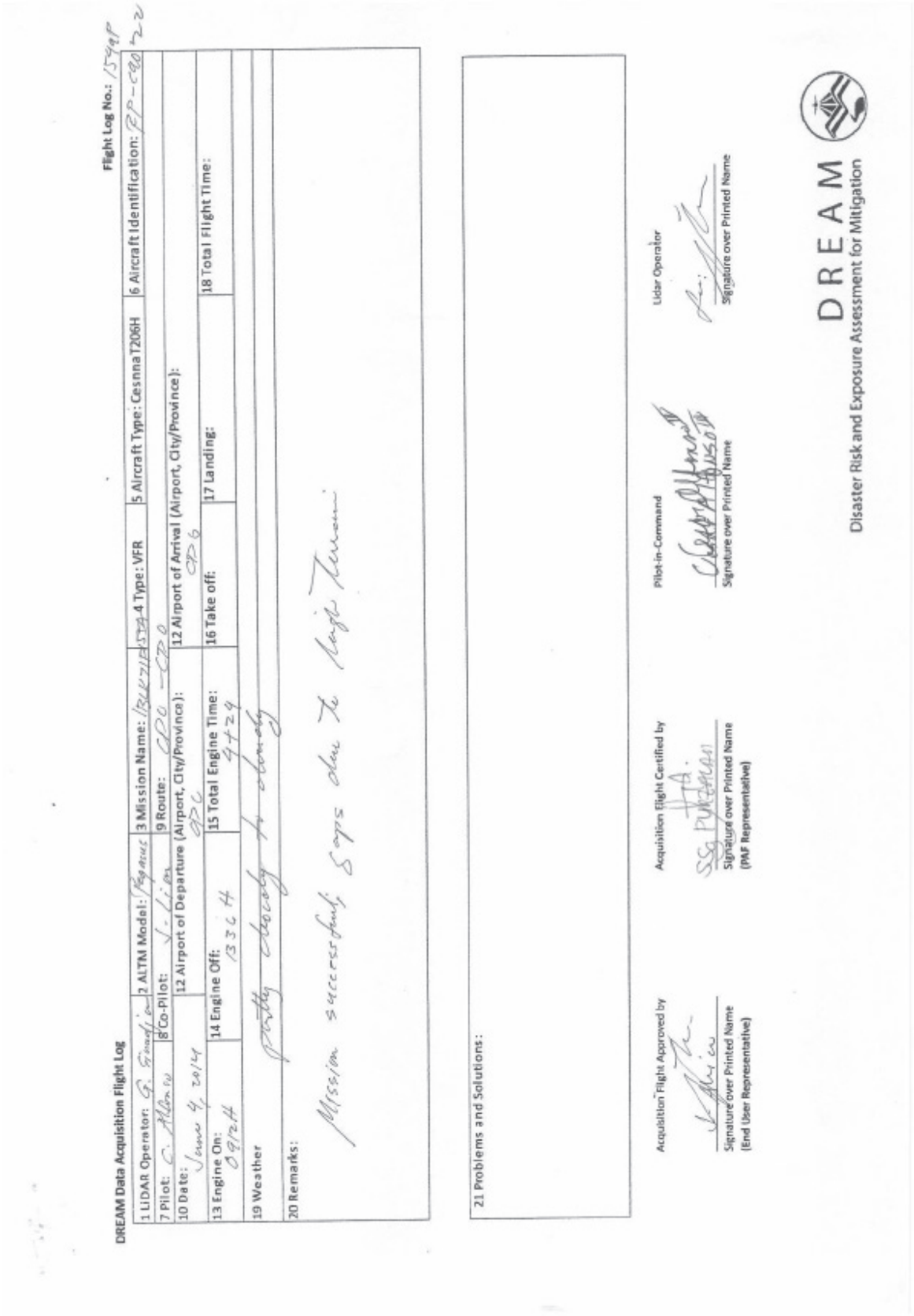
Received by

Name AC Bongat
Position SSES
Signature 3/11/16

Figure A-5.1. Transfer Sheet for Labangan Floodplain - C

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 1549P



DREAM Data Acquisition Flight Log

Flight Log No.: 1549P

1 LiDAR Operator: G. Granfil	2 ALTM Model: Pegasus	3 Mission Name: Blk72B1549P	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C980
7 Pilot: C. Alburo	8 Co-Pilot: J. Lira	9 Route: CDO - CBO			
10 Date: June 4, 2014		11 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CBO	
13 Engine On: 0912H	14 Engine Off: 1336H	15 Total Engine Time: 4+24	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy to cloudy				
20 Remarks:	Mission successful; 8 caps due to high Terrain				
21 Problems and Solutions:					

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

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

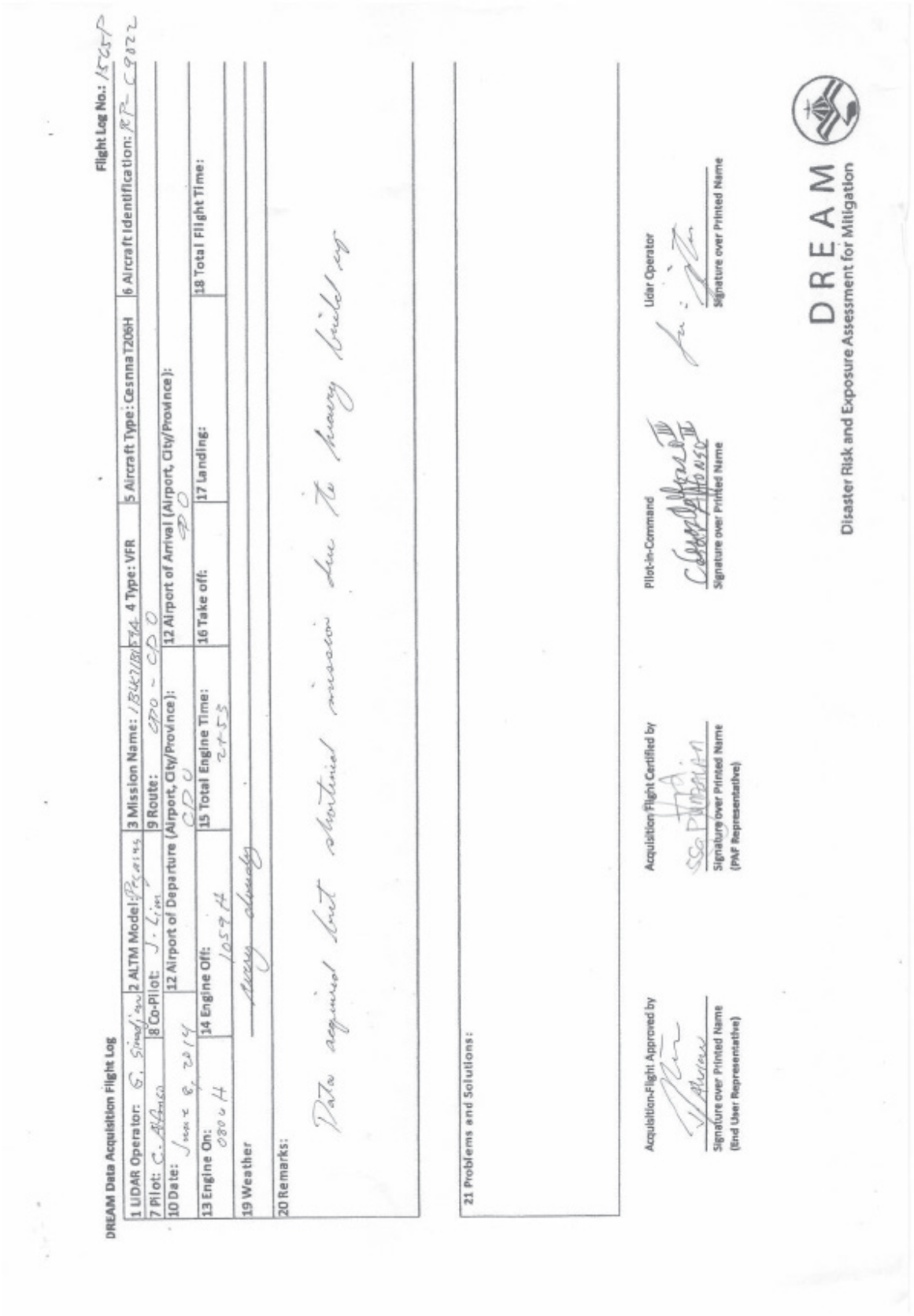
Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1549P

2. Flight Log for Mission 1565P



DREAM Data Acquisition Flight Log

Flight Log No.: 1565P

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: LBG2BBTA	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9072
7 Pilot: C. Abanes	8 Co-Pilot: J. Lim	9 Route: CDO - CDO			
10 Date: June 8, 2014	11 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0800 H	14 Engine Off: 1059 H	15 Total Engine Time: 2.5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Mostly cloudy					
20 Remarks: Data acquired but additional mission due to heavy cloud cover					
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)

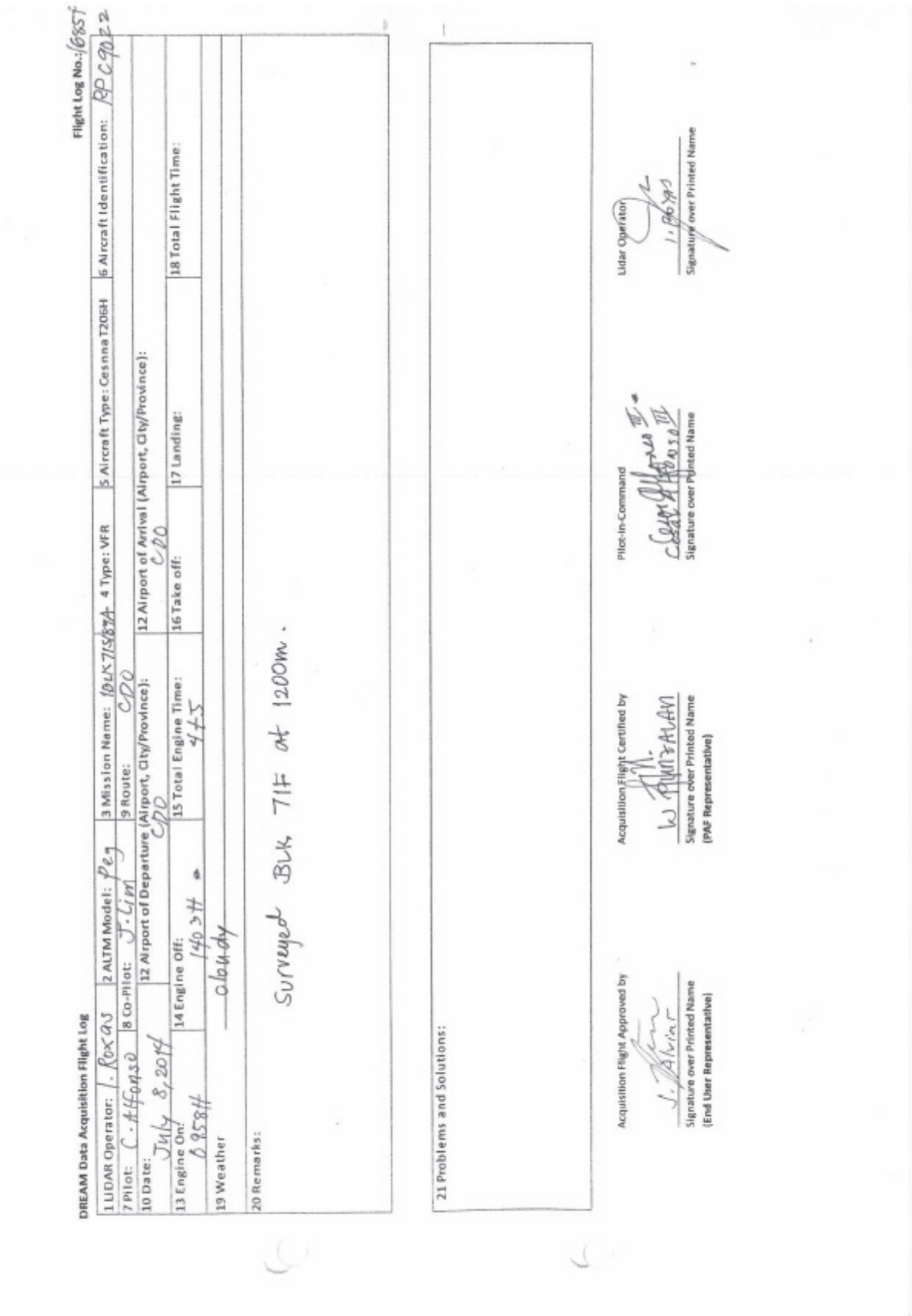
Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2. Flight Log for Mission 1565P

3. Flight Log for Mission 1685P



DREAM Data Acquisition Flight Log

Flight Log No.: 1685P

1 LIDAR Operator: J. Rocas	2 ALTM Model: Peg	3 Mission Name: 10LK715824	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 8, 2014	11 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0958H	14 Engine Off: 1430H	15 Total Engine Time: 4.5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks: Surveyed BLK 71F at 1200m.

21 Problems and Solutions:

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

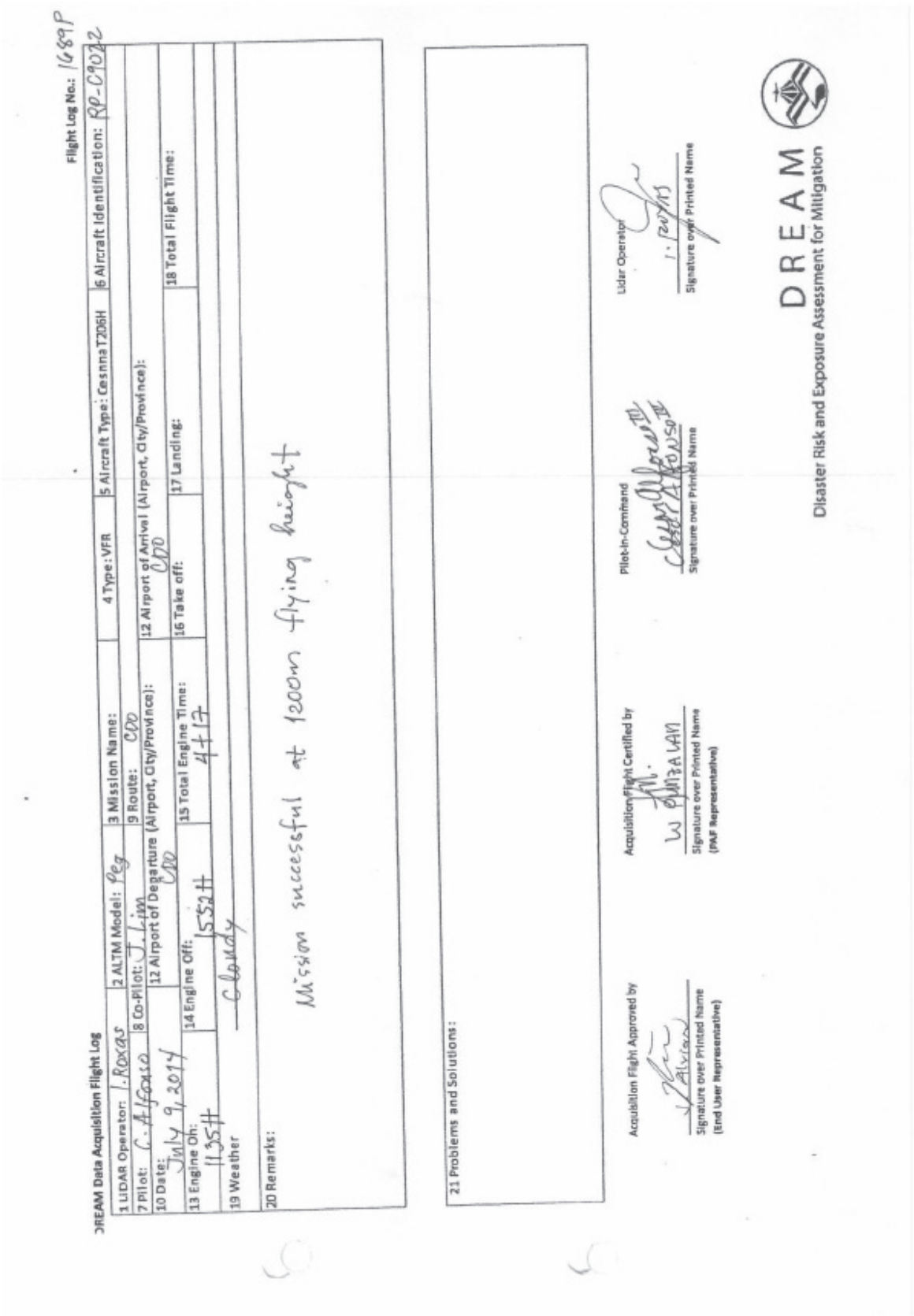
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1549P

4. Flight Log for Mission 1689P



DREAM Data Acquisition Flight Log

Flight Log No.: 1689P

1 LiDAR Operator: J. Roxas	2 ALTM Model: Peg	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9032
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 9, 2014	11 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 1135H	14 Engine Off: 1552H	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks: Mission successful at 1200m flying height

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
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2. Flight Log for Mission 1565P

5. Flight Log for Mission 23088P

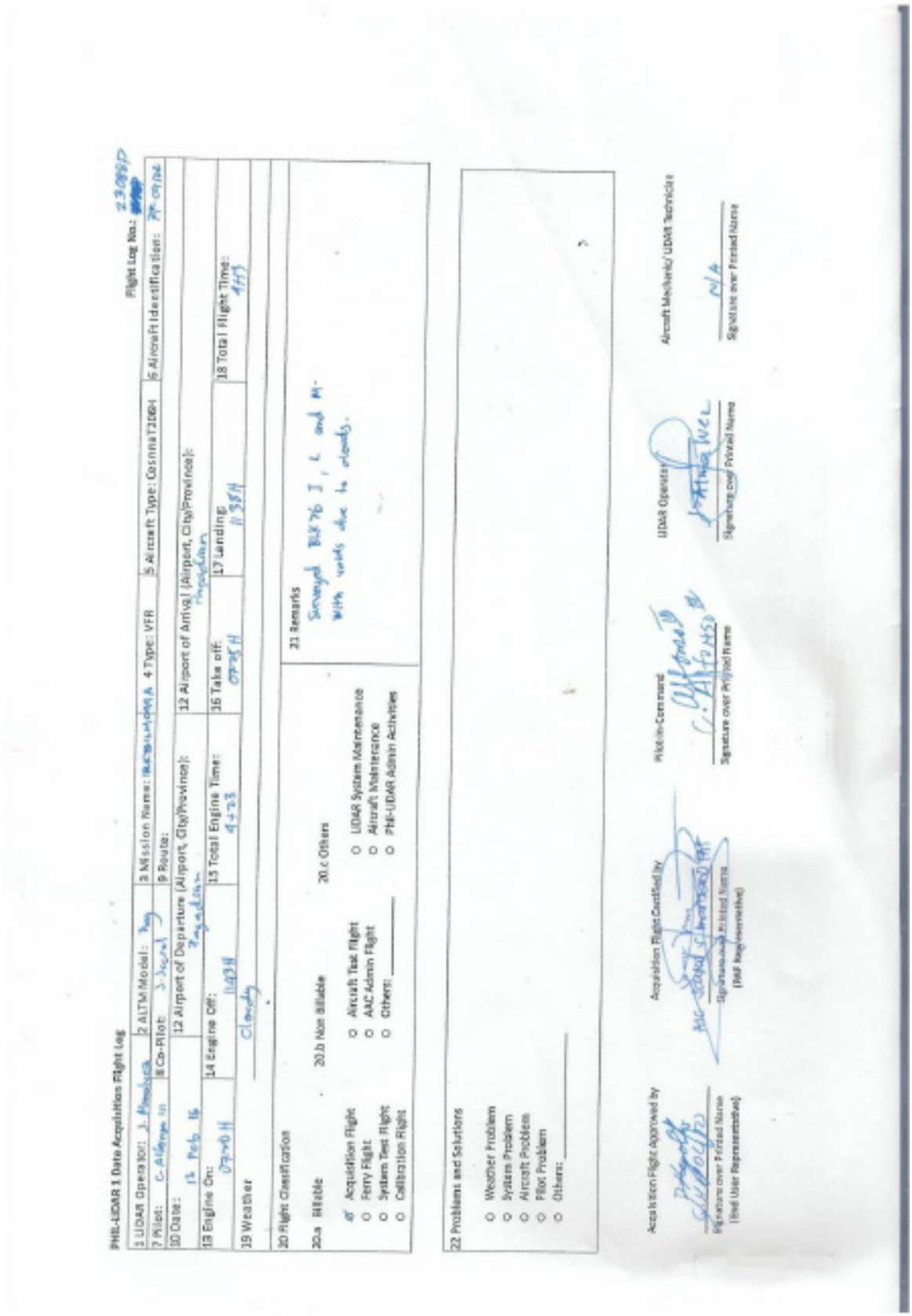


Figure A-6.5. Flight Log for Mission 23088P

Annex 7. Flight Status Report

Northern Mindanao
June 4-July 9, 2014

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1549P	BLK 71E	1BLK 71D155A	G. Sinadjan	June 4	Surveyed BLK 71E with gaps due to clouds; to be renamed to 1BLK71E155A; 231.82 sq.km
1565P	BLK 71F	1BLK71B159A	G. Sinadjan	June 8	Surveyed half of BLK 71F with gaps due to clouds; to be renamed 1BLK71F159A; 105.5 sq.km
1685P	BLK 71F	1BLK71S189A	I.Roxas	July 8	Surveyed BLK 71F at 1200m; 233.71 sq.km
1689P	BLK 71E and BLK 71ABCs	1BLK71S190A	I.Roxas	July 9	Surveyed BLK 71E and the gaps in BLK 71ABC; 278.697 sq.km

Flight No. : 1549P
Area: BLK 71E
Mission name: 1BLK71D155A
Parameters: Altitude: 1000m ; Scan Frequency: 30Hz;
Scan Angle: 25 degrees ; Overlap: 30 %

LAS

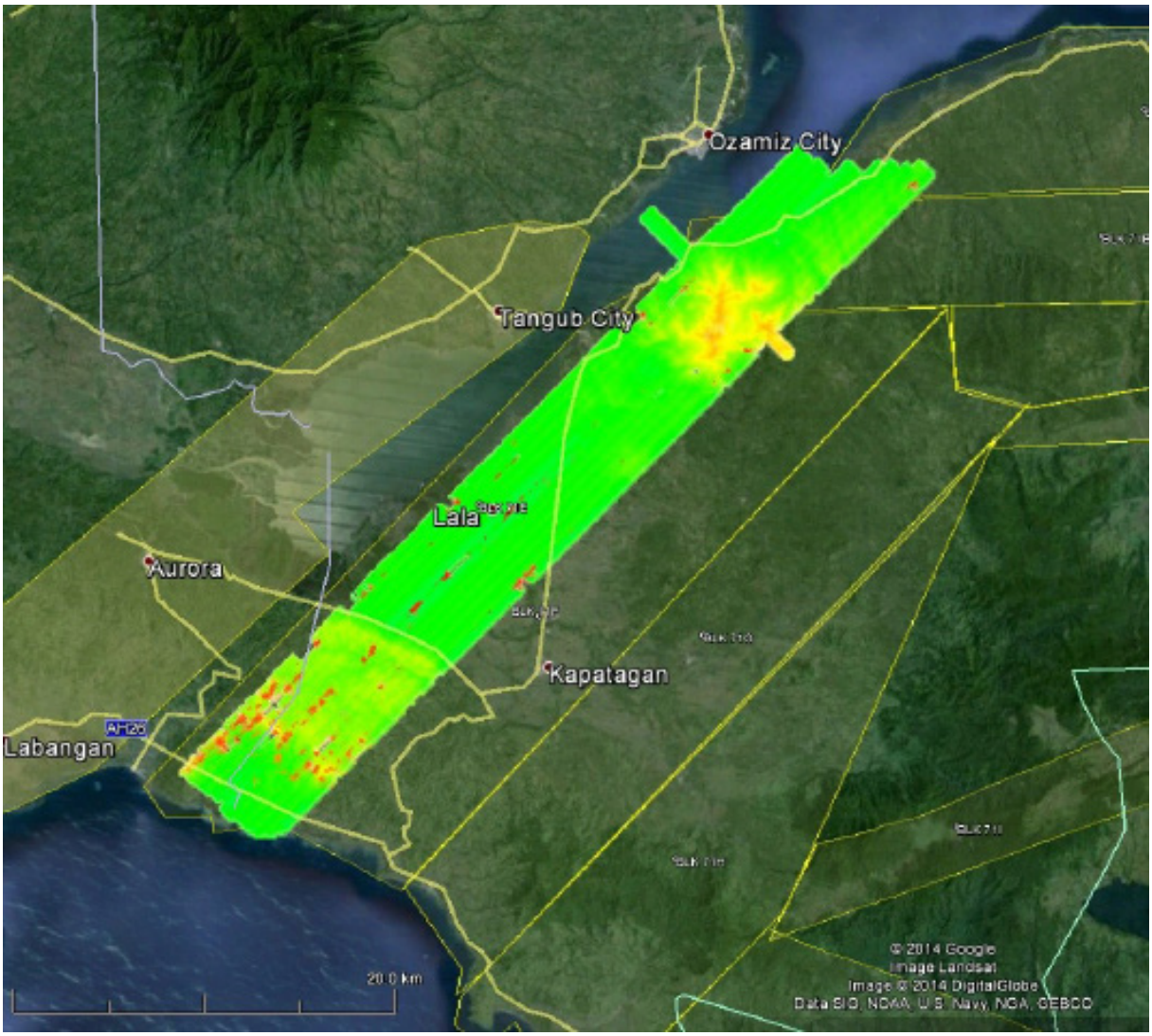


Figure A-7.1. Swath for Flight No. 1549P

Flight No. : 1565P
Area: BLK 71F
Mission name: 1BLK71B159A
Parameters: Altitude: 1000m ; Scan Frequency: 30Hz;
Scan Angle: 25 degrees ; Overlap: 30 %

LAS

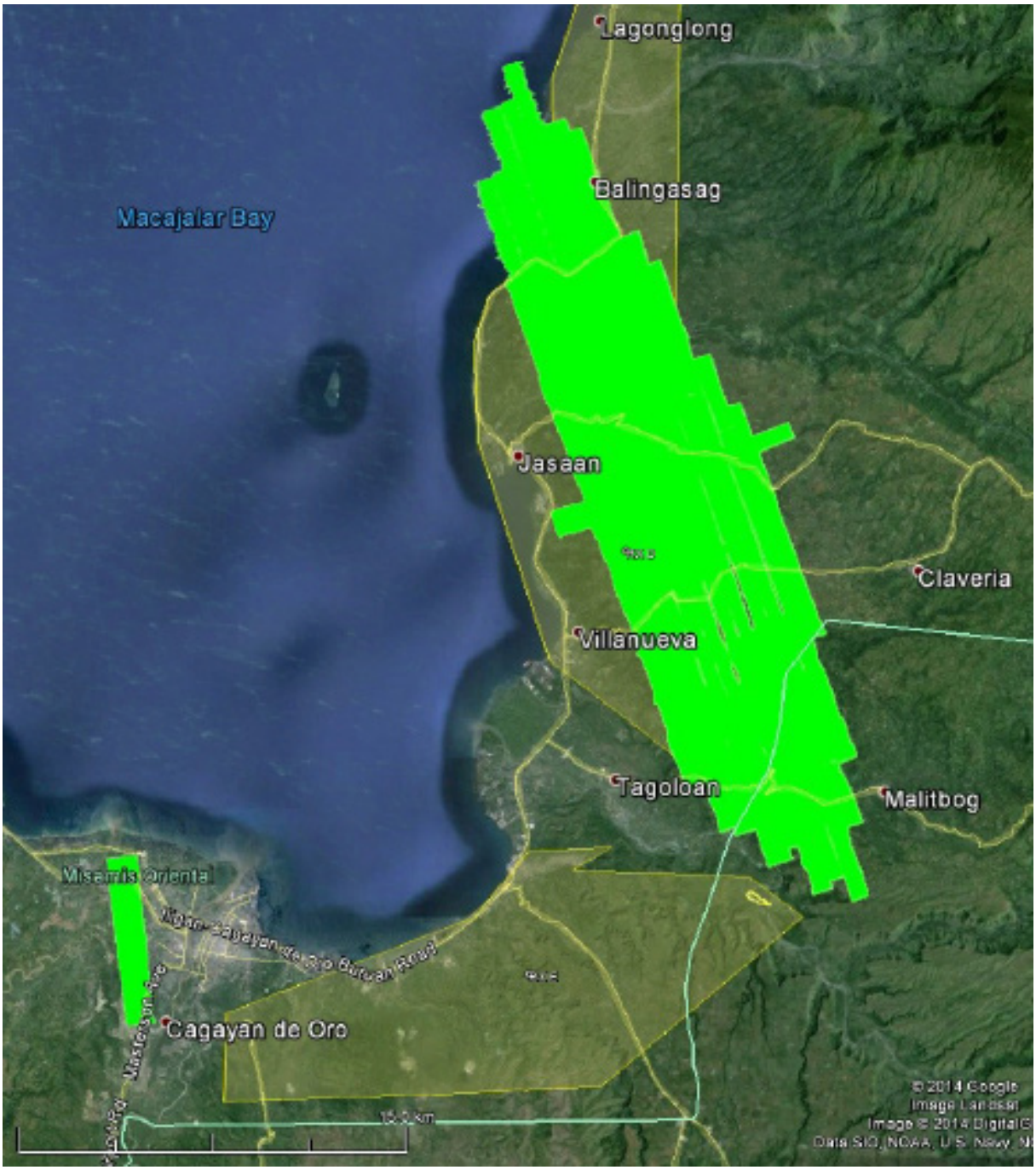


Figure A-7.2. Swath for Flight No. 1565P

Flight No. : 1685P
Area: BLK 71F
Mission name: 1BLK71S189A
Parameters: Altitude: 1000m ; Scan Frequency: 30Hz;
Scan Angle: 25 degrees ; Overlap: 30 %

LAS

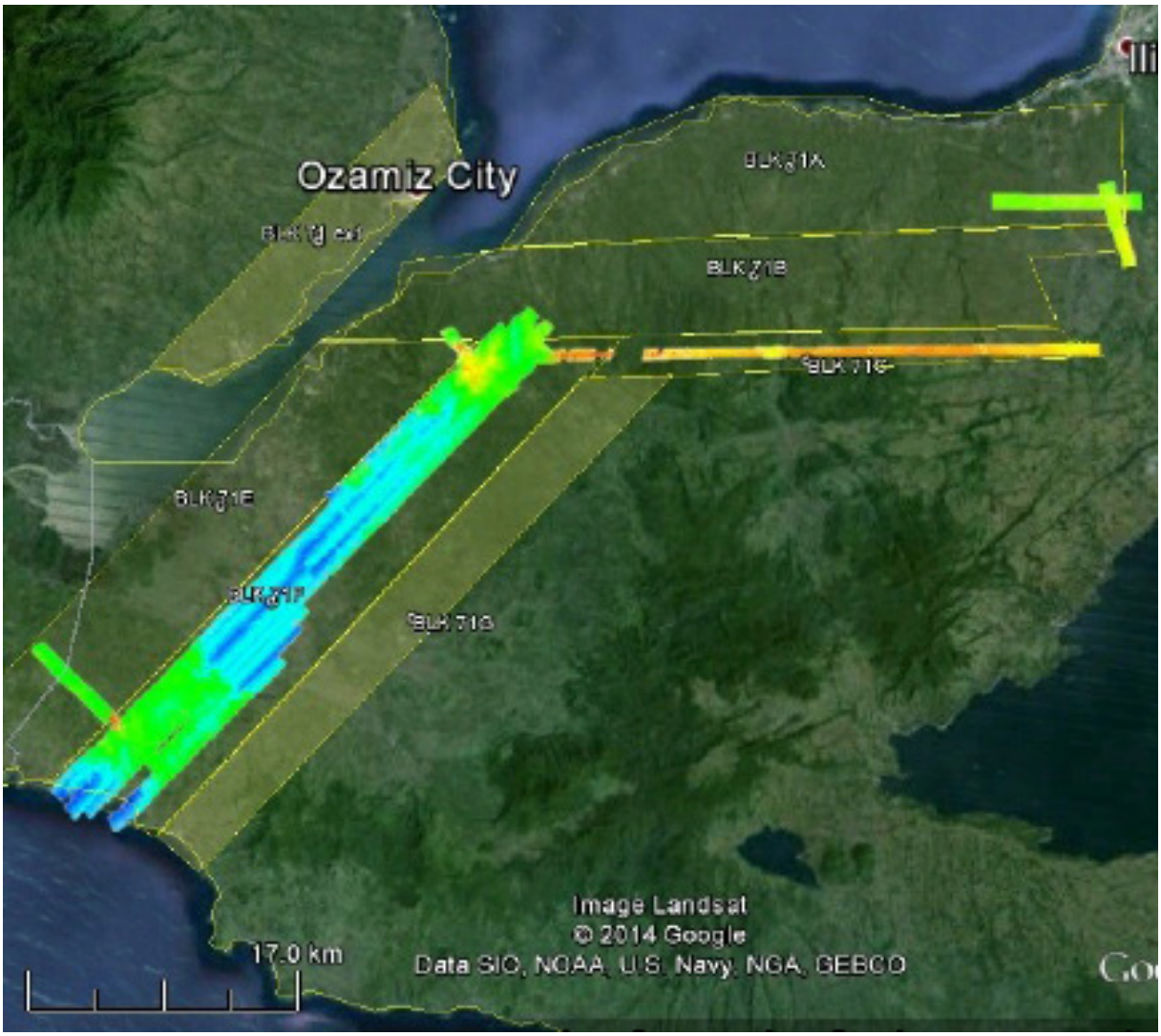


Figure A-7.3. Swath for Flight No. 1685P

Flight No. : 1689P
Area: BLK 71E and BLK 71ABCs
Mission name: 1BLK71S190A
Parameters: Altitude: 1200m ; Scan Frequency: 30Hz;
Scan Angle: 25 degrees ; Overlap: 30 %

LAS

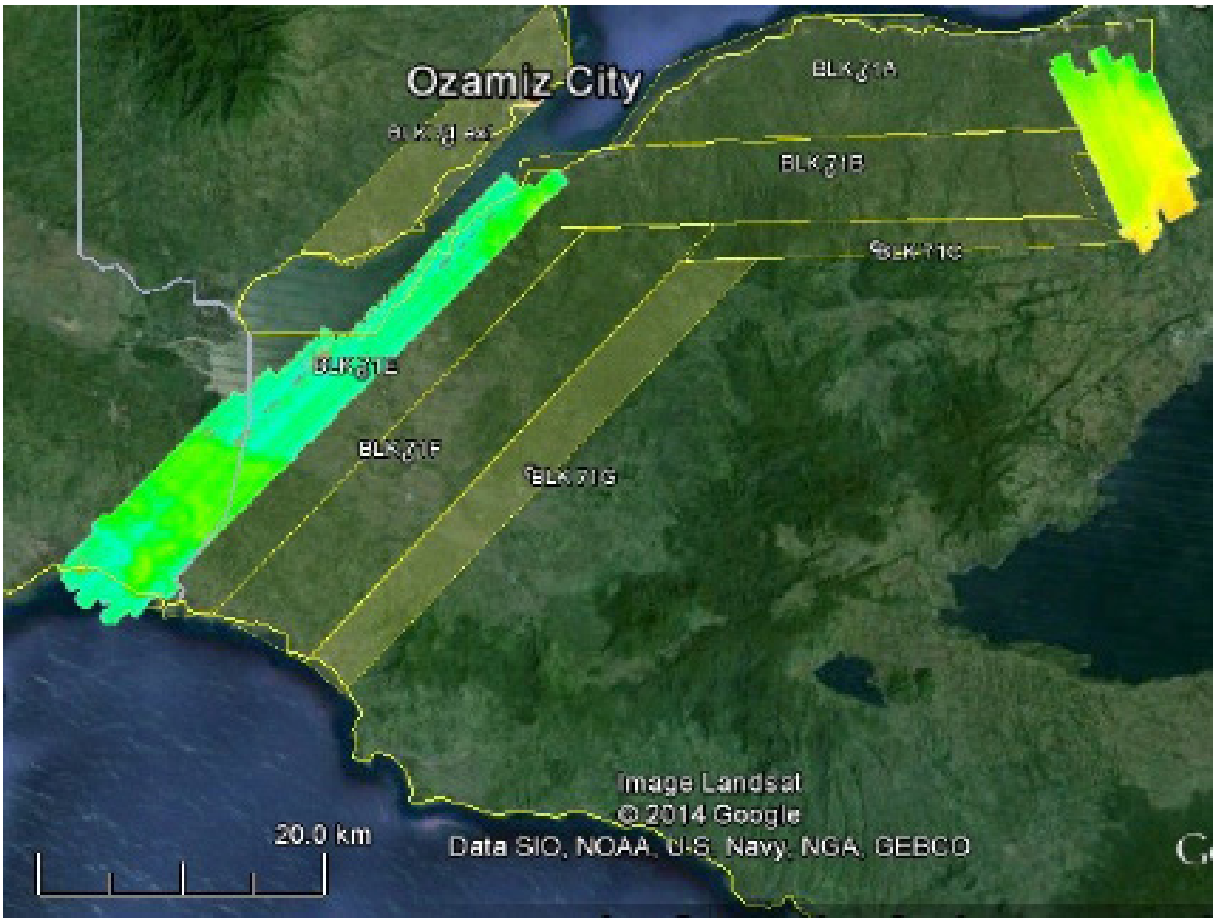


Figure A-7.4. Swath for Flight No. 1689P

PAGADIAN (BLK 76) WITH REFLIGHTS PEGASUS (9122) FLIGHT STATUS REPORT

FEBRUARY 13, 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23088	BLK I,L,M	1BLK76ILM044A	JM ALMALVEZ	FEB 13, 2016	Cloudy over L & M. Pegasus problem encountered so no tie lines over I; please use 23078's and 23092's tie line

Flight No. : 23088P
Area: BLK I, L, M
Mission name: 1BLK76ILM044A
Parameters: Altitude: 1200m ; Scan Frequency: 30Hz;
Scan Angle: 25 degrees ; Overlap: 30 %

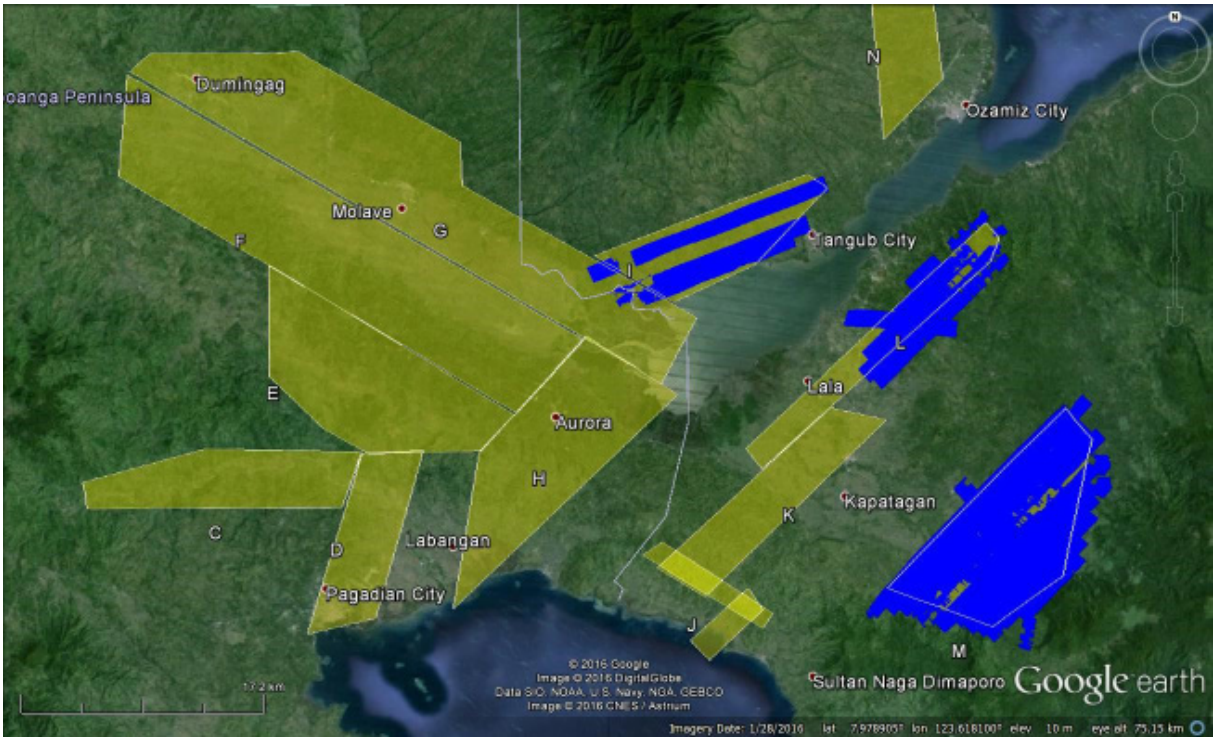


Figure A-7.5. Swath for Flight No. 23088P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission 76C

Flight Area	Pagadian
Mission Name	76C
Inclusive Flights	23084P, 23082P
Range data size	39.02
POS data size	420.9
Base data size	229.73
Image	n/a
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000175
IMU attitude correction stdev (<0.001deg)	0.000326
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	32.91
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	167
Maximum Height	692.28 m
Minimum Height	72.06 m
Classification (# of points)	
Ground	121,235,825
Low vegetation	71,710,830
Medium vegetation	147,783,768
High vegetation	312,856,812
Building	3,574,981
Orthophoto	Yes

