HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Lasang River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
University of the Philippines Mindanao

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LIST OF ACRONYMS AND ABBREVIATIONS

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

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1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Mindanao (UPM). UPM is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the thirteen (13) river basins in the Davao Region. The university is located in Davao City in the province of Davao del Sur.

1.2 Overview of the Lasang River Basin

The Lasang River is a stream in the province of Davao del Norte, on the southeastern side of Mindanao. Its headwaters originate from the mountains of Talaingod flowing down to northeast of Davao City, traverses through Panabo City, and finally drains towards the Davao Gulf. It is bounded by the Province of Bukidnon to the north and west, by the Municipality of Kapalong to the right, and by Davao City to the south. The river serves as one of Davao City's major drainage systems (HELP Davao Network, 2016). Lasang was derived from a Visayan word, which means "forest" (Business Week Mindanao, 2011).

The Lasang River Basin covers portions of the Municipality of Kapalong and Panabo City in Davao del Norte, and Davao City in Davao del Sur. The Department of Environment and Natural Resources (DENR) River Basin Control Office (RCBO) identified it to be as one of the one hundred forty (140) critical watersheds in the Philippines, having a drainage area of 467 km2 and an estimated 934 million cubic meter annual run-off. It is also one of the eight (8) principal river basins in Davao City (DOST, 2016). It has fifty-three (53) sub basins, twenty-six (26) junctions, and twenty-six (26) reaches.

The Lasang River Basin serves as the political boundary between the cities of Davao in Davao del Sur, and Panabo in Davao del Norte (ThinkNature, 2017). The municipality of Talaingod is located in Davao del Norte, northeast of Davao City. Currently, the total population of people residing within the immediate vicinity of the Lasang River is 28, 114, which is distributed among seven (7) barangays, namely: Alejandra Navarro, J.P. Laurel, Tagpore, Little Panay, Maduao, Sindaton, and Datu Abdul Dadia (NSO, 2010).

The river basin's main stem, the Lasang River, passes along Panabo City down to Davao City; and is part of the thirteen (13) river systems in the Davao Region under the PHIL-LiDAR 1 partner university, UPM. Panabo City is a component city in the province of Davao del Norte. It was formerly a barangay of Tagum City (previously Magugpo), and became a town on July 19, 1949 through the Presidential Proclamation No. 236 of President Manuel A. Roxas. It later achieved its cityhood status by virtue of Republic Act No. 9015, ratified on March 31, 2001 (Local Government of Panabo City, 2017). Panabo City is known as the "Banana Capital of the Philippines" due to its numerous banana plantations.

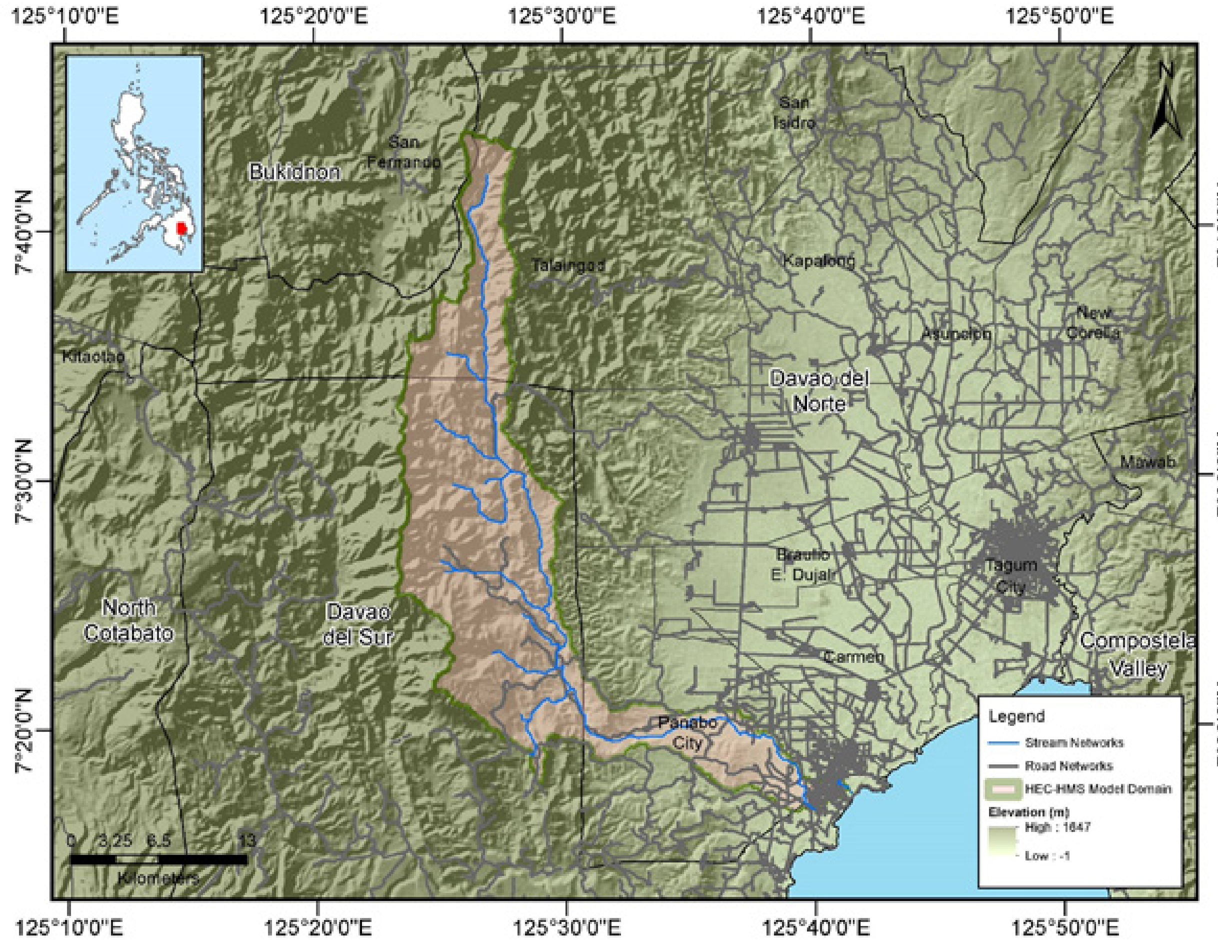

Figure 1. Location map of the Lasang River Basin (in brown)

The headwaters of the river system are located in the Pantaron Mountain Range, which is also called the Central Cordillera of Mindanao. The mountain range spans the regions of Northern Mindanao, Caraga, and Southern Mindanao; and is considered to be a biogeographic sub-region that houses rare species of flora and fauna (Poffenberger, 2003; Balane, 2012). The Lasang Watershed sits on the southeastern side of the mountain range. Environmental disturbances in the high-altitude areas or the uplands will have serious effects with the water systems in the lowland areas (Ragragio, 2014). The river used to be the main water highway of the Ata-Manobo tribes in Talaingod, Davao del Norte (ThinkNature, 2017). The Kalagans, or members of the Kaagan tribe, on the other hand, historically resided in mouths of rivers, including the Lasang River (City of Davao, 2011). The river once served as a site for the people from the highlands and the lowlands to congregate (Narboada, 2010).

he river is rich in mineral resources, such as limestone, guan, phosphate, and sand and gravel deposits. Mining of sand and gravel deposits serves as a source of income for the locals. Siltation from the Lasang River, especially after heavy rainfall, poses a threat to marine resources especially in the Panabo coastal areas. If not controlled, this phenomenon could gravely destroy marine life (Rare, 2013).

In 2011, a severe flood caused by strong storms destroyed the protection dike in the Lasang River, washing out rice lands and plantations, including banana plantations in Panabo City (Monforte, 2014; Damo, 2016). The said protection dike was built by the National Irrigation Administration (NIA) in 1978 to safeguard the Lasang River Irrigation System dam (Business Mirror, 2014).

According to the area's residents, local rainfall and upstream rainfall have been the usual causes of flooding near the river from 2000-2017. However, the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) only noted typhoon events recently, such as Pablo in 2012, and Crising in 2013. A recent flooding occurred on August 20, 2014, which displaced fifty (50) families due to torrential rains that lasted for an hour.

Figure 2. Lasang River flood history

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LASANG 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

To initiate the LiDAR acquisition survey of the Lasang Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the Lasang Floodplain in Davao del Norte. These missions were planned for seventeen (17) lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time, using the Gemini LiDAR sensor (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system is found in Table 1. Figure 3 shows the flight plans and base stations for Lasang floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK82A	1000	35	40	100	40	130	5
BLK82B	1000	35	40	100	40	130	5
BLK82C	1000	35	40	100	40	130	5
BLK82D	800	35	50	125	40	130	5
BLK82E	1000	30	40	100	50	130	5
BLK82F	850	30	50	125	40	130	5
BLK82G	900	30	40	125	50	130	5
BLK82H	1000	30	40	100	50	130	5
COM_BLKB	1000	35	40	100	50	130	5
COM_BLKC	1000	35	40	100	50	130	5
COM_BLKD	1000	35	40	100	50	130	5

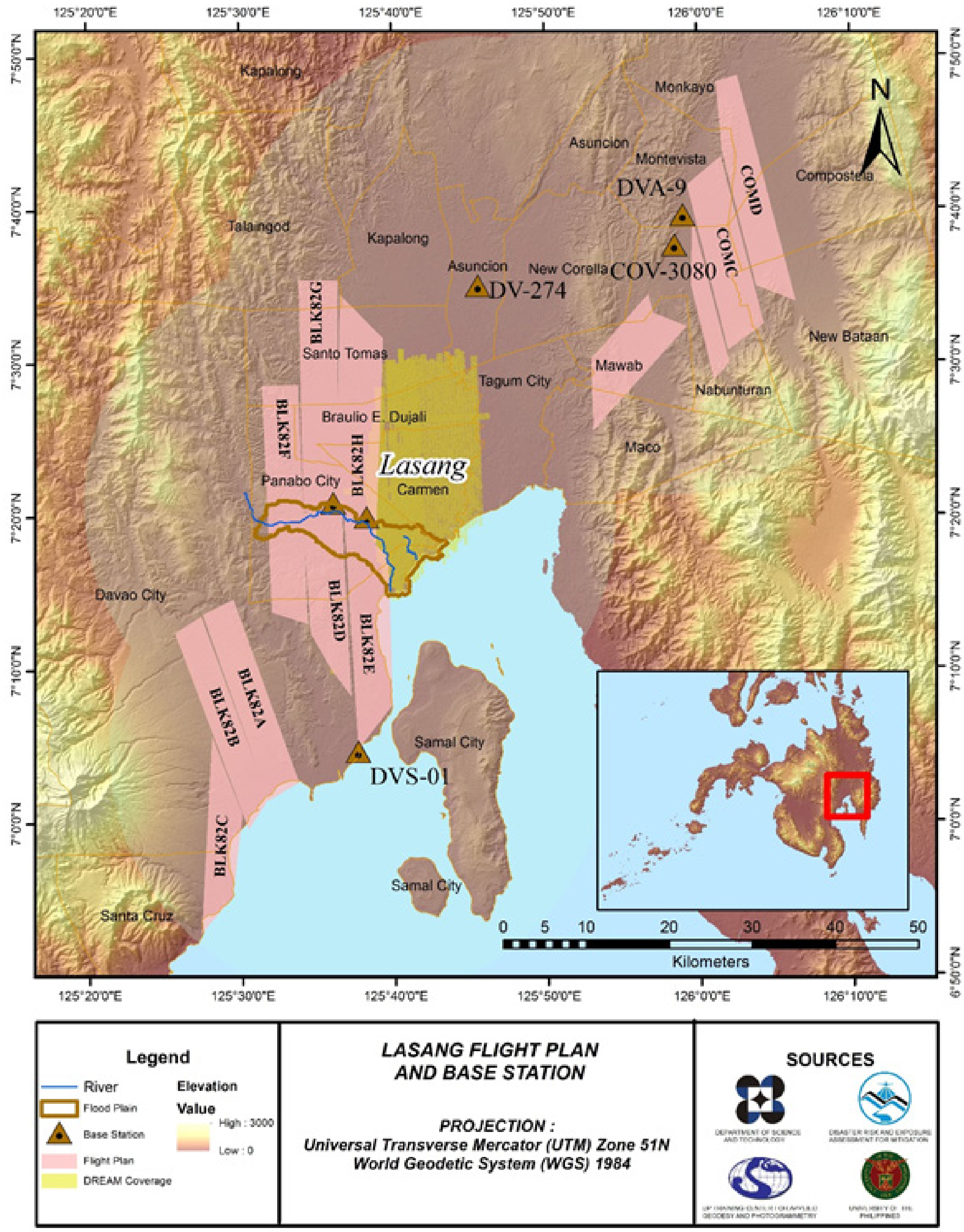

Figure 3. Flight plans and base stations used to cover the Lasang floodplain survey

2.2 Ground Base Station

The field team for this undertaking was able to recover four (4) NAMRIA ground control points: DVS-01 and DVA-133, both of second (2nd) order accuracy; and DVA-3237 and COV-3080, both of fourth (4th) order accuracy. Two (2) NAMRIA benchmarks were recovered: DV-274 and DVA-9, both of second (2nd) order accuracy. The benchmarks were used as vertical reference points, and were also established as ground control points. One (1) ground control point, DVS-01A, was also established. Fourth (4th) order ground control stations, established points, and benchmarks where then re-processed to obtain coordinates of second (2nd) order accuracy. The certifications for the NAMRIA reference points are found in Annex 2. The baseline processing reports for the re-processed control points and benchmarks are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey, held on July 16 – August 13, 2014. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Lasang floodplain are shown in Figure 3.The composition of the project team is shown in Annex 4.

Figure 4 to Figure 10 show the recovered NAMRIA reference and established points within the area. Table 2 to Table 8 enumerate the details about the NAMRIA control stations, benchmarks and established points. Table 9 lists all ground control points occupied during the acquisition, together with the corresponding dates of utilization.

Figure 4. GPS set-up over DVA-133 as located in front of the barangay hall of Manay (a) and NAMRIA reference point DVA-133 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point DVA-133 used as base station for the LiDAR data acquisition.

Station Name	DVA-133	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°20’57.02014” North 125°35’57.50044” East 23.957 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	566168.597 meters 812626.211 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°20’53.82313” North 125°36’2.99870” East 96.163 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	786976.44 meters 813130.63 meters

Figure 5. GPS set-up over DVA-3237 located beside the flagpole inside the compound of Nanyo Elementary School (a) and NAMRIA reference point DVA-3237 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point DVA-3237 used as base station for the LiDAR data acquisition.

Station Name	DVA-3237	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°19'59.95215" North 125°38'7.26797" East 17.228 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°19'56.76267" North 125°38'12.76731" East 89.553 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	790969.206 meters 811399.786 meters

Figure 6. GPS set-up over DVS-01 located at the east side of the pier in Davao City

Table 4. Details of the recovered NAMRIA horizontal control point DVS-01 used as base station for the LiDAR data acquisition.

Station Name	DVS-01	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°4’41.48387” North 125°37’31.24815” East -4.507 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	569084.935 meters 782663.345 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°4’38.36201” North 125°37’36.77094” East 68.275 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	790026.110 meters 783162.170 meters

Figure 7. GPS set-up over NW-123 in Cadiz, Negros Occidental going to San Carlos, along the national road (a) and NAMRIA reference point NW-123 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point NW-123 used as base station for the LiDAR Acquisition.

Station Name	DVS-01A	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°4’41.46785” North 125°37’31.08587” East -4.269 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°4’38.34598” North 125°37’36.60866” East 68.513 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	790021.135 meters 783161.647 meters

Figure 8. GPS set-up over COV-3080 as recovered in Barangay Magsaysay, Nabunturan, Compostela Valley (a) and NAMRIA reference point COV-3080 (b) as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point COV-3080 used as base station for the LiDAR data acquisition.

Station Name	COV-3080	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°37’39.82070” North 125°58’23.27481” East 81.656 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°37’36.58302” North 125°58’28.74368” East 154.250 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	828073.884 meters 844220.262 meters

Figure 9. GPS set-up over BMDVA-9 as recovered in Barangay Magsaysay, Nabunturan, Compostela Valley (a) and NAMRIA reference point BMDVA-9 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point BMDVA-9 used as base station for the LiDAR data acquisition.

Station Name	BMDVA-9	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°39’38.63849” North 125°58’55.85071” East 68.958 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°39’35.39278” North 125°59’1.31648” East 141.510 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	829047.949 meters 847880.427 meters

Figure 10. GPS set-up over BMDV-274 as recovered along the Tagum-Laak National Highway (a) and NAMRIA reference point BMDV-274 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point BMDV-274 used as base station for the LiDAR data acquisition.

Station Name	BMDVA-9	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°35'5.05546" North 125°45'29.30628" East 11.984 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7°35'1.80976" North 125°45'34.78141" East 84.130 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	804362.241 meters 839304.889 meters

Table 9. Ground control points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 22, 2014	7386GC	2BLK82CSD203A	DVS-01 & DVS-01A
July 23, 2014	7388GC	2BLK82AB204A	DVA-133 & DVA-3237
July 24, 2014	7390GC	2BLK82FH205A	DVA-133 & DVA-3237
July 27, 2014	7396GC	2BLK82GSH208A	DVS-01 & DVS-01A
July 29, 2014	7401GC	2BLK82EFGHS210B	DVS-01 & DVS-01A
August 9, 2014	7422GC	2COMA221A	COV-3080 & BMDVA-9
August 9, 2014	7423GC	2COMBSCD221B	COV-3080 & BMDVA-9
August 10, 2014	7424GC	2BLKDS222A	COV-3080 & BMDVA-9
August 11, 2014	7426GC	2BLK82V223A	DVA-133 & DVA-3237
August 11, 2014	7427GC	2BLK82V223B	DVA-133 & DVA-3237
August 13, 2014	7430GC	2TAGV225A	DV-274

2.3 Flight Missions

A total of eleven (11) flight missions were conducted to complete the LiDAR data acquisition in Lasang Floodplain, for a total of thirty six hours and thirty one minutes (36+31) of flying time for RP-C9322. Two (2) flights were also performed that included the Lasang floodplain, under the DREAM Program, with total area of 319.48 square kilometers (Table 10). 43.77 square kilometers of the total area surveyed under the DREAM Program are within the floodplain. Eleven (11) missions were acquired using the Gemini LiDAR system, while the two (2) missions under the DREAM Program were acquired using Pegasus LiDAR system. Annex 6 presents the flight logs. Table 11 shows the total area of actual coverage per mission and the corresponding flying hours for each mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Lasang Floodplain.

Flight Number	Mission Name	Area Surveyed within the Floodplain (km2)
335P	1TGM1AS199A	162.18
377P	1TGM1ABS210A	157.30
TOTAL		319.48

Table 11. Flight missions for LiDAR data acquisition in Lasang Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
July 22, 2014	7386GC	86.81	249.11	29.05	220.06	NA	4	29
July 23, 2014	7388GC	110.18	205.14	19.87	185.27	NA	4	5
July 24, 2014	7390GC	123.21	284.80	22.62	262.18	NA	4	5
July 27, 2014	7396GC	130.60	238.05	24.61	213.44	NA	3	41
July 29, 2014	7401GC	110.18	83.27	20.09	63.18	NA	1	59
August 9, 2014	7422GC	103.13	186.59	0	186.59	NA	3	47
August 9, 2014	7423GC	78.14	154.44	0	154.44	NA	3	11
August 10, 2014	7424GC	78.14	87.31	0	87.31	NA	2	41
August 11, 2014	7426GC	244.88	95.83	16.38	79.45	NA	2	41
August 11, 2014	7427GC	251.00	47.89	0	47.89	NA	2	29
August 13, 2014	7430GC	78.14	76.83	0	76.83	NA	3	23
TOTAL	1394.41	1709.26	132.62	1576.64	NA	36	31	17
Total		2596.51	1723.73	222.59	1501.14	2905	34	14

Table 12. 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
7386GC	800	35	50	125	40	130	5
7388GC	1000	30	40	100	50	130	5
7390GC	900	30	40	125	50	130	5
7396GC	1000	30	40	125	50	130	5
7401GC	850	30	50	125	40	130	5
7422GC	1000	35	40	100	50	130	5
7423GC	1000	35	40	100	50	130	5
7424GC	1000	35	40	100	50	130	5
7426GC	1000	35	40	100	50	130	5
7427GC	1000	35	40	100	50	130	5
7430GC	1000	35	40	100	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Lasang floodplain (See Annex 7 for the flight status reports). The Lasang floodplain is located in the province of Davao Del Norte, with the majority within Panabo City. Nearly all of Braulio Dujali, Carmen and Panabo City are covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for the Lasang floodplain is presented in Figure 11.

Table 13. List of municipalities and cities surveyed during Lasang Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Davao del Norte	Braulio E. Dujali	119.23	114.76	96.25 %
	Carmen	151.04	140.82	93.23 %
	Panabo City	301.68	272.14	90.21 %
	Santo Tomas	268.12	180.44	67.30 %
	Tagum City	181.63	31.02	17.08 %
	Talaingod	599.48	32.59	5.44 %
	New Corella	262.33	13.03	4.97 %
	Asuncion	244.62	6.02	2.46 %
	Kapalong	873.30	13.55	1.55 %
Compostela Valley	Mawab	136.65	81.74	59.82 %
	Nabunturan	243.54	113.30	46.52 %
	Montevista	171.50	60.28	35.15 %
	Compostela	262.13	51.12	19.50 %
	Monkayo	658.85	59.50	9.03 %
	Maco	250.55	19.00	7.58 %
	New Bataan	579.69	42.04	7.25 %
Davao del Sur	Davao City	2224.82	351.98	15.82 %
	Santa Cruz	267.54	36.03	13.47 %

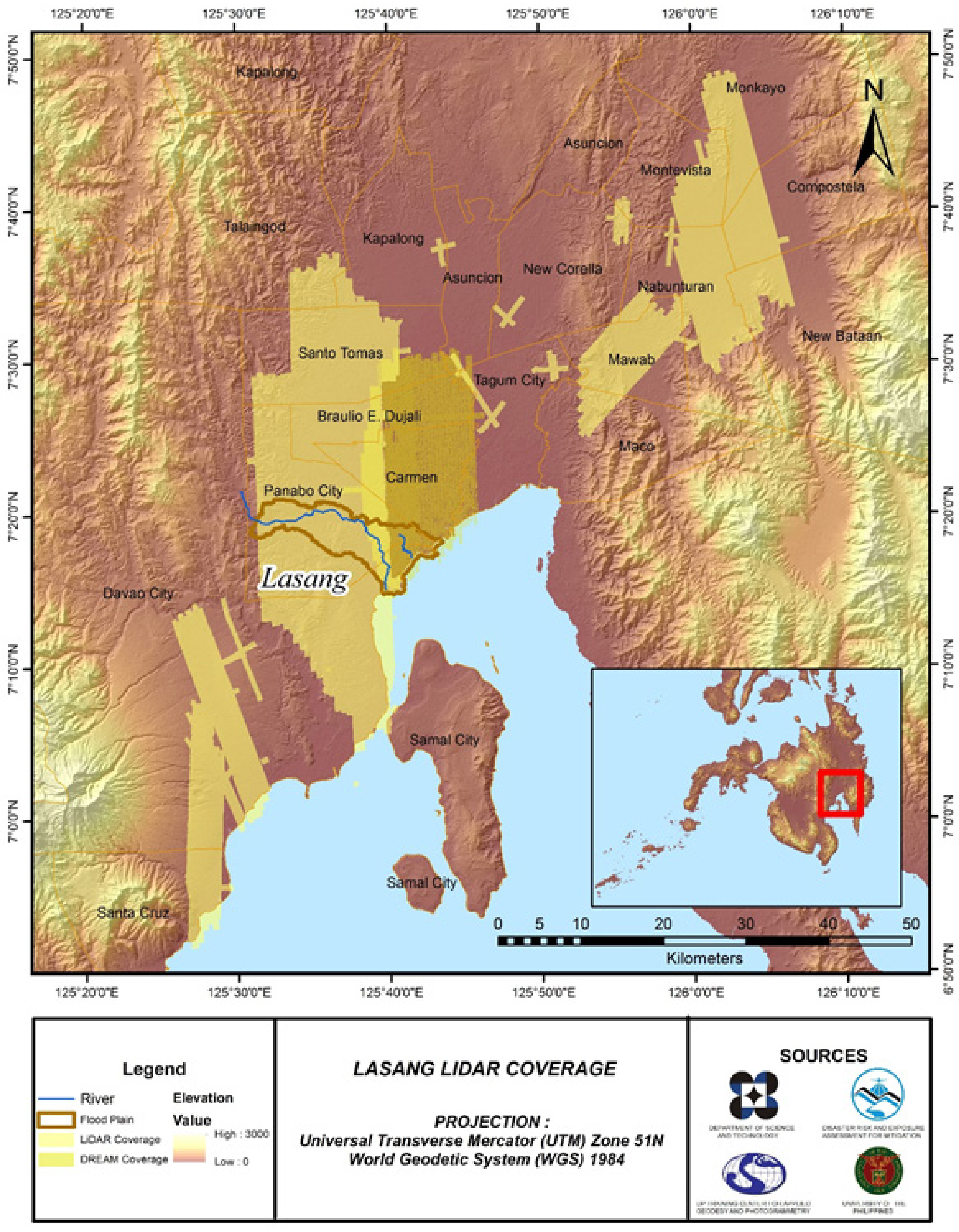

Figure 11. Actual LiDAR survey coverage of the Lasang Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LASANG 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 LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component (DAC) 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 conducted in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, were met. The point clouds were then categorized into various classes before generating Digital Elevation Models, such as the Digital Terrain Model and the 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 (DVBC). 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 diagram shown in Figure 12.

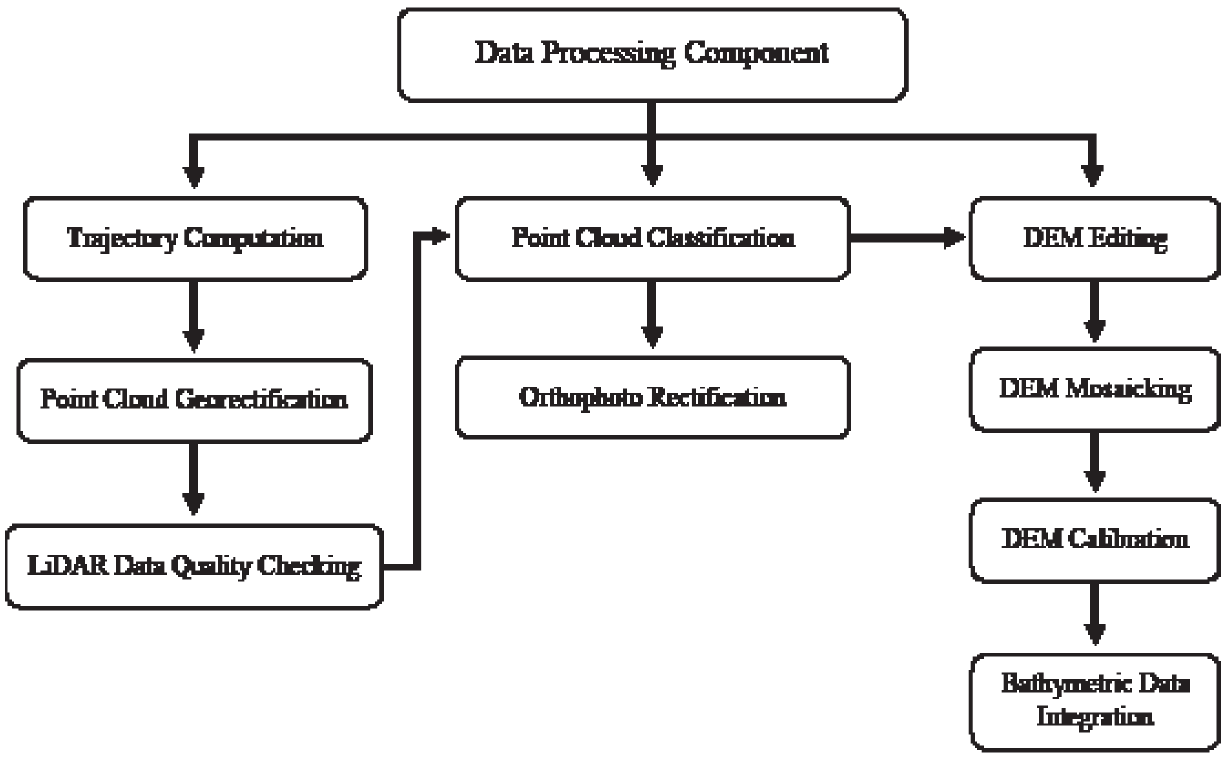

Figure 12. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for Lasang floodplain can be found in Annex 5. Missions flown during the first survey and second survey conducted in July and August 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Panabo City, Davao del Norte. The DAC transferred a total of 185.68 Gigabytes of Range data, 2.05 Gigabytes of POS data, and 91.43 Megabytes of GPS base station data to the data server on August 7, 2014 for the first survey, and on August 29, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Lasang River was fully transferred on August 29, 2014, as indicated on the Data Transfer Sheets for the Lasang floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7386GC, one of the Lasang flights, which are the North, East, and Down position RMSE values, are shown in Figure 13. 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 fell on July 20, 2014 00:00AM on that week. The y-axis is the RMSE value for that particular position.

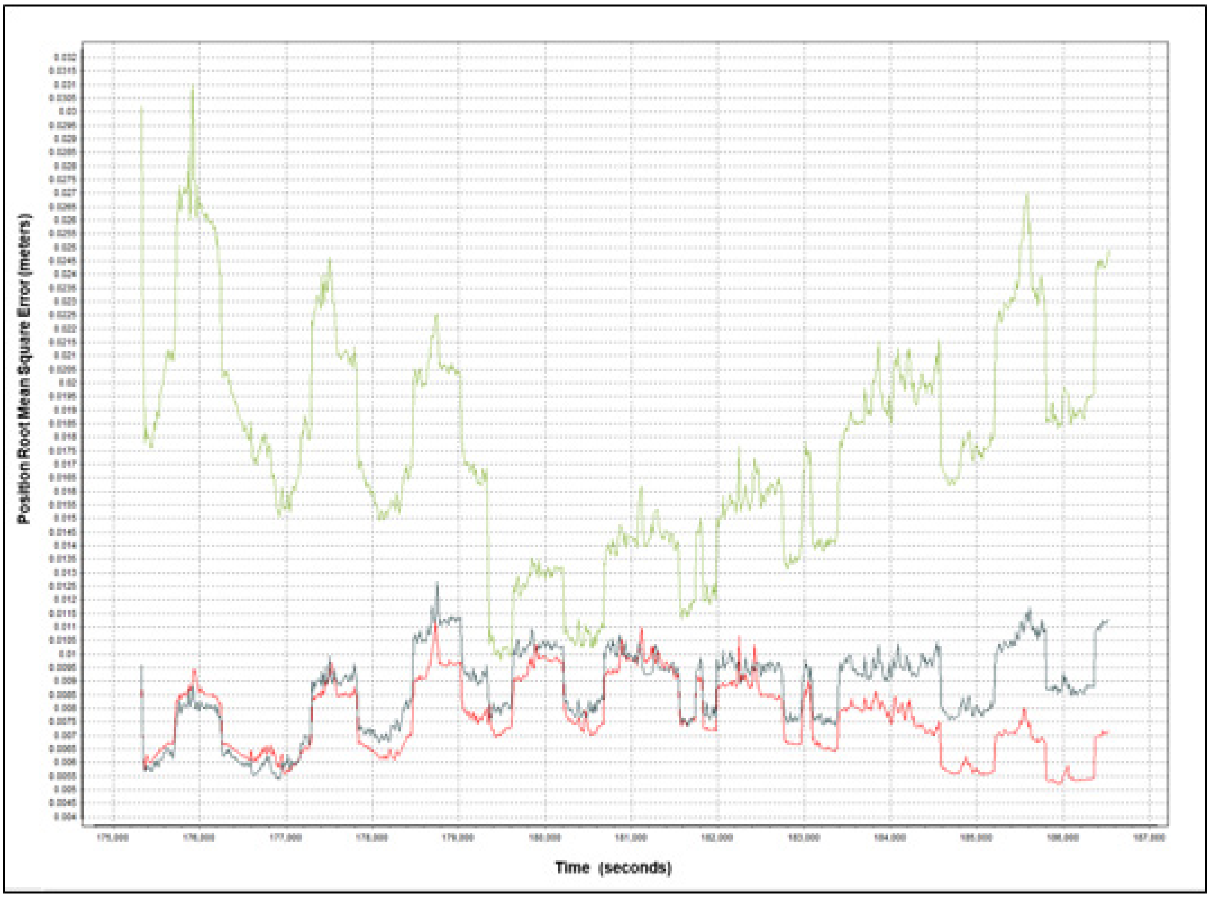

Figure 13. Smoothed Performance Metrics of a Lasang Flight 7386GC.

The time of flight was from 175000 seconds to 187000 seconds, which corresponds to morning of July 22, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute 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 corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 13 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 1. 25 centimeters, and the Down position RMSE peaks at 2.70 centimeters, which are within the prescribed accuracies described in the methodology.

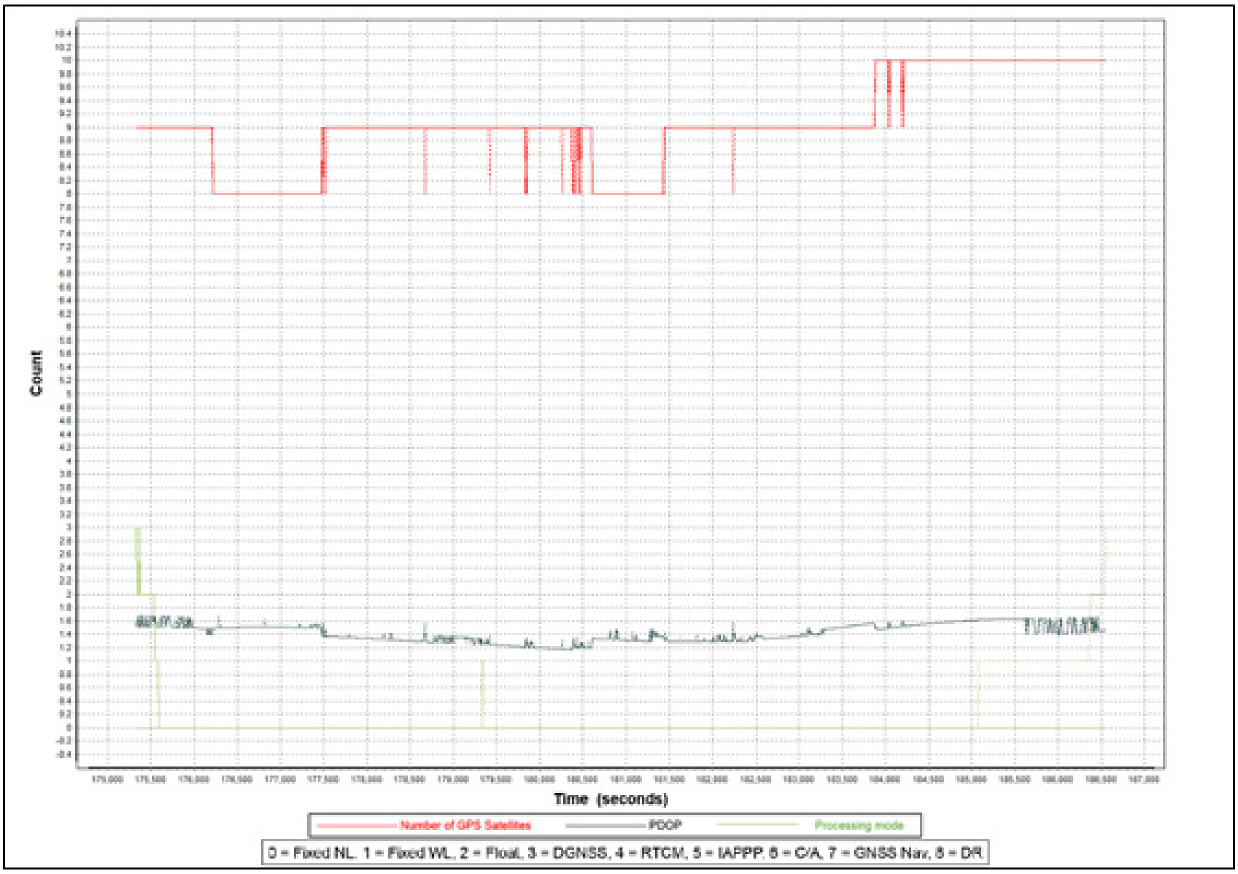

Figure 14. Solution Status Parameters of Lasang Flight 7386GC.

The Solution Status parameters of flight 7386GC, one of the Lasang flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 14. The graphs indicate that the number of satellites during the acquisition did not go down to seven (7). Majority of the time, the number of satellites tracked was between eight (8) and ten (10). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode remained at the value of zero (0) for majority of the survey, with some peaks up to three (3) attributed to the turns performed by the aircraft. The value of zero (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 Lasang flights is shown in Figure 15.

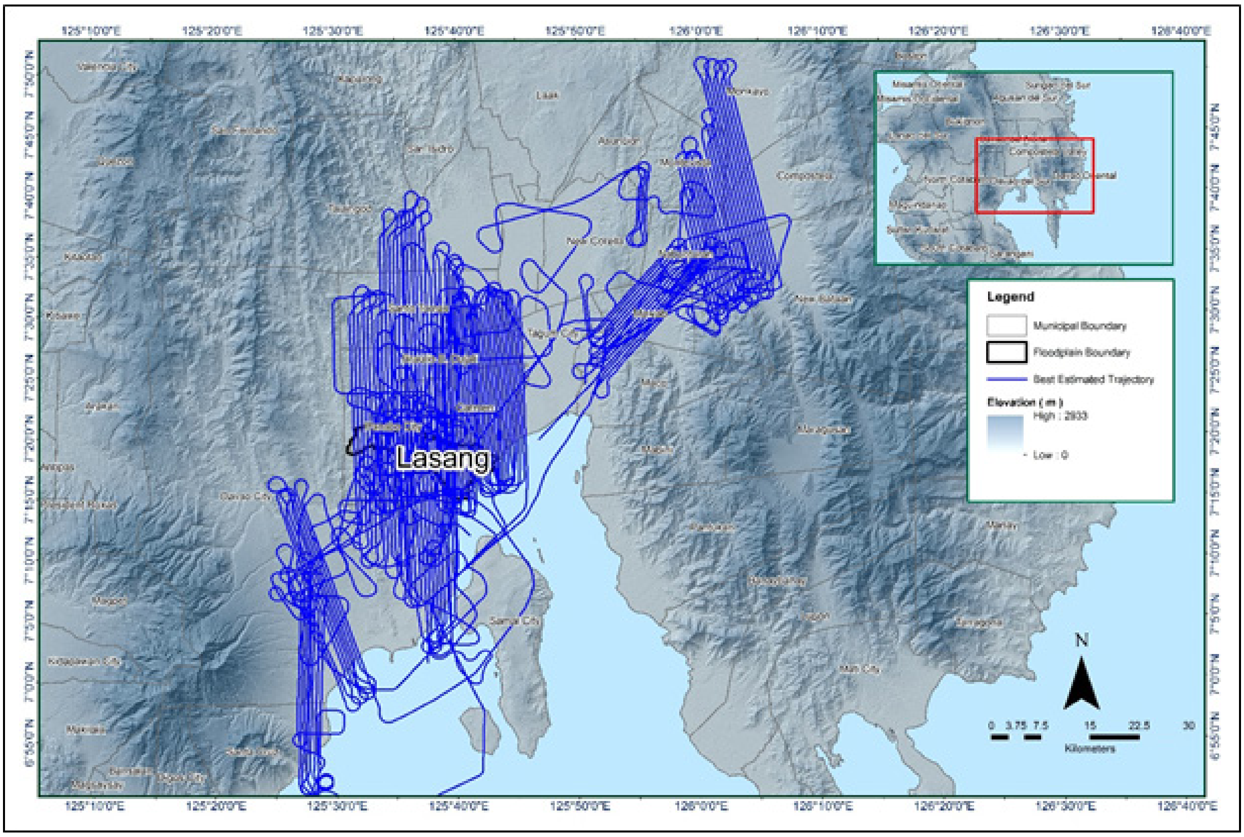

Figure 15. Best estimated trajectory conducted over the Lasang Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 125 flight lines, with each flight line containing one (1) channel for the Gemini system and two (2) channels for Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Lasang floodplain is given in Table 14.

Table 14. Self-Calibration Results values for Lasang flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000428
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000866
GPS Position Z-correction stdev	(<0.01meters)	0.0024

Optimum accuracy was obtained for all Lasang flights, based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for the individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Lasang floodplain is shown in Figure 16. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

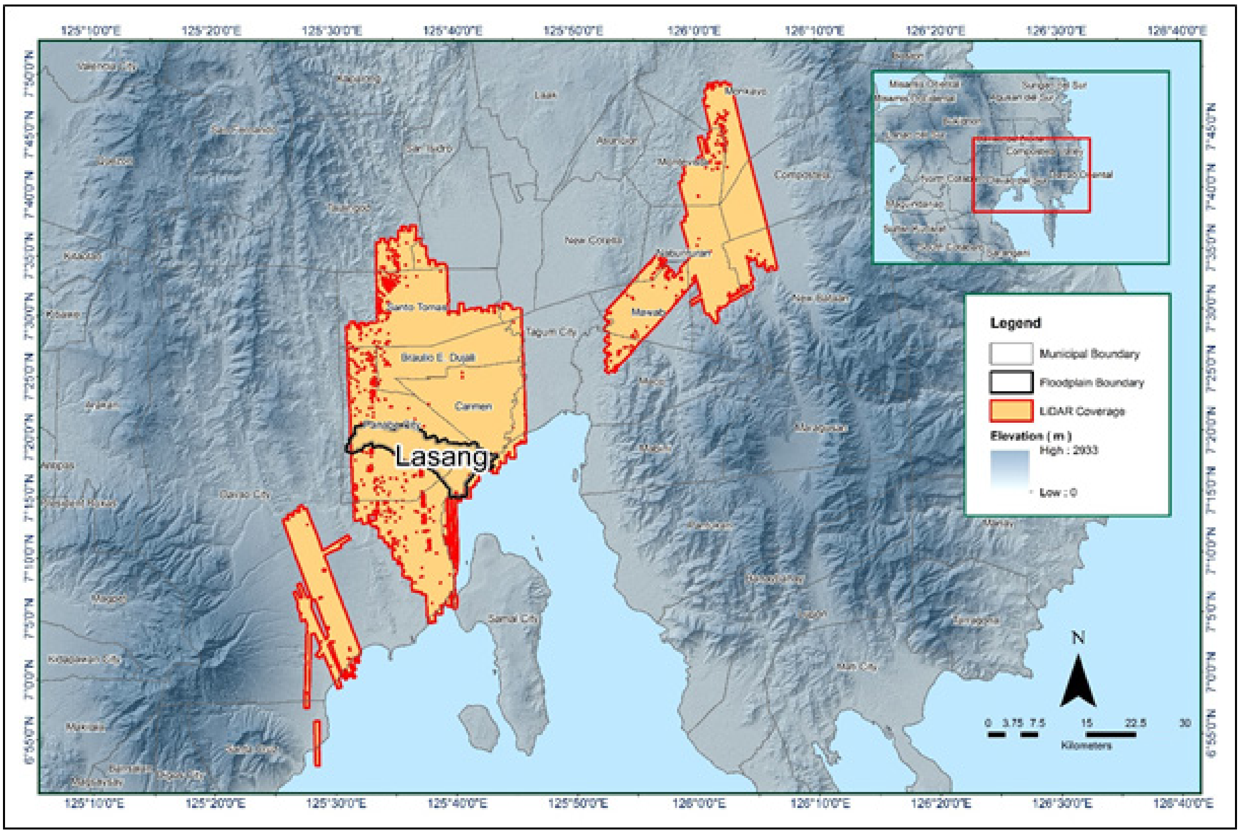

Figure 16. Boundary of the processed LiDAR data over Lasang Floodplain

The total area covered by the Lasang missions is 1743.25 sq.km, comprised of fifteen (15) flight acquisitions grouped and merged into twelve (12) blocks, as shown in Table 15.

Table 15. List of LiDAR blocks for Lasang floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
DavaoDelSur_Blk82H	7396GC	233.31
DavaoDelSur_Blk82E	7388GC	228.68
	7401GC	
DavaoDelSur_Blk82G	7390GC	127.53
DavaoDelSur_Blk82F	7390GC	145.42
	7401GC	
DavaoDelSur_Blk82_voids	7427GC	116.99
	7426GC	
DavaoDelSur_Blk82D	7386GC	138.07
DavaoDelSur_COM_BlkA	7423GC	118.28
DavaoDelSur_COM_BlkB	7424GC	112.77
	7423GC	
DavaoDelSur_COM_BlkB_Voids	7430GC	11.30
DavaoDelSur_COM_BlkD	7422GC	183.22
TagumAs	335P	192.83
	377P	
TagumA	335P	134.85
TOTAL		**1743.25 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is illustrated in Figure 17. Since the Gemini system employs one (1) channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. On the other hand, for the Pegasus system, which employs two (2) channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

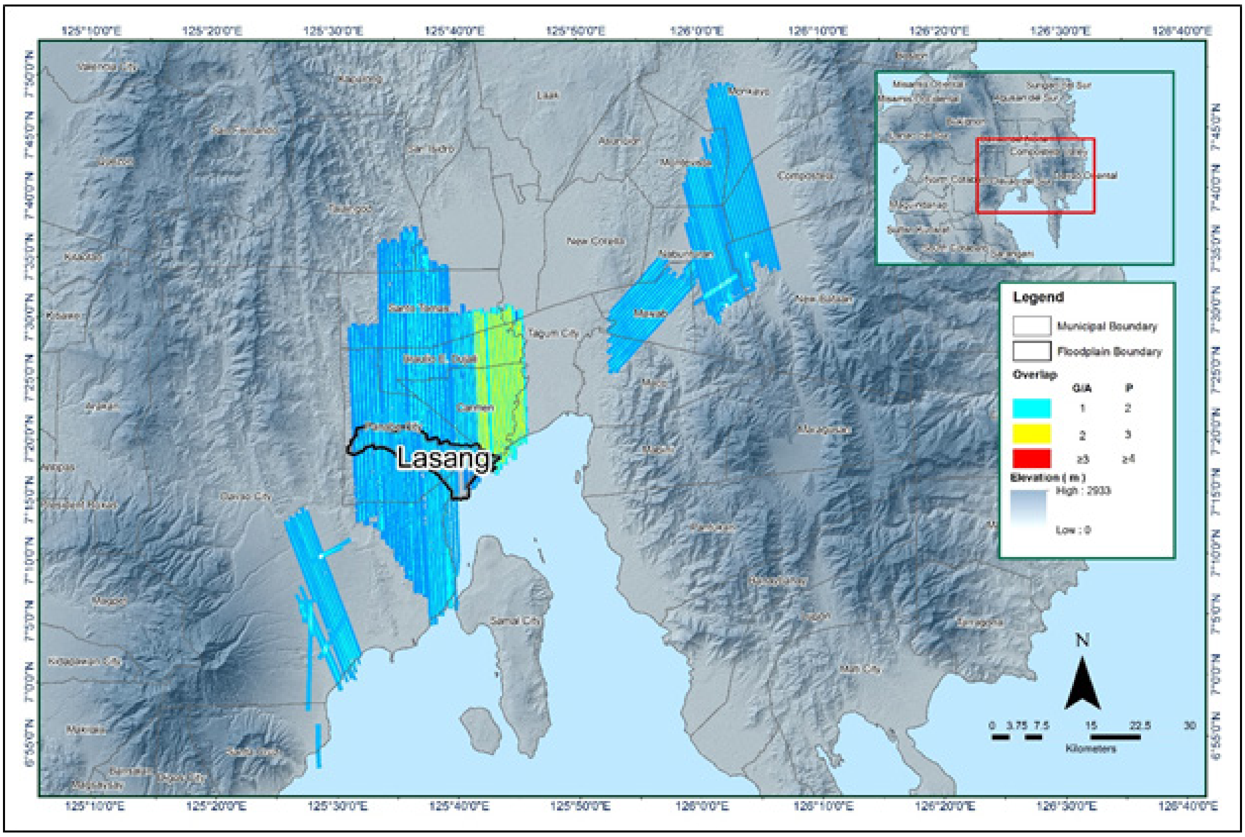

Figure 17. Image of data overlap for Lasang Floodplain.

The overlap statistics per block for the Lasang floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.09% and 52.96% 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 18. It was determined that all LiDAR data for Lasang floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.09 points per square meter.

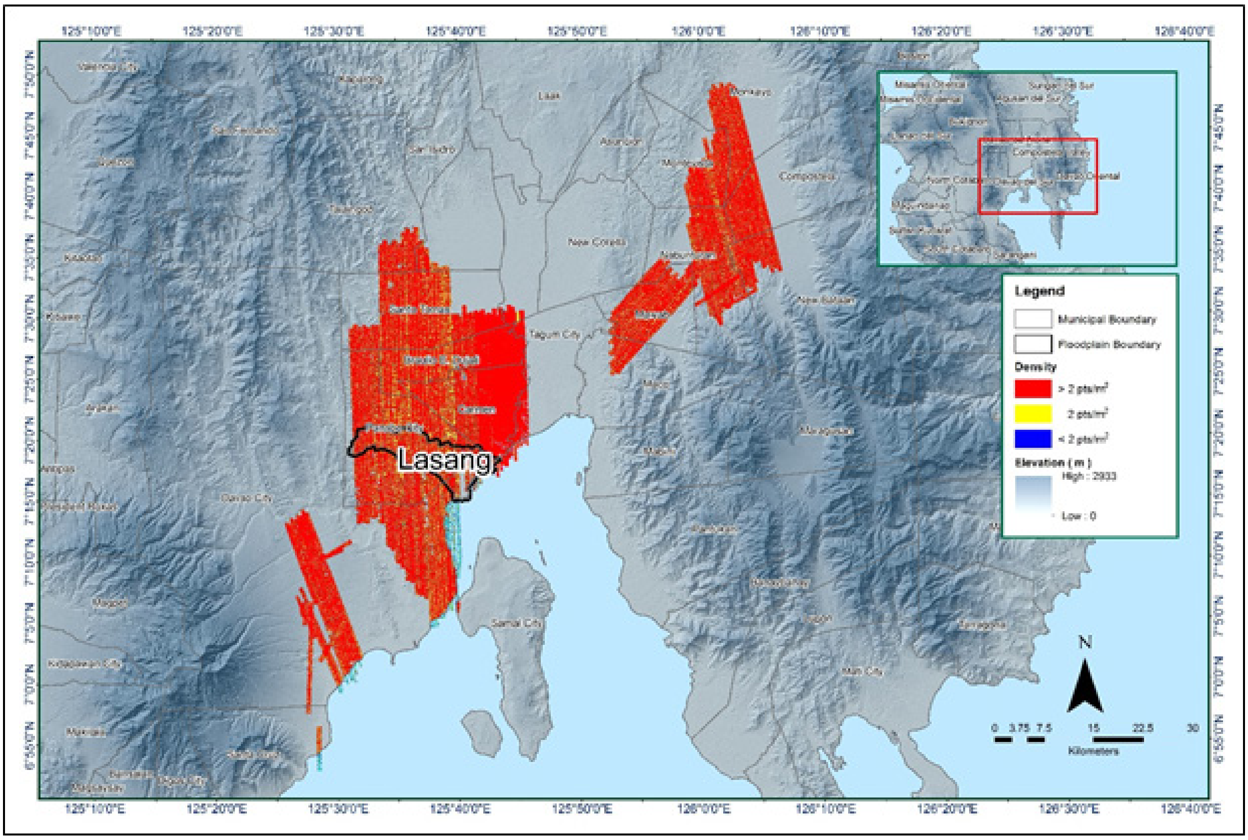

Figure 18. Pulse density map of merged LiDAR data for Lasang floodplain.

The elevation difference between overlaps of adjacent flight lines is depicted in Figure 19. 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 were investigated further using Quick Terrain Modeler software.

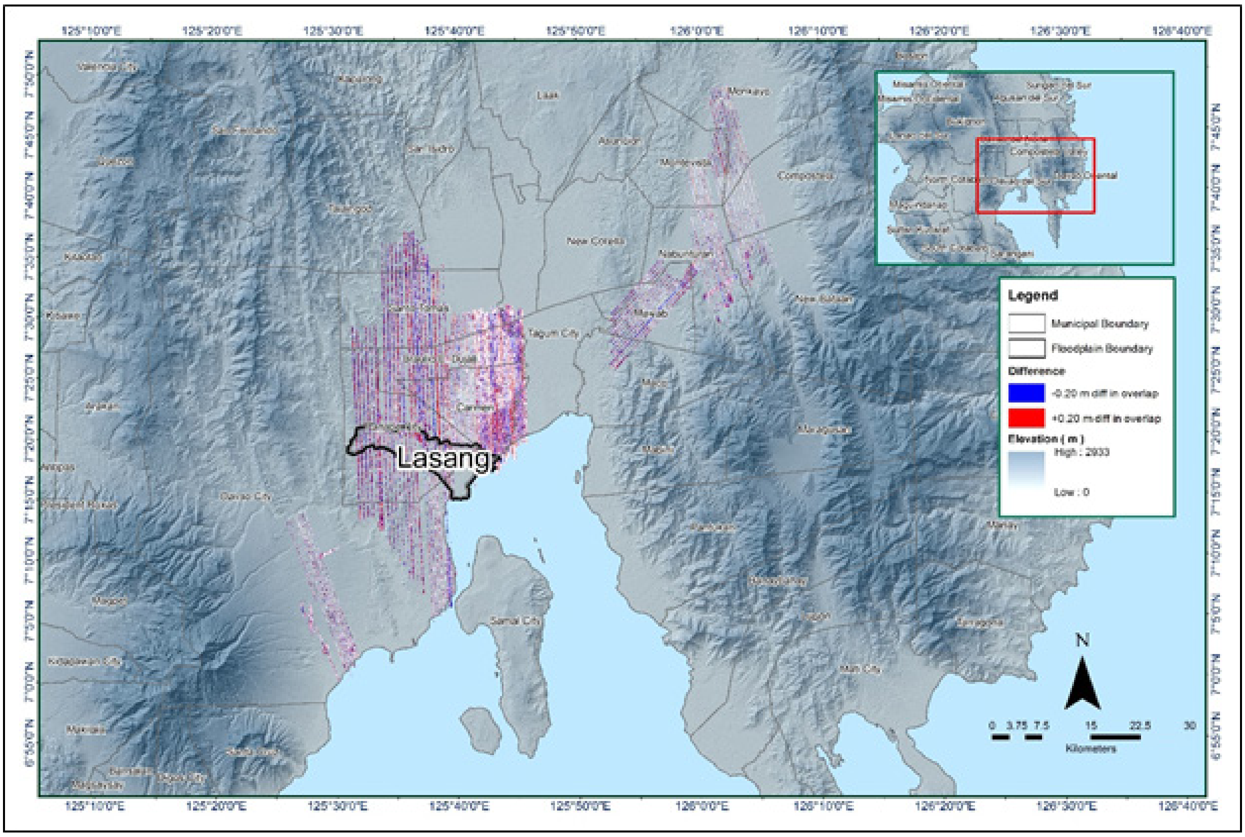

Figure 19. Elevation difference map between flight lines for Lasang floodplain.

A screen capture of the processed LAS data from a Lasang flight 7386GC loaded in QT Modeler is shown in Figure 20. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

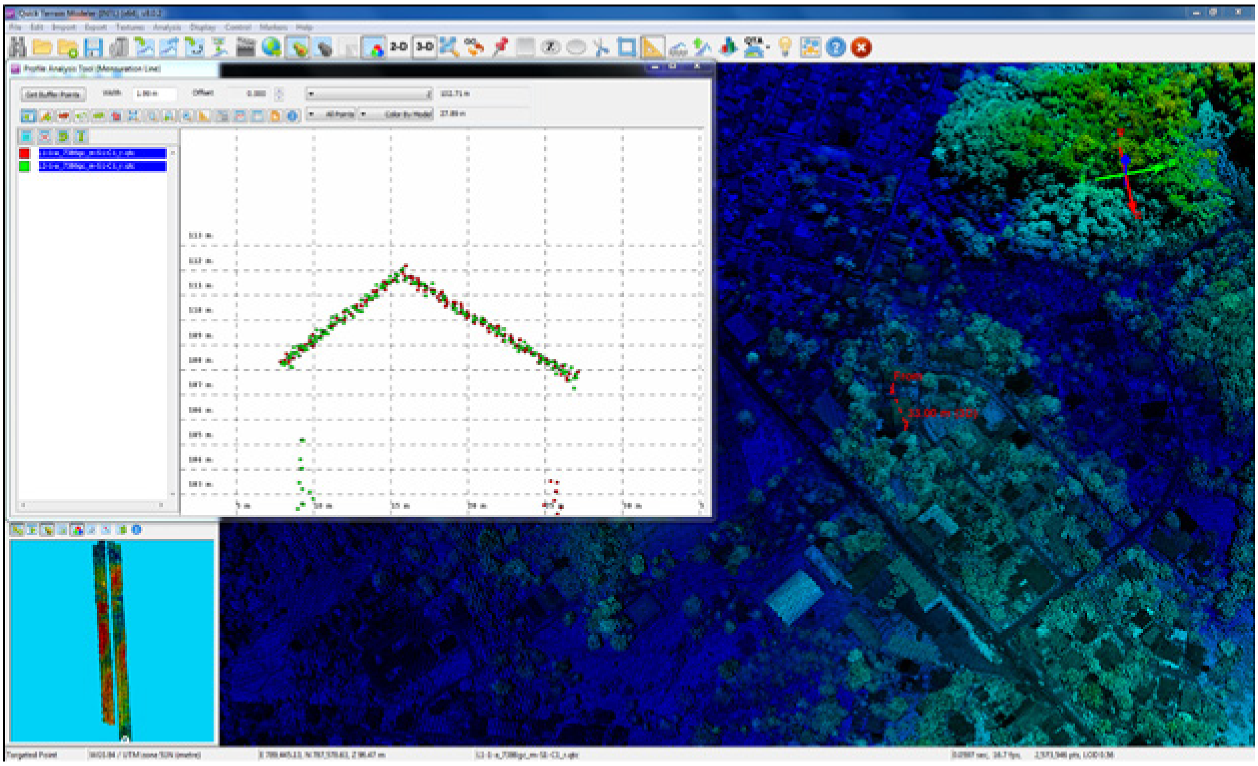

Figure 20. Quality checking for a Lasang flight 7386GC using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Lasang classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	823,870,699
Low Vegetation	775,717,242
Medium Vegetation	1,529,642,588
High Vegetation	2,275,225,962
Building	55,812,963

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Lasang floodplain is presented in Figure 21. A total of 2,408 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 725.77 meters and 58.59 meters, respectively.

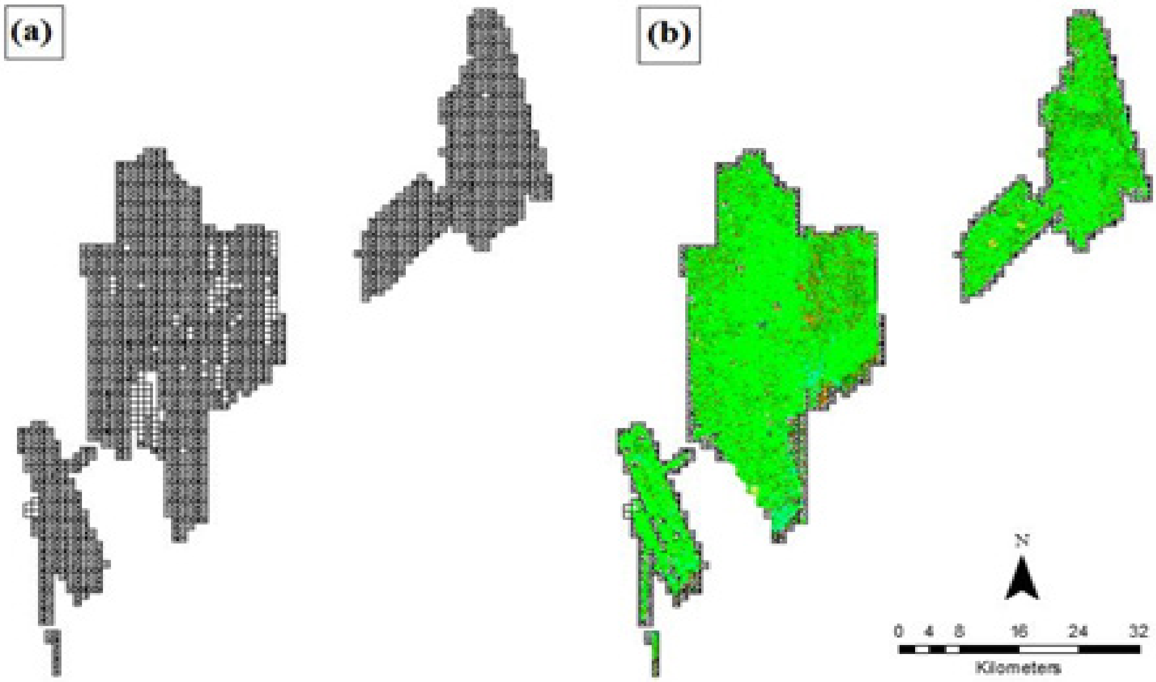

Figure 21. Tiles for Lasang floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 22. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be observed that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

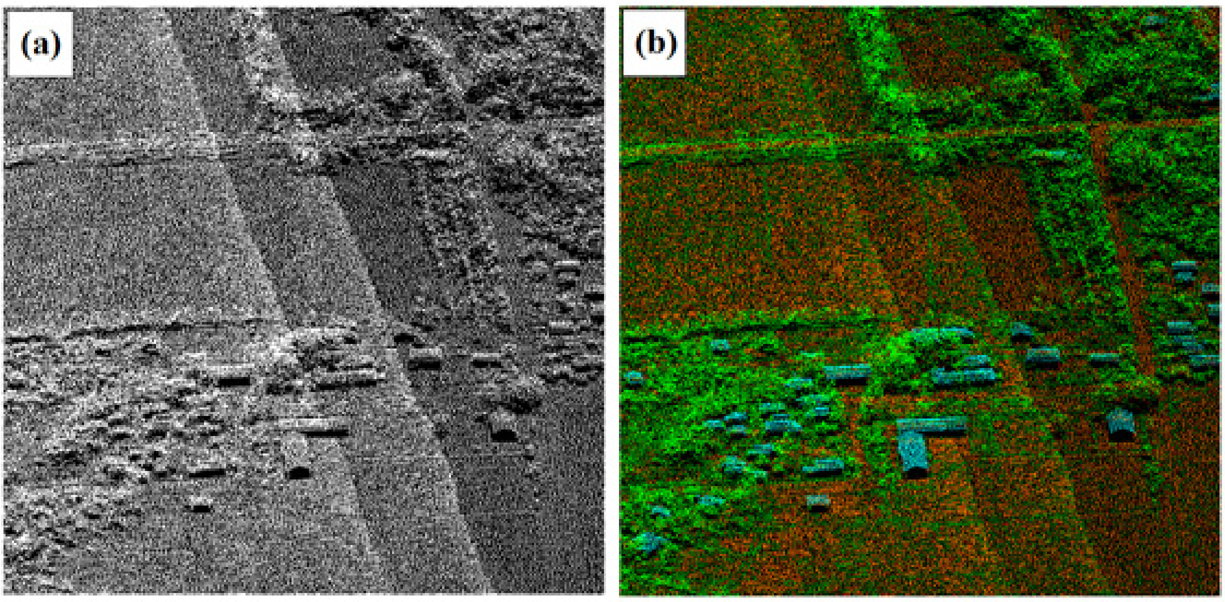

Figure 22. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM; and first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 23. It shows that DTMs are the representation of the bare earth, while the DSMs displays all features present, such as buildings and vegetation

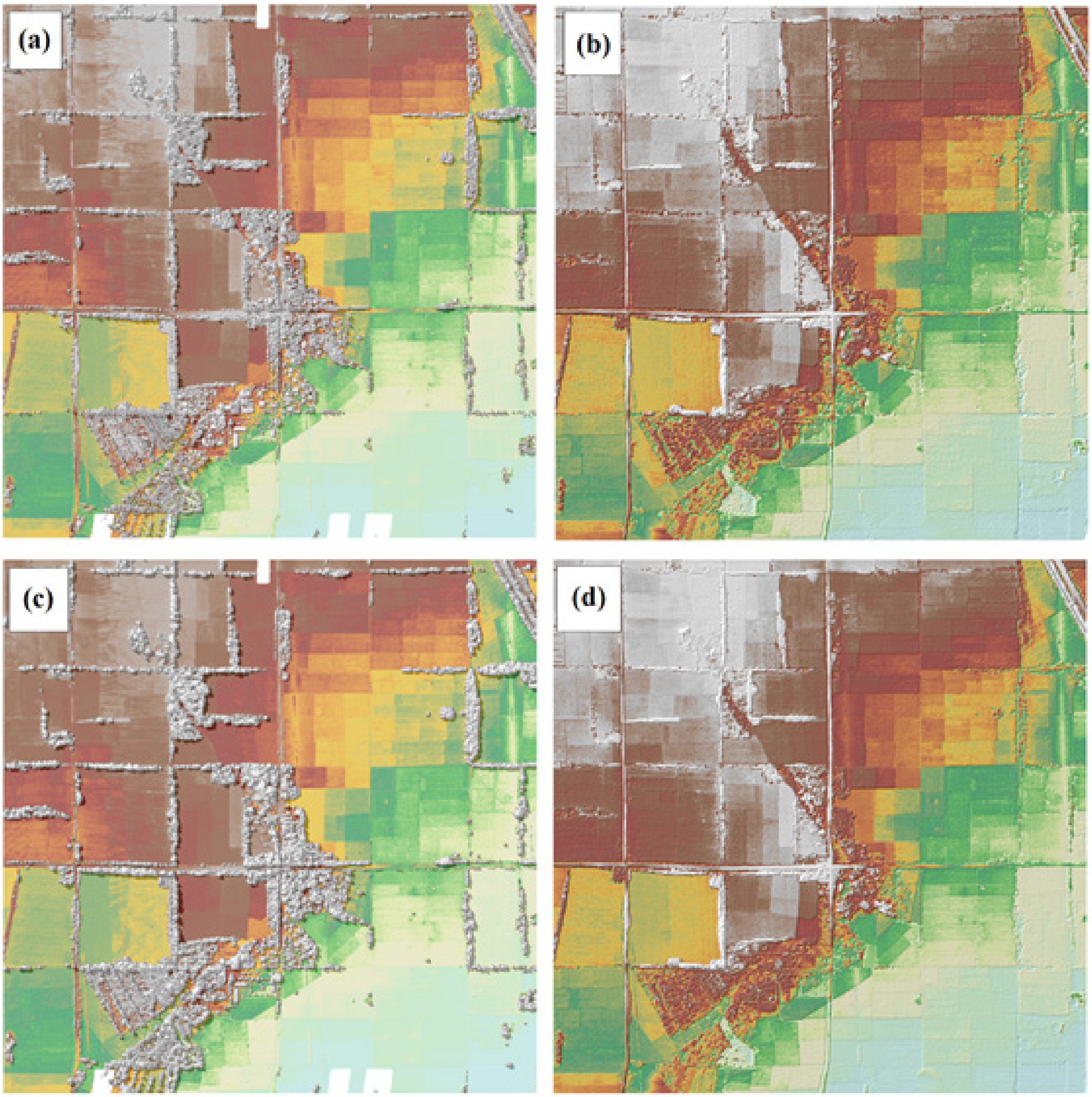

Figure 23. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Lasang Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Lasang floodplain.

3.8 DEM Editing and Hydro-Correction

Twelve (12) mission blocks were processed for the Lasang floodplain. These blocks are composed of Davao del Sur, Davao Oriental, Compostela Valley, and Tagum blocks, with a total area of 1743.25 square kilometers. Table 17 presents each block and the corresponding area in square kilometers (sq. km).

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
DavaoDelSur_Blk82H	233.31
DavaoDelSur_Blk82E	228.68
DavaoDelSur_Blk82G	127.53
DavaoDelSur_Blk82F	145.42
DavaoDelSur_Blk82_voids	116.99
DavaoDelSur_Blk82D	138.07
DavaoDelSur_COM_BlkA	118.28
DavaoDelSur_COM_BlkB	112.77
DavaoDelSur_COM_BlkB_Voids	11.30
DavaoDelSur_COM_BlkD	183.22
TagumAs	192.83
TagumA	134.85
TOTAL	**1743.25 sq.km**

Portions of DTM before and after manual editing are exhibited in Figure 24. The embankment (Figure 24a) was misclassified and removed during the classification process and had to be retrieved to complete the surface (Figure 24b) to allow for the correct flow of water. The bridge (Figure 24c) was also considered to be an impedance to the flow of water along the river, and had to be removed (Figure 24d) in order to hydrologically correct the river. Another example is a building that was still present in the DTM after classification (Figure 24e) and had to be removed through manual editing (Figure 24f).

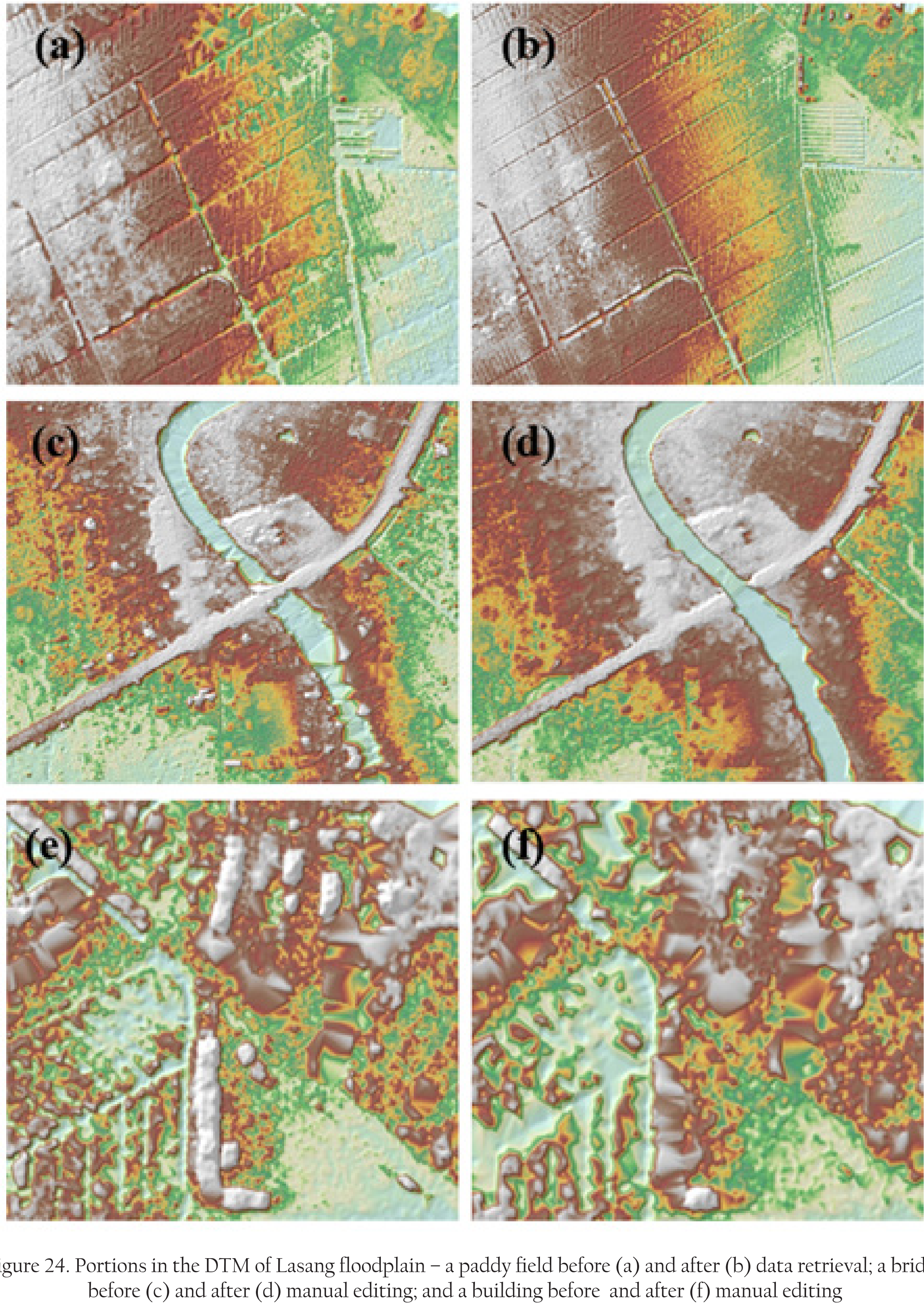

Figure 24. Portions in the DTM of Lasang floodplain – a paddy field before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing; and a building before and after (f) manual editing

3.9 Mosaicking of Blocks

Davao_Oriental Blk82E was used as the reference block at the start of mosaicking, as it was referred to a base station with an acceptable order of accuracy. Table 18 enumerates the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for the Lasang floodplain is shown in Figure 25. It can be seen that the entire Lasang floodplain is 93.6% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Lasang Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
DavaoDelSur_Blk82H	0.50	-97.75	0.00
DavaoDelSur_Blk 82E	0.00	0.00	0.00
DavaoDelSur_Blk 82G	0.00	0.00	3.69
DavaoDelSur_Blk 82F	-12.5	-6.74	-1.08
DavaoDelSur_Blk82_voids	0.00	0.50	0.50
DavaoDelSur_Blk82D	-12.5	-7.74	-2.57
DavaoDelSur_COM_BlkA	-0.20	0.00	0.83
DavaoDelSur_COM_BlkB	0.80	-0.50	-0.76
DavaoDelSur_COM_BlkB_Voids	-0.20	0.00	-0.59
DavaoDelSur_COM_BlkD	0.80	0.00	-1.78
TagumAs	0.00	0.00	0.00
TagumA	0.00	0.00	0.00

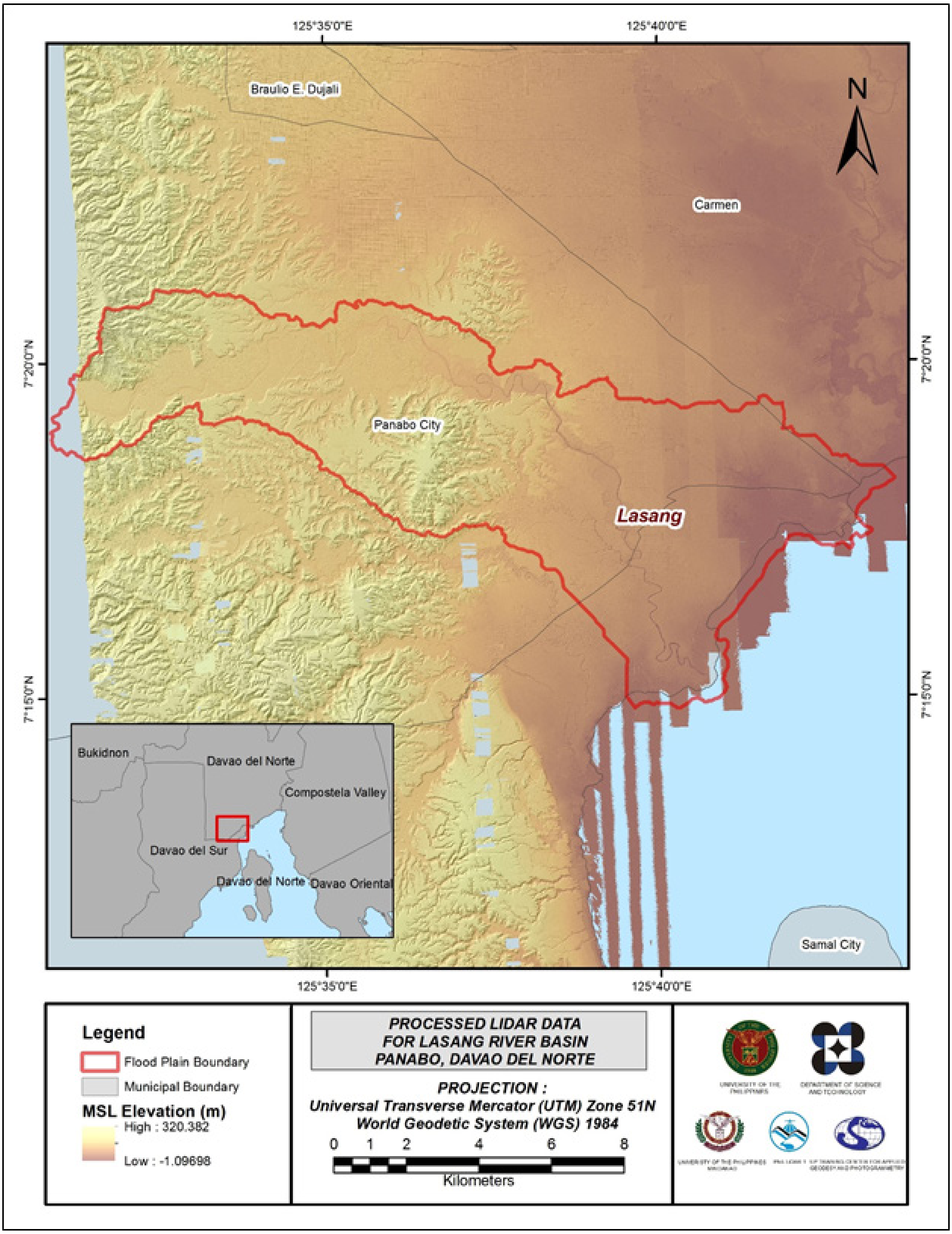

Figure 25. Map of Processed LiDAR Data for Lasang Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

To undertake the data validation of the Mosaicked LiDAR DEMs, the Data Validation and Bathymetry Component (DVBC) conducted a validation survey along the Lasang floodplain. The extent of the validation survey done by the DVBC in Lasang to collect points with which the LiDAR dataset was validated is illustrated in Figure 26, with the validation survey points in green. A total of 13,127 survey points were used for calibration and validation of the Lasang LiDAR data. Random selection of 80% of the survey points, resulting to 10,501 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points, to assess the quality of data and to obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 1.67 meters, with a standard deviation of 0.10 meters. Calibration of the Lasang LiDAR data was done by adding the height difference value, 1.67 meters, to the Lasang mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between the LiDAR data and the calibration data.

