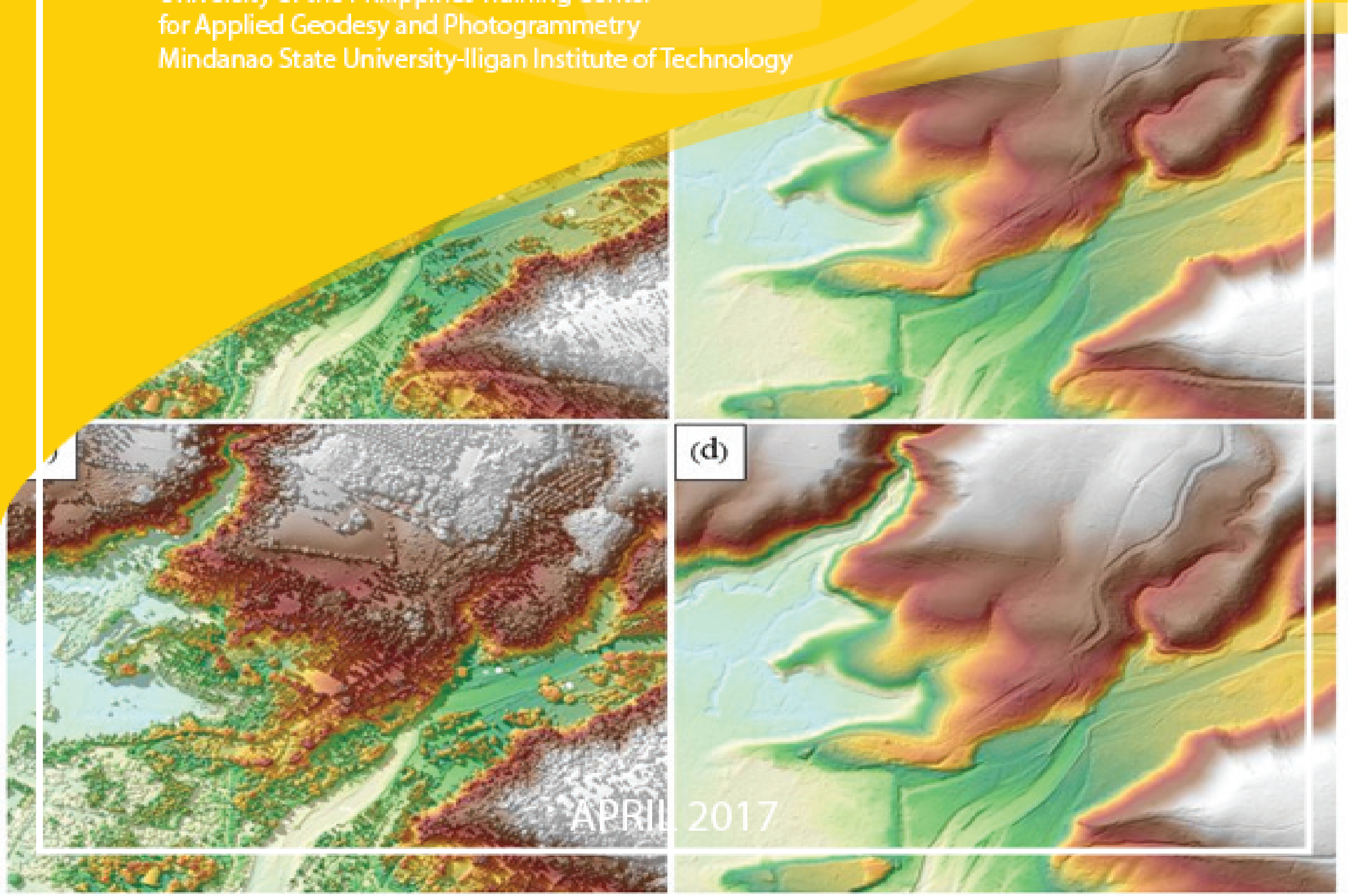
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Salug Diut 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
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit

kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
MSU-IIT	Mindanao State University – Iligan Institute of Technology
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SALUG DIUT RIVER

Enrico C. Paringit, Dr. Eng., Alan E. 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.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled 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. The university is located in Iligan City in the province of Lanao del Norte.

1.2 Overview of the Salug Diut River Basin

The Salug River Basin is located in the Municipality of Molave, Zamboanga del Sur. It is situated in the northeastern point of the province of Zamboanga del Sur. It has an approximate land area of 259 square kilometers with the estimated run-off of 874 MCM.

The Salug Diut River Basin is composed of four tributaries, namely: the main stream Salug Diut River, Parasan River, Usugan River, and Sudlon Creek. Salug Diut River is approximately 23.6 km in length and drains towards Visayan Sea. There is a total of 24,828 people living within the immediate vicinity of the river distributed among 11 barangays namely: Bogo Capalaran, Maloloy-on, Madasigon, and Blancia in the municipality of Molave, and barangays Upper Tiparak, Happy Valley, Lower Tiparak, Tungawan, Angeles, Kapalaran, and San Jose in the municipality of Tambulig according to 2010 census conducted by the NSO. Parts of the areas covered by the basin are cultivated for agricultural products such as coconut, cereal, and sugar, while other areas are developed for commercial and industrial use such as copra farms and lumber production. Flash floods occurred near the riverside last October 7, 2015 when Typhoon Lando hit most of the Zamboanga Peninsula with intermittent rainfall.

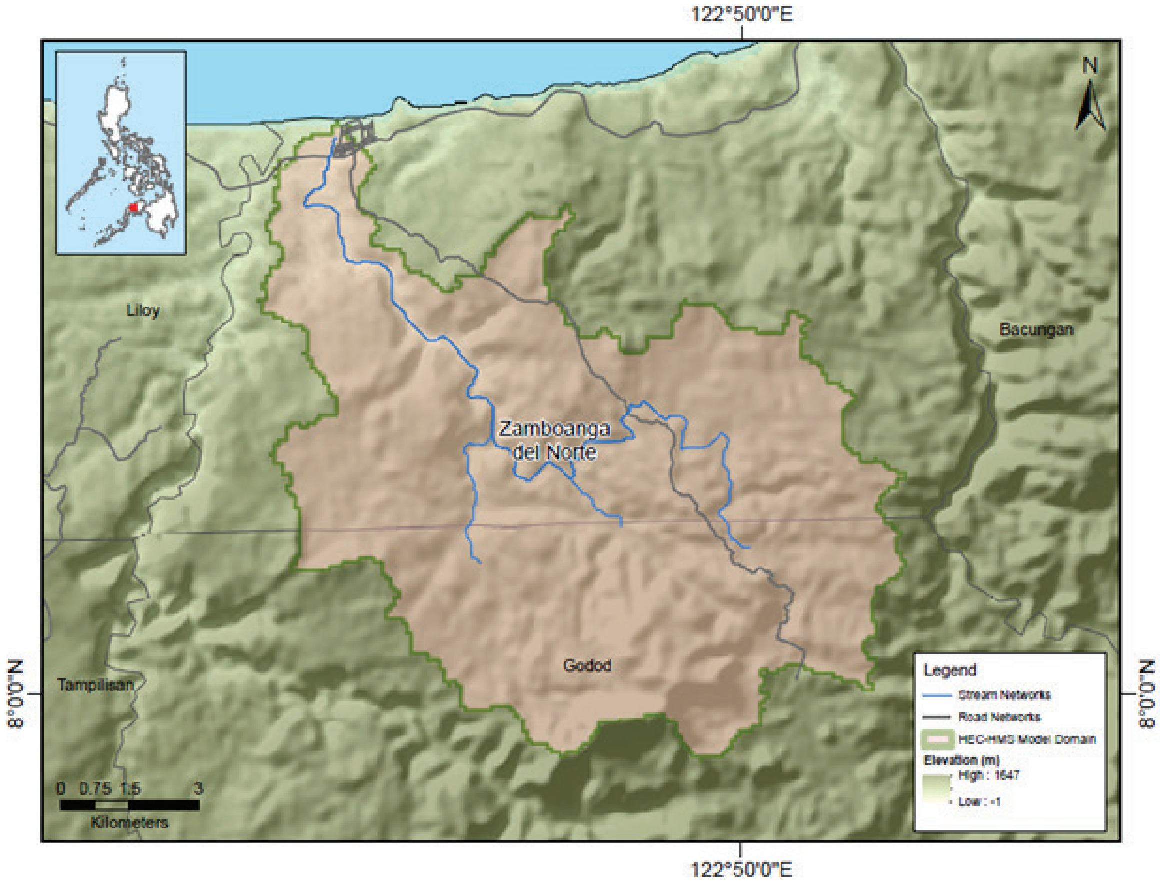

Figure 1. Map of the Salug Diut River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SALUG DIUT 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 Salug Diut Floodplain in Zamboanga del Sur province. These 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 Pegasus LiDAR system used are found in Table 1. Figure 2 shows the flight plan for Salug Diut Floodplain. ANNEX 1 shows the technical specification of the Pegasus LiDAR system and aerial camera.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed	Average Turn Time (Minutes)
BLK71E	1000/1200	30	50	200	30	120	5
BLK71Ext	550/1000	30	50	200	30	120	5
BLK71ABC	1200	30	50	200	30	120	5
BLK76E	1000/1200	30	50	200	30	120	5
BLK76F	1000/1200	30	50	200	30	120	5
BLK76G	1200/1100	30	50	200	30	120	5
BLK76H	1200	30	50	200	30	120	5
BLK76I	1200	30	50	200	30	120	5
BLK76J	1200	30	50	200	30	120	5
BLK76N	1200	30	50	200	30	120	5
BLK70A	1200	30	50	200	30	120	5
BLK72A	1200	30	50	200	30	120	5
BLK73A	1200	30	50	200	30	120	5

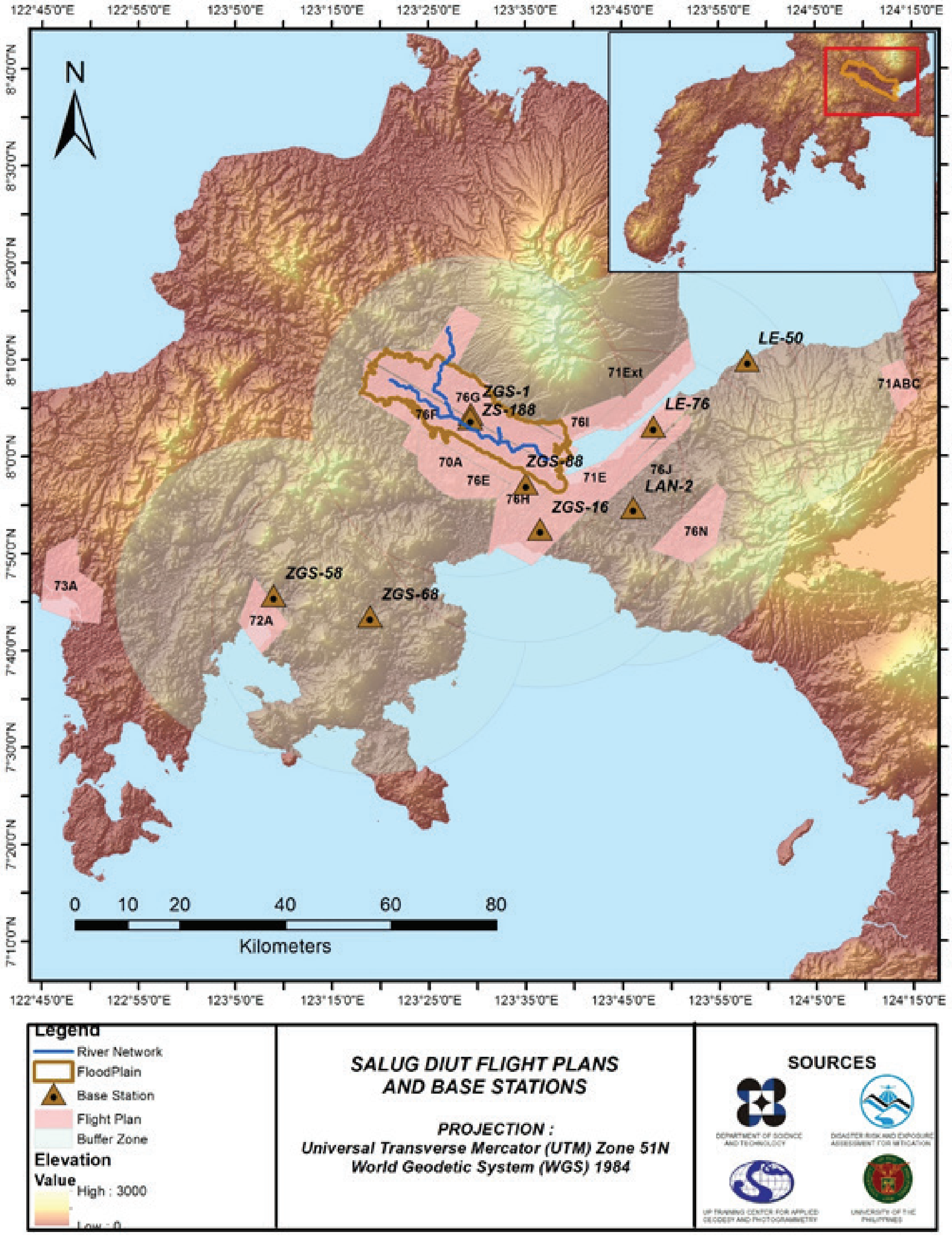

Figure 2. Flight plans and base stations used for Salug Diut Floodplain

2.2 Ground Base Station

Two (2) NAMRIA first-order accuracy ground control points (GCP): LAN-2 and ZGS-1, and four (4) second-order accuracy GCPs: ZGS-16, ZGS-58, ZGS-68, and ZGS-88 were recovered for use as base station during the survey. Also, LE-50, LE-76, and ZS-188, which are high-accuracy benchmarks, were used and re-processed as 2nd order control points for the project's accuracy. The certifications for the NAMRIA reference points are found in ANNEX 2 while the baseline processing reports are found in ANNEX 3. These points were used as base stations or reference points during flight operations for the entire duration of the survey (July 5 to July 9, 2014 and February 7 to 16 and 26, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, SPS 882, SPS 985, and Topcon GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Salug Diut Floodplain are shown in Figure 2 above.

Figure 3 to Figure 11 show the recovered NAMRIA reference points within the area, while Table 2 to Table 10 present the corresponding details about the following NAMRIA control stations and established points. In addition, Table 11 shows the list of all ground control points occupied in line with their respective mission names and flight numbers, together with the dates of acquisition. The data transfer sheets are found in ANNEX 6.

Figure 3. a) LAN-2 as recovered on top of a concrete irrigation canal water gate in Brgy. Pinoyak, under the municipality of Lala, Lanao del Norte; b) NAMRIA reference point LAN-2 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 data acquisition

Station Name	**LAN-2**	
Order of Accuracy	**1st Order**	
Relative Error (horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 54' 46.07859" N 123° 46' 0.85333" E 17.354 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 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" N 123° 46' 6.31720" E 83.9212 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984	Easting Northing	584,533.45 meters 874,680.35 meters

Figure 4. a) GPS set-up of ZGS-1 at National Irrigation Administration (NIA) compound, Brgy. Dipolo, Molave, Zamboanga del Sur; b) NAMRIA reference point ZGS-1 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 Order**	
Relative Error (horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 4' 26.98334" N 123° 29' 14.53868" E 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° 4' 23.40249" N 123° 29' 19.99013" E 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

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 Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 52’ 35.53106” N 123° 36’ 23.39905” E 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” N 123° 36’ 28.86762” E 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

Figure 6. a) GPS set-up over ZGS-58 a tBrgy. Sicade, Municipality of Kumalarang, Zamboanga del Sur; b) NAMRIA reference point ZGS-58 as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point ZGS-58 used as base station for the LiDAR data acquisition

Station Name	**ZGS-58**	
Order of Accuracy	**2nd Order**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 45’ 44.20587” N 123° 8’ 50.40994” E 31.65 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	516,245.79 meters 857,966.20 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 45’ 40.67639” N 123° 8’ 55.89231” E 96.974 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	516,245.79 meters 857,966.20 meters

Figure 7. a) GPS set-up over ZGS-68 at CENRO, Brgy. Poblacion, Municipality of Guipos, Zamboanga del Sur; b) NAMRIA reference point ZGS-58 as recovered by the field team

Table 6. 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 Order**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 43’ 33.12722” N 123° 18’ 488.96041” E 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” N 123° 18’ 54.44472” E 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

Figure 8. a) GPS set-up over ZGS-88 on a wedge-shaped island in Puroy Saray, Aurora, Zamboanga del Sur; b) NAMRIA reference point ZGS-88 as recovered by the field team

Table 7. Details of the recovered NAMRIA horizontal control point ZGS-88 used as base station for the LiDAR data acquisition

Station Name	ZGS-88	
Order of Accuracy	2ndOrder	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 57’ 13.25316” N 123° 34’ 56.50093” E 258.345 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	564,207.26 meters 879,474.685 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 57’ 9.71271” N 123° 35’ 1.96243” E 324.373 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	564,184.79 meters 879,166.85 meters

Figure 9. a) GPS set-up over LE-50 at the SW end of Barogohan Bridge and at the NE of the Covenant Baptist Church. Station is located at the town of Maigo, Lanao del Norte. b) NAMRIA reference point LE-50 as recovered by the field team

Table 8. Details of the recovered NAMRIA bench mark LE-50 with processed coordinates used as base station for the LiDAR data acquisition

Station Name	**LE-50**	
Order of Accuracy (vertical)	**1st Order**	
Relative Error (horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 09’ 54.972” N 123° 57’ 50.357” E 6.91 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	385,831.49 meters 902,974.41 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 09’ 51.11024” N 123° 57’ 55.36634” E 73.452 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	606,345.902 meters 902,577.426 meters

Figure 10. a) LE-76 as recovered at the southwest end of Bulod Bridge footwalk of Brgy. Bulod, Tubud, Lanao del Norte; b) NAMRIA reference point LE-76 as recovered by the field team

Table 9. Details of the recovered NAMRIA bench mark LE-76 with processed coordinates used as base station for the LiDAR data acquisition

Station Name	LE-76	
Order of Accuracy	**2nd Order**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 03’ 05.36825” N 123° 48’ 12.37307” E 9.355 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	368,112.93 meters 890,447.29 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 03’ 01.82183” N 123° 48’ 17.82405” E 75.717 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	588,530.790meters 890,021.013 meters

Figure 11. a) GPS set-up over ZS-188 at Dipolo Bridge, Brgy. Dipolo, Molave, Zamboanga del Sur; b) NAMRIA reference point ZS-188 as recovered by the field team

Table 10. Details of the recovered NAMRIA bench mark ZS-188 with processed coordinates used as base station for the LiDAR data acquisition

Station Name	**ZS-188**	
Order of Accuracy (vertical)	**1st Order**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 03' 56.69408" N 123° 29' 14.53868" E 19.832 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	553,627.634 meters 891,542.089 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 03' 53.11537" N 123° 29' 17.60722" E 85.4 meters

Table 11. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
5 JUL 2014	1673P	1BLK71S186A	LAN-2 & ZGS-88
6 JUL 2014	1677P	1BLK71S187A	LAN-2 & ZGS-88
9 JUL 2014	1689P	1BLK71S190A	LE-50 & LE-76
7 FEB 2016	23064P	1BLK76EF038A	ZGS-1 & ZS-188
7 FEB 2016	23066P	1BLK76F038B	ZGS-1 & ZS-188
9 FEB 2016	23072P	1BLK76EF040A	ZGS-1 & ZS-188
9 FEB 2016	23074P	1BLK76EFH040B	ZGS-1 & ZS-188
10 FEB 2016	23076P	1BLK76GH041A	ZGS-1 & ZS-188
13 FEB 2016	23088P	1BLK76ILM044A	ZGS-16 & ZS-188
14 FEB 2016	23092P	1BLK76GHI045A	ZGS-1 & ZS-188
16 FEB 2016	23100P	1BLK76EFG047A	ZGS-1 & ZS-188
26 FEB 2016	23140P	1BLK76BS057A	ZGS-58 & ZGS-68

2.3 Flight Missions

Twelve (12) missions were conducted to complete LiDAR data acquisition in Salug Diut Floodplain, for a total of forty-four hours and twenty minutes (44+20) of flying time for RP-C9022 and RP-C9122. All missions were acquired using Pegasus LiDAR system. The team line-up is shown in ANNEX 4. The laser and aerial camera (D-8900) was experiencing technical malfunction during some of the Pegasus flights which are sometimes resolved by restarting the LiDAR system or letting the system cool down. Sometimes a re-flight was necessary. Table 12 shows the total area of actual coverage and number of images and the corresponding flying hours per mission, while Table 13 presents the actual parameters used during the LiDAR data acquisition.The data transfer sheet, flight logs and flight status reports of each mission are shown in ANNEXES 5, 6 and 7, respectively.

Table 12. Ground control points used during LiDAR data acquisition

Date Sur-veyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
5-Jul-14	1673P	371.447	118.527	2.875	115.652	330	2	55
6-Jul-14	1677P	109.274	74.054	10.392	63.662	170	2	35
9-Jul-14	1689P	302.748	264.525	1.882	262.643	N/A	4	17
7-Feb-16	23064P	356.648	177.909	57.173	120.736	184	4	5
7-Feb-16	23066P	236.856	72.301	41.077	31.224	40	2	29
9-Feb-16	23072P	356.648	287.592	141.832	145.76	593	4	11
9-Feb-16	23074P	474.096	165.584	56.184	109.4	337	2	35

10-Feb-16	23076P	366.153	339.101	203.947	135.154	746	4	17
13-Feb-16	23088P	216.605	231.965	8.51	223.455	536	4	23
14-Feb-16	23092P	427.982	218.933	120.105	98.828	458	3	35
16-Feb-16	23100P	661.032	264.582	69.176	195.406	590	4	23
26-Feb-16	23140P	300.786	284.6	0.469	284.131	N/A	4	35
TOTAL		4180.28	2499.67	713.622	1786.05	3984	44	20

Table 13. 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)
1673P	1000	30	50	200	30	120	5
1677P	550	30	50	200	30	120	5
1689P	1200	30	50	200	30	120	5
23064P	1000	30	50	200	30	120	5
23066P	1000	30	50	200	30	120	5
23072P	1200/1000	30	50	200	30	120	5
23074P	1000/1200	30	50	200	30	120	5
23076P	1200/1000	30	50	200	30	120	5
23088P	1200	30	50	200	30	120	5
23092P	1000/1100	30	50	200	30	120	5
23100P	1100	30	50	200	30	120	5
23140P	1200	30	50	200	30	120	5

2.4 Survey Coverage

Salug Diut Floodplain is located in the province of Zamboanga del Sur situated mostly within the municipalities of Molave, Mahayag, Tambulig, and Dumingag. LiDAR swath coverage for these flights also covers most parts of other cities/municipalities such as Aurora, Ramon Magsaysay, Tambulig, and Tukuran. The list of municipalities and/or cities surveyed, with atleast one (1) square kilometer coverage is shown in Table 14. The actual coverage of the LiDAR acquisition for Salug Diut Floodplain is presented in Figure 12.

Table 14. List of municipalities and/or cities surveyed during Salug Diut Floodplain LiDAR survey

Province	City/Municipality	Area of Munici-pality/ City (km2)	Total Area Surveyed (km2	Percentage of Area Surveyed
Zamboanga del Sur	Aurora	162.224	161.722	100%
Zamboanga del Sur	Dumingag	318.867	105.291	33%
Zamboanga del Sur	Kumalarang	143.510	52.837	37%
Zamboanga del Sur	Labangan	176.437	44.86	25%
Zamboanga del Sur	Lapuyan	153.283	11.32	7%
Zamboanga del Sur	Mahayag	175.974	153.926	87%
Zamboanga del Sur	Midsalip	285.122	2.839	1%
Zamboanga del Sur	Molave	61.238	42.594	70%
Zamboanga del Sur	Ramon Magsaysay	92.841	92.841	100%
Zamboanga del Sur	Sominot	97.753	68.459	70%
Zamboanga del Sur	Tambulig	142.934	121.083	85%
Zamboanga del Sur	Tukuran	119.010	117.309	99%
Zamboanga Sibugay	Buug	134.890	2.502	2%
Zamboanga Sibugay	Kabasalan	317.273	46.891	15%
Zamboanga Sibugay	Naga	164.179	1.483	1%
Zamboanga Sibugay	Siay	186.474	32.233	17%
Zamboanga del Norte	Sergio Osmena Sr.	461.228	36.432	8%
Misamis Occidental	Bonifacio	103.870	30.462	29%
Misamis Occidental	Clarin	113.990	3.217	3%
Misamis Occidental	Ozamis City	149.437	44.549	30%
Misamis Occidental	Tangub City	141.820	64.894	46%
Lanao del Norte	Baloi	65.179	36.869	57%
Lanao del Norte	Baroy	62.083	22.157	36%
Lanao del Norte	Iligan City	650.867	21.849	3%
Lanao del Norte	Kapatagan	184.763	23.256	13%
Lanao del Norte	Kolambugan	70.698	11.416	16%
Lanao del Norte	Lala	125.181	41.296	33%
Lanao del Norte	Linamon	22.214	2.251	10%
Lanao del Norte	Matungao	52.501	1.454	3%

Lanao del Norte	Nunungan	418.219	59.521	14%
Lanao del Norte	Pantar	50.194	6.855	14%
Lanao del Norte	Salvador	46.464	25.209	54%
Lanao del Norte	Sapad	65.132	35.083	54%
Lanao del Norte	Tagoloan	25.060	2.198	9%
Lanao del Norte	Tangcal	118.942	6.457	5%
Lanao del Norte	Tubod	121.945	51.262	42%
	TOTAL	5781.80	1584.88	27.41%

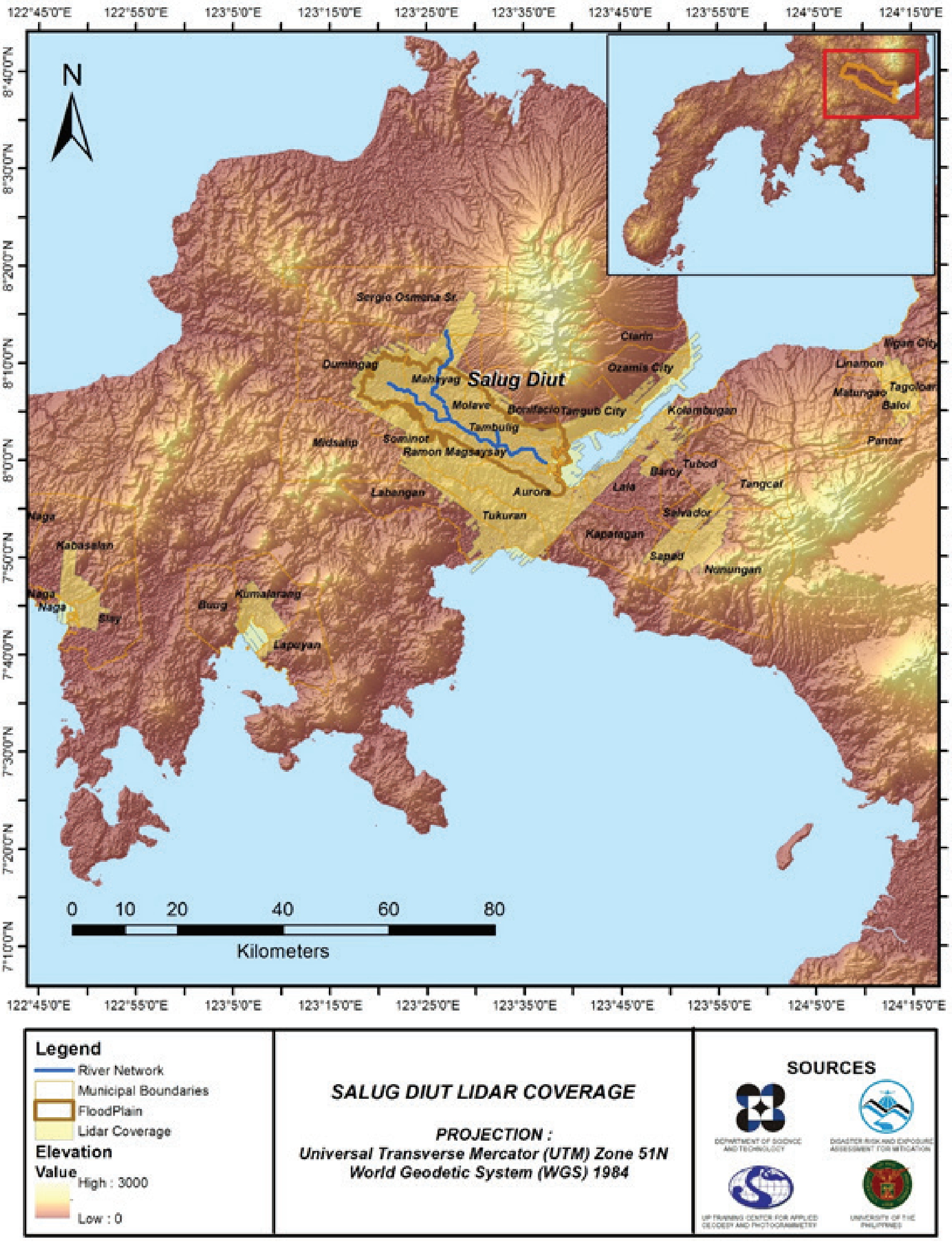

Figure 12. Actual LiDAR survey coverage for Salug Diut Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE SALUG DIUT 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

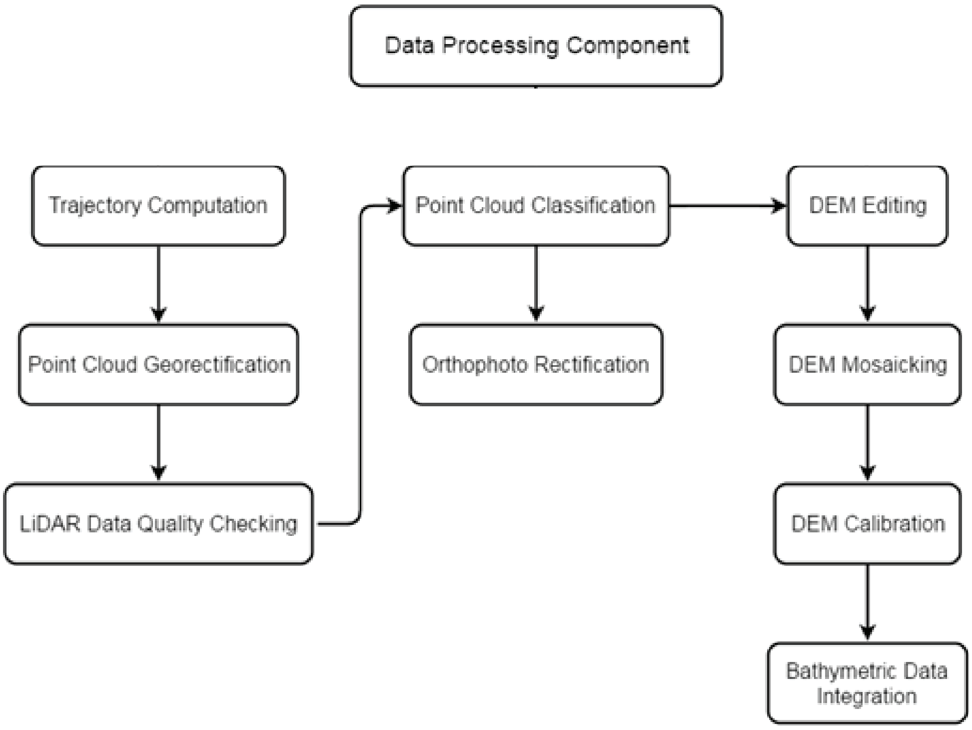


Figure 13. Schematic diagram for Data Pre-Processing Component

The data transmitted by the Data Acquisition Component were 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 was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, including the minimum point density and vertical and horizontal accuracies, were met. The point clouds were 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 were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was 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 13.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Salug Diut Floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on July 2014 as well as the succeeding surveys used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system on Molave and Mahayag, Zamboanga del Sur. The Data Acquisition Component (DAC) transferred a total of 257.05 Gigabytes of Range data, 2.90 Gigabytes of POS data, 855.05 Megabytes of GPS base station data, and 259.78 Gigabytes of raw image data to the data server on August 6, 2014 for the first survey and February 26, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Salug Diut was fully transferred on March 10, 2016, as indicated on the Data Transfer Sheets for Salug Diut Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 23100P, one of the Salug Diut flights, which is the North, East, and Down position RMSE values are shown in Figure 14. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell onFebruary 14, 2016 00:00 AM. The y-axis is the RMSE value for that particular position.

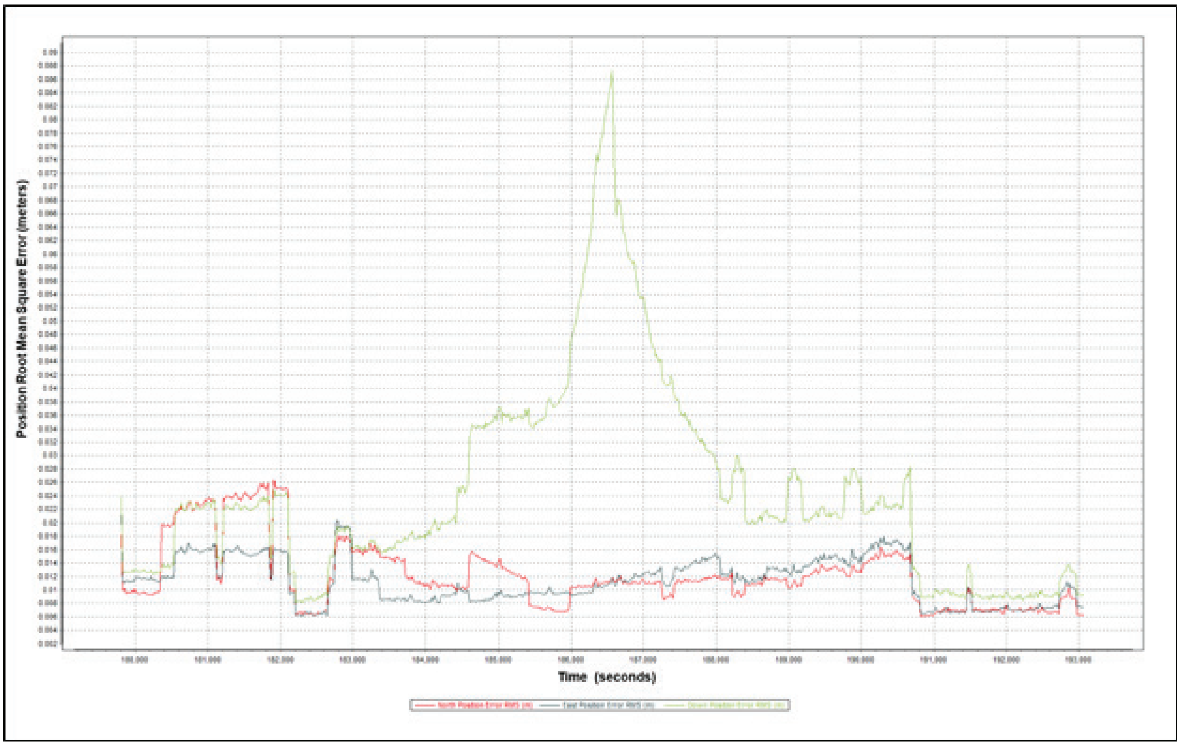


Figure 14. Smoothed Performance Metric Parameters of a Salug Diut Flight 23100P

The time of flight was from 100000 seconds to 193000 seconds, which corresponds to afternoon of February 16, 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 14 shows that the North position RMSE peaks at 2.60 centimeters, the East position RMSE peaks at 2.00 centimeters, and the Down position RMSE peaks at 8.70 centimeters, which are within the prescribed accuracies described in the methodology.

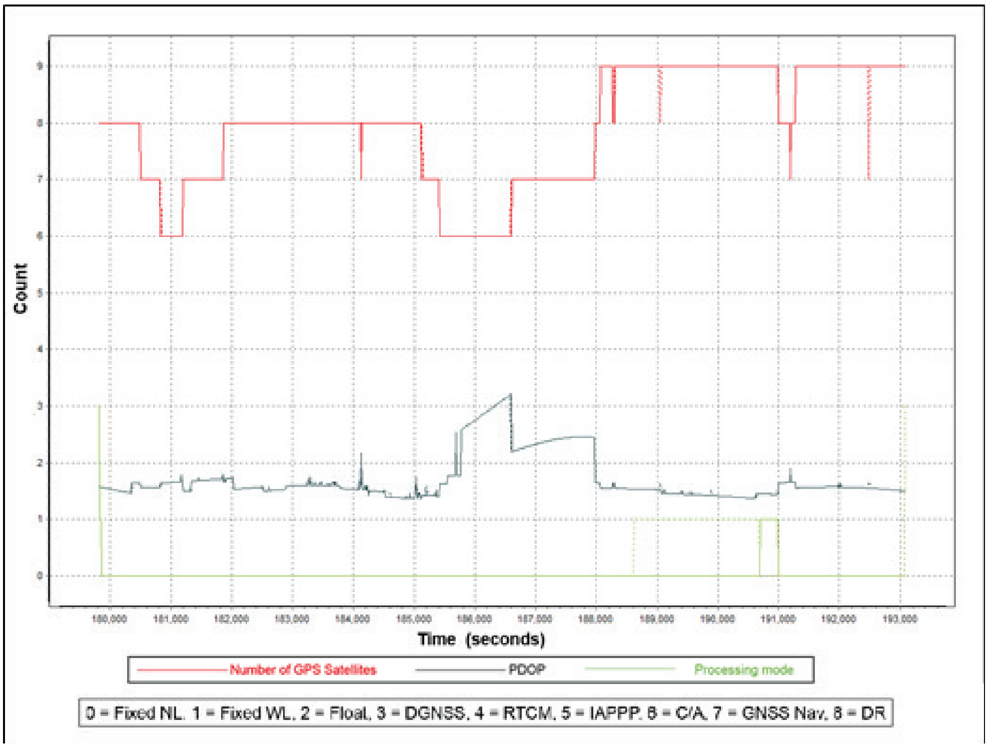


Figure 15. Solution Status Parameters of Salug Diut Flight 23100P

The Solution Status parameters of flight 23100P, one of the Salug Diut flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 15. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 6 and 9. 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 3 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 Salug Diut flights is shown in Figure 16.

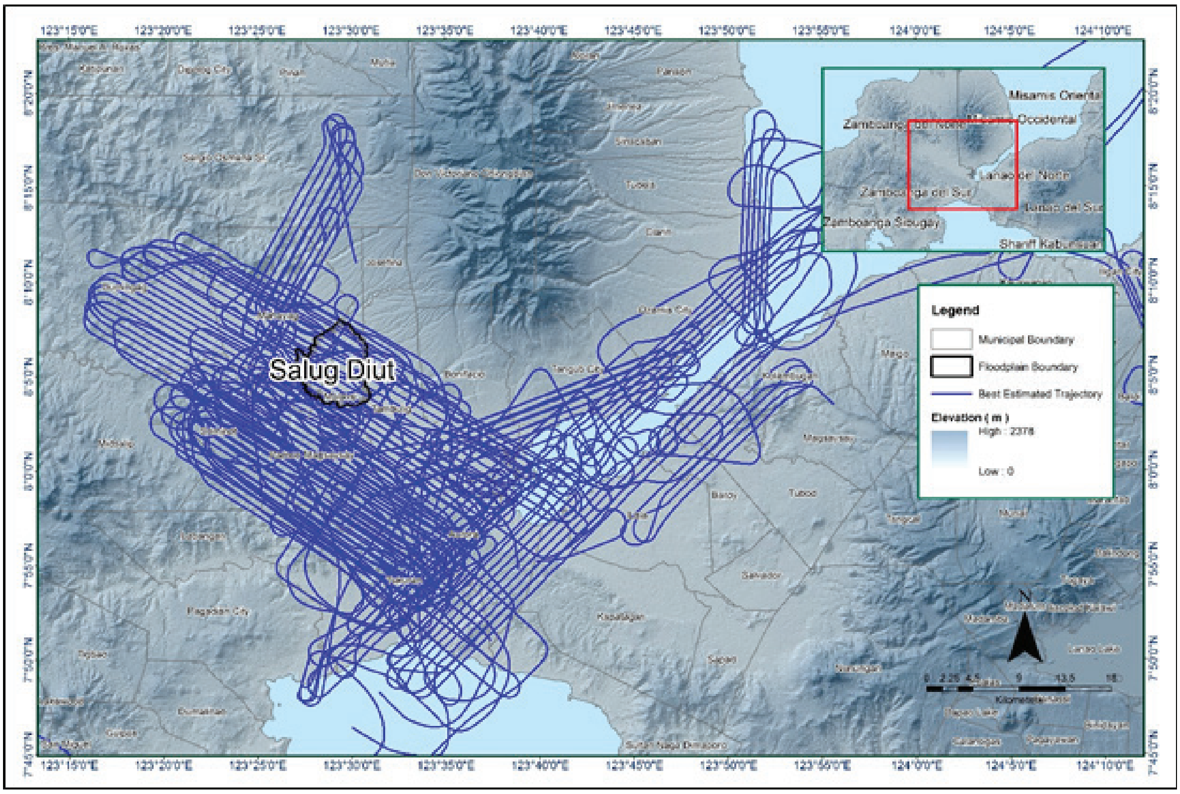


Figure 16. Solution Status Parameters of Salug Diut Flight 23100P

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 135 flight lines, with each flight line containing two channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Salug Diut Floodplain is given in Table 15.

Table 15. Self-calibration results values for Salug Diut 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 was obtained for all Salug Diut 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.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Salug Diut Floodplain is shown in Figure 17. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

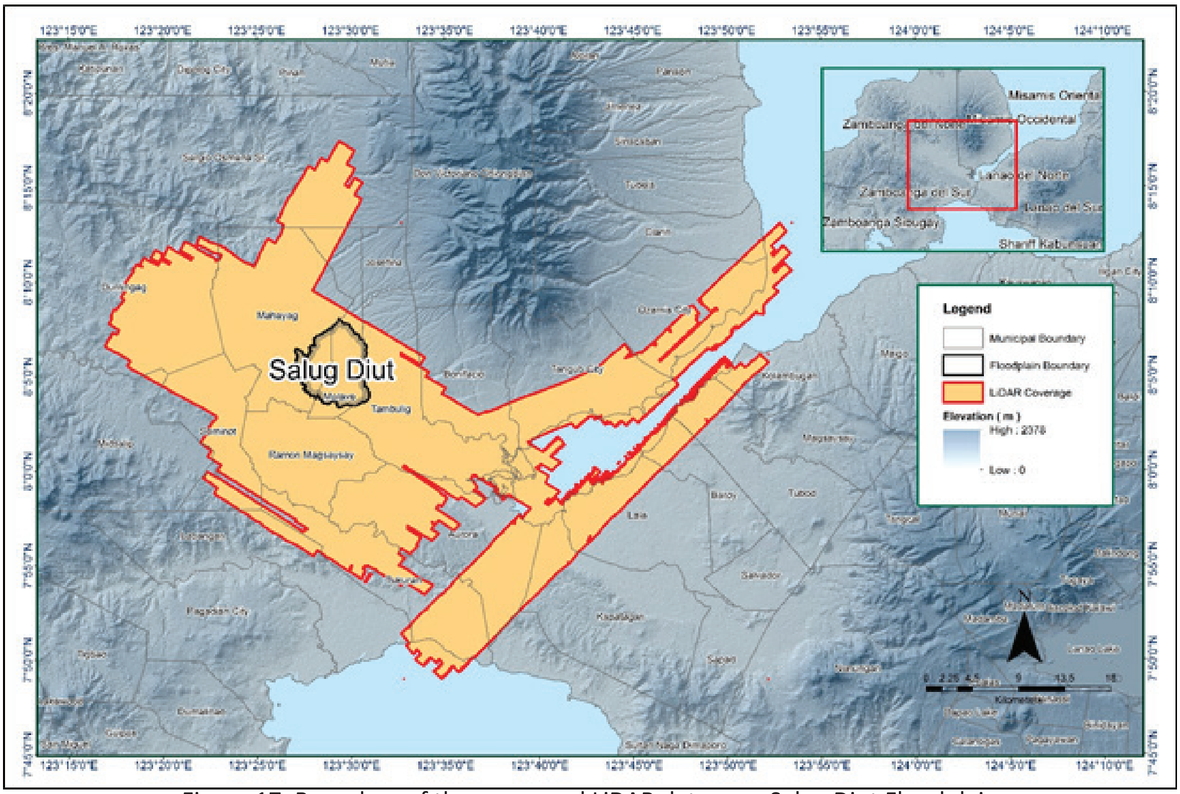


Figure 17. Boundary of the processed LiDAR data over Salug Diut Floodplain

The total area covered by the Salug Diut missions is 1,400.67 sq km that is comprised of thirteen (13) flight acquisitions grouped and merged into ten (10) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for Salug Diut Floodplain

LiDAR Blocks	Flight Numbers	Area (sq km)
Pagadian_Blk76E	23064P	155.99
	23072P	
	23074P	
Pagadian_Blk76E_supplement	23140P	16.26
Pagadian_Blk76F	23066P	242.61
	23072P	
	23074P	
Pagadian_Blk76F_additional	23100P	74.13
Pagadian_Blk76G	23064P	266.26
	23076P	
Pagadian_Blk76G_supplement	23092P	207.07
	23100P	
Pagadian_Blk76I	23088P	62.32
	23092P	
Pagadian_Blk76I_additional	23088P	42.94
NorthernMindanao_Blk71_extension	1665P	138.30
	1673P	
	1677P	
NorthernMindanao_Blk71E	1689P	194.58
TOTAL		1400.46 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 18. Since the Pegasus system employs two channels, an average value of 2 (blue) is expected 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.

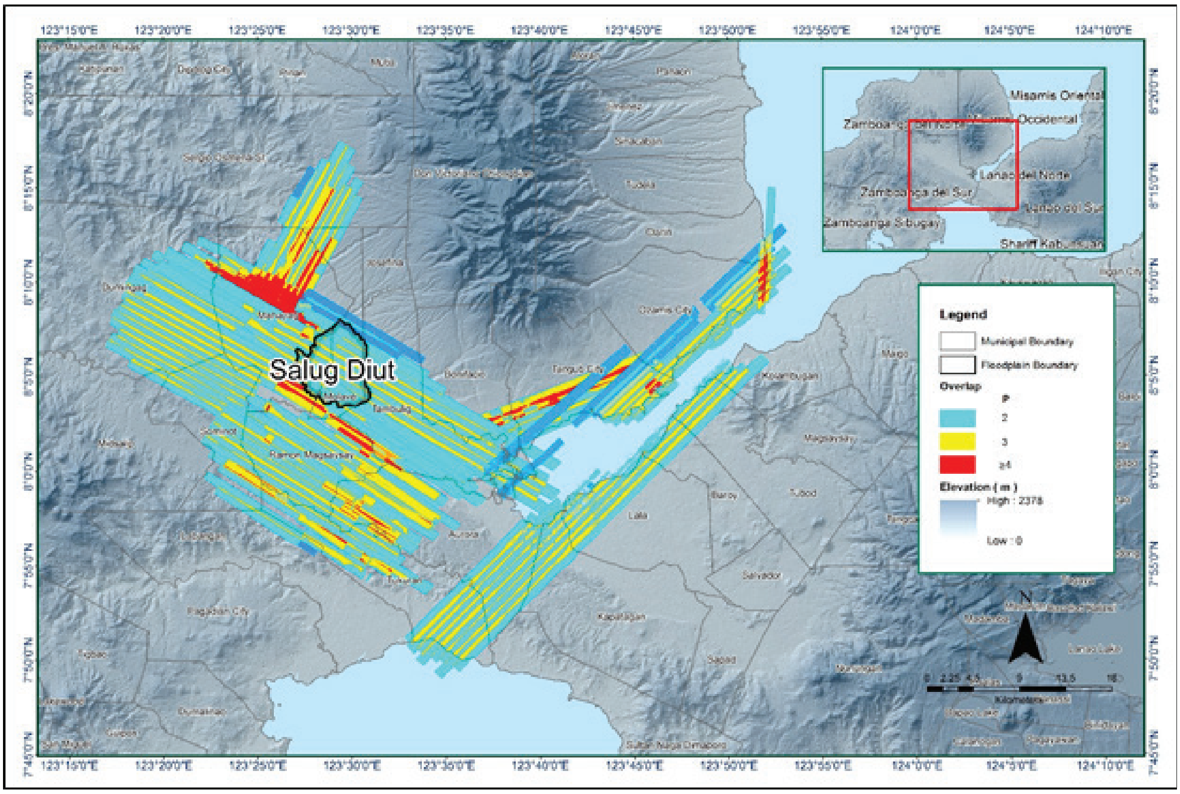


Figure 18. Image of data overlap for Salug Diut Floodplain

The overlap statistics per block for the Salug Diut Floodplain can be found in ANNEX 8. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.83% and 52.57%, 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 19. It was determined that all LiDAR data for Salug Diut Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.08 points per square meter.

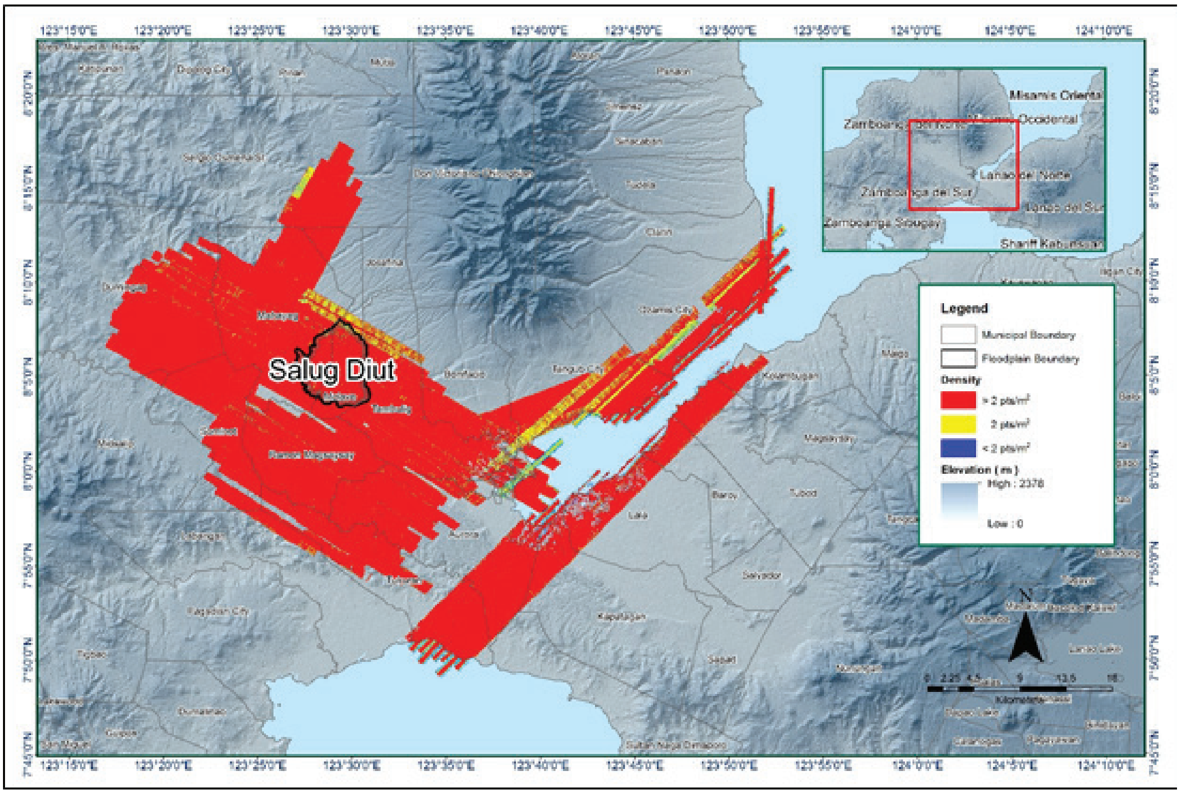


Figure 19. Pulse density map of merged LiDAR data for Salug Diut Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 20. 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.

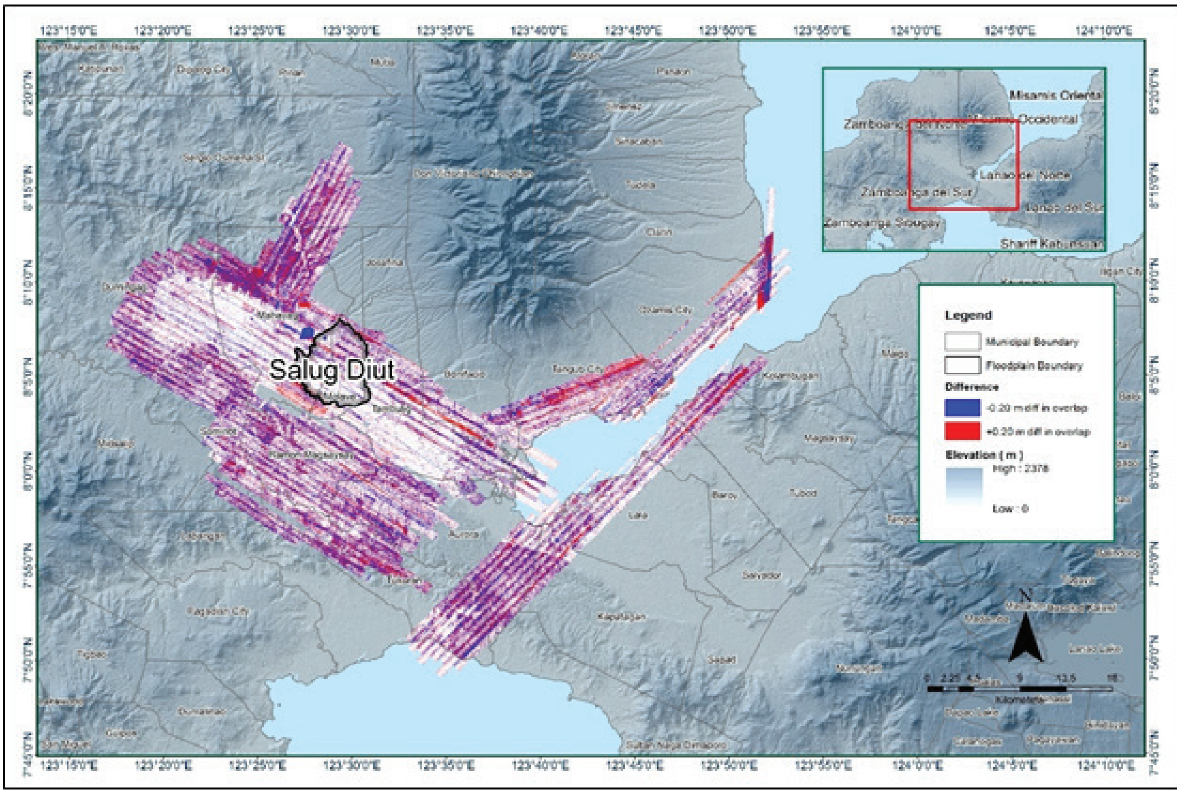


Figure 20. Map of elevation difference between flight lines for Salug Diut Floodplain

A screen capture of the processed LAS data from a Salug Diut flight 23100P loaded in QT Modeler is shown in Figure 21. 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.

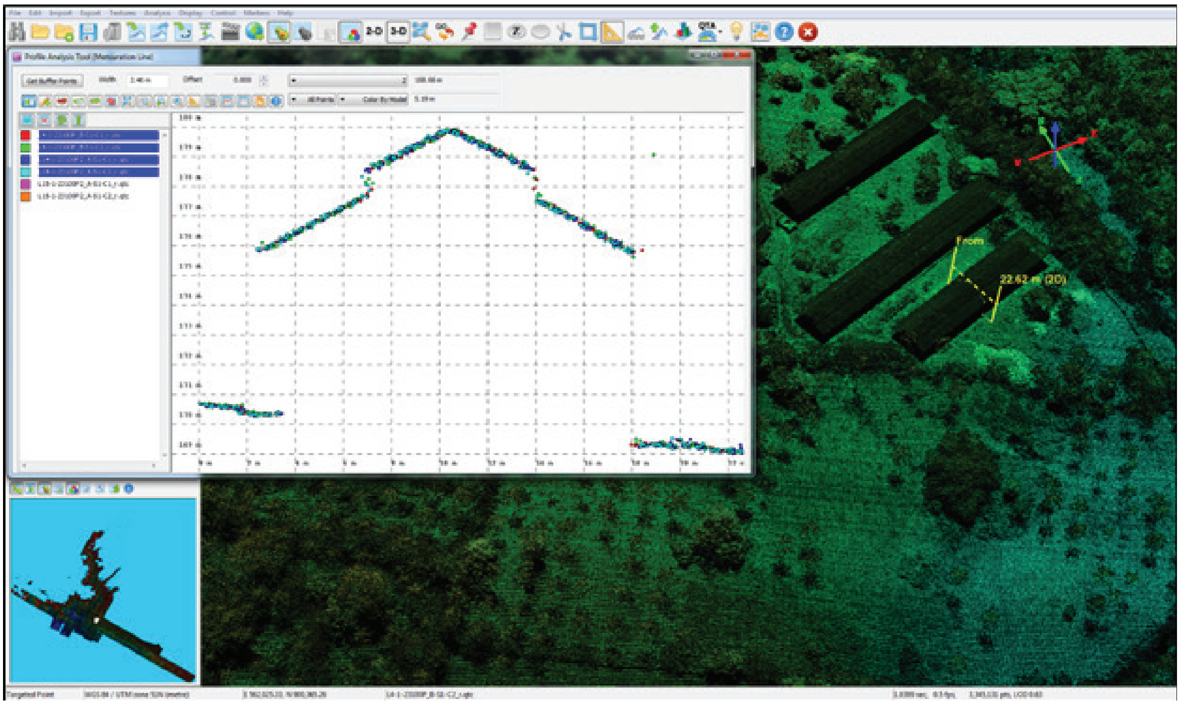


Figure 21. Quality checking for a Salug Diut flight 23100P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Salug Diut classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,639,030,306
Low Vegetation	1,253,420,959
Medium Vegetation	1,304,921,265
High Vegetation	2,466,115,189
Building	59,678,788

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Salug Diut Floodplain is shown in Figure 22. A total of 1,956 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 868.76 meters and 59.15 meters, respectively.

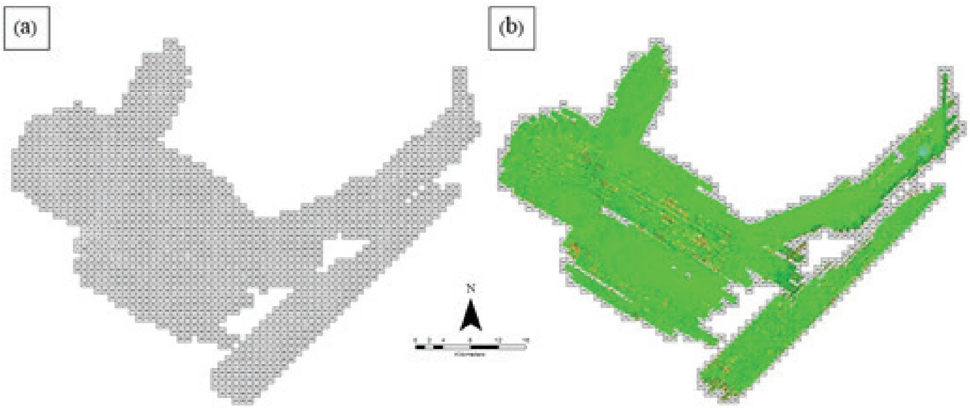


Figure 22. Tiles for Salug Diut Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 23. 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.

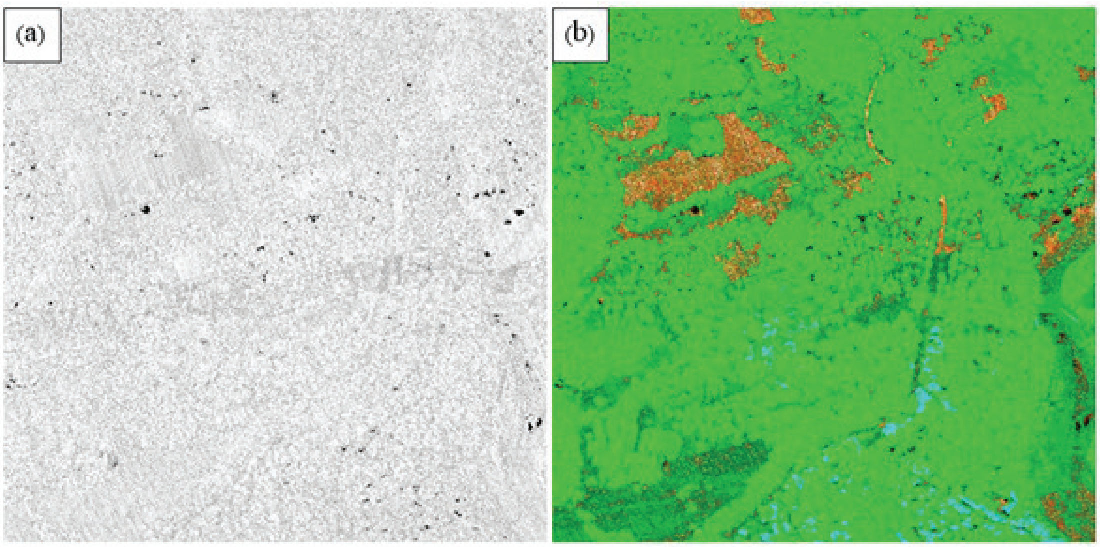


Figure 23. Point cloud before (a) and after (b) classification.

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

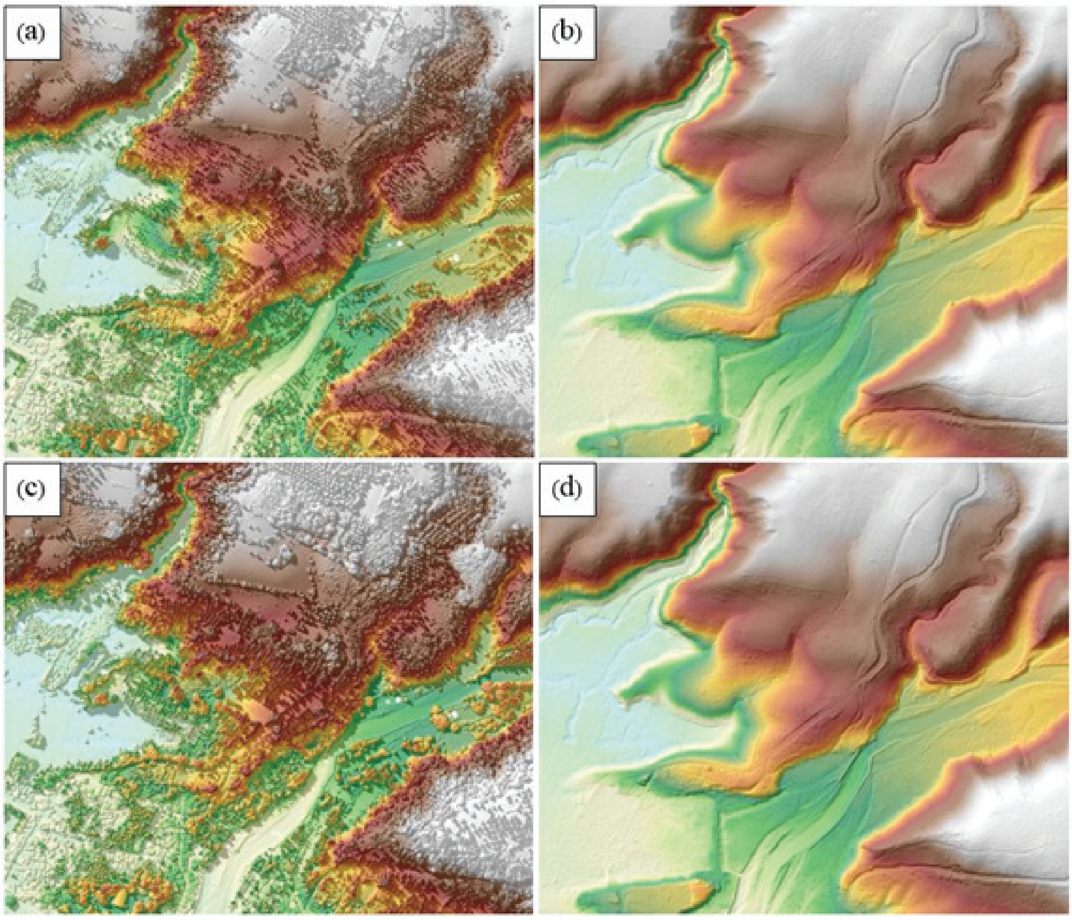


Figure 24. The production of last return DSM (a) and DTM (b); first return DSM (c) and secondary DTM (d) in some portion of Salug Diut Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,8241km by 1km tiles area covered by Salug Diut Floodplain is shown in Figure 25. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Salug Diut Floodplain survey attained a total of 1,011.15 sq km in orthophotogaph coverage comprised of 2,861 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 26.

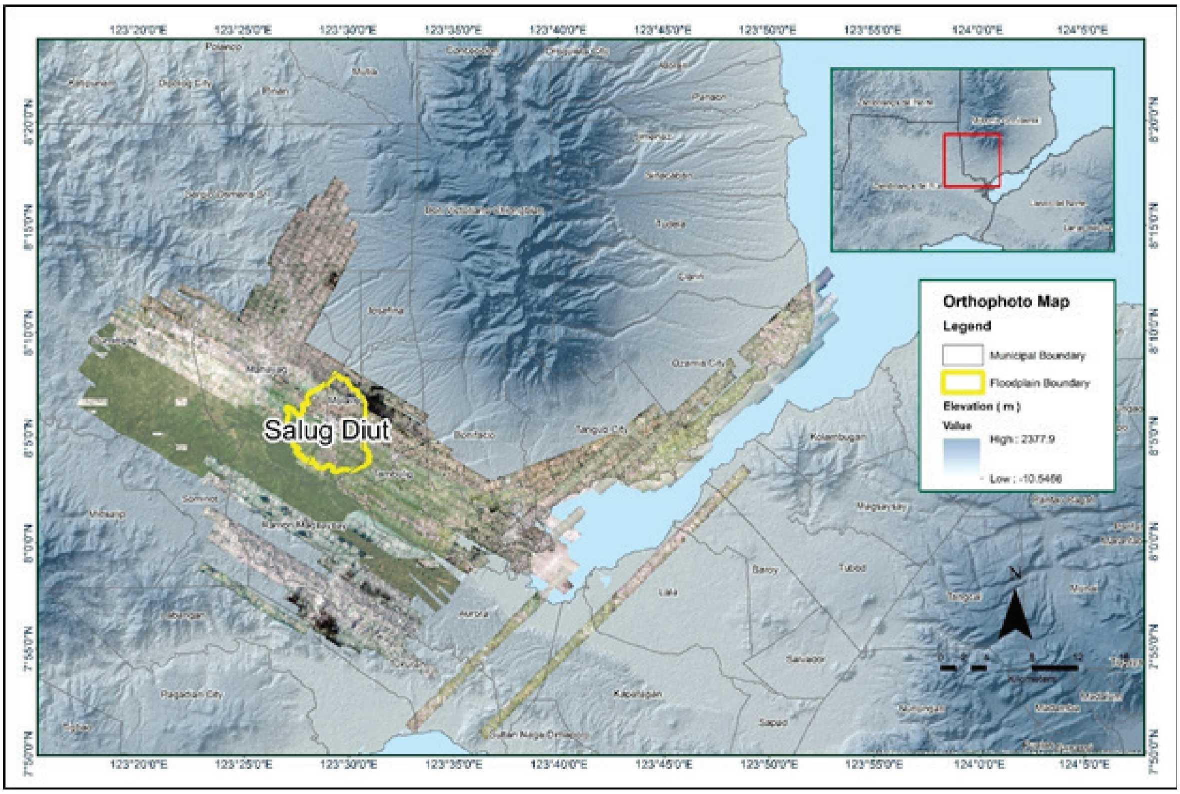


Figure 25. Salug Diut Floodplain with available orthophotographs

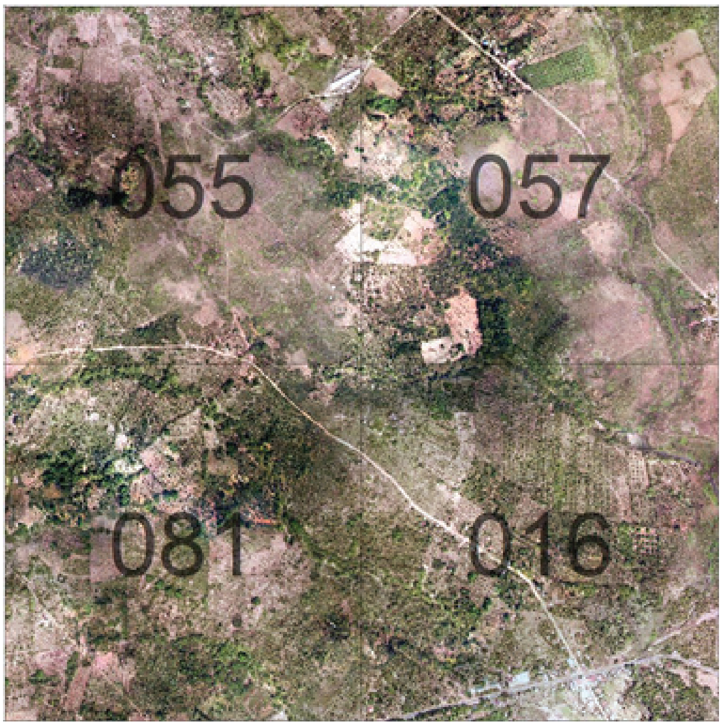


Figure 26. Sample orthophotograph tiles for Salug Diut Floodplain

3.8 DEM Editing and Hydro-Correction

Ten (10) mission blocks were processed for Salug Diut Floodplain. These blocks are composed of Pagadian and Northern Mindanao blocks with a total area of 1,400.46 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq km)
Pagadian_Blk76E	155.99
Pagadian_Blk76E_supplement	16.26
Pagadian_Blk76F	242.61
Pagadian_Blk76F_additional	74.13
Pagadian_Blk76G	266.26
Pagadian_Blk76G_supplement	207.07
Pagadian_Blk76I	62.32
Pagadian_Blk76I_additional	42.94
NorthernMindanao_Blk71_ extension	138.30
NorthernMindanao_Blk71E	194.58
TOTAL	1,400.46 sq km

Portions of DTM before and after manual editing are shown in Figure 27. The bridge (Figure 27a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 27b) in order to hydrologically correct the river. The river embankment (Figure 27c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 27d) to allow the correct flow of water.

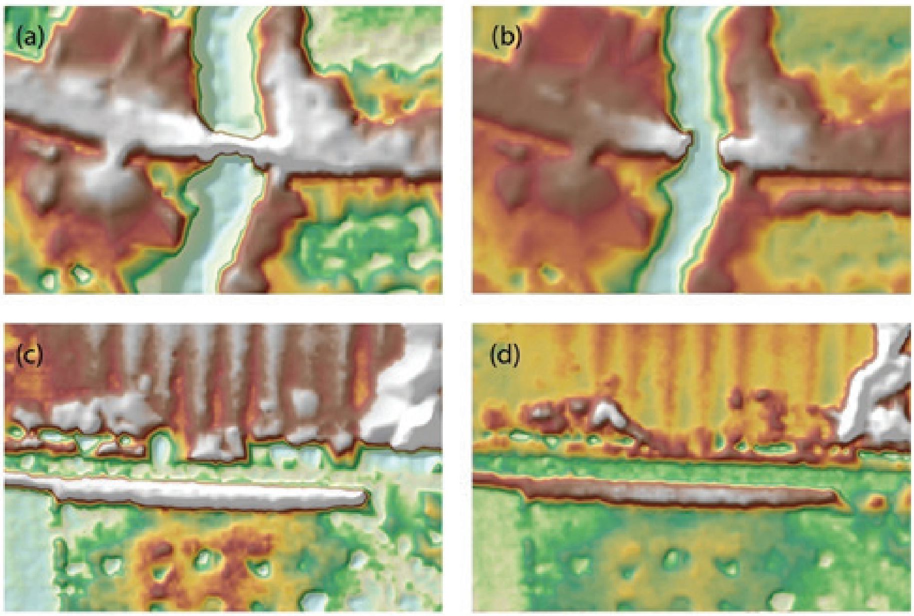


Figure 27. Portions in the DTM of Salug Diut Floodplain—a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

Pagadian_Blk71_extension was used as the reference block at the start of mosaicking because it is already vertically calibrated to MSL and it overlaps missions Pagadian_Blk76I, Pagadian_Blk76I_additional, and Pagadian_Blk76G of Salug Diut. Table 19 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Salug Diut Floodplain is shown in Figure 28. It can be seen that the entire Salug Diut Floodplain is 99.90% covered by LiDAR data.