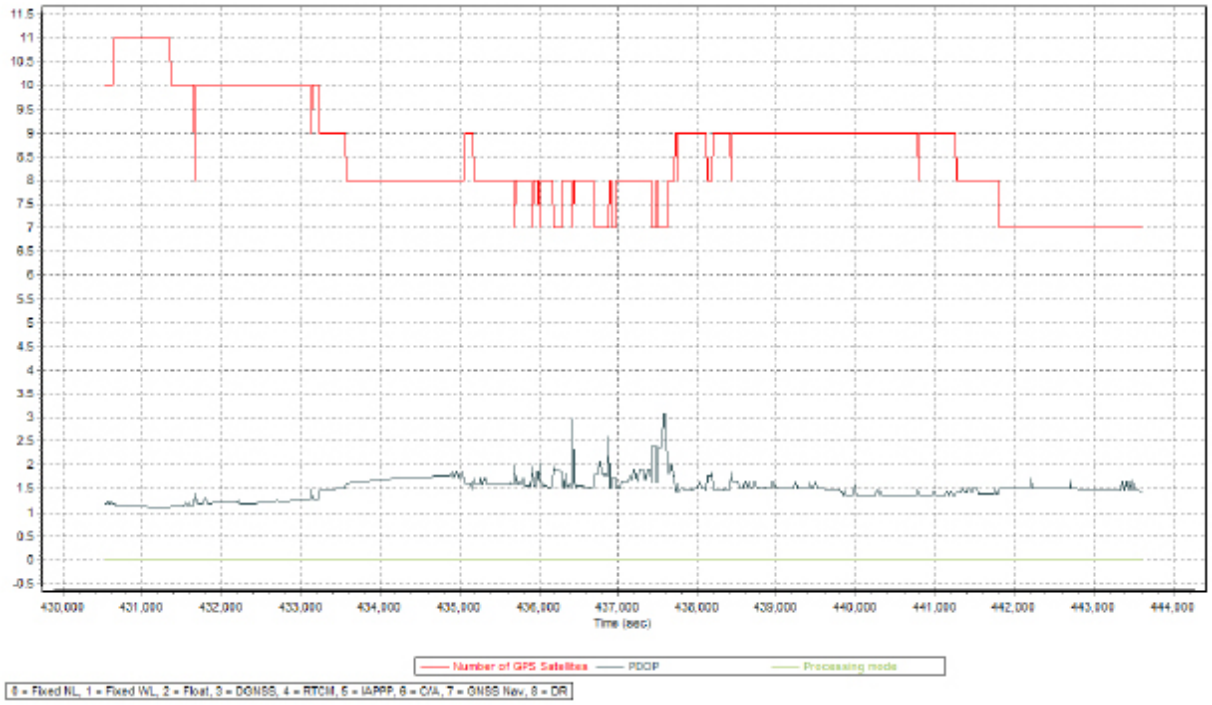


Figure A-8.1. Solution Status

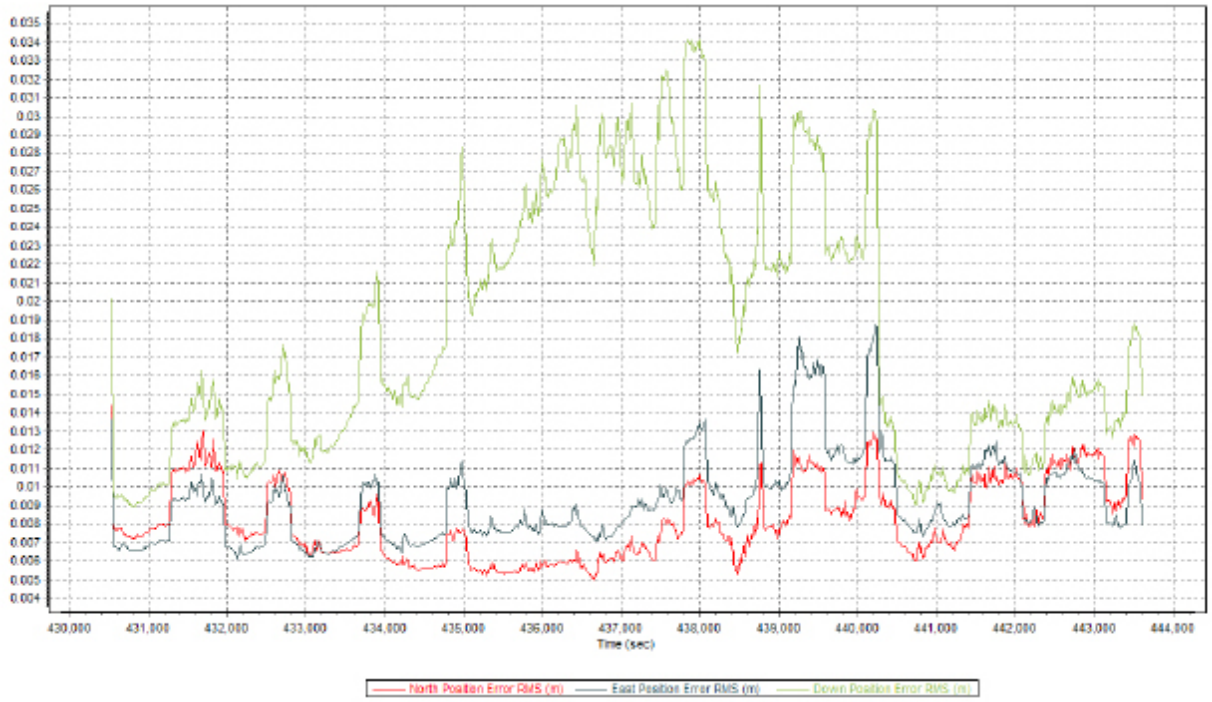


Figure A-8.2 Smoothed Performance Metric Parameters

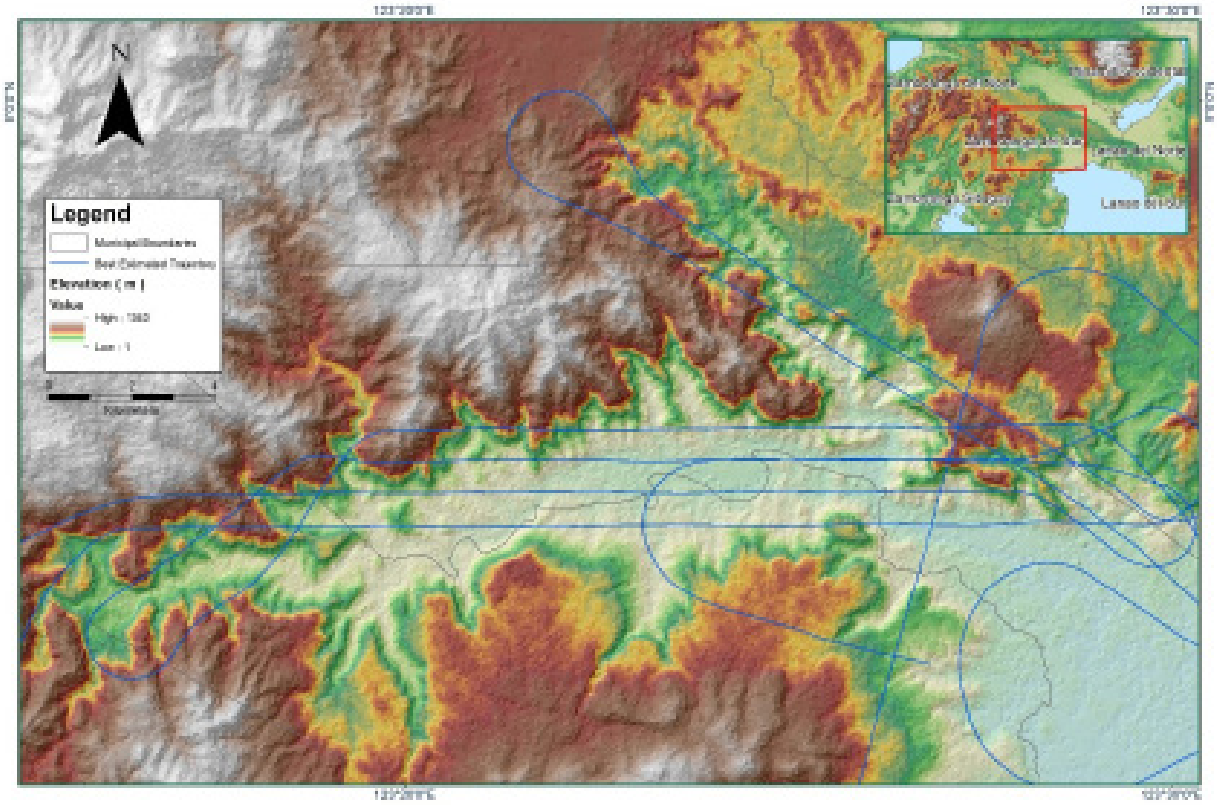


Figure A-8.3. Best Estimated Trajectory

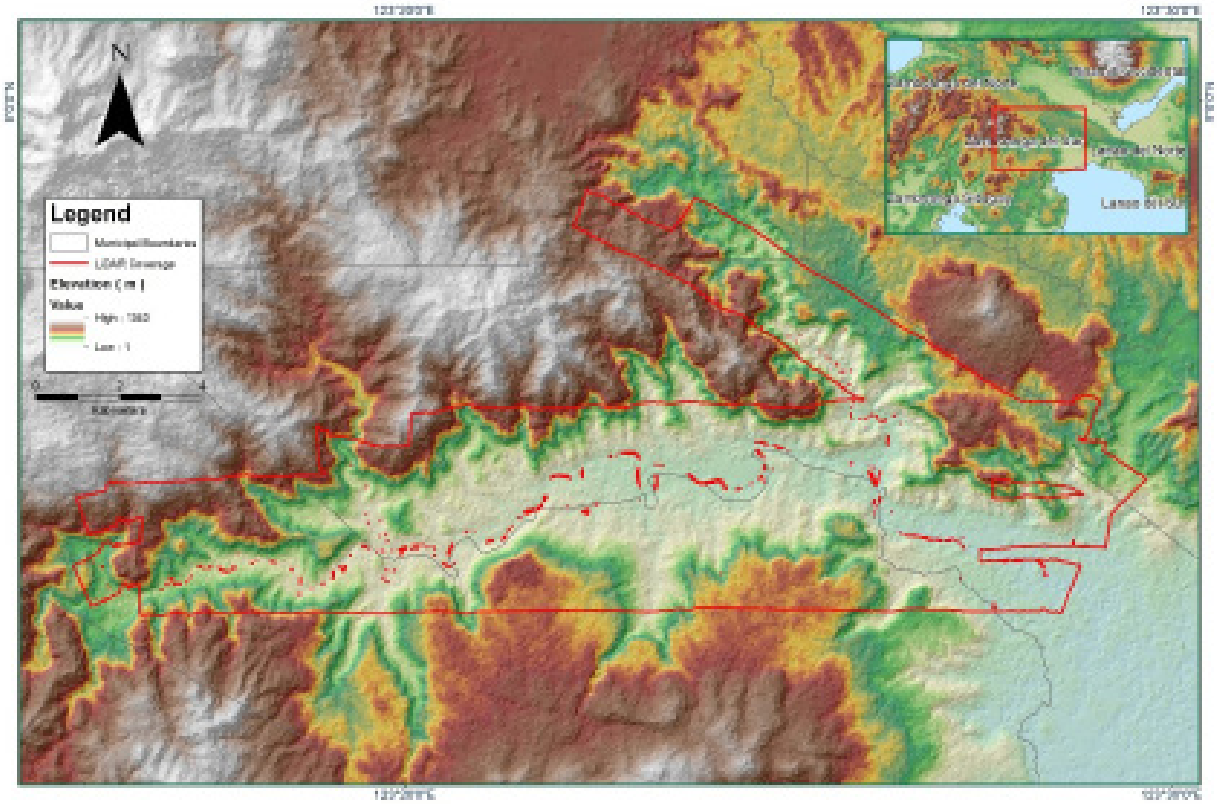


Figure A-8.4. Coverage of LiDAR Data

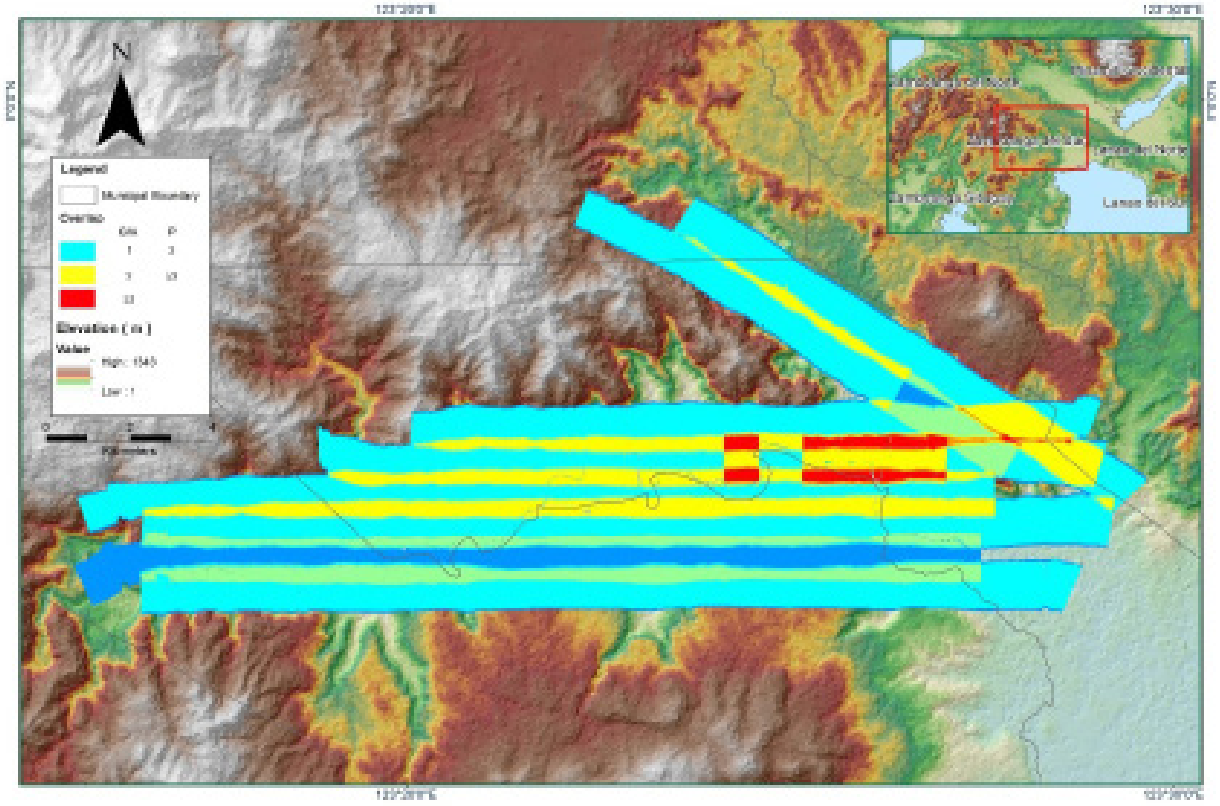


Figure A-8.5. Image of data overlap

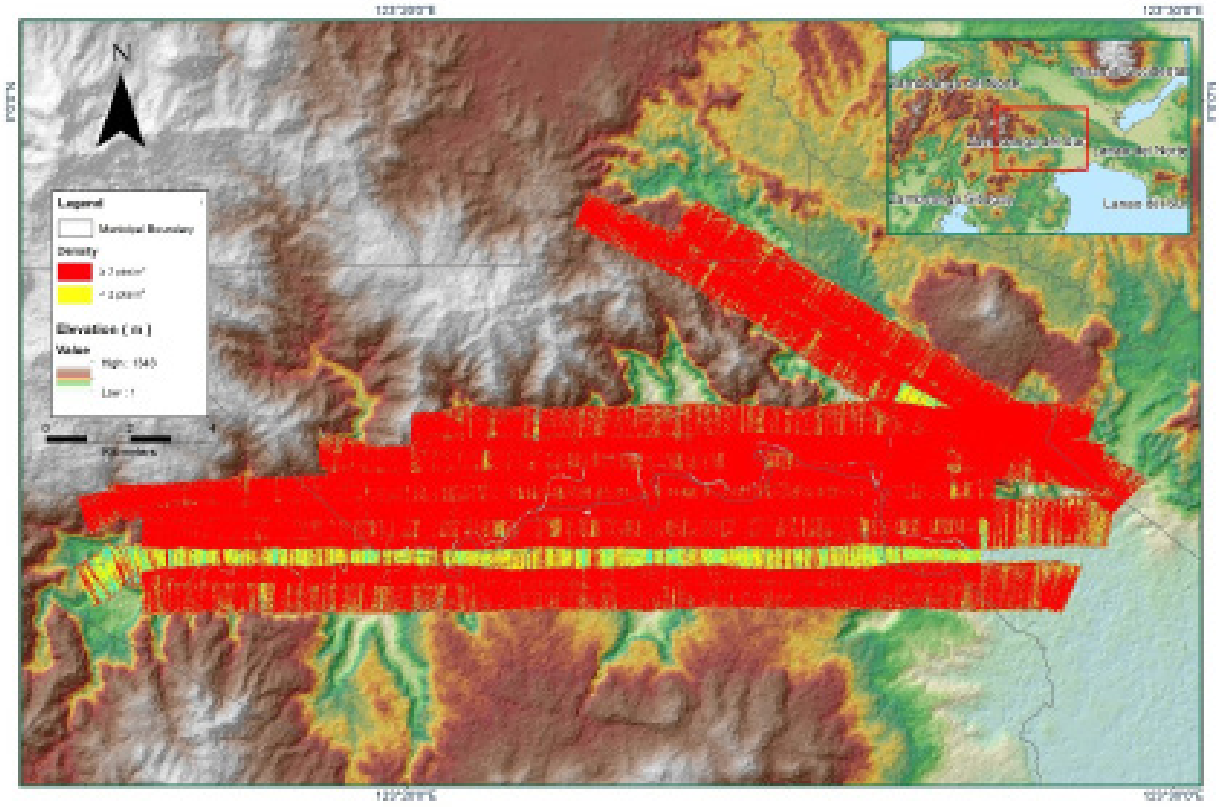


Figure A-8.6. Density map of merged LiDAR data

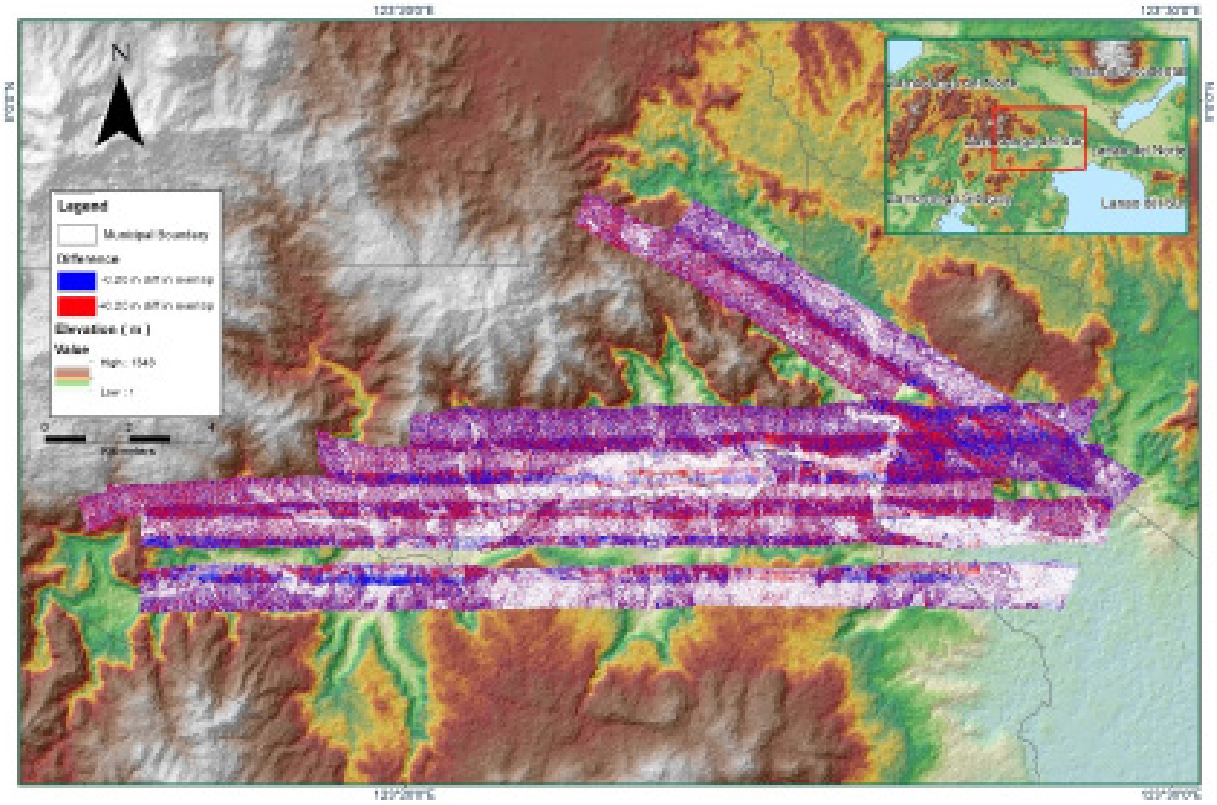


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission 76D

Flight Area	Pagadian
Mission Name	76D
Inclusive Flights	23078P
Range data size	13
POS data size	159
Base data size	152
Image	n/a
Transfer date	February 26, 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)	1.2
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	1.9
Boresight correction stdev (<0.001deg)	0.000185
IMU attitude correction stdev (<0.001deg)	0.000385
GPS position stdev (<0.01m)	0.0072
Minimum % overlap (>25)	35.06
Ave point cloud density per sq.m. (>2.0)	3.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	114
Maximum Height	448.34 m
Minimum Height	61.60 m
Classification (# of points)	
Ground	140,516,600
Low vegetation	65,433,235
Medium vegetation	67,241,339
High vegetation	169,635,078
Building	13,109,070
Orthophoto	Yes

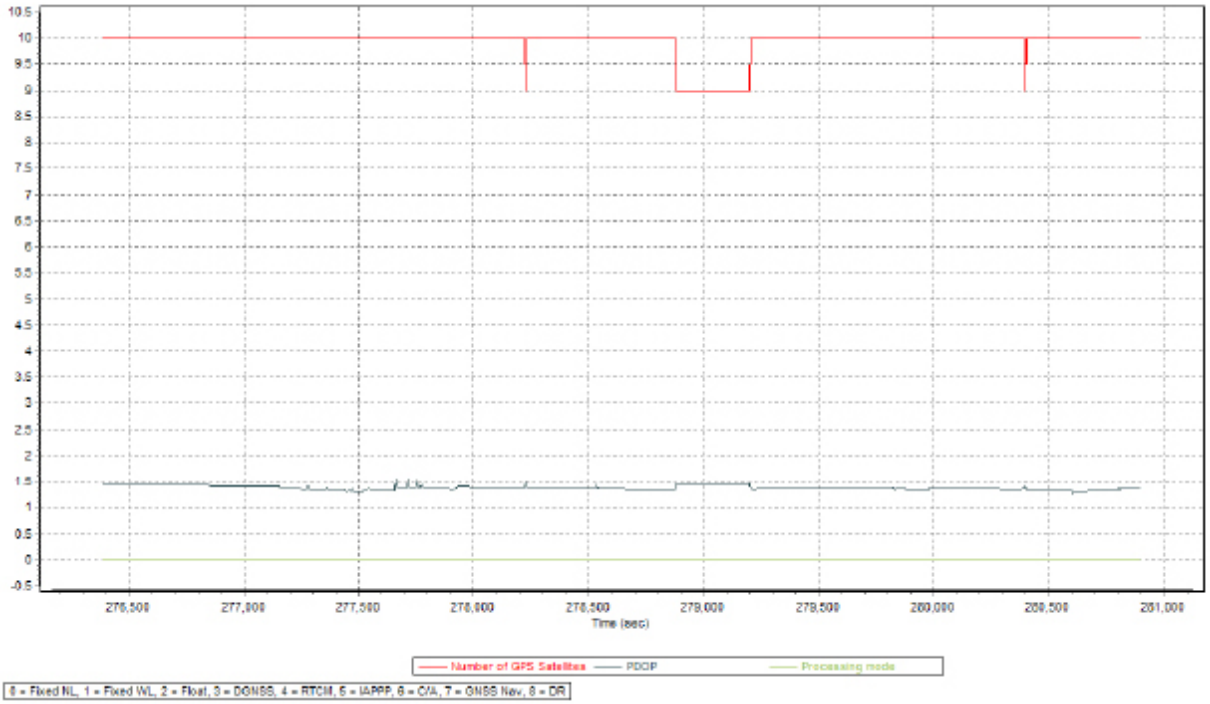


Figure A-8.8. Solution Status

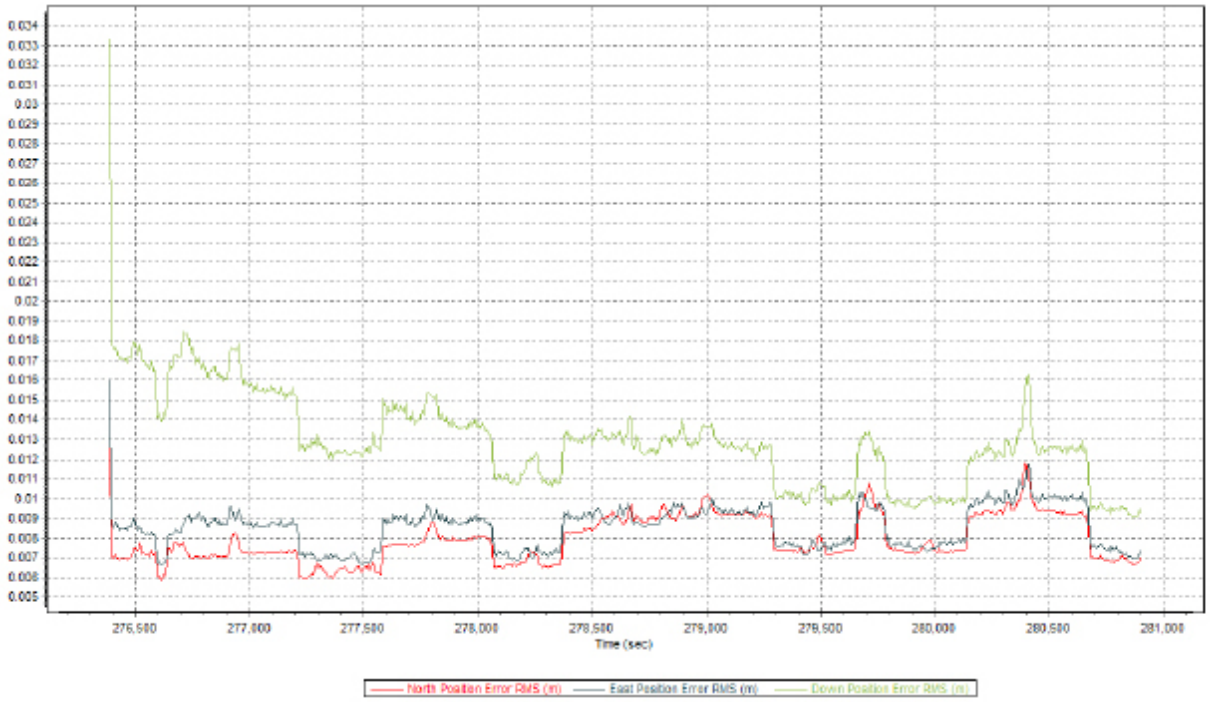


Figure A-8.9. Smoothed Performance of Metric Parameters

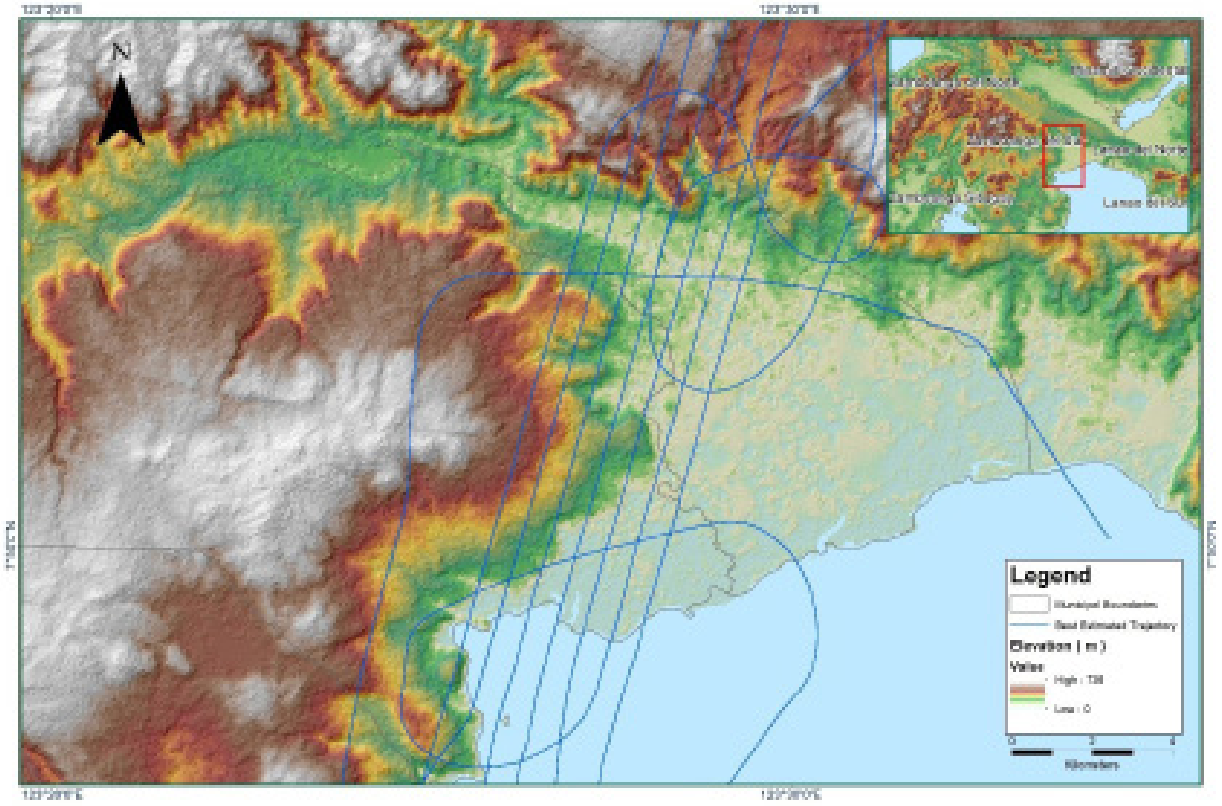


Figure A-8.10. Best Estimated Trajectory

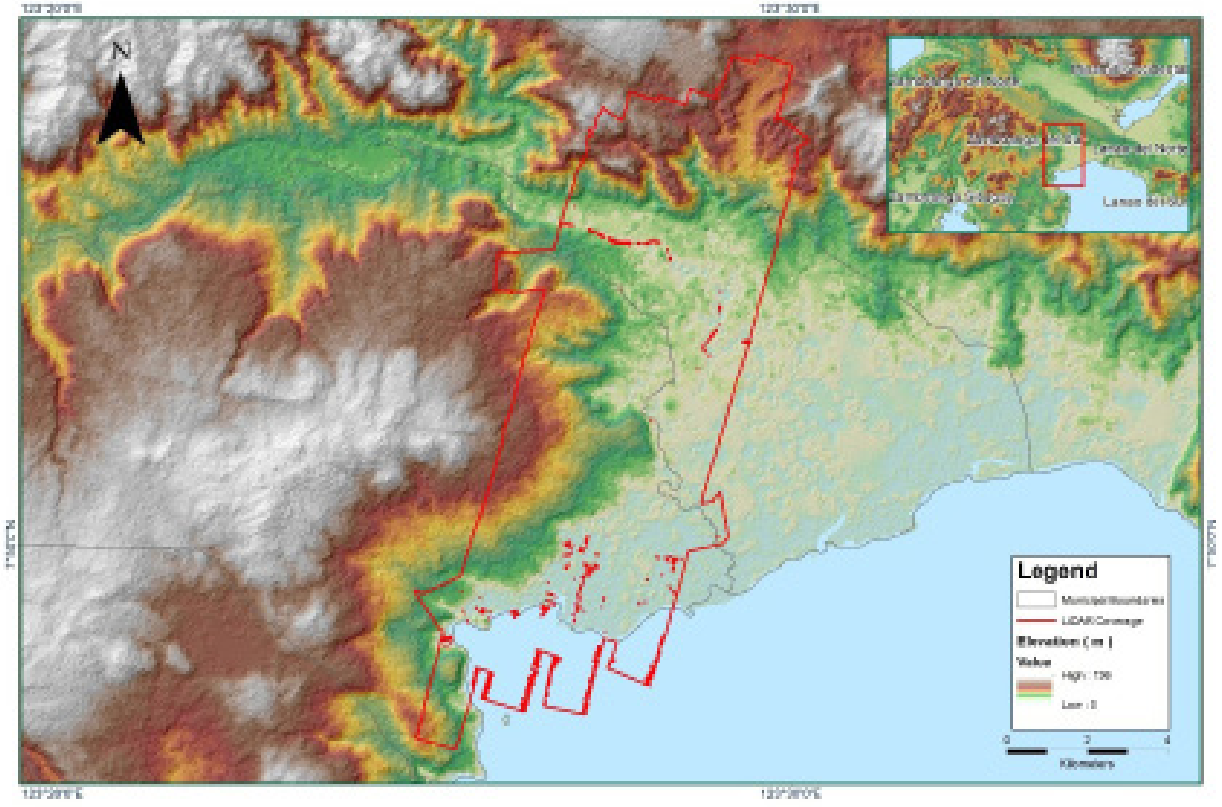


Figure A-8.11. Coverage of LiDAR Data

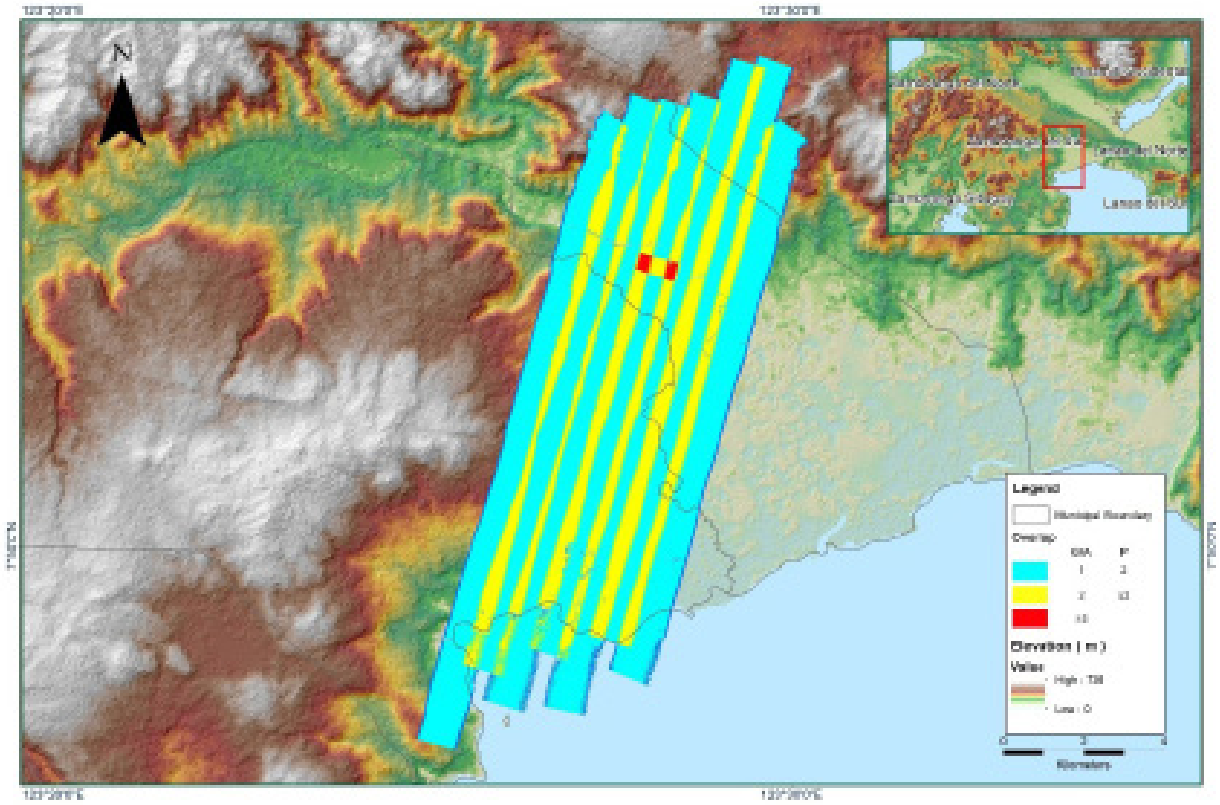


Figure A-8.12. Image of data overlap

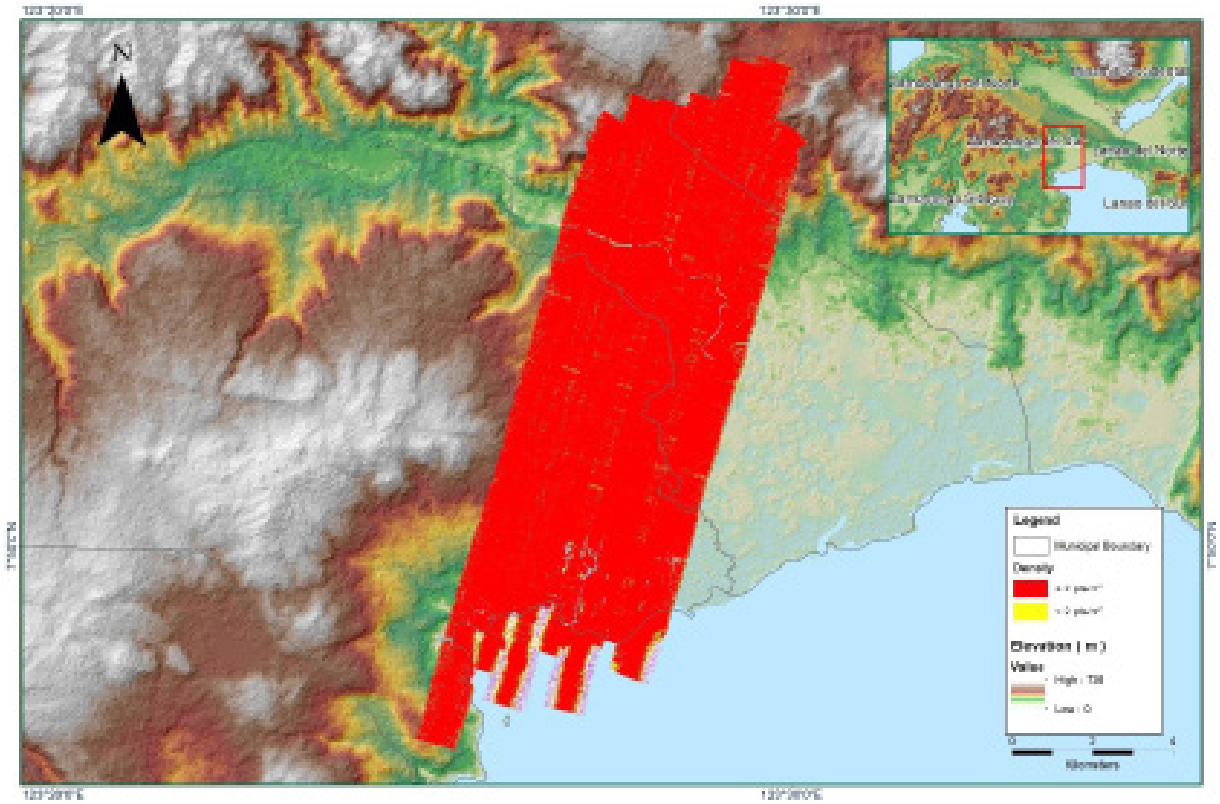


Figure A-8.13. Density map of merged LiDAR data

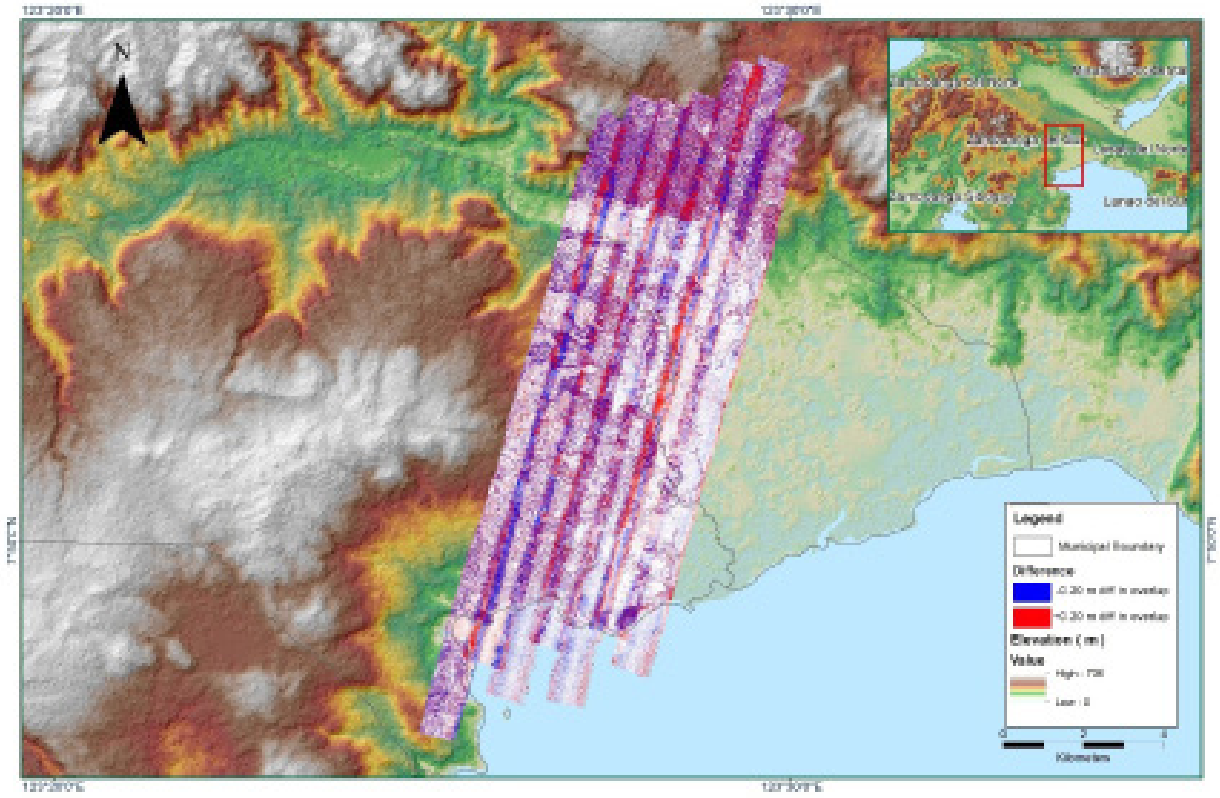


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission 76D_Additional

Flight Area	Pagadian
Mission Name	76D_Additional
Inclusive Flights	23104P
Range data size	18.3
POS data size	287.01
Base data size	116.78
Image	n/a
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	4.4
Boresight correction stdev (<0.001deg)	0.000179
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	38.62
Ave point cloud density per sq.m. (>2.0)	3.50
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	61
Maximum Height	614.00 m
Minimum Height	68.88 m
Classification (# of points)	
Ground	47,142,426
Low vegetation	36,515,601
Medium vegetation	48,835,844
High vegetation	116,954,106
Building	4,206,639
Orthophoto	Yes

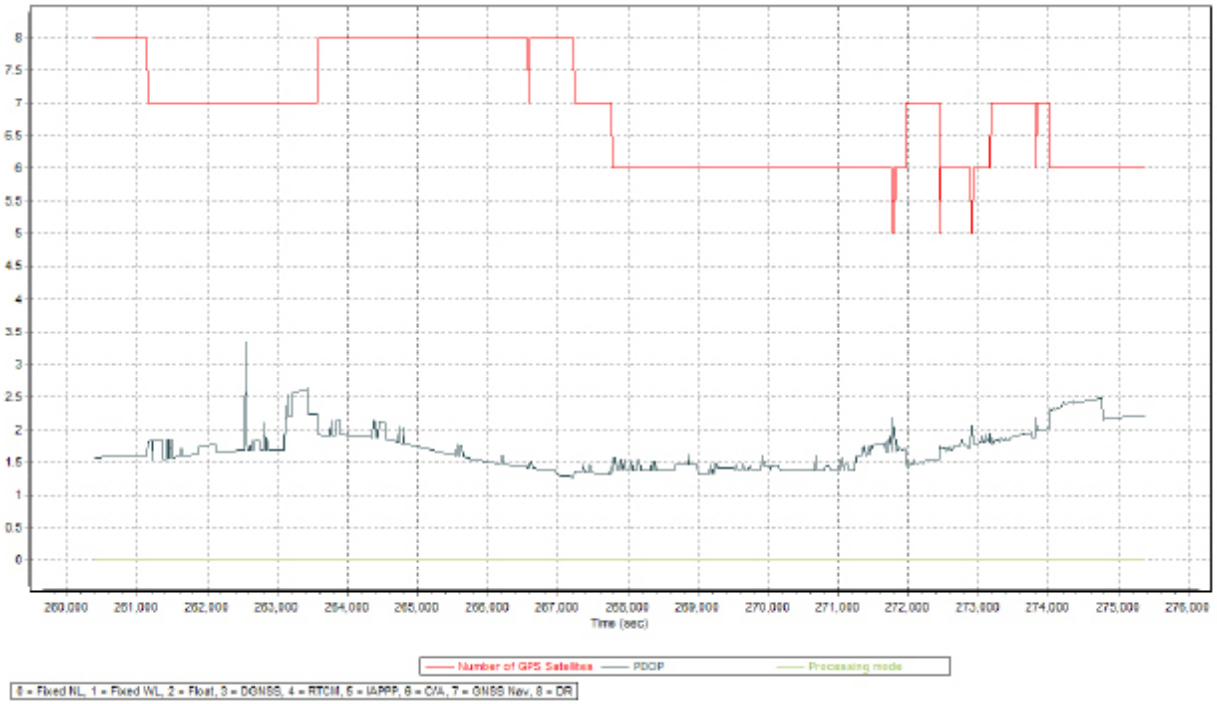


Figure A-8.15. Solution Status

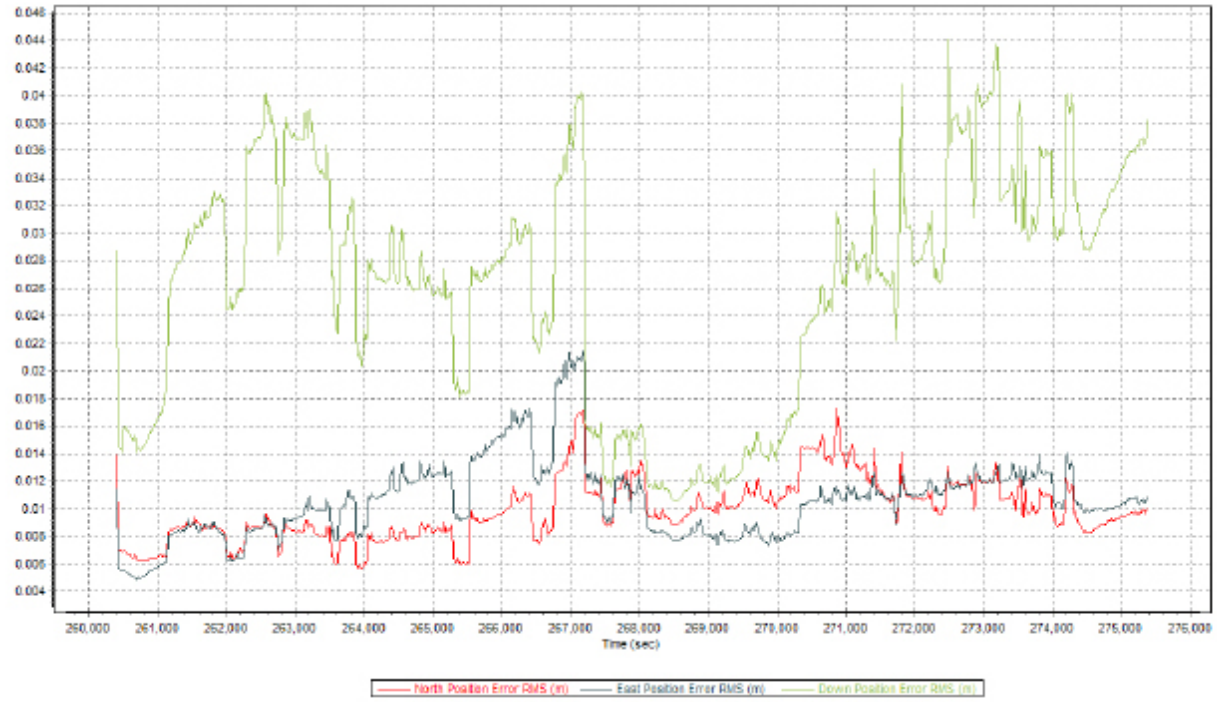


Figure A-8.16 Smoothed Performance Metric Parameters

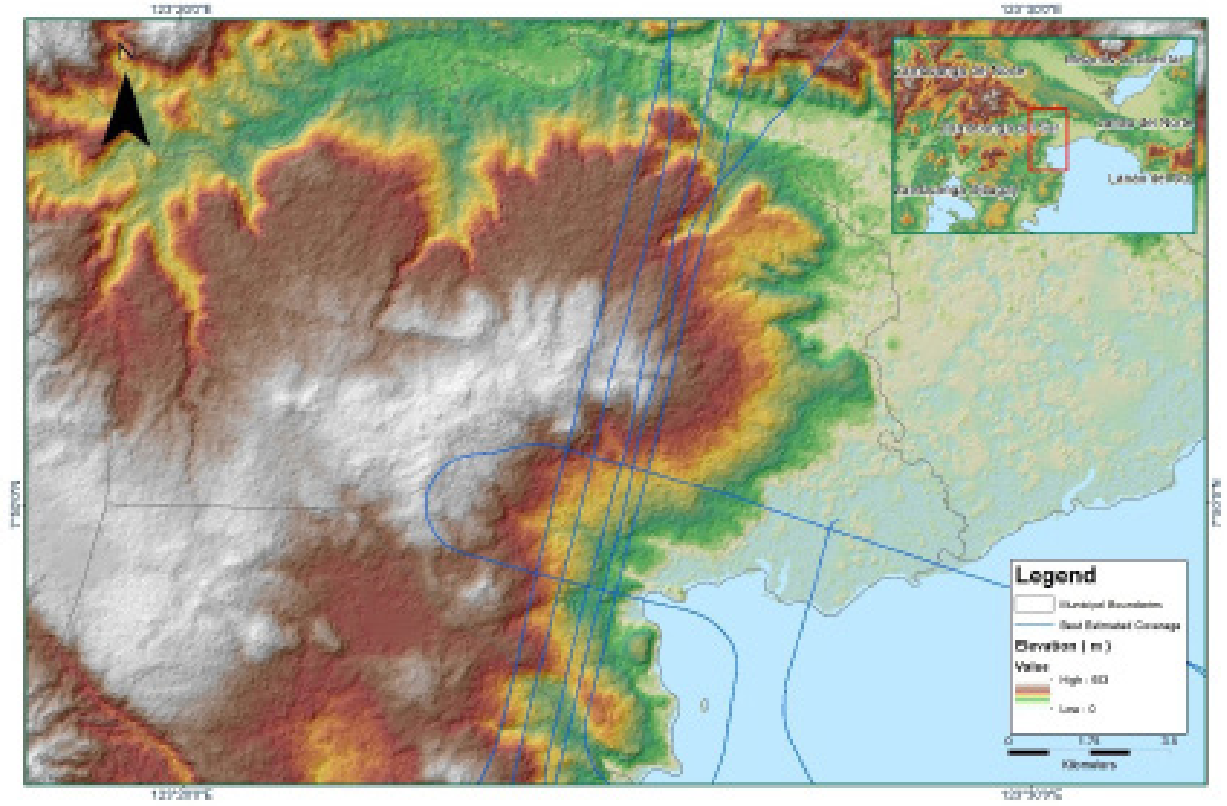


Figure A-8.17. Best Estimated Trajectory

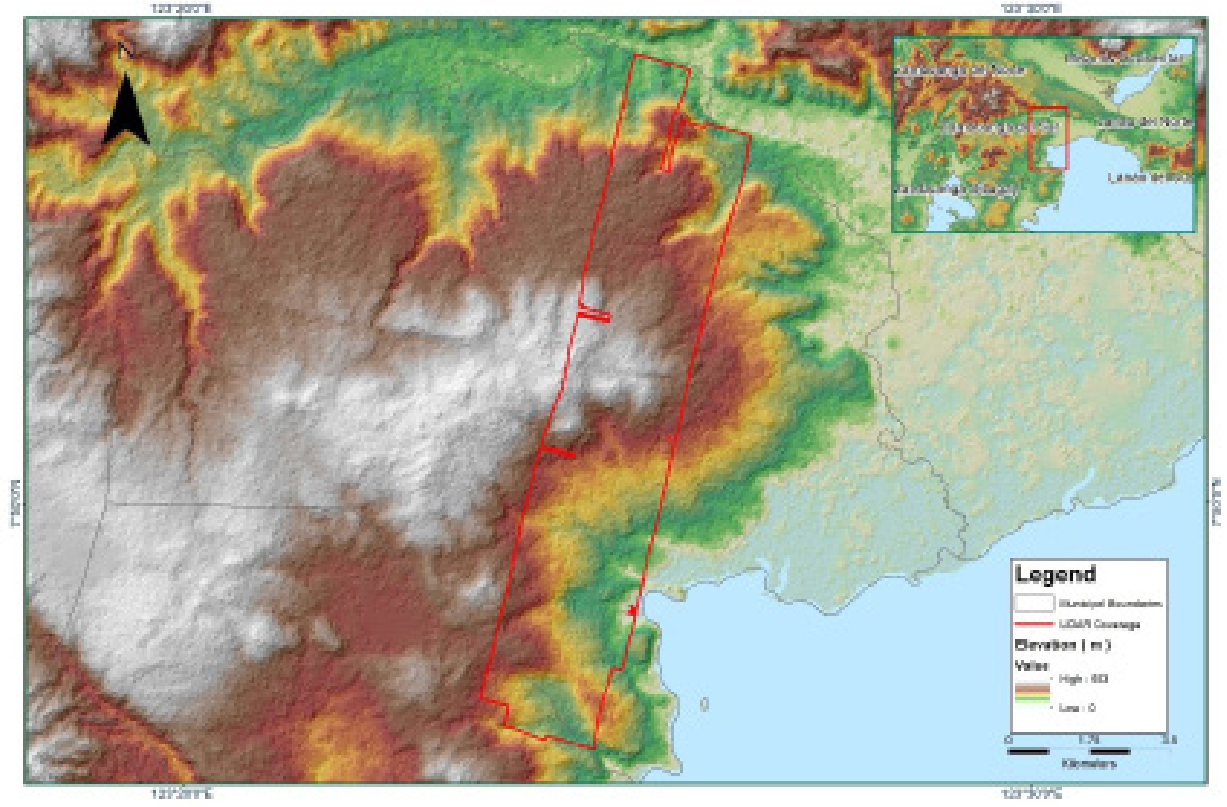


Figure A-8.18. Coverage of LiDAR Data

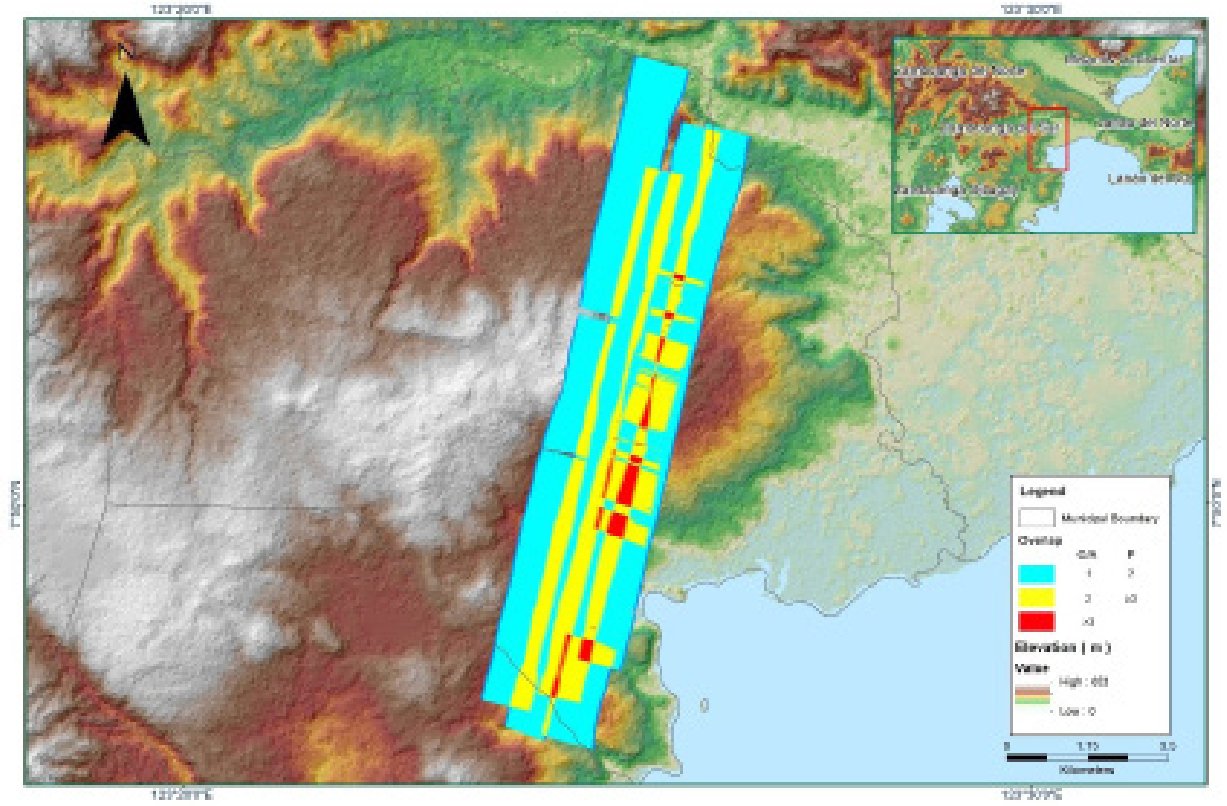


Figure A-8.19. Image of data overlap

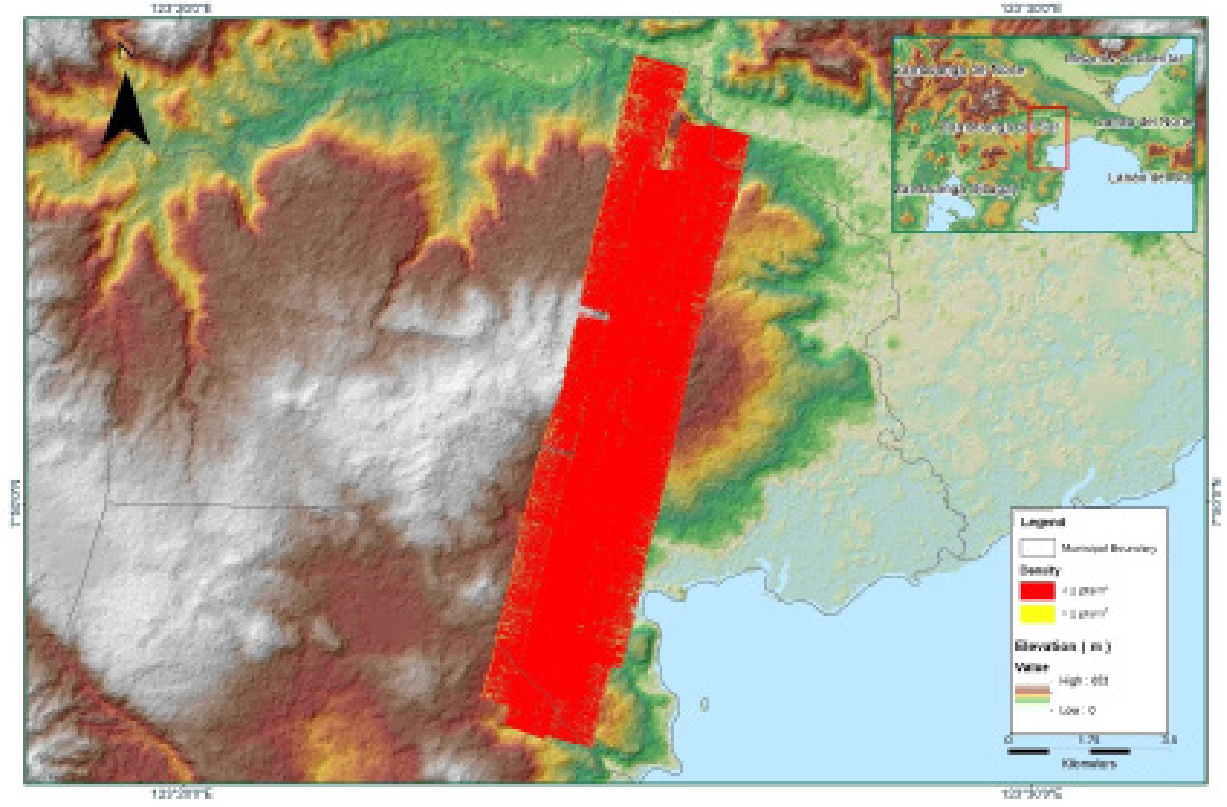


Figure A-8.20. Density map of merged LiDAR data

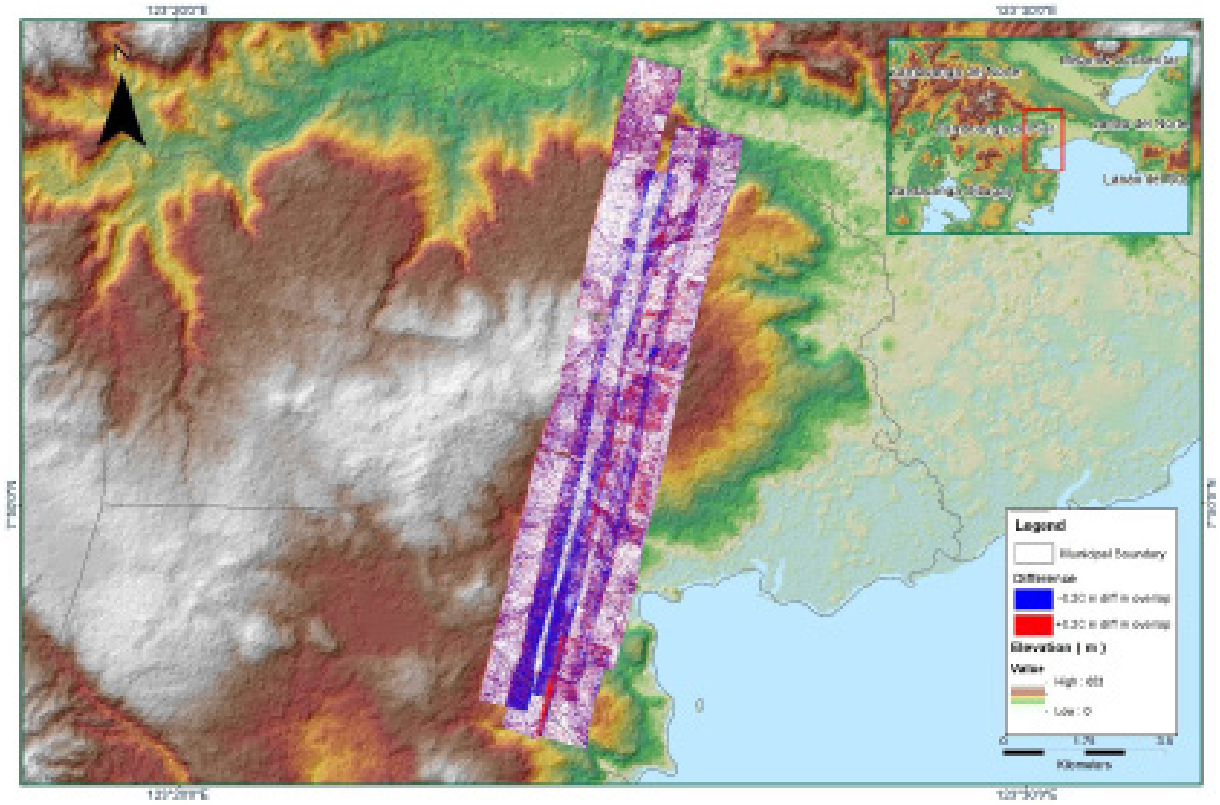


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission 76D_Supplement

Flight Area	Pagadian
Mission Name	76D_Supplement
Inclusive Flights	23084P, 23802P
Range data size	39.02
POS data size	420.9
Base data size	229.73
Image	n/a
Transfer date	March 01, 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)	5.4
RMSE for East Position (<4.0 cm)	5.6
RMSE for Down Position (<8.0 cm)	11.5
Boresight correction stdev (<0.001deg)	0.000305
IMU attitude correction stdev (<0.001deg)	0.000451
GPS position stdev (<0.01m)	0.0010
Minimum % overlap (>25)	22.63
Ave point cloud density per sq.m. (>2.0)	1.88
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	94
Maximum Height	492.70 m
Minimum Height	59.81 m
Classification (# of points)	
Ground	101,417,737
Low vegetation	33,877,520
Medium vegetation	20,839,456
High vegetation	59,785,381
Building	1,480,296
Orthophoto	Yes