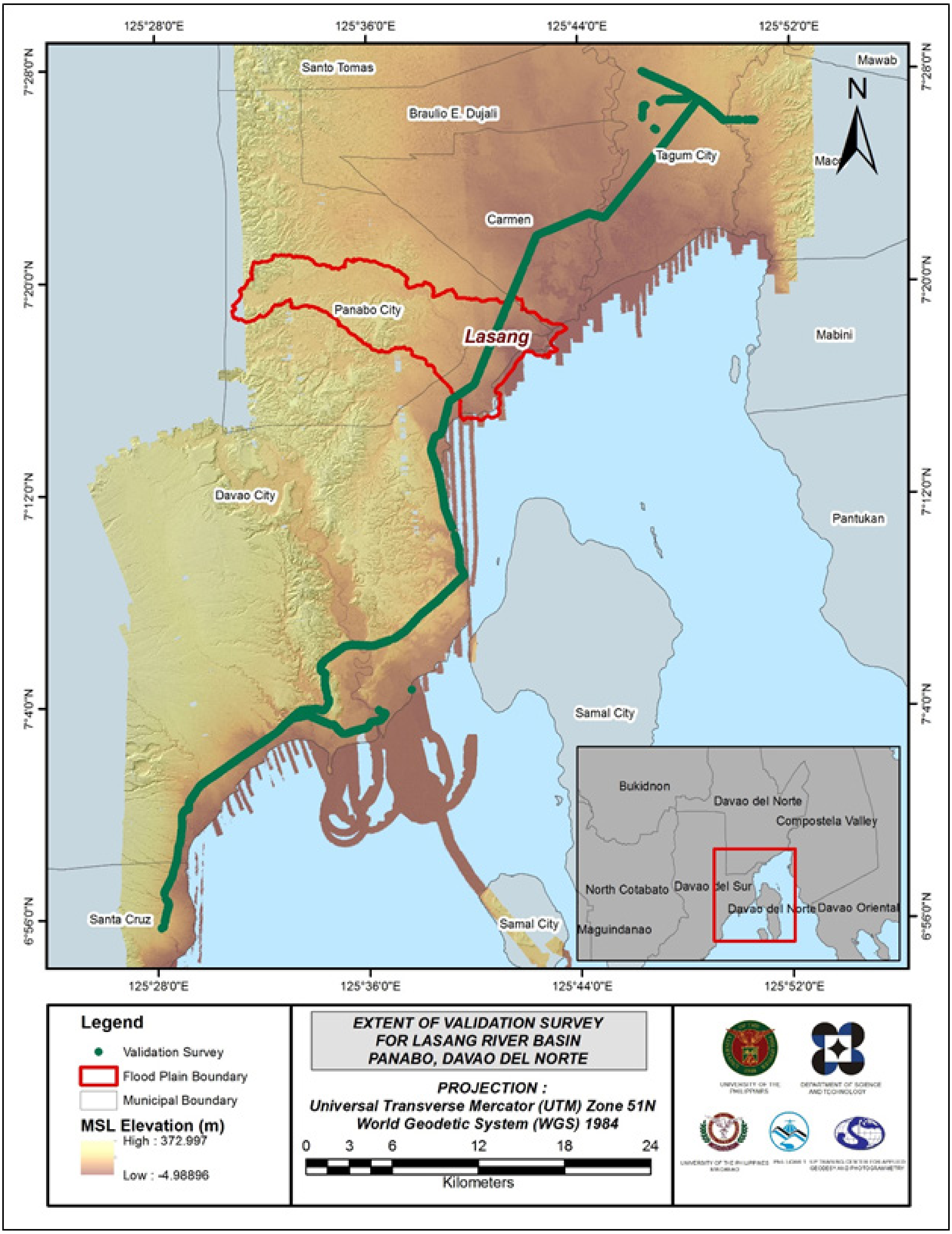

Figure 26. Map of Lasang Flood Plain with validation survey points in green.

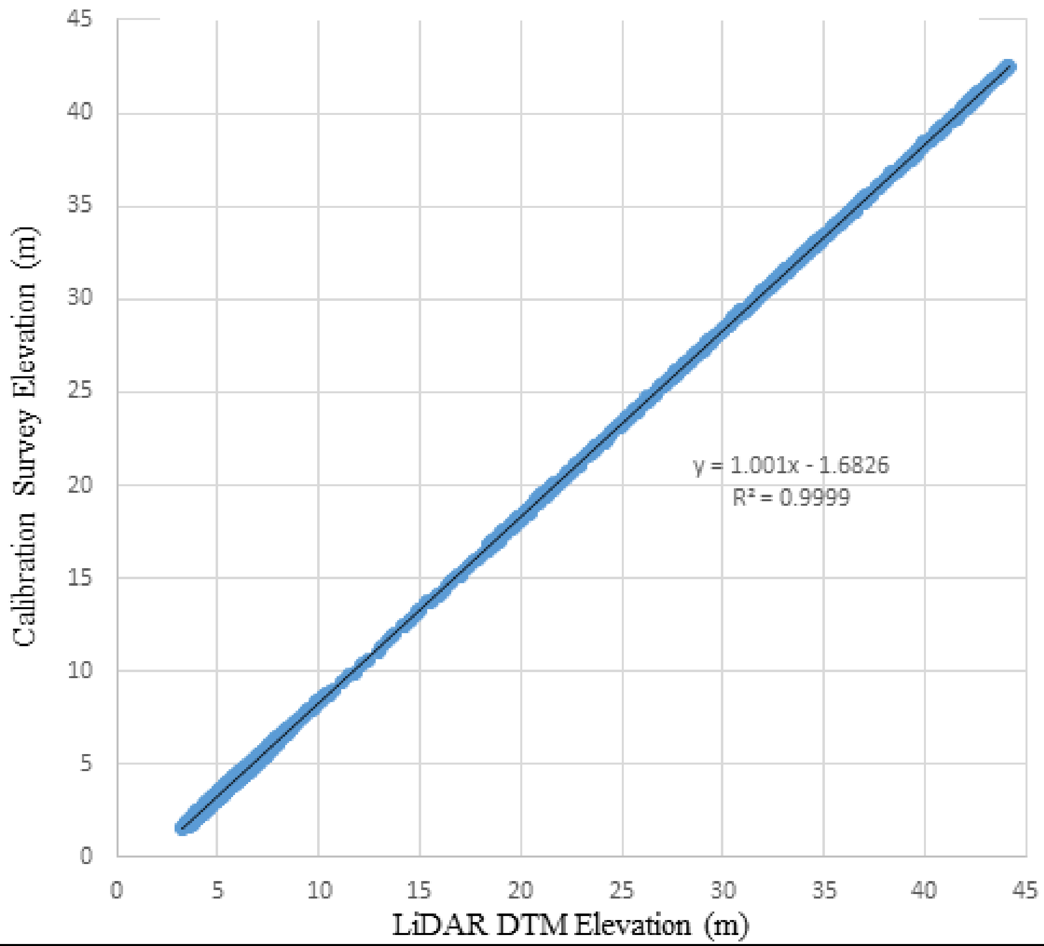

Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	1.67
Standard Deviation	0.10
Average	1.67
Minimum	1.47
Maximum	1.86

The remaining 20% of the total survey points, resulting to 2,625 points, were used for the validation of calibrated Lasang 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 reflected in Figure 28. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.16 meters, with a standard deviation of 0.16 meters, as presented in Table 20.

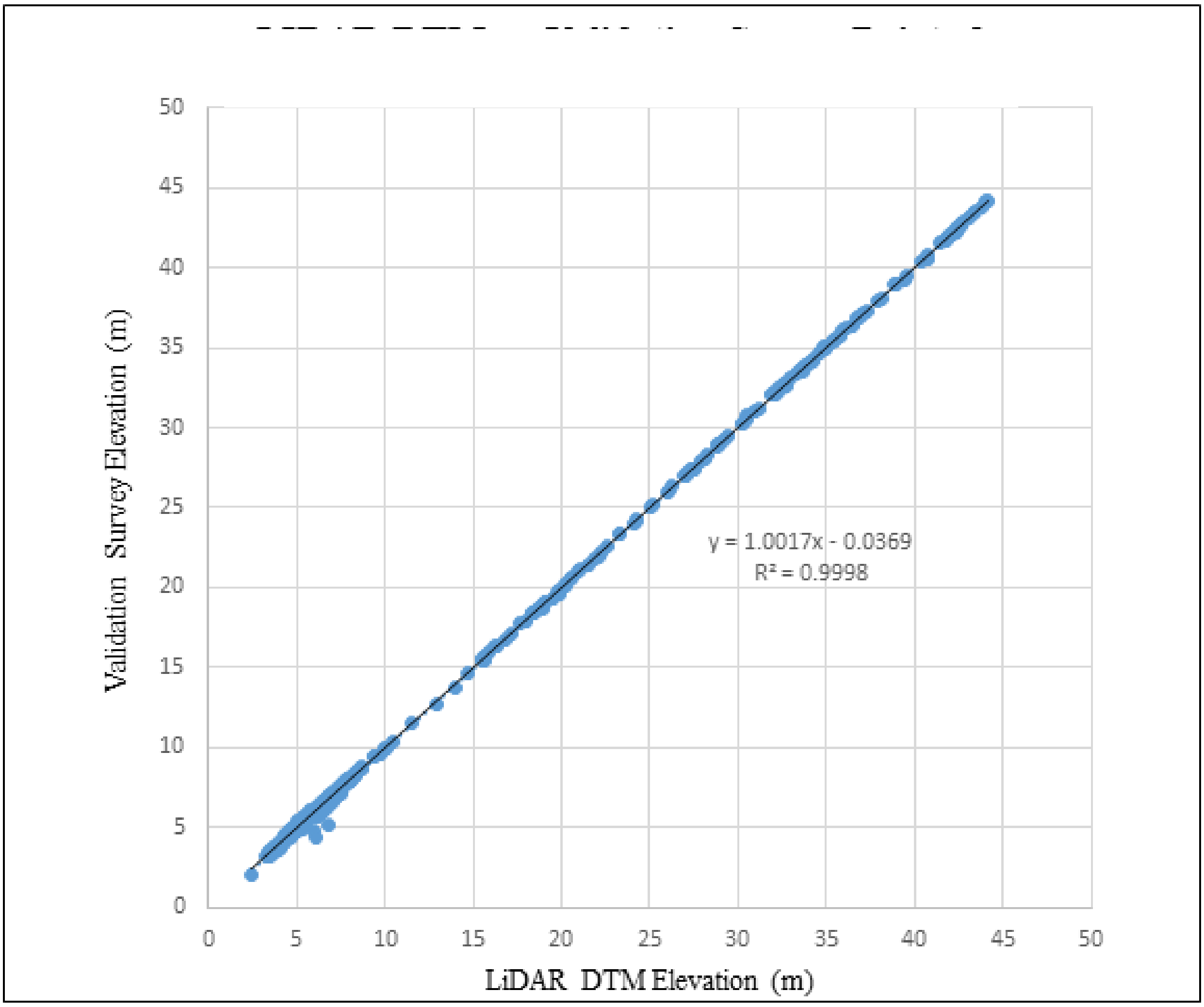

Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.16
Standard Deviation	0.16
Average	0.02
Minimum	-0.30
Maximum	0.34

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline and cross-section data was available for Lasang, with 1,253 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.53 meters. The extent of the bathymetric survey done by the DVBC in Lasang, integrated with the processed LiDAR DEM, is shown in Figure 29.

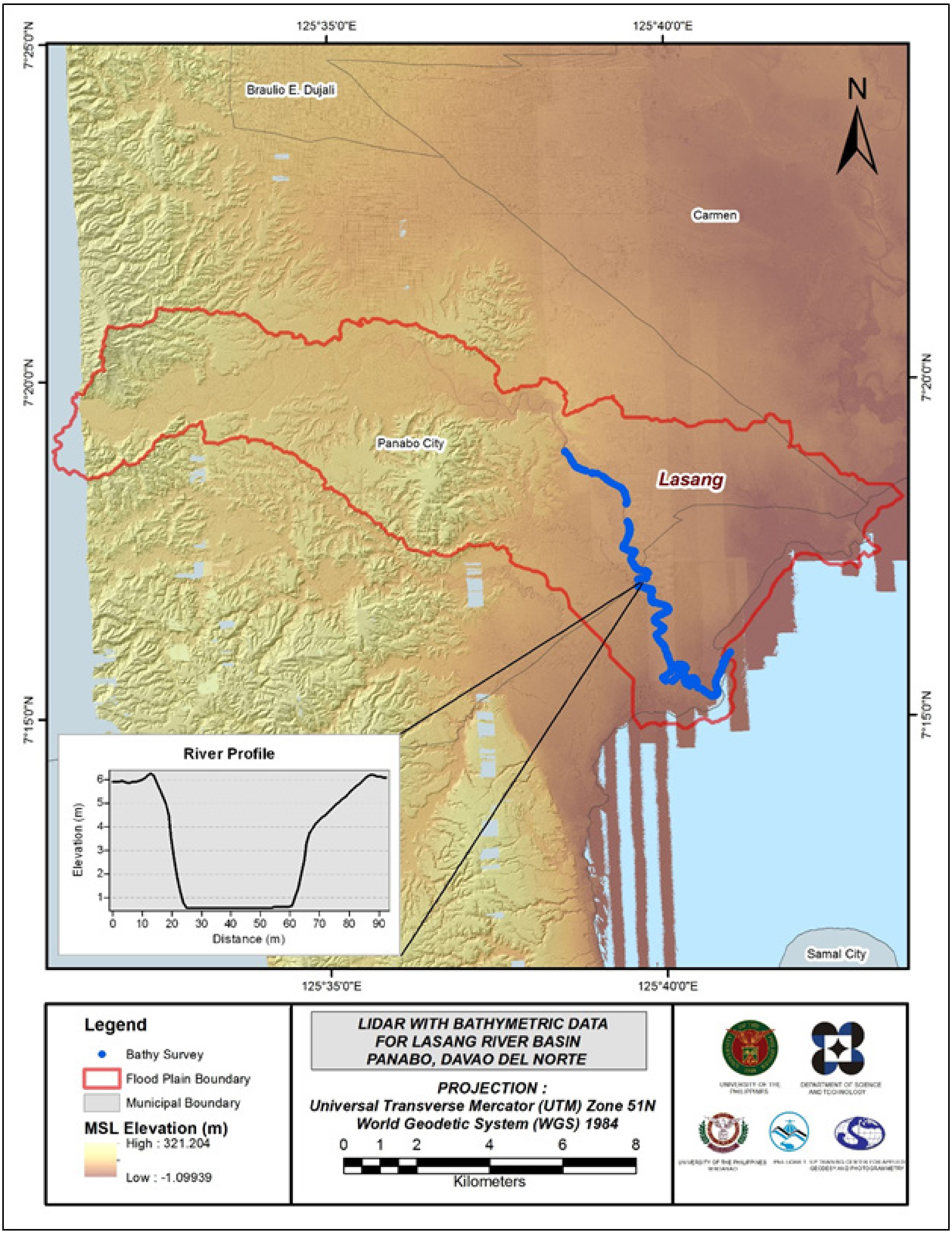

Figure 29. Map of Lasang Floodplain with bathymetric survey points shown in blue.

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 a 200-m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, consisting 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, which are essential for routing of disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

The Lasang floodplain, including its 200-m buffer, has a total area of 120.75 sq. km. For this area, a total of 5.0 sq. km, corresponding to a total of 2,139 building features, were considered for quality checking (QC). Figure 30 shows the QC blocks for the Lasang floodplain.

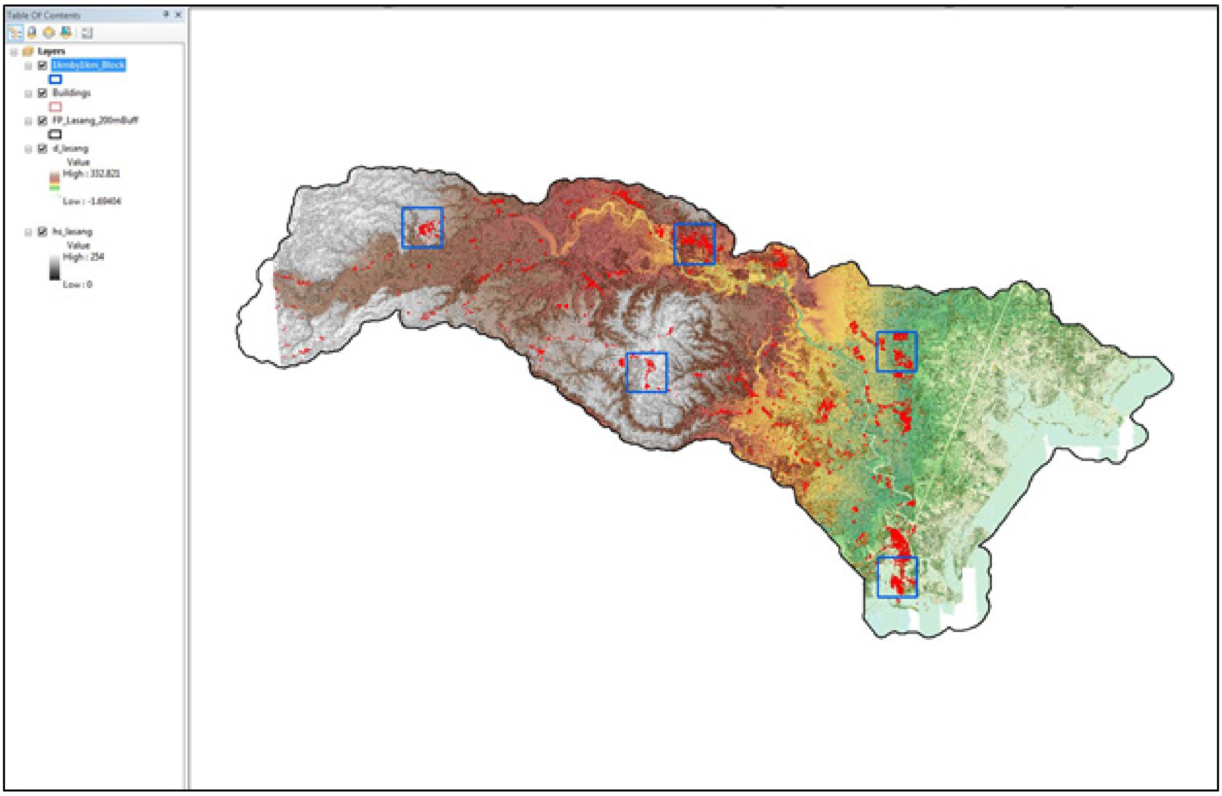

Figure 30. Blocks (in blue) of Lasang building features that were subjected to QC.

Quality checking of the Lasang building features resulted in the ratings shown in Table 21.

Table 21. Quality Checking Ratings for Lasang Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Lasang	97.09	100.00	93.76	PASSED

3.12.2 Height Extraction

Height extraction was done for 35,256 building features in the Lasang floodplain. Of these building features, 3,675 were filtered out after height extraction, resulting in 31,581 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 15.28 m

3.12.3 Feature Attribution

Field validation for the Lasang floodplain was completed in December 2015. However, in November of the same year, there were changes in the Feature Extraction Manual given by UP Diliman Data Pre-Processing Component, which prompted the conduct of another field work on October 5-10, 2016 for the digitized features in the additional area scope.

Before the actual field validation, courtesy calls were conducted to seek permission and assistance from the local government units (LGUs) of each barangay. This was done to ensure the smooth, safe and secure conduct of field validation in the area. Verification of barangay boundaries was also done to finalize the distribution of features for each barangay.

Local Barangay Health Workers (BHWs) were requested and hired to assist the UPM Phil-LiDAR 1 field enumerators during validation. The BHWs deployed by the barangay captains were given a brief orientation by the field enumerators before the actual field work. The team surveyed the twenty-six (26) barangays covered by the floodplain, namely: Barangays Paradise Embac, Mabuhay Davao, and Alejandro Navarro in Davao City; and Barangays Nanyo, Datu Abdul Dadia, Southern Davao, New Visayas, Gredu, JP Laurel, Cagangohan, New Pandan, San Francisco (Pob.), Sto. Niño, Salvacion, San Vicente, San Pedro, Little Panay, Maduao, Katipunan, New Malitbog, Manay, Kasilak, Cacao, Kauswagan, Mabuhay Carmen and Consolacion in Panabo City.

There were areas in the floodplain scope that were digitized using the DREAM data of the Tagum River, since the available DSM of UPM Phil-LiDAR 1 was incomplete. The digitization process and field validation for the remaining areas of the floodplain has been completed.

Table 22. Building Features Extracted for Lasang Floodplain.

Facility Type	No. of Features
Residential	29,331
School	527
Market	43
Agricultural/Agro-Industrial	1
Facilities	350
Medical Institutions	59
Barangay Hall	31
Military Institution	21
Sports Center/Gymnasium/Covered Court	25
Telecommunication Facilities	1
Transport Terminal	4
Warehouse	25
Power Plant/Substation	2
NGO/CSO Offices	12
Police Station	11
Water Supply/Sewerage	11
Religious Institutions	216
Bank	14
Factory	116
Gas Station	31
Fire Station	2
Other Government Offices	54
Other Commercial Establishments	695
Total	**31,581**

Table 23. Total Length of Extracted Roads for Lasang Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Lasang	274.63	63.38	0.00	41.23	0.00	379.24

Table 24. Number of Extracted Water Bodies for Lasang Floodplain.

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

A total of five (5) 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 31 shows the Digital Surface Model (DSM) of the Lasang floodplain, overlaid with its ground features.

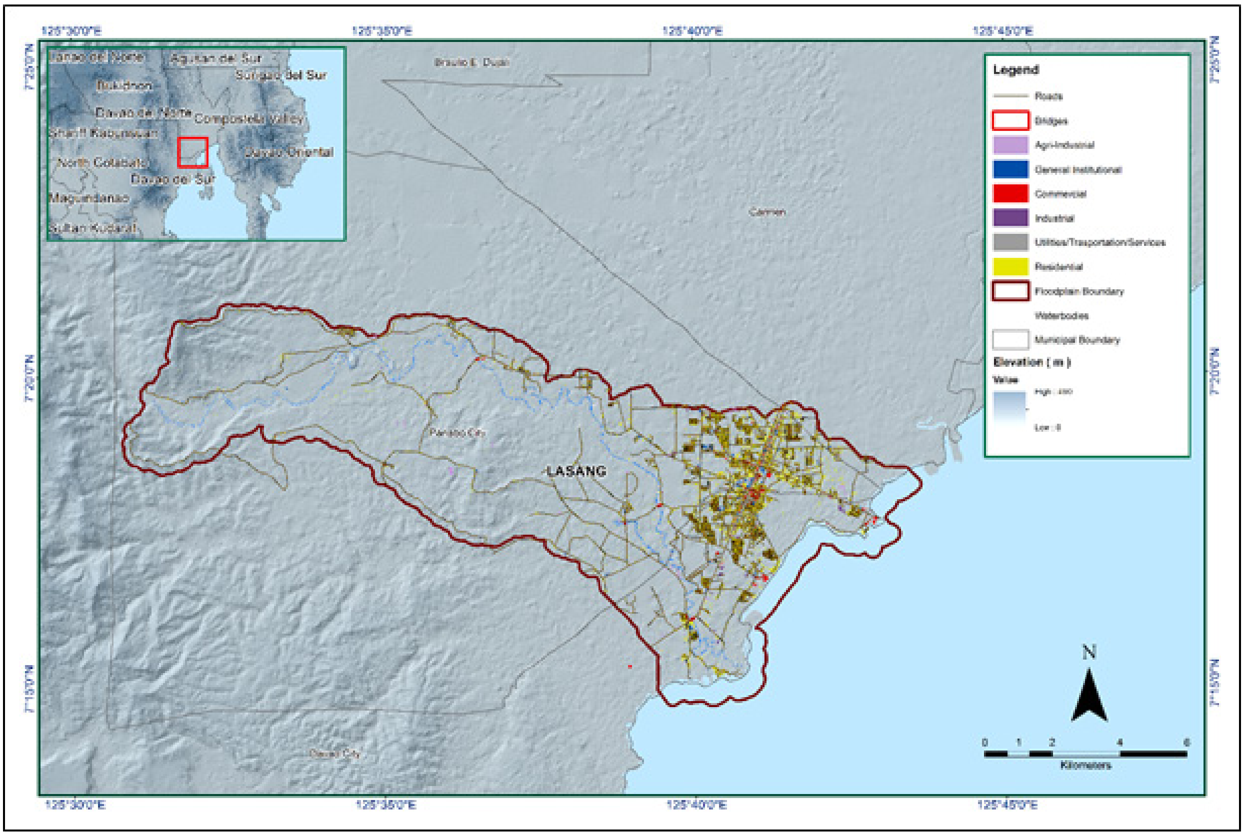

Figure 31. Extracted features for Lasang Floodplain.

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

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Lasang River from October 15 to 27, 2014, with the following scope of work: (i.) initial reconnaissance; (ii.) control survey for the establishment of a control point; (iii.) cross-section, bridge as-built, and water level marking in MSL of the Lasang Bridge piers; (iv.) ground validation data acquisition of about 83.034 km; and (v.) bathymetric survey from Barangay Little Panay in Panabo City in the province of Davao del Norte down to the mouth of the river in Barangay Vicente Hizon Sr. in Davao City in the province Davao del Sur, with an estimated length of 13.70 km using a Hi-Target™ Single Beam Echo Sounder and GNSS PPK survey technique.

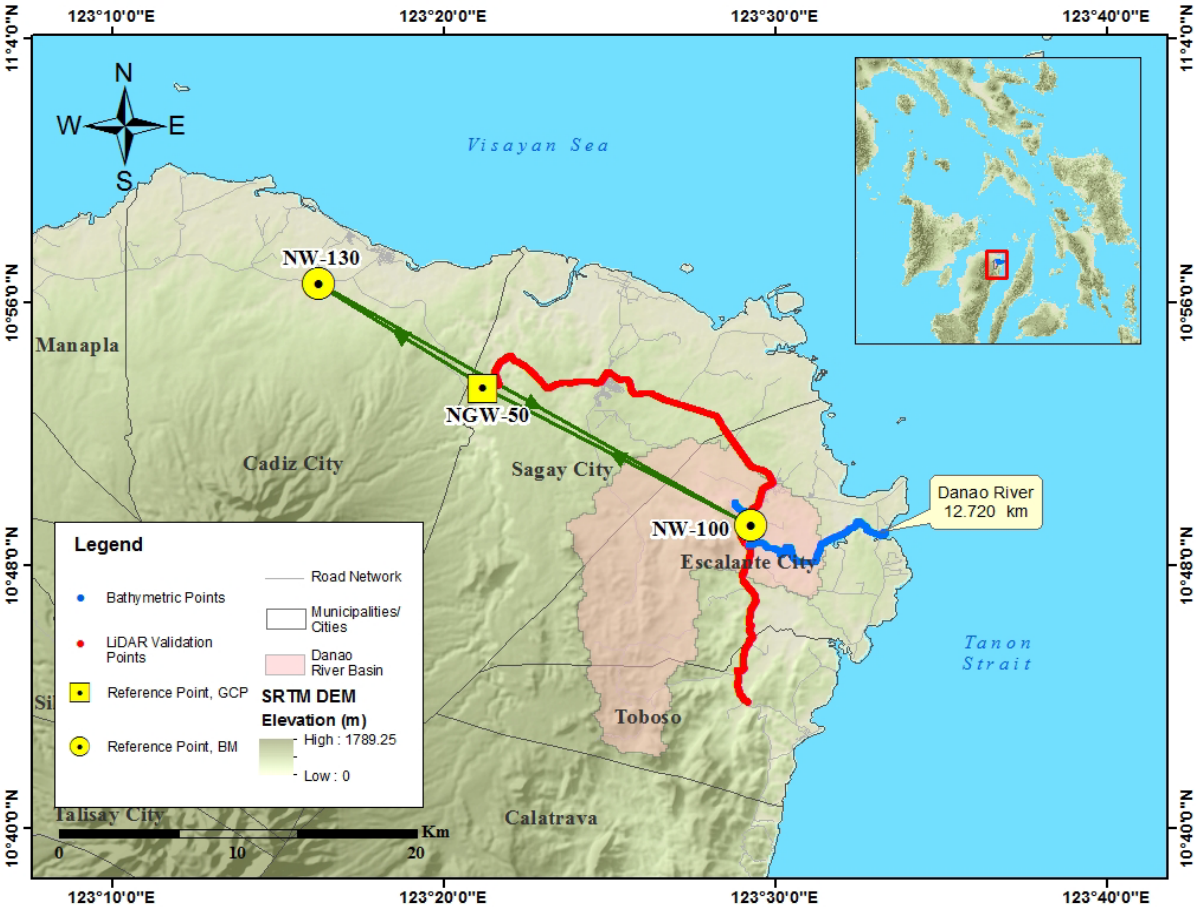


Figure 32. Extent of the bathymetric survey (in blue line) in Lasang River and the LiDAR data validation (in red)

4.2 Control Survey

A GNSS network was established on July 4 and 5, 2015 for a previous Phil-LiDAR survey in the Digos River, occupying the following reference points: DVS-1, a first order GCP in Barangay Leon Garcia Sr. in Davao City, Davao Del Sur; and DV-76, a first order benchmark located in Barangay Guadalupe in the Municipality of Carmen, Davao Del Norte.

The GNSS network used in the survey was composed of three (3) loops established on October 16, 2014, occupying the control point DVS-1, a first order GCP in Barangay Leon Garcia Sr., Davao City, Davao Del Sur, with fixed coordinates and elevation values from the previous Davao field work.

Three (3) control points were established along the approach of the following bridges namely: (i.) UP-KAE at the Kalye Apike Bridge in Barangay Calinan, Davao City, Davao Del Norte; (ii.) UP-LAS at the Lasang Bridge in Barangay Maduao, Panabo City, Davao Del Norte; and (iii.) UP-MTL at the Mintal Bridge in Barangay. Mintal, Davao City, Davao Del Sur. These were used as reference points for the survey.

The list of reference used and the GNSS network used in the survey are shown in Table 25 and Figure 33, respectively.

Table 25. List of references and control points used fieldwork in Davao Region survey
(Source: DREAM Report Series No. 2013.12.0)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
DVS-1	1st Order, GCP	7°04'38.36202"	125°37'36.77094"	68.500	0.771	2013
UP-KAE	UP Established	-	-	-	-	October 16, 2014
UP-LAS	UP Established	-	-	-	-	October 16, 2014
UP-MTL	UP Established	-	-	-	-	October 16, 2014

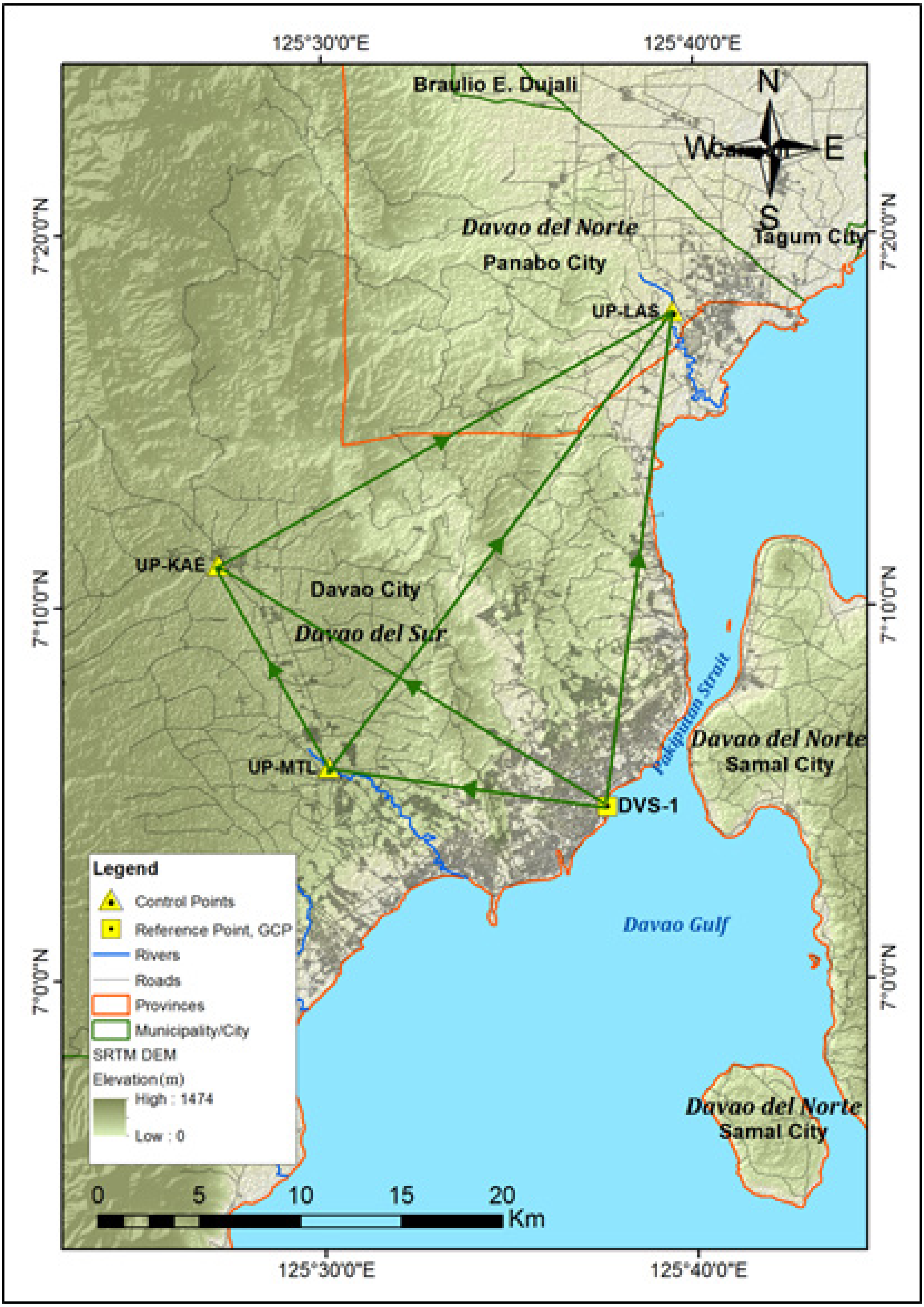


Figure 33. GNSS Network of Talomo and Lasang Rivers Field Survey

The GNSS set-up established in the location of the reference and control points are exhibited in Figure 34 to Figure 37.

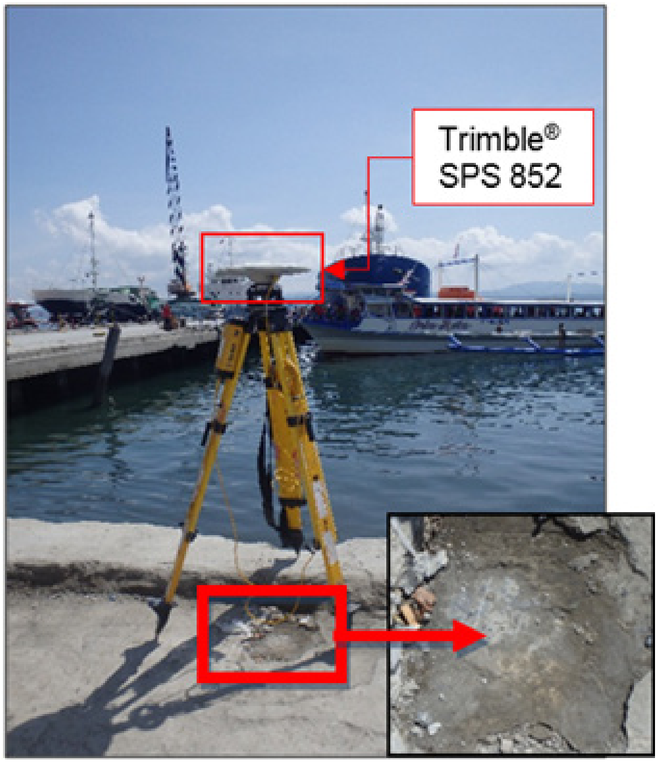


Figure 34. GNSS base receiver set up, Trimble® SPS 852 at DVS-1 in Sta. Ana Wharf, Davao City

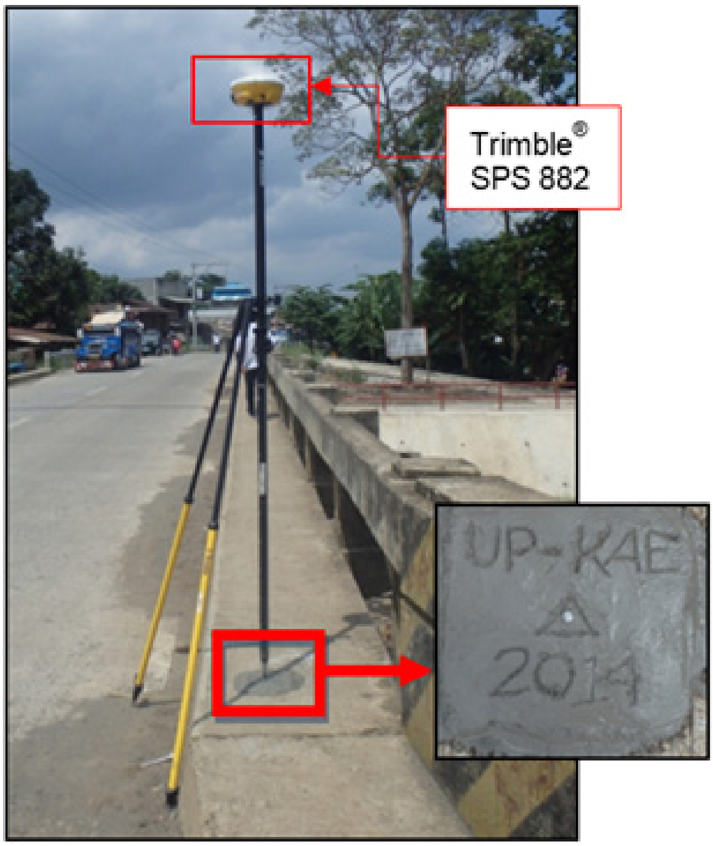


Figure 35. GNSS receiver occupation set up, Trimble® SPS 882 at control point UP-KAE, Kalye Apike Bridge in Brgy. Calinan, Davao City

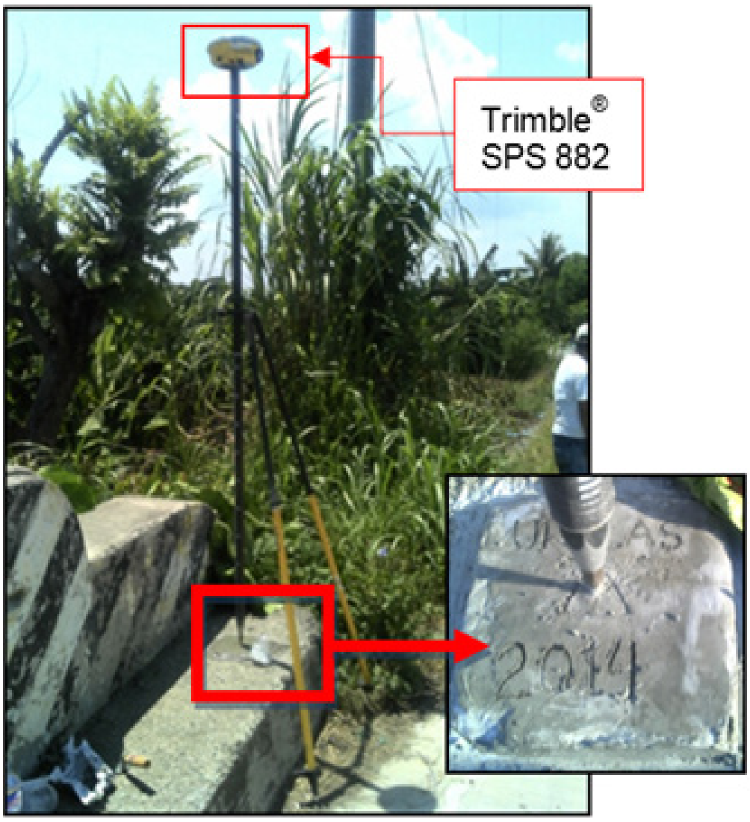


Figure 36. GNSS receiver occupation set up, Trimble® SPS 882 at control point UP-LAS in Brgy. Little Panay, Panabo City

Figure 37. GNSS receiver occupation set up, Trimble® SPS 882 at control point UP-MTL, Mintal Bridge in Brgy. Mintal, Davao City

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of 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, a resurvey is initiated. The baseline processing results of control points in the Lasang River Basin is summarized in Table 26, generated by TBC software.

Table 26. Baseline Processing Report for Lasang River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
DVS1 --- UPKAE (B3)	10-6-2014	Fixed	0.003	0.018	301°56'03"	22698.648
DVS1 --- UPMTL (B6)	10-6-2014	Fixed	0.003	0.020	278°05'36"	13963.237
DVS1 --- UPLAS (B1)	10-6-2014	Fixed	0.003	0.013	7°42'04"	24652.588
UPKAE --- UPMTL (B4)	10-6-2014	Fixed	0.003	0.018	151°31'59"	11419.131
UPKAE --- UPLAS (B2)	10-6-2014	Fixed	0.005	0.030	61°08'38"	25760.778
UPMTL --- UPLAS (B5)	10-6-2014	Fixed	0.003	0.020	37°18'28"	28249.074

As shown in Table 26, a total of six (6) baselines were processed, with reference point DVS-1 held fixed for grid and elevation values. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid Coordinates in Table 28 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,
ye is the Northing Error, and
ze is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 27 through Table 29 for the complete details.

The four (4) control points, DVS-1, UP-KAE, UP-LAS, and UP-MTL, were occupied and observed simultaneously to form a GNSS loop. The coordinates and elevation values of point DVS-1 were held fixed during the processing of the control points, as presented in Table 27. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 27. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
DVS-1	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 28. The fixed control points are LYT-101 with no values for grid errors; and LY-106 for elevation error.

Table 28. Adjusted Grid Coordinates

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
DVS1	790192.921	?	783116.705	?	0.771	?	ENe
UPKAE	770850.418	0.007	795019.989	0.006	197.198	0.052	
UPLAS	793358.273	0.006	807581.490	0.006	12.404	0.046	
UPMTL	776349.630	0.006	785005.363	0.006	110.718	0.051	

The network was fixed at reference point DVS-1, with known coordinates and elevation. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm and $z_e < 10\ cm$, with <20cm for horizontal, and z_e<10 cm for the vertical; the computation for the accuracy are as follows:

a. DVS-1
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. UP-KAE
Horizontal Accuracy = $\sqrt{((0.07)^2 + (0.06)^2)}$
= $\sqrt{(0.49 + 0.36)}$
= 0.92 cm < 20 cm
Vertical Accuracy = 5.2 cm < 10 cm

c. UP-LAS
Horizontal Accuracy = $\sqrt{((0.06)^2 + (0.06)^2)}$
= $\sqrt{(0.36 + 0.36)}$
= 0.85 cm < 20 cm
Vertical Accuracy = 4.6 cm < 10 cm

d. UP-MTL
Horizontal Accuracy = $\sqrt{((0.06)^2 + (0.06)^2)}$
= $\sqrt{(0.36 + 0.36)}$
= 0.85 cm < 20 cm
Vertical Accuracy = 5.1 cm < 10 cm

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

Table 29. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
DVS1	N7°04'38.36202"	E125°37'36.77094"	68.500	?	ENe
UPKAE	N7°11'09.07739"	E125°27'08.90858"	266.926	0.052	
UPLAS	N7°17'53.61604"	E125°39'24.47345"	80.420	0.046	
UPMTL	N7°05'42.29301"	E125°30'06.27926"	179.729	0.051	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 29. Based on the results 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 30.

Table 30. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
DVS1	1st Order, GCP	7°04'38.36202"	125°37'36.77094"	68.500	783116.705	790192.921	0.771
UPKAE	UP Established	7°11'09.07739"	125°27'08.90858"	266.926	795019.989	770850.418	197.198
UPLAS	UP Established	7°17'53.61604"	125°39'24.47345"	80.420	807581.490	793358.273	12.404
UPMTL	UP Established	7°05'42.29301"	125°30'06.27926"	179.729	785005.363	776349.630	110.718

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

Cross-section and bridge as-built survey were conducted on October 16 and 20, 2014, along the downstream side of the Lasang Bridge in Barangay Little Panay, Panabo City using GNSS receiver, Trimble® SPS 882, in PPK survey technique (shown in Figure 38).

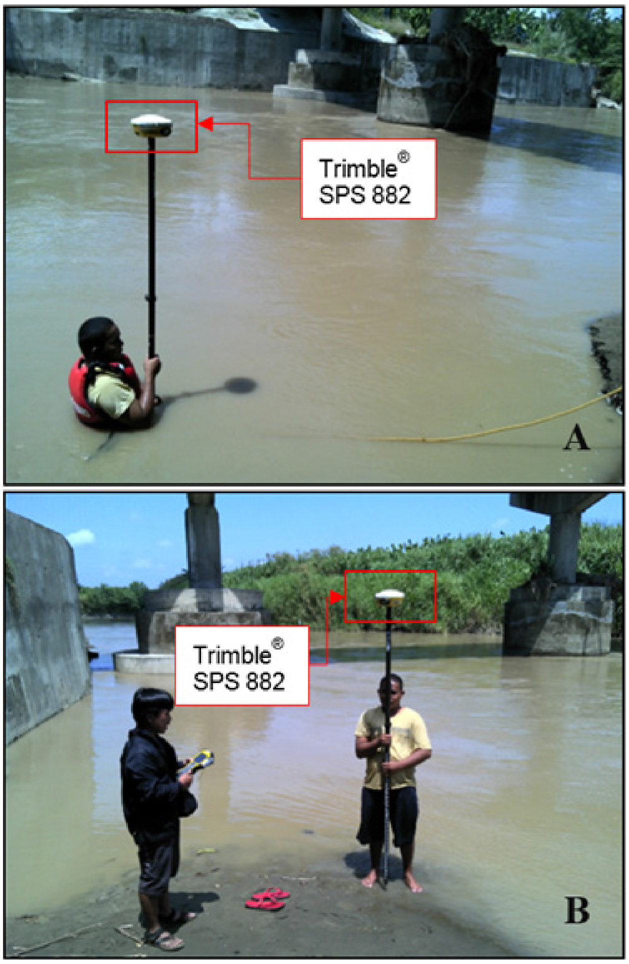


Figure 38. Cross-section survey at the Lasang Bridge in Panabo City

The length of the cross-sectional line surveyed in the Lasang Bridge is about 238.75 m, with a total of thirty-one (31) points acquired, using DVS-1 as the GNSS base station. Figure 39, Figure 40, and Figure 41 show the location map, the cross-section diagram, and the bridge as-built data form, respectively.

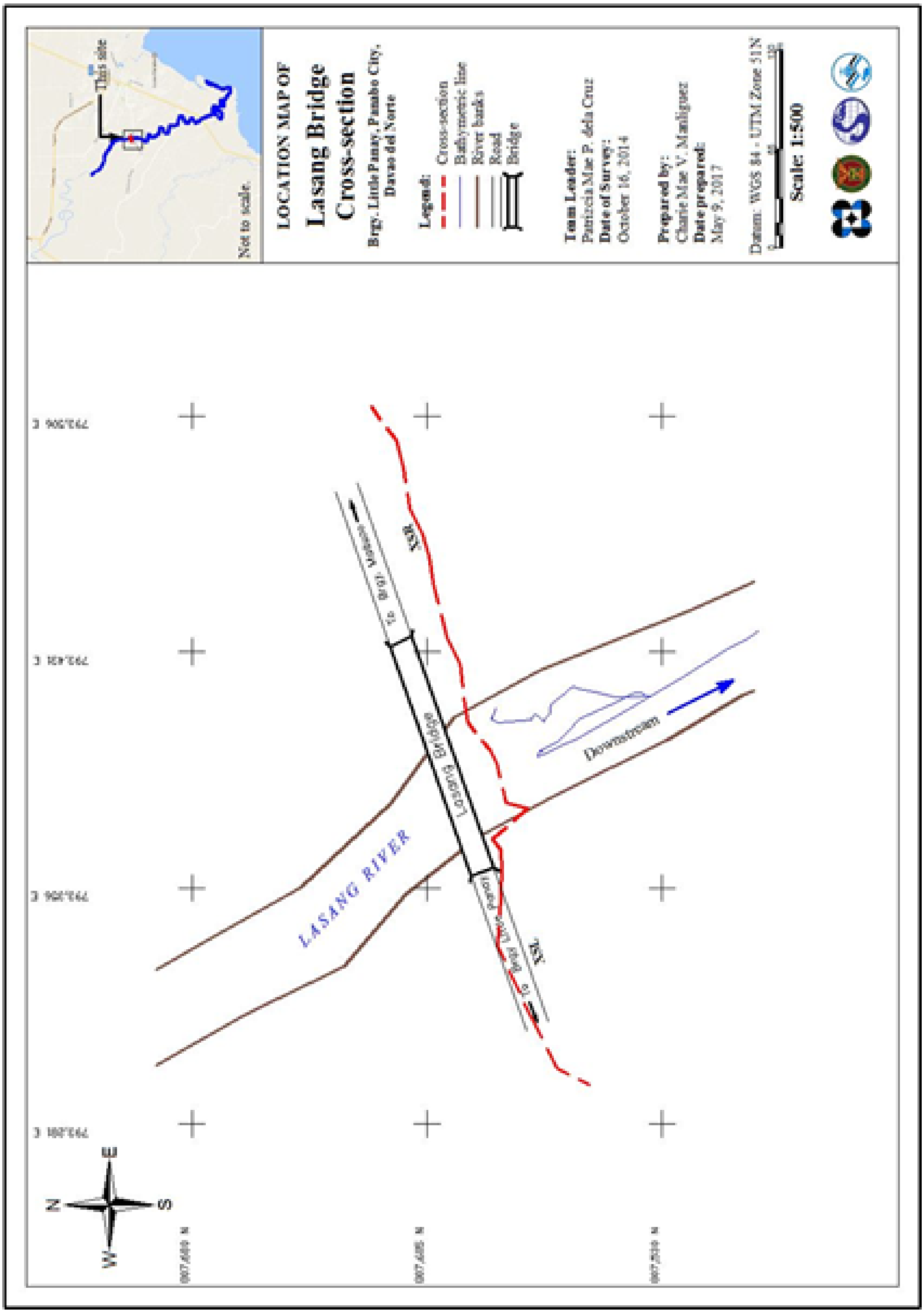


Figure 39. Location map of the Lasang Bridge cross-section

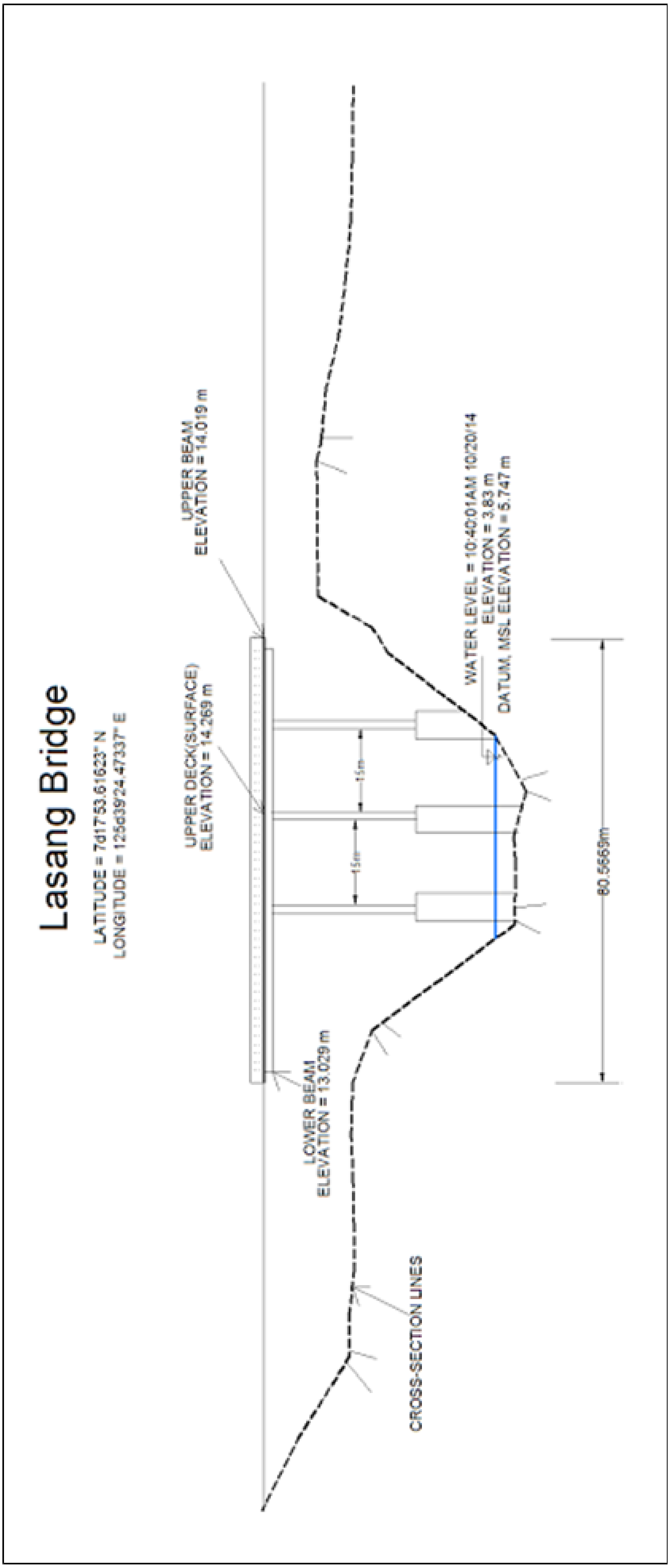


Figure 40. Lasang Bridge cross-section diagram

Bridge Data Form

Bridge Name: Lasang Bridge **Date:** October 16, 2014

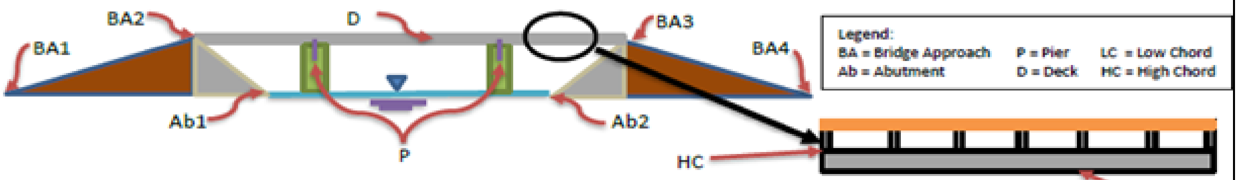
River Name: Lasang River **Time:** 5:10 PM

Location (Brgy, City,Region): Brgy. Little Panay Panabo City, Davao Del Norte

Survey Team: DVBC –Team Patrizcia Mae dela Cruz

Flow condition: low normal high **Weather Condition:** fair rainy

Latitude: 7d17'53.61623"N **Longitude:** 125d39'24.47337" E



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

Elevation: 12.185 m **Width:** 7.476 m **Span (BA3-BA2):** 80.567 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	14.269 m	13.029
2			
3			

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	14.248 m	BA3	156.815 m	13.728 m
BA2	76.248 m	13.842 m	BA4	218.446 m	11.037 m

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2	146.863 m	10.273 m

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

Shape: Circular **Number of Piers:** 3 **Height of column footing:** N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	108.882 m	14.269 m	1.20 cm
Pier 2	123.776 m	14.277 m	1.20 cm
Pier 3	138.714 m	14.279 m	1.20 cm
Pier 4			
Pier 5			
Pier 6			

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

Figure 41. Lasang Bridge Data Form

The water surface elevation of the Lasang River at its left and right banks was acquired using PPK survey technique on October 20, 2014 at 10:40:01 AM. The resulting water surface elevation data of 5.747 m above MSL was translated to water level markings on the piers of the Lasang Bridge, as shown in Figure 42. The markings served as a reference for flow data gathering and depth gauge deployment of the UPM PHIL-LIDAR 1.

Figure 42. Water level mark at the left (A) and right (B) piers of the Lasang Bridge, facing downstream

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 21 and 23, 2015 using a survey grade GNSS Rover receiver Trimble® SPS 882 in GNSS PPK survey technique mounted on a pole attached in front of the vehicle, as exhibited in Figure 43. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS Rover receiver.

On the first day of ground validation, the survey started in Barangay Toril in Davao City, and then traversed major roads going to Barangay Magugpo Poblacion in Tagum City. The second day of survey commenced in Barangay 4-A in Davao City along Maharlika Highway, and ended in Barangay Darong Santa Cruz in Davao del Sur. Point DVS-1 was used as the base station all throughout the conduct of the survey.

Figure 43. Validation points acquisition survey set-up (A) and the occupied base station, DVS-1, (B) at Sta. Ana Port

The survey acquired 13,126 ground validation points, with an approximate length of 94 km using the base station DVS-1, as illustrated in the map in Figure 44.

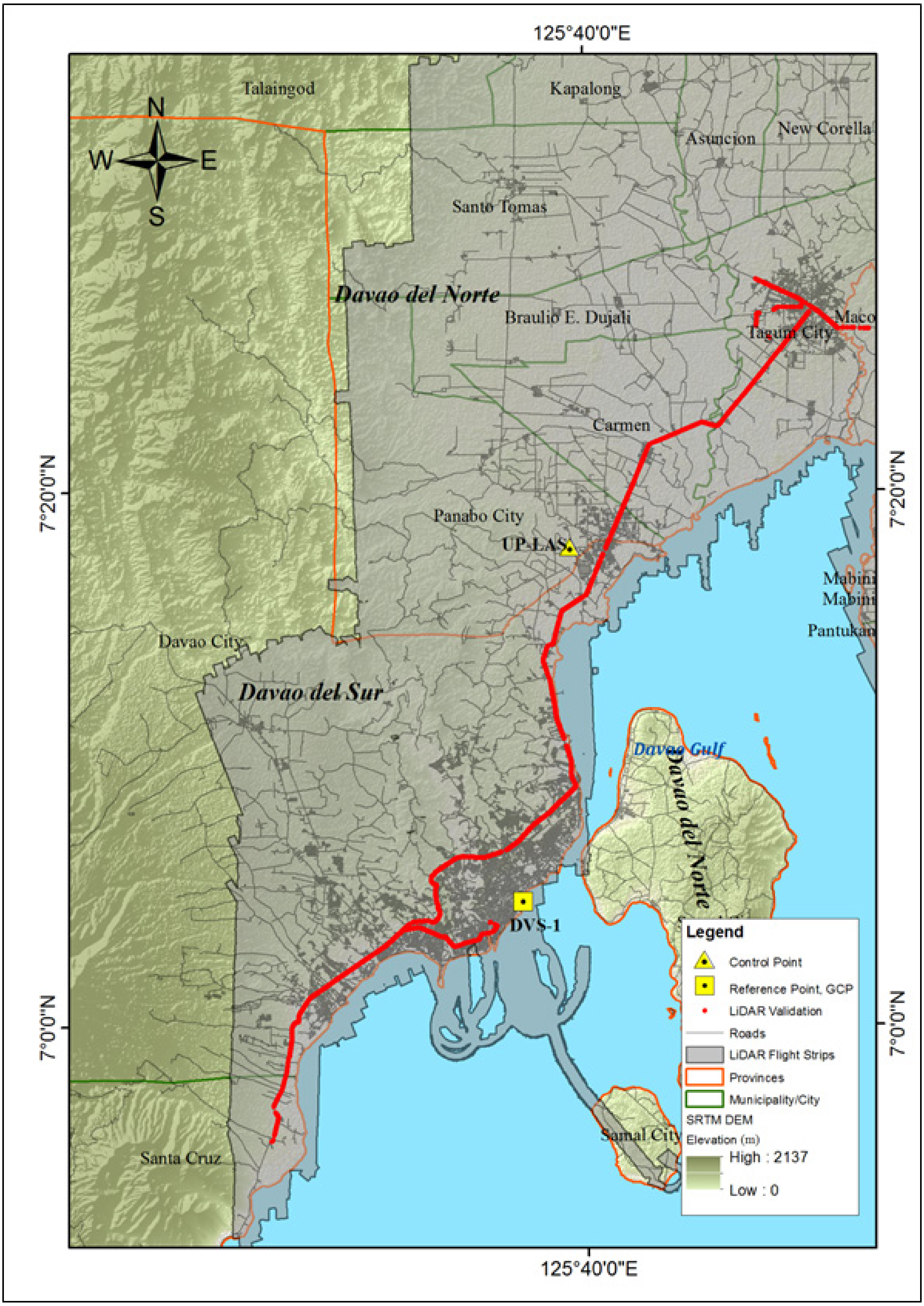


Figure 44. Extent of the LiDAR ground validation survey along Davao Region

4.7 River Bathymetric Survey

A bathymetric survey was executed on October 25, 2014 in the deeper portion of the river's downstream, using a rubber boat with an installed Hi-Target™ Single Beam Echo Sounder with mounted Trimble® SPS 882 GNSS receiver (pictured in Figure 45). The survey began in the Lasang Bridge in Barangay Maduao in Panabo City, with coordinates 7°17'53.66682" 125°39'26.26186", down to the mouth of the river in Barangay Vicente Hizon Sr. in Davao City, with coordinates 7°15'55.72151" 125°40'56.15739".

Figure 45. Setup of bathymetric survey using Hi-Target™ Single Beam Echo Sounder

A manual bathymetric survey, on the other hand, was conducted on October 20, 2014 using Trimble® SPS 882 in GNSS PPK survey technique, as shown in Figure 46. The survey was started in the upstream section of the river in Barangay Little Panay in Panabo City, with coordinates 7°18'55.95791" 125°38'30.51130", and was traversed by foot down the river, and was concluded at the starting point of bathymetric survey by boat. The control point DVS-1 was used as the GNSS base station all throughout the survey.

Figure 46. Actual execution of manual bathymetric survey along Lasang River

The bathymetric line of the river acquired a total of 1,310 points, covering an estimated length of 13.7 km, as shown in Figure 47. A CAD drawing was also produced to illustrate the Lasang riverbed profile. As shown in Figure 48, there is a gradual change in elevation between the river's upstream in Barangay Little Panay to its downstream or the mouth of the river in Barangay Vicente Hizon Sr., having a 3.2 m difference for every 1000 m, and a 7.2 m (MSL) difference.

Figure 47. Bathymetric points gathered from the Lasang River

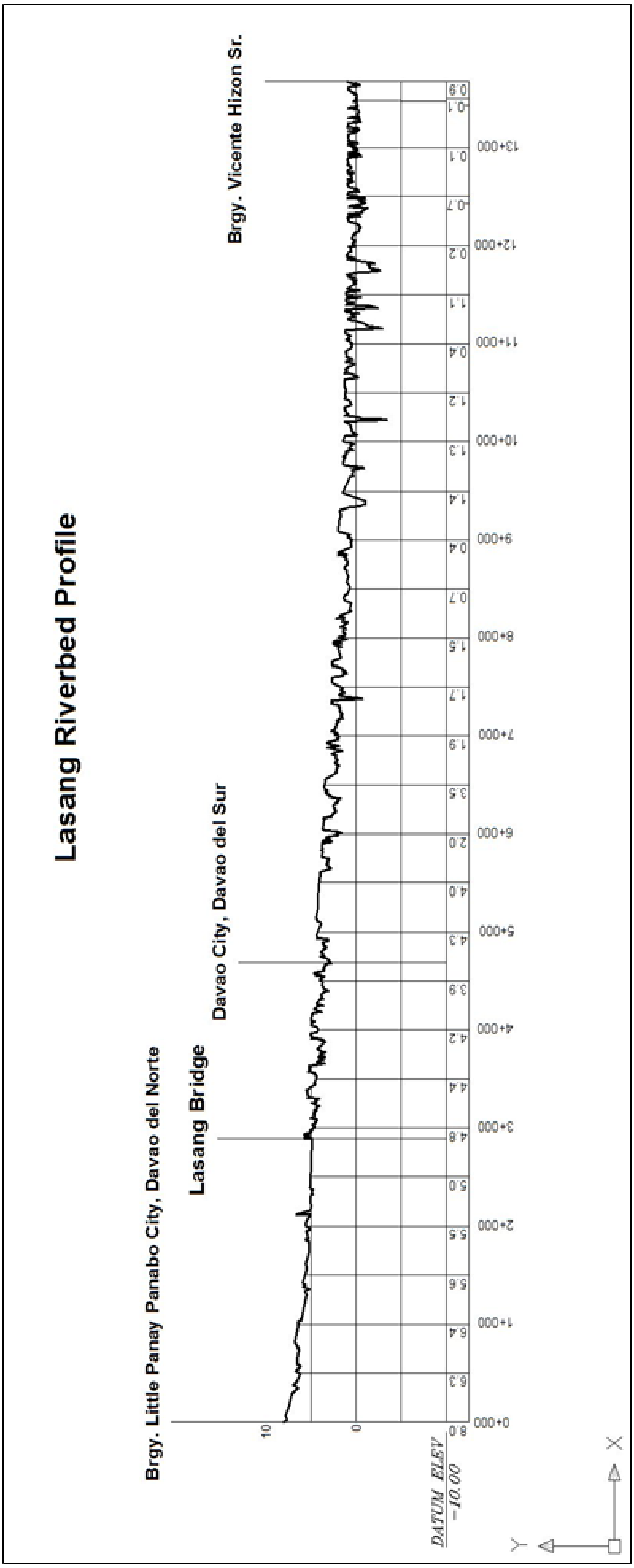


Figure 48. Riverbed profile of the Lasang River

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, Narvin Clyd Tan, and Hannah Aventurado

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 Hydologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the rain gauge installed by the UPM Phil-LiDAR 1 Team. The rain gauge is located in Barangay Tapak in Panabo City, Davao del Norte, with the following coordinates: 7° 30’ 57.13” N, 125° 27’ 5.8” E (Figure 49). The precipitation data collection occurred on June 25, 2015 at 4:00 PM until June 26, 2015 at 11:00 AM, with a 15-minute recording interval.

The total precipitation for this event in the installed rain gauge was 18 mm. It had a peak rainfall of 8.4 mm. on June 25, 2015 at 6:30 PM. The lag time between the peak rainfall and discharge was 7 hours and 40 minutes.

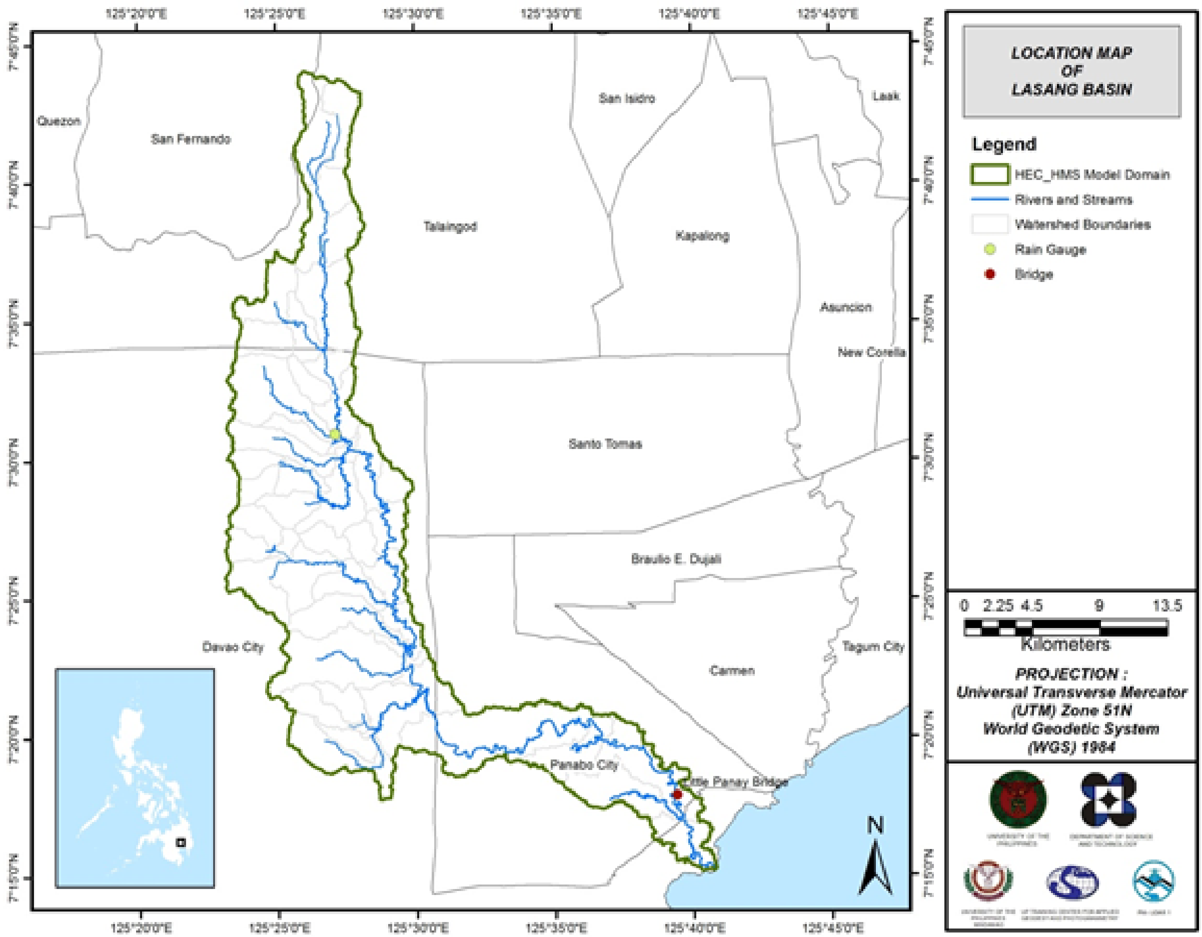


Figure 49. The location map of Lasang HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed at the Little Panay Bridge in Barangay Little Panay, Panabo City, Davao del Norte (7° 17' 53.84" N, 125° 39' 24.3" E) to establish the relationship between the observed water levels (H) at the Little Panay Bridge and outflow (Q) of the watershed at this location.