Table 19. Shift Values of each LiDAR Block of Salug Diut Floodplain

Mission Blocks	**Shift Values (meters)**		
	x	y	z
Pagadian_Blk76E	0.20	0.50	-1.85
Pagadian_Blk76E_supplement	0.40	-0.10	1.57
Pagadian_Blk76F	-0.80	1.40	-1.93
Pagadian_Blk76F_additional	0.15	0.45	-1.90
Pagadian_Blk76G	0.20	0.20	-1.93
Pagadian_Blk76G_supplement	0.20	0.20	-1.93
Pagadian_Blk76I	0.35	0.45	-1.72
Pagadian_Blk76I_additional	0.25	-0.50	-1.73
NorthernMindanao_Blk71_extension	0.00	0.00	0.00
NorthernMindanao_Blk71E	0.00	0.00	0.00

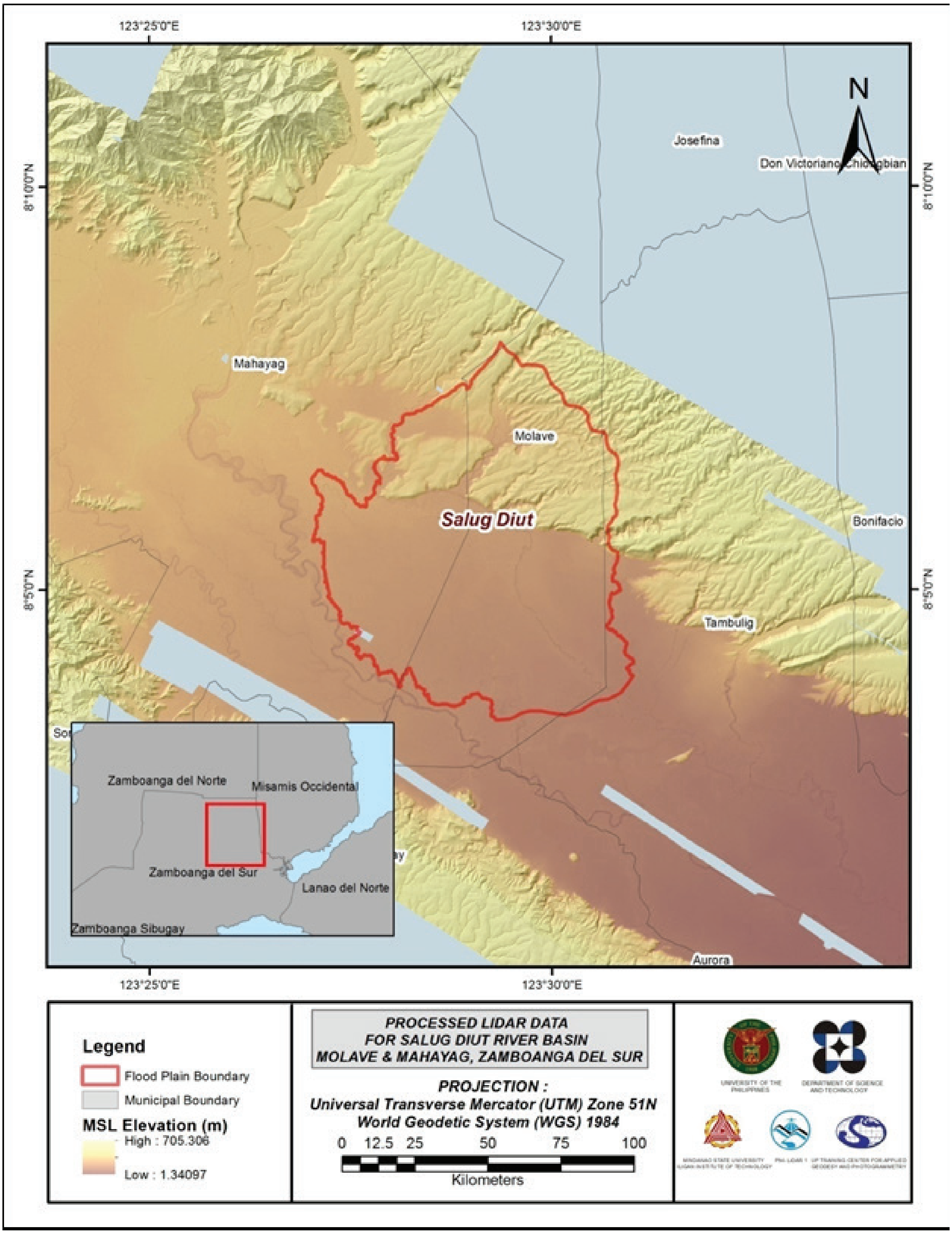


Figure 28. Map of processed LiDAR data for Salug Diut Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Salug Diut to collect points with which the LiDAR dataset was validated is shown in Figure 29. A total of 1,820 survey points were used for calibration and validation of Salug Diut LiDAR data. Random selection of 80% of the survey points, resulting in 1,456 points, was used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 30. 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 4.80 meters with a standard deviation of 0.08 meters. Calibration of Salug Diut LiDAR data was done by subtracting the height difference value, 4.80 meters, to Salug Diut mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

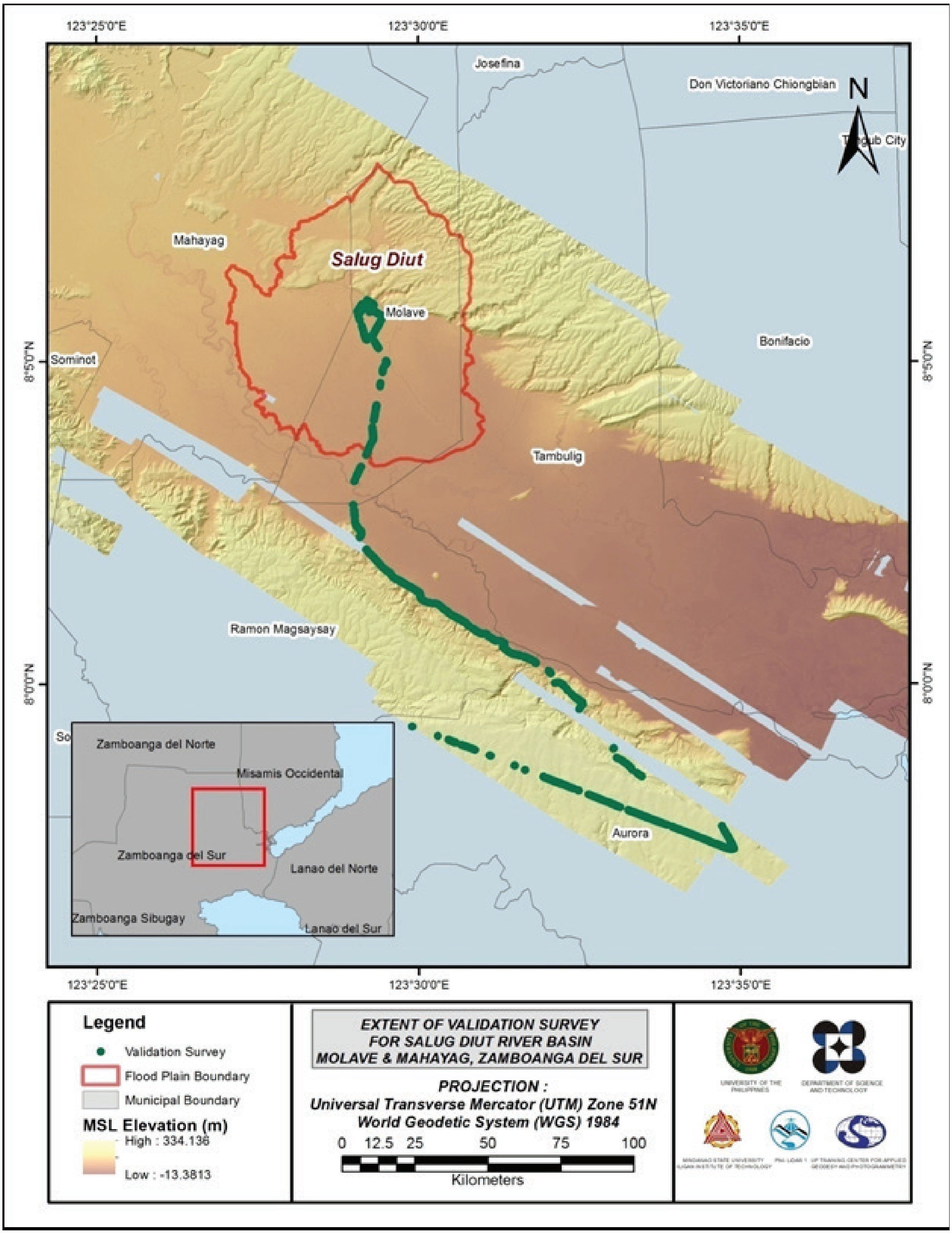


Figure 29. Map of Salug Diut Floodplain with validation survey points in green

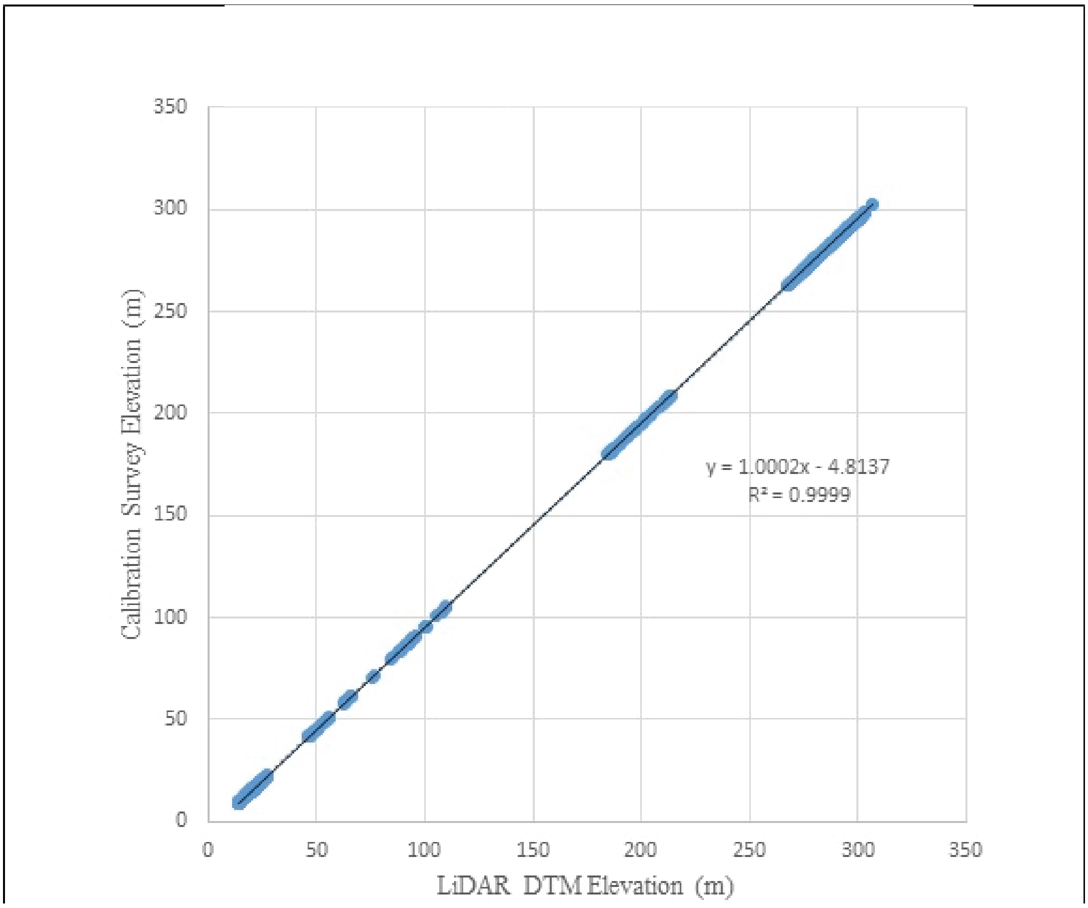


Figure 30. Correlation plot between calibration survey points and LiDAR data

Table 20. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	4.80
Standard Deviation	0.08
Average	-4.80
Minimum	-4.95
Maximum	-4.65

The remaining 20% of the total survey points, resulting in 364 points, were used for the validation of calibrated Salug Diut 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 31. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.08 meters with a standard deviation of 0.08 meters, as shown in Table 21.

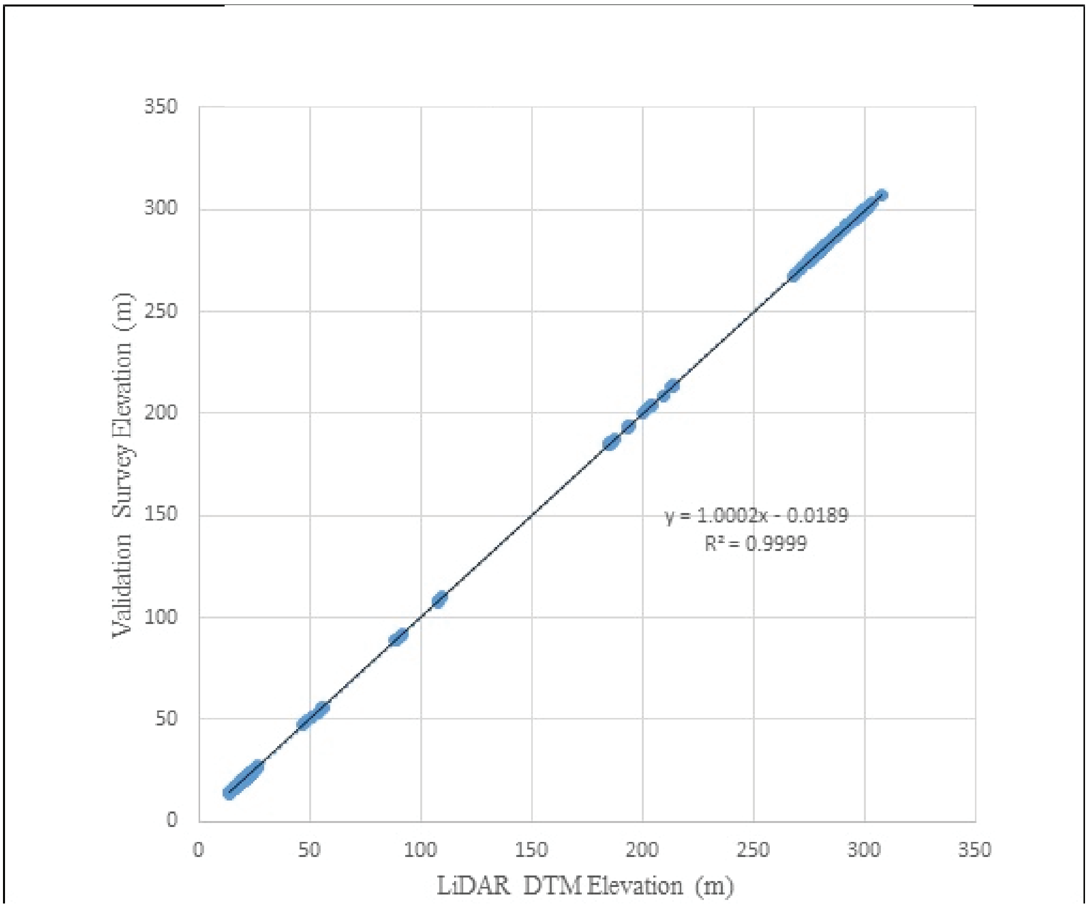


Figure 31. Correlation plot between validation survey points and LiDAR data

Table 21. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.08
Standard Deviation	0.08
Average	0.00
Minimum	-0.17
Maximum	0.16

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Salug Diut with 32,931 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.40 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Salug Diut integrated with the processed LiDAR DEM is shown in Figure 32.

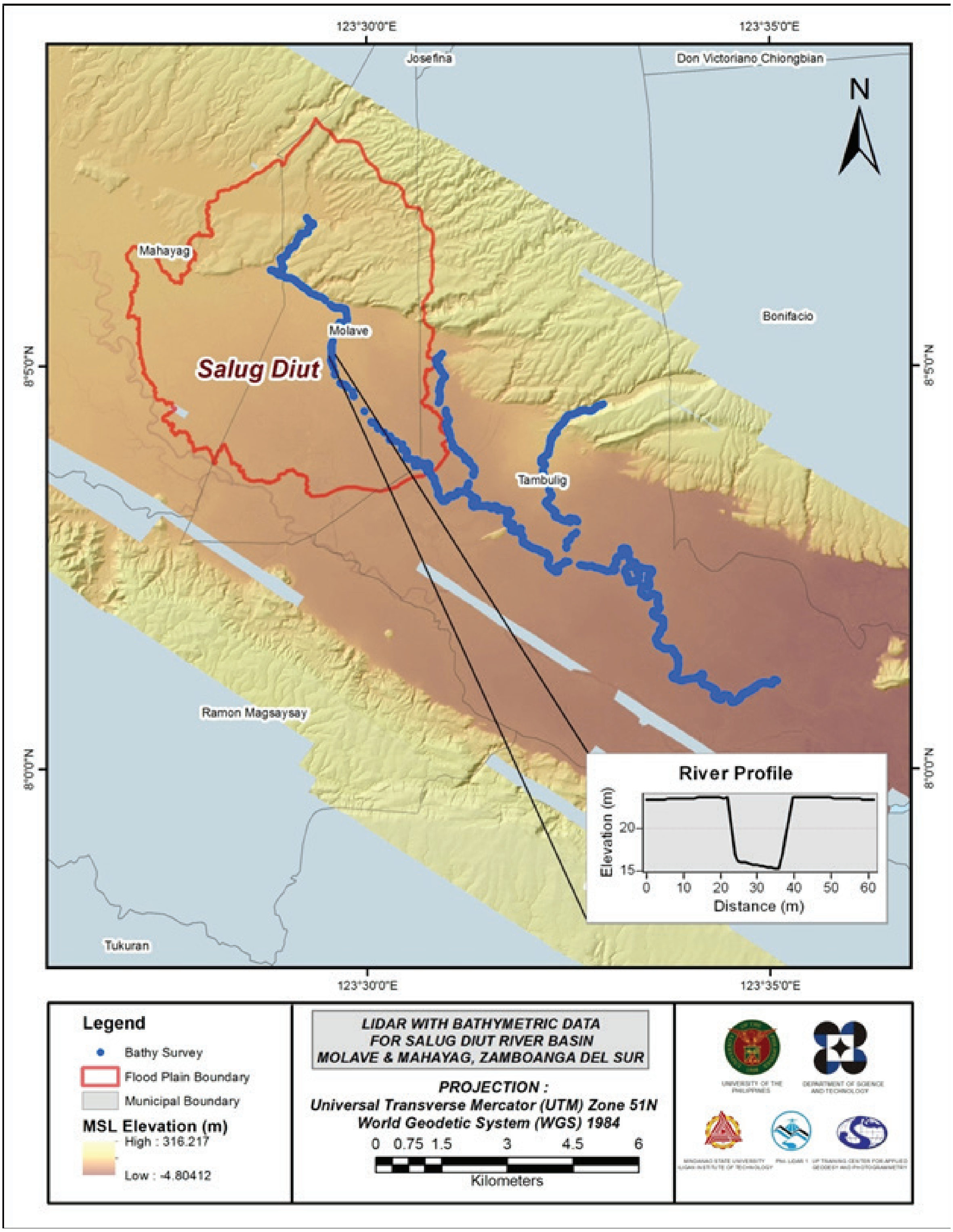


Figure 32. Map of Salug Diut Floodplain with bathymetric survey points shown in blue

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 200m buffer zone. Mosaicked LiDAR DEM with 1m 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

Salug Diut Floodplain, including its 200m buffer, has a total area of 48.60 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,097 building features, is considered for QC. Figure 33 shows the QC blocks for Salug Diut Floodplain.

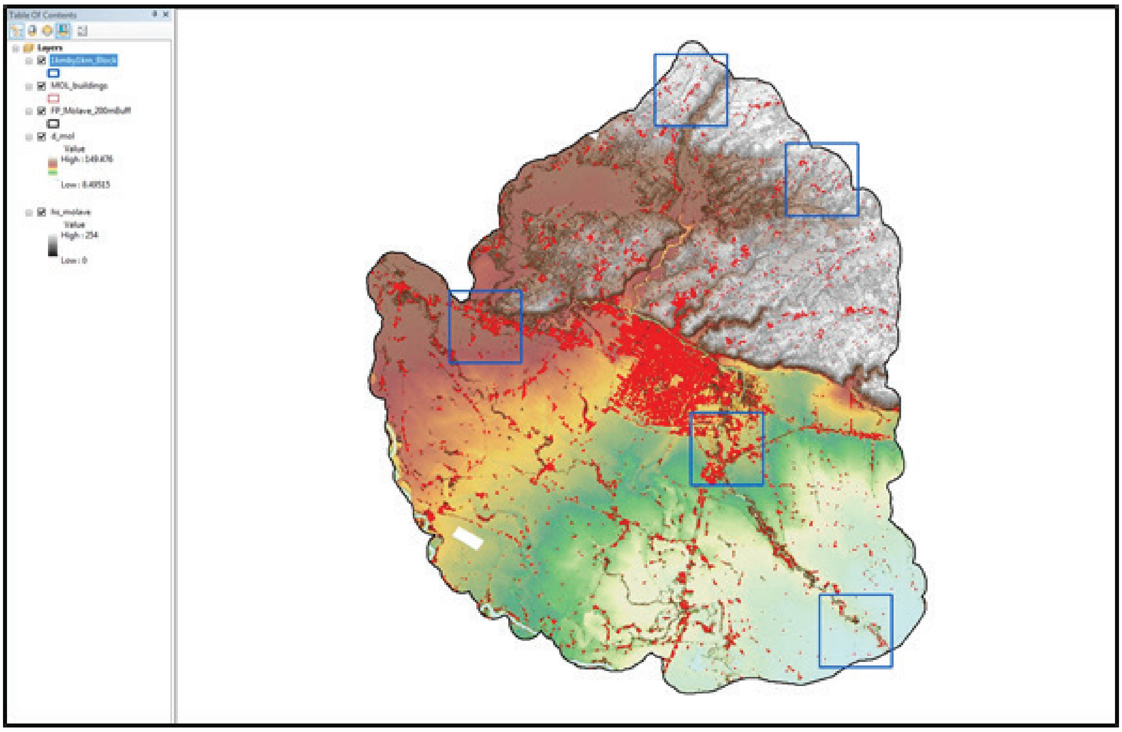


Figure 33. Blocks (in blue) of Salug Diut building features subjected to QC

Quality checking of Salug Diut building features resulted in the ratings shown in Table 22

Table 22. Quality checking ratings for Salug Diut Building Features

Floodplain	Completeness	Correctness	Quality	Remarks
Salug Diut	99.18	98.72	82.22	PASSED

3.12.2 Height Extraction

Height extraction was done for 12,180 building features in Salug Diut Floodplain. Of these building features, 321 were filtered out after height extraction, resulting in 11,859 buildings with height attributes. The lowest building height is at 2.00m, while the highest building is at 8.65m.

3.12.3 Feature Attribution

Salug Diut Floodplain is shared by three (3) municipalities namely Molave, Mahayag, and Tambulig. The building attribution on the municipalities 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 23 summarizes the number of building features per type. On the other hand, Table 24 shows the total length of each road type, while Table 25 shows the number of water features extracted per type.

Table 23. Building features extracted for Salug Diut Floodplain

Facility Type	No. of Features
Residential	11,375
School	115
Market	1
Agricultural/Agro-Industrial Facilities	47
Medical Institutions	15
Barangay Hall	14
Military Institution	0
Sports Center/Gymnasium/Covered Court	12
Telecommunication Facilities	0
Transport Terminal	1
Warehouse	10
Power Plant/Substation	1
NGO/CSO Offices	4
Police Station	3
Water Supply/Sewerage	2
Religious Institutions	36
Bank	8
Factory	1
Gas Station	5
Fire Station	0
Other Government Offices	74
Other Commercial Establishments	135
Total	11,859

Table 24. Total length of extracted roads for Salug Diut Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Salug Diut	87.23	25.11	0.00	8.93	0.00	121.27

Table 25. Number of extracted water bodies for Salug Diut Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Salug Diut	5	0	0	0	0	5

A total of 44 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 34 shows the Digital Surface Model (DSM) of Salug Diut Floodplain overlaid with its ground features.

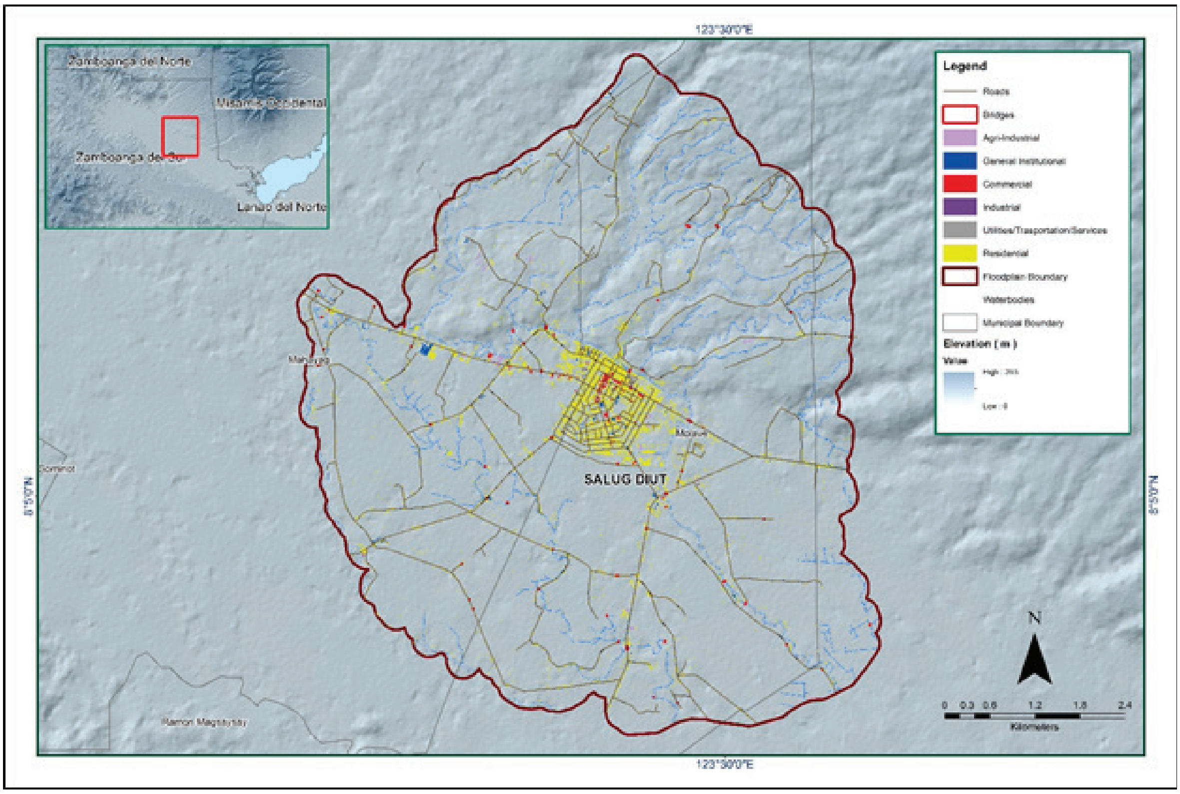


Figure 34. Extracted features for Salug Diut Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE SALUG DIUT 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

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

4.1 Summary of Activities

The DVBC conducted bridge cross-section and validation surveys in Salug Diut River and its three tributaries on July 11–12, 2015 and bathymetric surveys on November 23 to December 07, 2015 in partnership with the Mindanao State University – Iligan Institute of Technology (MSU-IIT). The bathymetric survey was conducted using an OHMEX™ single-beam echo sounder to determine the depth of the river while a Trimble® SPS 882 rover GPS gathered the coordinates and elevation values of the survey points.

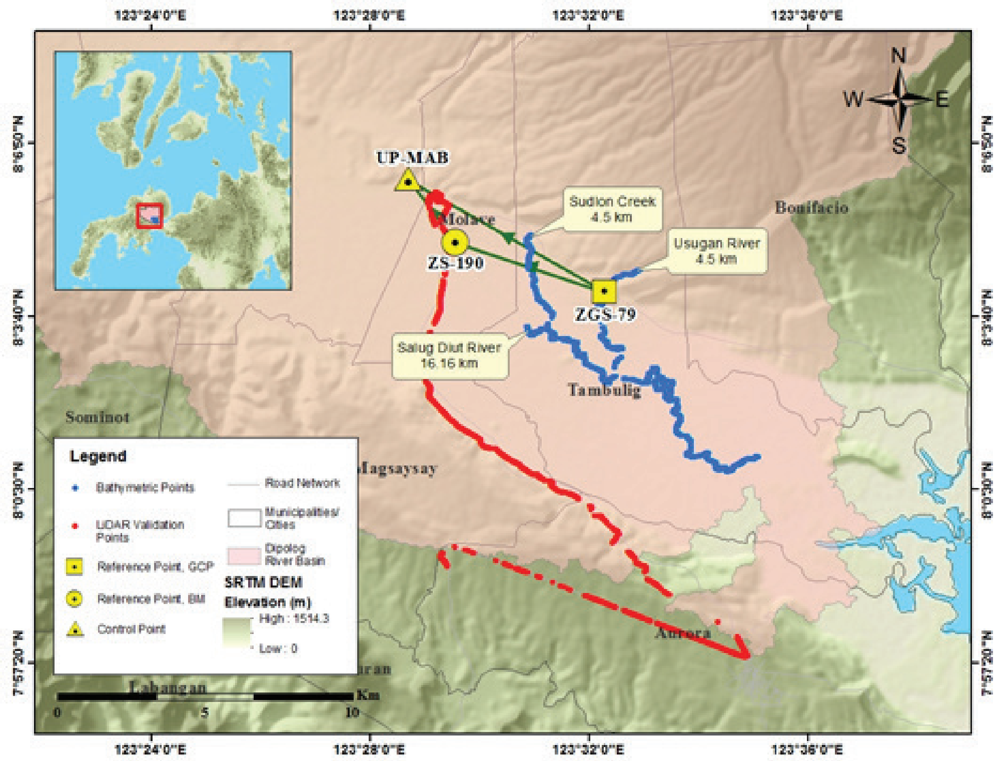


Figure 35. Extent of the bathymetric survey (in blue) in Salug Diut River and the LiDAR validation survey (in red)

4.2 Control Survey

The GNSS network used for Salug Diut River is composed of a single loop established on July 5, 2015 with the following reference points: ZGS-79, a second order GCP in Brgy. Riverside, Municipality of Tambulig; and ZS-190, a first order BM in Brgy. Blancia, Municipality of Molave, Zamboanga del Sur.

A control point namely UP-MAB was also established along the approach of Dipolo Bridge, in Brgy. San Isidro, Municipality of Mahayag, Zamboanga del Sur, to use as marker.

The summary of references and control points used is in Table 26 while the GNSS network is shown in Figure 36.

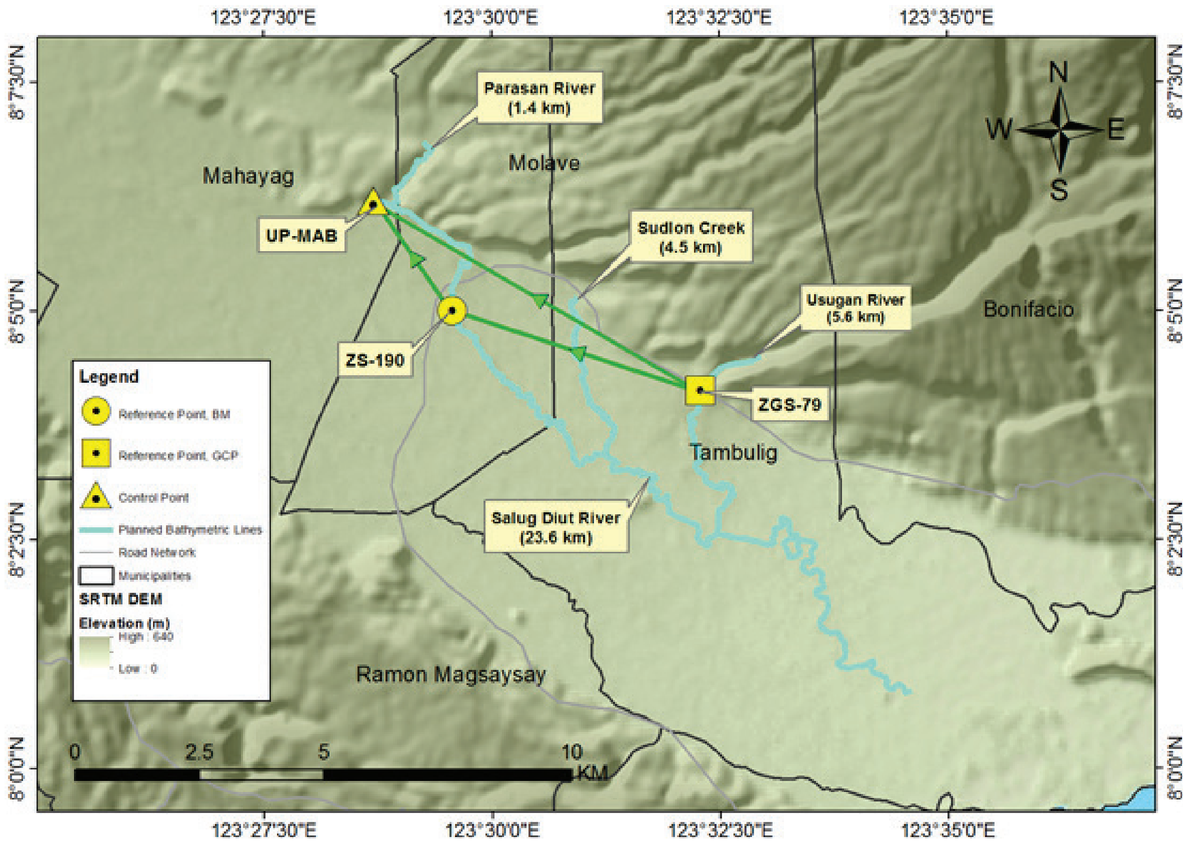


Figure 36. GNSS Network of Salug Diut field survey

Table 26. List of reference and control points occupied in Salug Diut River control survey (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	BM Ortho (m)	Date Established
ZS-190	1st order BM	-	-	92.143	24.032	2008
ZGS-79	2nd order GCP	8°04'07.74591"	123°32'17.19275"	101.138	-	2005
UP-MAB	UP Established	-	-	-	-	7-5-2015

The GNSS receiver set up for NAMRIA control points and TCAGP established control point in Salug Diut River is shown in Figure 37 to Figure 39.

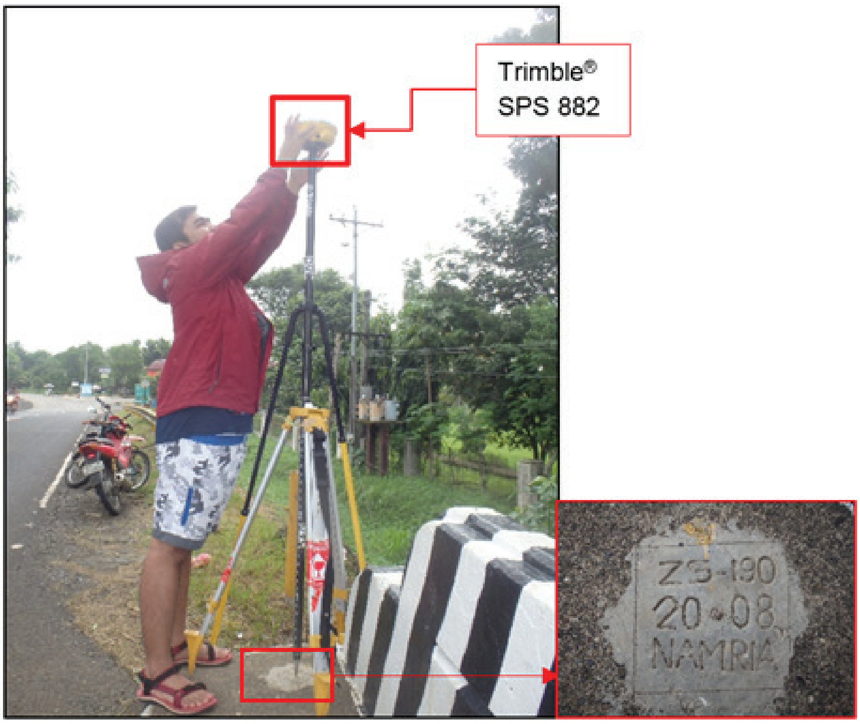


Figure 37. Trimble® SPS 882 GNSS receiver occupation at ZS-190 in Salug Diut Bridge, Brgy. Blancia, Molave, Zamboanga del Sur

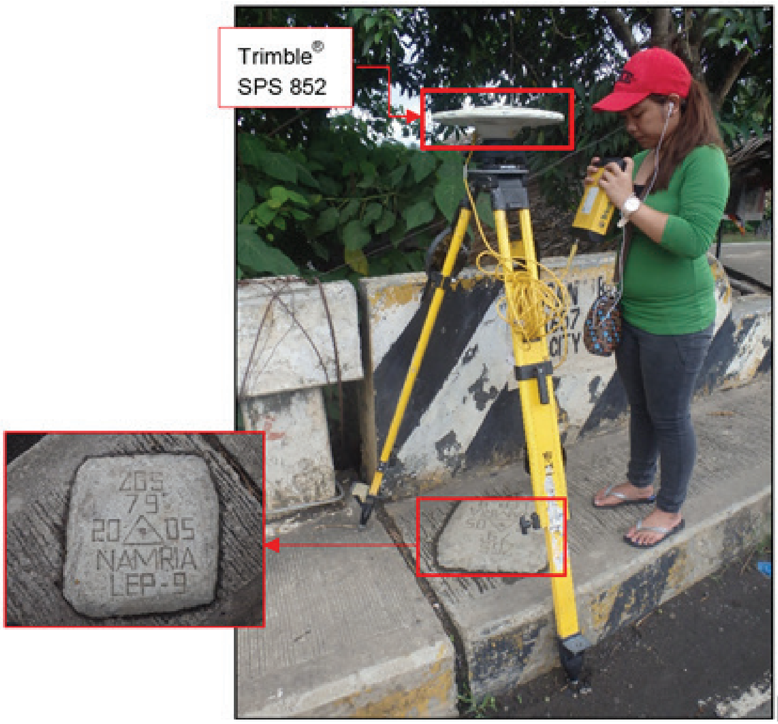


Figure 38. Trimble® SPS 852 GNSS base receiver setup at ZGS-79 in Usugan Bridge, Brgy. Riverside, Tambulig, Zamboanga del Sur

Figure 39. Trimble® SPS 882 GNSS receiver base occupation at UP-MAB, Mabuhay Bridge in Brgy. San Isidro, Mahayag, 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 was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Salug Diut River Basin is summarized in Table 27 generated by TBC software.

Table 27. Baseline processing report for Salug Diut River basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZGS-79 --- UP-MAB (B2)	7-5-2015	Fixed	0.003	0.018	300°07'26"	7610.335	-7.686
ZS-190 --- UP-MAB (B1)	7-5-2015	Fixed	0.004	0.018	324°10'18"	2701.869	1.302
ZGS-79 --- ZS-190 (B3)	7-5-2015	Fixed	0.006	0.029	288°02'17"	5259.669	-9.006

As shown in Table 27, a total of three (3) baselines were processed and all of them passed the required accuracy set by the project.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates 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:

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

Where:

xe is the Easting Error,
yeis the Northing Error, and
zeis the Elevation Error

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

The three control points, ZGS-79, ZS-190, and UP-MAB, were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of ZGS-79 and ZS-190 were held fixed during the processing and elevation of the unknown control points were computed.

Table 28. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZGS-79	Local	Fixed	Fixed		
ZS-190	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 29. All fixed control points have no values for grid and elevation errors.

Table 29. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)
UP-MAB						
552704.891	0.004	895754.264	0.004	25.387	0.026	
ZGS-79						
559290.041	?	891944.915	?	32.884	0.032	LL
ZS-190						
554288.529	0.005	893566.372	0.004	24.032	?	e

The network is fixed at reference points ZGS-79 and ZS-190 for coordinates and elevation, respectively. The list of adjusted grid coordinates of the network is shown in Table 30. Using the equation $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10$ cm for the vertical, the computation for accuracy that passed the required precision is as follows:

ZGS- 79
horizontal accuracy = Fixed
vertical accuracy = 3.2 < 10 cm

ZS-190
horizontal accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= 0.64 cm < 20 cm
vertical accuracy = Fixed

UP-MAB
horizontal accuracy = $\sqrt{((0.4)^2 + (0.4)^2}$
= $\sqrt{(0.16 + 0.16)}$
= 0.57 cm < 20 cm
vertical accuracy = 2.6 < 10 cm

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

Table 30. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
UP-MAB	N8°06'12.05567"	E123°28'42.18672"	93.448	0.026	
ZGS-79	N8°04'07.74591"	E123°32'17.19275"	101.138	0.032	LL
ZS-190	N8°05'00.75052"	E123°29'33.84588"	92.143	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 30. 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 31.

Table 31. Control points occupied in Salug Diut River control survey (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZS-190	1st Order BM	8°05'00.75052"	123°29'33.84588"	92.143	893566.372	554288.529	24.032
ZGS-79	2nd Order GCP	8°04'07.74591"	123°32'17.19275"	101.138	891944.915	559290.041	32.884
UP-MAB	UP Established	8°06'12.05567"	123°28'42.18672"	93.448	895754.264	552704.891	25.387

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

Cross-section and bridge as-built survey were done on November 24, 2015 for Usugan Bridge using GNSS receiver Trimble® SPS 882 in PPK survey technique at the upstream side of the bridge as shown in Figure 40.

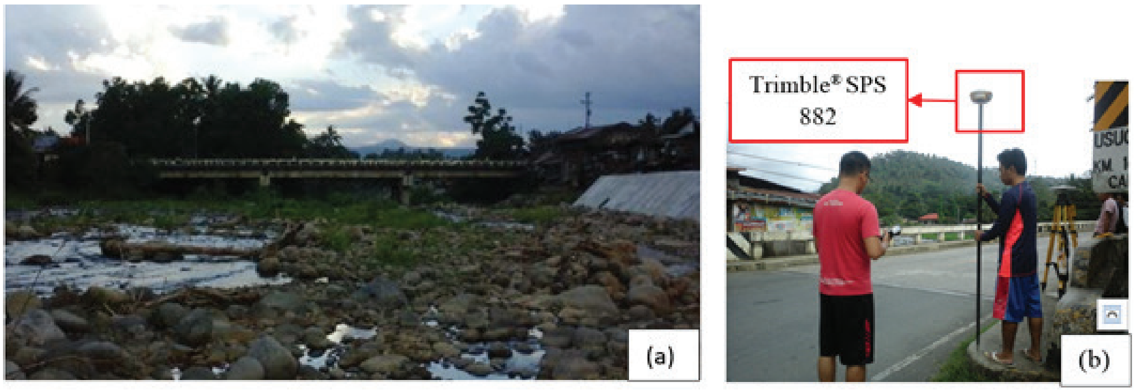


Figure 40. (a) Panoramic View of Usugan Bridge facing downstream; (b) cross-section and as-built survey of Usugan Bridge

Cross-section and as-built survey was done on November 29, 2015 for Sudlon Bridge using GNSS receiver Trimble® SPS 882 in PPK survey technique at the upstream side of the bridge as shown on Figure 41.

Figure 41. (a) Panoramic View of Sudlon Bridge facing upstream; (b) cross-section and as-built survey of Sudlon Bridge

For Maloloy-on and Mabuhay Bridges, cross-section and as-built survey was done on July 11, 2015 using GNSS receiver Trimble® SPS 882 in PPK survey technique at the upstream side of the bridges as shown in Figure 42 and Figure 43.

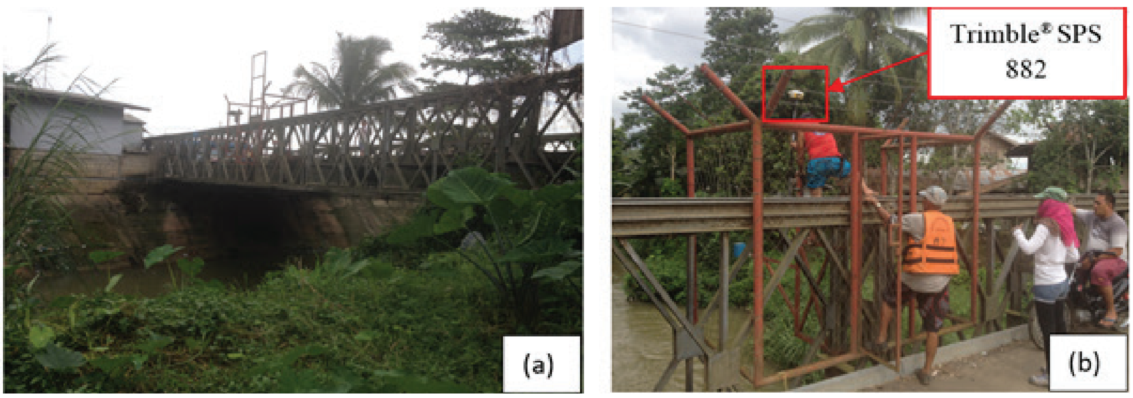


Figure 42. (a) Panoramic View of Maloloy-on Bridge facing upstream; (b) and cross-section and as-built survey of Maloloy-on Bridge

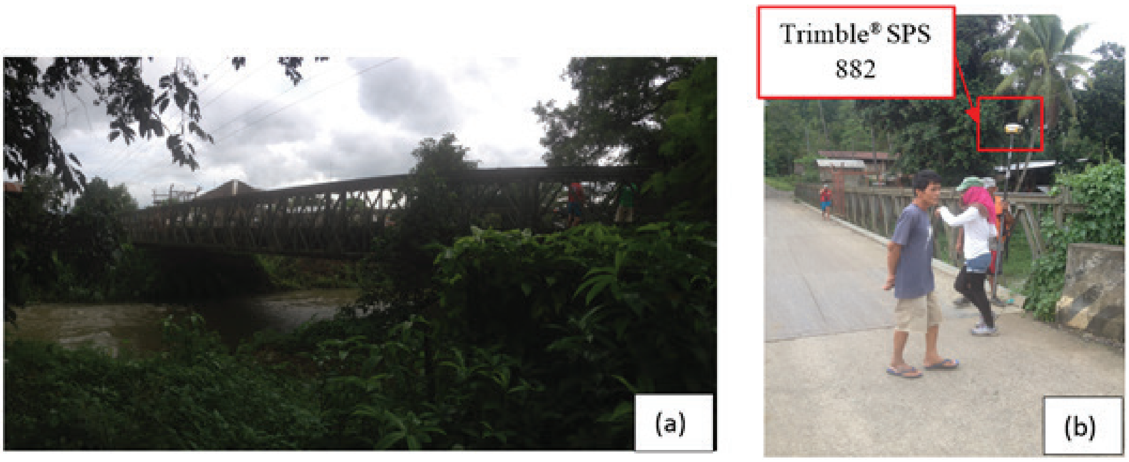


Figure 43. (a) Panoramic View of Mabuhay Bridge facing upstream; (b) cross section and as-built survey of Mabuhay Bridge

The cross-sectional line for the Usugan Bridge is about 231 meters with one hundred (100) cross-sectional points. Figure 44 and Figure 45 show the location map and cross-sectional diagram of Usugan bridge.

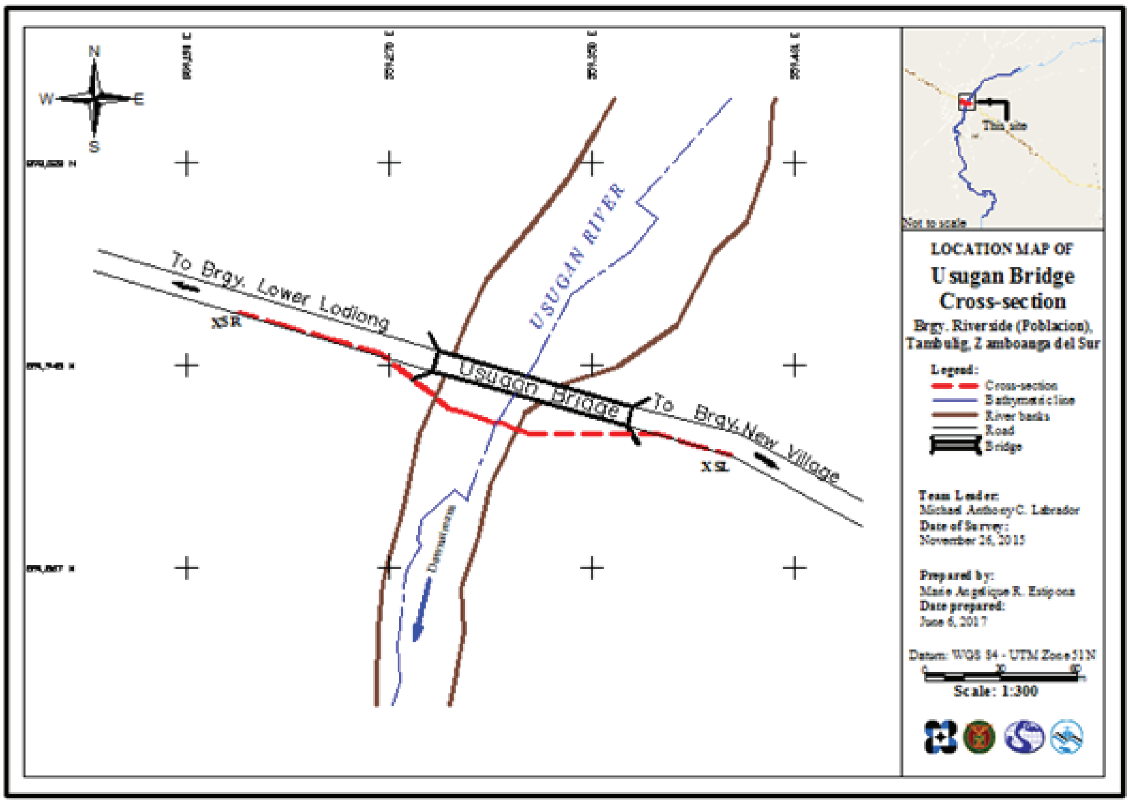


Figure 44. Usugan bridge cross-section location map

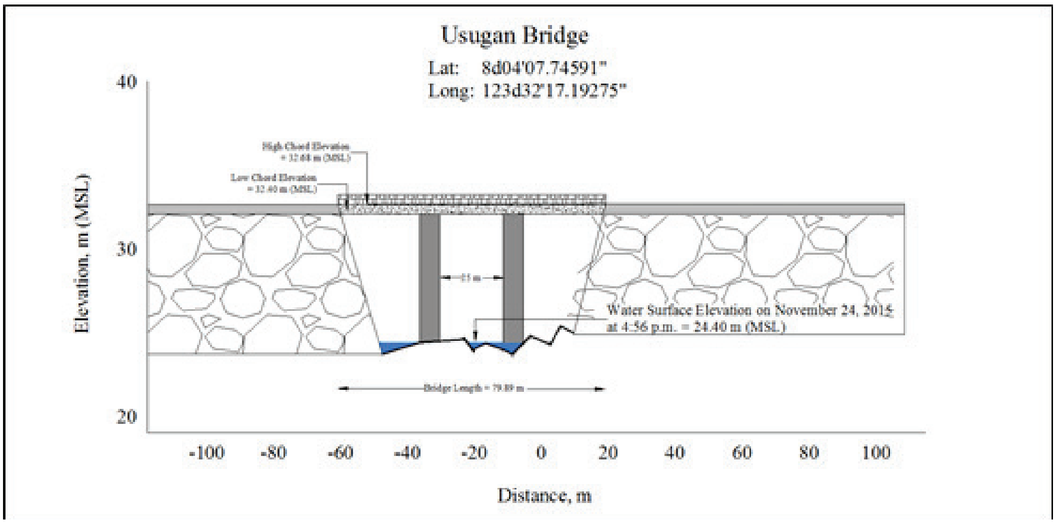


Figure 45. Usugan Bridge cross-sectional diagram

The cross-sectional line for the Sudlon Bridge is about 293 meters with seventy-six (76) cross-sectional points. Figure 46 and Figure 47 show the the location map and cross-sectional diagram of Sudlon Bridge.

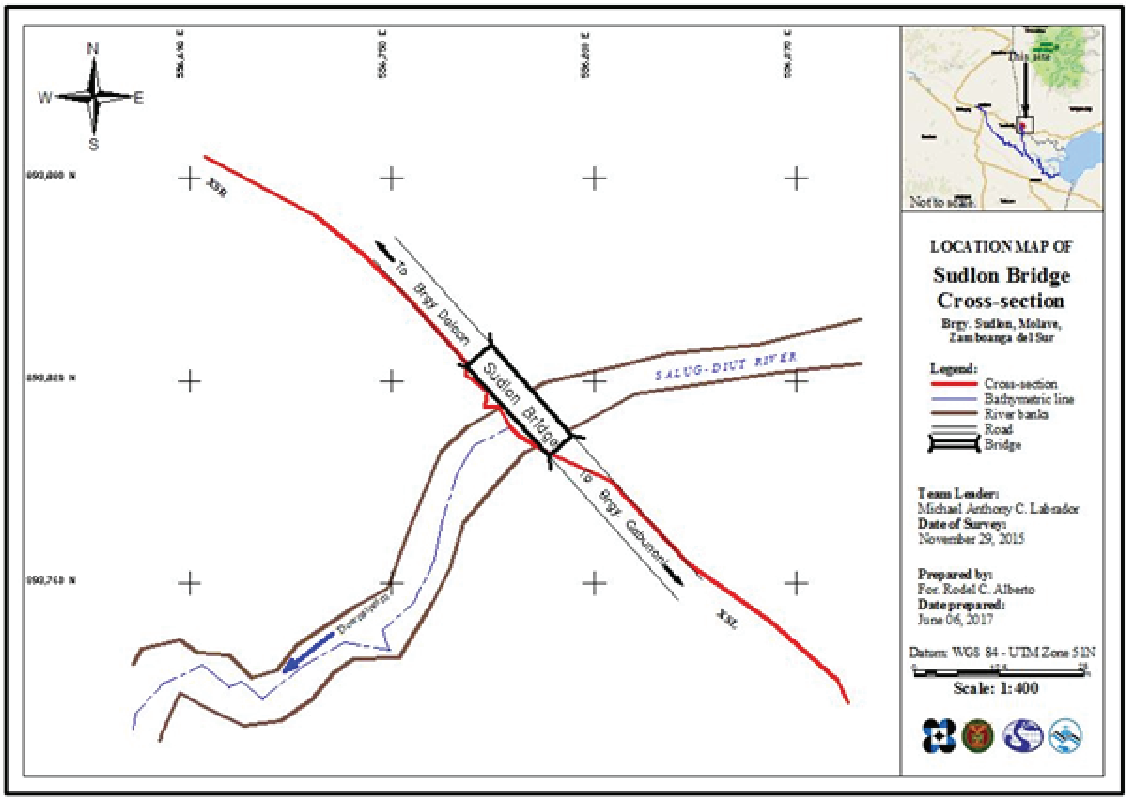


Figure 46. Sudlon bridge cross-section location map

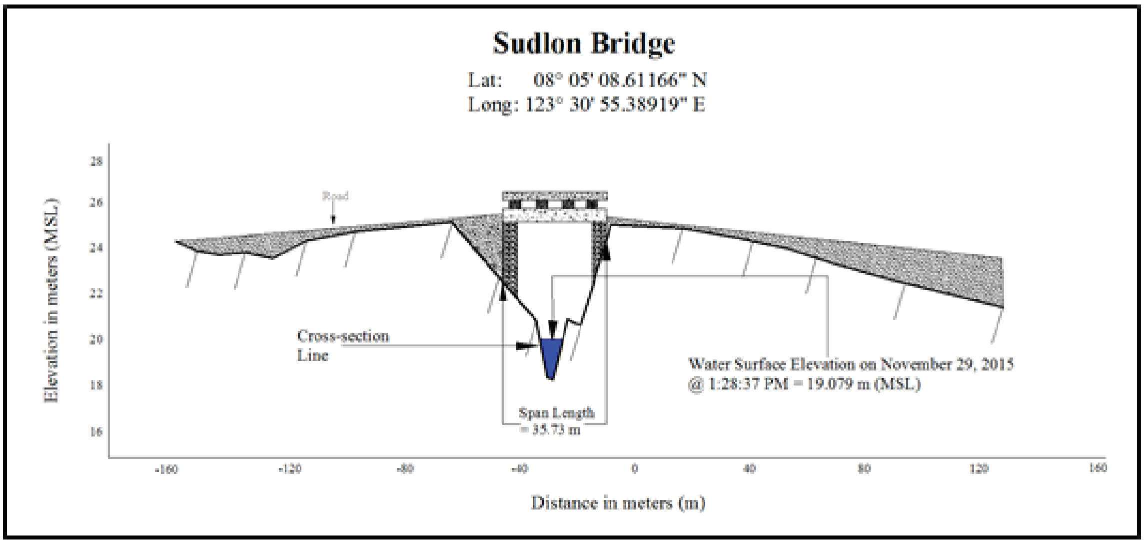


Figure 47. Sudlon Bridge cross-sectional diagram

The cross-sectional line for the Maloloy-on Bridge is about 127 meters with fifty (50) cross-sectional points. Figure 48 and Figure 49 show the location map and cross-sectional diagram of Maloloy-on Bridge.

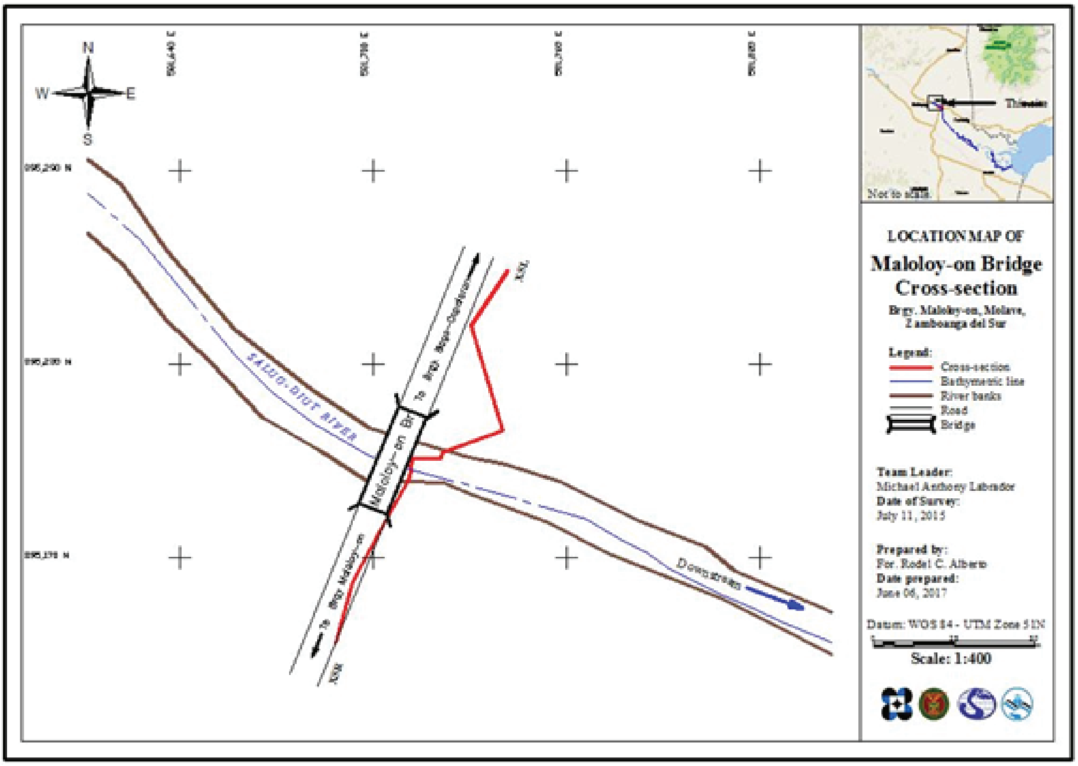


Figure 48. Maloloy-on bridge cross-section location map

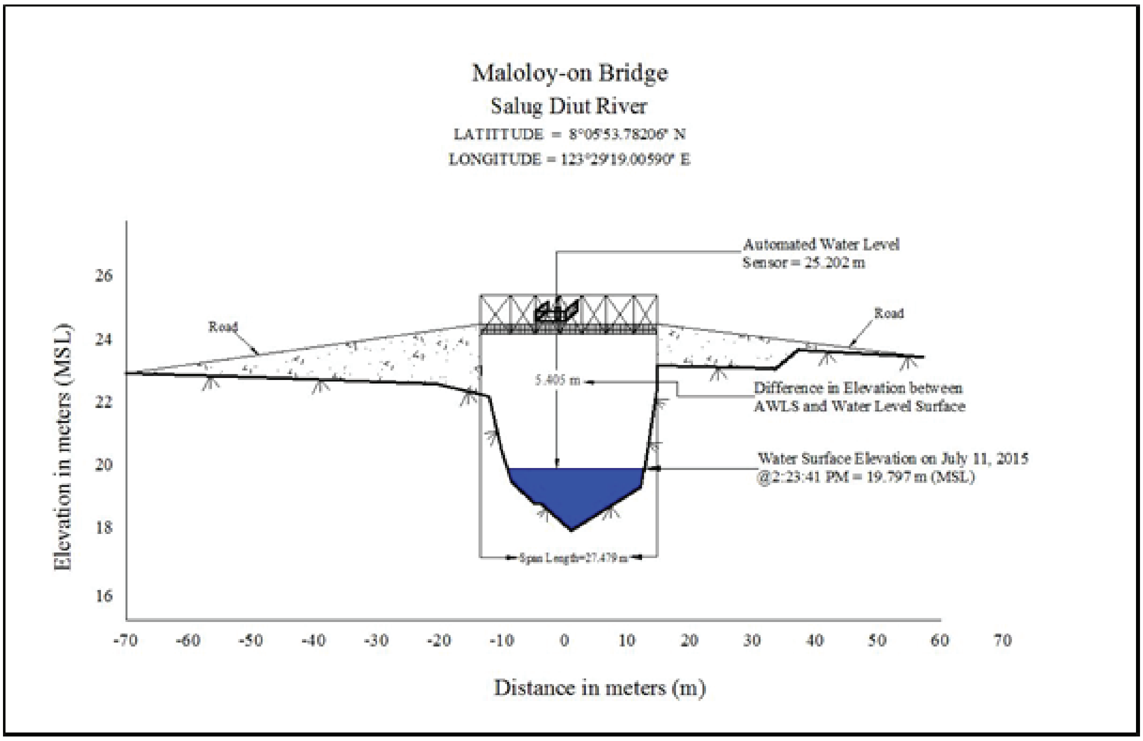


Figure 49. Maloloy-on Bridge cross-sectional diagram

The cross-sectional line for the Mabuhay Bridge is about 116 meters with twenty-six (26) cross-sectional points. Figure 50 and Figure 51 show the location map and cross-sectional diagram of Mabuhay Bridge.

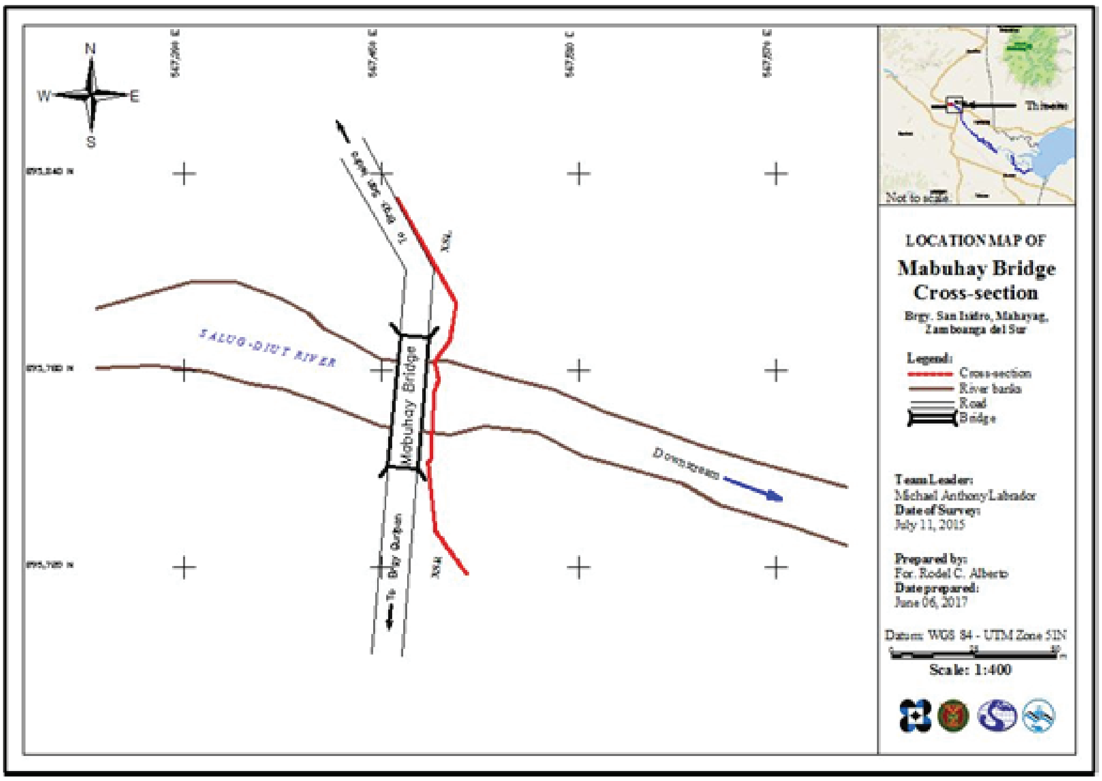


Figure 50. Mabuhay bridge cross-section location map

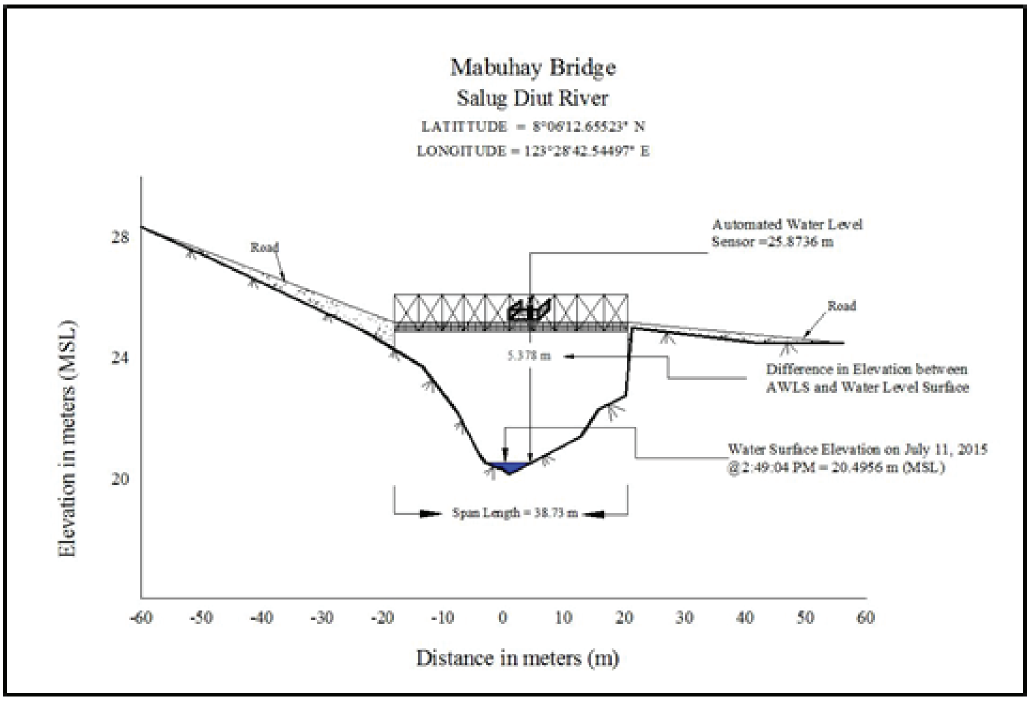
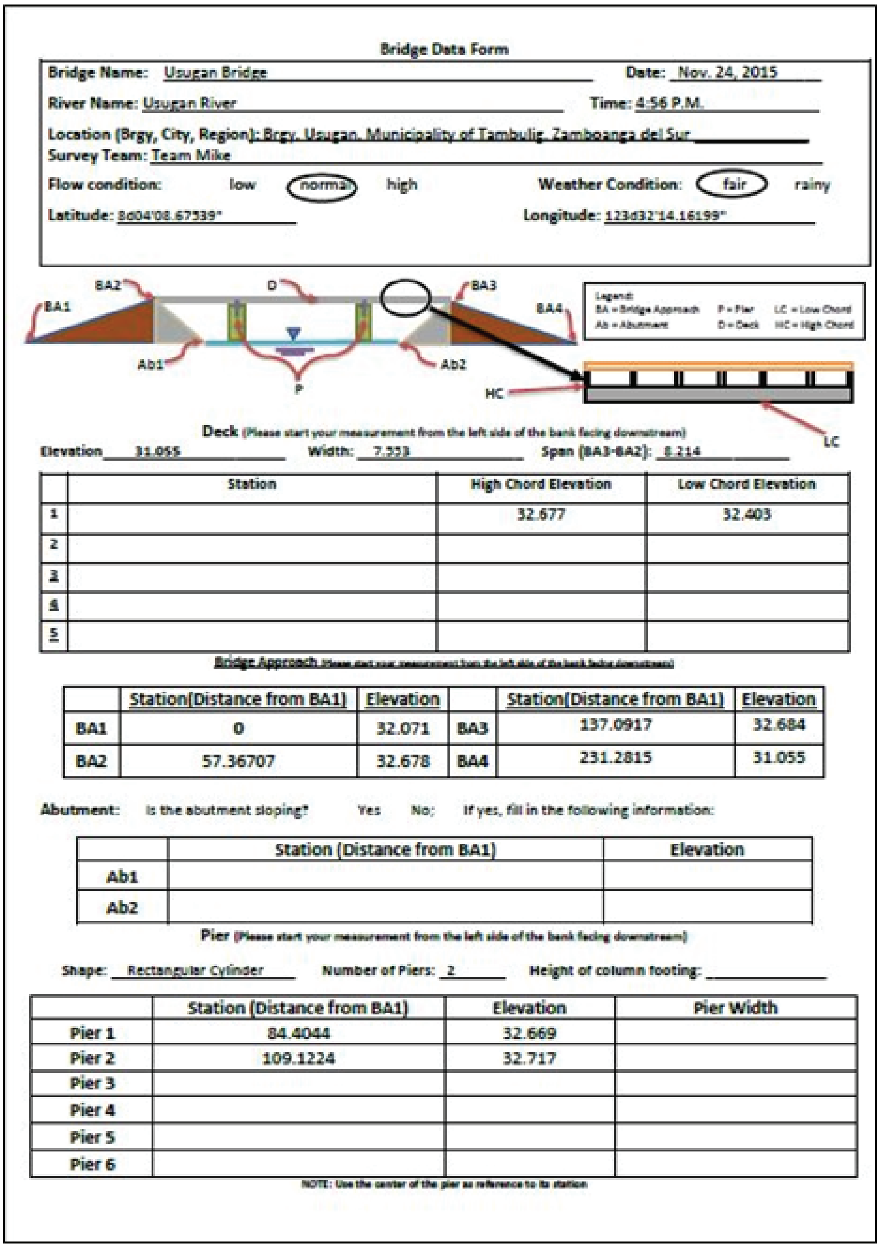


Figure 51. Mabuhay Bridge cross-sectional diagram

The bridge as-built form of the four bridges are shown in Figure 52 to Figure 55, respectively.



Bridge Data Form

Bridge Name: Usugan Bridge Date: Nov. 24, 2015

River Name: Usugan River Time: 4:56 P.M.

Location (Brgy, City, Region): Brgy. Usugan, Municipality of Tambulig, Zamboanga del Sur

Survey Team: Team Mike

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 8d04'08.67339" Longitude: 123d32'14.16199"

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

Elevation 31.055 Width: 7.553 Span (BA3-BA2): 8.214

	Station	High Chord Elevation	Low Chord Elevation
1		32.677	32.403
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	32.071	BA3	137.0917	32.684
BA2	57.36707	32.678	BA4	231.2815	31.055

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: Rectangular Cylinder Number of Piers: 2 Height of column footing:

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	84.4044	32.669	
Pier 2	109.1224	32.717	
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 52. Mabuhay Bridge cross-sectional diagram

Bridge Data Form

Bridge Name: Sudlon Bridge Date: Nov. 29, 2015

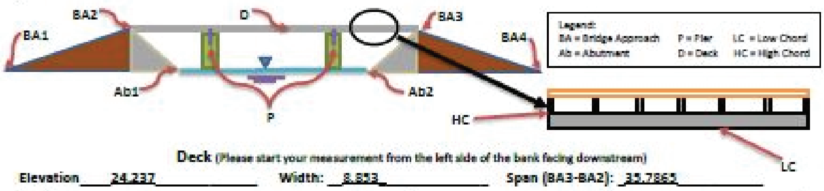
River Name: Sudlon Creek Time: 1:28 P.M.

