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

LiDAR Surveys and Flood Mapping of Ogod River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
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For questions/queries regarding this report, contact:

Ms. Joanaviva C. Plopenio
Project Leader, Phil-LiDAR 1 Program
Ateneo de Naga University
Naga City, Philippines 4400
E-mail: inecar@gbox.adnu.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND OGOD RIVER

Enrico C. Paringit, Dr. Eng., Ms. Joanaviva C. Plopenio, and Engr. Ferdinand Bien

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The 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 Ateneo de Naga University (ADNU). ADNU 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 24 river basins in the Bicol Region. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Ogod River Basin

The Ogod River Basin has a drainage area of 122 km2 and an estimated annual run-off of 165 MCM (million cubic meters) according to the Department of Environment and Natural Resources – River Basin Control Office (DENR – RBCO). The river basin covers the municipalities of Daraga in Albay, Jovellar, Pilar and Donsol, all in the province of Sorsogon.

Its main stem, Ogod River, is part of the 24 river systems in Bicol Region. It is one of the major rivers found in Donsol that drains near the municipality of Pilar and is considered as one of the arteries of the larger Donsol River which is rich in vegetation and mangrove plantation, and has a suitable temperature for firefly habitation. This river is famous for its ecotourism such as firefly watching, and plankton luminescence river tours. The headwater of this river system extends northwards into the province of Albay and it drains at the Burias Pass.

Aside from the swelling of the river during heavy rains, the Municipality of Pilar is also listed as a landslide prone area by the Mines and Geosciences Bureau (MGB). An estimated population of 15, 569 people living near the Ogod river is at risk because of these hazards.

This river basin is found in Albay and Sorsogon provinces. The major stream that drains the Ogod River Basin is named Donsol River. This is spanned by the Dancalan Bridge. This is also the river where firefly watching occurs. The total length of the river is around 100 km. The river empties out to the northern part of the Ticao Pass. The northeast part of the RB is bound by Mayon Volcano. The rest of the area surrounding the RB is the same rolling and hilly topography. The various municipalities (with corresponding population) with jurisdiction over the river basin includes four (4) first class municipalities: Gionobatan (82,361 last 2015 census), Camalig (66,904 last 2015 census), Daraga (126,595 last 2015 census) and Oas (67,960 last 2015 census); there are two (2) third class municipalities: Donsol (47,563 last 2010 census) and Pio Duran (46,693 last 2015 census) one (1) fourth class municipality: Jovellar (17, 308 last 2015 census) and one (1) component city: Ligao City (111,399 last 2015 census).

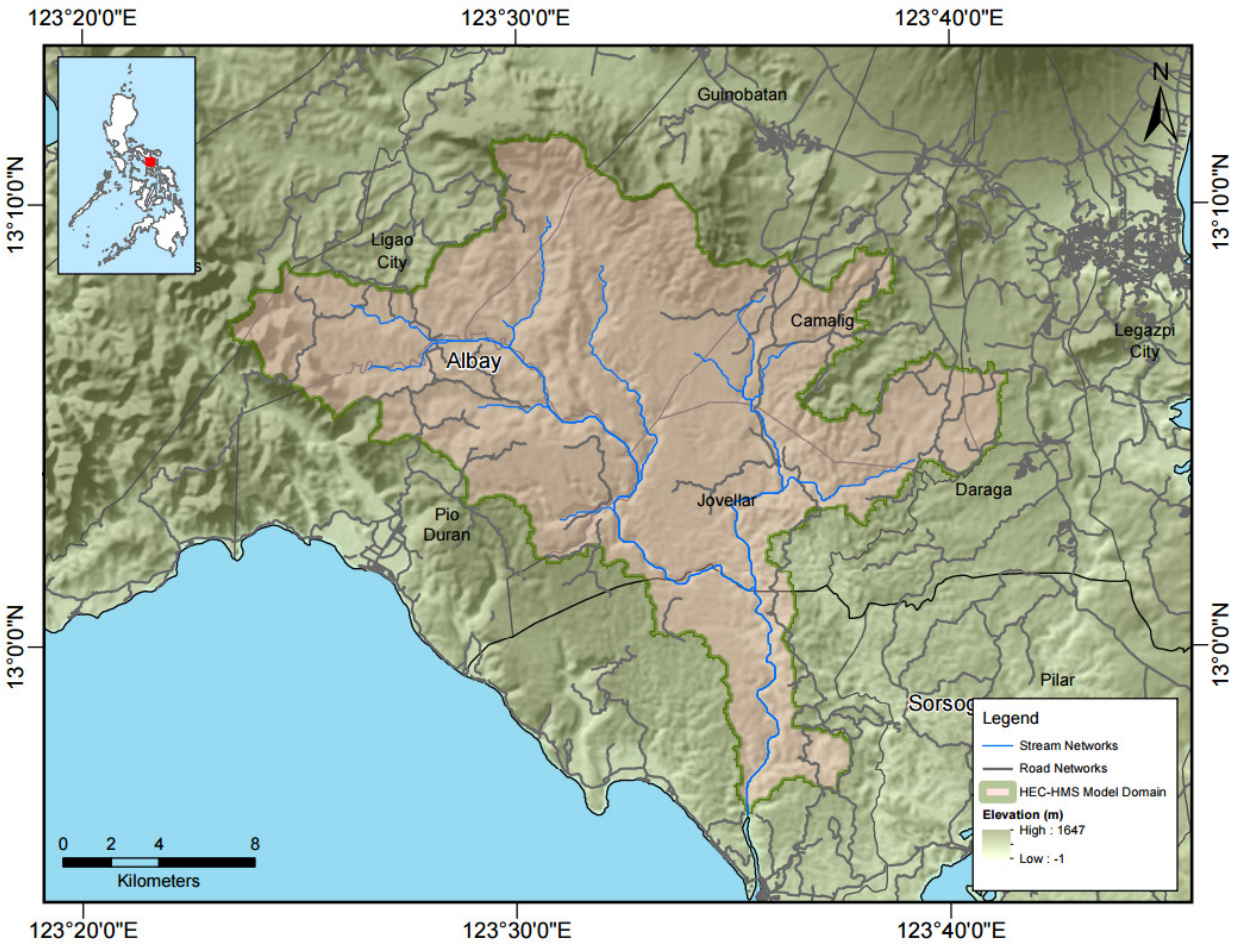


Figure 1. Map of Ogod River Basin (in brown)

The RB is located in the southwestern area of mainland Bicol Region and experiences type III of the modified Corona classification of climate where it is dry during the November-April months and wet the remaining months. The river is also important in terms of environmental state of the area since whale sharks are known to frequent the sea where Donsol River empties. Major land use upstream is basically brushland and grassland usually interspersed with small scale agricultural use. Upland pollutants caused by poor land use may cause adverse impact on the whale sharks.

Donsol promotes tourism as major source of income due to whale shark interaction and firefly watching activities for tourists. The area is also highly agricultural with coconut and root crops as major products. Donsol is also a fishing town. The nearby town of Jovellar also boasts of an underground river and cave system which also draws tourists.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE OGOD FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuna, Engr. Gerome Hipolito, For. Ma. Verlina Tonga, and Jasmine Alviar

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Ogod Floodplain in Albay, Camarines Sur and Sorsogon. These missions were planned for 20 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Ogod floodplain.

Table 1. Flight planning parameters for Gemini LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK19A	1000	30	50	125	50	130	5
BLK19C	1000	30	50	125	50	130	5
BLK19D	1000	30	50	125	50	130	5
	750	40	50	125	40	130	5
BLK19E	1000	30	50	125	50	130	5
BLK19F	1000	30	50	125	50	130	5
	650	30	40	125	50	130	5
BLK19G	1000	30	50	125	50	130	5
BLK19H	1000	30	50	125	50	130	5
BLK19I	1000	30	50	125	50	130	5
BLK19J	1000	30	50	125	50	130	5
BLK19K	1000	30	50	125	50	130	5
BLK19L	1000	30	50	125	50	130	5
BLK19M	1000	30	50	125	50	130	5
BLK19N	1000	30	50	125	50	130	5
BLK19O	1000	30	50	125	50	130	5
BLK19P	1000	30	50	125	50	130	5

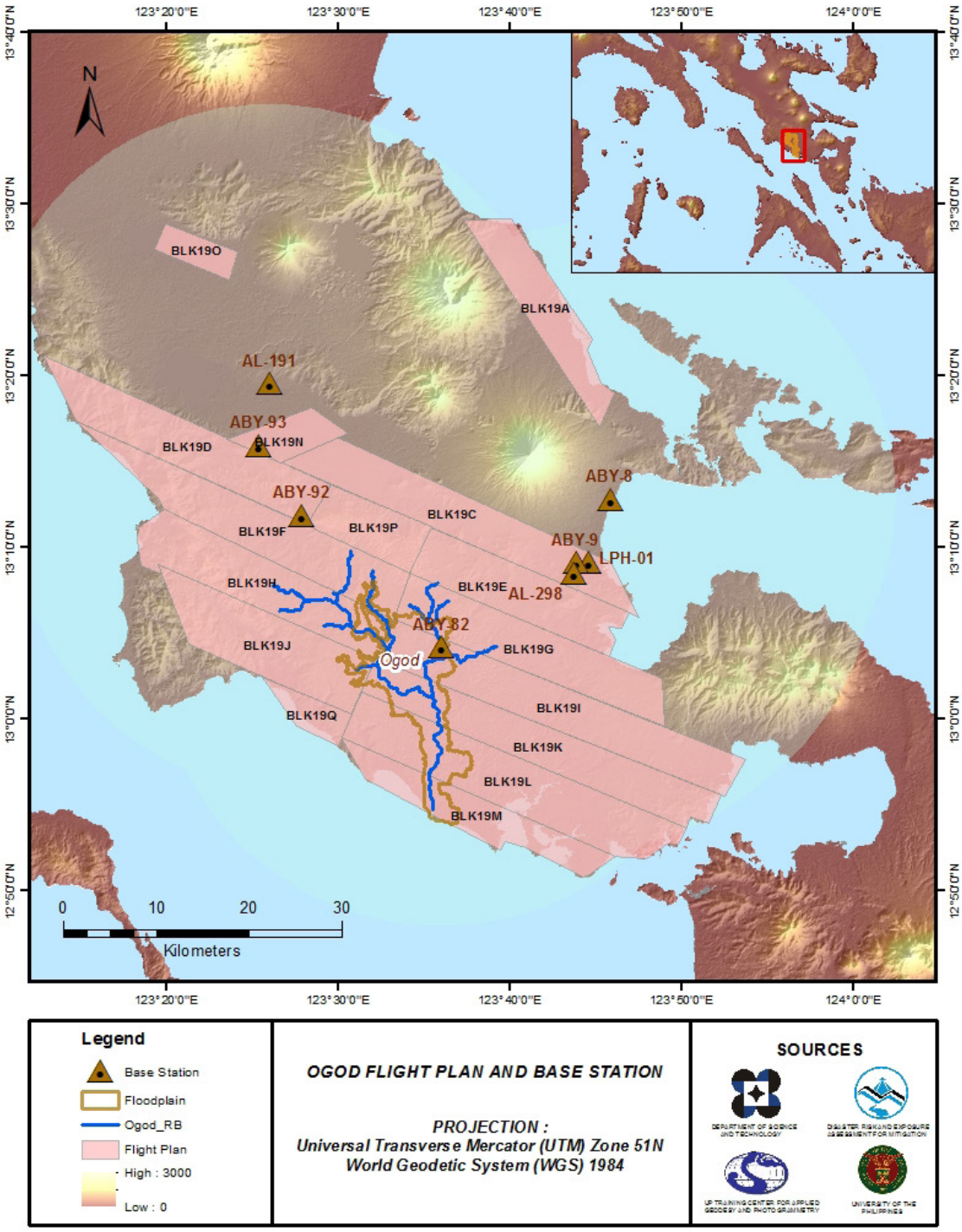


Figure 2. Flight plan and base stations used for Ogod floodplain.

2.2 Ground Base Stations

The project team was able to recover four (4) NAMRIA horizontal ground control points of second (2nd) order accuracy, ABY-92, ABY-8, ABY-93 and ABY-82 and one (1) of third (3rd) order accuracy, ABY-9. Two (2) NAMRIA benchmarks were recovered: AL-298 and AL-191 which are of second (2nd) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. One (1) ground control point, LPH-1, was also established to cover areas that are not within 30km from the NAMRIA control points. The certification for the base station is found in Annex 2 while the baseline processing reports for established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (March 26 – April 30, 2014 and February 24 – March 20, 2016) especially on the days that flight missions were conducted. Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 882, SPS 985 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ogod floodplain are shown in Figure 2.