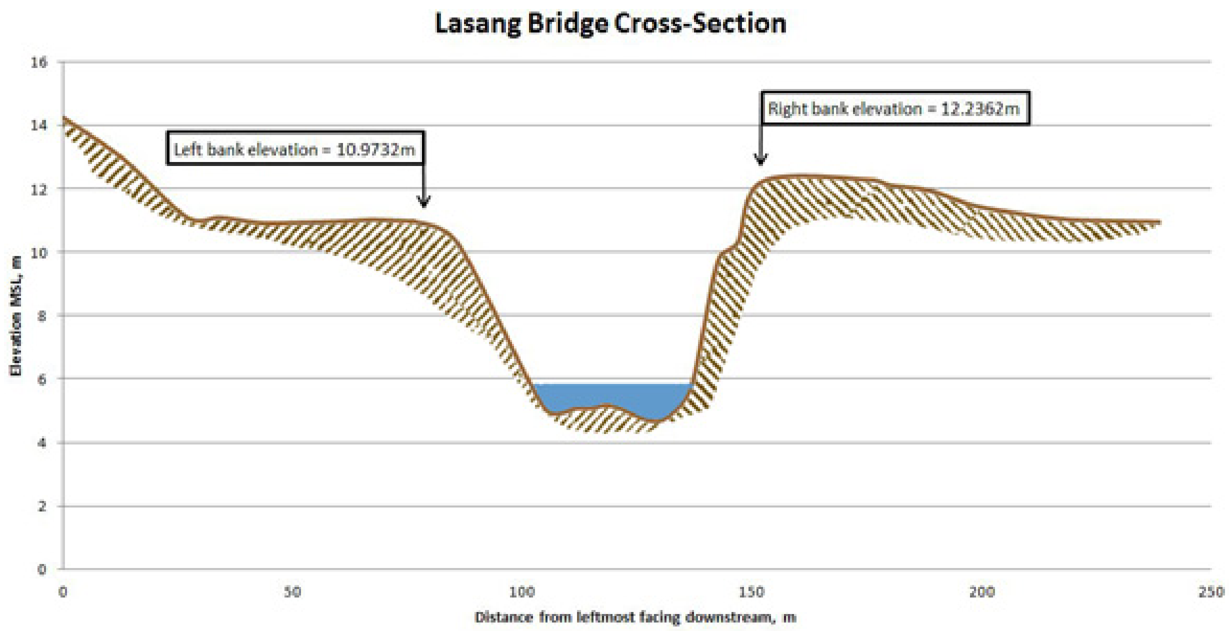


Figure 50. Cross-Section Plot of Lasang Footbridge

For the Little Panay Bridge, the rating curve is expressed as Q = 0.0182e1.2105x, as depicted in Figure 51.

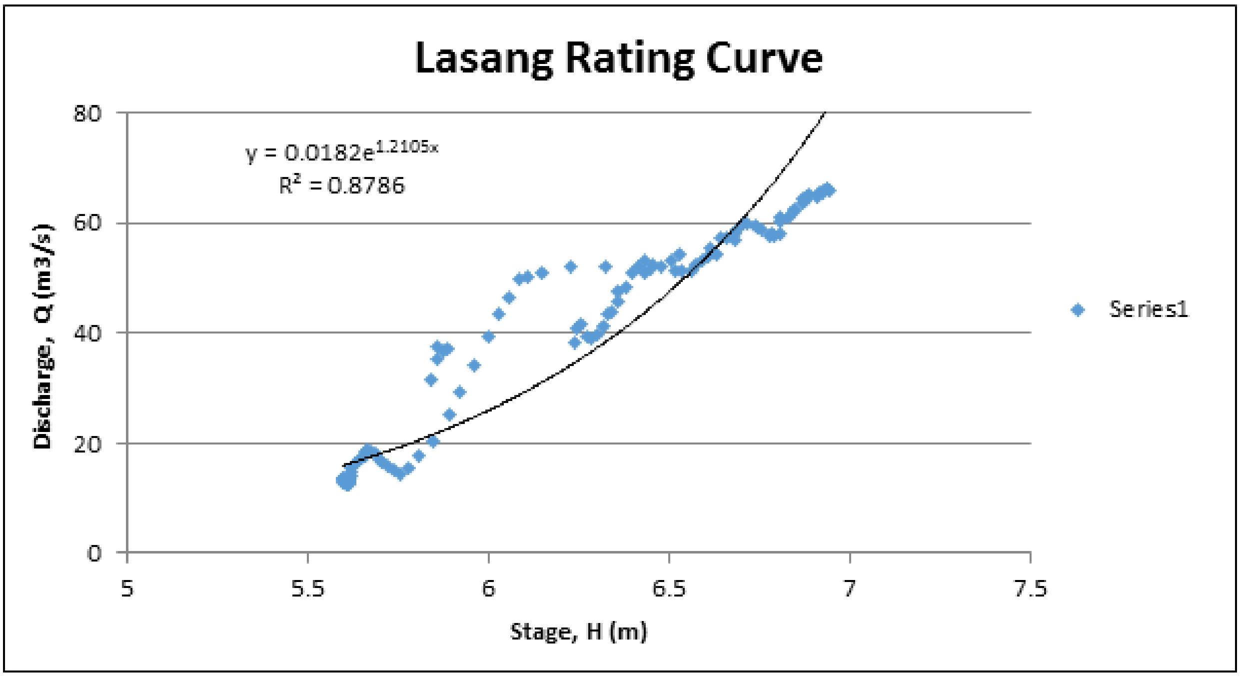


Figure 51. Rating Curve at Little Panay Bridge, Panabo City, Davao del Norte

The rating curve equation was used to compute for the river outflow at the Little Panay Bridge for the calibration of the HEC-HMS model for Lasang, as shown in Figure 52. The total rainfall for this event was 18 mm, and the peak discharge was 66.2 m3/s at 2:10 AM of June 26, 2015.

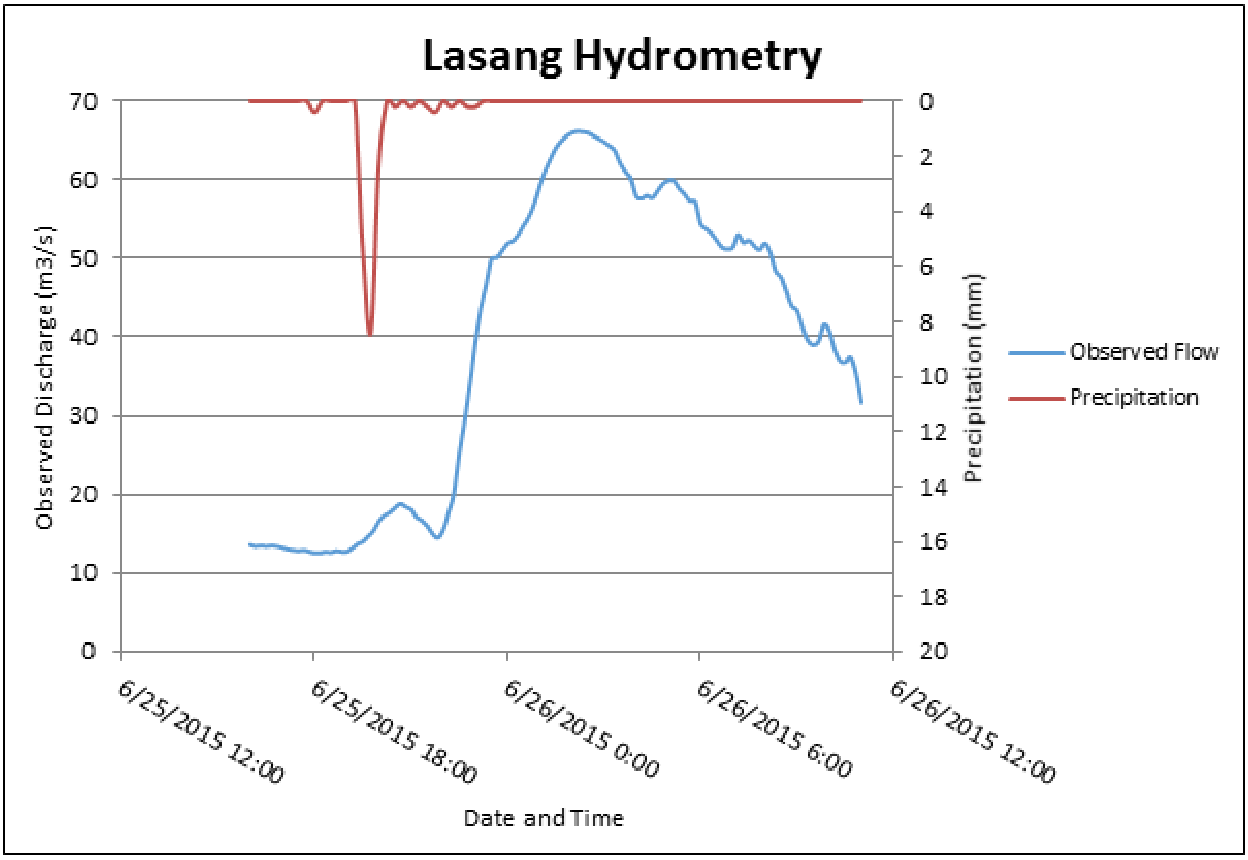


Figure 52. Rainfall and outflow data at Lasang used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Mactan Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Lasang watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 31. RIDF values for Mactan 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	19.5	30	38.2	53.2	65.2	71.6	80.3	85.8	91.4
5	25.1	39.3	51	73.2	88.8	96.4	108.7	114.9	121.1
10	28.8	45.4	59.4	86.5	104.5	112.8	127.5	134.1	140.7
15	30.9	48.9	64.2	94	113.3	122.1	138.1	145	151.8
20	32.4	51.3	67.6	99.3	119.5	128.6	145.5	152.6	159.5
25	33.5	53.2	70.1	103.3	124.2	133.6	151.2	158.5	165.5
50	37	59	78.1	115.8	138.9	149	168.8	176.5	183.9
100	40.5	64.7	85.9	128.1	153.5	164.2	186.3	194.4	202.1

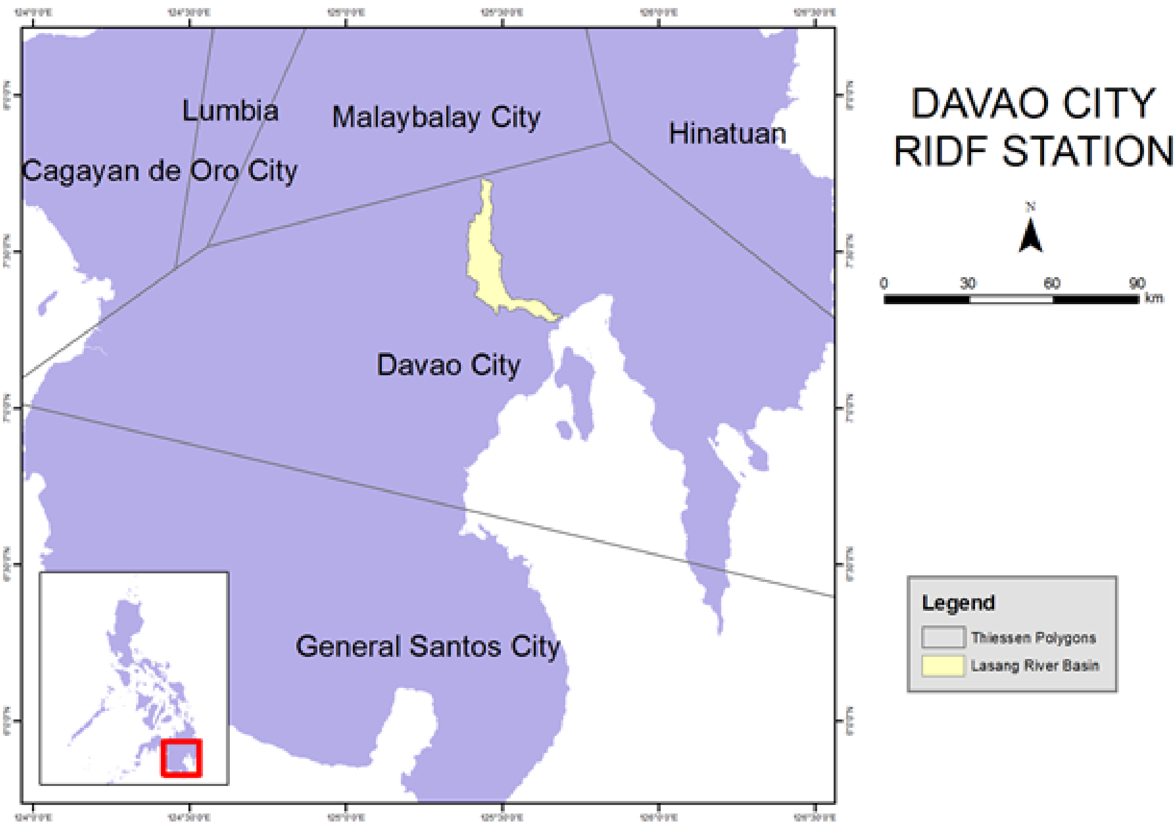


Figure 53. Location of Davao RIDF Station relative to the Lasang River Basin

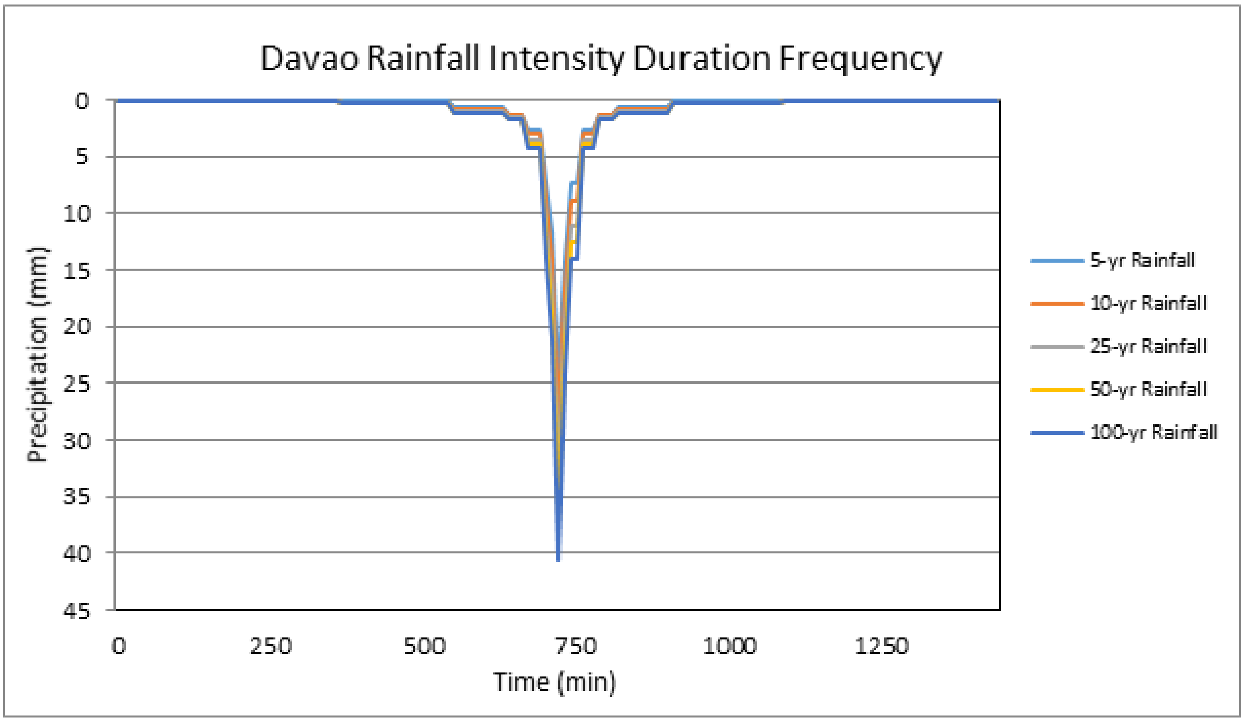


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset came from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004.The soil and land cover of the Lasang River Basin are shown in Figures 55 and 56, respectively.

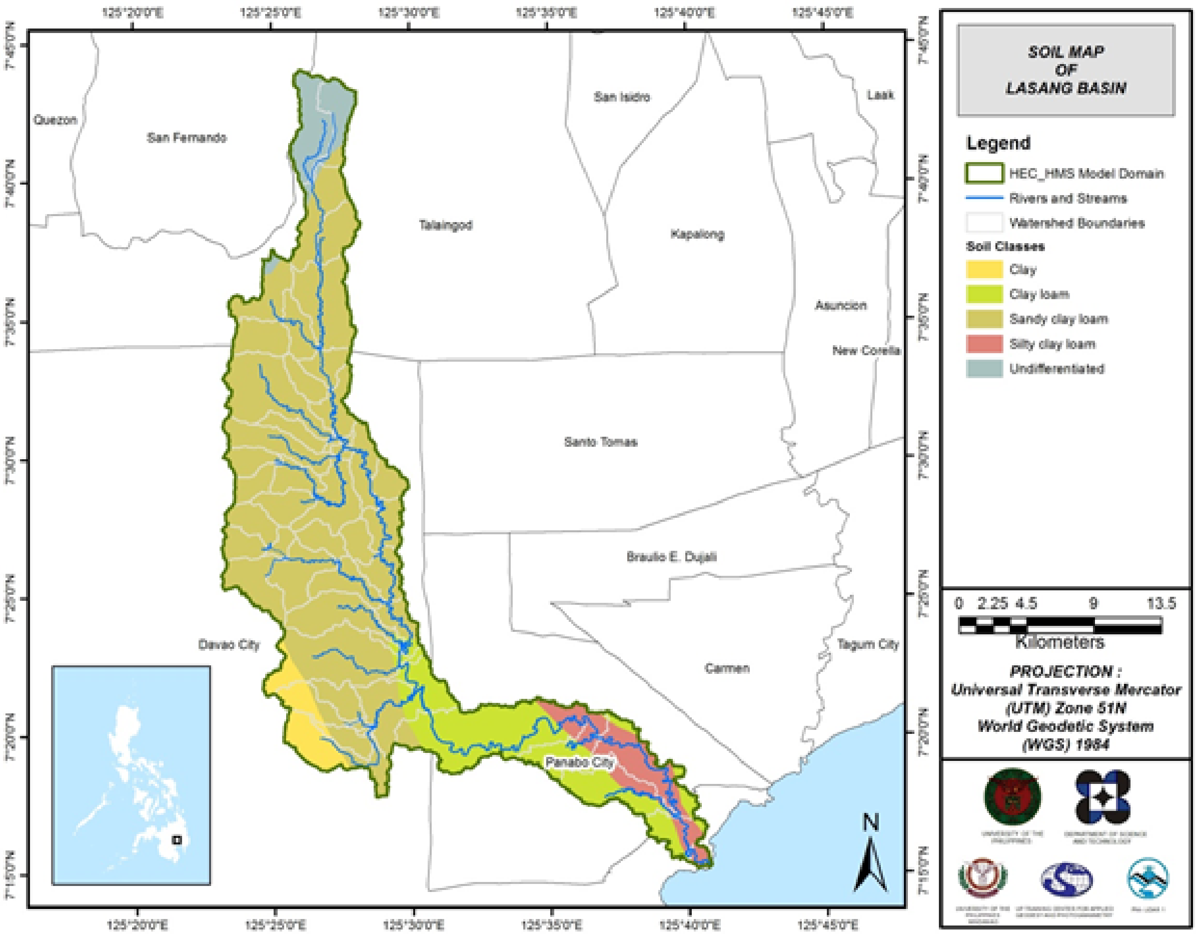


Figure 55. Soil Map of the Lasang River Basin (Source: DA)

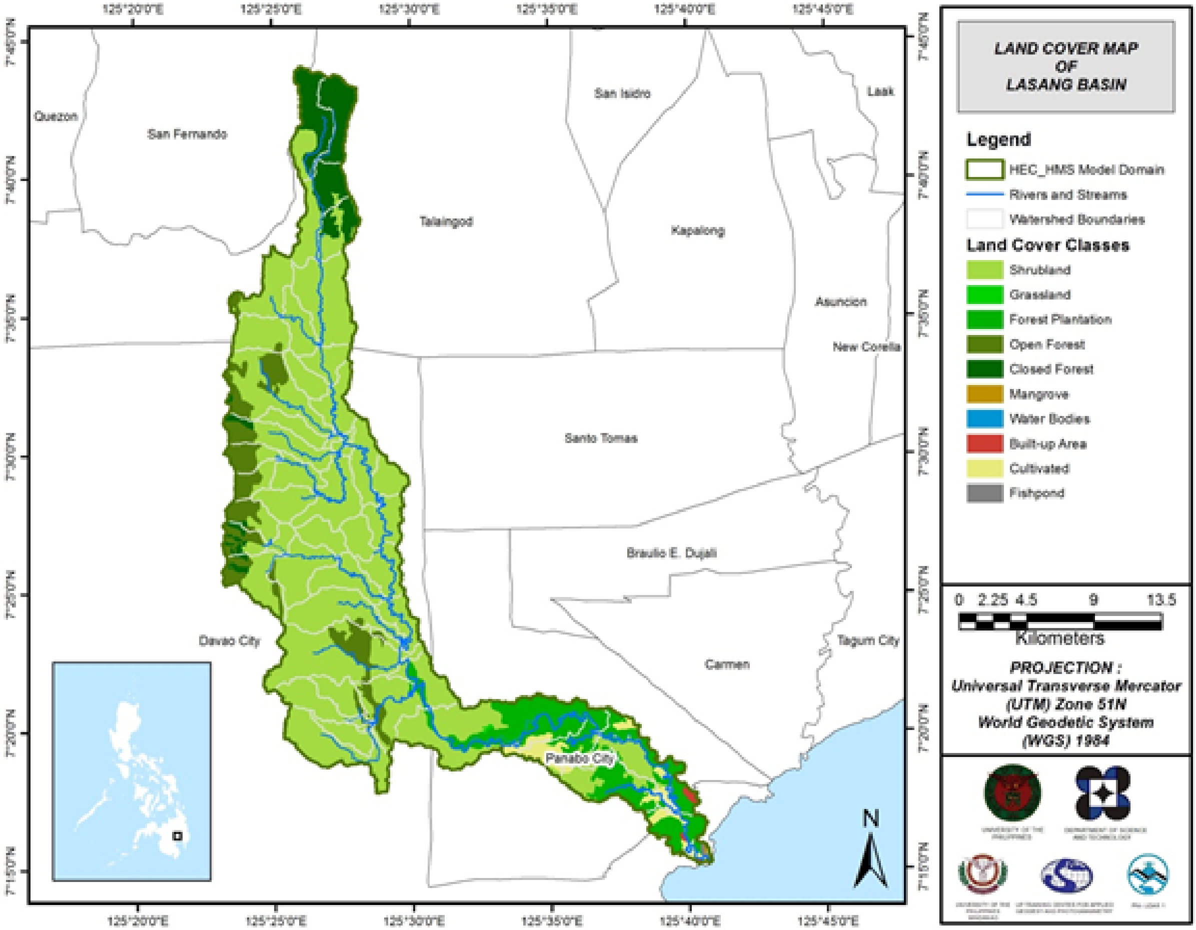


Figure 56. Land Cover Map of the Lasang River Basin (Source: NAMRIA)

For Lasang, five (5) soil classes were identified. These are clay, clay loam, sandy clay loam, silty clay loam, and undifferentiated land. Moreover, ten (10) land cover classes were identified. These are shrublands, grasslands, forest plantations, open forests, closed forests, mangroves, water bodies, built-up areas, fishponds, and cultivated areas.

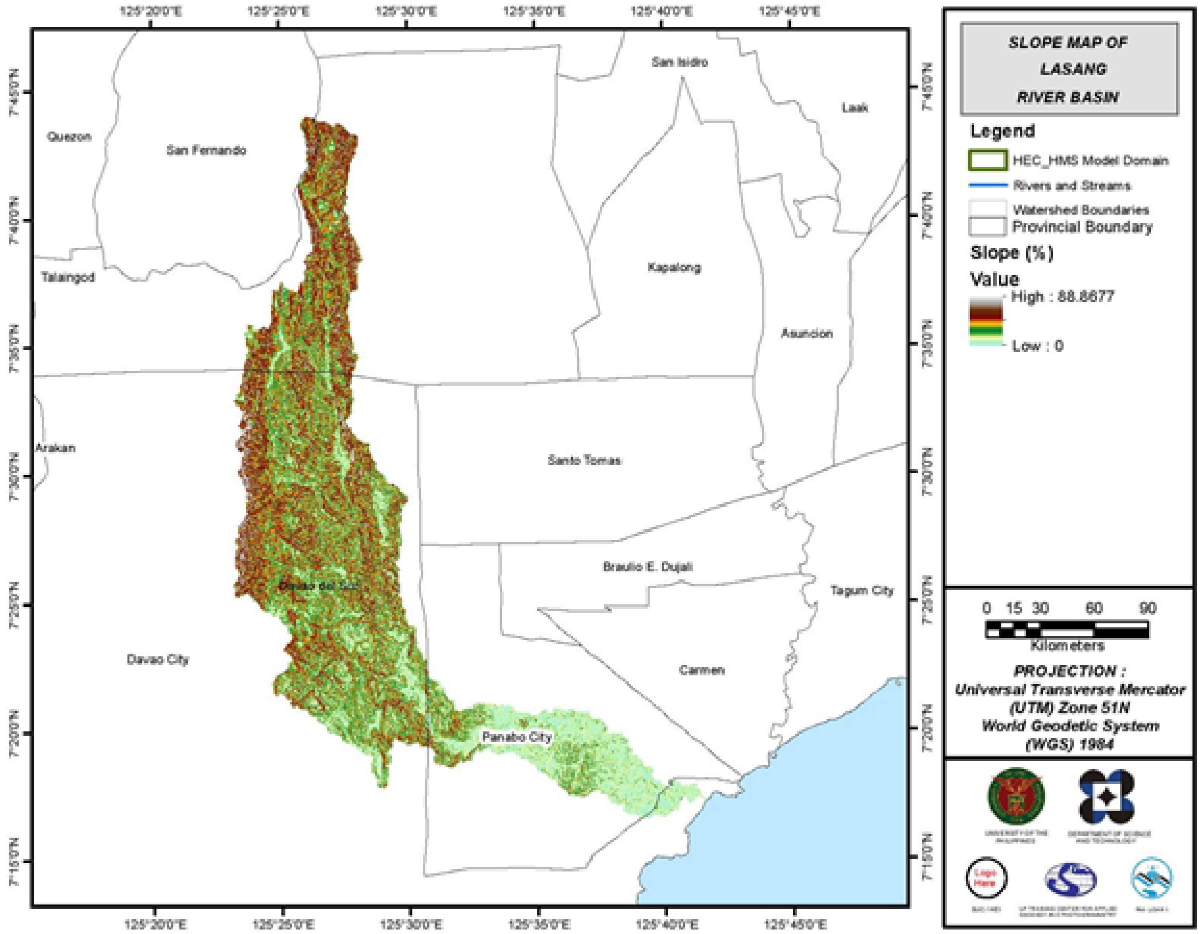


Figure 57. Slope map of the Lasang River Basin

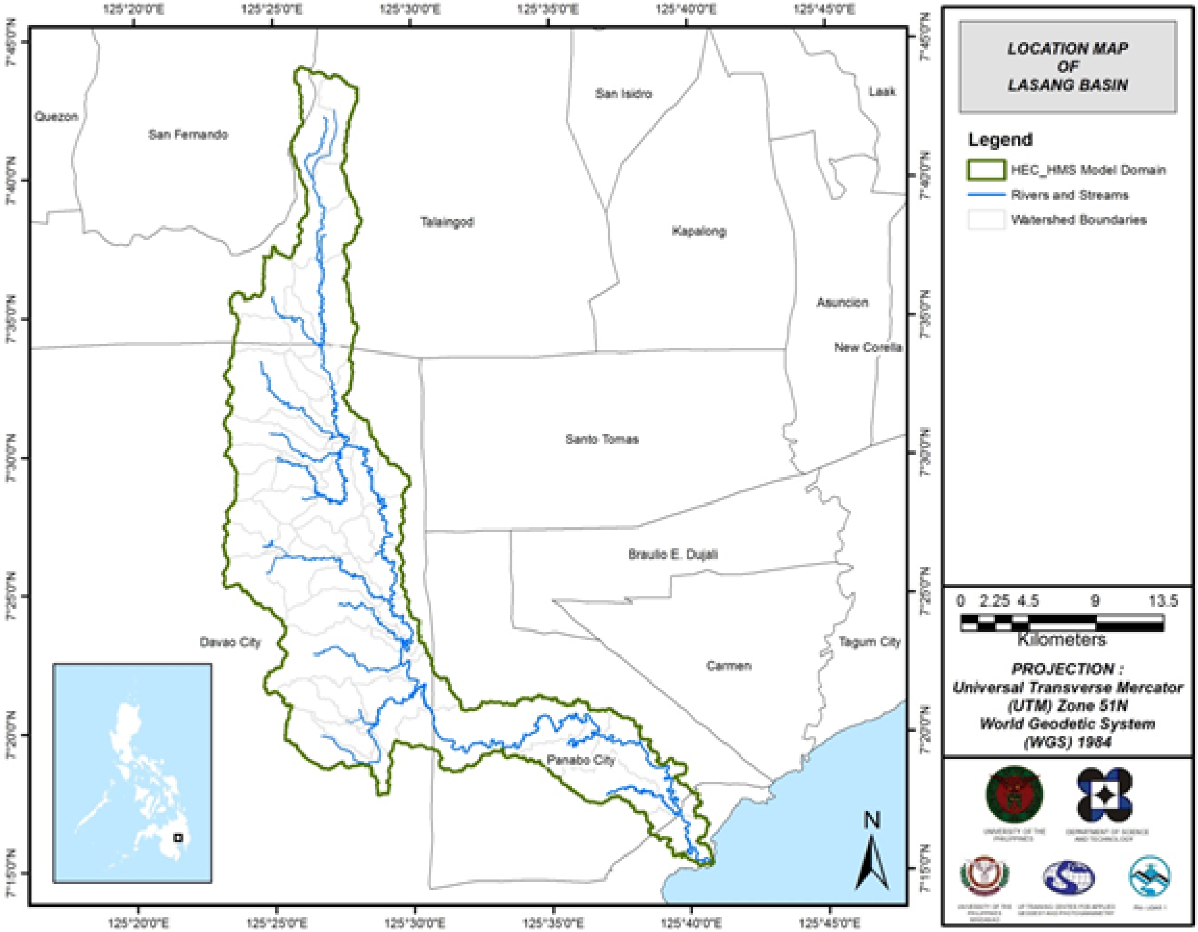


Figure 58. Stream delineation map of Lasang River Basin

Using the SAR-based DEM, the Lasang basin was delineated and further subdivided into sub basins. The model consists of fifty-three (53) sub basins, twenty-six (26) reaches, and twenty-six (26) junctions, as shown in Figure 59. The main outlet is at the Little Panay Bridge. See Annex 10 for the Lasang Model Reach Parameters.

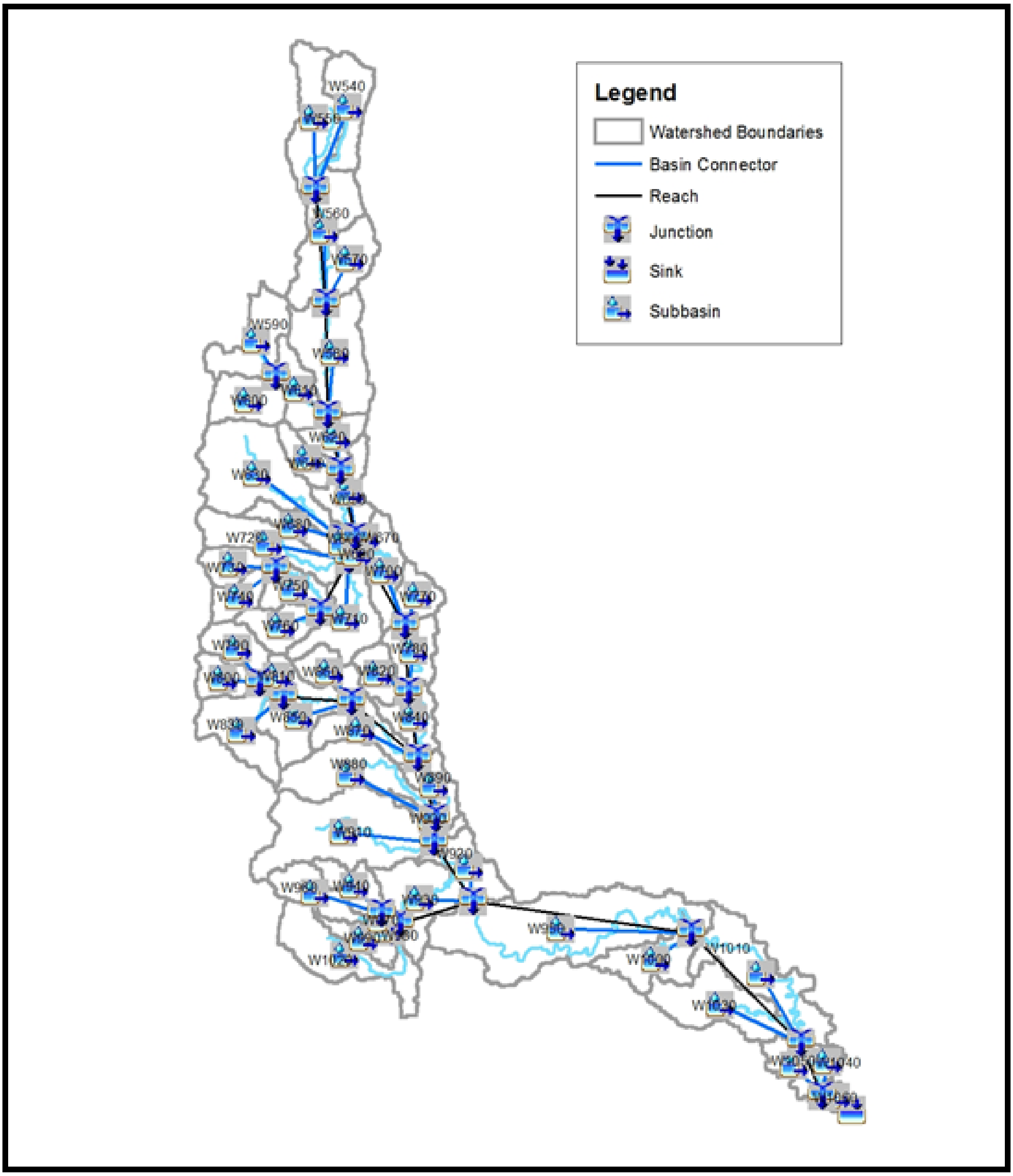


Figure 59. The Lasang river basin model generated using HEC-HMS.

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 60).

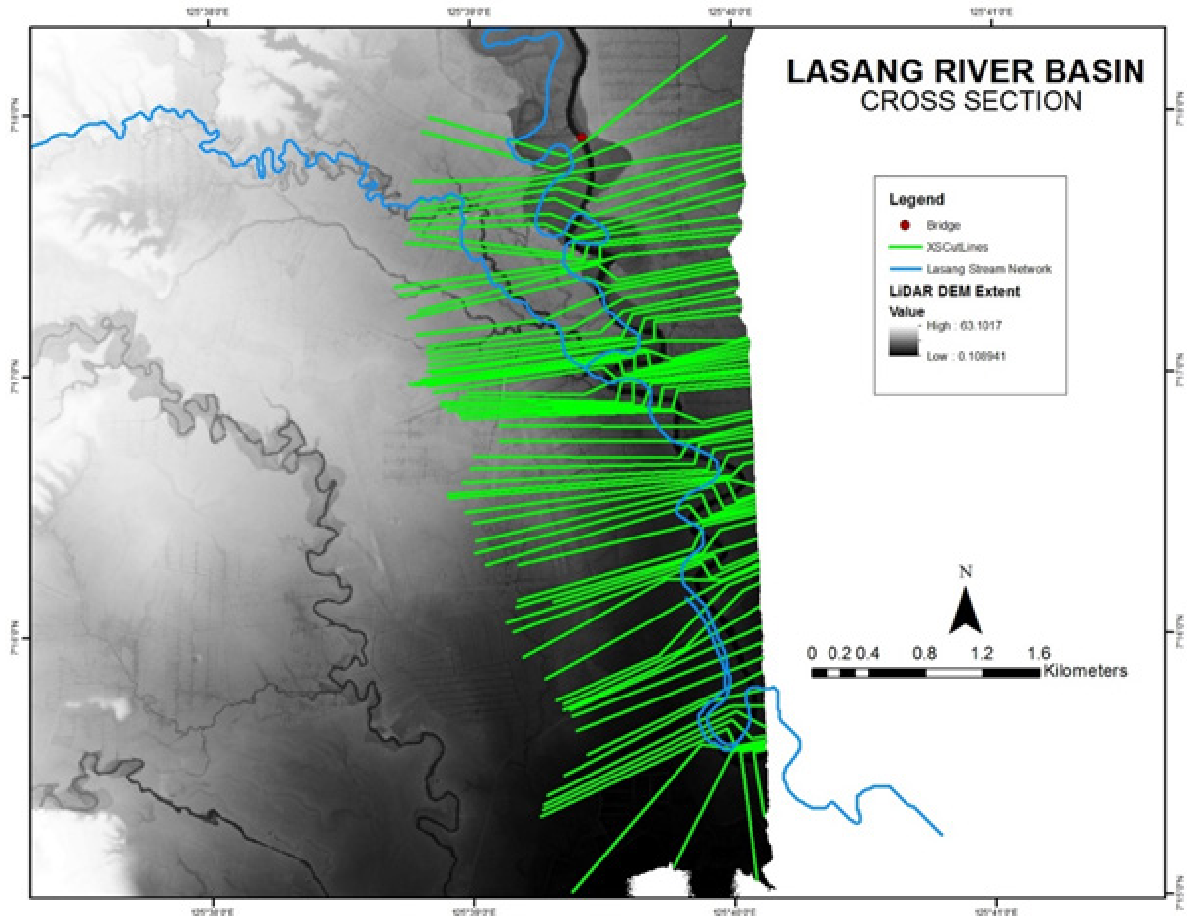


Figure 60. River cross-section of the Lasang River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

Based on the elevation and flow direction, it is seen that the water will generally flow from the north of the model to the south, following the main channel. As such, boundary elements northwest of the model are assigned as outflow elements.

Figure 61. A screenshot of the river sub catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro))

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 11.9 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 generated flood hazard maps for Lasang are in Figures 65, 67, and 69.

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 24,900,100.00 m2. The generated flow depth maps for Lasang are in Figures 66, 68, and 70.

There is a total of 52,492,077.22 m3 of water entering the model, of which 5,016,626.73 m3 is due to rainfall and 47,475,450.50 m3 is inflow from basins upstream. 1,243,242.38 m3 of this water is lost to infiltration and interception, while 12,186,731.34 m3 is stored by the flood plain. The rest, amounting up to 39,002,802.58 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Lasang HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data. See Annex 9 for the Lasang Model Basin Parameters.

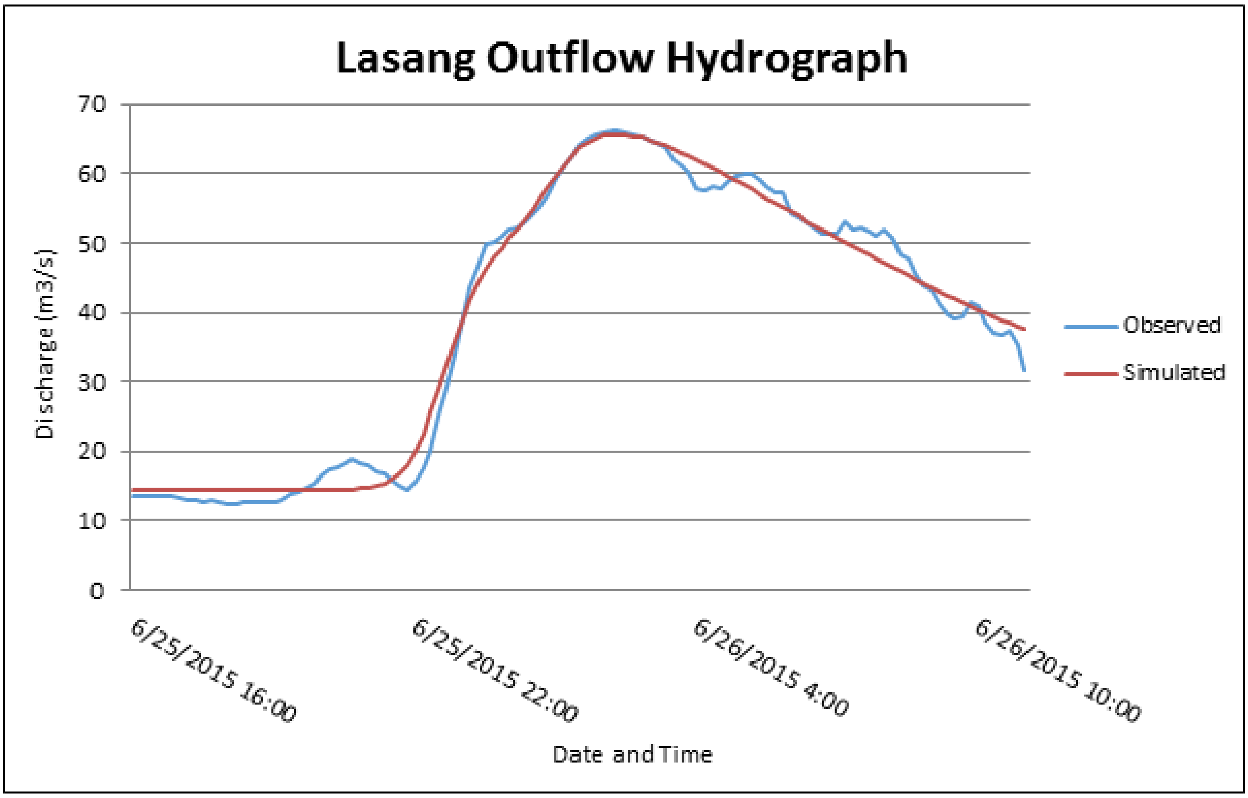


Figure 62. Outflow Hydrograph of Lasang produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 32 are the adjusted ranges of values of the parameters used in calibrating the model for the Lasang River Basin.

Table 32. Range of Calibrated Values for Lasang

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.49 – 22.29
			Curve Number	35 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.128 – 14.95
			Storage Coefficient (hr)	0.0167 – 19.47
	Baseflow	Recession	Recession Constant	0.00001 - 1
			Ratio to Peak	0.0095 - 1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0003 – 0.16

Initial abstraction is defined as 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 0.49 mm to 22.29 mm for this parameter means that there is a small initial fraction of the storm depth after which runoff begins, increasing the river outflow.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 65 to 90 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Lasang, the basin mainly consists of shrublands, and the soil mostly consists of sandy clay loam.

Time of concentration and storage coefficient are the travel time and index of temporary runoff storage in a watershed. The range of calibrated values from 0.0167 hours to 19.47 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 values within the range of 0.00001 to 1 indicate that the discharge leaving or receding from every sub basin within Lasang differs significantly. Values of ratio to peak within the range of 0.0095 to 1 indicate an average receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. The Lasang River Basin reaches' Manning's coefficients ranging from 0.0003 to 0.16, shows that there is a variety in surface roughness all over the catchment (Brunner, 2010).

Table 33. Summary of the Efficiency Test of Lasang HMS Model

Accuracy Measure	Value
RMS Error	2.2
r2	0.988
NSE	0.99
RSR	-0.40
PBIAS	0.11

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 2.2 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 represents an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured at 0.988.

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 0.99.

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 -0.40.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units are quantified. The model has an RSR value of 0.11.

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 63) presents the Lasang outflow using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in five (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 a significant increase in the outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

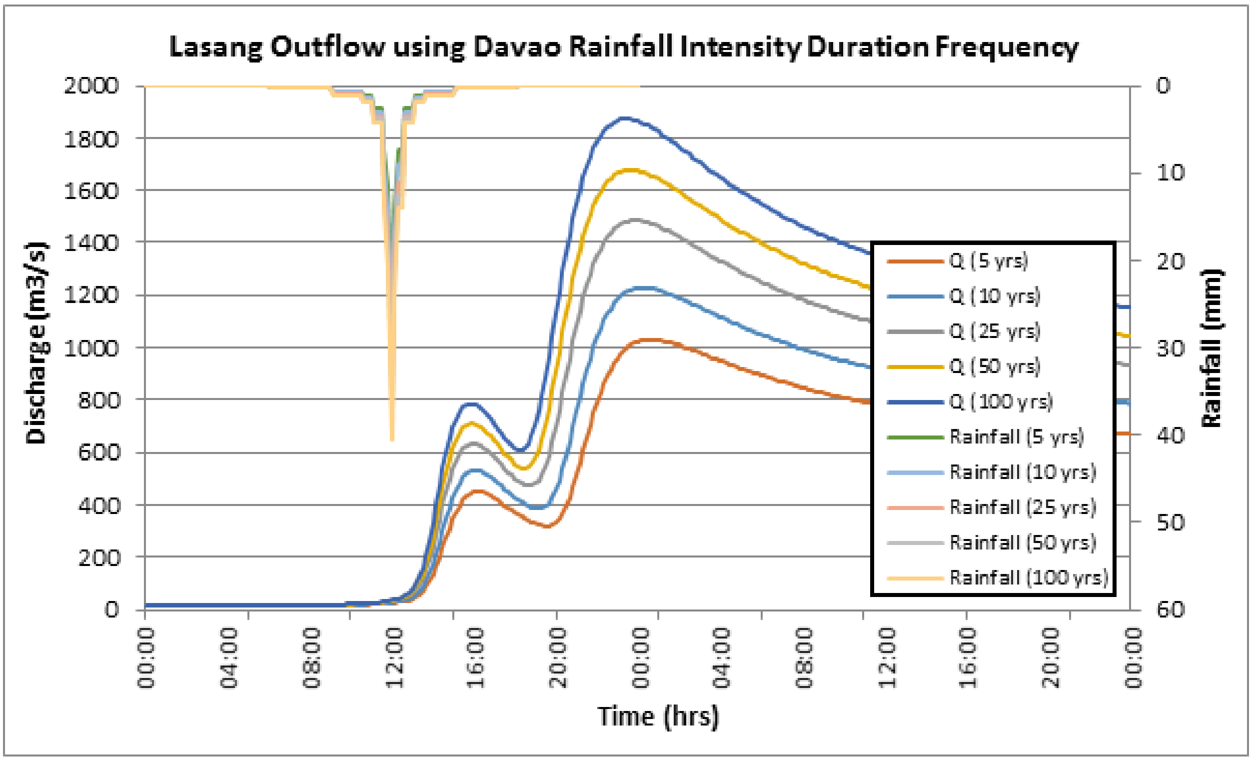


Figure 63. Outflow hydrograph at the Lasang Station generated using the Davao RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Lasang discharge using the Davao RIDF in five (5) different return periods is shown in Table 34.

Table 34. Peak values of the Lasang HEC-HMS Model outflow using the Mactan RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	121.1	25.1	1030.4	12 hours
10-Year	140.7	28.8	1227.8	12 hours
25-Year	165.5	33.5	1485.9	11 hours, 50 minutes
50-Year	183.9	37	1678.2	11 hours, 40 minutes
100-Year	202.1	40.5	1872.4	11 hours, 30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is presented. The sample generated map of the Lasang River using the calibrated HMS base flow is shown in Figure 64.

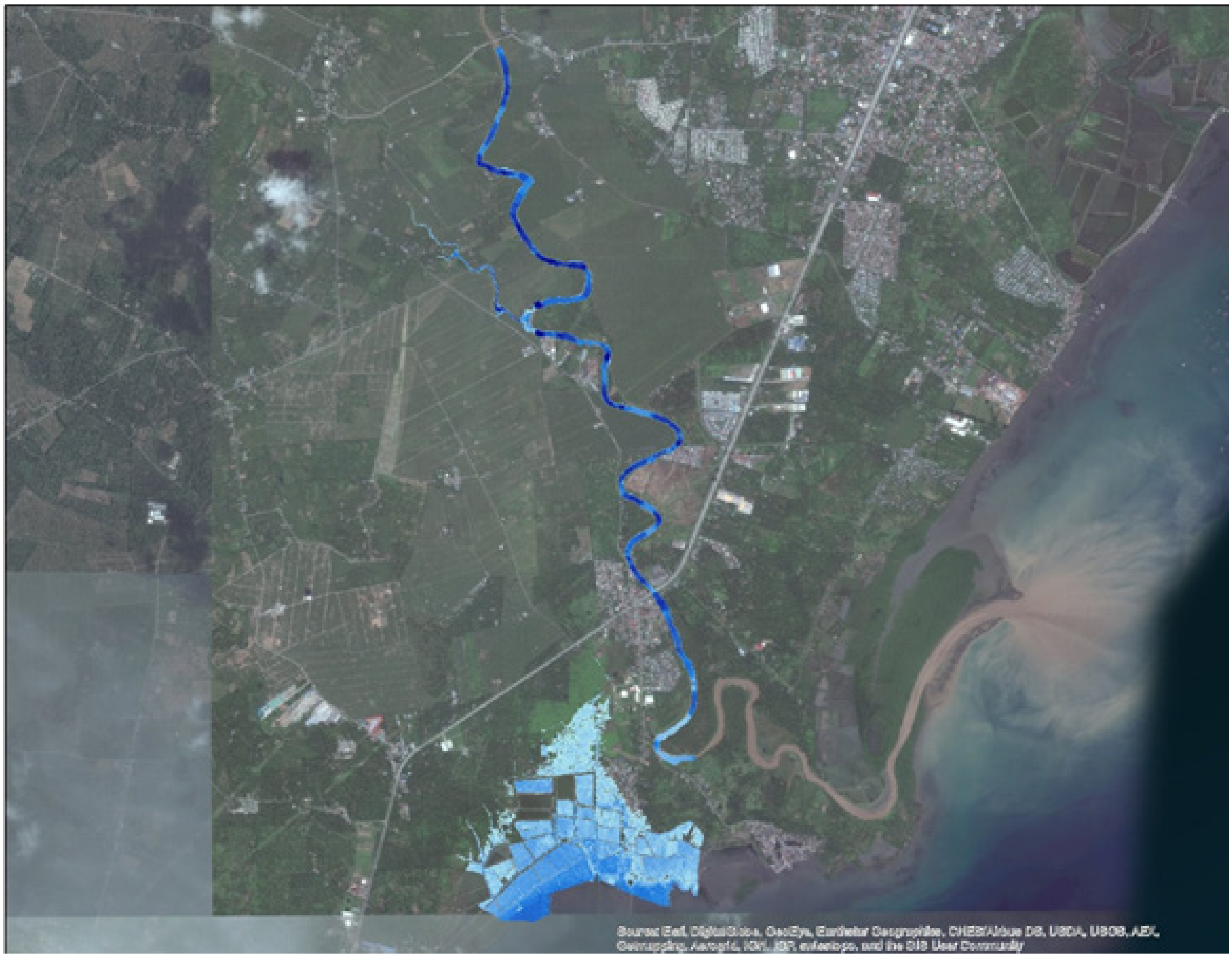


Figure 64. Sample output of Lasang RAS Model

5.9 Flood Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Lasang floodplain are shown in Figures 65 to 70. The floodplain, with an area of 47.14 sq. km., covers two (2) municipalities from two (2) provinces. Table 35 indicates the percentage of area affected by flooding per municipality.

Table 35. Municipalities/ cities affected by flooding in the Lasang Floodplain

Province	City / Municipality	Total Area	Area Flooded	% Flooded
Davao del Norte	Panabo City	301.68	30.5756	10.14%
Davao del Sur	Davao City	2224.82	16.5086	0.74 %

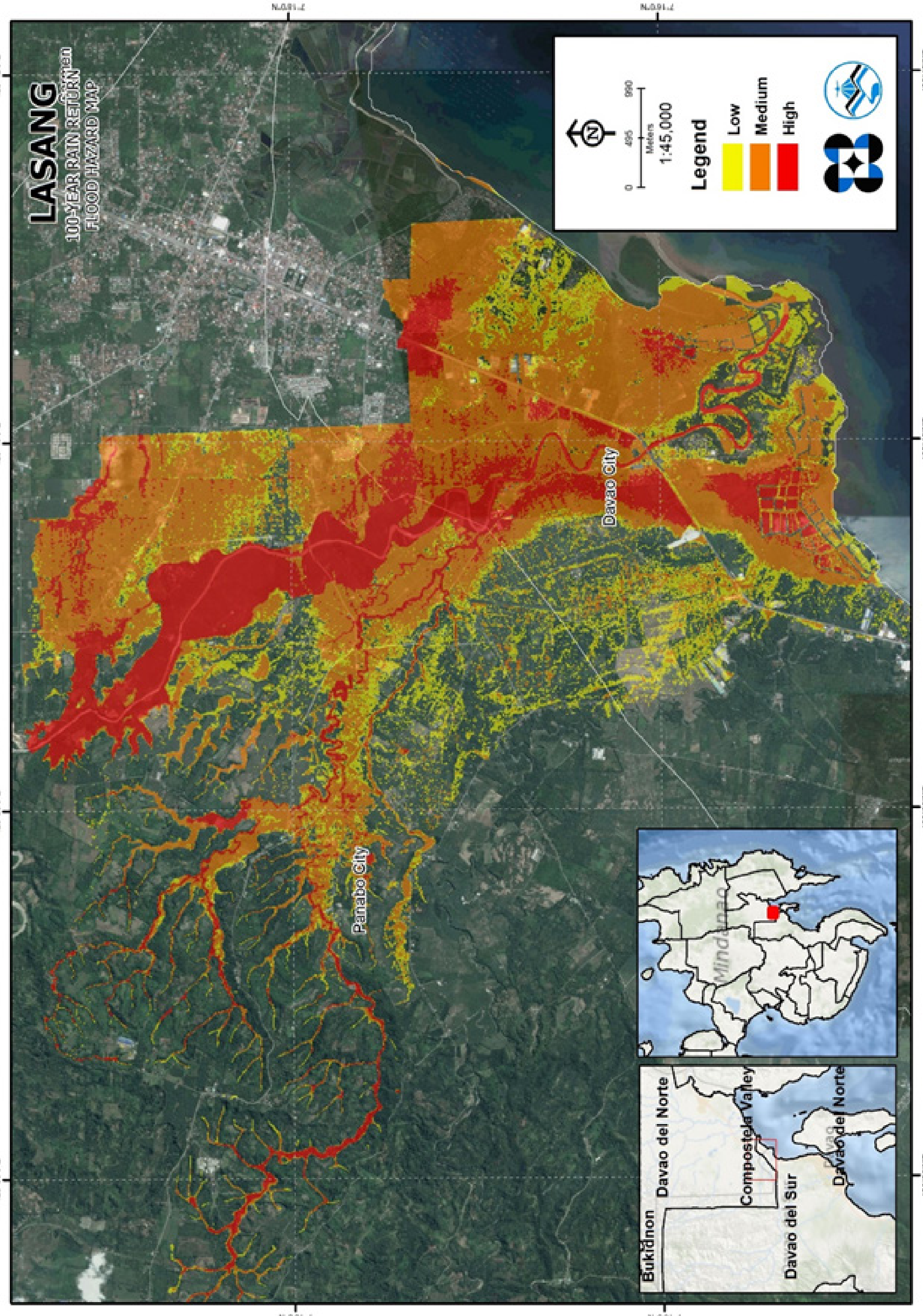


Figure 65. 100-year Flood Hazard Map for Lasang Floodplain overlaid on Google Earth imagery

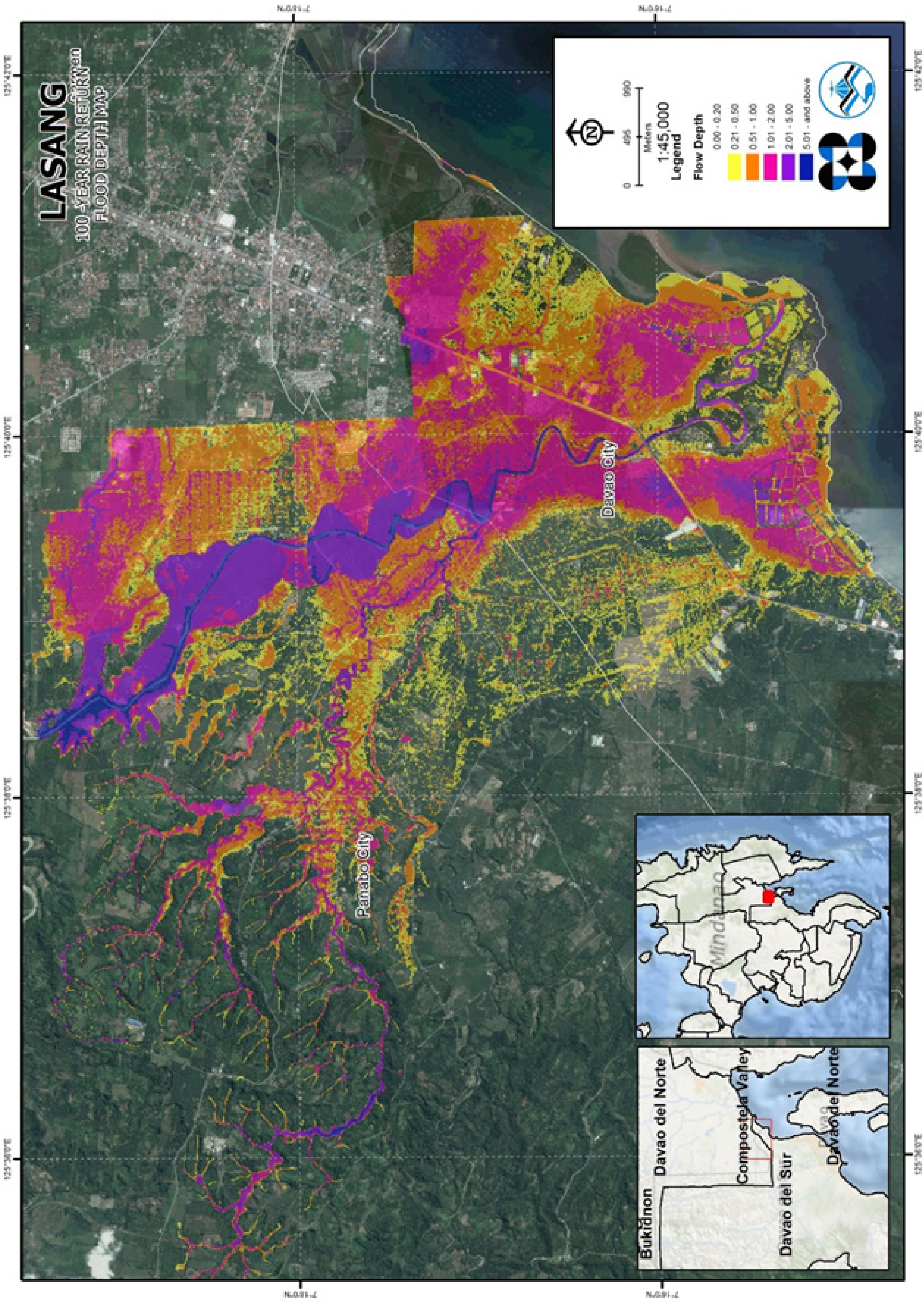


Figure 66. 100-year Flow Depth Map for Lasang Floodplain overlaid on Google Earth imagery

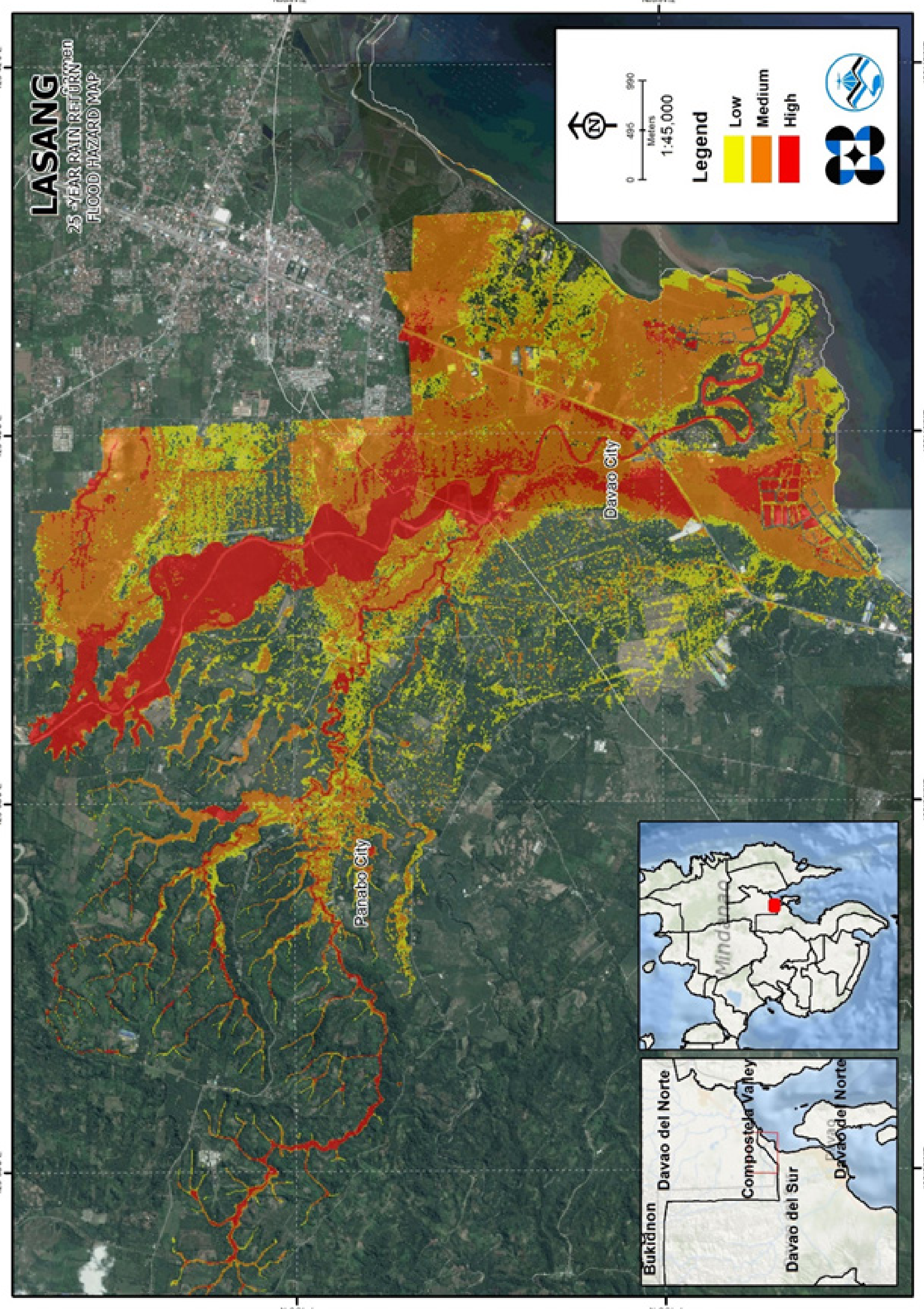


Figure 67. 25-year Flood Hazard Map for Lasang Floodplain overlaid on Google Earth imagery

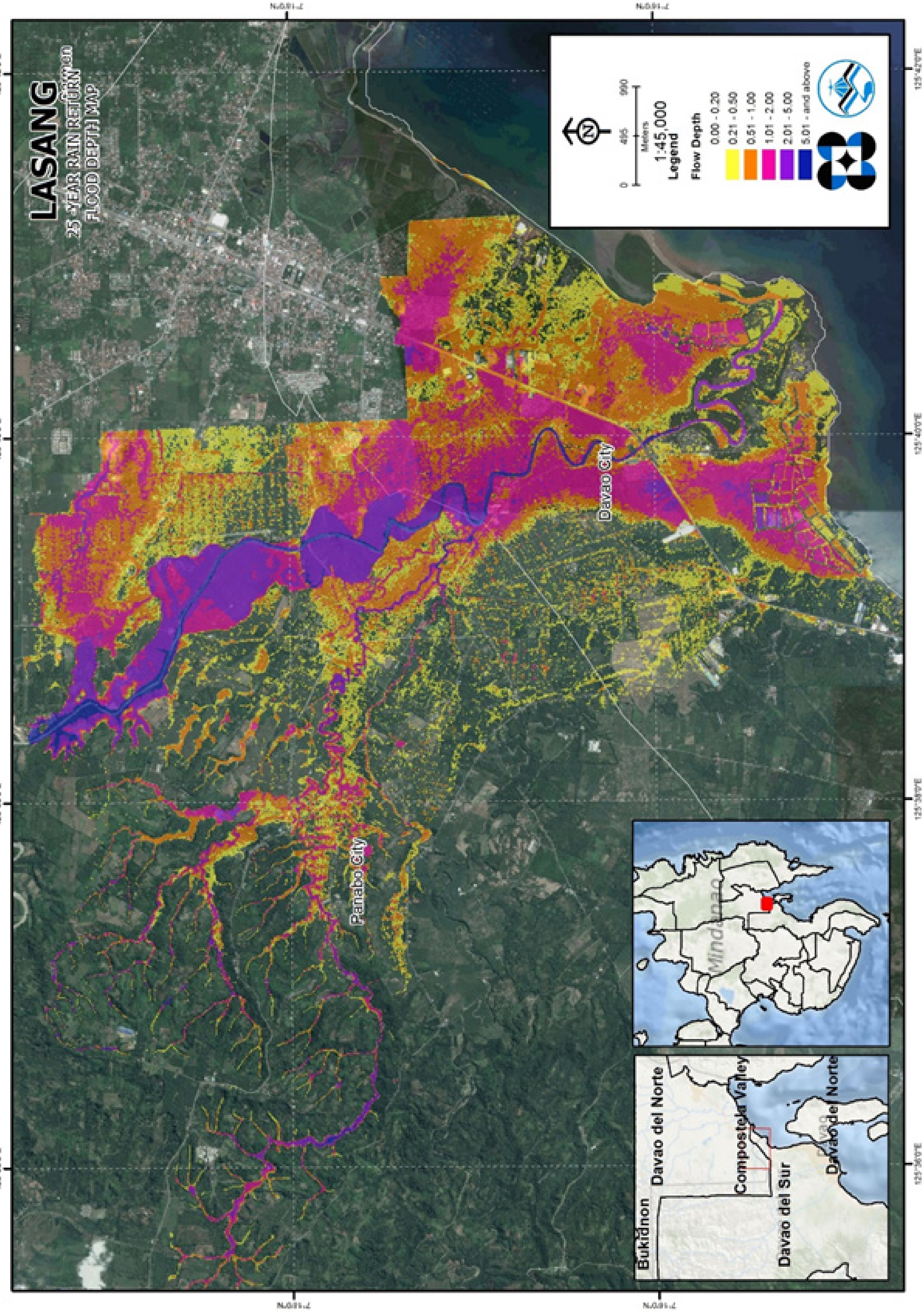


Figure 68. 25-year Flow Depth Map for Lasang Floodplain overlaid on Google Earth imagery

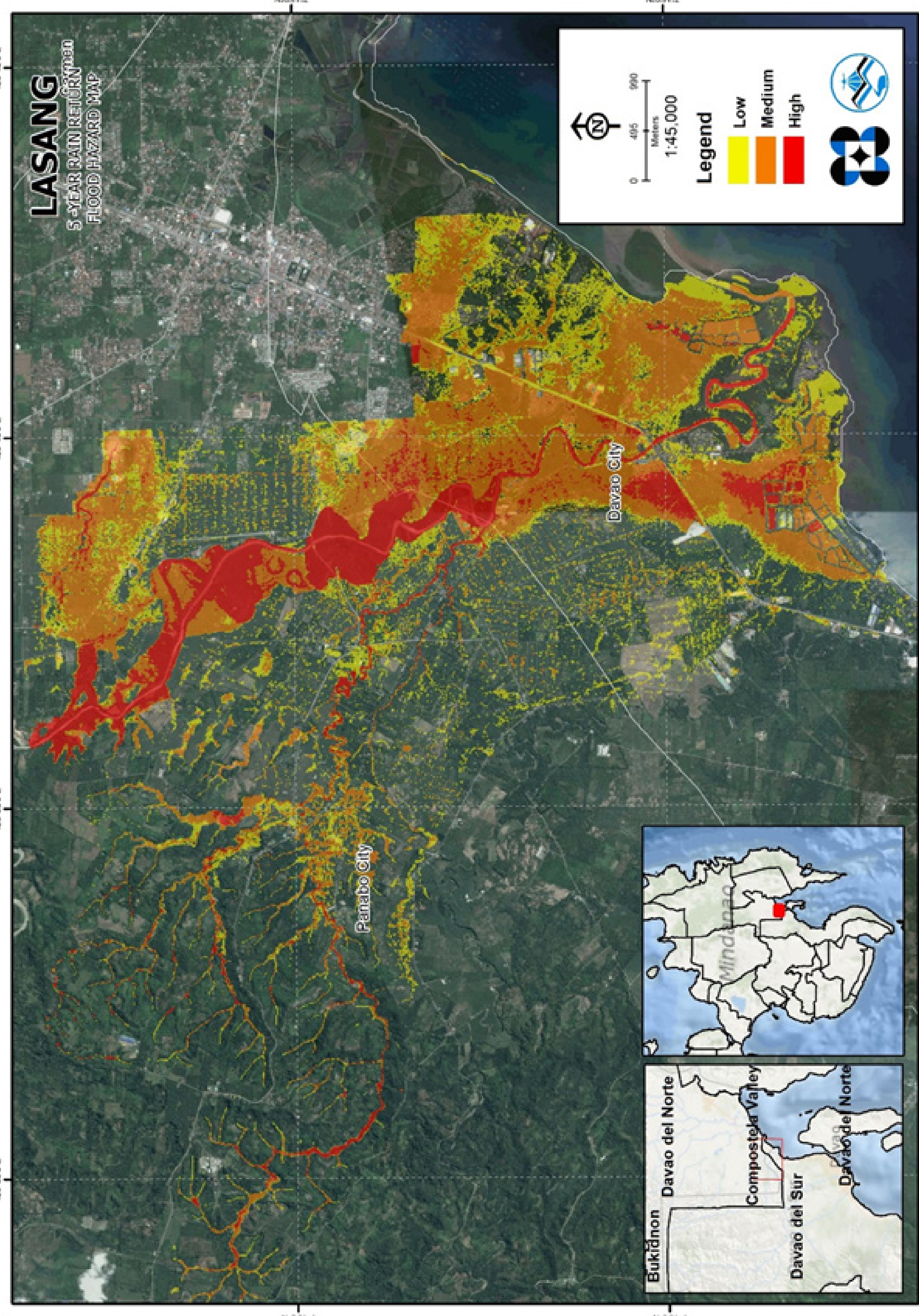


Figure 69. 5-year Flood Hazard Map for Lasang Floodplain overlaid on Google Earth imagery

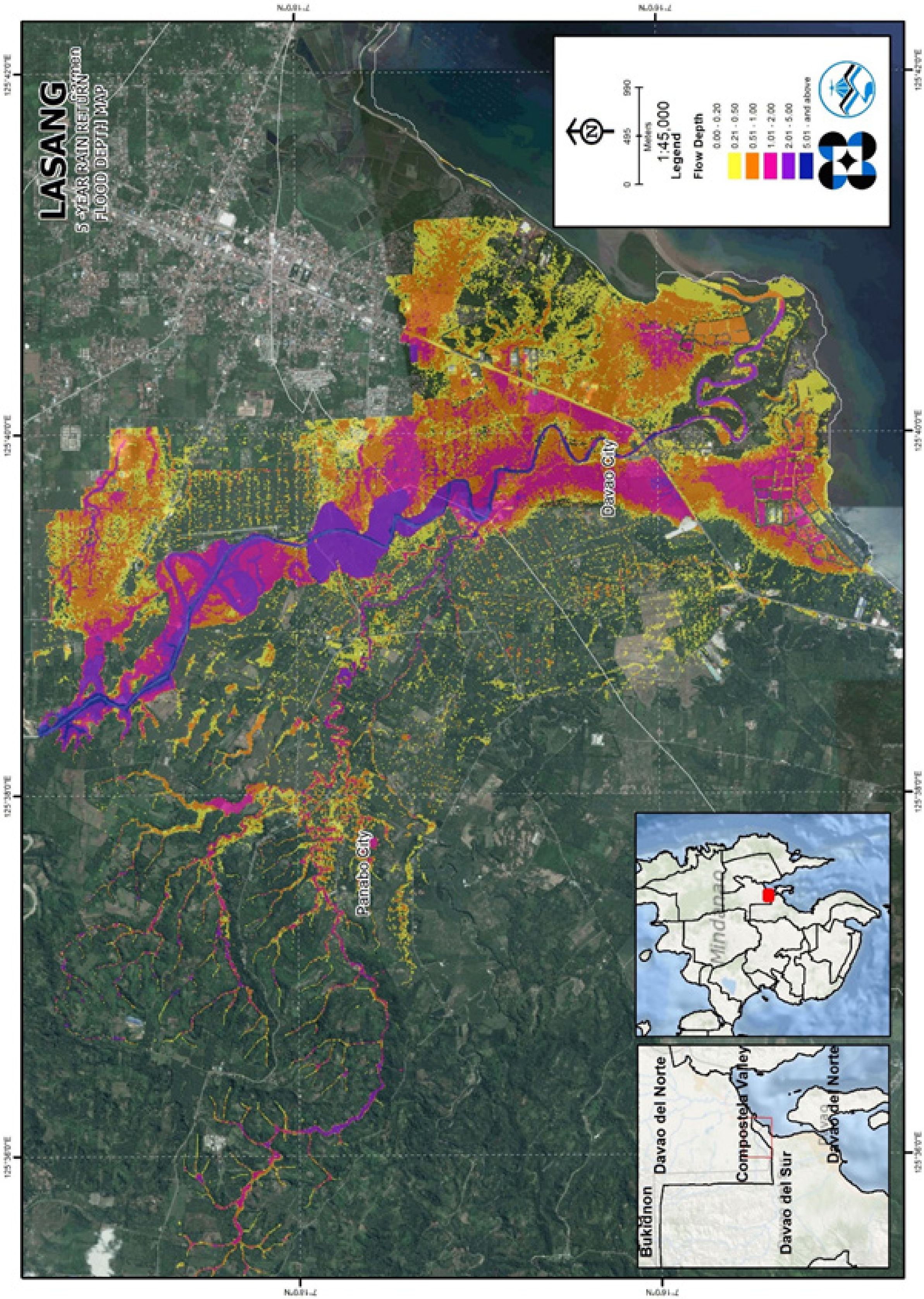


Figure 70. 5-year Flood Depth Map for Lasang Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Lasang River Basin, grouped by municipality, are listed below. For the said basin, two (2) municipalities from two (2) provinces consisting of thirteen (13) barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 7.30% of the municipality of Panabo City, with an area of 301.68 sq. km. will experience flood levels of less than 0.20 meters. 0.94% of the area will experience flood levels of 0.21 to 0.50 meters. 0.81%, 0.54%, 0.46%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected Areas in Panabo City, Davao del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Panabo City (in sq. km.)				
	Buenavista	Datu Abdul Dadia	Little Panay	Maduao	New Visayas
0.03-0.20	3.05	0.032	6.93	0.53	0.058
0.21-0.50	0.087	0.00029	0.67	0.38	0.092
0.51-1.00	0.086	0.0004	0.54	0.34	0.21
1.01-2.00	0.093	0.00053	0.67	0.22	0.05
2.01-5.00	0.044	0.0011	0.53	0.61	0.0098
> 5.00	0	0.0054	0.17	0.075	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Panabo City (in sq. km.)				
	San Nicolas	San Pedro	Sindaton	Tagpore	Upper Licanan
0.03-0.20	0.16	0.00022	1.55	7.37	2.35
0.21-0.50	0.014	0.0016	0.68	0.86	0.054
0.51-1.00	0.0016	0.0004	0.8	0.43	0.034
1.01-2.00	0.0006	0	0.33	0.23	0.033
2.01-5.00	0	0	0.11	0.072	0.014
> 5.00	0	0	0.015	0.0032	0.0013