Location (Brgy, City, Region): Brgy. Sudlon, Municipality of Molave, Zamboanga del Sur

Survey Team: Team Mike

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 8d05'05.76761" Longitude: 123d27'05.53480"



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

Elevation: 24.237 Width: 8.853 Span (BA3-BA2): 35.7865

	Station	High Chord Elevation	Low Chord Elevation
1		25.338	23.349
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	24.237	BA3	149.684	25.099
BA2	113.962	25.094	BA4	288.232	21.370

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

	Station (Distance from BA1)	Elevation
Ab1	117.884	22.774
Ab2	120.805	21.436

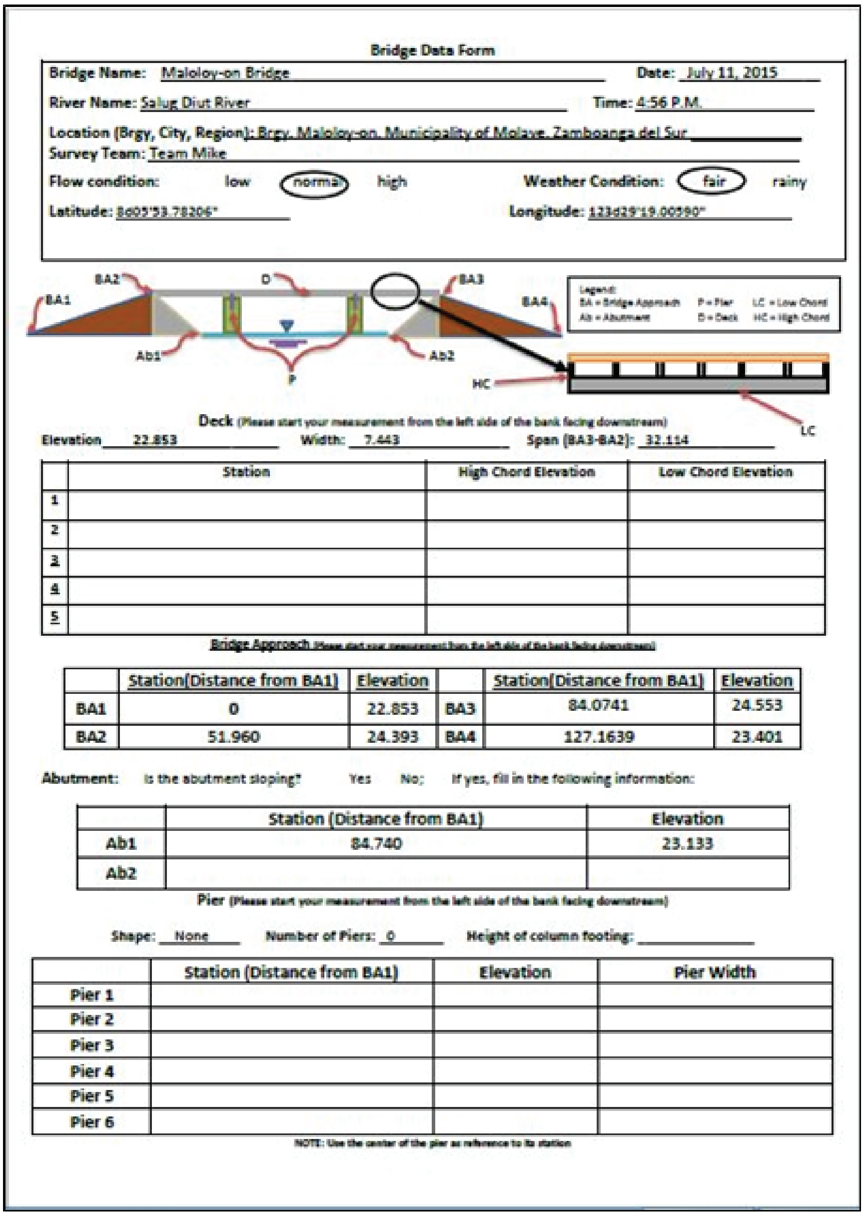
Pier (Please start your measurement from the left side of the bank facing downstream)

Shape: Rectangular Number of Piers: 0 Height of column footing:

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			

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

Figure 53. Sudlon Bridge data form



Bridge Data Form

Bridge Name: Maloloy-on Bridge Date: July 11, 2015

River Name: Salug Diut River Time: 4:56 P.M.

Location (Brgy, City, Region): Brgy. Maloloy-on, Municipality of Molave, Zamboanga del Sur

Survey Team: Team Mike

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 8d05'53.78206" Longitude: 123d29'19.00590"

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

Elevation 22.853 Width: 7.443 Span (BA3-BA2): 32.114

	Station	High Chord Elevation	Low Chord Elevation
1			
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	22.853	BA3	84.0741	24.553
BA2	51.960	24.393	BA4	127.1639	23.401

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

	Station (Distance from BA1)	Elevation
Ab1	84.740	23.133
Ab2		

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

Shape: None Number of Piers: 0 Height of column footing:

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 54. Maloloy-on Bridge data form

Bridge Data Form

Bridge Name: Mabuhay Bridge　　Date: July 11, 2015

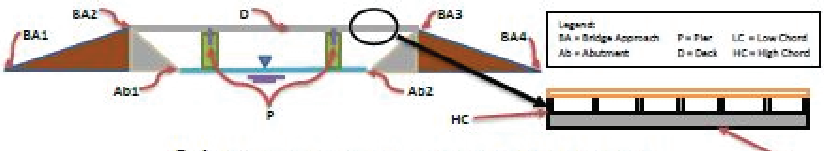
River Name: Salug Diut River　　Time: 2:49 P.M.

Location (Brgy, City, Region): Brgy. San Isidro, Municipality of Mahayag, Zamboanga del Sur

Survey Team: Team Mike

Flow condition: low　normal　high　　Weather Condition: fair　rainy

Latitude: 8d06'12.65523"　　Longitude: 123d28'42.54497"



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

Elevation: 28.323　　Width: 7.633　　Span (BA3-BA2): 38.729

	Station	High Chord Elevation	Low Chord Elevation
1			
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	28.323	BA3	80.580	25.393
BA2	41.851	25.292	BA4	116.375	24.484

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

	Station (Distance from BA1)	Elevation
Ab1	80.277	22.701
Ab2		

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

Shape: None　　Number of Piers: 0　　Height of column footing: ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 55. Mabuhay Bridge data form

Water surface elevation of the tributaries in Salug Diut River was determined using Trimble® SPS 882 in PPK mode technique. Usugan river was measured on November 24, 2015 at 4:54 P.M., Sudlon Creek on November 29, 2015 at 1:28 P.M., and Salug Diut River along Maloloy-on bridge on July 11, 2015 at 4:56 P.M. The water surface elevation was translated onto marking the pier and abutments using a digital level. The right side of the pier or abutments were marked using red and white paint as shown in Figure 56 to Figure 58. The marked pier or abutment shall serve as reference for flow data gathering and depth gauge deployment by the accompanying HEI, Mindanao State University – Iligan Institute of Technology, who is responsible for the Salug Diut River and its tributaries.

Figure 56. Water level markings on the side of the pier in Usugan Bridge

Figure 57. Water level markings on the abutment of Sudlon Bridge

Figure 58. Water level markings on the abutment of Sudlon Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on July 12, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height of 2.223 meters was measured from the ground up to the bottom of notch of the GNSS Rover receiver. The activity started from Brgy. Sambulawan, Municipality of Tukuran, Zamboanga del Sur to Brgy. Calolot, Municipality of Tambulig, Zamboanga del Sur.

A total of 2,224 ground validation points were acquired with an approximate length of 16.13 km using ZGS-79 as the GNSS base station, as shown in the map in Figure 60.

Figure 59. Validation points acquisition set-up for Salug Diut River Basin

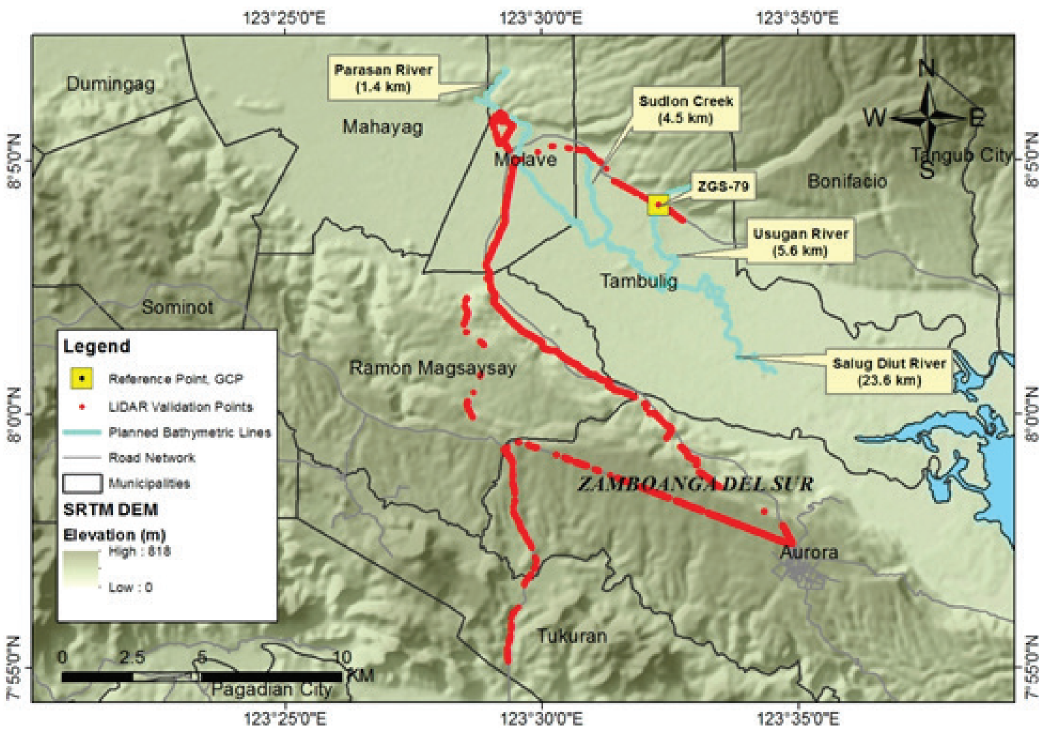


Figure 60. Validation points acquisition survey covering the length of Salug Diut River Basin

4.7 River Bathymetric Survey

Bathymetric survey of the Salug Diut River and its tributaries was conducted on November 24 to December 07, 2015 utilizing a GNSS Rover receiver, Trimble® SPS 882 in PPK survey technique mounted on top of a pole and Ohmex™ single-beam echo sounder shown in Figure 61 was used. The survey with echo sounder started from the upstream in Parasan River, in Brgy. Mabuhay, Municipality of Mahayag with coordinates 8°06'49.27516"123°29'15.83668" traversing the main stream of the Salug Diut River down to the mouth of the river in Brgy. San Jose, Municipality of Tambulig with coordinates 8°01'06.07794"123°35'03.59052".

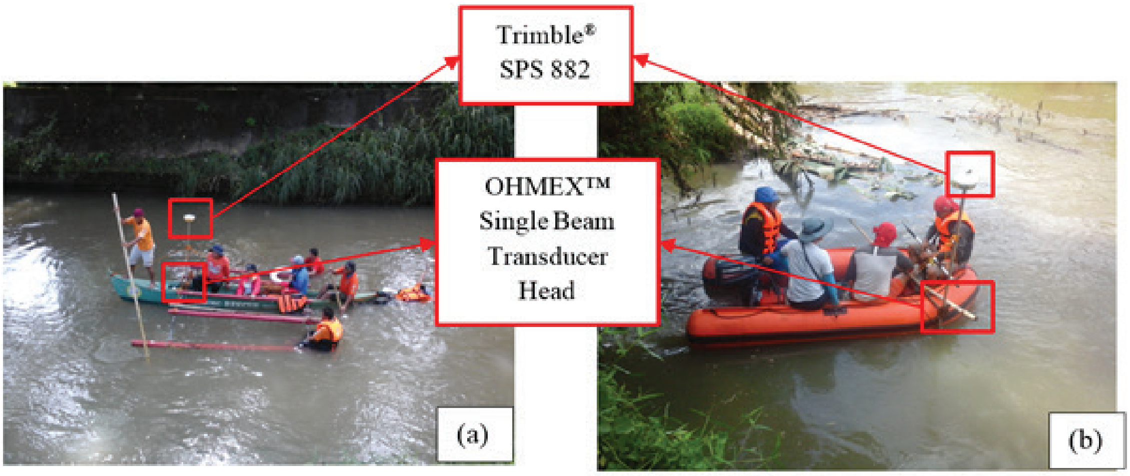


Figure 61. Bathymetric survey in (a) Parasan River in Brgy. Mabuhay, Municipality of Molave and (b) bathymetric survey in Salug Diut River in Brgy. Upper Tiparak, Municipality of Tambulig

Manual bathymetric survey, as shown in Figure 62, utilized a GNSS Rover receiver, Trimble® SPS 882 in PPK survey technique mounted on top of a pole also on November 24 to December 7, 2015. One team in Usugan River started from Brgy. Limamawanin the Municipality of Tambulig with coordinates 8°04'31.46163"123°32'56.02380" reaching the main stream of Salug Diut River in Brgy. Tungawan, Municipality of Tambulig with coordinates 8°02'34.25579"123°32'27.44854". And lastly, another manual bathymetry was performed in Sudlon Creek in Brgy. Gabunon, Municipality of Tambulig with coordinates 8°05'09.14299"123°30'56.13129" to reach the main stream of Salug Diut River in Brgy. Upper Tiparak, Municipality of Tambulig with coordinates 8°03'32.75683"123°31'15.66296". The control point ZGS-79 was used as the base station. The coverage of the bathymetric survey is illustrated in Figure 63.

Figure 62. Manual bathymetric survey in Usugan River, Brgy. Usugan, Municipality of Tambulig

The tributaries of Salug Diut River: Parasan River, Sudlon creek and Usugan River has a total of 2,677, 674 and 7,101 bathymetric points with each of them measuring up to 1.4, 4.5, and 5.6 km, respectively. Meanwhile, the Salug Diut main stream has 23,704 bathymetric points with an approximate length of 23.6 km. The tributaries and the main stream are illustrated in the map shown in Figure 63.

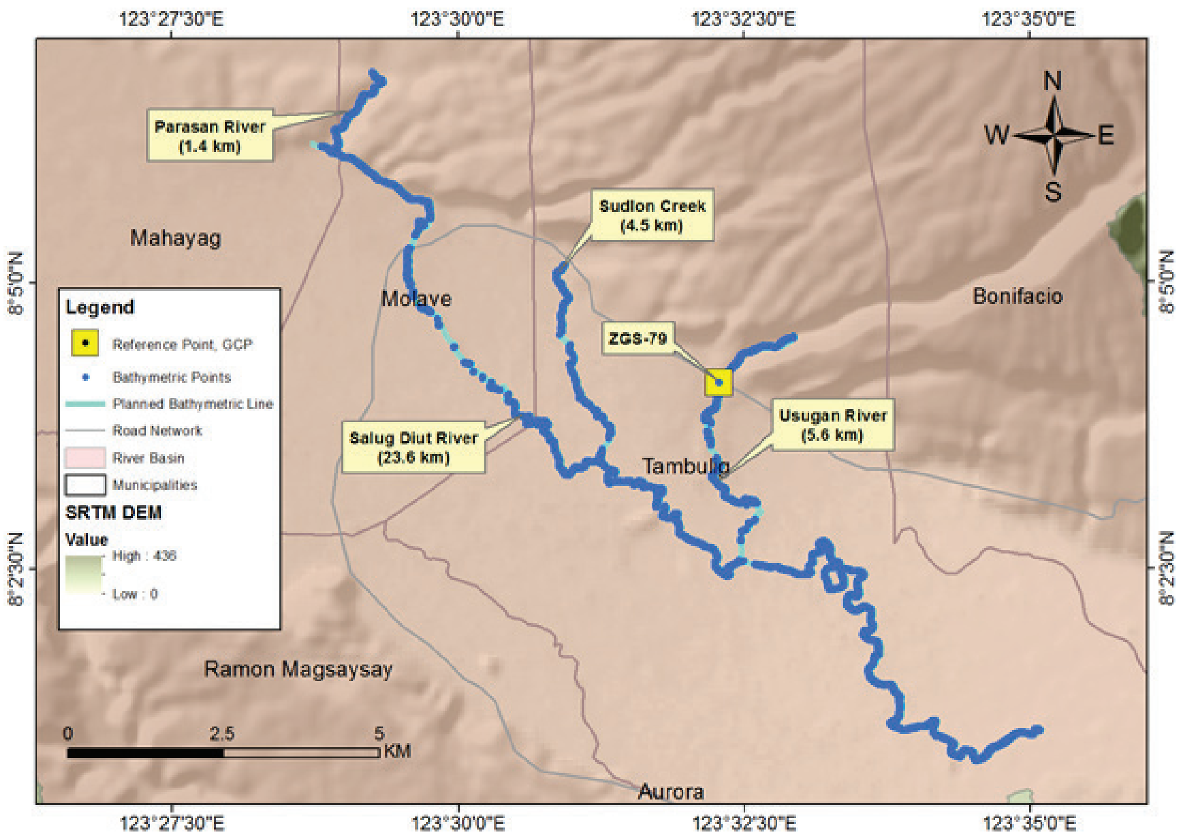


Figure 63. Bathymetric survey coverage of the Salug Diut River

CAD drawings were also produced to illustrate the Salug Diut riverbed profile from the upstream in Brgy. Mabuhay to Brgy. San Jose. In Parasan River,a drop in elevation of 13.78 meters with respect to MSL was observed within the approximated distance of 1.4 kilometers as shown in Figure 64.

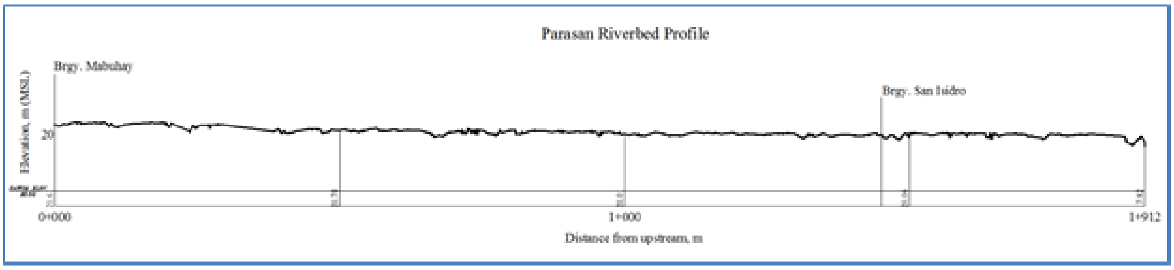


Figure 64. Riverbed profile of Parasan River

In the Salug Diut main stream, a drop in elevation of 4.94 meters with respect to MSL was observed within the approximated distance of 23.6 kilometers as shown in Figure 65.

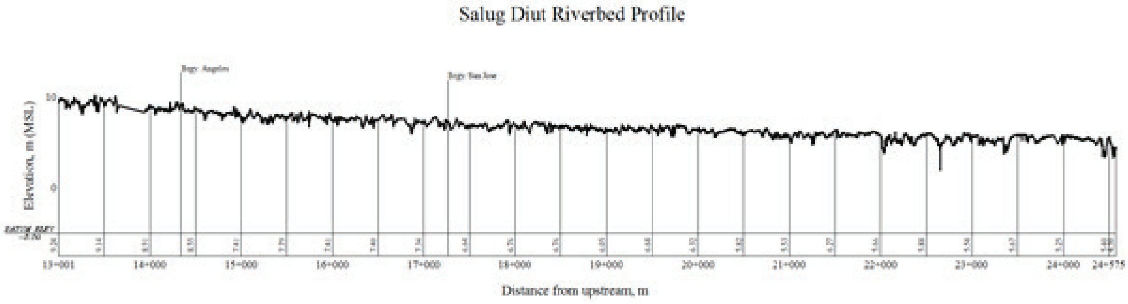


Figure 65. Riverbed Profile of Salug Diut River

In Sudlon Creek, a drop in elevation of 5.15 meters with respect to MSL was observed within the approximated distance of 4.5 kilometers as shown in Figure 66.

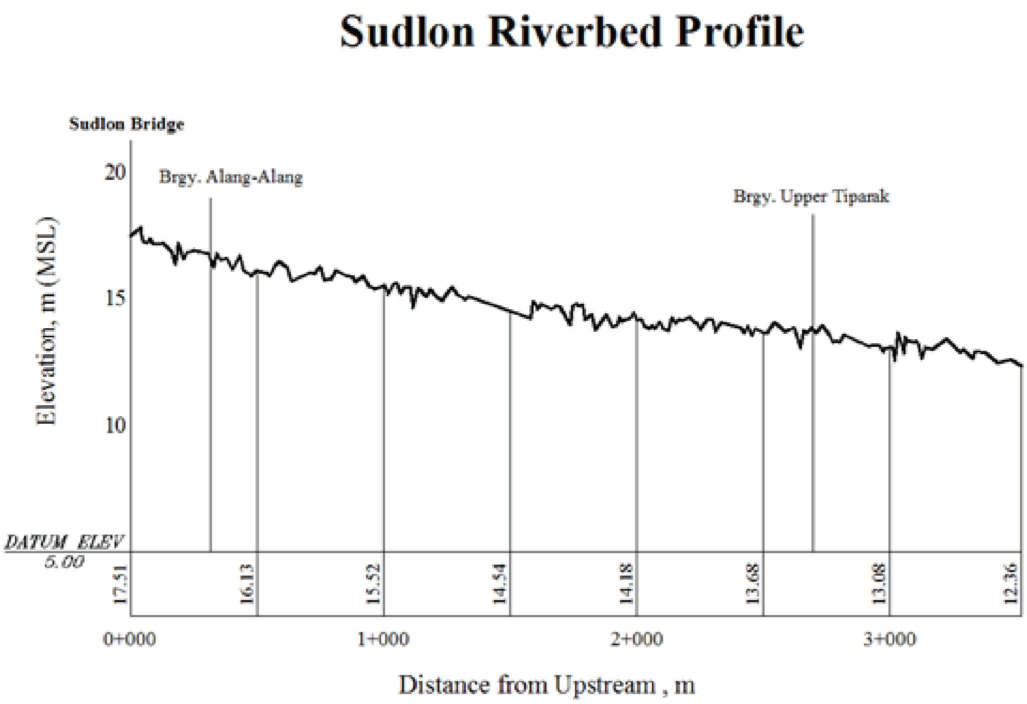


Figure 66. Riverbed Profile of Sudlon Creek

Lastly, in Usugan River, a drop in elevation of 41.64 meters with respect to MSL was observed within the approximated distance of 5.6 kilometers as shown in Figure 67.

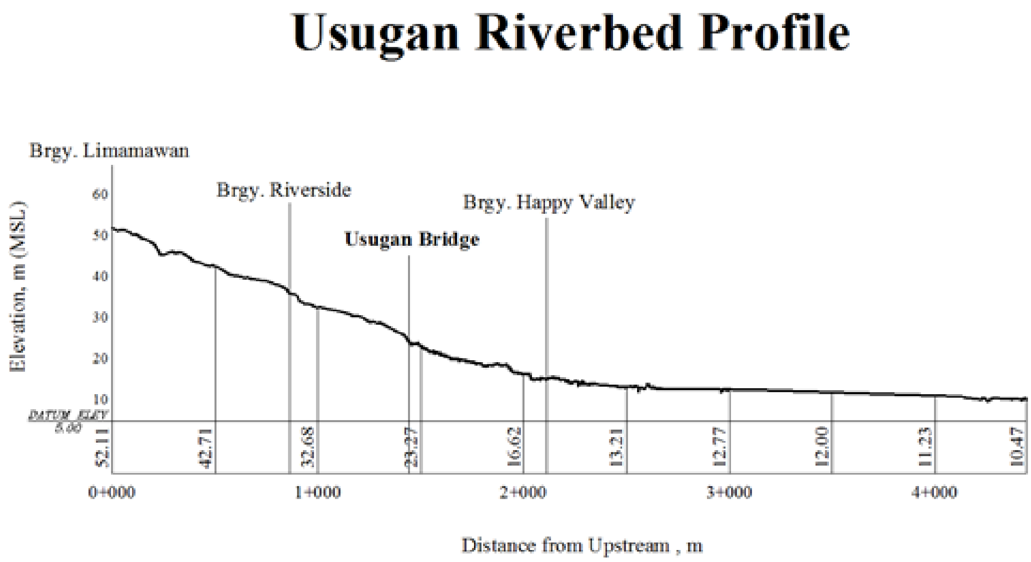


Figure 67. Riverbed Profile of Usugan River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the river basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from the Automatic Rain Gauge (ARG) installed upstream through DOST – Advanced Science and Technology Institute (ASTI). The aforementioned ARG was installed in Sudlon, Salug Diut with coordinates 8°5'24.36"N Latitude and 123°29'58.02"E Longitude. The location of the rain gauge is shown in Figure 68.

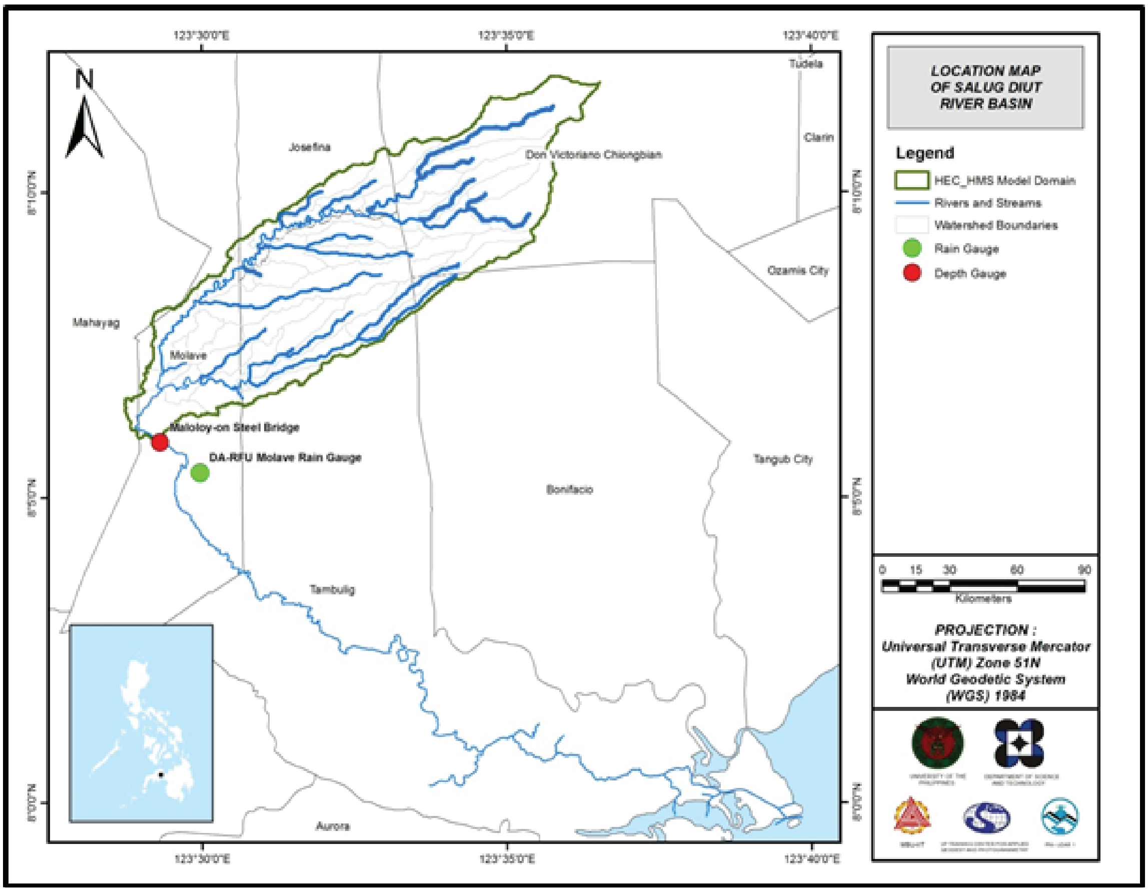


Figure 68. The location map of Salug Diut HEC-HMS model used for calibration

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 to or equal to 1.

Figure 70 shows the highest R-Squared value of 0.9734 compared to the graphs using the original Q. In this case, Q boxed values with Q at bank-full were plotted versus the stage

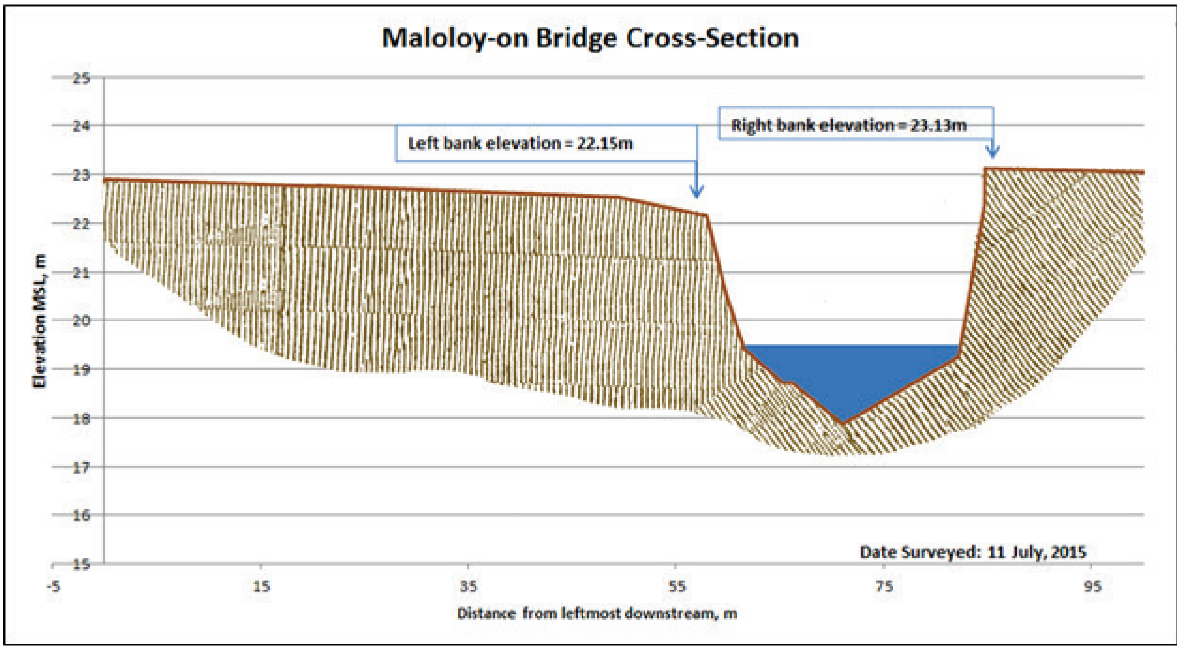


Figure 69. Cross-section plot of Maloloy-on Steel Bridge

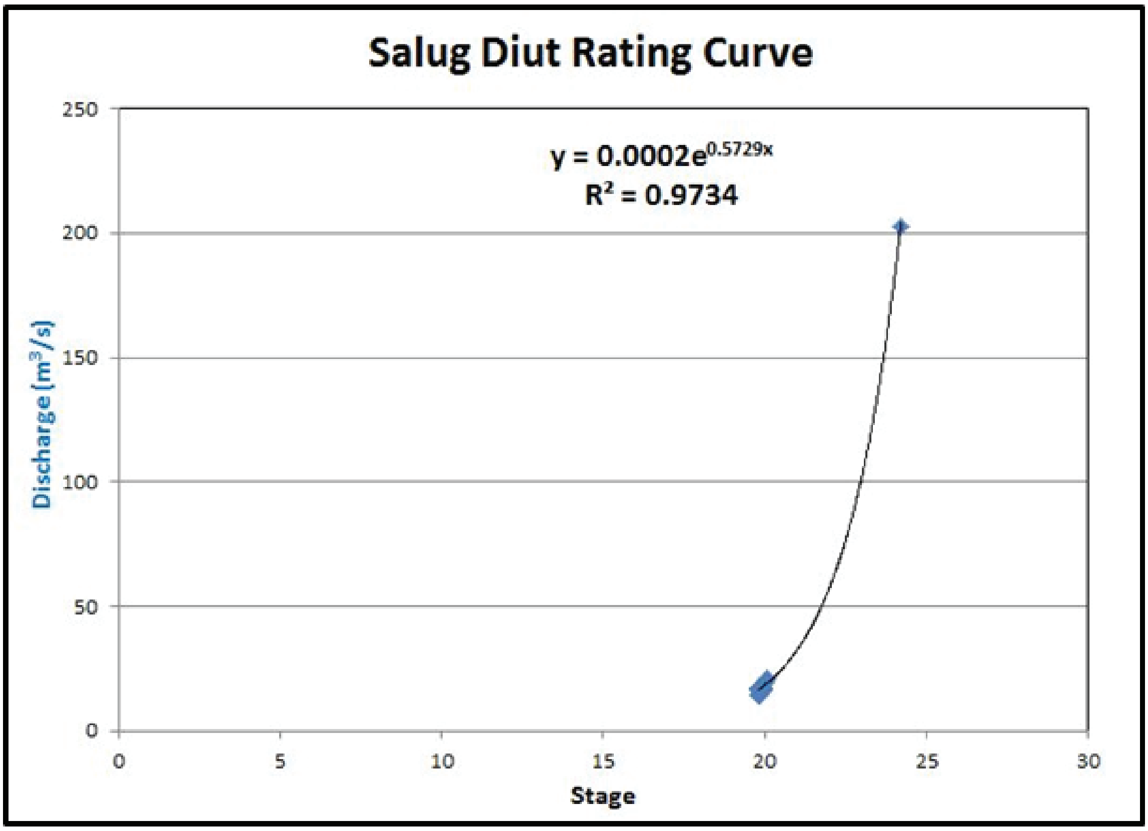


Figure 70. Rating curve at Maloloy-on Steel Bridge

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

Total rainfall accumulated for the second rainfall event between 24 November 2015, 15:00 to 25 November 2015, 13:00 is 18 mm. It peaked on 24 November 2015, 17:15 with a rainfall depth value of 9.2 mm. Peak discharge is recorded as 17.7 m3/s on 24 November 2015, 21:00. Lag time between the peak rainfall and discharge is 3 hours and 45 minutes.

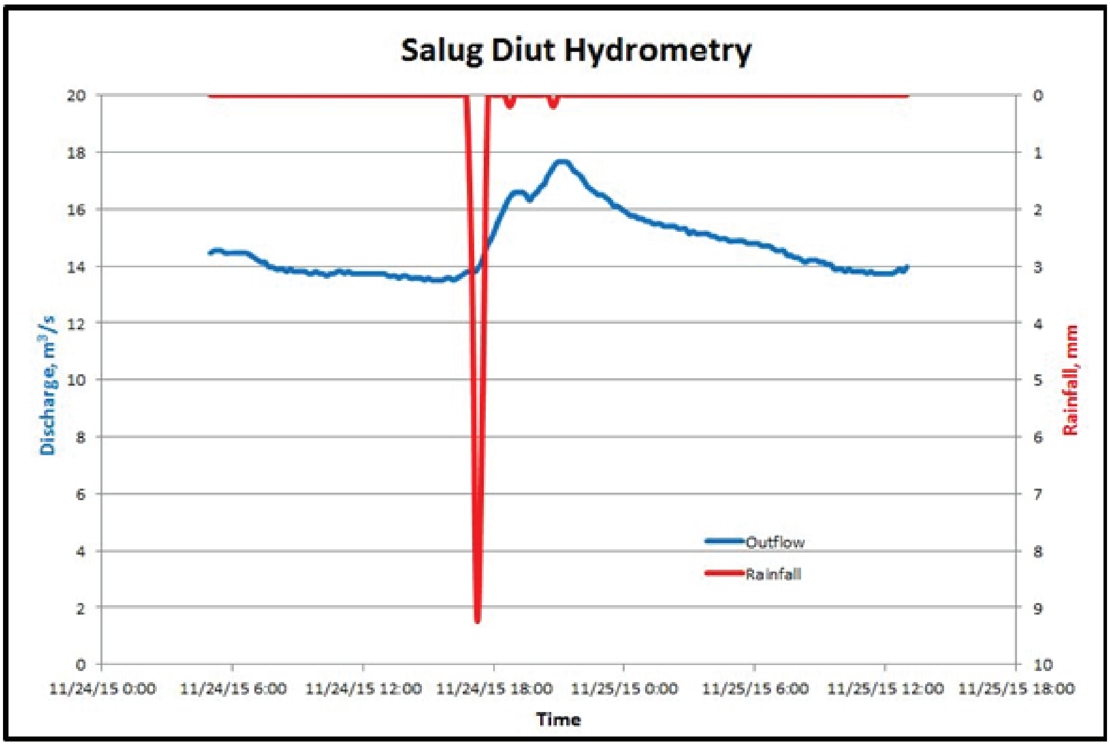


Figure 71. Rainfall and outflow data at Maloloy-on Steel Bridge used for modeling

5.2 RIDF Station

The Philippine 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 was chosen based on its proximity to the Salug Diut watershed. The extreme values for this watershed were computed based on a 51-year record.

Table 32. 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

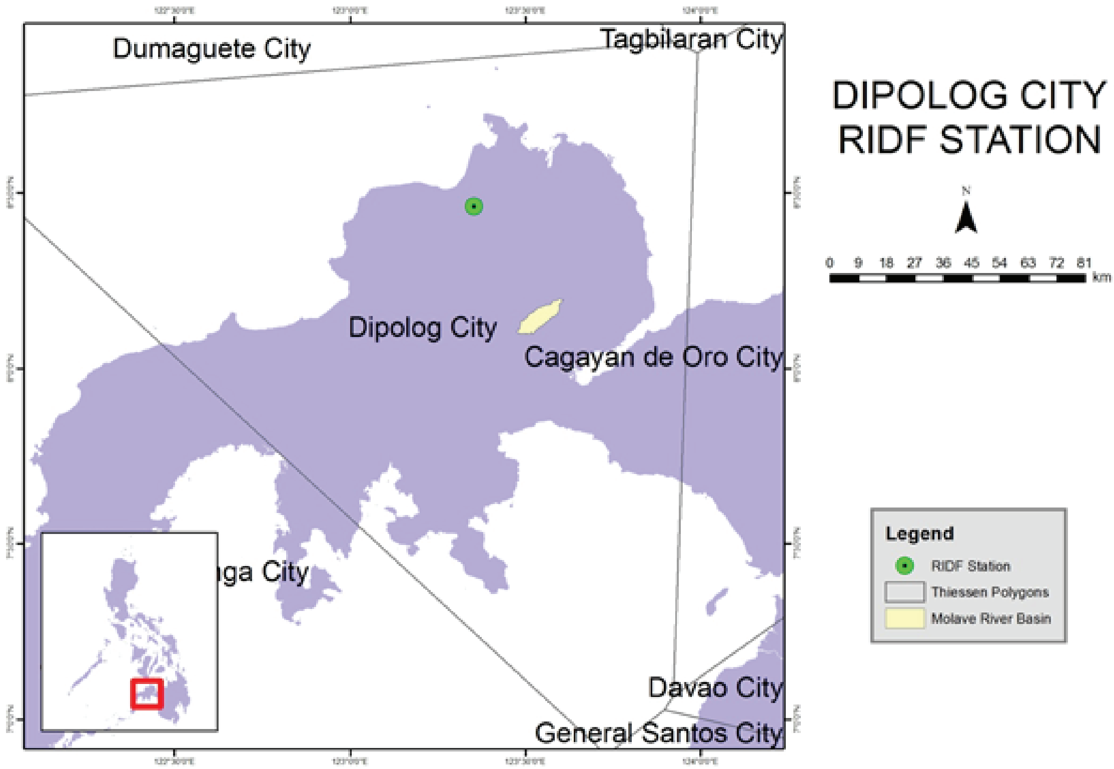


Figure 72. Location of Dipolog RIDF station relative to Salug Diut River Basin

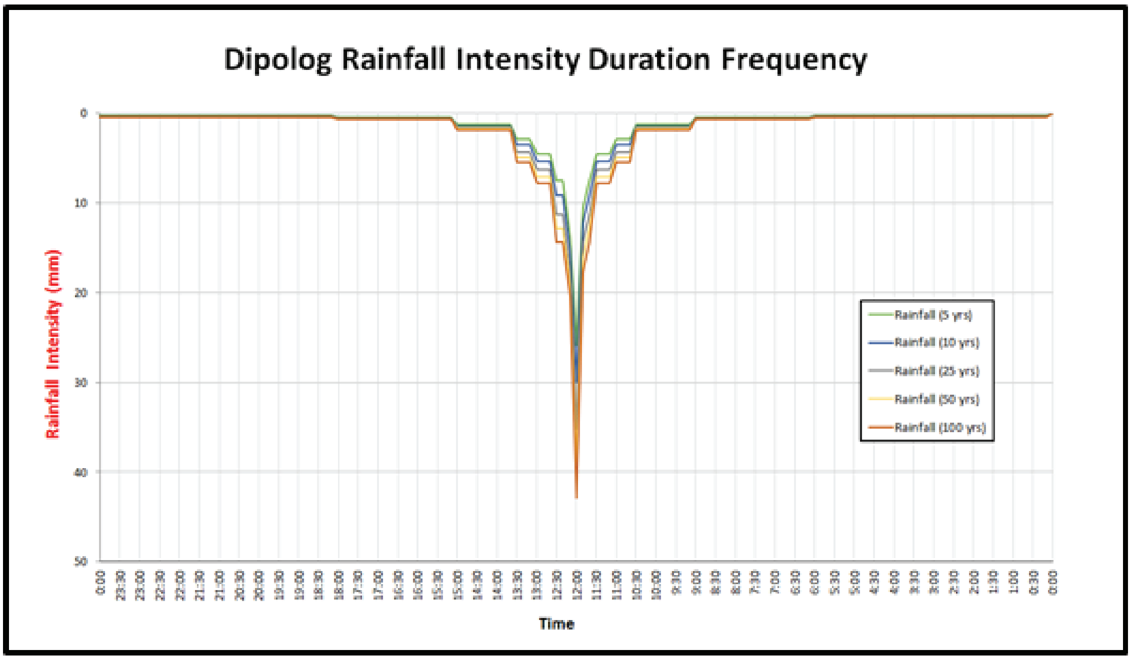


Figure 73. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil texture dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The soil texture map (Figure 74) of the Salug Diut River basin was used as one of the factors for the estimation of the CN parameter.

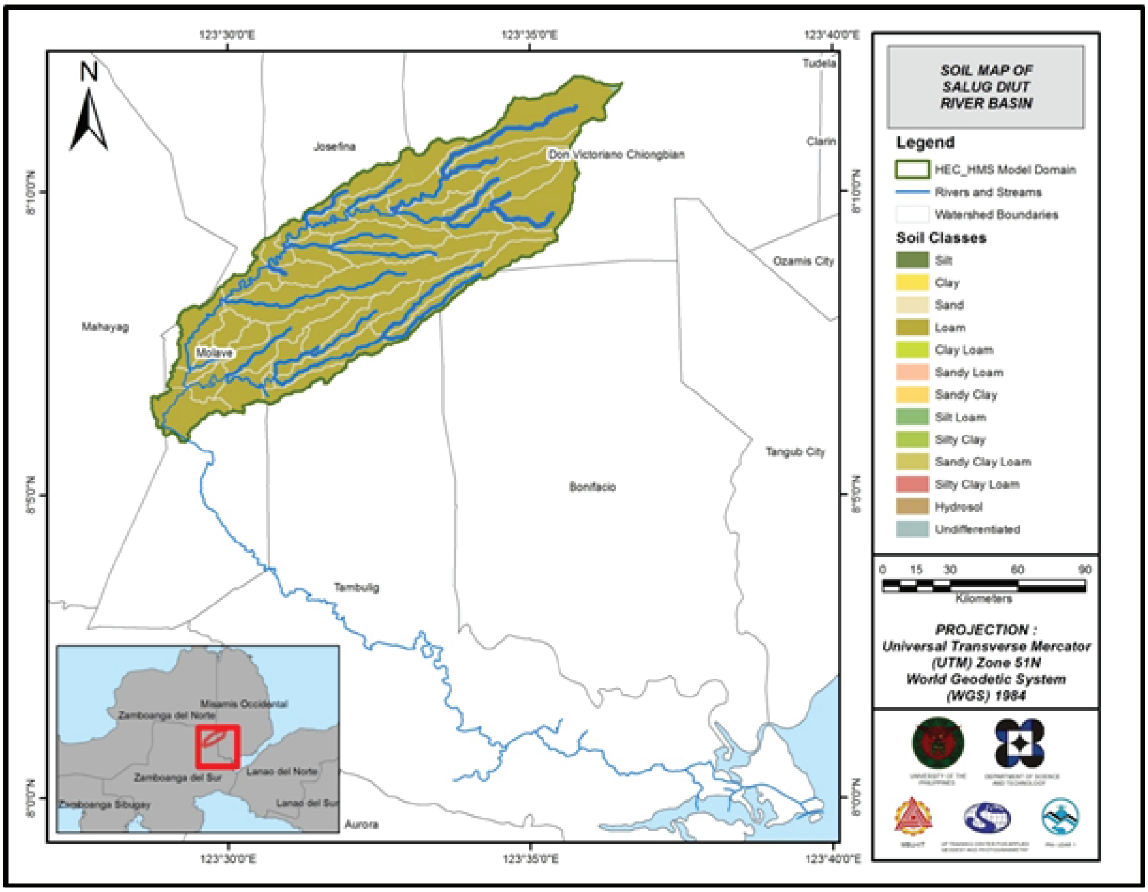


Figure 74. Soil map of Salug Diut River Basin

The land cover data was generated in 2003 by the National Mapping and Resource information Authority (NAMRIA), DENR. Figure 75 shows the land cover inside Salug Diut River Basin. The land cover map of Salug Diut River Basin was used as another factor for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

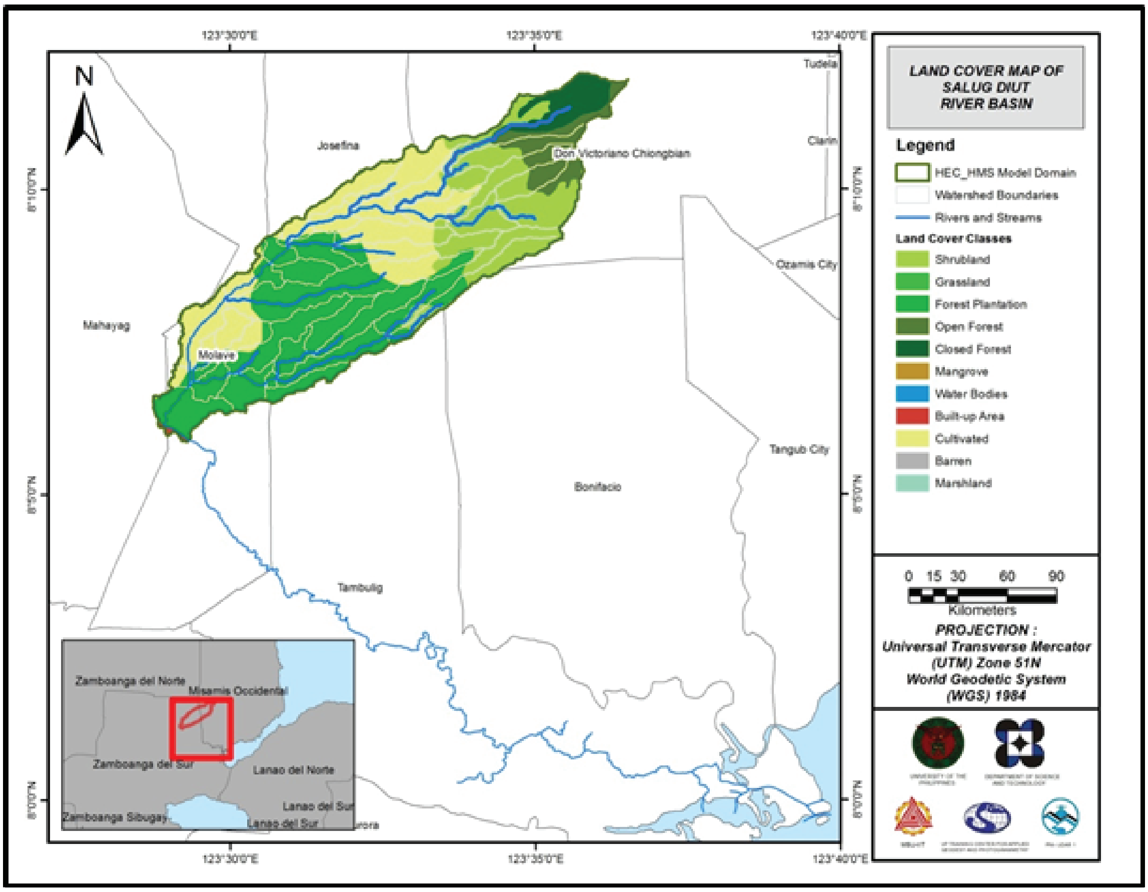


Figure 75. Land cover map of Salug Diut River Basin (Source: NAMRIA)

For Salug Diut, the soil class identified was hydrosol. The land cover types identified were shrubland, grassland, forest plantation, open forest, closed forest, and cultivated.

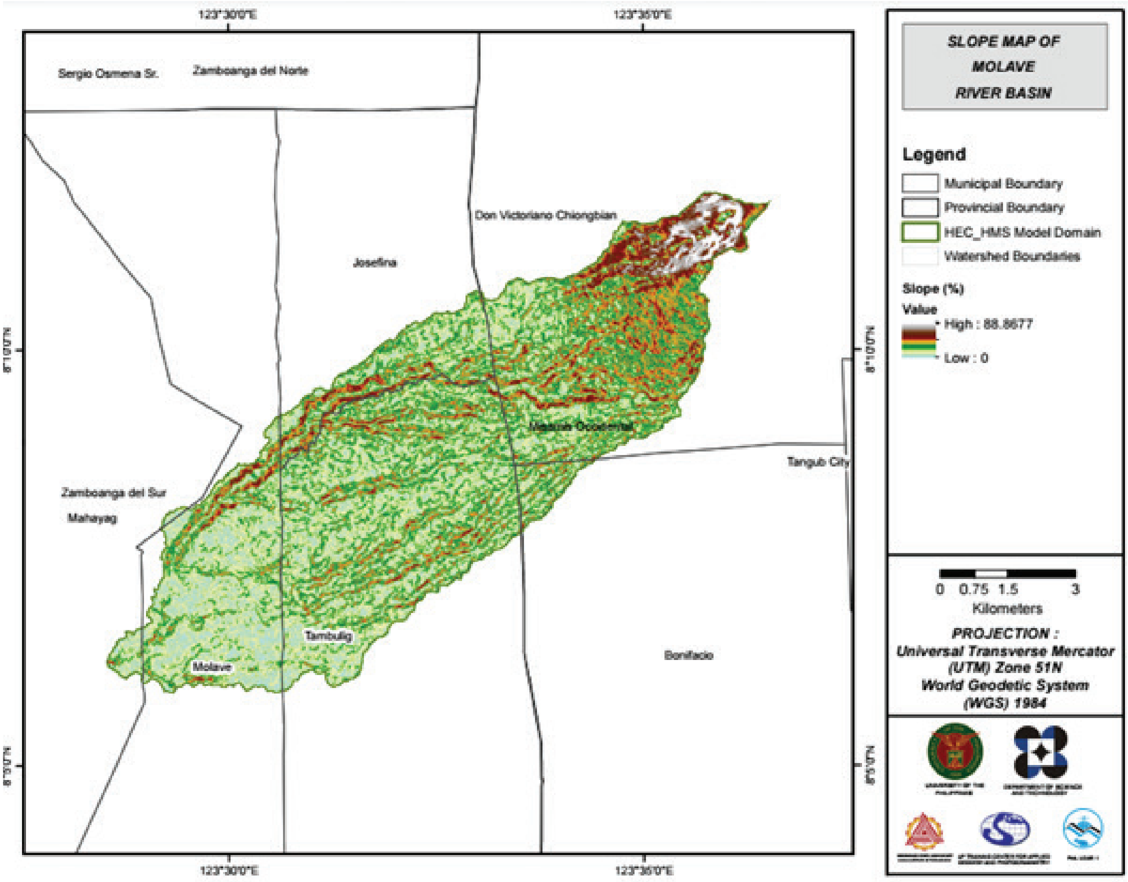


Figure 76. Land cover map of Salug Diut River Basin (Source: NAMRIA)

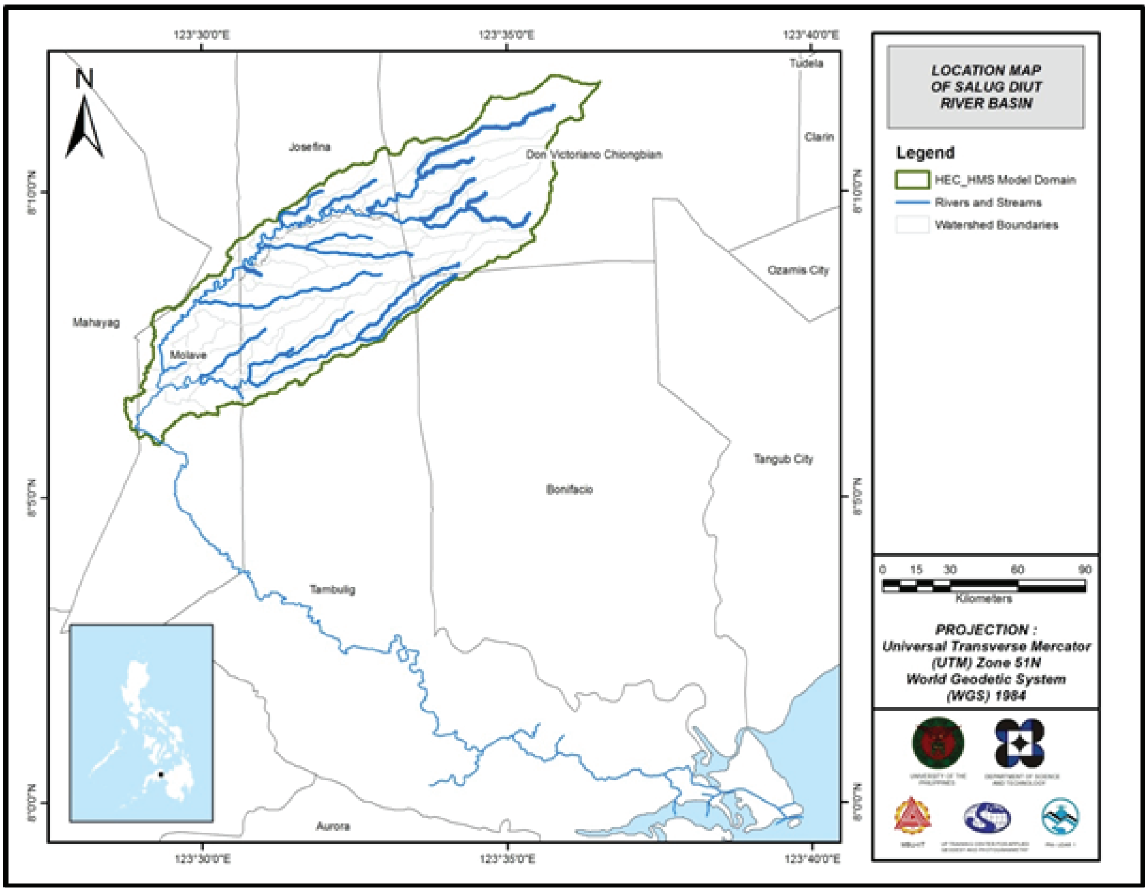


Figure 77. Stream delineation map of Salug Diut River

Using the SAR-based DEM, the Salug Diut basin was delineated and further subdivided into subbasins. The model consists of 37 subbasins, 18 reaches, and 18 junctions. The main outlet is located at Maloloy-on Bridge, Salug Diut. This basin model is illustrated in Figure 78. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Maloloy-on Bridge.

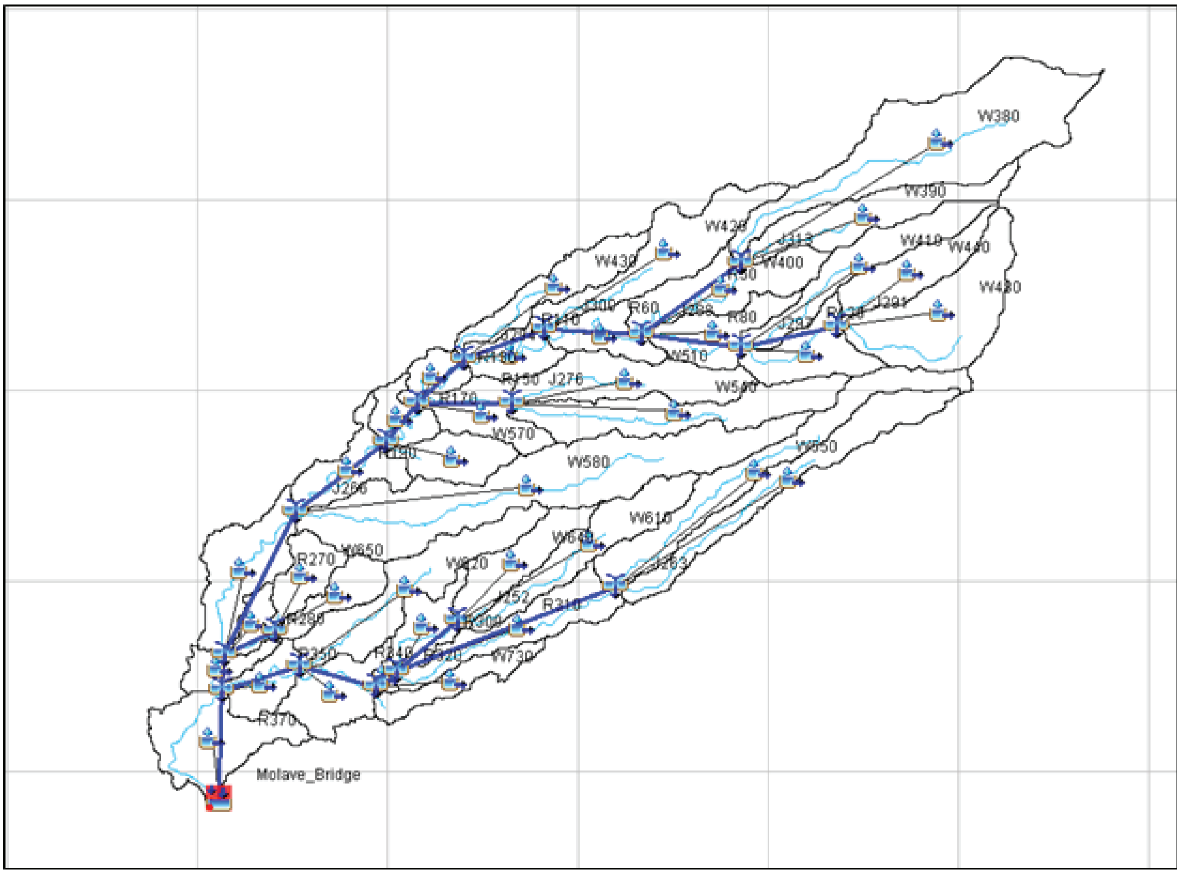


Figure 78. Stream delineation map of Salug Diut River

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 HEC GeoRAS tool and was post-processed in ArcGIS.

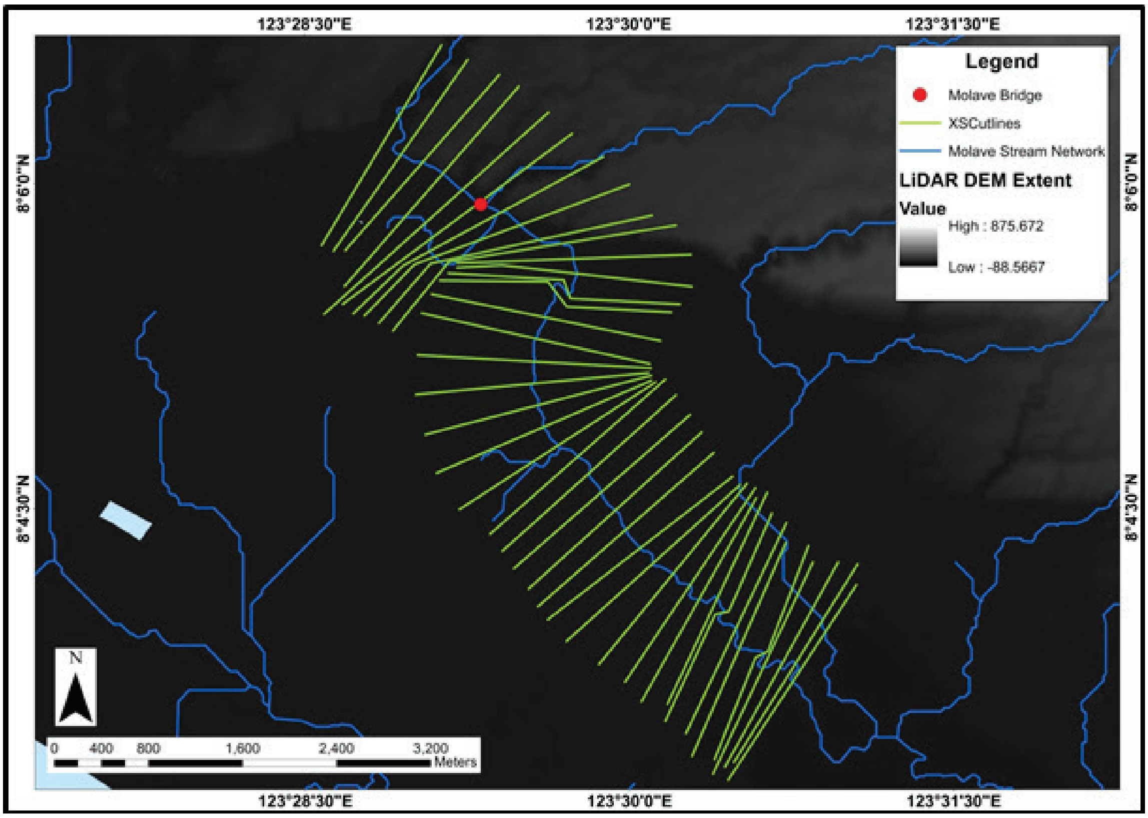


Figure 79. River cross-section of Salug Diut River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

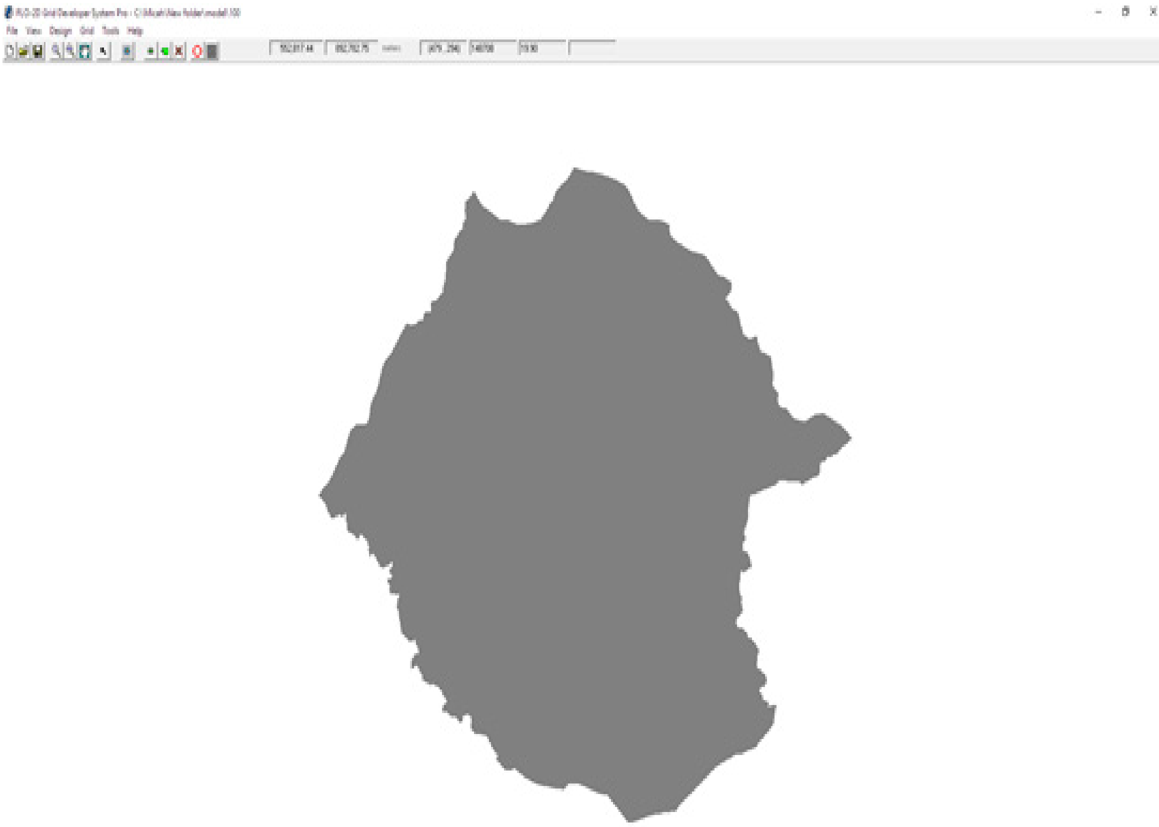


Figure 80. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 89.51855 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 64099500.00 m2.

There is a total of 36704201.96 m3 of water entering the model. Of this amount, 17200491.51 m3 is due to rainfall while 19503710.45 m3 is inflow from other areas outside the model. 7585406.50 m3 of this water is lost to infiltration and interception, while 5923137.44 m3 is stored by the flood plain. The rest, amounting up to 23195620.28 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Salug Diut HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 80 shows the comparison between the two discharge data.

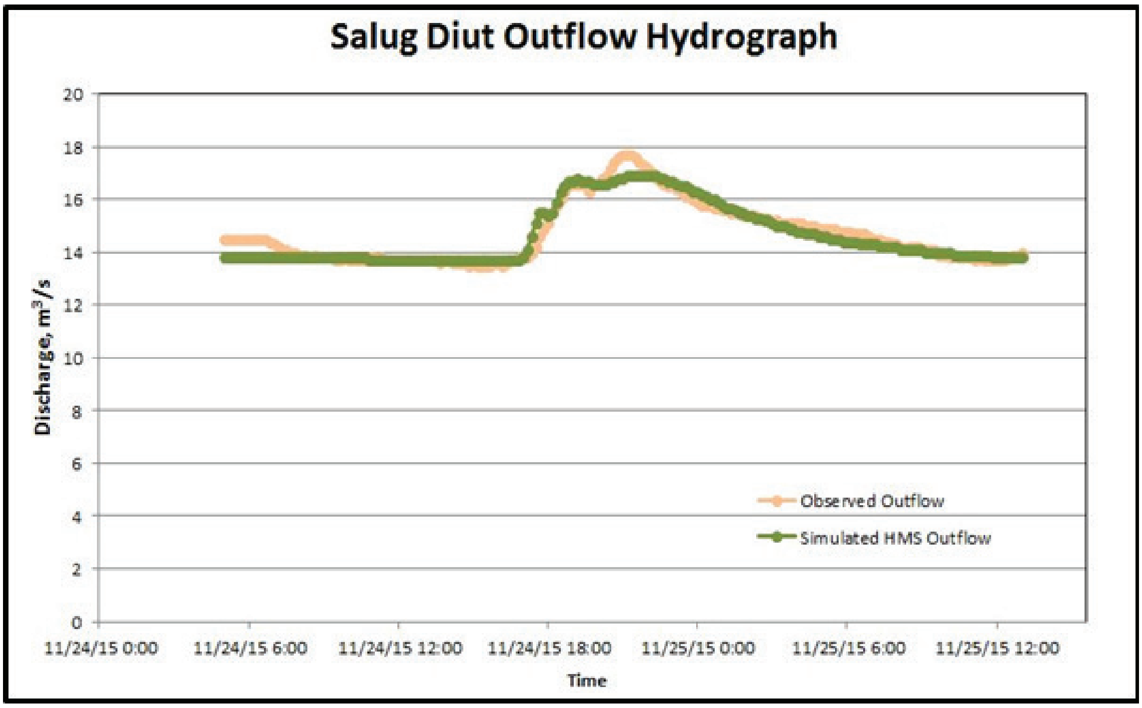


Figure 81. Outflow Hydrograph of Salug Diut Bridge generated in HEC-HMS model compared with observed outflow

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

Table 33. Range of calibrated values for Salug Diut

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	9 - 30
			Curve Number	40 - 60
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 - 9
			Storage Coefficient (hr)	0.08 - 8
	Baseflow	Recession	Recession Constant	0.98
			Ratio to Peak	0.1 – 0.3
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

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 9 to 30 mm means that there is minimal to 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 40 to 60 for curve number is relatively low compared to the advisable values for Philippine watersheds depending on the soil and land cover of the area.

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 0.02 to 9 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.98 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.1 to 0.3 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Salug Diut watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 34. Summary of the Efficiency Test of Salug Diut HMS Model

RMSE	0.49
r2	0.97
NSE	0.93
PBIAS	0.44
RSR	0.27

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.49 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A value 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 0.97.

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 0.93.

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 0.44.

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 0.27.

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 81) shows the Salug Diut outflow using the Dipolog RIDF in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

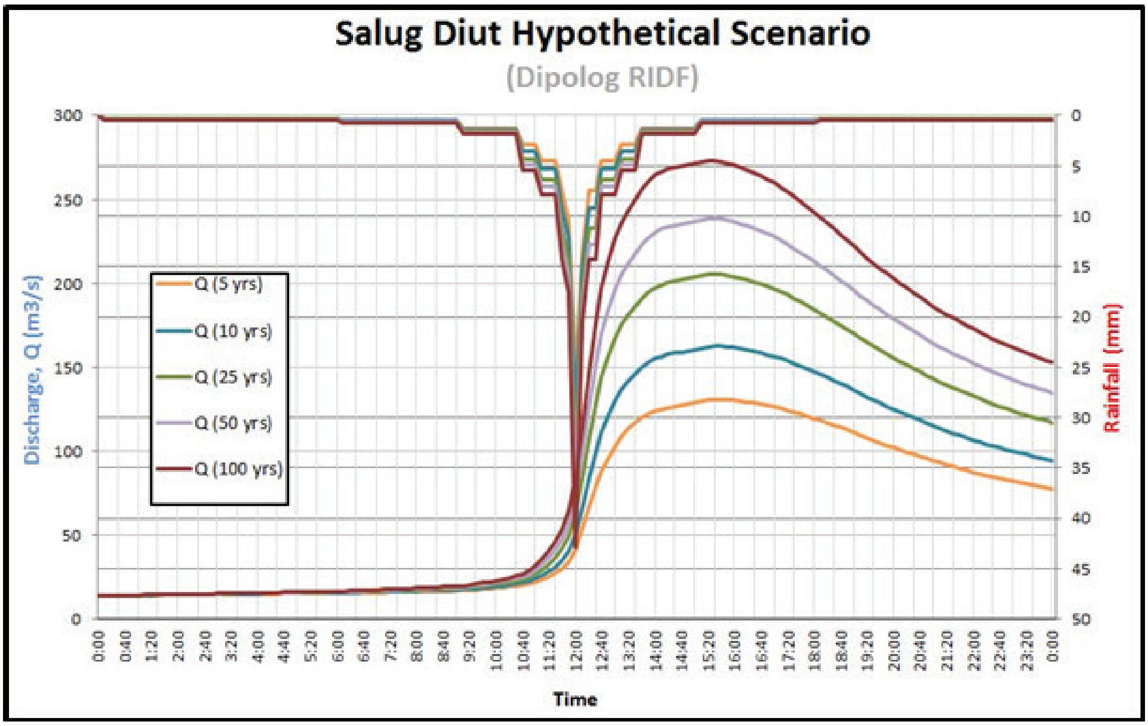


Figure 82. Outflow Hydrograph of Salug Diut Bridge generated in HEC-HMS model compared with observed outflow

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Salug Diut discharge using the Dipolog RIDF in five different return periods is shown in Table 35.

Table 35. Peak values of the Salug Diut HEC-HMS Model outflow using Dipolog RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	178.32	25.9	441.3	15 hours 40 mins
10-Year	206.37	30	543.6	15 hours 30 mins
25-Year	241.91	35.2	676.2	15 hours 30 mins
50-Year	268.14	39	777.7	15 hours 30 mins
100-Year	294.55	42.9	880	15 hours 30 mins

5.7.2 Discharge Data using Dr. Horritts's Recommended Hydrologic Method

The river discharge values for the nine rivers entering the floodplain are shown in Figure 82 to Figure 87 and the peak values are summarized in Table 36 to Table 41.