Figure 3 to Figure 10 show the recovered NAMRIA reference points within the area, in addition Table 2 to Table 9 show the details about the following NAMRIA control stations and established points, Table 10 shows the list of all ground control points occupied during the acquisition with the corresponding dates of survey.

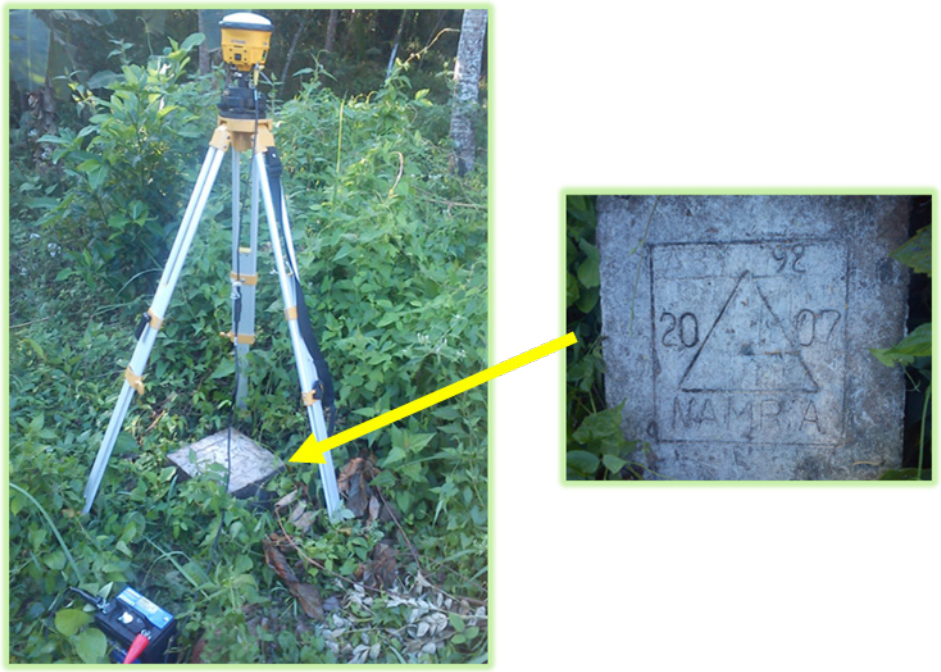


Figure 3. GPS set-up over ABY-92 beside the baseline of the basketball court at about 19 meters from the barangay hall (a) and NAMRIA reference point ABY-92 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ABY-92 used as base station for the LiDAR data acquisition.

Station Name	ABY-92	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 11’ 56.27238” North
	Longitude	123° 27’ 47.60156” East
	Ellipsoidal Height	127.30900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	550193.31 meters
	Northing	1459094.57 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 11’ 51.38974” North
	Longitude	123° 27’ 52.59990” East
	Ellipsoidal Height	180.74900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	550193.31 meters
	Northing	1459094.57 meters

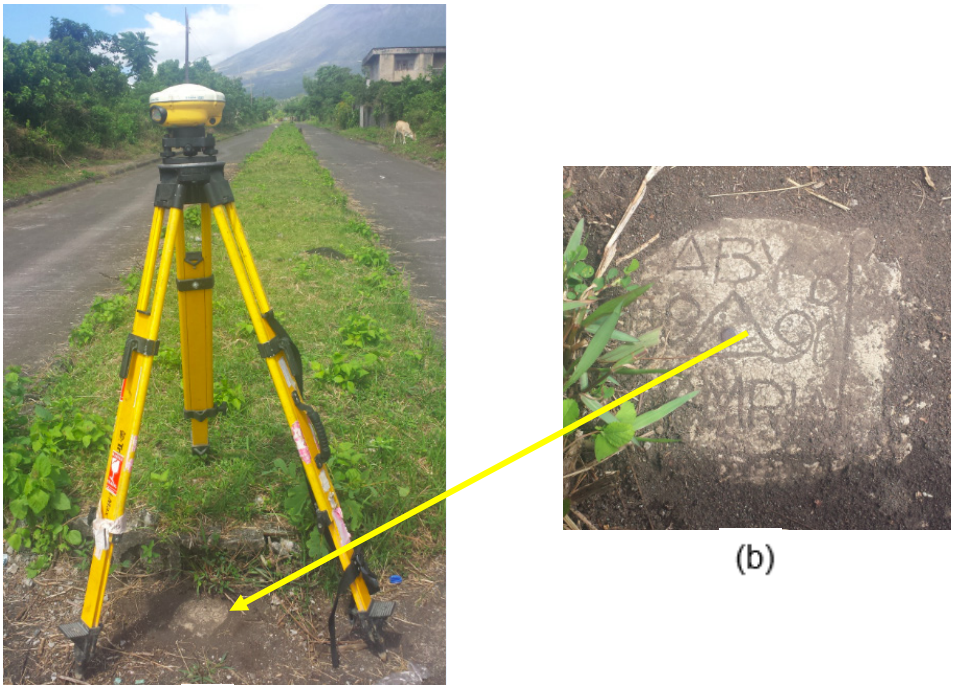


Figure 4. GPS set-up over ABY-8 at the center of the island of Mayon Riviera Subdivision. Highest prominent mark is the electric timber post 9.50 meters SE of the station (a) and NAMRIA reference point ABY-8 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ABY-8 used as base station for the LiDAR data acquisition.

Station Name	ABY-8	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 12’ 51.92876” North
	Longitude	123° 45’ 45.95336” East
	Ellipsoidal Height	6.33900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	582646.93 meters
	Northing	1460883.61 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 12’ 47.06720” North
	Longitude	123° 45’ 50.94829” East
	Ellipsoidal Height	60.47000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	582646.93 meters
	Northing	1460883.61 meters

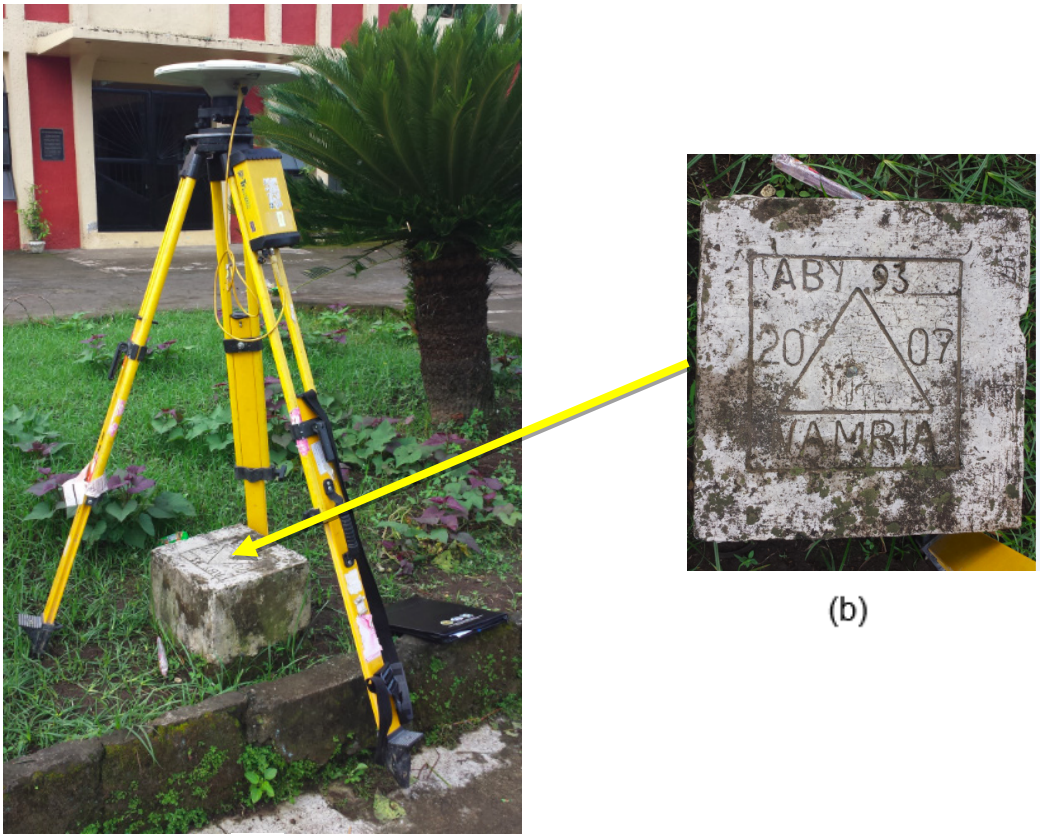


Figure 5. GPS set-up over ABY-93 in front of Burabod Chapel (about 10 m) beside Burabod basketball court in Libon Town proper (a) and NAMRIA reference point ABY-93 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ABY-93 used as base station for the LiDAR data acquisition.

Station Name	ABY-93	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 16' 0.55893" North
	Longitude	123° 25' 14.84177" East
	Ellipsoidal Height	19.22500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	545598.649 meters
	Northing	1467103.957 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 15' 55.65621" North
	Longitude	123° 25' 19.83465" East
	Ellipsoidal Height	72.37800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	545582.69 meters
	Northing	1466590.45 meters

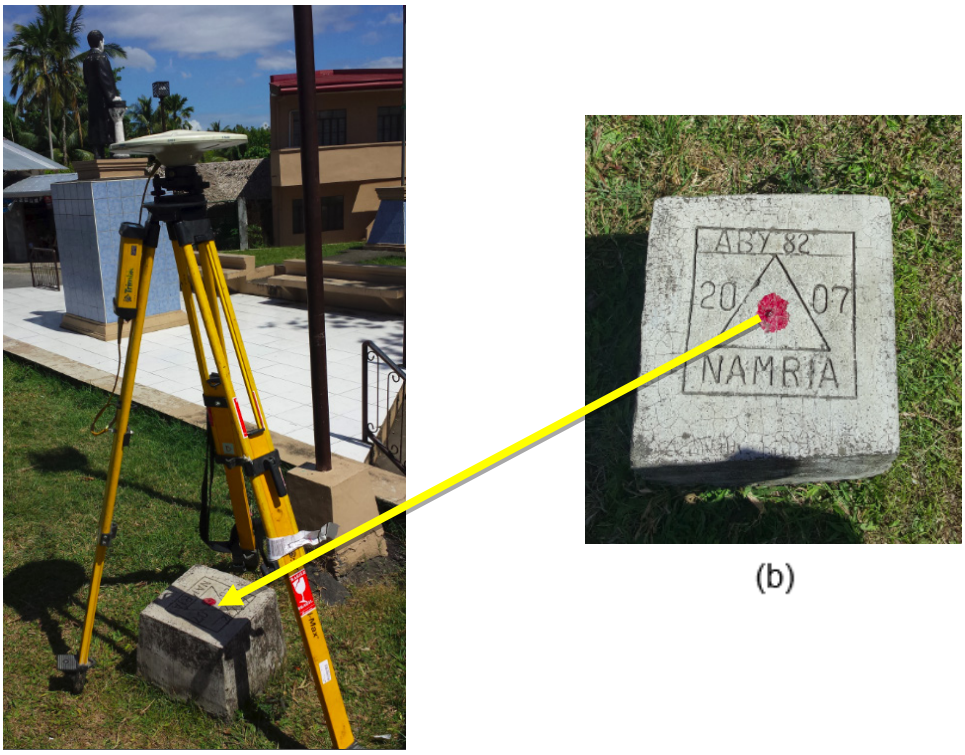


Figure 6. GPS set-up over ABY-82 at the from the right corner (about 12 m) of the Rizal monument in front of Jovellar Catholic Church and 12 meters from the road centerline (a) and NAMRIA reference point ABY-82 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ABY-82 used as base station for the LiDAR data acquisition.

Station Name	ABY-82	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 4' 16.27314" North
	Longitude	123° 35' 53.17428" East
	Ellipsoidal Height	39.77600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	564865.27 meters
	Northing	1445500.97 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 4' 11.43271" North
	Longitude	123° 35' 58.18268" East
	Ellipsoidal Height	93.89000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	564, 842.57 meters
	Northing	1,444,995.02 meters

Figure 7. GPS set-up over ABY-9 inside Legaspi Airport Compound 52.0 meters SE of Legaspi Airport Flagpole, 35 meters NE of Legaspi Airport Welcome Post 3.30 meters NW of Lamp (a) and NAMRIA reference point ABY-9 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point ABY-9 used as base station for the LiDAR data acquisition.