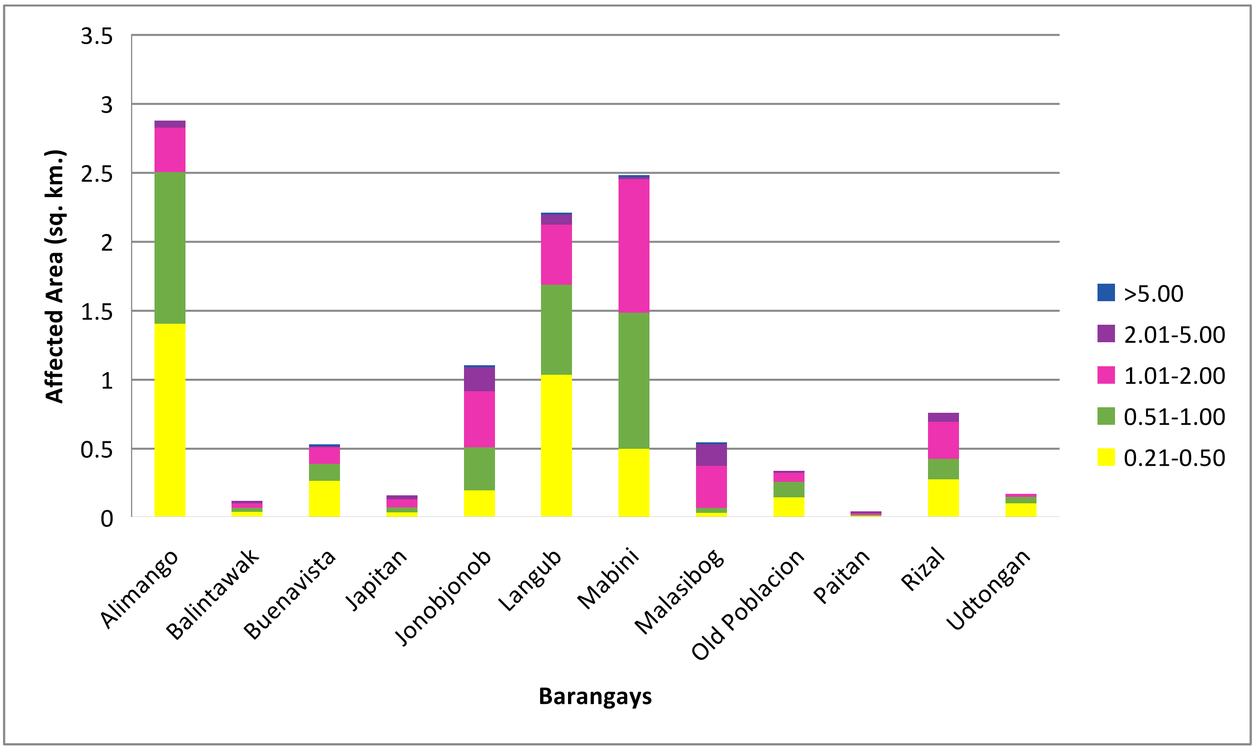


Figure 71. Affected Areas in Panabo City, Davao del Norte during 5-Year Rainfall Return Period

For the 5-year return period, 0.31% of the municipality of Davao City, with an area of 2224.82 sq. km., will experience flood levels of less than 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters. 0.17%, 0.10%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 37 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected Areas in Davao City, Davao del Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Davao City (in sq. km)		
	Alejandra Navarro	Bunawan	Vicente Hizon Sr.
0.03-0.20	4.65	0.39	1.82
0.21-0.50	1.27	0.037	2.02
0.51-1.00	0.97	0.004	2.84
1.01-2.00	0.91	0.0002	1.21
2.01-5.00	0.1	0	0.21
> 5.00	0.0004	0	0.089

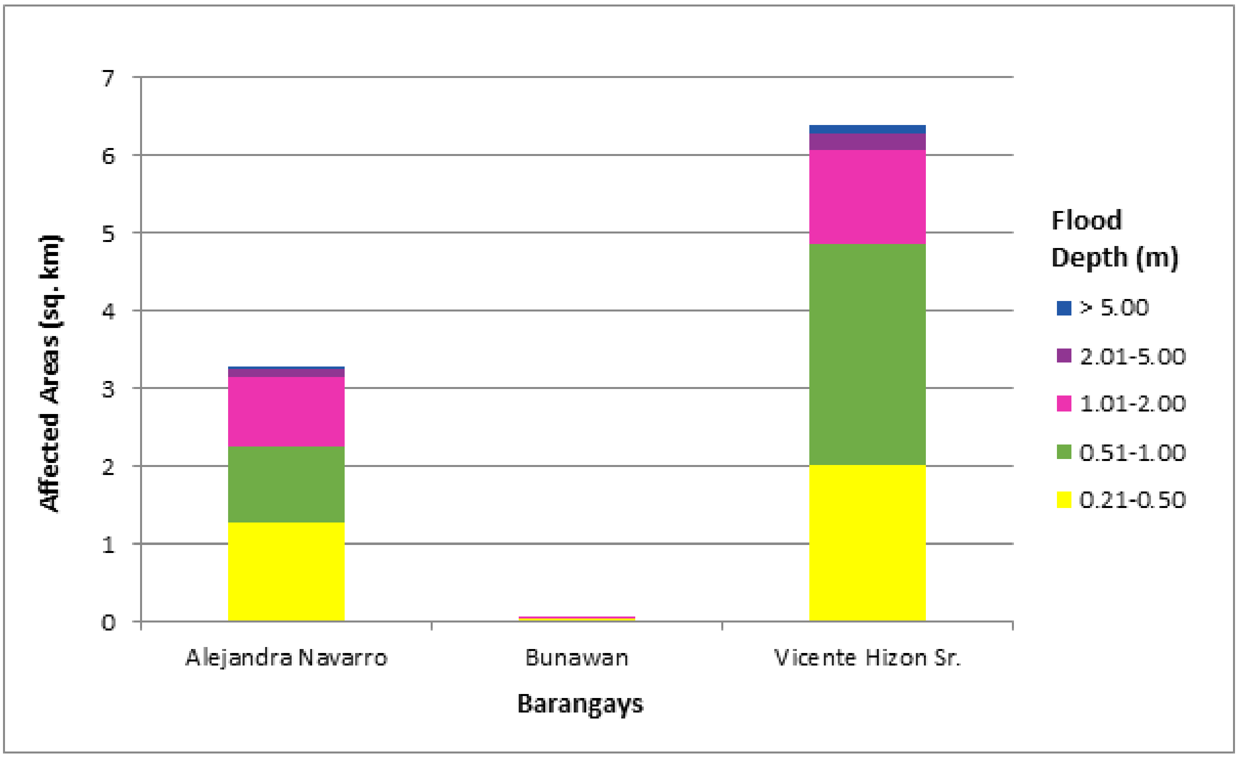


Figure 72. Affected Areas in Davao City, Davao del Sur during 5-Year Rainfall Return Period

For the 25-year return period, 6.25% of the municipality of Panabo City, with an area of 301.68 sq. km., will experience flood levels of less than 0.20 meters. 1.15% of the area will experience flood levels of 0.21 to 0.50 meters. 1.14%, 0.79%, 0.69%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected Areas in Panabo City, Davao del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Panabo City (in sq. km.)				
	Buenavista	Datu Abdul Dadia	Little Panay	Maduao	New Visayas
0.03-0.20	2.98	0.03	6.17	0.2	0.0094
0.21-0.50	0.085	0.0009	0.78	0.27	0.04
0.51-1.00	0.085	0.0005	0.76	0.57	0.19
1.01-2.00	0.12	0.00094	0.62	0.4	0.16
2.01-5.00	0.079	0.0014	0.95	0.65	0.016
> 5.00	0.0093	0.0063	0.24	0.085	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Panabo City (in sq. km.)				
	San Nicolas	San Pedro	Sindaton	Tagpore	Upper Licanan
0.03-0.20	0.15	0.0002	0.66	6.34	2.32
0.21-0.50	0.023	0.00048	0.91	1.3	0.06
0.51-1.00	0.0028	0.0015	1.01	0.79	0.04
1.01-2.00	0.0003	0	0.65	0.4	0.041
2.01-5.00	0.0004	0	0.24	0.13	0.022
> 5.00	0	0	0.018	0.0074	0.0025

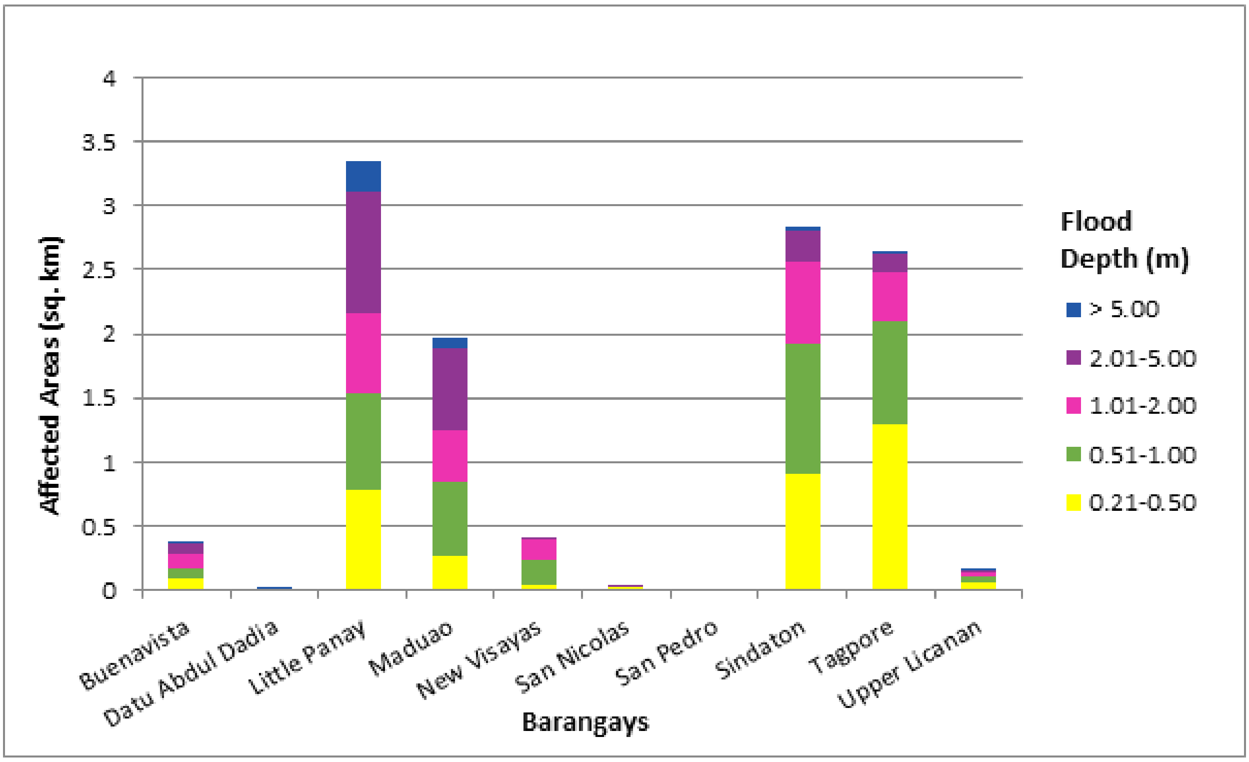


Figure 73. Affected Areas in Panabo City, Davao del Norte during 25-Year Rainfall Return Period

For the 25-year return period, 0.24% of the municipality of Davao City, with an area of 2224.82 sq. km., will experience flood levels of less than 0.20 meters. 0.14% of the area will experience flood levels of 0.21 to 0.50 meters. 0.18%, 0.16%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected Areas in Davao City, Davao del Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Davao City (in sq. km)		
	Alejandra Navarro	Bunawan	Vicente Hizon Sr.
0.03-0.20	3.84	0.37	1.05
0.21-0.50	1.59	0.053	1.43
0.51-1.00	1.05	0.0071	2.97
1.01-2.00	1.19	0.00059	2.36
2.01-5.00	0.21	0	0.28
> 5.00	0.0011	0	0.095

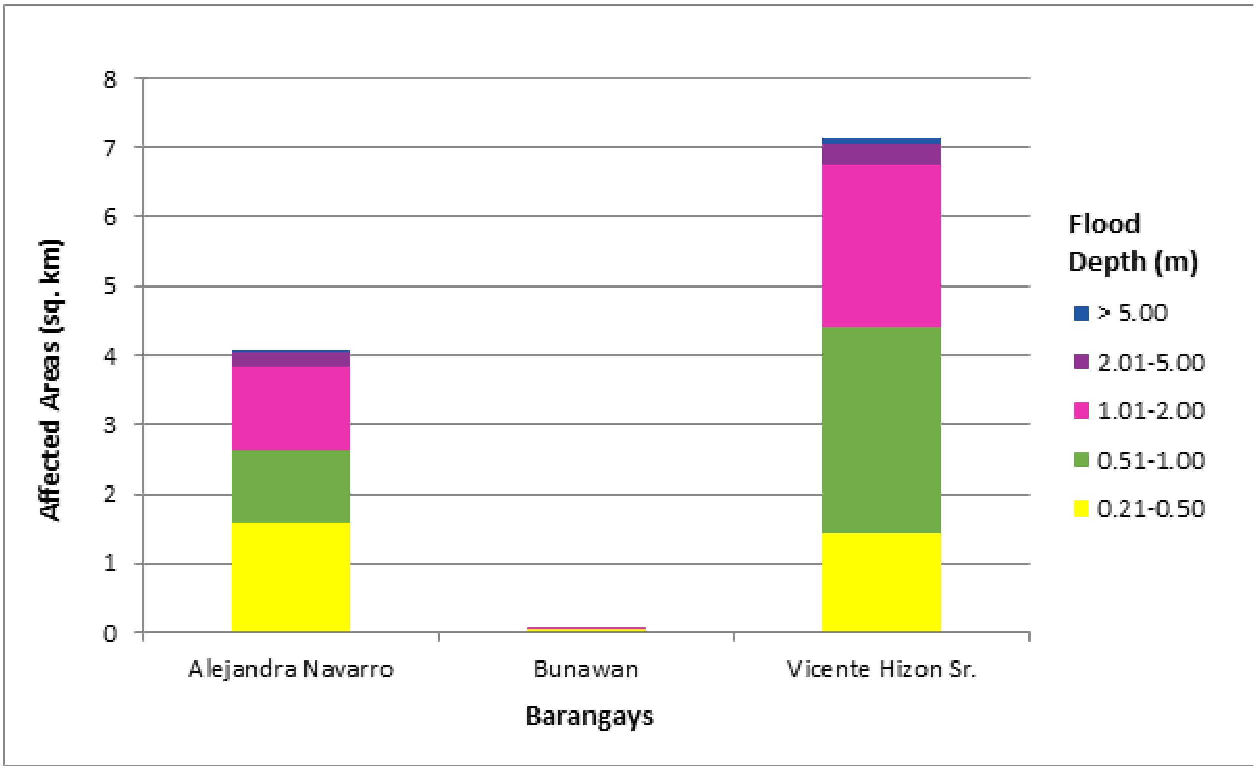


Figure 74. Affected Areas in Davao City, Davao del Sur during 25-Year Rainfall Return Period

For the 100-year return period, 5.68% of the municipality of Panabo City, with an area of 301.68 sq. km., will experience flood levels of less than 0.20 meters. 1.00% of the area will experience flood levels of 0.21 to 0.50 meters. 1.40%, 1.09%, 0.82%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected Areas in Panabo City, Davao del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Panabo City (in sq. km.)				
	Buenavista	Datu Abdul Dadia	Little Panay	Maduao	New Visayas
0.03-0.20	2.94	0.028	5.67	0.13	0.0025
0.21-0.50	0.09	0.00067	0.78	0.13	0.013
0.51-1.00	0.081	0.0007	0.95	0.6	0.1
1.01-2.00	0.12	0.0012	0.68	0.54	0.27
2.01-5.00	0.11	0.0024	1.14	0.68	0.026
> 5.00	0.02	0.0067	0.3	0.092	0
Affected Area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Panabo City (in sq. km.)**				
	San Nicolas	**San Pedro**	**Sindaton**	**Tagpore**	**Upper Licanan**
0.03-0.20	0.14	0	0.25	5.68	2.3
0.21-0.50	0.029	0.0015	0.48	1.44	0.062
0.51-1.00	0.0042	0.00066	1.38	1.07	0.045
1.01-2.00	0.0003	0	1.03	0.6	0.044
2.01-5.00	0.0004	0	0.32	0.17	0.03
> 5.00	0	0	0.019	0.01	0.0028

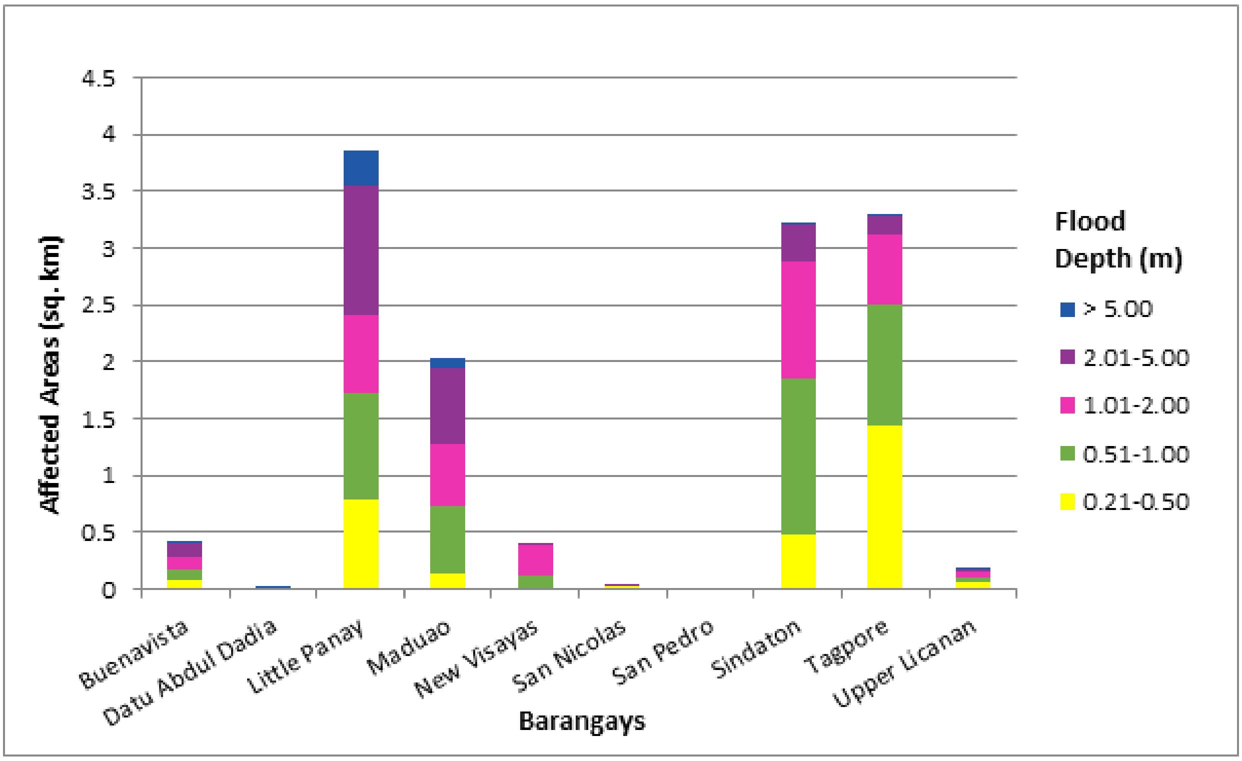


Figure 75. Affected Areas in Panabo City, Davao del Norte during 100-Year Rainfall Return Period

For the 100-year return period, 0.19% of the municipality of Davao City, with an area of 2224.82 sq. km., will experience flood levels of less than 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters. 0.17%, 0.21%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected Areas in Davao City, Davao del Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Davao City (in sq. km)		
	Alejandra Navarro	Bunawan	Vicente Hizon Sr.
0.03-0.20	3.28	0.35	0.67
0.21-0.50	1.81	0.071	1.07
0.51-1.00	1.18	0.0087	2.59
1.01-2.00	1.3	0.00089	3.37
2.01-5.00	0.32	0	0.39
> 5.00	0.0013	0	0.098

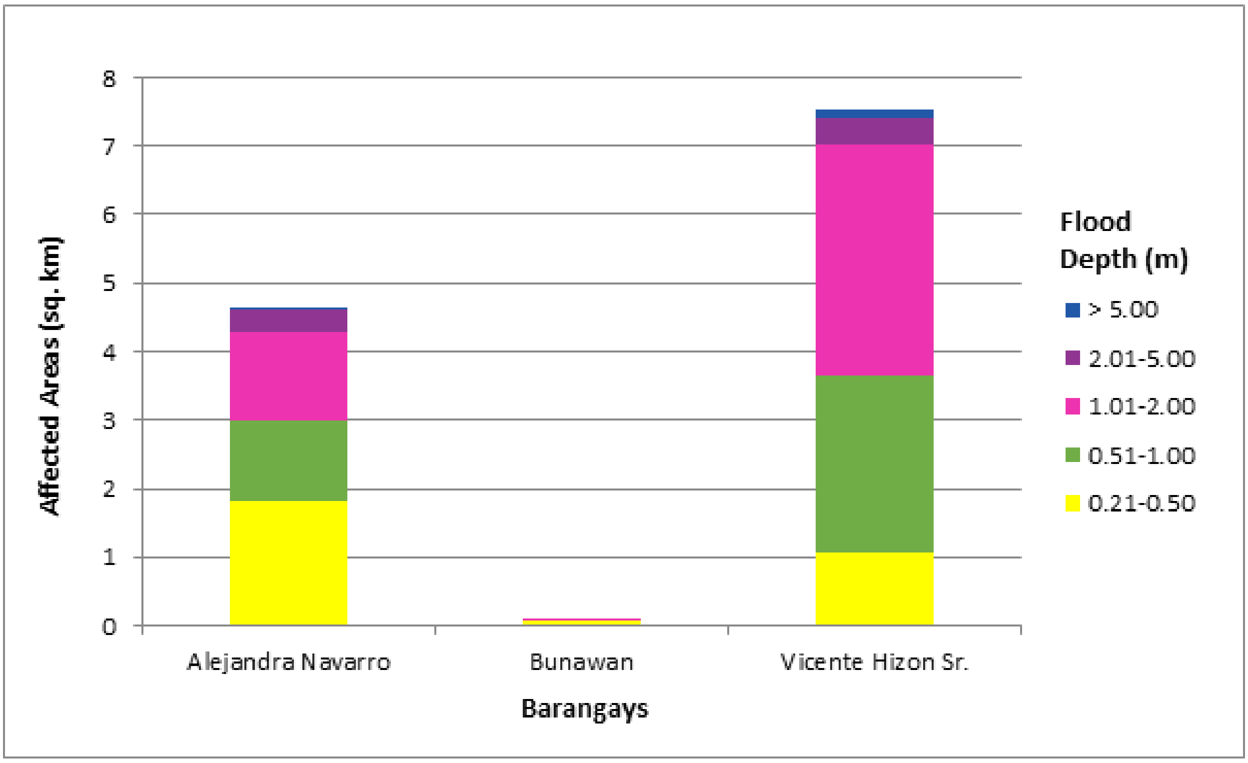


Figure 76. Affected Areas in Davao City, Davao del Sur during 100-Year Rainfall Return Period

Among the barangays in the municipality of Panabo City in Davao del Norte, Little Panay is projected to have the highest percentage of area that will experience flood levels, at 3.15%. Meanwhile, Tagpore posted the second highest percentage of area that may be affected by flood depths, at 2.97%.

Among the barangays in the municipality of Davao City in Davao del Sur, Vicente Hizon Sr. is projected to have the highest percentage of area that will experience flood levels, at 0.37%. Meanwhile, Alejandra Navarro posted the second highest percentage of area that may be affected by flood depths, at 0.36%.

The generated flood hazard maps for the Lasang Floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the hazard maps – "Low", "Medium", and "High" – the affected institutions were each given an individual assessment for each Flood Hazard Scenario (5-year, 25-year, and 100-year).

Table 42. 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	6.28	6.67	6.07
Medium	8.92	11.68	13.6
High	3.31	4.97	6.29
TOTAL	**18.51**	**23.32**	**25.96**

Of the thirty-three (33) identified educational institutions in the Lasang floodplain, one (1) school was assessed to be relatively prone to flooding, as it is exposed to Medium-level flooding for the 5-year return period, and to High-level flooding in the 25- and 100-year rainfall scenarios. This is the J. P. Laurel Elementary School in Barangay Vicente Hizon Sr. Three (3) other institutions were found to be also susceptible to flooding, assessed to experience Medium-level flooding in the 5- and 25-year return periods, and High-level flooding in the 100-year rainfall scenario. See Annex 12 for the list of educational institutions exposed to flooding.

Nine (9) medical institutions were identified in the Lasang floodplain. The J. P. Laurel Health Center in Barangay Vicente Hizon Sr. was found to be relatively prone to flooding, being assessed to be exposed to Medium-level flooding for the 5-year return period, and High-level flooding for the 25- and 100-year rainfall scenarios. See Annex 13 for the list of medical institutions exposed to flooding.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in the river basin and gathered data on the actual flood level in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews some residents with knowledge or experience of flooding in the particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 78.

The flood validation survey was conducted on December 11-18, 2015. The flood validation consists of 217 points randomly selected all over the Lasang floodplain. It has an RMSE value of 0.81. The validation points are found in Annex 11.

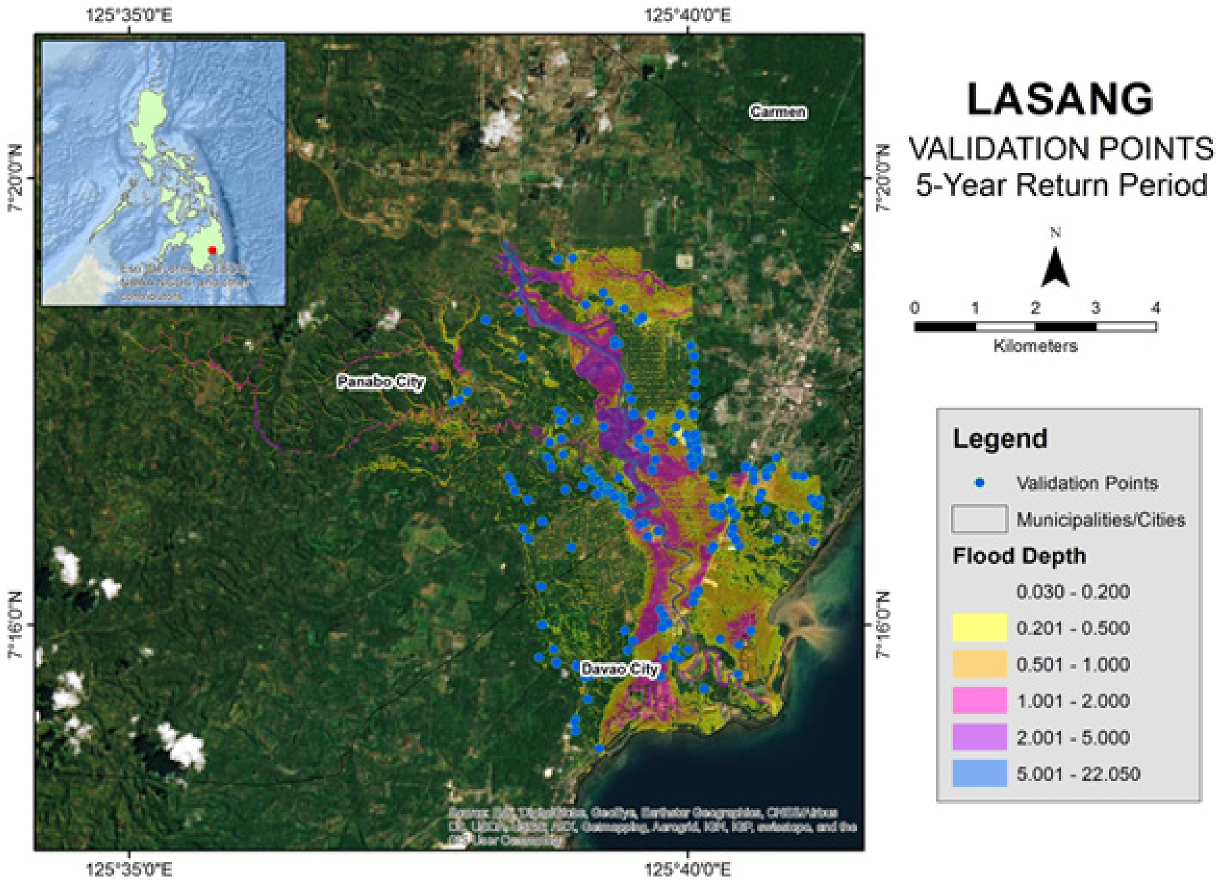


Figure 77. Flood Validation Points of the Lasang River Basin

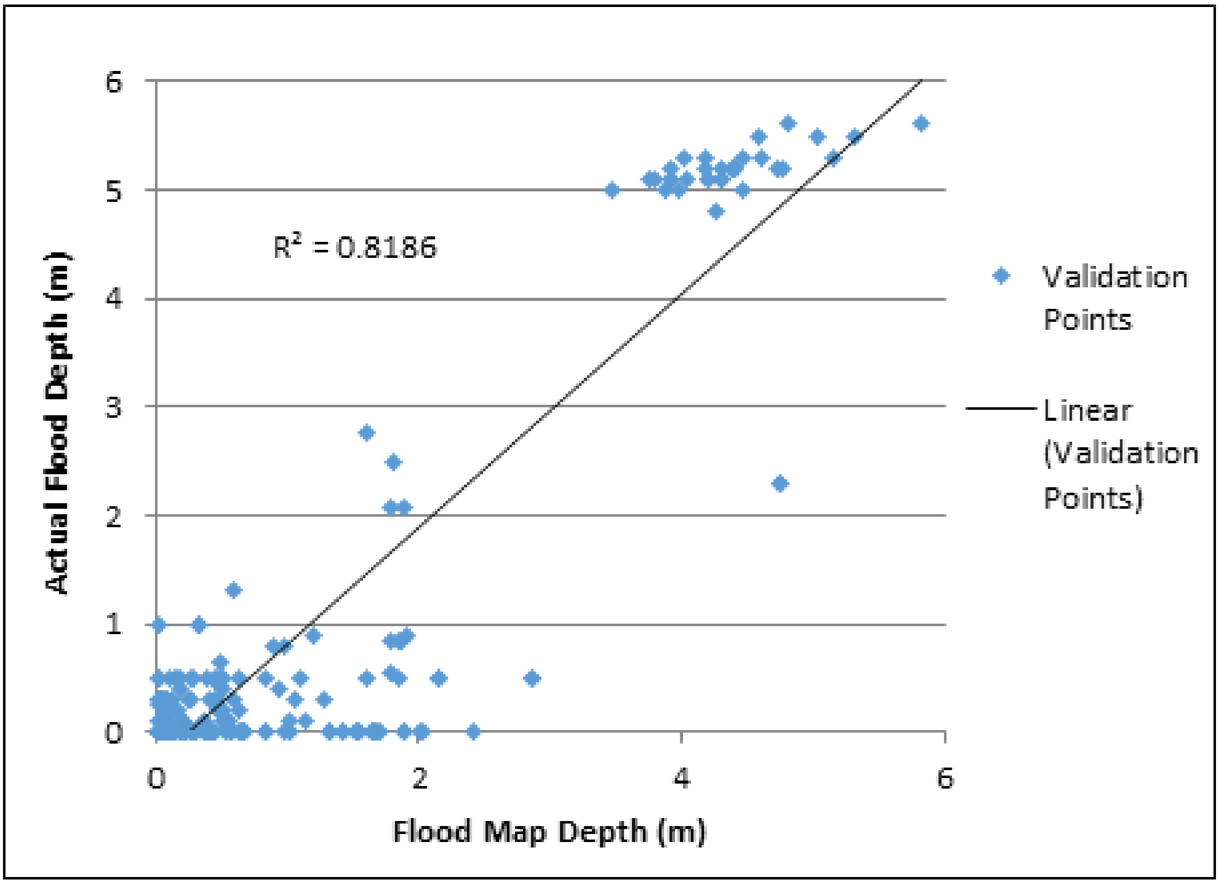


Figure 78. Flood map depth vs actual flood depth

Table 43. Actual Flood Depth vs. Simulated Flood Depth in Lasang

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
0-0.20	53	24	18	20	3	0	118
0.21-0.50	20	13	5	5	4	0	47
0.51-1.00	1	3	2	6	0	0	12
1.01-2.00	0	0	1	0	0	0	1
2.01-5.00	0	0	0	4	7	0	11
> 5.00	0	0	0	0	24	4	28
Total	74	40	26	35	38	4	217

The overall accuracy generated by the flood model is estimated at 36.41%, with 79 points correctly matching the actual flood depths. There were eighty-seven (87) points estimated one (1) level above and below the correct flood depths; while there were twenty-four (24) points and twenty-seven (27) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depth, respectively. A total of eighty-five (85) points were overestimated, while a total of fifty-three (53) points were underestimated in the modeled flood depths of the Lasang River Basin.

Table 44. Summary of Accuracy Assessment in Lasang River Basin Survey

	No. of Points	**%**
Correct	79	36.41
Overestimated	85	39.17
Underestimated	53	24.42
Total	217	100

REFERENCES

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

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

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

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

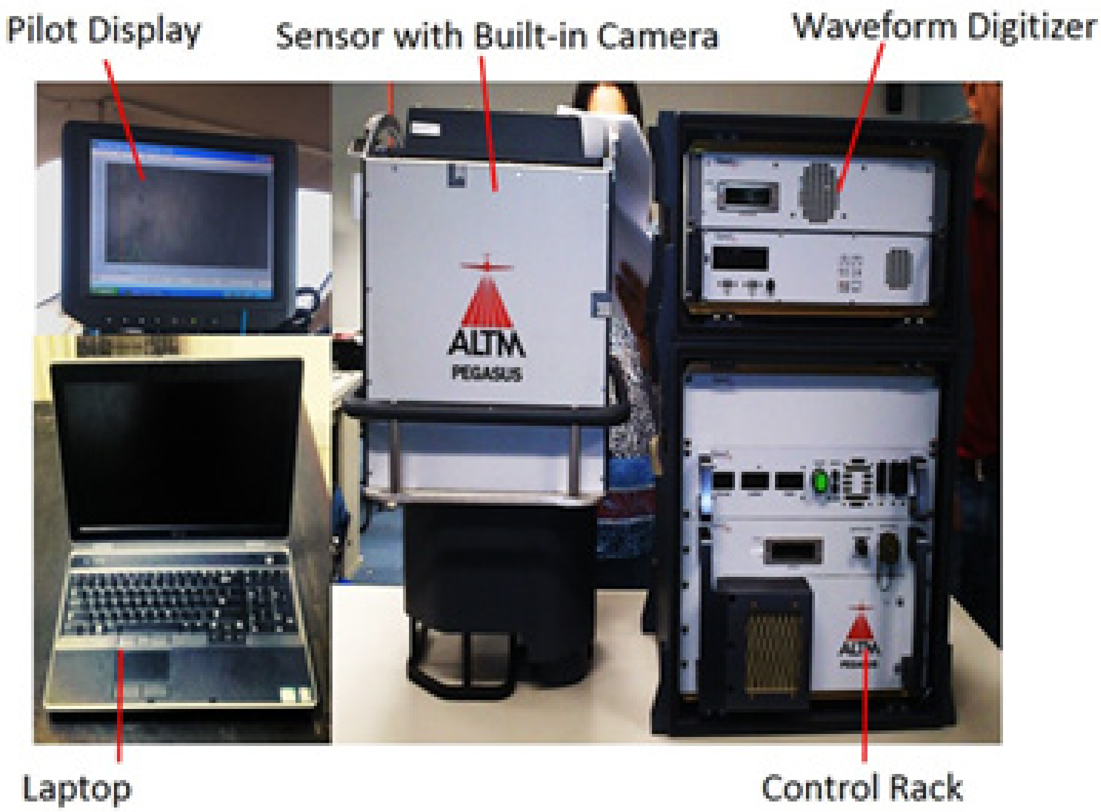
Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

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

ANNEXES

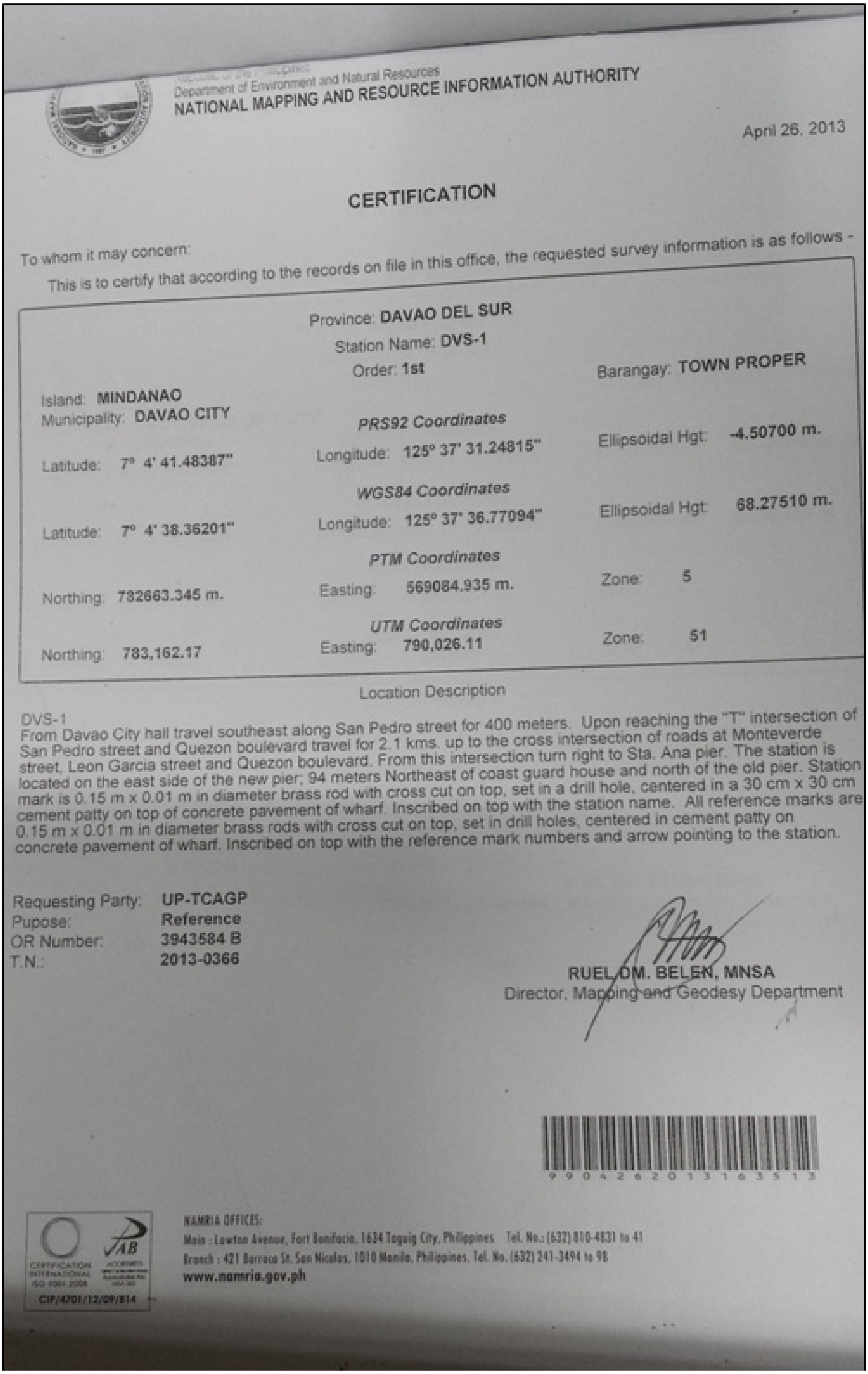
Annex 1. Technical Specifications of the Gemini LiDAR Sensor used in the Lasang Floodplain Survey



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

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

1. DVS-01



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

April 26, 2013

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: DAVAO DEL SUR
Station Name: DVS-1
Order: 1st

Island: MINDANAO
Municipality: DAVAO CITY
Barangay: TOWN PROPER

PRS92 Coordinates

Latitude: 7° 4' 41.48387"	Longitude: 125° 37' 31.24815"	Ellipsoidal Hgt: -4.50700 m.

WGS84 Coordinates

Latitude: 7° 4' 38.36201"	Longitude: 125° 37' 36.77094"	Ellipsoidal Hgt: 68.27510 m.

PTM Coordinates

Northing: 782663.345 m.	Easting: 569084.935 m.	Zone: 5

UTM Coordinates

Northing: 783,162.17	Easting: 790,026.11	Zone: 51

Location Description

DVS-1
From Davao City hall travel southeast along San Pedro street for 400 meters. Upon reaching the "T" intersection of San Pedro street and Quezon boulevard travel for 2.1 kms. up to the cross intersection of roads at Monteverde street, Leon Garcia street and Quezon boulevard. From this intersection turn right to Sta. Ana pier. The station is located on the east side of the new pier; 94 meters Northeast of coast guard house and north of the old pier. Station mark is 0.15 m x 0.01 m in diameter brass rod with cross cut on top, set in a drill hole, centered in a 30 cm x 30 cm cement patty on top of concrete pavement of wharf. Inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rods with cross cut on top, set in drill holes, centered in cement patty on concrete pavement of wharf. Inscribed on top with the reference mark numbers and arrow pointing to the station.

Requesting Party: UP-TCAGP
Pupose: Reference
OR Number: 3943584 B
T.N.: 2013-0366

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

9 9 0 4 2 6 2 0 1 3 1 6 3 5 1 3

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

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

2. DVA-3237

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

July 25, 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: **DAVAO DEL NORTE**
Station Name: **DVA-3237**
Order: **4th**

Island: **MINDANAO**
Municipality: **CITY OF PANABO**
Barangay: **NANYO**
MSL Elevation:

PRS92 Coordinates

Latitude:	7° 19' 59.93670"	Longitude:	125° 38' 7.27962"	Ellipsoidal Hgt:	16.91200 m.

WGS84 Coordinates

Latitude:	7° 19' 56.74722"	Longitude:	125° 38' 12.77896"	Ellipsoidal Hgt:	89.23800 m.

PTM / PRS92 Coordinates

Northing:	810878.179 m.	Easting:	570151.447 m.	Zone:	5

UTM / PRS92 Coordinates

Northing:	811,399.31	Easting:	790,969.56	Zone:	51

Location Description

DVA-3237

The station is located beside the flagpole inside the compound of Nanyo Elementary School.

Marked is the head of a 4" copper nail embedded and centered on a 0.25cm. x 0.25cm. x 1.00m. concrete monument with inscriptions "DVA-3237; 2008; LMS XI."

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1737**

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

9907252014132105

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. DVA-133

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

July 25, 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: **DAVAO DEL NORTE**
Station Name: **DVA-133**
Order: **2nd**

Island: **MINDANAO**		Barangay: **MANAY**
Municipality: **CITY OF PANABO**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **7° 20' 57.02014"**	Longitude: **125° 35' 57.50044"**	Ellipsoidal Hgt: **23.95700 m.**
	WGS84 Coordinates	
Latitude: **7° 20' 53.82313"**	Longitude: **125° 36' 2.99870"**	Ellipsoidal Hgt: **96.16300 m.**
	PTM / PRS92 Coordinates	
Northing: **812626.211 m.**	Easting: **566168.597 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **813,130.63**	Easting: **786,976.44**	Zone: **51**

Location Description

DVA-133
"DVA-133" is in Barangay Manay, Municipality of Panabo. To reach the station travel for about 9 kms. from the intersection of National Highway and barangay road turn right going to Barangay Manay. Station is located infront of the Barangay Hall 15 m. from the flagpole and "NW" of volleyball court. Mark is the head of 4" copper nail embedded in a 30 x 30 cm. concrete monument with the inscription "DVA-133 2007 NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1736**

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

9907252014132046

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

4. DV-274

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

September 05, 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: **DAVAO DEL NORTE**
Station Name: **DV-274**

Island: **Mindanao**	Municipality: **ASUNCION (SAUG)**	Barangay: **CANATAN**
Elevation: **16.6719 m.**	Order: **2nd Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

DV-274
STATION MARK : Mark is the head of a 4" bronze nail set in drilled hole on a box culvert and cemented on top with a 15cm x 15cm putty with inscription BM DV-274, NAMRIA, 2013.

ACCESS : The station is located along the Tagum-Laak National Highway on a box culvert near the road to Purok 3 Junction.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8075532 A**
T.N.: **2014-1946**

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

9 9 0 9 0 5 2 0 1 4 1 2 5 0 2 7

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

Annex 3. Baseline Processing Report of Reference Points Used

1. DVS-01A

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
DVS-01 --- DVS-01A (B1)	DVS-01	DVS-01A	Fixed	0.001	0.001	264°18'19"	5.002	-0.009
DVS-01 --- DVS-01A (B2)	DVS-01	DVS-01A	Fixed	0.001	0.001	264°19'14"	4.993	-0.006
DVS-01 --- DVS-01A (B3)	DVS-01	DVS-01A	Fixed	0.001	0.001	264°19'50"	4.999	0.844

Acceptance Summary

Processed	Passed	Flag	Fail
3	3	0	0

Vector Components (Mark to Mark)

From:	DVS-01				
Grid		Local		Global	
Easting	790026.116 m	Latitude	N7°04'41.48388"	Latitude	N7°04'38.36201"
Northing	783162.167 m	Longitude	E125°37'31.24815"	Longitude	E125°37'36.77094"
Elevation	0.546 m	Height	-4.507 m	Height	68.275 m

To:	DVS-01A				
Grid		Local		Global	
Easting	790021.138 m	Latitude	N7°04'41.46772"	Latitude	N7°04'38.34585"
Northing	783161.643 m	Longitude	E125°37'31.08595"	Longitude	E125°37'36.60874"
Elevation	0.537 m	Height	-4.516 m	Height	68.266 m

Vector					
ΔEasting	-4.978 m	NS Fwd Azimuth	264°18'19"	ΔX	4.016 m
ΔNorthing	-0.525 m	Ellipsoid Dist.	5.002 m	ΔY	2.942 m
ΔElevation	-0.009 m	ΔHeight	-0.009 m	ΔZ	-0.494 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'08"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.000 m
σ ΔElevation	0.000 m	σ ΔHeight	0.000 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000001708		
Y	-0.0000000623	0.0000001761	
Z	-0.0000000132	0.0000000282	0.0000000414

2. DVA-3237

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
DVA-133 --- DVA-3237 (B1)	DVA-133	DVA-3237	Fixed	0.004	0.014	113°46'08"	4349.013	-6.729

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	DVA-133				
Grid		Local		Global	
Easting	786976.453 m	Latitude	N7°20'57.02014"	Latitude	N7°20'53.82313"
Northing	813130.631 m	Longitude	E125°35'57.50044"	Longitude	E125°36'02.99870"
Elevation	27.682 m	Height	23.957 m	Height	96.163 m

To:	DVA-3237				
Grid		Local		Global	
Easting	790969.206 m	Latitude	N7°19'59.95215"	Latitude	N7°19'56.76267"
Northing	811399.786 m	Longitude	E125°38'07.26797"	Longitude	E125°38'12.76731"
Elevation	21.363 m	Height	17.228 m	Height	89.553 m

Vector					
ΔEasting	3992.752 m	NS Fwd Azimuth	113°46'08"	ΔX	-3362.078 m
ΔNorthing	-1730.845 m	Ellipsoid Dist.	4349.013 m	ΔY	-2141.245 m
ΔElevation	-6.319 m	ΔHeight	-6.729 m	ΔZ	-1739.408 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000160458		
Y	-0.0000220689	0.0000368585	
Z	-0.0000043801	0.0000072587	0.0000024695

3. COV-3080

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
COV-3080 --- DVA-133 (B1)	DVA-133	COV-3080	Fixed	0.006	0.015	53°13'56"	51492.390	57.699
DVA-133 --- COV-3080 (B2)	DVA-133	COV-3080	Fixed	0.009	0.015	53°13'57"	51492.407	57.746

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	DVA-133				
Grid		Local		Global	
Easting	786976.463 m	Latitude	N7°20'57.02014"	Latitude	N7°20'53.82313"
Northing	813130.631 m	Longitude	E125°35'57.60044"	Longitude	E125°36'02.99870"
Elevation	27.682 m	Height	23.957 m	Height	96.163 m

To:	COV-3080				
Grid		Local		Global	
Easting	828073.884 m	Latitude	N7°37'39.82070"	Latitude	N7°37'36.58302"
Northing	844220.262 m	Longitude	E125°58'23.27481"	Longitude	E125°58'28.74368"
Elevation	85.293 m	Height	81.656 m	Height	154.260 m

Vector					
ΔEasting	41097.431 m	NS Fwd Azimuth	53°13'56"	ΔX	-31156.949 m
ΔNorthing	31089.631 m	Ellipsoid Dist.	51492.390 m	ΔY	-27338.626 m
ΔElevation	57.611 m	ΔHeight	57.699 m	ΔZ	30550.573 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000189171		
Y	-0.0000247966	0.0000455082	
Z	-0.0000046642	0.0000043494	0.0000031390

4. DV-274

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-2 --- DV-274 (B1)	UP-2	DV-274	Fixed	0.003	0.003	176°57'31"	1450.483	-3.121
UP-2 --- DV-274 (B2)	UP-2	DV-274	Fixed	0.003	0.004	176°57'32"	1450.481	-3.120

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	UP-2				
Grid		Local		Global	
Easting	804276.006 m	Latitude	N7°35'52.20741"	Latitude	N7°35'48.95814"
Northing	840763.891 m	Longitude	E125°45'26.79579"	Longitude	E125°45'32.26973"
Elevation	18.727 m	Height	15.104 m	Height	87.223 m

To:	DV-274				
Grid		Local		Global	
Easting	804362.244 m	Latitude	N7°35'05.05546"	Latitude	N7°35'01.80976"
Northing	839304.889 m	Longitude	E125°45'29.30539"	Longitude	E125°45'34.78152"
Elevation	15.682 m	Height	11.983 m	Height	84.129 m

Vector					
ΔEasting	86.238 m	NS Fwd Azimuth	176°57'31"	ΔX	-172.494 m
ΔNorthing	-1449.001 m	Ellipsoid Dist.	1450.483 m	ΔY	107.773 m
ΔElevation	-3.045 m	ΔHeight	-3.121 m	ΔZ	-1436.156 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000019558		
Y	-0.0000007386	0.0000020877	
Z	-0.0000004999	0.0000001404	0.0000006159

5. DVA-9

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
COV-3080 --- BMDVA-9 (B1)	COV-3080	BMDVA-9	Fixed	0.003	0.009	15°17'53"	3784.017	-12.722
COV-3080 --- BMDVA-9 (B2)	COV-3080	BMDVA-9	Fixed	0.003	0.010	15°17'54"	3784.017	-12.720

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	COV-3080				
Grid		Local		Global	
Easting	828073.897 m	Latitude	N7°37'39.82061"	Latitude	N7°37'36.58292"
Northing	844220.259 m	Longitude	E125°58'23.27523"	Longitude	E125°58'28.74410"
Elevation	85.316 m	Height	81.680 m	Height	154.274 m

To:	BMDVA-9				
Grid		Local		Global	
Easting	829047.949 m	Latitude	N7°39'38.63849"	Latitude	N7°39'35.39278"
Northing	847880.427 m	Longitude	E125°58'55.85071"	Longitude	E125°59'01.31649"
Elevation	72.396 m	Height	68.958 m	Height	141.510 m

Vector					
ΔEasting	974.053 m	NS Fwd Azimuth	15°17'53"	ΔX	-515.246 m
ΔNorthing	3660.168 m	Ellipsoid Dist.	3784.017 m	ΔY	-989.610 m
ΔElevation	-12.920 m	ΔHeight	-12.722 m	ΔZ	3615.861 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.004 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000080056		
Y	-0.0000100138	0.0000154198	
Z	-0.0000023857	0.0000031744	0.0000014452

Annex 4.The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	Research Associate (RA)	FOR. MA. VERLINA TONGA	UP-TCAGP
		ENGR. LARAH KRISELLE PARAGAS	
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JOHN BRYAN DONGUINES	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC

Annex 5. Data Transfer Sheet for Lasang Floodplain

Transfer Sheet for Lasang Floodplain - A

DATA TRANSFER SHEET
07/08/2014(Davao Oriental - ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
7/18/2014	7378GC	2BLK82A199A	Gemini	NA	242	493	243	NA	NA	24.1	NA	8.53	1KB	1KB	7/7	16	Z:\DAC\RAW_DATA
7/22/2014	7386GC	2BLK82CSD203A	Gemini	NA	141/159	637	267	NA	NA	29.2	NA	8.87	1KB	1KB	3/3	NA	Z:\DAC\RAW_DATA
7/23/2014	7388GC	2BLK82AB204A	Gemini	NA	89	488	228	NA	NA	21.4	NA	8.69	1KB	1KB	4/3	10	Z:\DAC\RAW_DATA
7/24/2014	7390GC	2BLK82FH205A	Gemini	NA	93	591	241	NA	NA	29	NA	17.6	1KB	1KB	2/4	NA	Z:\DAC\RAW_DATA
7/27/2014	7396GC	2BLK82GSH208A	Gemini	NA	280	769	214	NA	NA	27.1	NA	5.65	1KB	1KB	4/4	NA	Z:\DAC\RAW_DATA
7/29/2014	7401GC	2BLK82EFGHSJ210B	Gemini	NA	83	339	104	NA	NA	8.25	NA	7.1	1KB	1KB	12/12/12	NA	Z:\DAC\RAW_DATA

Received from

Name TN ANOYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

8/1/2014

Transfer Sheet for Lasang Floodplain - B

DATA TRANSFER SHEET
08/28/2014(Davao ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	QUICK PROCESS (kml Boundary)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)			Actual	KML	
8/4/2014	7412GC	2BLK87CS0216A	Gemini	21	310	537	165	NA	NA	24.2	NA	4.99	1KB	1KB	1082	3/3/7/3/3	NA	Z:\DAC\RAWDATA
8/5/2014	7414GC	2BLK87E217A	Gemini	3.68	88	158	145	NA	NA	7.62	NA	3.11	1KB	1KB	786	5/5	NA	Z:\DAC\RAWDATA
8/6/2014	7416GC	2BLK87F218A	Gemini	5.39	184	194	148	NA	NA	8.31	NA	3.55	1KB	1KB	1616	5	11	Z:\DAC\RAWDATA
8/7/2014	7418GC	2BLK87FV218A	Gemini	12.7	181	355	180	NA	NA	14.4	NA	3.49	1KB	1KB	1233	9/10	NA	Z:\DAC\RAWDATA
7/9/2014	7422GC	2CDMA221A	Gemini	16.5	248	423	219	NA	NA	19.8	NA	9.95	1KB	1KB	2848	5	12	Z:\DAC\RAWDATA
8/9/2014	7423GC	2CDMBSCD221B	Gemini	11	210	395	175	NA	NA	16.6	NA	9.95	1KB	1KB	1090	7/9/3	NA	Z:\DAC\RAWDATA
8/10/2014	7424GC	2CDMDS222A	Gemini	8.44	39	236	157	NA	NA	9.69	NA	4.38	1KB	1KB	1064	3/3	8	Z:\DAC\RAWDATA
8/11/2014	7426GC	2BLK82V223A	Gemini	8.44	119	279	135	NA	NA	9.61	NA	7.83	1KB	1KB	1613	7/11	NA	Z:\DAC\RAWDATA
8/11/2014	7427GC	2BLK82V223B	Gemini	4.32	64	184	132	NA	NA	3.65	NA	7.83	1KB	1KB	434	8	8	Z:\DAC\RAWDATA
8/12/2014	7428GC	2TAGV224A	Gemini	20.1	287	530	223	NA	NA	22.6	NA	4.44	1KB	1KB	2687	23/23	NA	Z:\DAC\RAWDATA
8/13/2014	7430GC	2TAGV225A	Gemini	3.95	34	326	179	NA	NA	9.38	NA	3.58	1KB	1KB	1283	18/18	NA	Z:\DAC\RAWDATA

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature
8/29/14

Annex 6. Flight logs for the flight missions

1. Flight Log for 7386GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7356

1 LIDAR Operator: LK Paragas	2 ALTM Model: 5+C	3 Mission Name: 2BLK82C S203A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9322
7 Pilot: R. Sumbe II	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: 7-22-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 8+6	14 Engine Off: 12+35	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed 16 lines of Blk 82C & D (without CASI)					

21 Problems and Solutions:

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

2. Flight Log for 7388GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7388

1 LiDAR Operator: MV Tonga	2 ALTM Model: GC	3 Mission Name: 2BLK82DA B204A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9322
7 Pilot: Donguines	8 Co-Pilot: Agawin	9 Route:			
10 Date: 7-23-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 8+19	14 Engine Off: 12+24	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Surveyed the Rest of BlK82A B & 6 lines of BLK82D (without CASI)

21 Problems and Solutions:

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

3. Flight Log for 7390GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7390

1 LIDAR Operator: LK Paraynas	2 ALTM Model: GTC	3 Mission Name: 2BLK82FH205A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9322
7 Pilot: Dongwines	8 Co-Pilot: Agawin	9 Route:			
10 Date: 7-24-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 7:56	14 Engine Off: 12:41	15 Total Engine Time: 4:45	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed Blk 82F & Blk 82H

(without CASI)

21 Problems and Solutions:

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

4. Flight Log for 7396GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7396

1 LiDAR Operator: LK Paragas	2 ALTM Model: GC	3 Mission Name: 4BLK82GS208A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: Donguines	8 Co-Pilot: Agawin	9 Route:			
10 Date: 7-27-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 9+21	14 Engine Off: 13+2	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed BLK82G & remaining lines of BLK82H

21 Problems and Solutions:

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

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

Pilot-in-Command
B. DONGUINES
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

5. Flight Log for 7401GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7401

1 LIDAR Operator: LK Paragas	2 ALTM Model: GFC	3 Mission Name: 2BLK82 EFGHS210B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9322
7 Pilot: B. Donguines	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: 7-29-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 14+41	14 Engine Off: 16+40	15 Total Engine Time: 1+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed Blk 82G and voids of Blocks 82E, F, H					

21 Problems and Solutions:

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

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

Pilot-in-Command
B. DONGUINES
Signature over Printed Name

Lidar Operator
LK Paragas
Signature over Printed Name

6. Flight Log for 7422GC Mission

DREAM Data Acquisition Flight Log

2COMAB221A

Flight Log No.: 7422

1 LIDAR Operator: MV Tongga	2 ALTM Model: GTC	3 Mission Name: 2BLK	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9322
7 Pilot: B. Dongguines	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: 8-9-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 9+32	14 Engine Off: 13+19	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed COMA and 4lines of COMB

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Perry Mars		B. Dongguines	MV Tongga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

7. Flight Log for 7423GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7423

1 LIDAR Operator: LK Paragas	2 ALTM Model: GC	3 Mission Name: 2BDMBSCD214B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Donguines	8 Co-Pilot: Aggawin	9 Route:			
10 Date: 8-9-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 14+29	14 Engine Off: 17+40	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Finished CoMD, the rest of CoMB and 3 lines of CoMC

21 Problems and Solutions:

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

8. Flight Log for 7424GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7424

1 LiDAR Operator: MVTonga	2 ALTM Model: 6C	3 Mission Name: 2COM	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Danguines	8 Co-Pilot: Adawin	9 Route:			
10 Date: 8-10-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 8+52	14 Engine Off: 11+33	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Surveyed the rest of COMC

21 Problems and Solutions:

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

9. Flight Log for 7426GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7426

1 LiDAR Operator: LK Paragas	2 ALTM Model: GC	3 Mission Name: 2BLK82V223A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Donguines	8 Co-Pilot: Agawin	9 Route:			
10 Date: 8-11-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 9+31	14 Engine Off: 12+12	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Surveyed voids in Blk 82

21 Problems and Solutions:

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

10. Flight Log for 7427GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7427

1 LiDAR Operator: MV Tongo	2 ALTM Model: GC	3 Mission Name: 2BLK82V223B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Donguines	8 Co-Pilot: Aquino	9 Route:			
10 Date: 8-11-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 1412	14 Engine Off: 1631	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Surveyed voids in BLK 82

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

B. DONGUINES

Signature over Printed Name

Lidar Operator

Signature over Printed Name

11. Flight Log for 7430GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7430

1 LiDAR Operator: MV Tongga	2 ALTM Model: GC	3 Mission Name: 2TACV225A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Dongwinas	8 Co-Pilot: Ajjabia	9 Route:			
10 Date: 8-13-14	12 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD		
13 Engine On: 7738	14 Engine Off: 1141	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed lines in Tagum floodplain voids

21 Problems and Solutions:

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

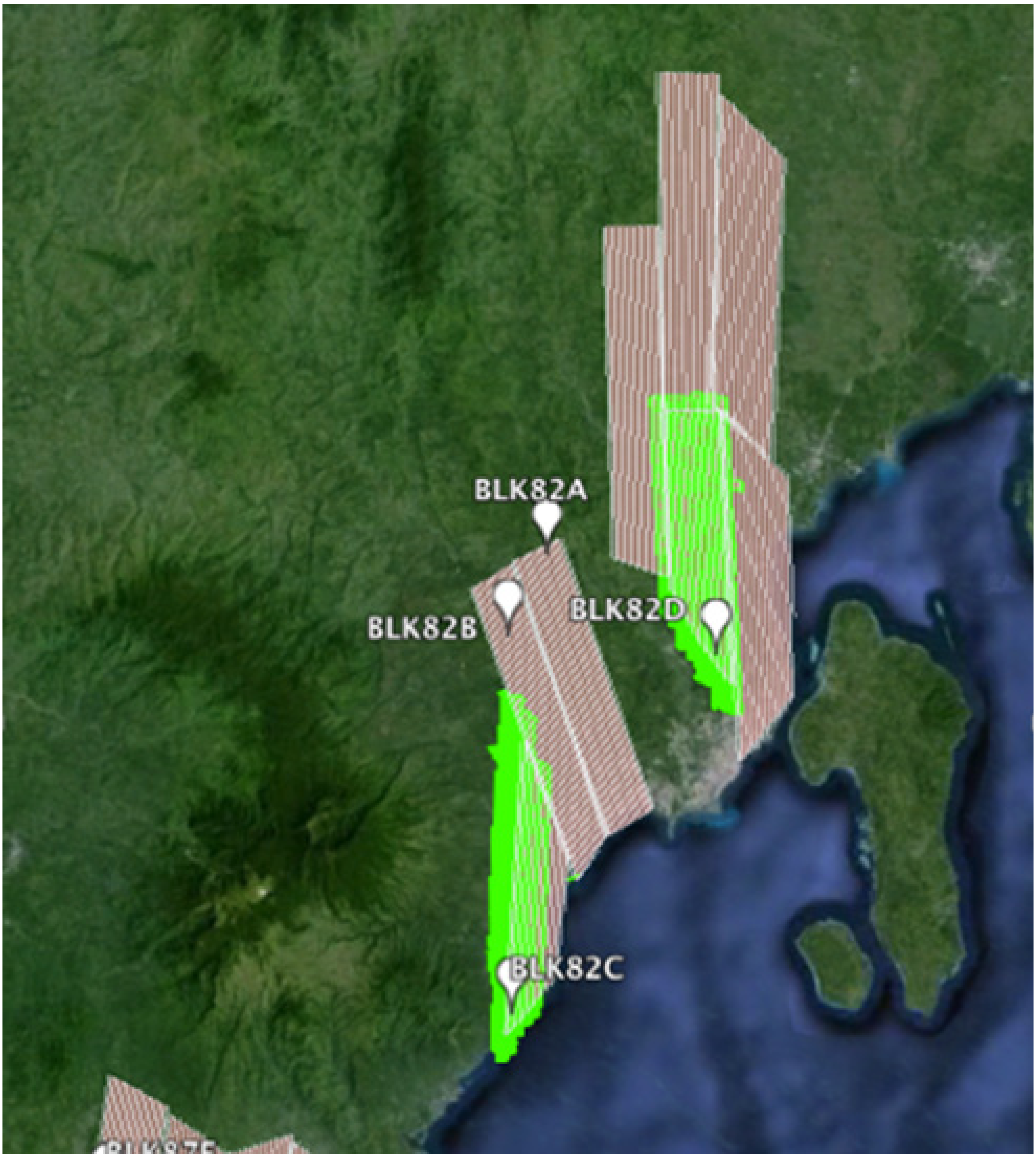
Annex 7. Flight Status

FLIGHT STATUS REPORT
Davao Del Sur and Compostela Valley
(July 16 – August 13, 2014)

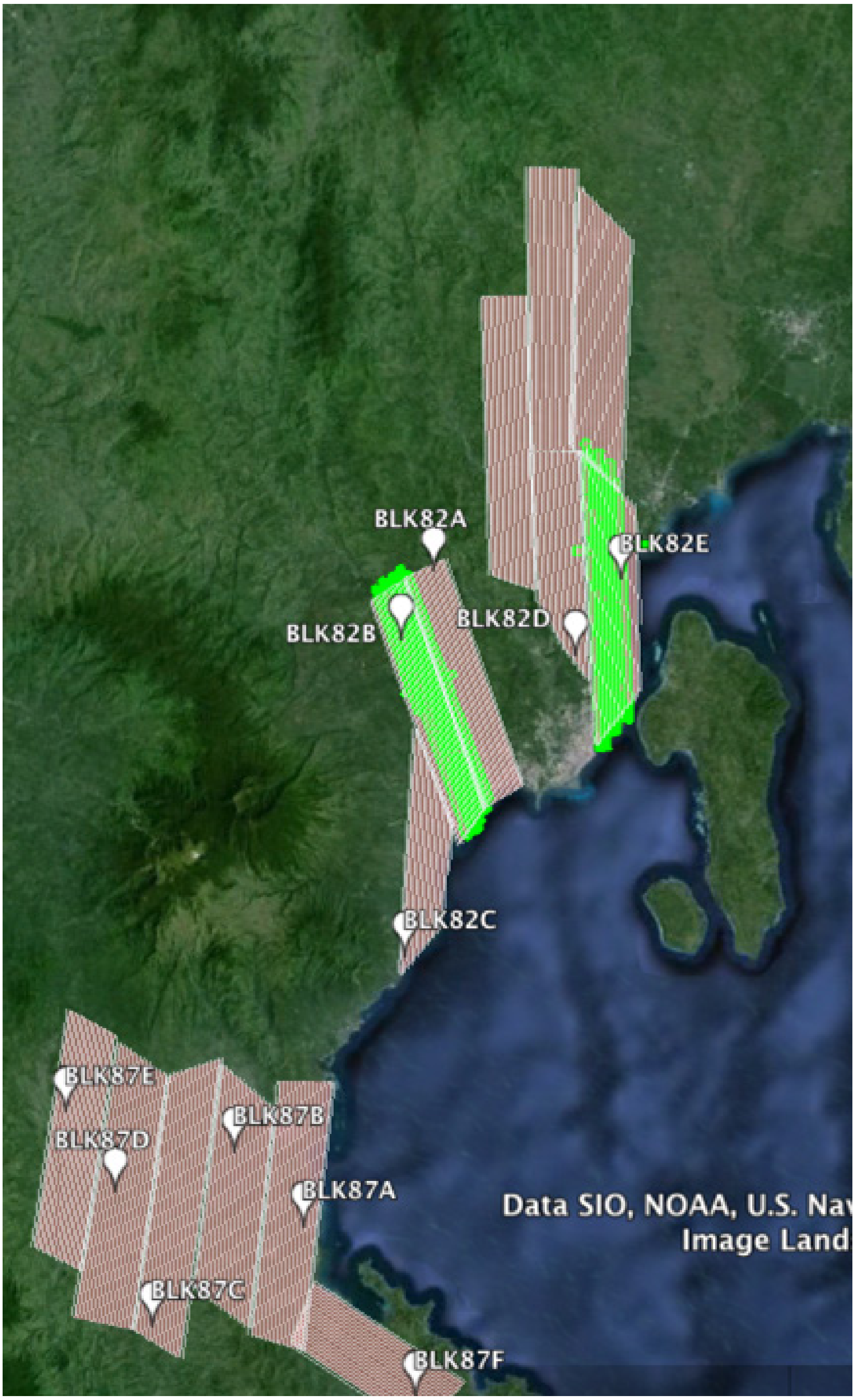
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7386GC	BLK82D	2BLK82CSD203A	LK PARAGAS	July 22, 2014	Completed BLK82C (9 lines) and surveyed BLK82C (7 lines) without CASI @ 800 AGL
7388GC	BLK82E	2BLK82AB204A	MVE TONGA	July 23, 2014	Completed the remaining lines of BLK82AB (8 lines) and proceed to BLK82D (6 lines) without CASI @ 1000 AGL
7390GC	BLK82G	2BLK82FH205A	LK PARAGAS	July 24, 2014	Surveyed BLK82F (7 lines) with voids and BLK82H (6 lines) without CASI @ 900 AGL
7396GC	BLK82H	2BLK82GSH208A	LK PARAGAS	July 27, 2014	Surveyed BLK82GH (10 lines) but encountered small patches of bad swath; flown without CASI @ 1000 AGL
7401GC	BLK82E	2BLK82EFGHS210B	LK PARAGAS	July 29, 2014	Surveyed BLK87EFGH (7 lines) without CASI @ 850 AGL
7422GC	COM_ BLKD	2COMA221A	MVE TONGA	Aug 9, 2014	13 lines @1000m
7423GC	COM_ BLKB	2COMBSCD221B	LK PARAGAS	Aug 9, 2014	13 lines @1000m, some lines cut due to high terrain
7424GC	COM_ BLKB	2BLKDS222A	MVE TONGA	Aug 10, 2014	10 lines @1000m
7426GC	BLK82 VOIDS	2BLK82V223A	LK PARAGAS	Aug 11, 2014	14 lines that filled up BLK 82 voids
7427GC	BLK82 VOIDS	2BLK82V223B	MVE TONGA	Aug 11, 2014	Filled up voids in BLK 82@1000m
7430GC	COM_ BLKB VOIDS	2TAGV225A	MVE TONGA	Aug 13, 2014	Completed lines (voids) in Tagum floodplain@1000m

LAS BOUNDARIES PER FLIGHT

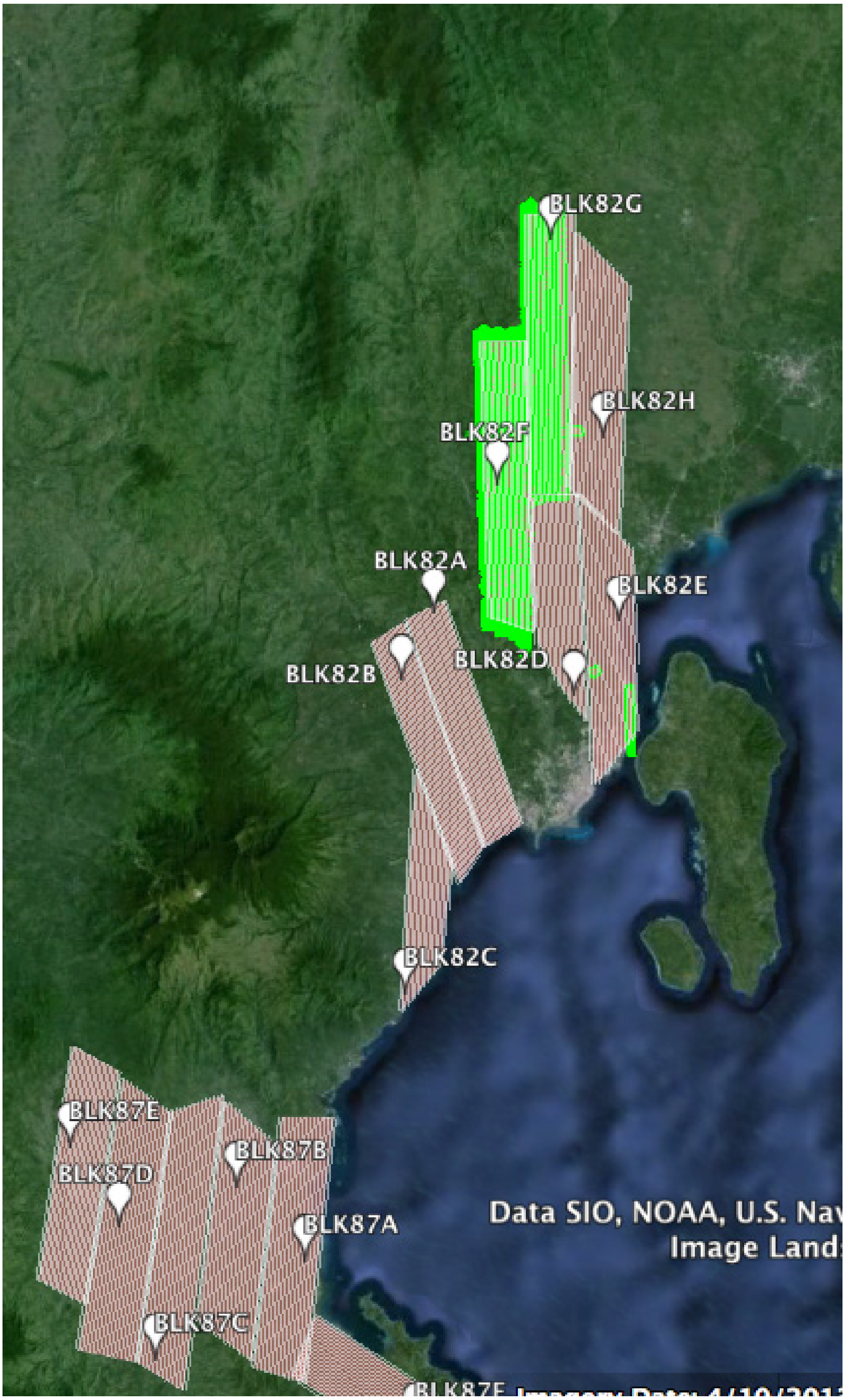
Flight No. :	7386GC	
Area:	BLK82C	
Mission name:	2BLK82CSD203A	
Parameters:	Altitude: 800 m;	Scan Frequency: 40 Hz;
	Scan Angle: 25 deg;	Overlap: 35 %
Area covered:	249.113 km2	