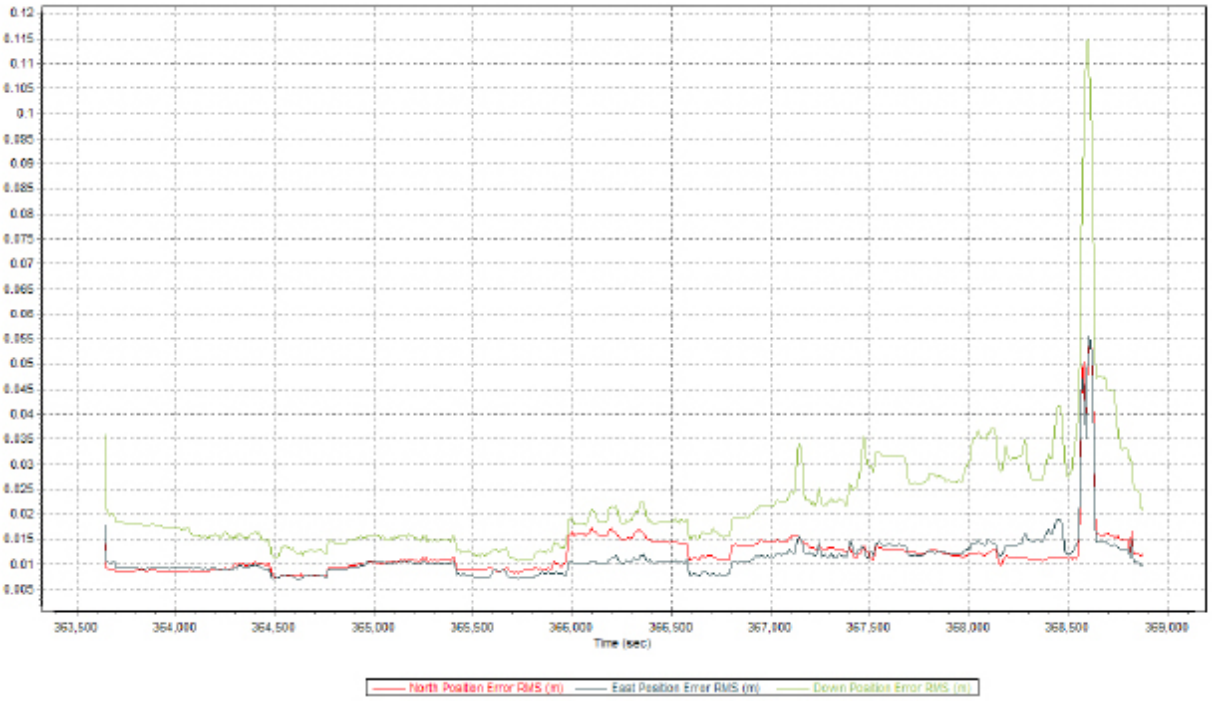


Figure A-8.22. Solution Status

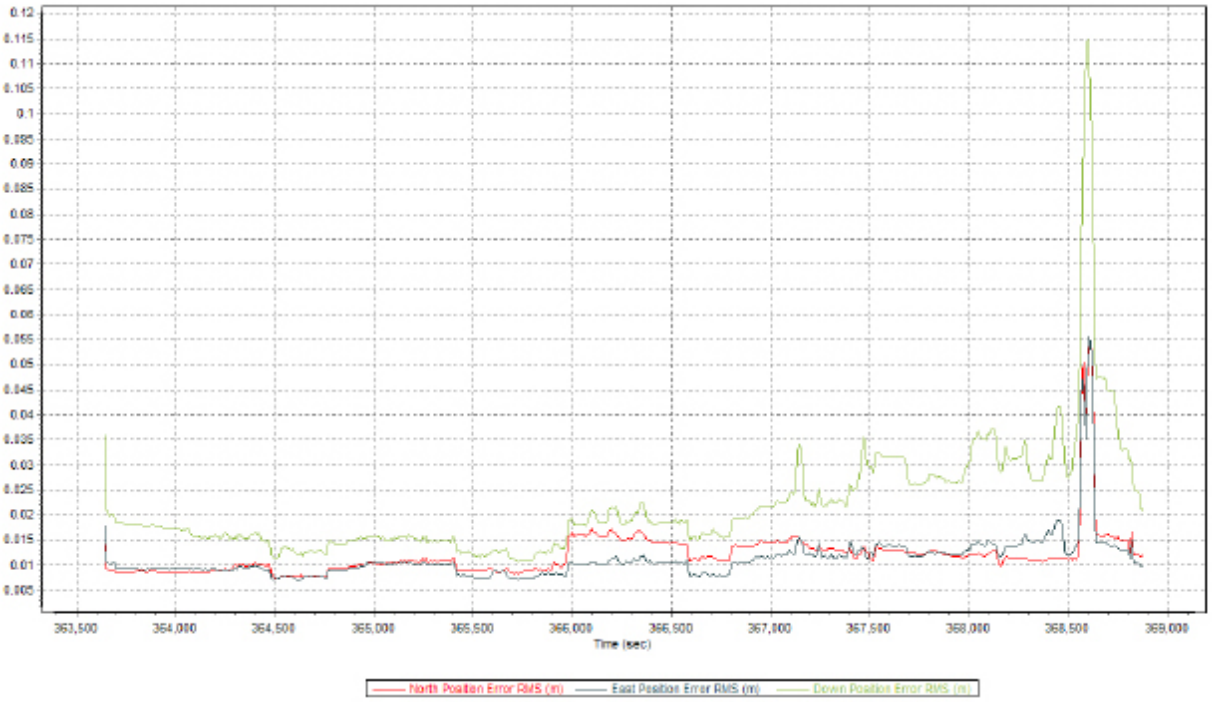


Figure A-8.23 Smoothed Performance Metric Parameters

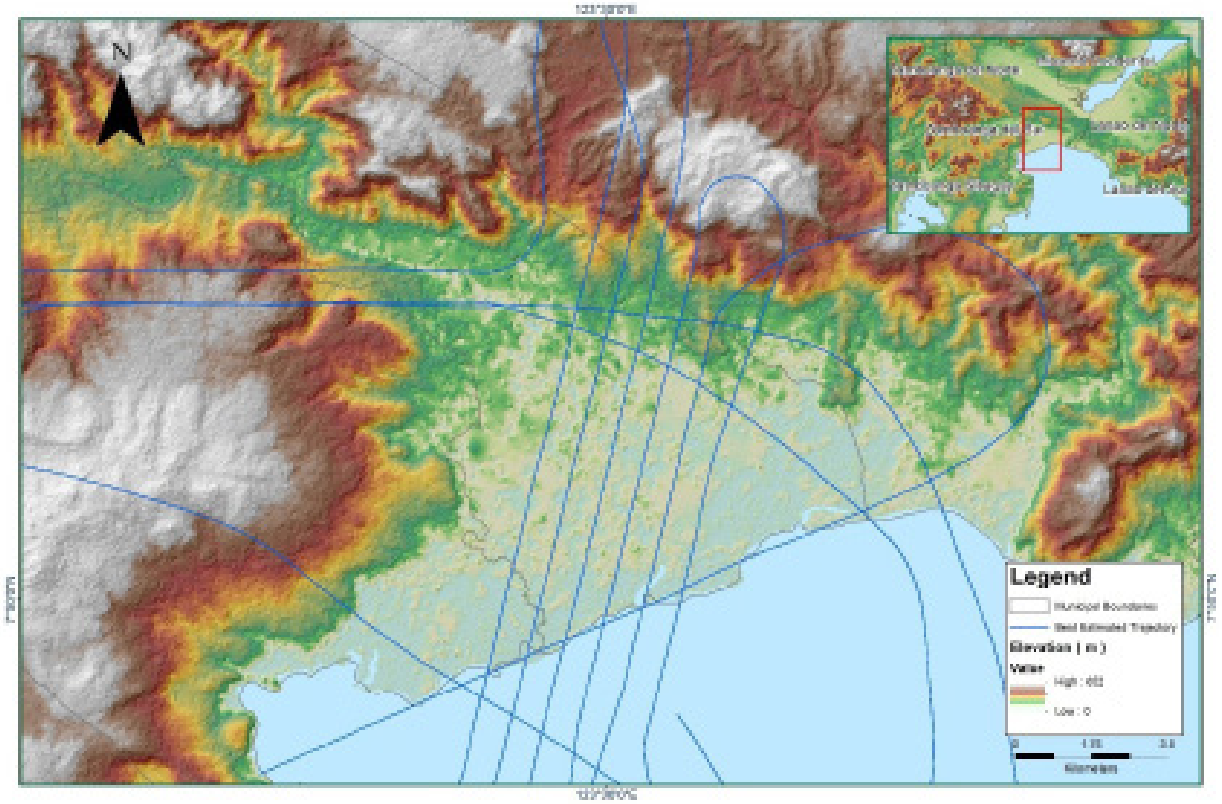


Figure A-8.24. Best Estimated Trajectory

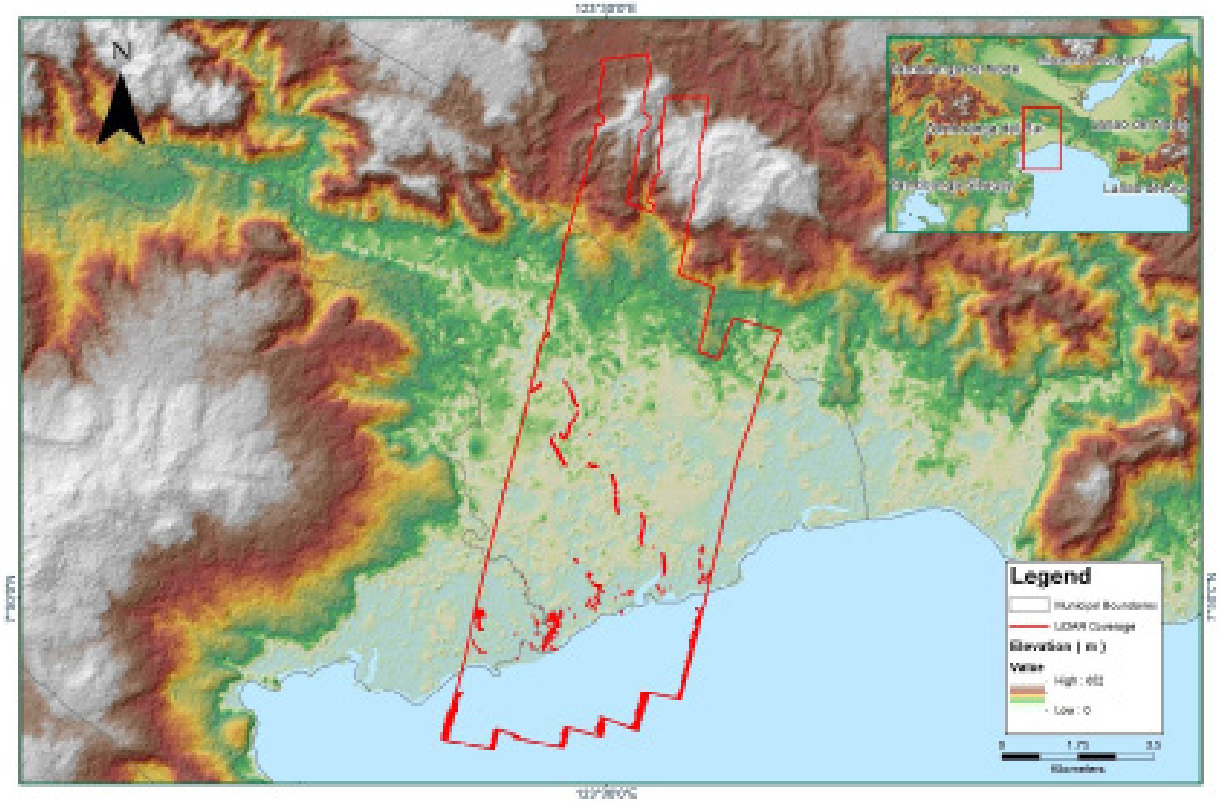


Figure A-8.25. Coverage of LiDAR Data

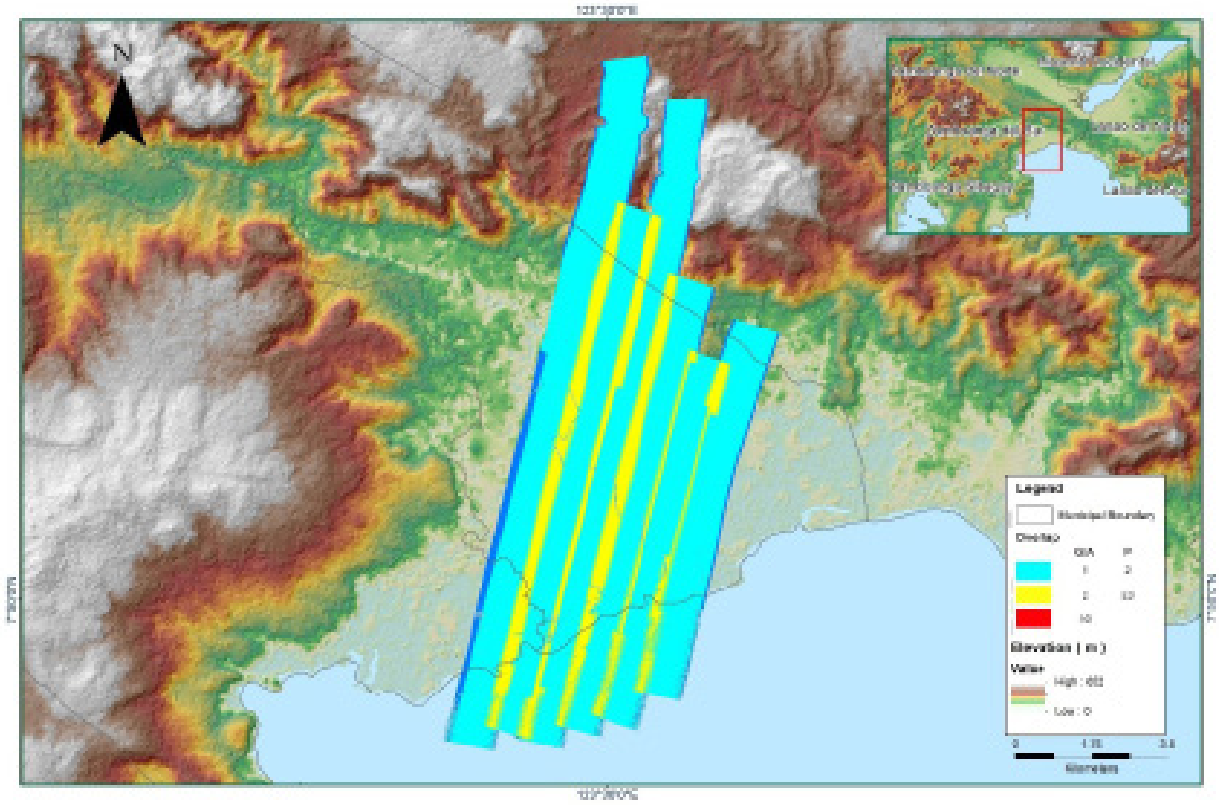


Figure A-8.26. Image of data overlap

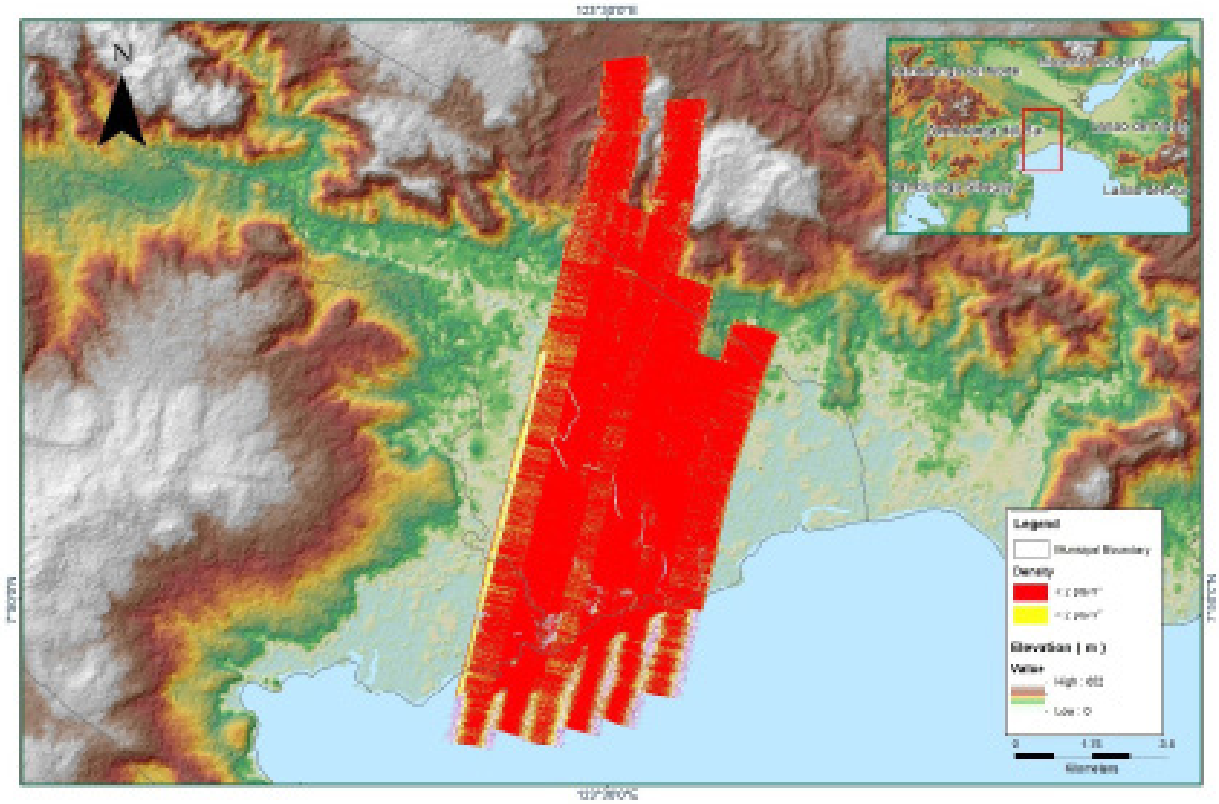


Figure A-8.27. Density map of merged LiDAR data

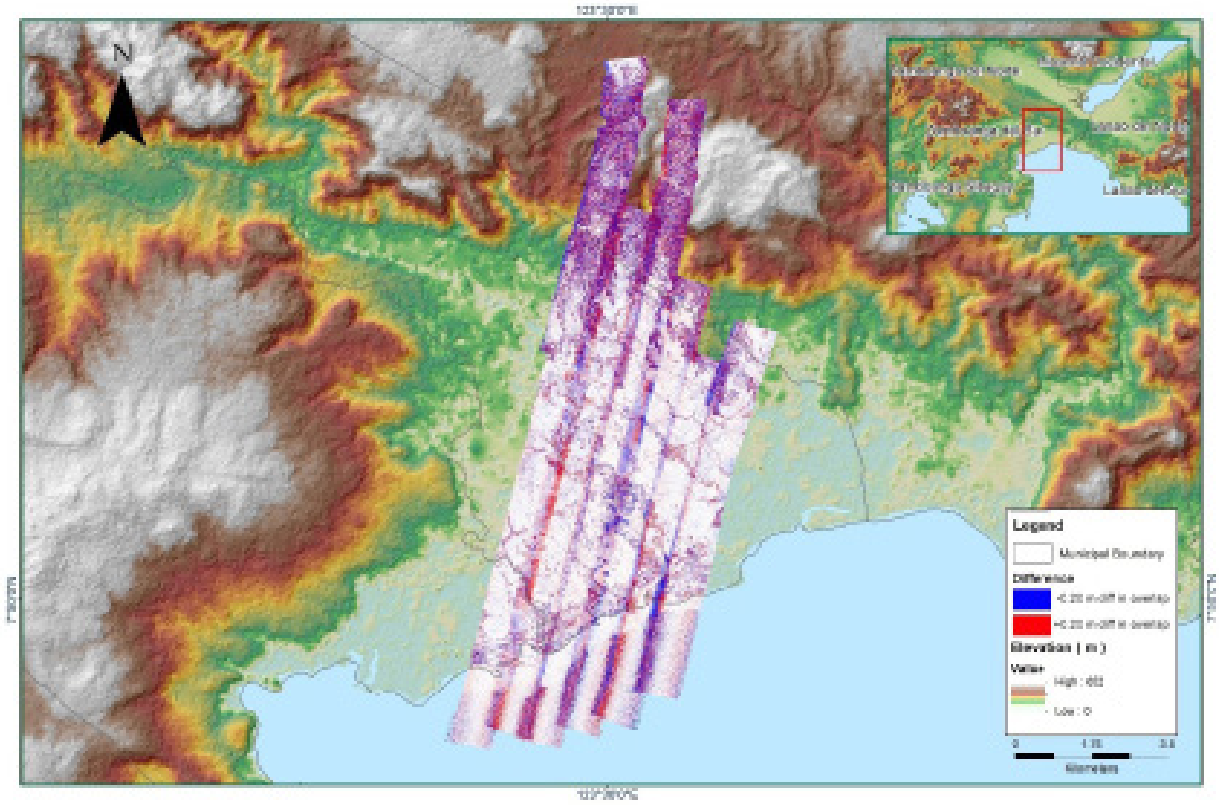


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission 76E

Flight Area	Pagadian
Mission Name	76E
Inclusive Flights	23064P, 23072P
Range data size	46.8
POS data size	528
Base data size	151.13
Image	n/a
Transfer date	February 26, 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)	1.3
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000217
IMU attitude correction stdev (<0.001deg)	0.000804
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	37.26
Ave point cloud density per sq.m. (>2.0)	3.66
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	209
Maximum Height	658.68 m
Minimum Height	88.03 m
Classification (# of points)	
Ground	225,310,073
Low vegetation	155,227,279
Medium vegetation	227,164,256
High vegetation	459,509,484
Building	4,927,365
Orthophoto	Yes

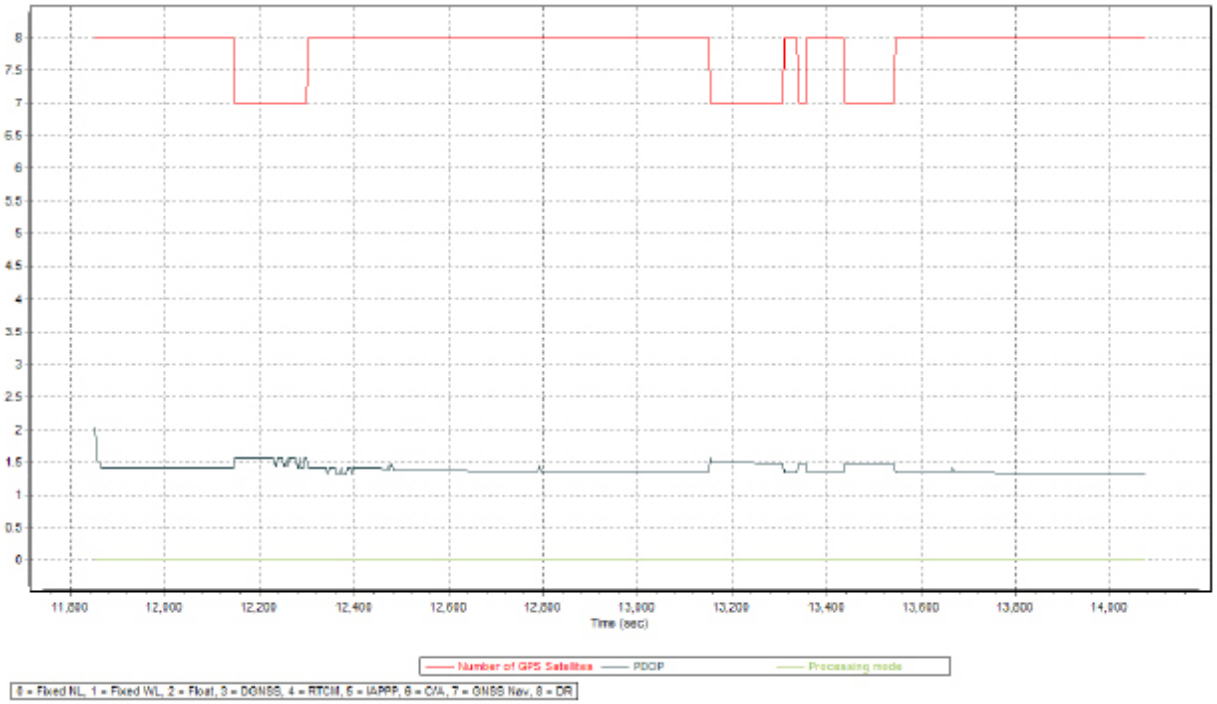


Figure A-8.29. Solution Status

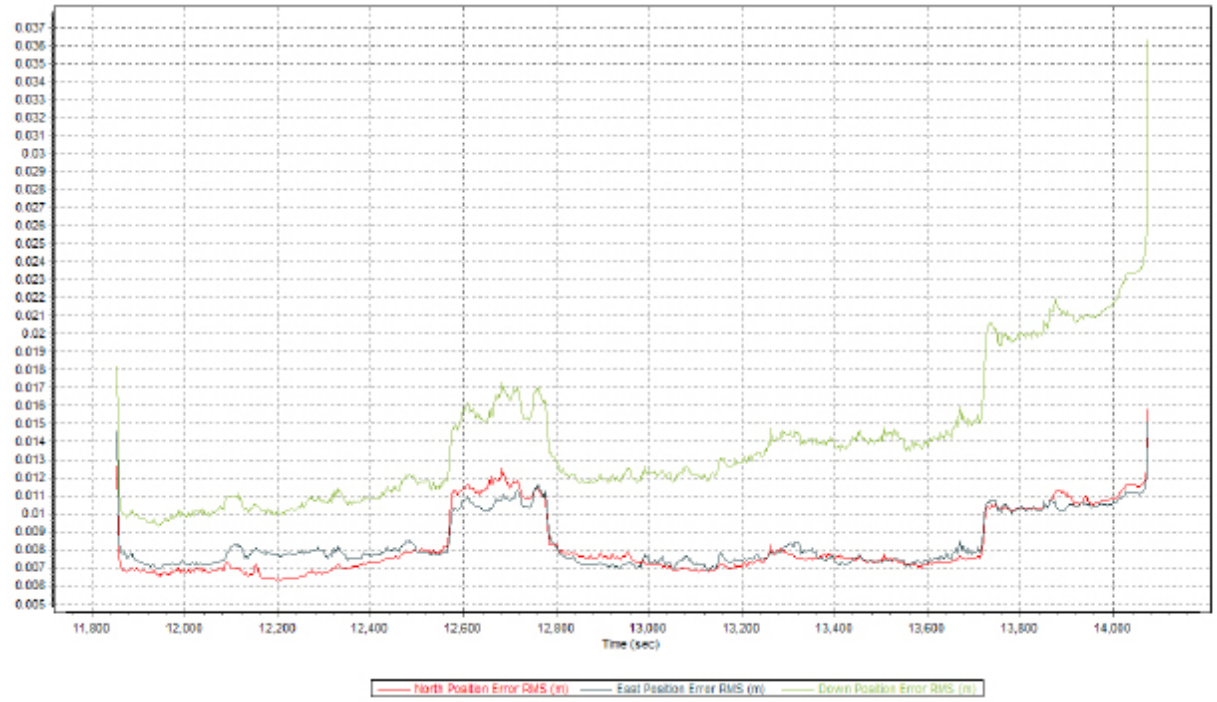


Figure A-8.30 Smoothed Performance Metric Parameters

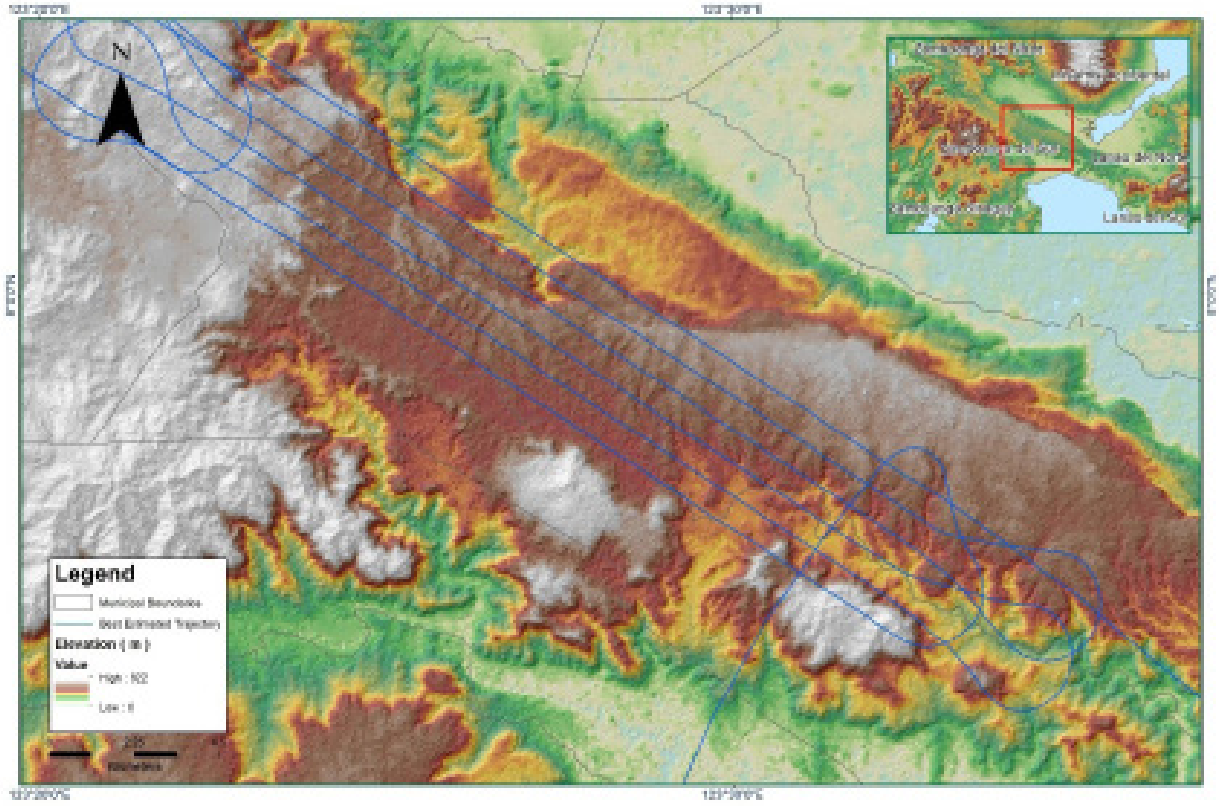


Figure A-8.31. Best Estimated Trajectory

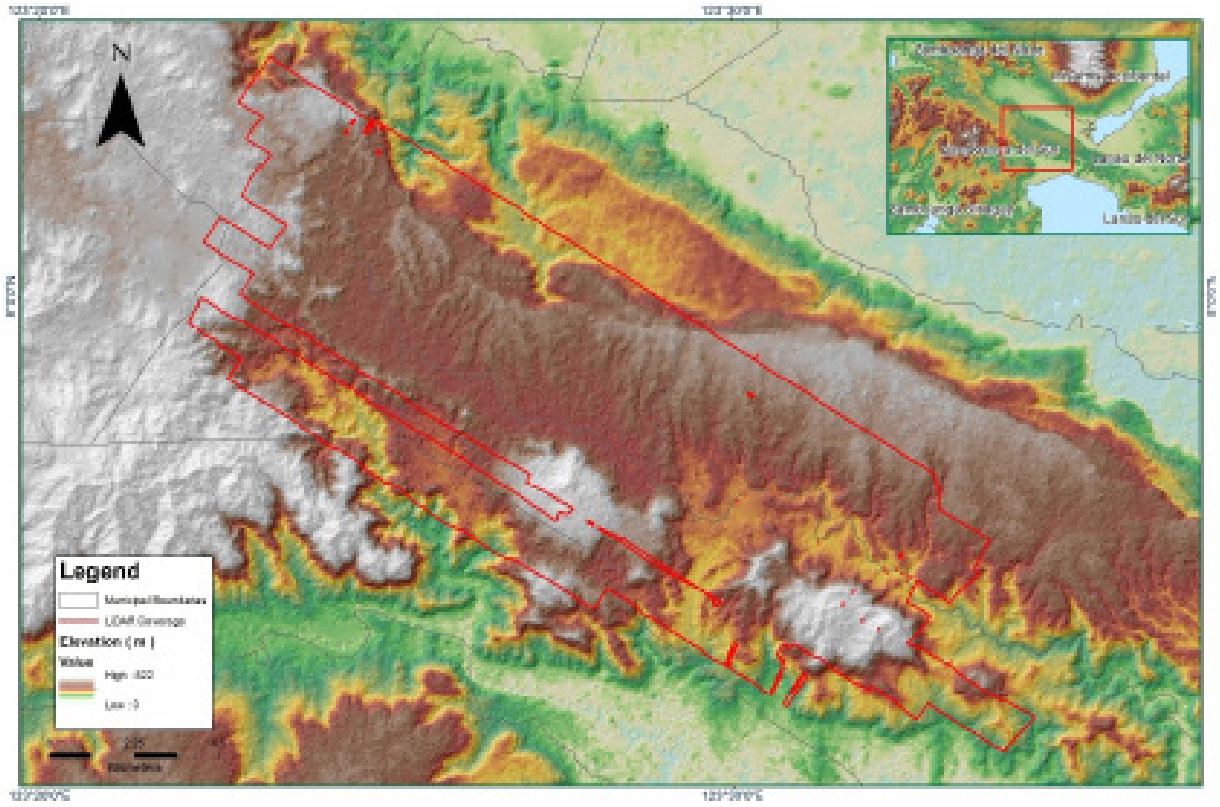


Figure A-8.32. Coverage of LiDAR Data

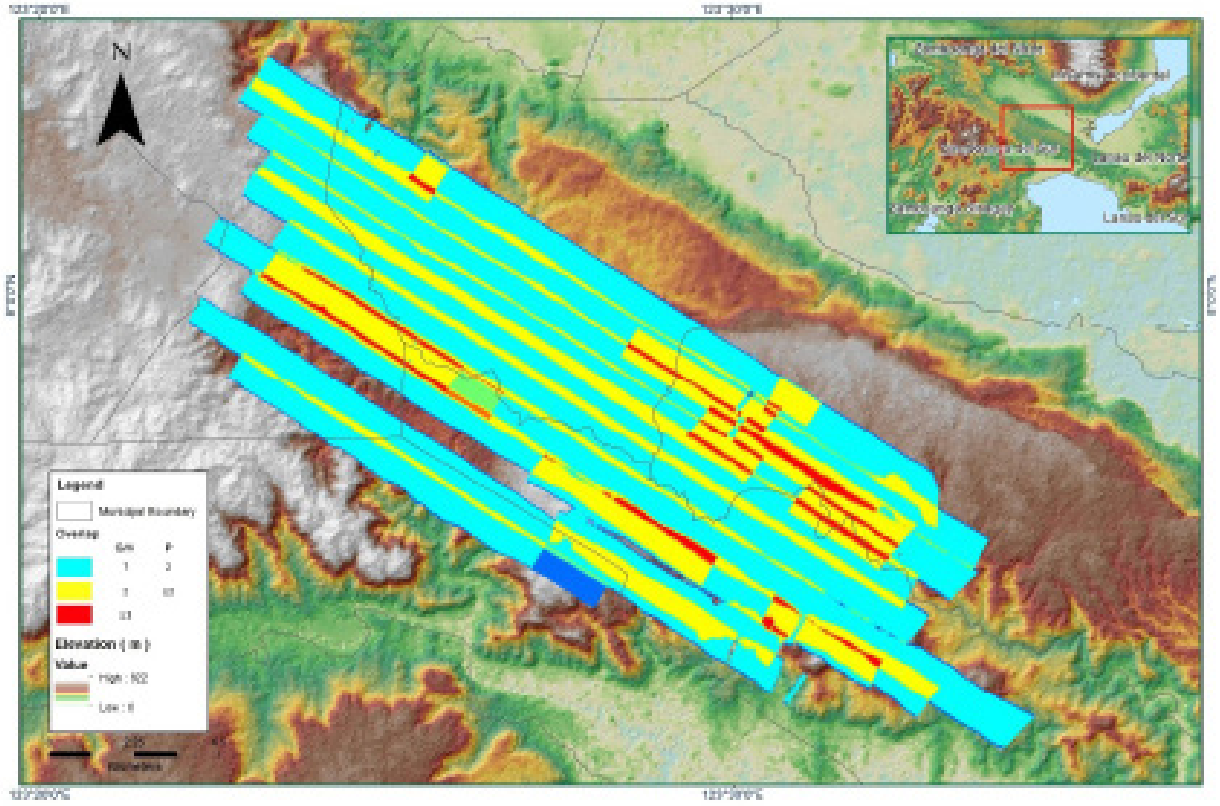
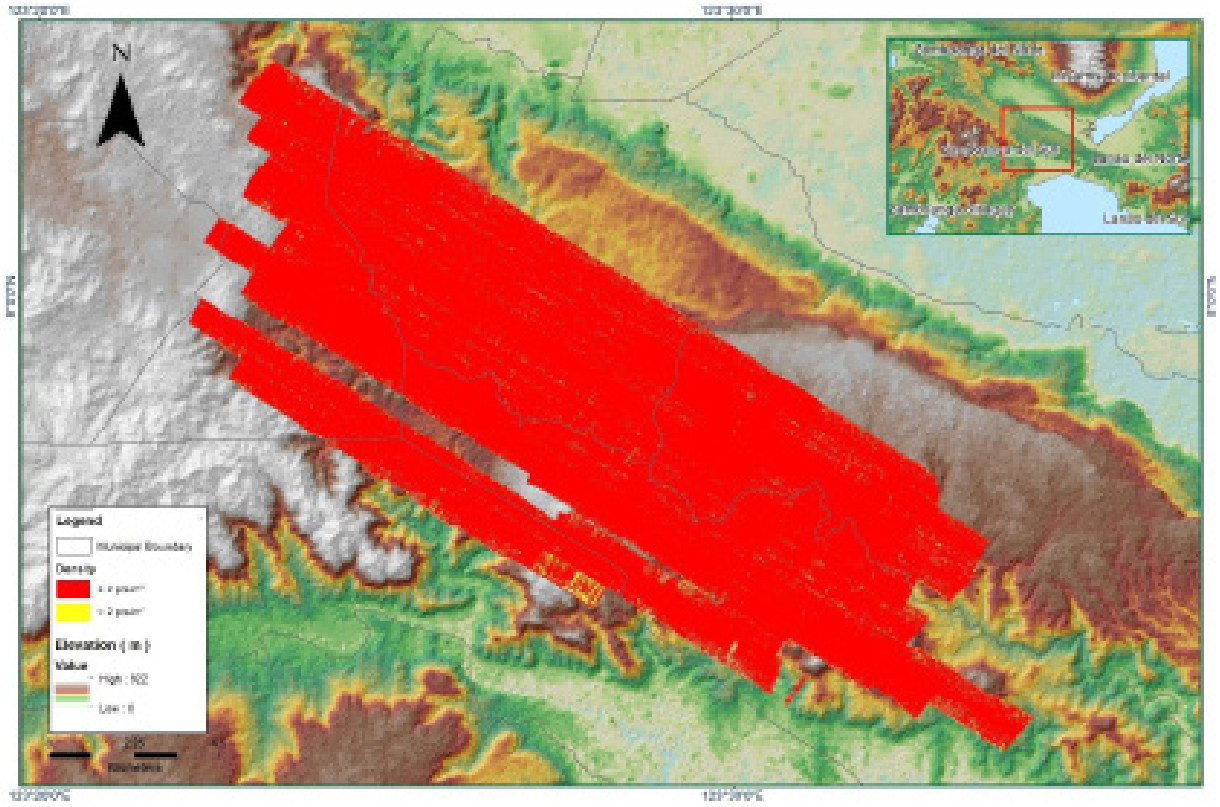


Figure A-8.33. Image of data overlap



FFigure A-8.34. Density map of merged LiDAR data

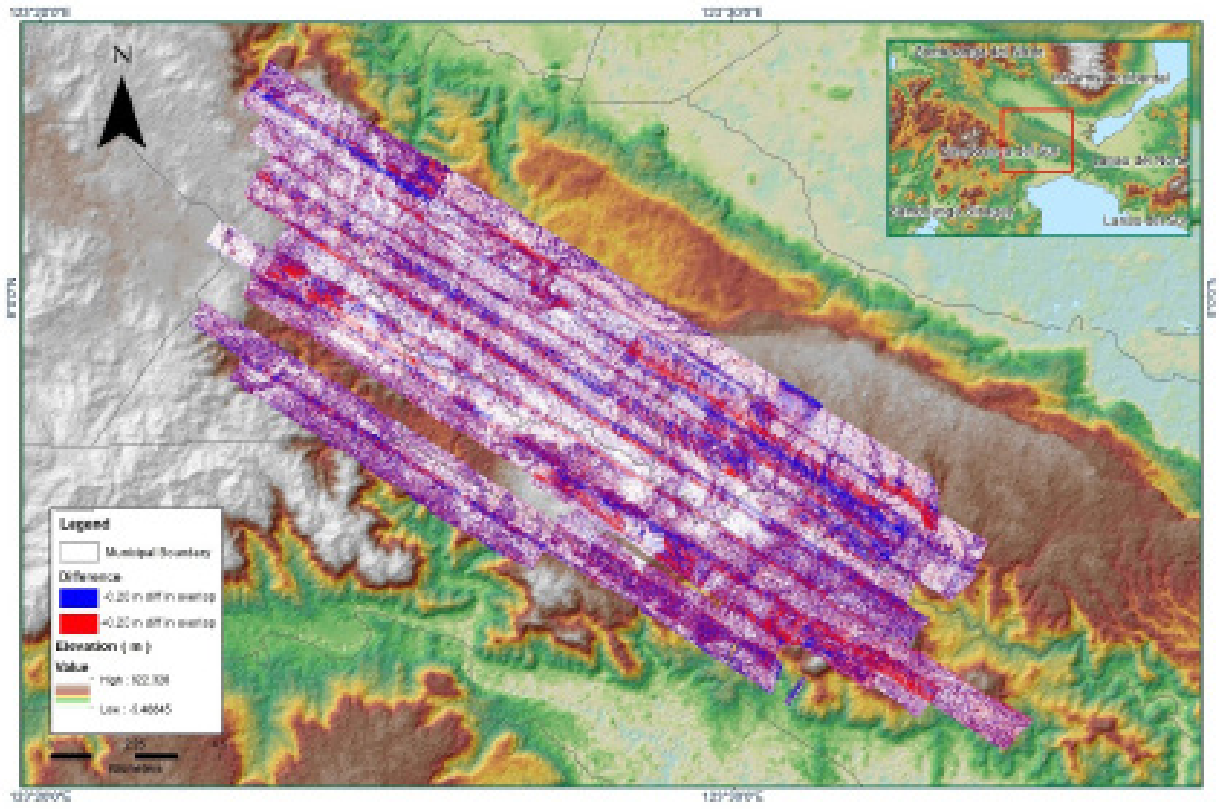


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission 76E_Additional

Flight Area	Pagadian
Mission Name	76E_Additional
Inclusive Flights	23100P
Range data size	27.31
POS data size	285.96
Base data size	103.23
Image	n/a
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.7
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	8.8
Boresight correction stdev (<0.001deg)	0.000214
IMU attitude correction stdev (<0.001deg)	0.000276
GPS position stdev (<0.01m)	0.0009
Minimum % overlap (>25)	44.35
Ave point cloud density per sq.m. (>2.0)	4.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	91
Maximum Height	658.88 m
Minimum Height	78.22 m
Classification (# of points)	
Ground	78,878,550
Low vegetation	59,379,525
Medium vegetation	110,539,775
High vegetation	204,582,572
Building	2,243,123
Orthophoto	Yes