Station Name	ABY-9	
Order of Accuracy	3rd Order	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 9' 11.38733" North
	Longitude	123° 43' 45.95874" East
	Ellipsoidal Height	14.54010 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	579082.538 meters
	Northing	1454607.115 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 9' 6.53800" North
	Longitude	123° 43' 50.95900" East
	Ellipsoidal Height	68.754 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	579054.86 meters
	Northing	1454097.98 meters

Figure 8. GPS set-up over AL-289 at the south west end of Sagpon Bridge at KM 528+166 and about 4.8 meters SW of the centerline of the road, along the Legazpi-Daraga national road (a) and NAMRIA benchmark AL-289 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA benchmark AL-298 used as vertical reference point and established base station for the LiDAR data acquisition.

Station Name	AL-298	
Order of Accuracy (benchmark)	2nd Order	
Elevation (Mean Sea Level)	11.6955 meters	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 08' 30.79294" North
	Longitude	123° 45' 43.86268" East
	Ellipsoidal Height	65.914 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 08' 30.79294" North
	Longitude	123° 43' 43.86268" East
	Ellipsoidal Height	65.914 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	578994.349 meters
	Northing	1452940.789 meters

Figure 9. GPS set-up over AL-191 along the Albay-Sorsogon National road at the edge of the center island at about 5 meters south of the centerline of the road (a) and NAMRIA benchmark AL-191 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA benchmark AL-191 used as vertical reference point and established base station for the LiDAR data acquisition.

Station Name	AL-191	
Order of Accuracy	2nd Order	
Elevation	17.5055	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 19' 36.00214" North
	Longitude	123° 25' 55.27136" East
	Ellipsoidal Height	19.069 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 19' 31.08584" North
	Longitude	123° 26' 00.25899" East
	Ellipsoidal Height	72.087 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	546787.787 meters
	Northing	1473210.531 meters

(a)

Figure 10. GPS set-up over LPH-01 the rooftop a building at La Piazza Hotel and Convention Center located at Tahao Road, Legazpi, Albay (a) as established by the field team.

Table 9. Details of established ground control point LPH-01 used as base station for the LiDAR data acquisition.

Station Name	LPH-01	
Order of Accuracy	3rd Order	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 09' 08.50554" North
	Longitude	123° 44' 32.88949" East
	Ellipsoidal Height	65.236 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 09' 08.50554" North
	Longitude	123° 44' 32.88949" East
	Ellipsoidal Height	65.236 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	580467.016 meters
	Northing	1454103.670 meters

Table 10. Ground Control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
03-29-14	7156GC	2BLK19E088A	ABY-9, LPH-01
03-30-14	7158GC	2BLK19ES089A & 2BLK19G089A	ABY-9, LPH-01
03-31-14	7160GC	2BLK19I90A	ABY-9, LPH-01
03-31-14	7161GC	2BLK19IS090B	ABY-9, LPH-01
04-03-14	7167GC	2BLK19K093A & 2BLK10IS093A	ABY-9, LPH-01
04-04-14	7168GC	2BLK19L094A	ABY-9, LPH-01
04-05-14	7171GC	2BLK19M095A	ABY-92, LPH-01
04-06-14	7172GC	2BLK19CS096A & 2BLK19D096A	ABY-92, LPH-01
04-07-14	7174GC	2BLK19F097A	ABY-92, AL-298
04-07-14	7175GC	2BLK19H097B	ABY-92, LPH-01
04-08-14	7176GC	2BLK19HS098A	ABY-9, ABY-92
04-12-14	7184GC	2BLK19J102A	ABY-92
04-20-14	7200GC	2BLK19JS110A & 2BLK19N110A	ABY-8, ABY-92
04-22-14	7204GC	2BLK19A112A	ABY-8, ABY-92
04-26-14	7212GC	2BLK19P116A & 2BLK190116A	ABY-8, ABY-9, ABY-92
04-26-14	7213GC	2BLK19OS116B & VOIDS	ABY-8, ABY-9, ABY-92
04-28-14	7216GC	2BLK19AS118A & VOIDS	ABY-8, ABY-9
02-28-16	3825G	2BLK19JFS059B	ABY-82
02-29-16	3829G	2BLK19FS060B	ABY8, ABY-9, ABY-82
03-04-16	3843G	2BLK19DS064A	ABY-93, AL-191

2.3 Flight Missions

Twenty (20) missions were conducted to complete the LiDAR data acquisition in Ogod floodplain, for a total of sixty three hours and forty eight minutes (63+48) of flying time for RP-C9322 and RP-C9022. All missions were acquired using the Gemini LiDAR system. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for LiDAR data acquisition in Ogod floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within Floodplain (km2)	Area Surveyed Outside Flood-plain (km2)	Flying Hours	
						Hr	Min
03-29-14	7156GC	106.73	40.41	-	40.41	2	11
03-30-14	7158GC	241.81	282.19	7.83	274.36	4	29
03-31-14	7160GC	171.14	19.42	3.48	15.94	1	35
03-31-14	7161GC	171.14	138.71	25.38	113.33	2	29
04-03-14	7167GC	179.98	247.35	43.12	204.23	3	53
04-04-14	7168GC	171.15	229.12	24.24	204.88	3	29
04-05-14	7171GC	75.70	119.2	11	108.2	2	59
04-06-14	7172GC	301.96	274.32	-	274.32	4	35
04-07-14	7174GC	142.51	207.35	3.08	204.27	3	29
04-07-14	7175GC	144.01	121.07	10.64	110.43	2	35
04-08-14	7176GC	144.01	45.93	0.84	45.09	1	41
04-12-14	7184GC	142.22	90.72	6.71	84.01	2	23
04-20-14	7200GC	295.56	180.65	0.78	179.87	4	5
04-22-14	7204GC	238.37	129.43	-	129.43	3	41
4-26-14	7212GC	57.43	101.47	-	101.47	4	11
4-26-14	7213GC	24.27	94.15	5.71	88.44	2	35
4-28-14	7216GC	122.54	135.24	9.31	125.93	3	11
02-28-16	3825G	100.44	91.04	15.46	75.58	3	11
02-29-16	3829G	67.93	78.19	6.11	72.08	2	17
03-04-16	3843G	157.73	195.1	-	195.1	4	30
TOTAL		3056.63	2821.06	173.69	2647.37	63	48

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)
7156GC	1100	35	40	100	50	130	5
7158GC	1100	35	40	100	50	130	5
7160GC	1000	45	40	100	50	130	5
7161GC	1000	45	40	100	50	130	5
7167GC	1000	40	40	100	50	130	5
7168GC	1100	40	40	100	50	130	5
7171GC	900	20	40	100	50	130	5
7172GC	1100	50	40	100	50	130	5
7174GC	1300	30	34	100	50	130	5
7175GC	1100	50	40	100	50	130	5
7176GC	1300	35	34	100	50	130	5
7184GC	1300	30	34	100	50	130	5
7200GC	1300	50	40	100	50	130	5
7204GC	1300	40	34	100	50	130	5
7212GC	1300	50	34 and 40	100	50	130	5
7213GC	1100	30	40	100	50	130	5
7216GC	1300	50	34 and 40	100	50	130	5
3825G	650	40	50	125	40	130	5
3829G	750	40	50	125	40	130	5
3843G	750	40	50	125	40	130	5

2.4 Survey Coverage

Ogod Floodplain is located in the provinces of Albay, Camarines Sur and Sorsogon with majority of the floodplain situated within the municipalities of Albay. 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 Ogod floodplain is presented in Figure 11.

Table 13. List of municipalities and cities surveyed during Ogod floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Albay	Jovellar	82.35	82.35	100%
	Pio Duran	133.24	132.56	99%
	Camalig	136.54	118.64	87%
	Daraga	135.66	117.03	86%
	Libon	222.82	180.64	81%
	Guinobatan	174.07	141.07	81%
	Legazpi City	153.18	110.98	72%
	Oas	239.58	171.05	71%
	Ligao City	258.51	168.52	65%
	Malilipot	45.42	16.83	37%
	Tiwi	124.4	40.47	33%
	Malinao	106.78	33.94	32%
	Tabaco City	112.24	16.03	14%
	Polangui	148.89	19.5	13%
	Bacacay	115.2	8.15	7%
	Santo Domingo	60.83	3.22	5%
Camarines Sur	Bato	75.94	39.71	52%
	Balatan	59.84	23.07	39%
Sorsogon	Baao	106.5	30.66	29%
	Iriga City	130.05	4.22	3%
	Nabua	96.61	2.78	3%
	Donsol	153	153	100%
	Pilar	196.62	196.22	100%
	Castilla	197.27	159.29	81%
	TOTAL	3265.54	1969.93	60.32%

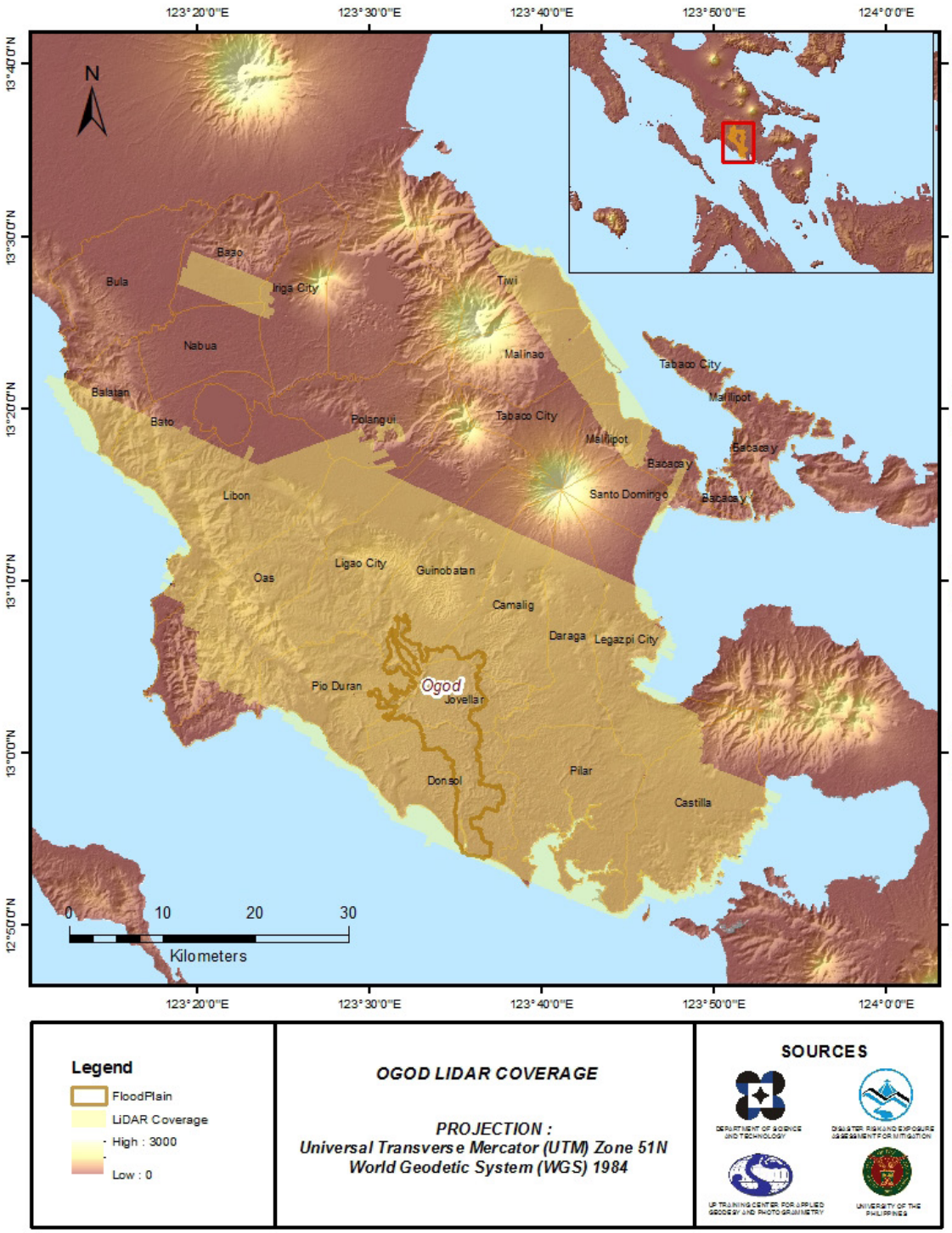


Figure 11. Actual LiDAR data acquisition for Ogod floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE OGOD FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat, Engr. Harmond F. Santos, EEngr. Ma. Ailyn L. Olanda, Engr. Chelou P. Prado, Engr. Christy T. Lubiano, Jerry P. Ballori, Jaylyn L. Paterno, Engr. Ferdinand E. Bien, Lowie Vincent Bisana, Carlota M. Dovocol, Richmund P. Saldo, Adrian T. Pajarillo, Frederick D. Olaño, Engr.Kevin Kristian L. Peñaserada, Engr. Jayrik T. San Buenaventura, Engr. Jess Andre S. Soller, and Arnulfo G.Enciso, Jr.