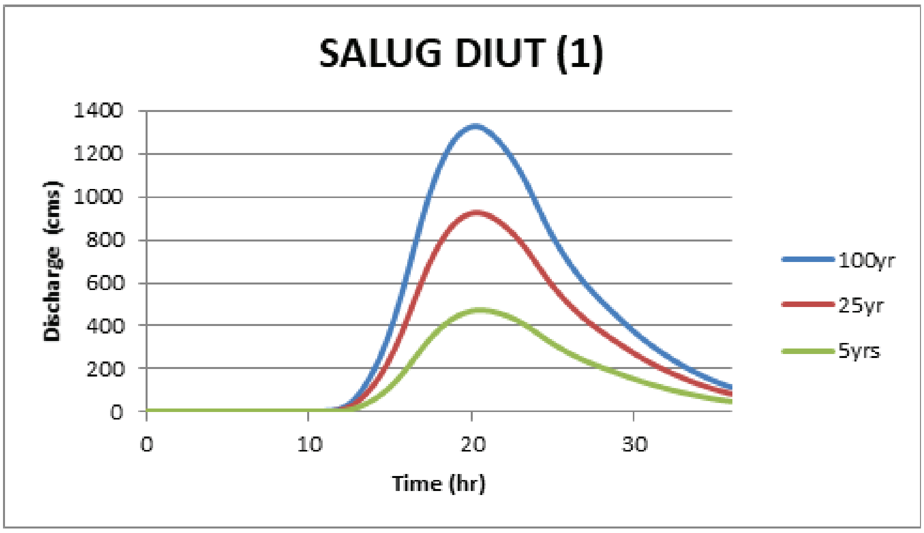


Figure 83. Outflow Hydrograph of Salug Diut Bridge generated in HEC-HMS model compared with observed outflow

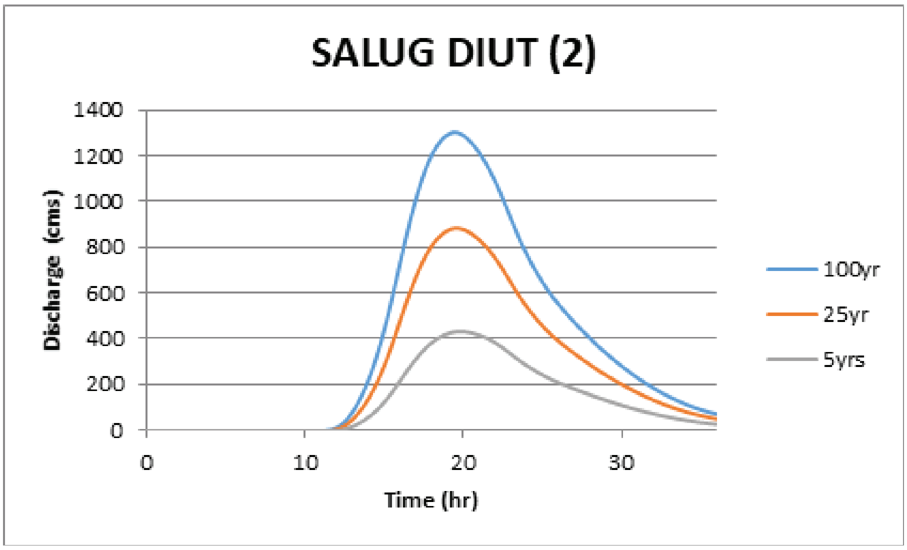


Figure 84. Outflow Hydrograph of Salug Diut Bridge generated in HEC-HMS model compared with observed outflow

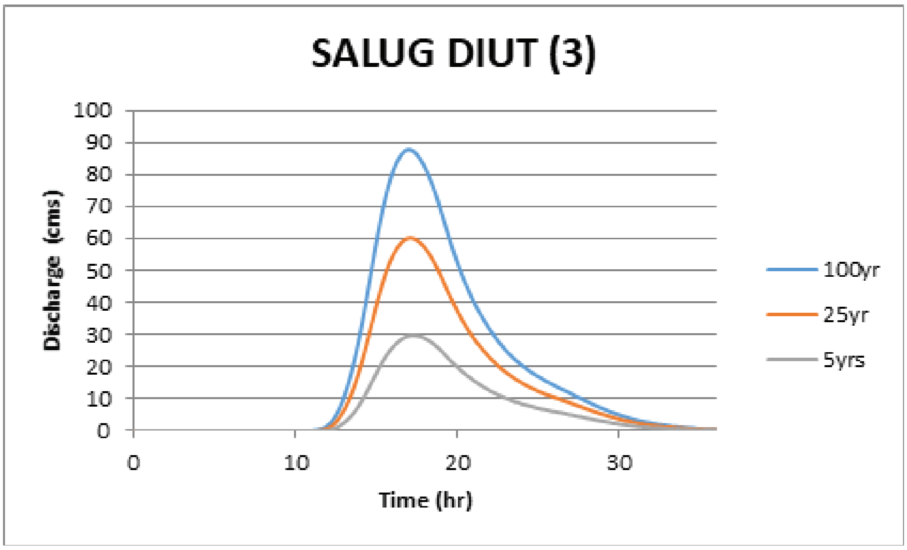


Figure 85. Salug Diut River (3) generated discharge using 5-, 25-, and 100-year Dipolog RIDF in HEC-HMS

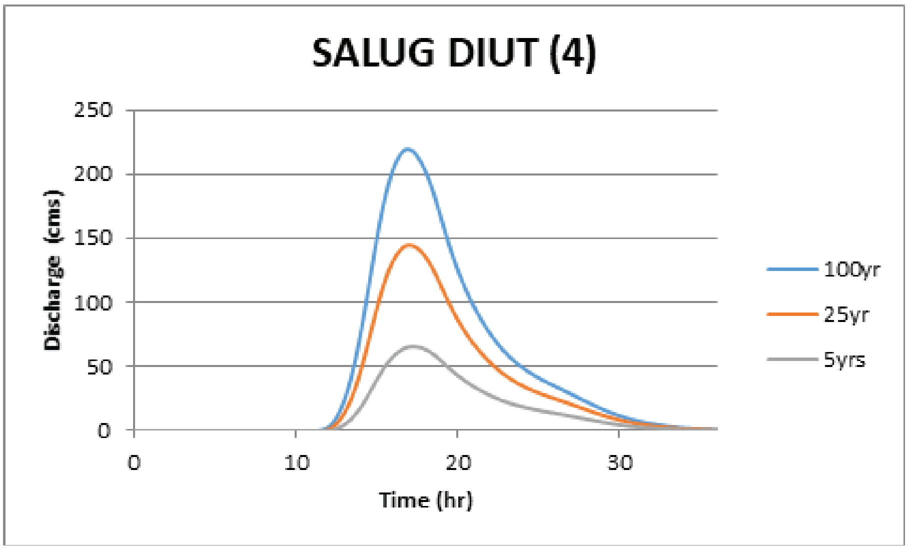


Figure 86. Salug Diut River (4) generated discharge using 5-, 25-, and 100-year Dipolog RIDF in HEC-HMS

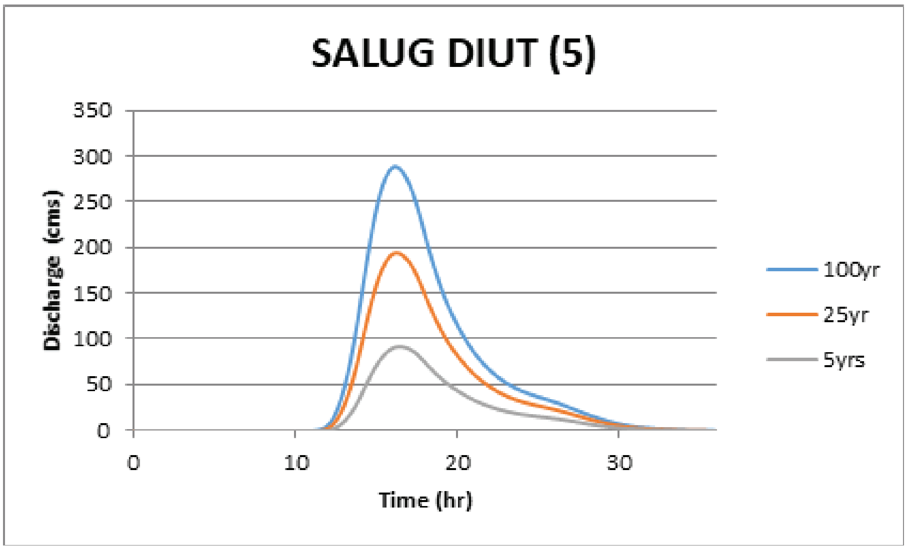


Figure 87. Salug Diut River (5) generated discharge using 5-, 25-, and 100-year Dipolog RIDF in HEC-HMS

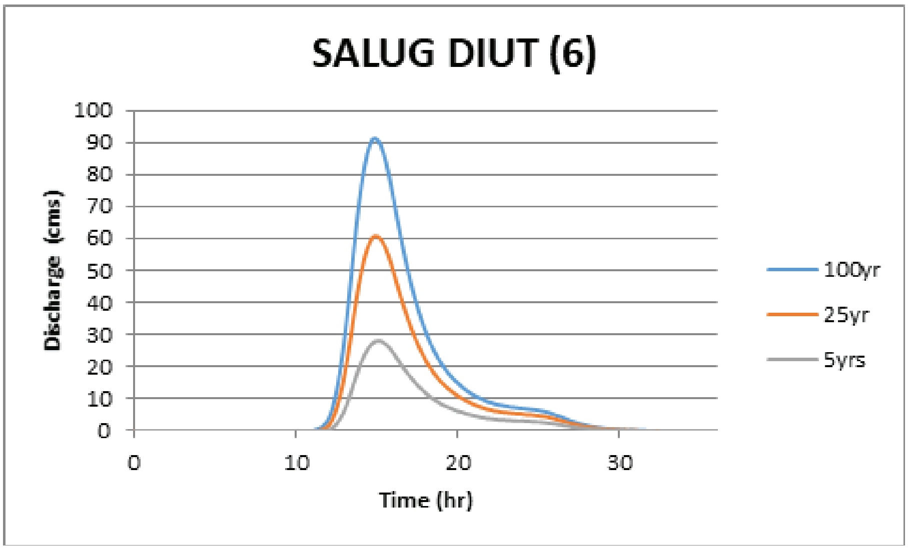


Figure 88. Salug Diut River (6) generated discharge using 5-, 25-, and 100-year Dipolog RIDF in HEC-HMS

Table 36. Summary of Salug Diut River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1323.6	20 hours, 10 minutes
25-Year	926	20 hours, 20 minutes
5-Year	474.3	20 hours, 30 minutes

Table 37. Summary of Salug Diut River (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1300.3	19 hours, 30 minutes
25-Year	886.1	19 hours, 30 minutes
5-Year	430.9	19 hours, 40 minutes

Table 38. Summary of Salug Diut River (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	87.8	17 hours
25-Year	60.4	17 hours
5-Year	29.8	17 hours, 10 minutes

Table 39. Summary of Salug Diut River (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	219.2	16 hours, 50 minutes
25-Year	144.7	16 hours, 50 minutes
5-Year	65.7	17 hours, 10 minutes

Table 40. Summary of Salug Diut River (5) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	289.2	16 hours, 10 minutes
25-Year	194.5	16 hours, 10 minutes
5-Year	91.6	16 hours, 20 minutes

Table 41. Summary of Salug Diut River (6) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	91.1	14 hours, 50 minutes
25-Year	60.8	14 hours, 50 minutes
5-Year	28.1	15 hours

Table 42. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Salug Diut (1)	417.384	429.907	716.769	PASS	PASS
Salug Diut (2)	379.192	646.683	700.832	PASS	PASS
Salug Diut (3)	26.224	28.053	98.361	PASS	FAIL
Salug Diut (4)	57.816	406.466	204.149	FAIL	FAIL
Salug Diut (5)	80.608	834.784	214.904	FAIL	FAIL
Salug Diut (6)	24.728	395.426	76.264	FAIL	FAIL

Two from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods and one passed the conditions for validation only using the bankful discharge method. Four did not pass specific discharge methods and will need further recalculation. The passing values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis 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 Salug Diut River using the calibrated HMS base flow is shown in Figure 88.

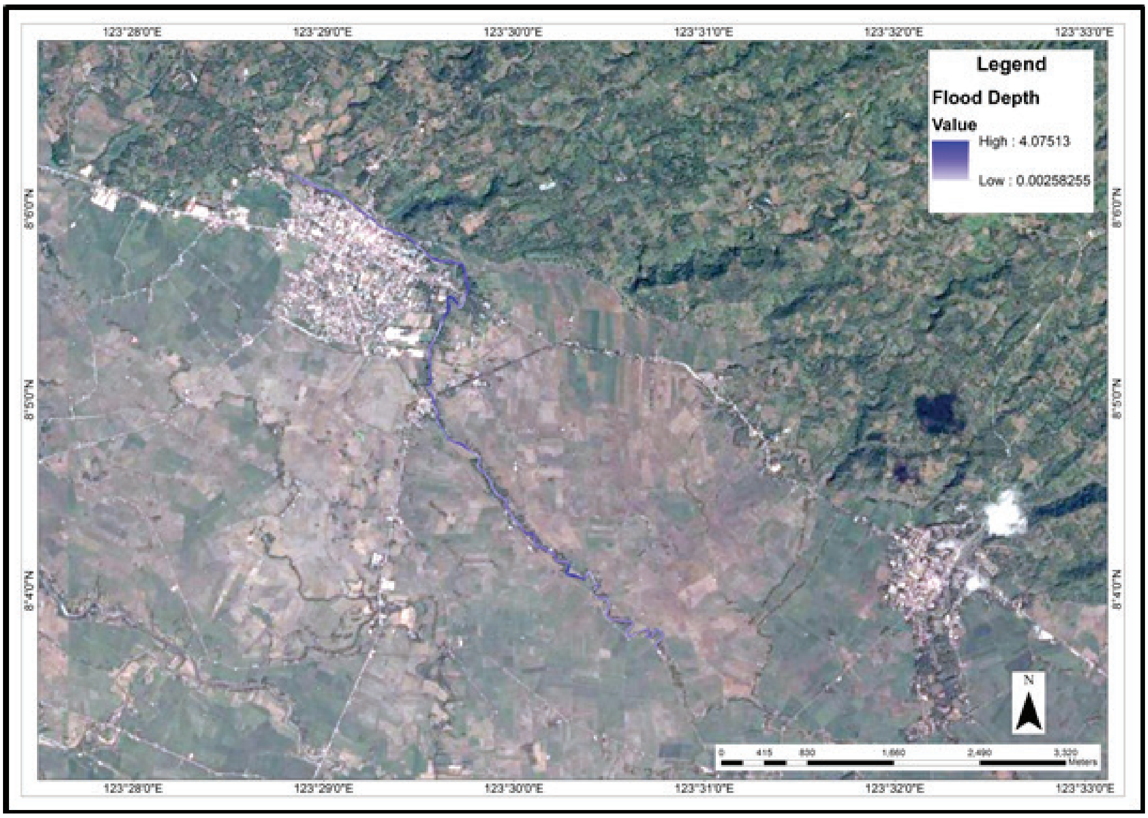


Figure 89. Sample output of Salug Diut RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 89 to Figure 94 show the 100-, 25-, and 5-year rain return scenarios of the Salug Diut Floodplain. The floodplain, with an area of 57.97 sq.km., covers three municipalities, namely Tambulig, Mahayag, and Molave. Table 43 shows the percentage of area affected by flooding per municipality.

Table 43. Municipalities affected in Salug Diut Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Tambulig	142.93	5.18	4%
Mahayag	175.97	23.92	14%
Molave	61.24	28.87	47%

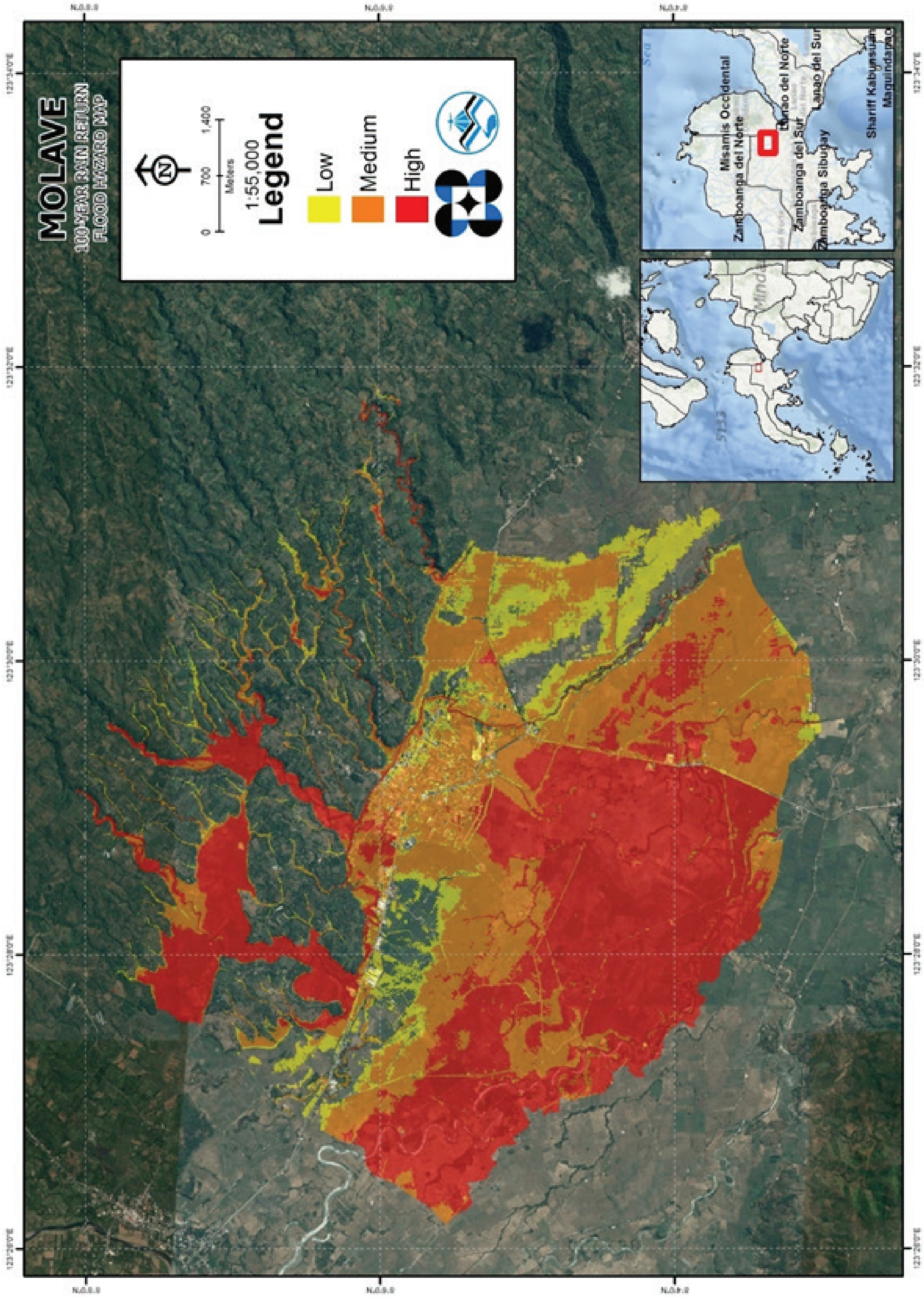


Figure 90. 100-year hazard map for Salug Diut (Molave) Floodplain overlaid in Google Earth imagery

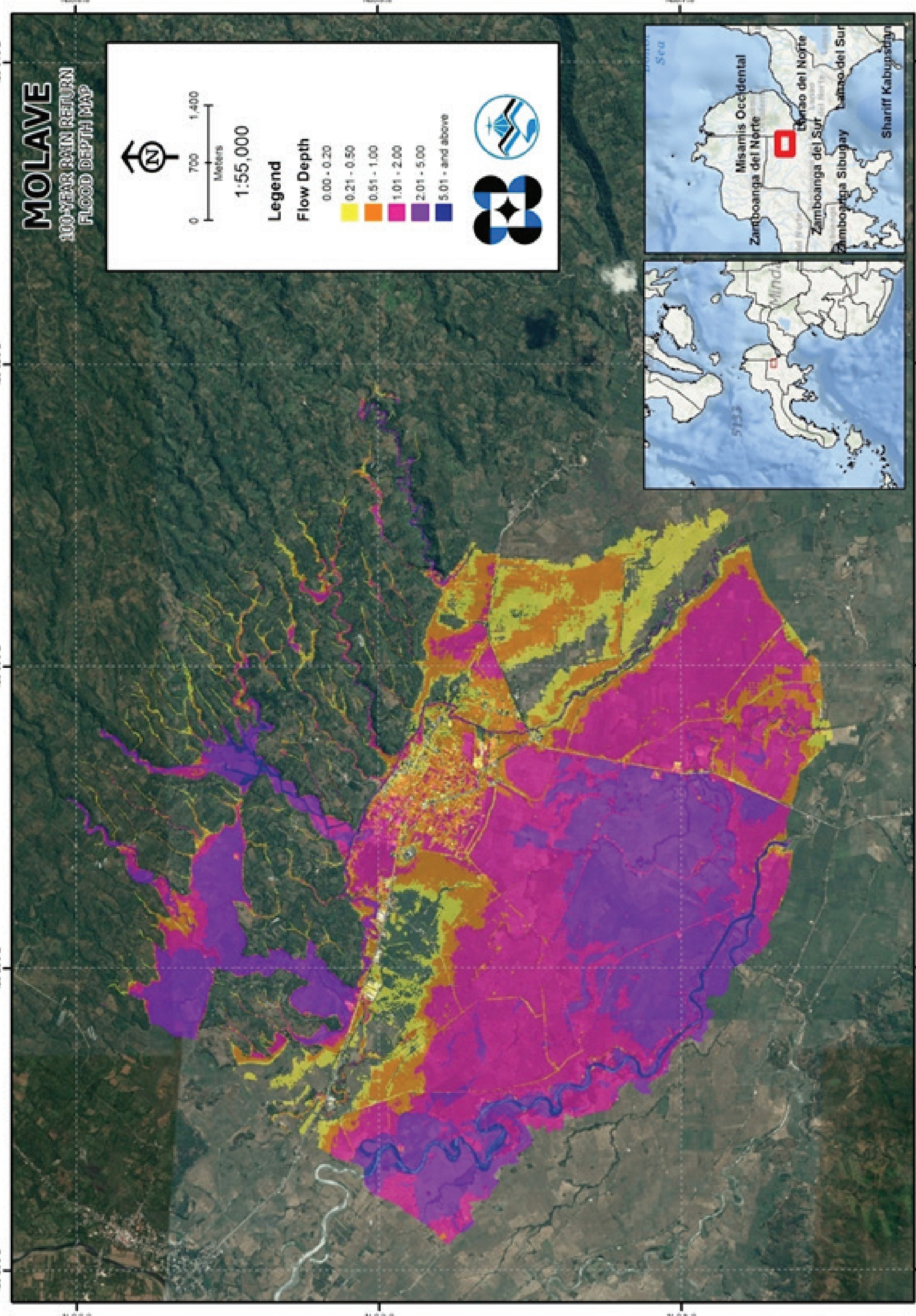


Figure 91. 100-year flow depth map for Salug Diut (Molave) Floodplain overlaid in Google Earth imagery

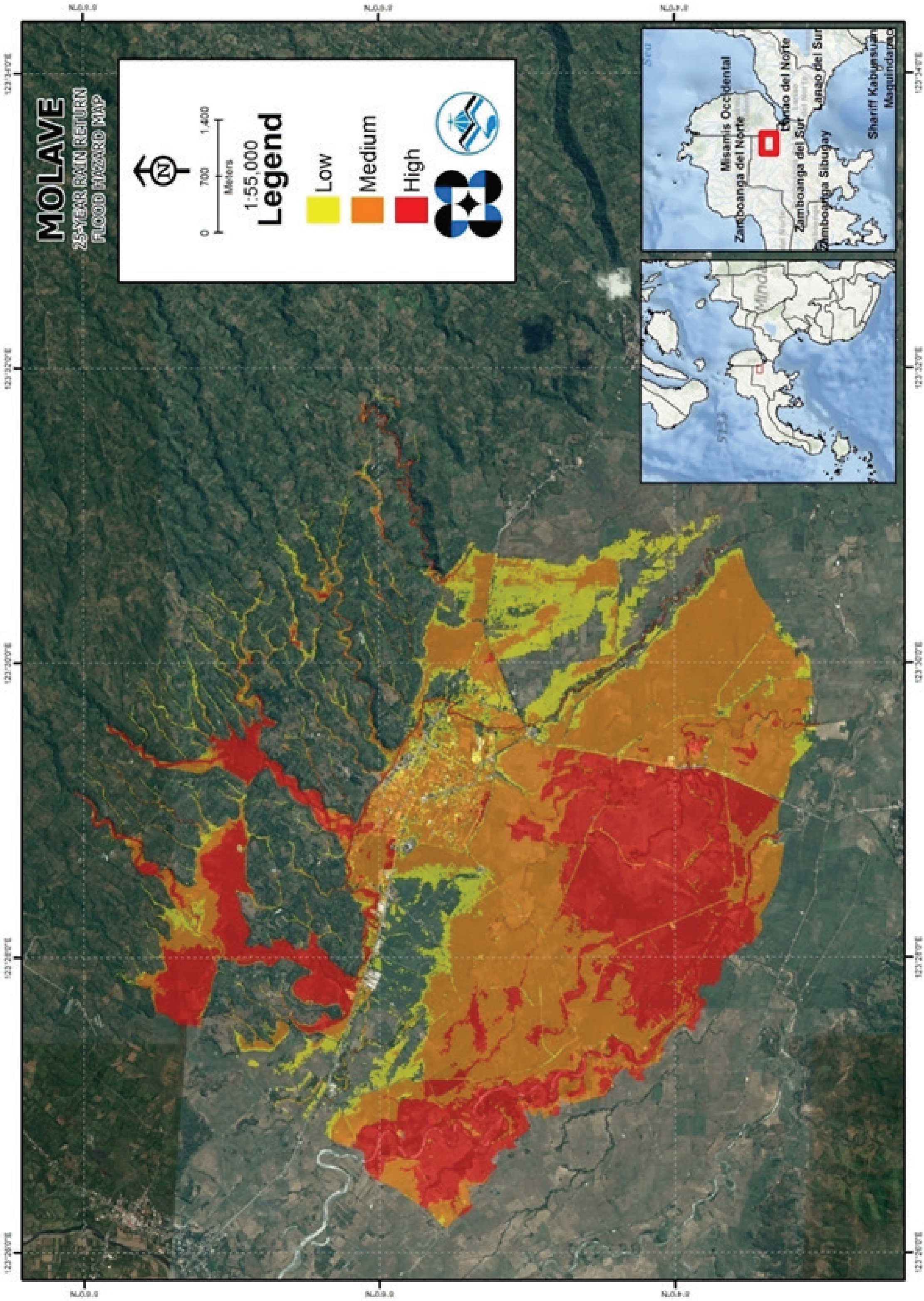


Figure 92. 25-year hazard map for Salug Diut (Molave) Floodplain overlaid in Google Earth imagery

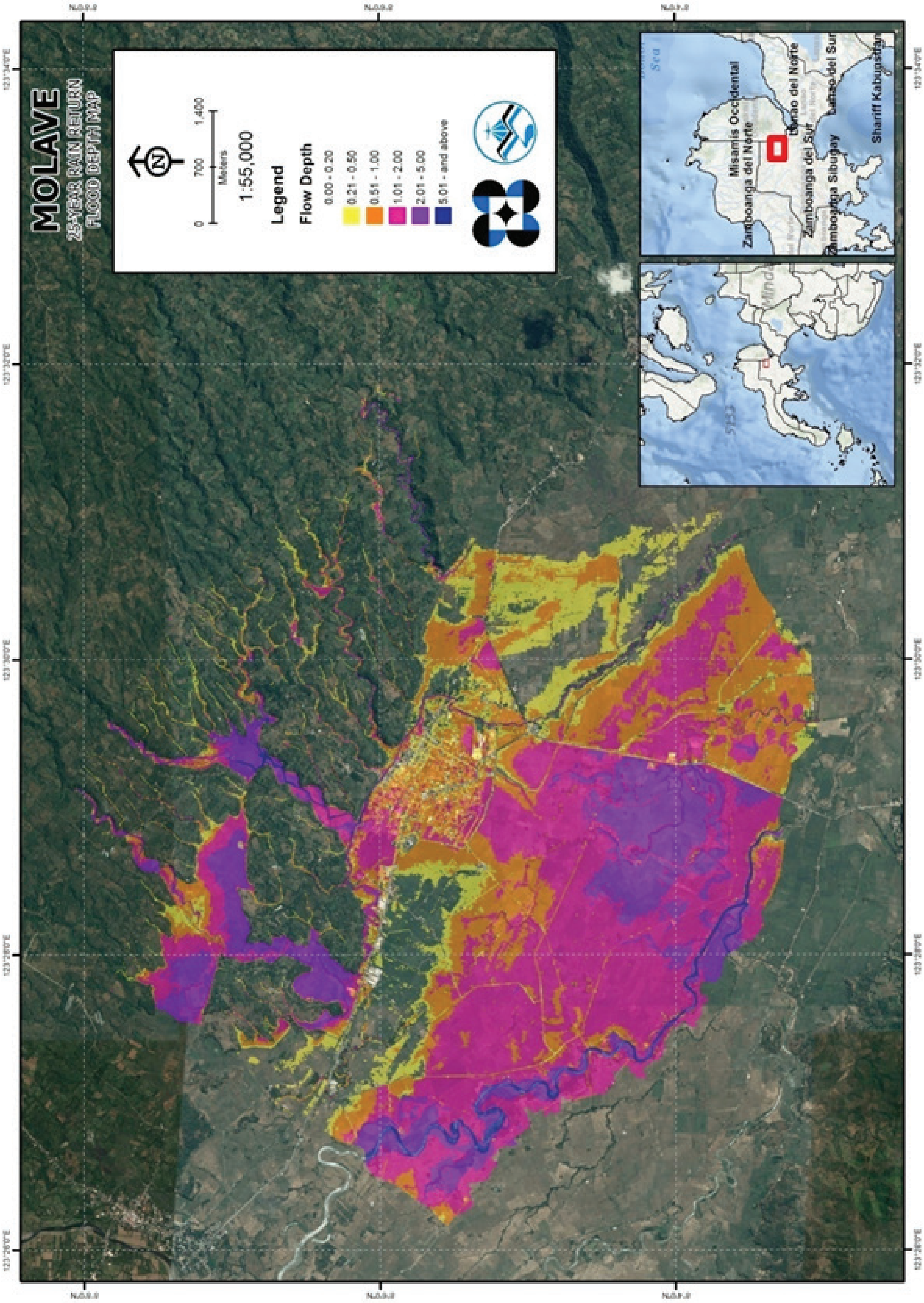


Figure 93. 25-year flow depth map for Salug Diut (Molave) Floodplain overlaid in Google Earth imagery

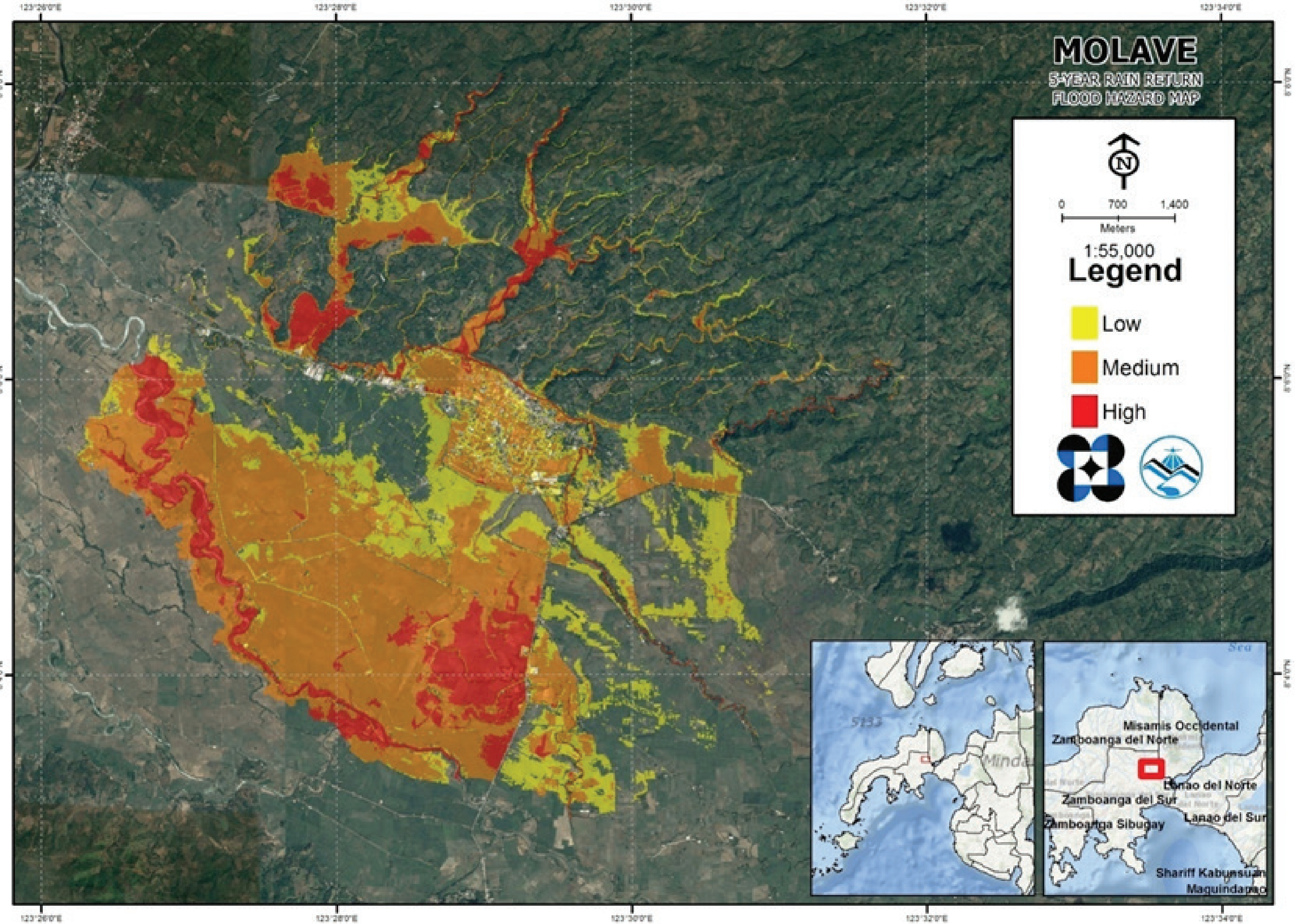


Figure 94. 5-year hazard map for Salug Diut (Molave) Floodplain overlaid in Google Earth imagery

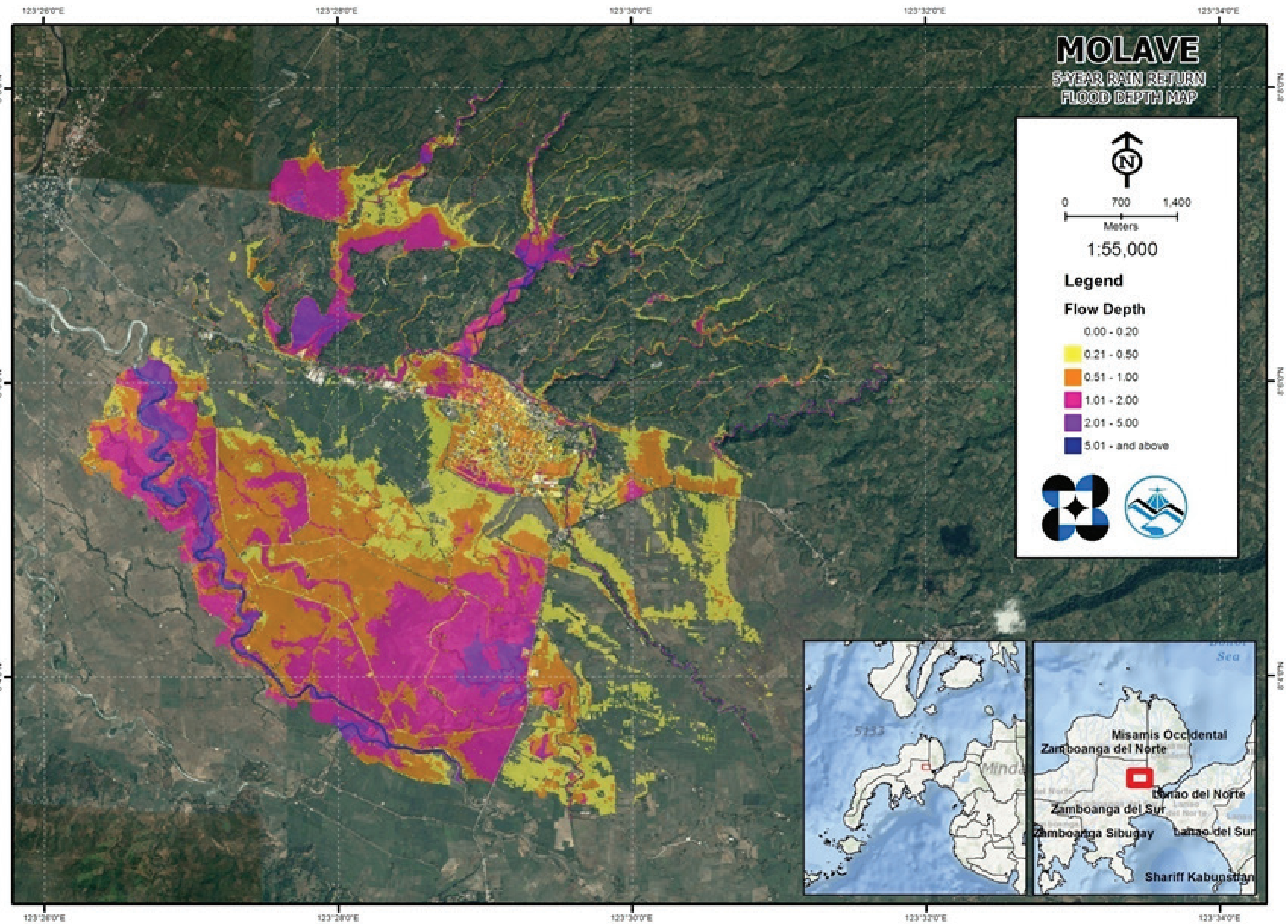


Figure 95. 5-year flow depth map for Salug gDiut (Molave) Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Salug Diut River Basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 34 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 5.66% of the municipality of Mahayag with an area of 175.97 sq km will experience flood levels of less 0.20 meters; 1.52% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.19%, 2.44%, 0.58%, and 0.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected areas in Mahayag, Zamboanga del Sur during a 5-year rainfall return period

MOLAVE BASIN		Affected Barangays in Mahayag										
		Bag-Ong Balamban	Diwan	Guripan	Lourmah	Marabanan	Poblacion	San Isidro	San Vicente	Tuboran	Tumapic	Upper Santo Niño
Affected Area (sq km.)	0.03-0.20	0.086	0.56	1.41	2.49	1.36	0.018	2.62	0.11	1.28	0.0084	0.0089
	0.21-0.50	0.091	0.03	1.16	0.62	0.27	0.001	0.35	0.0099	0.11	0.017	0.0071
	0.51-1.00	0.33	0.094	2.54	1.55	0.17	0.0074	0.49	0.037	0.086	0.23	0.077
	1.01-2.00	0.5	0.24	0.96	0.91	0.19	0.039	0.54	0.12	0.18	0.46	0.15
	2.01-5.00	0.11	0.25	0.02	0.33	0.054	0.0022	0.038	0.00055	0.026	0.17	0.031
	> 5.00	0.084	0	0.03	0.1	0	0	0.0073	0	0	0.11	0.027

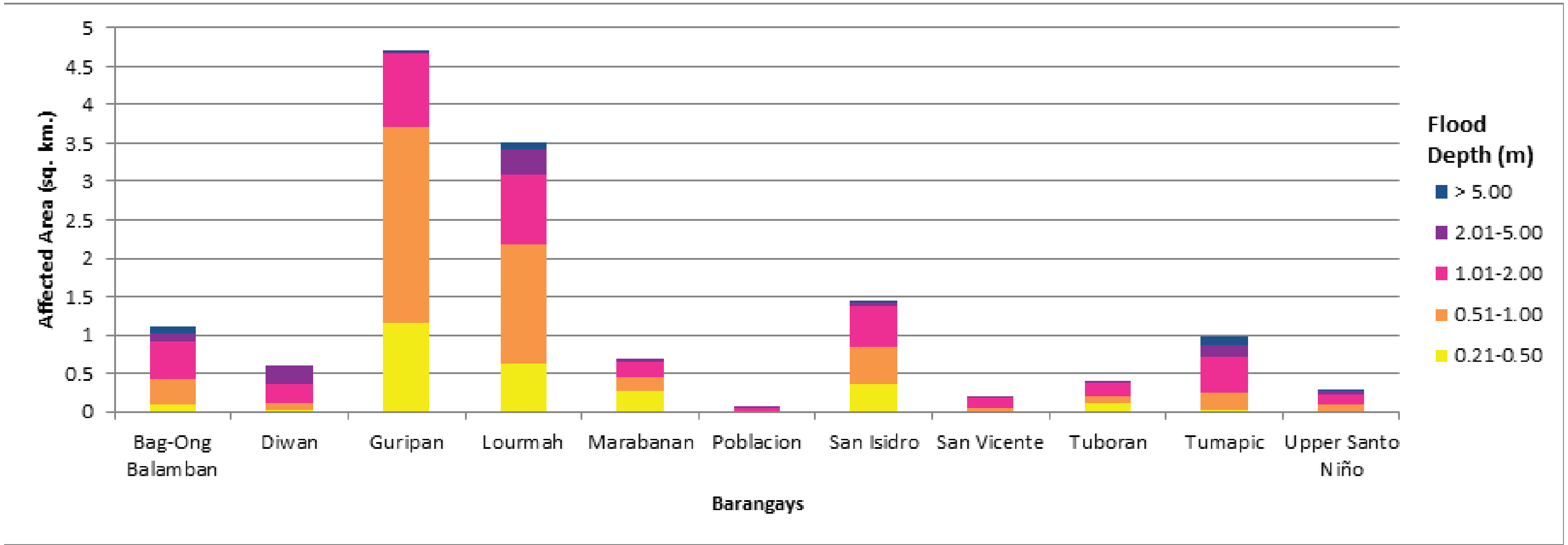


Figure 96. Affected areas in Mahayag, Zamboanga del Sur during a 5-year rainfall return period

For the municipality of Molave, with an area of 61.24 sq km, 26.33% will experience flood levels of less 0.20 meters; 7.03% of the area will experience flood levels of 0.21 to 0.50 meters; while 5.68%, 6.73%, 1.20%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected areas in Molave, Zamboanga del Sur during a 5-year rainfall return period

MOLAVE BASIN		Affected Barangays in Molave													
		Blancia	Bogo Capalaran	Culo	Dalaon	Dipolo	Lower Dimalinao	Mabuhay	Madasigon	Makuguihon	Maloloy-On	Miligan	Parasan	Rizal	Sudlon
Affected Area (sq km.)	0.03-0.20	1.57	1.24	0.11	3.36	0.87	3.41	1.37	0.2	0.13	0.13	0.27	0.63	0.032	2.79
	0.21-0.50	0.66	0.06	0.25	0.55	0.76	0.2	0.092	0.15	0.11	0.11	0.46	0.013	0.029	0.85
	0.51-1.00	0.41	0.096	0.2	0.52	0.62	0.11	0.11	0.12	0.081	0.15	0.75	0.013	0.26	0.05
	1.01-2.00	0.094	0.026	0.082	0.1	0.57	0.065	0.22	0.012	0.0064	0.014	0.74	0.013	2.17	0.0057
	2.01-5.00	0.018	0.0093	0	0.014	0.11	0.031	0.082	0.014	0.0019	0.0055	0	0.0088	0.42	0.025
	> 5.00	0.0019	0.0049	0	0.0008	0.049	0.0003	0.024	0.003	0.00052	0.00038	0	0	0.019	0.0007

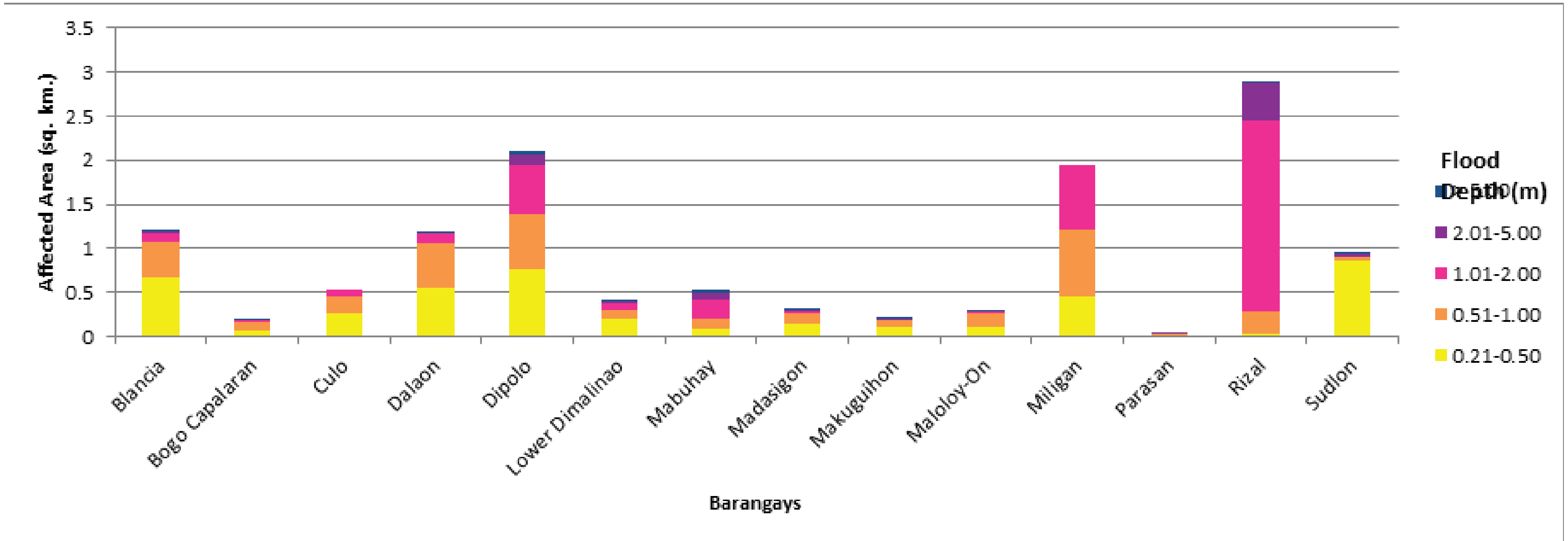


Figure 97. Affected areas in Molave, Zamboanga del Sur during a 5-year rainfall return period

For the municipality of Tambulig, with an area of 142.93 sq km, 3.22% will experience flood levels of less 0.20 meters; 0.27% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.07%, 0.03%, 0.03%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected areas in Tambulig, Zamboanga del Sur during a 5-year rainfall return period

MOLAVE BASIN		Affected Barangays in Molave								
		Alang-Alang	Balugo	Dimalinao	Gabunon	Libato	Lower Usogan	Pelocoban	Tuluan	Upper Tiparak
Affected Area (sq km.)	0.03-0.20	0.61	0.065	0.49	0.32	1.94	0.3	0.075	0.081	0.72
	0.21-0.50	0.12	0.015	0.032	0.05	0.051	0.094	0.0014	0.0033	0.025
	0.51-1.00	0.0099	0.00031	0.01	0.029	0.045	0.0083	0.00068	0.0012	0.0008
	1.01-2.00	0	0.00076	0.0024	0.0014	0.035	0	0.0005	0.0014	0.0041
	2.01-5.00	0	0.0002	0.0001	0.0004	0.034	0	0	0.0006	0.0033
	> 5.00	0	0	0	0	0.0019	0	0	0	0

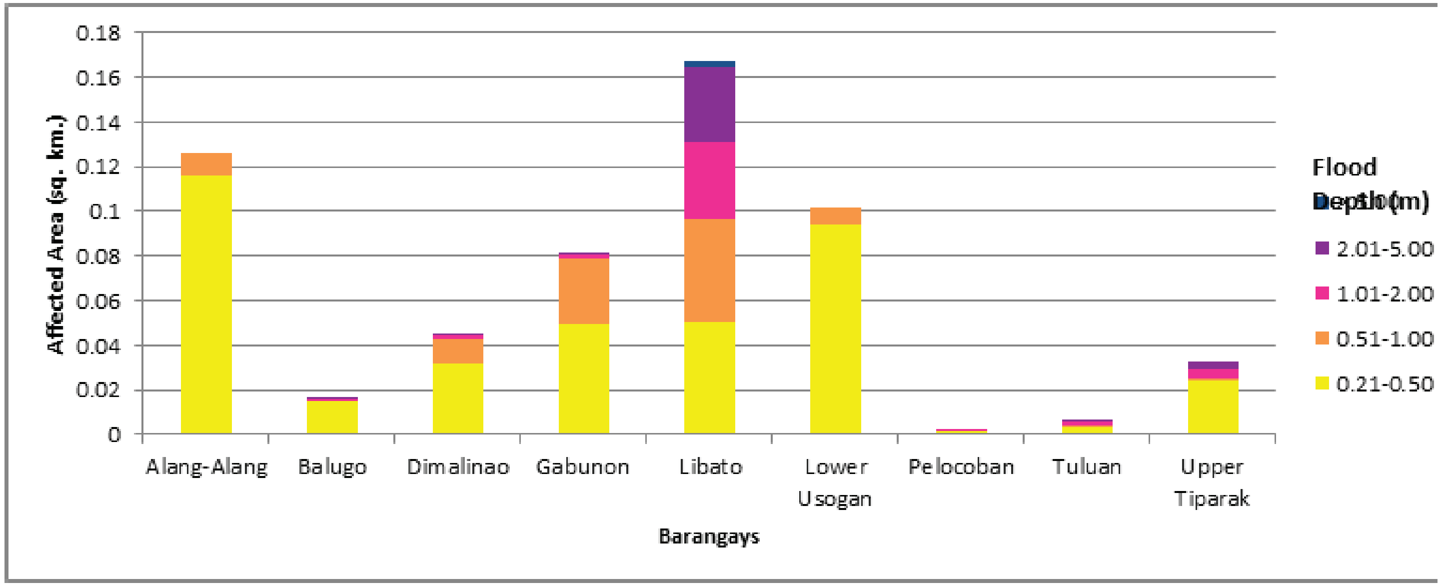


Figure 98. Affected areas in Tambulig, Zamboanga del Sur during a 5-year rainfall return period

For the 25-year return period, 4.54% of the municipality of Mahayag with an area of 175.97 sq km will experience flood levels of less 0.20 meters; 0.86% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.77%, 4.63%, 1.57%, and 0.23% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected areas in Mahayag, Zamboanga del Sur during a 25-year rainfall return period

MOLAVE BASIN		Affected Barangays in Mahayag										
		Bag-Ong Balamban	Diwan	Guripan	Lourmah	Marabanan	Poblacion	San Isidro	San Vicente	Tuboran	Tumapic	Upper Santo Niño
Affected Area (sq km.)	0.03-0.20	0	0.52	0.77	1.71	1.24	0.017	2.42	0.099	1.19	0.0049	0.002
	0.21-0.50	0.01	0.02	0.52	0.54	0.14	0.00027	0.15	0.0031	0.12	0.005	0.0026
	0.51-1.00	0.11	0.029	1.44	0.83	0.23	0.001	0.31	0.0064	0.07	0.083	0.014
	1.01-2.00	0.64	0.094	3.15	2.38	0.27	0.015	0.67	0.073	0.11	0.6	0.13
	2.01-5.00	0.34	0.51	0.21	0.42	0.17	0.034	0.49	0.095	0.18	0.19	0.12
	> 5.00	0.098	0	0.032	0.11	0.0005	0	0.0087	0	0	0.12	0.029

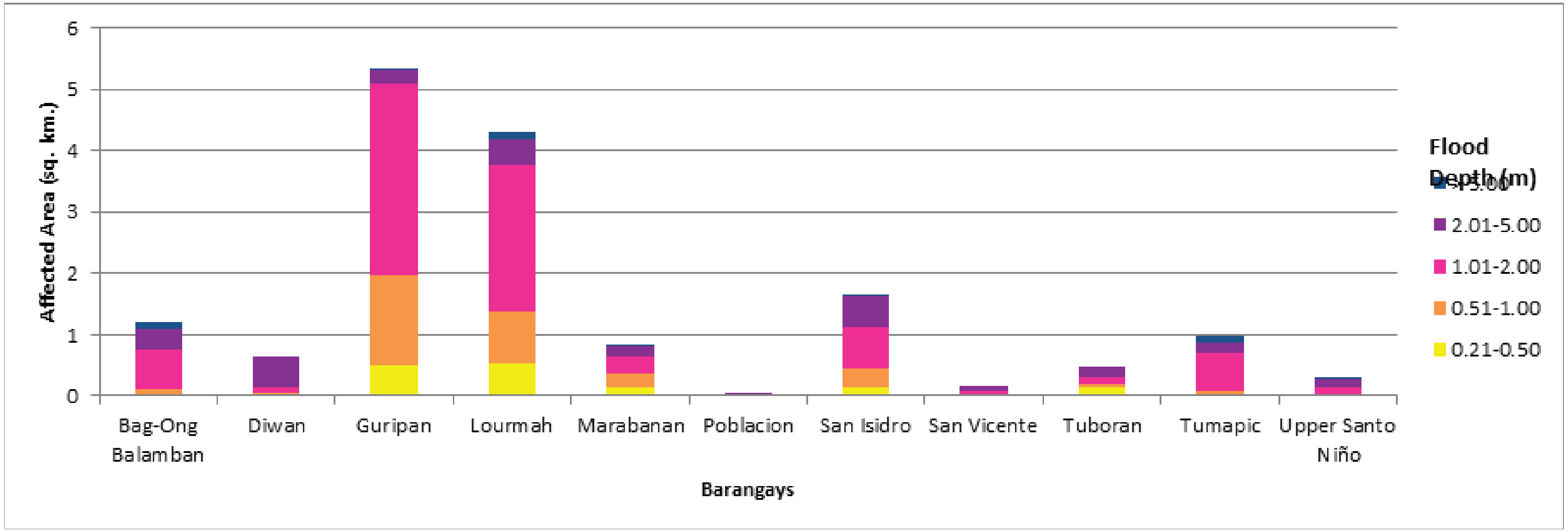


Figure 99. . Affected areas in Mahayag, Zamboanga del Sur during 25-year rainfall return period

For the municipality of Molave, with an area of 61.24 sq km, 18.77% will experience flood levels of less 0.20 meters; 5.22% of the area will experience flood levels of 0.21 to 0.50 meters; while 8.32%, 9.59%, 5.03%, and 0.22% 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 48 are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected areas in Molave, Zamboanga del Sur during a 25-year rainfall return period

MOLAVE BASIN		Affected Barangays in Molave													
		Blancia	Bogo Capalaran	Culo	Dalaon	Dipolo	Lower Dimalinao	Mabuhay	Madasigon	Makuguihon	Maloloy-On	Miligan	Parasan	Rizal	Sudlon
Affected Area (sq km.)	0.03-0.20	0.49	1.21	0.062	2.97	0.093	3.29	1.29	0.13	0.075	0.078	0.04	0.62	0.01	1.12
	0.21-0.50	0.44	0.047	0.079	0.59	0.2	0.21	0.053	0.14	0.099	0.095	0.052	0.01	0.012	1.17
	0.51-1.00	0.94	0.1	0.25	0.7	1.3	0.14	0.075	0.17	0.13	0.19	0.22	0.012	0.027	0.84
	1.01-2.00	0.85	0.062	0.26	0.25	1.05	0.068	0.15	0.05	0.02	0.039	1.63	0.017	0.86	0.57
	2.01-5.00	0.038	0.01	0	0.021	0.29	0.092	0.28	0.014	0.0017	0.0047	0.29	0.019	2	0.026
	> 5.00	0.002	0.0052	0	0.002	0.055	0.0046	0.043	0.0039	0.00085	0.0013	0	0	0.02	0.0008

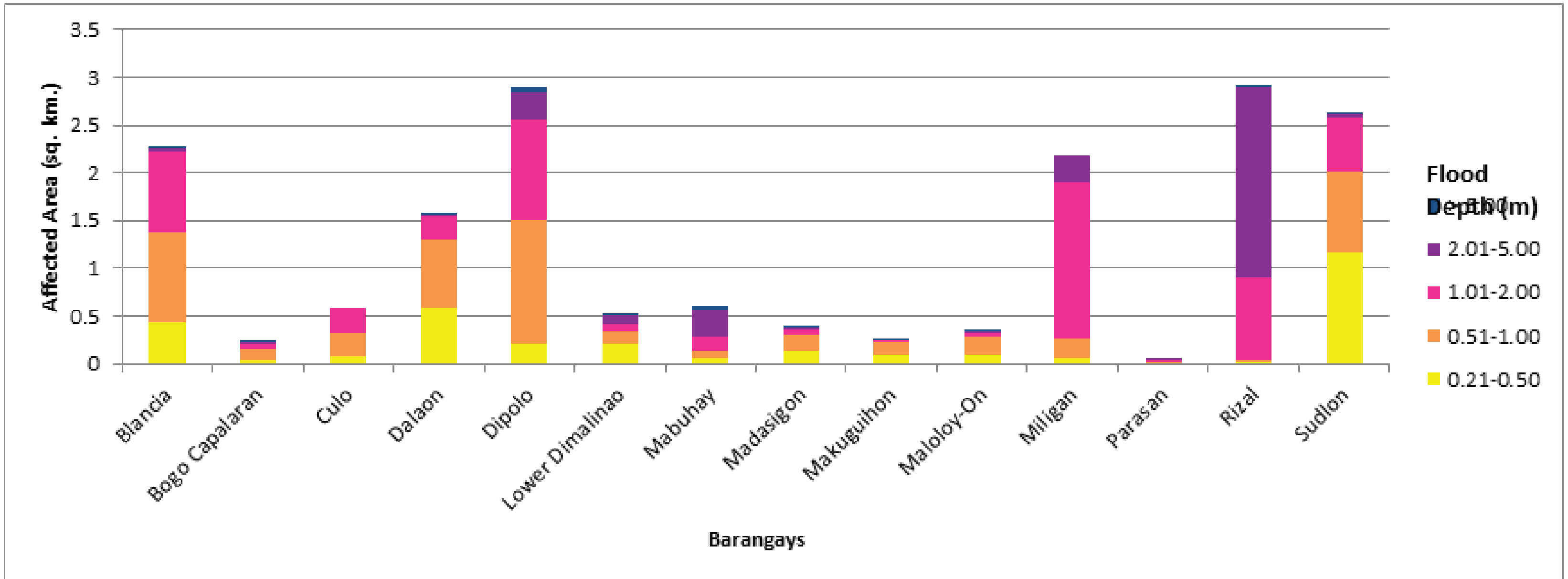


Figure 100. Affected areas in Molave, Zamboanga del Sur during a 25-year rainfall return period

For the municipality of Tambulig, with an area of 142.93 sq km, 2.58% will experience flood levels of less 0.20 meters; 0.39% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.46%, 0.15%, 0.04%, and 0.005% 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 49 are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected areas in Tambulig, Zamboanga del Sur during a 25-year rainfall return period

MOLAVE BASIN		Affected Barangays in Molave								
		Alang-Alang	Balugo	Dimalinao	Gabunon	Libato	Lower Usogan	Pelocoban	Tuluan	Upper Tiparak
Affected Area (sq km.)	0.03-0.20	0.42	0.043	0.48	0.31	1.9	0.034	0.075	0.078	0.35
	0.21-0.50	0.27	0.013	0.037	0.039	0.048	0.072	0.0016	0.0041	0.072
	0.51-1.00	0.04	0.025	0.014	0.046	0.052	0.21	0.00084	0.0019	0.27
	1.01-2.00	0	0.00047	0.0052	0.0037	0.045	0.089	0.00054	0.0017	0.064
	2.01-5.00	0	0.0008	0.0001	0.0006	0.053	0	0	0.0014	0.0036
	> 5.00	0	0	0	0	0.0071	0	0	0	0

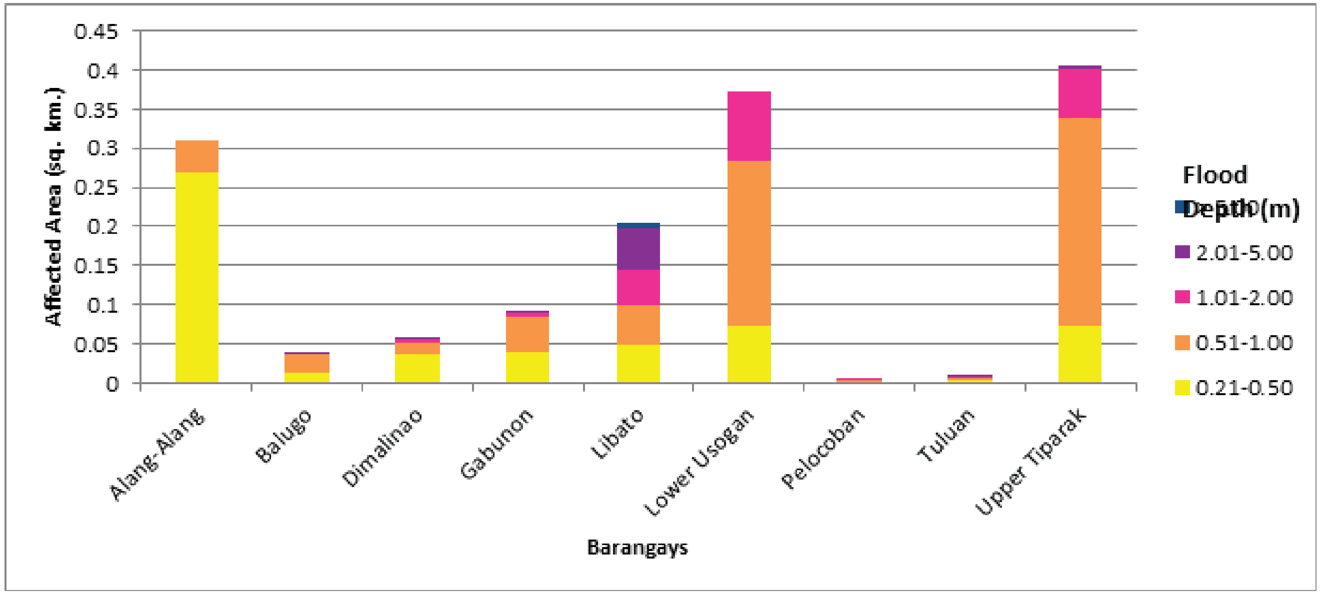


Figure 101. Affected areas in Tambulig, Zamboanga del Sur during a 25-year rainfall return period

For the 100-year return period, 3.93% of the municipality of Mahayag with an area of 175.97 sq km will experience flood levels of less 0.20 meters; 0.76% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.12%, 4.11%, 3.42%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected areas in Mahayag, Zamboanga del Sur during 100-year rainfall return period

MOLAVE BASIN		Affected Barangays in Mahayag										
		Bag-Ong Balamban	Diwan	Guripan	Lourmah	Marabanan	Poblacion	San Isidro	San Vicente	Tuboran	Tumapic	Upper Santo Niño
Affected Area (sq km.)	0.03-0.20	0	0.51	0.52	1.09	1.2	0.016	2.36	0.093	1.13	0.001	0
	0.21-0.50	0	0.018	0.36	0.64	0.05	0.0003	0.1	0.0031	0.16	0.0034	0.0003
	0.51-1.00	0.0071	0.03	0.78	0.71	0.14	0.00049	0.21	0.0034	0.076	0.0095	0.0033
	1.01-2.00	0.33	0.047	2.58	2.73	0.28	0.0018	0.56	0.012	0.066	0.55	0.068
	2.01-5.00	0.75	0.57	1.84	0.7	0.38	0.049	0.8	0.17	0.26	0.31	0.2
	> 5.00	0.11	0	0.034	0.14	0.0018	0	0.01	0	0	0.12	0.03

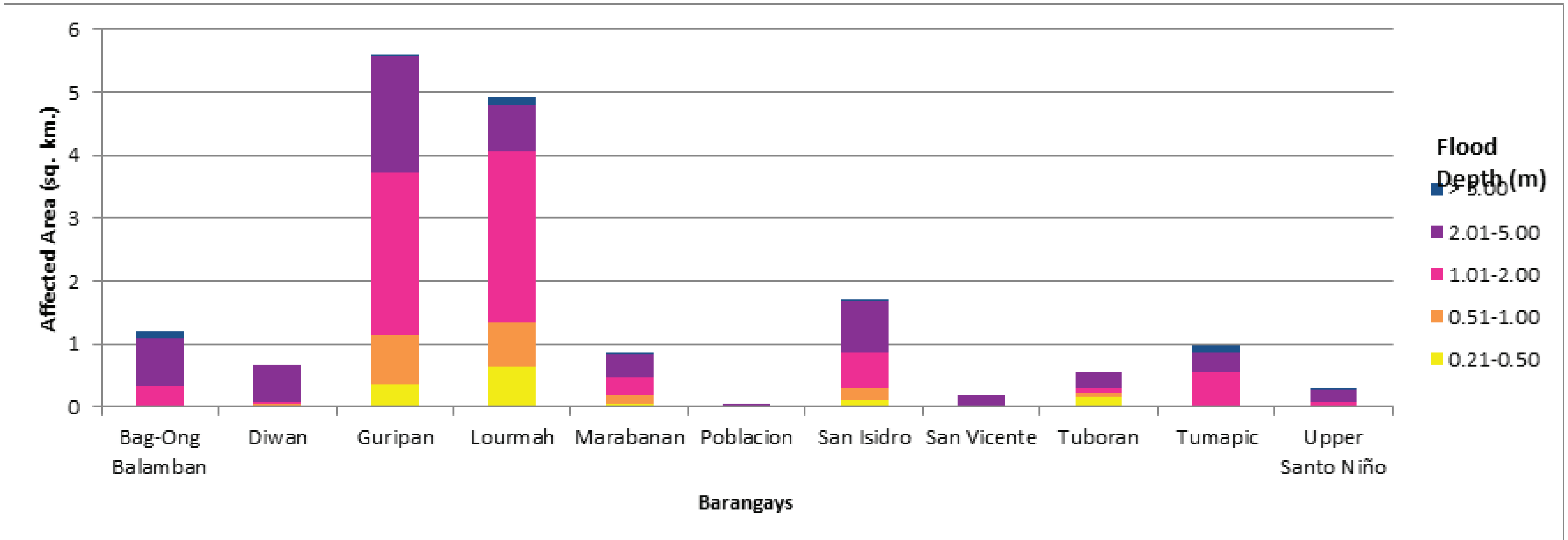


Figure 102. Affected areas in Mahayag, Zamboanga del Sur during a 100-year rainfall return period

For the municipality of Molave, with an area of 61.24 sq km, 17.15% will experience flood levels of less 0.20 meters; 4.33% of the area will experience flood levels of 0.21 to 0.50 meters; while 6.42%, 11.37%, 7.55%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected areas in Molave, Zamboanga del Sur during a 100-year rainfall return period

MOLAVE BASIN		Affected Barangays in Molave													
		Blancia	Bogo Capalaran	Culo	Dalaon	Dipolo	Lower Dimalinao	Mabuhay	Madasigon	Makuguihon	Maloloy-On	Miligan	Parasan	Rizal	Sudlon
Affected Area (sq km.)	0.03-0.20	0.36	1.19	0.042	2.78	0.032	3.24	1.26	0.095	0.052	0.051	0.023	0.62	0.0078	0.74
	0.21-0.50	0.3	0.044	0.055	0.55	0.099	0.2	0.041	0.12	0.087	0.085	0.022	0.0093	0.0066	1.02
	0.51-1.00	0.48	0.091	0.23	0.76	0.56	0.16	0.044	0.2	0.15	0.2	0.093	0.0091	0.02	0.94
	1.01-2.00	1.54	0.09	0.32	0.41	1.82	0.086	0.12	0.067	0.035	0.074	1.08	0.017	0.32	1
	2.01-5.00	0.065	0.012	0	0.034	0.42	0.1	0.35	0.013	0.0015	0.004	1.01	0.027	2.55	0.026
	> 5.00	0.0022	0.0059	0	0.0023	0.061	0.023	0.076	0.0044	0.001	0.002	0	0.0011	0.02	0.0009

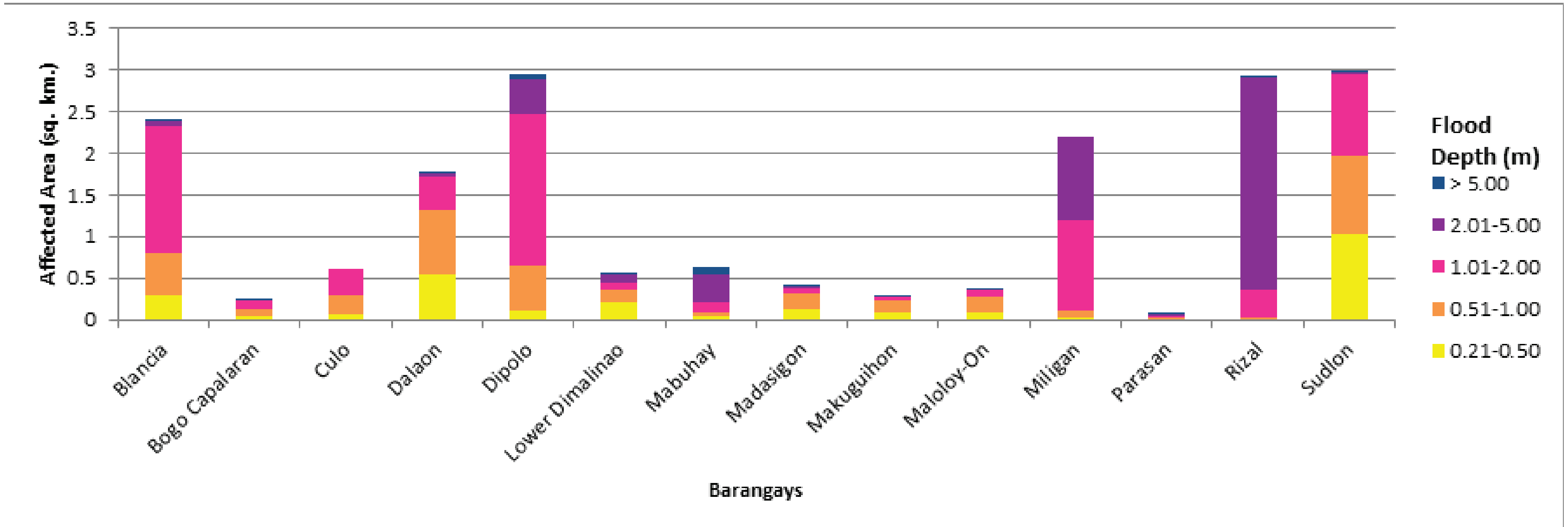


Figure 103. Affected areas in Molave, Zamboanga del Sur during a 100-year rainfall return period

For the municipality of Tambulig, with an area of 142.93 sq km, 2.35% will experience flood levels of less 0.20 meters; 0.51% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.32%, 0.37%, 0.05%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 52 are the affected areas in square kilometers by flood depth per barangay.

Table 52. Affected areas in Tambulig, Zamboanga del Sur during a 100-year rainfall return period

MOLAVE BASIN		Affected Barangays in Molave								
		Alang-Alang	Balugo	Dimalinao	Gabunon	Libato	Lower Usogan	Pelocoban	Tuluan	Upper Tiparak
Affected Area (sq km.)	0.03-0.20	0.26	0.019	0.47	0.31	1.87	0.011	0.074	0.076	0.26
	0.21-0.50	0.4	0.032	0.037	0.038	0.044	0.041	0.0019	0.0054	0.13
	0.51-1.00	0.067	0.027	0.017	0.047	0.053	0.13	0.0008	0.002	0.12
	1.01-2.00	0	0.0027	0.0067	0.0042	0.054	0.22	0.00078	0.0021	0.24
	2.01-5.00	0	0.0011	0.0004	0.0006	0.062	0	0	0.0018	0.0032
	> 5.00	0	0	0	0	0.017	0	0	0	0

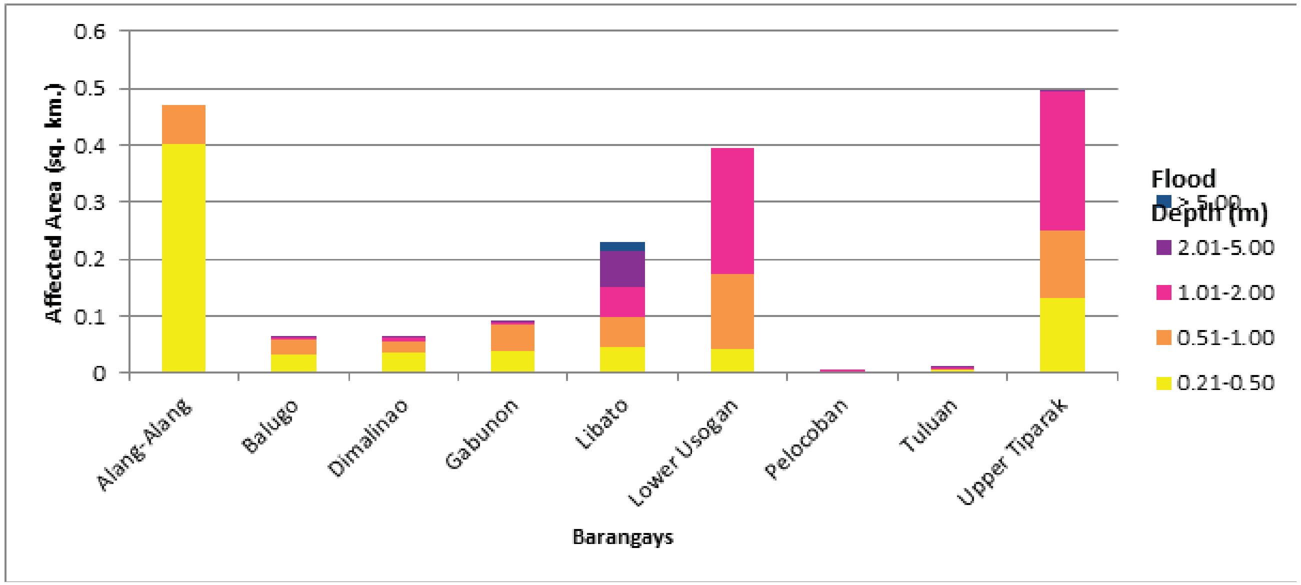


Figure 104. Affected areas in Tambulig, Zamboanga del Sur during a 100-year rainfall return period

Among the barangays in the municipality of Mahayag, Guripan is projected to have the highest percentage of area that will experience flood levels at 3.48%. Meanwhile, Lourmah posted the second highest percentage of area that may be affected by flood depths at 3.42%.