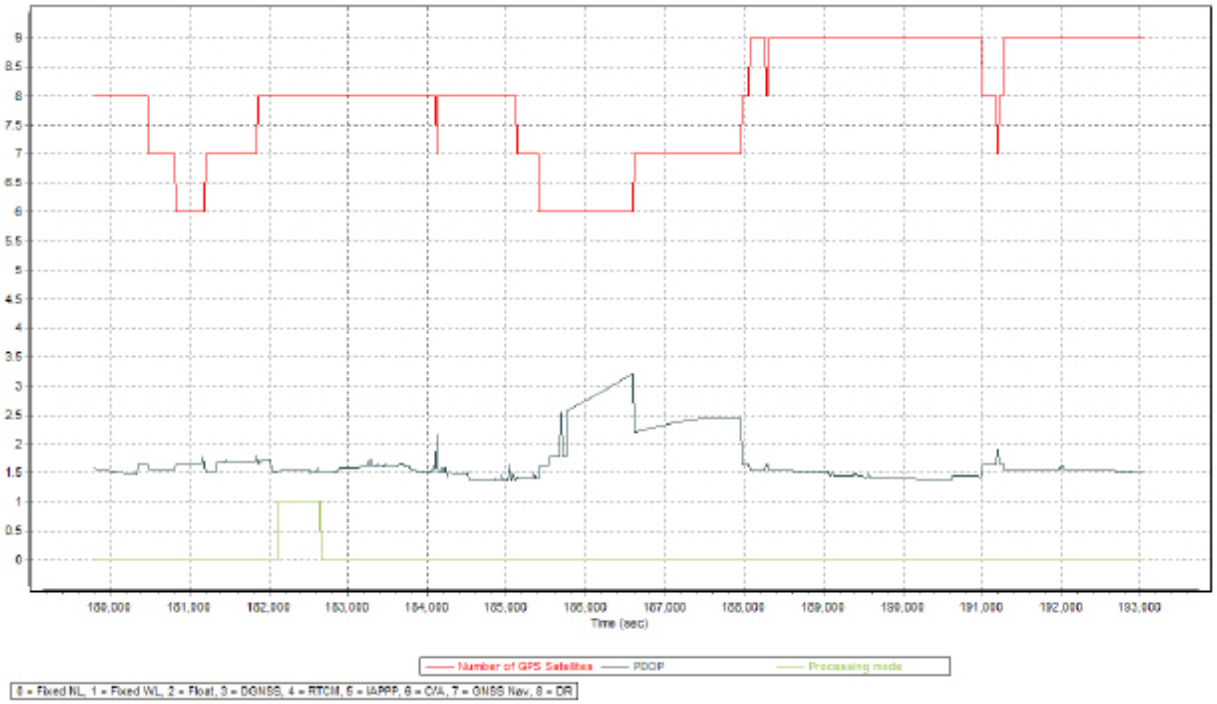


Figure A-8.36. Solution Status

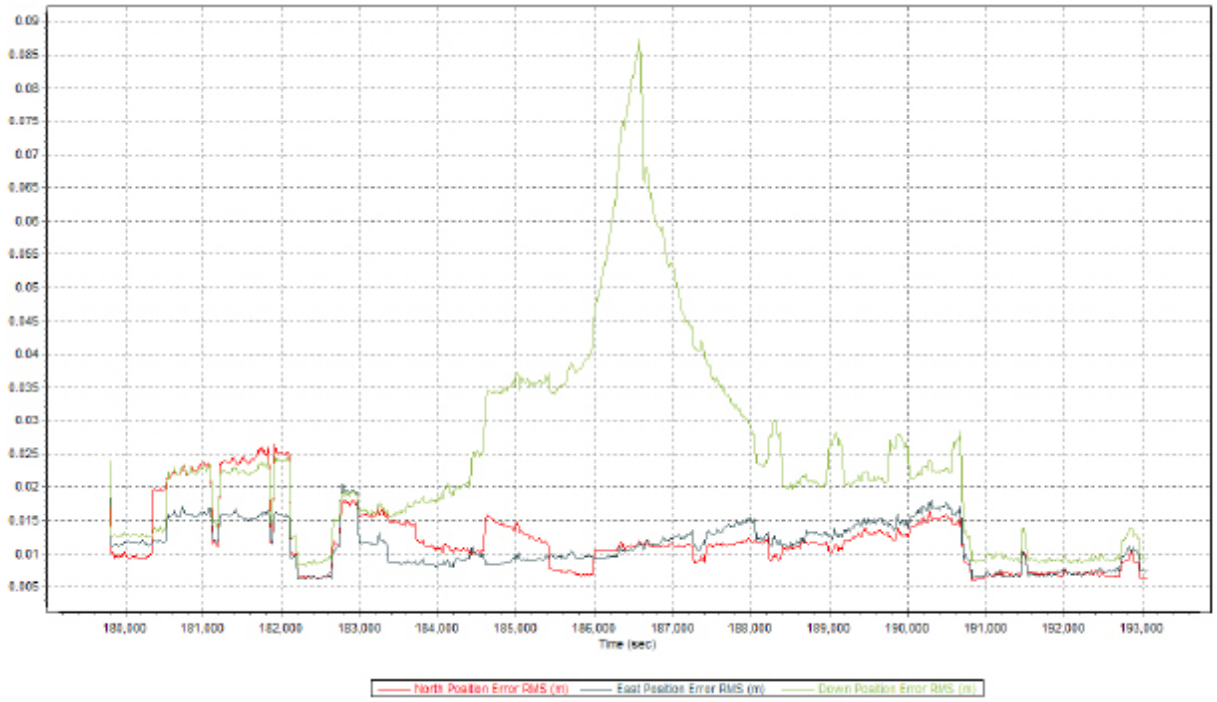


Figure A-8.37 Smoothed Performance Metric Parameters

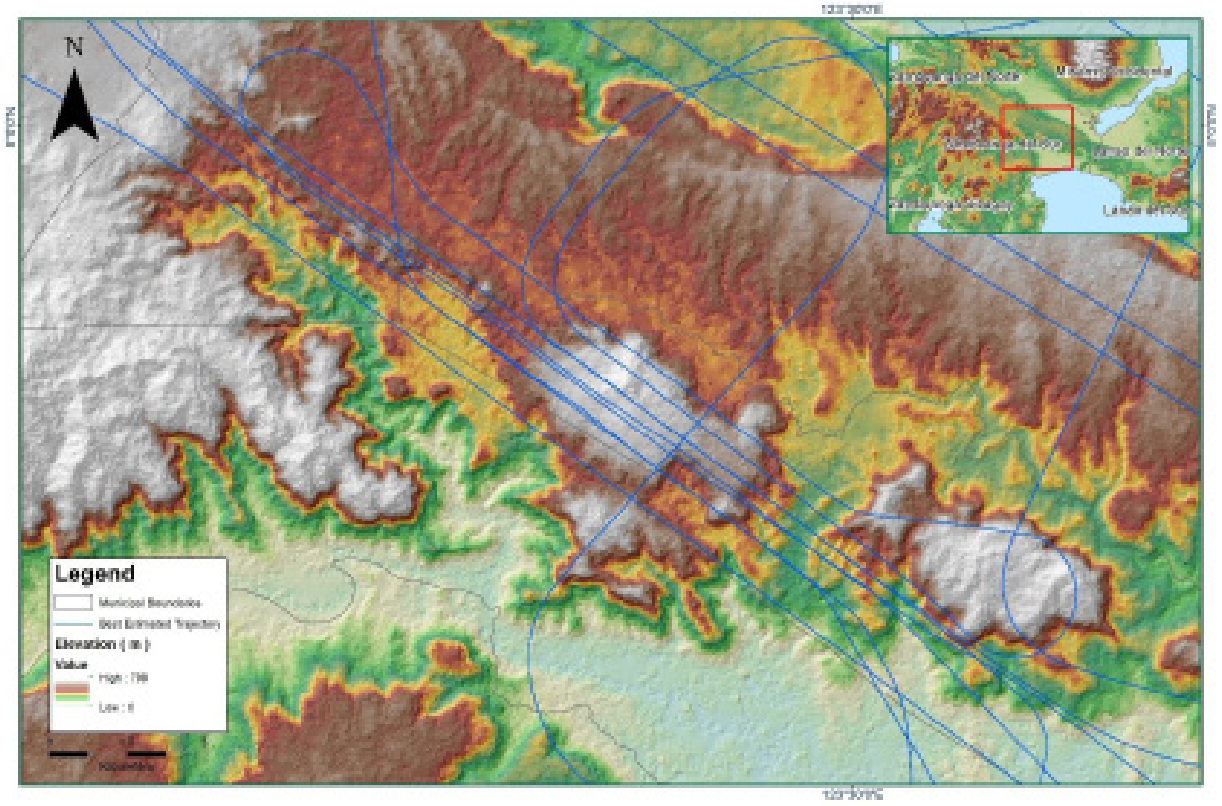


Figure A-8.38. Best Estimated Trajectory

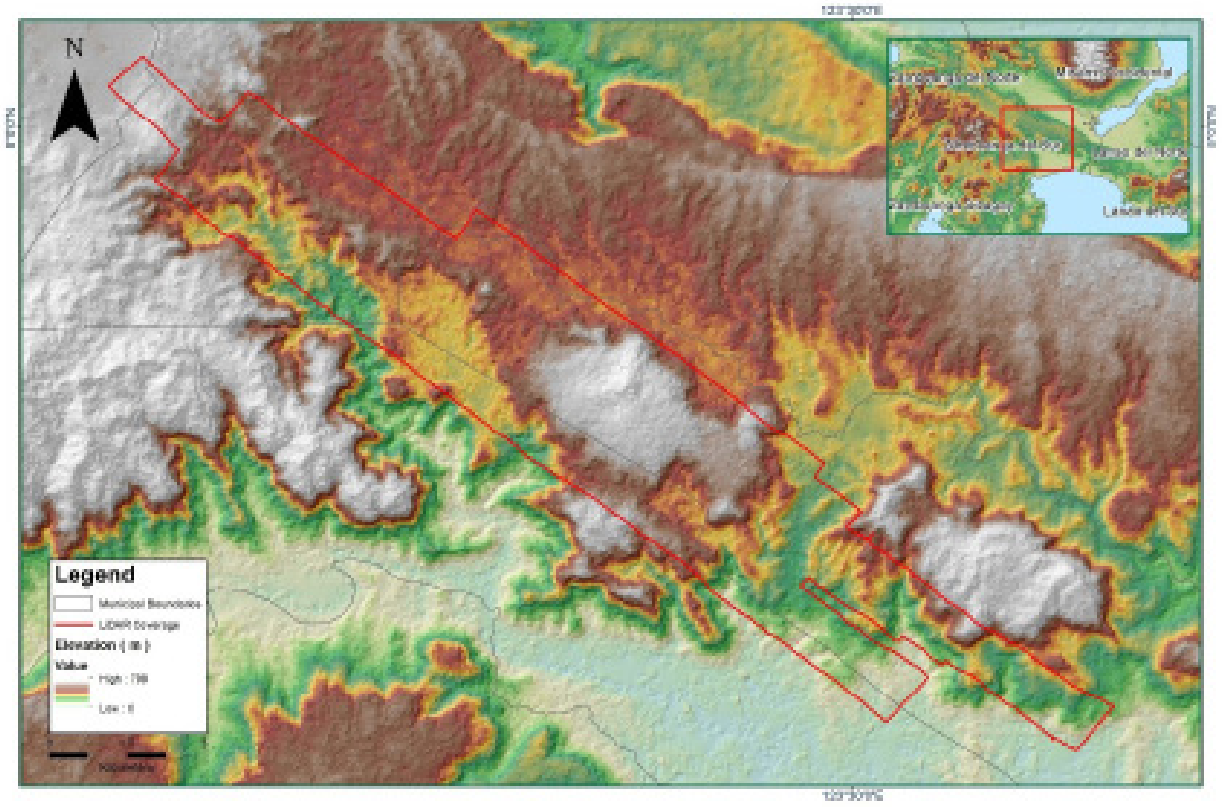


Figure A-8.39. Coverage of LiDAR Data

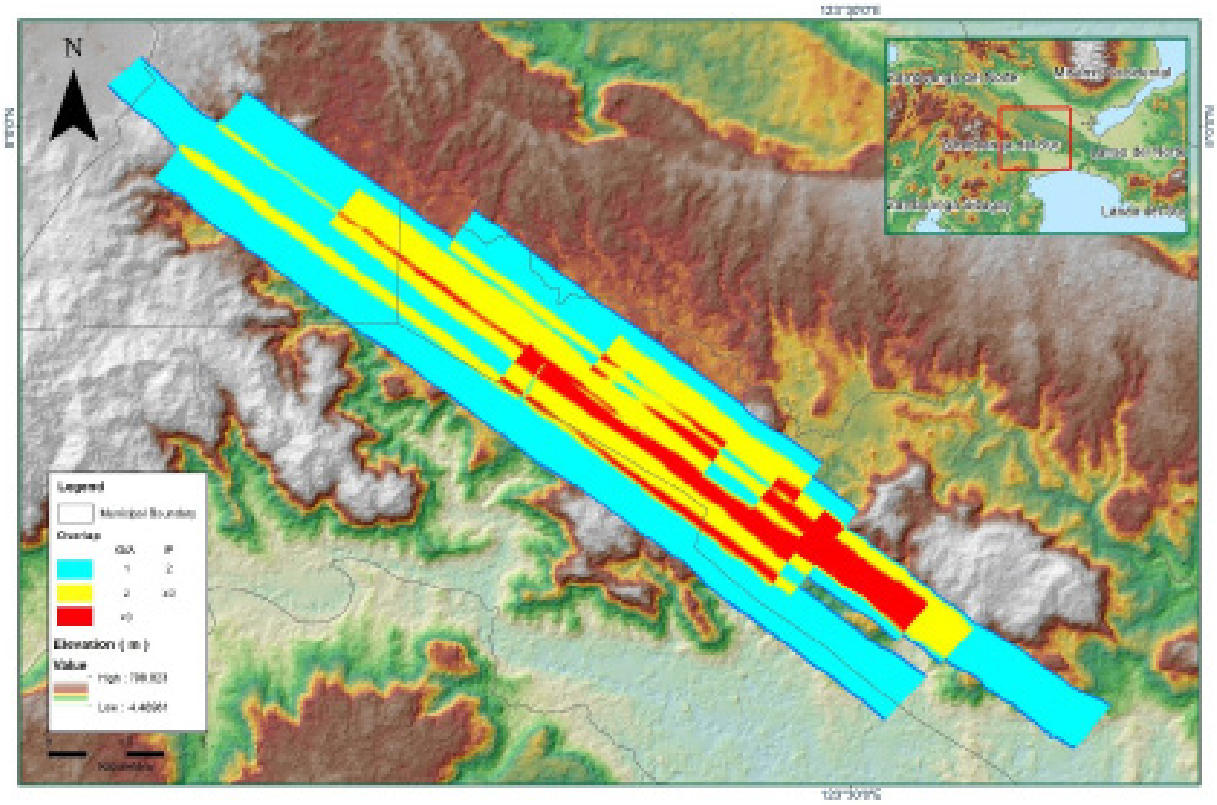


Figure A-8.40. Image of data overlap

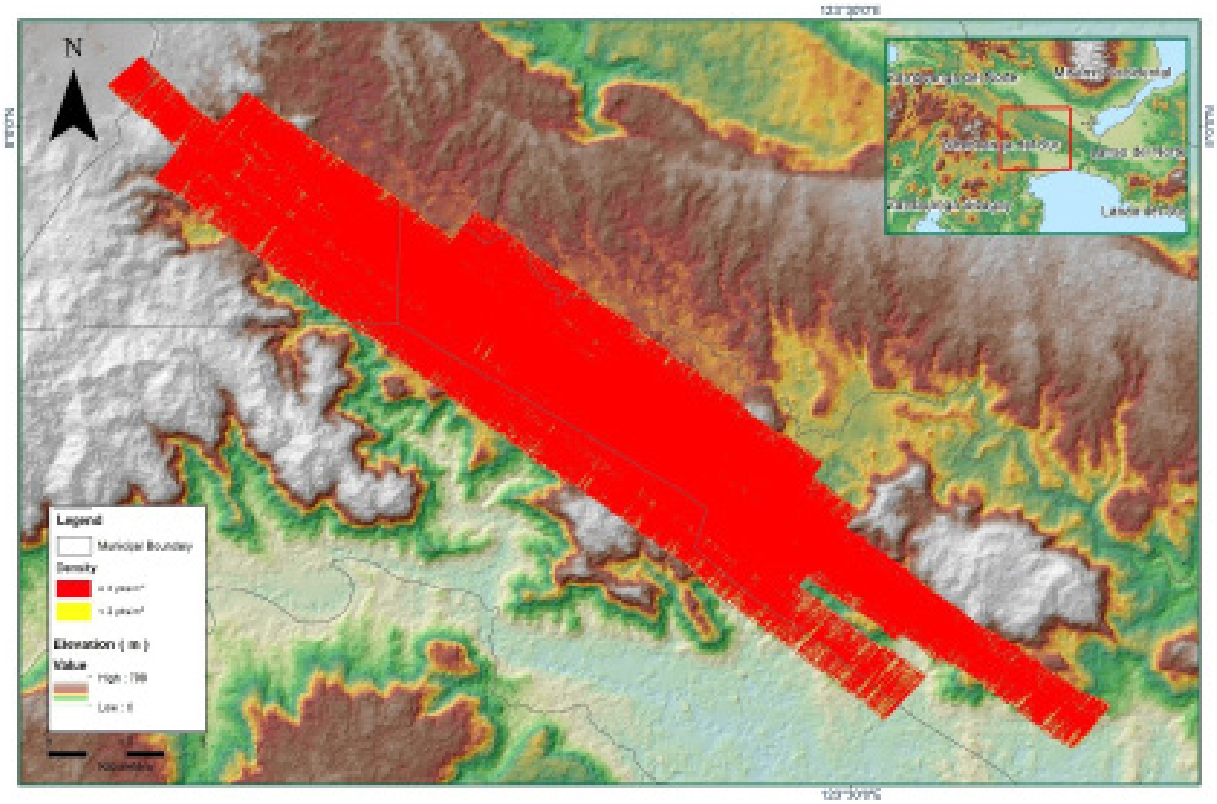


Figure A-8.41. Density map of merged LiDAR data

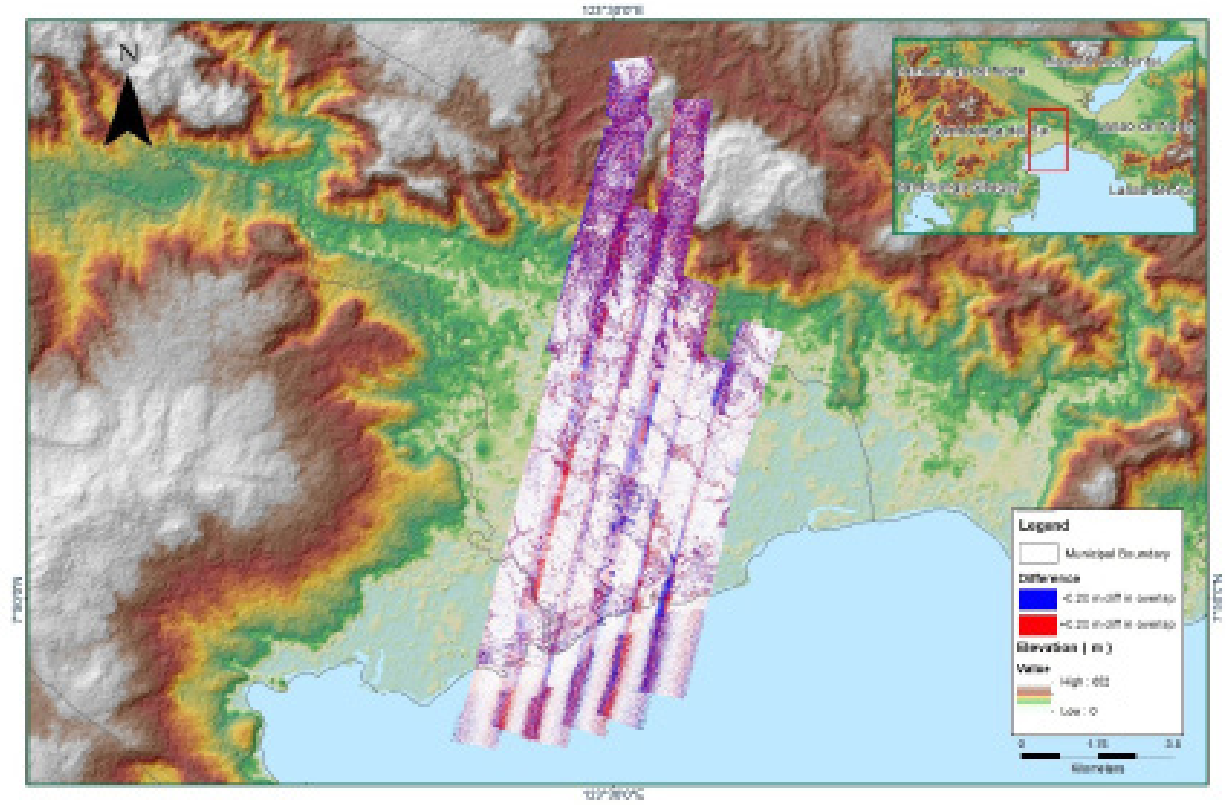


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission 76H

Flight Area	Pagadian
Mission Name	76H
Inclusive Flights	23074P, 23076P, 23092P
Range data size	70.43
POS data size	644.46
Base data size	407.72
Image	n/a
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.3
Boresight correction stdev (<0.001deg)	0.000219
IMU attitude correction stdev (<0.001deg)	0.001811
GPS position stdev (<0.01m)	0.0071
Minimum % overlap (>25)	50.05
Ave point cloud density per sq.m. (>2.0)	4.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	271
Maximum Height	580.66 m
Minimum Height	58.09 m
Classification (# of points)	
Ground	235817232
Low vegetation	217,878,270
Medium vegetation	289,709,415
High vegetation	584,076,541
Building	10,163,570
Orthophoto	Yes

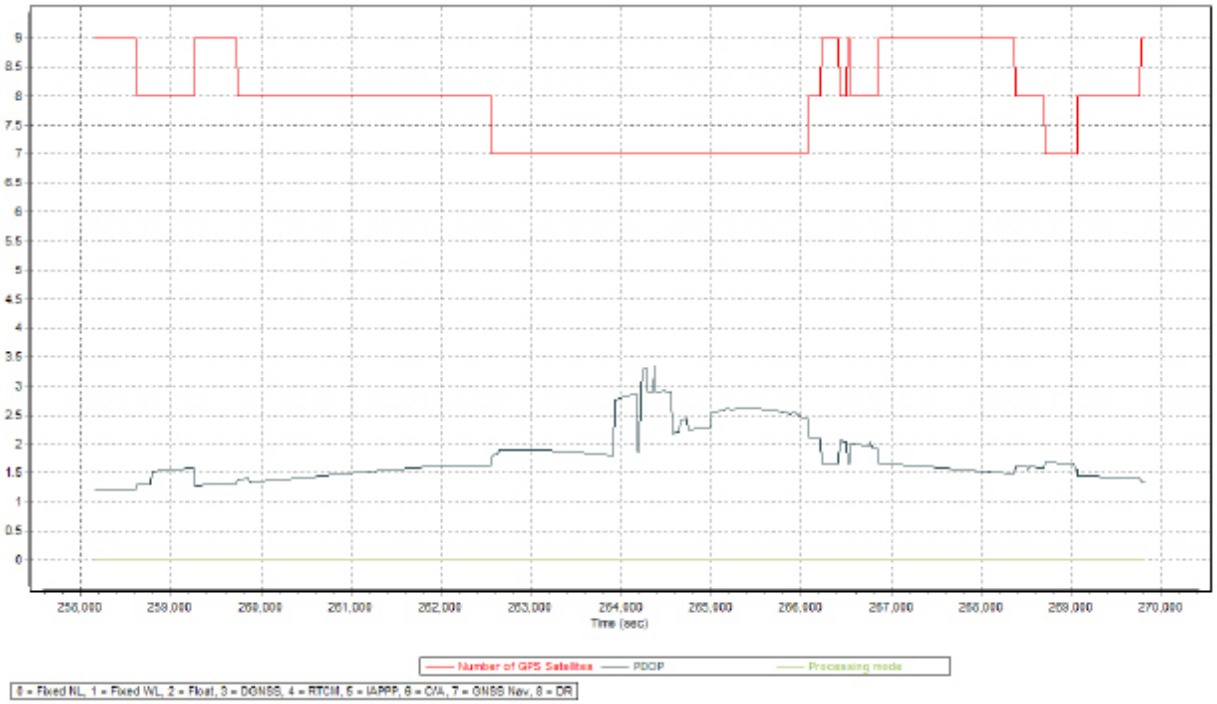


Figure A-8.43. Solution Status

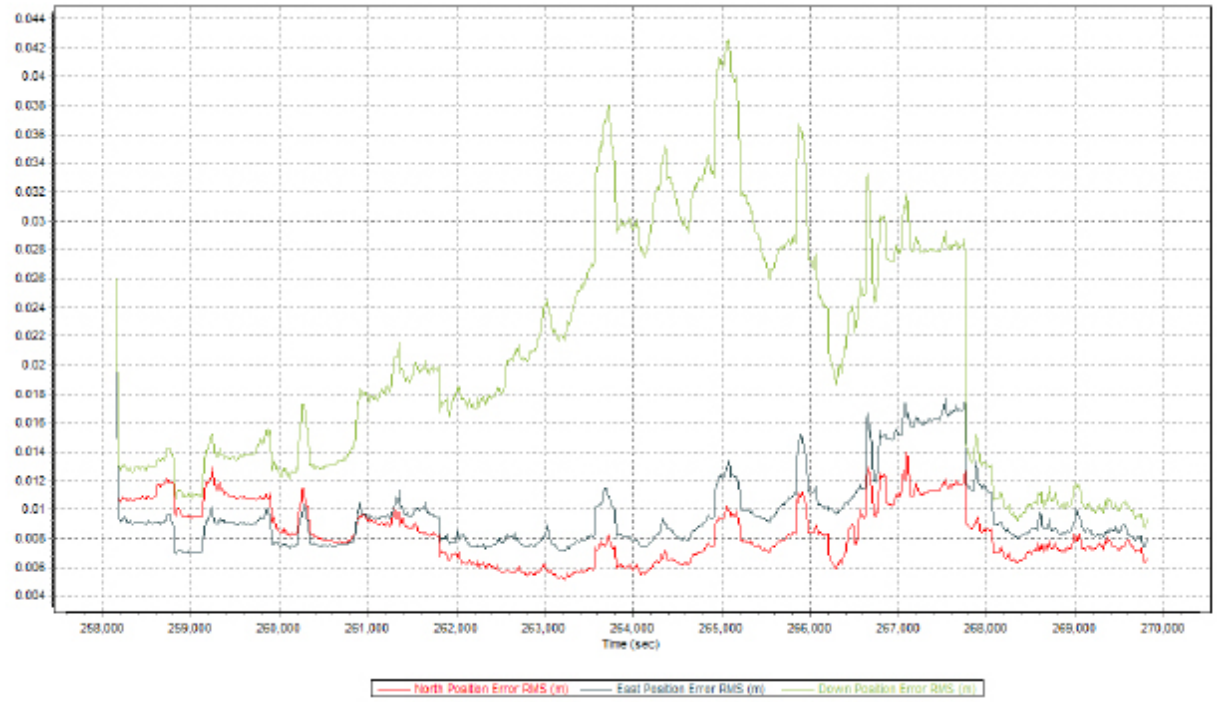


Figure A-8.44 Smoothed Performance Metric Parameters

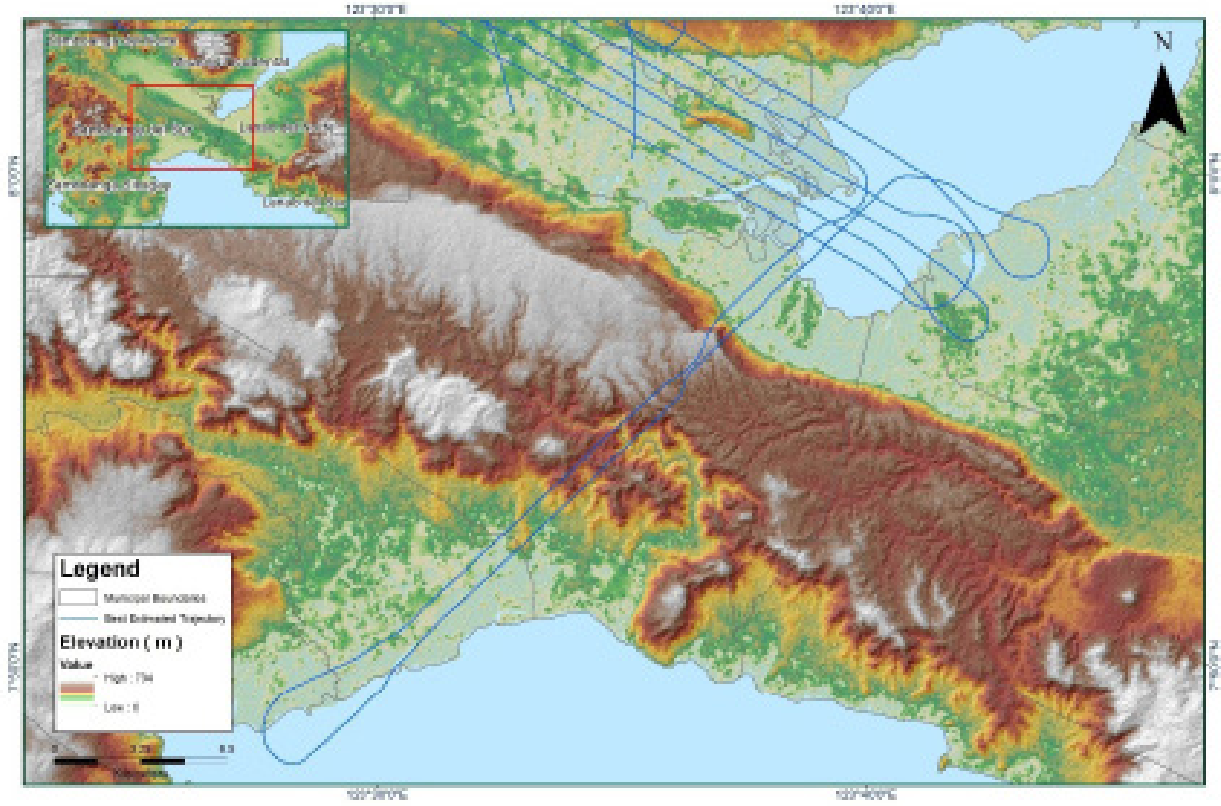


Figure A-8.45. Best Estimated Trajectory

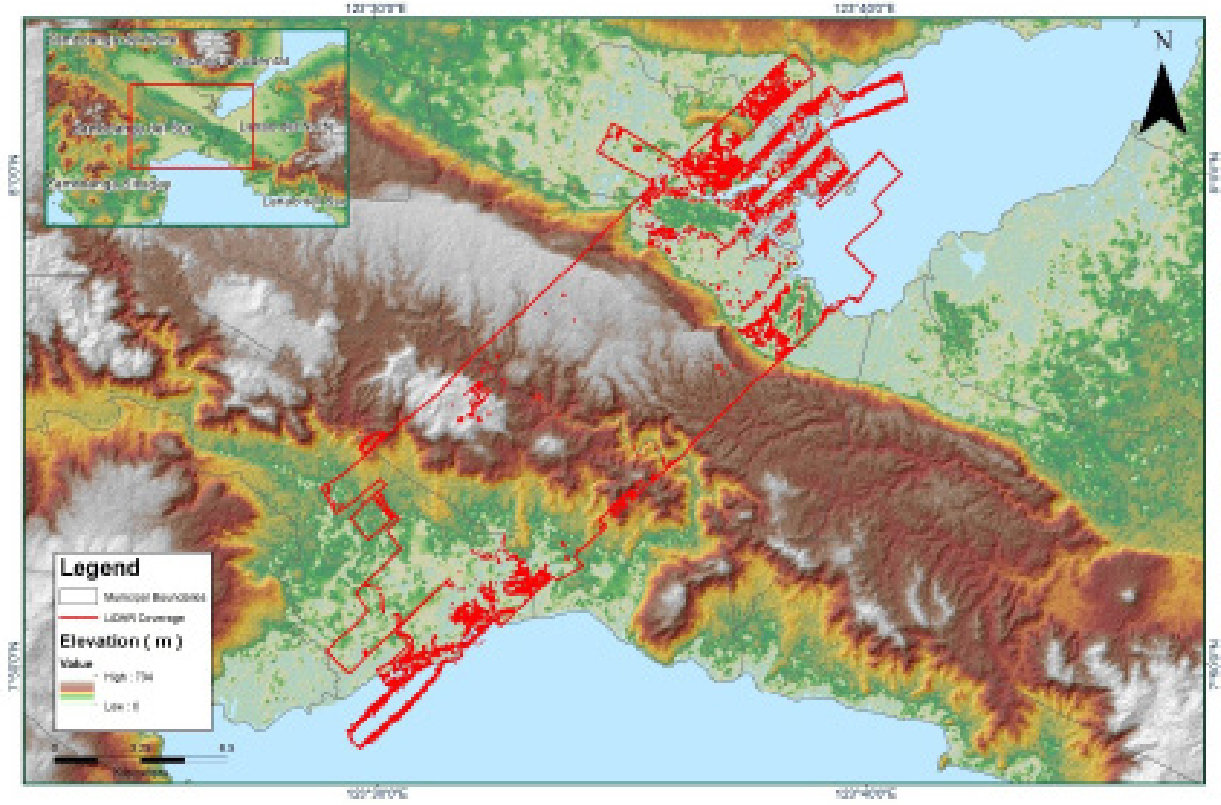


Figure A-8.46. Coverage of LiDAR Data

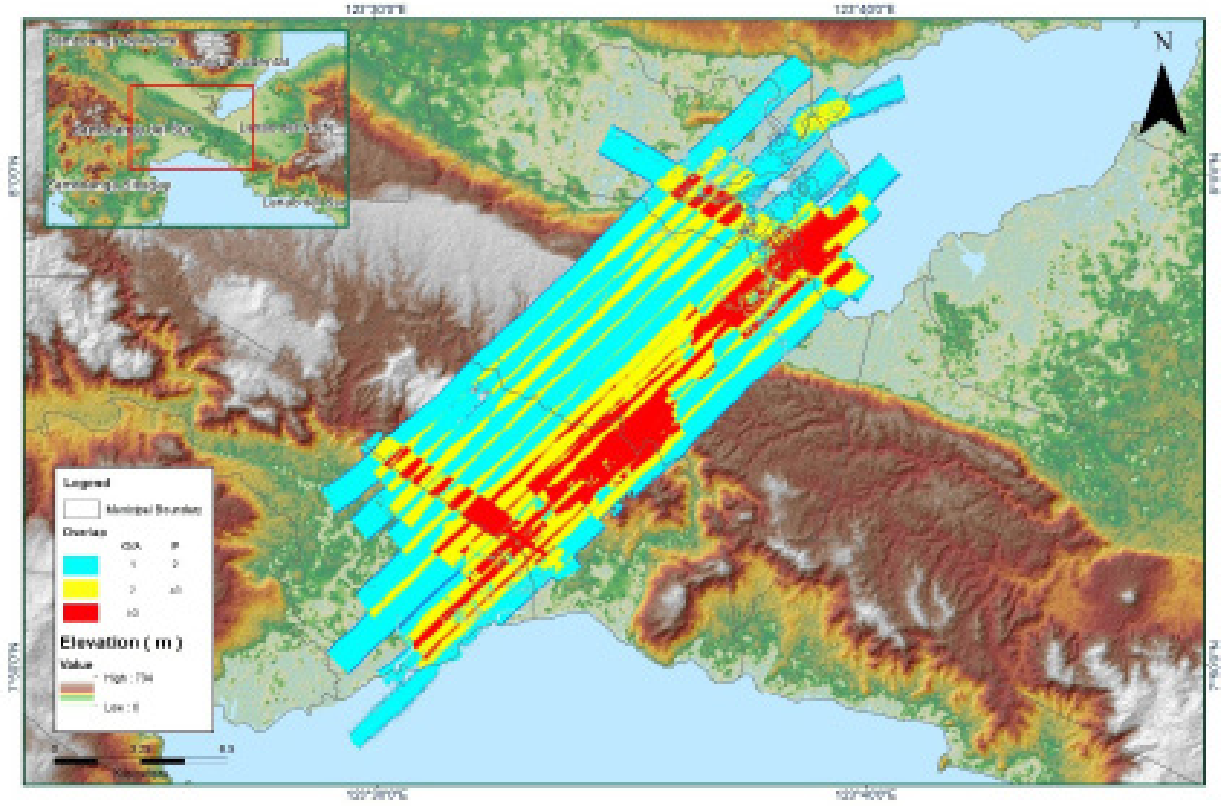


Figure A-8.47. Image of data overlap

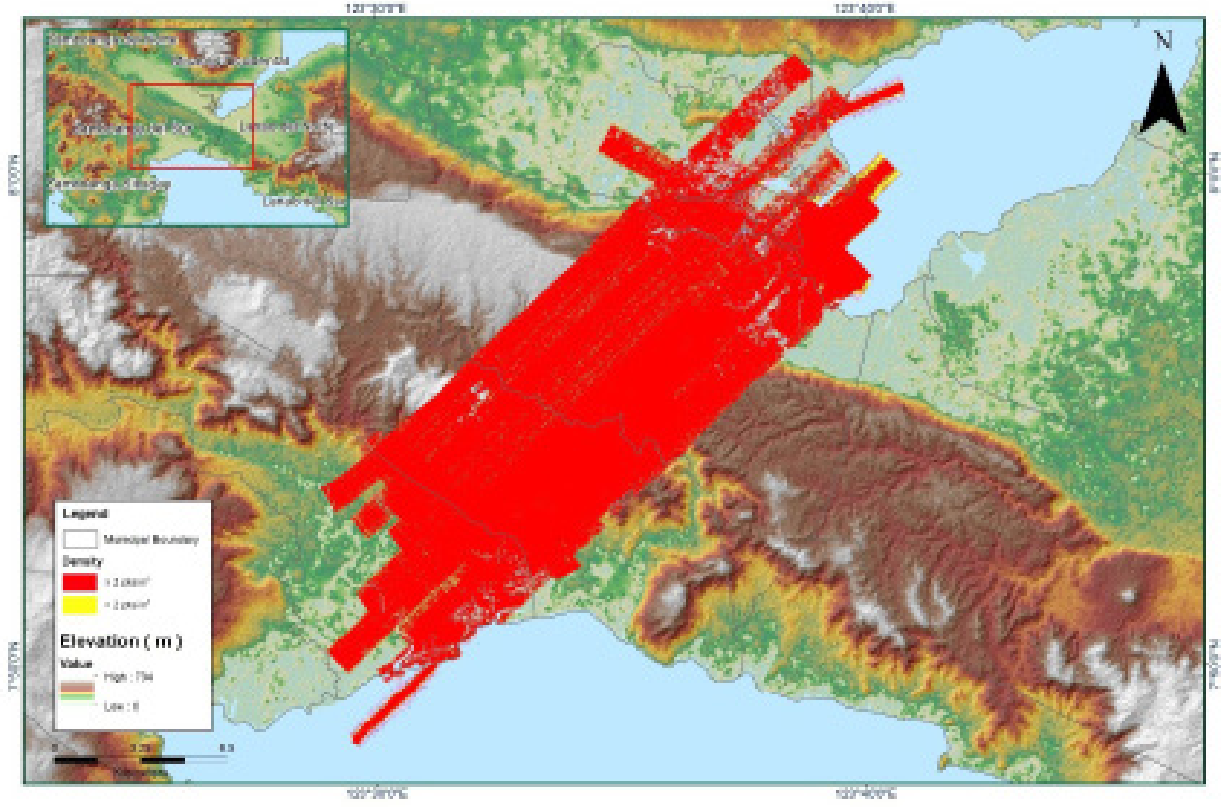


Figure A-8.48. Density map of merged LiDAR data

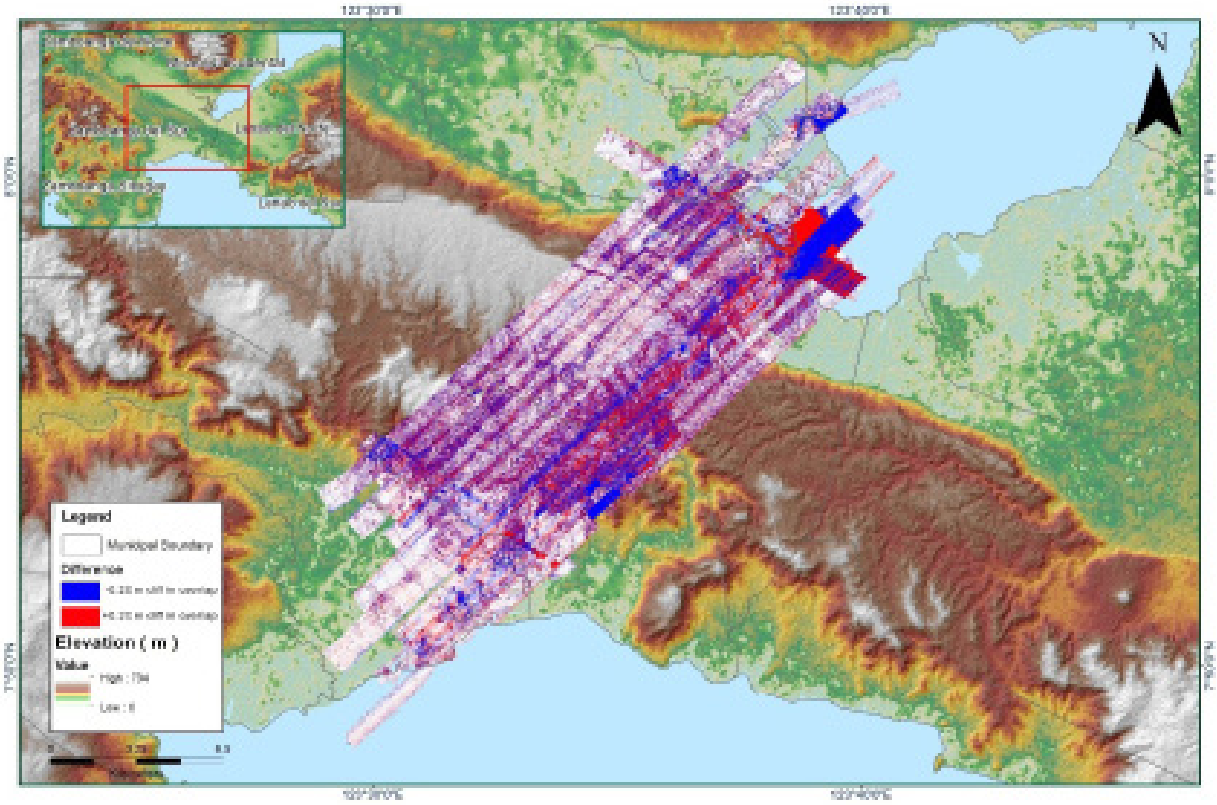


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission 76H_Supplement

Flight Area	Pagadian
Mission Name	76H_Supplement
Inclusive Flights	23128P
Range data size	23.3
POS data size	273
Base data size	44.4
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)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.000228
IMU attitude correction stdev (<0.001deg)	0.004166
GPS position stdev (<0.01m)	0.0190
Minimum % overlap (>25)	34.41
Ave point cloud density per sq.m. (>2.0)	4.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	177
Maximum Height	580.95 m
Minimum Height	56.45 m
Classification (# of points)	
Ground	213,072,476
Low vegetation	126,750,007
Medium vegetation	187,589,150
High vegetation	482,035,989
Building	2,958,653
Orthophoto	No

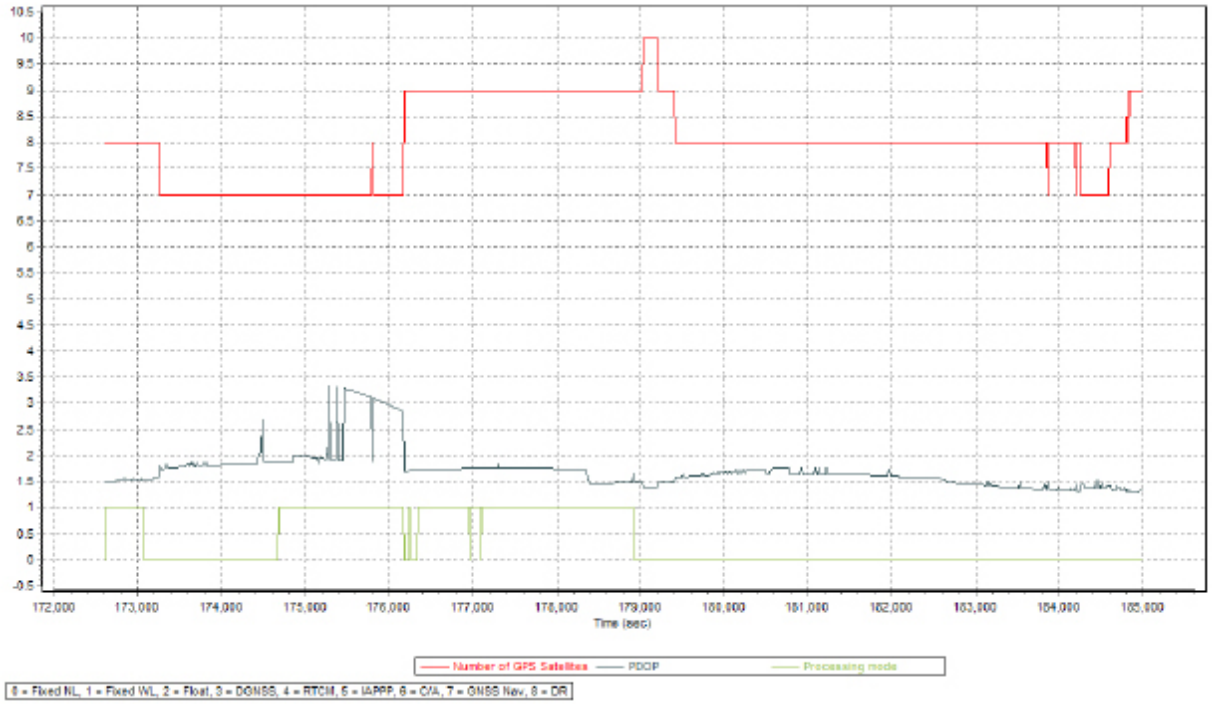


Figure A-8.50. Solution Status

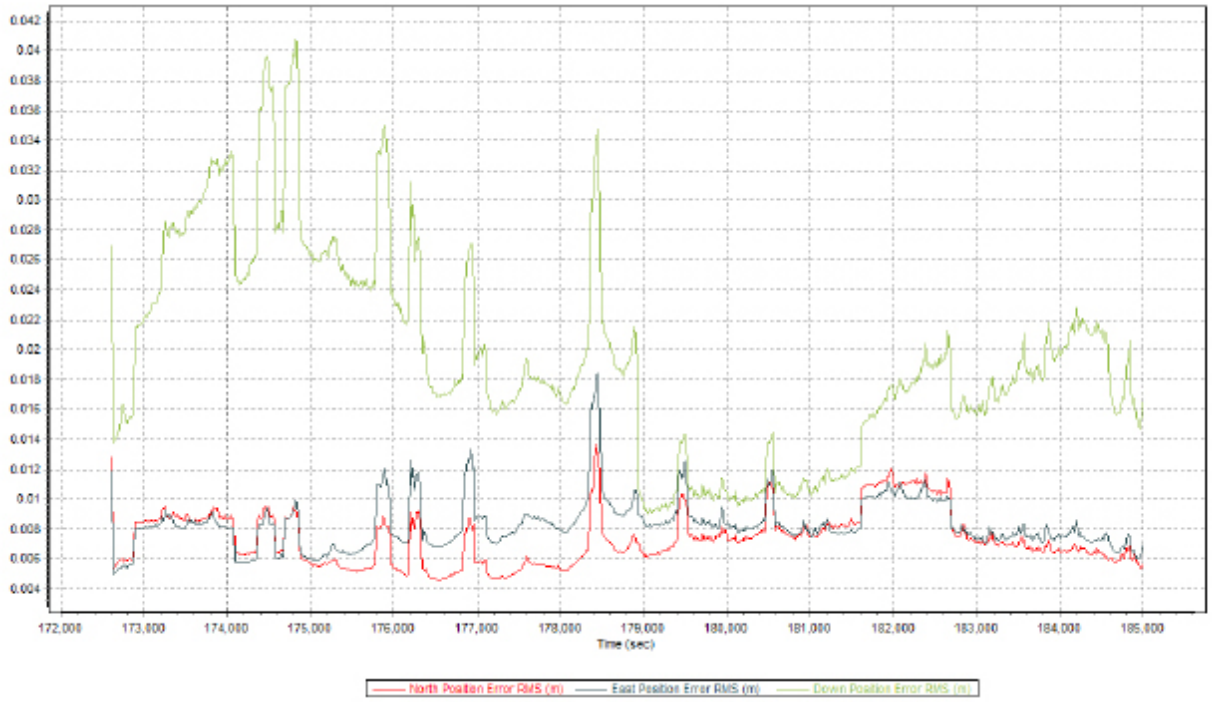


Figure A-8.51 Smoothed Performance Metric Parameters

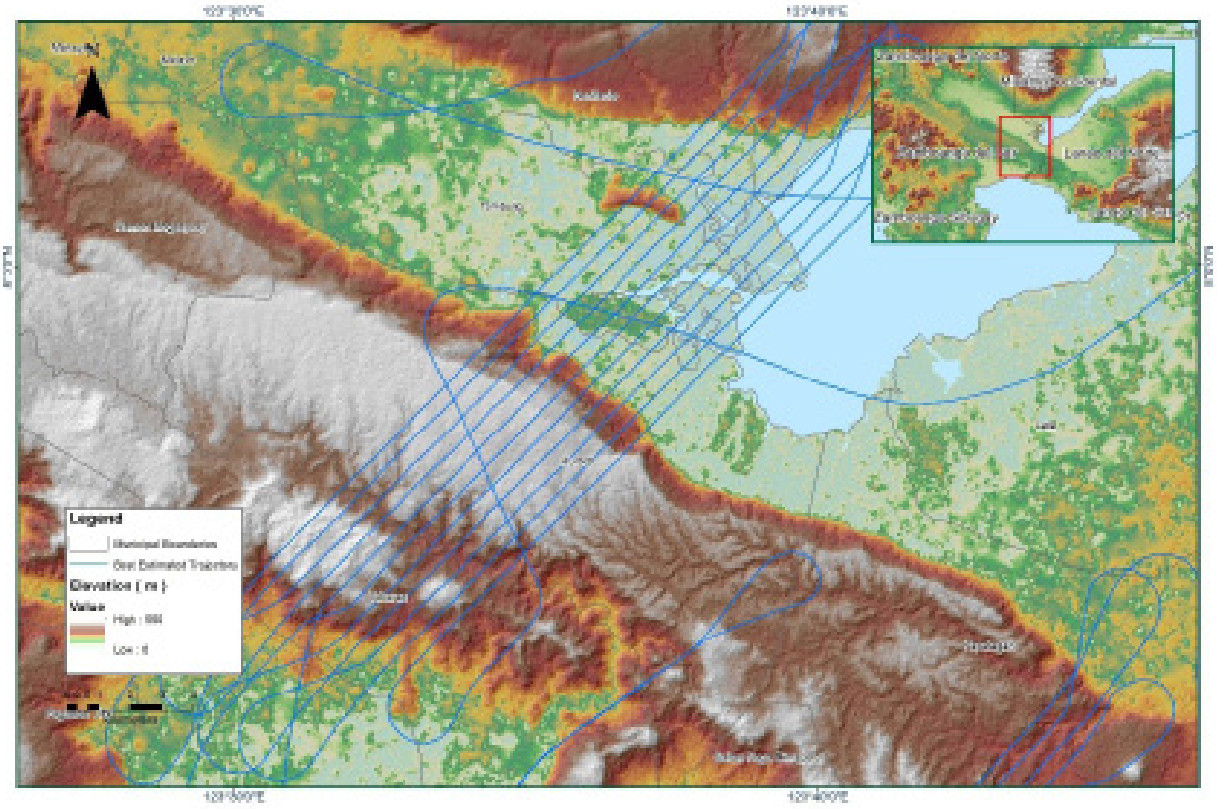


Figure A-8.52. Best Estimated Trajectory

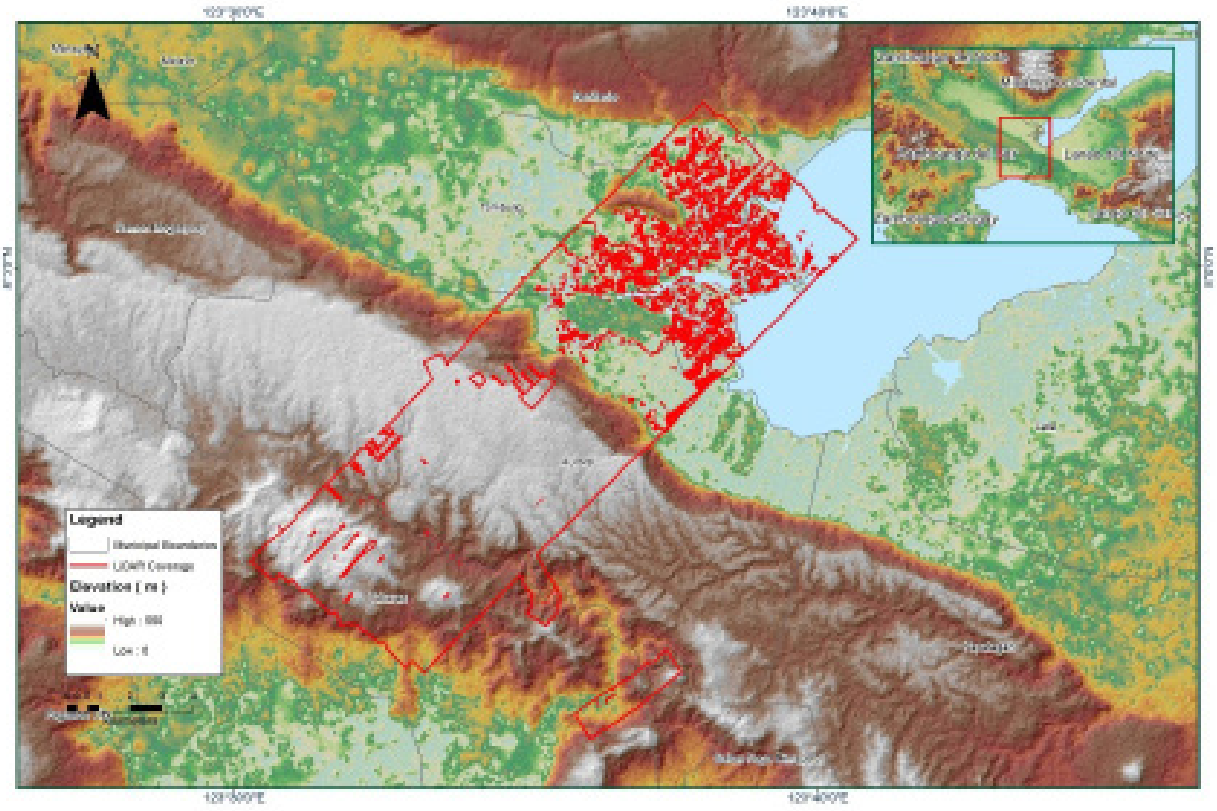


Figure A-8.53. Coverage of LiDAR Data

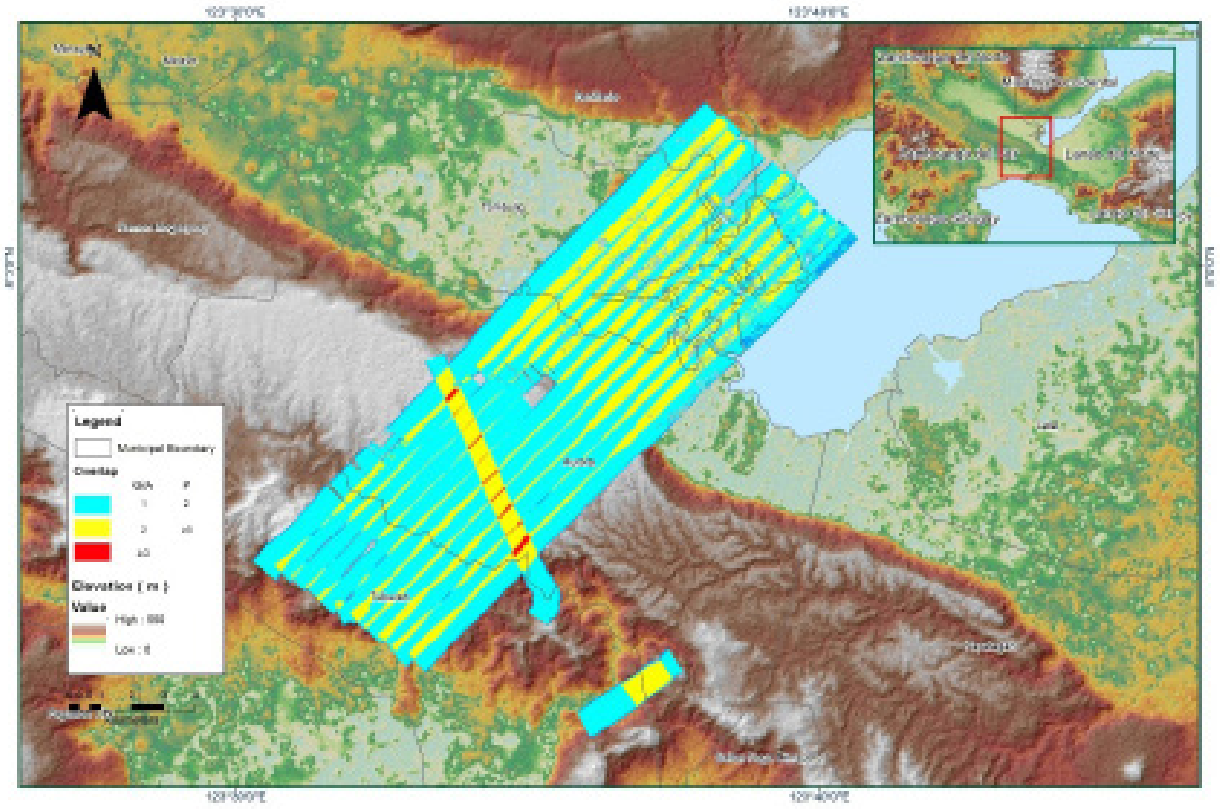


Figure A-8.54. Image of data overlap

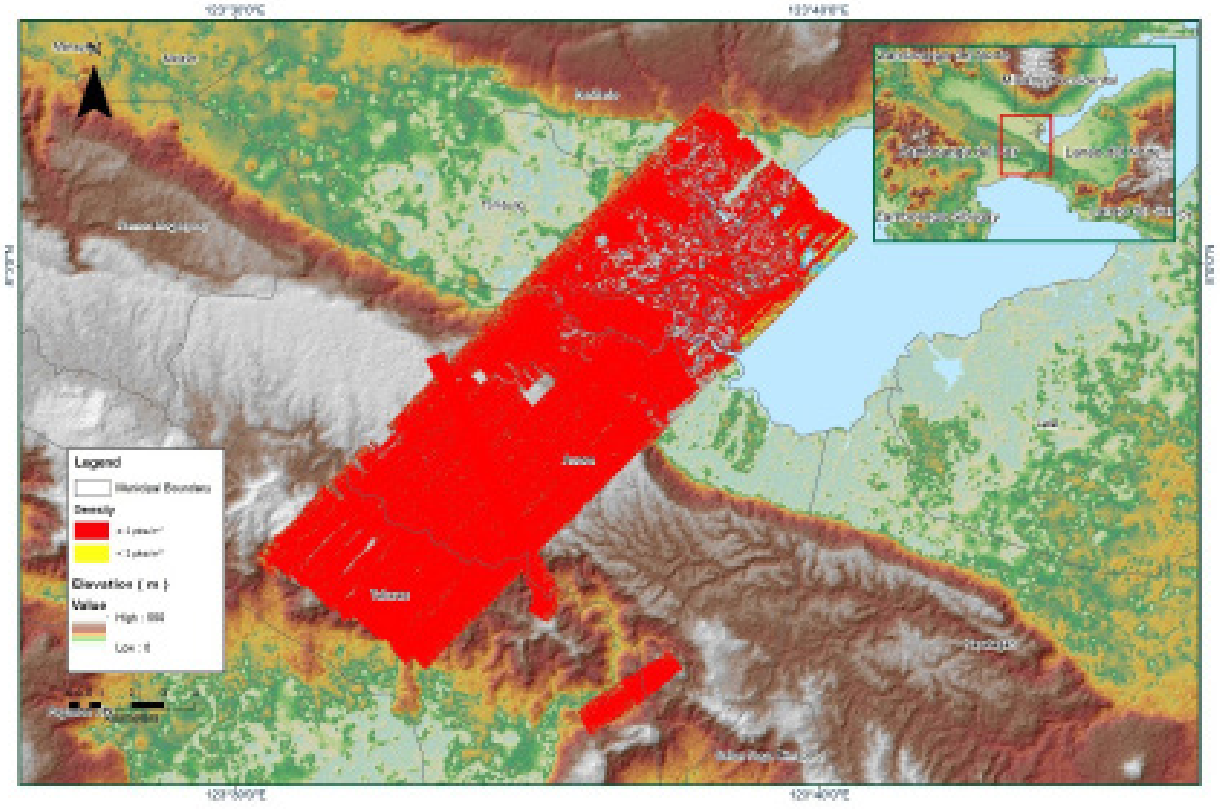


Figure A-8.55. Density map of merged LiDAR data

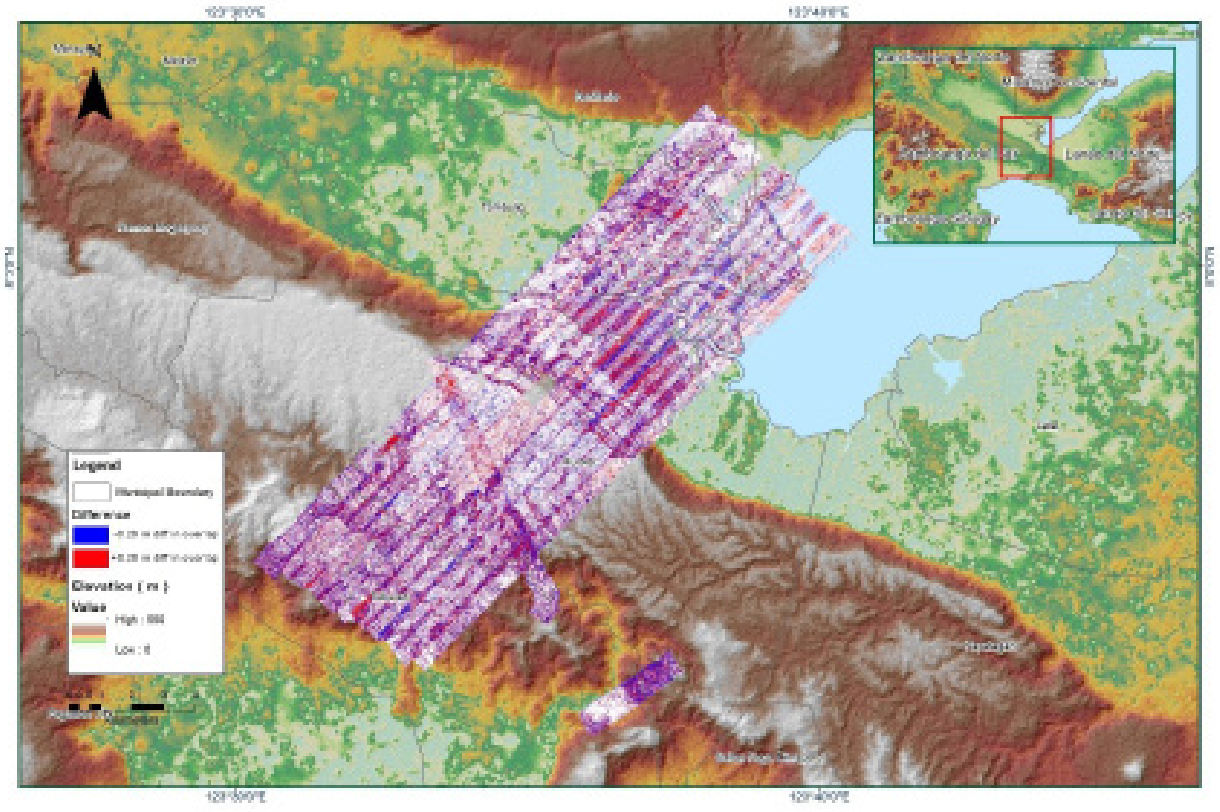


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission 76K

Flight Area	Pagadian
Mission Name	76K
Inclusive Flights	23084P
Range data size	29.36
POS data size	276.9
Base data size	129.73
Image	n/a
Transfer date	March 01, 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)	1.3
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.7
Boresight correction stdev (<0.001deg)	0.000134
IMU attitude correction stdev (<0.001deg)	0.000524
GPS position stdev (<0.01m)	0.0064
Minimum % overlap (>25)	39.61
Ave point cloud density per sq.m. (>2.0)	3.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	280
Maximum Height	475.01 m
Minimum Height	62.15 m
Classification (# of points)	
Ground	263,061,671
Low vegetation	186,080,376
Medium vegetation	173,663,045
High vegetation	1,062,882,246
Building	4,176,141
Orthophoto	Yes