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

3.1 Overview of the LIDAR Data Pre-Processing

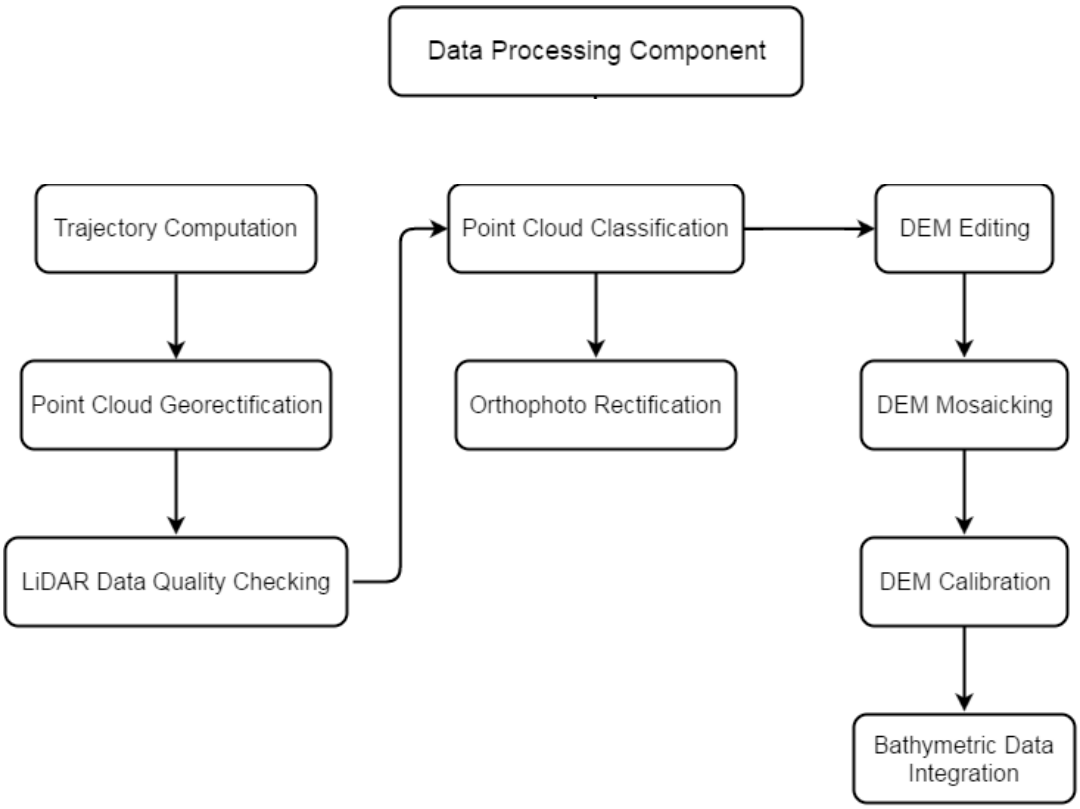


Figure 12. Schematic Diagram for Data Pre-Processing Component.

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

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

These processes are summarized in the flowchart shown in Figure 12.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ogod floodplain can be found in Annex 5: Data Transfer Sheets. Missions flown during the first survey conducted on March 2014 and second survey conducted on February 2016 both used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Donsol, Sorsogon and Jovellar, Albay. The Data Acquisition Component (DAC) transferred a total of 341.14 Gigabytes of Range data, 3.22 Gigabytes of POS data, 154.37 Megabytes of GPS base station data, and 611.83 Gigabytes of raw image data to the data server on April 29, 2014 for the first survey and March 18, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ogod was fully transferred on March 21, 2016, as indicated on the Data Transfer Sheets for Ogod floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 3843G, one of the Ogod flights, which is 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 on that week fell on March 4, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

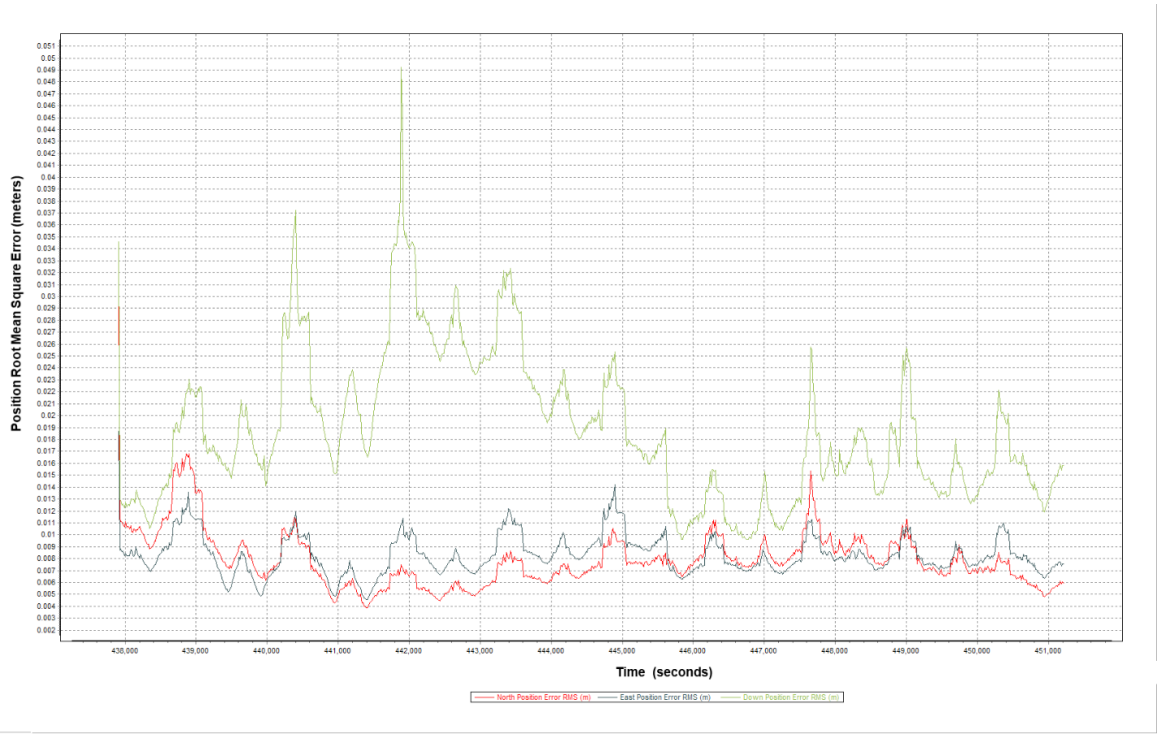


Figure 13. Smoothed Performance Metrics of Ogod Flight 3843G.

The time of flight was from 438000 seconds to 451000 seconds, which corresponds to morning of March 4, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 13 shows that the North position RMSE peaks at 1.70 centimeters, the East position RMSE peaks at 1.40 centimeters, and the Down position RMSE peaks at 4.90 centimeters, which are within the prescribed accuracies described in the methodology.

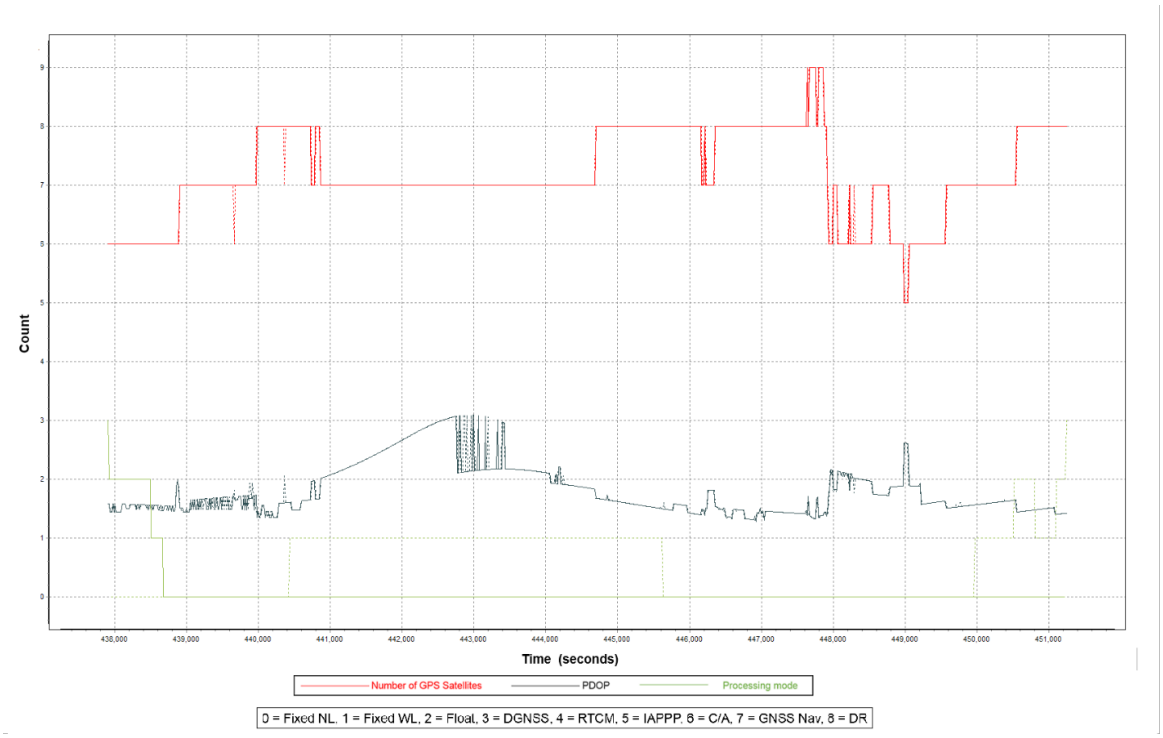


Figure 14. Solution Status Parameters of Ogod Flight 3843G.

The *Solution Status* parameters of flight 3843G, one of the Ogod flights, which are the number of GPS satellites, Positional Dilution of Precision, 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 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Ogod flights is shown in Figure 15.

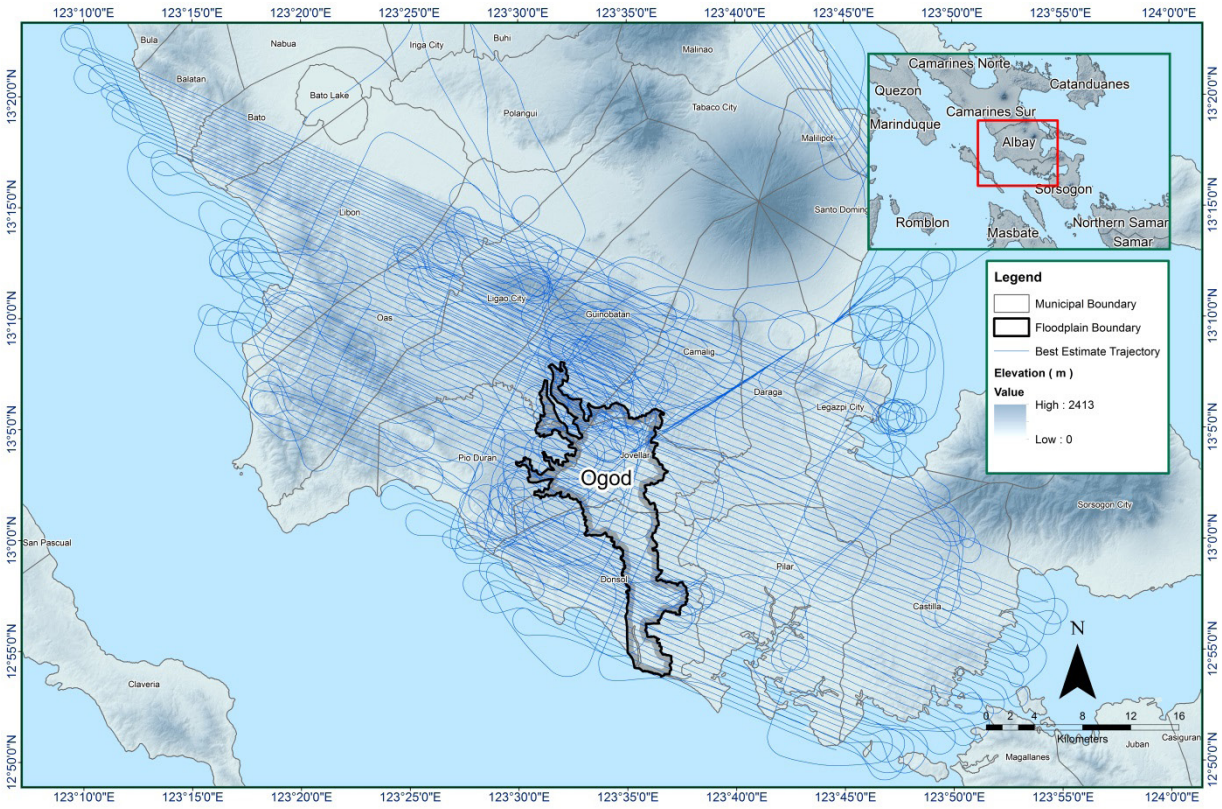


Figure 15. Best Estimated Trajectory for Ogod floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 181 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Ogod floodplain are given in Table 14.