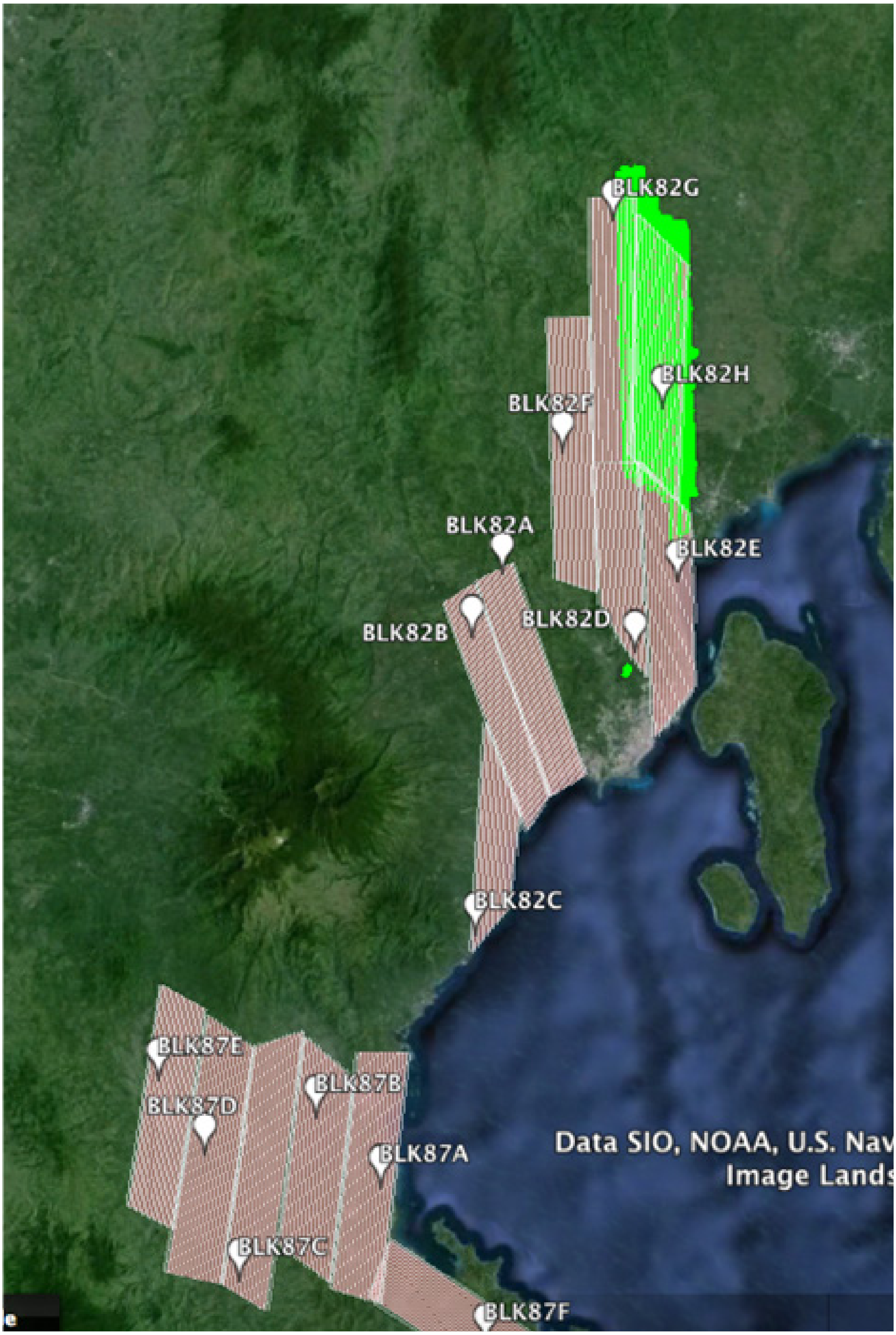
Flight No. :	7388GC	
Area:	BLK82E	
Mission name:	2BLK82AB204A	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz
	Scan Angle: 20 deg;	Overlap: 30%
Area covered:	205.14 km2	



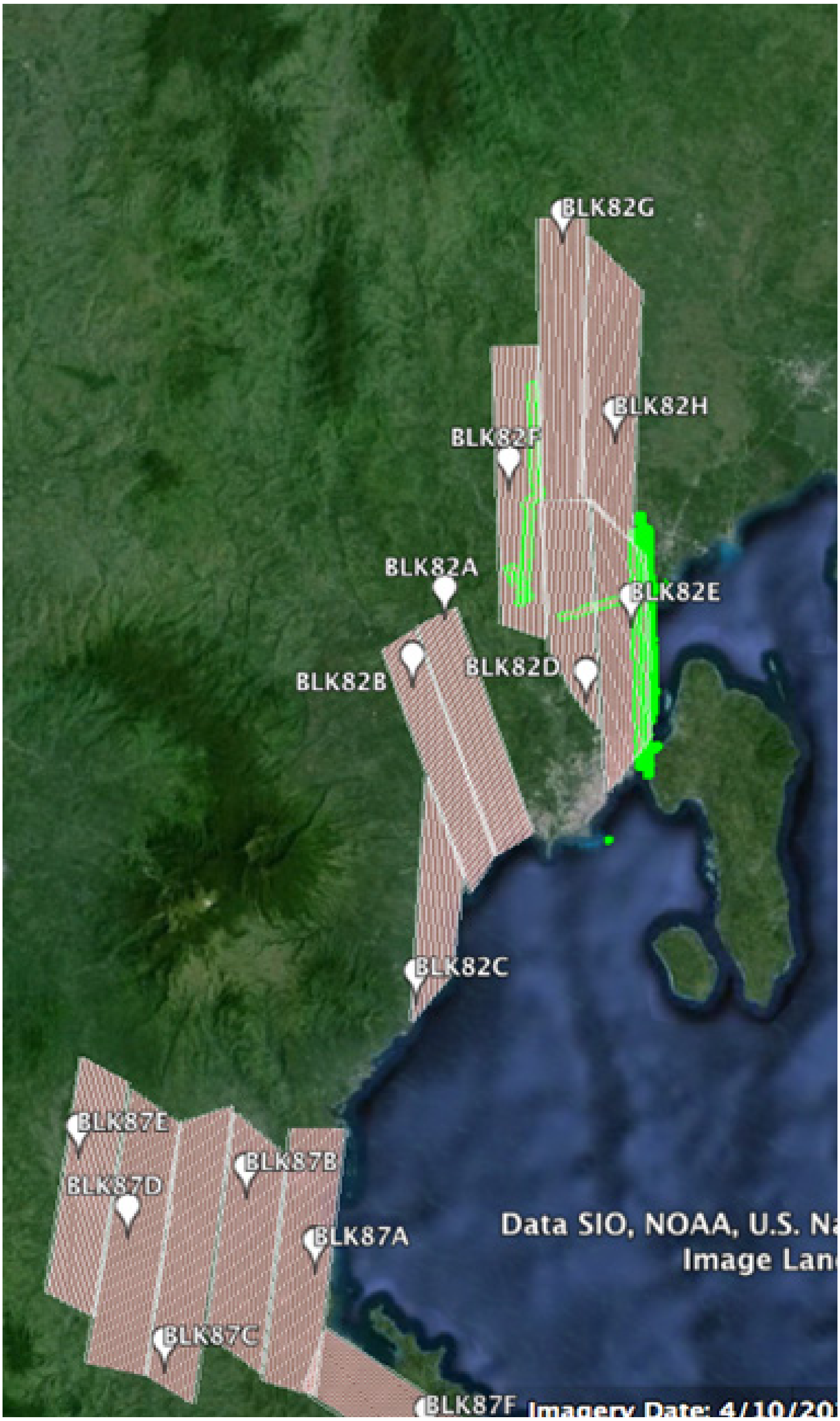
Flight No. :	390GC	
Area:	BLK82G	
Mission name:	2BLK82FH205A	
Parameters:	Altitude: 900 m;	Scan Frequency: 50 Hz
	Scan Angle: 20 deg;	Overlap: 30 %
Area covered:	284.80 km2	



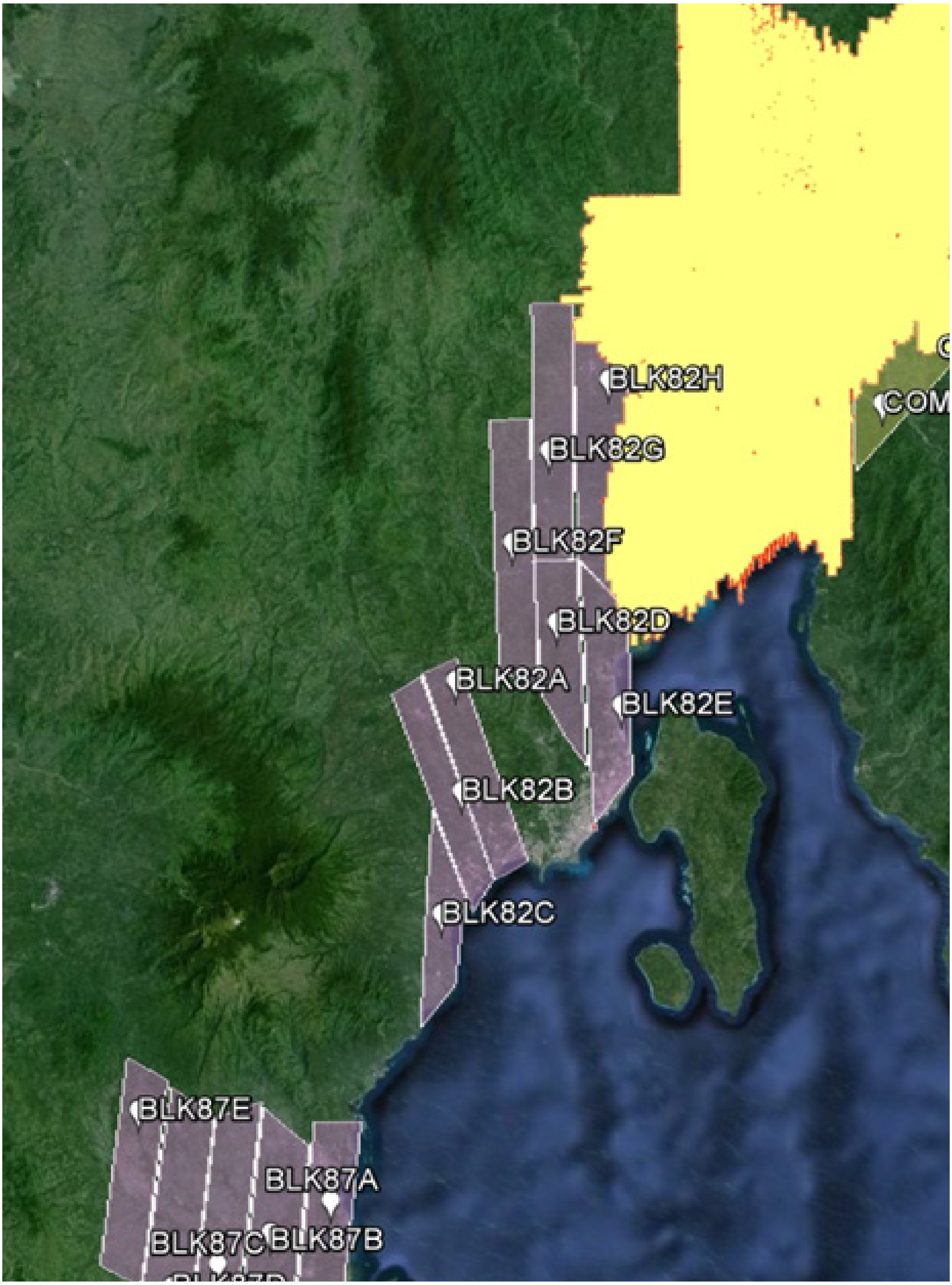
Flight No. :	7396GC	
Area:	BLK82H	
Mission name:	2BLK82GSH208A	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz
	Scan Angle: 20 deg;	Overlap: 30 %
Area covered:	238.05 km2	



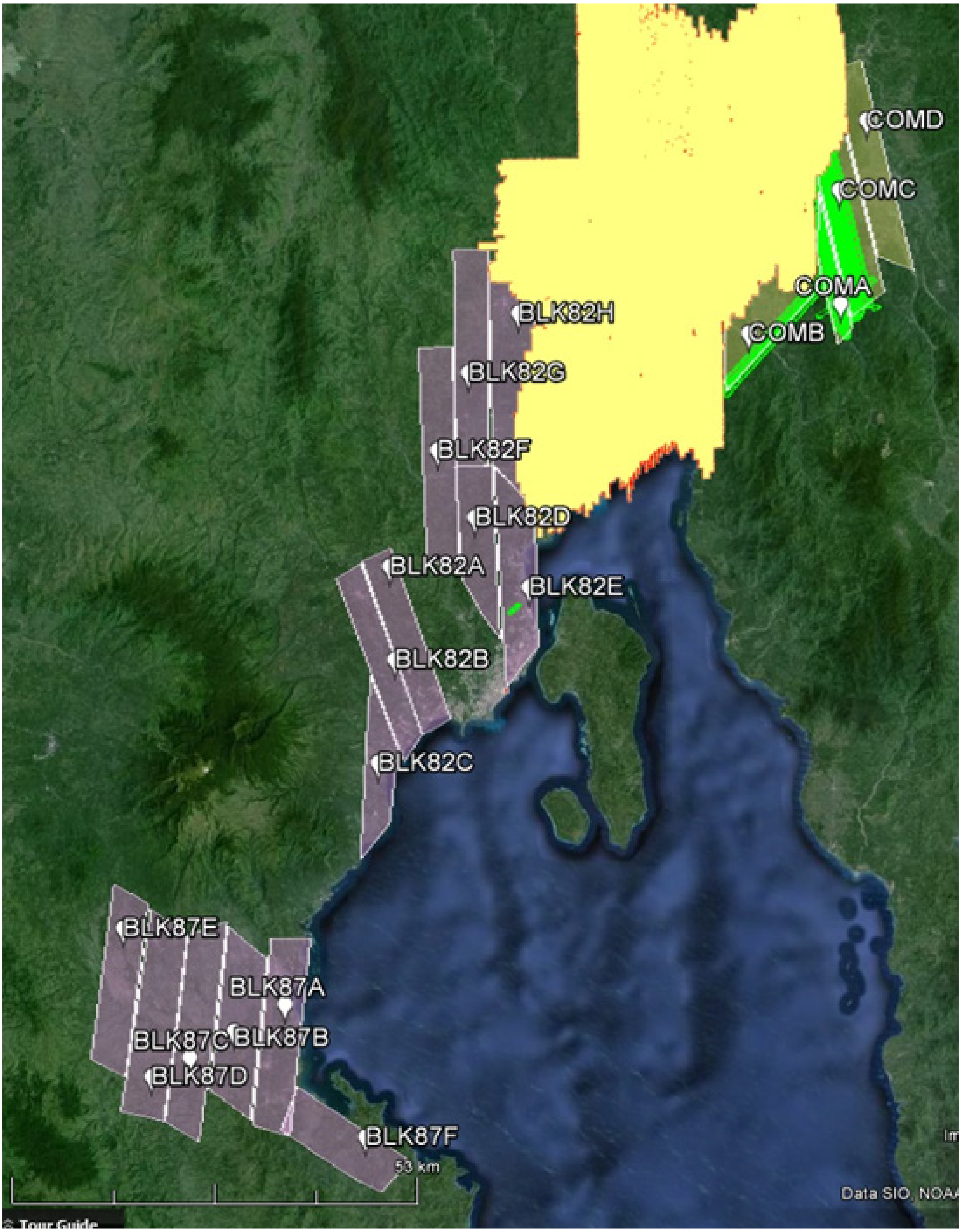
Flight No. :	7401GC	
Area:	BLK82E	
Mission name:	2BLK82EFGHS210B	
Parameters:	Altitude: 850 m;	Scan Frequency: 40 Hz
	Scan Angle: 25 deg;	Overlap: 30 %
Area covered:	83.27 km2	



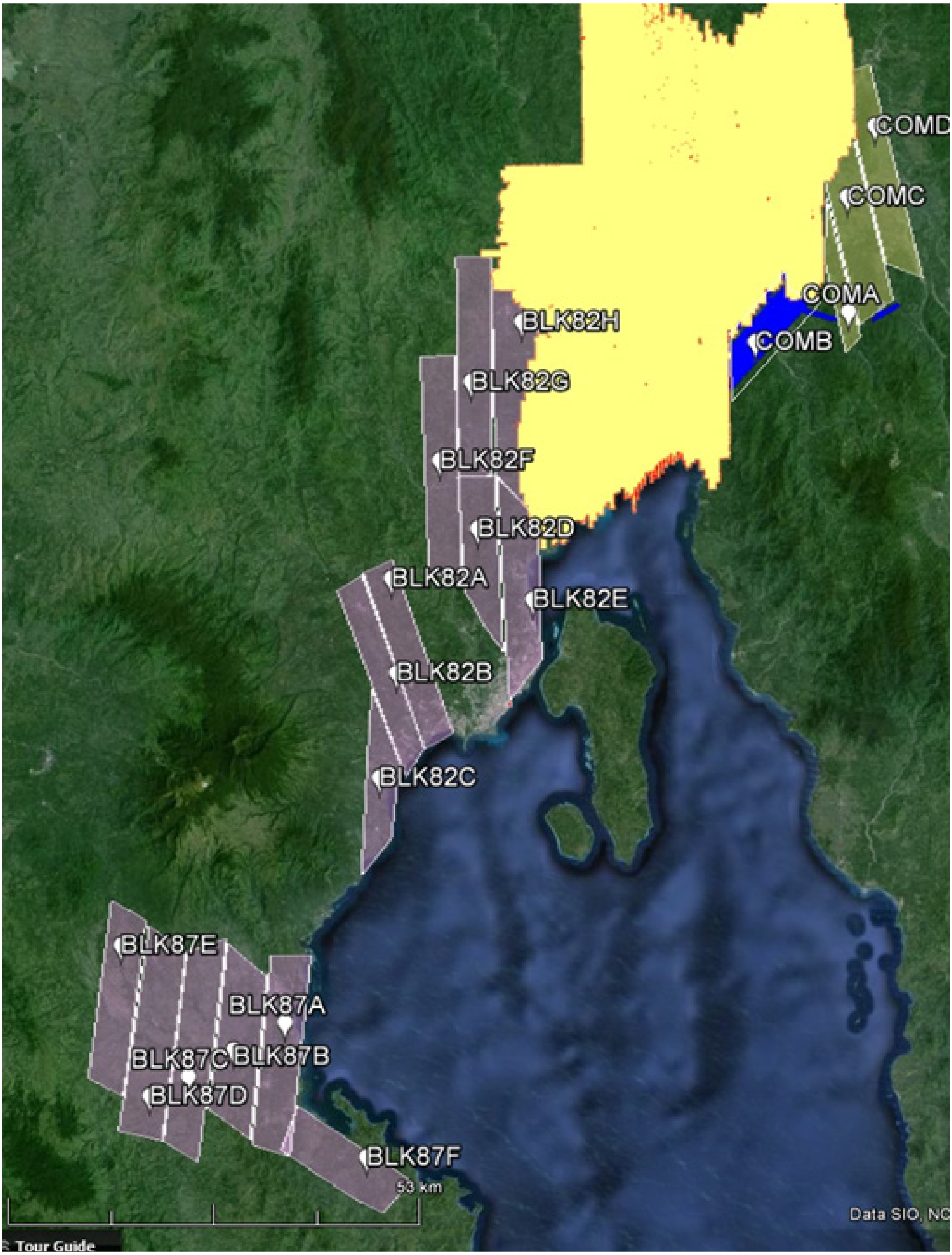
Flight No. :	7422GC	
Area:	COM_BLKD	
Mission name:	2COMA221A	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz
	Scan Angle: 20 deg;	Overlap: 35 %
Area covered:	186.59 km2	



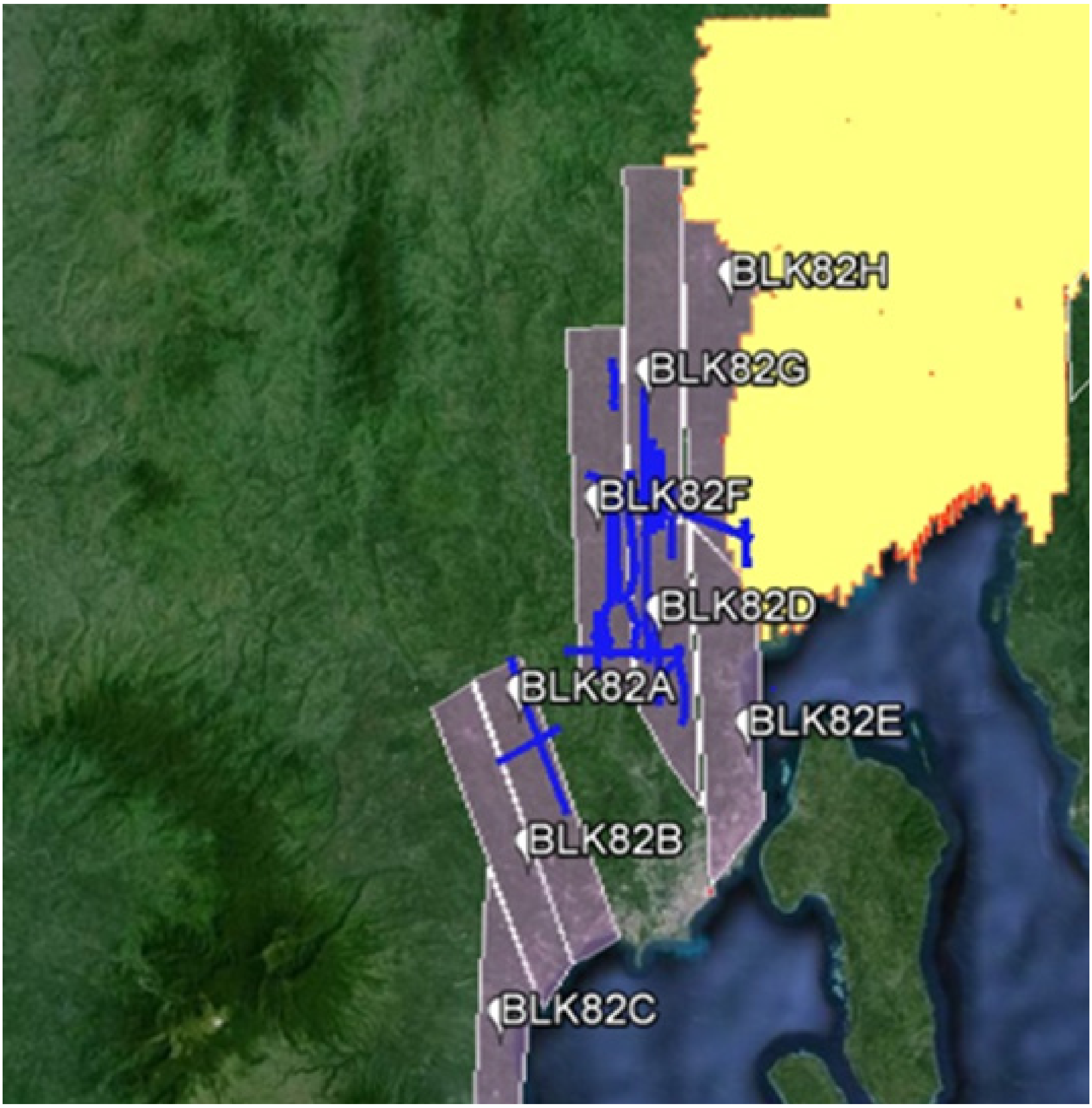
Flight No. :	7423GC	
Area:	COM_BLKB	
Mission name:	2COMBSCD221B	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz
	Scan Angle: 20 deg;	Overlap: 35 %
Area covered:	154.44 km2	



Flight No. :	7424GC	
Area:	COM_BLKB	
Mission name:	2COMDS222A	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz
	Scan Angle: 20 deg;	Overlap: 35 %
Area covered:	87.31 km2	

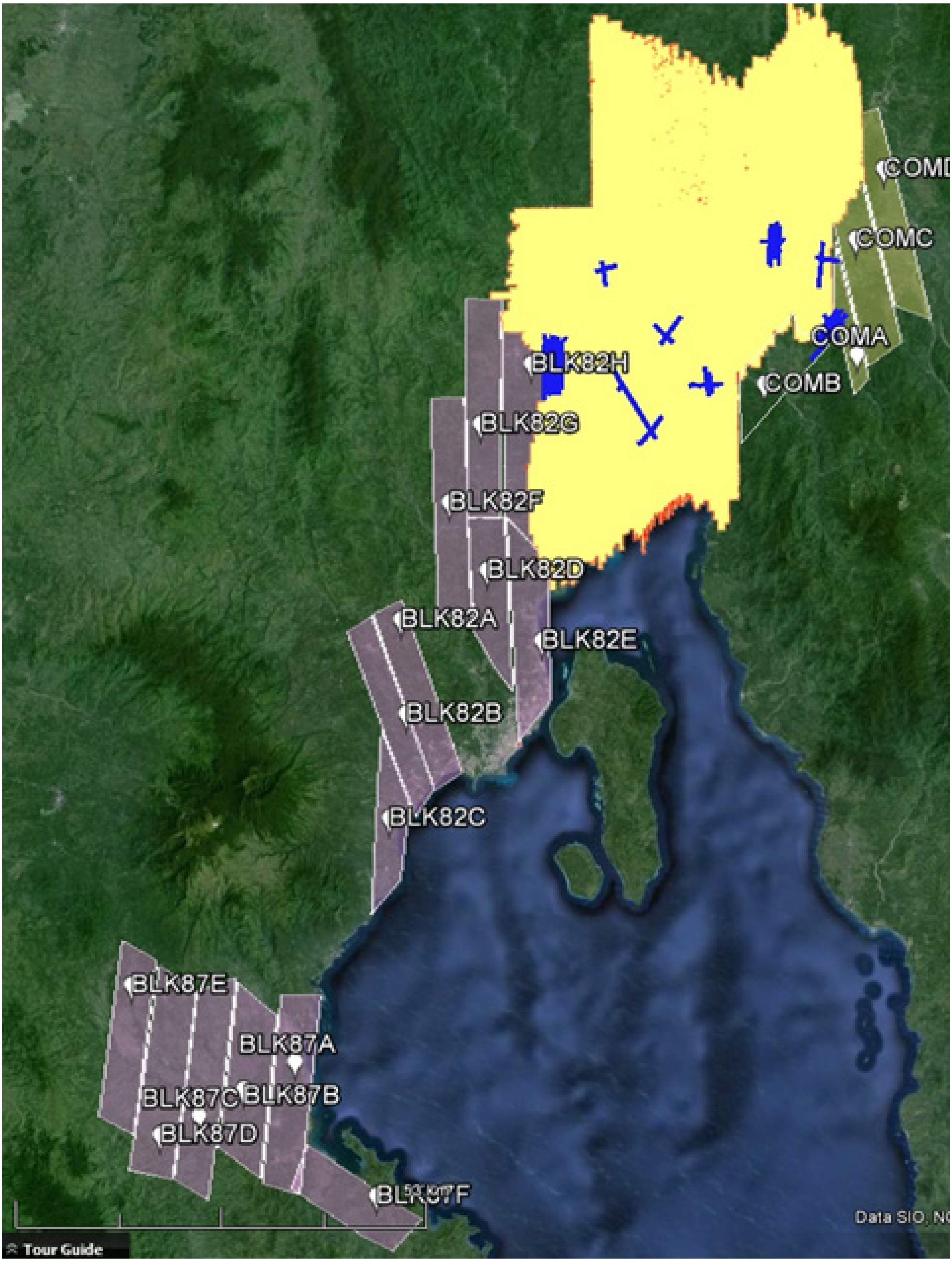


Flight No. :	7426GC	
Area:	BLK82_voids	
Mission name:	2BLK82V223A	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz;
	Scan Angle: 20 deg;	Overlap: 35 %
Area covered:	95.83 km2	



Flight No. :	7427GC	
Area:	BLK82B_voids	
Mission name:	2BLK82V223B	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz;
	Scan Angle: 20 deg;	Overlap: 35 %
Area covered:	47.89 km2	

Flight No. :	7430GC	
Area:	COM_BLKB_Voids	
Mission name:	2TAGV225A	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz
	Scan Angle: 20 deg;	Overlap: 35 %
Area covered:	76.83 sq.km2	



Annex 8. Mission Summary Reports

Flight Area	Davao Oriental
Mission Name	Blk82H
Inclusive Flights	7396G
Range data size	27.1 GB
Base data size	5.65 MB
POS	214 MB
Image	na
Transfer date	August 7, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.42
RMSE for Down Position (<8.0 cm)	2.95
Boresight correction stdev (<0.001deg)	0.000183
IMU attitude correction stdev (<0.001deg)	0.633546
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	32.07%
Ave point cloud density per sq.m. (>2.0)	2.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	297
Maximum Height	268.45 m
Minimum Height	69.39 m
Classification (# of points)	
Ground	42,297,308
Low vegetation	25,219,386
Medium vegetation	218,790,998
High vegetation	382,856,949
Building	204,130
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Jeffrey Delica

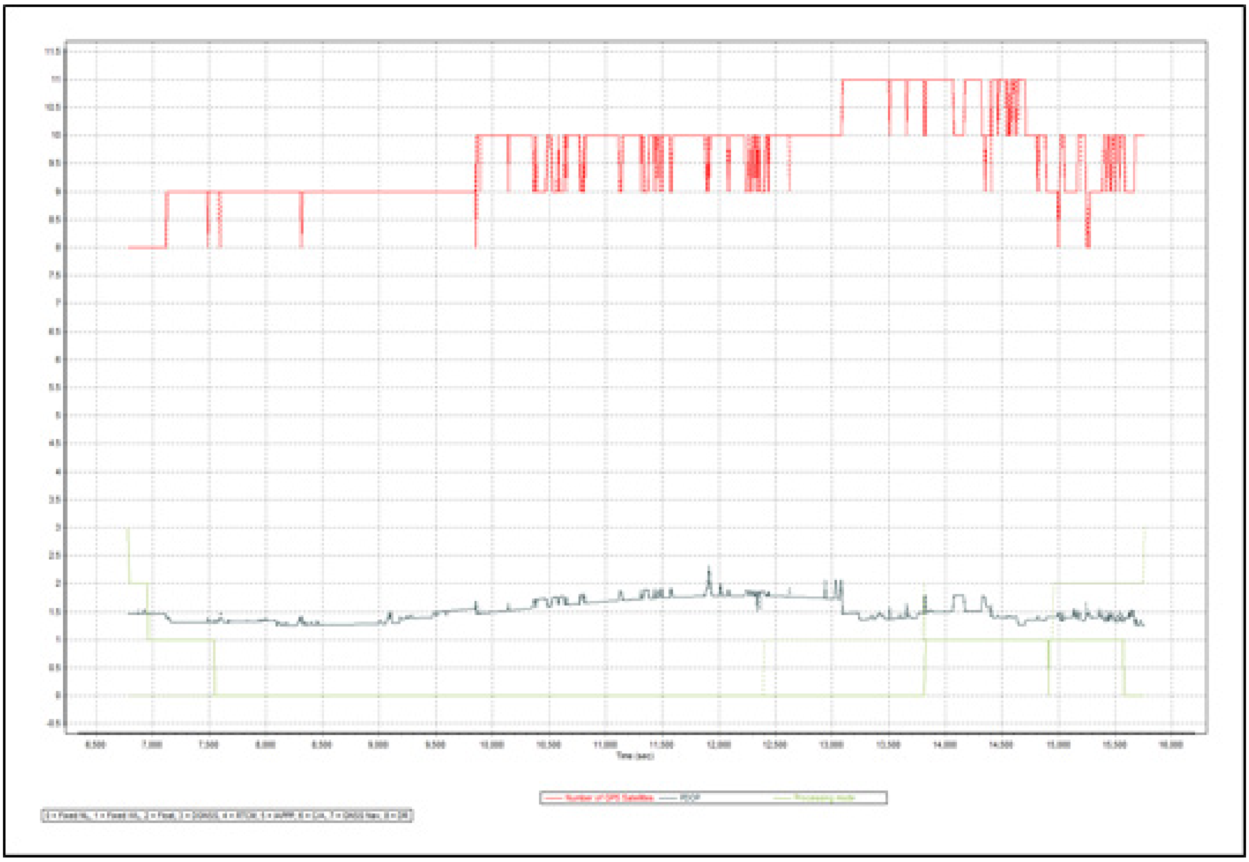


Figure A-8.1. Solution Status

Figure A-8.2. Smoothed Performance Metric Parameters

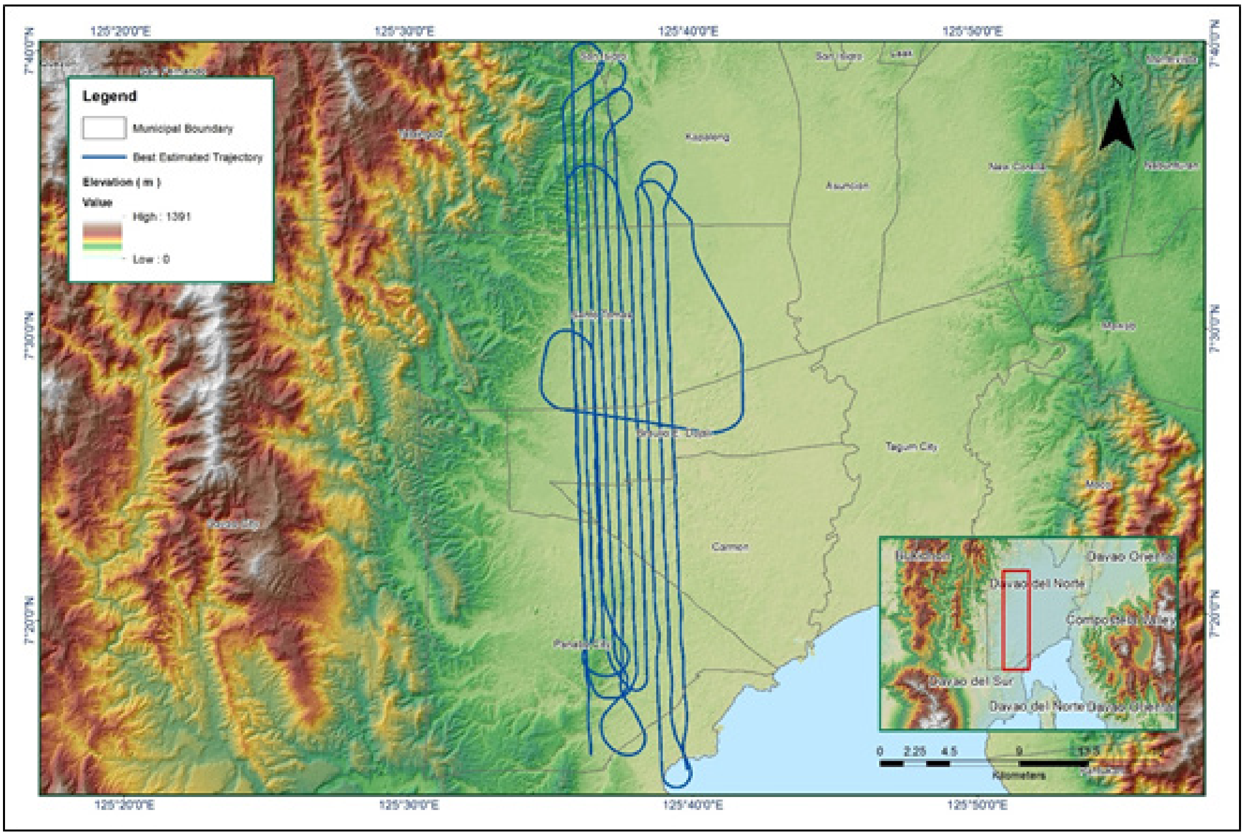


Figure A-8.3. Best Estimated Trajectory

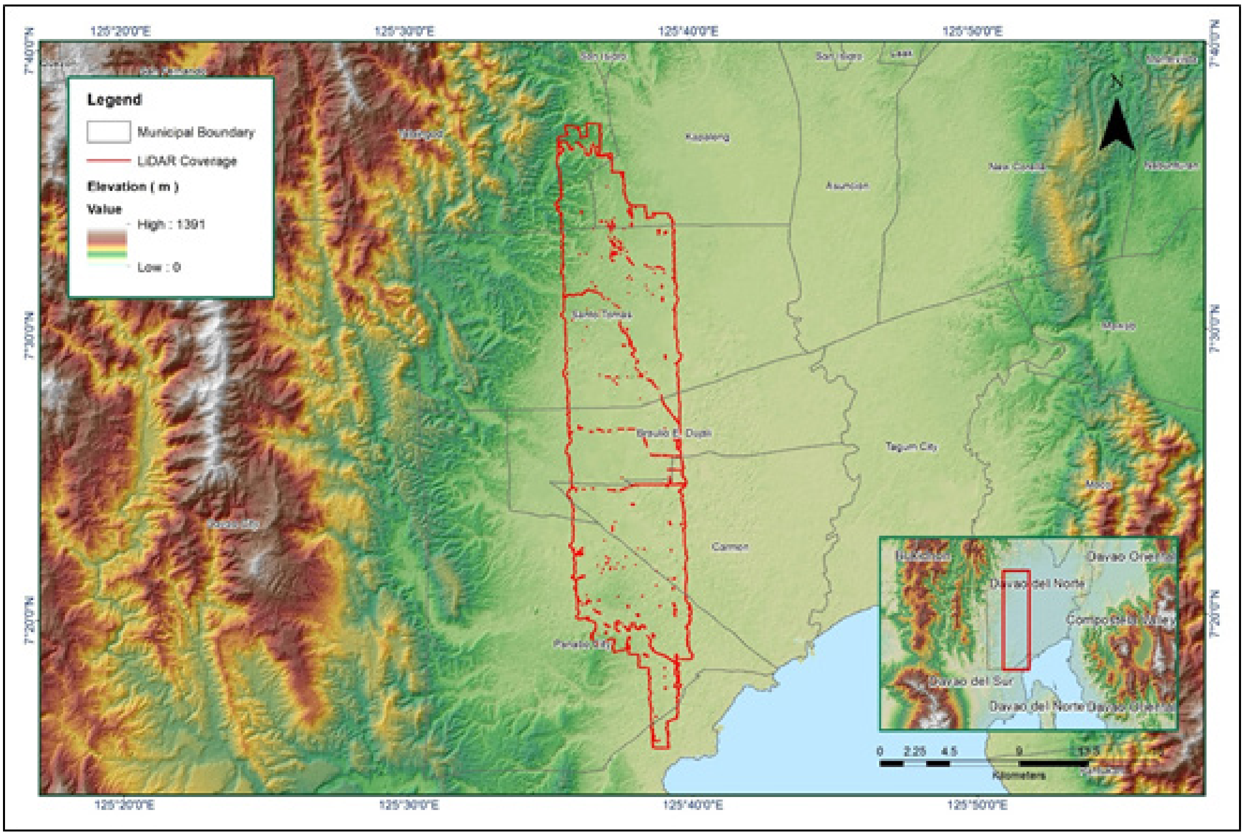


Figure A-8.4. Coverage of LiDAR data

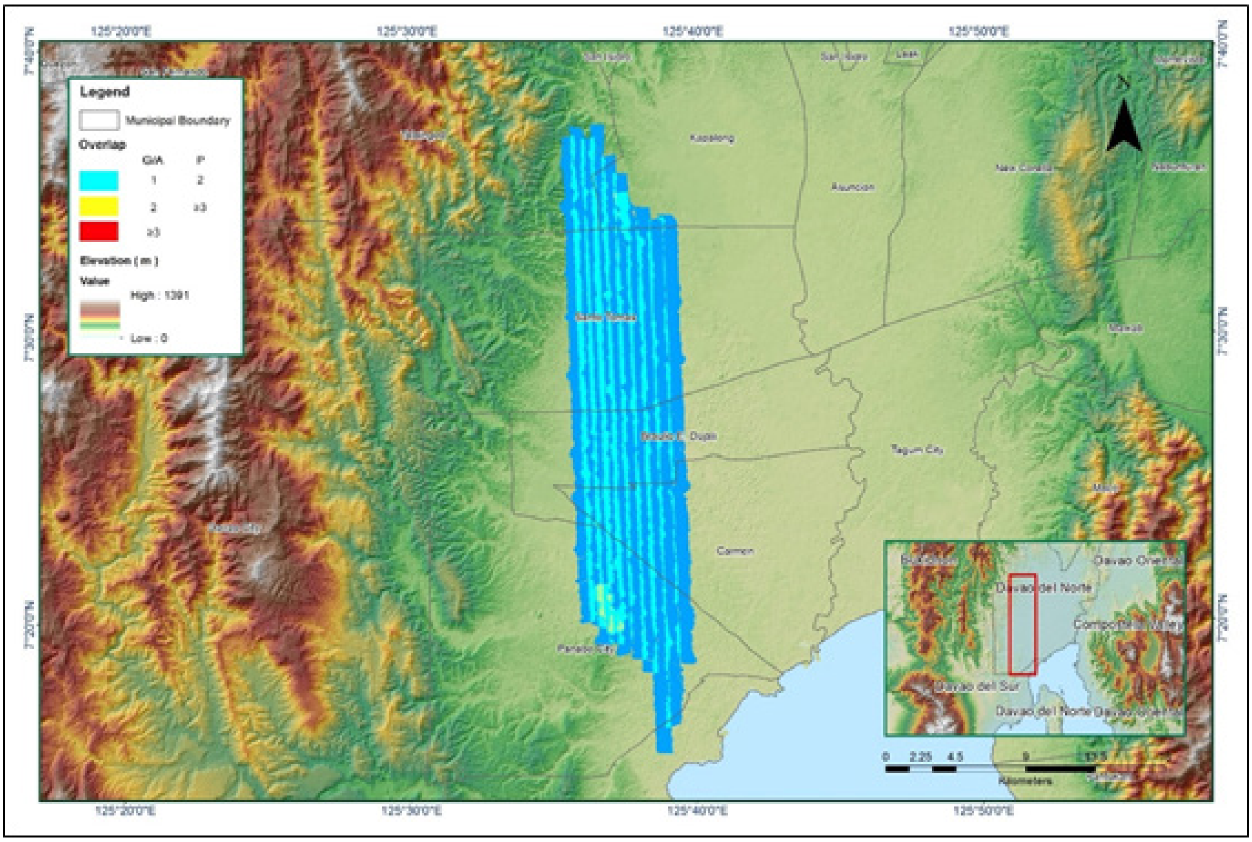


Figure A-8.5. Image of data overlap

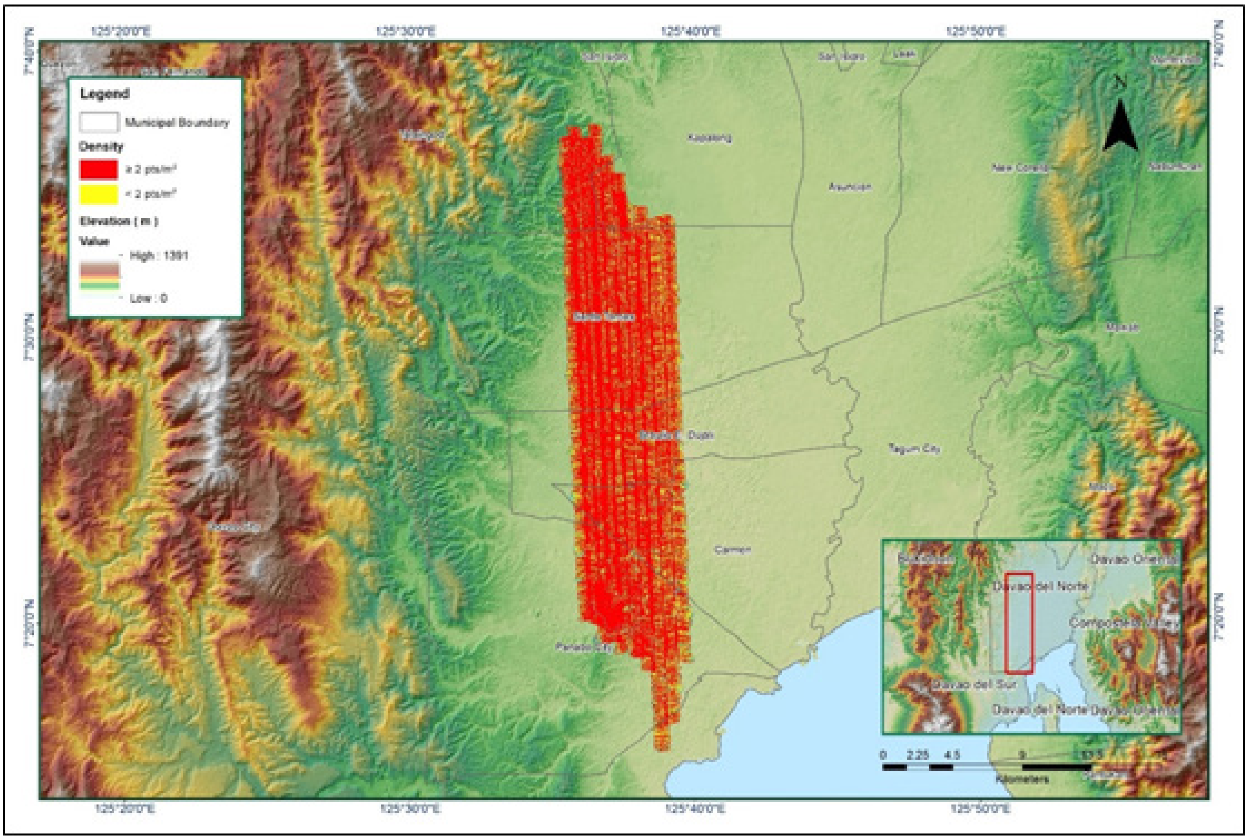


Figure A-8.6. Density map of merged LiDAR data

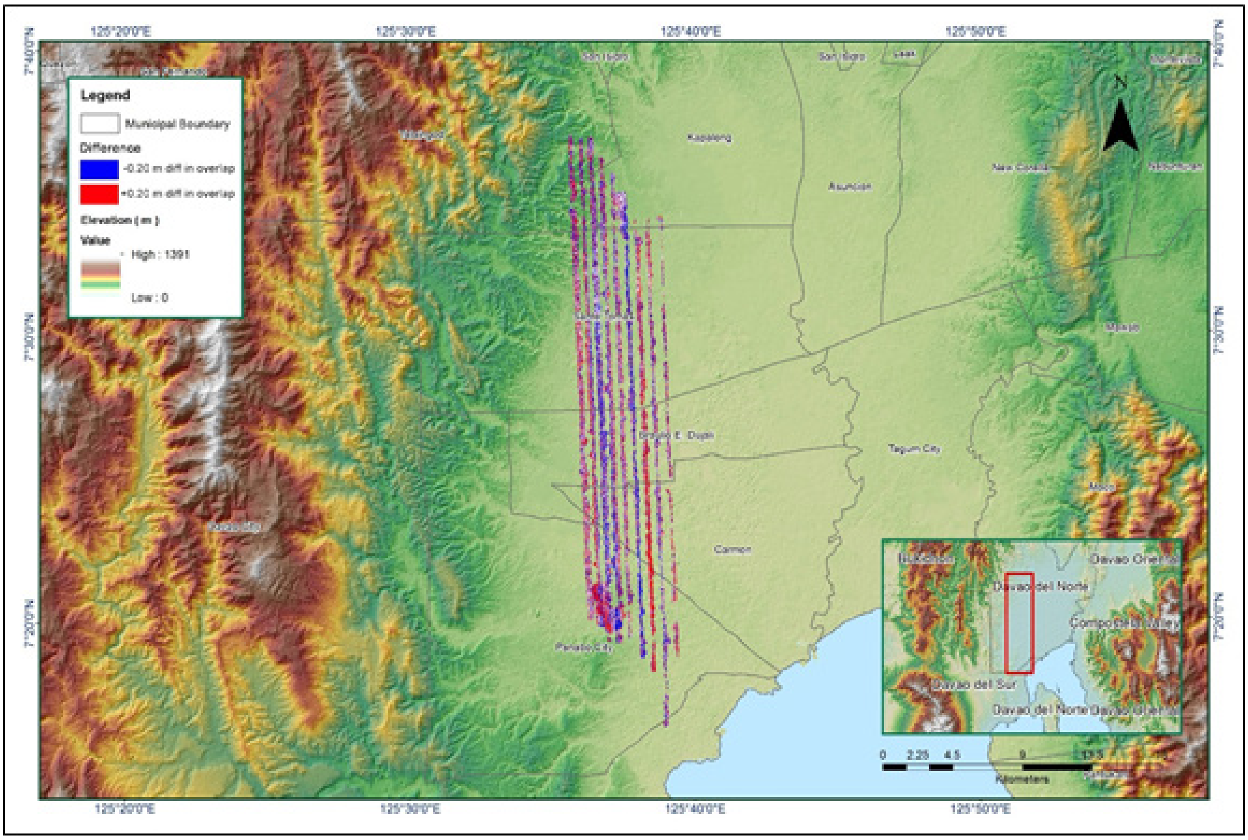


Figure A-8.7. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82E
Inclusive Flights	7388G,7401G
Range data size	29.65 GB
Base data size	15.79 MB
POS	332 MB
Image	na
Transfer date	August 7, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.05
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.000183
IMU attitude correction stdev (<0.001deg)	0.633546
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	24.76%
Ave point cloud density per sq.m. (>2.0)	2.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	318
Maximum Height	403.82 m
Minimum Height	62.44 m
Classification (# of points)	
Ground	75,679,213
Low vegetation	78,983,338
Medium vegetation	146,928,343
High vegetation	282,014,947
Building	24,716,788
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Ailyn Biñas

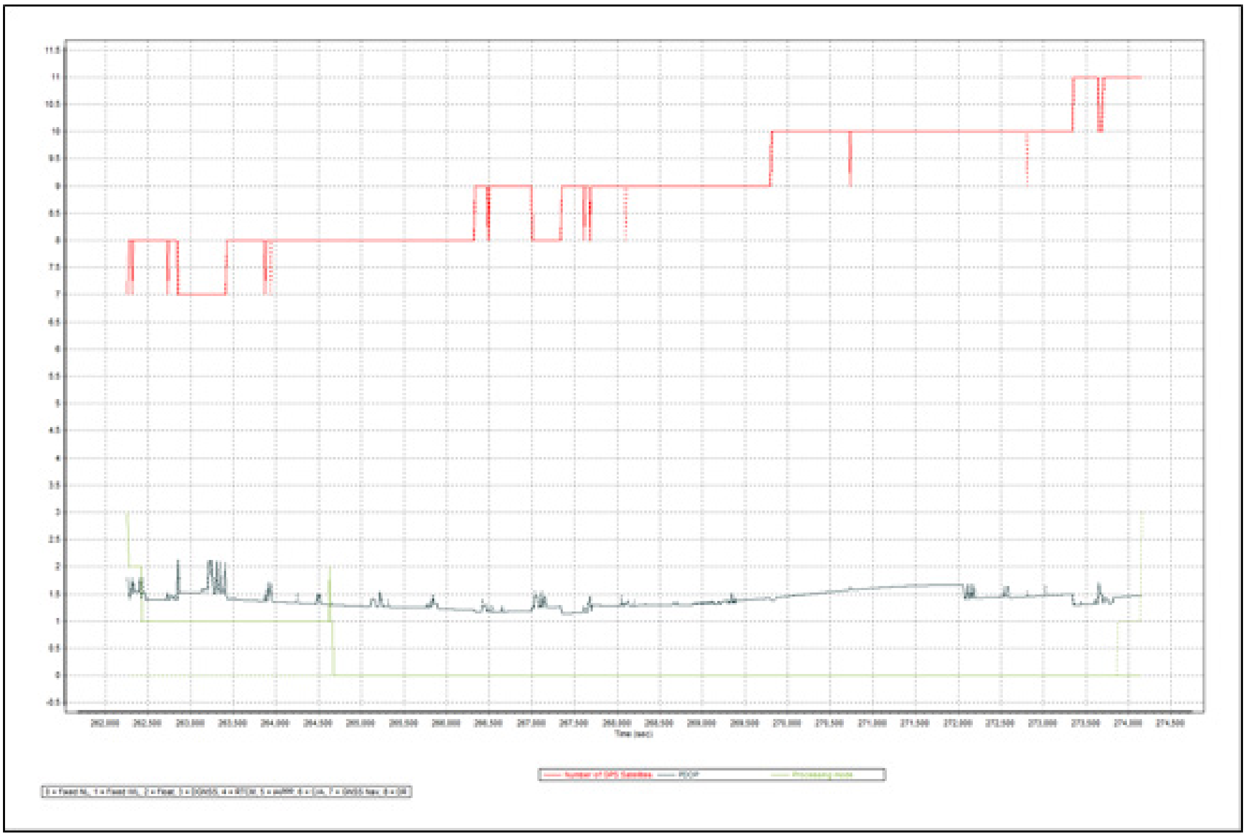


Figure A-8.8. Solution Status

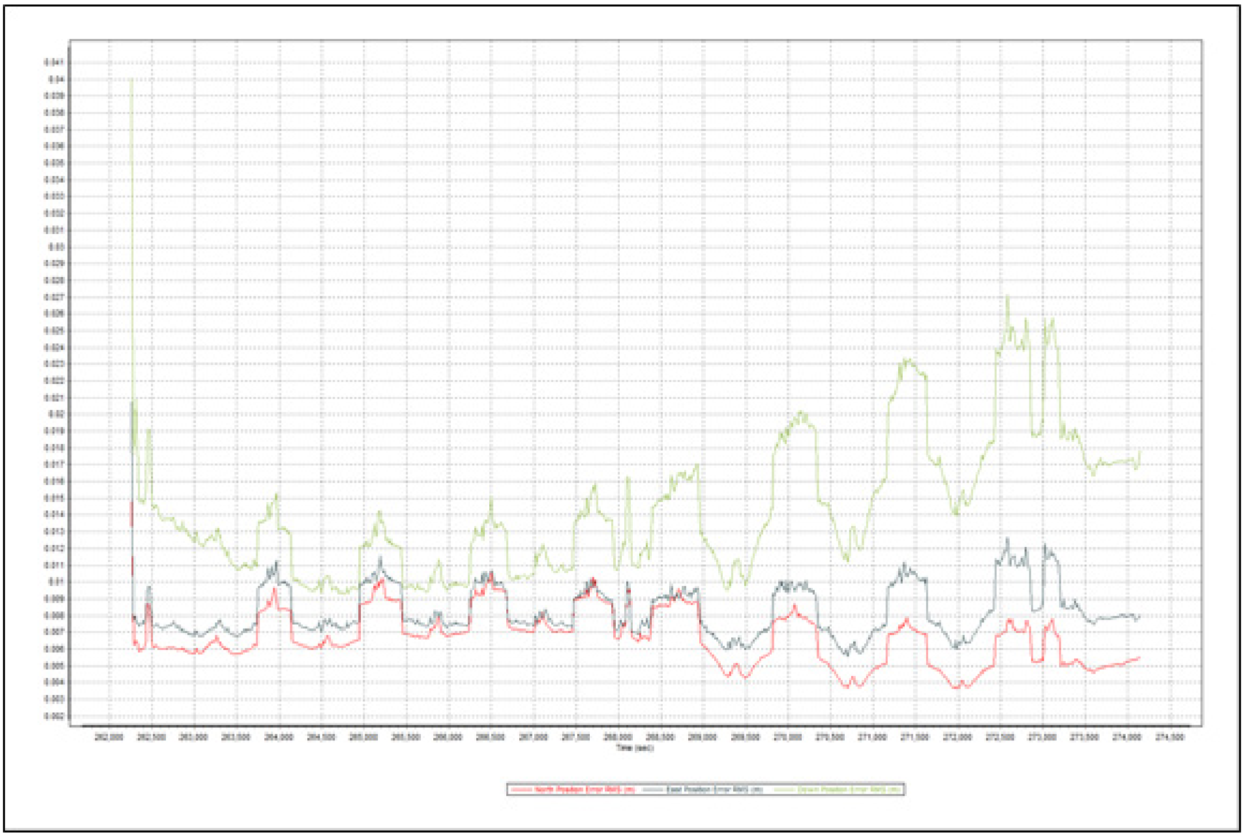


Figure A-8.9. Smoothed Performance Metric Parameters

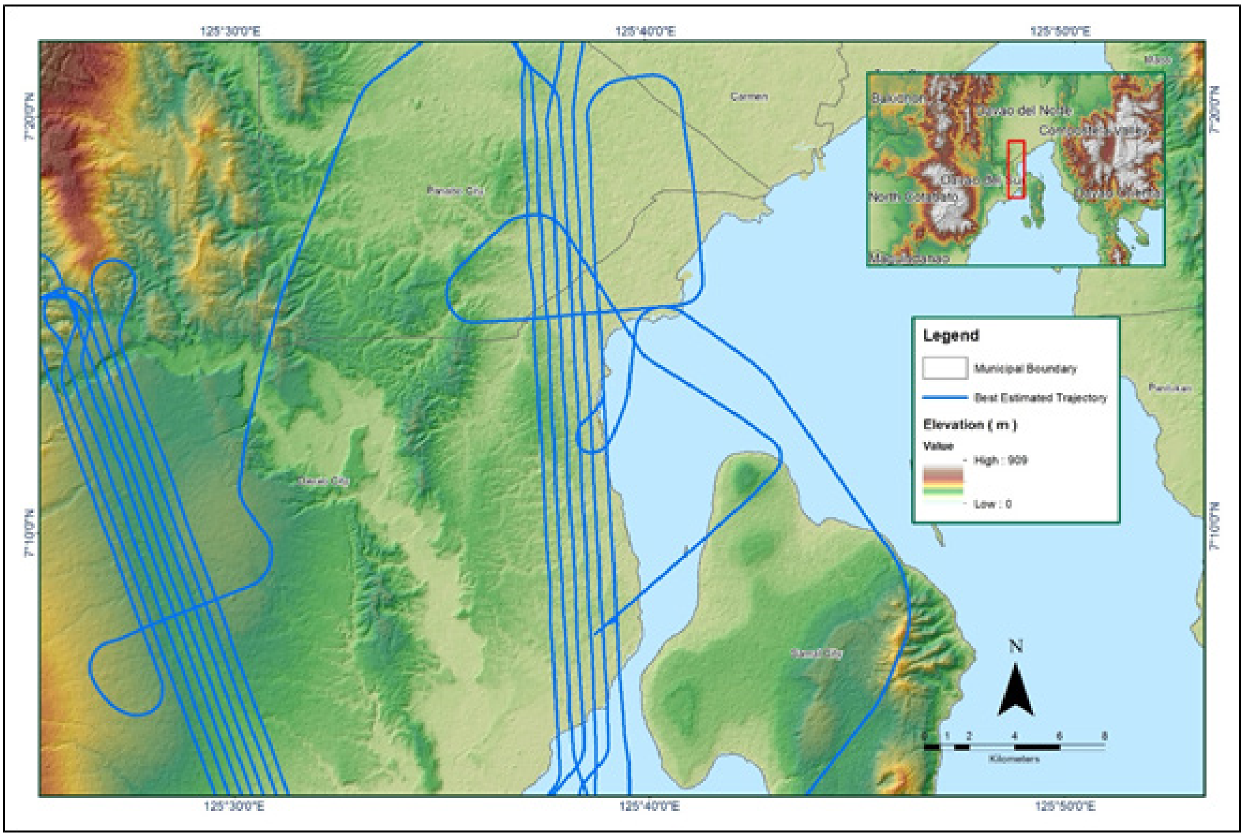


Figure A-8.10. Best Estimated Trajectory

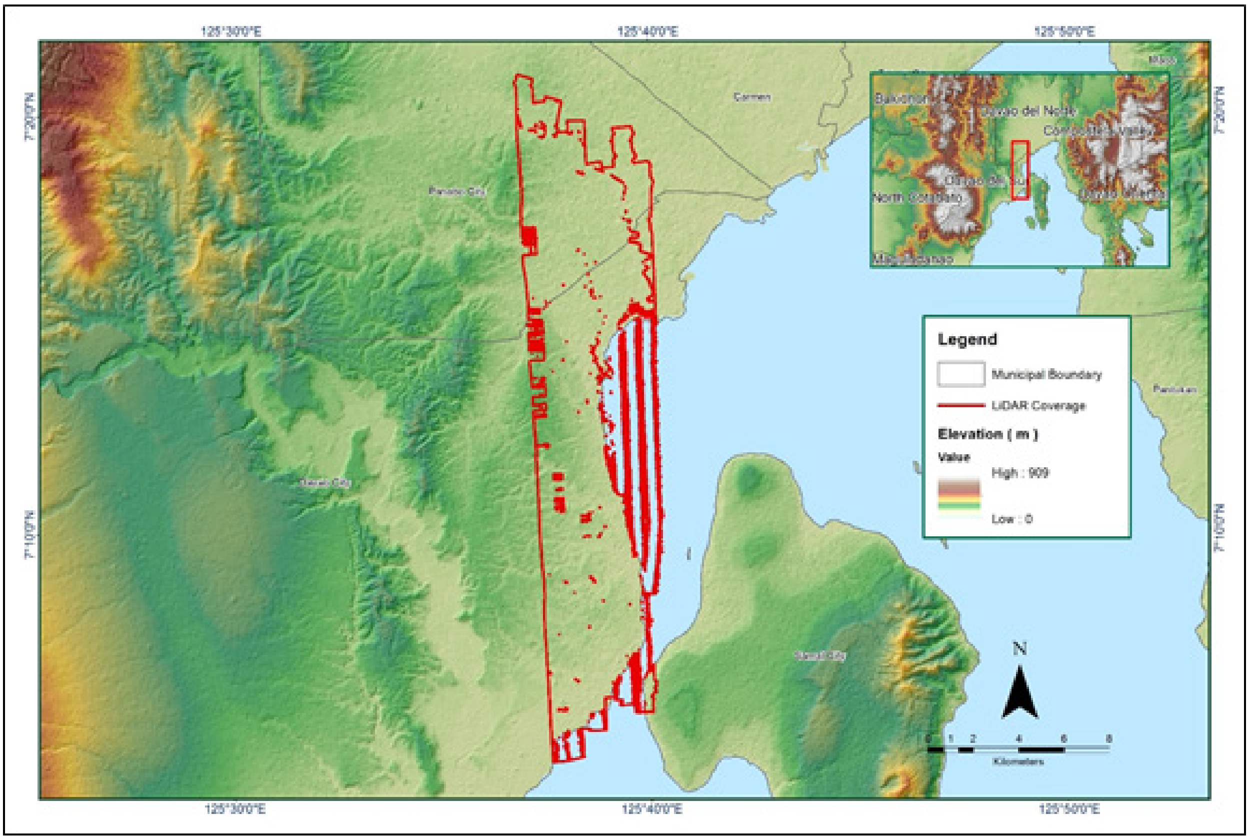


Figure A-8.11. Coverage of LiDAR data

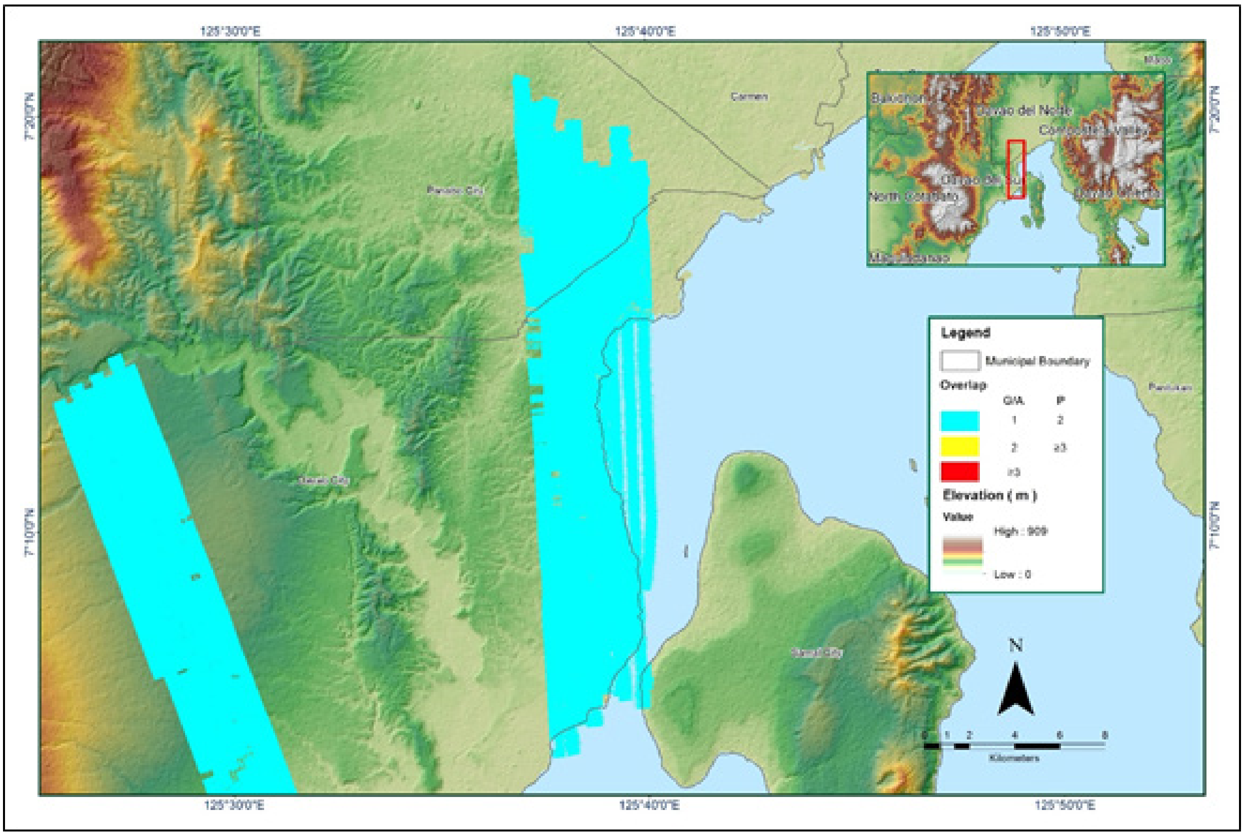


Figure A-8.12. Image of data overlap

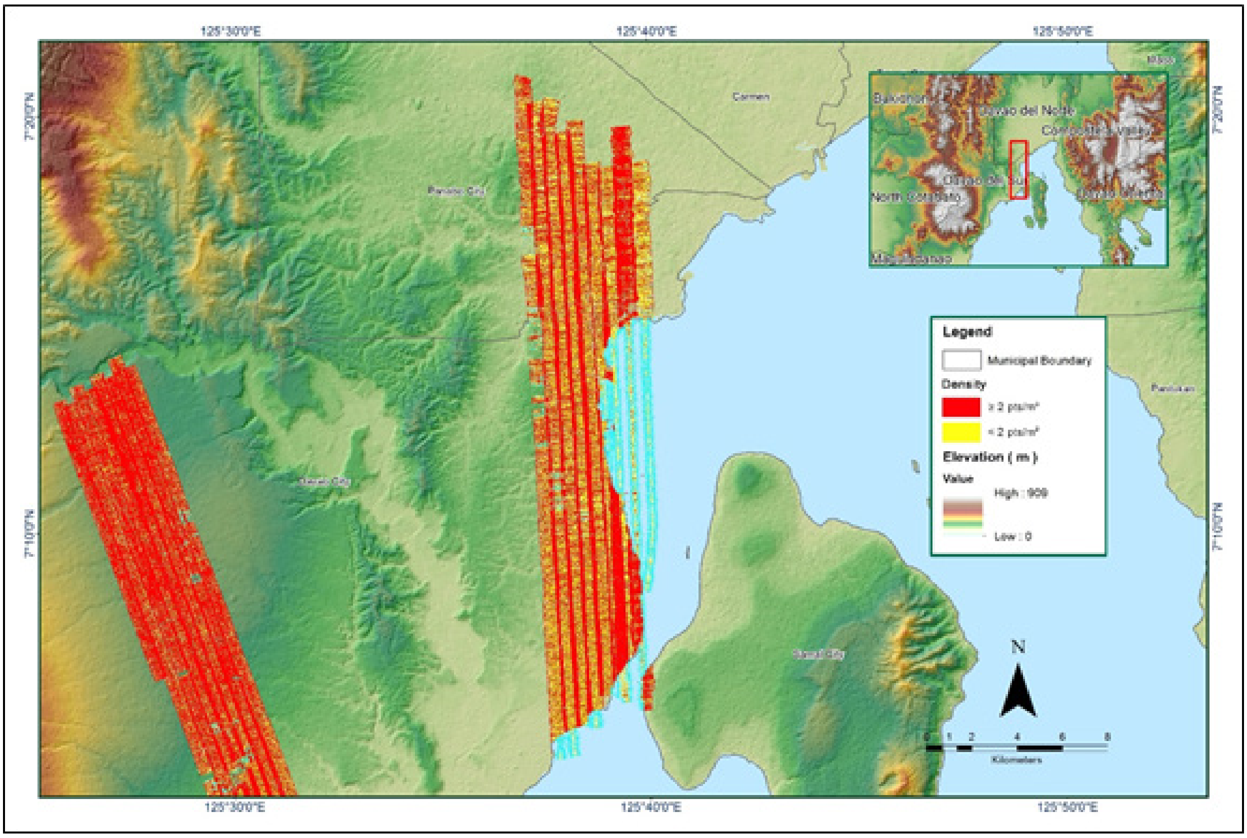


Figure A-8.13. Density map of merged LiDAR data

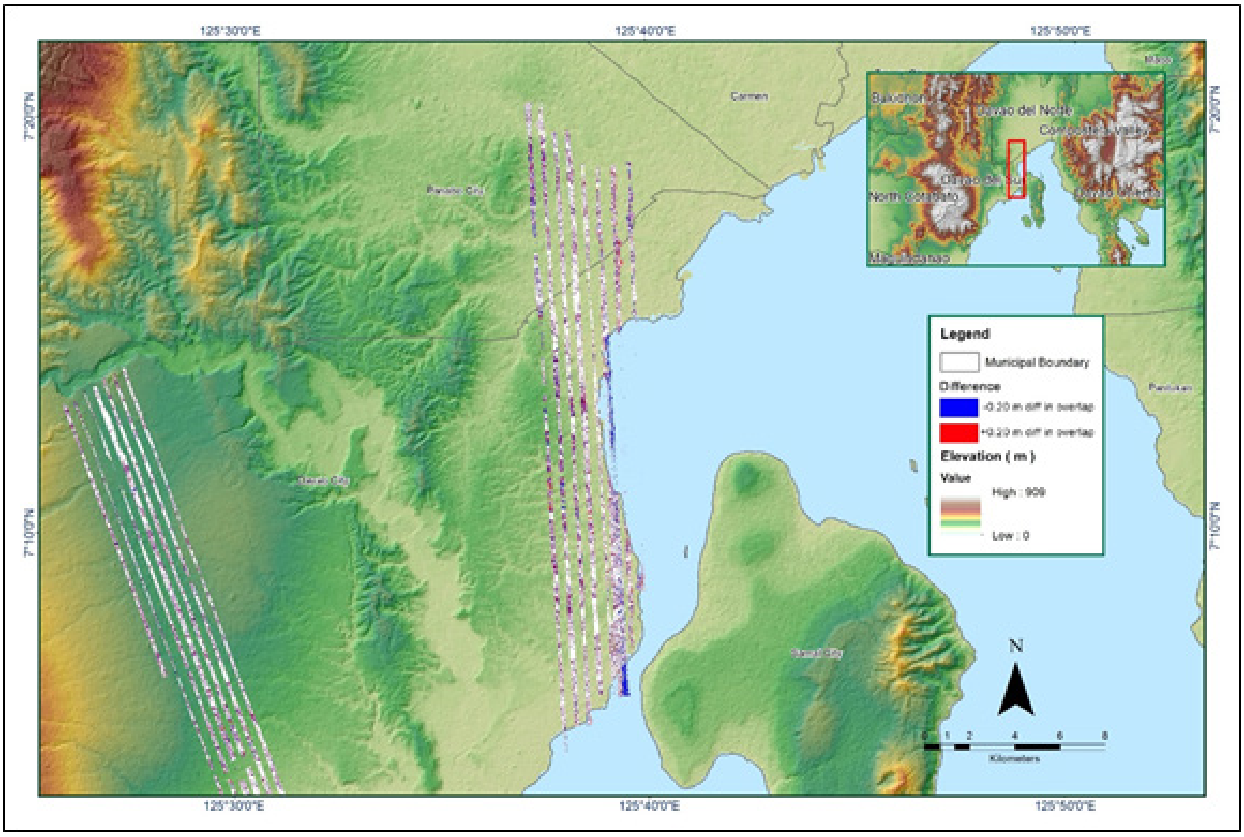


Figure A-8.14. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82G
Inclusive Flights	7390G
Range data size	29 GB
Base data size	17.6 MB
POS	241 MB
Image	na
Transfer date	August 7, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.039697
IMU attitude correction stdev (<0.001deg)	0.0201
GPS position stdev (<0.01m)	0.020852
Minimum % overlap (>25)	26.21%
Ave point cloud density per sq.m. (>2.0)	2.87
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	172
Maximum Height	392.77 m
Minimum Height	83.32 m
Classification (# of points)	
Ground	26,905,321
Low vegetation	14,433,599
Medium vegetation	121,726,040
High vegetation	195,005,210
Building	170,673
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. John Dill Macapagal