Among the barangays in the municipality of Molave, Dalaon is projected to have the highest percentage of area that will experience flood levels at 7.42%. Meanwhile, Lower Dimalinao posted the second highest percentage of area that may be affected by flood depths at 6.22%.

Among the barangays in the municipality of Tambulig, Libato is projected to have the highest percentage of area that will experience flood levels at 1.47%. Meanwhile, Upper Tiparak posted the second highest percentage of area that may be affected by flood depths at 0.53%.

Moreover, the generated flood hazard maps for the Salug Diut Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps—“Low”, “Medium”, and “High”—the affected institutions were given their individual assessment for each flood hazard scenario

Table 53. 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	7.35	5.25	4.70
Medium	15.37	17.41	14.22
High	4.60	12.16	18.28

Of the 29 identified educational institutions in Salug Diut Floodplain, 4 schools were assessed to be exposed to the low-level flooding in a 5-year scenario while 8 schools were assessed to be exposed to medium-level flooding. In the 25-year scenario, 6 schools were assessed to be exposed to low-level flooding while 8 schools were assessed to be exposed to medium-level flooding and 2 schools were assessed to be exposed to high-level flooding in the same scenario. In the 100-year scenario, 3 schools were assessed for low-level flooding and 10 schools for medium-level flooding. In the same scenario, 3 schools were assessed to be exposed to high-level flooding. See ANNEX 12 for a detailed enumeration of schools inside Salug Diut Floodplain.

Of the 17 identified health institutions in Salug Diut Floodplain, 2 were assessed to be exposed to low-level flooding in a 5-year scenario while 6 were assessed to be exposed to medium-level flooding in the same scenario. In the 25-year scenario, 4 were assessed to be exposed to low-level flooding while 8 were assessed to be exposed to medium-level flooding. In the 100-year scenario, 2 schools were assessed for low-level flooding and 9 for medium-level flooding. In the same scenario, 1 was assessed to be exposed to high-level flooding, which is a health center in Brgy. Miligan. See ANNEX 13 for a detailed enumeration of health insitutions inside Salug Diut 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 then 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 or interview 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 104.

The flood validation consists of 316 points randomly selected all over the Salug Diut Floodplain. It has an RMSE value of 0.64.

The flood validation data were obtained on November 29, 2016

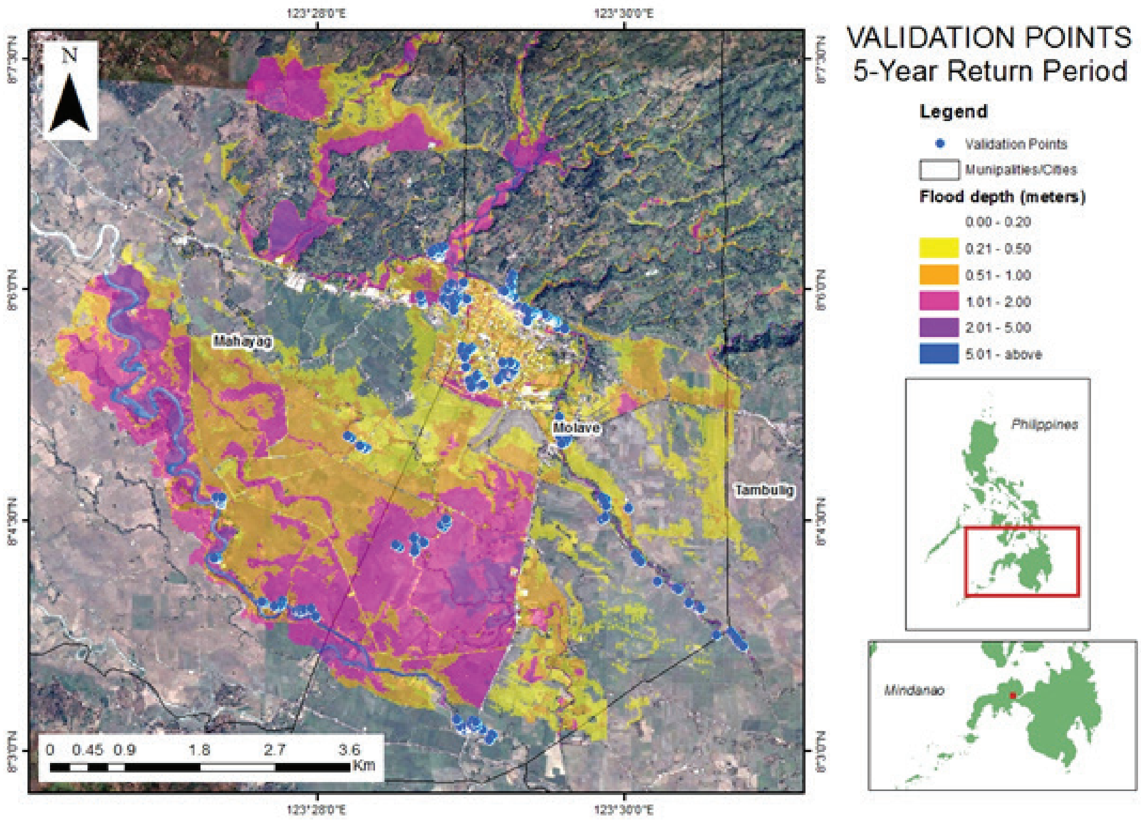


Figure 105. Validation points for 5-year flood depth map of Salug Diut Floodplain

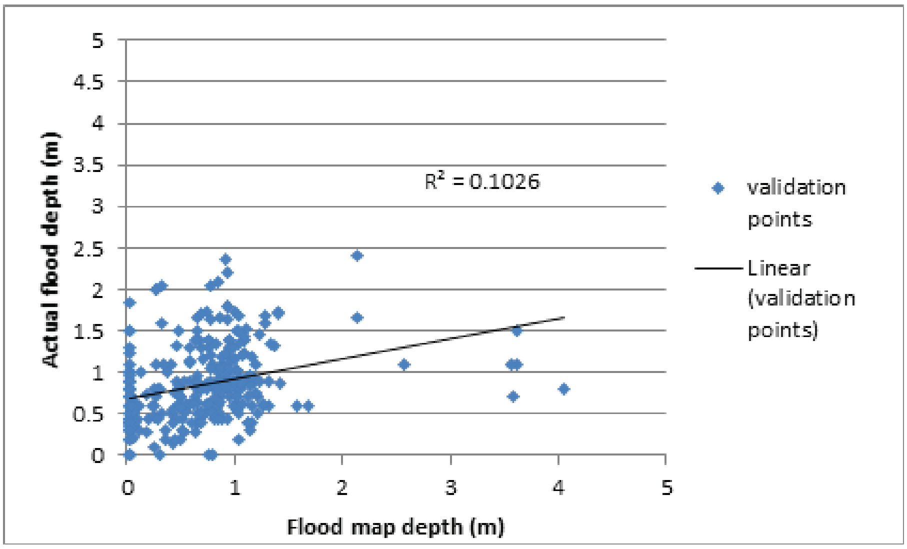


Figure 106. Flood map depth vs. actual flood depth

Table 54. Affected areas in Tambulig, Zamboanga del Sur during a 100-year rainfall return period

SALUG DIUT BASIN		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
Actual Flood Depth (m)	0-0.20	7	6	2	2	0	0	17
	0.21-0.50	34	8	19	6	0	0	67
	0.51-1.00	33	18	59	36	2	0	148
	1.01-2.00	6	8	38	21	5	0	78
	2.01-5.00	0	1	4	0	1	0	6
	> 5.00	0	0	0	0	0	0	0
	Total	80	41	122	65	8	0	316

The overall accuracy generated by the flood model is estimated at 30.38%, with 96 points correctly matching the actual flood depths. In addition, there were 156 points estimated one level above and below the correct flood depths while there were 55 points and 9 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 78 points were overestimated while a total of 142 points were underestimated in the modeled flood depths of Salug Diut.

Table 55. Summary of accuracy assessment in Salug Diut

	No. of Points	%
Correct	96	30.38
Overestimated	78	24.68
Underestimated	142	44.94
Total	316	100

REFERENCES

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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.

Annex 1. Technical Specifications of the LiDAR Sensors Used in the Salug Diut Floodplain Survey

1. Pegasus

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

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

2. D-8900 Aerial Camera

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

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

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 patty 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 patty 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

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

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CIP/4701/12/09/814

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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

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**
Municipality: **TUKURAN**
Barangay: **BACLAY**
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 58 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

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ZGS-58

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

February 24, 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-58**
Order: **2nd**

Island:	**MINDANAO**	Barangay:	**SICADE**		
Municipality:	**KUMALARANG**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**7° 45' 44.20587"**	Longitude:	**123° 8' 50.40994"**	Ellipsoidal Hgt:	**31.65000 m.**
		WGS84 Coordinates			
Latitude:	**7° 45' 40.67639"**	Longitude:	**123° 8' 55.89231"**	Ellipsoidal Hgt:	**96.97400 m.**
		PTM / PRS92 Coordinates			
Northing:	**858266.608 m.**	Easting:	**516251.478 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**857,966.20**	Easting:	**516,245.79**	Zone:	**51**

Location Description

ZGS-58
Is located about 200 m. NNE of the intersection of the national highway and the road going to Poblacion, Kumalarang. It is about 190 m. NE of the PNP Checkpoint and Collection post, 190 m. NNE of a waiting shed and 400 m. NNE of ZGS-59. 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-58 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089868 I**
T.N.: **2016-0411**

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

9902242016140321

CI/4701/12/09/814

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ZGS-68

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-68**	
	Order: **2nd**	
Island: **MINDANAO**	Barangay: **POBLACION**	
Municipality: **GUIPOS**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **7° 43' 33.12722"**	Longitude: **123° 18' 48.96041"**	Ellipsoidal Hgt: **205.94100 m.**
	WGS84 Coordinates	
Latitude: **7° 43' 29.62251"**	Longitude: **123° 18' 54.44472"**	Ellipsoidal Hgt: **271.74800 m.**
	PTM / PRS92 Coordinates	
Northing: **854250.138 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 2005 NAMRIA/LEP-IX".

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

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

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ZGS-88

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-88**	
Island: **MINDANAO**	Order: **2nd**	Barangay: **SAN JOSE**
Municipality: **AURORA**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **7° 57' 13.25316"**	Longitude: **123° 34' 56.50093"**	Ellipsoidal Hgt: **258.34500 m.**
	WGS84 Coordinates	
Latitude: **7° 57' 9.71271"**	Longitude: **123° 35' 1.96243"**	Ellipsoidal Hgt: **324.37300 m.**
	PTM / PRS92 Coordinates	
Northing: **879474.685 m.**	Easting: **564207.26 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **879,166.85**	Easting: **564,184.79**	Zone: **51**

Location Description

ZGS-88
Is located on the S end of the W wedge-shaped island in Purok Saray, Brgy. San Jose, Aurora. It is about 500 m. N of the municipal hall, 30 m. W of the Seaoil Gasoline Station and 5 m. E of the W side of the road. Mark is the head of a 3 in. copper nail embedded and centered on a 27 cm. x 26 cm. x cement putty, with inscriptions "ZGS-88 2005 NAMRIA LEP IX".

Requesting Party:	**UP TCAGP / Engr. Christopher Cruz**
Pupose:	**Reference**
OR Number:	**8796507 A**
T.N.:	**2014-1601**

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

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CIF/4701/12/09/814

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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

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CIP/4701/12/09/814

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: **8799670 A**
T.N.: **2014-1787**

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

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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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Reports of Reference Points Used

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

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°57'55.36634"
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

ZS-188

Vector Components (Mark to Mark)

From:	ZGS-1				
Grid		Local		Global	
Easting	553699.482 m	Latitude	N8°04'26.98335"	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

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	Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	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, Data Download and Transfer	Senior Science Research Specialist (SSRS) 2014	JASMINE ALVIAR	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016	ENGR. GEROME HIPOLITO / PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA) 2014/2016	ENGR. GRACE SINADJAN	UP-TCAGP
	RA 2014/2016	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA 2016	JONATHAN ALMALVEZ/ ENGR. KENNETH QUISADO	UP-TCAGP
Ground Survey	RA 2014	LANCE CINCO	UP-TCAGP
	RA 2016	ENGR. GEF SORIANO / JASMIN DOMINGO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
		SSG JAYCO MANZANO	PAF
	Pilot	CAPT. CESAR SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JOSEPH LIM	AAC
		CAPT. JERICO JECIEL	AAC

Annex 5. Data Transfer Sheet for Salug Diut Floodplain

1673P, 1677P, 1689P

DATA TRANSFER SHEET
08/06/2014(Northern Mindanao - ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	SHP	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	
7/3/2014	1665P	1BLK71ES184A	Pegasus	606	93	4.69	94.5	169	NA	NA	6.77	NA	6.94	1KB	1KB	35	NA	Z:\Airborne_Raw
7/5/2014	1673P	1BLK71ES186A	Pegasus	1.05	379	7.58	335	190	22.4	167	12.5	27.8	5.09	1KB	1KB	92/84	NA	Z:\Airborne_Raw
7/6/2014	1677P	1BLK71S187A	Pegasus	695	68	5.33	188	141	11.2	86	7.79	NA	4.94	1KB	1KB	130	NA	Z:\Airborne_Raw
7/8/2014	1685P	1BLK71S189A	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	1BLK71S189B	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	12.6	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	175	NA	NA	16.9	NA	4.06	1KB	1KB	53	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
8/6/14

23064P, 23066P, 23072P, 23074P, 23076P

DATA TRANSFER SHEET
Pagadian 2/19/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6-Feb	23062	1BLK76F037A	PEGASUS	268	NA	4.12	143	11.9	96.9	6.97	NA	57.2	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
7-Feb	23064	1BLK76EF038A	PEGASUS	1.95	NA	10.2	270	12.1	92.1	20.2	NA	5.13	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
7-Feb	23066	1BLK76F038B	PEGASUS	750	NA	4.63	99.8	2.76	20.5	7.2	NA	5.13	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
9-Feb	23072	1BLK76EF040A	PEGASUS	2.84	NA	12.5	258	38.7	291	26.6	NA	146	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
9-Feb	23074	1BLK76EFH040B	PEGASUS	1.56	NA	6.64	163	20.6	167	15.4	NA	145	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
10-Feb	23076	1BLK76GH041A	PEGASUS	3.3	NA	14.4	278	49.7	376	32.7	NA	152	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
10-Feb	23078	1BLK76DI041B	PEGASUS	1.33	NA	6.57	159	17.8	151	13	NA	152	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
11-Feb	23080	1BLK76AB042A	PEGASUS	1.2	NA	9.56	233	22.1	177	16	NA	100	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA
11-Feb	23082	1BLK76CDs042B	PEGASUS	990	NA	5.11	144	12.9	111	9.66	NA	100	1KB	1KB	312/347/332/318	NA	Z:\DAC\RAW DATA

Received from
Name CJ Sagrado
Position
Signature

Received by
Name AC Bongat
Position SSRS
Signature 2/22/16

16-12

23088P, 23092P, 23100P

DATA TRANSFER SHEET
PAGADIAN 2/29/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2016-02-17	23104P	1BLK76DLM48A	Pegasus	1.81 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\23104P
2016-02-16	23100P	1BLK76G047A	Pegasus	2.83 GB	NA	12.33 MB	285.96 MB	38 GB	297.52 KB	27.31 GB	0 B	103.23 MB	132 B	341B	0 B	NA	Z:\DAC\RAW DATA\23100P
2016-02-15	23096P	1BLK76NO46A	Pegasus	665.91 MB	NA	4.64 MB	164.2 MB	9.7 GB	82.64 KB	7.07 GB	0 B	90.32 MB	133 B	603 B	0 B	NA	Z:\DAC\RAW DATA\23096P
2016-02-14	23092P	1BLK76IG045A	Pegasus	2.19 GB	NA	10.66 MB	203.46 MB	28.87 GB	230.75 KB	22.33 GB	0 B	110.72 MB	132 B	279 B	0 B	NA	Z:\DAC\RAW DATA\23092P
2016-02-13	23088P	1BLK76ILM044A	Pegasus	2.48 GB	NA	11.64 MB	283.62 MB	35.45 GB	263.38 KB	24.65 GB	0 B	101.29 MB	133 B	889 B	0 B	NA	Z:\DAC\RAW DATA\23088P
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	129.73 MB	133 B	362 B	0 B	NA	Z:\DAC\RAW DATA\23084P

Received from

Name R. Punto
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/1/16

23140P

DATA TRANSFER SHEET
PAGADIAN 3/7/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
02/20/2016	23116P	1BLK76NO051A	Pegasus	2.29 GB	NA	11.9 MB	294 MB	NA	NA	24.4 GB	0 B	63.8 MB	2KB	2KB	148/252/232	NA	Z:\DAC\RAW DATA
02/21/2016	23120P	1BLK69D052A	Pegasus	2.6 GB	NA	12 MB	298 MB	22.5 GB	NA	25.9 GB	0 B	59.6 MB	2KB	1KB	580/100/91/82	NA	Z:\DAC\RAW DATA
02/22/2016	23124P	1BLK69AB053A	Pegasus	1.89 GB	NA	11.4 MB	270 MB	NA	NA	21.1 GB	0 B	3.12 MB	1KB	NA	125/108/98/87/78/76	NA	Z:\DAC\RAW DATA
02/23/2016	23128P	1BLK70B054A	Pegasus	2.22 GB	NA	12.8 MB	273 MB	311 MB	NA	23.3	0 B	44.4 MB	1KB	NA	92/90/80/73	NA	Z:\DAC\RAW DATA
02/24/2016	23132P	1BLK73A055A	Pegasus	10.3 MB	NA	12.5 MB	266 MB	NA	NA	24.4 GB	0 B	49.7 MB	2KB	1KB	84/84/72/76/57	NA	Z:\DAC\RAW DATA
02/26/2016	23140P	1BLK73BS057A	Pegasus	2.47 GB	NA	13.5 MB	305 MB	NA	NA	26.5 GB	0 B	65.9 MB	2KB	1KB	85/83	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 3/10/16

Annex 6. Flight Logs for the Flight Missions

Flight Log for 1673P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 167

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK71ES186A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 5, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0933H	14 Engine Off: 1238H	15 Total Engine Time: 3+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: very cloudy					

20 Remarks:

Attempted to survey Lanao and Pagadian but transferred to Tangub and Ozamis due to heavy build up in the previous areas

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
V. [illegible]	W. Dunzalan	Cesar Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for1677P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1677

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK71S187A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 6, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 1021H	14 Engine Off: 1256H	15 Total Engine Time: 2+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	very cloudy				

20 Remarks:

Heavy build up over all remaining survey areas; surveyed supplementary lines to BLK 71ext

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	W. Anzalan	Cesar Alfonso III	G. Sinadjan
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 1689P Mission

Flight Log No.: 1689P

DREAM Data Acquisition Flight Log

1 LIDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO	12 Airport of Arrival (Airport, City/Province): CDO		
10 Date: July 9, 2014	12 Airport of Departure (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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	W. Punzalan	Cesar Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Flight Log for 23064P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log — Flight Log No.: 23064P

1BLK76EF038A

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: Cesar Alfonso III	8 Co-Pilot: Jerico Jeciel	9 Route: Pag - Pag			
10 Date: 07 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0756H	14 Engine Off: 1301H	15 Total Engine Time: 4+05	16 Take off: 0801H	17 Landing: 1256H	18 Total Flight Time: 3+55
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

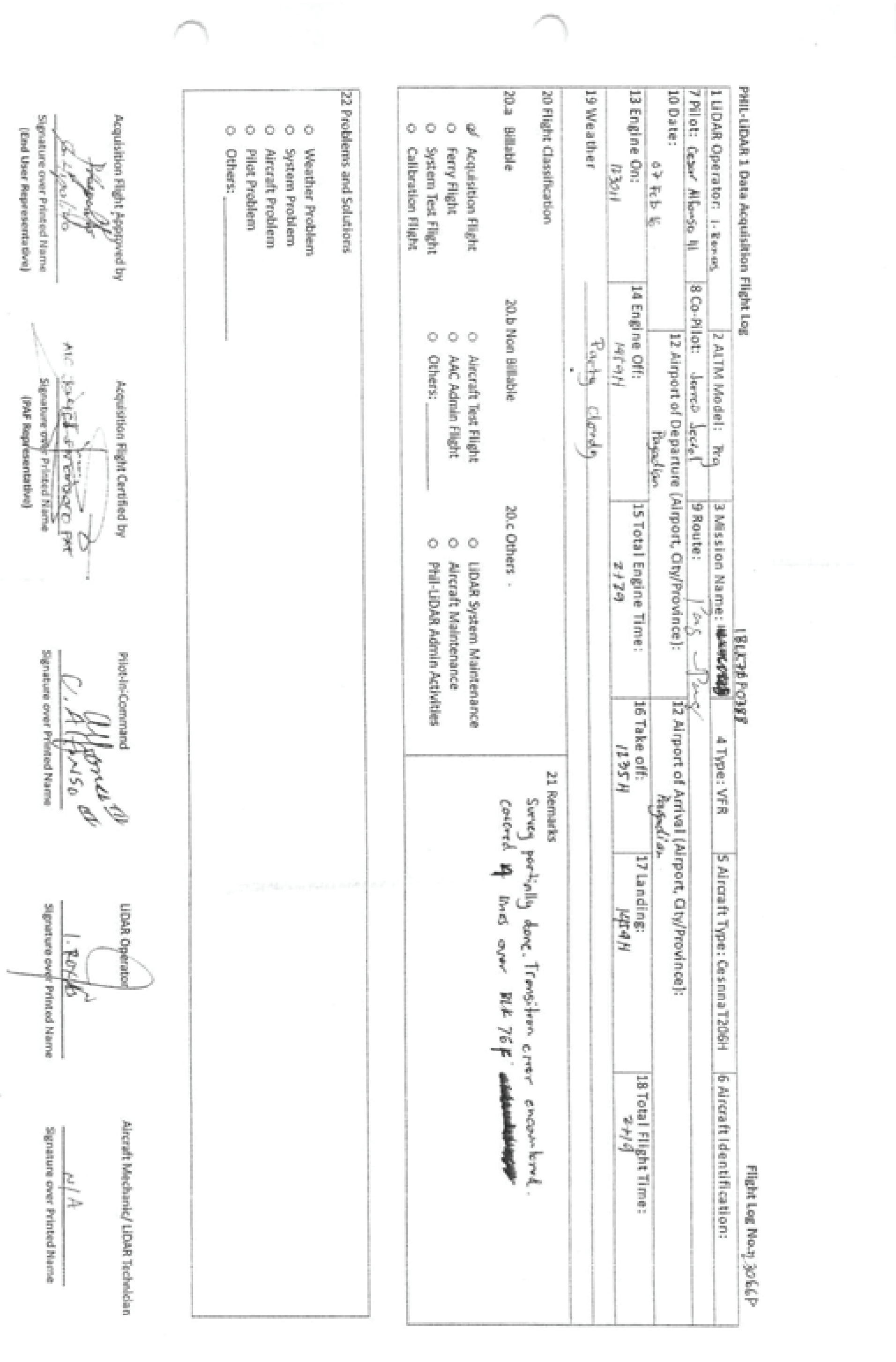
Survey partially done. Transition error encountered. Covered 14 lines over BLK76F and E.

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
G. Alfonso	A1C Jan Rey Emmanuel PAF	C. Alfonso III	I. Roxas	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 23066P Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23066P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK76F0388	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: Cesar Alfonso III	8 Co-Pilot: Jerred Lecrel	9 Route: Pag - Pag			
10 Date: 07 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 1230H	14 Engine Off: 1459H	15 Total Engine Time: 2+29	16 Take off: 1235H	17 Landing: 1454H	18 Total Flight Time: 2+19
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Survey partially done. Transition error encountered.
Covered 4 lines over BLK 76F

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature]	AIC [signature] PAF	C. Alfonso III	I. Roxas	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 23072P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23072P

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Peg	3 Mission Name: 1BLK76EF040A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: Cesar Alfonso III	8 Co-Pilot: Jerico Jeciel	9 Route: Pagadian - Pagadian			
10 Date: 09 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0759H	14 Engine Off: 1205H	15 Total Engine Time: 4+6	16 Take off: 0759H	17 Landing: 1200H	18 Total Flight Time: 4+01
19 Weather: Partly cloudy					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
☑ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: ______	○ Phil-LiDAR Admin Activities
○ Calibration Flight		

21 Remarks

Completed BLK 76 F

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ______

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
G. Alfonso	A1C Jayson Morano PAF	C. Alfonso III	J. Almalvez	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 23074P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23074P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK76EFH040B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: Cesar Alfonso III	8 Co-Pilot: Jerico Jecieel	9 Route: Pagadian - Pagadian			
10 Date: 09 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 1241H	14 Engine Off: 1516	15 Total Engine Time: 2+35	16 Take off: 1246H	17 Landing: 1511H	18 Total Flight Time: 2+25
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Covered 4 lines in BLK76H, and voids in BLK'S 76E and F

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
G. Hipolito	A1C Jaycob F Mongaro PAF	C. Alfonso III	I. Roxas	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 23076P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23076P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK76BH041A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9-C9022
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jeciel	9 Route: Pagadian - Pagadian			
10 Date: 10 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0709H	14 Engine Off: 1126H	15 Total Engine Time: 4+17	16 Take off: 0714H	17 Landing: 1121H	18 Total Flight Time: 4+07
19 Weather	Partly Cloudy				

20 Flight Classification

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

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

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

21 Remarks

Covered 7 lines in BLK76H, 9 in BLK76B

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
E. Agosto	A1C Jaycee V. Manzano PAF	C. Alfonso III	I. Roxas	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 23088P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23088P

1 LIDAR Operator: J. Almalvez	2 ALTM Model: Peg	3 Mission Name: 2BLK76ILM044A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jecrel	9 Route:			
10 Date: 13 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0720H	14 Engine Off: 1143H	15 Total Engine Time: 4+23	16 Take off: 0725H	17 Landing: 1138H	18 Total Flight Time: 4H3
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK76 I, L and M- with voids due to clouds.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
[signature]	AIC Sayed S. Marmaro PAF	C. Alfonso III	J. Almalvez	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 23092P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23092P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK76GHI049A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jecrel	9 Route:			
10 Date: 19 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0835H	14 Engine Off: 1210H	15 Total Engine Time: 3+35	16 Take off: 0840H	17 Landing: 1205H	18 Total Flight Time: 3+25
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed voids over BLK76 G, H and I.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
G. Hipolito	MC Bayudo B Manzano PAF	C. Alfonso III	I. Roxas	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 23100P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 23100P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 3BLK76EF047A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 16 Feb 16	12 Airport of Departure (Airport, City/Province): Pangasinan		12 Airport of Arrival (Airport, City/Province): Pangasinan		
13 Engine On: 0941H	14 Engine Off: 1404H	15 Total Engine Time: 4+23	16 Take off: 0946H	17 Landing: 1359H	18 Total Flight Time: 4+18
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Covered voids in BLK 76 F and G

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
G. Hipolito	A1C Jaybert Mandane PAF	C. Alfonso, III	I. Roxas	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status

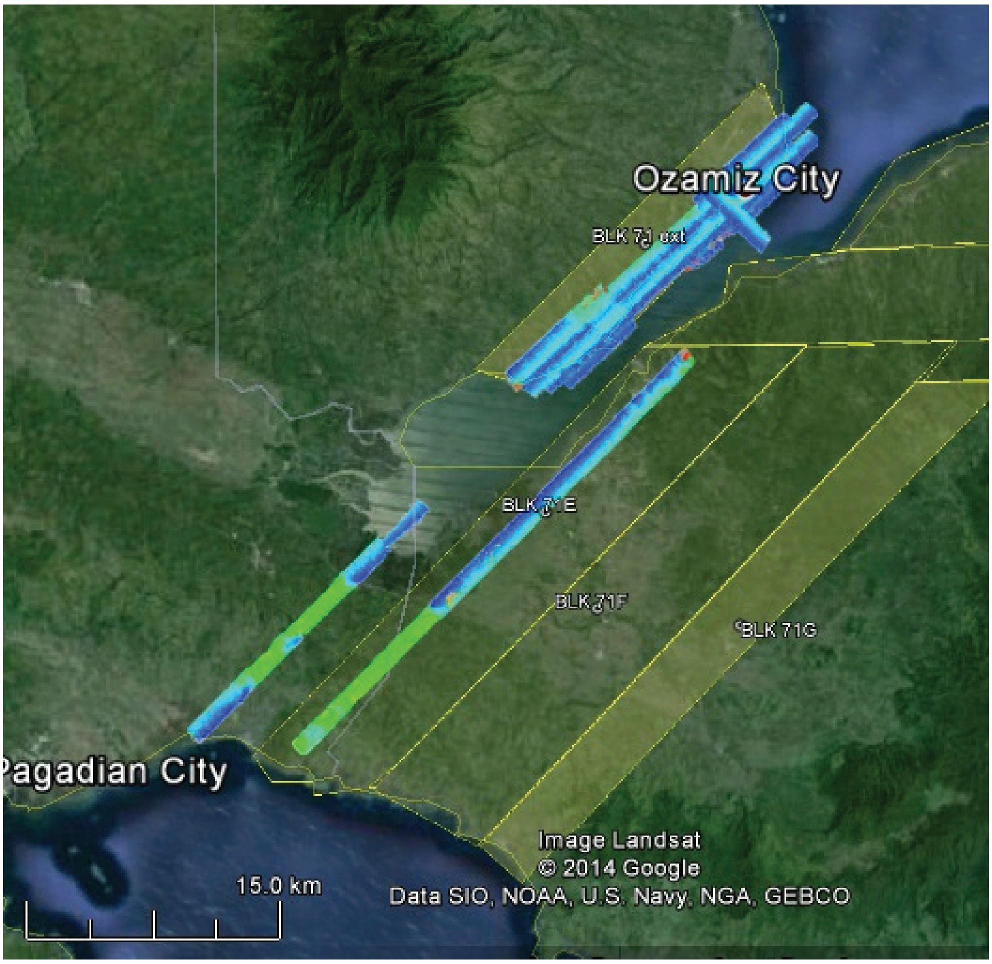
FLIGHT STATUS REPORT
Northern Mindanao / Pagadian
July 5 to 9, 2014 & February 7 to 26, 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1673P	BLK 71 ext	1BLK71ES186A	I.Roxas	July 5	Attempted to survey Lanao and Pagadian but transferred to Tangub and Ozamis due to heavy build up in the previous areas; 63.7 sq km
1677P	BLK 71 ext	1BLK71S187A	G. Sinadjan	July 6	Heavy build over all remaining survey areas; surveyed supplementary lines to BLK 71ext; 89.67 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
23064	BLK E,F	1BLK76EF038A	IN ROXAS	FEB 7, 2016	Transition Error encountered; Covered 12 lines over BLK76E and BLK76F
23066	BLK F	1BLK76F038B	IN ROXAS	FEB 7, 2016	Transition Error encountered; Covered 4 lines over BLK76F. Use 23064's tie line
23072	BLK E,F	1BLK76EF040A	JM ALMALVEZ	FEB 9, 2016	Completed BLK76F
23074	BLK E,F,H	1BLK76EFH040B	IN ROXAS	FEB 9, 2016	Covered 4 lines in BLK76H, and voids in BLK76E and BLK76F. Use 23072's tie line
23076	BLK G,H	1BLK76GH041A	IN ROXAS	FEB 10, 2016	Covered 7 lines in BLK76H, 9 in BLK76G. Cloudy in southern part
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
23092	BLK G,H,I	1BLK76GHI045A	IN ROXAS	FEB 14, 2016	Cloudy w/ some rain. Surveyed voids over G & H; completed I; please also process tie lines especially in 76G as they also cover voids and flood plain
23100	BLK E,F,G	1BLK76EFG047A	IN ROXAS	FEB 16, 2016	Covered voids/gaps over BLK76E,F; continued 76G; please also process the perpendicular lines to BLK76G
23140P	BLK 73B, 72A, 70A	1BLK73BS057A	K QUISADO	FEB 26, 2016	Encountered lost channel A. Completed BLK73B and voids over BLK72A and 70A

SWATH PER FLIGHT MISSION

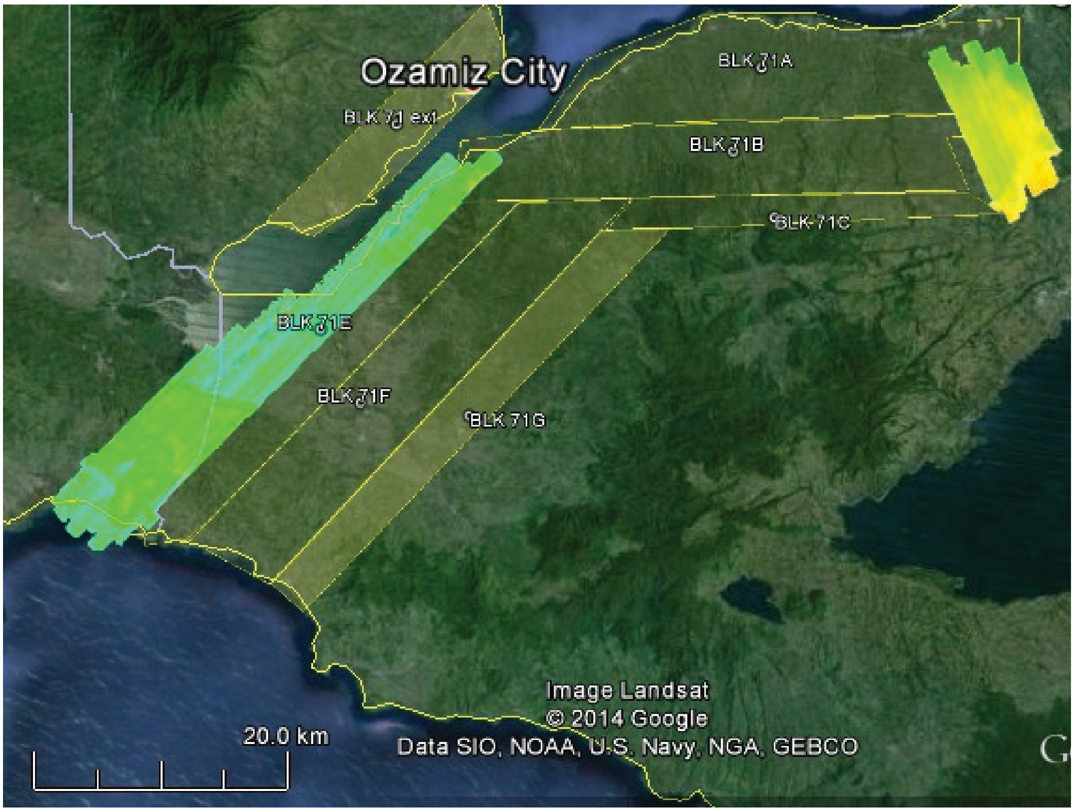
Flight No. : 1673P
Area: BLK 71 ext
Mission Name: 1BLK71ES186A

LAS



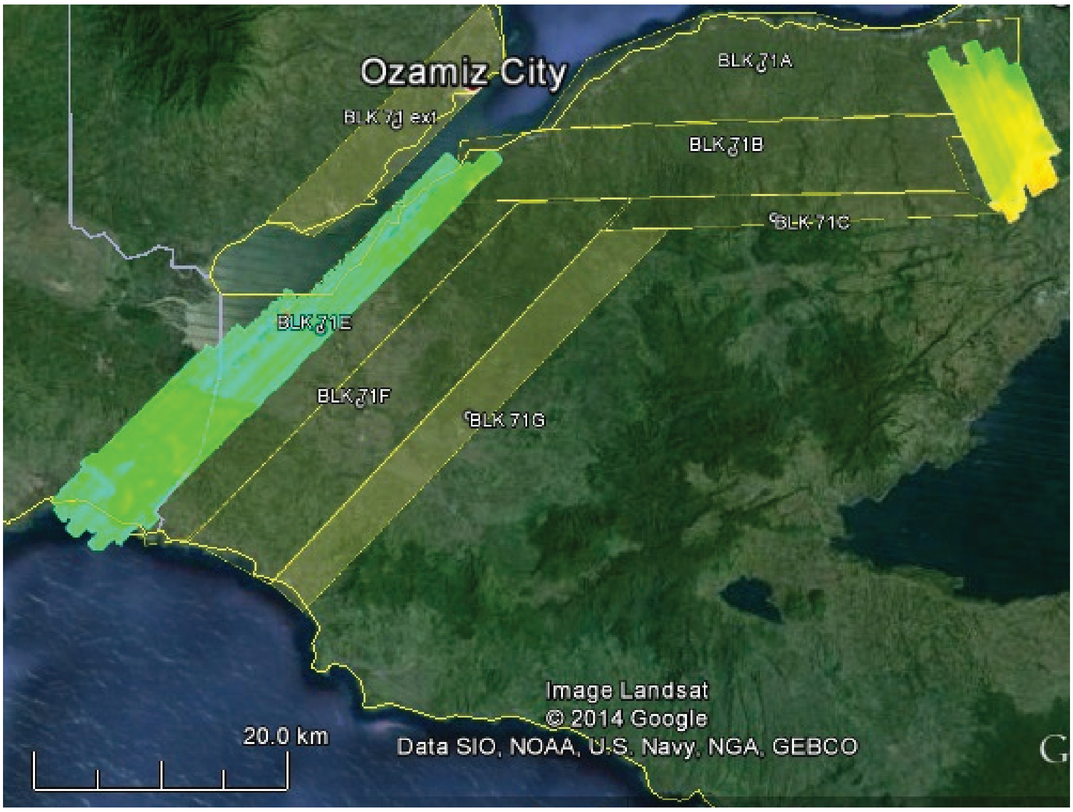
Flight No. : 1689P
Area: BLK 71E and BLK 71ABCs
Mission Name: 1BLK71S190A

LAS

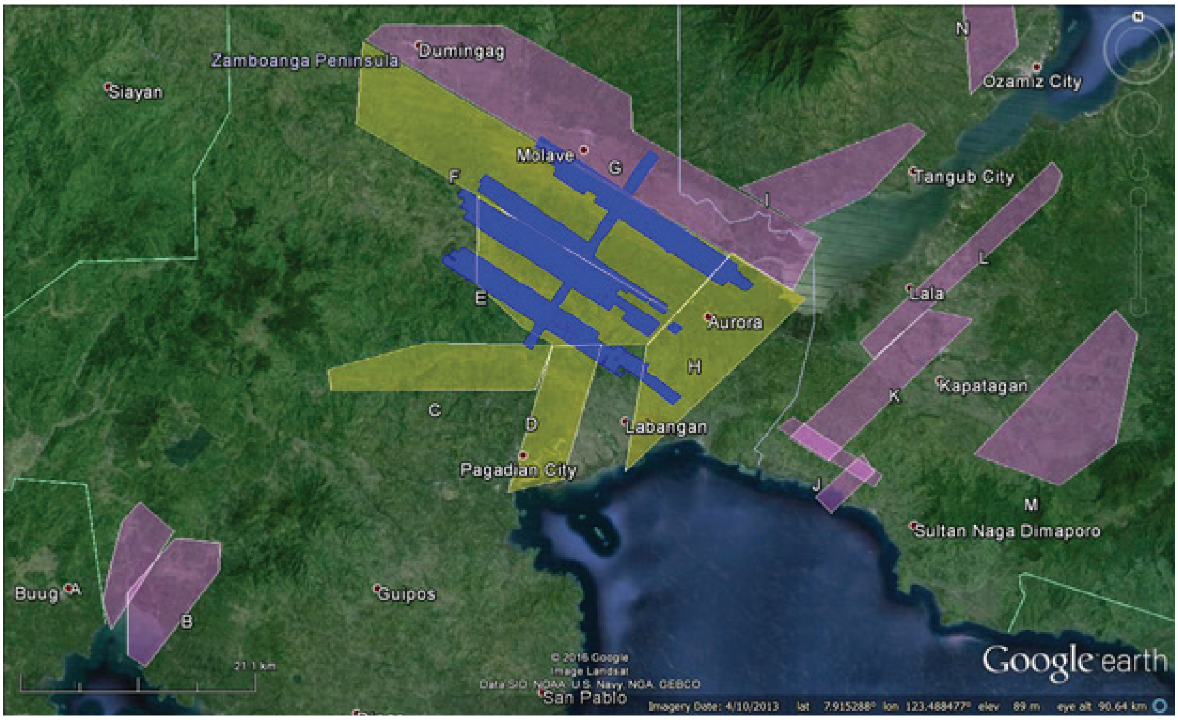


Flight No. :	1689P
Area:	BLK 71E and BLK 71ABCs
Mission Name:	1BLK71S190A

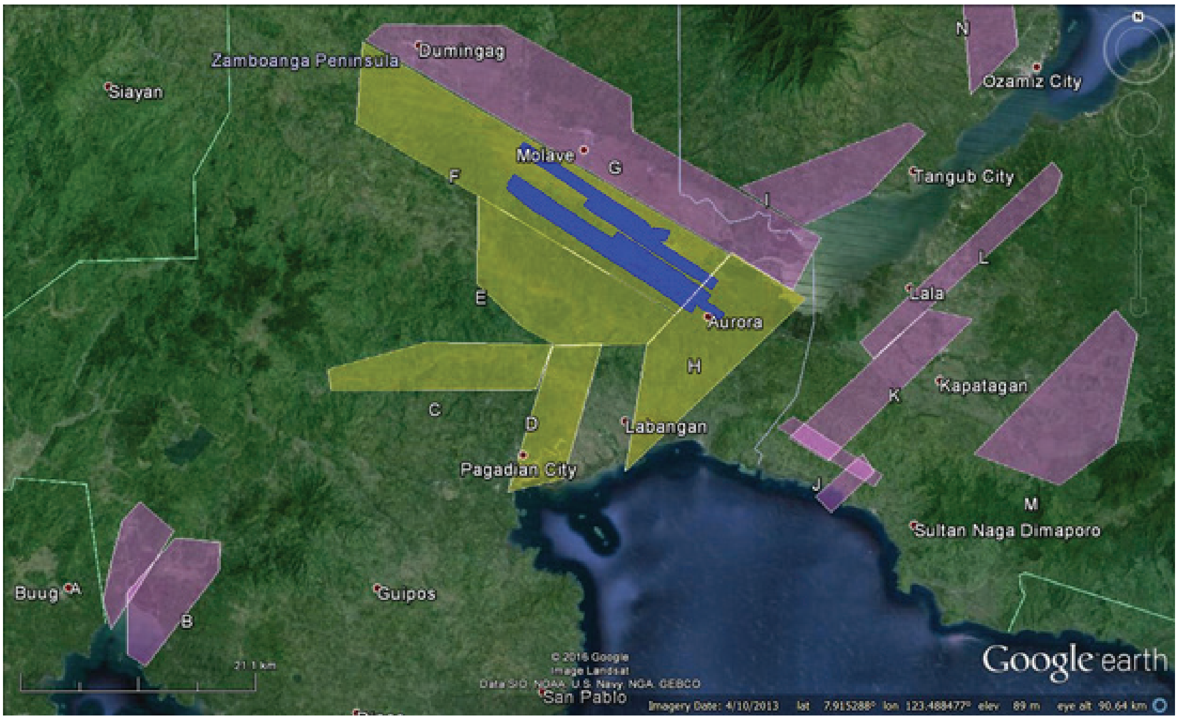
LAS



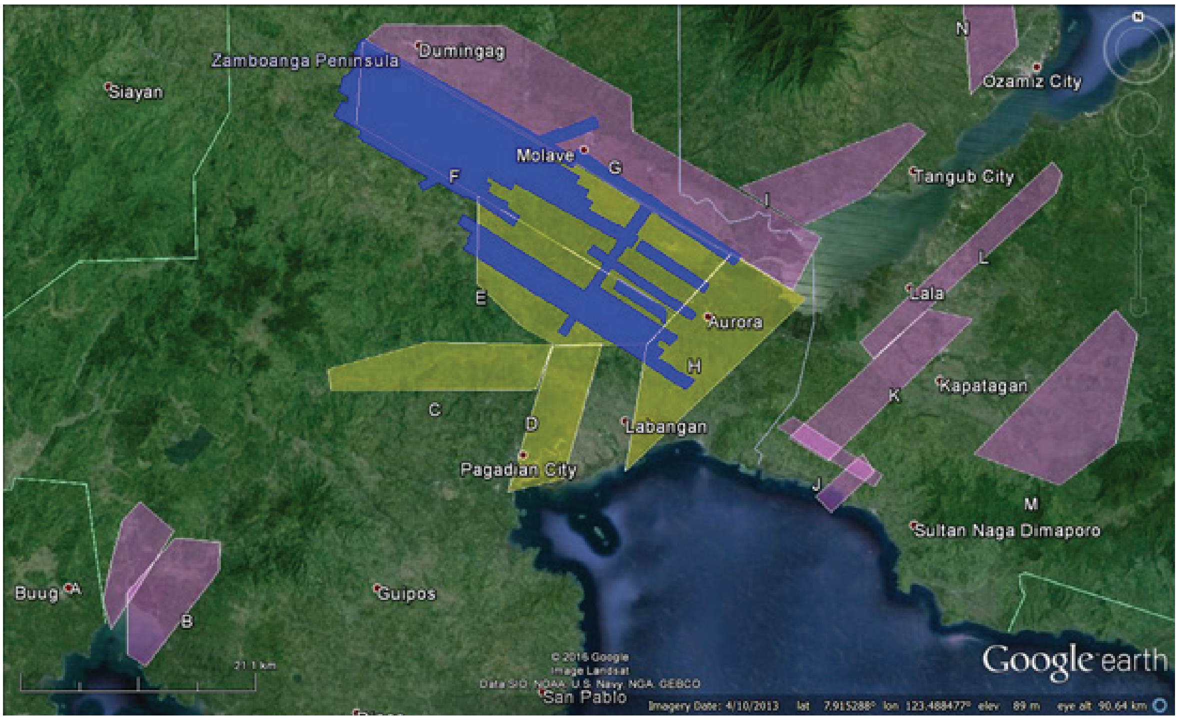
Flight No.: 23064
Target Area: BLK E,F
Mission Name: 1BLK76EF038A
Total Area Surveyed: 177.91



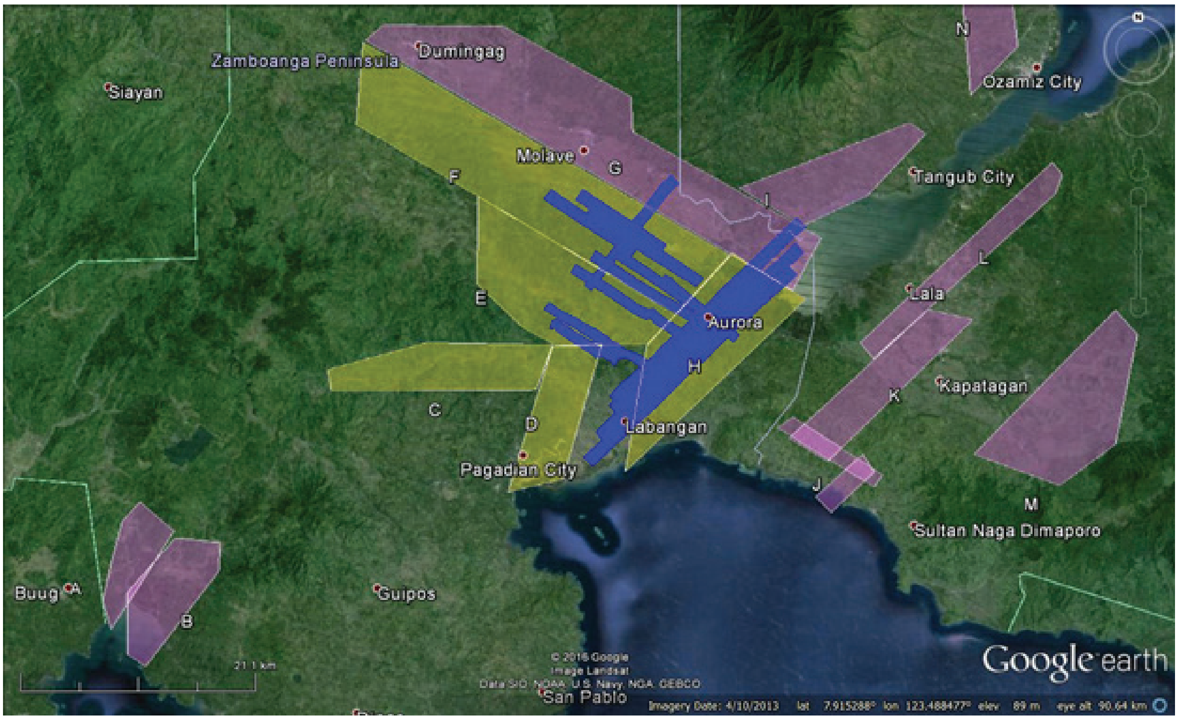
Flight No.: 23066
Target Area: BLK F
Mission Name: 1BLK76F038B
Total Area Surveyed: 72.3



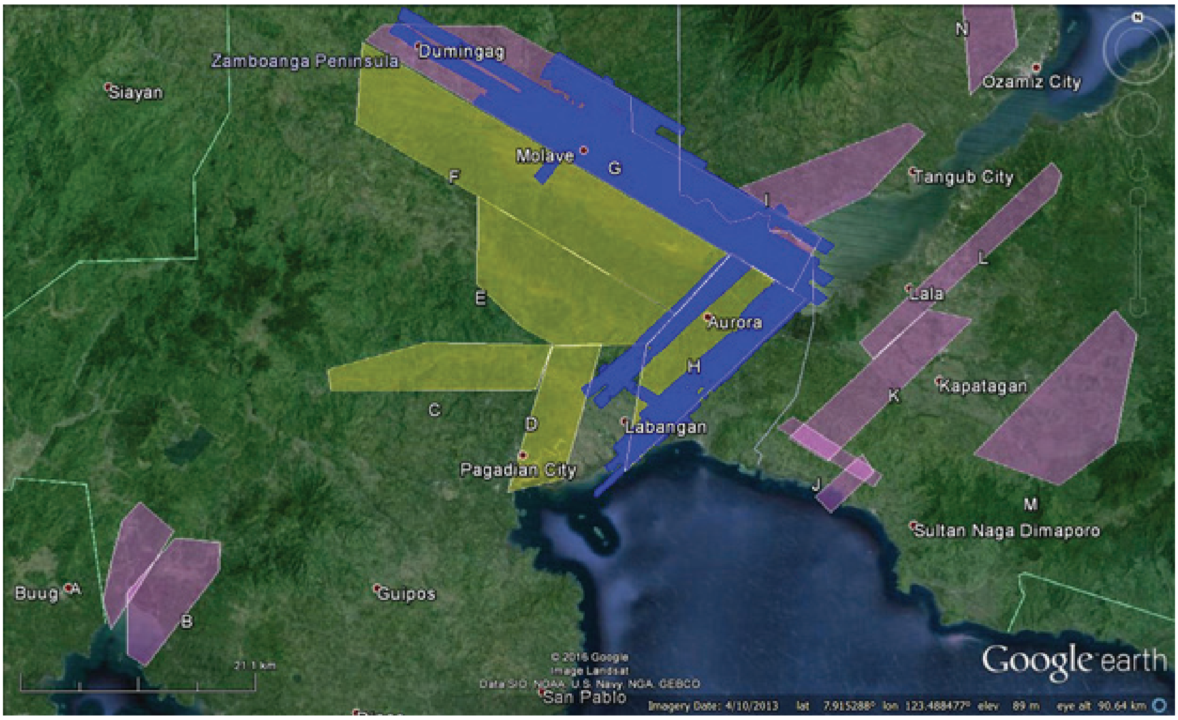
Flight No.: 23072
Target Area: BLK E,F
Mission Name: 1BLK76EF040A
Total Area Surveyed: 287.592



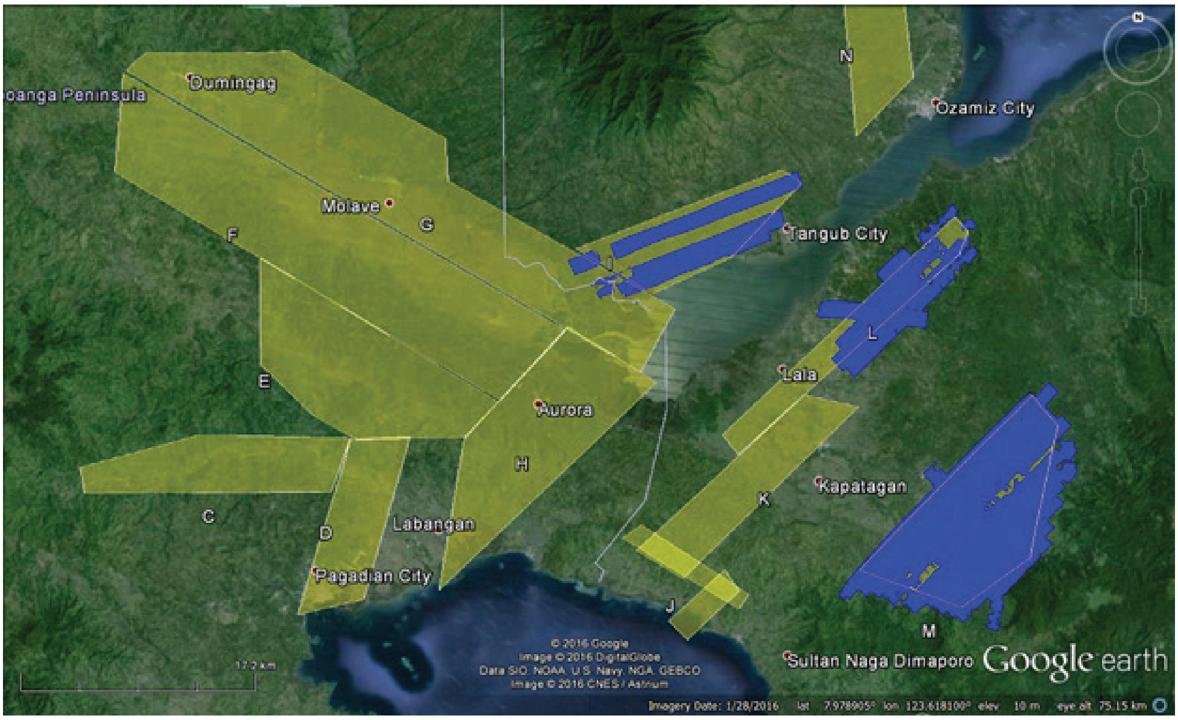
FligFlight No.: 23074
Target Area: BLK E,F,H
Mission Name: 1BLK76EFH040B
Total Area Surveyed: 165.584



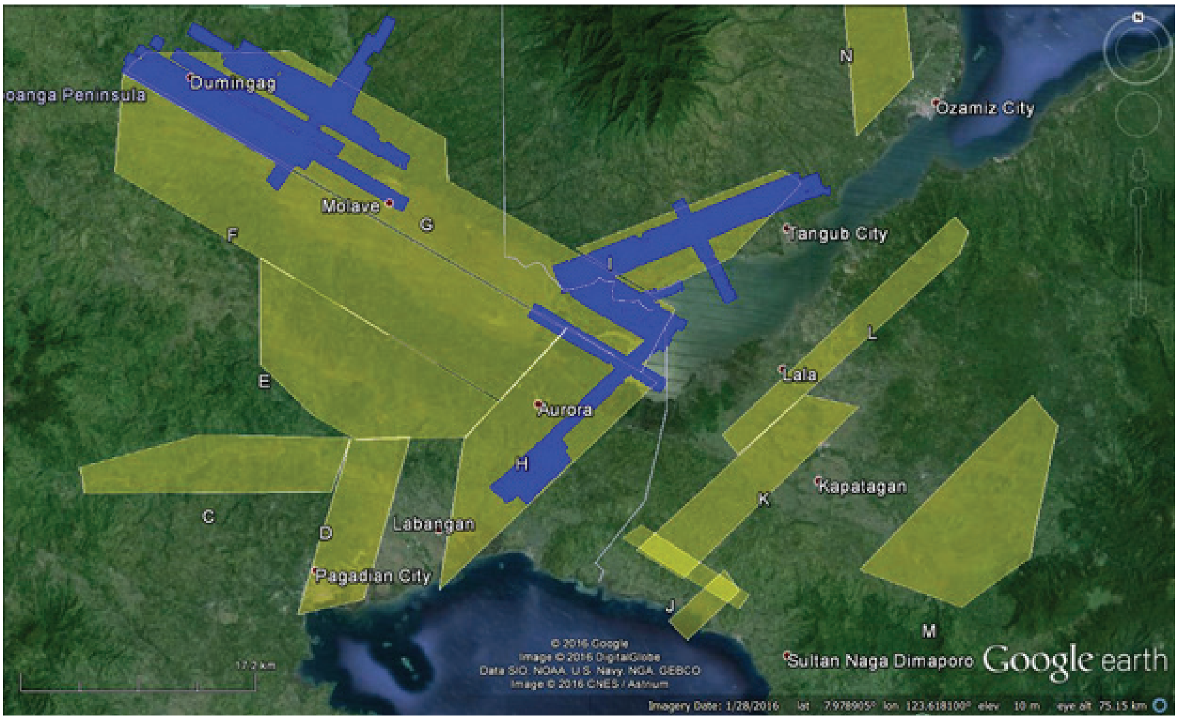
Flight No.: 23076
Target Area: BLK G,H
Mission Name: 1BLK76GH041A
Total Area Surveyed: 339.101



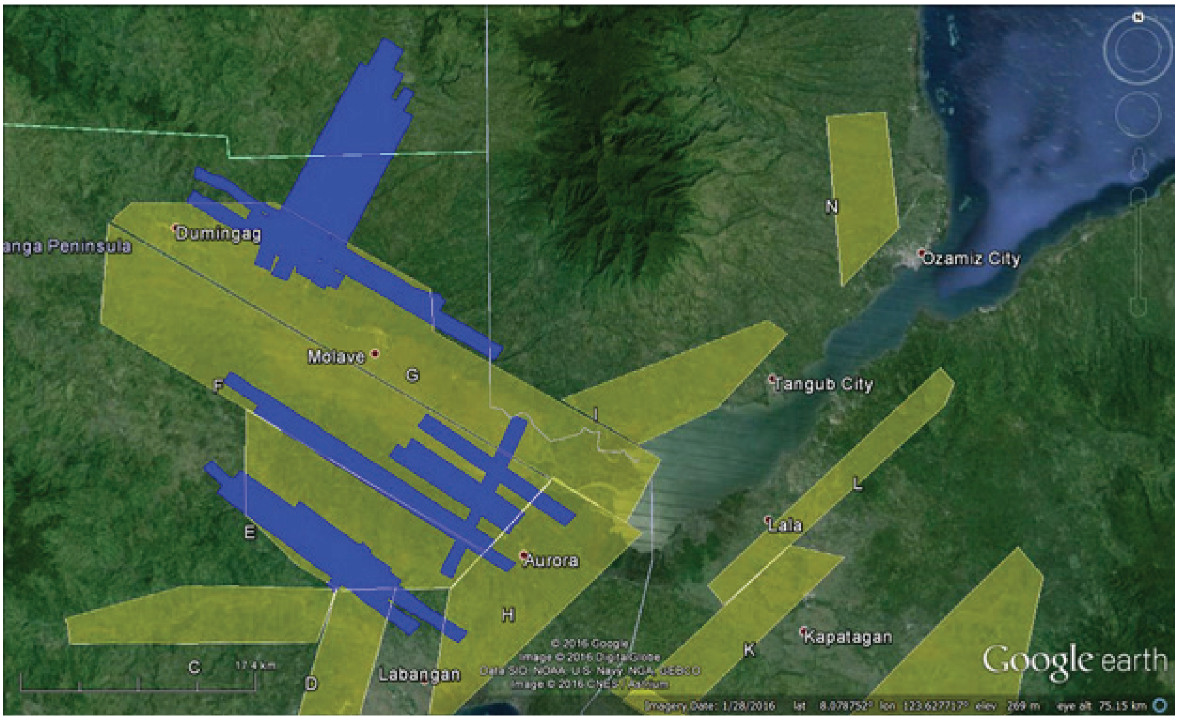
Flight No.: 23088
Target Area: BLK I,L,M
Mission Name: 1BLK76ILM044A
Total Area Surveyed: 231.966



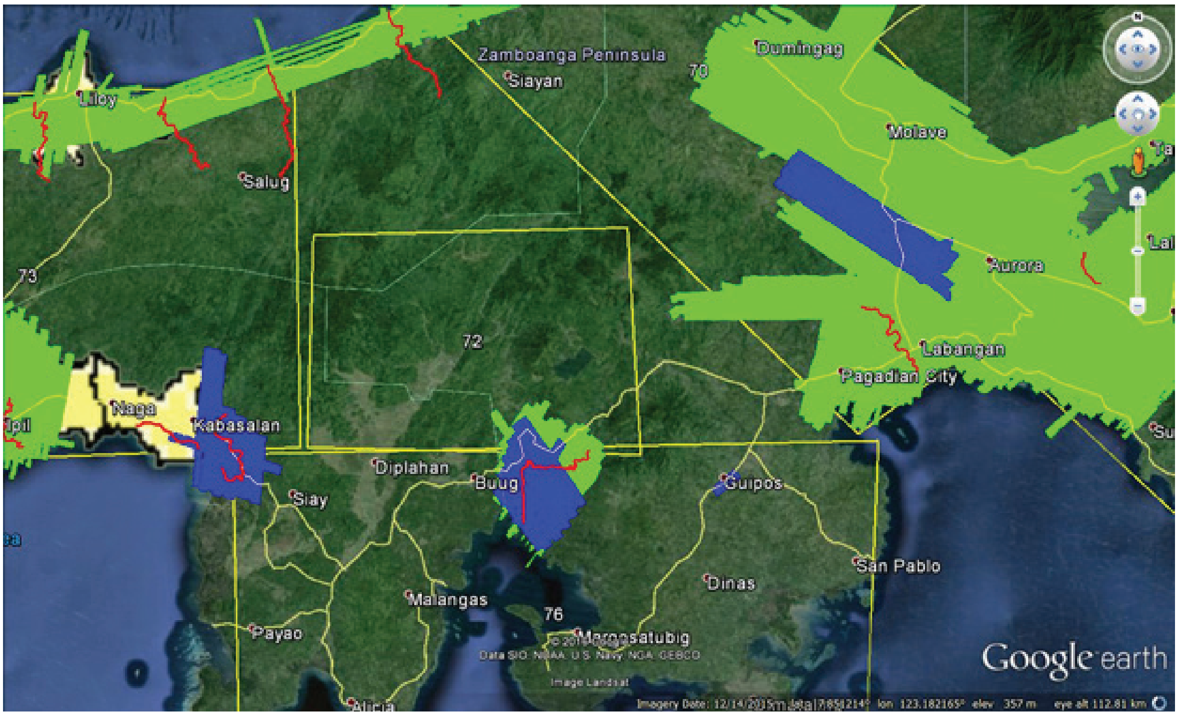
Flight No.: 23092
Target Area: BLK G,H,I
Mission Name: 1BLK76GHI045A
Total Area Surveyed: 218.933



Flight No.: 23100
Target Area: BLK E,F,G
Mission Name: 1BLK76EFG047A
Total Area Surveyed: 262.016



Flight No.: 23140P
Target Area: BLK 73B, 72A, 70A
Mission Name: 1BLK73BS057A
Total Area Surveyed: 253.07



Annex 8. Mission Summary Reports

Flight Area	Pagadian
Mission Name	76E
Inclusive Flights	23064P, 23072P
Range data size	46.8 GB
POS data size	528 MB
Base data size	151.13 MB
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
Processed by	Engr. Abigail Joy Ching,
	Engr. Merven Matthew Natino,
	Maria Tamsyn Malabanan

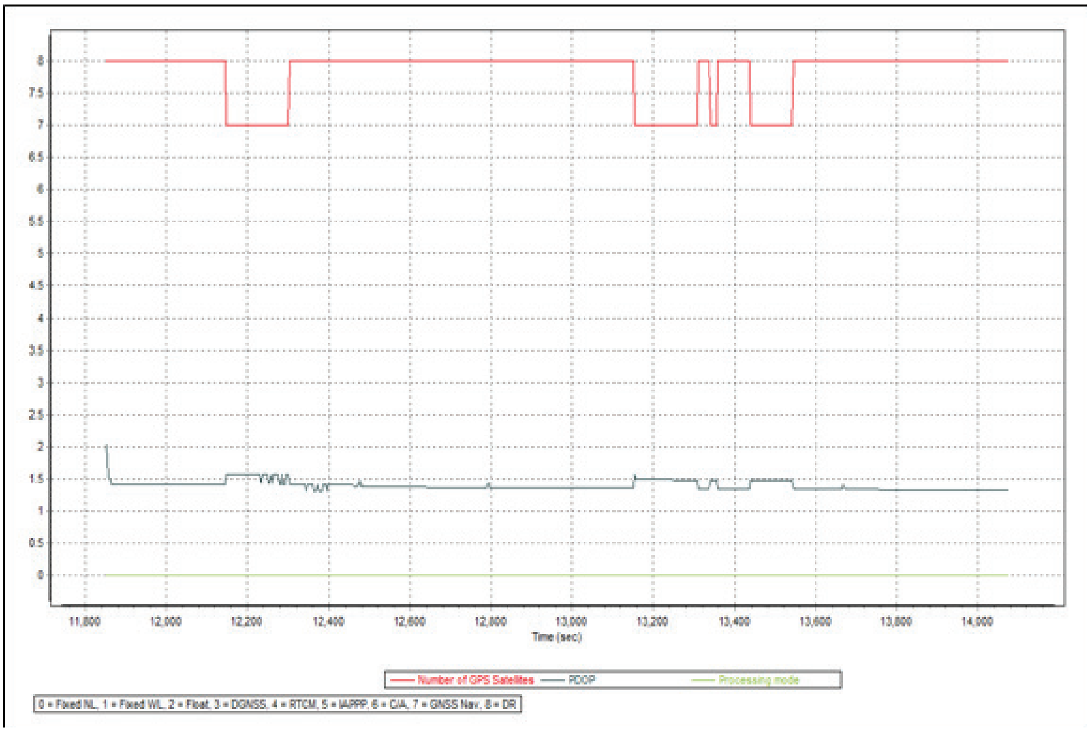


Figure A.8.1. Solution Status

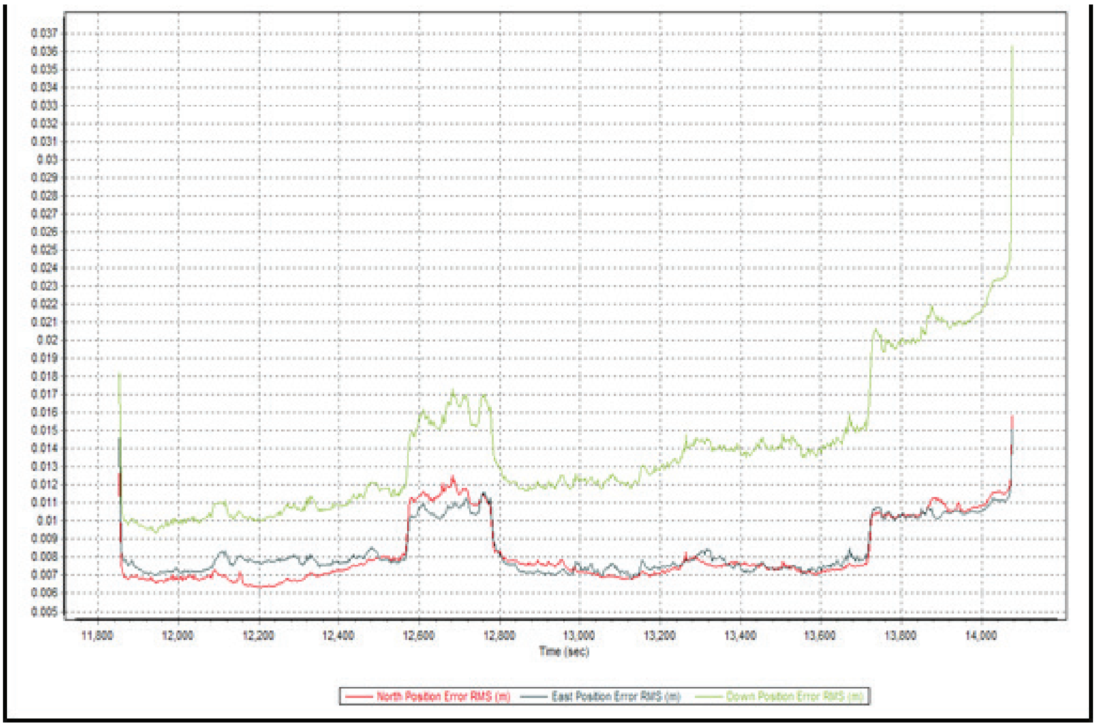


Figure A.8.2. Smoothed Performance Metric Parameters

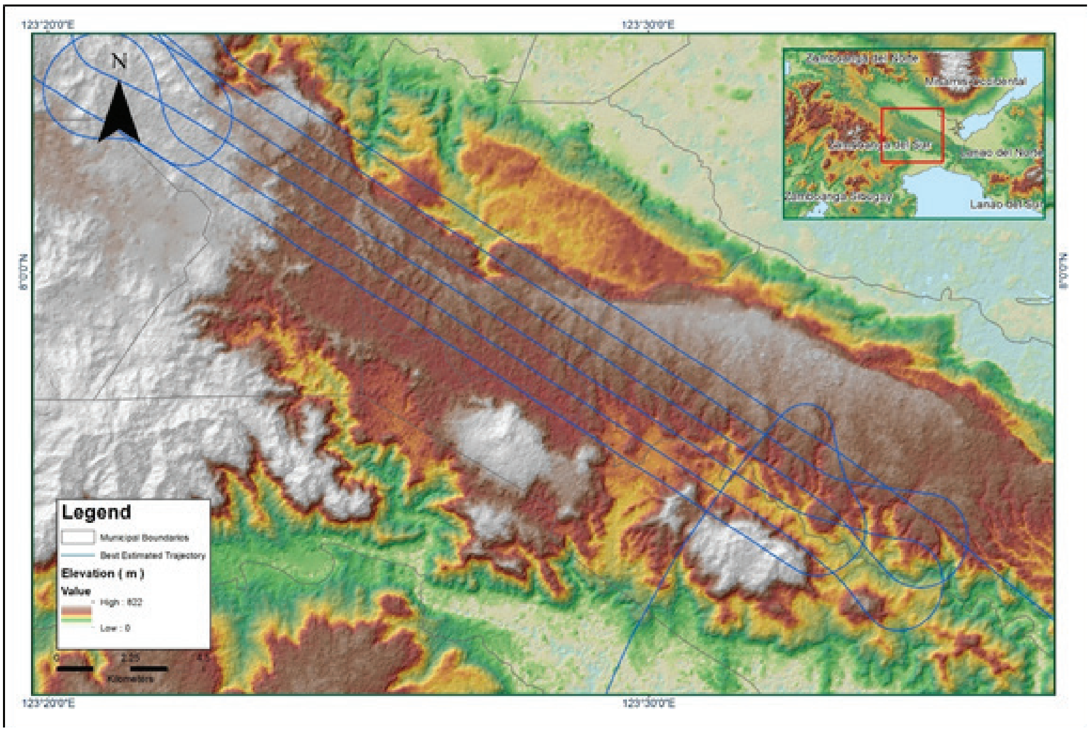


Figure A.8.3. Best Estimated Trajectory

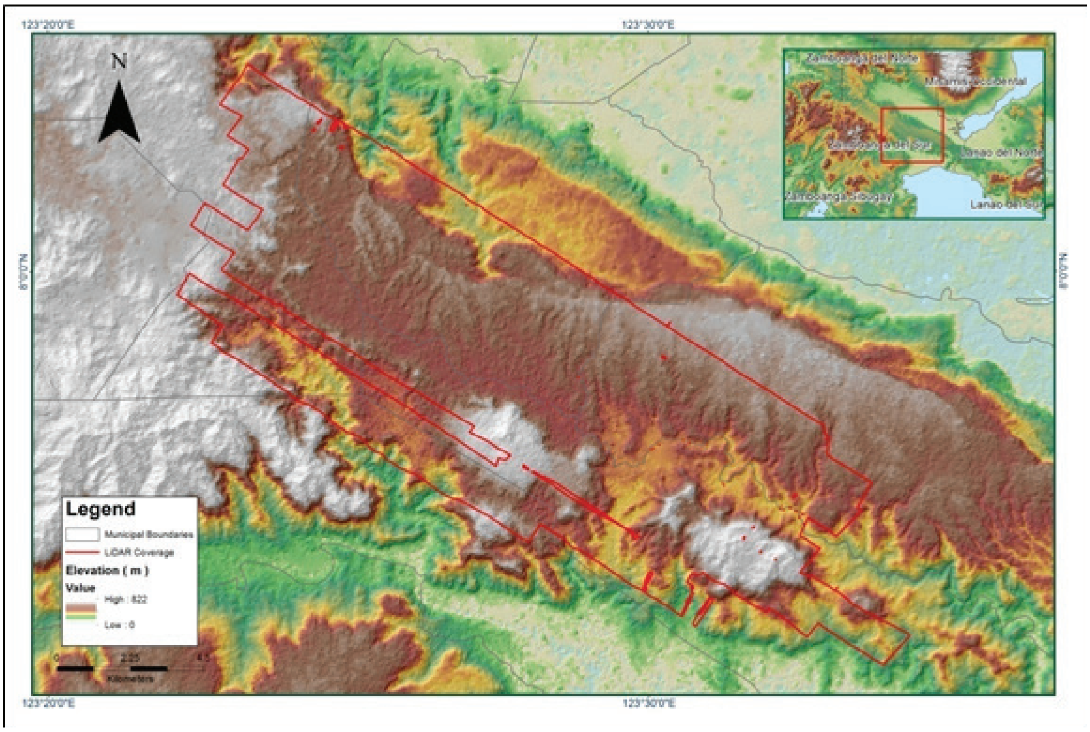


Figure A.8.4. Coverage of LiDAR data

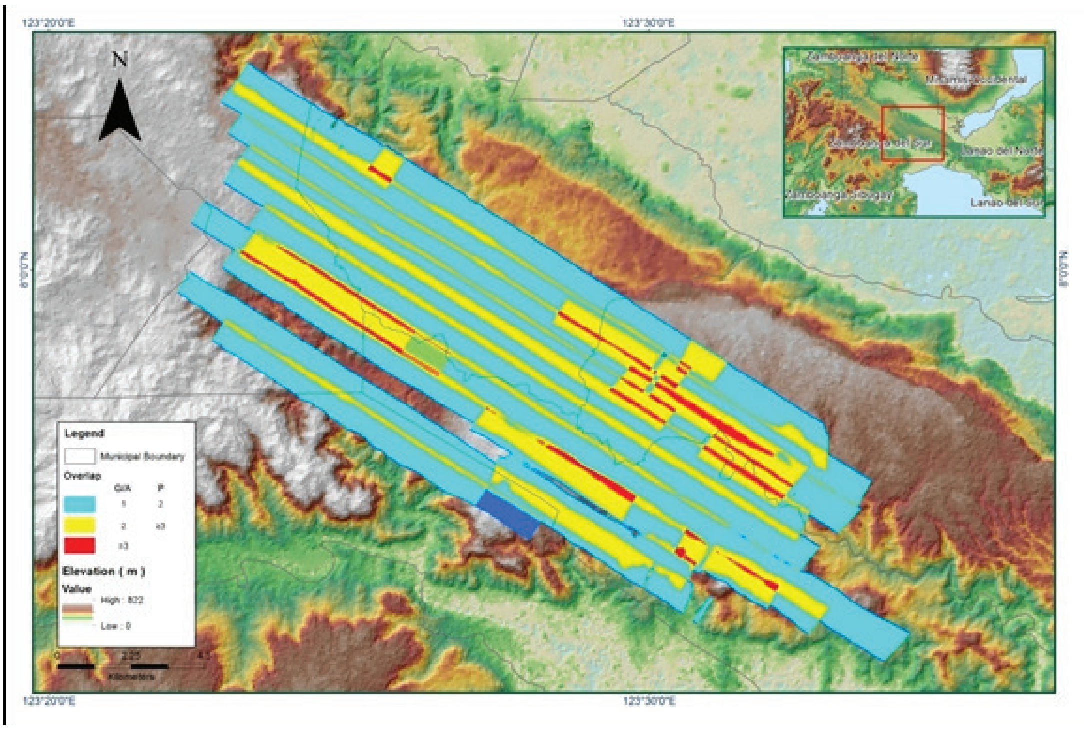


Figure A.8.5. Image of data overlap

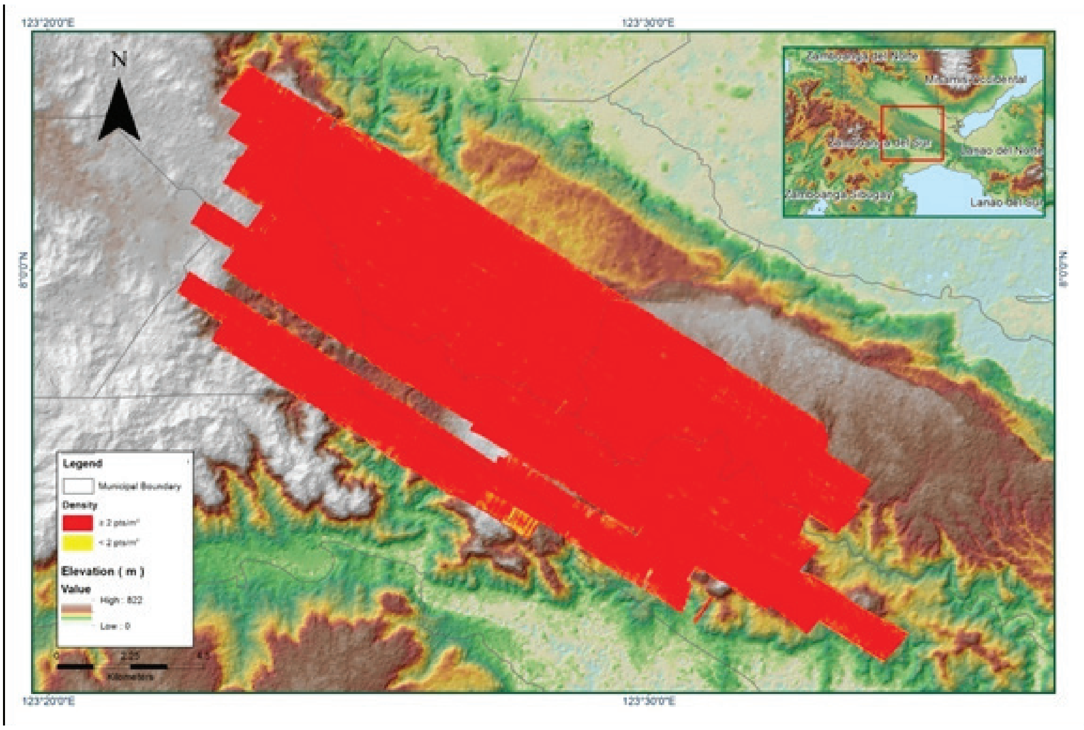


Figure A.8.6. Density map of merged LiDAR data

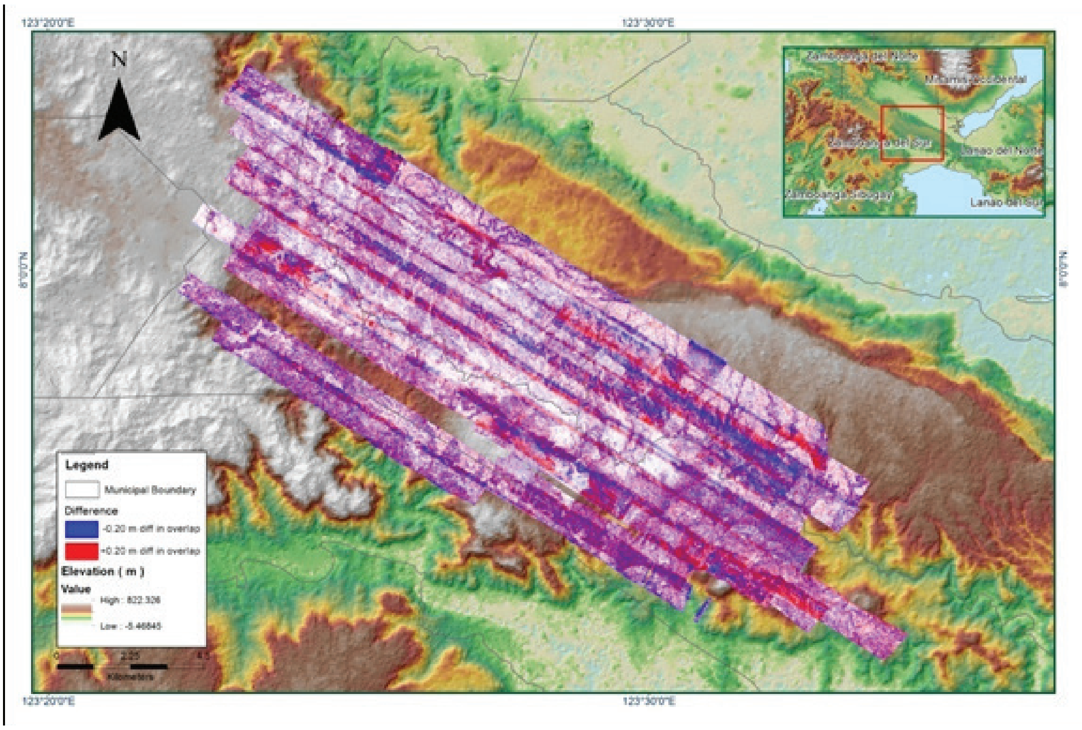


Figure A.8.7.Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	76E_Supplement
Inclusive Flights	23140P
Range data size	26.5 GB
POS data size	305 MB
Base data size	65.9 MB
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)	4.5
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000161
IMU attitude correction stdev (<0.001deg)	0.000225
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	30.00
Ave point cloud density per sq.m. (>2.0)	2.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	28
Maximum Height	511.96 m
Minimum Height	198.96 m
Classification (# of points)	
Ground	24,842,998
Low vegetation	13,550,525
Medium vegetation	16,093,113
High vegetation	31,517,197
Building	579,523
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat,
	Engr. Velina Angela Bemida,
	Vincent Louise Azucena