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

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000140
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000997
GPS Position Z-correction stdev	(<0.01meters)	0.0058

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

3.5 LiDAR Quality Checking

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

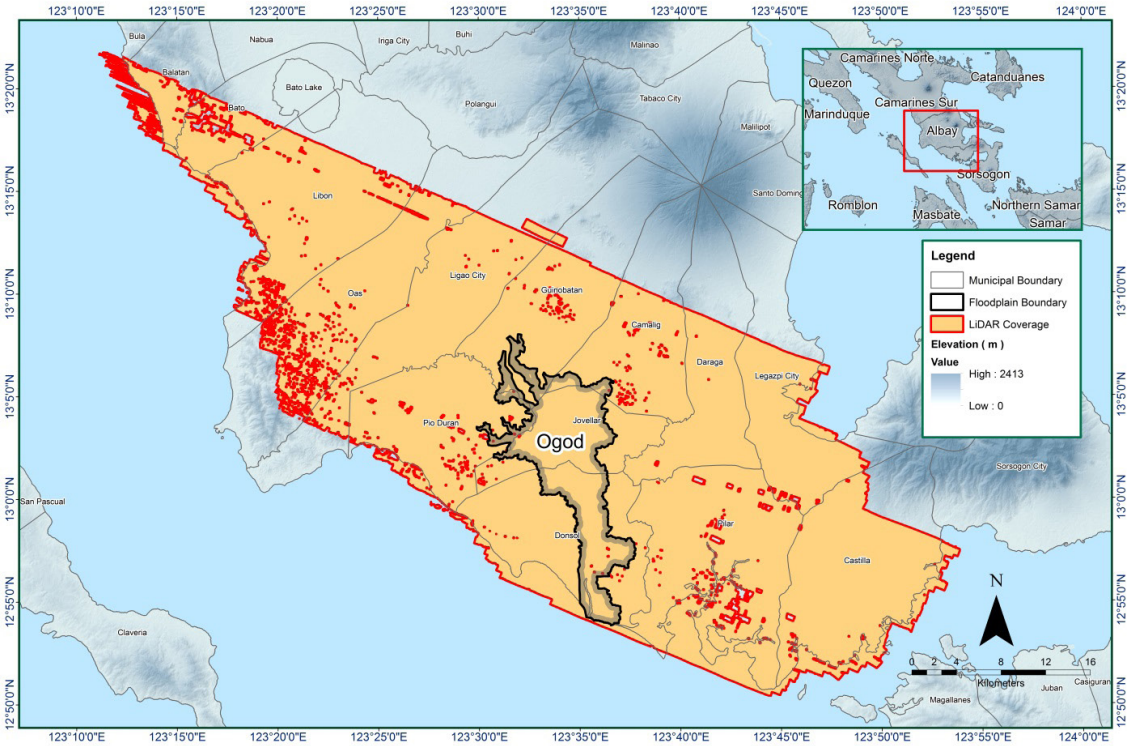


Figure 16. Boundary of the processed LiDAR data over Ogod Floodplain.

The total area covered by the Ogod missions is 2266.88 sq.km that is comprised of twenty one (21) flight acquisitions grouped and merged into sixteen (16) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Ogod floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Albay_Sorsogon_Blk19J	7184GC 7200GC 7204GC 7216GC	17.50
Albay_Sorsogon_Blk19I	7160GC 7161GC	407.11
Albay_Sorsogon_Blk19H	7175GC 7176GC 7212GC 7213GC	148.89
Albay_Sorsogon_Blk19F	7174GC 7216GC	199.52
Albay_Sorsogon_Blk19EG	7156GC 7158GC 7216GC	301.83
Albay_Sorsogon_Blk19D	7172GC	162.61
Albay_Sorsogon_Blk19P	7212GC 7213GC	83.10
Albay_Sorsogon_Blk19M	7171GC	116.50
Albay_Sorsogon_Blk19M_additional	7171GC	48.22
Albay_Sorsogon_Blk19L_additional	7213GC	1.20
Albay_Sorsogon_Blk19L	7168GC	192.24
Albay_Sorsogon_Blk19K	7167GC	238.90
Albay_Sorsogon_Blk19J_additional	7200GC	17.50
Albay_Sorsogon_reflights_Blk19Q	3825G	62.49
Albay_Sorsogon_reflights_Blk19F	3825G 3829G	93.70
Albay_Sorsogon_reflights_Blk19D	3843G	175.57
	TOTAL	**2266.88 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 17. Since the Gemini and Gemini-CASI systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

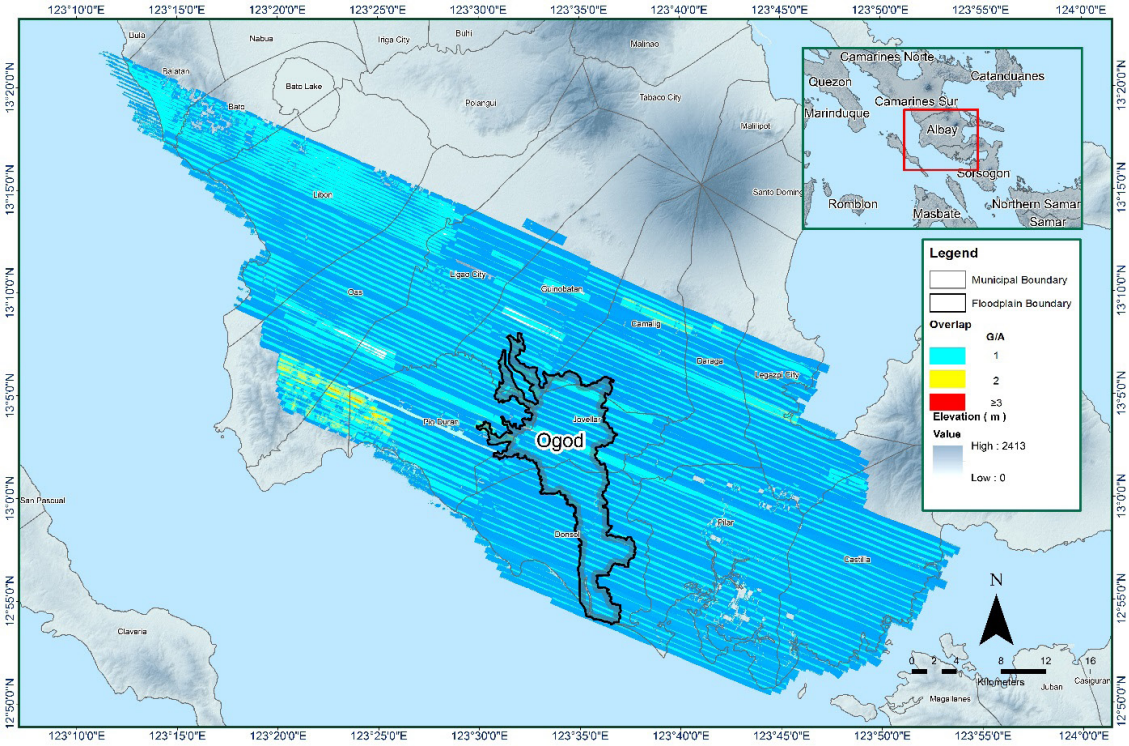


Figure 17. Image of data overlap for Ogod floodplain.

The overlap statistics per block for the Ogod floodplain can be found in Annex 8: Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 13.70% and 58.61% 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 Ogod floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.77 points per square meter.

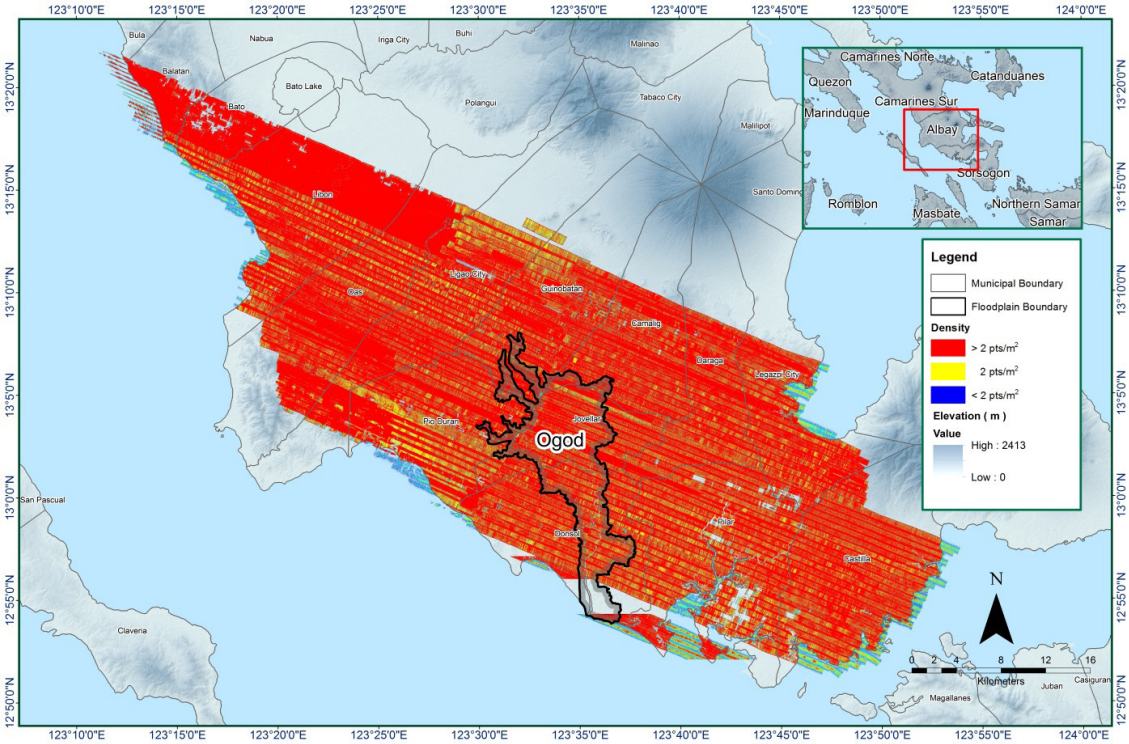


Figure 18. Pulse density map of merged LiDAR data for Ogod floodplain.

The elevation difference between overlaps of adjacent flight lines is shown 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 need to be investigated further using Quick Terrain Modeler software.