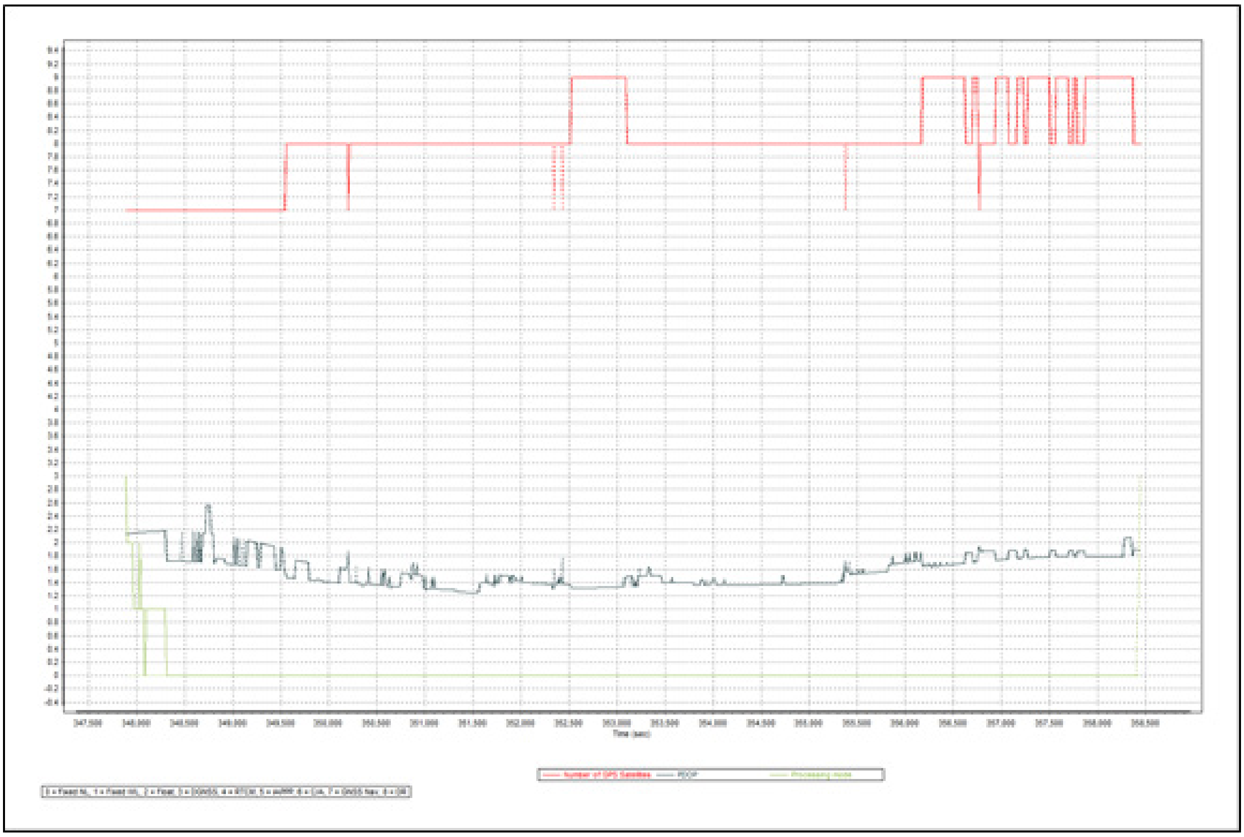


Figure A-8.15. Solution Status

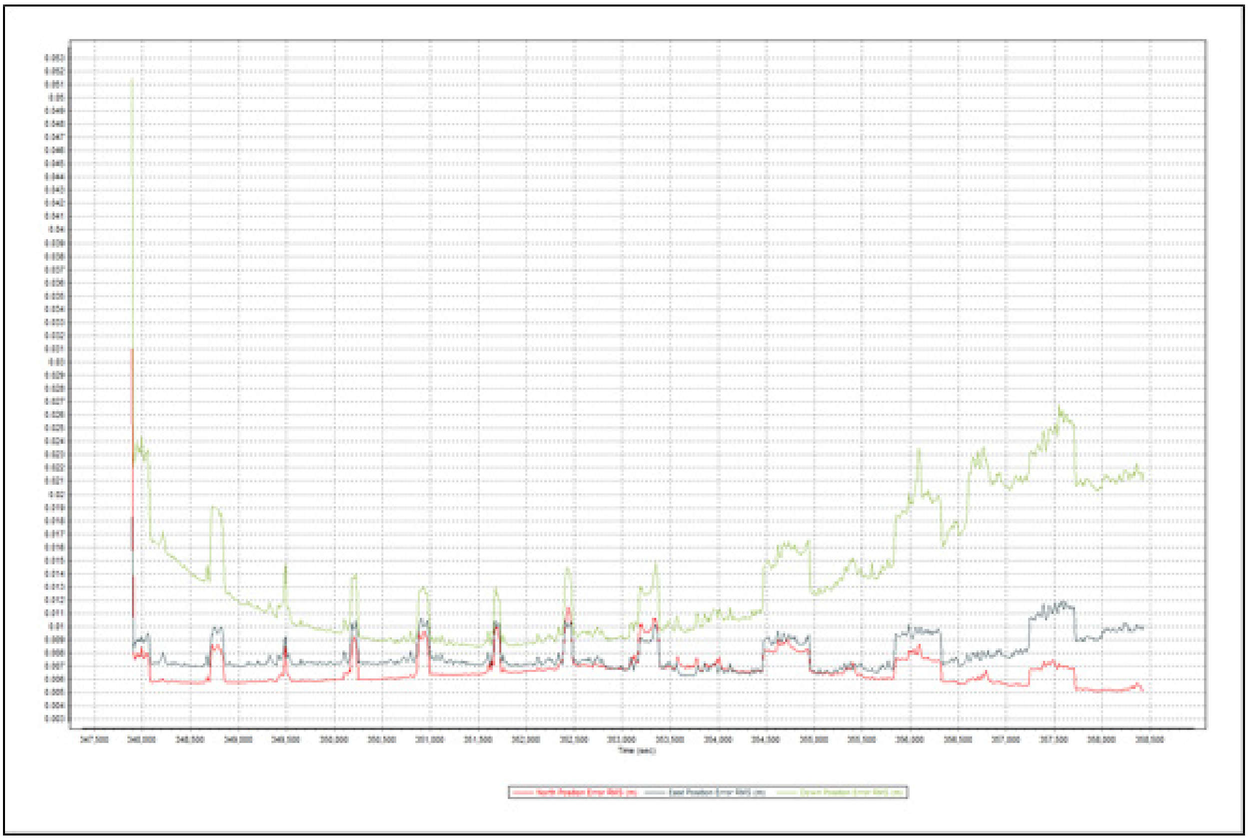


Figure A-8.16. Smoothed Performance Metric Parameters

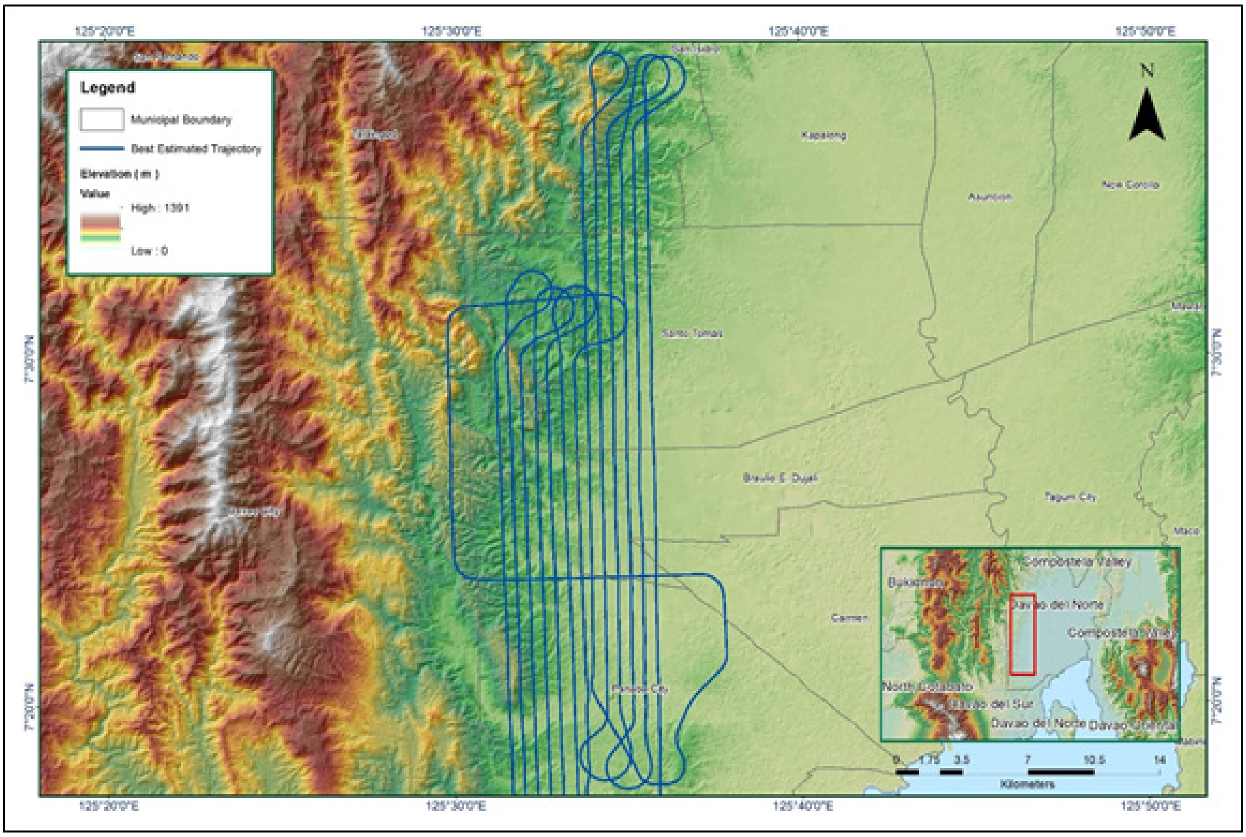


Figure A-8.17. Best Estimated Trajectory

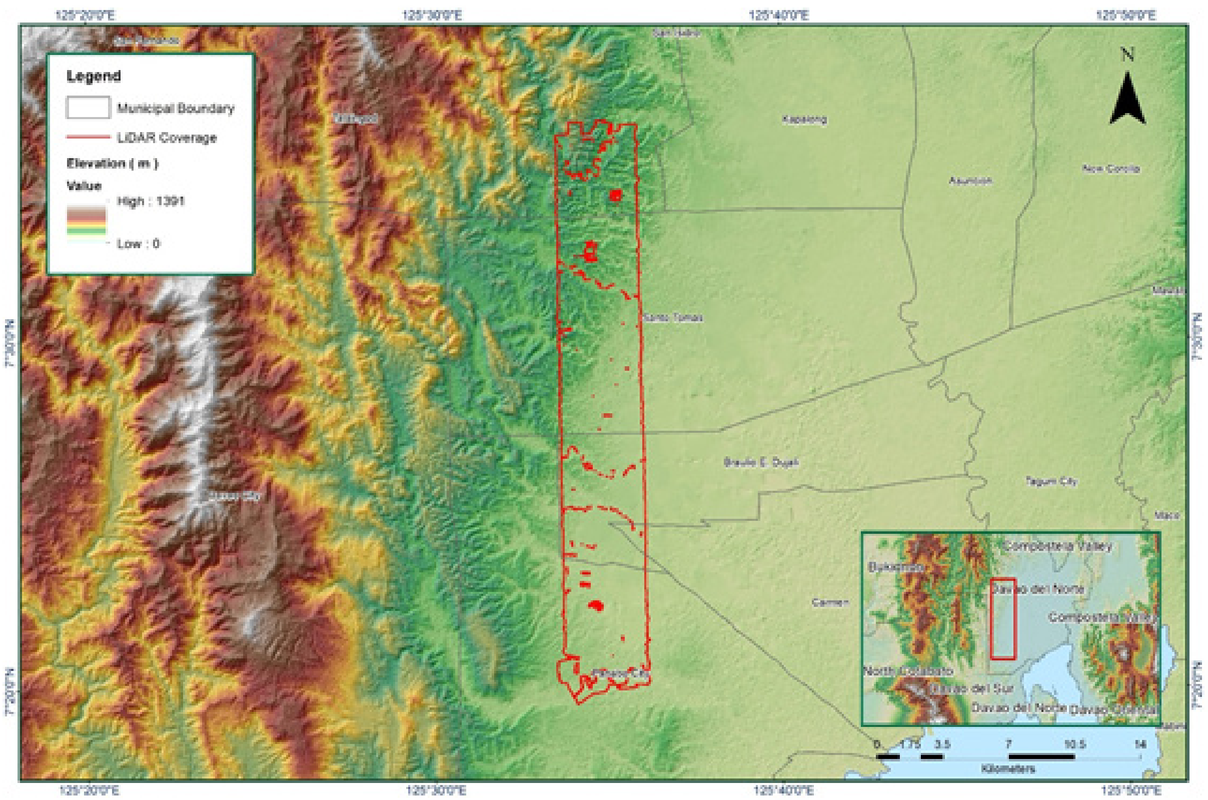


Figure A-8.18. Coverage of LiDAR data

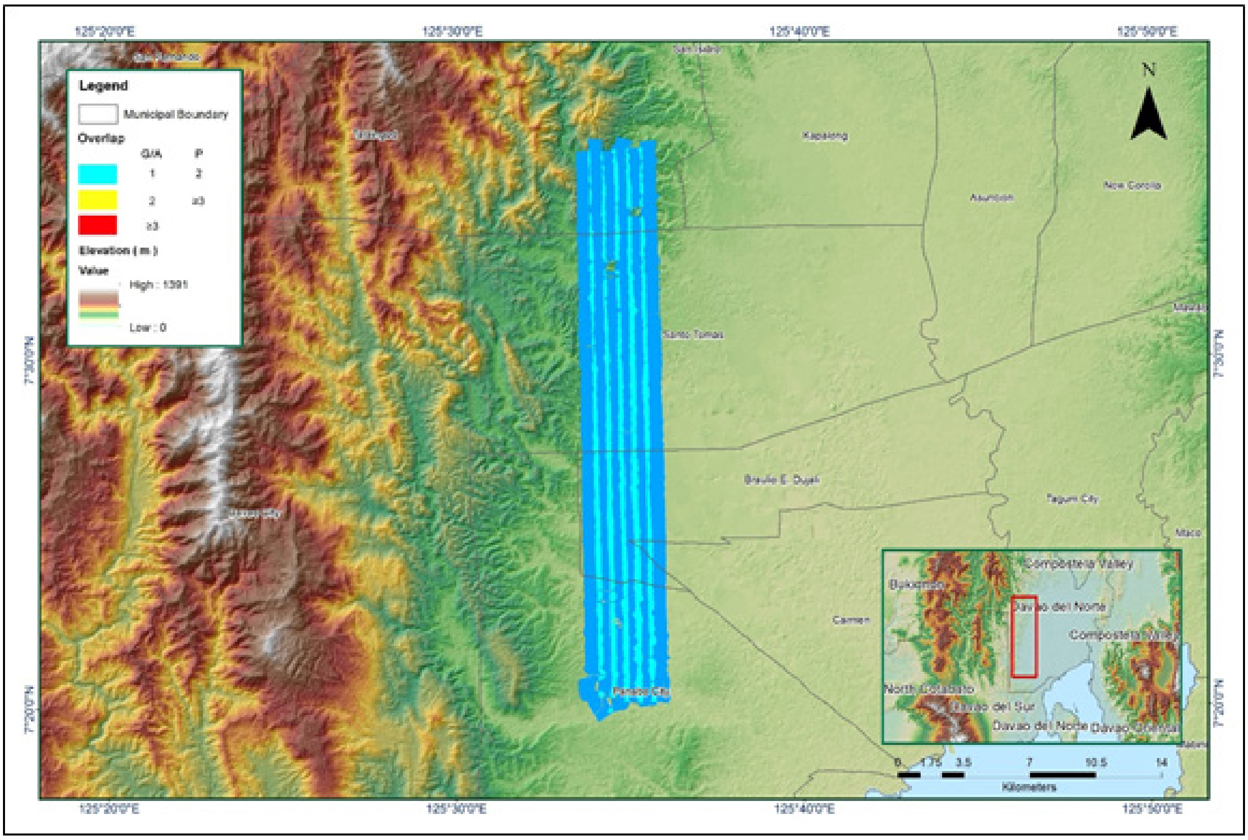


Figure A-8.19. Image of data overlap

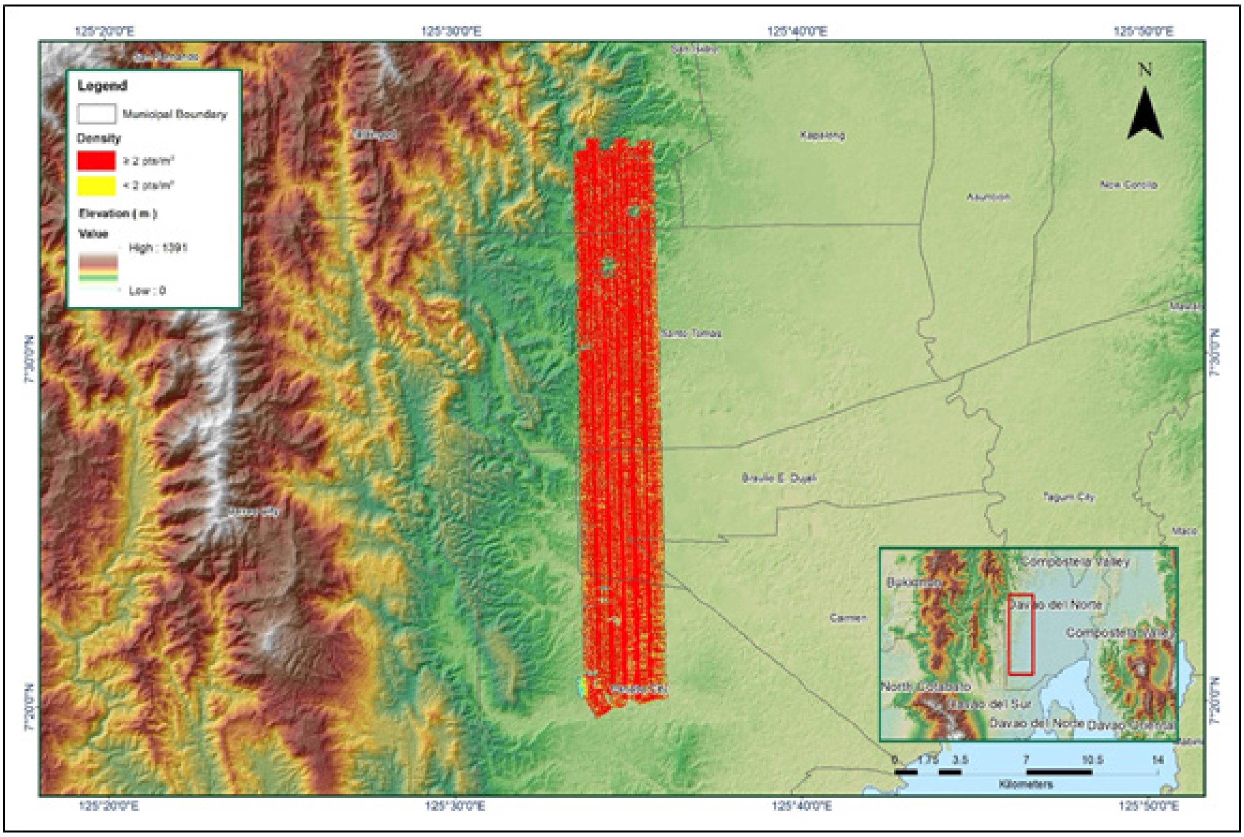


Figure A-8.20. Density map of merged LiDAR data

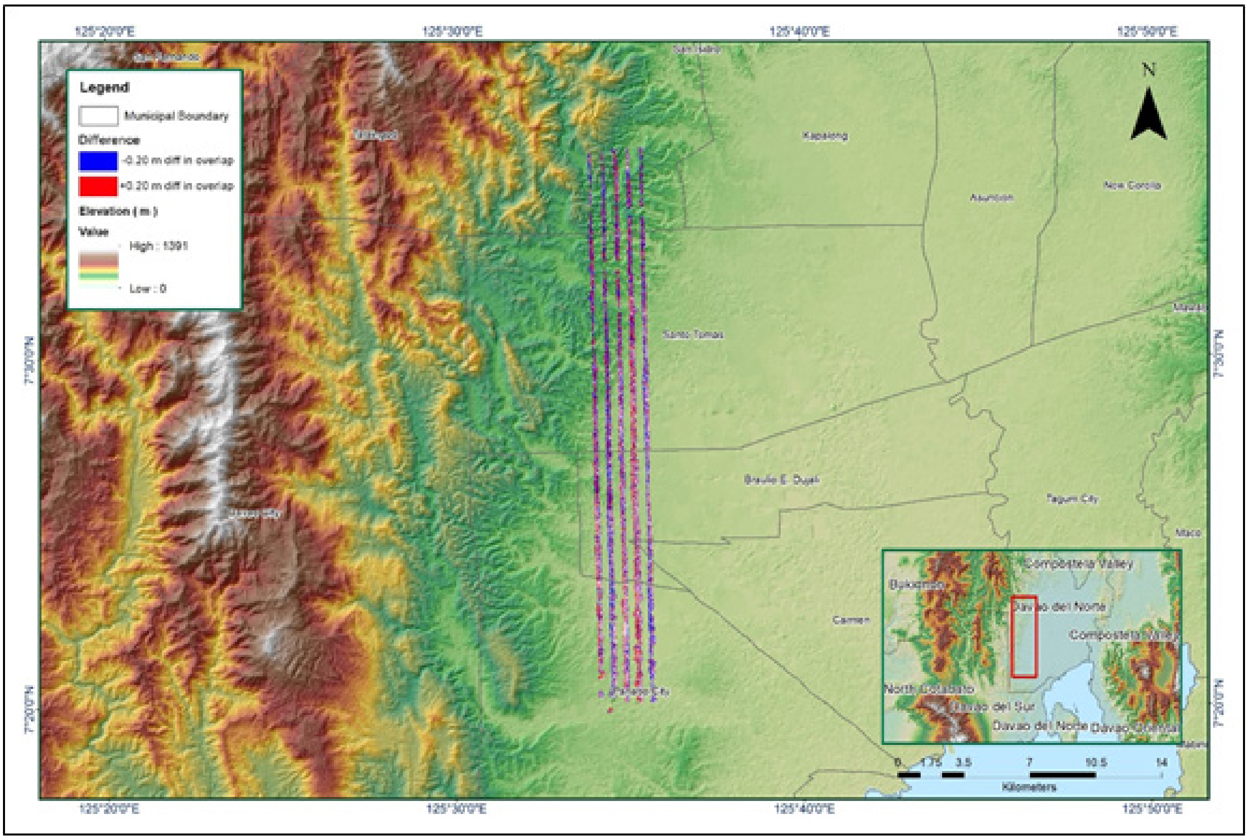


Figure A-8.21. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82F
Inclusive Flights	7390G,7401G
Range data size	37.25 GB
Base data size	24.7 MB
POS	345 MB
Image	na
Transfer date	August 7, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.15
RMSE for East Position (<4.0 cm)	1.12
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.039697
IMU attitude correction stdev (<0.001deg)	0.020852
GPS position stdev (<0.01m)	0.0201
Minimum % overlap (>25)	24.83%
Ave point cloud density per sq.m. (>2.0)	3.11
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	193
Maximum Height	435.58 m
Minimum Height	87.79 m
Classification (# of points)	
Ground	33,127,019
Low vegetation	19,133,314
Medium vegetation	126,888,919
High vegetation	239,159,334
Building	288,694
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Jovy Narisma

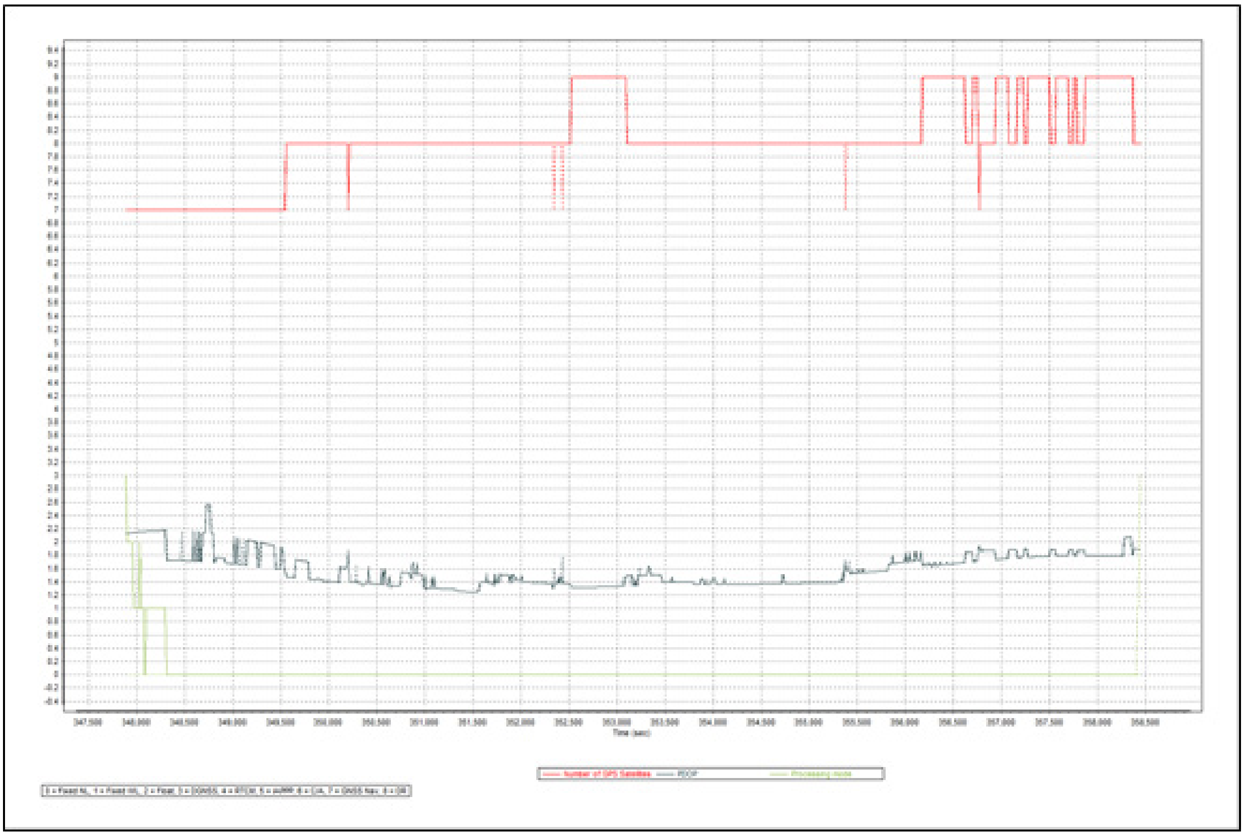


Figure A-8.22. Solution Status

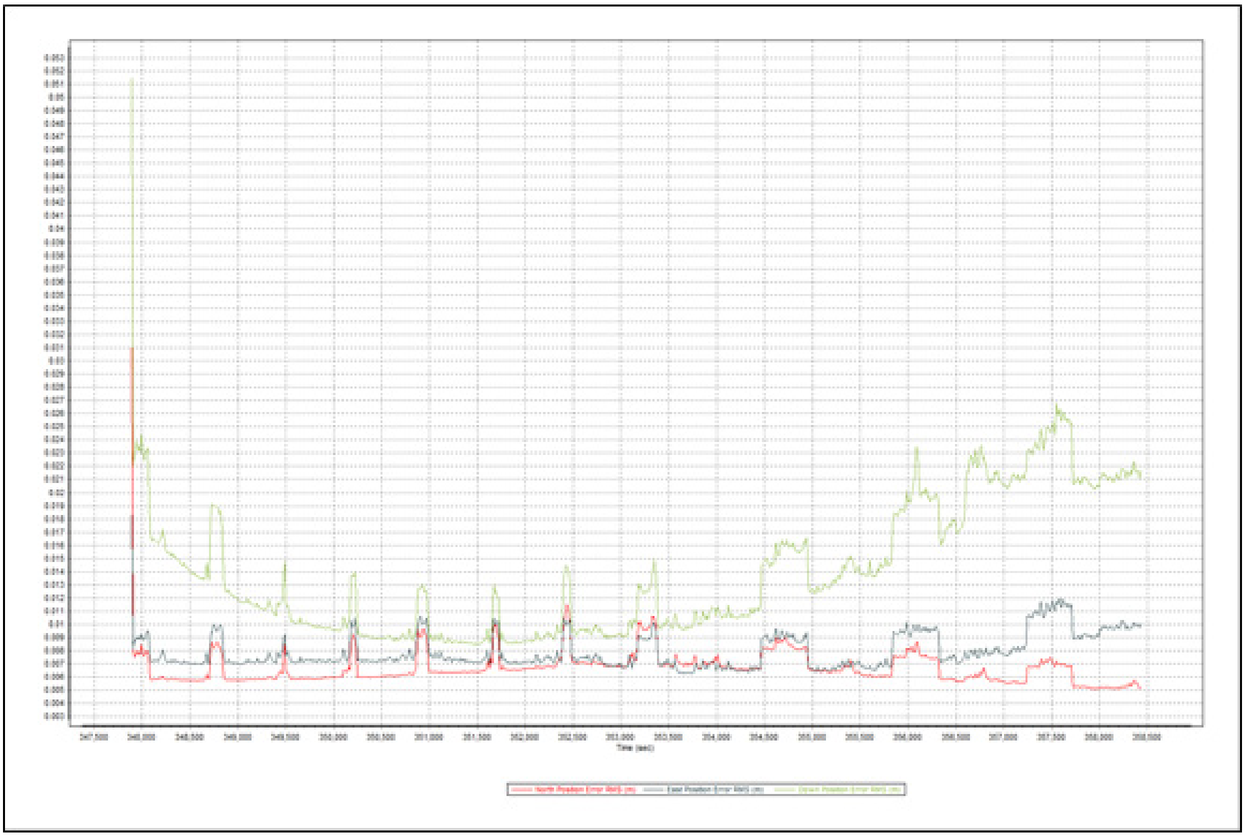


Figure A-8.23. Smoothed Performance Metric Parameters

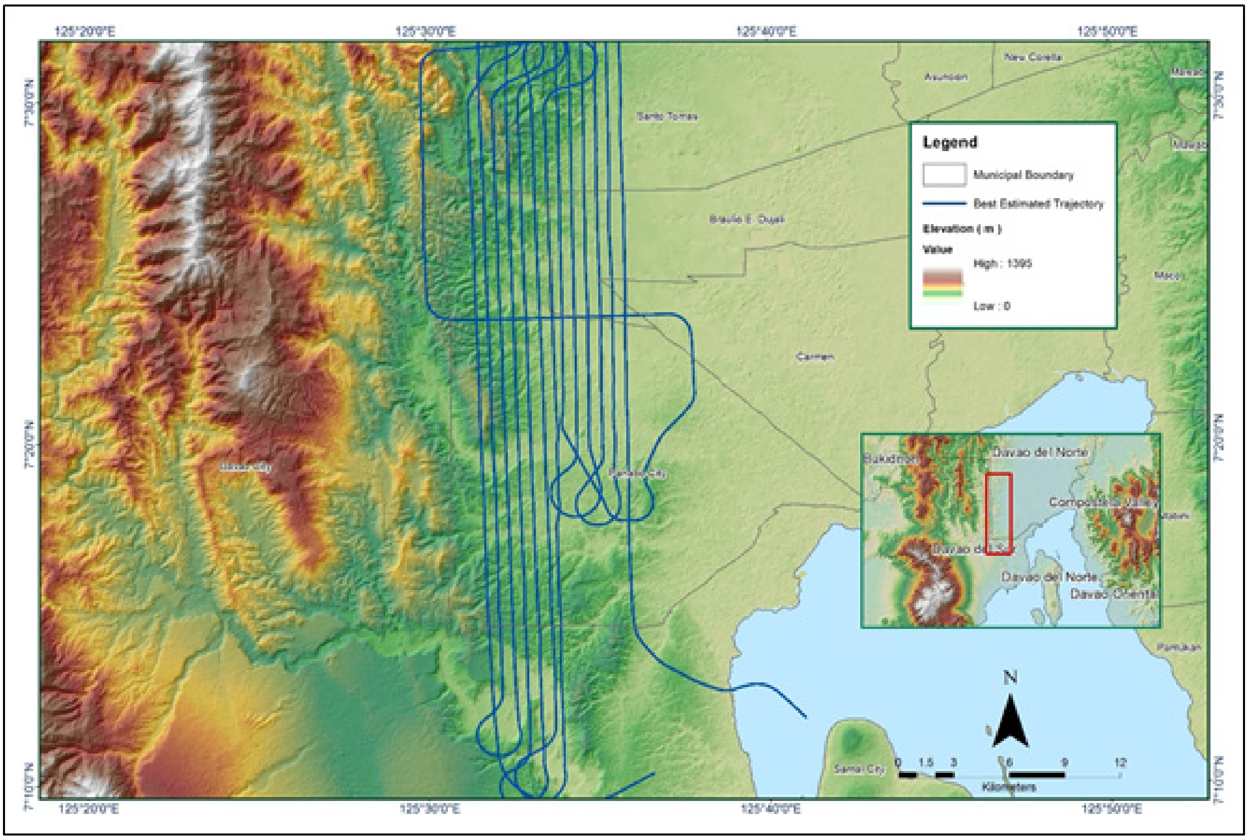


Figure A-8.24. Best Estimated Trajectory

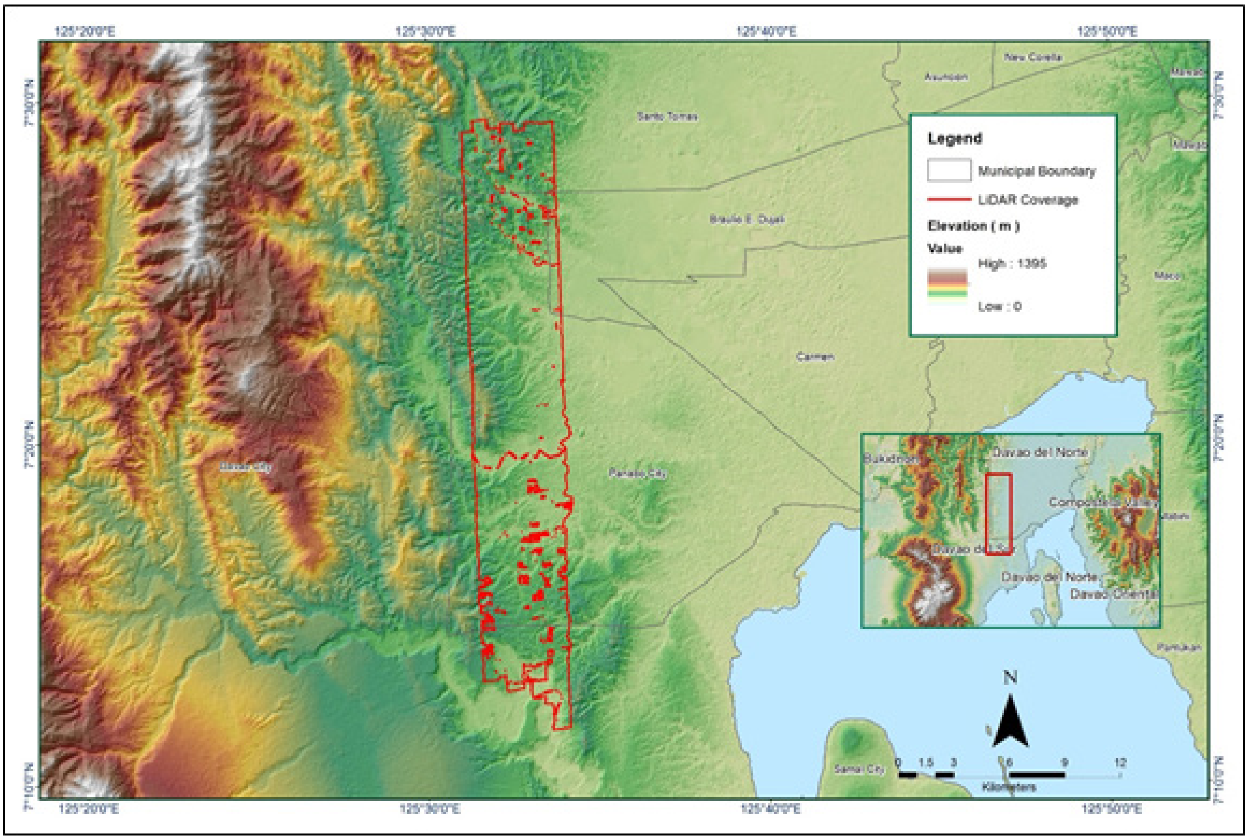


Figure A-8.25. Coverage of LiDAR data

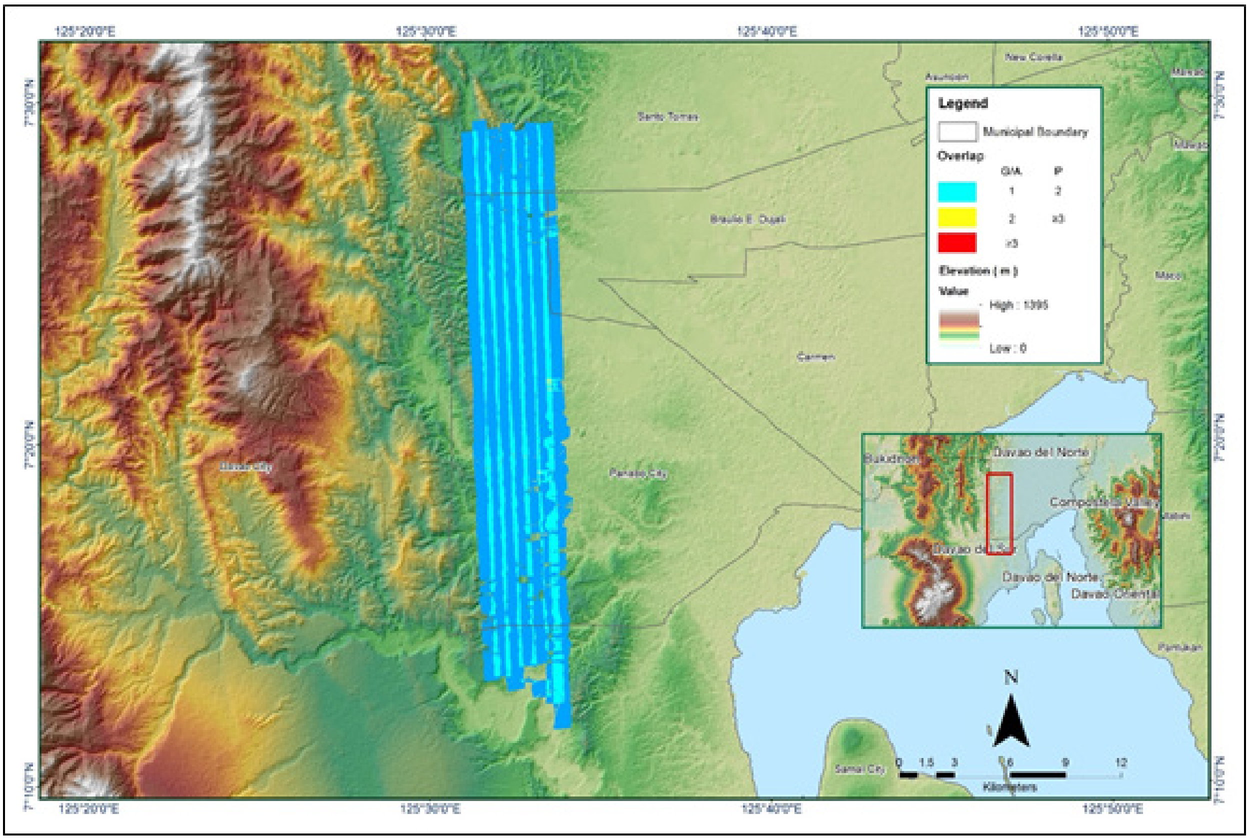


Figure A-8.26. Image of data overlap

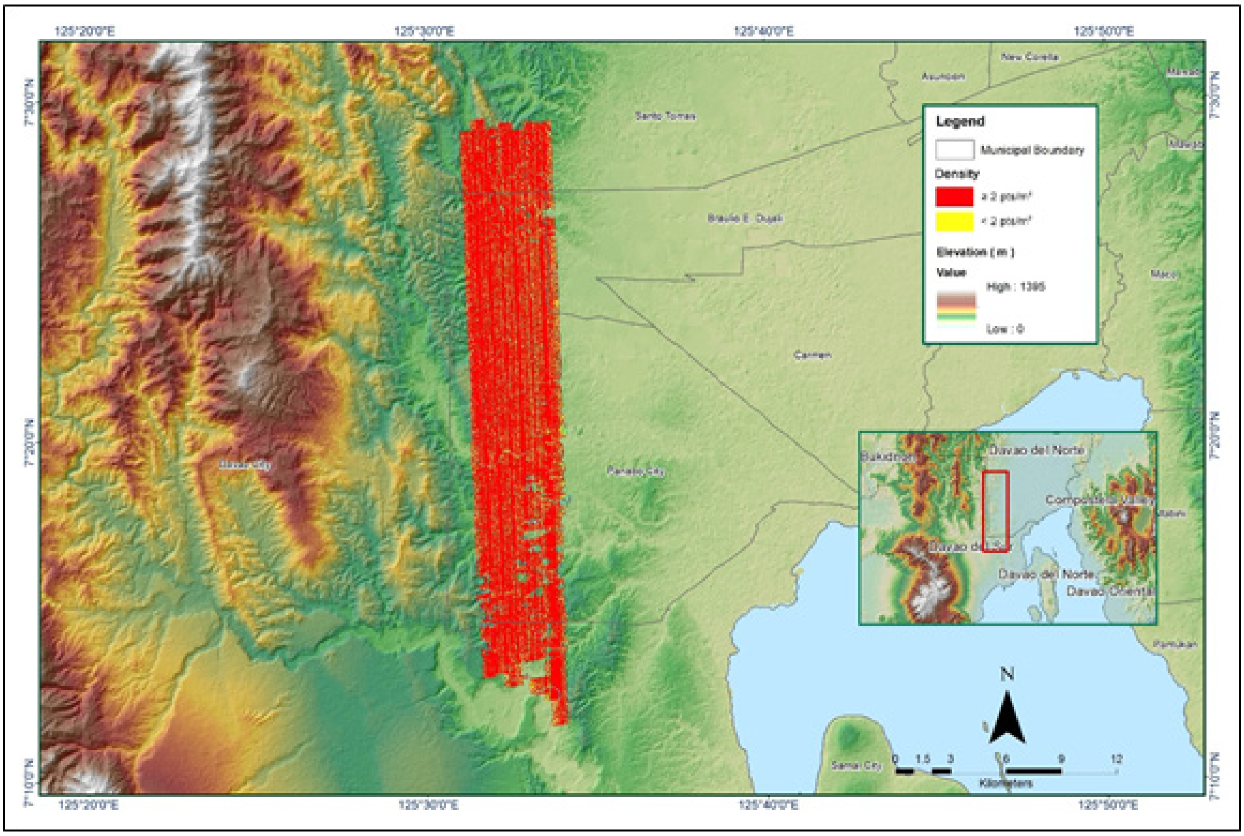


Figure A-8.27 Density map of merged LiDAR data

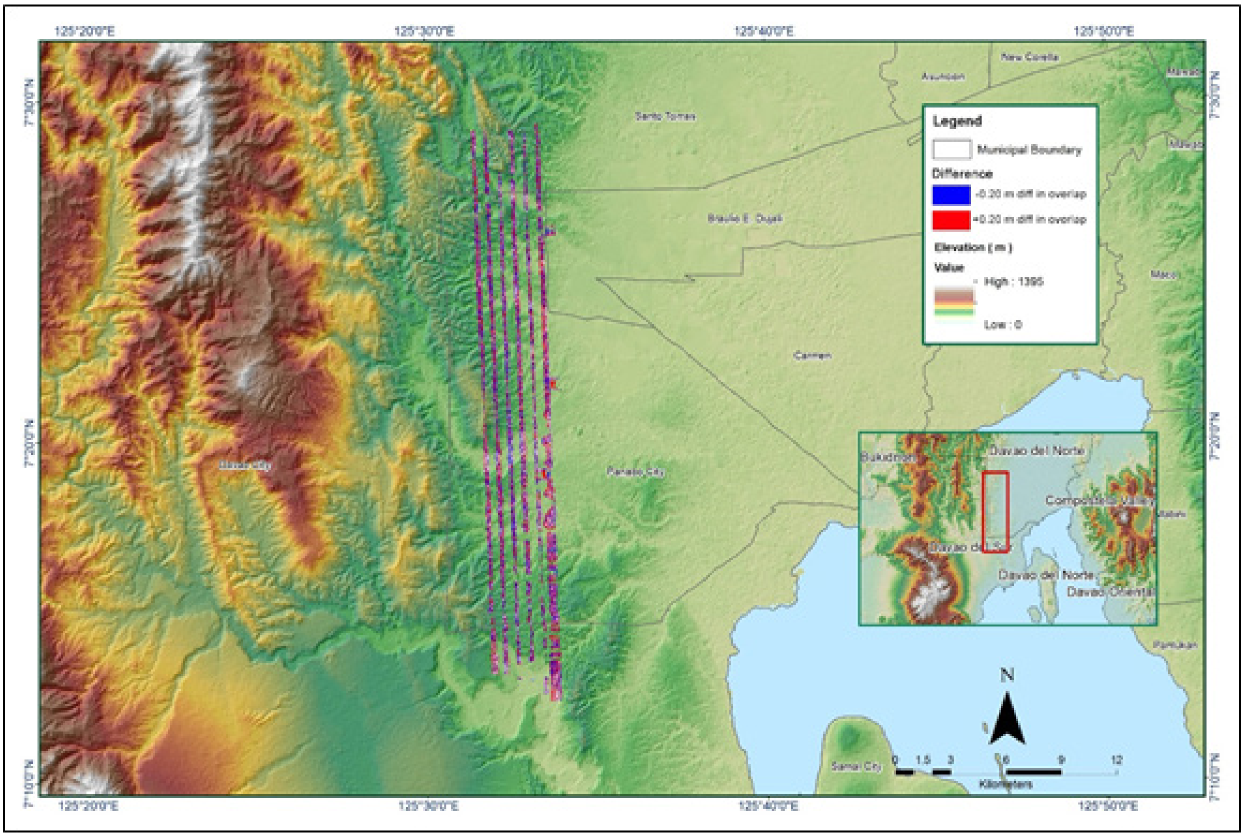


Figure A-8.28. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82 Voids
Inclusive Flights	7427G,7426G
Range data size	15.26 GB
Base data size	15.66 MB
POS	267 MB
Image	na
Transfer date	August 29, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	3.1
RMSE for Down Position (<8.0 cm)	7.4
Boresight correction stdev (<0.001deg)	0.001127
IMU attitude correction stdev (<0.001deg)	0.016683
GPS position stdev (<0.01m)	0.0248
Minimum % overlap (>25)	10.46%
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	272
Maximum Height	421.89 m
Minimum Height	67.51 m
Classification (# of points)	
Ground	40,594,810
Low vegetation	34,398,304
Medium vegetation	58,498,265
High vegetation	166,572,237
Building	4,853,133
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Engr. Jeffrey Delica

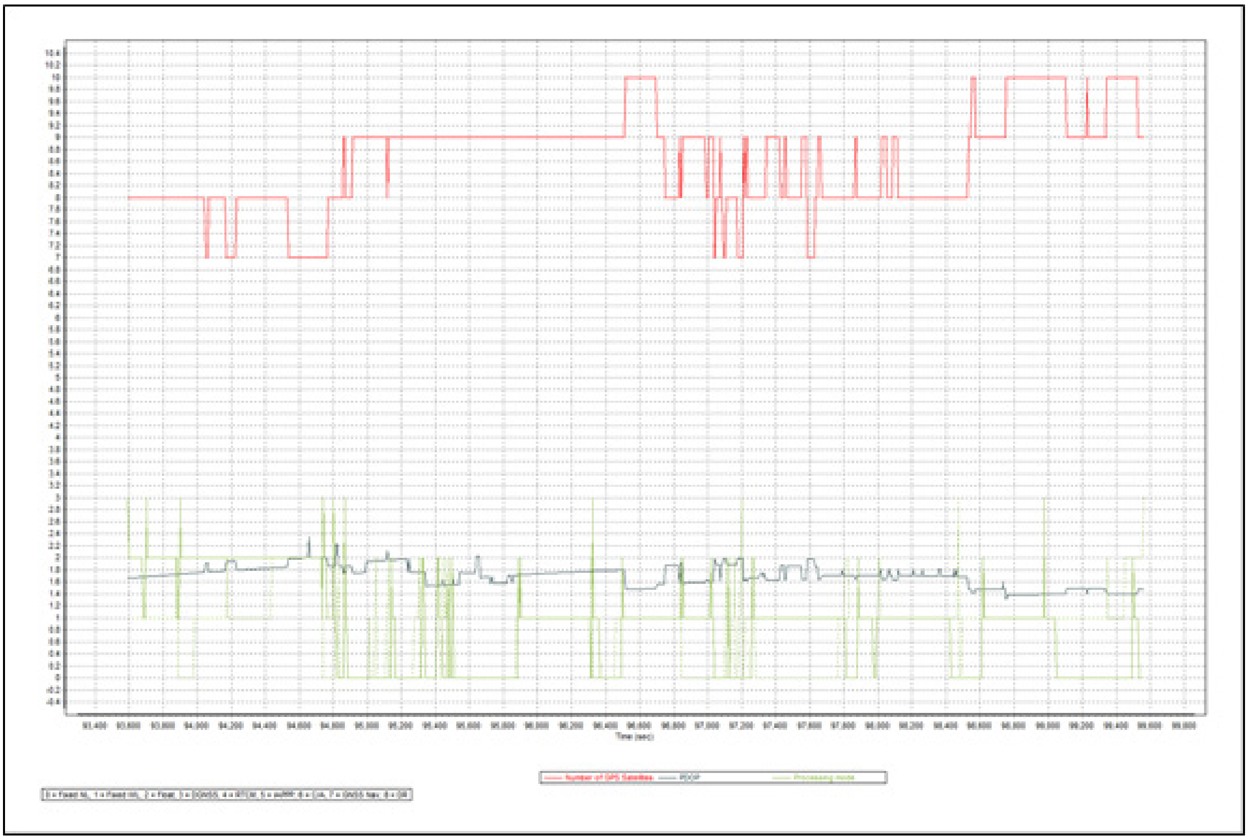


Figure A-8.29. Solution Status

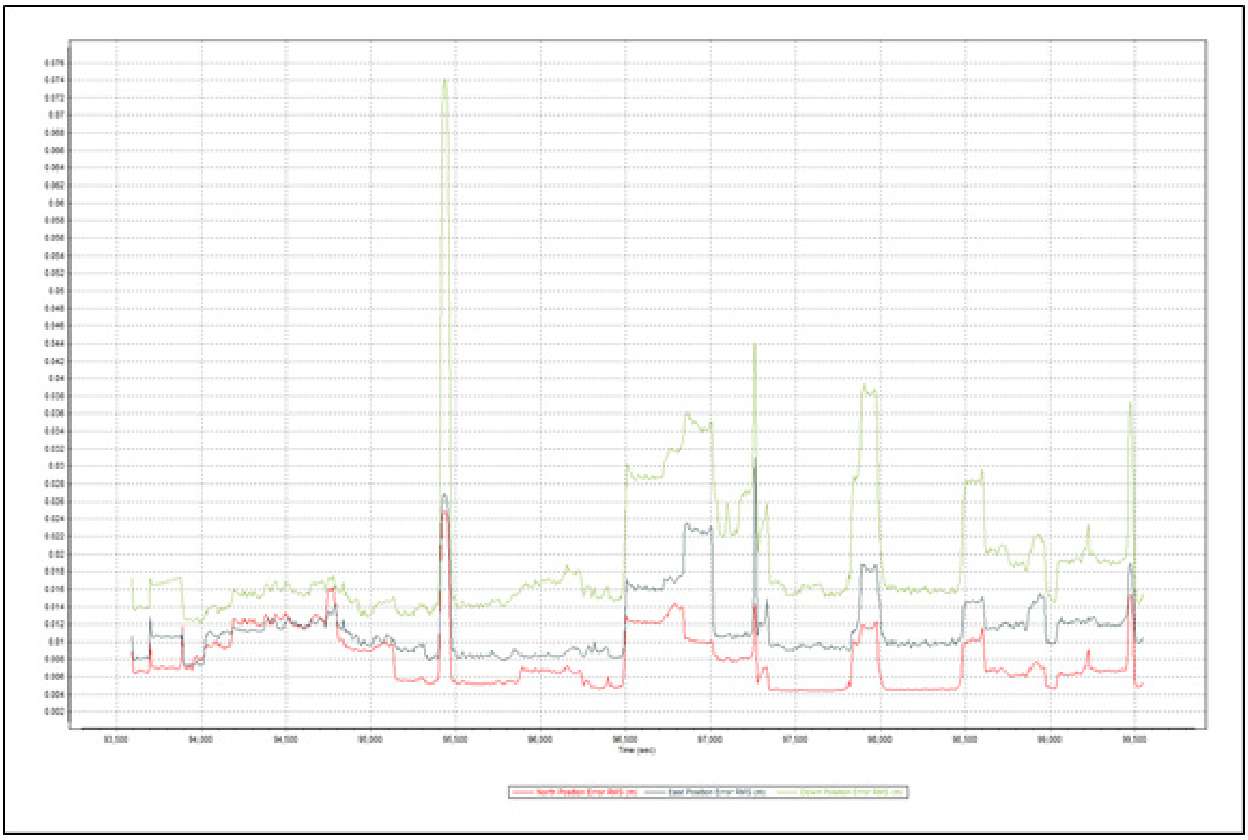


Figure A-8.30. Smoothed Performance Metric Parameters

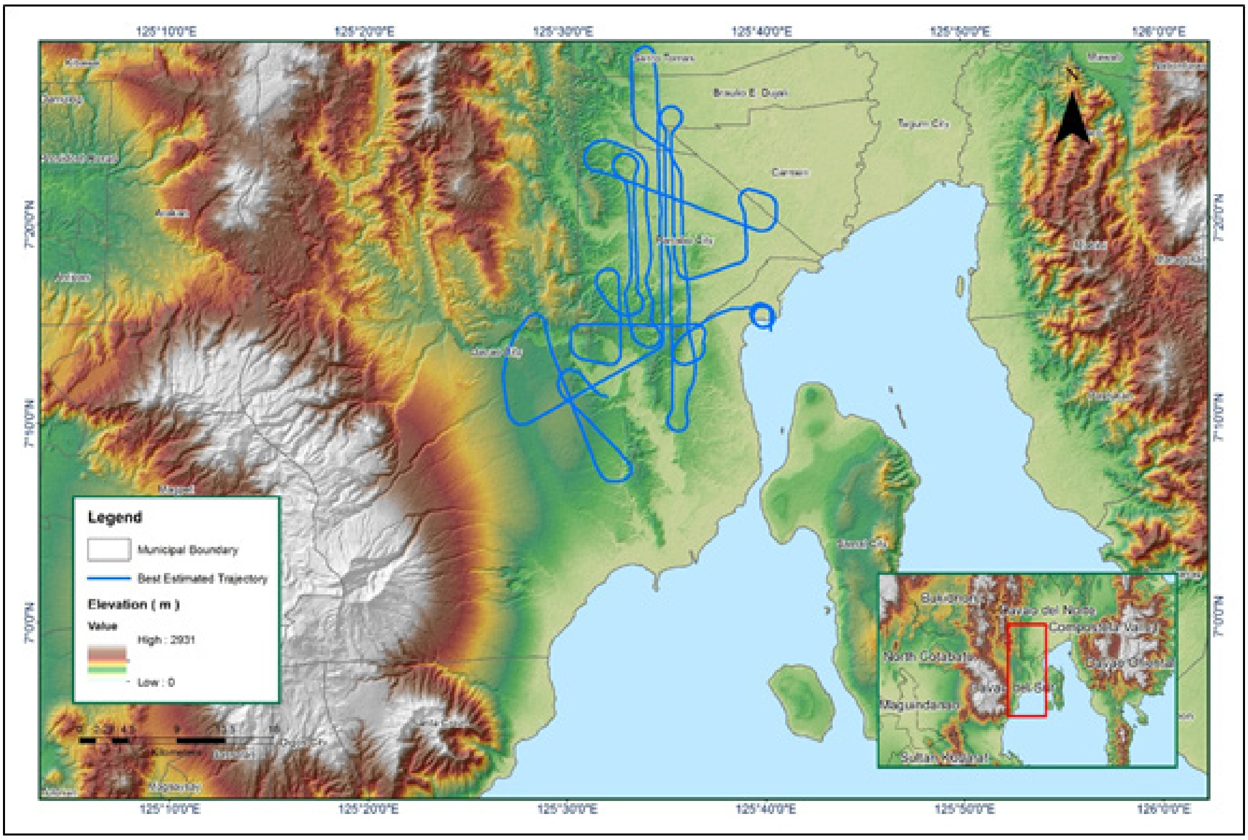


Figure A-8.31. Best Estimated Trajectory

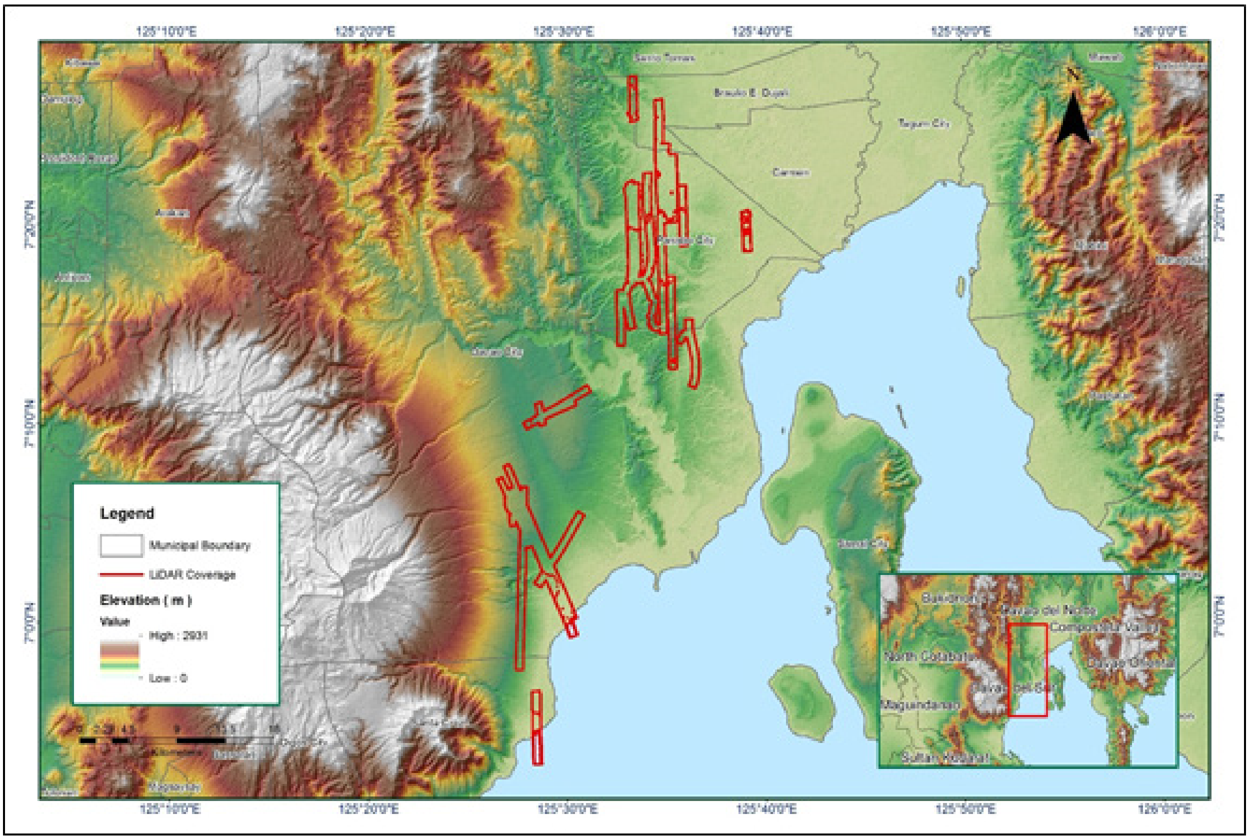


Figure A-8.32. Coverage of LiDAR data

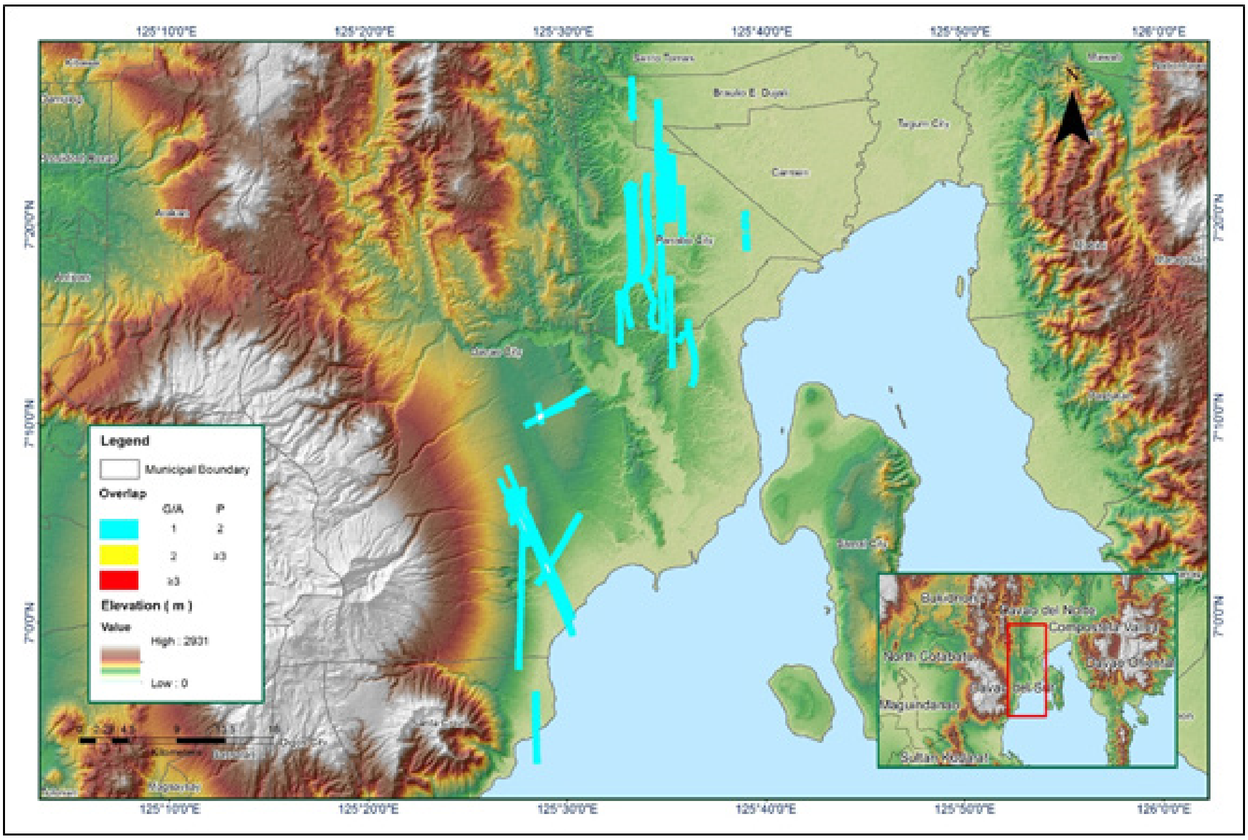


Figure A-8.33. Image of data overlap

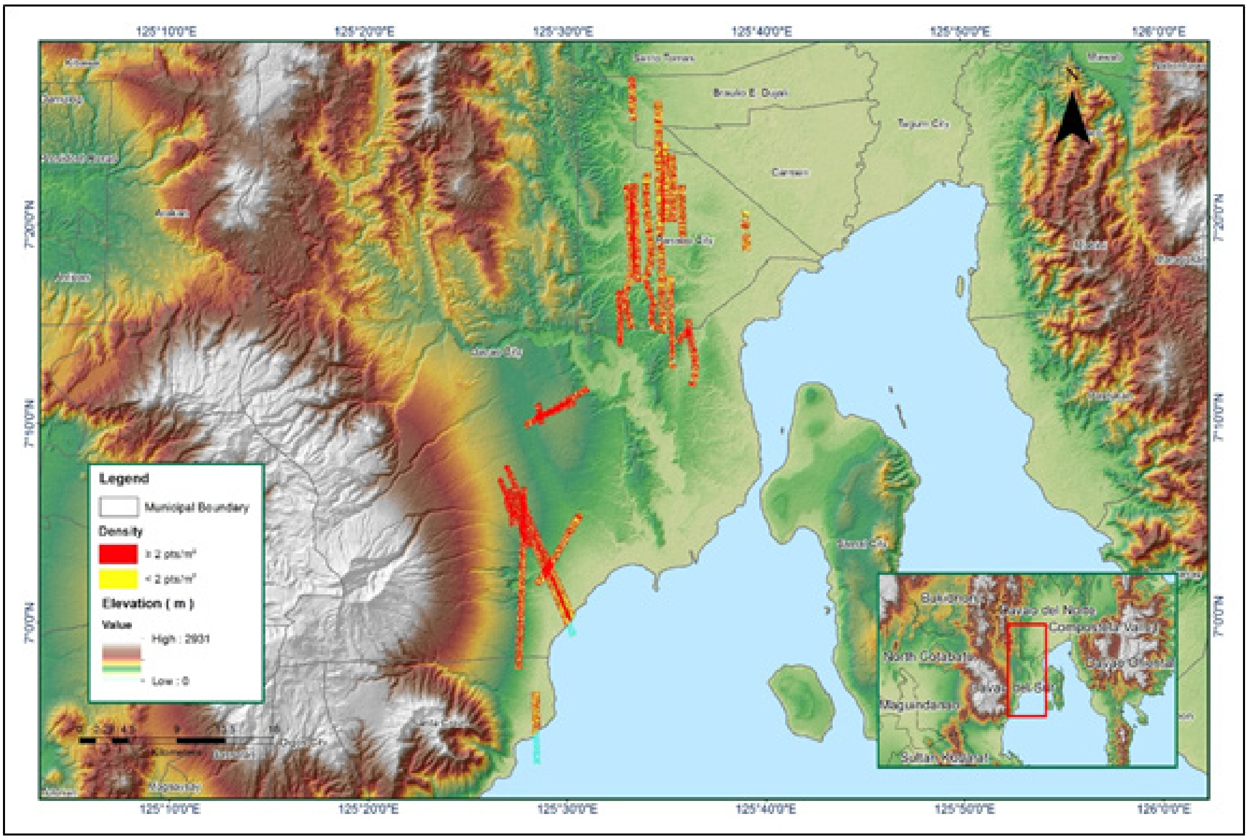


Figure A-8.34. Density map of merged LiDAR data

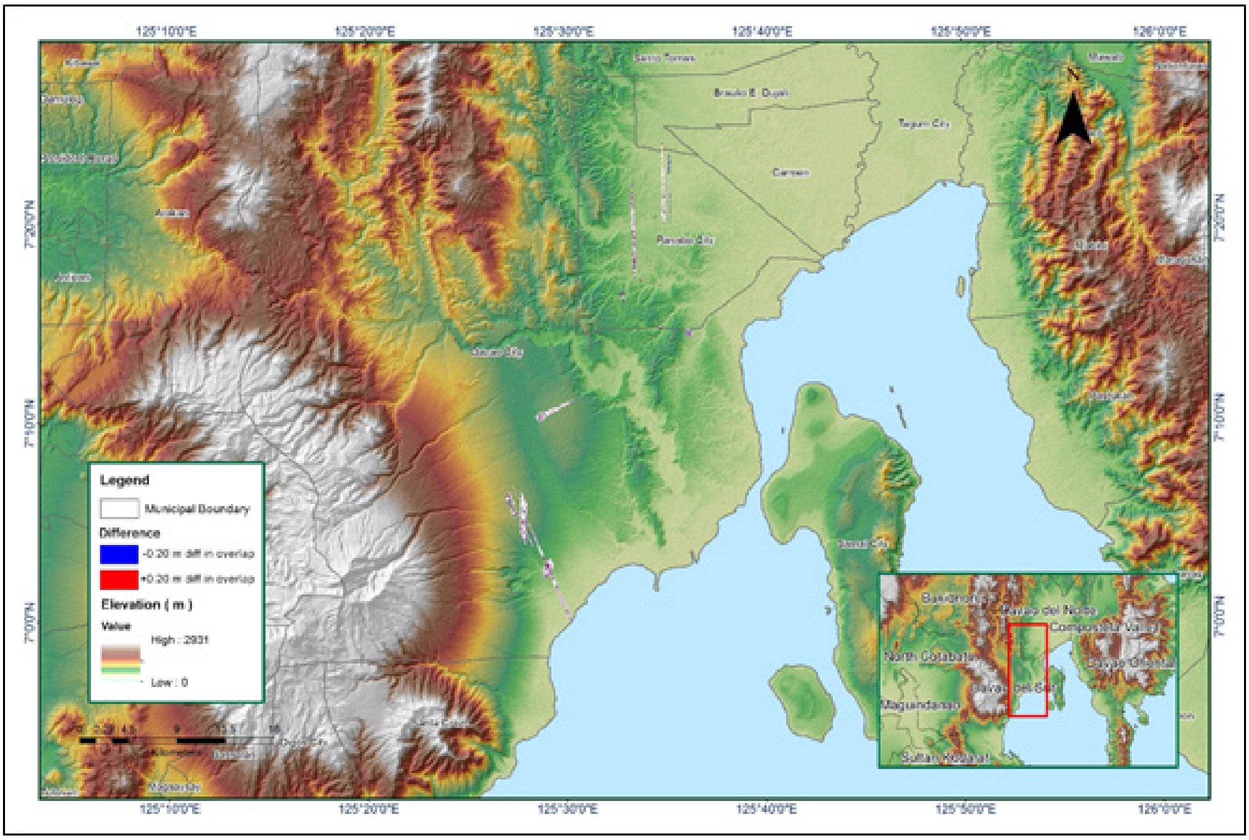


Figure A-8.35. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	Blk82D
Inclusive Flights	7386G
Range data size	29.2 GB
Base data size	8.87 MB
POS	267 MB
Image	na
Transfer date	August 7, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.12
RMSE for East Position (<4.0 cm)	1.28
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.004262
IMU attitude correction stdev (<0.001deg)	0.008215
GPS position stdev (<0.01m)	0.0201
Minimum % overlap (>25)	17.65%
Ave point cloud density per sq.m. (>2.0)	3.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	178
Maximum Height	329.35 m
Minimum Height	78.54 m
Classification (# of points)	
Ground	32,635,850
Low vegetation	27,124,432
Medium vegetation	112,218,008
High vegetation	254,480,628
Building	1,075,578
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Ailyn Biñas