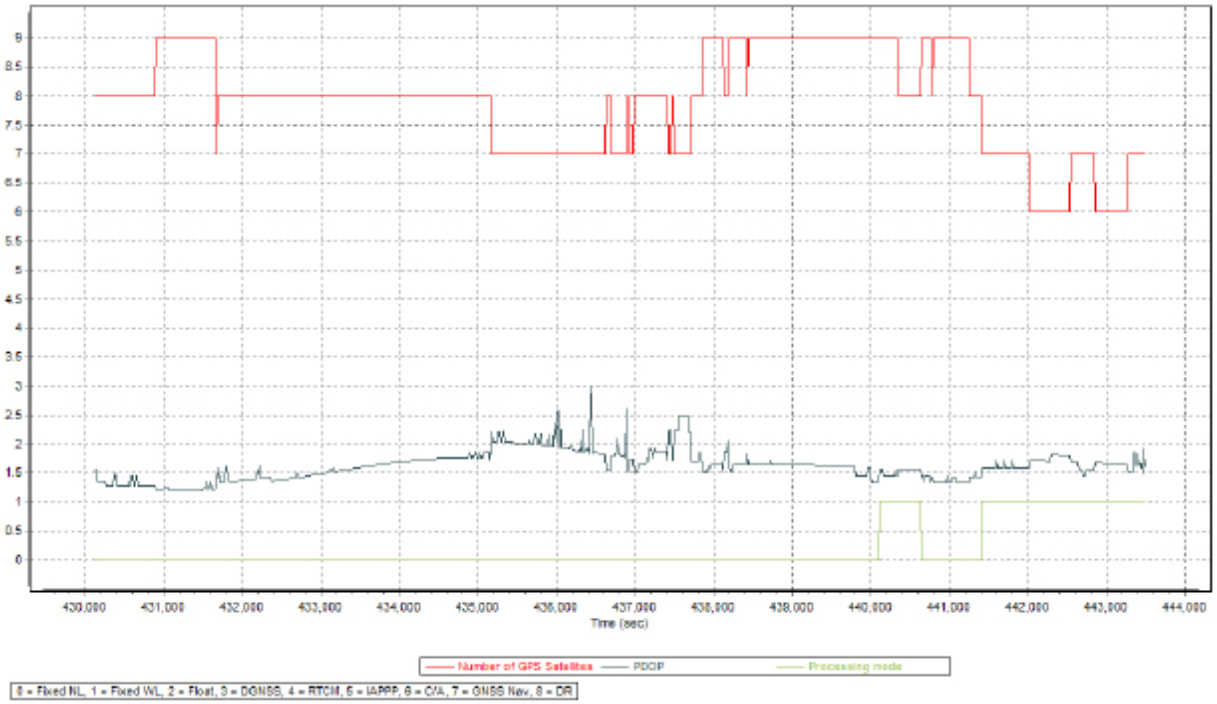


Figure A-8.57. Solution Status

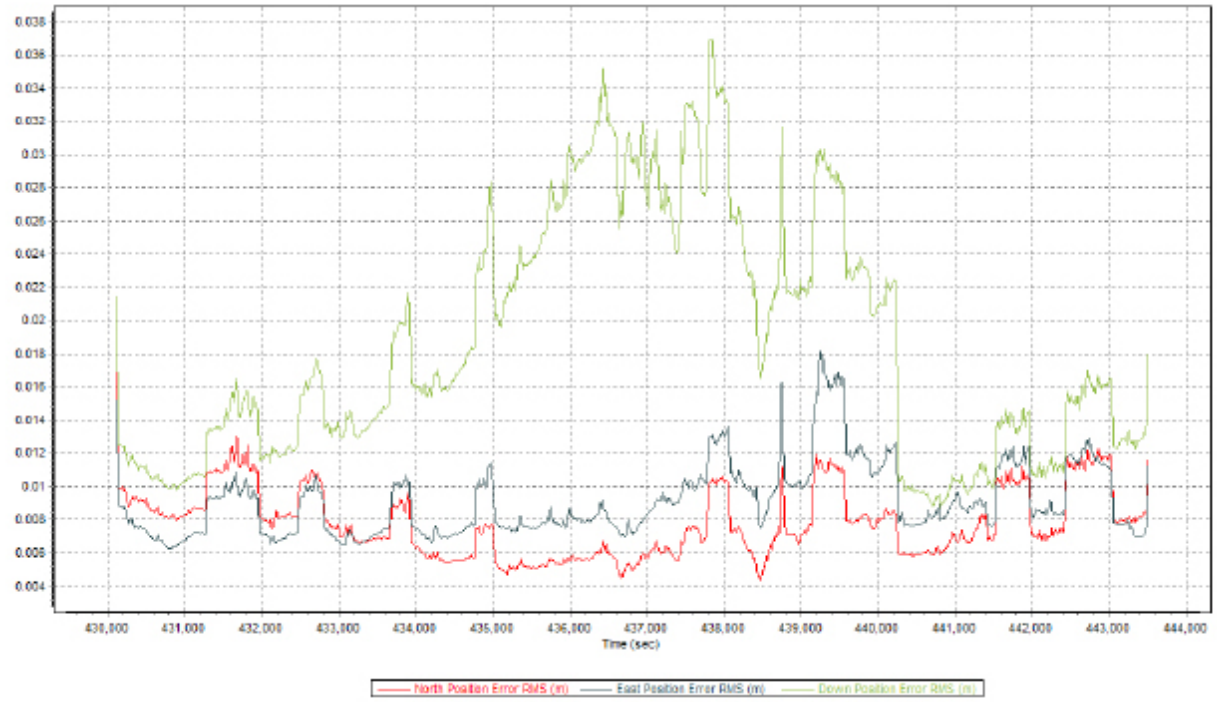


Figure A-8.58 Smoothed Performance Metric Parameters

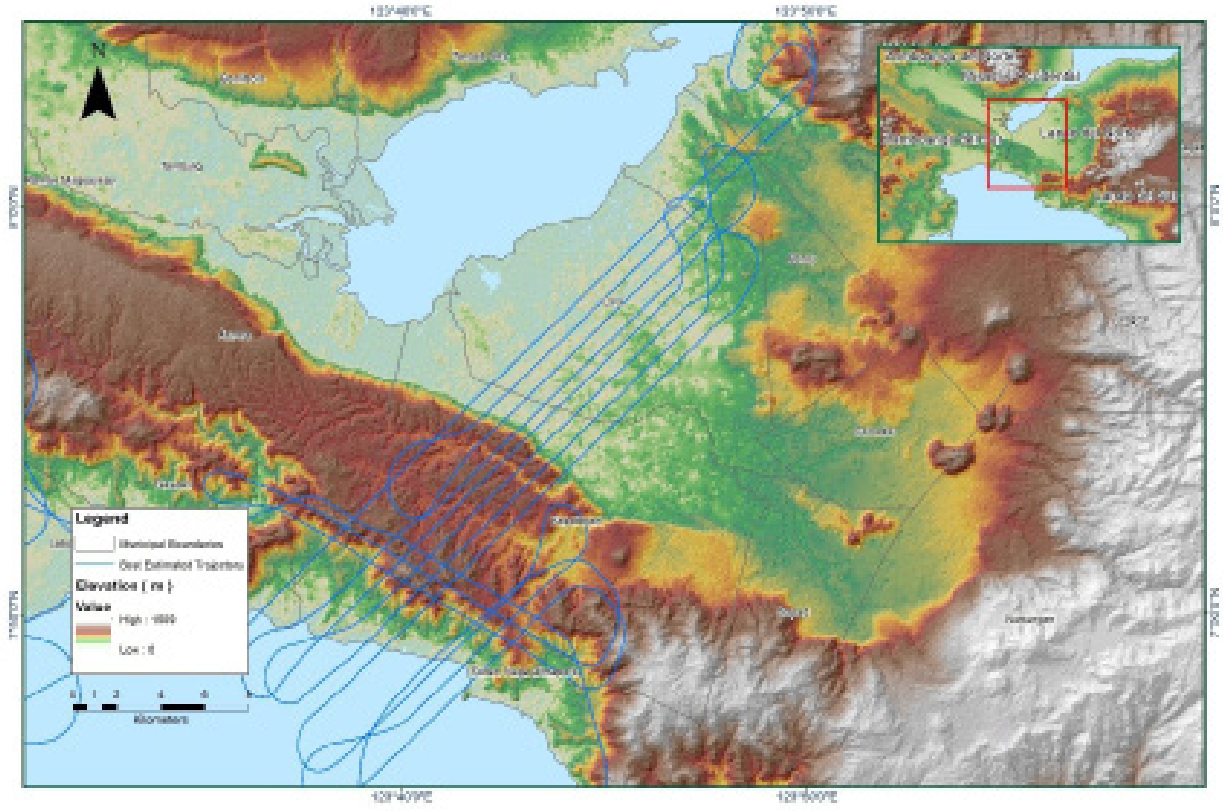


Figure A-8.59. Best Estimated Trajectory

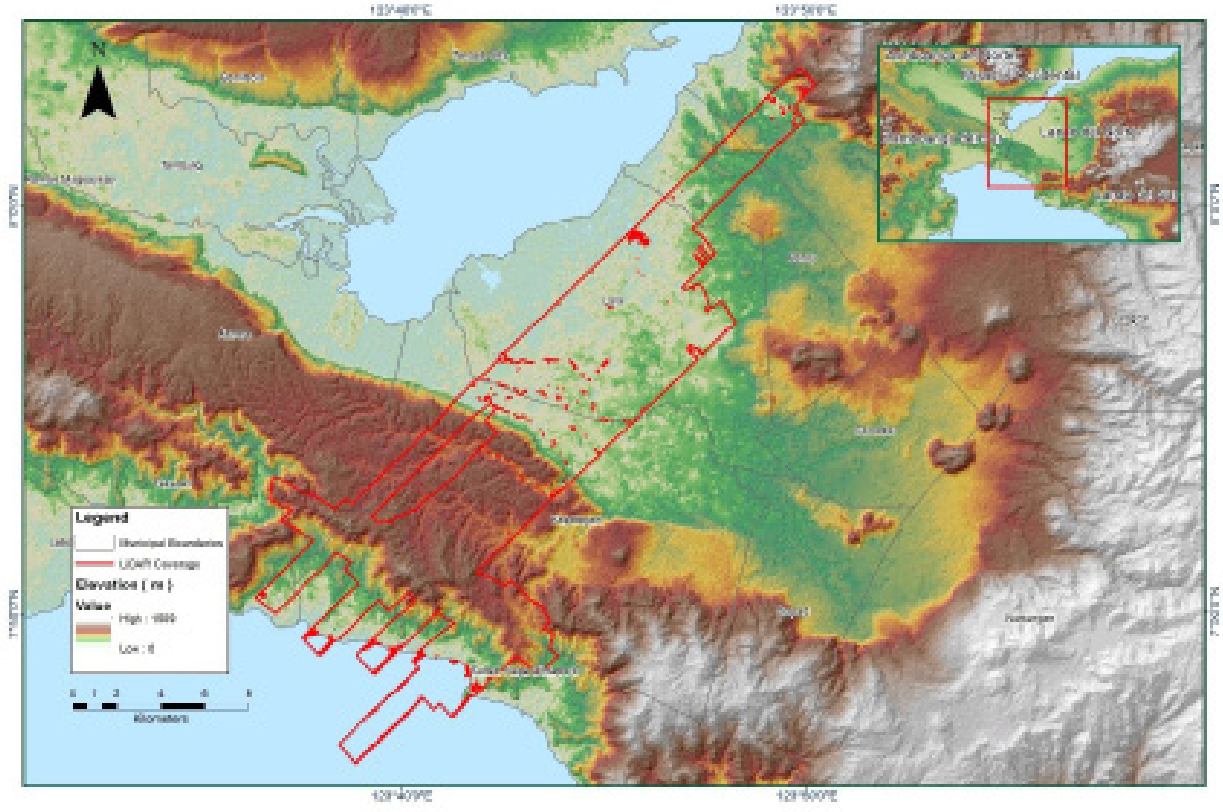


Figure A-8.60. Coverage of LiDAR Data

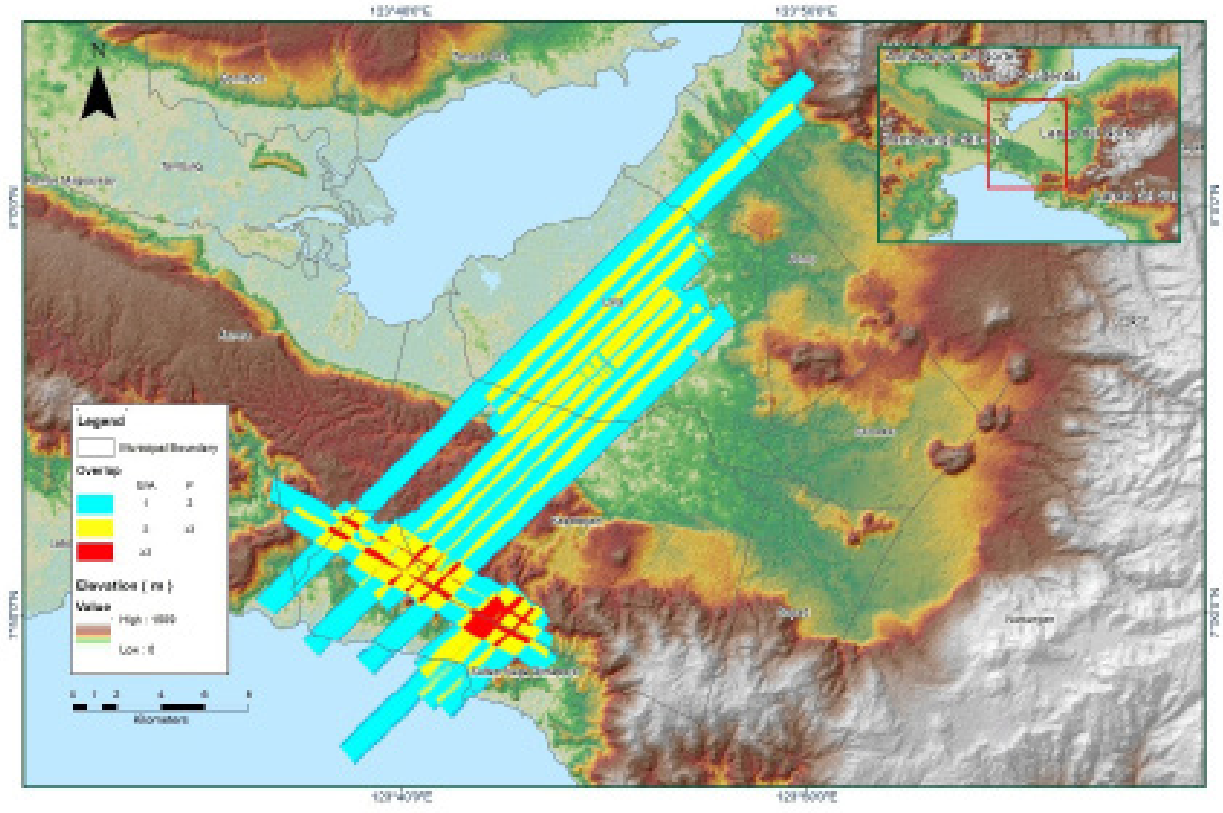


Figure A-8.61. Image of data overlap

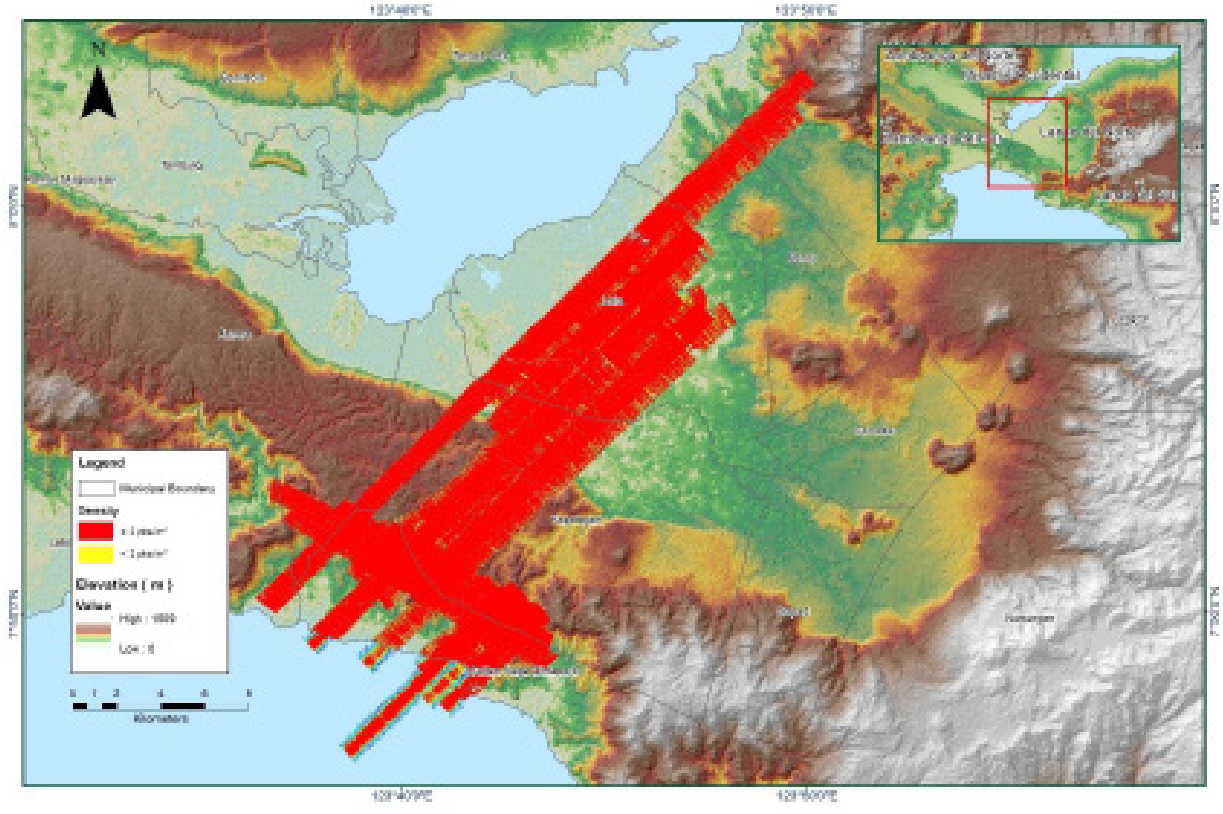


Figure A-8.62. Density map of merged LiDAR data

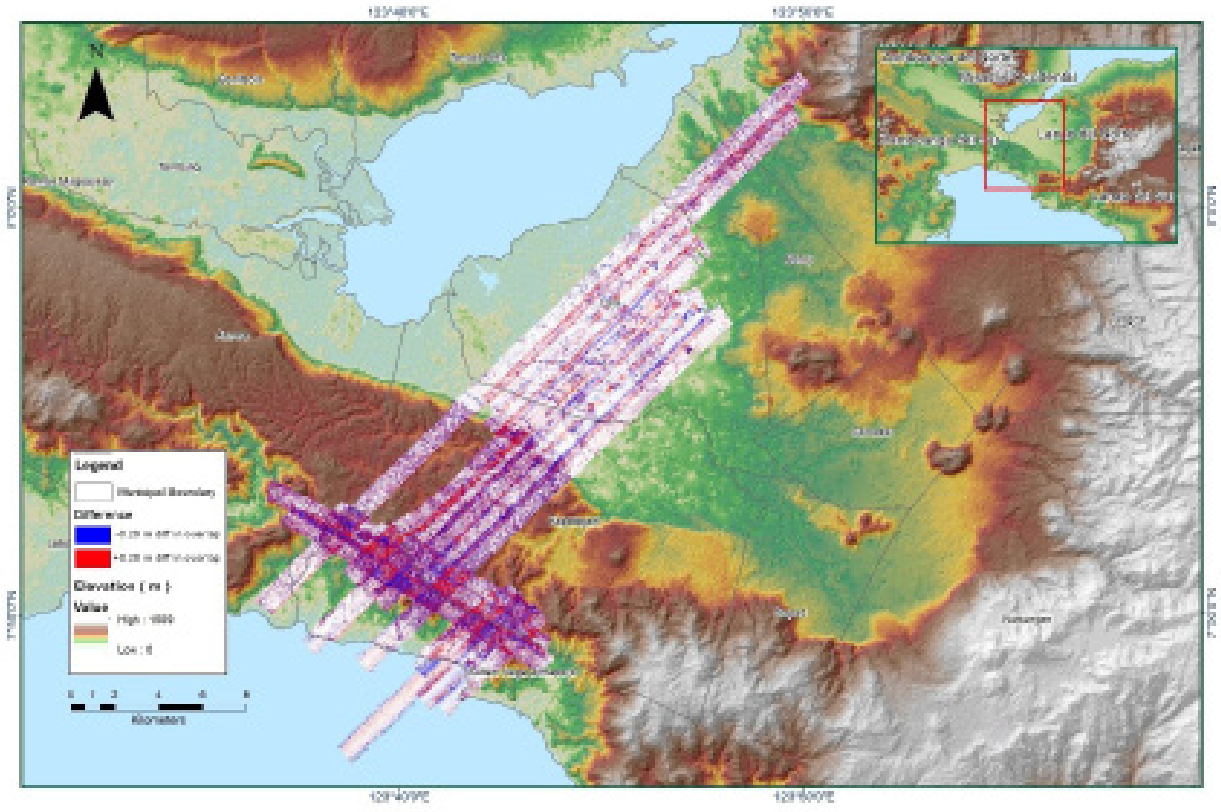


Figure A-8.63. Density map of merged LiDAR data

Table A-8.10. Mission Summary Report for Mission 76T

Flight Area	Pagadian
Mission Name	76D
Inclusive Flights	23078P
Range data size	13
POS data size	159
Base data size	152
Image	n/a
Transfer date	February 26, 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)	1.2
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	1.9
Boresight correction stdev (<0.001deg)	0.000185
IMU attitude correction stdev (<0.001deg)	0.000385
GPS position stdev (<0.01m)	0.0072
Minimum % overlap (>25)	35.06
Ave point cloud density per sq.m. (>2.0)	3.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	114
Maximum Height	448.34 m
Minimum Height	61.60 m
Classification (# of points)	
Ground	140,516,600
Low vegetation	65,433,235
Medium vegetation	67,241,339
High vegetation	169,635,078
Building	13,109,070
Orthophoto	Yes

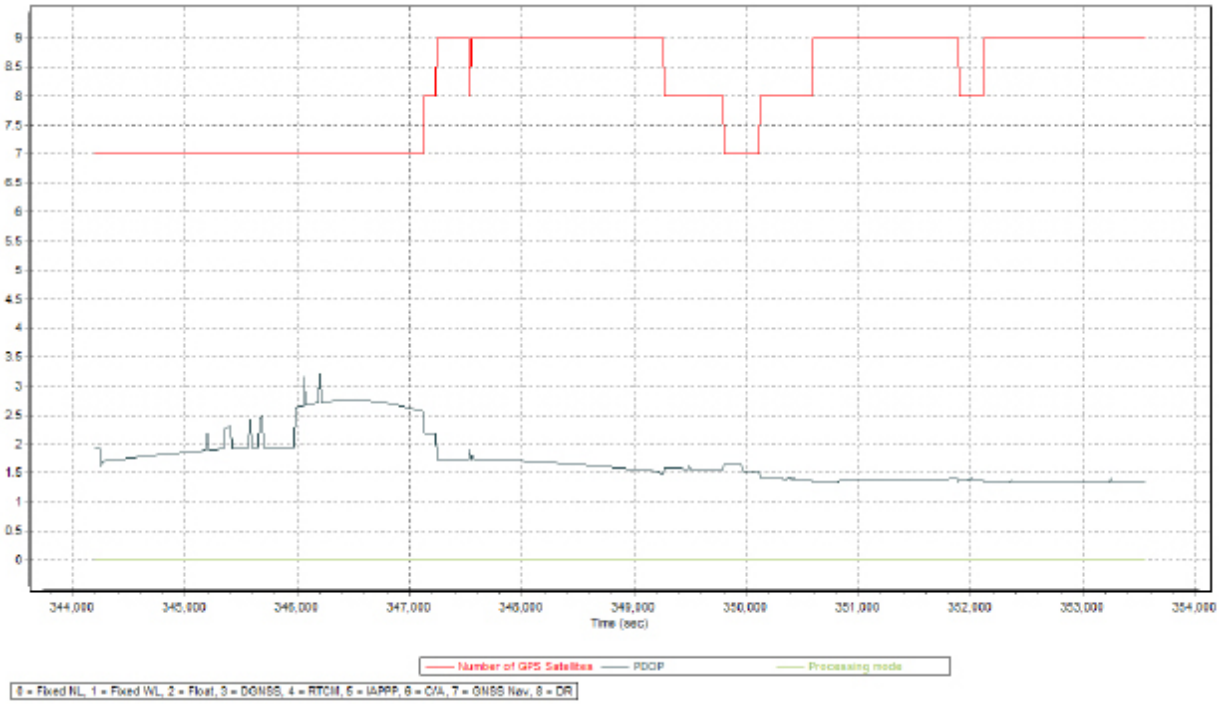


Figure A-8.64. Solution Status

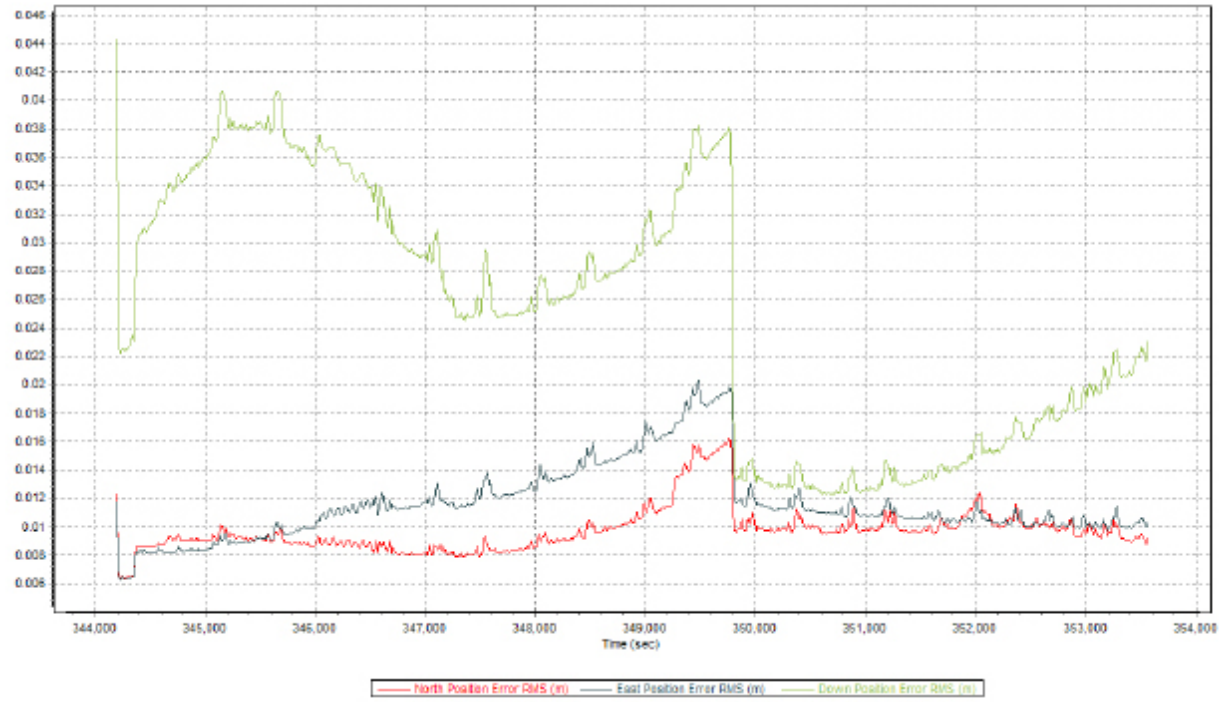


Figure A-8.65 Smoothed Performance Metric Parameters

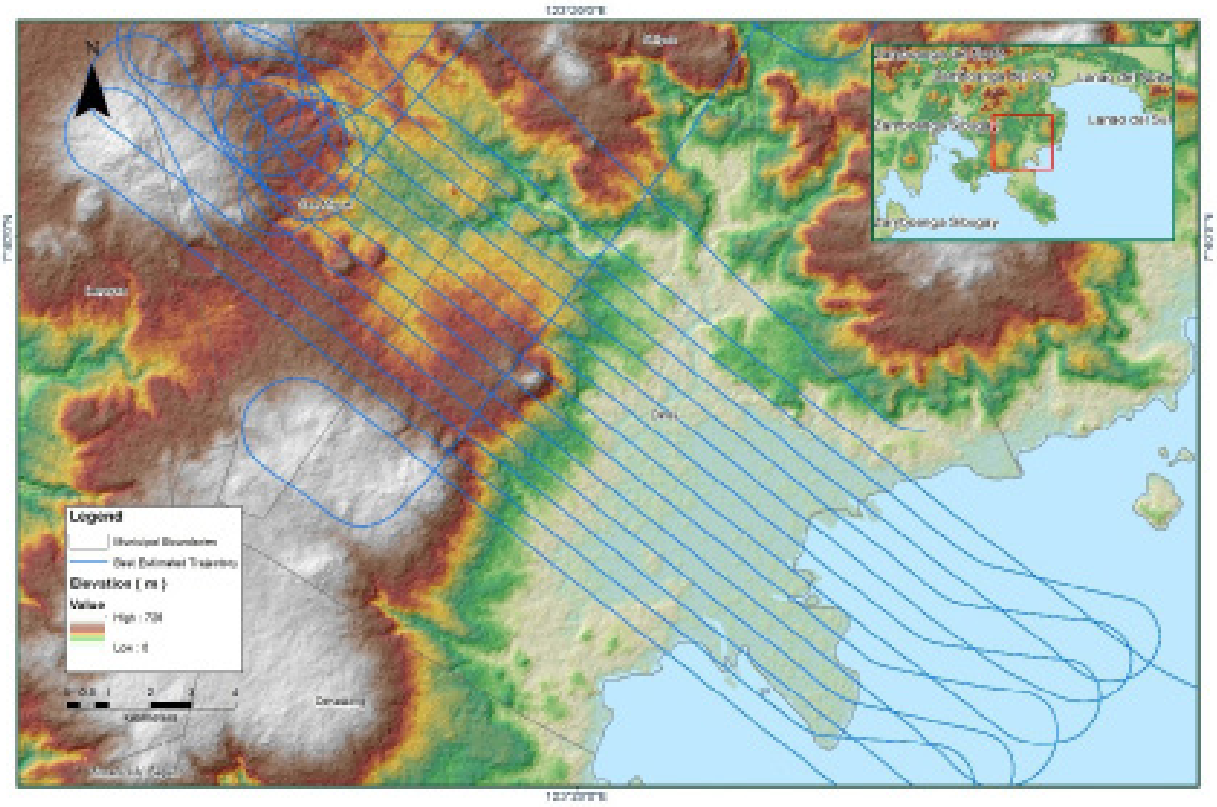


Figure A-8.66. Best Estimated Trajectory

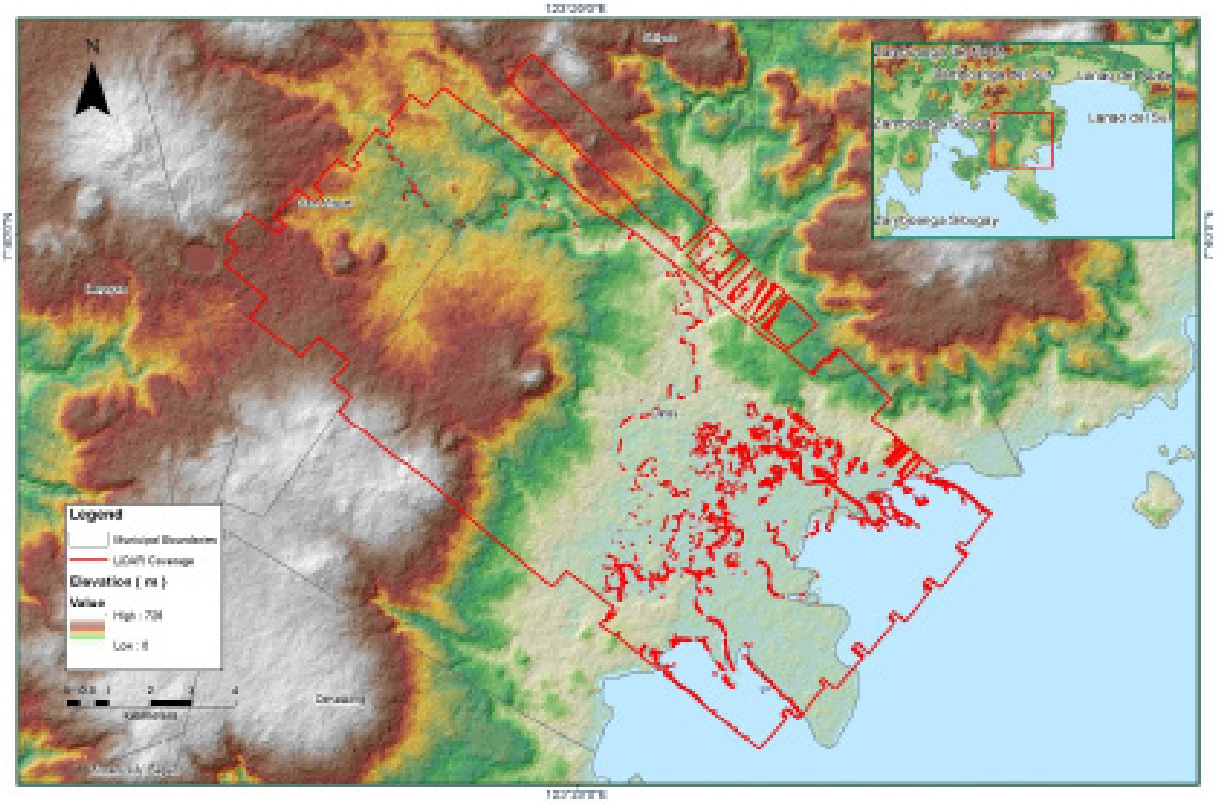


Figure A-8.67. Coverage of LiDAR Data

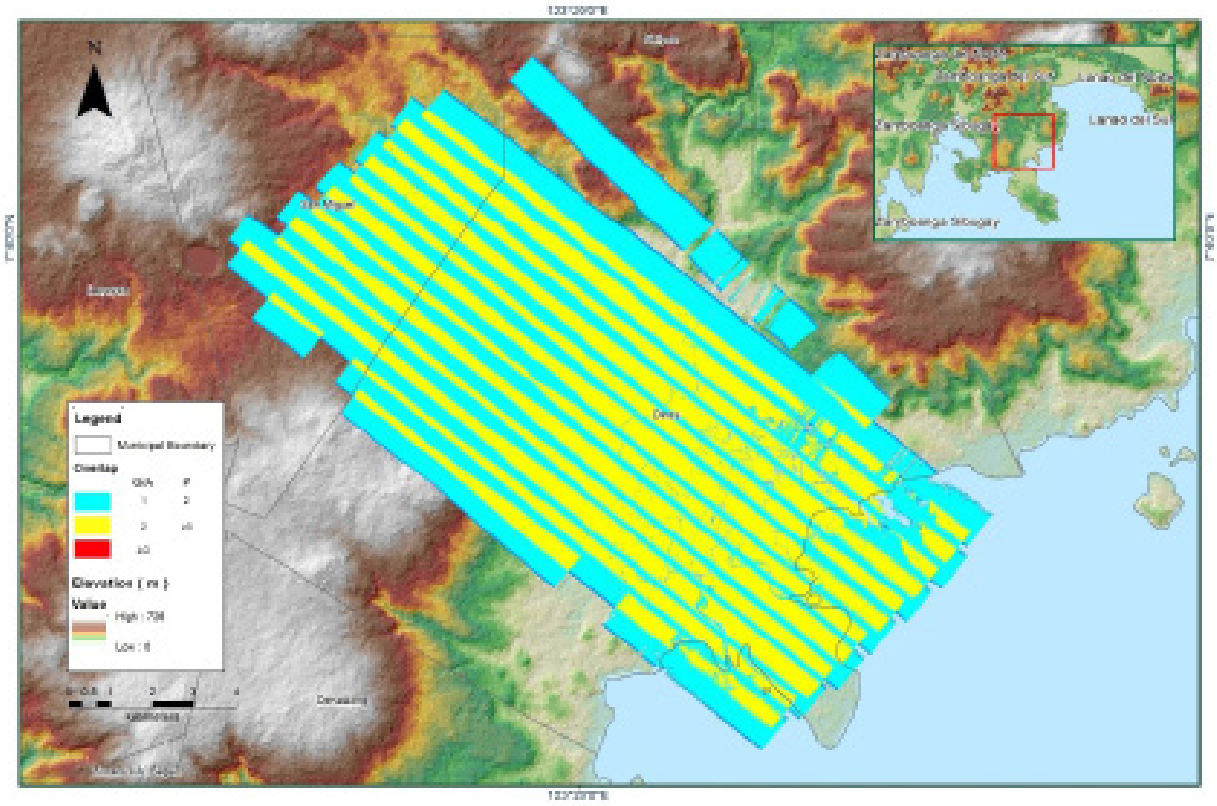


Figure A-8.68. Image of data overlap

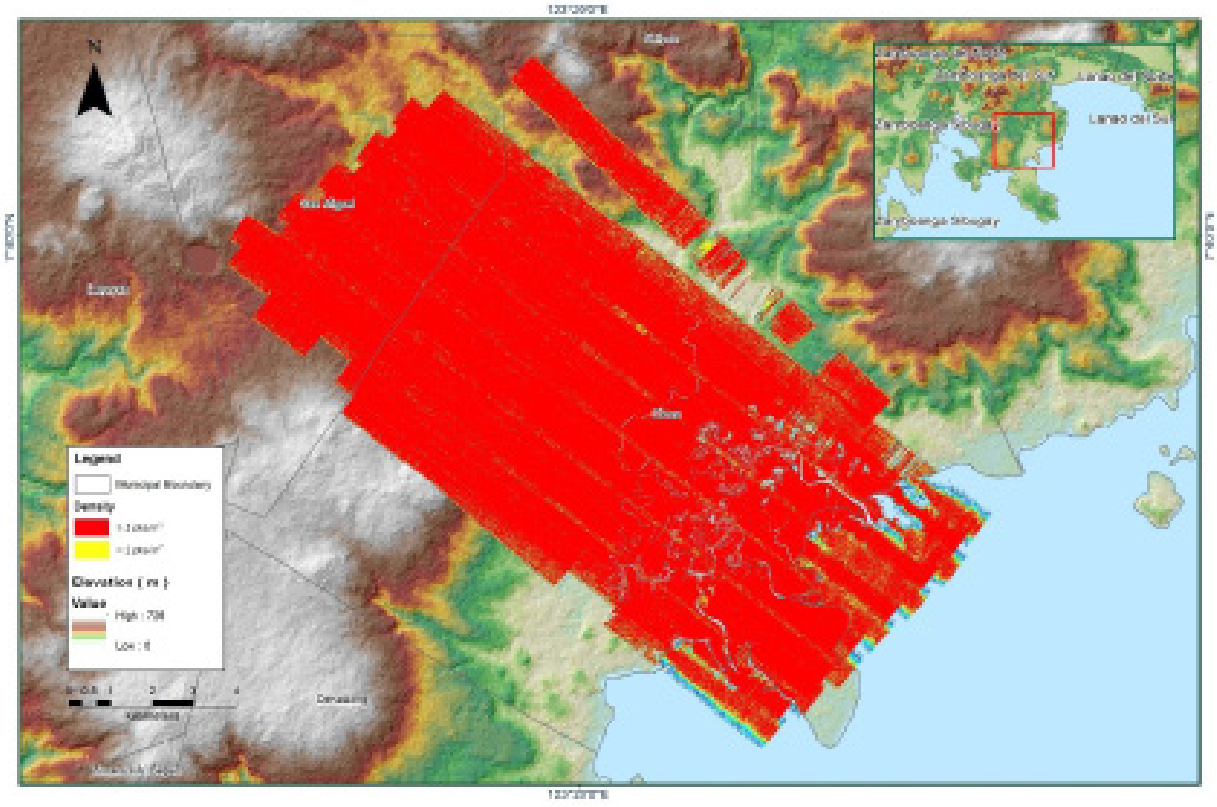


Figure A-8.69. Density map of merged LiDAR data

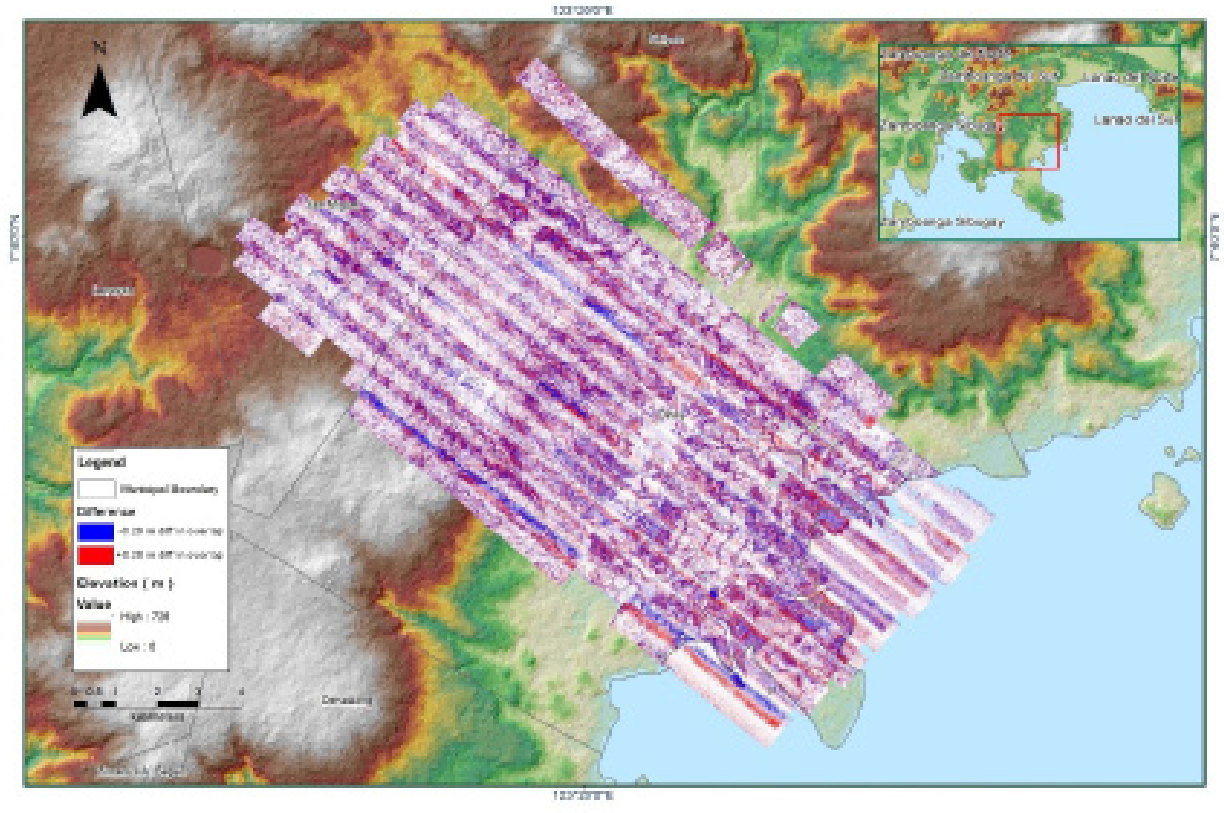


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission 76S

Flight Area	Pagadian
Mission Name	76S
Inclusive Flights	23160P
Range data size	15.70
POS data size	185 MB
Base data size	88.80 MB
Image	n/a
Transfer date	March 16, 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)	1.3
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	3.7
Boresight correction stdev (<0.001deg)	0.000138
IMU attitude correction stdev (<0.001deg)	1.246524
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	36.55
Ave point cloud density per sq.m. (>2.0)	2.46
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	272
Maximum Height	512.80 m
Minimum Height	67.82 m
Classification (# of points)	
Ground	225,618,191
Low vegetation	131,924,734
Medium vegetation	118,733,689
High vegetation	303,550,685
Building	2,349,456
Orthophoto	No