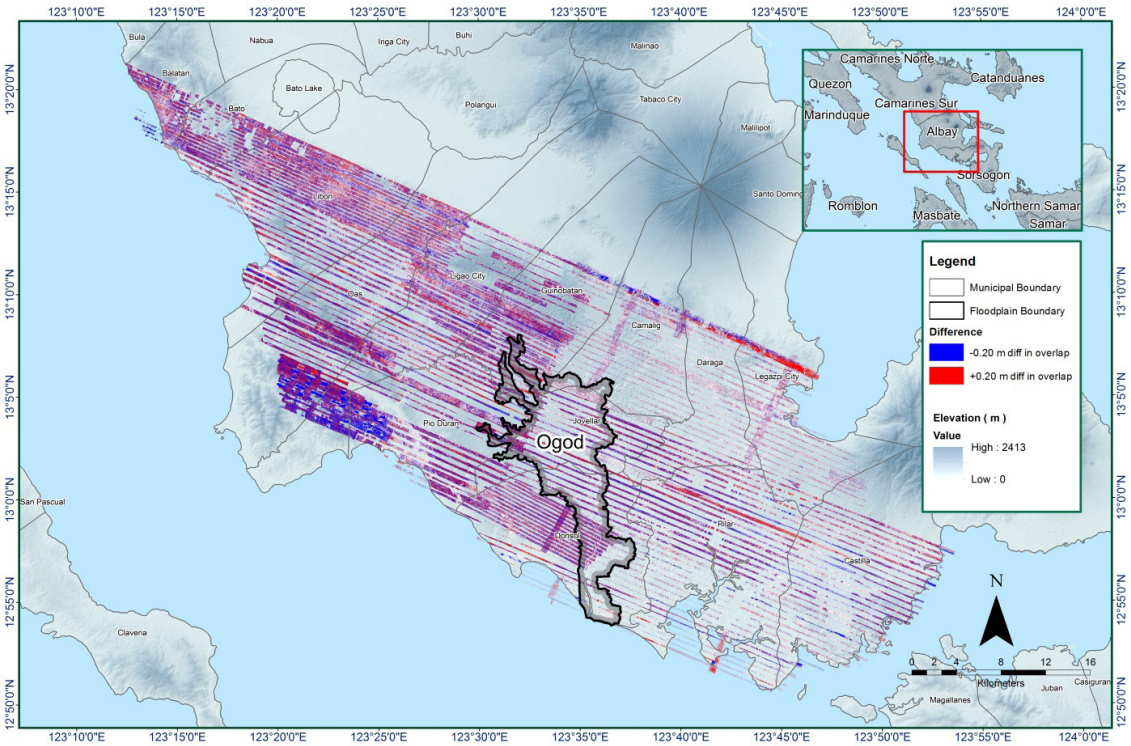


Figure 19. Elevation difference map between flight lines for Ogod floodplain.

A screen capture of the processed LAS data from Ogod flight 3843G loaded in QT Modeler is shown in Figure 20. The upper left image shows the elevations of the points from two 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 are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

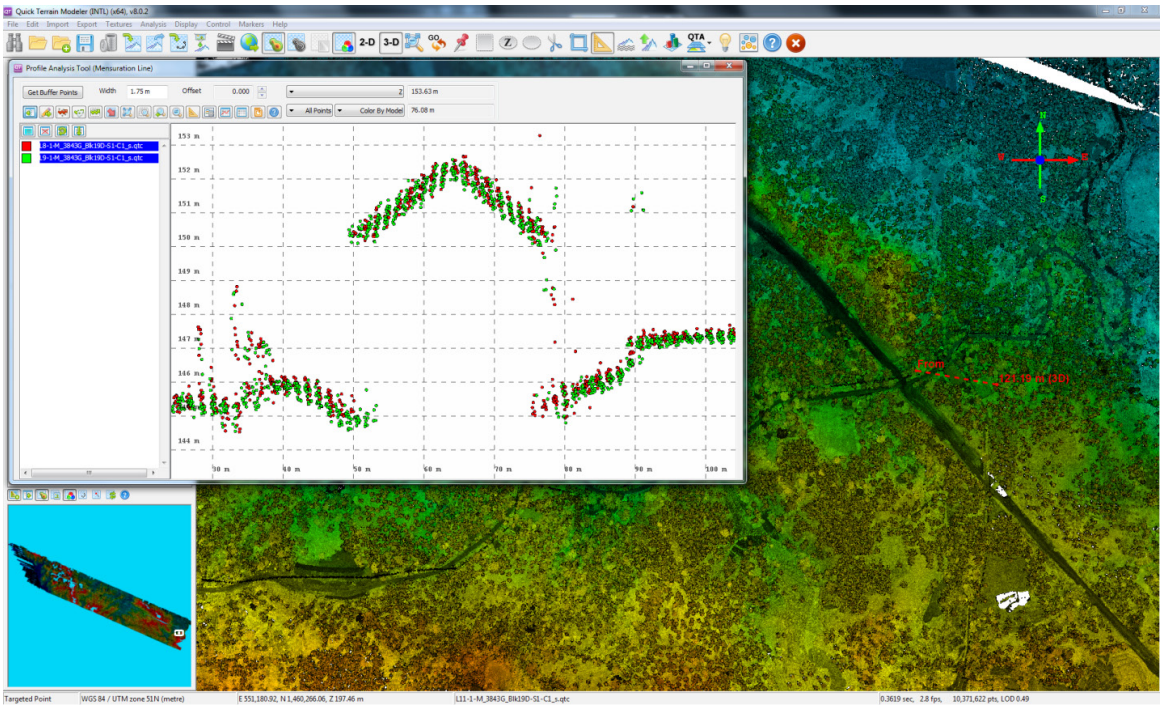


Figure 20. Quality checking for Ogod flight 3843G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Ogod classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	953,394,813
Low Vegetation	810,025,777
Medium Vegetation	1,697,993,873
High Vegetation	4,152,545,262
Building	41,222,386

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ogod floodplain is shown in Figure 21. A total of 3,113 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 584 meters and 52.66 meters respectively.

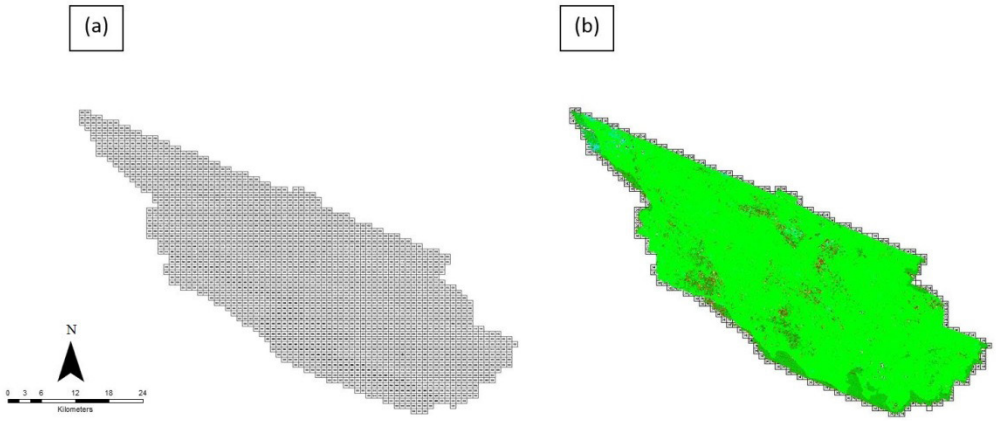


Figure 21. Tiles for Ogod floodplain (a) and classification results (b) in TerraScan.

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 seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

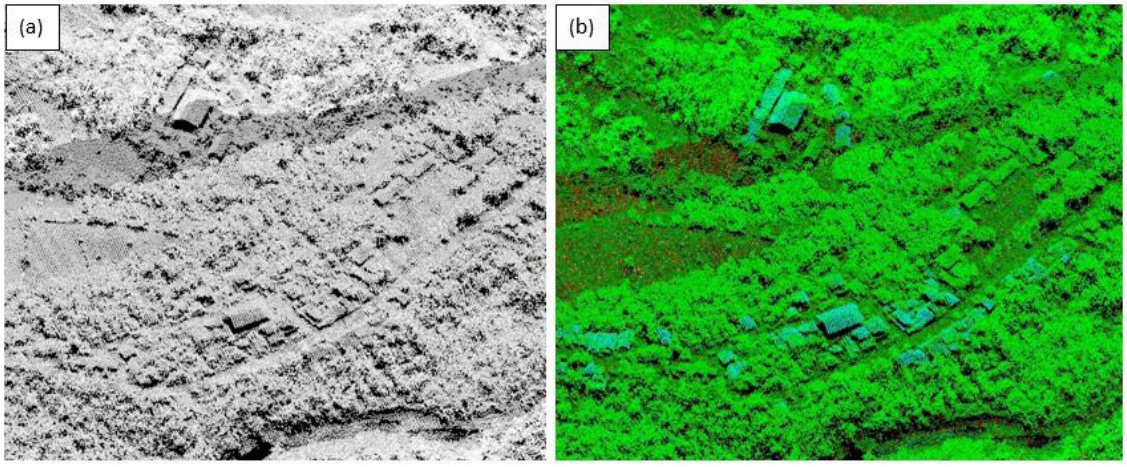


Figure 22. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, 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 on the DSMs, all features are present such as buildings and vegetation.

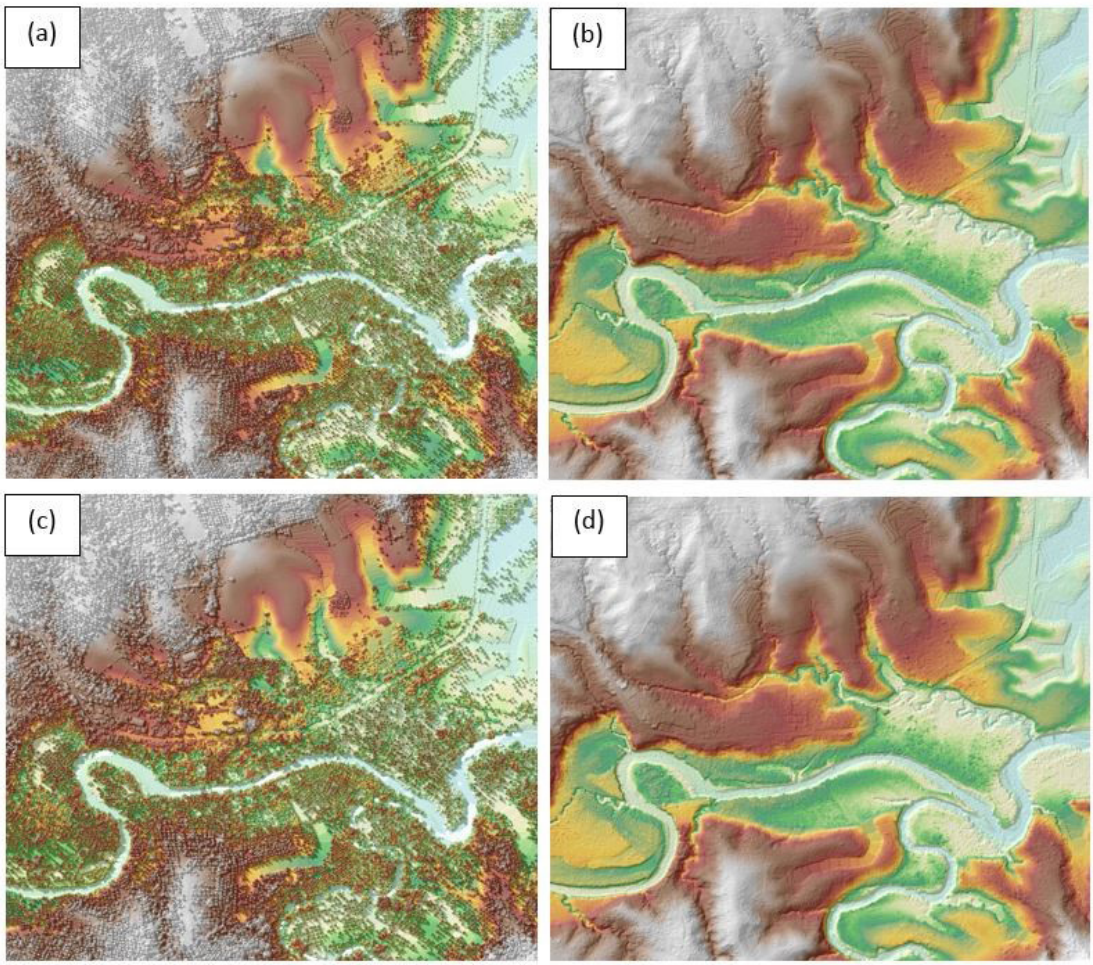


Figure 23. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ogod floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 371 1km by 1km tiles area covered by Ogod floodplain is shown in Figure 24. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Ogod floodplain has a total of 269sq.km orthophotogaph coverage comprised of 1986 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 25.