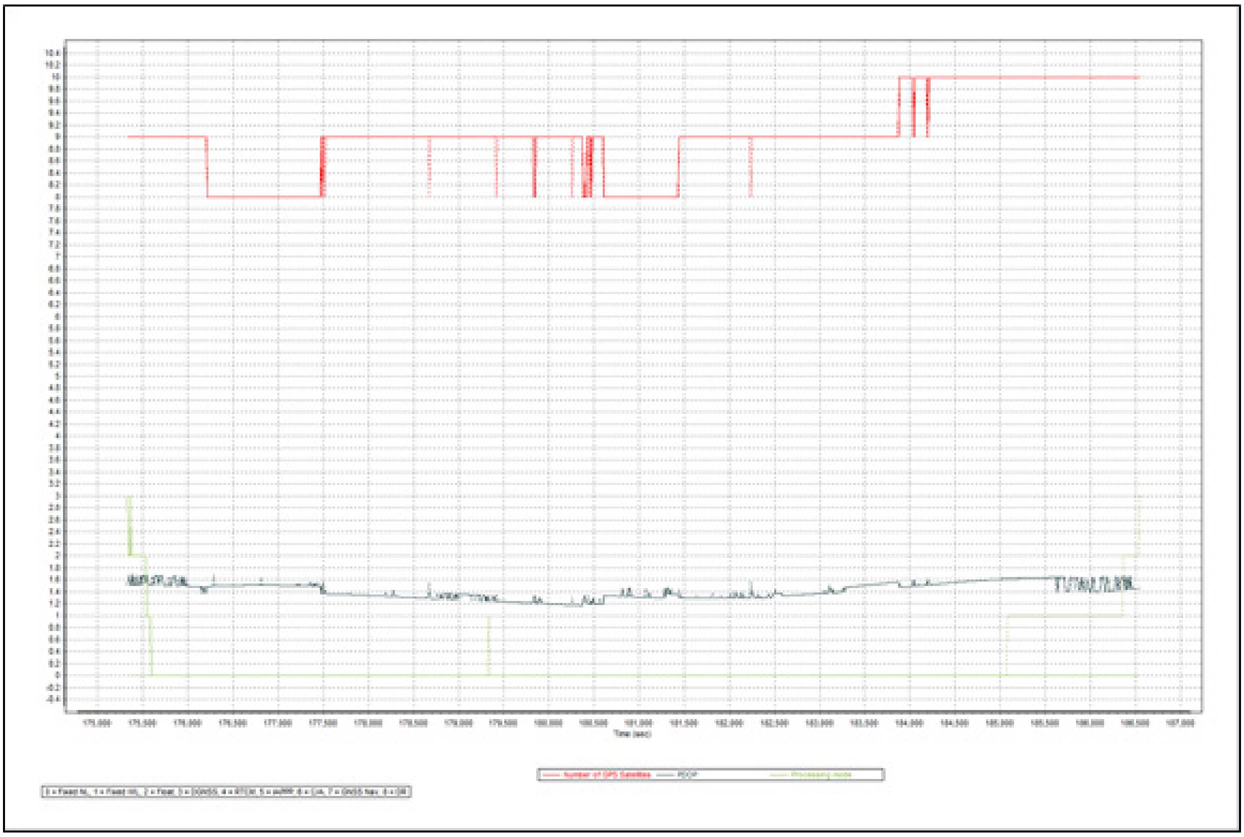


Figure A-8.36. Solution Status

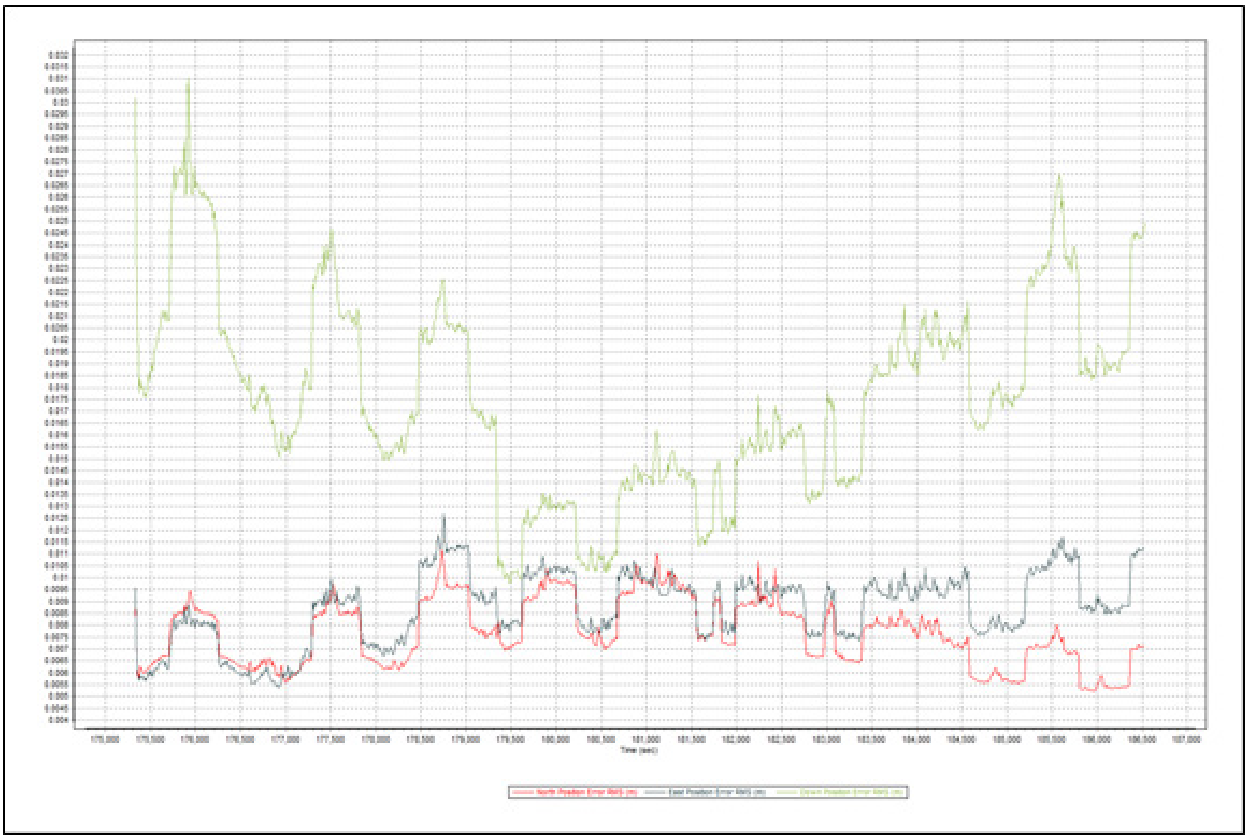


Figure A-8.37. Smoothed Performance Metric Parameters

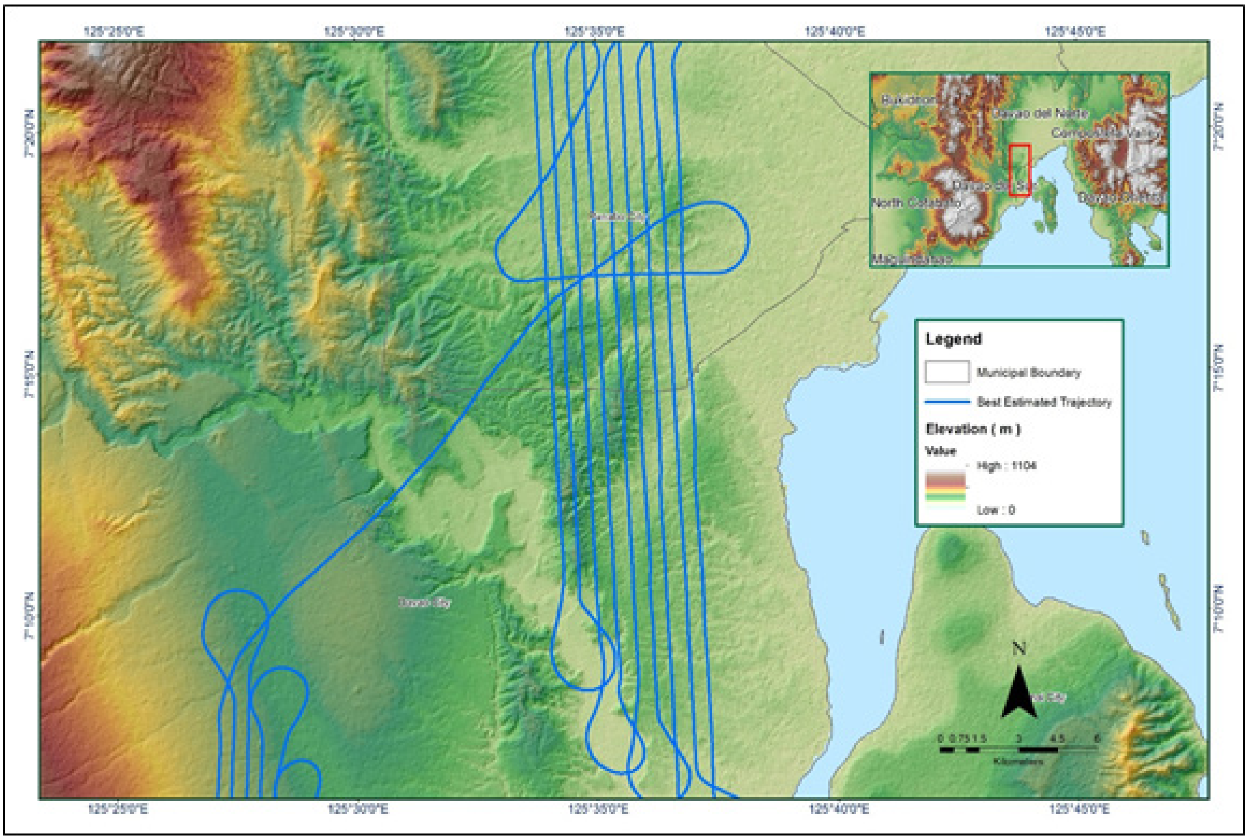


Figure A-8.38. Best Estimated Trajectory

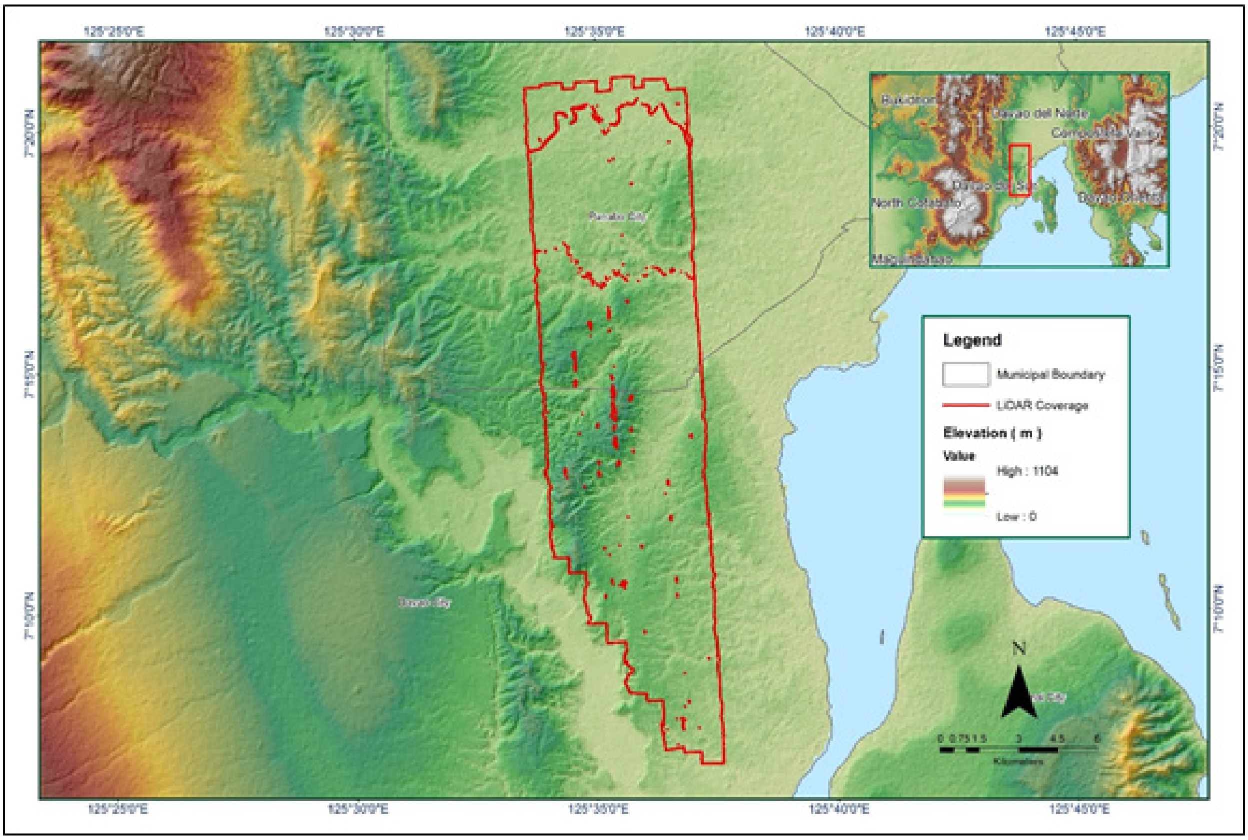


Figure A-8.39. Coverage of LiDAR data

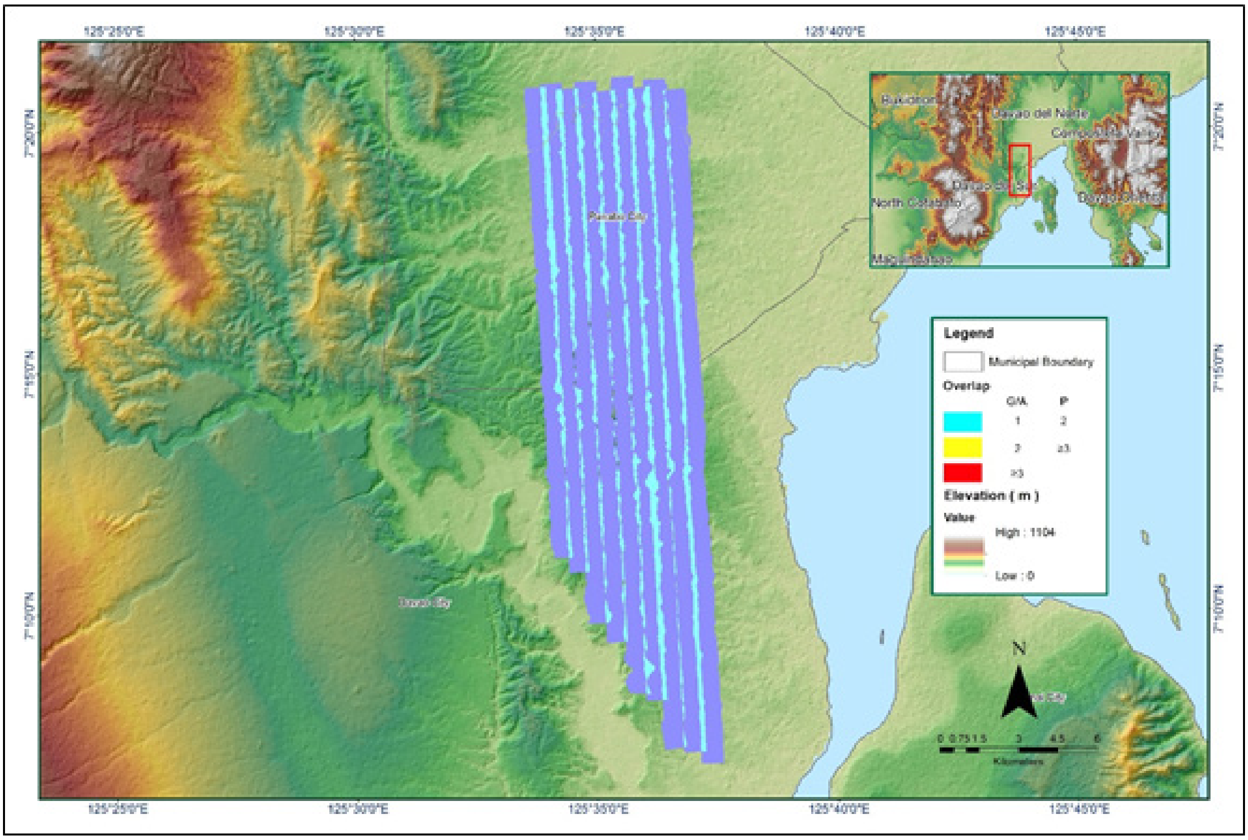


Figure A-8.40. Image of data overlap

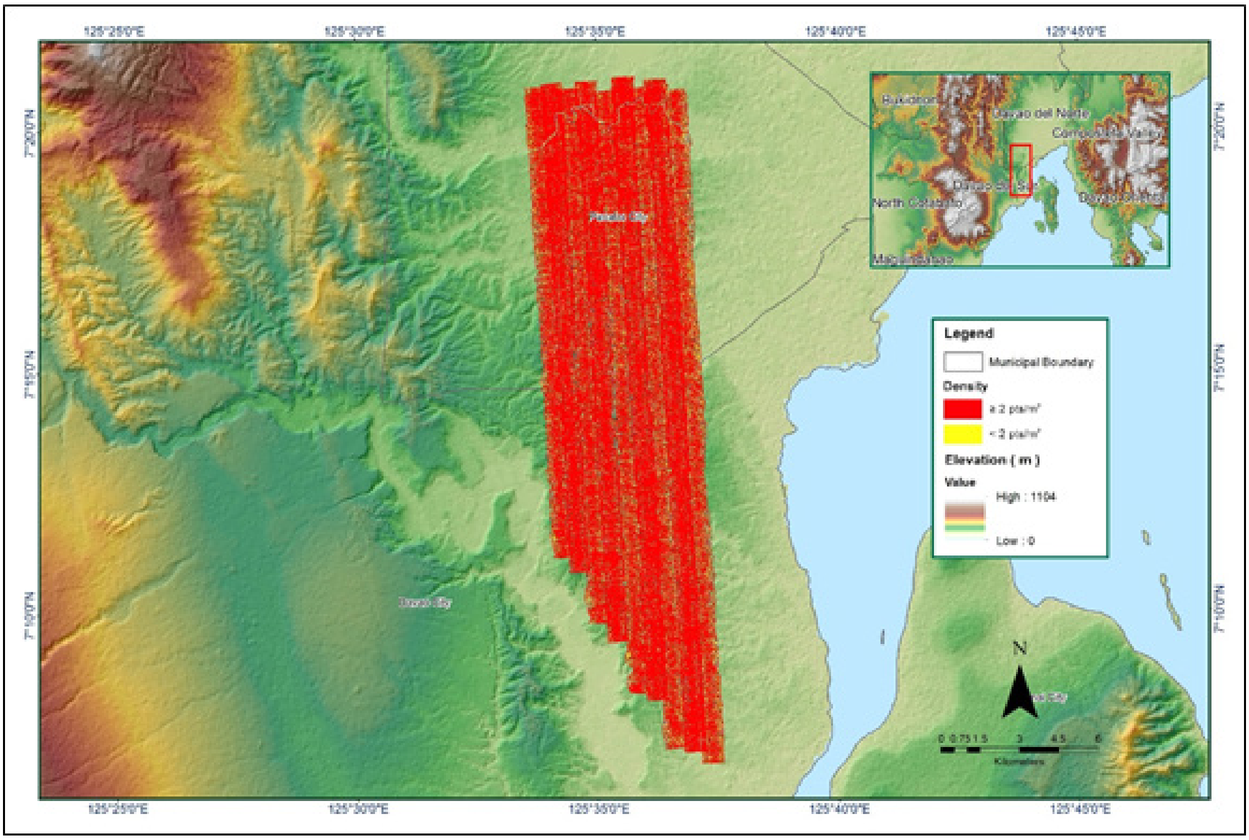


Figure A-8.41. Density map of merged LiDAR data

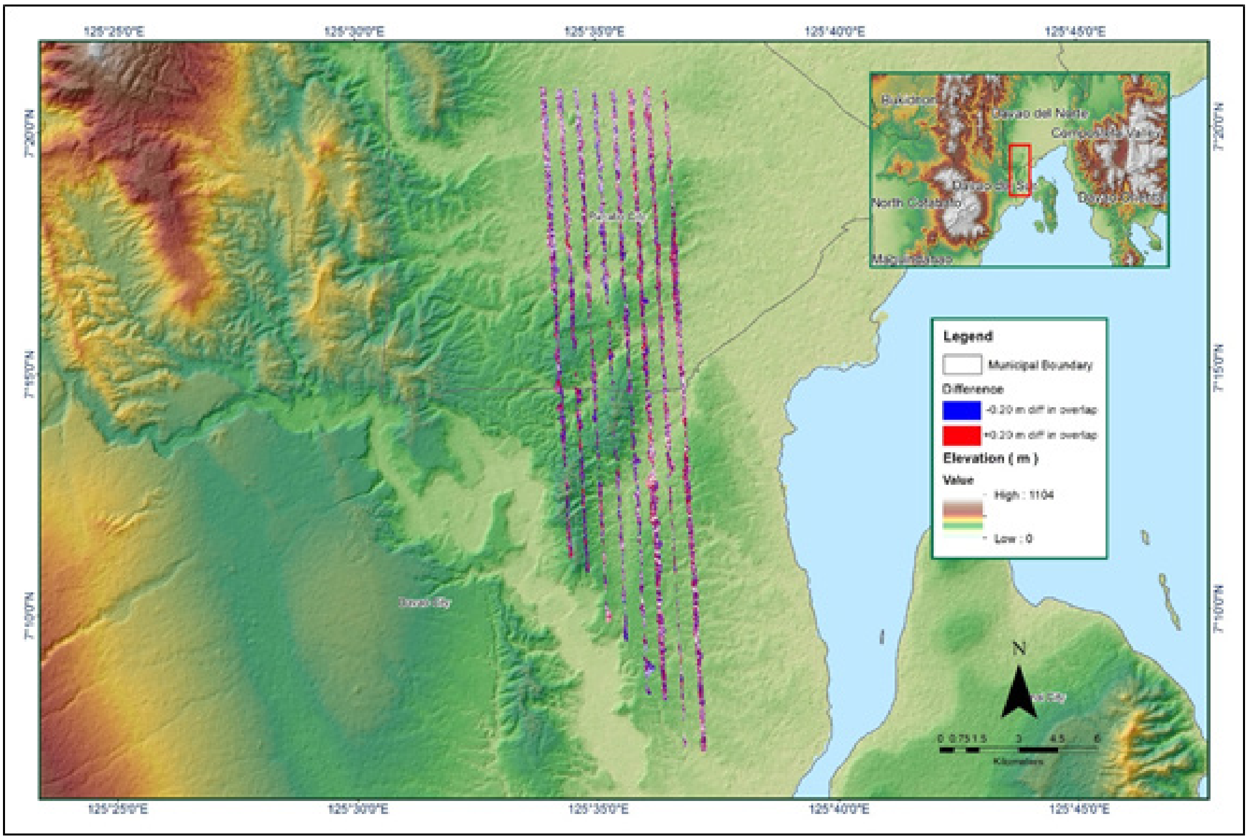


Figure A-8.42. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	COM A
Inclusive Flights	7423G
Range data size	16.6 GB
Base data size	9.95 MB
POS	175 MB
Image	na
Transfer date	August 29, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.09
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000428
IMU attitude correction stdev (<0.001deg)	0.000866
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	27.24%
Ave point cloud density per sq.m. (>2.0)	3.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	157
Maximum Height	449.79 m
Minimum Height	124.19 m
Classification (# of points)	
Ground	49130286
Low vegetation	67830086
Medium vegetation	97664212
High vegetation	141449959
Building	1712778
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr, John Dill Macapagal

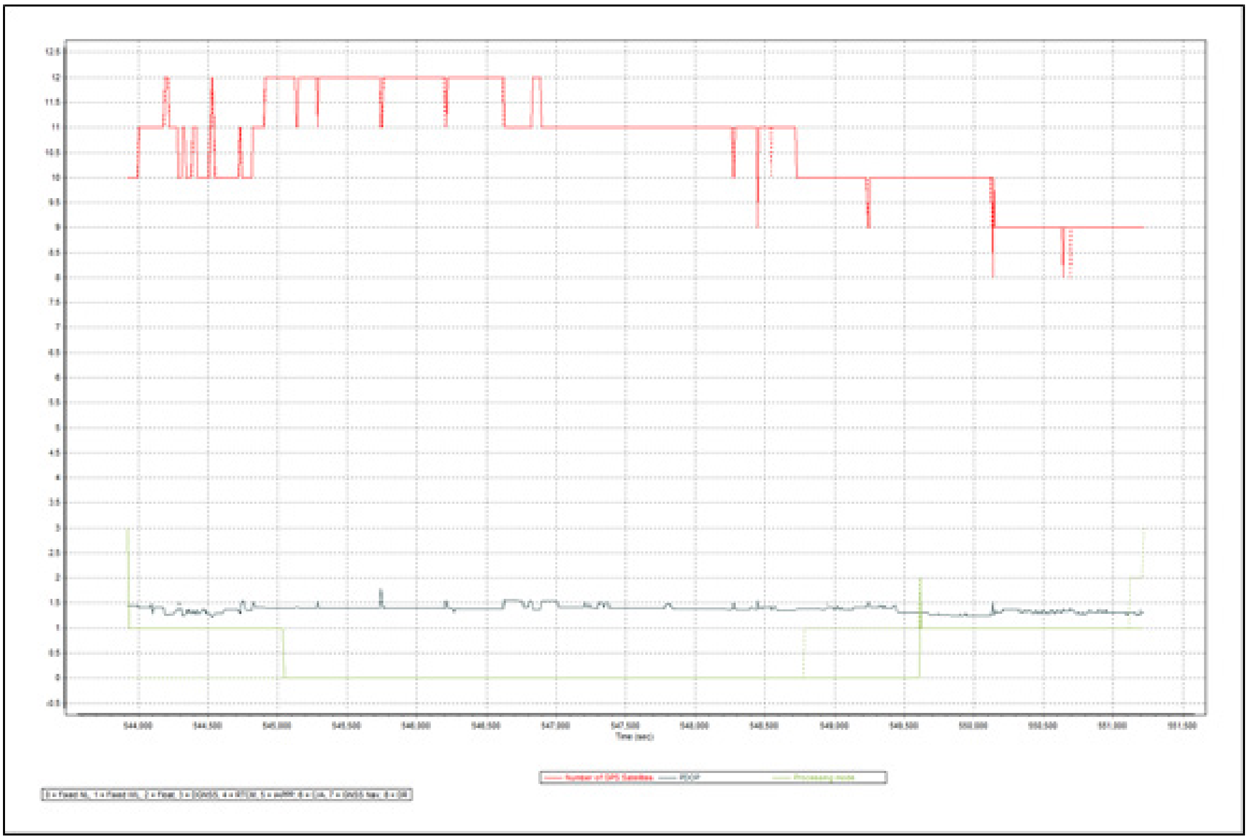


Figure A-8.43. Solution Status

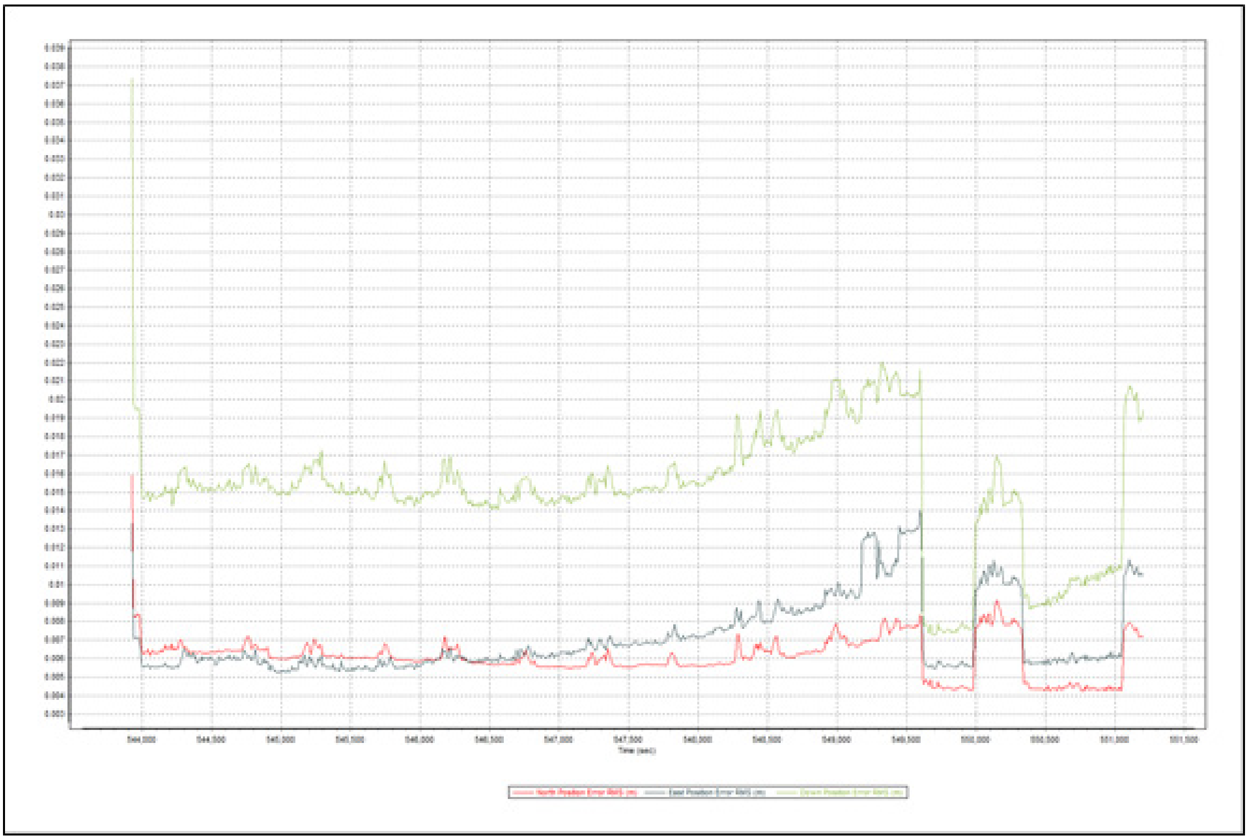


Figure A-8.44. Smoothed Performance Metric Parameters

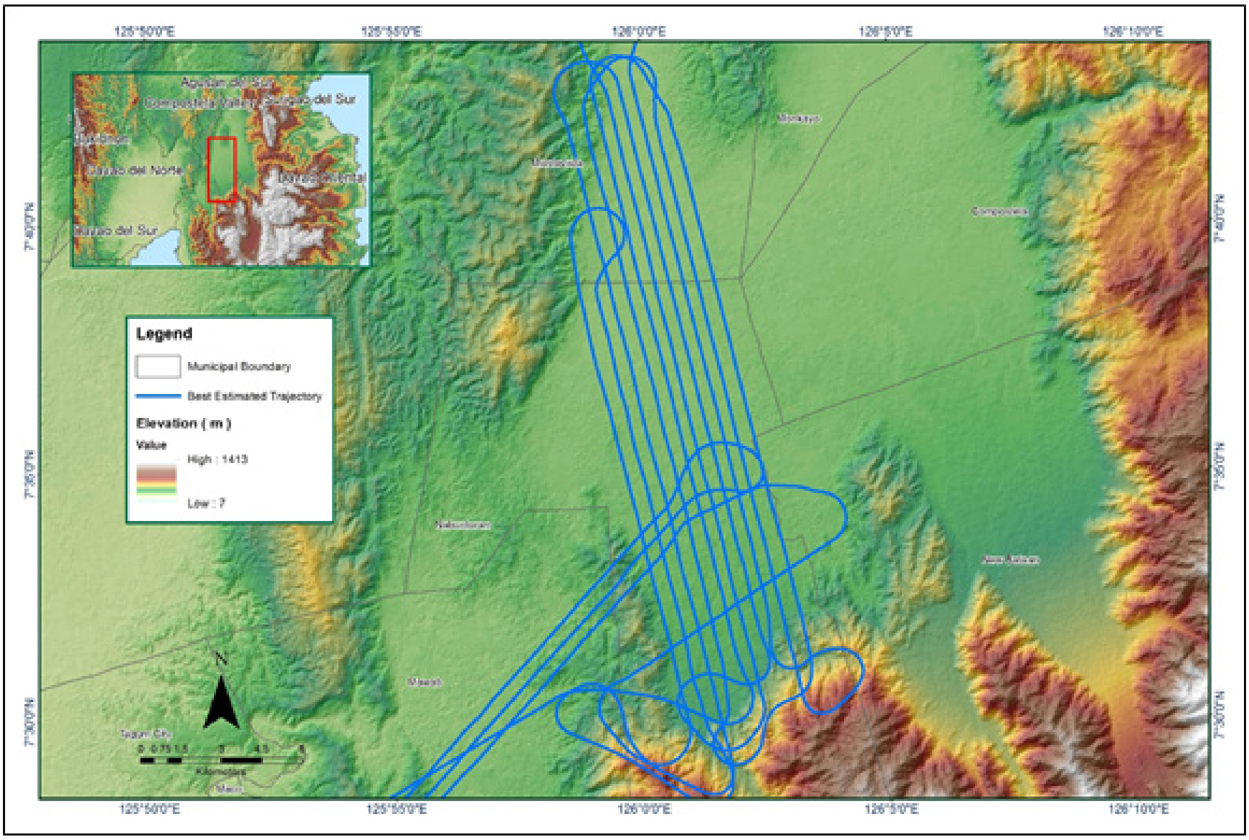


Figure A-8.45. Best Estimated Trajectory

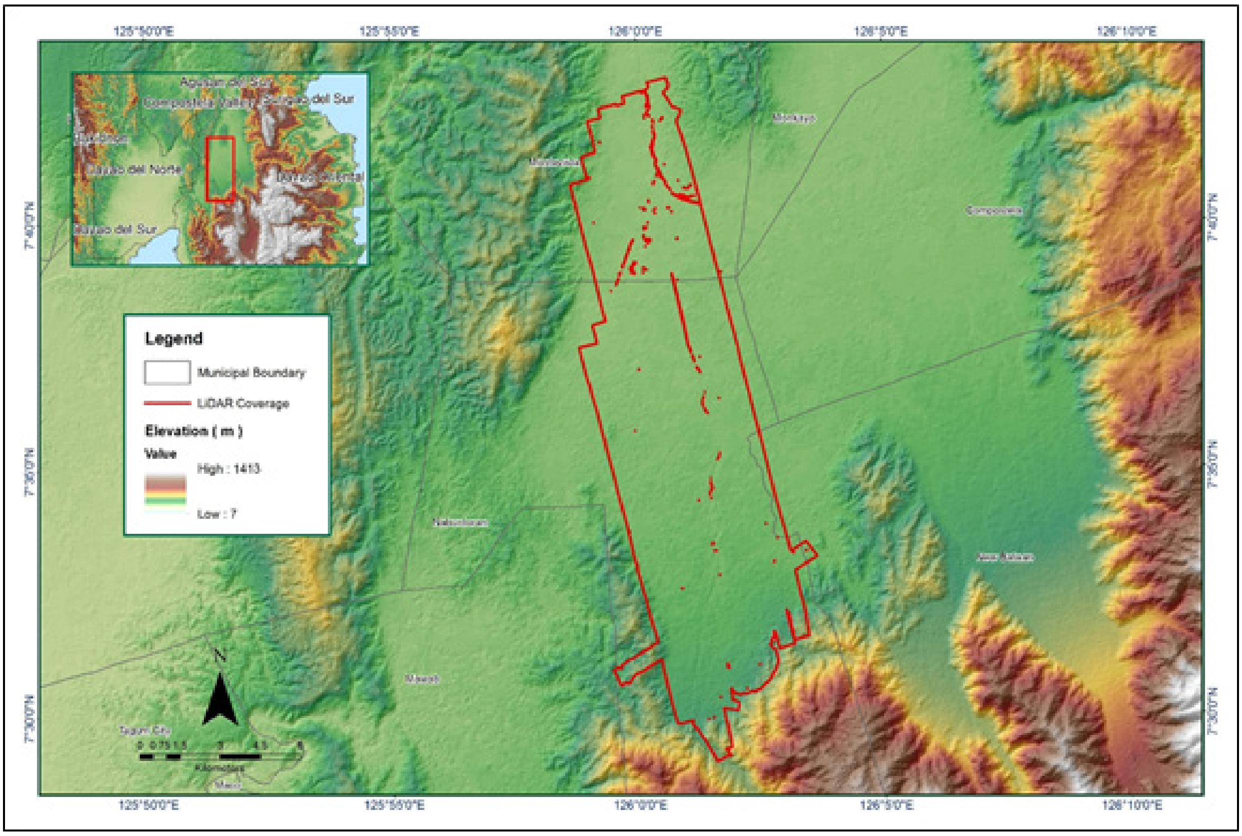


Figure A-8.46. Coverage of LiDAR data

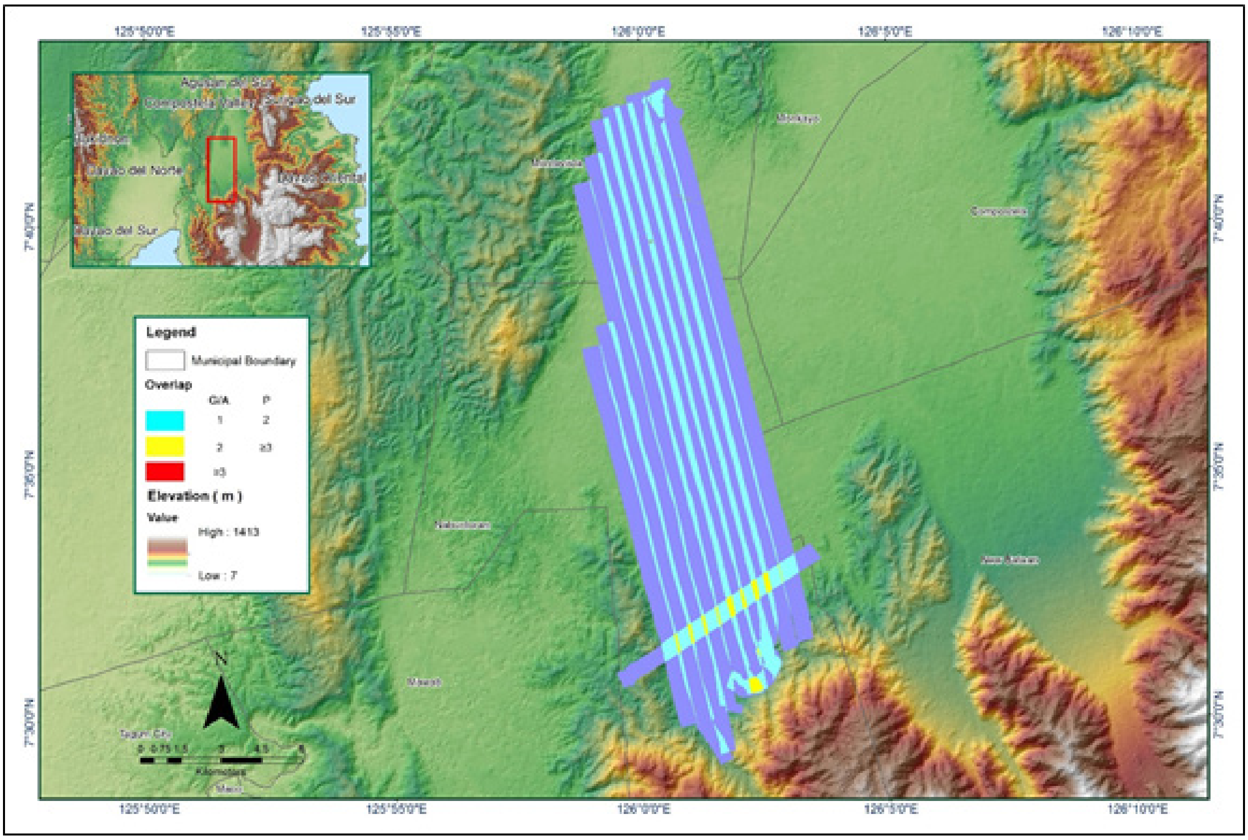


Figure A-8.47. Image of data overlap

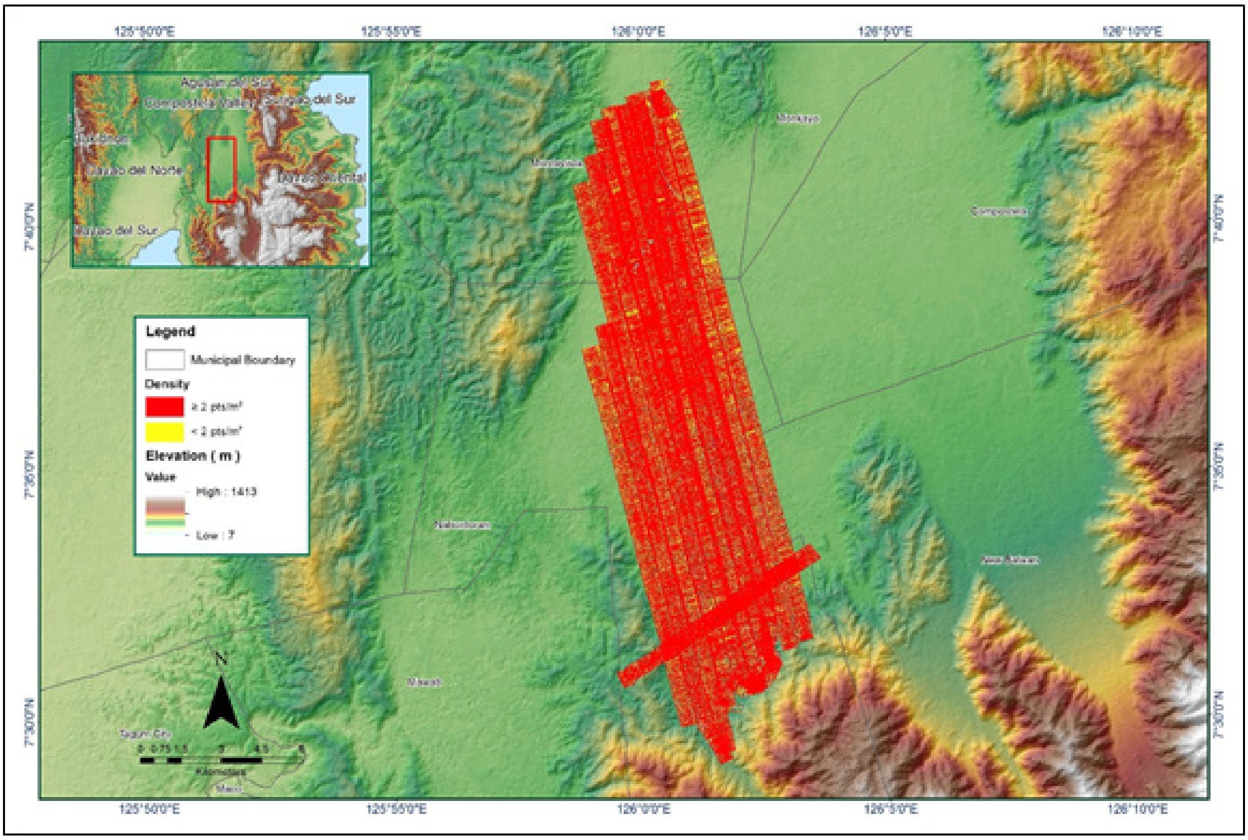


Figure A-8.48. Density map of merged LiDAR data

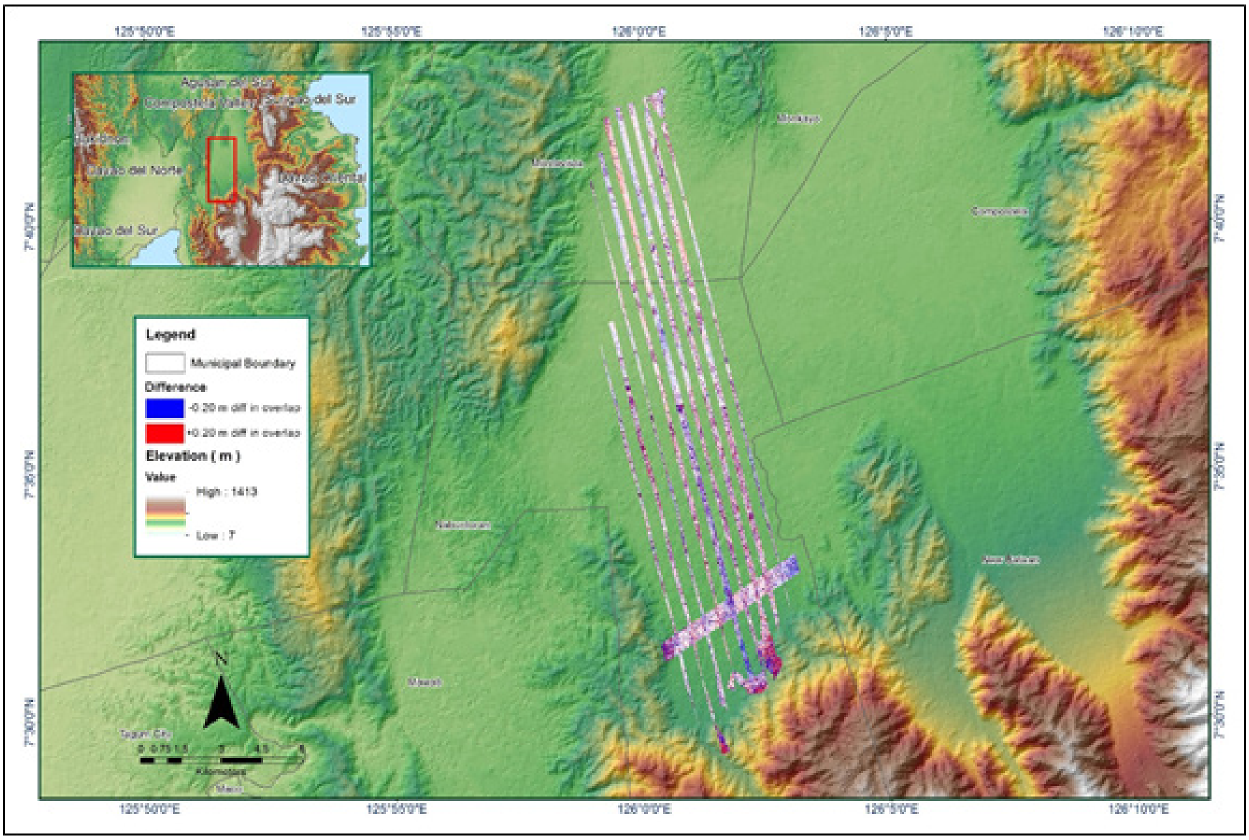


Figure A-8.49. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	COM B
Inclusive Flights	7423G,7424G
Range data size	26.29 GB
Base data size	14.33 MB
POS	332 MB
Image	na
Transfer date	August 29, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.095
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.05
Boresight correction stdev (<0.001deg)	0.000315
IMU attitude correction stdev (<0.001deg)	0.000482
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	23.56%
Ave point cloud density per sq.m. (>2.0)	3.06
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	158
Maximum Height	509.89 m
Minimum Height	90.00 m
Classification (# of points)	
Ground	37966933
Low vegetation	38234910
Medium vegetation	71207266
High vegetation	178167622
Building	2420193
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. John Dill Macapagal

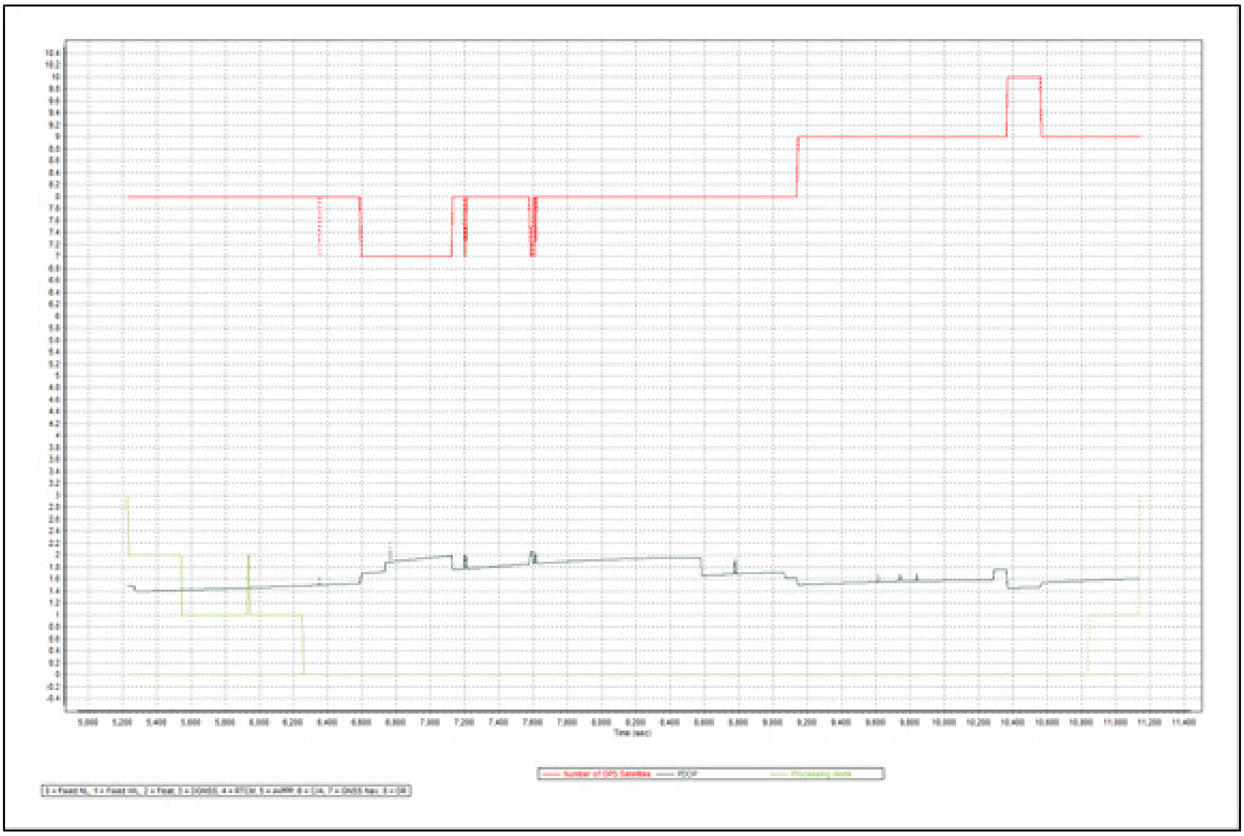


Figure A-8.50. Solution Status

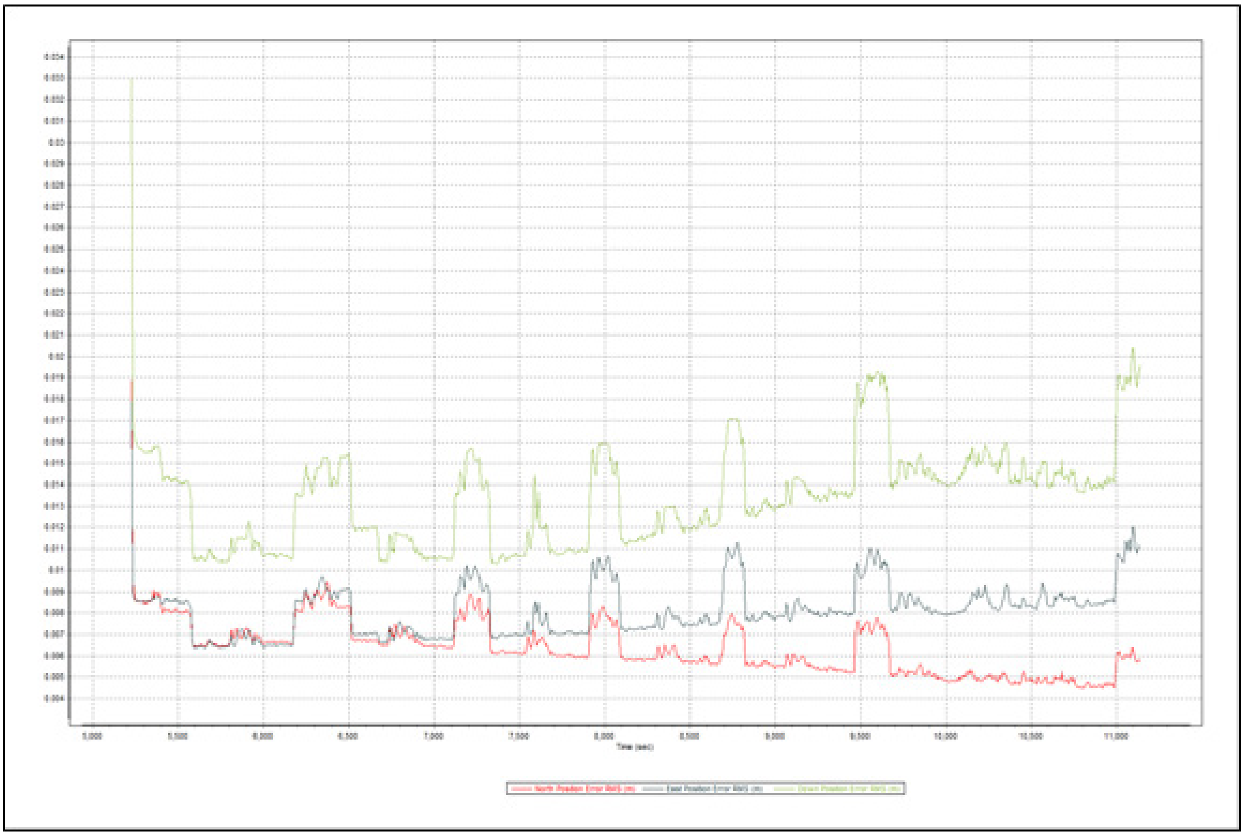


Figure A-8.51. Smoothed Performance Metric Parameters

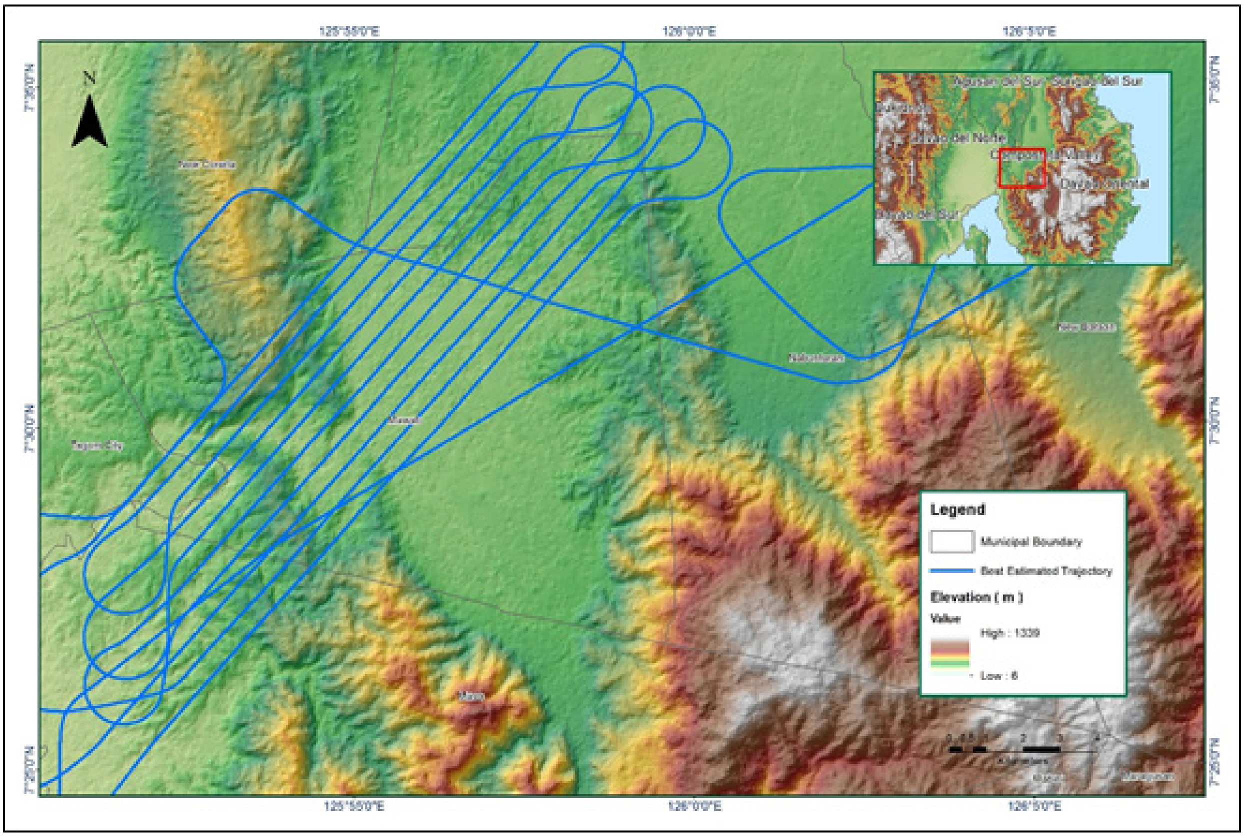


Figure A-8.52. Best Estimated Trajectory

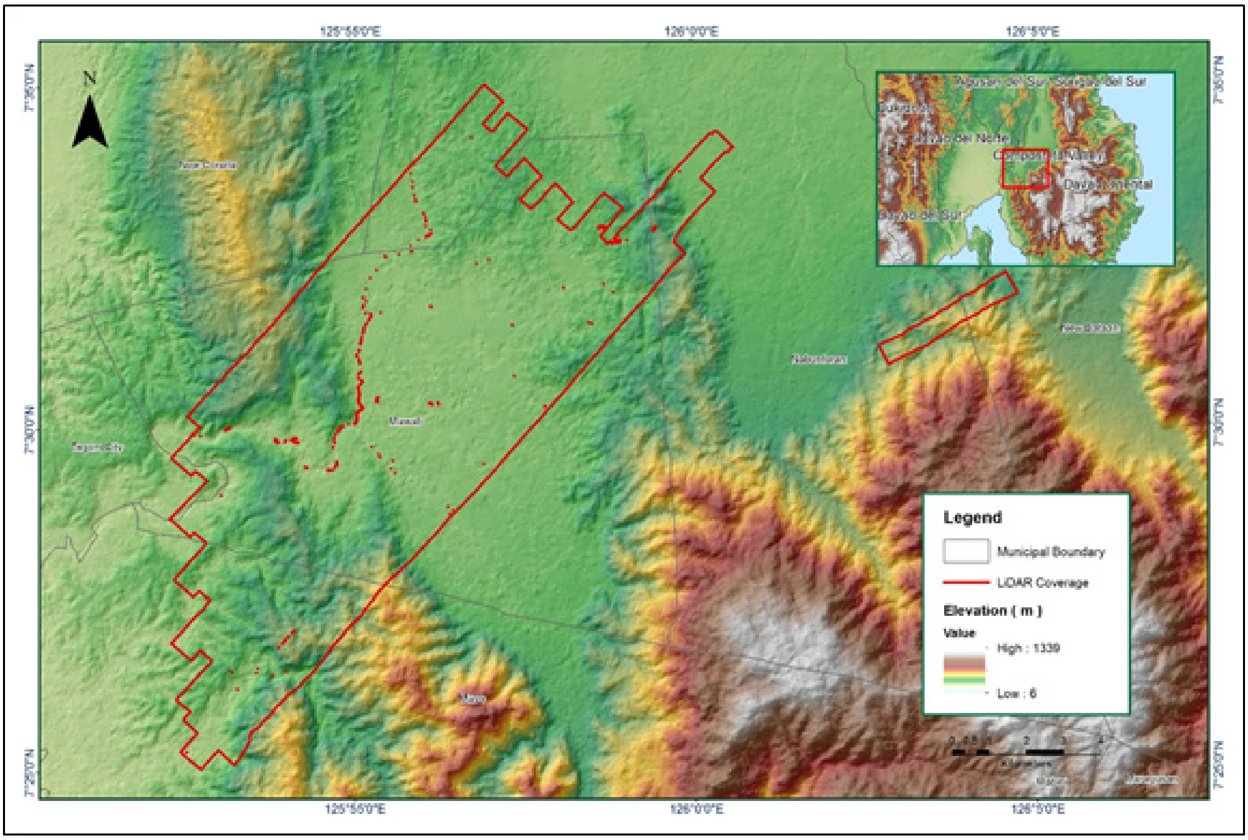


Figure A-8.53. Coverage of LiDAR data

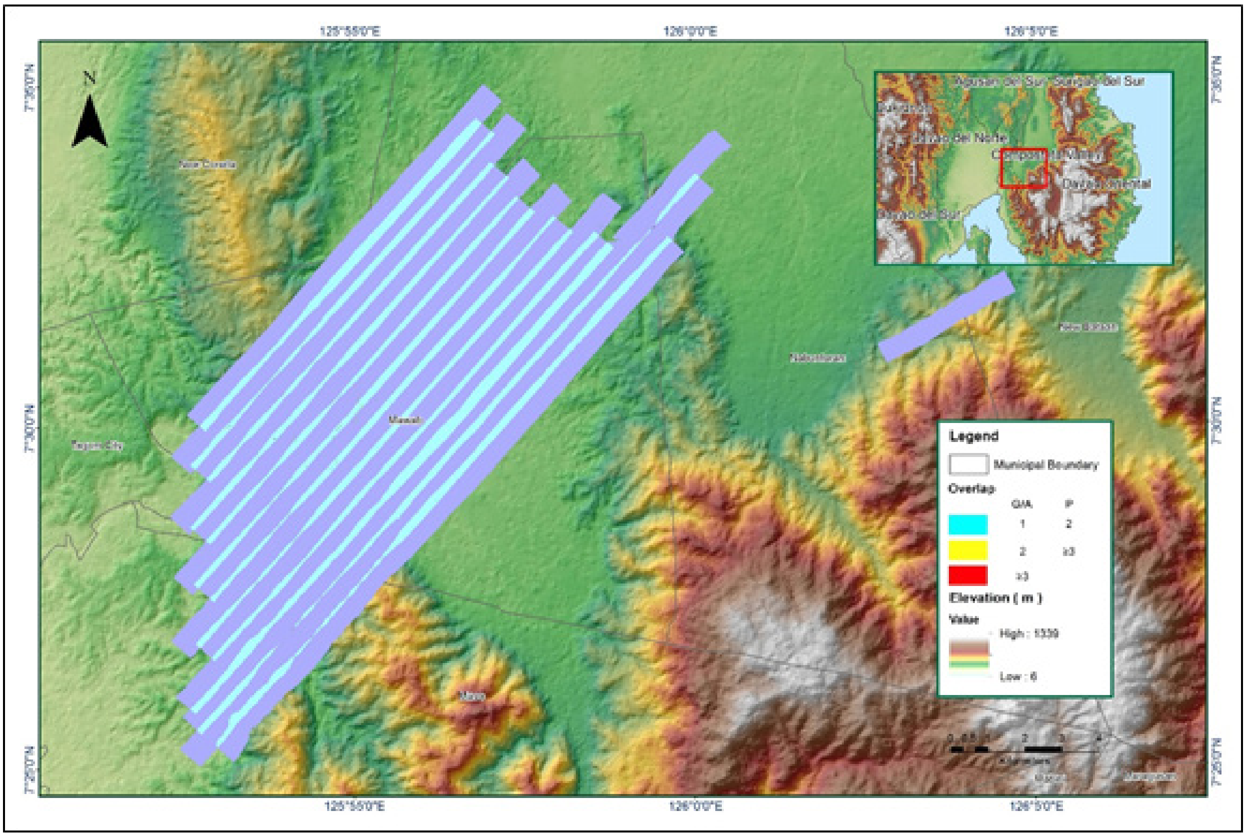


Figure A-8.54. Image of data overlap

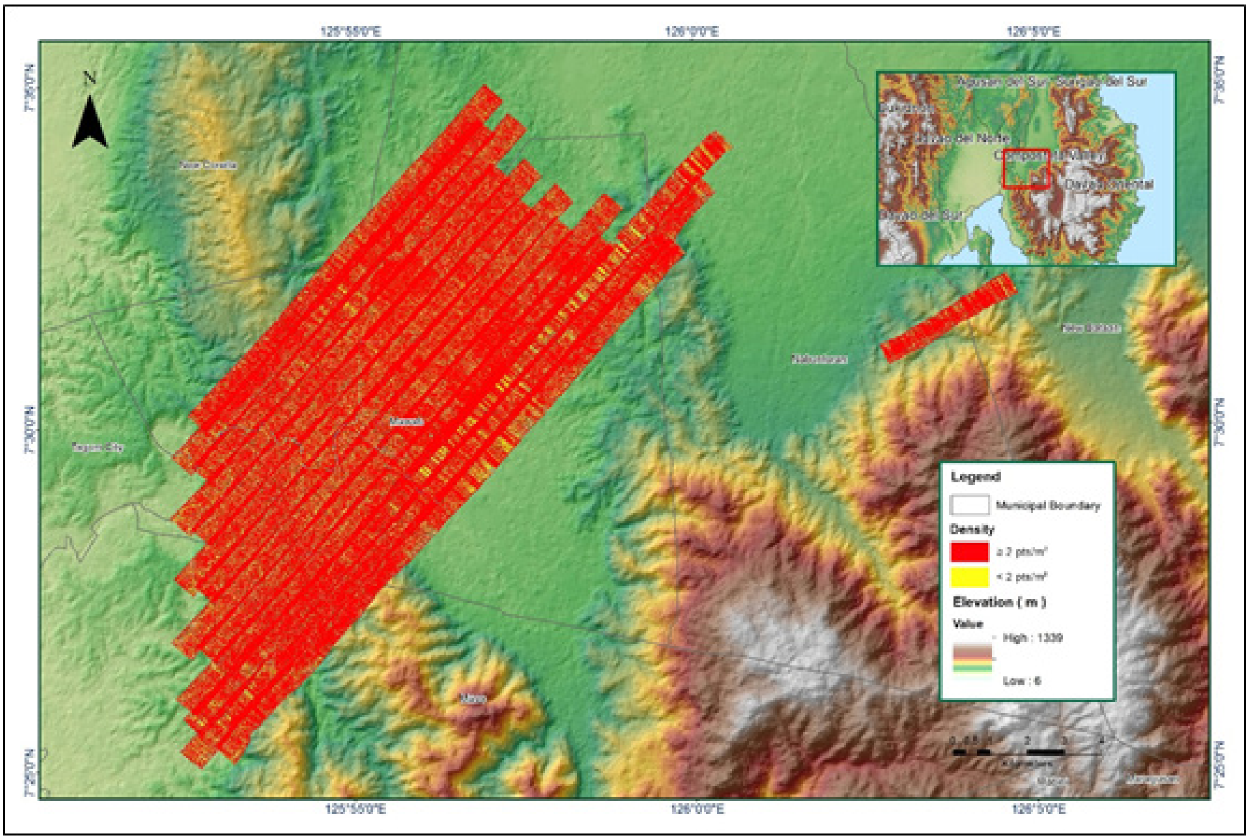


Figure A-8.55. Density map of merged LiDAR data

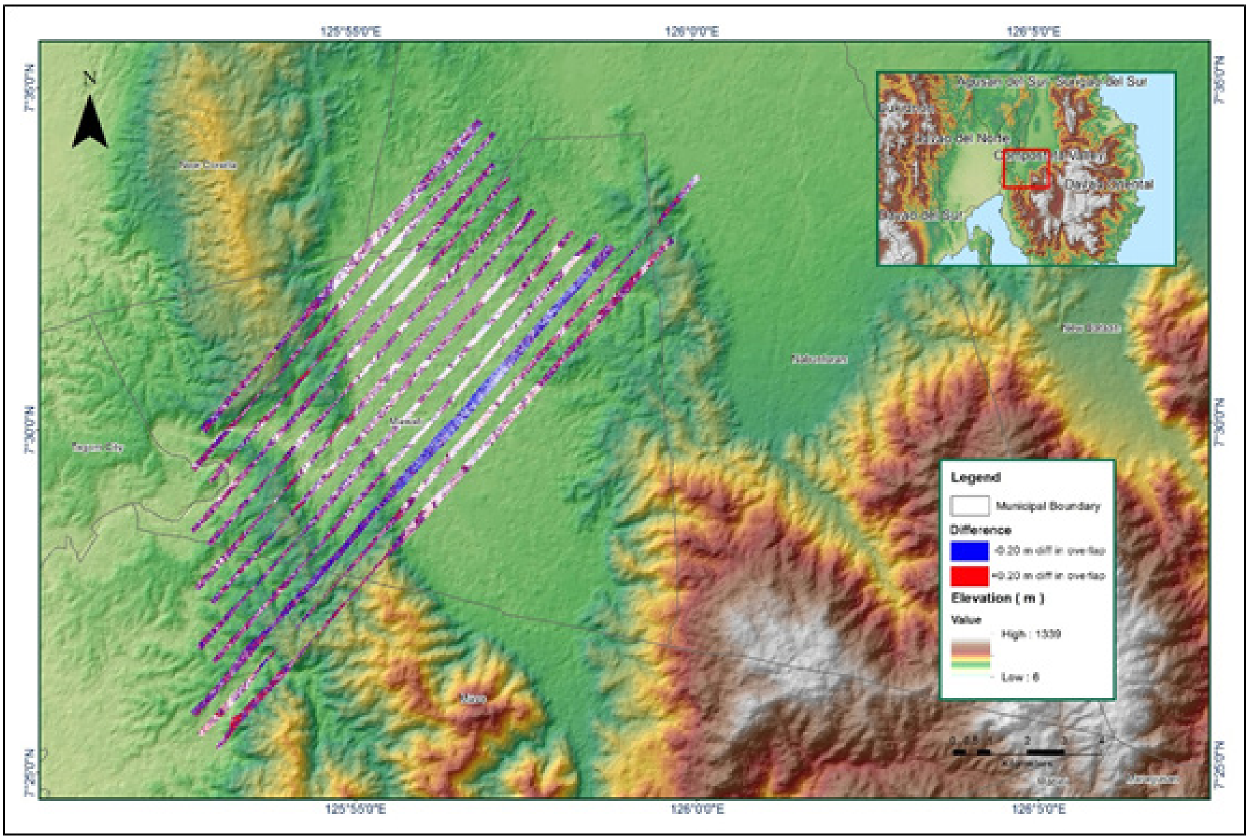


Figure A-8.56. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	COM B Voids
Inclusive Flights	7430G
Range data size	9.38 GB
Base data size	3.58 MB
POS	179 MB
Image	na
Transfer date	August 29, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.001410
IMU attitude correction stdev (<0.001deg)	0.005675
GPS position stdev (<0.01m)	0.0123
Minimum % overlap (>25)	26.09%
Ave point cloud density per sq.m. (>2.0)	3.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	25
Maximum Height	339.9 m
Minimum Height	135.63 m
Classification (# of points)	
Ground	4369074
Low vegetation	4367720
Medium vegetation	9431096
High vegetation	19858733
Building	283362
Orthophoto	No
Processed by	Engr. Jommer Medina, Aljon Rie Araneta, Jovy Narisma