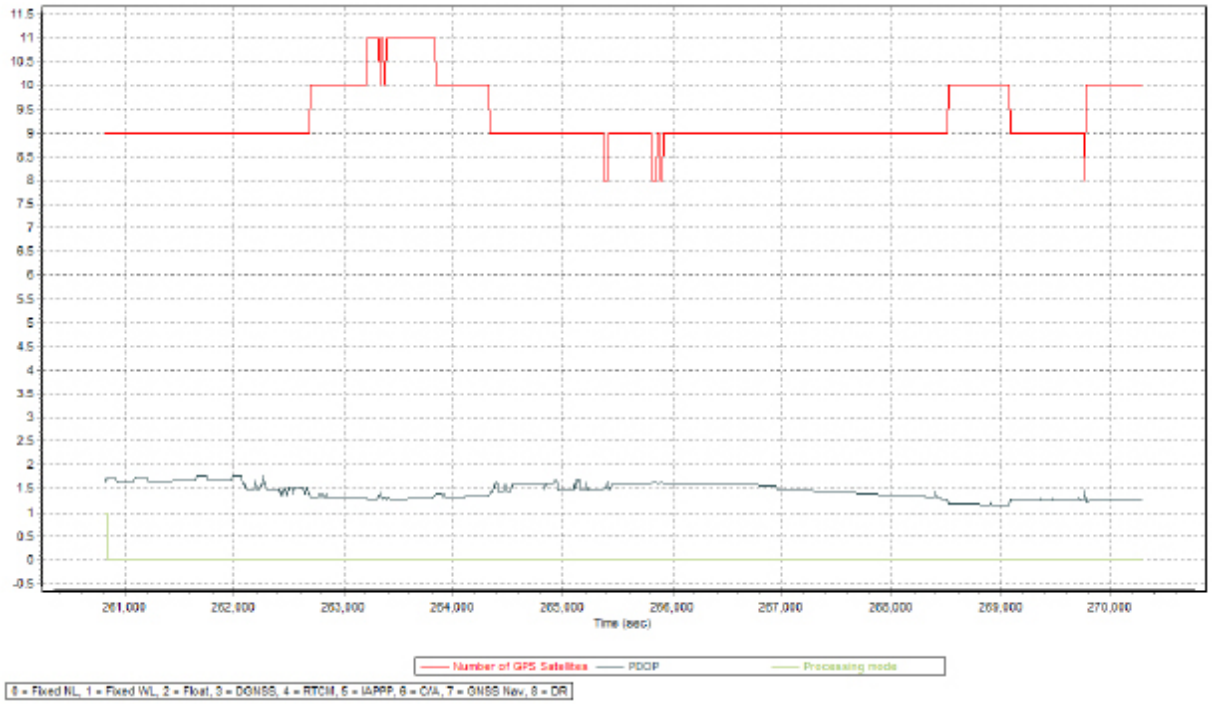


Figure A-8.71. Solution Status

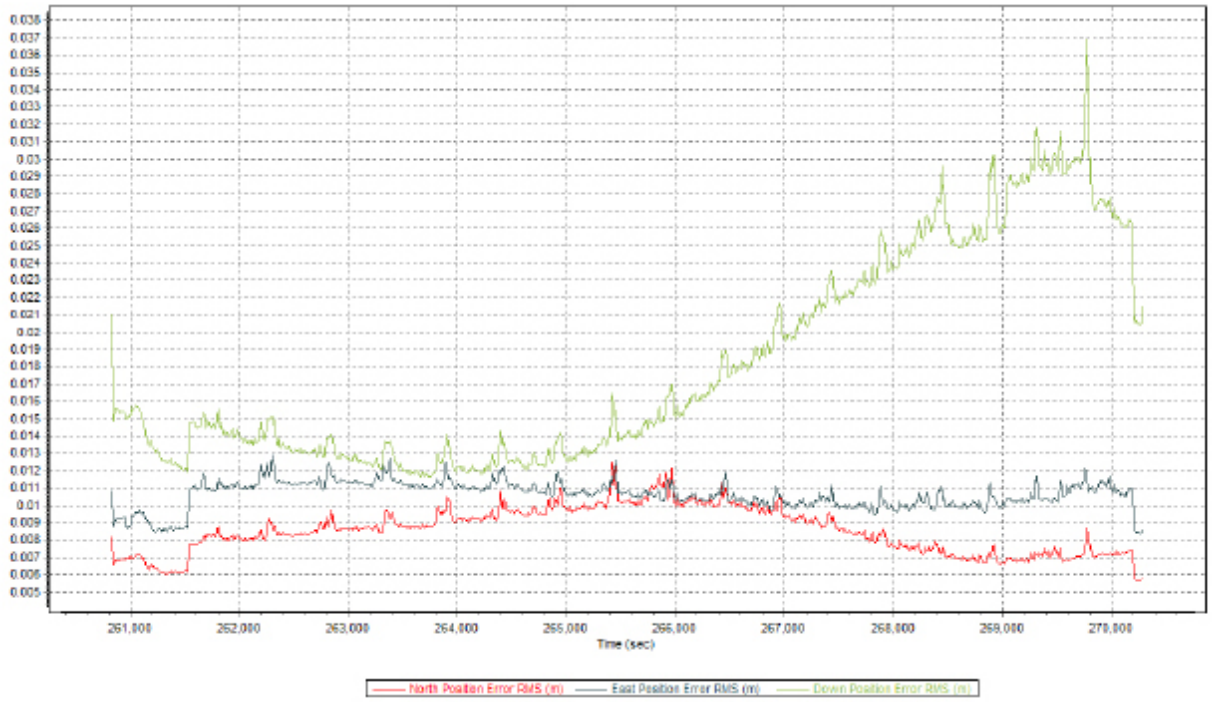


Figure A-8.72. Smoothed Performance Metric Parameters

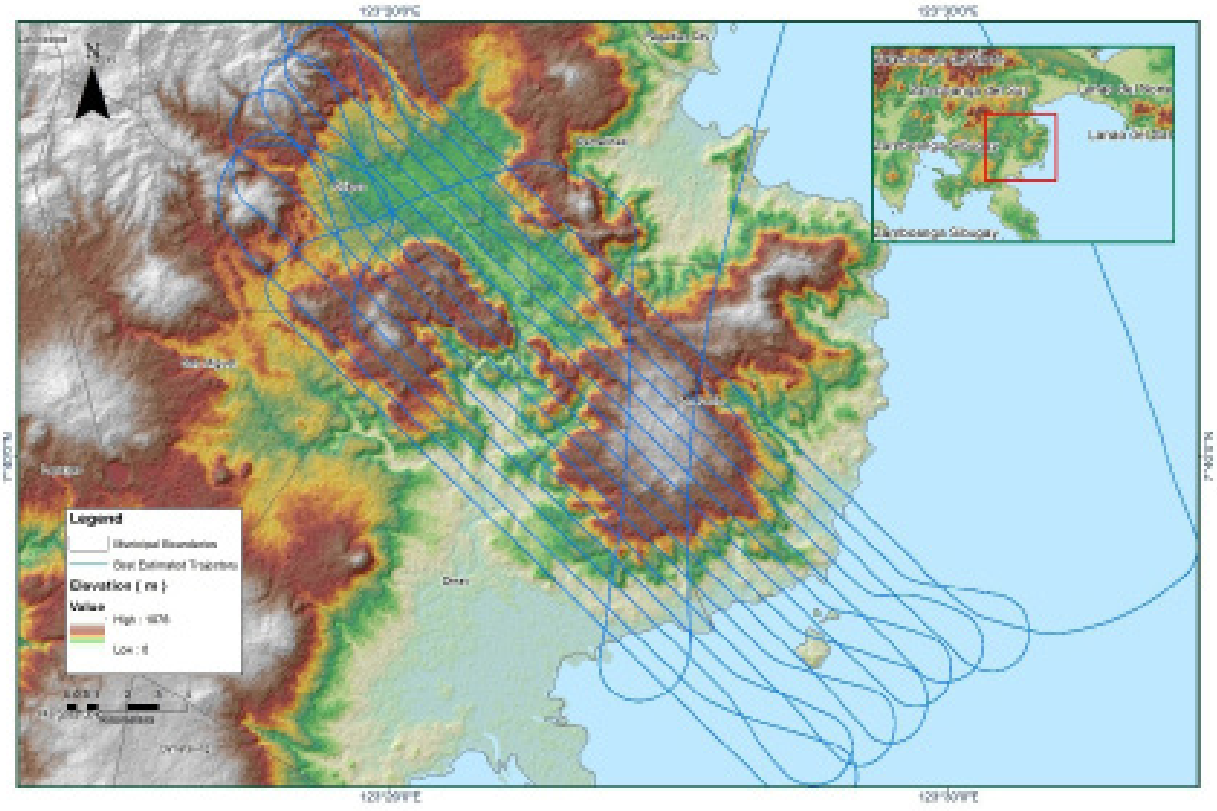


Figure A-8.73. Best Estimated Trajectory

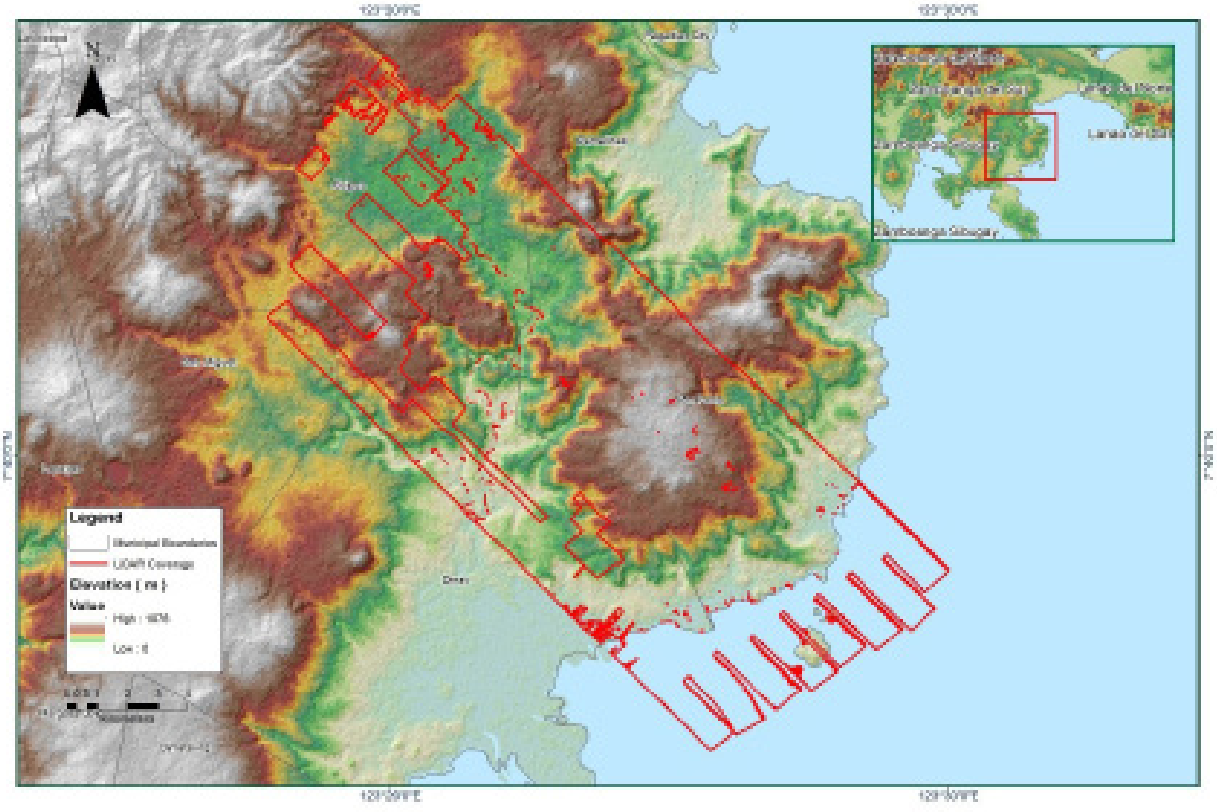


Figure A-8.74. Coverage of LiDAR Data

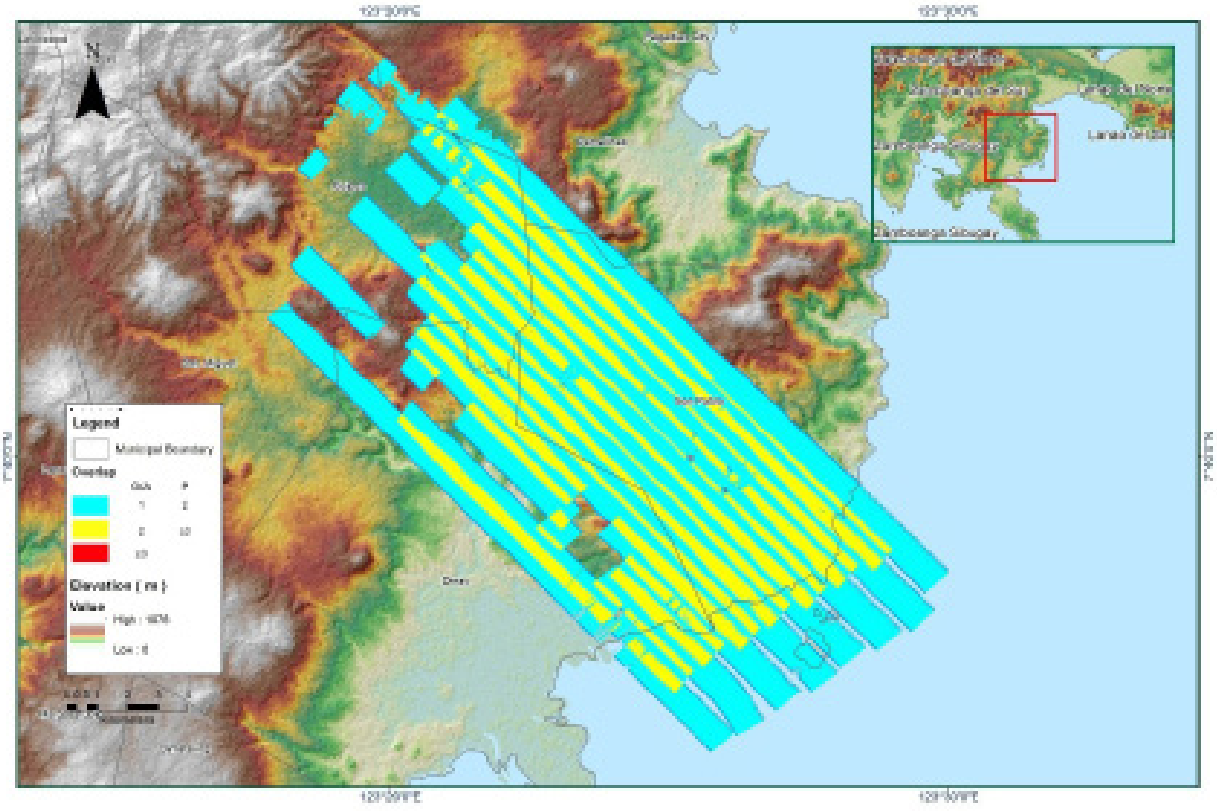


Figure A-8.75. Image of data overlap

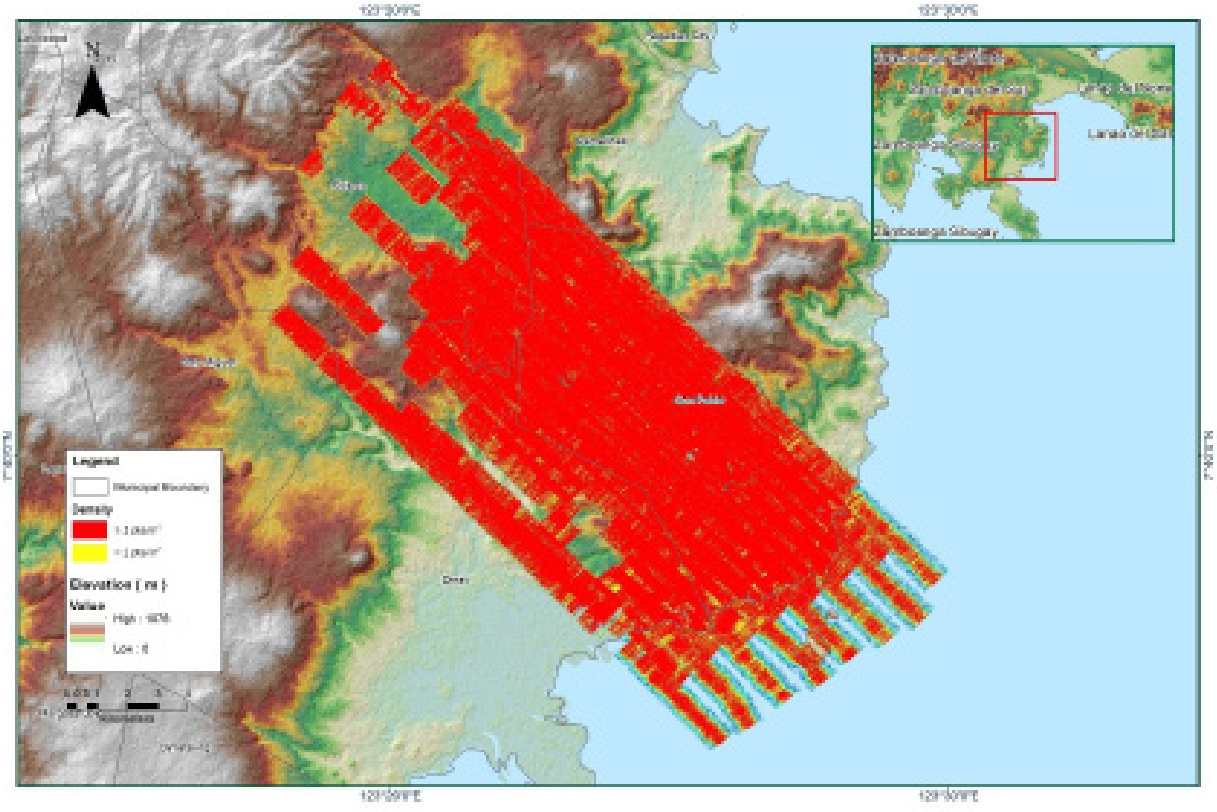


Figure A-8.76. Density map of merged LiDAR data

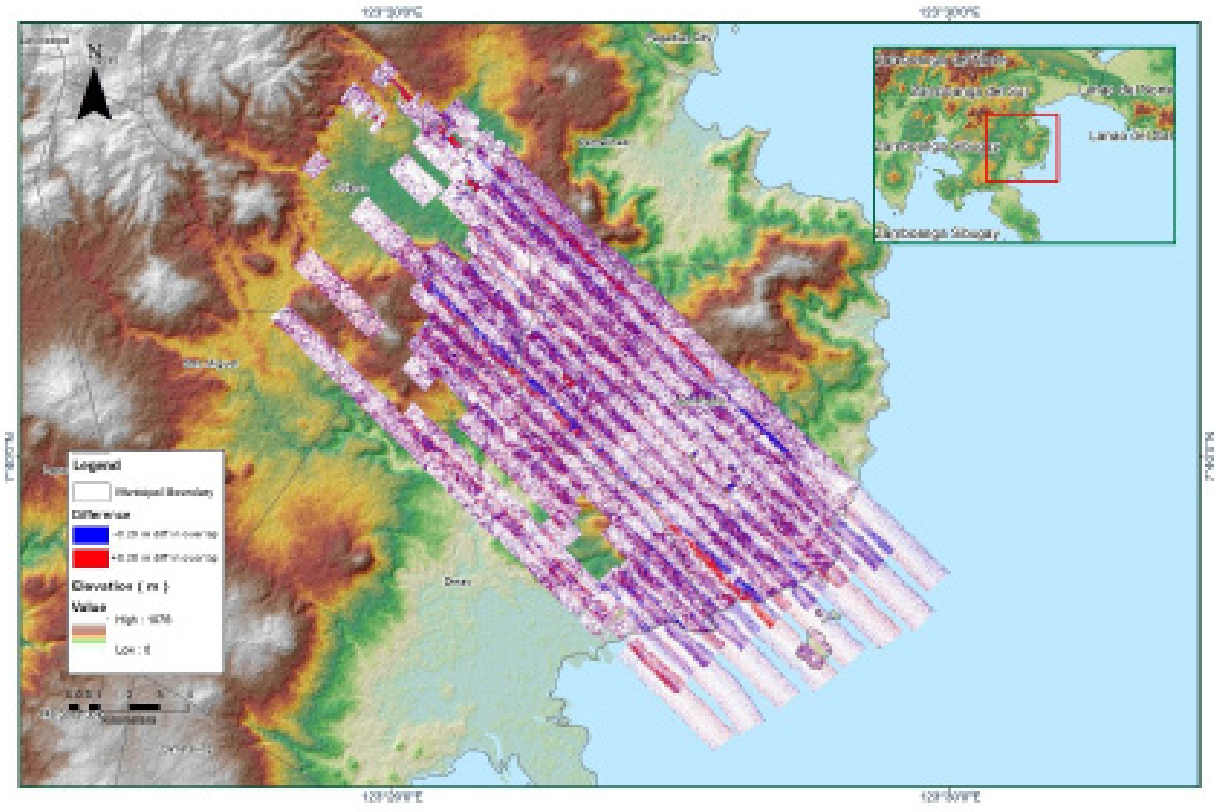


Figure A-8.77. Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission 76R

Flight Area	Pagadian
Mission Name	76R
Inclusive Flights	23156P, 2830P
Range data size	30.2
POS data size	310
Base data size	84.6
Image	n/a
Transfer date	March 16, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.0
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000123
IMU attitude correction stdev (<0.001deg)	0.000367
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	44.25
Ave point cloud density per sq.m. (>2.0)	3.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	204
Maximum Height	1051.50 m
Minimum Height	68.29 m
Classification (# of points)	
Ground	298,210,940
Low vegetation	130,065,535
Medium vegetation	149,120,589
High vegetation	413,708,279
Building	2,725,690
Orthophoto	No

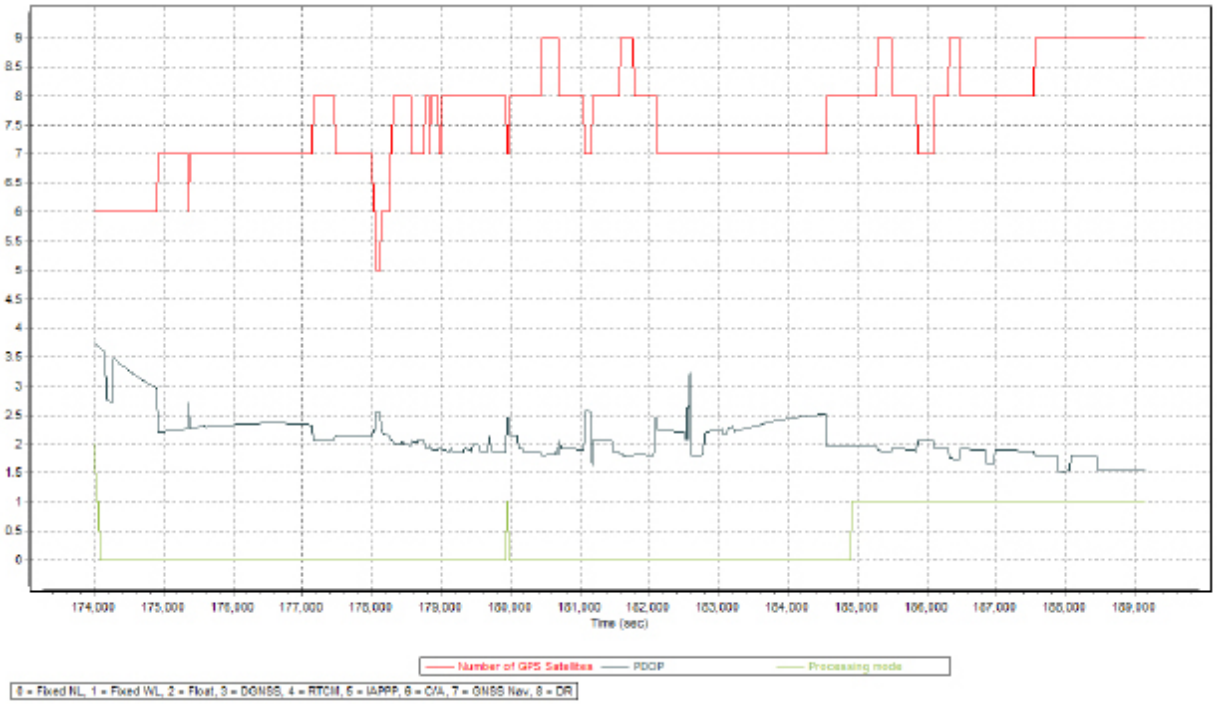


Figure A-8.78. Solution Status

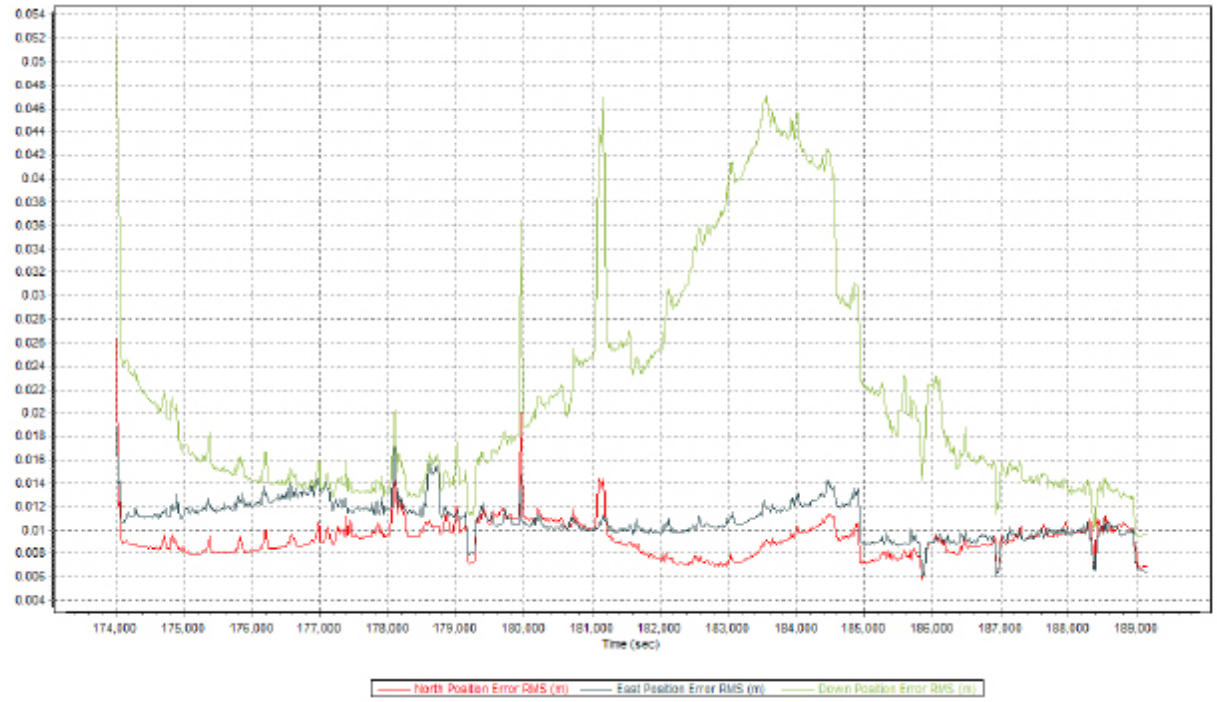


Figure A-8.79. Smoothed Performance Metric Parameters

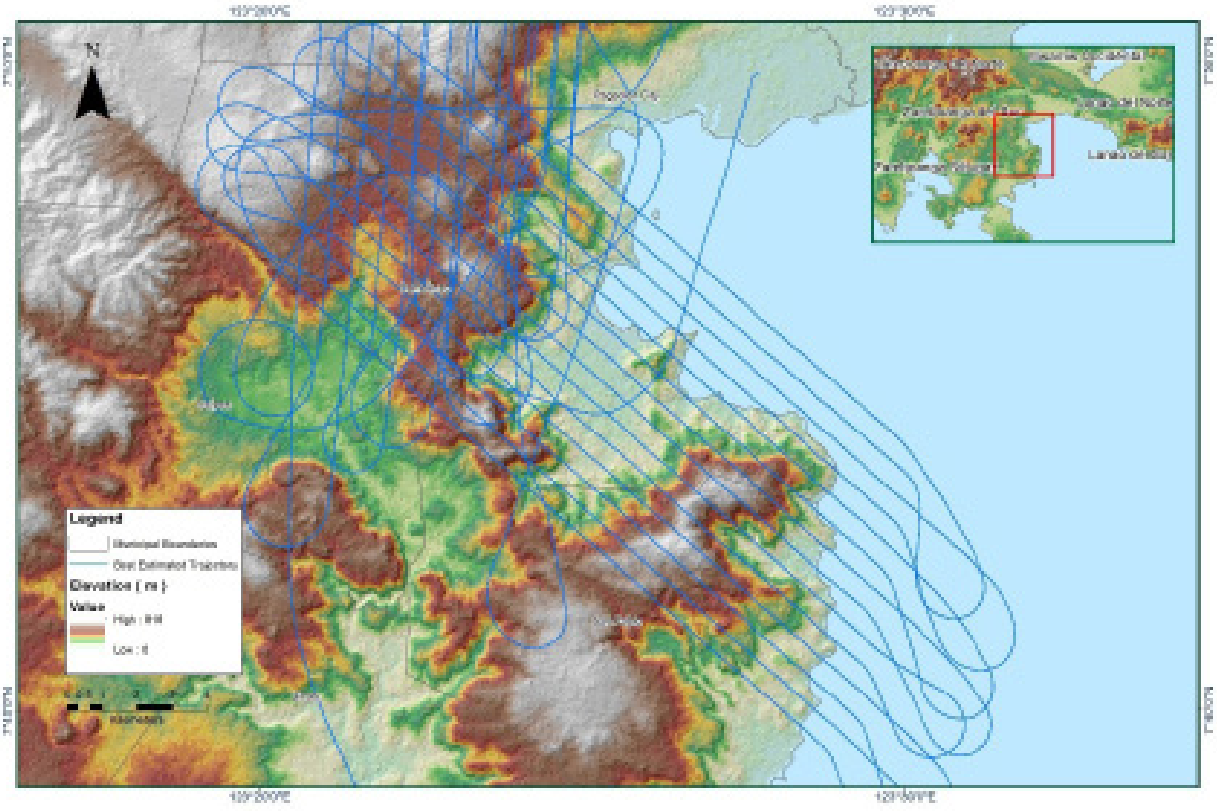


Figure A-8.80. Best Estimated Trajectory

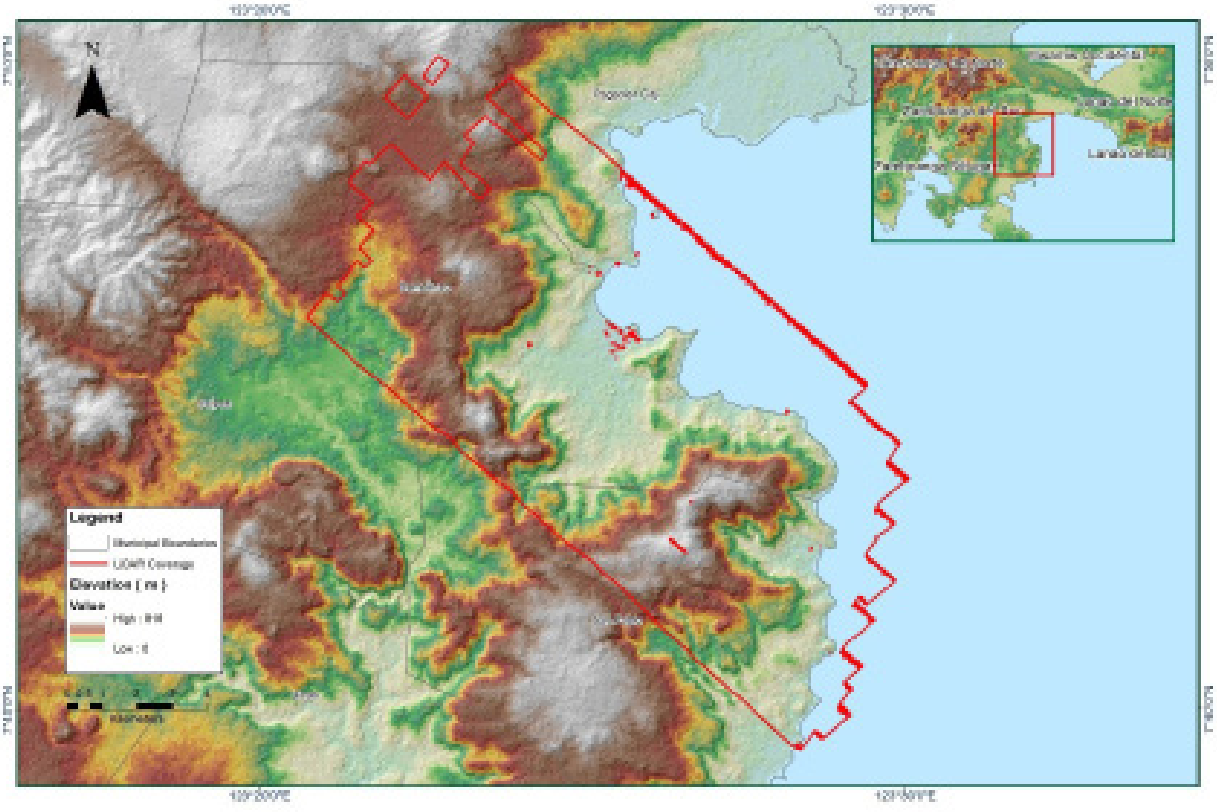


Figure A-8.81. Coverage of LiDAR Data

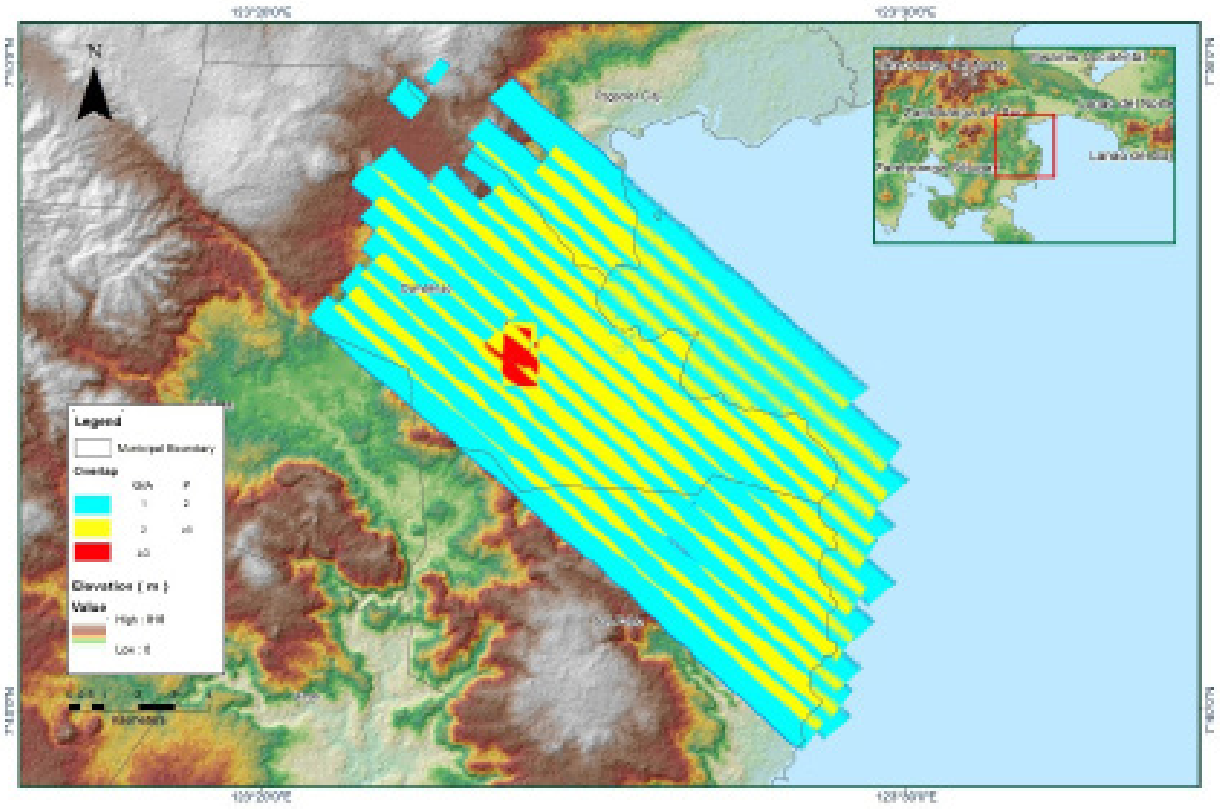


Figure A-8.82. Image of data overlap

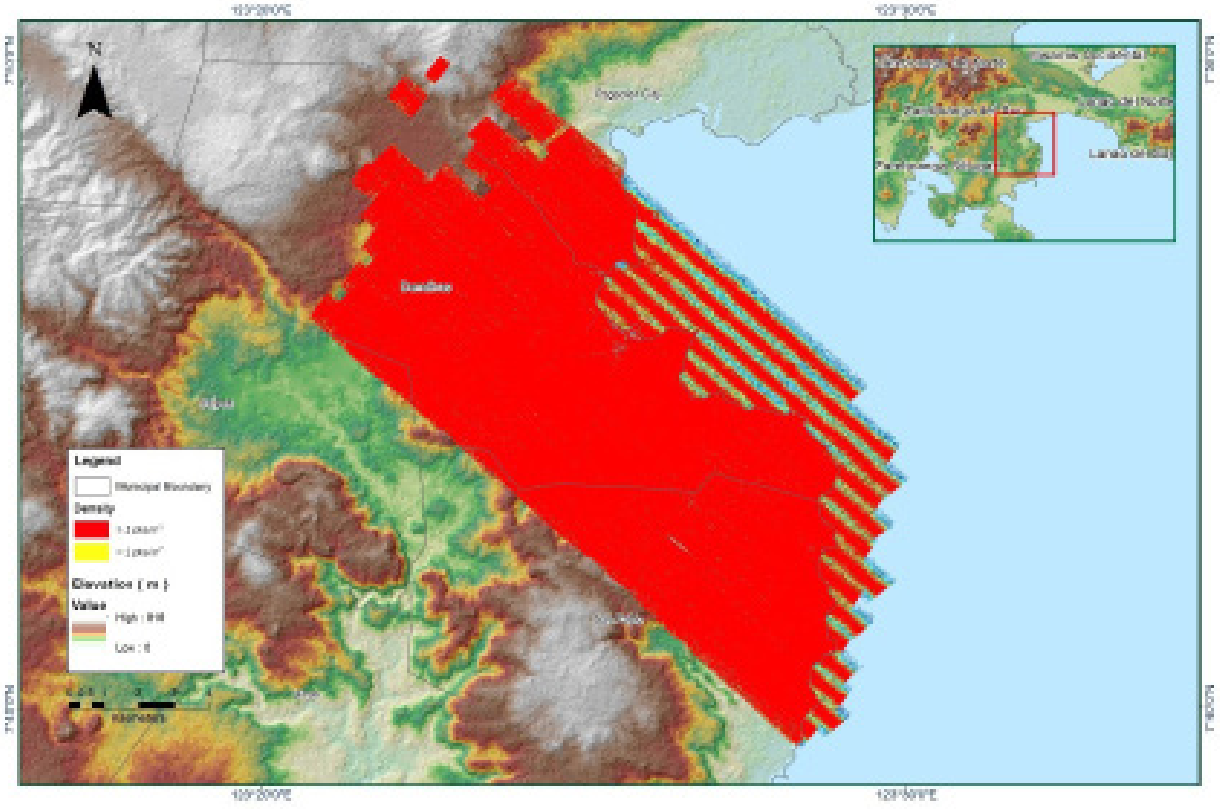


Figure A-8.83. Density map of merged LiDAR data

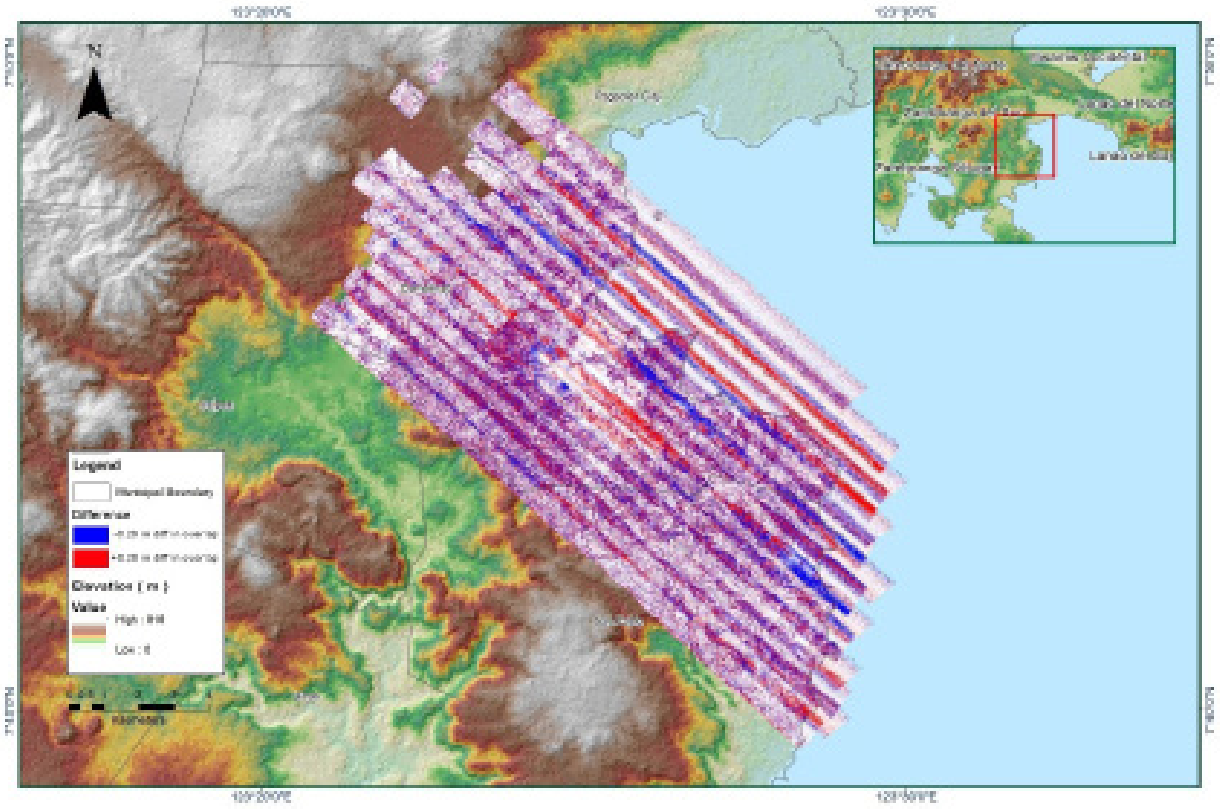


Figure A-8.84. Elevation difference between flight lines

Table A-8.13. Mission Summary Report for Mission 76Q

Flight Area	Pagadian
Mission Name	76Q
Inclusive Flights	23156P, 2830P
Range data size	30.2
POS data size	310
Base data size	84.6
Image	n/a
Transfer date	March 16, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.0
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000146
IMU attitude correction stdev (<0.001deg)	0.000566
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	41.44
Ave point cloud density per sq.m. (>2.0)	3.87
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	130
Maximum Height	794.48 m
Minimum Height	76.35 m
Classification (# of points)	
Ground	197,560,259
Low vegetation	122,503,963
Medium vegetation	114,776,318
High vegetation	303,144,620
Building	2,008,274
Orthophoto	No

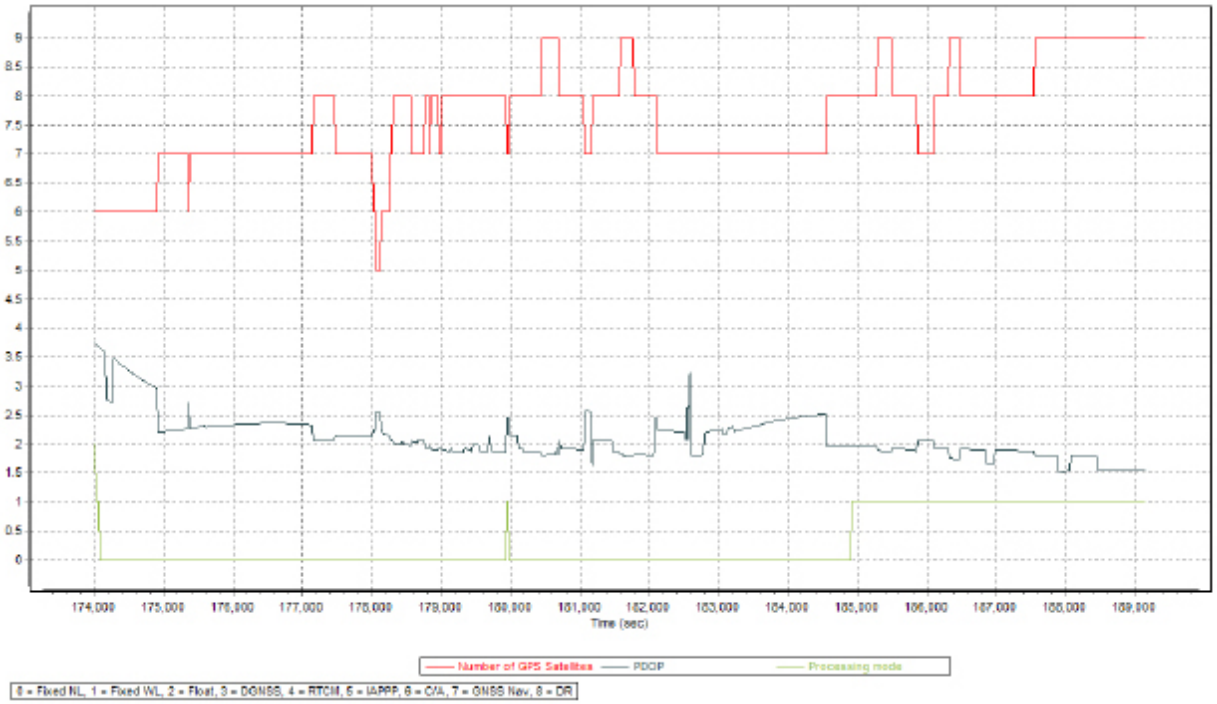


Figure A-8.85. Solution Status

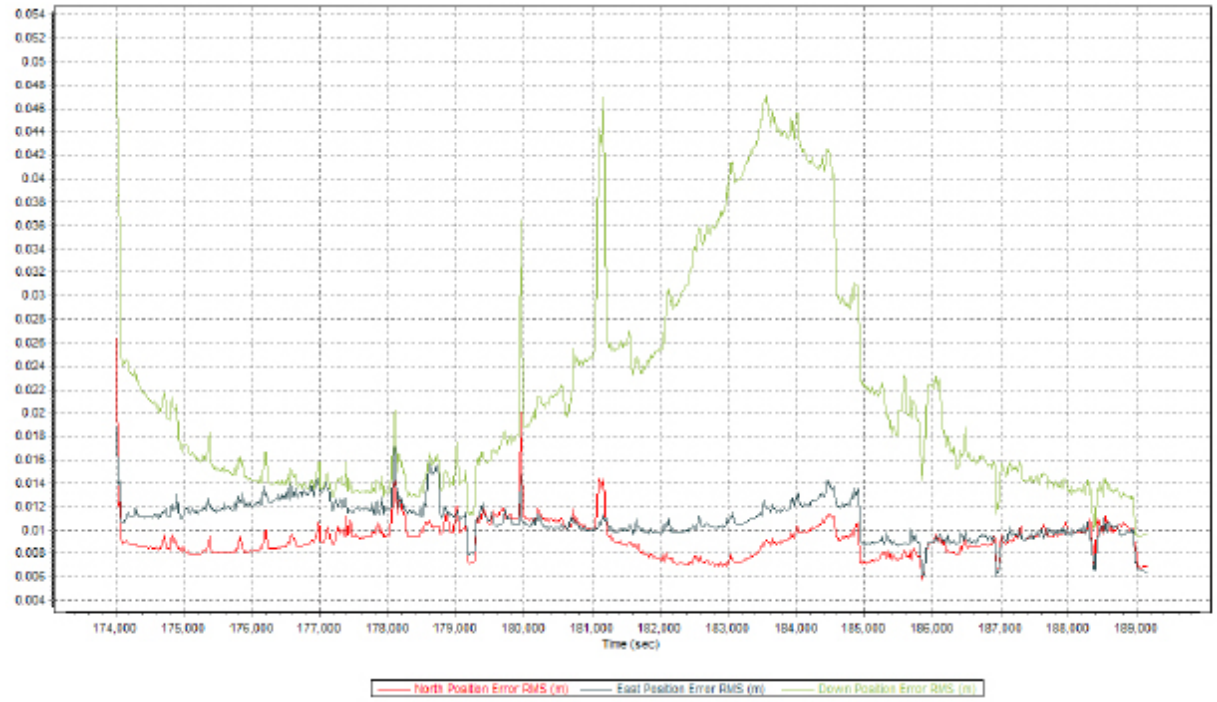


Figure A-8.86. Smoothed Performance Metric Parameters

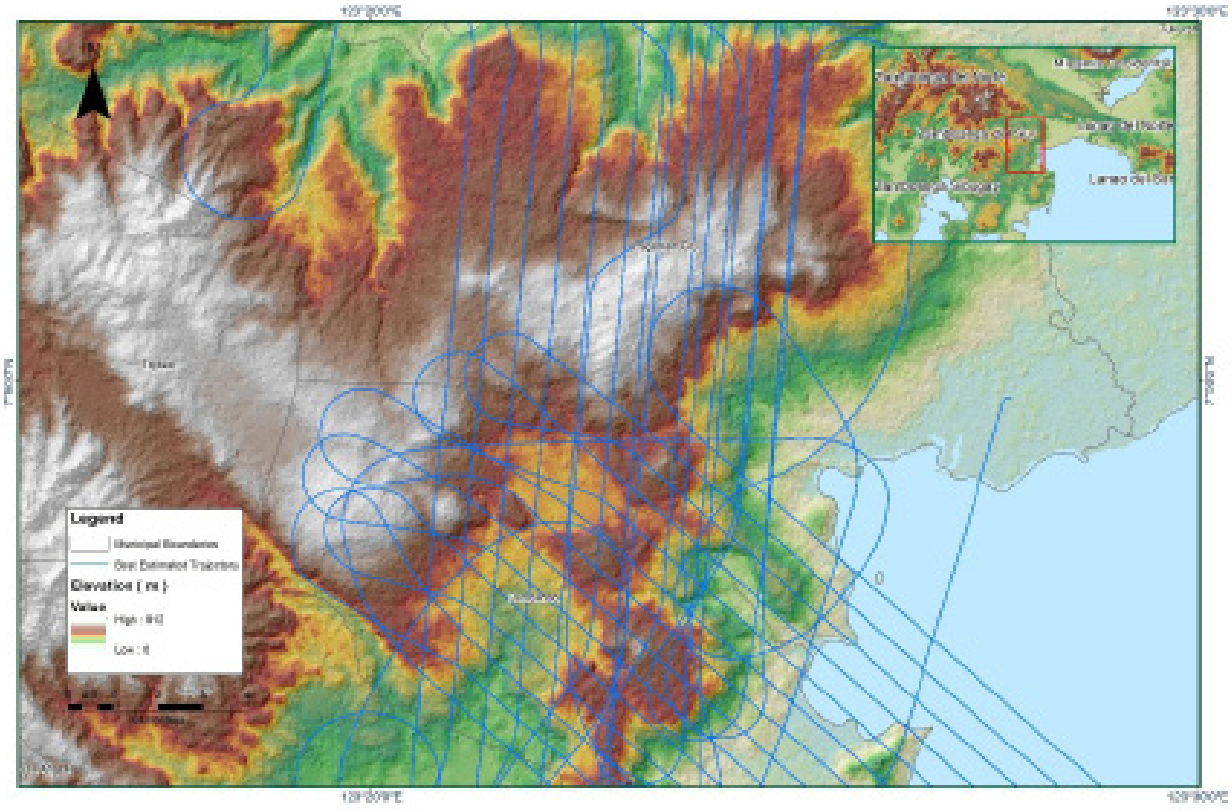


Figure A-8.87. Best Estimated Trajectory

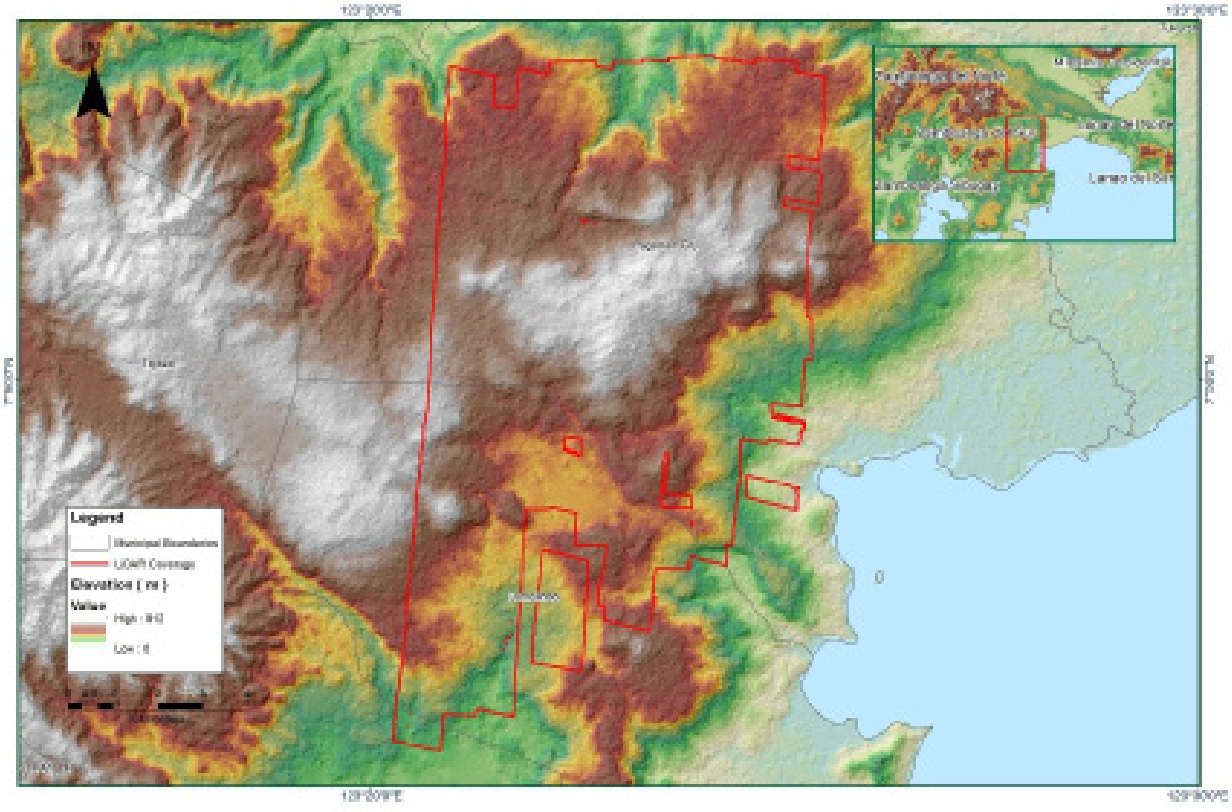


Figure A-8.88. Coverage of LiDAR Data

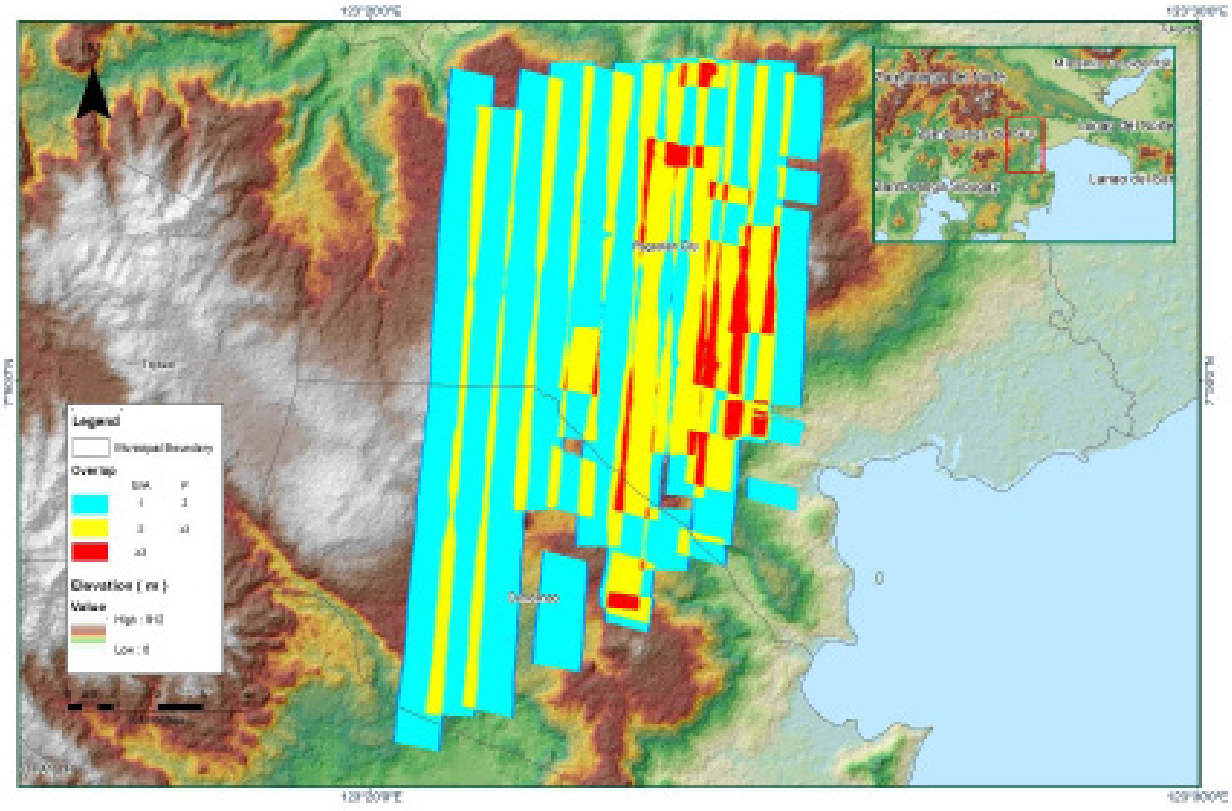


Figure A-8.89. Image of data overlap

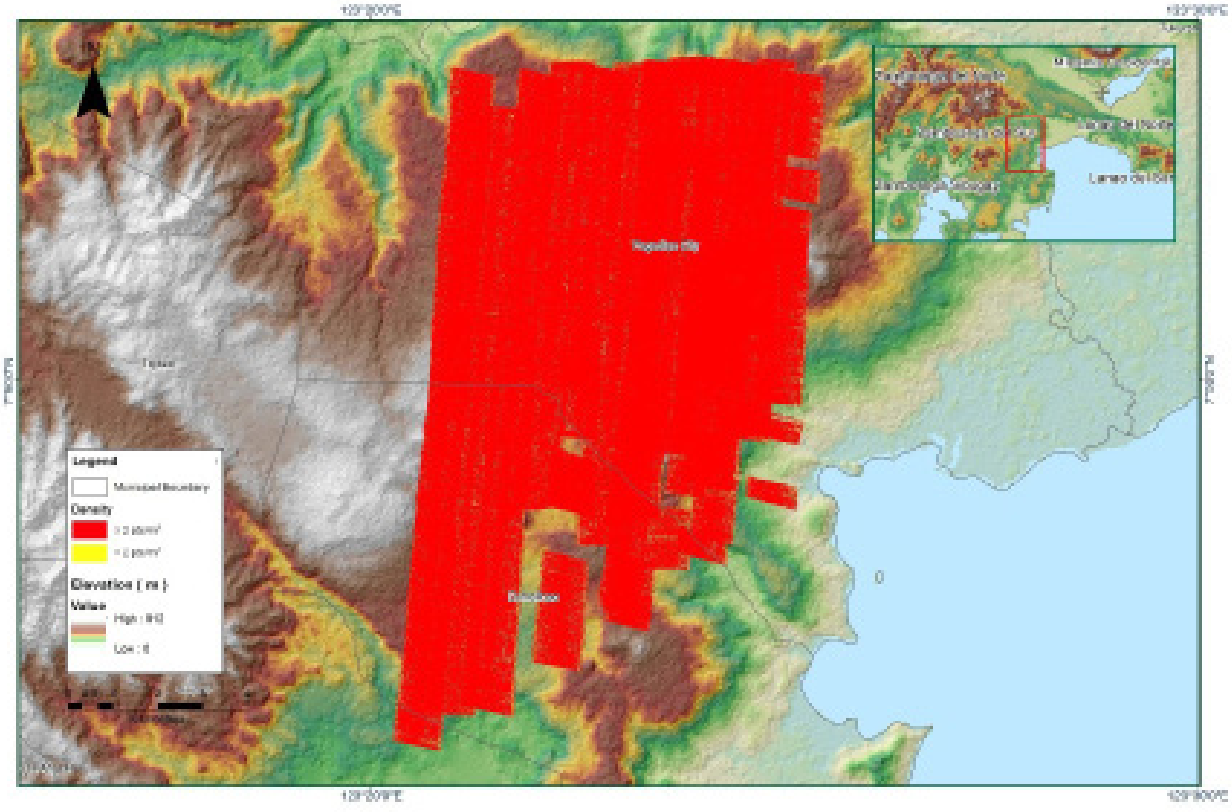


Figure A-8.90. Density map of merged LiDAR data

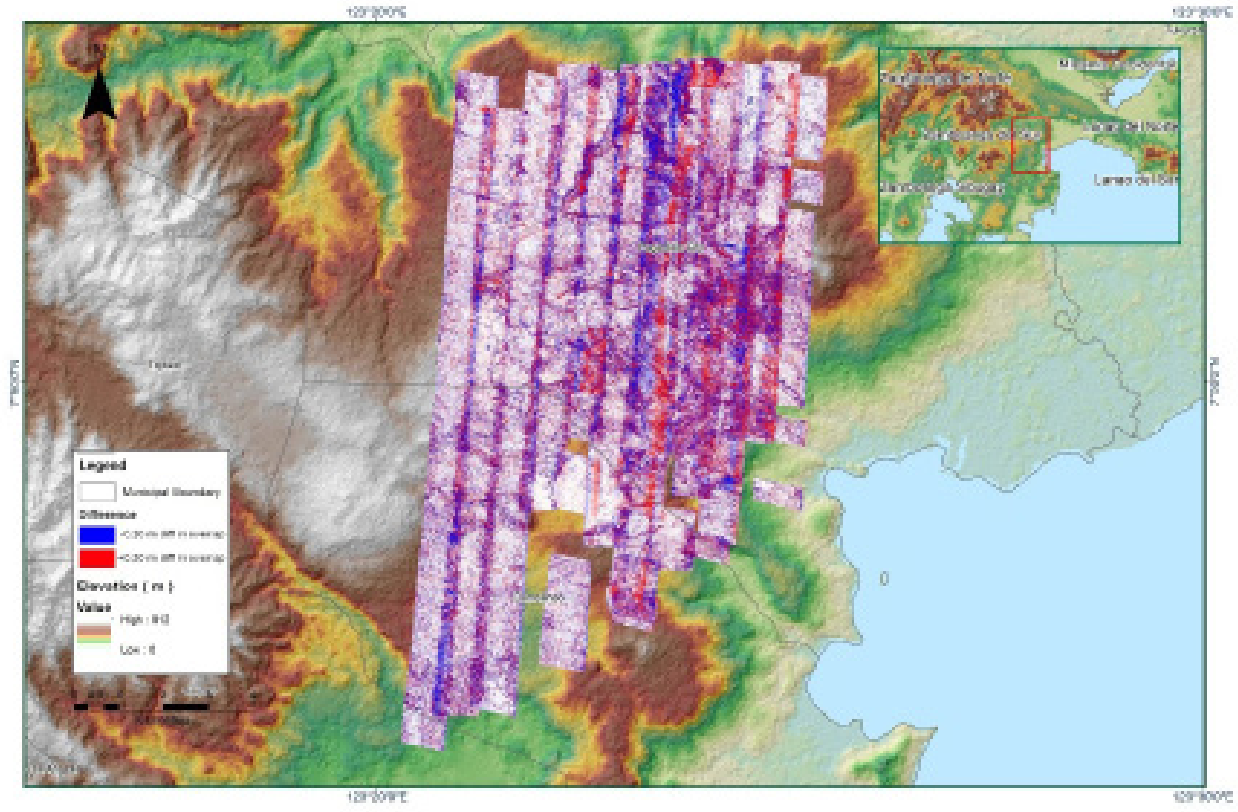


Figure A-8.91. Elevation difference between flight lines

Table A-8.14. Mission Summary Report for Mission Blk70D

Flight Area	Dipolog
Mission Name	Blk70D
Inclusive Flights	2137P
Range data size	1BLK70D302A
POS data size	11.2 GB
Base data size	190 MB
Image	28.3 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)	0.9
RMSE for East Position (<4.0 cm)	1.15
RMSE for Down Position (<8.0 cm)	2.5
Boresight correction stdev (<0.001deg)	0.000311
IMU attitude correction stdev (<0.001deg)	0.000693
GPS position stdev (<0.01m)	0.0070
Minimum % overlap (>25)	35.12%
Ave point cloud density per sq.m. (>2.0)	3.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	111
Maximum Height	558.89 m
Minimum Height	75.16 m
Classification (# of points)	
Ground	119,530,538
Low vegetation	109,353,873
Medium vegetation	78,619,467
High vegetation	54,546,202
Building	4,480,383
Orthophoto	YES