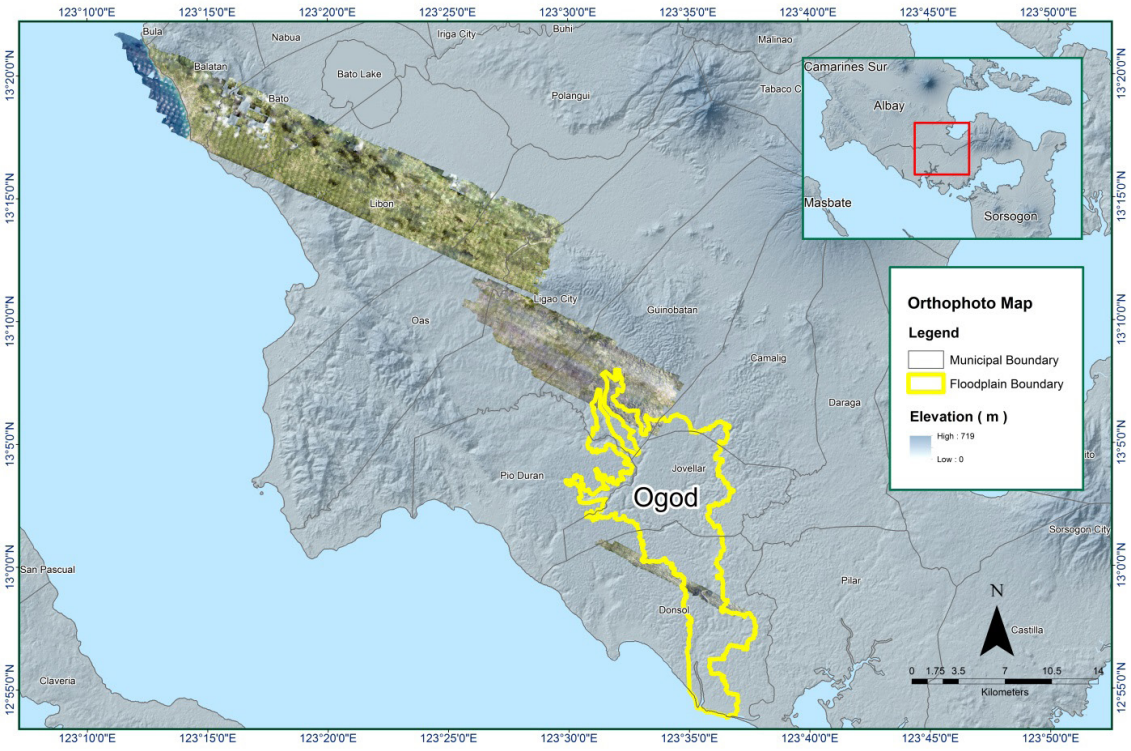


Figure 24. Ogod floodplain with available orthophotographs.

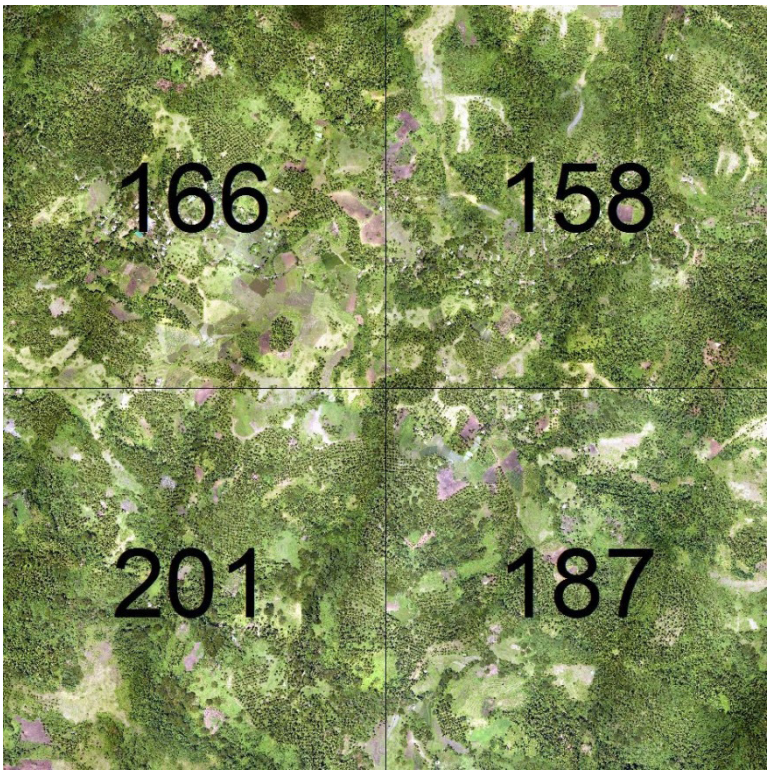


Figure 25. Sample orthophotograph tiles for Ogod floodplain.

3.8 DEM Editing and Hydro-Correction

Sixteen (16) mission blocks were processed for Ogod floodplain. These blocks are composed of Albay_Sorsogon and Albay_Sorsogon_reflights blocks with a total area of 2,266.88 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Albay_Sorsogon_Blk19J	17.50
Albay_Sorsogon_Blk19I	407.11
Albay_Sorsogon_Blk19H	148.89
Albay_Sorsogon_Blk19F	199.52
Albay_Sorsogon_Blk19EG	301.83
Albay_Sorsogon_Blk19D	162.61
Albay_Sorsogon_Blk19P	83.10
Albay_Sorsogon_Blk19M	116.50
Albay_Sorsogon_Blk19M_additional	48.22
Albay_Sorsogon_Blk19L_additional	1.20
Albay_Sorsogon_Blk19L	192.24
Albay_Sorsogon_Blk19K	238.90
Albay_Sorsogon_Blk19J_additional	17.50
Albay_Sorsogon_reflights_Blk19Q	62.49
Albay_Sorsogon_reflights_Blk19F	93.70
Albay_Sorsogon_reflights_Blk19D	175.57
TOTAL	2266.88 sq.km

Portions of DTM before and after manual editing are shown in Figure 26. The mountain ridge (Figure 26a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 26b) to allow the correct flow of water. The misclassified linear feature (Figure 26c) is also considered to be an impedance to the flow of water and has to be removed (Figure 26d) in order to hydrologically correct the river.

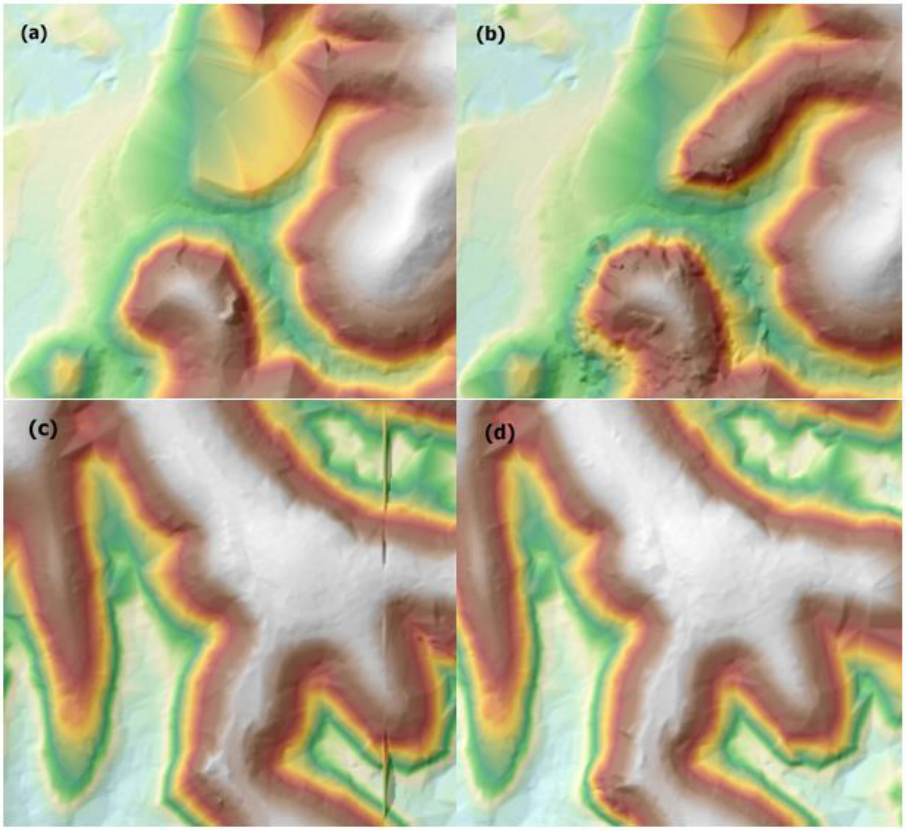


Figure 26. Portions in the DTM of Ogod floodplain – a mountain ridge before (a) and after (b) data retrieval; a misclassified linear feature before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Albay Sorsogon Blk19M was used as the reference block at the start of mosaicking because it is the located in the estuary of the river.Table 18. Shift Values of each LiDAR Block of Ogod floodplain.

Mosaicked LiDAR DTM for Ogod floodplain is shown in Figure 27. It can be seen that the entire Ogod floodplain is 100% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Ogod floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
AlbaySorsogon_Blk19J	-2	2	-2.20
AlbaySorsogon_Blk19I	0.26	1	-1.36
AlbaySorsogon_Blk19H	-3	1	-1.74
AlbaySorsogon_Blk19F	-4	1	-1.45
AlbaySorsogon_Blk19EG	1	1.25	-1.34
AlbaySorsogon_Blk19P	1	1	-1.94
AlbaySorsogon_Blk19M	-2	2	-2.22
AlbaySorsogon_Blk19M_additional	-2	2	-2.22
AlbaySorsogon_Blk19L_additional	0	2	-2.17
AlbaySorsogon_Blk19L	0	2	-2.16
AlbaySorsogon_Blk19K	-1	1	-1.12
AlbaySorsogon_Blk19J_additional	-2	2	-2.20
AlbaySorsogon_reflights_Blk19Q	-1	2	-1.90
AlbaySorsogon_reflights_Blk19F	-5	2	-1.68
AlbaySorsogon_reflights_Blk19D	1	1	-1.74

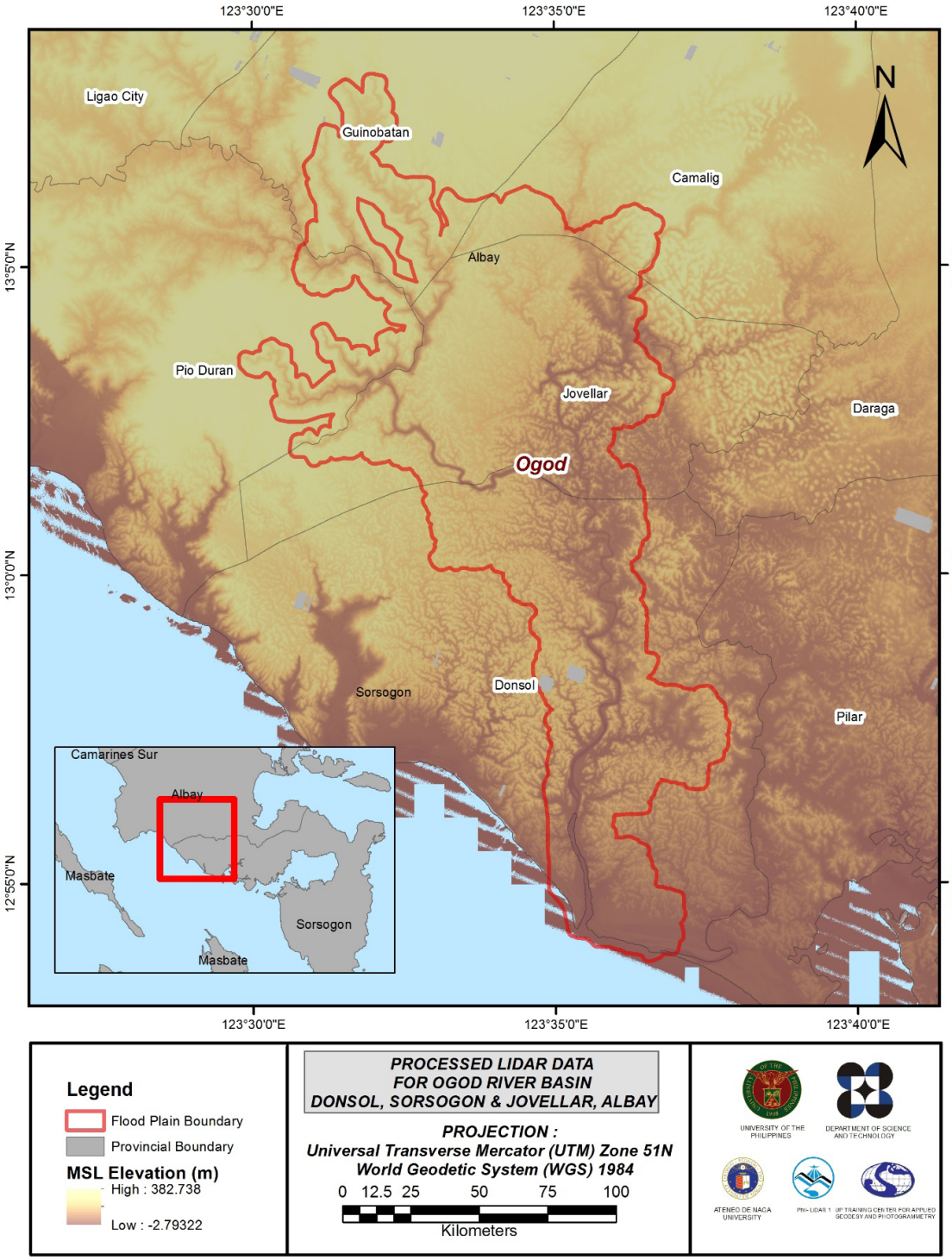


Figure 27. Map of Processed LiDAR Data for Ogod Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ogod to collect points with which the LiDAR dataset is validated is shown in Figure 28. A total of 11,856 survey points from the Bicol floodplain were used for calibration Ogod LiDAR data. Random selection of 80% of the survey points, resulting to 10,864 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 29. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.41 meters with a standard deviation of 0.17 meters. Calibration of Ogod LiDAR data was done by adding the height difference value, 0.41 meters, to Ogod mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