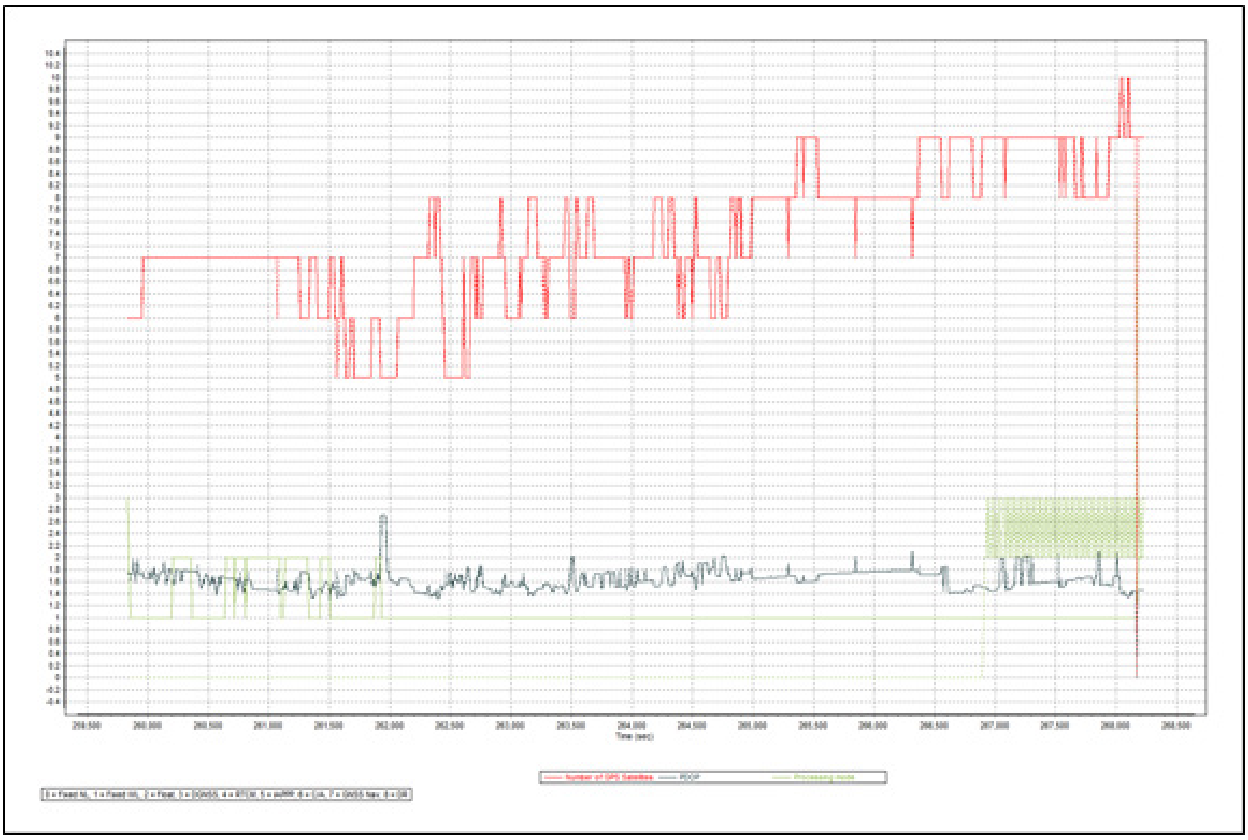


Figure A-8.57. Solution Status

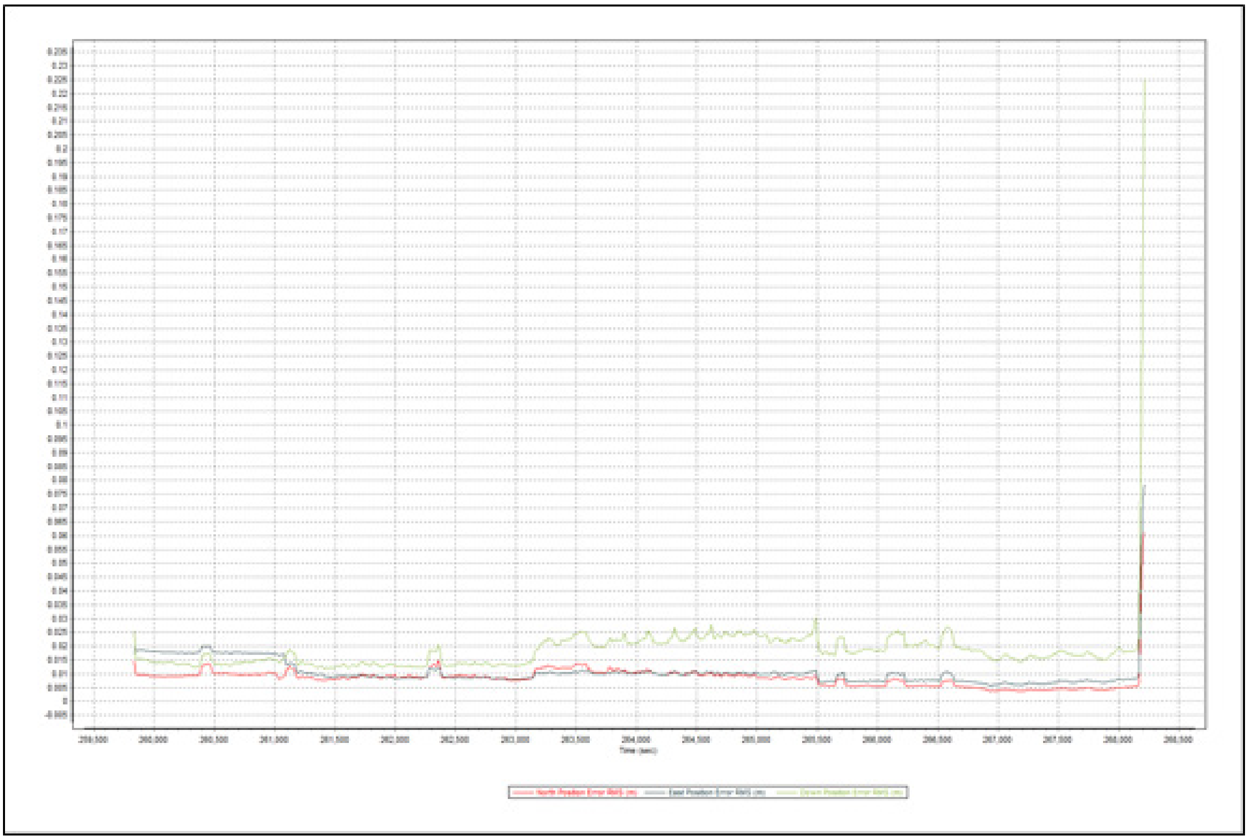


Figure A-8.58. Smoothed Performance Metric Parameters

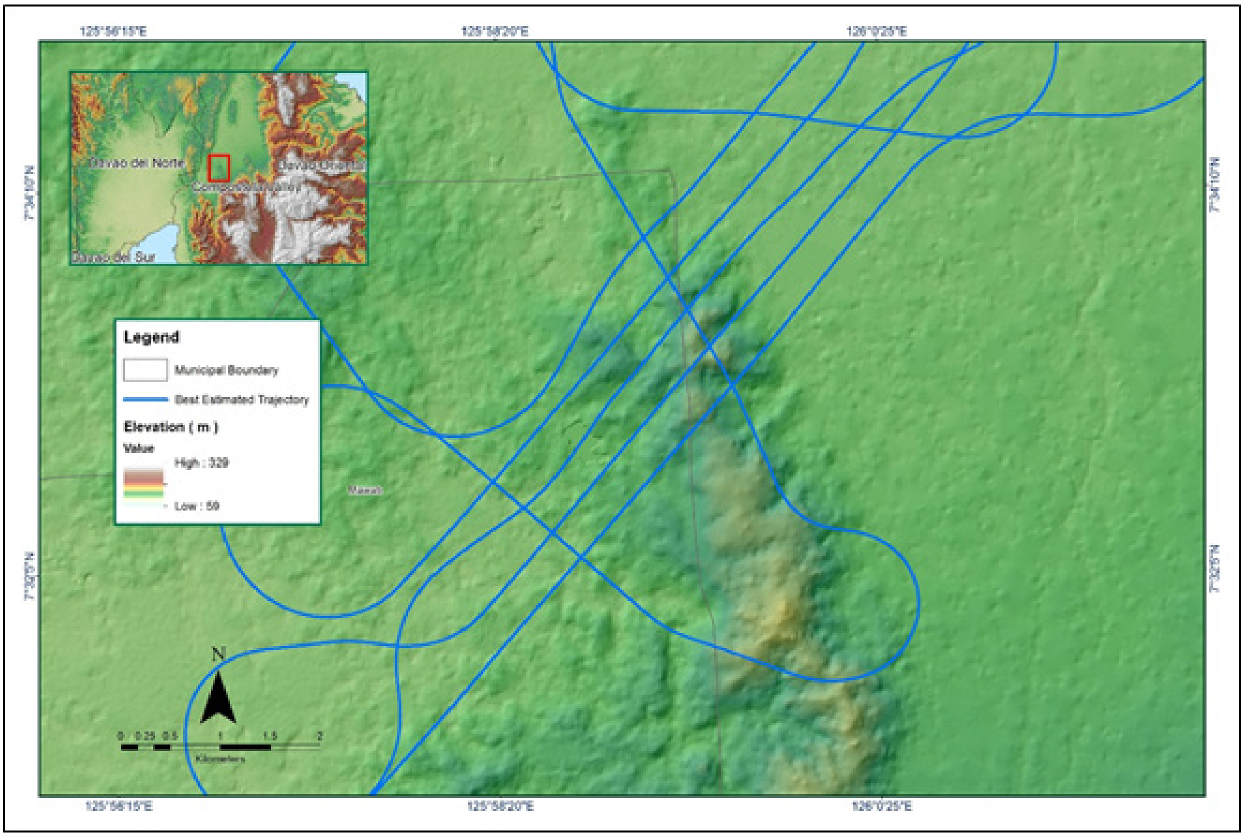


Figure A-8.59. Best Estimated Trajectory

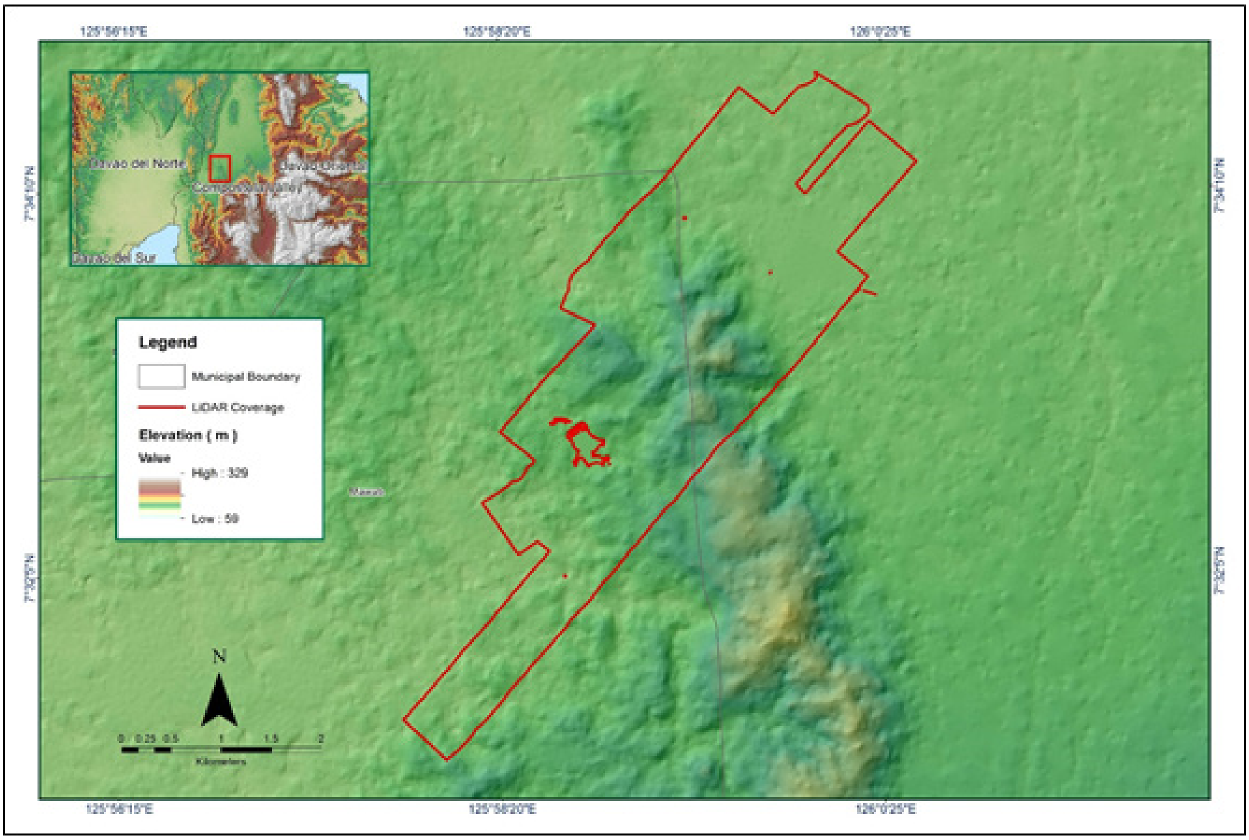


Figure A-8.60. Coverage of LiDAR data

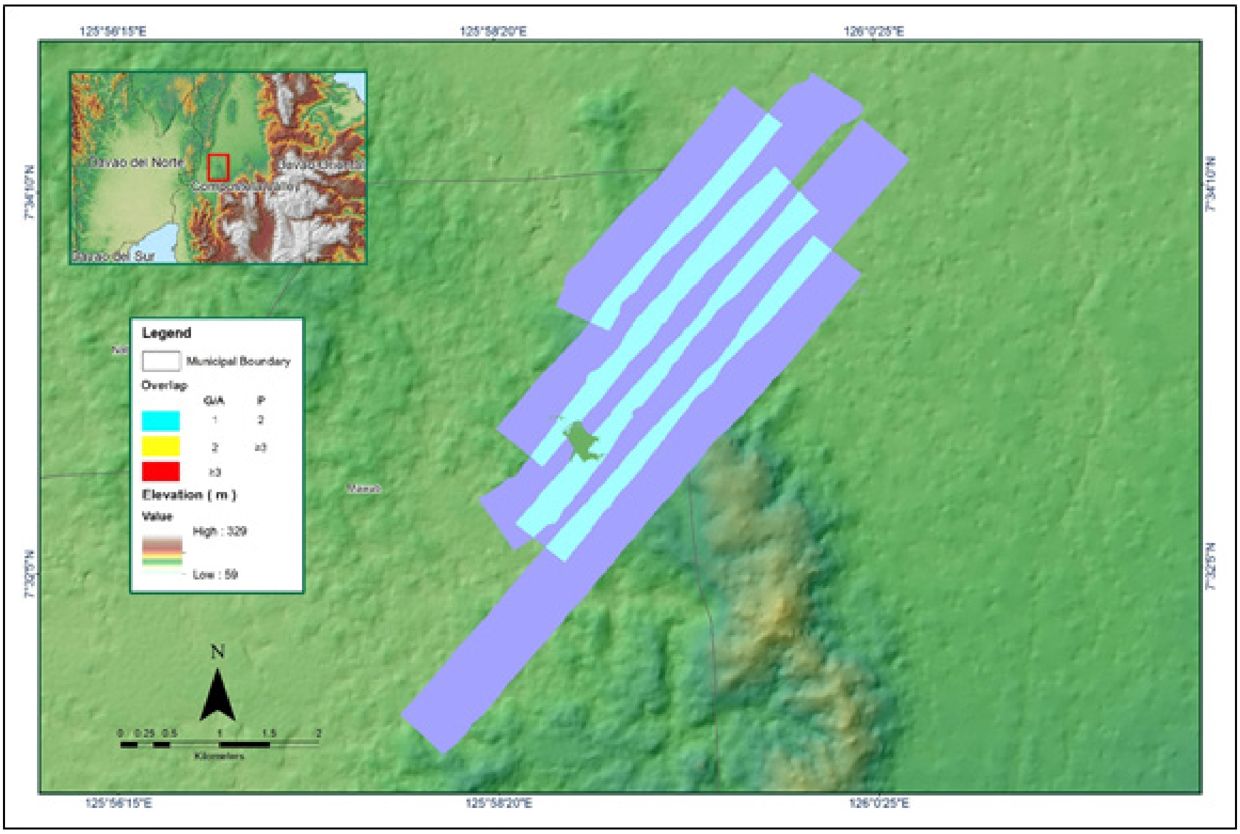


Figure A-8.61. Image of data overlap

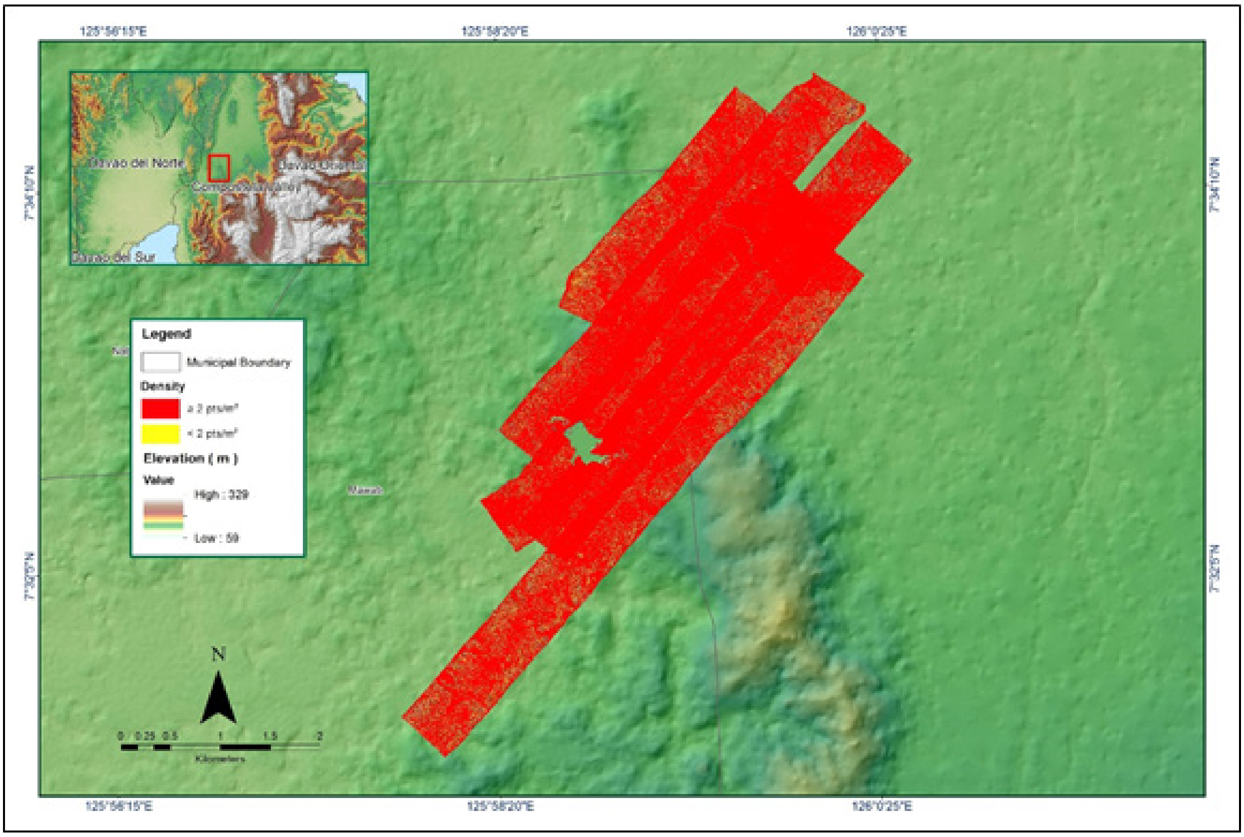


Figure A-8.62. Density map of merged LiDAR data

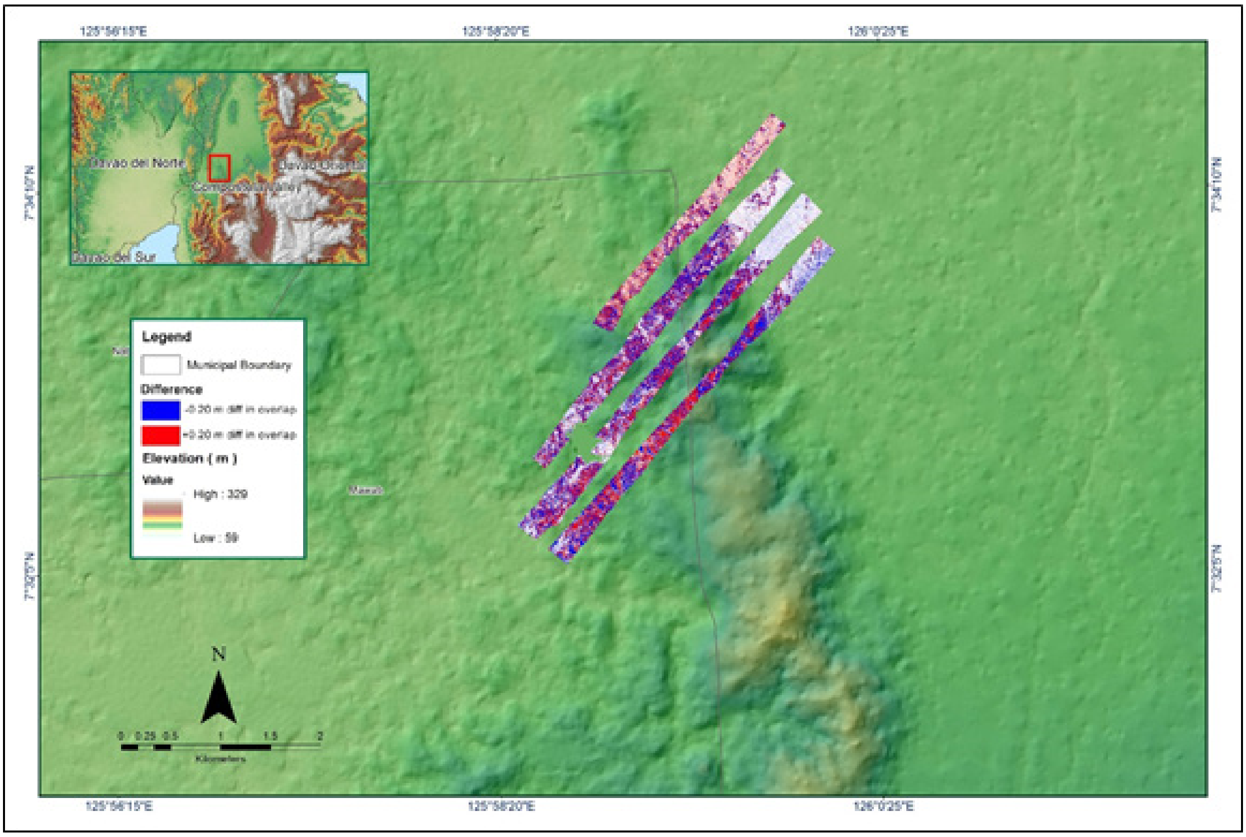


Figure A-8.63. Elevation difference between flight lines

Flight Area	Davao Oriental
Mission Name	COM D
Inclusive Flights	7422G
Range data size	19.8 GB
Base data size	9.95 MB
POS	219 MB
Image	na
Transfer date	August 29, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.5
RMSE for East Position (<4.0 cm)	3.6
RMSE for Down Position (<8.0 cm)	1.12
Boresight correction stdev (<0.001deg)	0.000445
IMU attitude correction stdev (<0.001deg)	0.001013
GPS position stdev (<0.01m)	0.0082
Minimum % overlap (>25)	20.68%
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	235
Maximum Height	430.92 m
Minimum Height	112.1 m
Classification (# of points)	
Ground	80969395
Low vegetation	99596380
Medium vegetation	170443469
High vegetation	173837424
Building	2269413
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Jovy Narisma

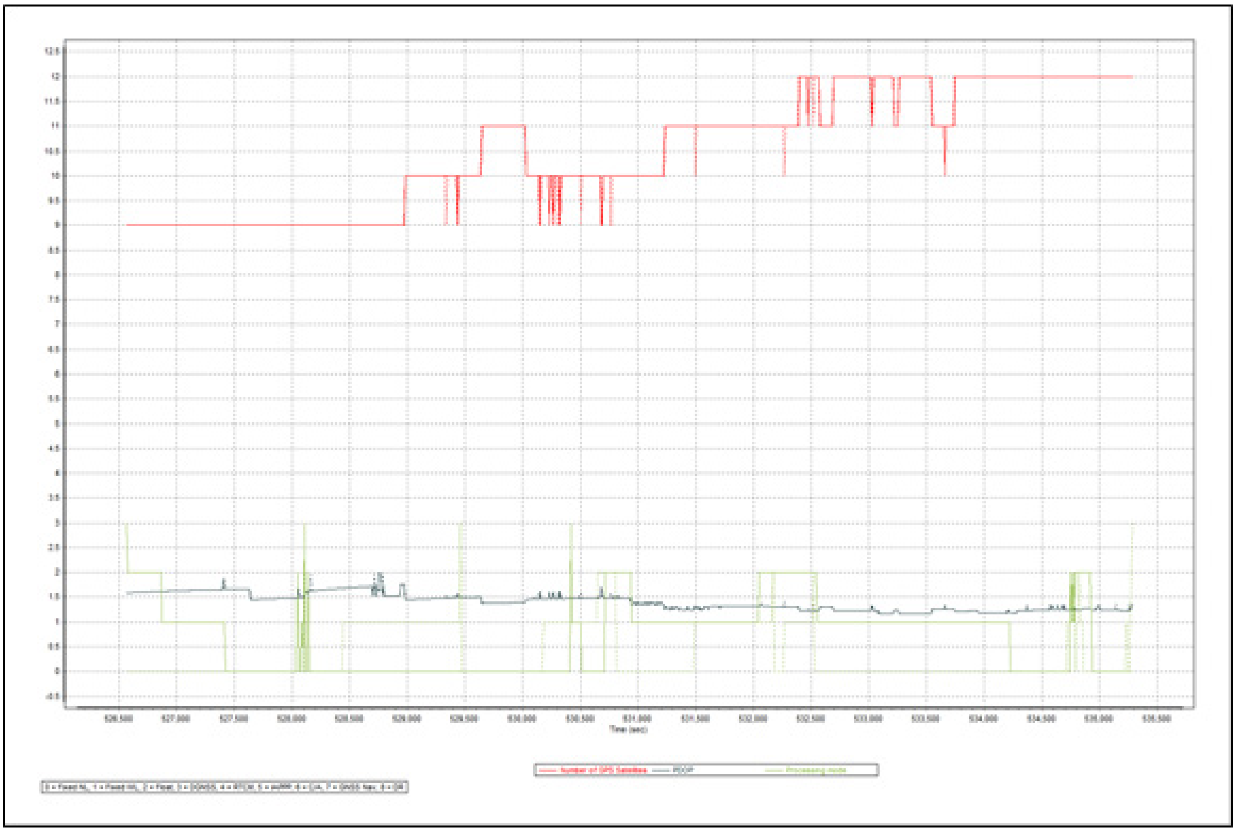


Figure A-8.64. Solution Status

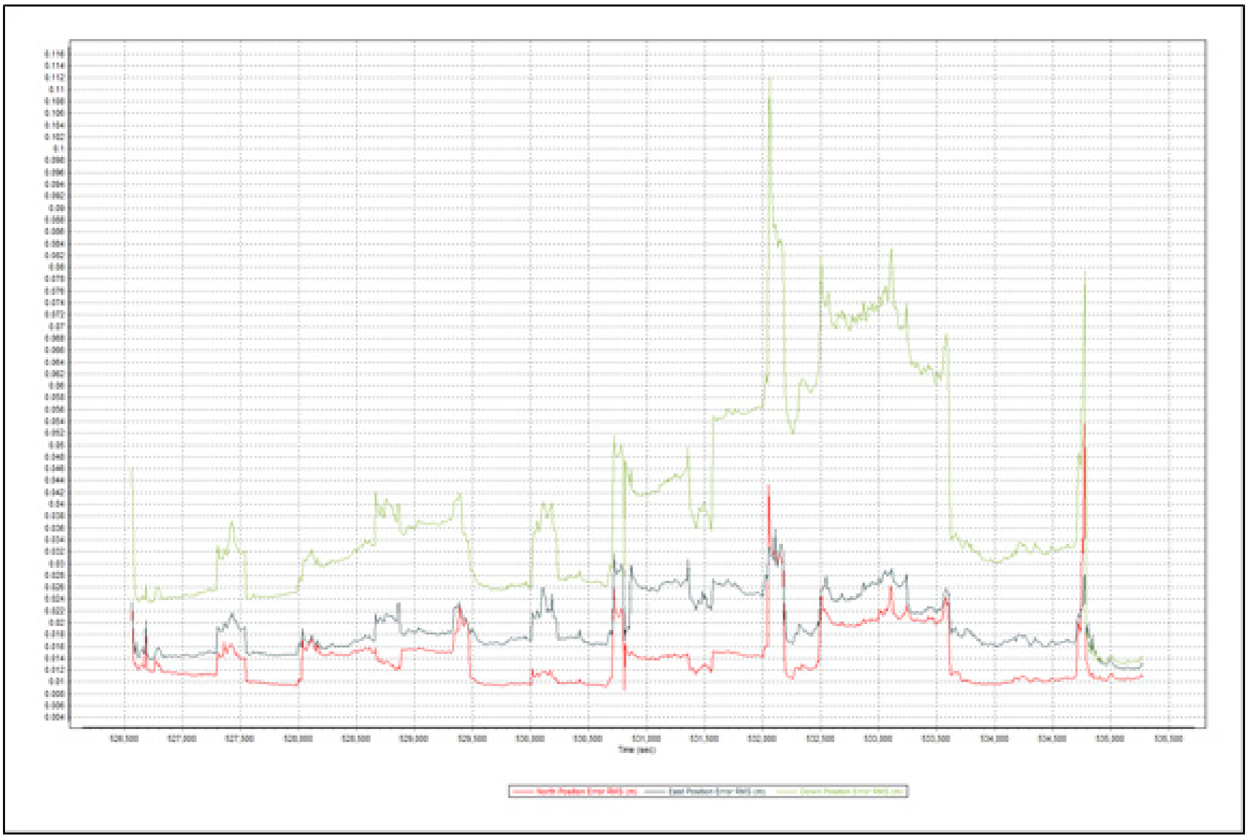


Figure A-8.65. Smoothed Performance Metric Parameters

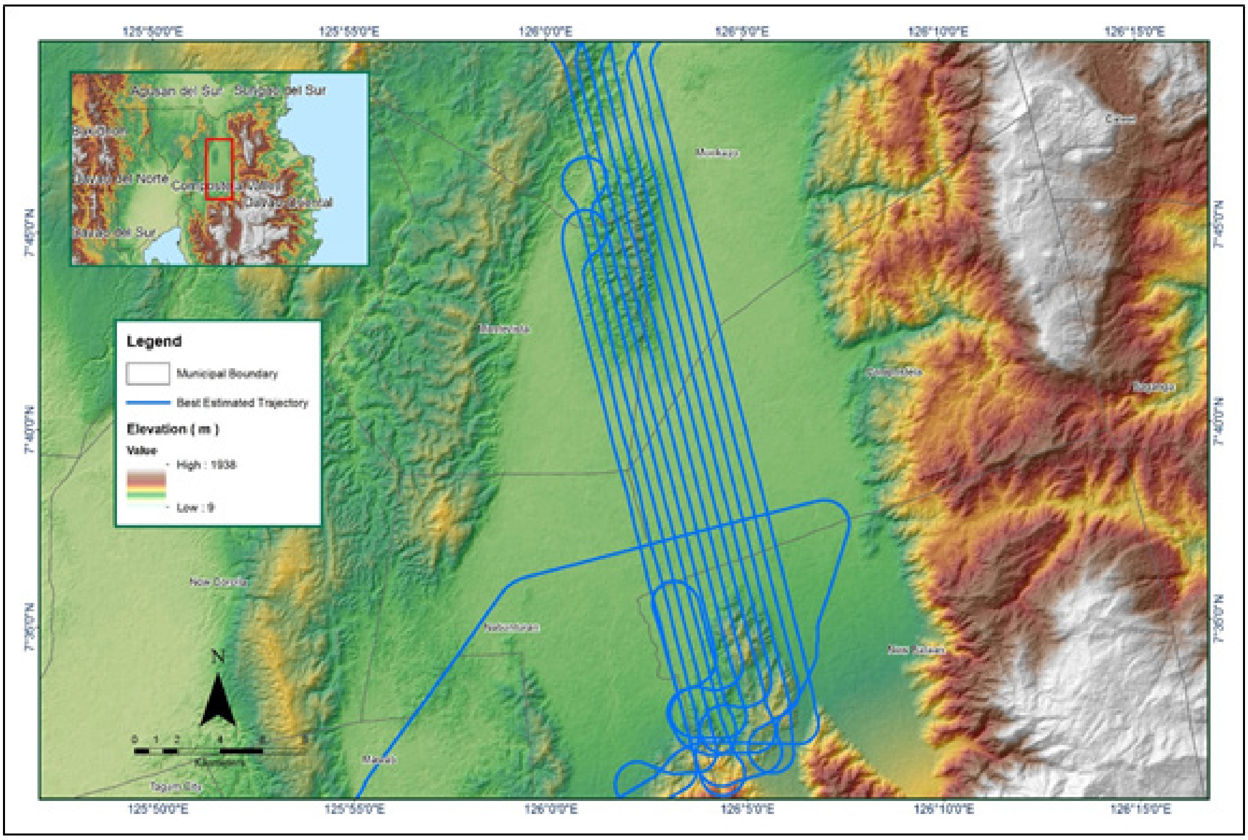


Figure A-8.66. Best Estimated Trajectory

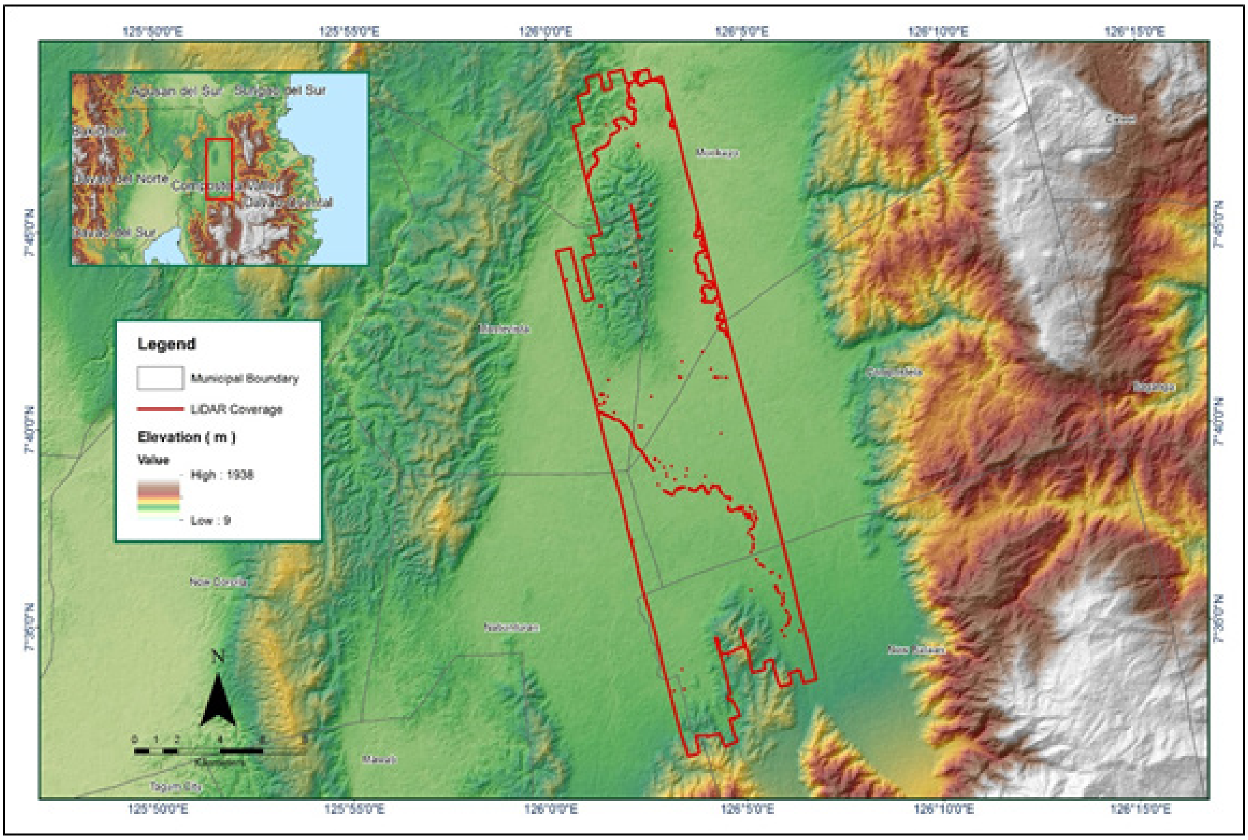


Figure A-8.67. Coverage of LiDAR data

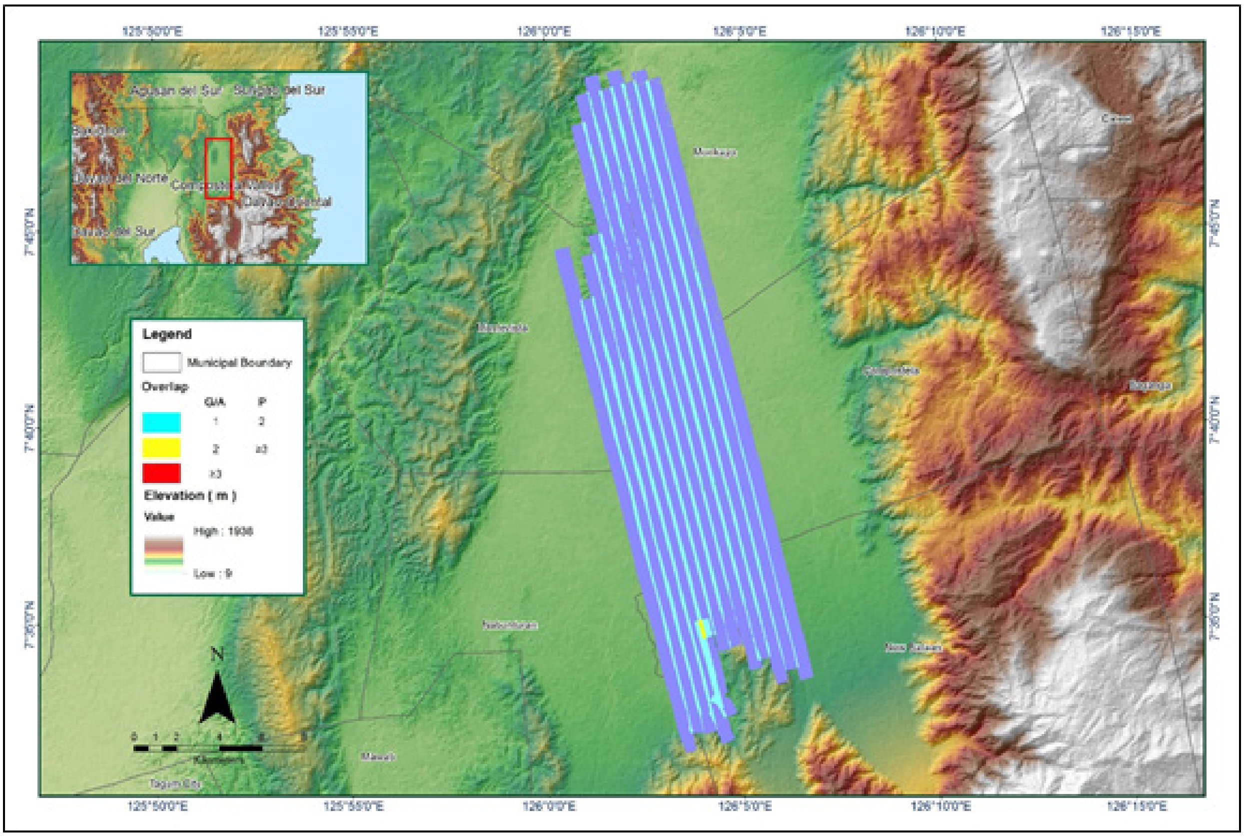


Figure A-8.68. Image of data overlap

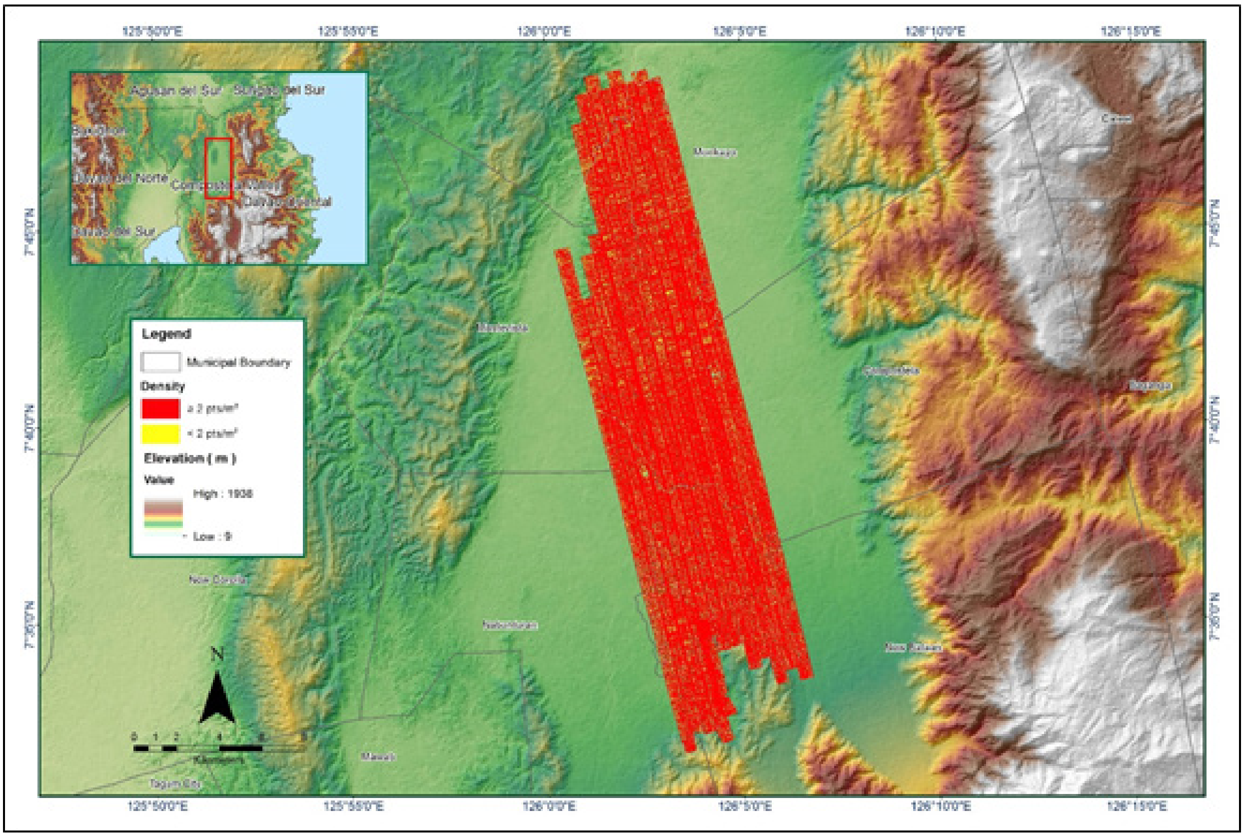


Figure A-8.69. Density map of merged LiDAR data

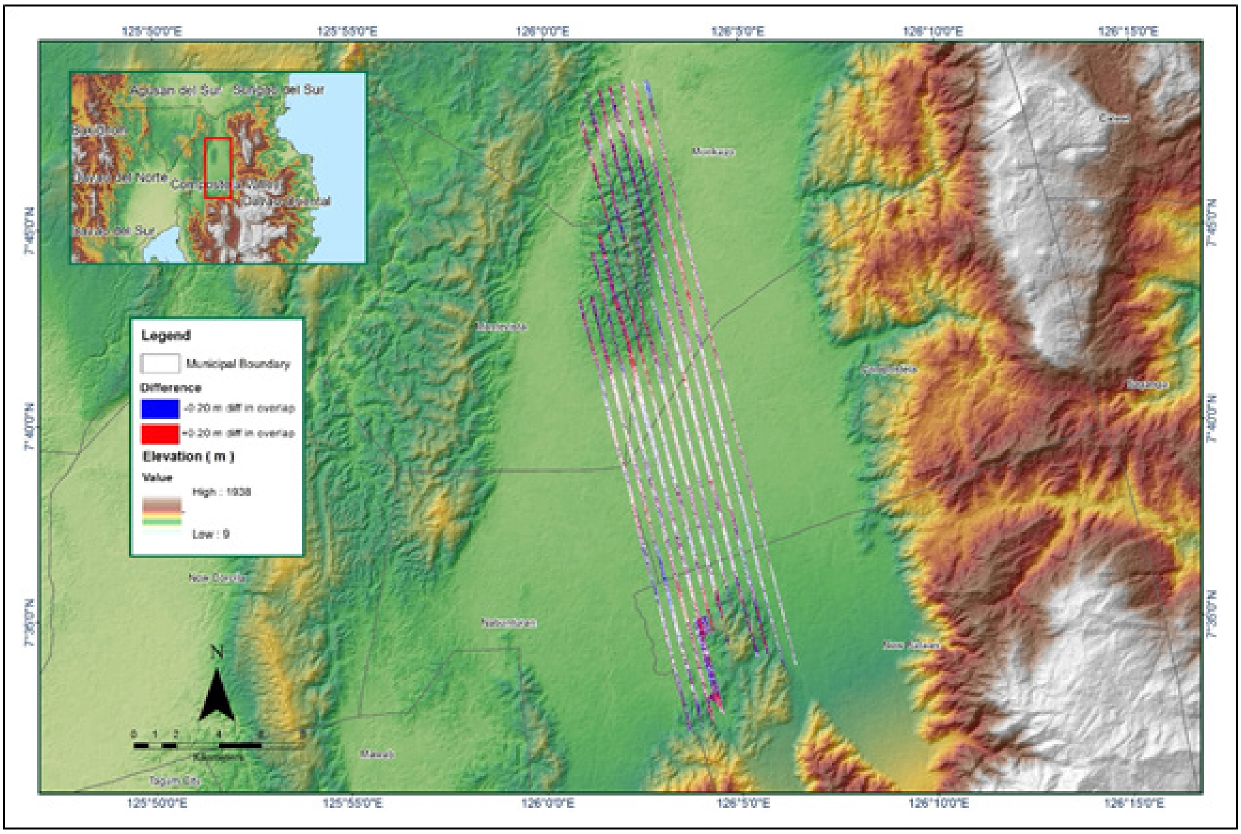


Figure A-8.70. Elevation difference between flight lines

Annex 9. Lasang 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
W1000	0.74632	98.451	0	0.16594	0.24509	Discharge	0.31102	0.10722	Ratio to Peak	0.25125
W1010	0.48952	99	0	4.0425	0.9129	Discharge	0.5586	0.11797	Ratio to Peak	0.22777
W1020	7.2574	59.24	0	8.4307	11.469	Discharge	0.46603	1.00E-05	Ratio to Peak	0.35
W1030	1.3316	99	0	2.7327	2.2685	Discharge	0.4832	0.76518	Ratio to Peak	0.7676
W1040	1.4104	96.122	0	5.0734	2.5807	Discharge	0.075552	0.36474	Ratio to Peak	0.99521
W1050	0.9947	99	0	12.253	2.7479	Discharge	0.17611	1.00E-05	Ratio to Peak	1
W1060	0.78424	98.799	0	6.4226	1.9939	Discharge	0.055418	0.92588	Ratio to Peak	1
W540	10.906	35.209	0	3.8433	14.393	Discharge	0.28214	0.002272	Ratio to Peak	0.5
W550	12.783	35.27	0	4.6086	7.7751	Discharge	0.42279	0.032885	Ratio to Peak	0.35
W560	1.1891	97.02	0	2.5239	0.016667	Discharge	0.40301	1	Ratio to Peak	0.96646
W570	5.0582	99	0	0.24948	0.016667	Discharge	0.24969	0.95939	Ratio to Peak	0.9
W580	7.9746	84.985	0	9.0683	9.7484	Discharge	0.57665	0.010337	Ratio to Peak	0.5
W590	6.4263	98.878	0	1.5506	0.016667	Discharge	0.32475	0.67153	Ratio to Peak	0.49031
W600	1.7592	99	0	2.196	0.016667	Discharge	0.25958	0.99496	Ratio to Peak	1
W610	7.239	35.511	0	6.4018	8.1759	Discharge	0.21215	0.003597	Ratio to Peak	0.5
W620	7.4852	35.086	0	8.3639	24.965	Discharge	0.17311	0.008607	Ratio to Peak	0.5
W630	10.71	99	0	7.0624	10.5	Discharge	0.69358	0.12216	Ratio to Peak	0.5
W640	17.819	35.266	0	4.1499	15.39	Discharge	0.15011	0.01782	Ratio to Peak	0.33333
W650	8.7065	97.082	0	8.0446	7.3438	Discharge	0.23361	0.087638	Ratio to Peak	0.5
W660	11.957	35.119	0	7.3085	73.614	Discharge	0.019818	0.005754	Ratio to Peak	0.5
W670	22.29	44.224	0	0.64624	6.0447	Discharge	0.016355	0.005655	Ratio to Peak	0.343
W680	7.9498	99	0	7.1945	9.9624	Discharge	0.14628	0.18583	Ratio to Peak	0.5

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
W690	12.443	55.086	0	6.297	10.228	Discharge	0.032991	0.054887	Ratio to Peak	0.31342
W700	8.3914	35.177	0	8.2062	6.9774	Discharge	0.25424	0.060204	Ratio to Peak	0.33333
W710	13.412	35.242	0	9.8735	37.024	Discharge	0.38262	0.4079	Ratio to Peak	0.5
W720	19.286	96.6	0	3.7965	5.0618	Discharge	0.3567	0.41414	Ratio to Peak	0.5
W730	13.509	79.55	0	14.953	0.016667	Discharge	0.16049	0.93649	Ratio to Peak	0.5
W740	12.357	90.315	0	2.9294	9.3852	Discharge	0.14733	0.76964	Ratio to Peak	0.5
W750	7.2229	40.823	0	3.4308	8.452	Discharge	0.1879	0.82871	Ratio to Peak	0.5
W760	10.553	99	0	5.2667	3.4053	Discharge	0.21542	1	Ratio to Peak	0.5
W770	8.2323	35.238	0	6.5356	9.4957	Discharge	0.14962	0.16899	Ratio to Peak	0.36815
W780	12.089	35.222	0	6.916	7.4214	Discharge	0.22498	0.042743	Ratio to Peak	0.21522
W790	2.8486	99	0	3.4747	2.3304	Discharge	0.19696	0.087538	Ratio to Peak	0.009521
W800	3.6928	99	0	3.3495	5.1912	Discharge	0.16012	0.0747	Ratio to Peak	0.091026
W810	10.85	47.6	0	8.5421	7.2625	Discharge	7.75E-02	0.10388	Ratio to Peak	0.32504
W820	8.1364	35.235	0	2.6384	18.148	Discharge	1.55E-01	0.001384	Ratio to Peak	0.5
W830	4.3975	98.857	0	3.4574	5.6746	Discharge	0.34259	0.023983	Ratio to Peak	0.13943
W840	17.188	35.339	0	7.3847	8.189	Discharge	0.22326	0.000124	Ratio to Peak	0.30261
W850	11.38	36.728	0	5.589	6.4955	Discharge	0.35393	0.007237	Ratio to Peak	0.23333
W860	11.575	35.246	0	3.8869	9.6118	Discharge	0.16776	0.004689	Ratio to Peak	0.45
W870	12.453	35.235	0	3.139	7.536	Discharge	0.26272	9.32E-05	Ratio to Peak	0.5
W880	12.496	35.319	0	4.0896	14.708	Discharge	0.45404	1.00E-05	Ratio to Peak	0.5
W890	7.0188	39.126	0	5.3919	8.8412	Discharge	0.18285	1.00E-05	Ratio to Peak	0.33333
W900	9.4343	41.399	0	8.0263	19.469	Discharge	0.069274	1.00E-05	Ratio to Peak	0.19581
W910	7.4777	35	0	5.0837	12.585	Discharge	0.86405	1.00E-05	Ratio to Peak	0.29381
W920	7.7861	35.236	0	4.0569	9.8154	Discharge	0.247	8.53E-05	Ratio to Peak	0.30131

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
W930	7.1232	38.827	0	5.6142	9.4458	Discharge	0.41964	4.60E-05	Ratio to Peak	0.33333
W940	12.454	91.654	0	4.7325	3.6922	Discharge	0.18117	1.00E-05	Ratio to Peak	0.33333
W950	2.5792	98.795	0	0.12817	4.2009	Discharge	1.2728	0.38824	Ratio to Peak	0.029864
W960	4.946	99	0	2.5923	8.6282	Discharge	0.22471	1.00E-05	Ratio to Peak	0.5
W970	7.6113	92.173	0	1.3418	7.2223	Discharge	0.022637	1.00E-05	Ratio to Peak	0.45576
W980	7.5269	51.491	0	2.689	6.49	Discharge	0.015078	1.00E-05	Ratio to Peak	0.22867
W990	4.3229	99	0	8.3748	5.1471	Discharge	0.14709	1.00E-05	Ratio to Peak	0.49501

Annex 10. Lasang Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	3553.6	0.016292	0.14443	Trapezoid	26.8	1
R110	Automatic Fixed Interval	5172.4	0.009934	0.16161	Trapezoid	26.8	1
R130	Automatic Fixed Interval	869.71	0.020794	0.000314	Trapezoid	26.8	1
R150	Automatic Fixed Interval	1079.1	0.003184	0.11919	Trapezoid	26.8	1
R160	Automatic Fixed Interval	1316.6	0.020621	0.003783	Trapezoid	26.8	1
R200	Automatic Fixed Interval	5638.6	0.02053	0.055842	Trapezoid	26.8	1
R230	Automatic Fixed Interval	7952.3	0.006119	0.07192	Trapezoid	26.8	1
R240	Automatic Fixed Interval	9641.1	0.00842	0.072164	Trapezoid	26.8	1
R270	Automatic Fixed Interval	6570.1	0.001149	0.070641	Trapezoid	26.8	1
R290	Automatic Fixed Interval	1598.5	0.12092	0.042726	Trapezoid	26.8	1
R30	Automatic Fixed Interval	6870.6	0.024547	0.012703	Trapezoid	26.8	1
R310	Automatic Fixed Interval	5055.5	0.02349	0.059038	Trapezoid	26.8	1
R330	Automatic Fixed Interval	6306.3	0.011836	0.04073	Trapezoid	26.8	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R340	Automatic Fixed Interval	5788.4	0.008104	0.002573	Trapezoid	26.8	1
R360	Automatic Fixed Interval	7542.5	0.004039	0.003783	Trapezoid	26.8	1
R370	Automatic Fixed Interval	1338.4	0.004827	0.016552	Trapezoid	26.8	1
R390	Automatic Fixed Interval	6253	0.00491	0.058513	Trapezoid	26.8	1
R420	Automatic Fixed Interval	1510.2	0.027284	0.043511	Trapezoid	26.8	1
R430	Automatic Fixed Interval	9155.3	0.013053	0.014586	Trapezoid	26.8	1
R440	Automatic Fixed Interval	655.98	0.028496	0.019541	Trapezoid	26.8	1
R470	Automatic Fixed Interval	25034	0.00146	0.069887	Trapezoid	26.8	1
R500	Automatic Fixed Interval	15292	0.001148	0.070862	Trapezoid	26.8	1
R510	Automatic Fixed Interval	4045.2	0.002131	0.085828	Trapezoid	26.8	1
R530	Automatic Fixed Interval	3104.8	0.001	0.070859	Trapezoid	26.8	1
R70	Automatic Fixed Interval	7224.8	0.011809	0.081941	Trapezoid	26.8	1
R80	Automatic Fixed Interval	5447.2	0.021928	0.08304	Trapezoid	26.8	1

Annex 11. Lasang Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	7.283674	125.678221	0.03	0.25	0.0484	Intense local rainfall	5-Year
2	7.278456	125.674299	0.03	0.00	0.0009		5-Year
3	7.262868	125.666696	0.08	0.00	0.0064		5-Year
4	7.261520	125.665421	0.08	0.00	0.0064		5-Year
5	7.259300	125.674095	0.03	0.00	0.0009		5-Year
6	7.294042	125.666970	0.07	0.20	0.0169	Rainfall/ October 2015	5-Year
7	7.293499	125.667058	0.19	0.40	0.0441	Pablo/ 2014	5-Year
8	7.292322	125.667413	0.11	0.10	0.0001	Pablo/ 2014	5-Year
9	7.291956	125.668135	0.14	0.50	0.1296	Rainfall/ 2015	5-Year
10	7.291525	125.679897	0.03	0.30	0.0729	Intense local rainfall/ 2015	5-Year
11	7.288979	125.682687	0.04	0.30	0.0676	Rainfall/ December 2015	5-Year
12	7.288882	125.683773	0.08	0.20	0.0144	Rainfall/ December 2014	5-Year
13	7.282977	125.673783	0.03	0.30	0.0729	Intense local rainfall/ 2015	5-Year
14	7.280088	125.673313	0.03	0.00	0.0009		5-Year
15	7.295038	125.666524	0.3	0.00	0.0900		5-Year
16	7.294037	125.667785	0.26	0.50	0.0576	Typhoon/ 2007	5-Year
17	7.292861	125.668049	0.5	0.50	0.0000	Typhoon/ 2007	5-Year
18	7.291234	125.668130	0.41	0.00	0.1681		5-Year
19	7.290085	125.679074	0.37	0.10	0.0729	Intense local rainfall/ 2015	5-Year
20	7.289817	125.678439	0.21	0.00	0.0441		5-Year
21	7.284260	125.686098	0.51	0.20	0.0961	Rainfall/ November 2015	5-Year
22	7.283975	125.673155	0.28	0.00	0.0784		5-Year
23	7.282900	125.671520	0.17	0.50	0.1089	Intense local rainfall/ 2014	5-Year
24	7.281172	125.673410	0.44	0.00	0.1936		5-Year
25	7.280696	125.662186	0.39	0.00	0.1521		5-Year
26	7.279507	125.680006	0.4	0.00	0.1600		5-Year
27	7.279362	125.673852	0.64	0.50	0.0196	Intense local rainfall/ 2015	5-Year
28	7.279023	125.685343	0.29	0.50	0.0441	Intense local rainfall/ 2015	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
29	7.277938	125.670133	0.45	0.30	0.0225	Intense local rainfall/ 2015	5-Year
30	7.264557	125.671502	0.49	0.65	0.0256	Intense local rainfall/ September 2014	5-Year
31	7.295212	125.667792	0.65	0.00	0.4225		5-Year
32	7.294942	125.667519	0.52	0.10	0.1764	Low pressure area/ October 2015	5-Year
33	7.291512	125.666955	1.02	0.10	0.8464	Typhoon/ 2012	5-Year
34	7.289457	125.678256	0.39	0.00	0.1521		5-Year
35	7.288961	125.670379	0.27	0.30	0.0009	Typhoon/ 2014	5-Year
36	7.288824	125.678342	0.93	0.40	0.2809	Intense local rainfall/ 2013	5-Year
37	7.286298	125.677603	0.46	0.50	0.0016	Intense local rainfall/ 2014	5-Year
38	7.285531	125.685020	0.57	0.00	0.3249		5-Year
39	7.285487	125.677237	0.17	0.20	0.0009	Intense local rainfall/ 2015	5-Year
40	7.285433	125.686286	0.63	0.20	0.1849	Rainfall/ October 2015	5-Year
41	7.285151	125.672891	0.51	0.50	0.0001	Intense local rainfall/ September 2014	5-Year
42	7.284715	125.685467	0.47	0.20	0.0729	Typhoon/ November 2015	5-Year
43	7.284255	125.671618	0.97	0.80	0.0289	Intense local rainfall/ 2014	5-Year
44	7.284081	125.670441	0.89	0.80	0.0081	Intense local rainfall/ 2014	5-Year
45	7.283523	125.673153	0.59	0.30	0.0841	Intense local rainfall/ 2015	5-Year
46	7.282928	125.682108	0.5	0.40	0.0100	Rainfall/ October 15, 2015	5-Year
47	7.282644	125.684278	0.46	0.44	0.0004	Rainfall/ September 2015	5-Year
48	7.282292	125.682647	0.41	0.30	0.0121	Rainfall/ 2014	5-Year
49	7.278388	125.670498	0.98	0.00	0.9604		5-Year
50	7.291271	125.661796	1.66	0.00	2.7556		5-Year
51	7.290515	125.667402	2.04	0.00	4.1616		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
52	7.290197	125.675274	1.05	0.30	0.5625	Intense local rainfall/ August 2013	5-Year
53	7.289739	125.676357	1.29	0.30	0.9801	Intense local rainfall/ 2013	5-Year
54	7.288745	125.676351	1.13	0.10	1.0609	Intense local rainfall/ 2012	5-Year
55	7.288203	125.676438	1.09	0.50	0.3481	Intense local rainfall/ 2015	5-Year
56	7.283358	125.670527	1.68	0.00	2.8224		5-Year
57	7.281973	125.660112	2.41	0.00	5.8081		5-Year
58	7.281616	125.659386	2.01	0.00	4.0401		5-Year
59	7.279802	125.660642	1.7	0.00	2.8900		5-Year
60	7.271805	125.668196	1.78	2.06	0.0784	Typhoon/ December 4, 1998	5-Year
61	7.271085	125.667649	1.88	2.06	0.0324	Typhoon/ December 4, 1998	5-Year
62	7.270003	125.667371	1.8	2.50	0.4900	Intense local rainfall/ 1990s	5-Year
63	7.265796	125.675943	1.91	0.90	1.0201	Intense local rainfall/ 1986	5-Year
64	7.263637	125.674211	1.2	0.90	0.0900	Typhoon/ June 2014	5-Year
65	7.266701	125.644909	0.03	0.50	0.2209	Intense local rainfall/ December 14, 2015	5-Year
66	7.265815	125.657302	0.03	0.00	0.0009		5-Year
67	7.264271	125.658559	0.03	1.00	0.9409	Upstream rainfall/ 2013	5-Year
68	7.262986	125.646607	0.03	0.30	0.0729	Upstream rainfall/ 2013	5-Year
69	7.261733	125.644427	0.04	0.00	0.0016		5-Year
70	7.260995	125.647047	0.03	0.00	0.0009		5-Year
71	7.260525	125.650121	0.11	0.20	0.0081	Intense local rainfall/ 2013-2014	5-Year
72	7.259326	125.654368	0.03	0.50	0.2209	Upstream rainfall/ August 2015	5-Year
73	7.258891	125.651379	0.06	0.00	0.0036		5-Year
74	7.257162	125.669015	0.13	0.00	0.0169		5-Year
75	7.255546	125.651721	0.1	0.00	0.0100		5-Year
76	7.250857	125.649974	0.03	0.00	0.0009		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
77	7.248217	125.653398	0.03	0.30	0.0729	Buhawi/ 1997	5-Year
78	7.262970	125.664796	0.19	0.50	0.0961	Upstream rainfall/ 2015	5-Year
79	7.262830	125.657737	0.63	0.00	0.3969		5-Year
80	7.261978	125.664428	0.29	0.00	0.0841		5-Year
81	7.259158	125.652195	0.59	1.30	0.5041	Intense local rainfall/ November 2013	5-Year
82	7.252574	125.649984	0.38	0.50	0.0144	Intense local rainfall/ 2015	5-Year
83	7.252123	125.649801	0.45	0.50	0.0025	Intense local rainfall/ 2015	5-Year
84	7.268857	125.662478	1.78	0.85	0.8649	Intense local rainfall/ 1996	5-Year
85	7.267950	125.663015	1.86	0.85	1.0201	Intense local rainfall/ 1998	5-Year
86	7.267136	125.663101	1.84	0.85	0.9801	Intense local rainfall/ 1980s	5-Year
87	7.266861	125.663733	1.78	0.55	1.5129	Upstream rainfall/ 2000	5-Year
88	7.266234	125.662824	1.84	0.50	1.7956	Yolanda/ November 8, 2013	5-Year
89	7.261534	125.663068	1.6	2.75	1.3225	Intense local rainfall/ 2013	5-Year
90	7.259006	125.662601	1.6	0.50	1.2100	Intense local rainfall/ 2014	5-Year
91	7.313439	125.641563	0.03	0.00	0.0009		5-Year
92	7.312203	125.636578	0.04	0.00	0.0016		5-Year
93	7.302138	125.657878	0.03	0.00	0.0009		5-Year
94	7.298495	125.647267	0.06	0.20	0.0196	Intense local rainfall/ 2013	5-Year
95	7.298039	125.648079	0.03	0.00	0.0009		5-Year
96	7.306568	125.642066	0.08	0.00	0.0064		5-Year
97	7.297303	125.650156	0.03	0.00	0.0009		5-Year
98	7.297138	125.647621	0.13	0.30	0.0289	Intense local rainfall/ October 2015	5-Year
99	7.301466	125.633800	0.53	0.00	0.2809		5-Year
100	7.300207	125.632616	0.47	0.30	0.0289	Intense local rainfall/ 2015	5-Year
101	7.299762	125.631437	0.83	0.50	0.1089	Intense local rainfall/ October 2015	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
102	7.308319	125.667055	0.03	0.10	0.0049	Intense local rainfall/ 2009	5-Year
103	7.321344	125.649484	0.08	0.30	0.0484	Intense local rainfall/ July 2014	5-Year
104	7.321177	125.647220	0.07	0.30	0.0529	Upstream rainfall/ 1990s	5-Year
105	7.314806	125.654875	0.06	0.00	0.0036		5-Year
106	7.306689	125.667498	0.04	0.00	0.0016		5-Year
107	7.304340	125.667574	0.06	0.00	0.0036		5-Year
108	7.302984	125.667657	0.05	0.30	0.0625	Intense local rainfall/ November 2015	5-Year
109	7.300815	125.667644	0.04	0.00	0.0016		5-Year
110	7.313798	125.657223	0.21	0.10	0.0121	Intense local rainfall/ 2009	5-Year
111	7.312069	125.659294	0.26	0.00	0.0676		5-Year
112	7.308653	125.656378	0.14	0.00	0.0196		5-Year
113	7.316257	125.653979	0.55	0.10	0.2025	Intense local rainfall/ 2009	5-Year
114	7.314375	125.651434	0.66	0.00	0.4356		5-Year
115	7.312518	125.659840	0.68	0.00	0.4624		5-Year
116	7.309108	125.655747	0.33	1.00	0.4489	Intense local rainfall/ 2013	5-Year
117	7.308385	125.655743	1.43	0.00	2.0449		5-Year
118	7.300238	125.658228	0.03	0.00	0.0009		5-Year
119	7.298052	125.661112	0.03	0.00	0.0009		5-Year
120	7.298105	125.667447	0.41	0.00	0.1681		5-Year
121	7.298027	125.665456	0.43	0.00	0.1849		5-Year
122	7.293635	125.659275	0.36	0.00	0.1296		5-Year
123	7.288682	125.656350	0.23	0.00	0.0529		5-Year
124	7.296223	125.664902	0.58	0.00	0.3364		5-Year
125	7.294539	125.659281	1.01	0.00	1.0201		5-Year
126	7.293089	125.659906	0.83	0.00	0.6889		5-Year
127	7.285592	125.659500	1.32	0.00	1.7424		5-Year
128	7.298158	125.658578	1.89	0.00	3.5721		5-Year
129	7.295252	125.660914	1.54	0.00	2.3716		5-Year
130	7.294057	125.664437	1.65	0.00	2.7225		5-Year
131	7.292907	125.660176	1.53	0.00	2.3409		5-Year
132	7.289828	125.661244	2.86	0.50	5.5696	Typhoon/ December 2012	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
133	7.285971	125.656515	4.41	5.20	0.6241	Intense local rainfall/ 2013	5-Year
134	7.285879	125.656696	4.75	2.30	6.0025	Intense local rainfall/ 2013	5-Year
135	7.285791	125.656333	4.39	5.20	0.6561	Intense local rainfall/ 2013	5-Year
136	7.285517	125.656875	4.3	5.10	0.6400	Intense local rainfall/ 2013	5-Year
137	7.284973	125.657052	4.2	5.10	0.8100	Intense local rainfall/ 2013	5-Year
138	7.296287	125.654042	2.16	0.50	2.7556	Low pressure area/ June 2012	5-Year
139	7.300238	125.658228	0.03	0.00	0.0009		5-Year
140	7.298052	125.661112	0.03	0.00	0.0009		5-Year
141	7.298105	125.667447	0.41	0.00	0.1681		5-Year
142	7.298027	125.665456	0.43	0.00	0.1849		5-Year
143	7.293635	125.659275	0.36	0.00	0.1296		5-Year
144	7.288682	125.656350	0.23	0.00	0.0529		5-Year
145	7.296223	125.664902	0.58	0.00	0.3364		5-Year
146	7.294539	125.659281	1.01	0.00	1.0201		5-Year
147	7.293089	125.659906	0.83	0.00	0.6889		5-Year
148	7.285592	125.659500	1.32	0.00	1.7424		5-Year
149	7.298158	125.658578	1.89	0.00	3.5721		5-Year
150	7.295252	125.660914	1.54	0.00	2.3716		5-Year
151	7.294057	125.664437	1.65	0.00	2.7225		5-Year
152	7.292907	125.660176	1.53	0.00	2.3409		5-Year
153	7.289828	125.661244	2.86	0.50	5.5696	Typhoon/ December 2012	5-Year
154	7.285971	125.656515	4.41	5.20	0.6241	Intense local rainfall/ 2013	5-Year
155	7.285879	125.656696	4.75	2.30	6.0025	Intense local rainfall/ 2013	5-Year
156	7.285791	125.656333	4.39	5.20	0.6561	Intense local rainfall/ 2013	5-Year
157	7.285517	125.656875	4.3	5.10	0.6400	Intense local rainfall/ 2013	5-Year
158	7.284973	125.657052	4.2	5.10	0.8100	Intense local rainfall/ 2013	5-Year
159	7.296287	125.654042	2.16	0.50	2.7556	Low pressure area/ June 2012	5-Year
160	7.308319	125.667055	0.03	0.10	0.0049	Intense local rainfall/ 2009	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
161	7.321344	125.649484	0.08	0.30	0.0484	Intense local rainfall/ July 2014	5-Year
162	7.321177	125.647220	0.07	0.30	0.0529	Upstream rainfall/ 1990s	5-Year
163	7.314806	125.654875	0.06	0.00	0.0036		5-Year
164	7.306689	125.667498	0.04	0.00	0.0016		5-Year
165	7.304340	125.667574	0.06	0.00	0.0036		5-Year
166	7.302984	125.667657	0.05	0.30	0.0625	Intense local rainfall/ November 2015	5-Year
167	7.300815	125.667644	0.04	0.00	0.0016		5-Year
168	7.313798	125.657223	0.21	0.10	0.0121	Intense local rainfall/ 2009	5-Year
169	7.312069	125.659294	0.26	0.00	0.0676		5-Year
170	7.308653	125.656378	0.14	0.00	0.0196		5-Year
171	7.316257	125.653979	0.55	0.10	0.2025	Intense local rainfall/ 2009	5-Year
172	7.314375	125.651434	0.66	0.00	0.4356		5-Year
173	7.312518	125.659840	0.68	0.00	0.4624		5-Year
174	7.309108	125.655747	0.33	1.00	0.4489	Intense local rainfall/ 2013	5-Year
175	7.308385	125.655743	1.43	0.00	2.0449		5-Year
176	7.291546	125.645688	0.05	0.00	0.0025		5-Year
177	7.287872	125.640417	0.03	0.00	0.0009		5-Year
178	7.280995	125.642097	0.06	0.20	0.0196	Intense local rainfall/ October 2015	5-Year
179	7.278241	125.649320	0.03	0.00	0.0009		5-Year
180	7.272394	125.644761	0.07	0.00	0.0049		5-Year
181	7.294426	125.647787	0.12	0.00	0.0144		5-Year
182	7.293894	125.646064	0.03	0.00	0.0009		5-Year
183	7.291984	125.648044	0.18	0.00	0.0324		5-Year
184	7.290278	125.646314	0.06	0.10	0.0016	Intense local rainfall/ 2015	5-Year
185	7.288778	125.639970	0.12	0.20	0.0064	Intense local rainfall/ 2014	5-Year
186	7.287449	125.651003	0.05	0.00	0.0025		5-Year
187	7.286832	125.648375	0.11	0.50	0.1521	Intense local rainfall/ January 2012	5-Year
188	7.286604	125.640863	0.1	0.10	0.0000	Intense local rainfall/ 2015	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
189	7.285328	125.642846	0.24	0.30	0.0036	Intense local rainfall/ August 2014	5-Year
190	7.282153	125.644909	0.28	0.00	0.0784		5-Year
191	7.279544	125.642903	0.18	0.00	0.0324		5-Year
192	7.293894	125.645973	1.67	0.00	2.7889		5-Year
193	7.289794	125.651651	3.75	5.10	1.8225	Intense local rainfall/ 2014	5-Year
194	7.289793	125.651922	3.97	5.00	1.0609	Intense local rainfall/ 2014	5-Year
195	7.289792	125.652013	4.47	5.30	0.6889	Intense local rainfall/ May 2014	5-Year
196	7.288976	125.652460	4.31	5.20	0.7921	Intense local rainfall/ May 2014	5-Year
197	7.288705	125.652459	4.61	5.30	0.4761	Intense local rainfall/ 2014	5-Year
198	7.288252	125.652637	3.88	5.00	1.2544	Intense local rainfall/ 2014	5-Year
199	7.288158	125.653270	3.92	5.10	1.3924	Intense local rainfall/ 2015	5-Year
200	7.287523	125.653719	3.91	5.10	1.4161	Intense local rainfall/ May 2014	5-Year
201	7.287342	125.653808	3.91	5.20	1.6641	Intense local rainfall/ 2013	5-Year
202	7.287157	125.654531	4.04	5.10	1.1236	Intense local rainfall/ 2013	5-Year
203	7.287155	125.654803	4.02	5.30	1.6384	Intense local rainfall/ 2013	5-Year
204	7.286704	125.654800	5.04	5.50	0.2116	Intense local rainfall/ May 2014	5-Year
205	7.286530	125.653623	3.48	5.00	2.3104	Intense local rainfall/ May 2014	5-Year
206	7.286434	125.654618	4.18	5.30	1.2544	Intense local rainfall/ May 2014	5-Year
207	7.286431	125.654979	4.81	5.60	0.6241	Intense local rainfall/ 2015	5-Year
208	7.286249	125.655340	3.79	5.10	1.7161	Intense local rainfall/ 2014	5-Year
209	7.286081	125.653077	4.58	5.50	0.8464	Intense local rainfall/ September 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
210	7.285704	125.655699	4.19	5.20	1.0201	Intense local rainfall/ 2013	5-Year
211	7.284431	125.657140	4.73	5.20	0.2209	Intense local rainfall/ May 2014	5-Year
212	7.284250	125.657139	4.27	4.80	0.2809	Intense local rainfall/ 2015	5-Year
213	7.283889	125.657046	5.15	5.30	0.0225	Intense local rainfall/ 2013	5-Year
214	7.283708	125.657045	5.31	5.50	0.0361	Intense local rainfall/ September 2015	5-Year
215	7.283616	125.657316	5.83	5.60	0.0529	Intense local rainfall/ 2015	5-Year
216	7.283434	125.657677	4.47	5.00	0.2809	Intense local rainfall/ May 2014	5-Year
217	7.283161	125.657947	4.77	5.20	0.1849	Intense local rainfall/ 2014	5-Year
				RMSE	0.810185		

Annex 12. Educational Institutions Affected by Flooding in Lasang Floodplain

DAVAO DEL NORTE				
PANABO CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
KAUSWAGAN NATIONAL HIGHSCHOOL	Buenavista			
DAY CARE CENTER	Little Panay		Low	Medium
KATIPUNAN COVERED COURT	Little Panay			
KATIPUNAN DAYCARE CENTER	Little Panay			
KATIPUNAN ELEMENTARY SCHOOL	Little Panay			
LITTLE PANAY ELEMENTARY SCHOOL	Little Panay	Low	Medium	Medium
LITTLE PANAY HIGH SCHOOL	Little Panay			Low
ARABIC SCHOOL	Sindaton			Low
DATU ABDUL DADIA DAY CARE CENTER	Sindaton	Medium	Medium	Medium
DATU ABDUL DADIA ELEMENTARY SCHOOL	Sindaton	Medium	Medium	Medium
DAVAO ARABIC ACADEMY	Sindaton	Low	Medium	Medium
KINDER ARABIC SCHOOL	Sindaton		Low	Medium
MA'HAD ADMINISTRATION OFFICE	Sindaton		Low	Low
NEW VISAYAS ELEMENTARY SCHOOL	Sindaton		Low	Medium
TAHDERIYYAH LEARNING CENTER	Sindaton	Low	Medium	Medium
MADULIN DAY CARE CENTER	Tagpore			
NARCISO B. GALAPIN ELEMENTARY SCHOOL	Tagpore	Low	Low	Medium
SAMOWAG ELEMENTARY SCHOOL	Upper Licanan			

DAVAO DEL SUR				
DAVAO CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
A.L NAVARO ELEMENTARY SCHOOL	Alejandra Navarro			Low
ALEDIA ELEMENTARY SCHOOL	Alejandra Navarro	Low	Low	Medium
GABRIEL TABORIN	Alejandra Navarro			Low
GABRIEL TABORIN GYM	Alejandra Navarro	Medium	Medium	Medium
ST. ANNE LEARNING CENTER	Alejandra Navarro	Medium	Medium	High
TAMBONGON ELEMENTARY SCHOOL	Alejandra Navarro	Medium	Medium	High
A.L NAVARO ELEMENTARY SCHOOL	Vicente Hizon Sr.	Low	Low	Medium
ALTERNATIVE LEARNING SYSTEM	Vicente Hizon Sr.	Low	Medium	Medium
CANGANGOHAN DAY CARE CENTER	Vicente Hizon Sr.	Medium	Medium	High

Annex 13. Health Institutions Affected by Flooding in Lasang Floodplain

DAVAO DEL NORTE				
PANABO CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
KAUSWAGAN HEALTH CARE CENTER	Buenavista			
HEALTH CENTER	Little Panay			Low
KATIPUNAN HEALTH CENTER	Little Panay			Low
BARANGAY HEALTH CENTER	Sindaton		Low	Medium
BARANGAY HEATH CENTER	Sindaton	Low	Medium	Medium
HEALTH CENTER	Upper Licanan			

DAVAO DEL NORTE				
PANABO CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BUENAVENTURA MEDICAL	Alejandra Navarro	Low	Medium	Medium
BARANGAY HEALTH STATION	Vicente Hizon Sr.	Low	Medium	Medium
J.P LAUREL HEALTH CENTER	Vicente Hizon Sr.	Medium	High	High