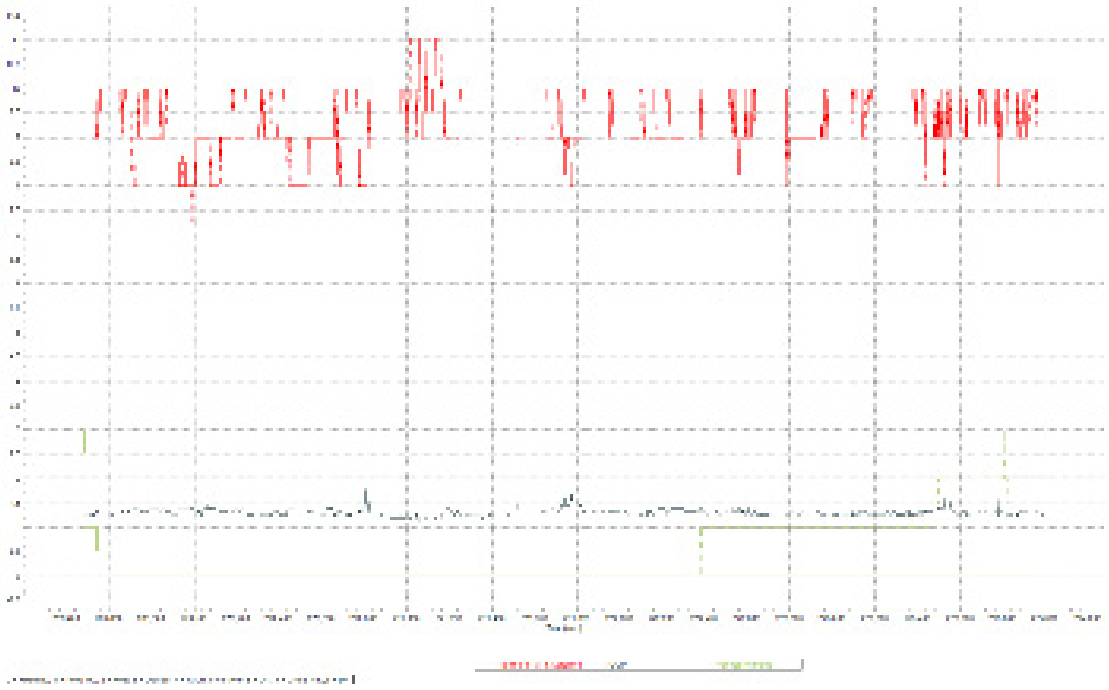


Figure A-8.92. Solution Status

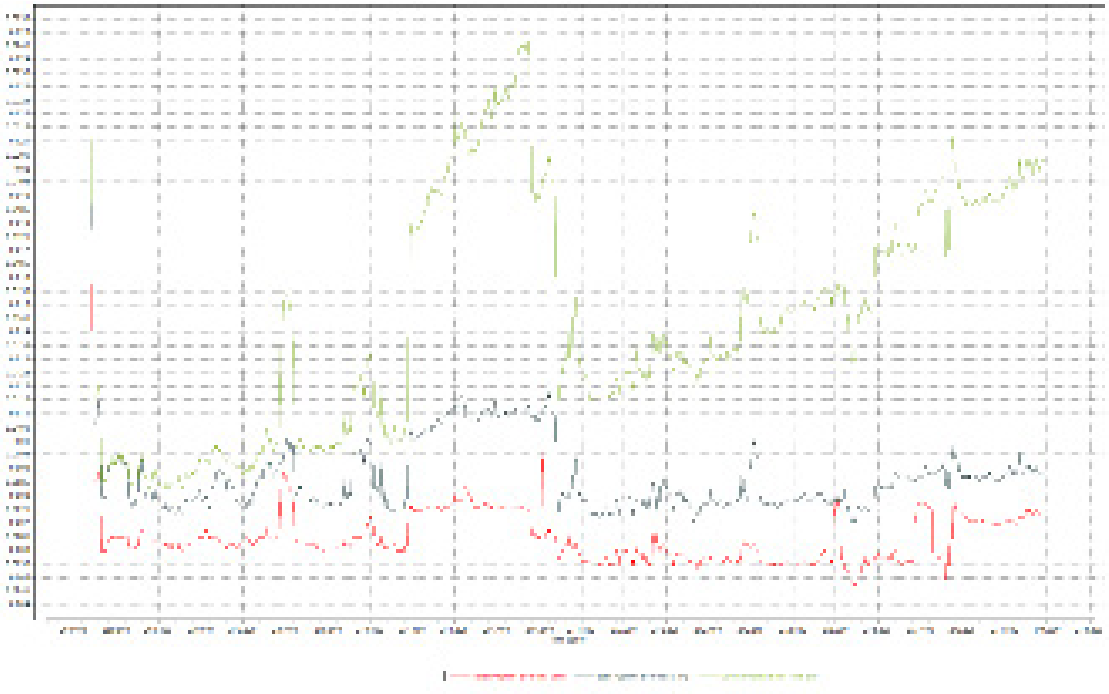


Figure A-8.93. Smoothed Performance Metric Parameters

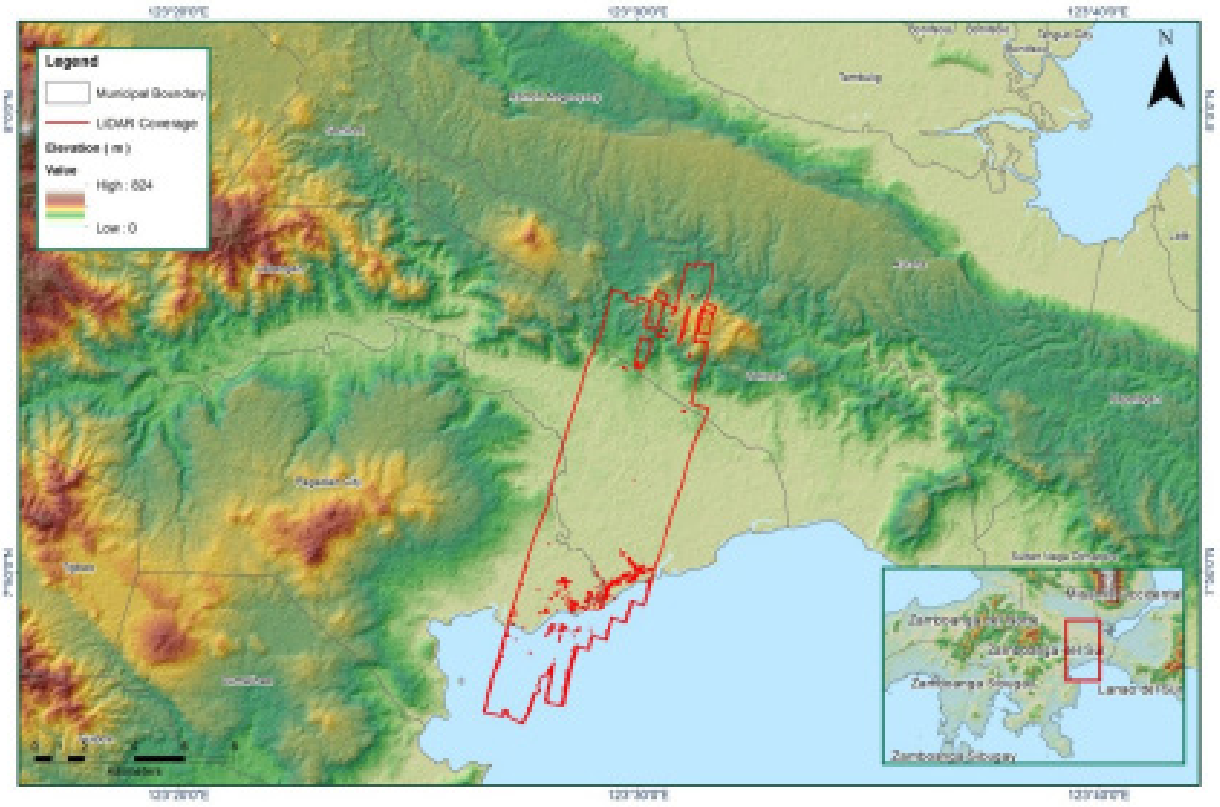


Figure A-8.94. Best Estimated Trajectory

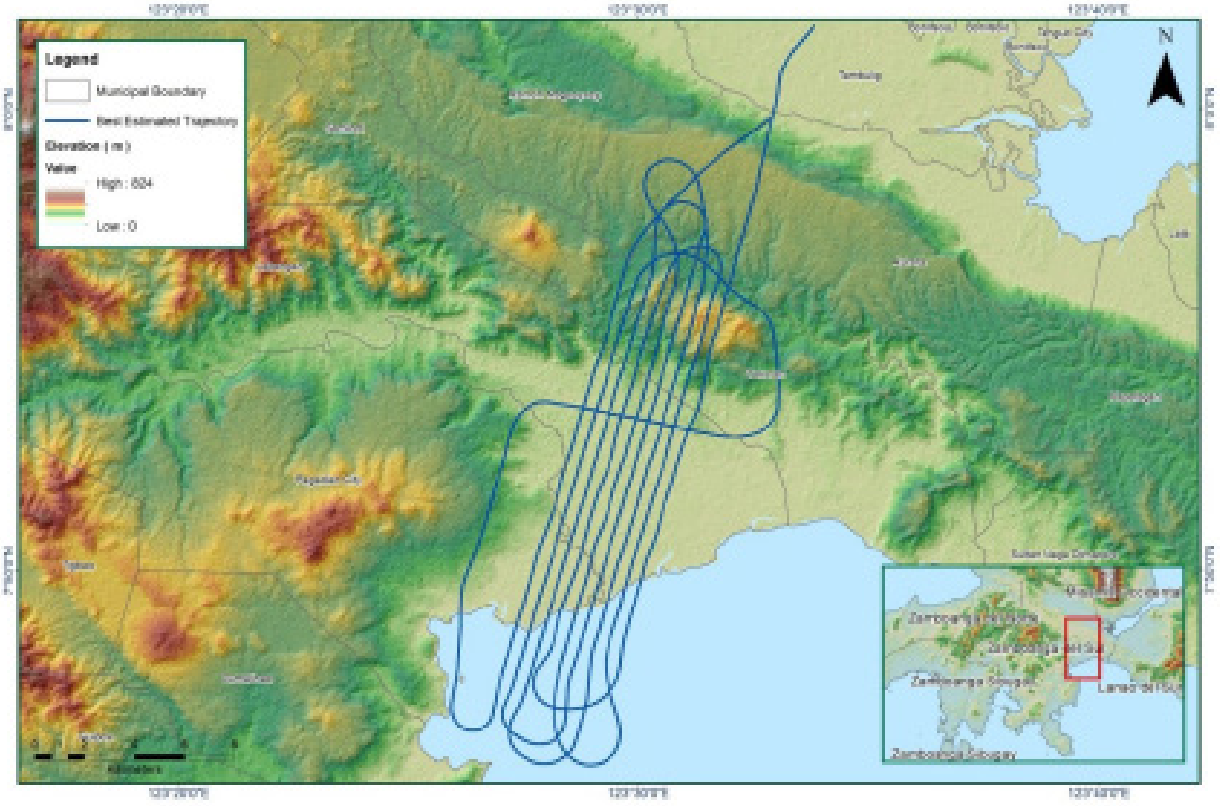


Figure A-8.95. Coverage of LiDAR Data

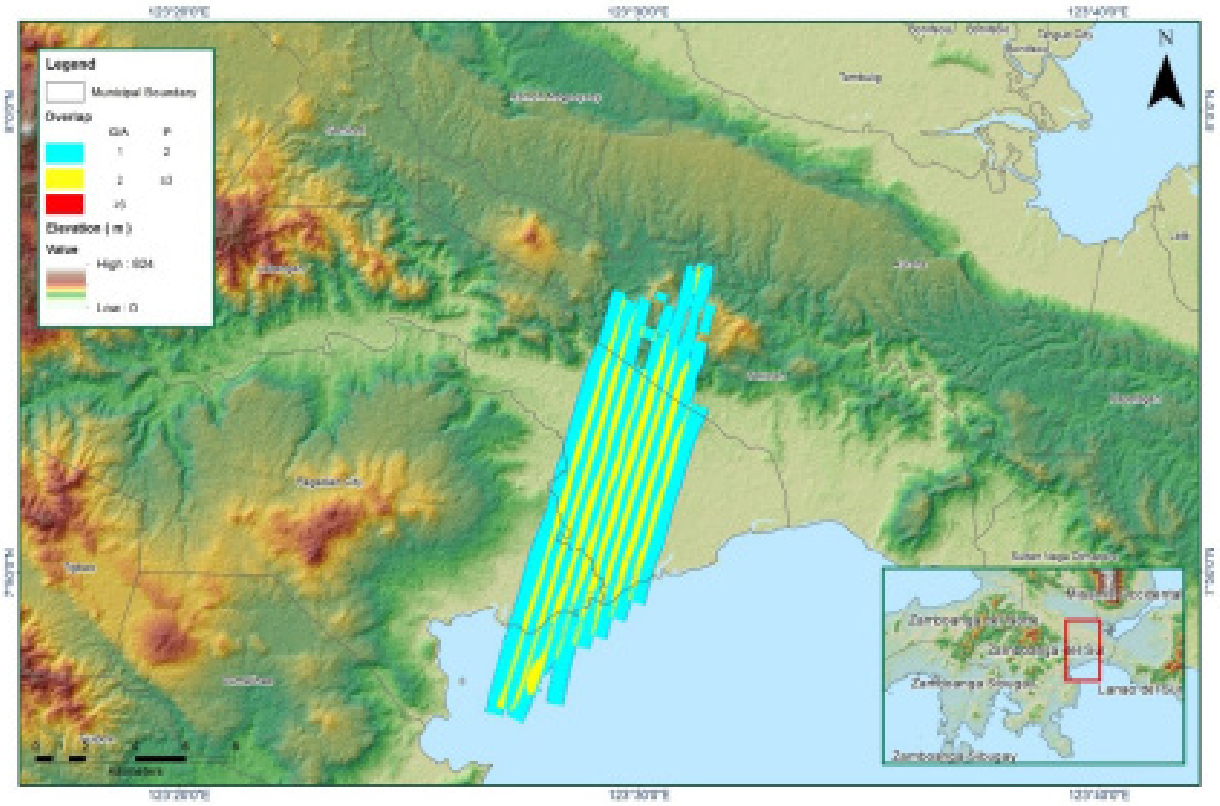


Figure A-8.96. Image of data overlap

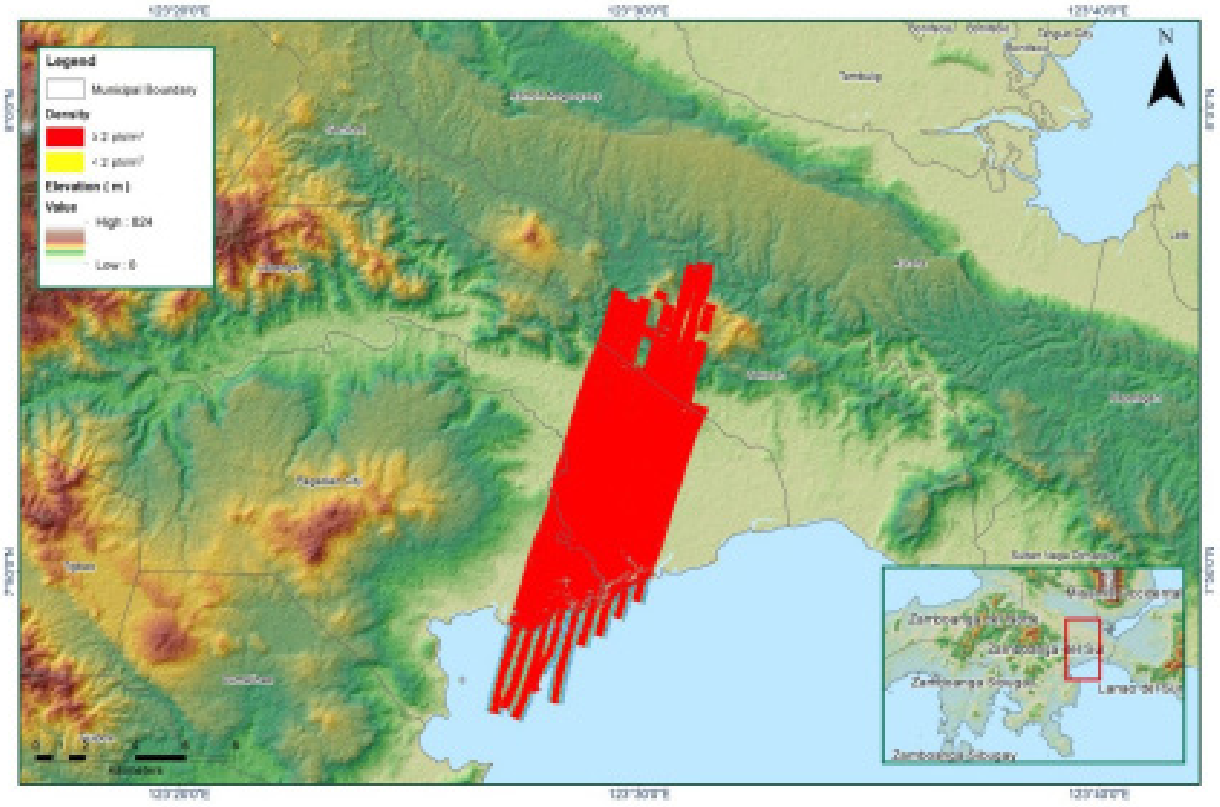


Figure A-8.97. Density map of merged LiDAR data

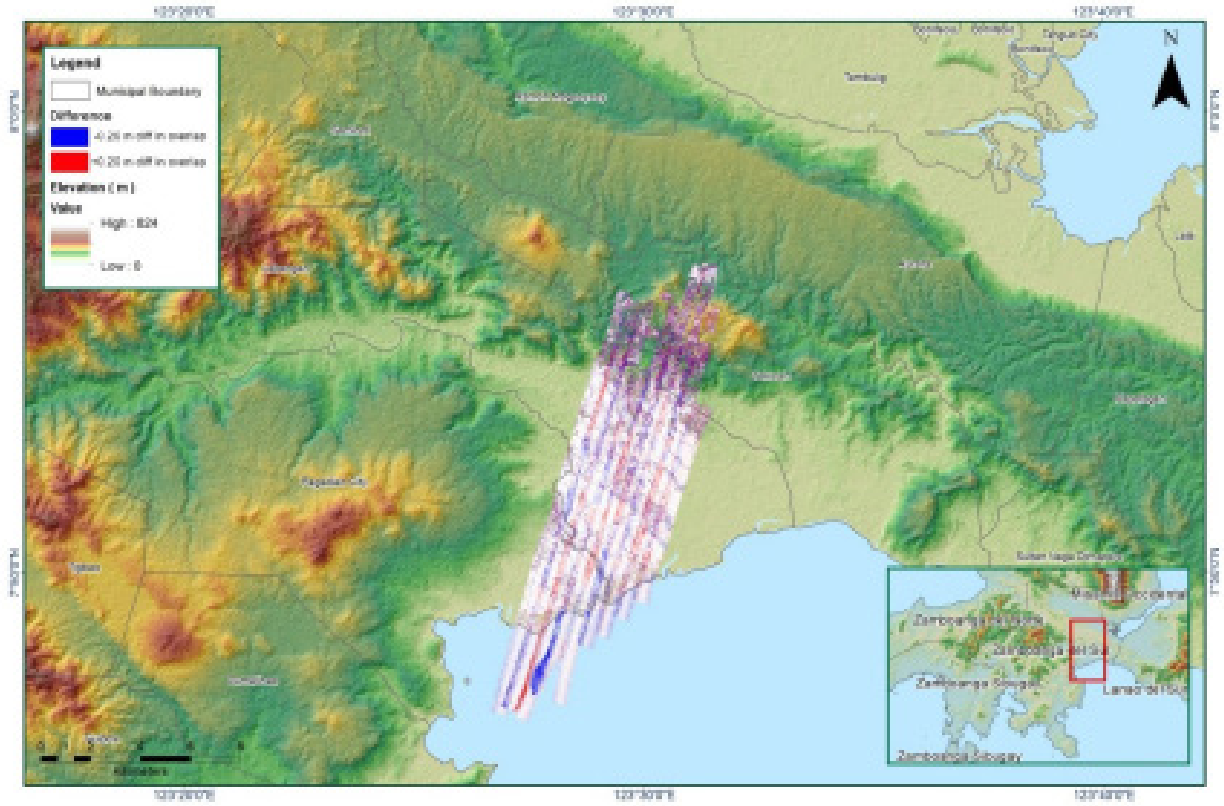


Figure A-8.98. Elevation difference between flight lines

Table A-8.15. Mission Summary Report for Mission Blk71E

Flight Area	Northern Mindanao
Mission Name	Blk71E
Inclusive Flights	1689P
Range data size	27.1 GB
POS data size	257 MB
Base data size	n/a
Image	August 6, 2014
Transfer date	March 01, 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)	2.5
RMSE for East Position (<4.0 cm)	5.5
RMSE for Down Position (<8.0 cm)	10
Boresight correction stdev (<0.001deg)	0.000536
IMU attitude correction stdev (<0.001deg)	0.001171
GPS position stdev (<0.01m)	0.0079
Minimum % overlap (>25)	35.35%
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	253
Maximum Height	476.79
Minimum Height	66.37
Classification (# of points)	
Ground	157,189,225
Low vegetation	118,155,426
Medium vegetation	187,516,392
High vegetation	168,342,412
Building	7,092,549
Orthophoto	NO

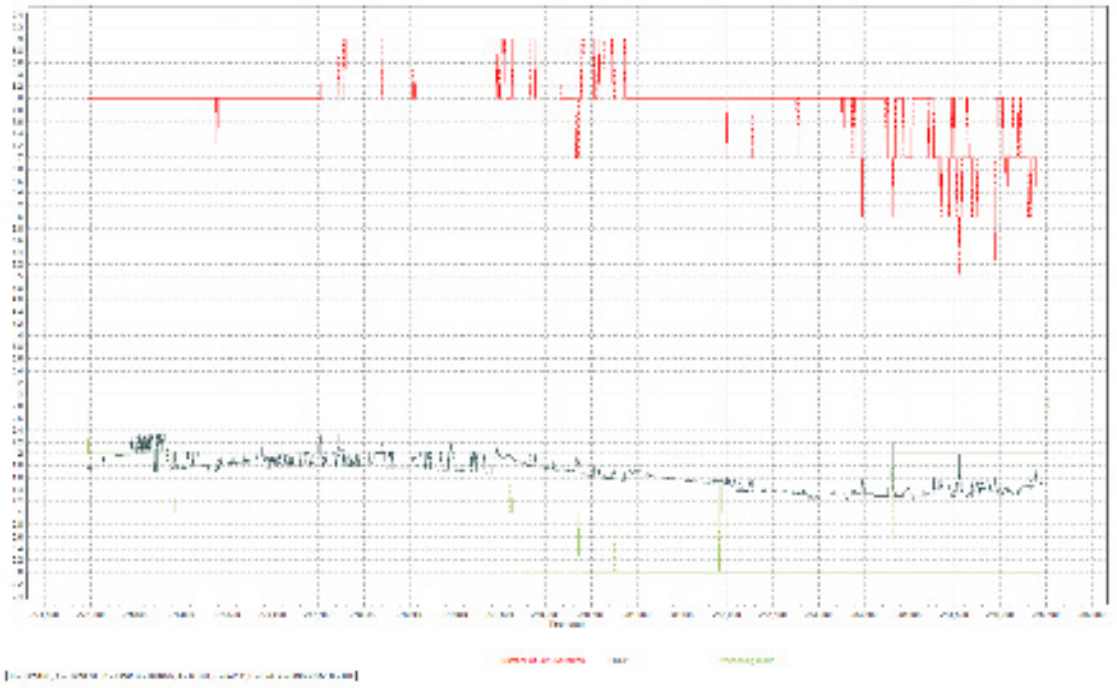


Figure A-8.99. Solution Status

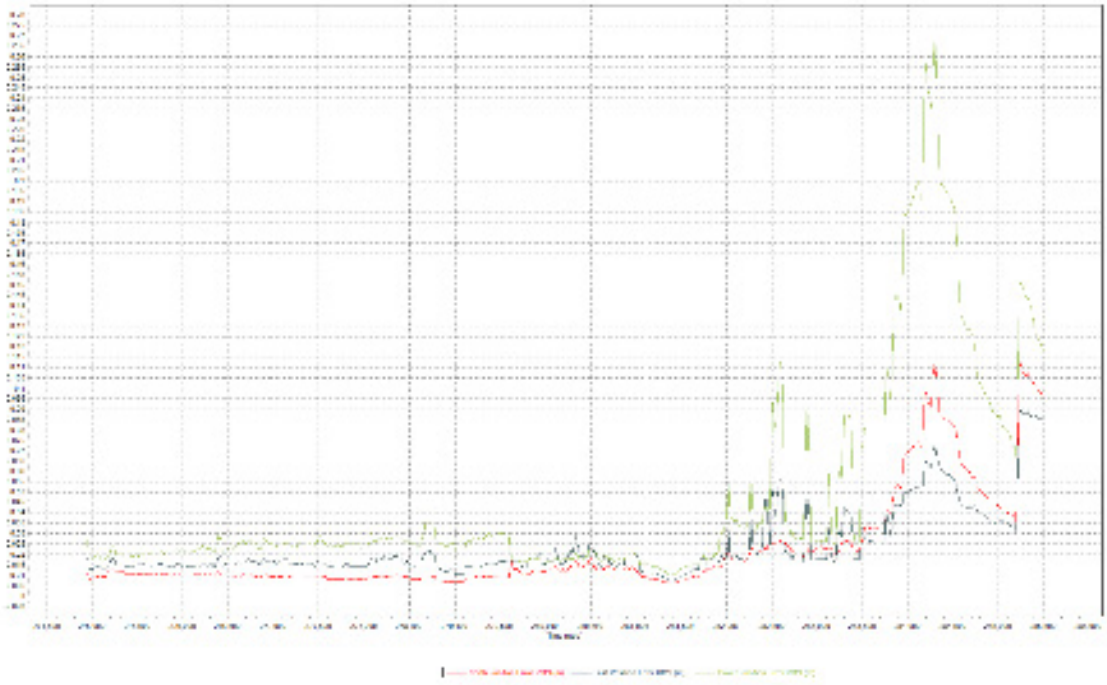


Figure A-8.100. Smoothed Performance Metric Parameters

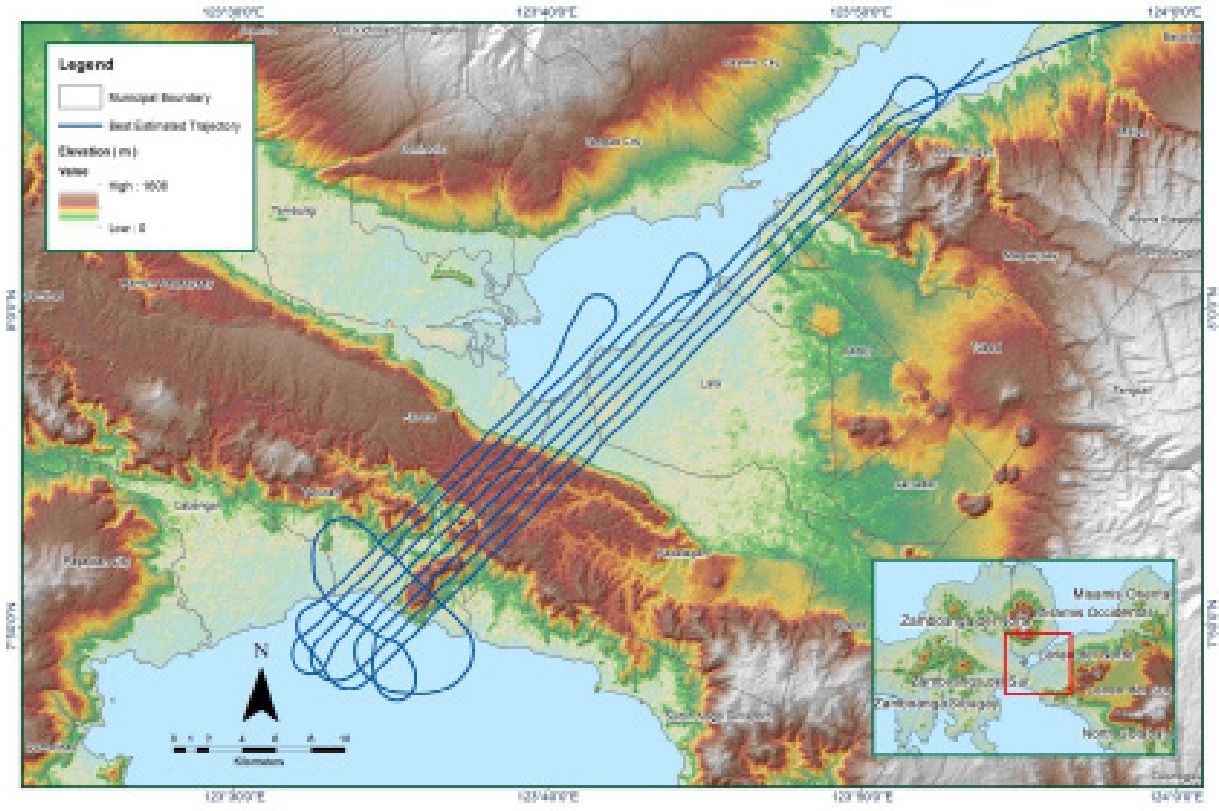


Figure A-8.101. Best Estimated Trajectory

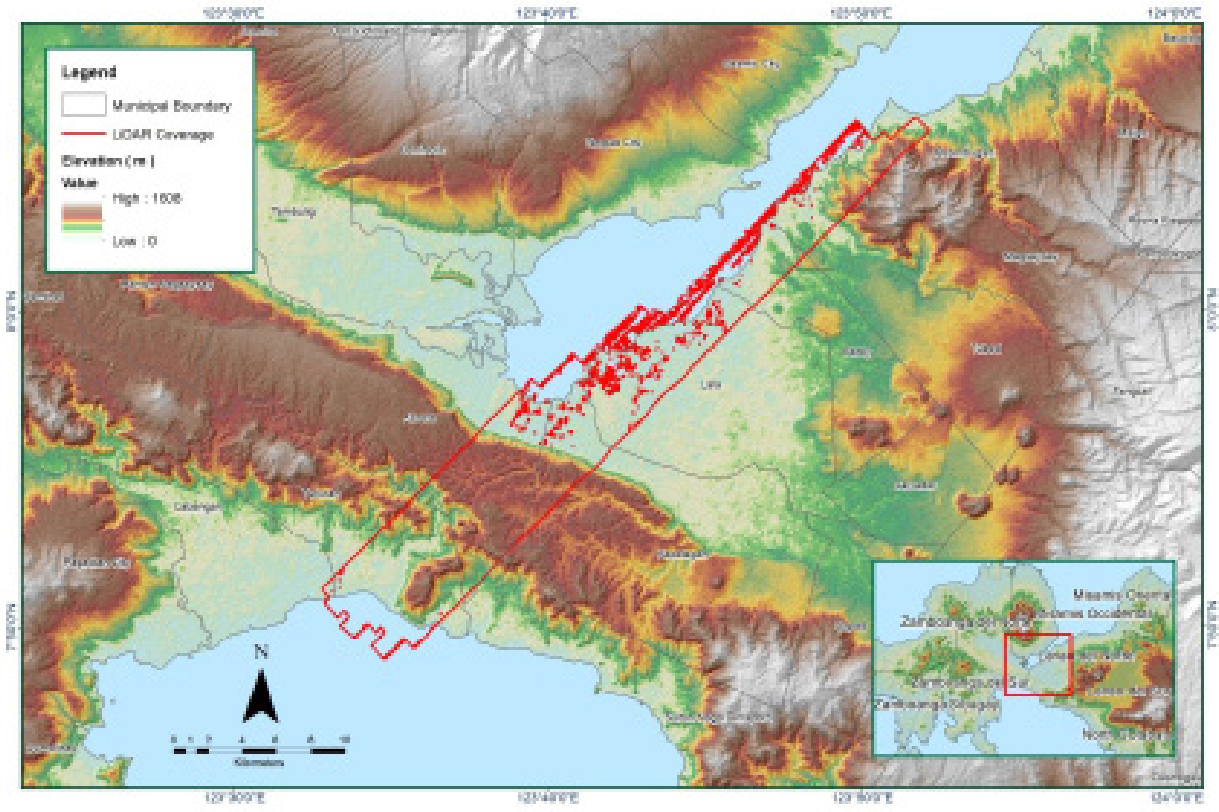


Figure A-8.102. Coverage of LiDAR Data

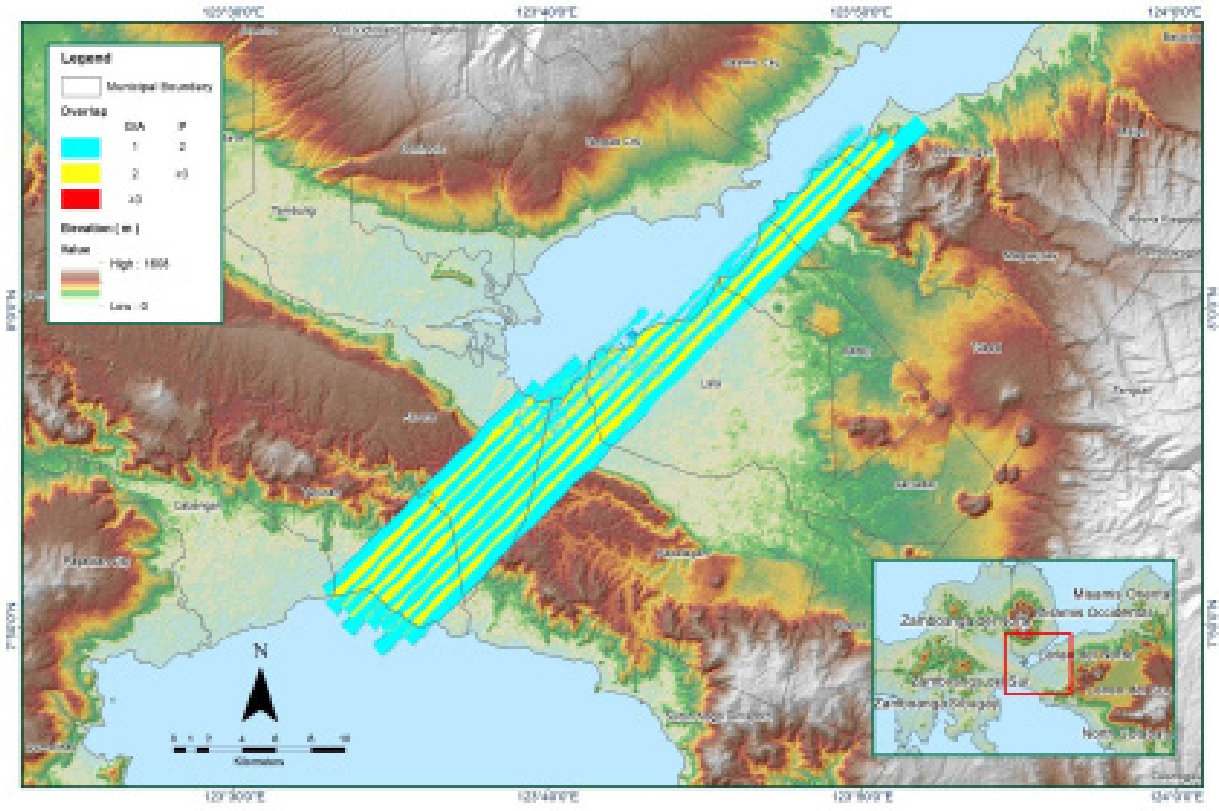


Figure A-8.103. Image of data overlap

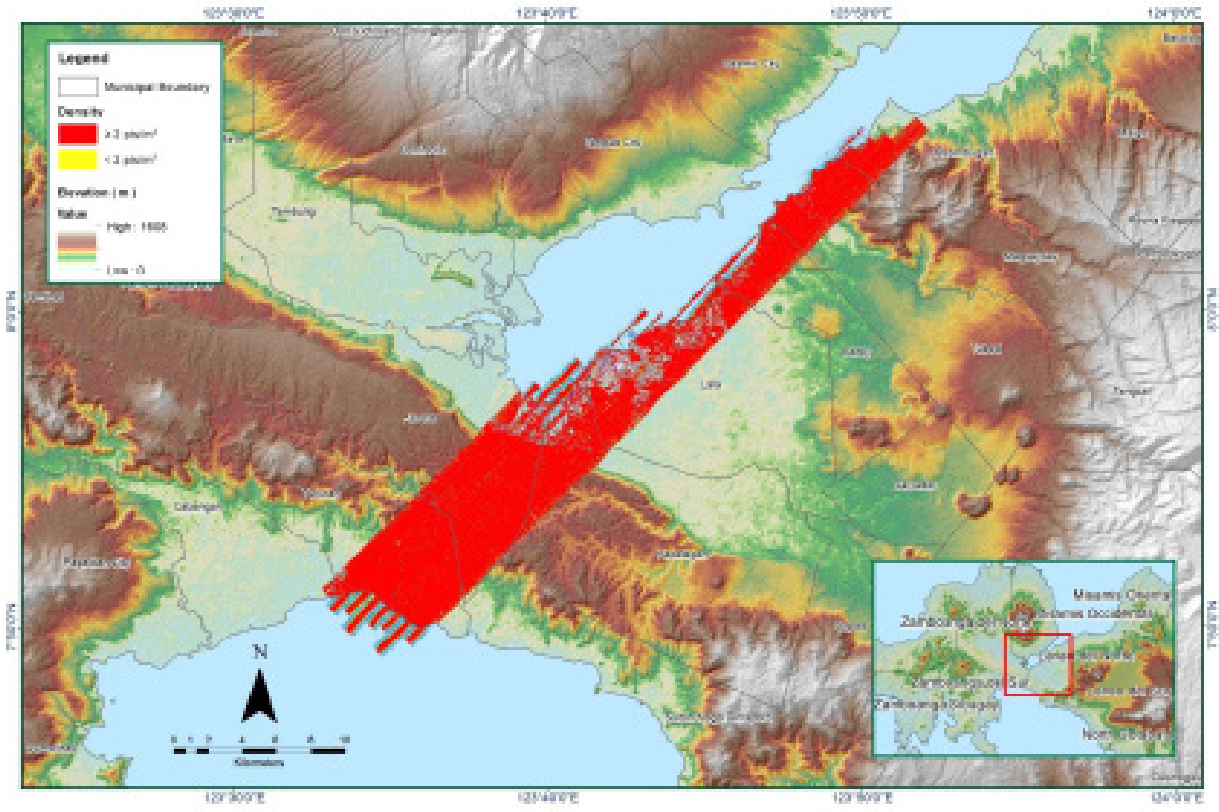


Figure A-8.104. Density map of merged LiDAR data

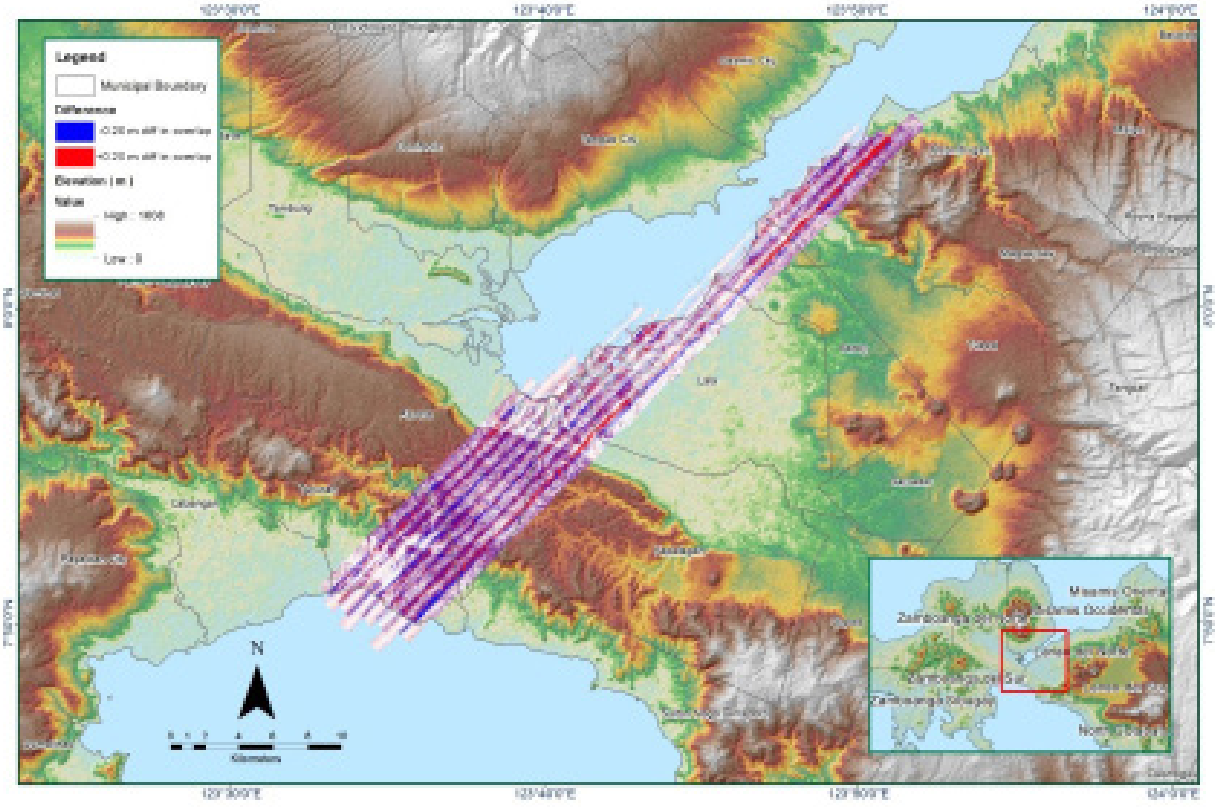


Figure A-8.105. Elevation difference between flight lines

Table A-8.16. Mission Summary Report for Mission Blk71F

Flight Area	Northern Mindanao
Mission Name	Blk71F
Inclusive Flights	1565P, 1549P, 1685P
Range data size	70.3 GB
POS data size	674 MB
Base data size	59.1 GB
Image	June 23, 2014
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)	1.1
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000471
IMU attitude correction stdev (<0.001deg)	0.004323
GPS position stdev (<0.01m)	0.0198
Minimum % overlap (>25)	51.56%
Ave point cloud density per sq.m. (>2.0)	4.06
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	614
Maximum Height	685.55
Minimum Height	64.65
Classification (# of points)	
Ground	591,908,481
Low vegetation	609,869,904
Medium vegetation	757,441,192
High vegetation	606,070,790
Building	21,867,436
Orthophoto	Yes