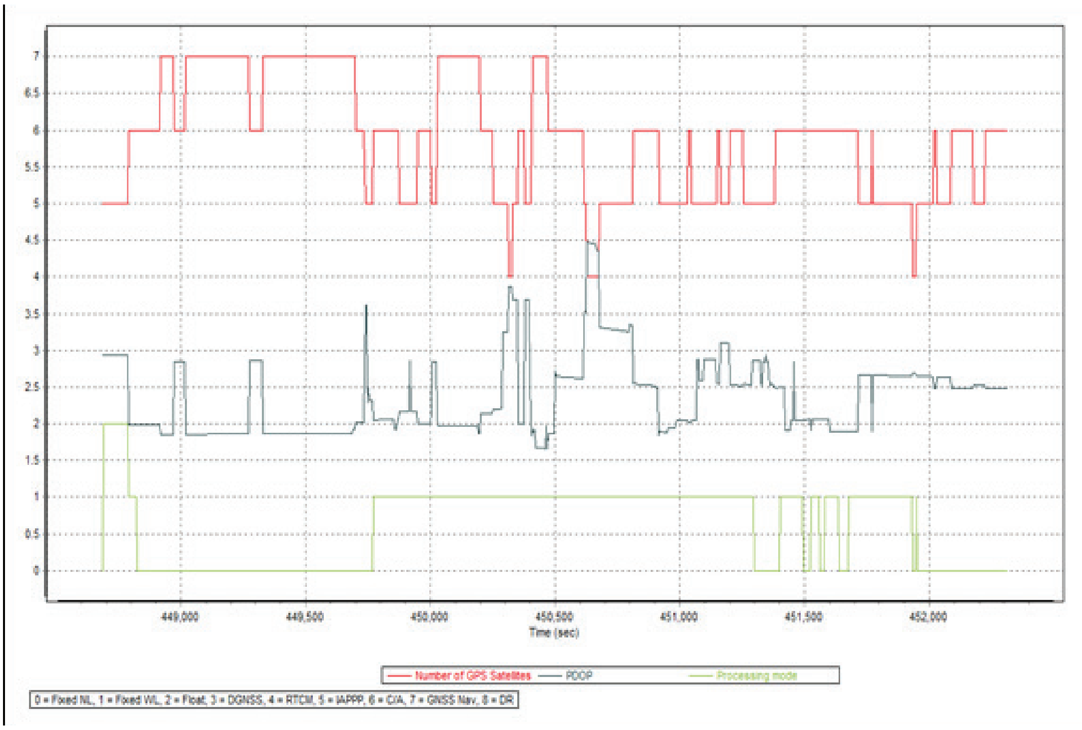


Figure A.8.8. Solution Status

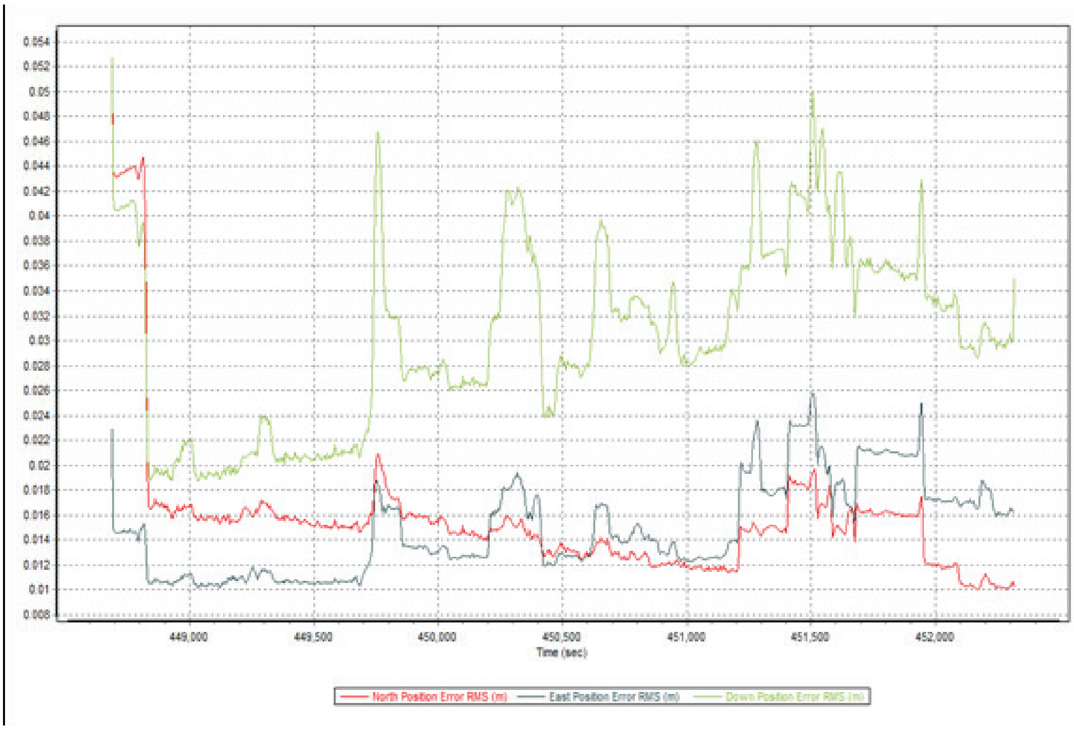


Figure A.8.9. Smoothed Performance Metric Parameters

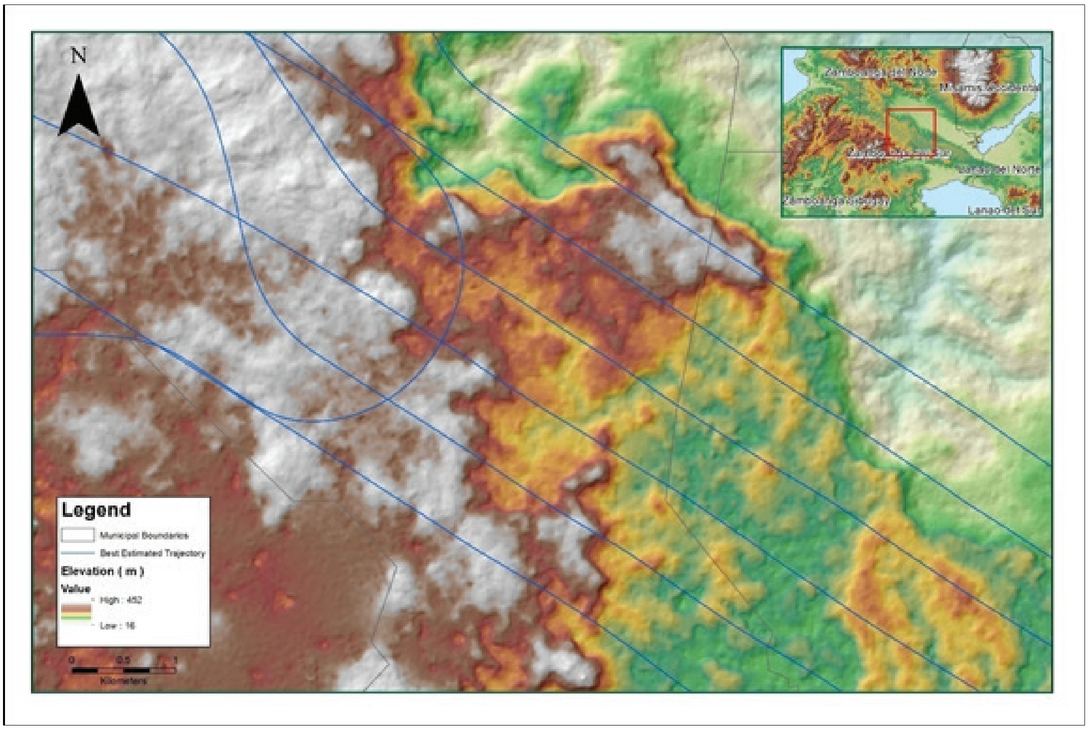


Figure A.8.10. Best Estimated Trajectory

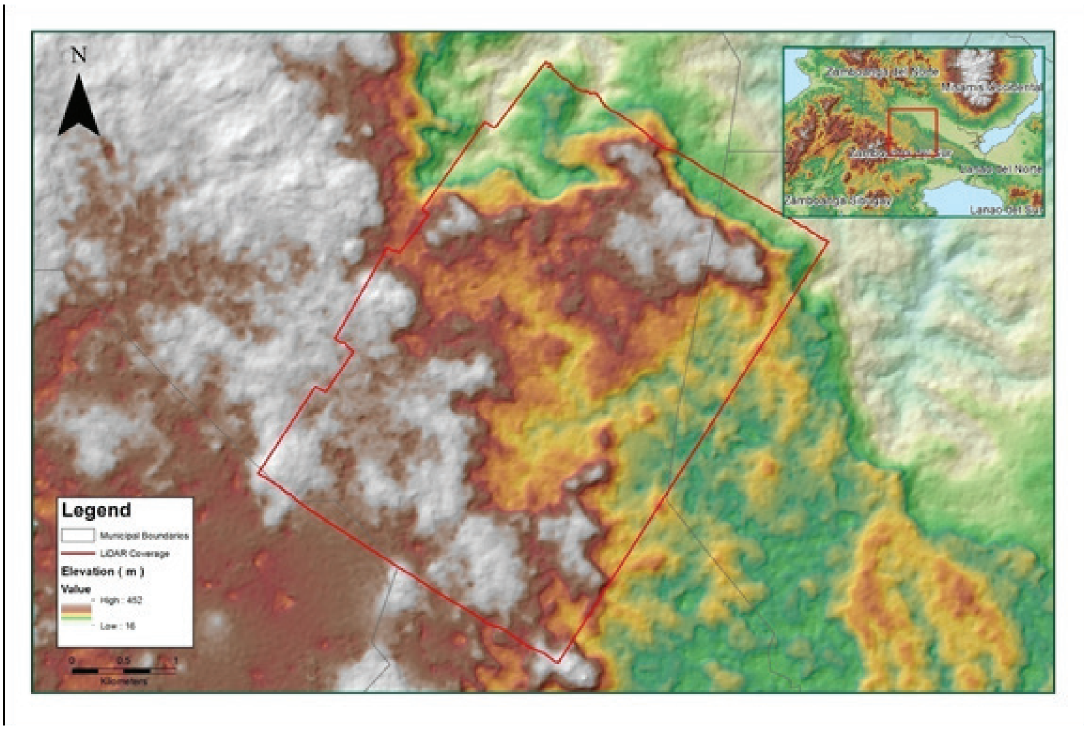


Figure A.8.11. Coverage of LiDAR data

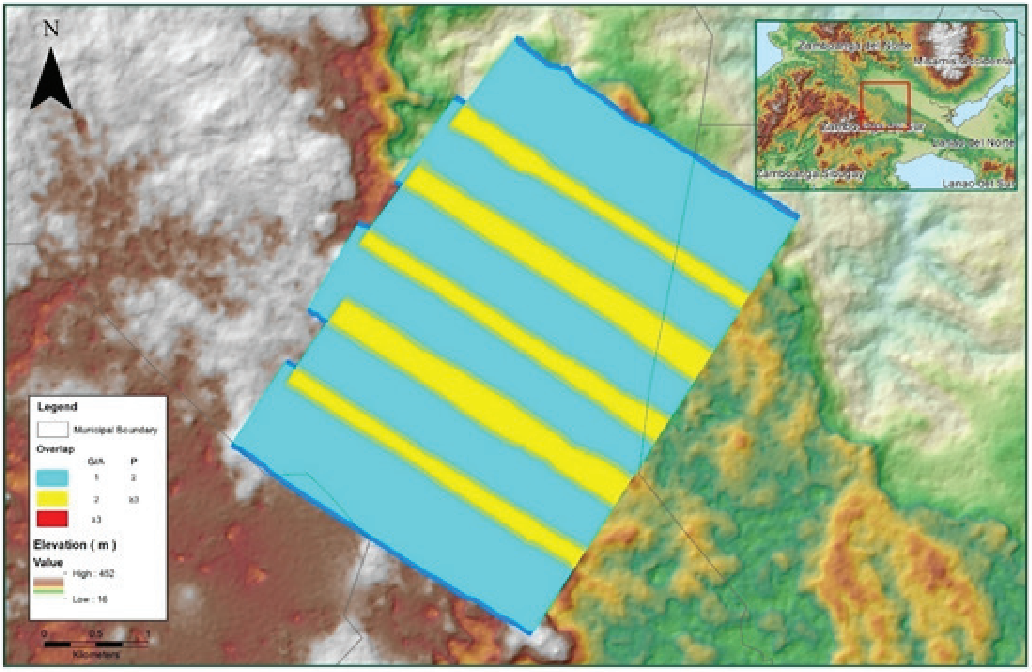


Figure A.8.12. Image of data overlap

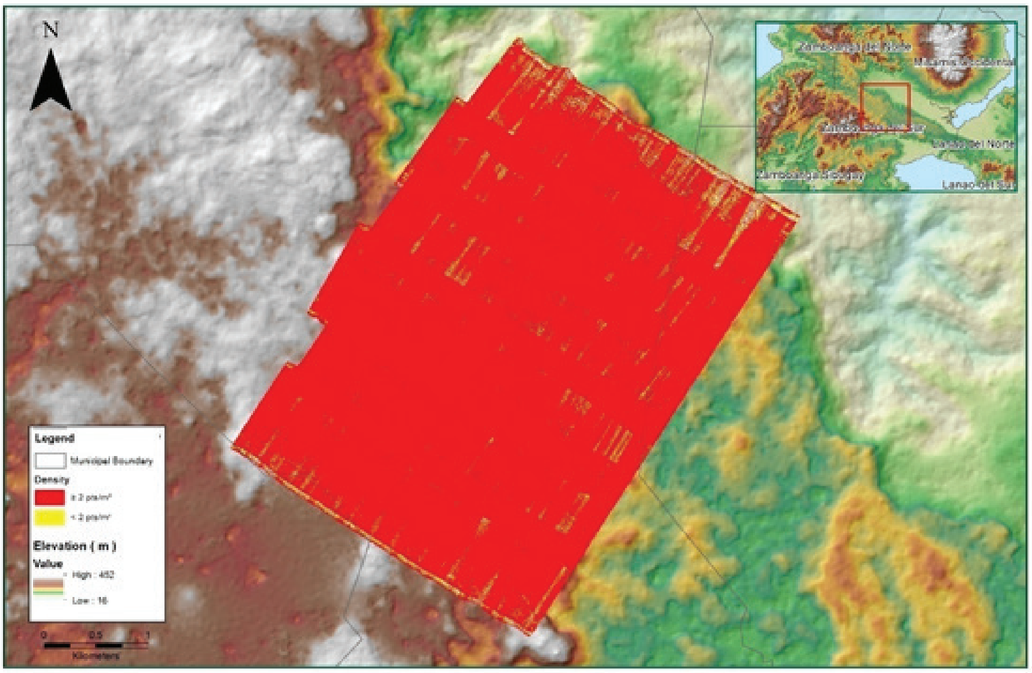


Figure A.8.13. Density map of merged LiDAR data

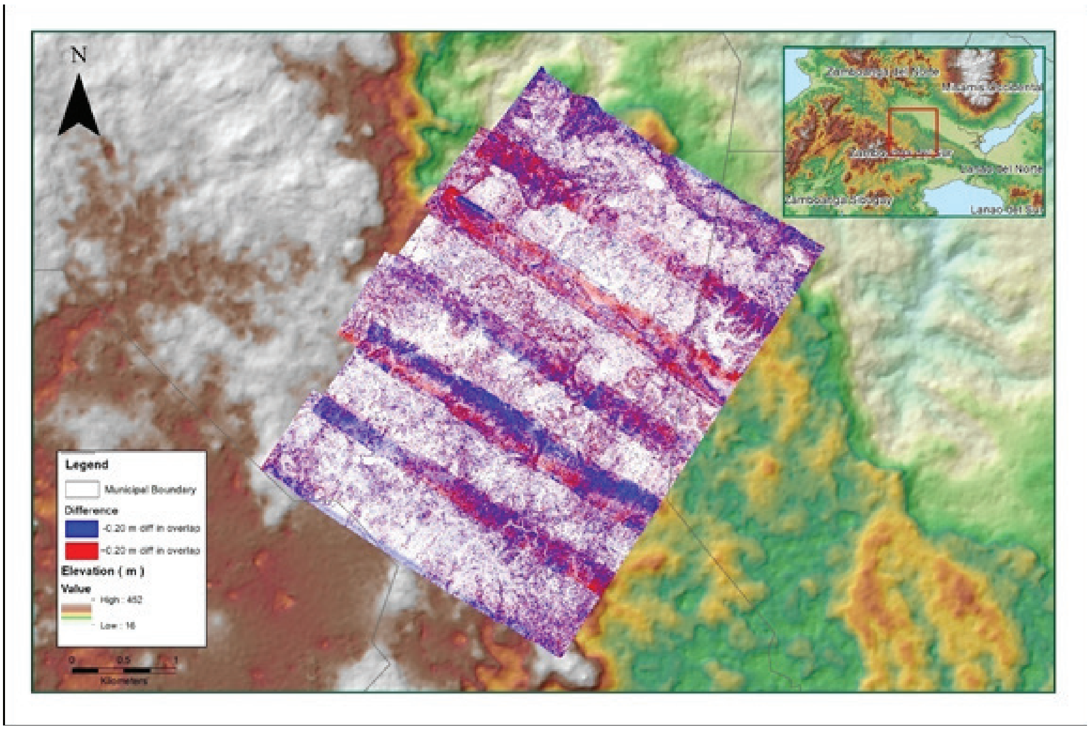


Figure A.8.14. Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	76F
Inclusive Flights	23072P
Range data size	26.6 GB
POS data size	258 MB
Base data size	146 MB
Image	n/a
Transfer date	February 26, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
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)	1.6
RMSE for Down Position (<8.0 cm)	4.3
Boresight correction stdev (<0.001deg)	0.000410
IMU attitude correction stdev (<0.001deg)	0.000138
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	40.78
Ave point cloud density per sq.m. (>2.0)	3.24
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	339
Maximum Height	516.01 m
Minimum Height	67.68 m
Classification (# of points)	
Ground	356,962,563
Low vegetation	292,886,933
Medium vegetation	240,788,235
High vegetation	511,383,780
Building	7,405,368
Orthophoto	Yes
Processed by	Engr. Regis Guhiting,
	Engr. Velina Angela Bemida,
	Maria Tamsyn Malabanan

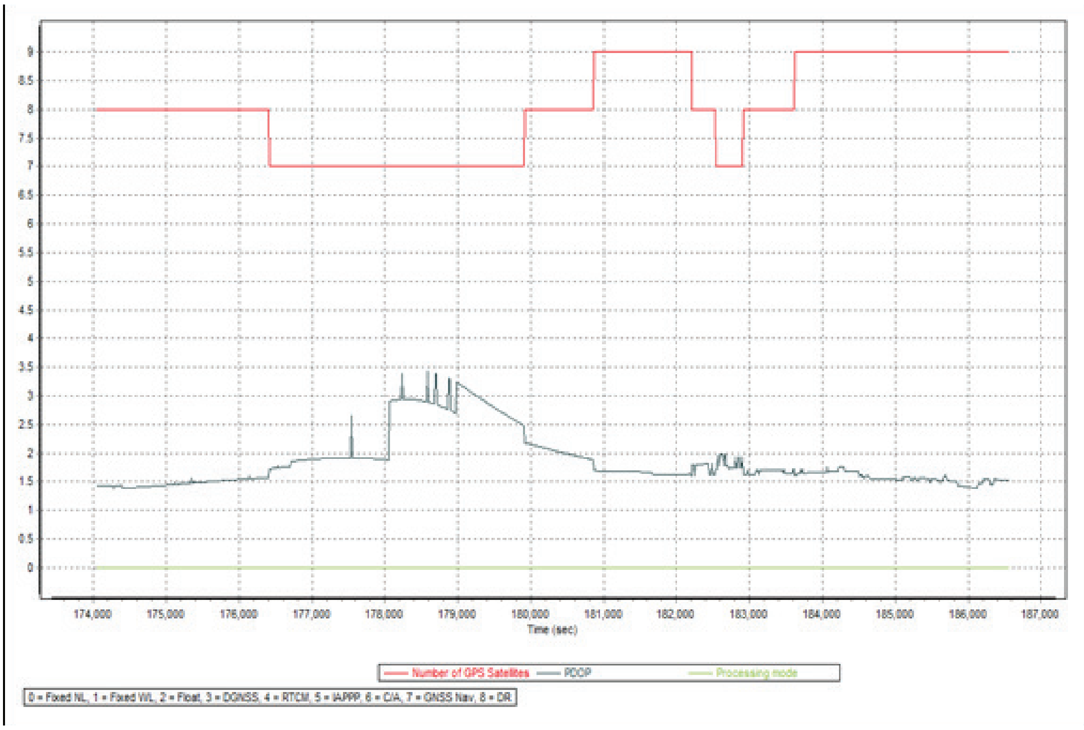


Figure A.8.15. Solution Status

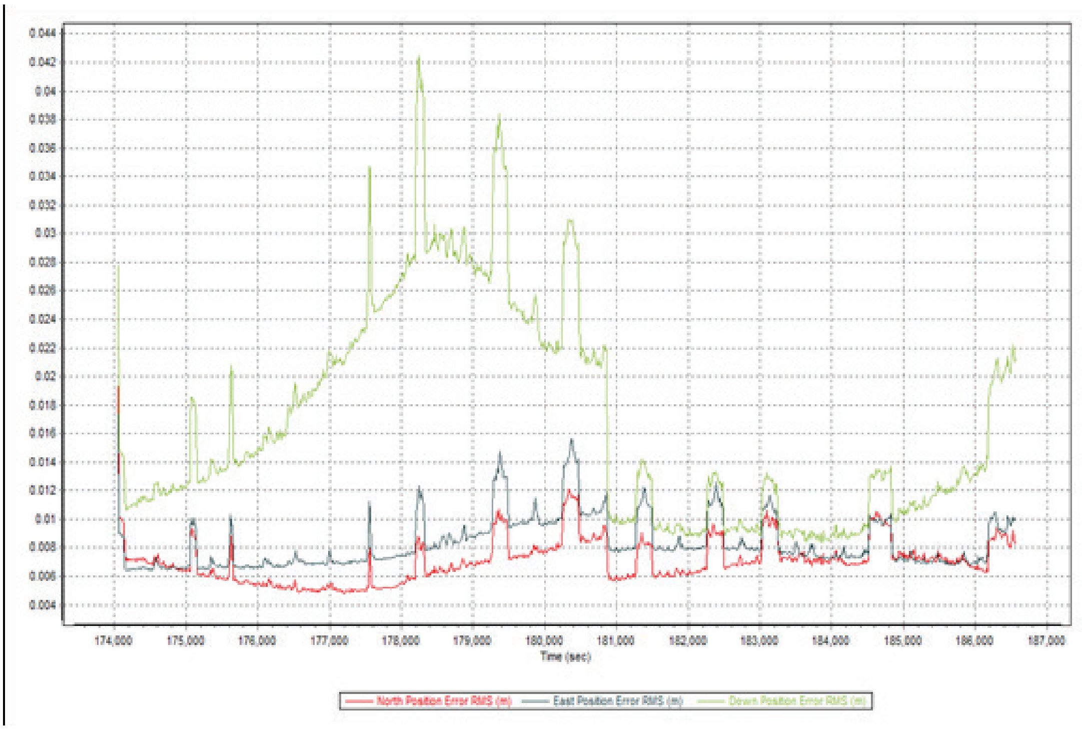


Figure A.8.16. Smoothed Performance Metric Parameters

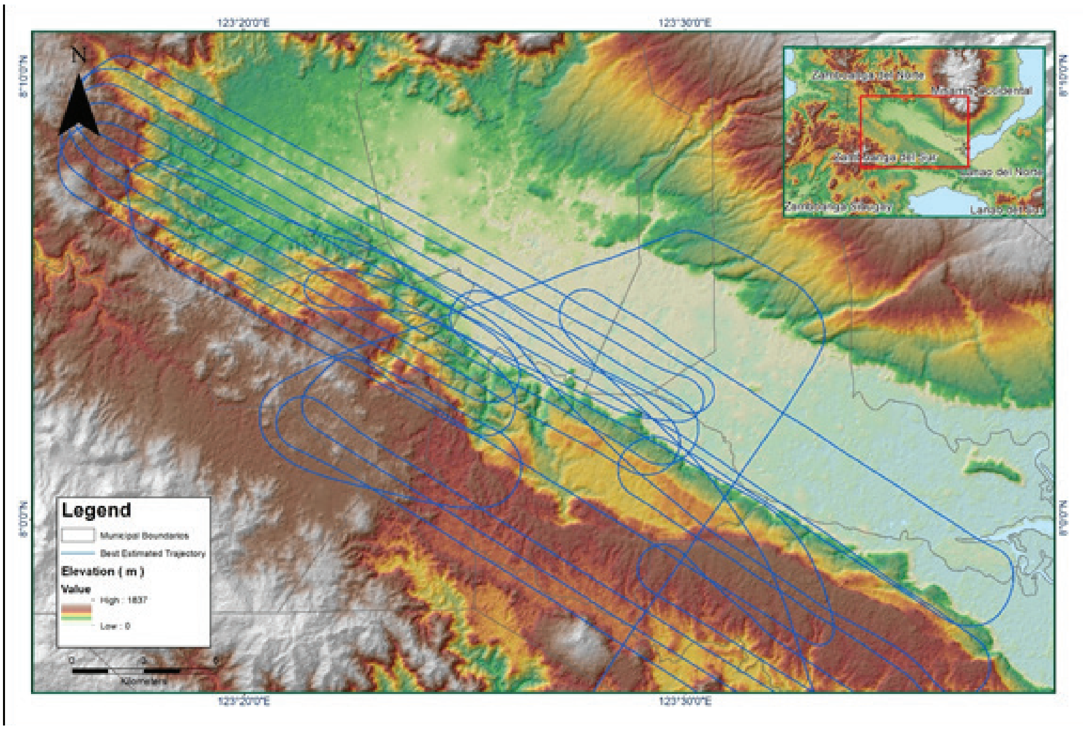


Figure A.8.17. Best Estimated Trajectory

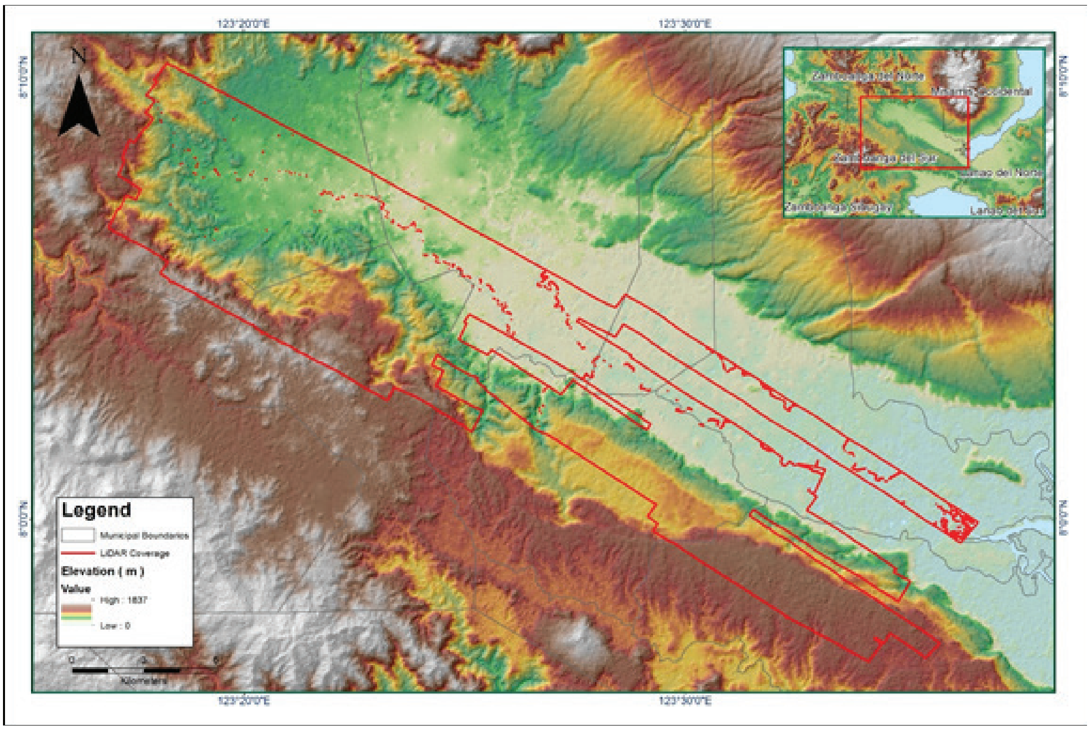


Figure A.8.18. Coverage of LiDAR Data

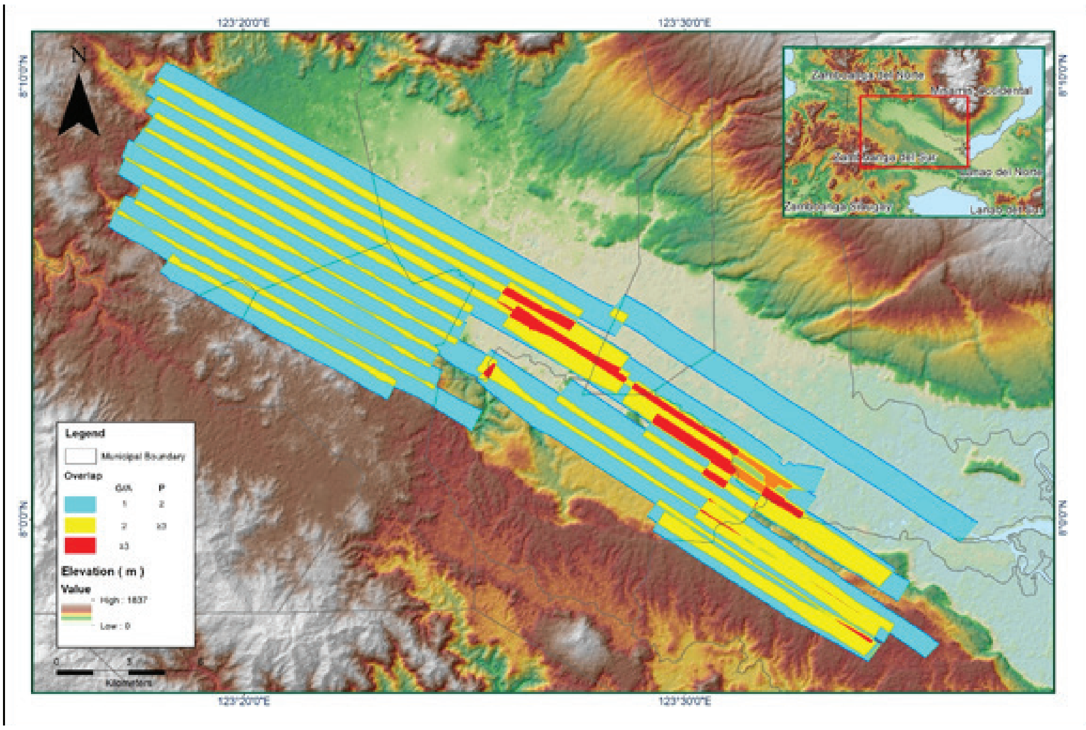


Figure A.8.19. Image of data overlap

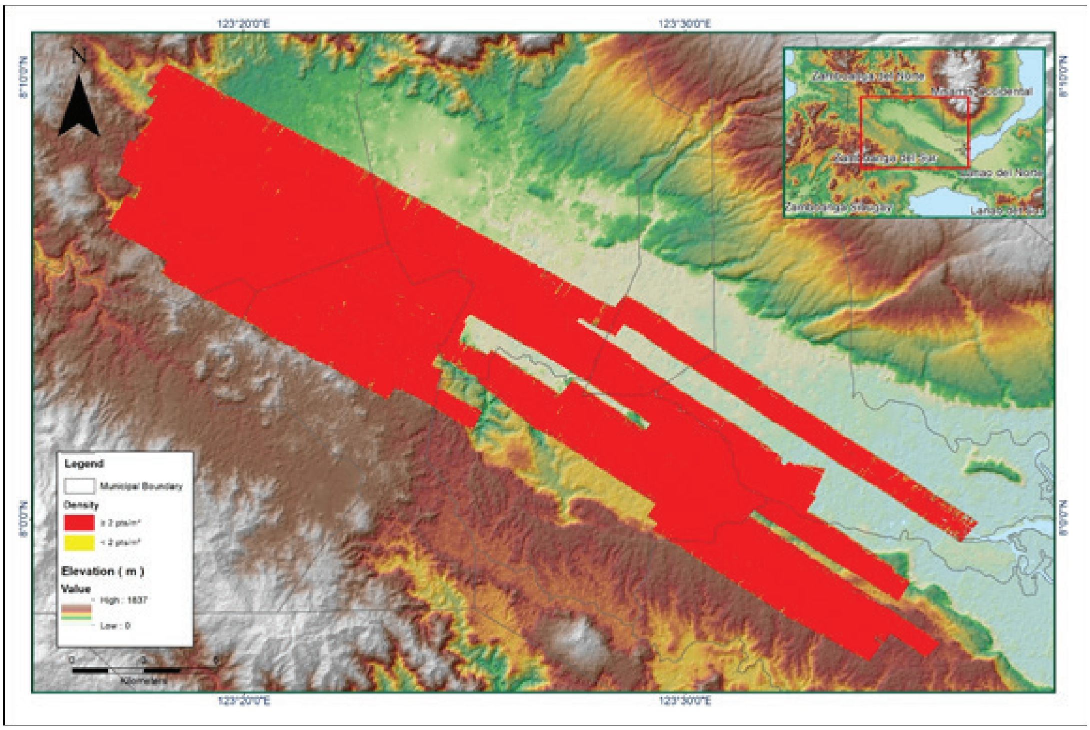


Figure A.8.20. Density map of merged LiDAR data

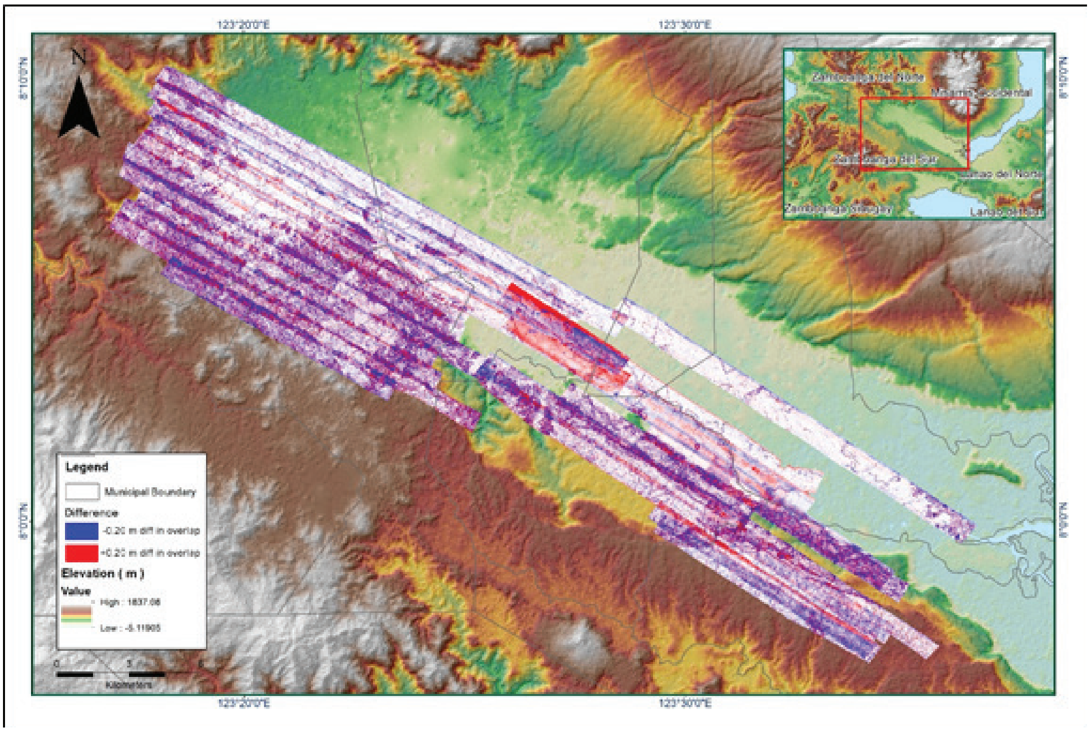


Figure A.8.21. Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	76F_Additional
Inclusive Flights	23100P
Range data size	27.31 GB
POS data size	285.96 MB
Base data size	103.23 MB
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)	0.000242
IMU attitude correction stdev (<0.001deg)	0.000750
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	10.67
Ave point cloud density per sq.m. (>2.0)	2.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	141
Maximum Height	423.18 m
Minimum Height	67.06 m
Classification (# of points)	
Ground	88,251,520
Low vegetation	50,155,602
Medium vegetation	52,914,939
High vegetation	165,251,451
Building	1,978,484
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan,
	Engr. Merven Matthew Natino,
	Alex John Escobido

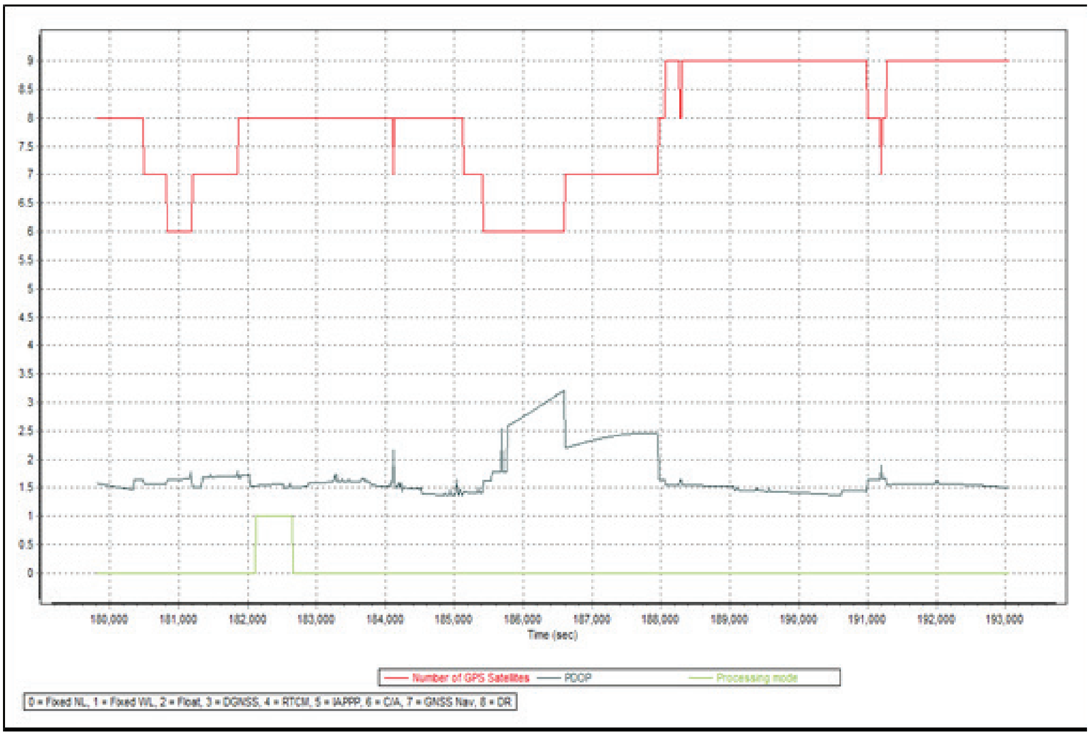


Figure A.8.22. Solution Status

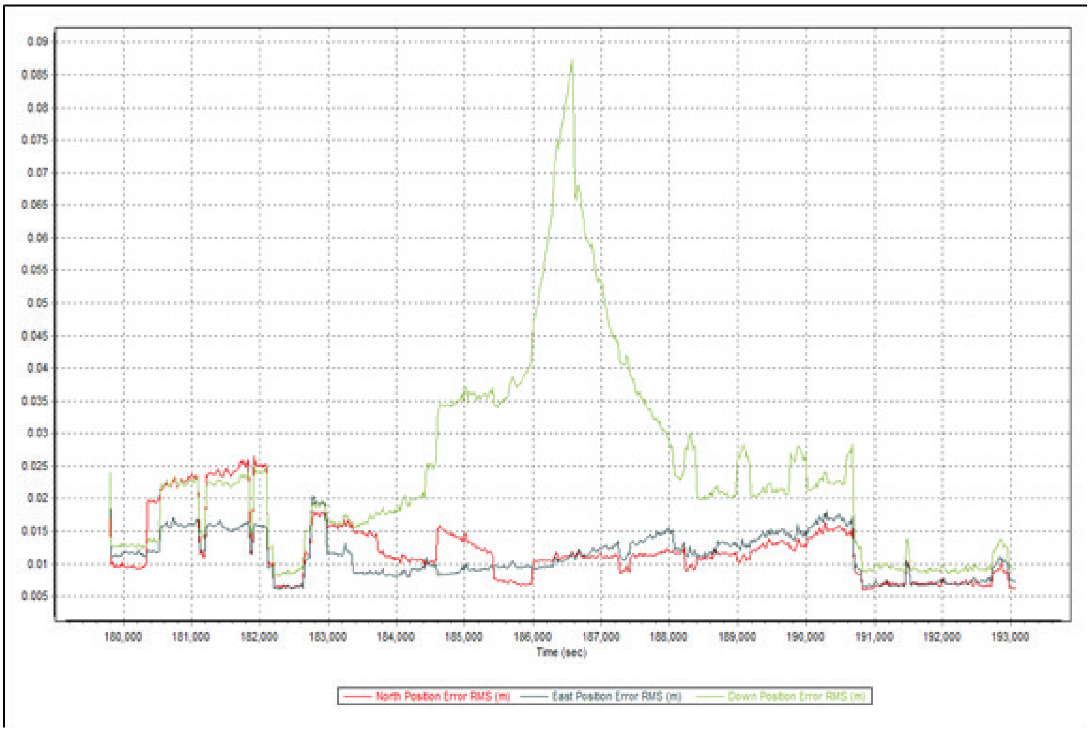


Figure A.8.23. Smoothed Performance Metric Parameters

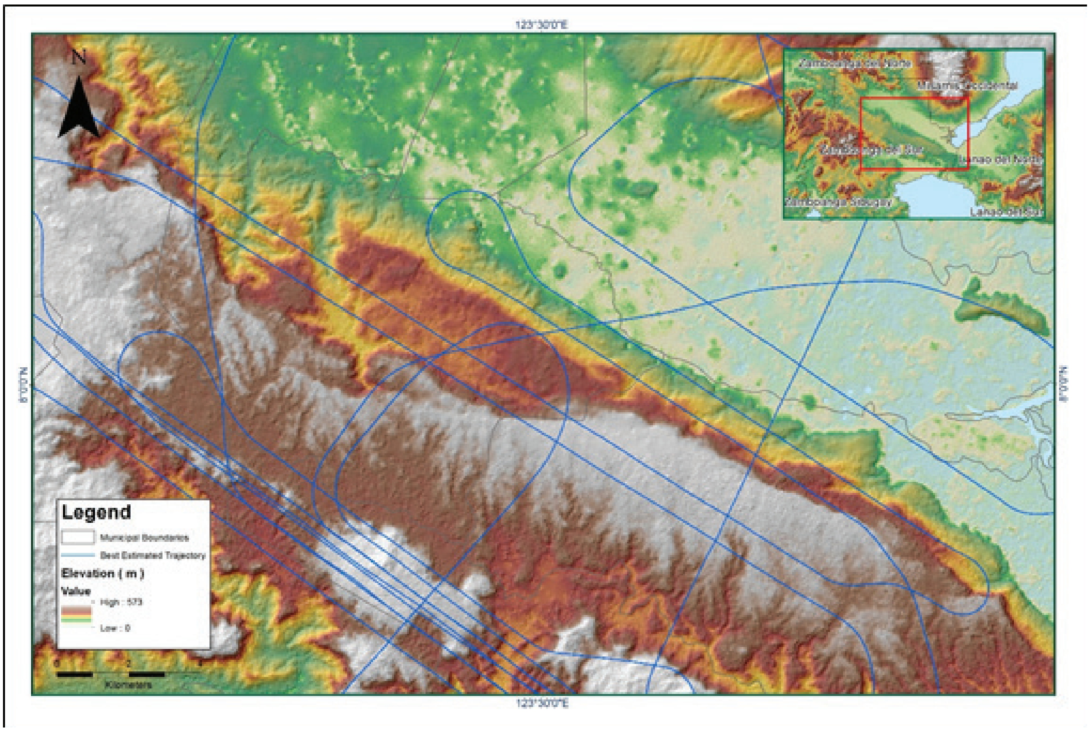


Figure A.8.24. Best Estimated Trajectory

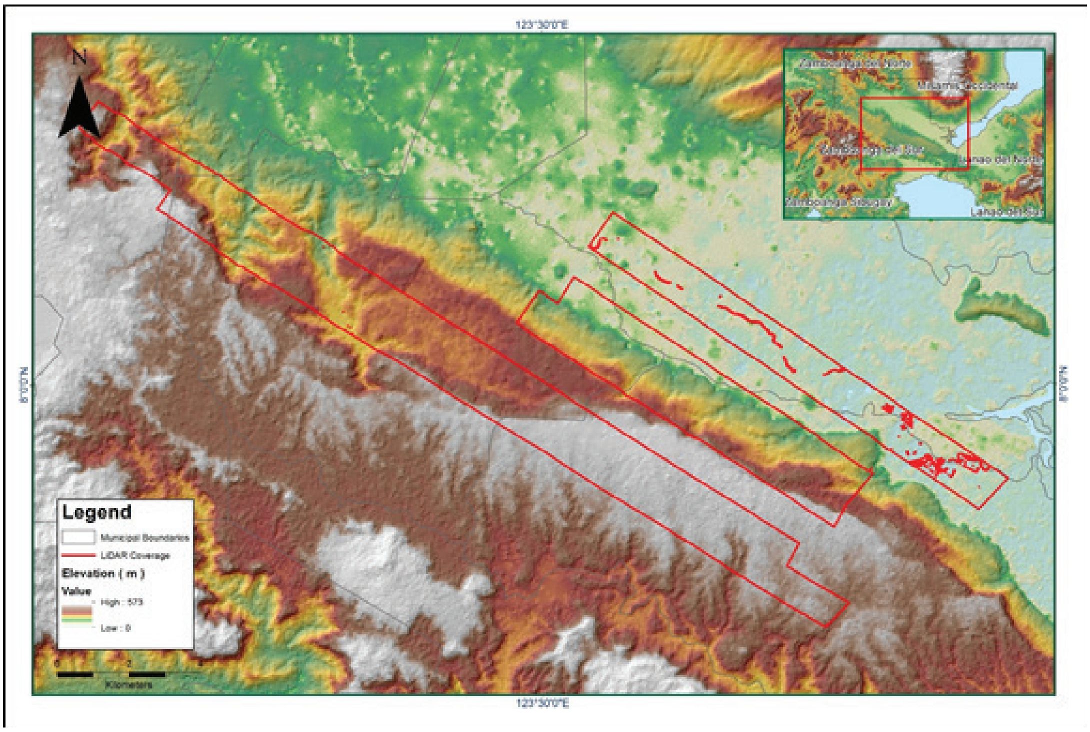


Figure A.8.25 Coverage of LiDAR data

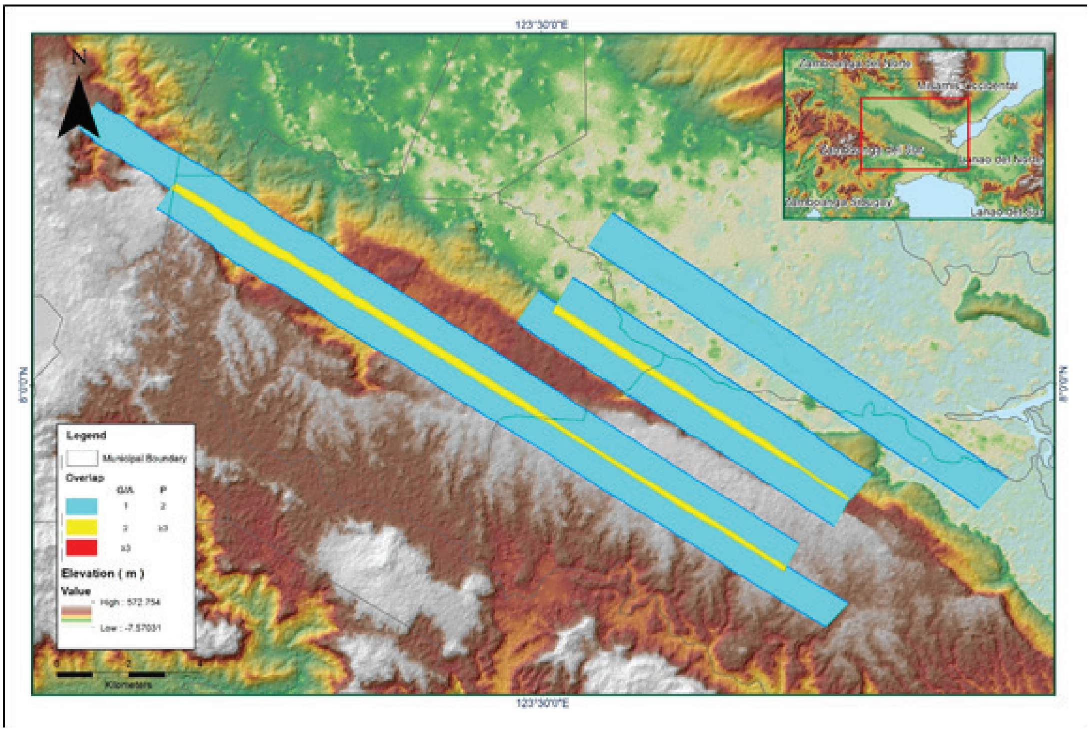


Figure A.8.26. Image of data overlap

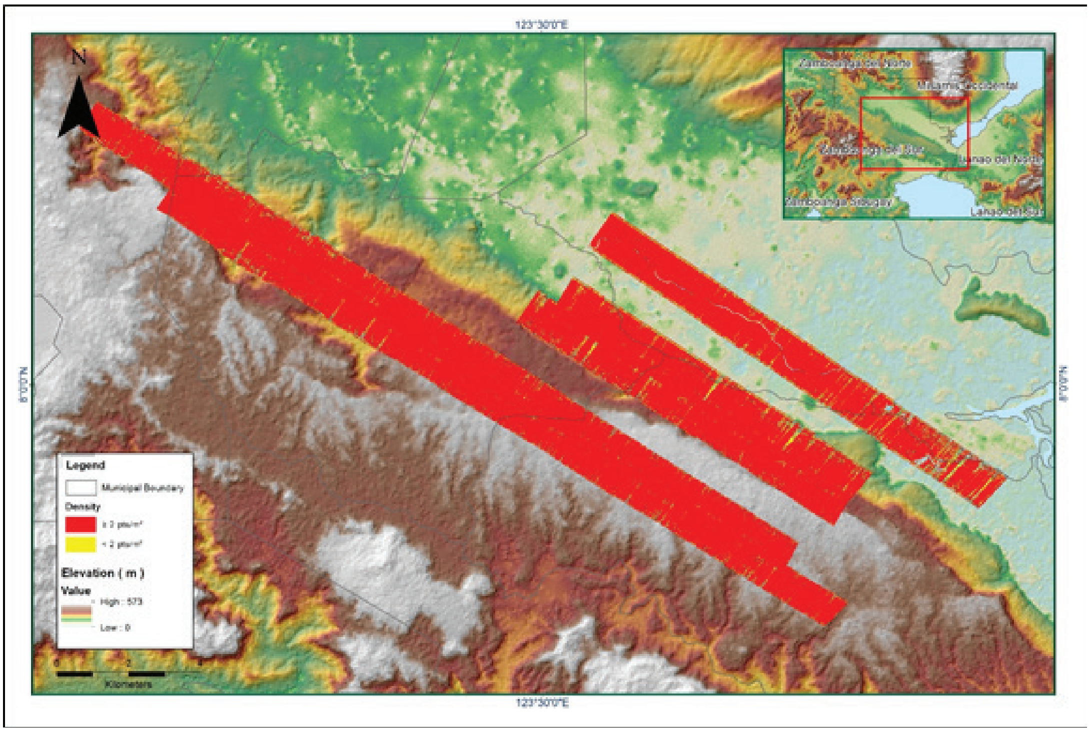


Figure A.8.27. Density map of merged LiDAR data

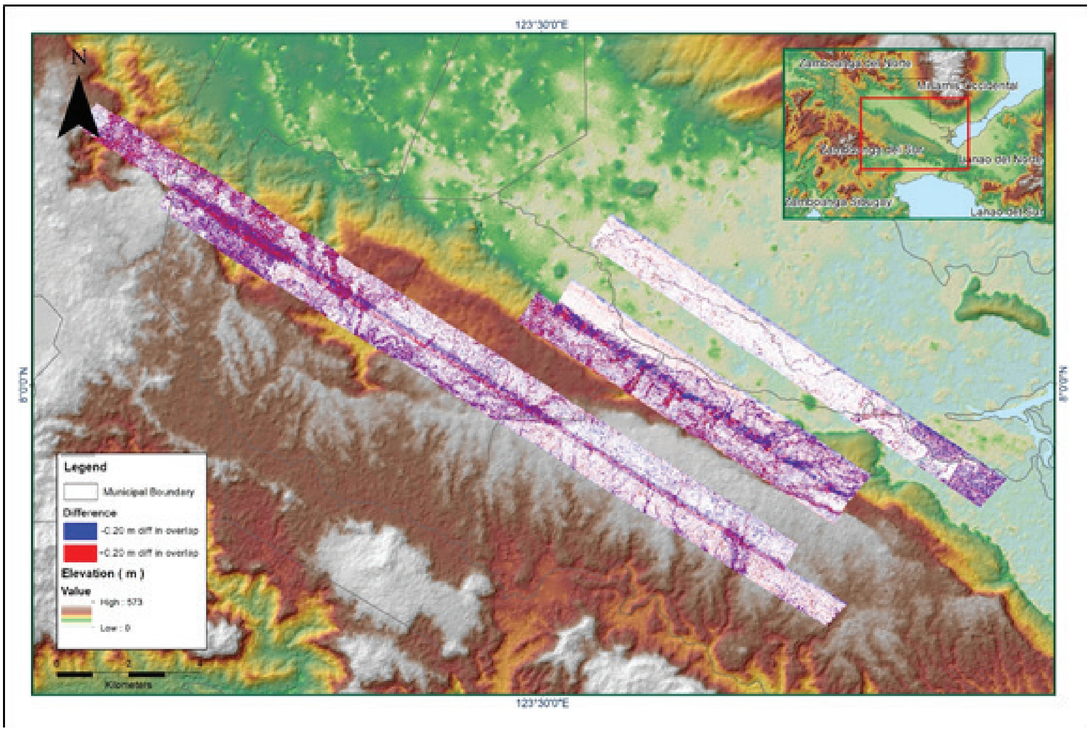


Figure A.8.28. Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	76G
Inclusive Flights	23076P, 23064P
Range data size	52.9 GB
POS data size	548 MB
Base data size	157.13 MB
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)	3.6
RMSE for East Position (<4.0 cm)	5.1
RMSE for Down Position (<8.0 cm)	7.7
Boresight correction stdev (<0.001deg)	0.000354
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	50.05
Ave point cloud density per sq.m. (>2.0)	2.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	369
Maximum Height	387.27 m
Minimum Height	67.01 m
Classification (# of points)	
Ground	302,687,829
Low vegetation	216,231,938
Medium vegetation	156,803,541
High vegetation	306,423,669
Building	8,350,642
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Merven Matthew Natino, Jovy Narisma

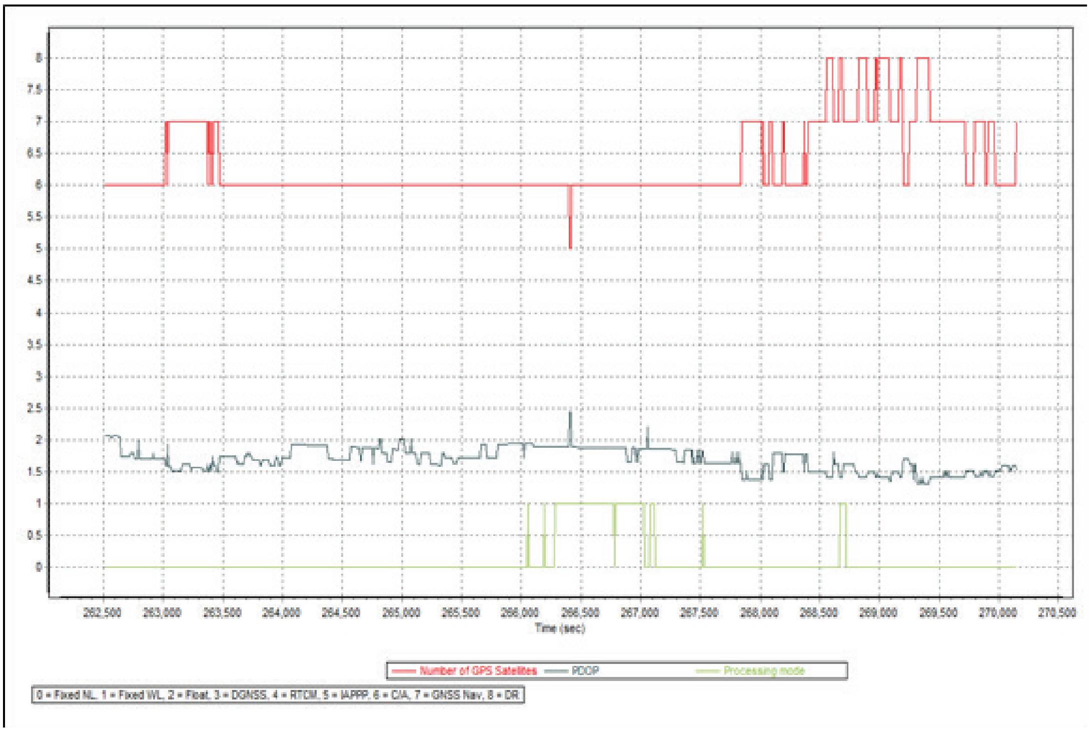


Figure A.8.29. Solution Status

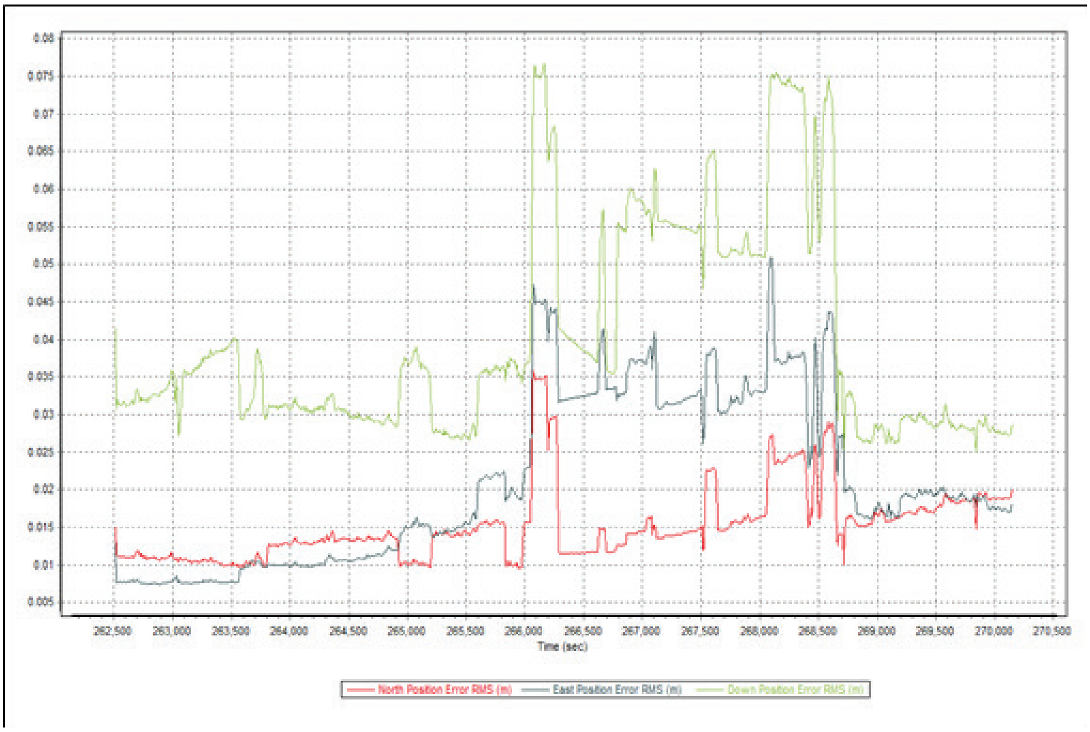


Figure A.8.30 . Smoothed Performance Metric Parameters

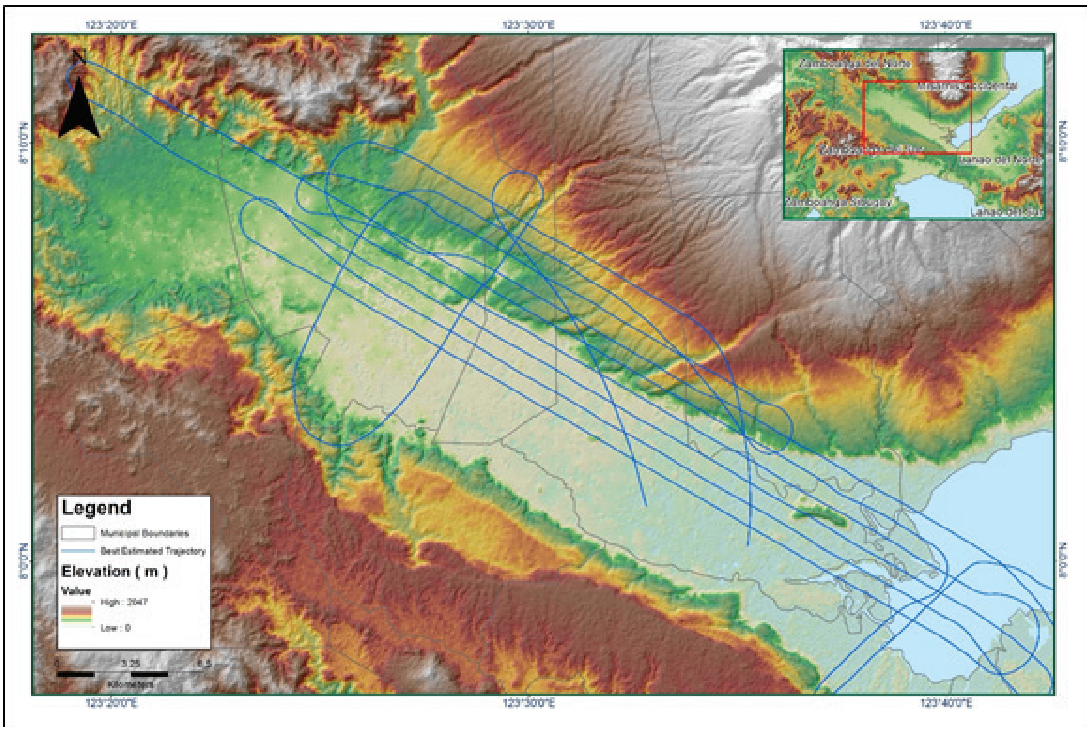


Figure A.8.31. Best Estimated Trajectory

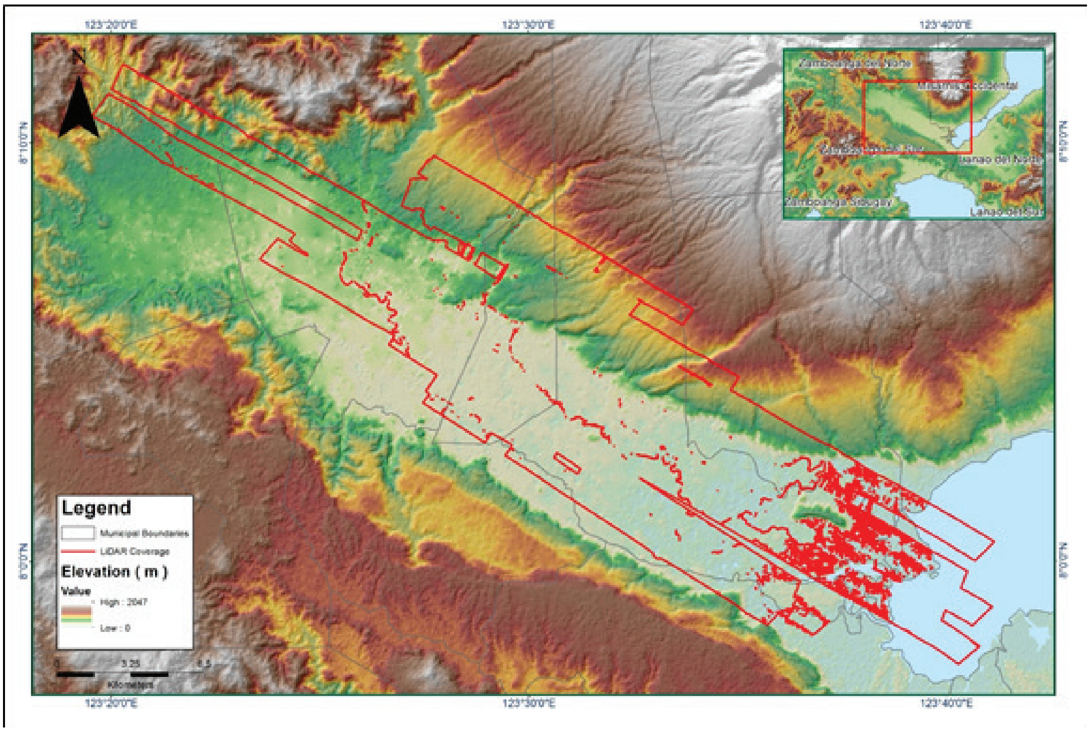


Figure A.8.32. Coverage of LiDAR data

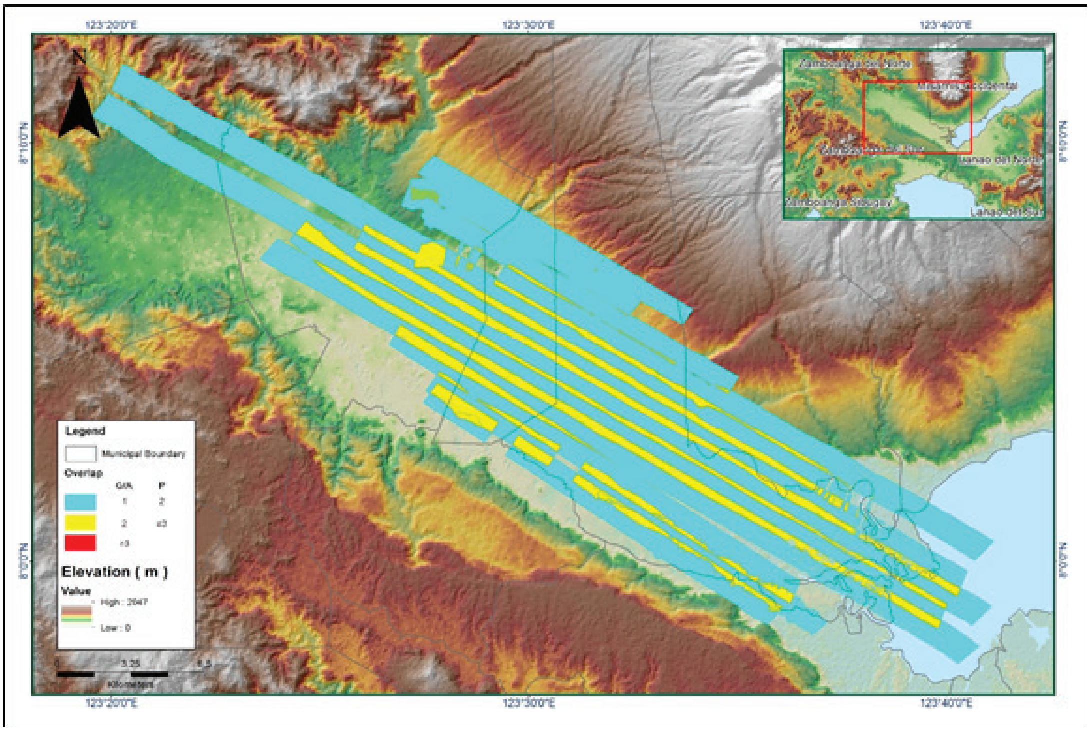


Figure A.8.33.Image of data overlap

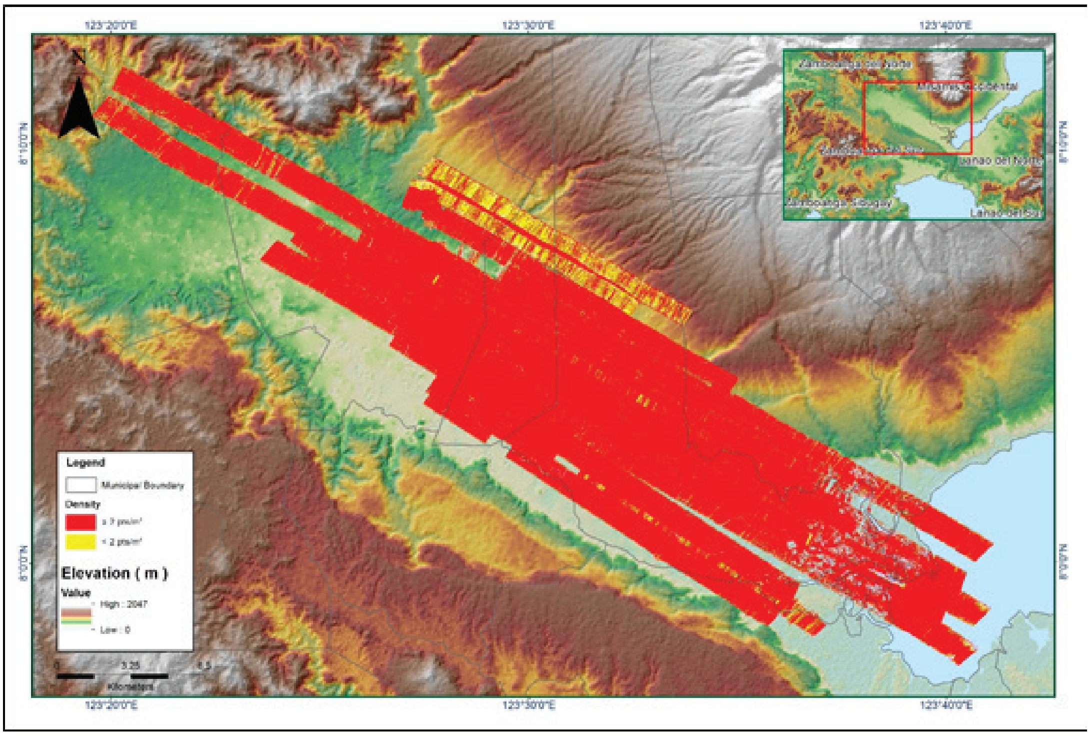


Figure A.8.34. Density map of merged LiDAR data

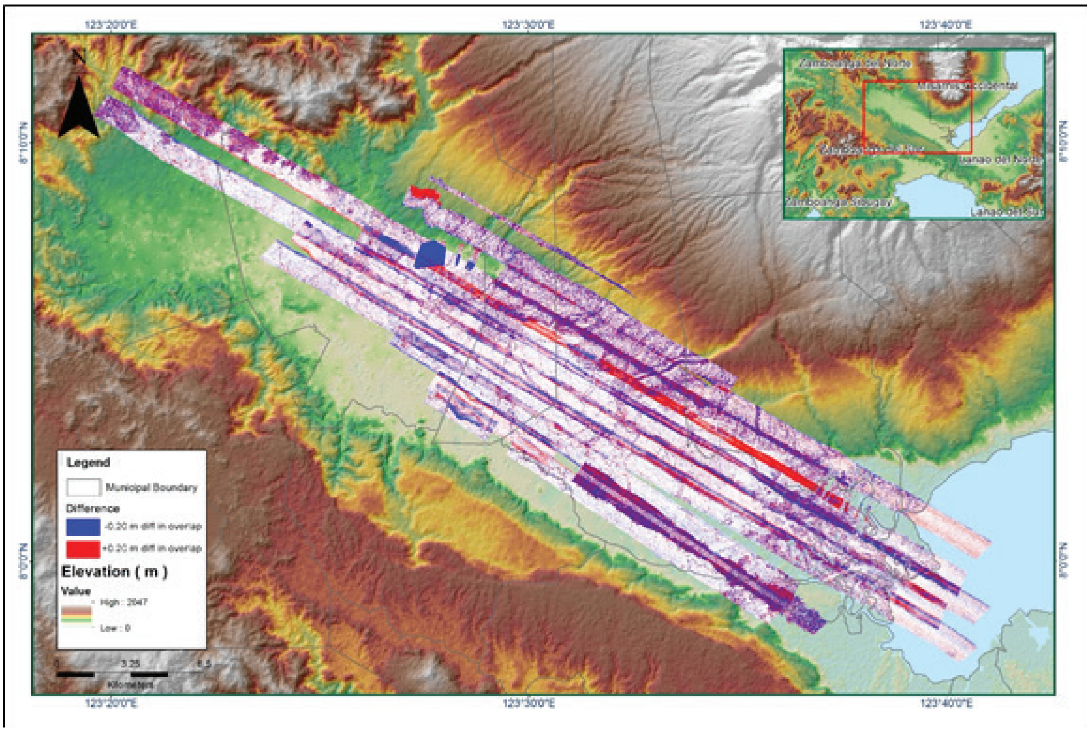


Figure A.8.35. Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	76G_Supplement
Inclusive Flights	23092P, 23100P
Range data size	49.64 GB
POS data size	489.42 MB
Base data size	213.95 MB
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)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000181
IMU attitude correction stdev (<0.001deg)	0.003365
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	23.77
Ave point cloud density per sq.m. (>2.0)	3.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	202
Maximum Height	714.62 m
Minimum Height	79.55 m
Classification (# of points)	
Ground	237,558,288
Low vegetation	199,107,840
Medium vegetation	212,069,544
High vegetation	430,190,026
Building	5,870,677
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan,
	Engr. Chelou Prado,
	Jovy Narisma

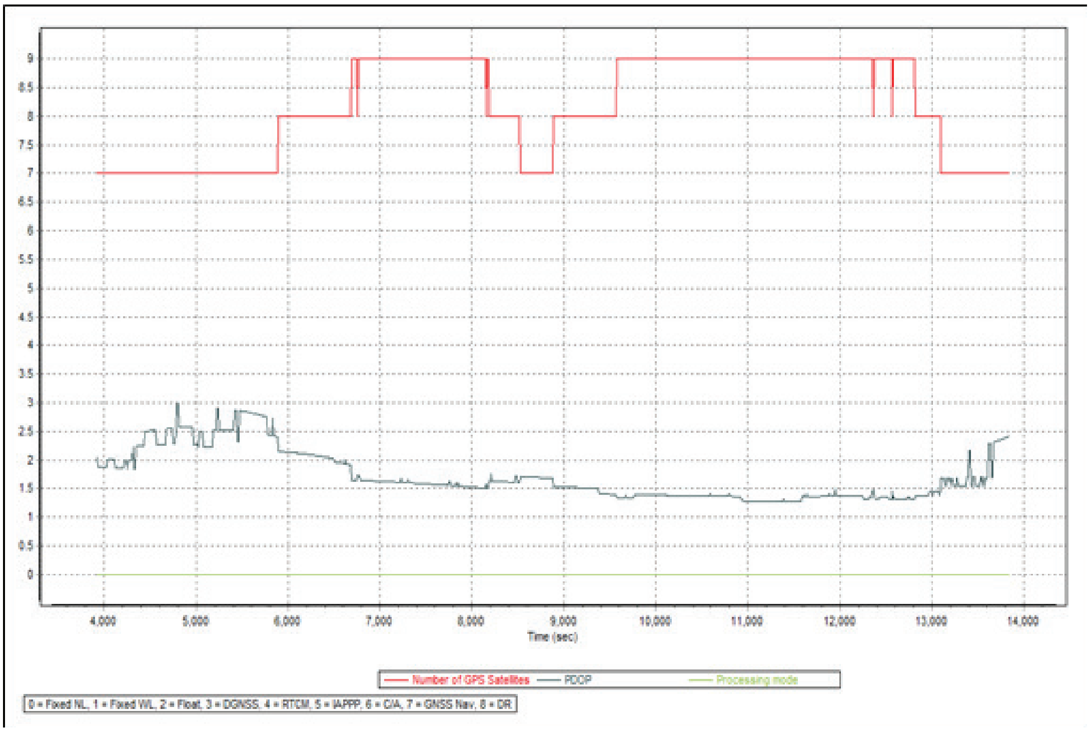


Figure A.8.36. Solution Status

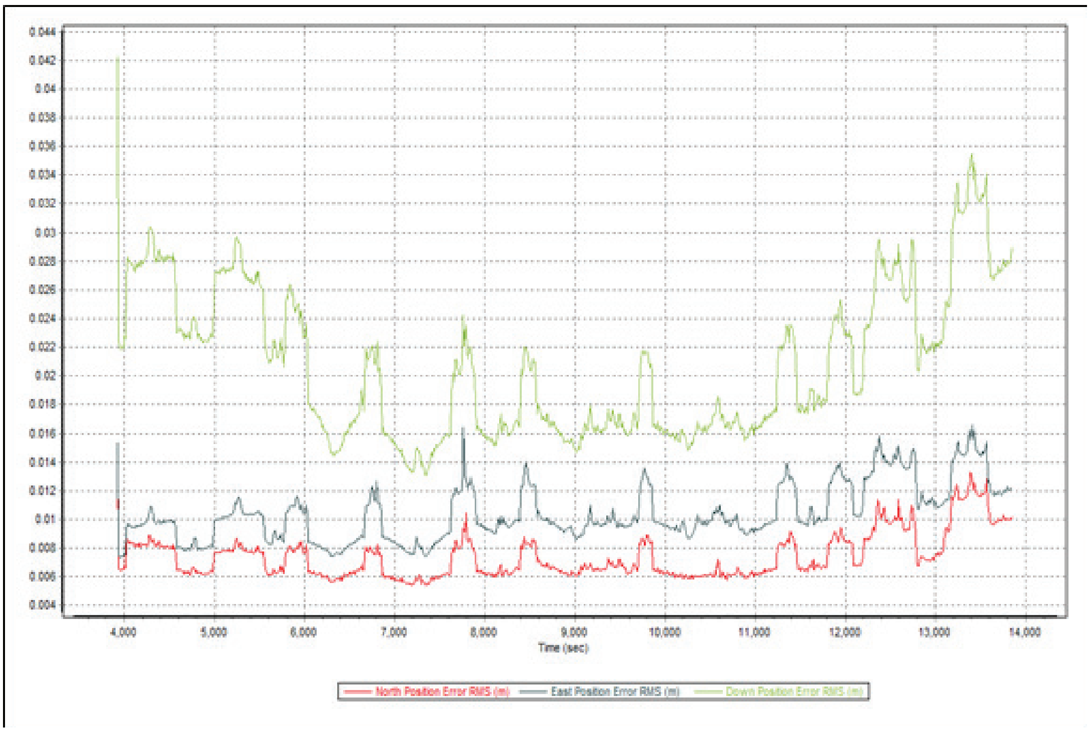


Figure A.8.37. Smoothed Performance Metric Parameters

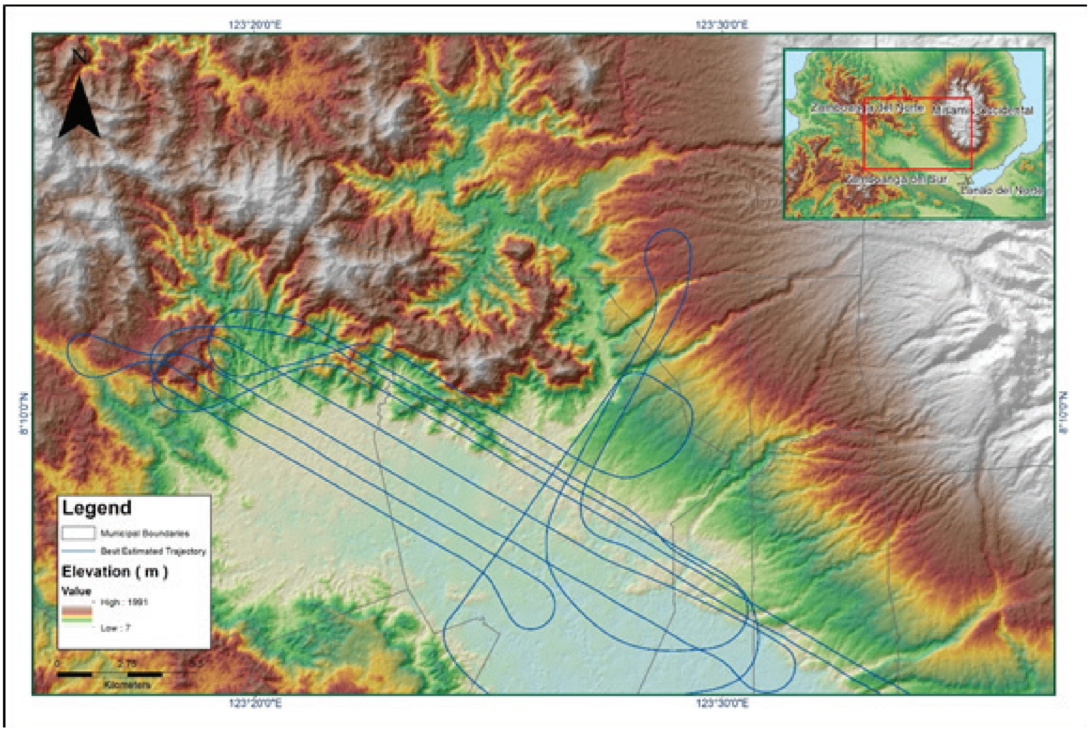


Figure A.8.38. Best Estimated Trajectory

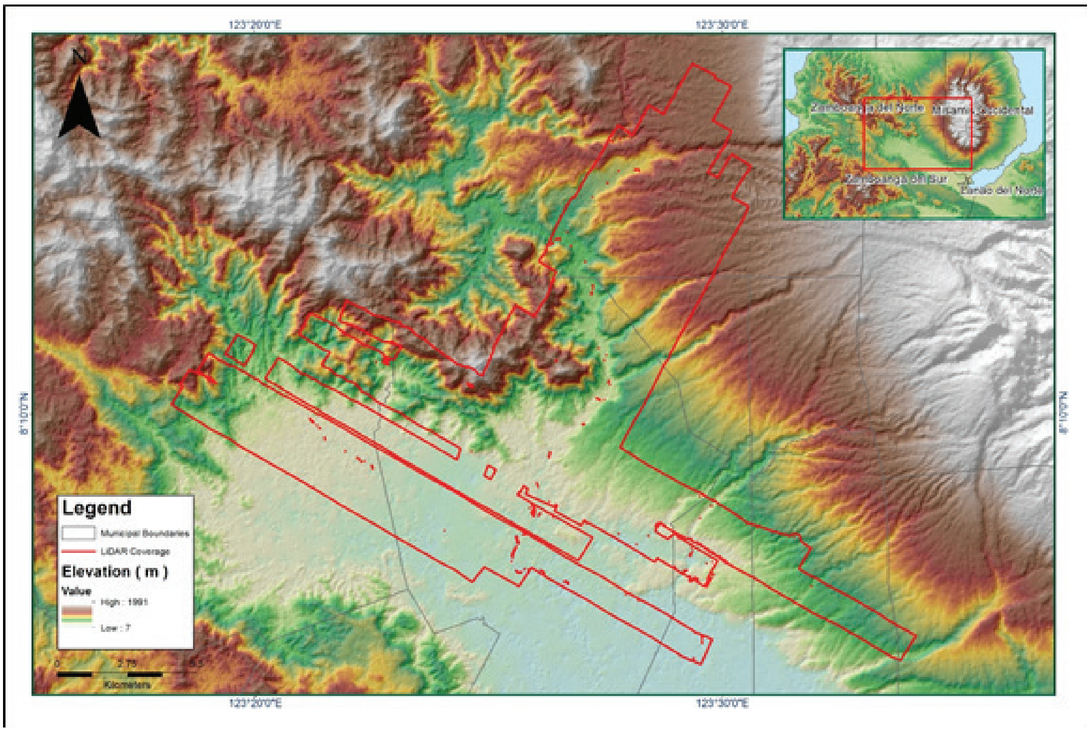


Figure A.8.39.Coverage of LiDAR data

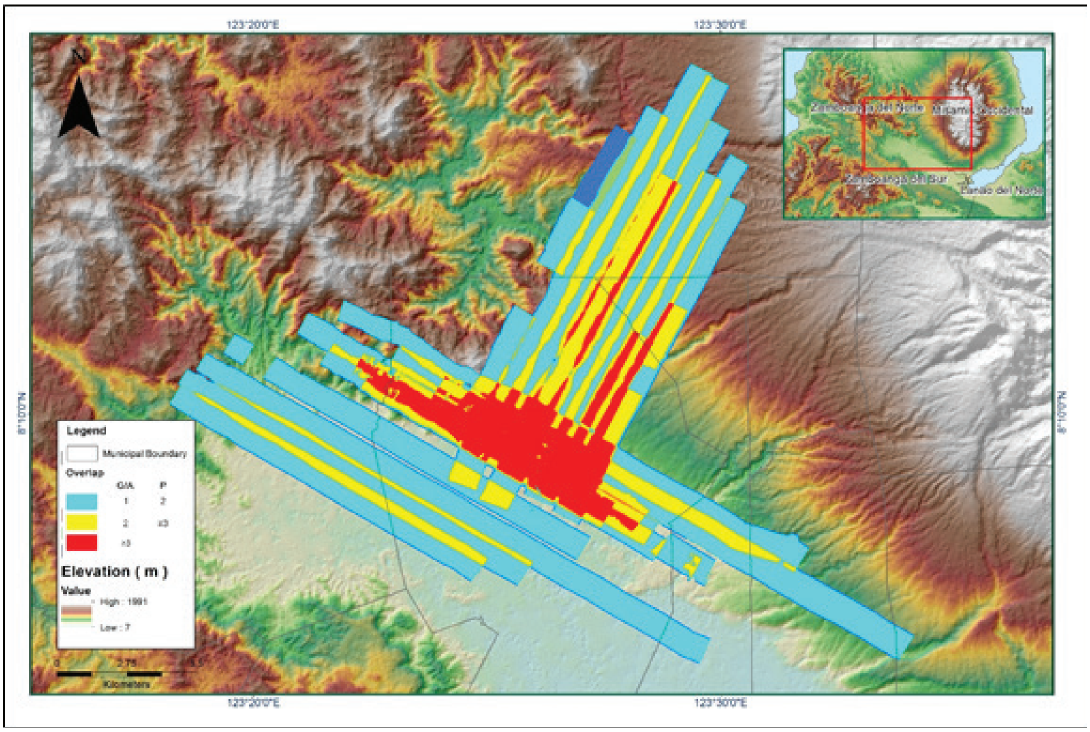


Figure A.8.40 Image of data overlap

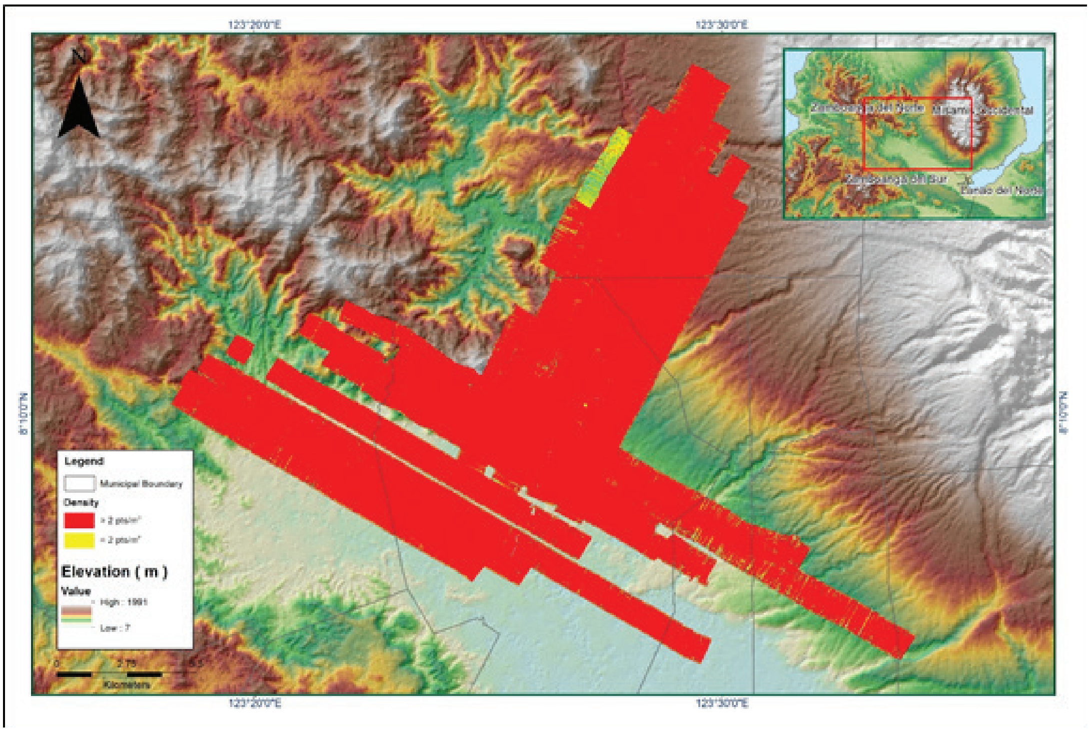


Figure A.8.41.Coverage of LiDAR data

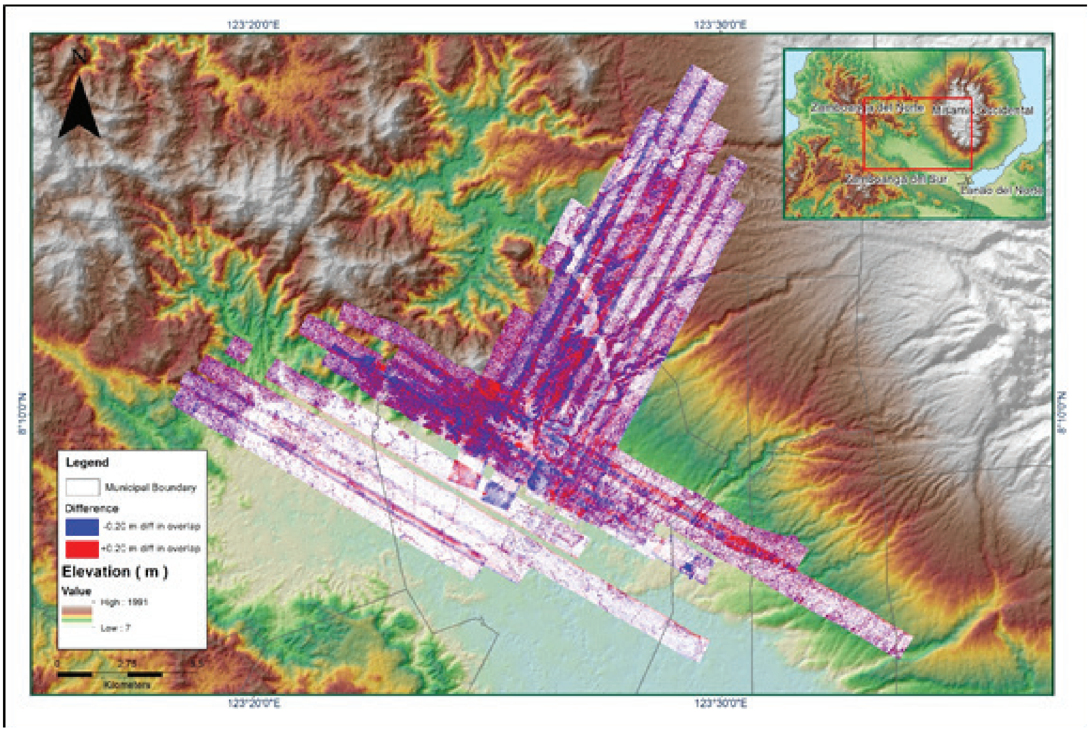


Figure A.8.42.Elevation difference between flight lines

Flight Area	**Pagadian**
Mission Name	76I
Inclusive Flights	23088P, 23092P
Range data size	46.98 GB
POS data size	487.08 MB
Base data size	211.99 MB
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)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000369
IMU attitude correction stdev (<0.001deg)	0.001254
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	52.57
Ave point cloud density per sq.m. (>2.0)	4.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	100
Maximum Height	326.08
Minimum Height	59.15
Classification (# of points)	
Ground	74,430,912
Low vegetation	88,671,219
Medium vegetation	93,736,117
High vegetation	225,713,168
Building	4,653,764
Orthophoto	Yes
Processed by	Engr. Regis Guhiting,
	Engr. Edgardo Gubatanga, Jr.,
	Marie Denise Bueno

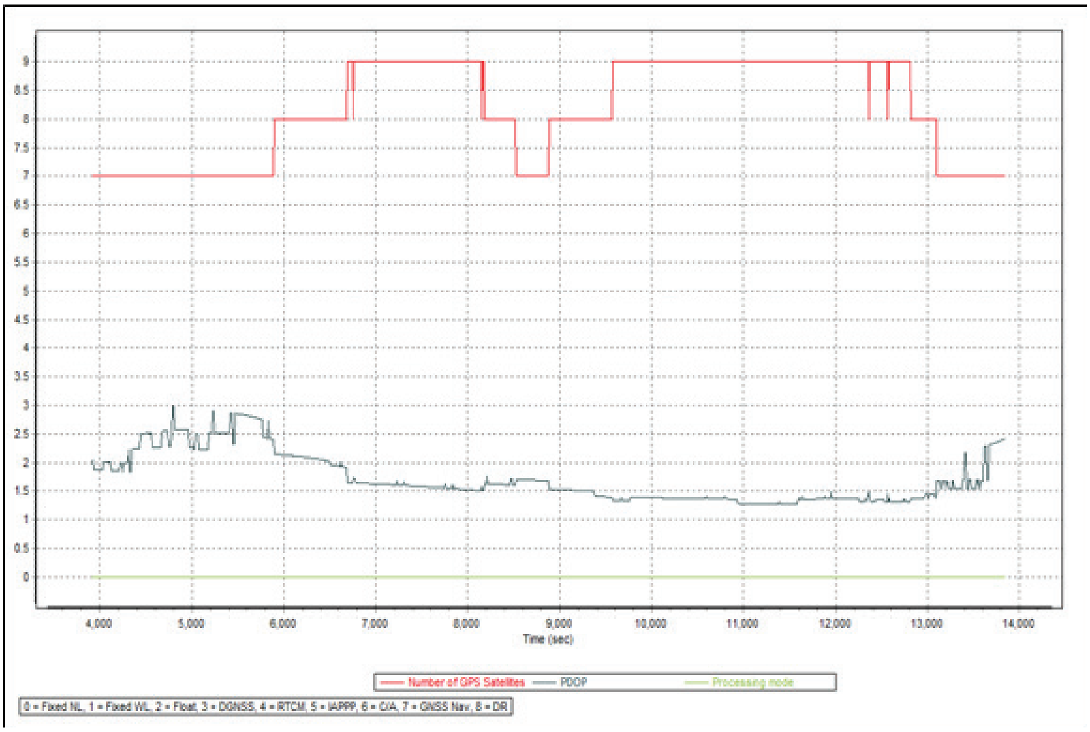


Figure A.8.43. Solution Status

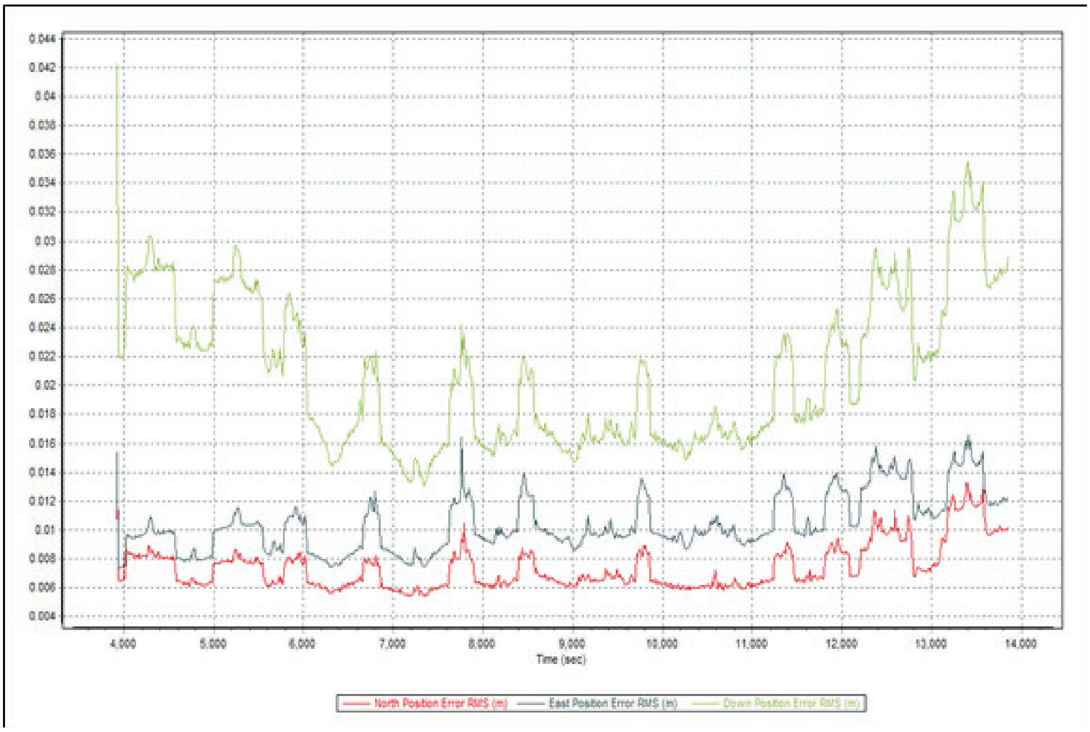


Figure A.8.44 Smoothed Performance Metric Parameters

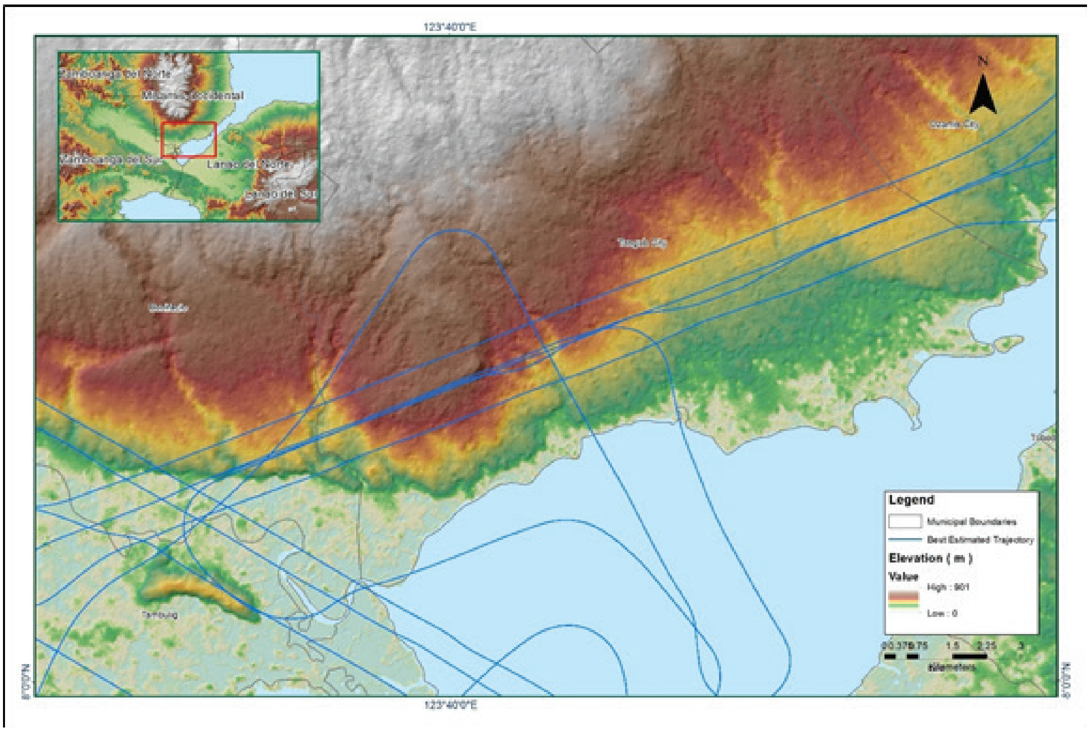


Figure A.8.45 . Best Estimated Trajectory

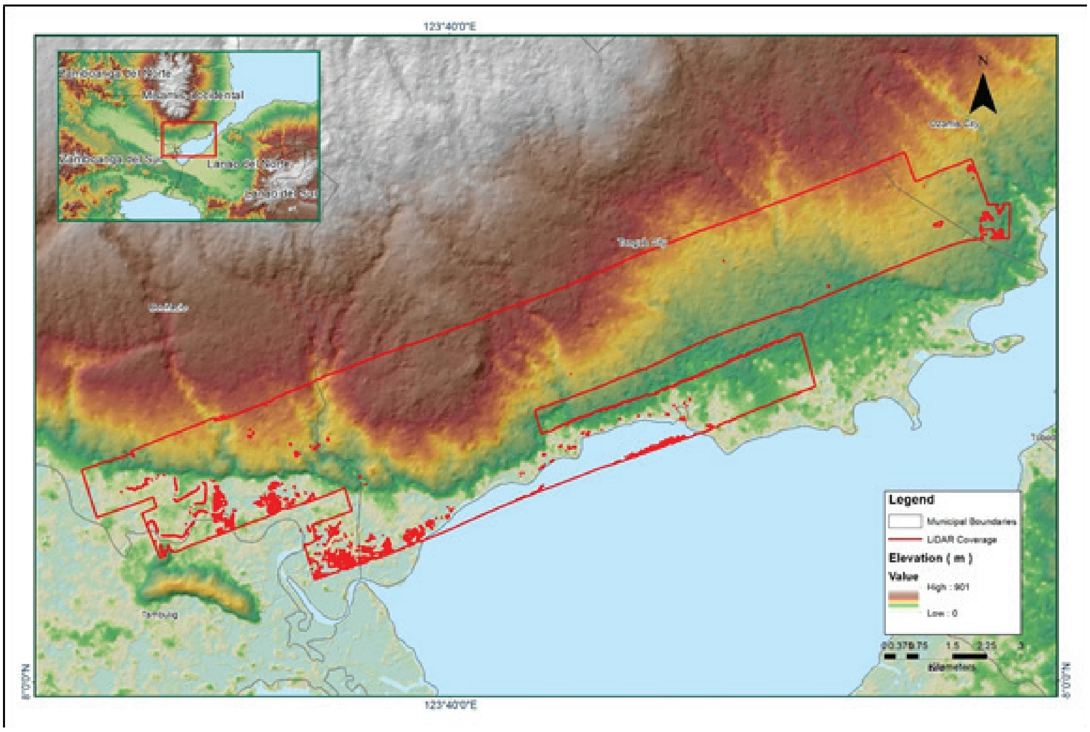


Figure A.8.46.Coverage of LiDAR data

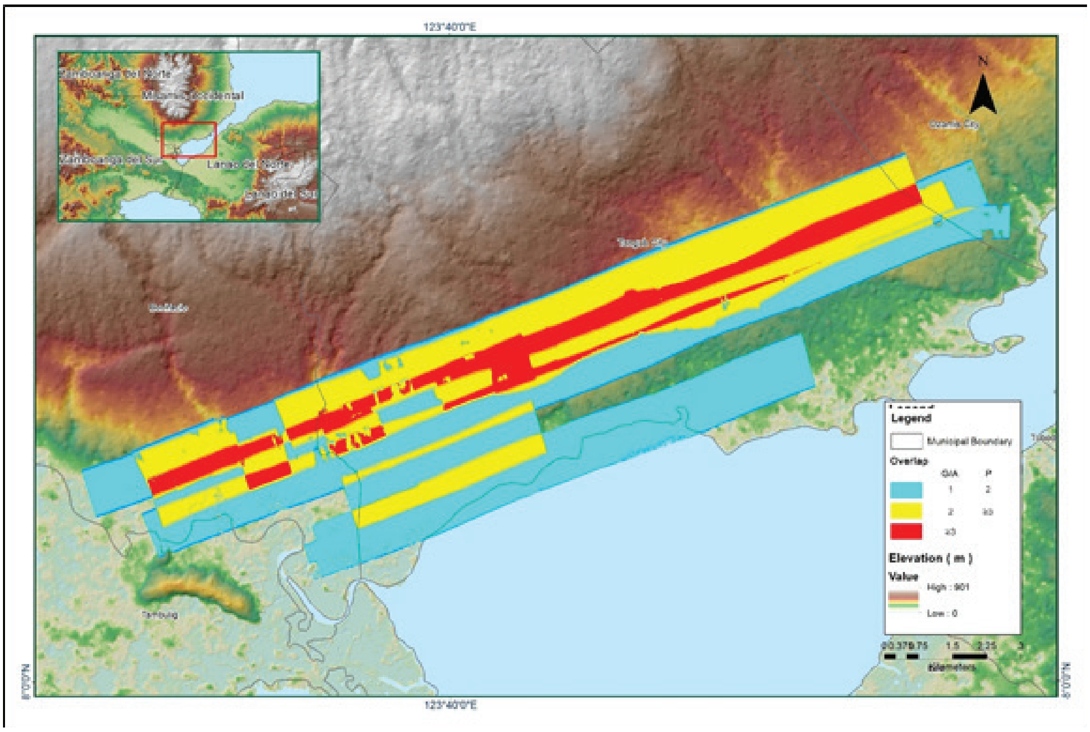


Figure A.8.47 Image of data overlap

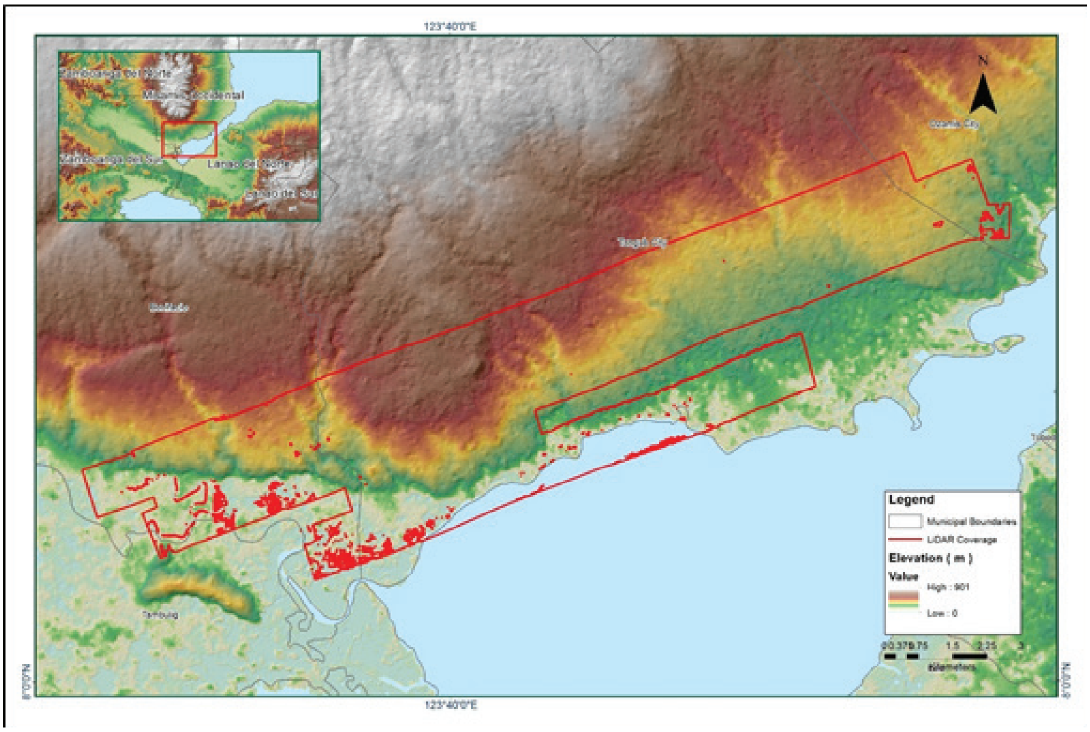


Figure A.8.48. Coverage of LiDAR data

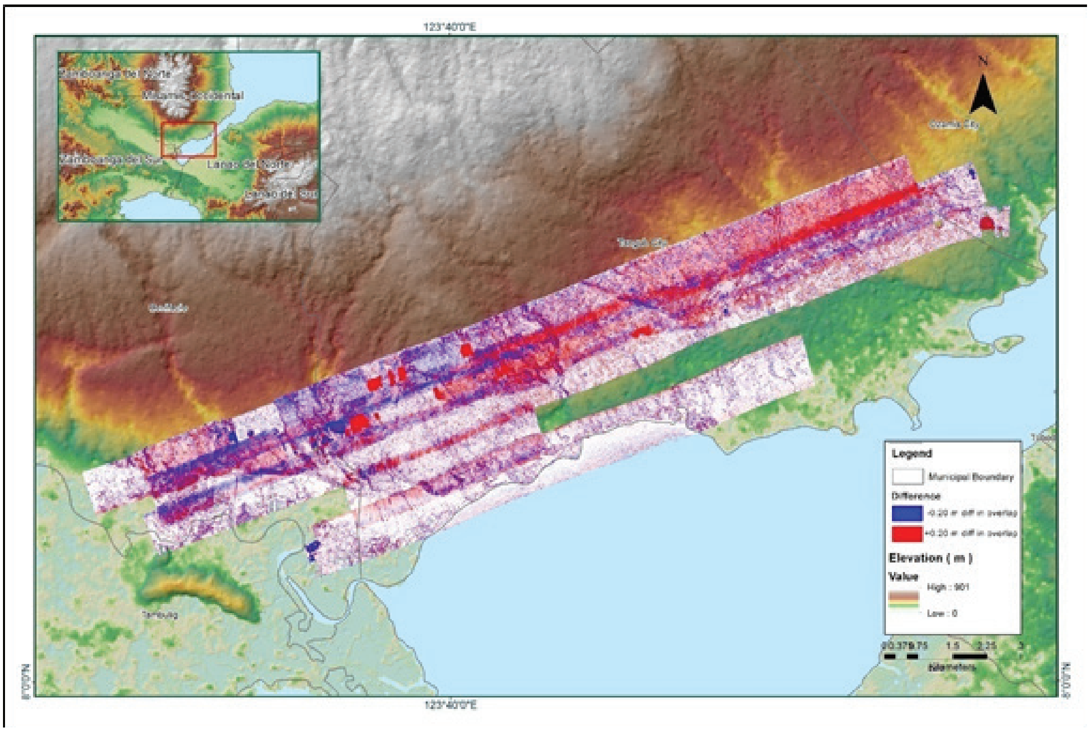


Figure A.8.49.Elevation difference between flight lines

Flight Area	**Pagadian**
Mission Name	Blk76I_additional
Inclusive Flights	23088P
Range data size	24.65 GB
POS data size	283.62 MB
Base data size	101.29 MB
Image	35.45 GB
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)	1.24
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.22
Boresight correction stdev (<0.001deg)	0.000139
IMU attitude correction stdev (<0.001deg)	0.000082
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	24.77
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	72
Maximum Height	321.08
Minimum Height	67.52
Classification (# of points)	
Ground	63889750
Low vegetation	23205040
Medium vegetation	21659026
High vegetation	87182655
Building	1567242
Orthophoto	No
Processed by	Engr. Regis Guhiting,
	Engr. Edgardo Gubatanga, Jr.,
	Engr. Elainne Lopez

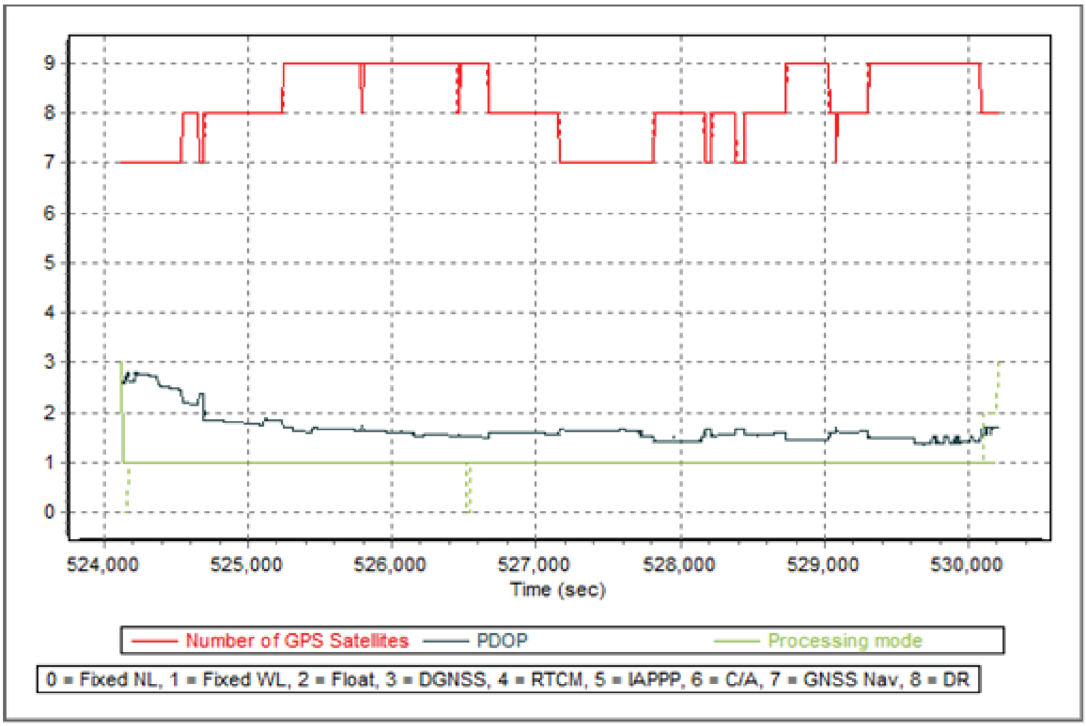


Figure A.8.50. Solution Status

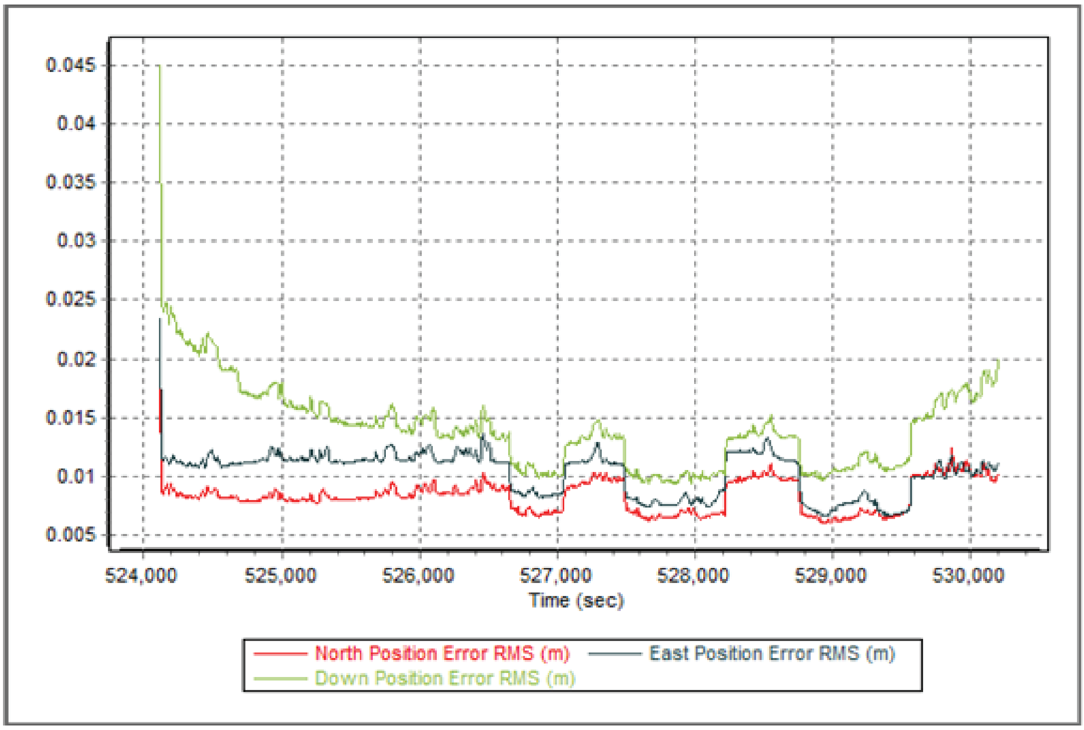


Figure A.8.51. Smoothed Performance Metric Parameters

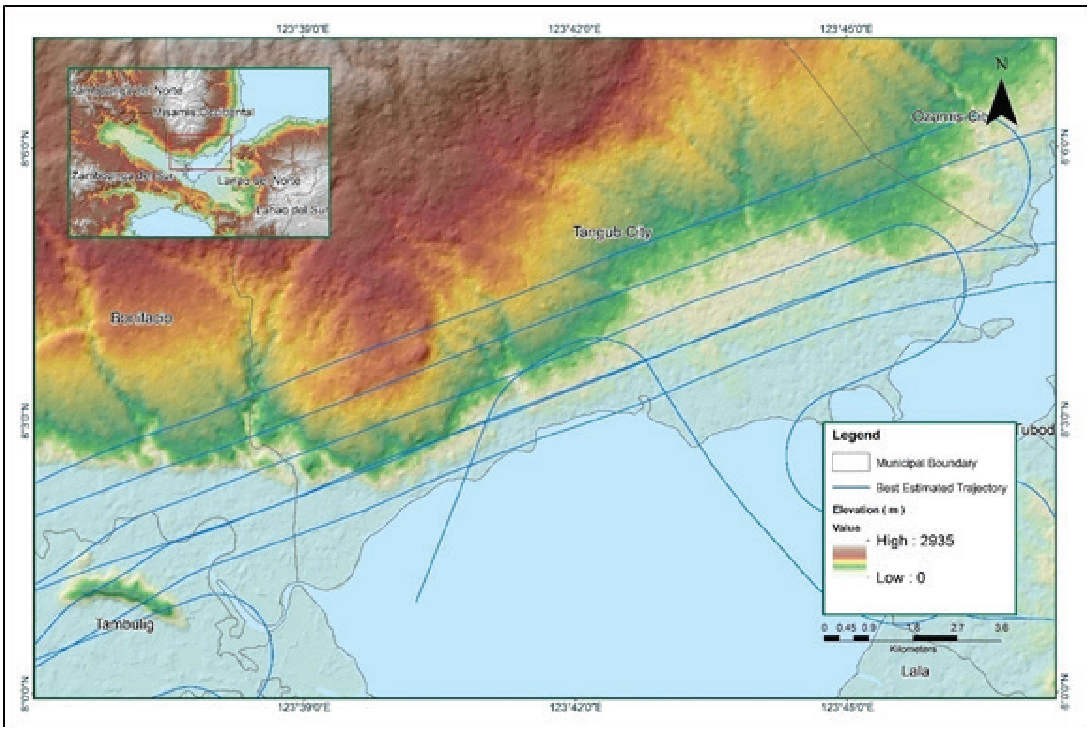


Figure A.8.52. Best Estimated Trajectory

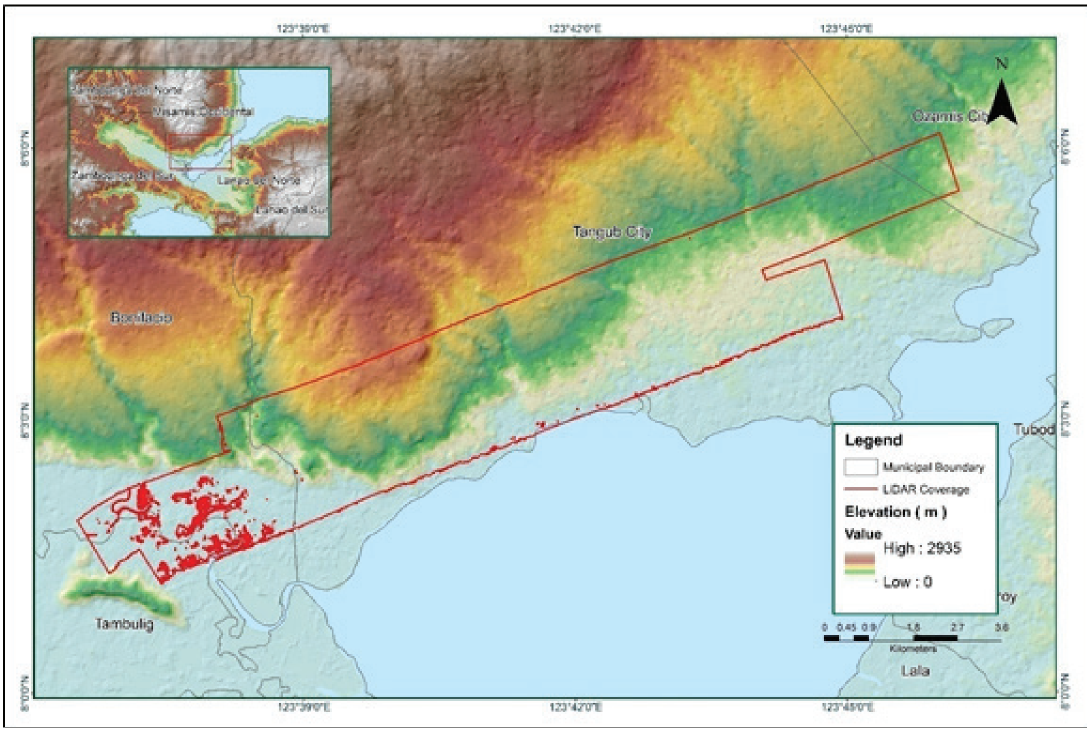


Figure A.8.53.Coverage of LiDAR data

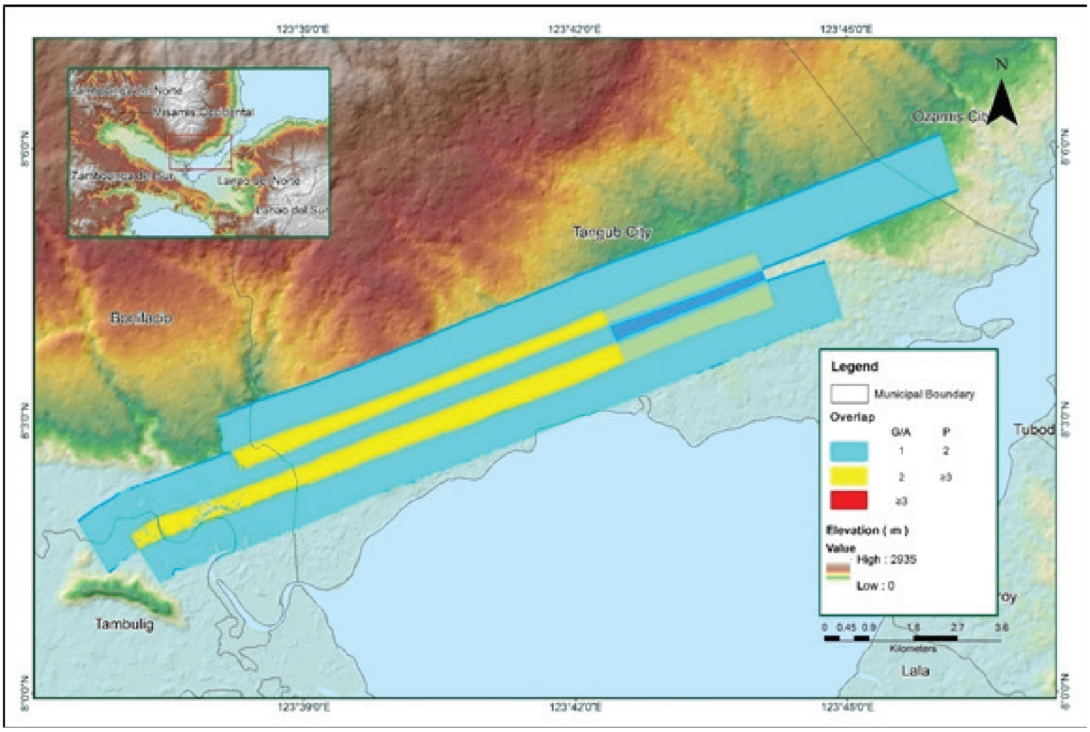


Figure A.8.54 Image of data overlap

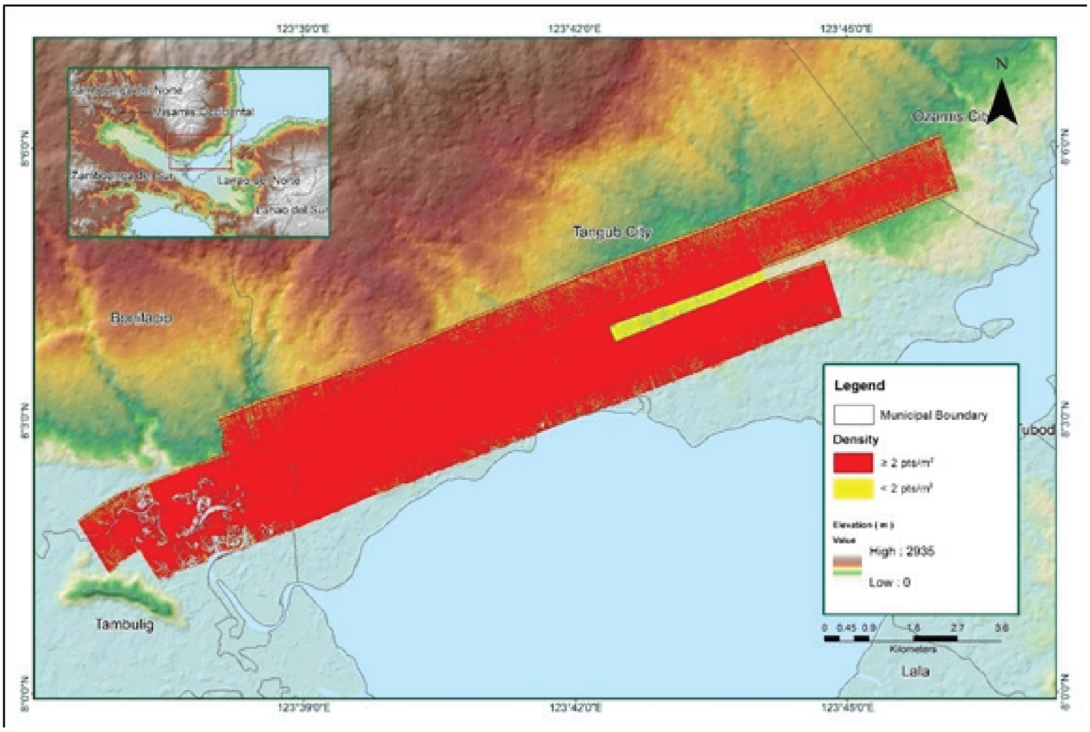


Figure A.8.55.Coverage of LiDAR data

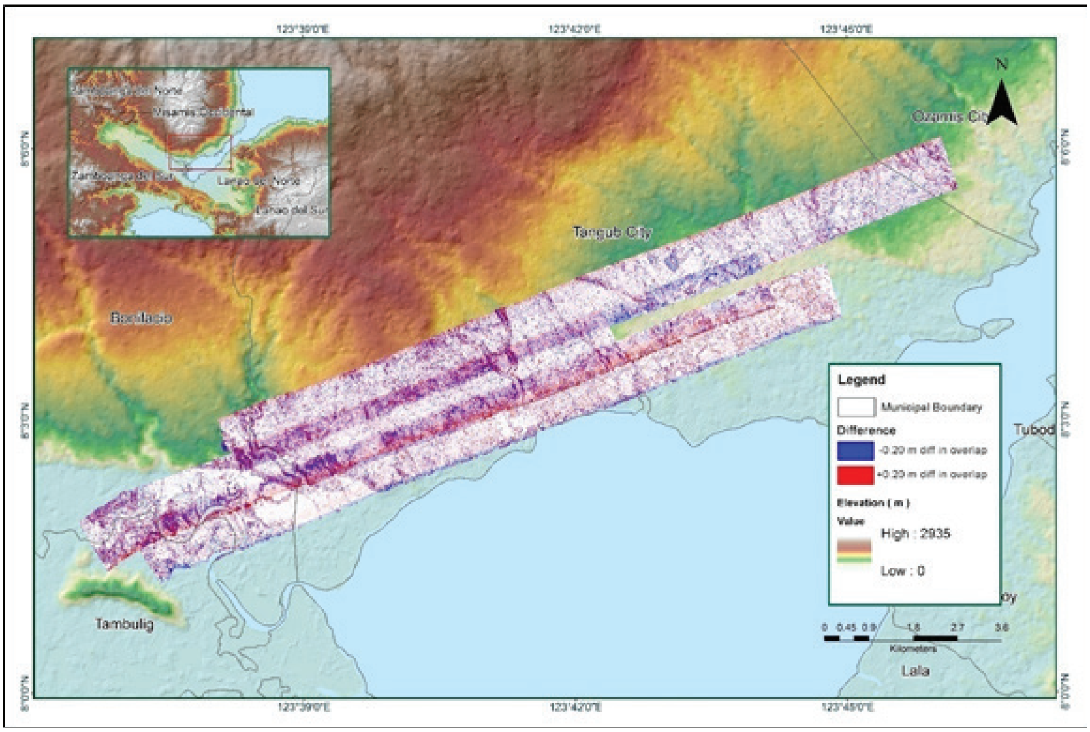


Figure A.8.56.Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	Blk71Extension
Inclusive Flights	1665P, 1673P, 1677P
Range data size	27.06 GB
POS	500 MB
Base Data size	16.97 MB
Image	33.6 GB
Transfer date	August 6, 2014
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)	3.0
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000243
IMU attitude correction stdev (<0.001deg)	0.001298
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	27.83%
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	243
Maximum Height	868.76 m
Minimum Height	63.2 m
Classification (# of points)	
Ground	107,907,148
Low vegetation	96,229,157
Medium vegetation	96,176,102
High vegetation	80,601,347
Building	17,253,174
Orthophoto	Yes
Processed by	Engr. Analyn Naldo,
	Engr. Edgardo Gubatanga, Jr.,
	Engr. Elainne Lopez