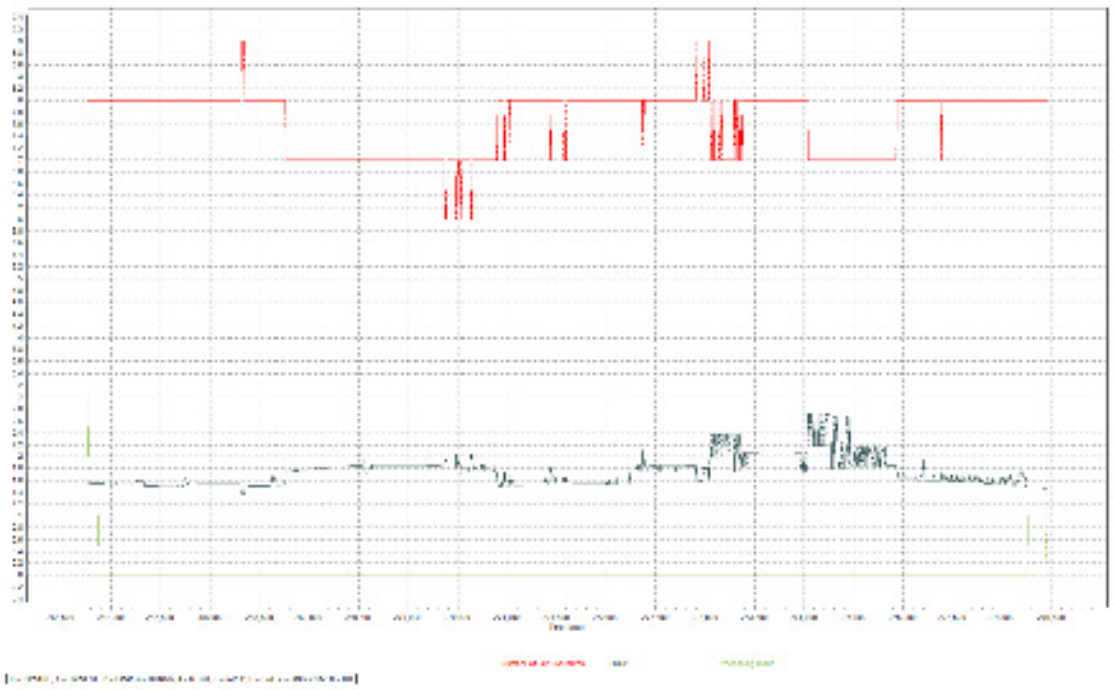


Figure A-8.106 Solution Status

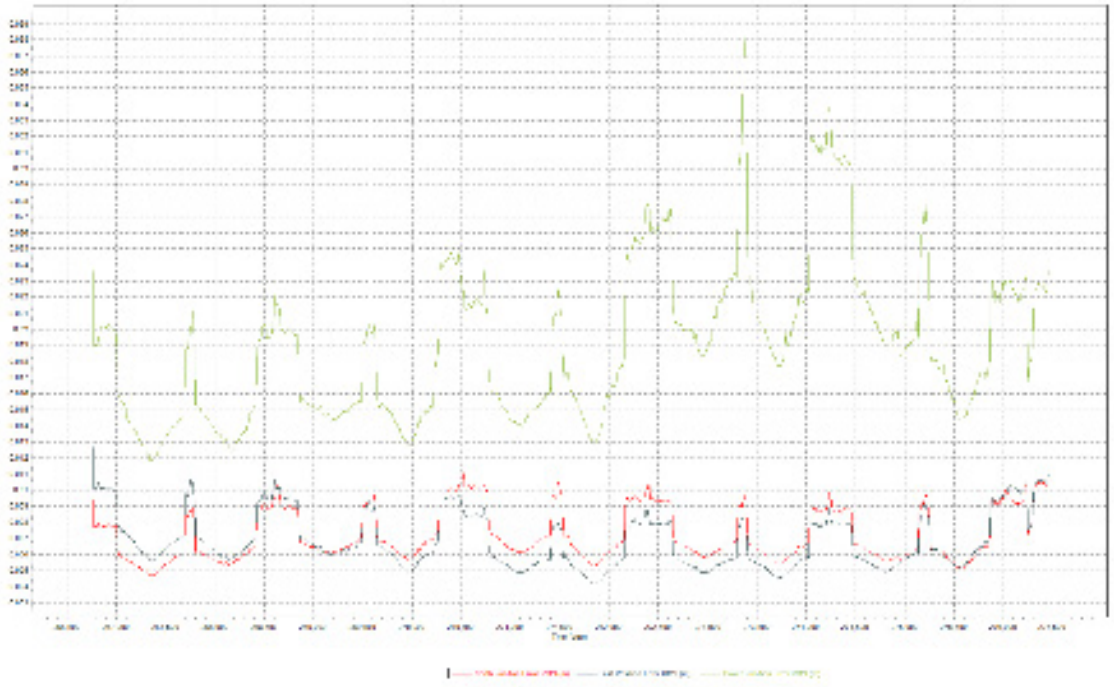


Figure A-8.107. Smoothed Performance Metric Parameters

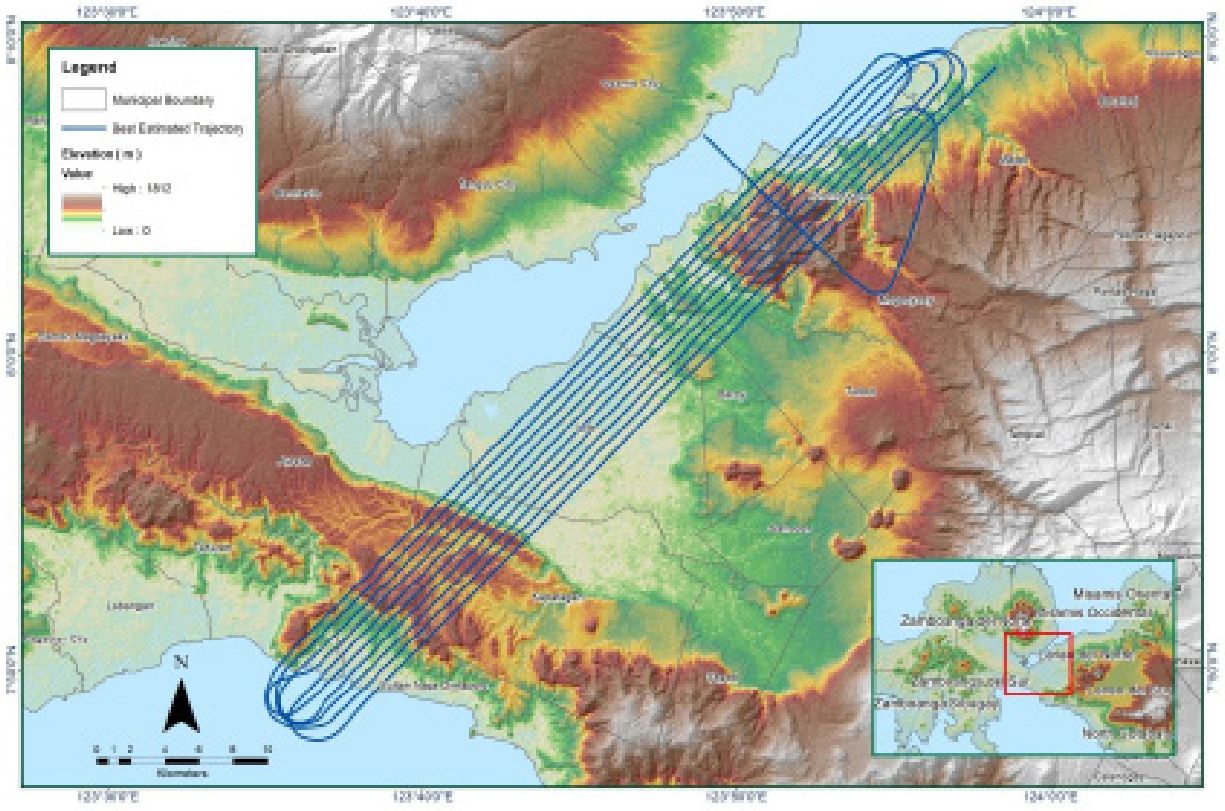


Figure A-8.108. Best Estimated Trajectory

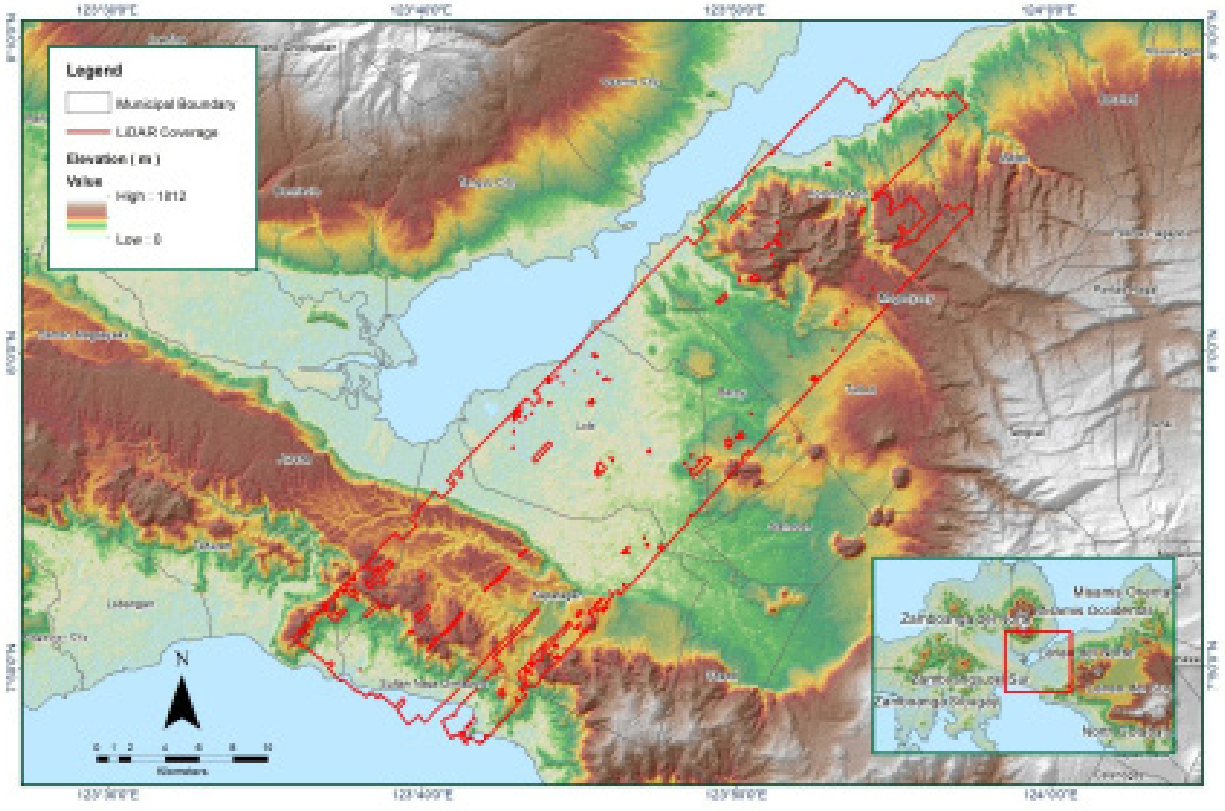


Figure A-8.109. Coverage of LiDAR Data

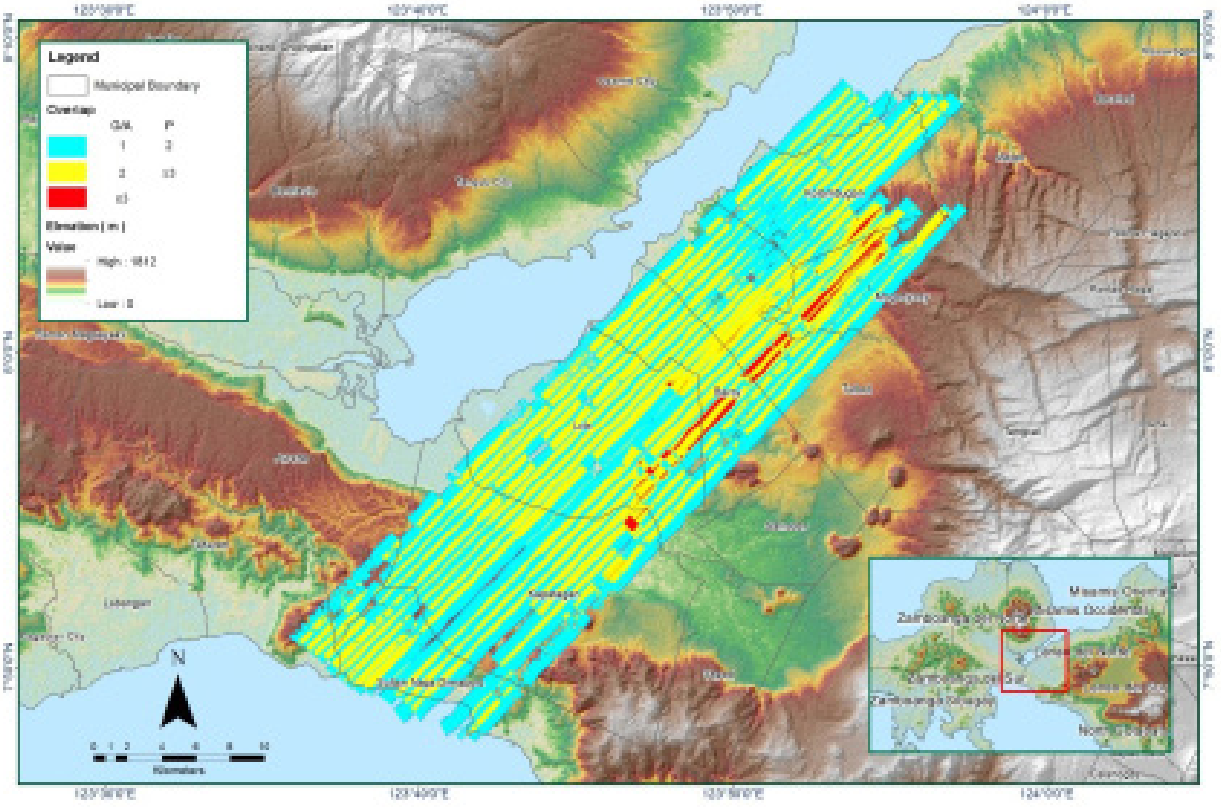


Figure A-8.110. Image of data overlap

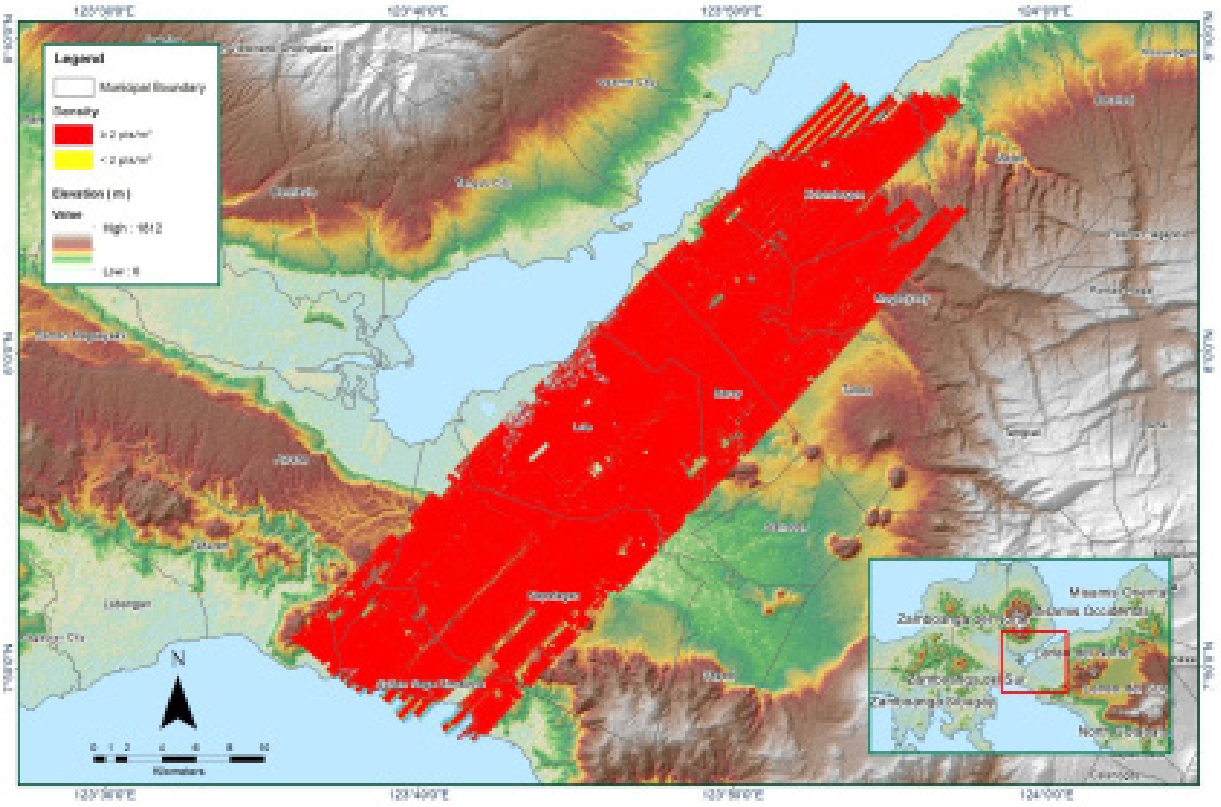


Figure A-8.111. Density map of merged LiDAR data

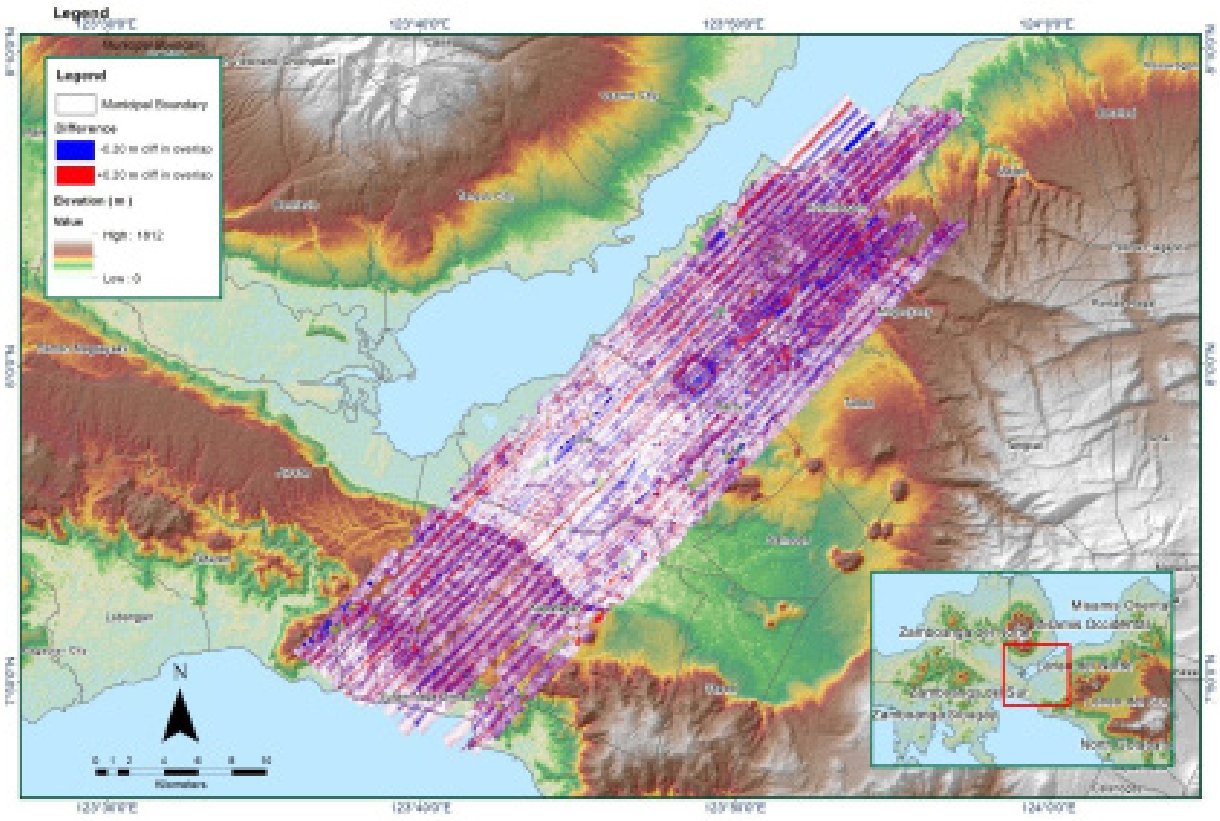


Figure A-8.112. Elevation difference between flight lines

Annex 9. Labangan Model Basin Parameters

Table A-9.1. Labangan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	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
W1000	63.6372841	56.164	0.0	1.16446	3.02337	Discharge	0.81874	1	Ratio to Peak	0.155
W1010	63.617	56.172	0.0	0.732842	1.90274	Discharge	0.64801	1	Ratio to Peak	0.155
W1020	35.4243429	69.712	0.0	0.302566	0.78561	Discharge	0.16296	1	Ratio to Peak	0.155
W1030	24.706	76.745	0.0	0.449438	1.1669	Discharge	0.82862	1	Ratio to Peak	0.155
W1040	31.571	72.087	0.0	0.412588	1.071245	Discharge	0.46033	1	Ratio to Peak	0.155
W1050	49.636	62.159	0.0	0.45837	1.190105	Discharge	0.44742	1	Ratio to Peak	0.155
W1060	29.965	73.125	0.0	0.479952	1.24614	Discharge	0.74696	1	Ratio to Peak	0.155
W1070	28.878	73.845	0.0	0.821326	2.13248	Discharge	1.9000	1	Ratio to Peak	0.155
W1080	46.258	63.802	0.0	0.692384	1.797705	Discharge	0.95484	1	Ratio to Peak	0.155
W1090	42.216	65.886	0.0	0.660462	1.714825	Discharge	1.2006	1	Ratio to Peak	0.155
W1100	41.286	66.385	0.0	0.83314	2.163105	Discharge	1.6907	1	Ratio to Peak	0.155
W560	38.563	67.890	0.0	0.614504	1.59551	Discharge	0.58185	1	Ratio to Peak	0.155
W570	63.094	56.375	0.0	0.697884	1.81195	Discharge	0.86807	1	Ratio to Peak	0.155
W580	58.364	58.281	0.0	1.14895	2.98312	Discharge	2.5814	1	Ratio to Peak	0.155
W590	58.894	58.061	0.0	1.108162	2.87721	Discharge	1.3319	1	Ratio to Peak	0.155
W600	52.041	61.040	0.0	1.260886	3.273725	Discharge	2.7161	1	Ratio to Peak	0.155
W610	60.951	57.223	0.0	0.816728	2.12051	Discharge	0.67906	1	Ratio to Peak	0.155
W620	59.333	57.880	0.0	0.708708	1.84002	Discharge	1.2340	1	Ratio to Peak	0.155
W630	65.0387075	55.627	0.0	0.822052	2.13437	Discharge	0.97413	1	Ratio to Peak	0.155
W640	59.042	58	0.0	0.417626	1.084335	Discharge	0.22564	1	Ratio to Peak	0.155

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	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
W650	68.925	54.190	0.0	0.584804	1.51837	Discharge	0.61612	1	Ratio to Peak	0.155
W670	53.790	60.251	0.0	0.44506	1.155525	Discharge	0.30238	1	Ratio to Peak	0.155
W680	73.247	52.677	0.0	0.675136	1.752905	Discharge	0.77646	1	Ratio to Peak	0.155
W690	49.581	62.185	0.0	1.038686	2.69682	Discharge	0.99003	1	Ratio to Peak	0.155
W700	32.683	71.385	0.0	0.27379	0.71085	Discharge	0.13536	1	Ratio to Peak	0.155
W710	36.339	69.171	0.0	0.541398	1.40567	Discharge	1.0072	1	Ratio to Peak	0.155
W720	59.545	57.793	0.0	0.55099	1.430555	Discharge	0.55586	1	Ratio to Peak	0.155
W730	57.781	58.525	0.0	0.646338	1.67811	Discharge	0.53419	1	Ratio to Peak	0.155
W740	24.136	77.159	0.0	0.32285	0.838215	Discharge	0.22116	1	Ratio to Peak	0.155
W760	37.988	68.217	0.0	0.546216	1.418165	Discharge	0.51159	1	Ratio to Peak	0.155
W770	51.368	61.349	0.0	0.451946	1.173445	Discharge	0.4585433	1	Ratio to Peak	0.155
W790	54.381	59.989	0.0	0.60577	1.57283	Discharge	0.65056	1	Ratio to Peak	0.155
W800	38.906	67.697	0.0	0.777722	2.019255	Discharge	0.87602	1	Ratio to Peak	0.155
W810	47.737	63.072	0.0	0.578248	1.50136	Discharge	0.71813	1	Ratio to Peak	0.155
W820	32.754	71.341	0.0	0.364584	0.94661	Discharge	0.42645	1	Ratio to Peak	0.155
W830	74.160	52.368	0.0	0.728442	1.89126	Discharge	1.1134	1	Ratio to Peak	0.155
W840	56.2458807	59.177	0.0	0.516252	1.34036	Discharge	0.77478	1	Ratio to Peak	0.155
W850	56.407	59.108	0.0	0.509146	1.321915	Discharge	0.51942	1	Ratio to Peak	0.155
W860	58.694	58.144	0.0	0.586454	1.370355	Discharge	0.68650	1	Ratio to Peak	0.155
W870	49.019	62.453	0.0	0.527802	1.370355	Discharge	0.86145	1	Ratio to Peak	0.155

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	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
W880	49.278	62.329	0.0	0.49115	1.275225	Discharge	0.49600	1	Ratio to Peak	0.155
W910	22.997	78	0.0	0.25135	0.652575	Discharge	0.12843	1	Ratio to Peak	0.155
W920	32.052	71.782	0.0	0.395846	1.02774	Discharge	0.46652	1	Ratio to Peak	0.155
W930	44.156	64.869	0.0	0.69344	1.800435	Discharge	0.49889	1	Ratio to Peak	0.155
W950	61.163	57.138	0.0	1.005796	2.61142	Discharge	1.8678	1	Ratio to Peak	0.155
W960	47.5388047	63.169	0.0	0.654566	1.69946	Discharge	0.74313	1	Ratio to Peak	0.155
W970	22.997	78	0.0	0.486244	1.262485	Discharge	0.47206	1	Ratio to Peak	0.155
W980	34.550	70.237	0.0	0.325798	0.84588	Discharge	0.31421	1	Ratio to Peak	0.155

Annex 10. Labangan Model Reach Parameters

Table A-10.1. Labangan Model Reach Parameters

Muskingum-Cunge Channel Routing							
Reach Number	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	Side Slope
R100	Automatic Fixed Interval	426.98	0.0022071	0.019	Trapezoid	68.142	1
R120	Automatic Fixed Interval	70.711	0.0037886	0.019	Trapezoid	50.062	1
R130	Automatic Fixed Interval	1968.1	0.0015048	0.019	Trapezoid	47.062	1
R160	Automatic Fixed Interval	3527.9	0.0032171	0.019	Trapezoid	52.138	1
R170	Automatic Fixed Interval	5791.3	0.0282395	0.019	Trapezoid	19.3025	1
R180	Automatic Fixed Interval	5179.2	0.0027361	0.019	Trapezoid	50.764	1
R190	Automatic Fixed Interval	3068.5	0.0034529	0.019	Trapezoid	20.12	1
R210	Automatic Fixed Interval	1130.5	.0008758828017581965	0.019	Trapezoid	71.058	1
R260	Automatic Fixed Interval	865.27	0.0135575	0.019	Trapezoid	26.992	1
R270	Automatic Fixed Interval	2316.9	0.0099952	0.019	Trapezoid	53.036	1
R280	Automatic Fixed Interval	713.14	0.0024604	0.019	Trapezoid	44.492	1
R290	Automatic Fixed Interval	3469.9	0.0028291	0.019	Trapezoid	44.482	1
R300	Automatic Fixed Interval	2417.5	0.0577566	0.019	Trapezoid	29.634	1
R330	Automatic Fixed Interval	1625.4	0.0073536	0.019	Trapezoid	62.896	1
R350	Automatic Fixed Interval	2909.4	0.0136856	0.019	Trapezoid	39.782	1
R380	Automatic Fixed Interval	5146.3	0.0074035	0.019	Trapezoid	33.658	1
R390	Automatic Fixed Interval	1826.4	0.0092365	0.019	Trapezoid	33.87	1
R40	Automatic Fixed Interval	7653.8	0.0165765	0.019	Trapezoid	12.74	1
R400	Automatic Fixed Interval	2076.5	0.0156066	0.019	Trapezoid	37.257	1
R410	Automatic Fixed Interval	211.42	0.0251975	0.019	Trapezoid	30.595	1
R420	Automatic Fixed Interval	1647.2	0.0085933	0.019	Trapezoid	23.1	1
R430	Automatic Fixed Interval	1442.3	0.0229847	0.019	Trapezoid	13.158	1
R450	Automatic Fixed Interval	2605.9	0.0323290	0.019	Trapezoid	17.582	1
R490	Automatic Fixed Interval	4994.3	0.0259402	0.019	Trapezoid	22.392	1

Annex 11. Labangan Field Validation Points

Table A-11.1. Labangan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Latitude	Longitude					
1	7.839859	123.453422	0.03	0	0.03	June 1, 2016	5 - Year
2	7.842456	123.451873	0.03	0	0.03	June 1, 2016	5 - Year
3	7.838454	123.457031	0.03	0.10	-0.07	June 1, 2016	5 - Year
4	7.830302	123.453395	0.03	0.15	-0.12	June 1, 2016	5 - Year
5	7.858746	123.461978	0.03	0	0.03	June 1, 2016	5 - Year
6	7.857845	123.463442	0.03	0	0.03	June 1, 2016	5 - Year
7	7.858637	123.457362	0.03	0	0.03	June 1, 2016	5 - Year
8	7.858219	123.457473	0.03	0	0.03	June 1, 2016	5 - Year
9	7.877264	123.537111	0.03	0	0.03	June 1, 2016	5 - Year
10	7.897020	123.512500	0.03	0.30	-0.27	June 1, 2016	5 - Year
11	7.895248	123.511821	0.03	0	0.03	June 1, 2016	5 - Year
12	7.875355	123.538149	0.03	0	0.03	June 1, 2016	5 - Year
13	7.873579	123.538303	0.03	0.58	-0.55	June 1, 2016	5 - Year
14	7.877758	123.530678	0.03	0	0.03	June 1, 2016	5 - Year
15	7.878842	123.530683	0.03	0	0.03	June 1, 2016	5 - Year
16	7.854314	123.549577	0.03	0.42	-0.39	June 1, 2016	5 - Year
17	7.854131	123.549024	0.03	0	-0.27	June 1, 2016	5 - Year
18	7.853942	123.546496	0.03	0	0.03	June 1, 2016	5 - Year
19	7.841743	123.528454	0.03	0.15	-0.12	June 1, 2016	5 - Year
20	7.840757	123.526709	0.03	0.29	-0.26	June 1, 2016	5 - Year
21	7.842481	123.528040	0.03	0	0.03	June 1, 2016	5 - Year
22	7.853559	123.532236	0.03	0.15	-0.12	June 1, 2016	5 - Year
23	7.851147	123.531918	0.03	0.20	-0.17	June 1, 2016	5 - Year
24	7.855854	123.523714	0.03	0	0.03	June 1, 2016	5 - Year
25	7.856711	123.521480	0.03	0	0.03	June 1, 2016	5 - Year
26	7.859058	123.518425	0.03	0.36	-0.33	June 1, 2016	5 - Year
27	7.862401	123.496994	0.03	0	0.03	June 1, 2016	5 - Year
28	7.861622	123.497024	0.03	0.20	-0.17	June 1, 2016	5 - Year
29	7.906151	123.489278	0.03	0	0.03	June 1, 2016	5 - Year
30	7.905085	123.489693	0.03	0.18	-0.15	June 1, 2016	5 - Year
31	7.905029	123.489298	0.03	1.28	-1.25	June 1, 2016	5 - Year
32	7.907871	123.486404	0.03	0.04	-0.01	June 1, 2016	5 - Year
33	7.908141	123.488876	0.03	0	0.03	June 1, 2016	5 - Year
34	7.902870	123.489296	0.03	0	0.03	June 1, 2016	5 - Year
35	7.901440	123.489408	0.03	0.07	-0.04	June 1, 2016	5 - Year
36	7.900172	123.490062	0.03	0.08	-0.05	June 1, 2016	5 - Year
37	7.897642	123.491076	0.03	0.16	-0.13	June 1, 2016	5 - Year
38	7.894552	123.492081	0.03	0.26	-0.23	June 1, 2016	5 - Year
39	7.860508	123.489425	0.03	0.24	-0.21	June 1, 2016	5 - Year
40	7.862784	123.492999	0.03	0.16	-0.13	June 1, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Latitude	Longitude					
41	7.847080	123.461118	0.03	0	0.03	June 1, 2016	5 - Year
42	7.875043	123.538138	0.03	0.24	-0.21	June 1, 2016	5 - Year
43	7.874207	123.530560	0.03	0.49	-0.46	June 1, 2016	5 - Year
44	7.853950	123.549812	0.03	0	0.03	June 1, 2016	5 - Year
45	7.841707	123.528137	0.03	0.15	-0.12	June 1, 2016	5 - Year
46	7.851590	123.531726	0.03	0	0.03	June 1, 2016	5 - Year
47	7.892100	123.510685	0.03	0.23	-0.2	June 1, 2016	5 - Year
48	7.908305	123.487311	0.03	0.23	-0.2	June 1, 2016	5 - Year
49	7.874442	123.531185	0.03	0	0.03	June 1, 2016	5 - Year
50	7.855065	123.547769	0.03	0.38	-0.35	June 1, 2016	5 - Year
51	7.863437	123.516283	0.03	0.24	-0.21	June 1, 2016	5 - Year
52	7.830361	123.500107	0.03	0.42	-0.39	June 1, 2016	5 - Year
53	7.840191	123.526878	0.03	0.35	-0.32	June 1, 2016	5 - Year
54	7.838369	123.513382	0.03	0	0.03	June 1, 2016	5 - Year
55	7.851391	123.457779	0.03	0	0.03	June 1, 2016	5 - Year
56	7.852216	123.465386	0.03	0	0.03	June 1, 2016	5 - Year
57	7.853974	123.545980	0.03	0	0.03	June 1, 2016	5 - Year
58	7.841837	123.527526	0.03	0	0.03	June 1, 2016	5 - Year
59	7.858649	123.518847	0.03	0	0.03	June 1, 2016	5 - Year
60	7.839369	123.453585	0.04	0	0.04	June 1, 2016	5 - Year
61	7.853817	123.547097	0.04	0	0.04	June 1, 2016	5 - Year
62	7.843107	123.462544	0.04	0.50	-0.46	June 1, 2016	5 - Year
63	7.841519	123.527841	0.04	0.42	-0.38	June 1, 2016	5 - Year
64	7.863836	123.485822	0.03	0.08	-0.05	June 1, 2016	5 - Year
65	7.864062	123.485928	0.04	0.14	-0.1	June 1, 2016	5 - Year
66	7.863134	123.495774	0.03	0.20	-0.17	June 1, 2016	5 - Year
67	7.854712	123.549077	0.04	0	0.04	June 1, 2016	5 - Year
68	7.854056	123.548251	0.04	0.18	-0.14	June 1, 2016	5 - Year
69	7.843751	123.483861	0.04	0	0.04	June 1, 2016	5 - Year
70	7.838728	123.454622	0.05	0	0.05	June 1, 2016	5 - Year
71	7.858894	123.458043	0.05	0	0.05	June 1, 2016	5 - Year
72	7.841635	123.527441	0.05	0	0.05	June 1, 2016	5 - Year
73	7.852484	123.532140	0.05	0.15	-0.1	June 1, 2016	5 - Year
74	7.837980	123.454725	0.05	0	0.05	June 1, 2016	5 - Year
75	7.862859	123.512518	0.04	0	0.04	June 1, 2016	5 - Year
76	7.861073	123.500535	0.03	0	0.03	June 1, 2016	5 - Year
77	7.853681	123.547941	0.05	0.56	-0.51	June 1, 2016	5 - Year
78	7.861657	123.488431	0.05	0.06	-0.01	June 1, 2016	5 - Year
79	7.845648	123.458413	0.06	0	0.06	June 1, 2016	5 - Year
80	7.850227	123.463272	0.06	0	0.06	June 1, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Latitude	Longitude					
81	7.874539	123.530541	0.06	0.26	-0.2	June 1, 2016	5 - Year
82	7.838491	123.514310	0.03	0.10	-0.07	June 1, 2016	5 - Year
83	7.849559	123.494391	0.03	0.31	-0.28	June 1, 2016	5 - Year
84	7.864283	123.486673	0.06	0	0.06	June 1, 2016	5 - Year
85	7.863806	123.485498	0.06	0.18	-0.12	June 1, 2016	5 - Year
86	7.837810	123.513353	0.04	0.17	-0.13	June 1, 2016	5 - Year
87	7.861577	123.500102	0.04	0.25	-0.21	June 1, 2016	5 - Year
88	7.843878	123.505544	0.03	0	0.03	June 1, 2016	5 - Year
89	7.852391	123.492362	0.04	0.23	-0.19	June 1, 2016	5 - Year
90	7.905630	123.489501	0.07	0	0.07	June 1, 2016	5 - Year
91	7.857297	123.520856	0.05	0.12	-0.07	June 1, 2016	5 - Year
92	7.843346	123.454347	0.04	0.05	-0.01	June 1, 2016	5 - Year
93	7.864139	123.514875	0.07	0.28	-0.21	June 1, 2016	5 - Year
94	7.852921	123.466611	0.08	0	0.08	June 1, 2016	5 - Year
95	7.862837	123.513036	0.06	0.13	-0.07	June 1, 2016	5 - Year
96	7.849178	123.462772	0.08	0	0.08	June 1, 2016	5 - Year
97	7.847754	123.460528	0.09	0	0.09	June 1, 2016	5 - Year
98	7.852584	123.457153	0.09	0	0.09	June 1, 2016	5 - Year
99	7.864243	123.491627	0.03	0.50	-0.47	June 1, 2016	5 - Year
100	7.860228	123.517657	0.1	0	0.1	June 1, 2016	5 - Year
101	7.847627	123.494500	0.07	0.31	-0.24	June 1, 2016	5 - Year
102	7.862728	123.487343	0.03	0	0.03	June 1, 2016	5 - Year
103	7.841224	123.456415	0.08	0	0.08	June 1, 2016	5 - Year
104	7.847452	123.501322	0.07	0	0.07	June 1, 2016	5 - Year
105	7.862847	123.515095	0.14	0.20	-0.06	June 1, 2016	5 - Year
106	7.850775	123.458266	0.14	0	0.14	June 1, 2016	5 - Year
107	7.837774	123.514037	0.03	0.30	-0.27	June 1, 2016	5 - Year
108	7.847406	123.494684	0.09	0.23	-0.14	June 1, 2016	5 - Year
109	7.852952	123.498405	0.03	0	0.03	June 1, 2016	5 - Year
110	7.863147	123.513722	0.18	0.18	0	June 1, 2016	5 - Year
111	7.852952	123.463696	0.15	0	0.15	June 1, 2016	5 - Year
112	7.897994	123.491116	0.22	0.07	0.15	June 1, 2016	5 - Year
113	7.844078	123.505257	0.03	0	0.03	June 1, 2016	5 - Year
114	7.888515	123.503156	0.05	0.40	-0.35	June 1, 2016	5 - Year
115	7.850809	123.510427	0.07	0.10	-0.03	June 1, 2016	5 - Year
116	7.846882	123.495216	0.14	0.31	-0.17	June 1, 2016	5 - Year
117	7.854867	123.499004	0.1	0.10	0	June 1, 2016	5 - Year
118	7.897939	123.490977	0.29	0.38	-0.09	June 1, 2016	5 - Year
119	7.874124	123.529828	0.2	0.63	-0.43	June 1, 2016	5 - Year
120	7.841271	123.463268	0.1	1.26	-1.16	June 1, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Latitude	Longitude					
121	7.873011	123.528499	0.21	0.29	-0.08	June 1, 2016	5 - Year
122	7.899036	123.490554	0.25	0	0.25	June 1, 2016	5 - Year
123	7.888491	123.503081	0.14	0.42	-0.28	June 1, 2016	5 - Year
124	7.873464	123.538060	0.27	0.42	-0.15	June 1, 2016	5 - Year
125	7.852884	123.504956	0.27	0.40	-0.13	June 1, 2016	5 - Year
126	7.852190	123.496428	0.35	0	0.35	June 1, 2016	5 - Year
127	7.844479	123.504898	0.15	0	0.15	June 1, 2016	5 - Year
128	7.901536	123.489697	0.31	0.04	0.27	June 1, 2016	5 - Year
129	7.854525	123.499092	0.27	0	0.27	June 1, 2016	5 - Year
130	7.846845	123.511949	0.33	0.40	-0.07	June 1, 2016	5 - Year
131	7.872529	123.528114	0.28	0.22	0.06	June 1, 2016	5 - Year
132	7.888833	123.503040	0.27	0.45	-0.18	June 1, 2016	5 - Year
133	7.859459	123.501869	0.32	0	0.32	June 1, 2016	5 - Year
134	7.842154	123.463673	0.28	0	0.28	June 1, 2016	5 - Year
135	7.844145	123.467931	0.34	0.56	-0.22	June 1, 2016	5 - Year
136	7.851830	123.466007	0.39	0	0.39	June 1, 2016	5 - Year
137	7.853116	123.499480	0.41	0.1	0.31	June 1, 2016	5 - Year
138	7.872361	123.527861	0.37	0.16	0.21	June 1, 2016	5 - Year
139	7.888862	123.503013	0.37	0.22	0.15	June 1, 2016	5 - Year
140	7.860693	123.490196	0.27	0.04	0.23	June 1, 2016	5 - Year
141	7.872276	123.527539	0.41	0.1	0.31	June 1, 2016	5 - Year
142	7.852307	123.500979	0.5	0	0.5	June 1, 2016	5 - Year
143	7.852614	123.501327	0.54	0	0.54	June 1, 2016	5 - Year
144	7.843767	123.506629	0.43	0	0.43	June 1, 2016	5 - Year
145	7.850453	123.527187	0.39	0.57	-0.18	June 1, 2016	5 - Year
146	7.840615	123.513886	0.38	0	0.38	June 1, 2016	5 - Year
147	7.889722	123.502273	0.46	0.6	-0.14	June 1, 2016	5 - Year
148	7.859239	123.491725	0.39	0.04	0.35	June 1, 2016	5 - Year
149	7.841572	123.513221	0.48	0	0.48	June 1, 2016	5 - Year
150	7.843274	123.455533	0.53	1.05	-0.52	June 1, 2016	5 - Year
151	7.842365	123.508719	0.54	0.2	0.34	June 1, 2016	5 - Year
152	7.852944	123.501354	0.67	0	0.67	June 1, 2016	5 - Year
153	7.825748	123.453206	0.47	1.37	-0.9	June 1, 2016	5 - Year
154	7.844201	123.511420	0.63	0	0.63	June 1, 2016	5 - Year
155	7.855844	123.500679	0.75	0.2	0.55	June 1, 2016	5 - Year
156	7.895047	123.510119	0.1	0.42	-0.32	June 1, 2016	5 - Year
157	7.860736	123.490473	0.61	0	0.61	June 1, 2016	5 - Year
158	7.889336	123.502328	0.76	0.3	0.46	June 1, 2016	5 - Year
159	7.842517	123.512547	0.8	0	0.8	June 1, 2016	5 - Year
160	7.842542	123.509533	0.96	0.3	0.66	June 1, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Latitude	Longitude					
161	7.889287	123.502248	1.04	0.6	0.44	June 1, 2016	5 - Year
162	7.860731	123.498978	1.07	0.65	0.42	June 1, 2016	5 - Year
163	7.854540	123.501356	1.25	0	1.25	June 1, 2016	5 - Year
164	7.861492	123.494412	1.08	0	1.08	June 1, 2016	5 - Year
165	7.888843	123.502782	1.28	0.2	1.08	June 1, 2016	5 - Year
166	7.888861	123.502770	1.28	0.1	1.18	June 1, 2016	5 - Year
167	7.866091	123.490544	1.07	0	1.07	June 1, 2016	5 - Year
168	7.842936	123.509792	1.36	0.38	0.98	June 1, 2016	5 - Year
169	7.842949	123.509908	1.4	0.28	1.12	June 1, 2016	5 - Year
170	7.892810	123.502746	1.41	0.44	0.97	June 1, 2016	5 - Year
171	7.891477	123.501978	1.43	0.56	0.87	June 1, 2016	5 - Year
172	7.896291	123.484041	0.96	0	0.96	June 1, 2016	5 - Year
173	7.843489	123.509654	1.59	0.21	1.38	June 1, 2016	5 - Year
174	7.888854	123.502757	1.65	0.3	1.35	June 1, 2016	5 - Year
175	7.860667	123.499353	1.96	0.4	1.56	June 1, 2016	5 - Year
176	7.858148	123.501748	2.14	0.28	1.86	June 1, 2016	5 - Year
177	7.907699	123.488980	0.42	0	0.42	June 1, 2016	5 - Year
178	7.858874	123.501501	2.32	0	2.32	June 1, 2016	5 - Year
179	7.892047	123.502375	2.29	0.68	1.61	June 1, 2016	5 - Year
180	7.893861	123.485117	1.84	0	1.84	June 1, 2016	5 - Year
181	7.893680	123.485171	1.99	0.36	1.63	June 1, 2016	5 - Year
182	7.866116	123.490649	2.32	0	2.32	June 1, 2016	5 - Year
183	7.892067	123.502309	2.62	0.3	2.32	June 1, 2016	5 - Year
184	7.892472	123.502722	2.78	0.57	2.21	June 1, 2016	5 - Year
185	7.892642	123.502799	2.86	0.49	2.37	June 1, 2016	5 - Year
186	7.859175	123.501319	3.29	0	3.29	June 1, 2016	5 - Year
187	7.860928	123.490986	3.85	0.18	3.67	June 1, 2016	5 - Year
188	7.841623	123.449397	0.03	0	0.03	June 1, 2016	5 - Year
189	7.831318	123.437873	0.03	0	0.03	June 1, 2016	5 - Year
190	7.832668	123.441838	0.03	0	0.03	June 1, 2016	5 - Year
191	7.835095	123.441969	0.03	0	0.03	June 1, 2016	5 - Year
192	7.835181	123.442095	0.03	0	0.03	June 1, 2016	5 - Year
193	7.830522	123.446898	0.03	0	0.03	June 1, 2016	5 - Year
194	7.823568	123.432283	0.03	0	0.03	June 1, 2016	5 - Year
195	7.823246	123.431877	0.03	0.19	-0.16	June 1, 2016	5 - Year
196	7.824947	123.437110	0.03	0	0.03	June 1, 2016	5 - Year
197	7.829141	123.433862	0.03	0	0.03	June 1, 2016	5 - Year
198	7.824589	123.434145	0.03	0	0.03	June 1, 2016	5 - Year
199	7.826742	123.418677	0.03	0	0.03	June 1, 2016	5 - Year
200	7.824822	123.432814	0.03	0	0.03	June 1, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Latitude	Longitude					
201	7.826247	123.432861	0.03	0	0.03	June 1, 2016	5 - Year
202	7.828956	123.430034	0.03	0	0.03	June 1, 2016	5 - Year
203	7.826085	123.429984	0.03	0	0.03	June 1, 2016	5 - Year
204	7.825269	123.424281	0.03	0	0.03	June 1, 2016	5 - Year
205	7.825523	123.420895	0.03	0	0.03	June 1, 2016	5 - Year
206	7.825600	123.422689	0.03	0	0.03	June 1, 2016	5 - Year
207	7.826121	123.422441	0.03	0	0.03	June 1, 2016	5 - Year
208	7.825608	123.421432	0.03	0	0.03	June 1, 2016	5 - Year
209	7.826108	123.420104	0.03	0	0.03	June 1, 2016	5 - Year
210	7.826770	123.419688	0.03	0	0.03	June 1, 2016	5 - Year
211	7.828480	123.422859	0.03	0	0.03	June 1, 2016	5 - Year
212	7.829338	123.439711	0.03	0	0.03	June 1, 2016	5 - Year
213	7.826786	123.442976	0.03	0	0.03	June 1, 2016	5 - Year
214	7.828132	123.443602	0.03	0	0.03	June 1, 2016	5 - Year
215	7.827646	123.449827	0.03	0	0.03	June 1, 2016	5 - Year
216	7.829367	123.451850	0.03	0.11	-0.08	June 1, 2016	5 - Year
217	7.823733	123.430916	0.03	0	0.03	June 1, 2016	5 - Year
218	7.823712	123.434478	0.03	0	0.03	June 1, 2016	5 - Year
219	7.827475	123.428575	0.03	0	0.03	June 1, 2016	5 - Year
220	7.826007	123.423604	0.03	0	0.03	June 1, 2016	5 - Year
221	7.825933	123.428291	0.03	0	0.03	June 1, 2016	5 - Year
223	7.825633	123.423976	0.03	0	0.03	June 1, 2016	5 - Year
224	7.828600	123.437446	0.03	0	0.03	June 1, 2016	5 - Year
225	7.831053	123.445142	0.03	0	0.03	June 1, 2016	5 - Year
226	7.830423	123.448501	0.03	0	0.03	June 1, 2016	5 - Year
227	7.830616	123.444961	0.04	0	0.04	June 1, 2016	5 - Year
228	7.824447	123.431779	0.03	0	0.03	June 1, 2016	5 - Year
229	7.824053	123.439122	0.04	0	0.04	June 1, 2016	5 - Year
230	7.828449	123.438913	0.04	0	0.04	June 1, 2016	5 - Year
231	7.829904	123.442707	0.04	0	0.04	June 1, 2016	5 - Year
232	7.832758	123.445075	0.04	0	0.04	June 1, 2016	5 - Year
233	7.837918	123.449725	0.04	0	0.04	June 1, 2016	5 - Year
234	7.823678	123.436363	0.04	0	0.04	June 1, 2016	5 - Year
235	7.825058	123.436052	0.04	0	0.04	June 1, 2016	5 - Year
236	7.829883	123.435280	0.04	0	0.04	June 1, 2016	5 - Year
237	7.826682	123.431959	0.04	0	0.04	June 1, 2016	5 - Year
238	7.825982	123.427891	0.04	0	0.04	June 1, 2016	5 - Year
239	7.827638	123.440747	0.05	0	0.05	June 1, 2016	5 - Year
240	7.828502	123.427585	0.05	0	0.05	June 1, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Latitude	Longitude					
241	7.823995	123.435942	0.04	0	0.04	June 1, 2016	5 - Year
242	7.826276	123.441069	0.05	0	0.05	June 1, 2016	5 - Year
243	7.830048	123.442970	0.06	0	0.06	June 1, 2016	5 - Year
244	7.828398	123.433832	0.06	0	0.06	June 1, 2016	5 - Year
245	7.824555	123.430904	0.06	0	0.06	June 1, 2016	5 - Year
246	7.831551	123.435763	0.05	0	0.05	June 1, 2016	5 - Year
247	7.823354	123.435727	0.05	0	0.05	June 1, 2016	5 - Year
248	7.825506	123.438403	0.06	0	0.06	June 1, 2016	5 - Year
249	7.824984	123.435760	0.06	0	0.06	June 1, 2016	5 - Year
250	7.828260	123.435381	0.06	0	0.06	June 1, 2016	5 - Year
251	7.835222	123.442353	0.06	0	0.06	June 1, 2016	5 - Year
252	7.842034	123.448178	0.07	0	0.07	June 1, 2016	5 - Year
253	7.828736	123.439584	0.07	0	0.07	June 1, 2016	5 - Year
254	7.823255	123.434049	0.03	0	0.03	June 1, 2016	5 - Year
255	7.824910	123.433786	0.03	0	0.03	June 1, 2016	5 - Year
256	7.832585	123.445531	0.08	0	0.08	June 1, 2016	5 - Year
257	7.837739	123.448794	0.08	0	0.08	June 1, 2016	5 - Year
258	7.832494	123.445741	0.09	0	0.09	June 1, 2016	5 - Year
259	7.823752	123.430412	0.05	0	0.05	June 1, 2016	5 - Year
260	7.824191	123.442067	0.11	0	0.11	June 1, 2016	5 - Year
261	7.824151	123.443867	0.04	0	0.04	June 1, 2016	5 - Year
262	7.824924	123.449582	0.06	0.28	-0.22	June 1, 2016	5 - Year
263	7.836060	123.444937	0.09	0.09	0	June 1, 2016	5 - Year
264	7.827142	123.444642	0.03	0.28	-0.25	June 1, 2016	5 - Year
265	7.825985	123.425260	0.03	0	0.03	June 1, 2016	5 - Year
266	7.826343	123.447680	0.21	0	0.21	June 1, 2016	5 - Year
267	7.833093	123.439319	0.41	0	0.41	June 1, 2016	5 - Year
268	7.833019	123.438810	0.43	0	0.43	June 1, 2016	5 - Year
269	7.833272	123.438254	0.51	0.05	0.46	June 1, 2016	5 - Year
270	7.827960	123.433620	0.36	0	0.36	June 1, 2016	5 - Year
271	7.832320	123.440401	0.85	0	0.85	June 1, 2016	5 - Year
272	7.836225	123.448243	0.85	0.65	0.2	June 1, 2016	5 - Year
273	7.833272	123.437834	1.33	0	1.33	June 1, 2016	5 - Year
274	7.823226	123.429716	1.53	0.06	1.47	June 1, 2016	5 - Year
275	7.824351	123.429782	1.72	0	1.72	June 1, 2016	5 - Year
276	7.825254	123.427121	2.15	0	2.15	June 1, 2016	5 - Year
277	7.826490	123.421676	2.06	0.98	1.08	June 1, 2016	5 - Year

Annex 12. Educational Institutions affected by flooding in Labangan Floodplain

Table A-12.1. Educational Institutions in Labangan, Zamboanga del Sur affected by flooding in Labangan Floodplain

ZAMBOANGA DEL SUR				
LABANGAN				
Building Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Balimbingan Elementary School	Balimbingan			
Day Care Center	Balimbingan			
Day Care Center	Bokong			Low
Bulanit Elementary School	Bulanit			
Day Care Center	Bulanit			
Tawagan Sur Elementary School	Bulanit	Medium	Medium	Medium
Day Care Center	Combo			
Alhadeetha Mindanao College	Dalapang		Low	
Dalapang Elementary School	Dalapang		Medium	Low
Dalapang Islamic School	Dalapang	Medium	High	Medium
Day Care Center	Dalapang	Low	Medium	Medium
Mahaad Al Islamic School	Dalapang			
Datu Ampanas Elementary School Faculty Office	Dimasangca			
Grade Low	Dimasangca			
Grade Medium	Dimasangca			
Grade High-4	Dimasangca			
Grade 5-6	Dimasangca			
Madrasa	Dimasangca			Low
Upper Bayao Elementary School	Dimasangca			
Day Care Center	Lantian			
Lantian Elementary School	Lantian		Low	
Tabak National High School	Lantian			
Lower Pulacan Elementary School	Lower Pulacan			
Tabak National High School	Lower Pulacan			
Arabic School	Lower Sang-An	Medium	Medium	Medium
Day Care Center	Lower Sang-An	Medium	Medium	Medium
Old Labangan Elementary School	Lower Sang-An	Low	Medium	Medium
Brgy. Day Care Center	New Labangan			
Day Care Center	New Labangan	High	High	High
Madrasah Ibno Taymiah Al Islamie	New Labangan	High	High	High
New Labangan Primary School	New Labangan			
Combo Elementary School	Old Labangan			
Day Care Center	Old Labangan			
Brgy. San Isidro Elementary School	San Isidro			

ZAMBOANGA DEL SUR				
LABANGAN				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
Day Care Center	San Isidro			
Bokong Elementary and National High School	Santa Cruz	Medium	High	High
Sta. Cruz Elementary School	Santa Cruz			
Tapodoc National High School	Tapodoc	Low	Medium	Medium
Day Care Center	Tapodoc	High	High	High
Tapodoc Elementary School	Tapodoc	Medium	Medium	Medium
Tawagan Norte Elementary School	Tawagan Norte		Low	
Tawagan Norte National High School	Tawagan Norte			
Day Care Center	Upper Campo Islam			
Madrasa Afdal Al- Islamia	Upper Campo Islam			
Day Care Center	Upper Pulacan			
Tabak Elementary School	Upper Pulacan			
Upper Pulacan Elementary School	Upper Pulacan			
Arabic School	Upper Sang-An		Low	Low
Sang-an Elementary School	Upper Sang-An	Low	Medium	Low

Table A-12.2. Educational Institutions in Pagadian City, Zamboanga del Sur affected by flooding in Labangan Floodplain

ZAMBOANGA DEL SUR				
PAGADIAN CITY				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Dumagoc Elem School	Balangasan			
Dumagoc Elem. School	Balangasan			
Sta. Lucia Central Elem. School	Balangasan	Medium	Medium	Medium
Sta. Lucia Elem. School	Balangasan	Medium	Medium	Medium
ZSMIT	Balangasan			
School bldg	Banale			
School Bldg	Banale			
School Bldg.	Banale			
'ZSNHS Bldg.	Bulatok			
The P.E.P. Foundation Inc.	Bgy. 40 - Cruzada			
Ben Sagun Elementary	Bulatok			
Brgy. Tuburan Central Elem. School	Bulatok			
Daycare Center	Bulatok			
Medina College	Bulatok			
Paglaum II Day Care Center	Bulatok			
Principal's Office	Bulatok			
School Bldg. 5	Bulatok			
School Building Low	Bulatok			
School Building Medium	Bulatok			
School Building High	Bulatok			
School Building 6	Bulatok			
School Buildng 4	Bulatok			
SDA Elem. School	Bulatok			
Division office	Dao			
Tomas Sagun Elem. School	Dao			
SMC Engineering	Gatas			
SMC College	Gatas			
Day Care Center	Kawit	Low	Low	Medium
Guard House	Kawit			
Kawit Elem. School	Kawit	Low	Low	Medium
Library	Kawit		Low	Low
Principal's Office	Kawit	Low	Low	Low
Divine Word College	Bgy. 8 - Bagumbayan	Medium	Medium	Medium

ZAMBOANGA DEL SUR				
PAGADIAN CITY				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
School Bldg	Kawit			
School Bldg.	Kawit	<Null>	<Null>	<Null>
School Gym	Kawit	Low	Medium	Medium
South Hills Vocational School	Kawit		Low	Low
ZSSAT Function Hall	Kawit			Low
ZSSAT High School	Kawit			
Co Tek Chun National Trade School	Lenienza	Medium	Medium	Medium
Day Care Center	Lenienza			
Lenienza Elementary School	Lenienza			
Pagadian College of Criminology Training Ground Shed	Lenienza			
PCC Training Ground Shed	Lenienza		Low	Low
Tiguma Elementary School	Lenienza			
'ZSNHS Bldg.	Lumbia			
'ZSNHS JICA Bldg.	Lumbia			
Camp Abelon Elem. School Waiting Shed	Lumbia		Low	Low
Daycare Center	Lumbia	<Null>	<Null>	<Null>
Pagadian Capitol College	Lumbia			
PCC Bulding	Lumbia			
Prk Limonsito Day Care Center	Lumbia			
School Bldg	Lumbia			
School Covered Court	Lumbia	<Null>	<Null>	<Null>
SMC Elementary School	Lumbia			
Upper Lumboy Day Care Center	Lumbia			
ZSNHS - Mediumnd yr	Lumbia			
ZSNHS Gym	Lumbia			
ZSNHS Admin Bldg	Lumbia			
School Bldg	San Francisco			
Columban College Gym	San Francisco	Low	Low	Low
Kumon	San Francisco			
Lucan College	San Francisco			
Pablo Litigio Elem School Bldg	San Francisco			
Prime Horizon School	San Francisco			

ZAMBOANGA DEL SUR				
PAGADIAN CITY				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Saint Columban College	San Francisco			
Zamboanga del Sur Eduacation Center	San Francisco			
Columban Bldg	San Jose			Low
Day Care Center	San Jose			
Division office	San Jose			
EMCOTECH	San Jose			
Holy Child Academy	San Jose			
Jack N Jill Preschool	San Jose			
Saint Coumban Elementary	San Jose			
Tomas Sagun Elem. School	San Jose			
San Pedro Elem. School	San Pedro	Low	Low	Low
San Pedro National High School Annex Stage	San Pedro		Low	Low
School Bldg	San Pedro			
School Bldg.	San Pedro			Low
Warlito T. Pulmones (Memorial) Elem. School	San Pedro			
Sta. Lucia National High School	Santa Lucia	Medium	Medium	Medium
Sta. Lucia Central Elem. School	Santa Lucia	Medium	Medium	Medium
Sta. Lucia National High School	Santa Lucia	Medium	Medium	Medium
'ZSNHS Bldg.	Santa Maria			
Day care center	Santa Maria			
Happy Hearts Montersori School	Santa Maria			
Library	Santa Maria			Low
Pagadian Golden School	Santa Maria	Medium	Medium	Medium
Pagadian Montesorri Center	Santa Maria			
School Stage	Santa Maria	Low	Low	Medium
Science Lab	Santa Maria	Low	Medium	Medium
SMC Elementary School	Santa Maria	Medium	Medium	Medium
ZNSHS -SciCur	Santa Maria	Low	Low	Medium
ZS-PCTA	Santa Maria	Low	Low	Medium
ZSNHS - Mediumnd yr	Santa Maria	Low	Low	Medium
School Bldg	Santiago	Low	Low	Medium

ZAMBOANGA DEL SUR				
PAGADIAN CITY				
Name	**Barangay**	**Rainfall Scenario**		
		5-YR	**25-YR**	**100-YR**
School Bldg.	Santiago			
Warlito T. Pulmones (Memorial) Elem. School	Santiago			
School Bldg	Santo Niño			
Sto. Nino Elem. School	Santo Niño			
Yllana Bay view College	Santo Niño			
Balangasan Central Elem. School	Santo Niño			
Balangasan Central Elem. School Gym	Santo Niño			
Phil. Technological & Marine Sciences	Santo Niño			
ZSMIT	Santo Niño			
Arabic School (Madrasa)	Tawagan Sur	Medium	High	High
Madrasa	Tawagan Sur	Low	Medium	Medium
Tawagan Sur Elementary School	Tawagan Sur	Low	Medium	Medium
Tawagan Sur National High School	Tawagan Sur	Low	Low	Medium
Arabic School (Madrasa)	Tiguma	Low	Medium	Medium
Co Tek Chun National Trade School	Tiguma			Low
Pagadian Avenue Learning Center	Tiguma			
Tiguma Elementary School	Tiguma			
Unibersidad de Zamboanga	Tiguma			
Pagadian Capitol College	Tuburan			
PCC	Tuburan			
Day Care Center	Tulawas			
Tulawas Integrated School	Tulawas			
Day Care Center	White Beach			
Muricay Elementary School	White Beach			
School Bldg	White Beach		Low	Medium
ZSSAT High School	White Beach			

Table A-12.3. Educational Institutions in Tukuran, Zamboanga del Sur affected by flooding in Labangan Floodplain

ZAMBOANGA DEL SUR				
TUKURAN				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Day Care Center	Alindahaw			
Panduma Elementary School	Alindahaw			Low
Camanga Day Care Center	Camanga	Low	Low	Low
Camanga Elementary School	Camanga			
Curvada Elementary School	Curvada			
Libertad Elementary School	Curvada			
Day Care Center	Lower Bayao			
Jose Suico Memorial Central School	Lower Bayao			
DayCare Center	Luy-A			
HE(Home Econ) Building	Luy-A			
Home Economics & Faculty Office	Luy-A			
Luy-a Elementary School	Luy-A	Low	Low	Medium
Luy-a Elementary Schoolk	Luy-A	Medium	Medium	Medium
Principal's Office/ Pre-School Classroom	Luy-A			
Tabuan Elementary School	Luy-A			
Tabuan Elementary School (Grade 4-6)	Luy-A			
Tabuan Elementary School Grade Low-4	Luy-A			
Tabuan National High School (Grade 7-Low)	Luy-A			
Day Care Center	Luy-A		Low	Low
Daycare Center	Militar	Medium	Medium	Medium
Faculty Office	Militar			
Militar Elementary School	Militar			
Militar Elementary School (Grade 4-6)	Militar			
Militar Elementary School (Grae Low-High)	Militar			
Militar Elementary School New Building (KALAHI-CIDSS)	Militar			
Day Care	Panduma Senior			
Panduma Elementary School	Panduma Senior		Low	Medium
Technical Vocational Highschool Campus Medium	Panduma Senior			
Technical Vocational Highschool Campus High	Panduma Senior			
Day Care	San Carlos			
Technical Vocational Highschool Campus Low	San Carlos			
Tukuran Central School	San Carlos			
Tukuran SPED Center	San Carlos			

ZAMBOANGA DEL SUR				
TUKURAN				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Seventh Day Adventist School of Church	San Carlos			
Bible Baptist Church	Santo Niño			
Day Care Center	Santo Niño			
Hyrons College Philippines	Santo Niño			
Star Of The Sea High School	Santo Niño			
Sto.NiÃ±o Central Elementary School	Santo Niño			Low
Sto.Niño Central Elementary School	Santo Niño			
Tinotungan Day Care Center	Tinotungan	Medium	High	High
Tinotungan Elementary School	Tinotungan			

Annex 13. Health Institutions affected by flooding in Labangan Floodplain

Table A-13.1. Health Institutions in Labangan, Zamboanga del Sur affected by flooding in Labangan Floodplain

ZAMBOANGA DEL SUR				
LABANGAN				
Building Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
New Health Center	Bokong			
Health Center	Bulanit	Low	Low	Low
Health Center	Combo			
Health Center	Dalapang	Medium	Medium	Medium
Health Center	Dimasangca			
Health Center	Lantian			
Health Center	Lower Campo Islam			
Health Center	Lower Pulacan			
H.A. Sindatoc Pharmacy	New Labangan	Medium	Medium	Medium
Health Center	New Labangan	High	High	High
Barangay Health Center	Old Labangan		Medium	Medium
Health Center	Santa Cruz			
Tawagan Norte Health Center	Tawagan Norte	Medium	Medium	Medium
Health Center	Upper Pulacan			

Table A-13.2. Health Institutions in Pagadian City, Zamboanga del Sur affected by flooding in Labangan Floodplain

ZAMBOANGA DEL SUR				
PAGADIAN CITY				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Brgy. Health Center	Balangasan			
Dumagoc New Health Center	Balangasan			
JH Jamellarin Hospital	Balintawak			
JH Jamellarin Hospital	Banale			
Chiong Clinic	Gatas			
SDC Clinic	Gatas			
Dental Clinic	Gatas			
Virata Medical Clinic	Gatas			
Health Center	Lenienza			
Dental Clinic	Lumbia			
Metro Pagadian Hospital	Lumbia			
Pagadian Doctor's Hospital	Lumbia			
Cabahug Dental Clinic	San Francisco			
Cabahug Hospital	San Francisco			Low
Dental Clinic	San Francisco			
Hofeleña Hospital	San Francisco			
Mother and Baby Care	San Francisco			
Pagadian City Medical Center	San Francisco			
SDC Clinic	San Francisco			
The Generic Pharmacy	San Francisco			
Aizah Hospital	San Pedro		Low	Low
Brgy. San Pedro Health Center	San Pedro			Low
Sta Lucia Main Health Center	Santa Lucia	Medium	Medium	Medium
Brgy. Health Center	Santa Maria	Medium	Medium	Medium
Grace Clinic	Santa Maria	Low	Low	Low
Ade Rico Optical	Santiago			Low
Edding Medical Clinic	Santiago			
Health Center	Santo Niño			
Health Center	Tawagan Sur			
Old Health Center	Tiguma			
Brgy. Birthing Home	Tuburan		Low	Low
Brgy. Health Center	Tulawas			
Health Center'	White Beach			

Table A-13.3. Health Institutions in Tukuran, Zamboanga del Sur affected by flooding in Labangan Floodplain

ZAMBOANGA DEL SUR				
TUKURAN				
Building Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Camanga Health Station	Camanga			
Botika ng Barangay	Curvada			
Tabak Hospital	Sambulawan			
Health Center	Santo Niño			