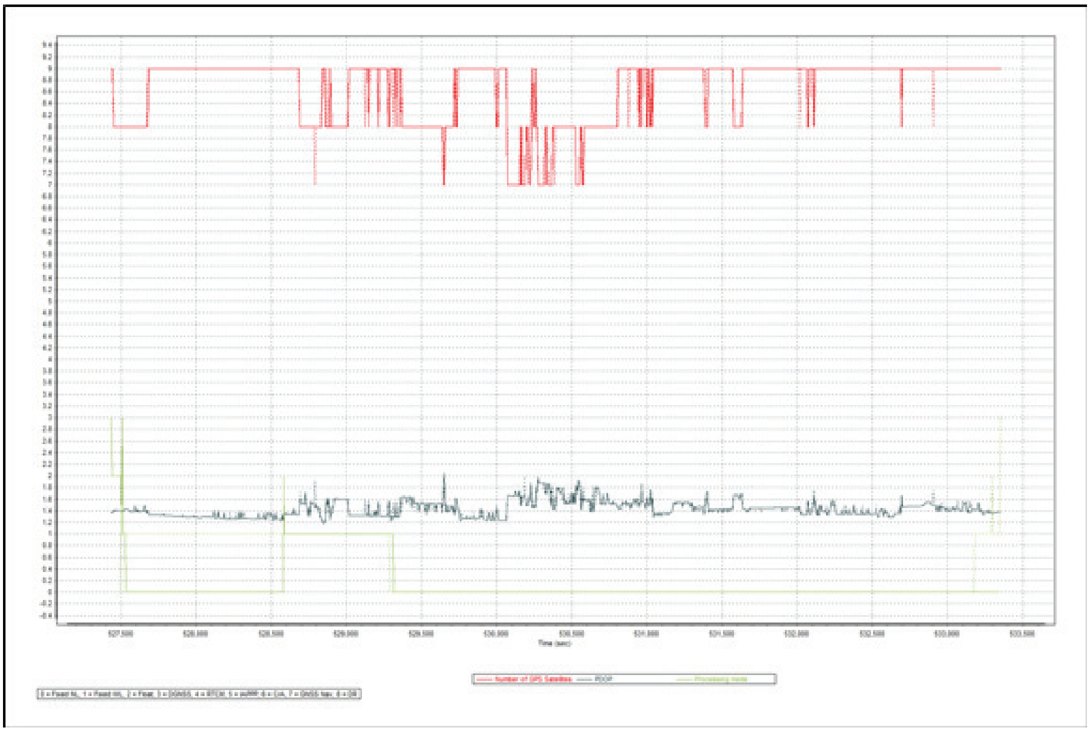


Figure A.8.57. Solution Status

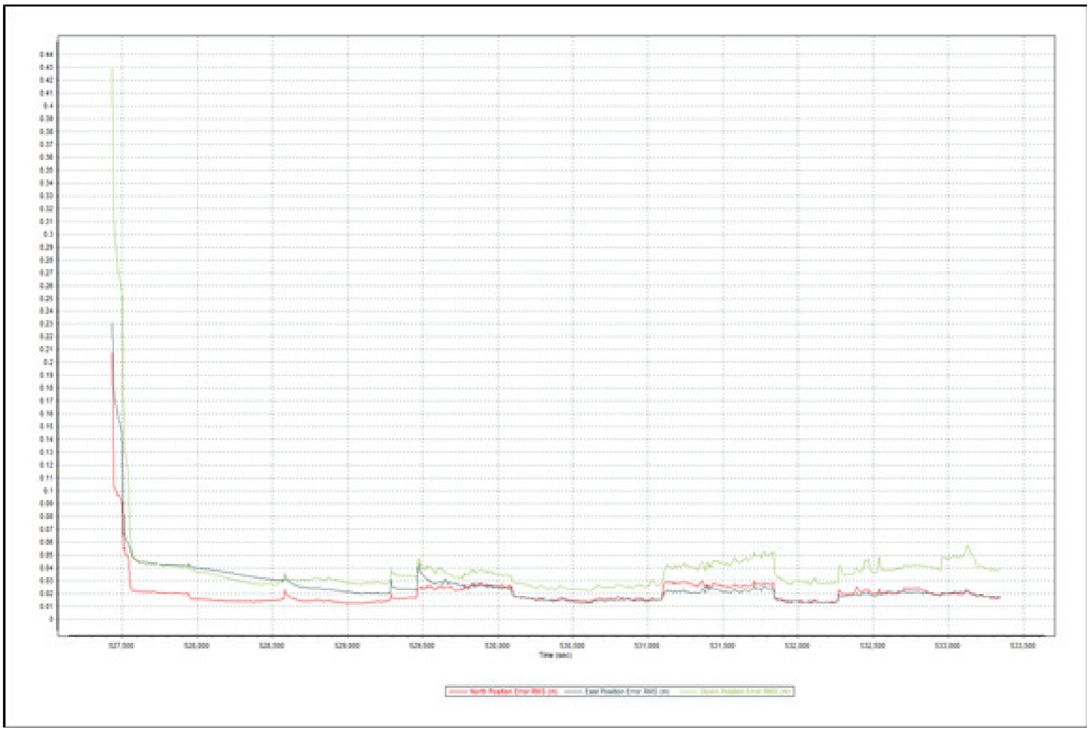


Figure A.8.58. Smoothed Performance Metric Parameters

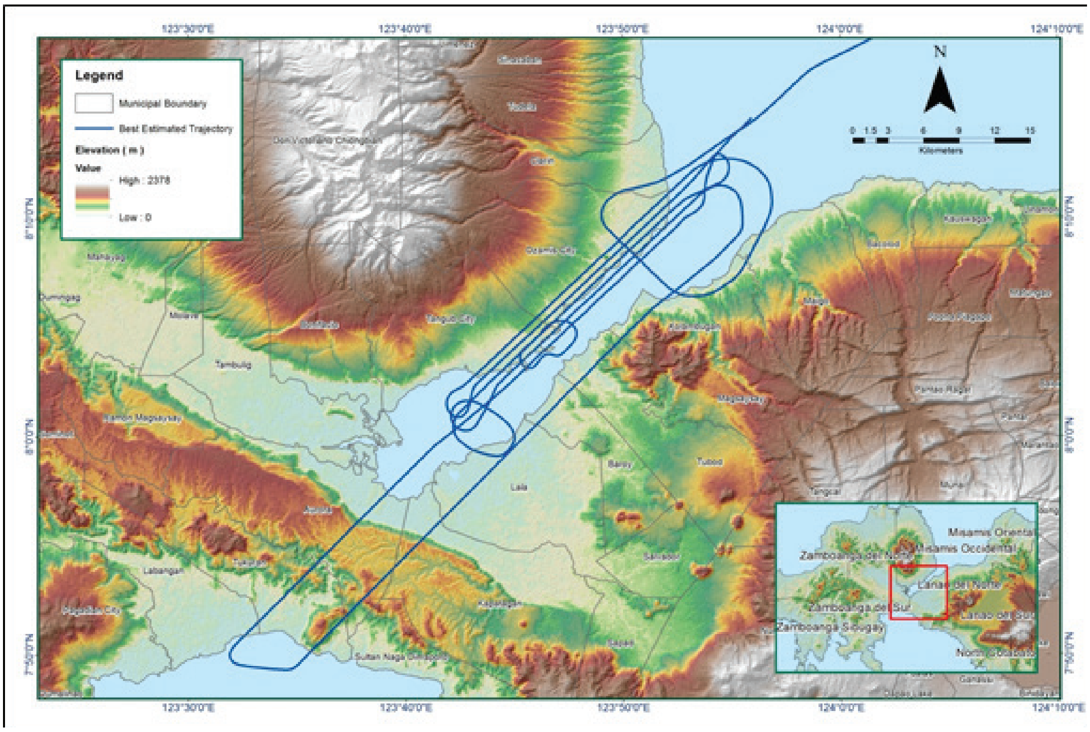


Figure A.8.59. Best Estimated Trajectory

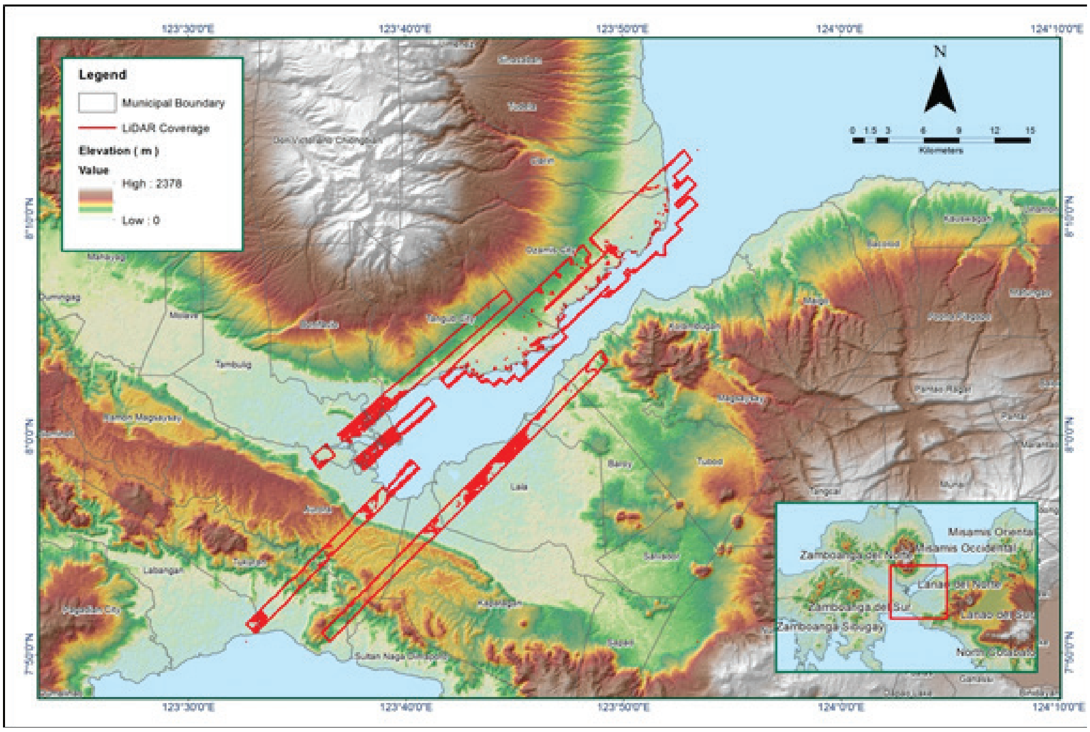


Figure A.8.60.Coverage of LiDAR data

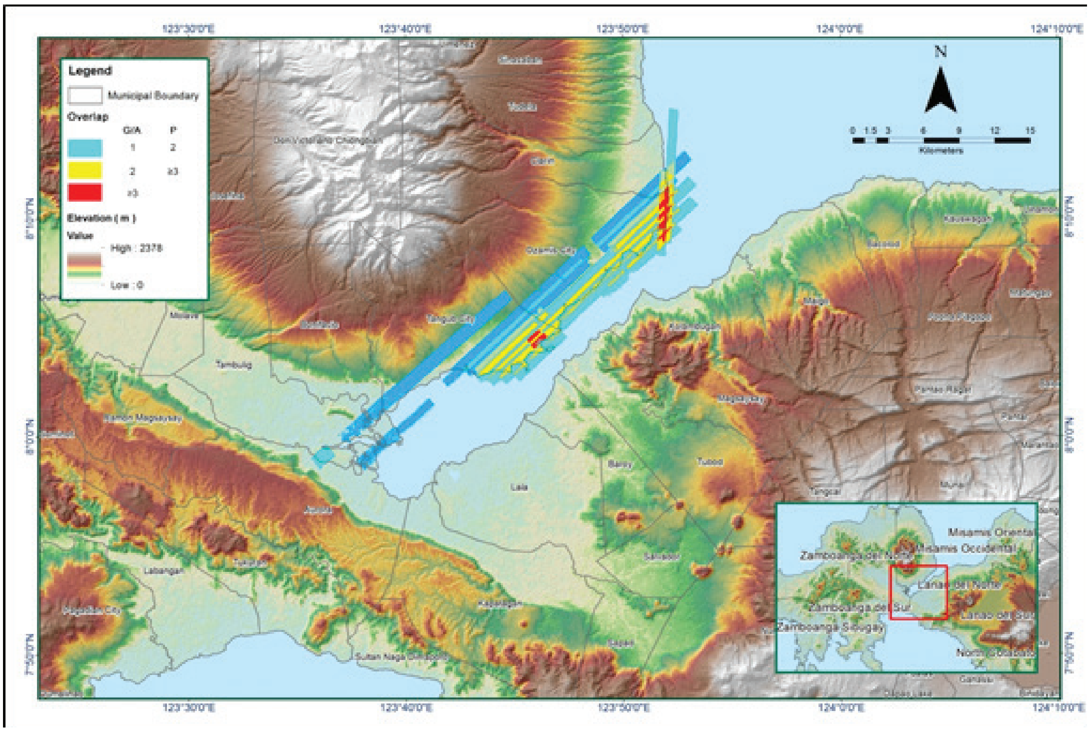


Figure A.8.61 Image of data overlap

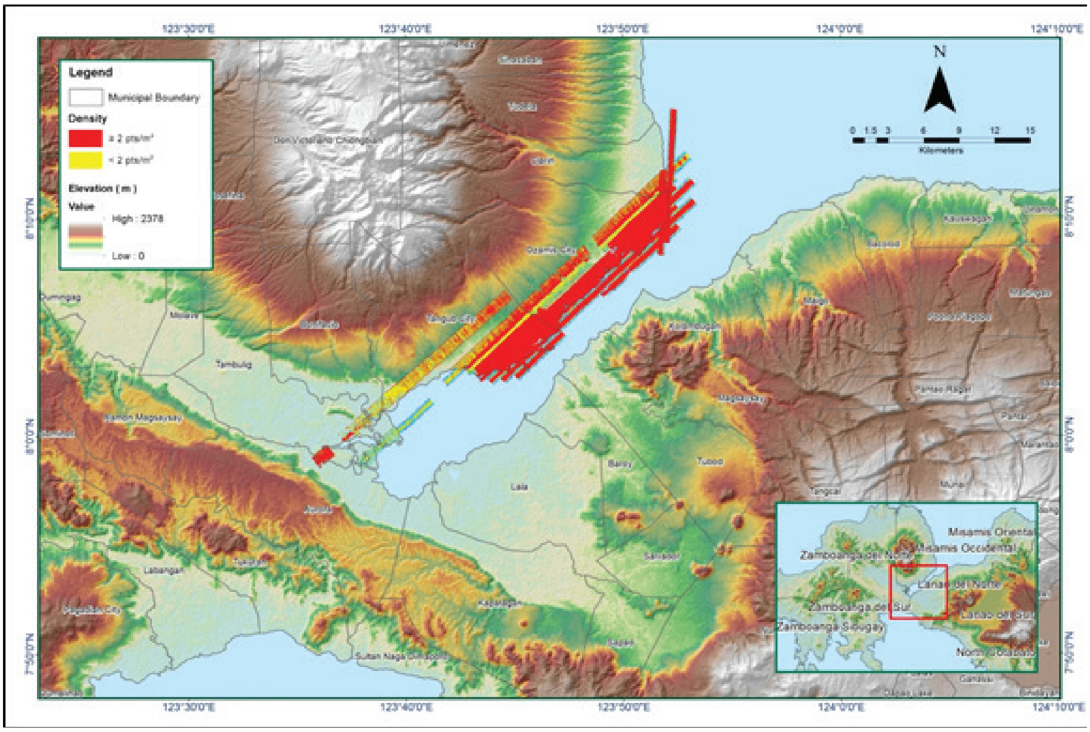


Figure A.8.62.Coverage of LiDAR data

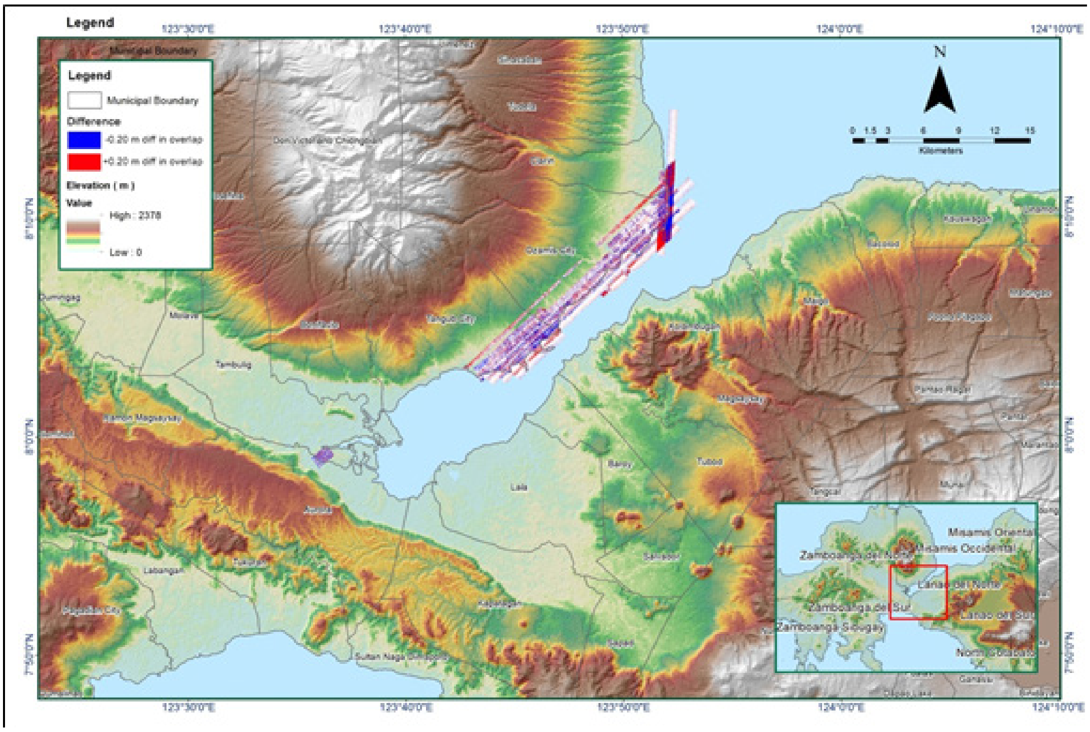


Figure A.8.63.Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	Blk71E
Inclusive Flights	1689P
Range data size	27.1 GB
Base data size	3.68 MB
POS	257 MB
Image	n/a
Transfer date	August 6, 2014
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	
Processed by	Engr. Carlyn Ann Ibañez,Engr. Melanie Hingpit,
	Engr. Jeffrey Delica
	Engr. Elainne Lopez

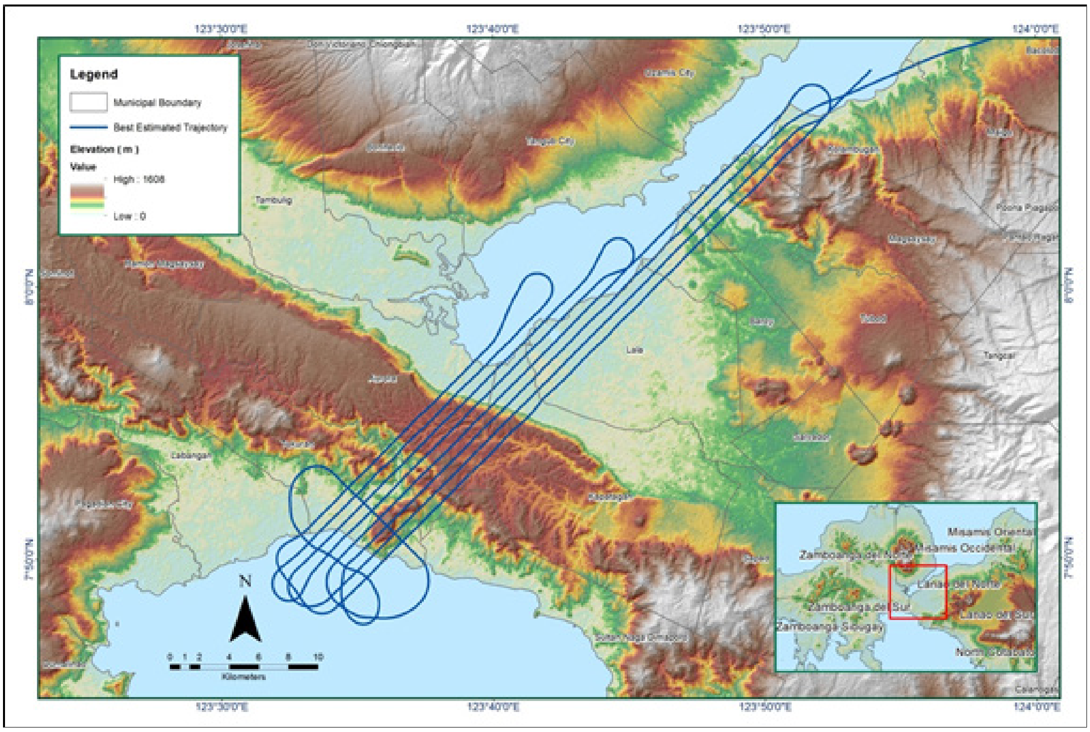


Figure A.8.64. Solution Status

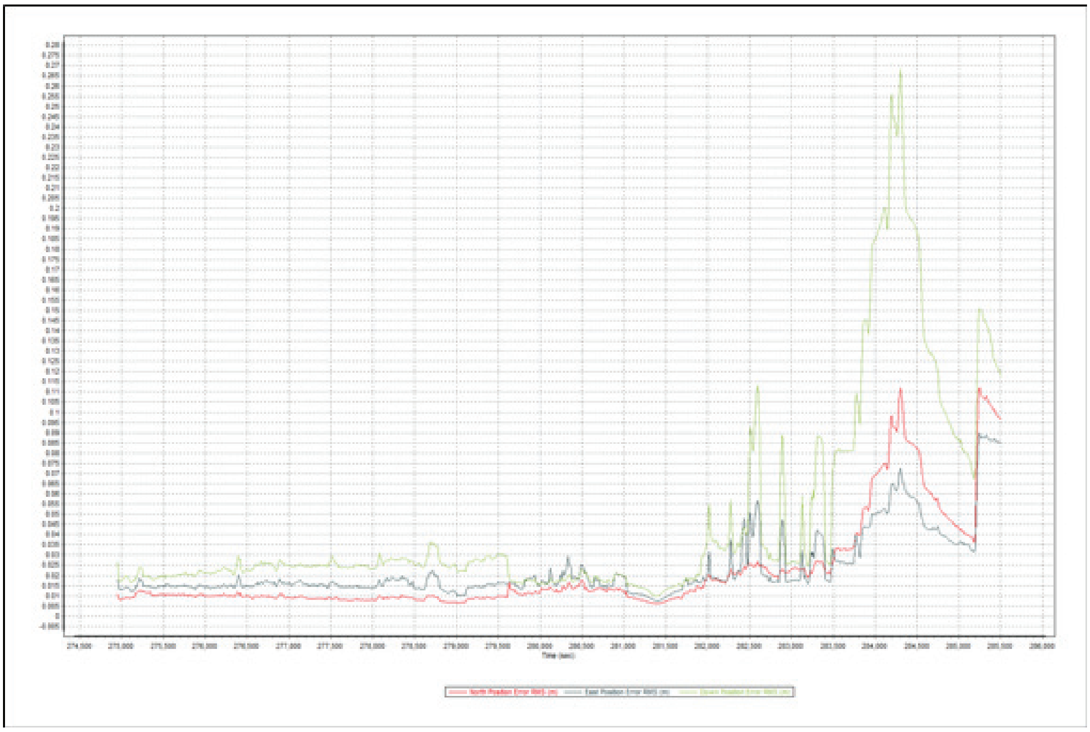


Figure A.8.65. Smoothed Performance Metric Parameters

Figure A.8.66. Best Estimated Trajectory (get figure from DAC)

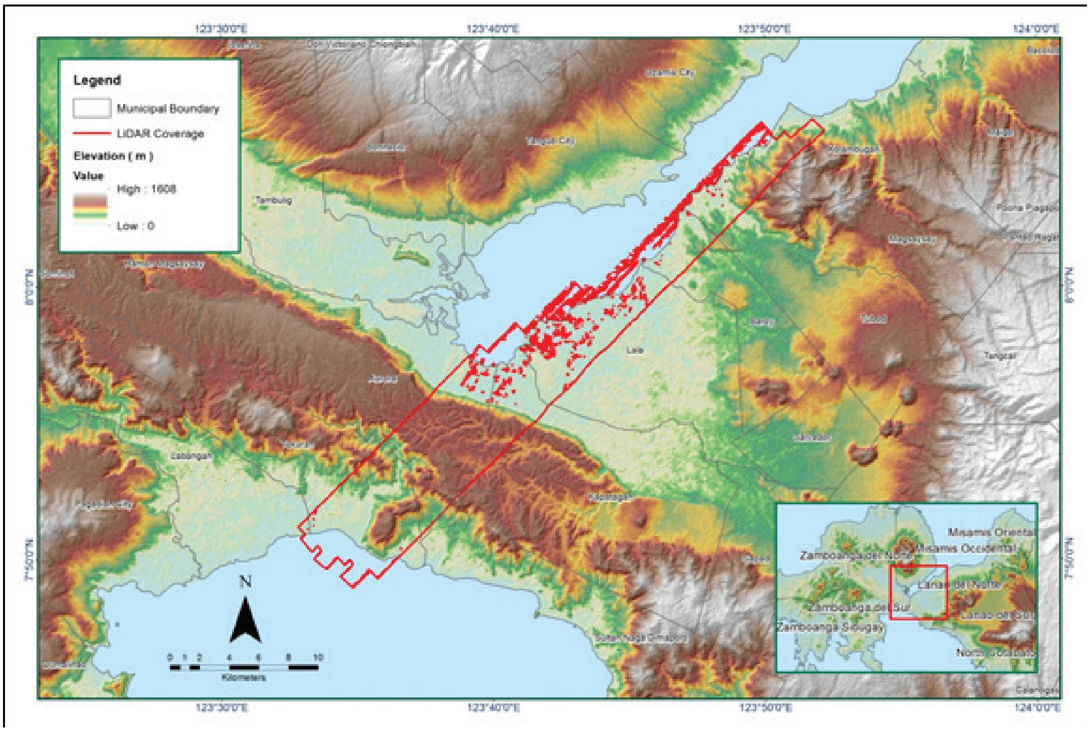


Figure A.8.67. Coverage of LiDAR data

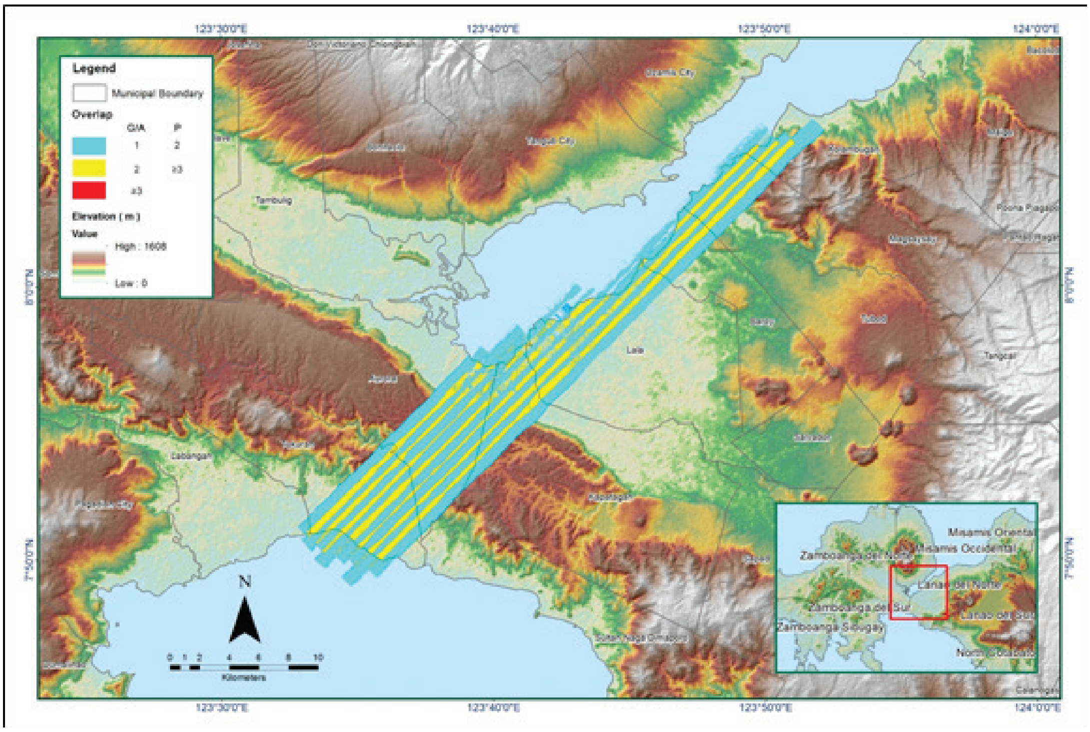


Figure A.8.68. Image of data overlap

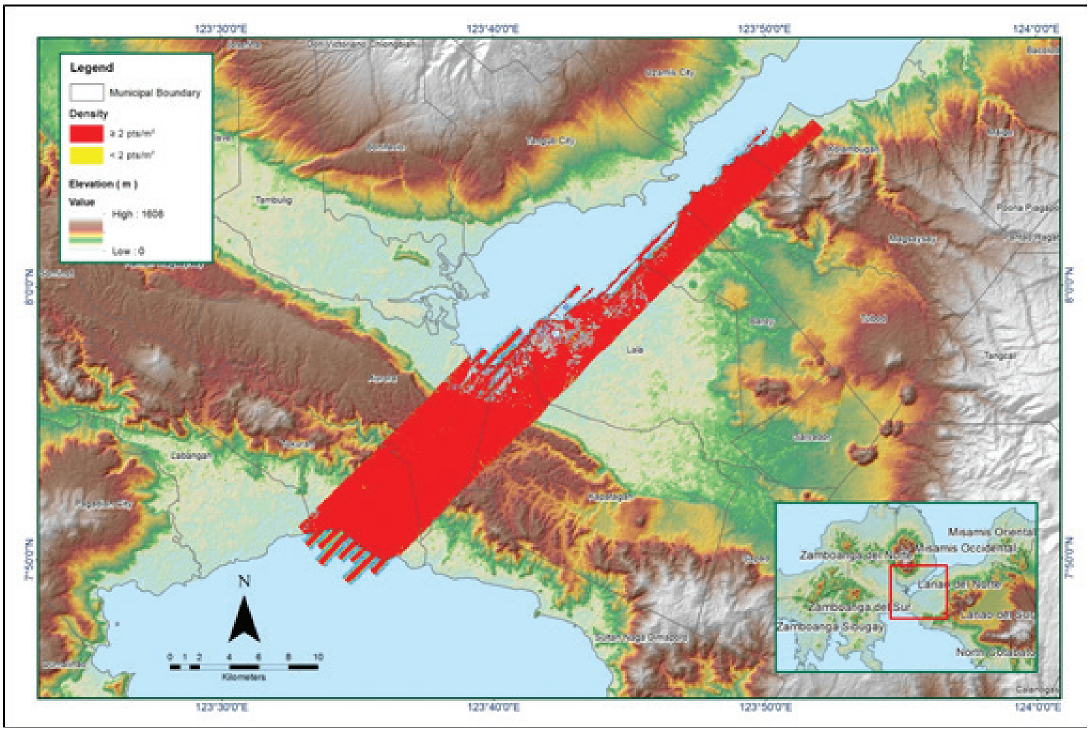


Figure A.8.69. Density map of merged LiDAR data

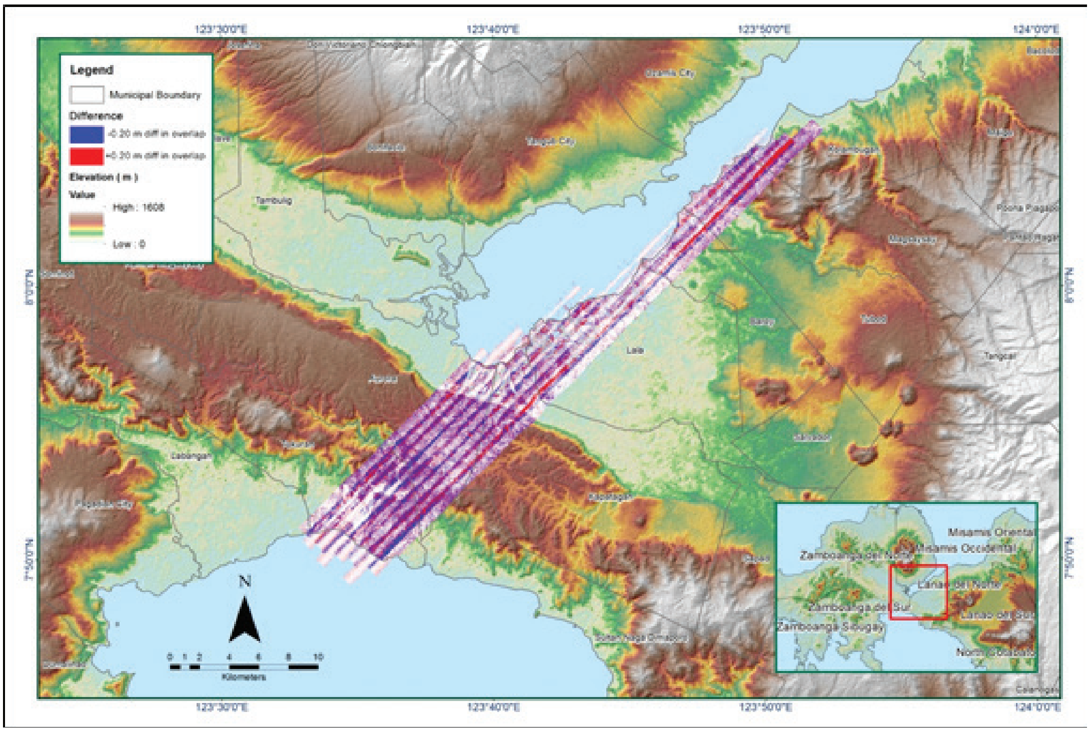


Figure A.8.70. Elevation difference between flight

Annex 9.Salug Diut Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W380	28.76	49.16	10	4.5463	7.6855	Discharge	1.1838	0.98	Ratio to Peak	0.325
W390	25.55	43.67	10	3.1029	3.5325	Discharge	0.42595	0.98	Ratio to Peak	0.325
W400	15.6	52.61	10	4.7806	3.6351	Discharge	0.42396	0.98	Ratio to Peak	0.325
W410	24	44.85	10	4.5357	5.1626	Discharge	0.39525	0.98	Ratio to Peak	0.325
W420	10.34	58.99	10	2.6451	3.0035	Discharge	0.50627	0.98	Ratio to Peak	0.3185
W430	9.31	60.41	10	0.433	3.749	Discharge	0.31388	0.98	Ratio to Peak	0.30589
W440	29.32	41.03	10	1.4668	3.7209	Discharge	0.30885	0.98	Ratio to Peak	0.325
W450	9.31	60.41	10	0.01667	3.0087	Discharge	0.20357	0.98	Ratio to Peak	0.2123355
W460	27.9	41.98	10	2.6235	2.989	Discharge	0.30137	0.98	Ratio to Peak	0.325
W470	9.31	60.41	10	0.53913	2.062	Discharge	0.19655	0.98	Ratio to Peak	0.216645
W480	29.81	40.7	10	3.3404	3.804	Discharge	0.66907	0.98	Ratio to Peak	0.325
W490	11.22	57.81	10	0.79563	3.0735	Discharge	0.28300	0.98	Ratio to Peak	0.325
W500	9.32	60.4	10	0.34004	1.3309	Discharge	0.13019	0.98	Ratio to Peak	0
W510	10.22	59.15	10	1.0832	4.1841	Discharge	0.45084	0.98	Ratio to Peak	0.2166645
W520	14.08	54.3	10	0.8208	1.9692	Discharge	0.27147	0.98	Ratio to Peak	0.325
W530	13.56	54.91	10	0.32615	0.83441	Discharge	0.15237	0.98	Ratio to Peak	0.2123355
W540	17.36	50.77	10	4.334	4.9343	Discharge	0.55444	0.98	Ratio to Peak	0.325
W550	22.23	46.29	10	3.6543	6.2086	Discharge	0.60565	0.98	Ratio to Peak	0.325
W560	10.46	58.81	10	0.48021	1.2295	Discharge	0.27381	0.98	Ratio to Peak	0.144443
W570	16.96	51.17	10	0.39275	1	Discharge	0.23765	0.98	Ratio to Peak	0.325
W580	14.63	53.67	10	8.7866	6.5323	Discharge	1.3168	0.98	Ratio to Peak	0.325
W590	25.99	43.34	10	5.5602	6.3462	Discharge	0.49934	0.98	Ratio to Peak	0.325

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W600	9.31	60.41	10	0.48124	1.6649	Discharge	0.42416	0.98	Ratio to Peak	0.30589
W610	15.62	52.58	10	5.5906	4.2604	Discharge	0.41401	0.98	Ratio to Peak	0.325
W620	15.24	52.99	10	0.75808	6.4245	Discharge	0.54597	0.98	Ratio to Peak	0.325
W630	17.01	51.12	10	5.4387	4.1397	Discharge	0.39470	0.98	Ratio to Peak	0.325
W640	17.01	51.12	10	5.9968	3.0641	Discharge	0.29443	0.98	Ratio to Peak	0.325
W650	9.31	60.41	10	0.29024	1.6066	Discharge	0.19023	0.98	Ratio to Peak	0.30589
W660	17.01	51.12	10	0.39655	7.6785	Discharge	0.20723	0.98	Ratio to Peak	0.325
W670	9.31	60.41	10	0.69436	1.211	Discharge	0.10824	0.98	Ratio to Peak	0.30589
W680	9.39	60.3	10	0.29216	3.3944	Discharge	0.18934	0.98	Ratio to Peak	0.3185
W690	9.59	60.02	10	0.34856	1.6241	Discharge	0.12700	0.98	Ratio to Peak	0.30589
W700	17.01	51.12	10	0.21349	0.73495	Discharge	0.0332249	0.98	Ratio to Peak	0.3185
W710	17.01	51.12	10	0.73665	6.3397	Discharge	0.30401	0.98	Ratio to Peak	0.325
W720	16.49	51.66	10	1.1325	2.9467	Discharge	0.18504	0.98	Ratio to Peak	0.325
W730	17.01	51.12	10	0.63374	5.5074	Discharge	0.20259	0.98	Ratio to Peak	0.325
W740	14.71	53.59	10	0.73717	0.0798449	Discharge	0.47571	0.98	Ratio to Peak	0.325

Annex 10. Salug Diut Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	2546.6	0.0269691	0.04	Trapezoid	13.618	1
R120	Automatic Fixed Interval	1936.5	0.0566882	0.04	Trapezoid	10.55	1
R130	Automatic Fixed Interval	1615.4	0.0258720	0.04	Trapezoid	20	1
R150	Automatic Fixed Interval	1678.8	0.0476926	0.04	Trapezoid	17.96	1
R170	Automatic Fixed Interval	1542.0	0.0145479	0.04	Trapezoid	13.814	1
R190	Automatic Fixed Interval	2814.9	0.0241940	0.04	Trapezoid	15.294	1
R270	Automatic Fixed Interval	3251.8	0.0179581	0.04	Trapezoid	23.066	1
R280	Automatic Fixed Interval	926.69	0.0308441	0.04	Trapezoid	20	1
R300	Automatic Fixed Interval	1588.1	0.0466859	0.035	Trapezoid	9.952	1
R310	Automatic Fixed Interval	4117.6	0.0365505	0.035	Trapezoid	12.762	1
R320	Automatic Fixed Interval	633.55	0.0022008	0.035	Trapezoid	10.216	1
R330	Automatic Fixed Interval	785.98	0.0057738	0.04	Trapezoid	27.17	1
R340	Automatic Fixed Interval	1820.7	0.0170238	0.035	Trapezoid	13.394	1
R350	Automatic Fixed Interval	2186.2	0.0077061	0.04	Trapezoid	15.59	1
R370	Automatic Fixed Interval	2630.6	0.0181864	0.04	Trapezoid	23.062	1
R50	Automatic Fixed Interval	3114.9	0.0522922	0.04	Trapezoid	10.55	1
R60	Automatic Fixed Interval	2246.5	0.0265355	0.04	Trapezoid	10.432	1
R80	Automatic Fixed Interval	1751.2	0.0456841	0.04	Trapezoid	20	1

Annex 11. Salug Diut Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	8.093794	123.482399	0.65	0.95	-0.301	Typhoon Karen / Oct. 11-12, 2016	5 - Year
2	8.093569	123.482270	0.83	0.90	-0.071	Typhoon Karen / Oct. 11-12, 2016	5 - Year
3	8.093412	123.482345	0.78	0.90	-0.121	Typhoon Karen / Oct. 11-12, 2016	5 - Year
4	8.093353	123.482293	0.81	0.80	0.006	Typhoon Karen / Oct. 11-12, 2016	5 - Year
5	8.093614	123.483261	0.90	0.90	0.002	Typhoon Karen / Oct. 11-12, 2016	5 - Year
6	8.093694	123.483406	0.46	0.90	-0.439	Typhoon Karen / Oct. 11-12, 2016	5 - Year
7	8.093644	123.483295	0.90	0.90	0.002	Typhoon Karen / Oct. 11-12, 2016	5 - Year
8	8.093606	123.483188	0.90	0.80	0.102	Typhoon Karen / Oct. 11-12, 2016	5 - Year
9	8.093398	123.483021	0.66	0.40	0.259	Typhoon Karen / Oct. 11-12, 2016	5 - Year
10	8.092774	123.482472	0.79	1.10	-0.311	Typhoon Karen / Oct. 11-12, 2016	5 - Year
11	8.092744	123.482567	0.41	1.10	-0.692	Typhoon Karen / Oct. 11-12, 2016	5 - Year
12	8.091593	123.482749	0.49	0.80	-0.312	Typhoon Karen / Oct. 11-12, 2016	5 - Year
13	8.090657	123.483841	0.94	0.90	0.038	Typhoon Karen / Oct. 11-12, 2016	5 - Year
14	8.090753	123.483947	0.85	1.00	-0.151	Typhoon Karen / Oct. 11-12, 2016	5 - Year
15	8.090573	123.484047	0.76	1.40	-0.645	Typhoon Karen / Oct. 11-12, 2016	5 - Year
16	8.090520	123.483880	1.05	0.90	0.145	Typhoon Karen / Oct. 11-12, 2016	5 - Year
17	8.090538	123.483843	1.05	0.50	0.545	Typhoon Karen / Oct. 11-12, 2016	5 - Year
18	8.090145	123.483058	1.10	0.94	0.164	Typhoon Karen / Oct. 11-12, 2016	5 - Year
19	8.090097	123.483024	1.18	0.94	0.241	Typhoon Karen / Oct. 11-12, 2016	5 - Year
20	8.090225	123.483102	0.64	0.90	-0.260	Typhoon Karen / Oct. 11-12, 2016	5 - Year
21	8.089700	123.483470	0.65	1.50	-0.853	Typhoon Karen / Oct. 11-12, 2016	5 - Year
22	8.089517	123.483530	1.10	1.24	-0.145	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
23	8.089474	123.483304	1.10	1.40	-0.302	Typhoon Karen / Oct. 11-12, 2016	5 - Year
24	8.089532	123.484444	0.35	0.30	0.050	Typhoon Karen / Oct. 11-12, 2016	5 - Year
25	8.089669	123.484684	0.41	0.50	-0.091	Typhoon Karen / Oct. 11-12, 2016	5 - Year
26	8.091735	123.487157	0.74	0.85	-0.109	Typhoon Karen / Oct. 11-12, 2016	5 - Year
27	8.091751	123.487153	0.74	0.85	-0.109	Typhoon Karen / Oct. 11-12, 2016	5 - Year
28	8.091573	123.487184	0.96	0.80	0.157	Typhoon Karen / Oct. 11-12, 2016	5 - Year
29	8.091593	123.487043	0.65	0.80	-0.151	Typhoon Karen / Oct. 11-12, 2016	5 - Year
30	8.091564	123.486989	0.69	0.80	-0.113	Typhoon Karen / Oct. 11-12, 2016	5 - Year
31	8.091537	123.486946	0.69	0.80	-0.113	Typhoon Karen / Oct. 11-12, 2016	5 - Year
32	8.091558	123.486918	0.69	0.50	0.187	Typhoon Karen / Oct. 11-12, 2016	5 - Year
33	8.091475	123.487486	0.80	0.50	0.300	Typhoon Karen / Oct. 11-12, 2016	5 - Year
34	8.091580	123.487402	0.48	0.60	-0.118	Typhoon Karen / Oct. 11-12, 2016	5 - Year
35	8.091314	123.487522	0.81	0.45	0.364	Typhoon Karen / Oct. 11-12, 2016	5 - Year
36	8.090982	123.486799	0.20	0.45	-0.250	Typhoon Karen / Oct. 11-12, 2016	5 - Year
37	8.090462	123.486880	0.77	0.00	0.765	Typhoon Karen / Oct. 11-12, 2016	5 - Year
38	8.090365	123.486584	0.50	0.20	0.297	Typhoon Karen / Oct. 11-12, 2016	5 - Year
39	8.090398	123.486365	0.28	0.47	-0.190	Typhoon Karen / Oct. 11-12, 2016	5 - Year
40	8.090225	123.486230	0.53	0.28	0.251	Typhoon Karen / Oct. 11-12, 2016	5 - Year
41	8.090519	123.487201	0.71	0.48	0.226	Typhoon Karen / Oct. 11-12, 2016	5 - Year
42	8.090583	123.487439	0.79	0.60	0.185	Typhoon Karen / Oct. 11-12, 2016	5 - Year
43	8.090890	123.487726	0.52	0.45	0.066	Typhoon Karen / Oct. 11-12, 2016	5 - Year
44	8.090906	123.487834	0.43	0.15	0.280	Typhoon Karen / Oct. 11-12, 2016	5 - Year
45	8.091061	123.487961	0.48	0.85	-0.373	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
46	8.091224	123.487897	0.52	0.30	0.223	Typhoon Karen / Oct. 11-12, 2016	5 - Year
47	8.091814	123.488016	0.46	0.43	0.033	Typhoon Karen / Oct. 11-12, 2016	5 - Year
48	8.092071	123.487735	0.45	0.75	-0.302	Typhoon Karen / Oct. 11-12, 2016	5 - Year
49	8.092092	123.487590	0.45	0.20	0.245	Typhoon Karen / Oct. 11-12, 2016	5 - Year
50	8.092074	123.486711	0.66	0.40	0.261	Typhoon Karen / Oct. 11-12, 2016	5 - Year
51	8.075125	123.497499	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
52	8.075388	123.497826	0.32	0.50	-0.180	Typhoon Karen / Oct. 11-12, 2016	5 - Year
53	8.071203	123.501085	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
54	8.070703	123.501504	0.04	0.40	-0.360	Typhoon Karen / Oct. 11-12, 2016	5 - Year
55	8.070599	123.501488	0.06	0.45	-0.390	Typhoon Karen / Oct. 11-12, 2016	5 - Year
56	8.070595	123.501472	0.06	0.45	-0.390	Typhoon Karen / Oct. 11-12, 2016	5 - Year
57	8.070513	123.501670	0.07	0.45	-0.380	Typhoon Karen / Oct. 11-12, 2016	5 - Year
58	8.068282	123.503524	0.03	0.20	-0.170	Typhoon Karen / Oct. 11-12, 2016	5 - Year
59	8.067619	123.505510	0.03	0.50	-0.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year
60	8.067435	123.505785	0.03	0.60	-0.570	Typhoon Karen / Oct. 11-12, 2016	5 - Year
61	8.065983	123.506926	0.03	0.00	0.030	Typhoon Karen / Oct. 11-12, 2016	5 - Year
62	8.065442	123.507843	0.09	0.45	-0.360	Typhoon Karen / Oct. 11-12, 2016	5 - Year
63	8.065562	123.508021	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
64	8.065536	123.508080	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
65	8.065493	123.508088	0.06	0.50	-0.440	Typhoon Karen / Oct. 11-12, 2016	5 - Year
66	8.065390	123.508140	0.03	0.50	-0.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year
67	8.062557	123.509854	0.03	0.00	0.030	Typhoon Karen / Oct. 11-12, 2016	5 - Year
68	8.062863	123.511403	0.03	0.45	-0.420	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
69	8.062456	123.511874	0.03	0.45	-0.420	Typhoon Karen / Oct. 11-12, 2016	5 - Year
70	8.062317	123.511934	0.03	0.20	-0.170	Typhoon Karen / Oct. 11-12, 2016	5 - Year
71	8.062263	123.511975	0.03	0.45	-0.420	Typhoon Karen / Oct. 11-12, 2016	5 - Year
72	8.061992	123.512222	0.07	0.65	-0.580	Typhoon Karen / Oct. 11-12, 2016	5 - Year
73	8.061493	123.512498	0.03	0.20	-0.170	Typhoon Karen / Oct. 11-12, 2016	5 - Year
74	8.061299	123.512752	0.03	0.45	-0.420	Typhoon Karen / Oct. 11-12, 2016	5 - Year
75	8.061323	123.512789	0.03	0.35	-0.320	Typhoon Karen / Oct. 11-12, 2016	5 - Year
76	8.052310	123.482524	0.93	1.02	-0.090	Typhoon Karen / Oct. 11-12, 2016	5 - Year
77	8.052289	123.482546	0.93	0.90	0.030	Typhoon Karen / Oct. 11-12, 2016	5 - Year
78	8.052295	123.482650	1.03	1.02	0.008	Typhoon Karen / Oct. 11-12, 2016	5 - Year
79	8.052614	123.482114	0.03	1.00	-0.970	Typhoon Karen / Oct. 11-12, 2016	5 - Year
80	8.053306	123.481783	0.93	1.20	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
81	8.052632	123.482793	1.03	0.90	0.128	Typhoon Karen / Oct. 11-12, 2016	5 - Year
82	8.052581	123.482849	1.03	0.60	0.428	Typhoon Karen / Oct. 11-12, 2016	5 - Year
83	8.052489	123.482878	1.03	1.02	0.008	Typhoon Karen / Oct. 11-12, 2016	5 - Year
84	8.052695	123.482892	1.03	0.85	0.178	Typhoon Karen / Oct. 11-12, 2016	5 - Year
85	8.052651	123.483207	1.03	0.60	0.428	Typhoon Karen / Oct. 11-12, 2016	5 - Year
86	8.052748	123.483247	1.03	0.55	0.478	Typhoon Karen / Oct. 11-12, 2016	5 - Year
87	8.052902	123.483288	1.03	0.00	1.028	Typhoon Karen / Oct. 11-12, 2016	5 - Year
88	8.053199	123.483508	1.03	1.50	-0.472	Typhoon Karen / Oct. 11-12, 2016	5 - Year
89	8.052816	123.483325	1.03	0.80	0.228	Typhoon Karen / Oct. 11-12, 2016	5 - Year
90	8.052912	123.483367	1.03	0.70	0.328	Typhoon Karen / Oct. 11-12, 2016	5 - Year
91	8.052602	123.483683	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
92	8.052523	123.483715	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
93	8.052529	123.483716	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
94	8.052280	123.484484	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
95	8.051774	123.485490	0.03	0.90	-0.870	Typhoon Karen / Oct. 11-12, 2016	5 - Year
96	8.051728	123.485608	0.03	0.90	-0.870	Typhoon Karen / Oct. 11-12, 2016	5 - Year
97	8.051241	123.485251	0.05	0.70	-0.650	Typhoon Karen / Oct. 11-12, 2016	5 - Year
98	8.053005	123.483921	0.03	0.00	0.030	Typhoon Karen / Oct. 11-12, 2016	5 - Year
99	8.052705	123.483992	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
100	8.053124	123.483868	0.03	0.90	-0.870	Typhoon Karen / Oct. 11-12, 2016	5 - Year
101	8.072111	123.475440	1.68	0.60	1.080	Typhoon Karen / Oct. 11-12, 2016	5 - Year
102	8.072353	123.475087	1.57	0.60	0.973	Typhoon Karen / Oct. 11-12, 2016	5 - Year
103	8.073189	123.477151	1.32	0.60	0.716	Typhoon Karen / Oct. 11-12, 2016	5 - Year
104	8.073024	123.477215	1.27	0.60	0.669	Typhoon Karen / Oct. 11-12, 2016	5 - Year
105	8.072988	123.477048	0.98	0.60	0.384	Typhoon Karen / Oct. 11-12, 2016	5 - Year
106	8.072038	123.477321	1.05	0.80	0.253	Typhoon Karen / Oct. 11-12, 2016	5 - Year
107	8.071819	123.477190	0.60	0.40	0.195	Typhoon Karen / Oct. 11-12, 2016	5 - Year
108	8.071546	123.477128	1.16	0.40	0.764	Typhoon Karen / Oct. 11-12, 2016	5 - Year
109	8.071593	123.477034	1.12	0.40	0.720	Typhoon Karen / Oct. 11-12, 2016	5 - Year
110	8.071619	123.477113	1.13	0.40	0.726	Typhoon Karen / Oct. 11-12, 2016	5 - Year
111	8.072655	123.478079	0.88	1.10	-0.222	Typhoon Karen / Oct. 11-12, 2016	5 - Year
112	8.072670	123.478063	1.20	1.10	0.100	Typhoon Karen / Oct. 11-12, 2016	5 - Year
113	8.072579	123.478153	0.30	0.80	-0.504	Typhoon Karen / Oct. 11-12, 2016	5 - Year
114	8.074290	123.480264	1.18	0.90	0.284	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
115	8.074491	123.480099	1.04	0.20	0.837	Typhoon Karen / Oct. 11-12, 2016	5 - Year
116	8.074738	123.480615	1.31	0.90	0.414	Typhoon Karen / Oct. 11-12, 2016	5 - Year
117	8.075110	123.480537	1.21	0.50	0.711	Typhoon Karen / Oct. 11-12, 2016	5 - Year
118	8.083911	123.470272	0.89	0.45	0.438	Typhoon Karen / Oct. 11-12, 2016	5 - Year
119	8.083924	123.470279	0.93	0.45	0.480	Typhoon Karen / Oct. 11-12, 2016	5 - Year
120	8.084090	123.469964	0.84	0.50	0.336	Typhoon Karen / Oct. 11-12, 2016	5 - Year
121	8.083046	123.471524	0.66	0.50	0.158	Typhoon Karen / Oct. 11-12, 2016	5 - Year
122	8.082801	123.471931	0.64	0.70	-0.065	Typhoon Karen / Oct. 11-12, 2016	5 - Year
123	8.082877	123.471798	0.69	0.40	0.289	Typhoon Karen / Oct. 11-12, 2016	5 - Year
124	8.083095	123.471382	0.72	0.50	0.220	Typhoon Karen / Oct. 11-12, 2016	5 - Year
125	8.083051	123.471297	0.48	1.50	-1.023	Typhoon Karen / Oct. 11-12, 2016	5 - Year
126	8.098806	123.482522	0.93	0.90	0.028	Typhoon Karen / Oct. 11-12, 2016	5 - Year
127	8.098975	123.482422	1.22	0.70	0.519	Typhoon Karen / Oct. 11-12, 2016	5 - Year
128	8.099117	123.482392	1.08	1.40	-0.316	Typhoon Karen / Oct. 11-12, 2016	5 - Year
129	8.099078	123.482481	1.37	1.32	0.052	Typhoon Karen / Oct. 11-12, 2016	5 - Year
130	8.099008	123.482653	1.00	1.73	-0.732	Typhoon Karen / Oct. 11-12, 2016	5 - Year
131	8.098989	123.482811	0.93	0.89	0.039	Typhoon Karen / Oct. 11-12, 2016	5 - Year
132	8.099703	123.481836	0.94	1.80	-0.865	Typhoon Karen / Oct. 11-12, 2016	5 - Year
133	8.100106	123.481736	0.91	2.37	-1.460	Typhoon Karen / Oct. 11-12, 2016	5 - Year
134	8.100278	123.480803	0.85	2.10	-1.253	Typhoon Karen / Oct. 11-12, 2016	5 - Year
135	8.100225	123.480644	0.65	1.66	-1.007	Typhoon Karen / Oct. 11-12, 2016	5 - Year
136	8.100211	123.480692	0.73	1.73	-0.996	Typhoon Karen / Oct. 11-12, 2016	5 - Year
137	8.100169	123.480664	0.69	1.70	-1.012	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
138	8.100019	123.480469	1.04	1.68	-0.640	Typhoon Karen / Oct. 11-12, 2016	5 - Year
139	8.100019	123.480506	0.95	0.78	0.166	Typhoon Karen / Oct. 11-12, 2016	5 - Year
140	8.099683	123.480439	0.92	0.93	-0.010	Typhoon Karen / Oct. 11-12, 2016	5 - Year
141	8.099964	123.480578	0.95	1.38	-0.427	Typhoon Karen / Oct. 11-12, 2016	5 - Year
142	8.100481	123.480753	1.13	0.96	0.174	Typhoon Karen / Oct. 11-12, 2016	5 - Year
143	8.100133	123.480747	0.46	1.32	-0.862	Typhoon Karen / Oct. 11-12, 2016	5 - Year
144	8.100650	123.481125	1.04	1.34	-0.297	Typhoon Karen / Oct. 11-12, 2016	5 - Year
145	8.100450	123.481828	0.85	0.87	-0.016	Typhoon Karen / Oct. 11-12, 2016	5 - Year
146	8.100453	123.481992	0.73	0.87	-0.137	Typhoon Karen / Oct. 11-12, 2016	5 - Year
147	8.100350	123.482156	0.26	0.46	-0.198	Typhoon Karen / Oct. 11-12, 2016	5 - Year
148	8.100417	123.482408	0.88	1.18	-0.300	Typhoon Karen / Oct. 11-12, 2016	5 - Year
149	8.100667	123.482417	0.91	1.22	-0.310	Typhoon Karen / Oct. 11-12, 2016	5 - Year
150	8.100800	123.482464	0.84	0.84	0.003	Typhoon Karen / Oct. 11-12, 2016	5 - Year
151	8.098794	123.480139	0.94	2.20	-1.260	Typhoon Karen / Oct. 11-12, 2016	5 - Year
152	8.098769	123.480283	1.11	1.53	-0.423	Typhoon Karen / Oct. 11-12, 2016	5 - Year
153	8.098953	123.480339	0.96	1.40	-0.442	Typhoon Karen / Oct. 11-12, 2016	5 - Year
154	8.098003	123.481317	0.59	1.12	-0.528	Typhoon Karen / Oct. 11-12, 2016	5 - Year
155	8.098011	123.481311	0.59	1.15	-0.558	Typhoon Karen / Oct. 11-12, 2016	5 - Year
156	8.098183	123.481269	0.70	1.16	-0.460	Typhoon Karen / Oct. 11-12, 2016	5 - Year
157	8.098206	123.481308	0.86	1.06	-0.202	Typhoon Karen / Oct. 11-12, 2016	5 - Year
158	8.098286	123.481331	0.86	1.06	-0.202	Typhoon Karen / Oct. 11-12, 2016	5 - Year
159	8.098475	123.481375	1.01	0.90	0.108	Typhoon Karen / Oct. 11-12, 2016	5 - Year
160	8.098467	123.481247	1.15	0.85	0.299	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
161	8.098400	123.481156	1.15	0.30	0.851	Typhoon Karen / Oct. 11-12, 2016	5 - Year
162	8.098314	123.480858	0.78	1.64	-0.858	Typhoon Karen / Oct. 11-12, 2016	5 - Year
163	8.098392	123.480961	1.15	0.95	0.196	Typhoon Karen / Oct. 11-12, 2016	5 - Year
164	8.098967	123.481022	0.86	0.72	0.135	Typhoon Karen / Oct. 11-12, 2016	5 - Year
165	8.099000	123.481283	0.94	1.80	-0.862	Typhoon Karen / Oct. 11-12, 2016	5 - Year
166	8.099156	123.481461	0.66	0.65	0.013	Typhoon Karen / Oct. 11-12, 2016	5 - Year
167	8.098978	123.481703	0.38	1.00	-0.619	Typhoon Karen / Oct. 11-12, 2016	5 - Year
168	8.098722	123.481669	0.89	0.96	-0.069	Typhoon Karen / Oct. 11-12, 2016	5 - Year
169	8.098747	123.481325	0.84	1.35	-0.514	Typhoon Karen / Oct. 11-12, 2016	5 - Year
170	8.098414	123.481367	0.96	1.12	-0.164	Typhoon Karen / Oct. 11-12, 2016	5 - Year
171	8.097822	123.481361	0.58	0.90	-0.320	Typhoon Karen / Oct. 11-12, 2016	5 - Year
172	8.098539	123.477961	1.28	1.60	-0.322	Typhoon Karen / Oct. 11-12, 2016	5 - Year
173	8.098664	123.477933	1.33	1.34	-0.006	Typhoon Karen / Oct. 11-12, 2016	5 - Year
174	8.098911	123.477875	1.20	0.75	0.451	Typhoon Karen / Oct. 11-12, 2016	5 - Year
175	8.099314	123.477806	0.87	0.90	-0.031	Typhoon Karen / Oct. 11-12, 2016	5 - Year
176	8.096033	123.492673	0.28	1.10	-0.820	Typhoon Karen / Oct. 11-12, 2016	5 - Year
177	8.095711	123.493439	0.03	1.10	-1.070	Typhoon Karen / Oct. 11-12, 2016	5 - Year
178	8.096593	123.492626	0.12	0.60	-0.480	Typhoon Karen / Oct. 11-12, 2016	5 - Year
179	8.096559	123.492578	0.12	0.30	-0.180	Typhoon Karen / Oct. 11-12, 2016	5 - Year
180	8.096701	123.492462	0.07	0.40	-0.330	Typhoon Karen / Oct. 11-12, 2016	5 - Year
181	8.096730	123.492359	0.08	0.40	-0.320	Typhoon Karen / Oct. 11-12, 2016	5 - Year
182	8.096468	123.492364	0.06	0.50	-0.440	Typhoon Karen / Oct. 11-12, 2016	5 - Year
183	8.096652	123.492104	0.10	0.60	-0.500	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
184	8.096627	123.492117	0.03	0.60	-0.570	Typhoon Karen / Oct. 11-12, 2016	5 - Year
185	8.096622	123.492085	0.03	0.60	-0.570	Typhoon Karen / Oct. 11-12, 2016	5 - Year
186	8.096679	123.492051	0.25	0.60	-0.350	Typhoon Karen / Oct. 11-12, 2016	5 - Year
187	8.096851	123.491851	0.31	0.80	-0.490	Typhoon Karen / Oct. 11-12, 2016	5 - Year
188	8.096843	123.491808	0.90	0.90	0.000	Typhoon Karen / Oct. 11-12, 2016	5 - Year
189	8.096897	123.491776	0.14	1.00	-0.860	Typhoon Karen / Oct. 11-12, 2016	5 - Year
190	8.096882	123.491674	0.28	2.00	-1.720	Typhoon Karen / Oct. 11-12, 2016	5 - Year
191	8.096912	123.491664	0.28	2.00	-1.720	Typhoon Karen / Oct. 11-12, 2016	5 - Year
192	8.096959	123.491660	0.03	1.00	-0.970	Typhoon Karen / Oct. 11-12, 2016	5 - Year
193	8.096940	123.491629	0.03	1.00	-0.970	Typhoon Karen / Oct. 11-12, 2016	5 - Year
194	8.096981	123.491586	0.03	1.00	-0.970	Typhoon Karen / Oct. 11-12, 2016	5 - Year
195	8.097038	123.491559	0.03	1.00	-0.970	Typhoon Karen / Oct. 11-12, 2016	5 - Year
196	8.097304	123.491239	0.03	0.00	0.030	Typhoon Karen / Oct. 11-12, 2016	5 - Year
197	8.099651	123.487711	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
198	8.099313	123.487790	0.47	0.80	-0.326	Typhoon Karen / Oct. 11-12, 2016	5 - Year
199	8.099276	123.487561	0.75	0.80	-0.051	Typhoon Karen / Oct. 11-12, 2016	5 - Year
200	8.099218	123.487893	0.31	0.00	0.310	Typhoon Karen / Oct. 11-12, 2016	5 - Year
201	8.100108	123.487664	0.78	2.05	-1.275	Typhoon Karen / Oct. 11-12, 2016	5 - Year
202	8.100253	123.487611	1.09	1.44	-0.355	Typhoon Karen / Oct. 11-12, 2016	5 - Year
203	8.100747	123.487572	0.06	0.21	-0.150	Typhoon Karen / Oct. 11-12, 2016	5 - Year
204	8.101086	123.487689	1.42	0.86	0.560	Typhoon Karen / Oct. 11-12, 2016	5 - Year
205	8.101664	123.487739	0.25	0.80	-0.550	Typhoon Karen / Oct. 11-12, 2016	5 - Year
206	8.101125	123.487631	0.03	0.97	-0.940	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
207	8.100947	123.487614	0.03	1.85	-1.820	Typhoon Karen / Oct. 11-12, 2016	5 - Year
208	8.100603	123.487703	1.22	1.45	-0.229	Typhoon Karen / Oct. 11-12, 2016	5 - Year
209	8.100414	123.487664	1.41	1.72	-0.309	Typhoon Karen / Oct. 11-12, 2016	5 - Year
210	8.100367	123.487722	1.41	1.70	-0.289	Typhoon Karen / Oct. 11-12, 2016	5 - Year
211	8.100011	123.487464	0.34	1.10	-0.760	Typhoon Karen / Oct. 11-12, 2016	5 - Year
212	8.100122	123.487422	0.27	0.70	-0.430	Typhoon Karen / Oct. 11-12, 2016	5 - Year
213	8.099917	123.487094	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
214	8.099861	123.486919	0.03	1.22	-1.190	Typhoon Karen / Oct. 11-12, 2016	5 - Year
215	8.099806	123.486844	0.33	1.60	-1.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
216	8.099750	123.486842	0.33	2.04	-1.710	Typhoon Karen / Oct. 11-12, 2016	5 - Year
217	8.099861	123.486694	1.28	1.68	-0.403	Typhoon Karen / Oct. 11-12, 2016	5 - Year
218	8.099353	123.487424	4.06	0.80	3.255	Typhoon Karen / Oct. 11-12, 2016	5 - Year
219	8.099448	123.487384	3.62	1.50	2.118	Typhoon Karen / Oct. 11-12, 2016	5 - Year
220	8.099453	123.487412	3.62	1.10	2.518	Typhoon Karen / Oct. 11-12, 2016	5 - Year
221	8.099542	123.487217	3.56	1.10	2.461	Typhoon Karen / Oct. 11-12, 2016	5 - Year
223	8.099687	123.486988	0.03	0.90	-0.870	Typhoon Karen / Oct. 11-12, 2016	5 - Year
224	8.099728	123.486928	0.03	1.50	-1.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year
225	8.099870	123.487040	0.03	0.90	-0.870	Typhoon Karen / Oct. 11-12, 2016	5 - Year
226	8.099840	123.486966	0.03	1.30	-1.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
227	8.098133	123.488564	0.03	1.50	-1.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year
228	8.098039	123.488739	1.08	1.20	-0.121	Typhoon Karen / Oct. 11-12, 2016	5 - Year
229	8.097956	123.488869	1.04	1.50	-0.459	Typhoon Karen / Oct. 11-12, 2016	5 - Year
230	8.097944	123.488944	0.93	1.63	-0.696	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
231	8.098058	123.489000	2.14	2.40	-0.261	Typhoon Karen / Oct. 11-12, 2016	5 - Year
232	8.097997	123.489122	0.86	1.65	-0.795	Typhoon Karen / Oct. 11-12, 2016	5 - Year
233	8.098039	123.489089	2.14	1.65	0.489	Typhoon Karen / Oct. 11-12, 2016	5 - Year
234	8.097958	123.489081	0.96	1.30	-0.344	Typhoon Karen / Oct. 11-12, 2016	5 - Year
235	8.096736	123.489542	0.03	0.70	-0.670	Typhoon Karen / Oct. 11-12, 2016	5 - Year
236	8.097371	123.490484	0.76	1.30	-0.539	Typhoon Karen / Oct. 11-12, 2016	5 - Year
237	8.097325	123.490372	0.68	1.30	-0.619	Typhoon Karen / Oct. 11-12, 2016	5 - Year
238	8.097377	123.490333	0.50	0.70	-0.204	Typhoon Karen / Oct. 11-12, 2016	5 - Year
239	8.097378	123.490308	0.50	0.70	-0.204	Typhoon Karen / Oct. 11-12, 2016	5 - Year
240	8.097326	123.490102	0.58	1.30	-0.716	Typhoon Karen / Oct. 11-12, 2016	5 - Year
241	8.097561	123.490301	3.58	0.70	2.878	Typhoon Karen / Oct. 11-12, 2016	5 - Year
242	8.097579	123.490269	2.58	1.10	1.478	Typhoon Karen / Oct. 11-12, 2016	5 - Year
243	8.097508	123.490070	0.66	0.90	-0.243	Typhoon Karen / Oct. 11-12, 2016	5 - Year
244	8.097489	123.489924	0.66	1.40	-0.736	Typhoon Karen / Oct. 11-12, 2016	5 - Year
245	8.097392	123.489899	0.64	1.40	-0.757	Typhoon Karen / Oct. 11-12, 2016	5 - Year
246	8.097341	123.489796	0.77	1.40	-0.633	Typhoon Karen / Oct. 11-12, 2016	5 - Year
247	8.097651	123.489727	0.99	1.30	-0.314	Typhoon Karen / Oct. 11-12, 2016	5 - Year
248	8.097632	123.489534	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
249	8.096610	123.489453	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
250	8.096831	123.489499	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
251	8.096539	123.489409	0.03	0.60	-0.570	Typhoon Karen / Oct. 11-12, 2016	5 - Year
252	8.103566	123.479711	0.84	0.90	-0.060	Typhoon Karen / Oct. 11-12, 2016	5 - Year
253	8.103549	123.479909	0.89	0.90	-0.009	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
254	8.103729	123.479728	1.10	0.90	0.196	Typhoon Karen / Oct. 11-12, 2016	5 - Year
255	8.103749	123.479630	0.91	0.90	0.011	Typhoon Karen / Oct. 11-12, 2016	5 - Year
256	8.103662	123.479301	0.78	1.20	-0.422	Typhoon Karen / Oct. 11-12, 2016	5 - Year
257	8.103878	123.479739	0.98	0.90	0.080	Typhoon Karen / Oct. 11-12, 2016	5 - Year
258	8.103818	123.479866	1.08	0.90	0.179	Typhoon Karen / Oct. 11-12, 2016	5 - Year
259	8.103875	123.479899	1.08	0.90	0.179	Typhoon Karen / Oct. 11-12, 2016	5 - Year
260	8.103909	123.479916	1.06	0.90	0.163	Typhoon Karen / Oct. 11-12, 2016	5 - Year
261	8.104121	123.479691	0.85	0.60	0.253	Typhoon Karen / Oct. 11-12, 2016	5 - Year
262	8.104682	123.480358	0.03	0.80	-0.770	Typhoon Karen / Oct. 11-12, 2016	5 - Year
263	8.104468	123.479763	0.03	0.70	-0.670	Typhoon Karen / Oct. 11-12, 2016	5 - Year
264	8.104418	123.479746	0.79	0.00	0.792	Typhoon Karen / Oct. 11-12, 2016	5 - Year
265	8.104374	123.479994	1.23	0.90	0.325	Typhoon Karen / Oct. 11-12, 2016	5 - Year
266	8.104267	123.479316	0.03	0.70	-0.670	Typhoon Karen / Oct. 11-12, 2016	5 - Year
267	8.104036	123.478968	0.23	0.60	-0.371	Typhoon Karen / Oct. 11-12, 2016	5 - Year
268	8.083775	123.493153	0.03	0.51	-0.480	Typhoon Karen / Oct. 11-12, 2016	5 - Year
269	8.084022	123.493028	0.54	0.54	0.004	Typhoon Karen / Oct. 11-12, 2016	5 - Year
270	8.084803	123.492919	0.75	0.63	0.120	Typhoon Karen / Oct. 11-12, 2016	5 - Year
271	8.084922	123.492928	0.43	0.55	-0.120	Typhoon Karen / Oct. 11-12, 2016	5 - Year
272	8.085028	123.493011	0.68	0.52	0.164	Typhoon Karen / Oct. 11-12, 2016	5 - Year
273	8.085450	123.492972	0.49	0.62	-0.133	Typhoon Karen / Oct. 11-12, 2016	5 - Year
274	8.085569	123.492897	0.55	0.63	-0.081	Typhoon Karen / Oct. 11-12, 2016	5 - Year
275	8.085767	123.492828	0.66	0.86	-0.204	Typhoon Karen / Oct. 11-12, 2016	5 - Year
276	8.085931	123.492814	0.59	0.63	-0.040	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
277	8.086186	123.492828	0.25	0.11	0.140	Typhoon Karen / Oct. 11-12, 2016	5 - Year
278	8.086144	123.492847	0.29	0.44	-0.150	Typhoon Karen / Oct. 11-12, 2016	5 - Year
279	8.085250	123.493014	0.50	0.58	-0.080	Typhoon Karen / Oct. 11-12, 2016	5 - Year
280	8.085222	123.493094	0.36	0.18	0.180	Typhoon Karen / Oct. 11-12, 2016	5 - Year
281	8.084403	123.492764	0.64	0.27	0.371	Typhoon Karen / Oct. 11-12, 2016	5 - Year
282	8.084136	123.492894	0.81	0.68	0.125	Typhoon Karen / Oct. 11-12, 2016	5 - Year
283	8.083808	123.493597	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
284	8.083814	123.493658	0.04	0.32	-0.280	Typhoon Karen / Oct. 11-12, 2016	5 - Year
285	8.083458	123.493442	0.18	0.29	-0.110	Typhoon Karen / Oct. 11-12, 2016	5 - Year
286	8.083339	123.493167	0.43	0.40	0.030	Typhoon Karen / Oct. 11-12, 2016	5 - Year
287	8.077311	123.497917	0.03	0.40	-0.370	Typhoon Karen / Oct. 11-12, 2016	5 - Year
288	8.077286	123.497489	0.19	0.73	-0.540	Typhoon Karen / Oct. 11-12, 2016	5 - Year
289	8.077531	123.497514	0.03	0.60	-0.570	Typhoon Karen / Oct. 11-12, 2016	5 - Year
290	8.076869	123.497806	0.06	0.53	-0.470	Typhoon Karen / Oct. 11-12, 2016	5 - Year
291	8.076586	123.497933	0.03	0.30	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
292	8.076256	123.500333	0.05	0.60	-0.550	Typhoon Karen / Oct. 11-12, 2016	5 - Year
293	8.076756	123.456125	0.85	0.90	-0.055	Typhoon Karen / Oct. 11-12, 2016	5 - Year
294	8.076925	123.456061	0.85	0.80	0.054	Typhoon Karen / Oct. 11-12, 2016	5 - Year
295	8.076947	123.456175	0.95	0.72	0.226	Typhoon Karen / Oct. 11-12, 2016	5 - Year
296	8.077119	123.456072	0.86	0.65	0.214	Typhoon Karen / Oct. 11-12, 2016	5 - Year
297	8.077514	123.455778	0.95	1.00	-0.049	Typhoon Karen / Oct. 11-12, 2016	5 - Year
298	8.077503	123.455697	1.00	1.16	-0.165	Typhoon Karen / Oct. 11-12, 2016	5 - Year
299	8.077244	123.456322	0.97	0.83	0.137	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
300	8.077456	123.456297	1.05	0.93	0.123	Typhoon Karen / Oct. 11-12, 2016	5 - Year
301	8.070881	123.455803	1.16	1.19	-0.029	Typhoon Karen / Oct. 11-12, 2016	5 - Year
302	8.070861	123.455608	1.05	0.88	0.173	Typhoon Karen / Oct. 11-12, 2016	5 - Year
303	8.070892	123.455489	0.92	0.82	0.095	Typhoon Karen / Oct. 11-12, 2016	5 - Year
304	8.065136	123.464408	0.98	0.90	0.082	Typhoon Karen / Oct. 11-12, 2016	5 - Year
305	8.065053	123.464714	0.78	1.05	-0.270	Typhoon Karen / Oct. 11-12, 2016	5 - Year
306	8.065269	123.464775	0.95	1.04	-0.090	Typhoon Karen / Oct. 11-12, 2016	5 - Year
307	8.065239	123.464839	0.86	0.50	0.360	Typhoon Karen / Oct. 11-12, 2016	5 - Year
308	8.065303	123.465222	1.12	0.70	0.421	Typhoon Karen / Oct. 11-12, 2016	5 - Year
309	8.065428	123.465917	1.26	0.63	0.628	Typhoon Karen / Oct. 11-12, 2016	5 - Year
310	8.064633	123.466439	1.07	0.63	0.444	Typhoon Karen / Oct. 11-12, 2016	5 - Year
311	8.066272	123.462761	0.53	0.90	-0.373	Typhoon Karen / Oct. 11-12, 2016	5 - Year
312	8.066319	123.462867	0.85	0.45	0.402	Typhoon Karen / Oct. 11-12, 2016	5 - Year
313	8.065822	123.462653	1.16	0.60	0.556	Typhoon Karen / Oct. 11-12, 2016	5 - Year
314	8.065639	123.462433	1.02	0.70	0.323	Typhoon Karen / Oct. 11-12, 2016	5 - Year
315	8.065733	123.462011	0.78	0.52	0.261	Typhoon Karen / Oct. 11-12, 2016	5 - Year
316	8.066064	123.460836	0.76	0.63	0.131	Typhoon Karen / Oct. 11-12, 2016	5 - Year

Annex 12. Educational Institutions Affected by Flooding in Salug Diut Flood-plain

ZAMBOANGA DEL SUR				
MAHAYAG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Roman Tagdulang Elem. School	Diwan			
Maestrado Elem. School	Guripan			
Villasis Elem. School	Guripan	Low	Medium	Medium
Maestrado Elem. School	Guripan		Low	Low
Day Care Center	Lourmah		Low	Medium
Miligan Elementary School	Lourmah	Medium	Medium	Medium
San Isidro Central School	Lourmah			
Mabuhay Elem. School	San Isidro			

ZAMBOANGA DEL SUR				
MOLAVE				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Blancia Central School	Blancia		Low	Medium
Day Care Center	BogoCapalaran			
Molave Bliss Elementary School	BogoCapalaran	Medium	Medium	Medium
Zamboanga del Sur Maritime Institure of Technology	Culo	Low	Medium	Medium
Day Care Center	Dalaon			
Anatalio Y Lovitania Elem. School	Dalaon	Low	Low	Medium
Day Care Center	Dalaon		Low	Low
BogoCapalaran Elem. School	Lower Dimalinao			
Lower Dimalinao Elem. School	Lower Dimalinao			
Principal's Office	Lower Dimalinao			
Parasan National High School	Mabuhay			
Parasan Elementary School	Mabuhay			
Parasan National High School	Mabuhay	Low	Low	Low
Molave Regional Pilot School	Maloloy-On	Medium	Medium	Medium
MRPS Sped Center	Maloloy-On	Medium	Medium	Medium
Ornamental Plants. Project of CWL	Maloloy-On	Medium	Medium	Medium
Day Care Center	Miligan	Medium	Medium	High
Rizal Elem. School	Miligan	Medium	High	High
Rizal Elem. School	Miligan	Medium	High	High
Brgy. Alang-alang Elem. School	Sudlon			

ZAMBOANGA DEL SUR				
TAMBULIG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Dalaon Elem. School	Libato			

Annex 13. Health Institutions Affected by Flooding in Salug Diut Floodplain

ZAMBOANGA DEL SUR				
MAHAYAG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Health Center	Guripan		Medium	Medium
Purok GK Center	Guripan			
Villasis Health Center	Guripan	Medium	Medium	Medium
Health Center	Lourmah	Low	Medium	Medium
Health Center	Lourmah			
Bliss Health Center	San Isidro	Medium	Medium	Medium

ZAMBOANGA DEL SUR				
MOLAVE	Barangay	Rainfall Scenario		
		Building Name	Barangay	Rainfall Scenario
		5-year	25-year	100-year
Blancia Hospital	Blancia		Low	Medium
Brgy. Health Center	BogoCapalaran			
Salug Valley Medical Center	Culo		Low	Low
Salug Valley Medical Center	Makuguihon			
Acebedo Optical Clinic	Maloloy-On	Medium	Medium	Medium
Estrella-Obenza Dental Clinic's Laboratory	Maloloy-On	Medium	Medium	Medium
Expert Care	Maloloy-On	Low	Low	Medium
Mercury Drug	Maloloy-On		Low	Low
Salug Valley Medical Center	Maloloy-On	Medium	Medium	Medium
Health Center	Miligan	Medium	Medium	High

ZAMBOANGA DEL SUR				
TAMBULIG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Dalaon Health Center	Libato			