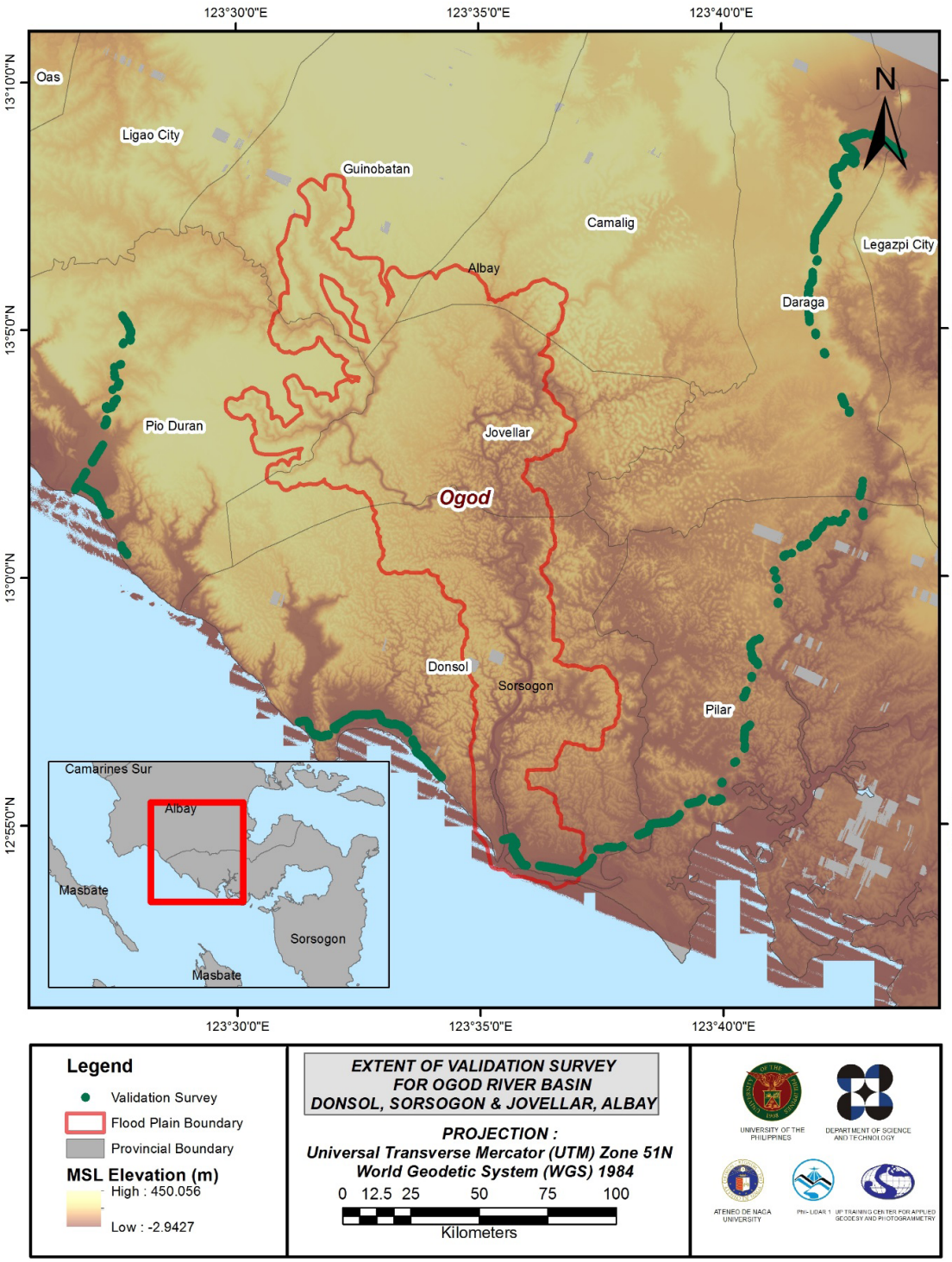


Figure 28. Map of Ogod Flood Plain with validation survey points in green.

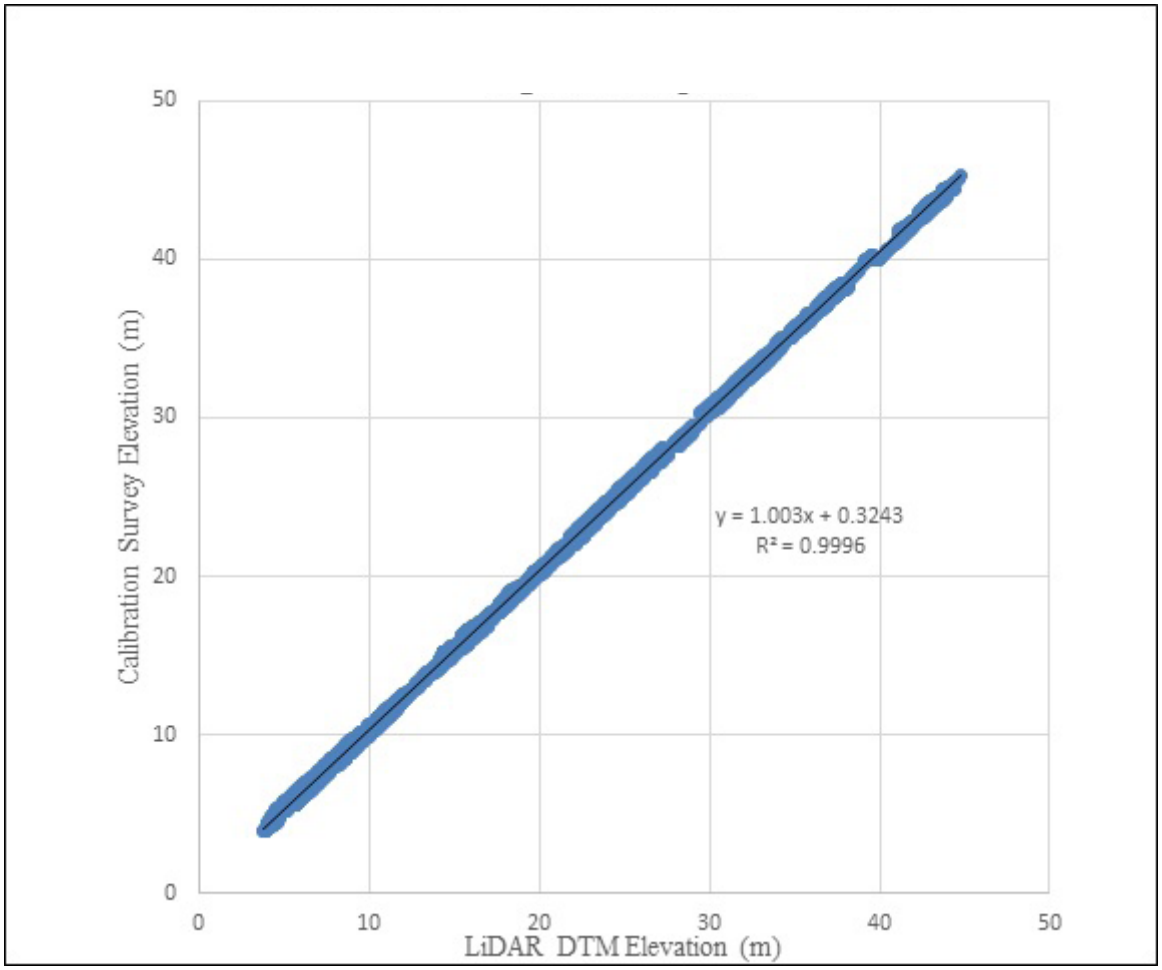


Figure 29. Correlation plot between calibration survey points and LiDAR data

Table 19. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.41
Standard Deviation	0.17
Average	0.38
Minimum	-0.08
Maximum	0.83

A total of 4,270 points were collected by DVBC for the Ogod river basin. Random selection of points, resulting to 1,075 points, were used for the validation of calibrated Ogod DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 30. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.19 meters, as shown in Table 20.

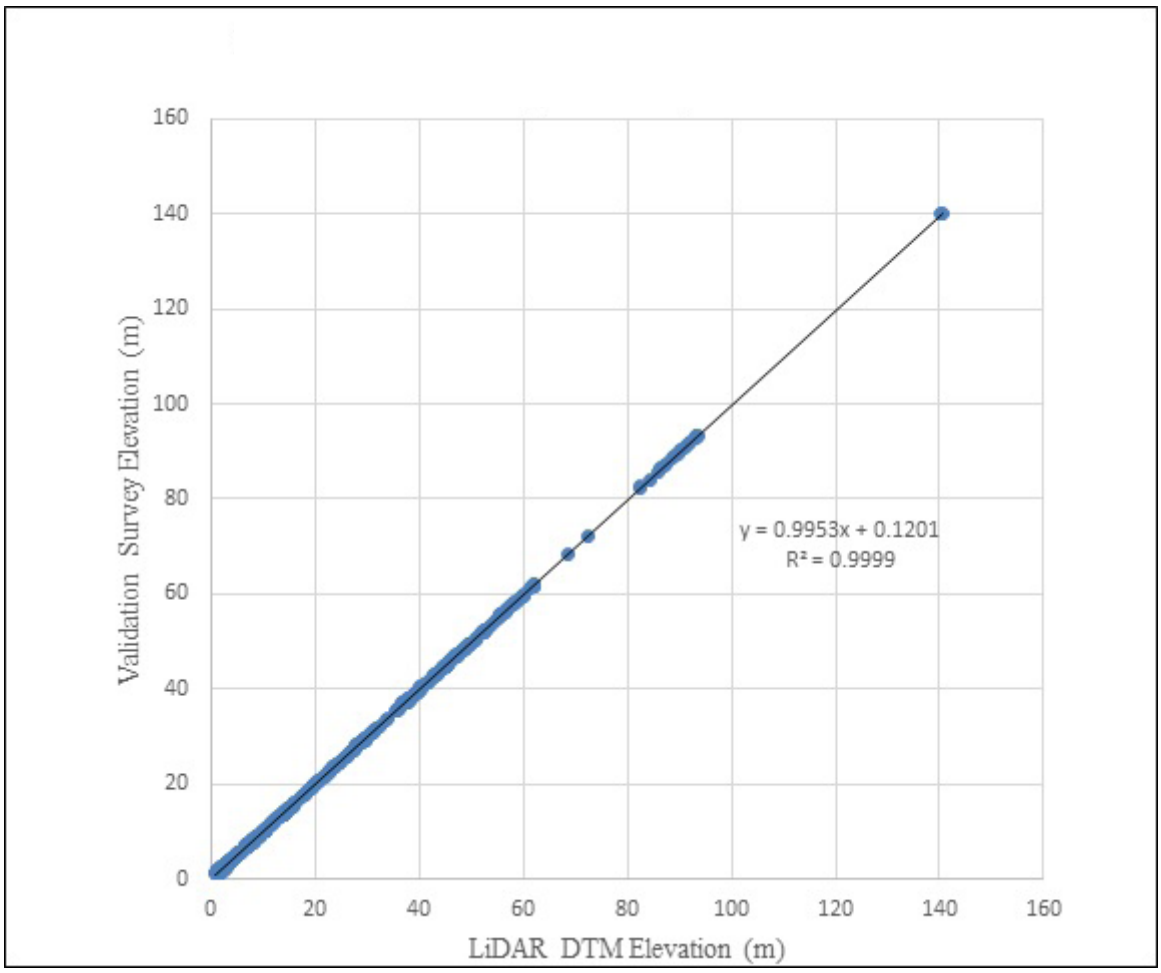


Figure 30. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.21
Standard Deviation	0.19
Average	0.10
Minimum	-0.26
Maximum	0.46

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Ogod with 5,929 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 0.86 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ogod integrated with the processed LiDAR DEM is shown in Figure 31.

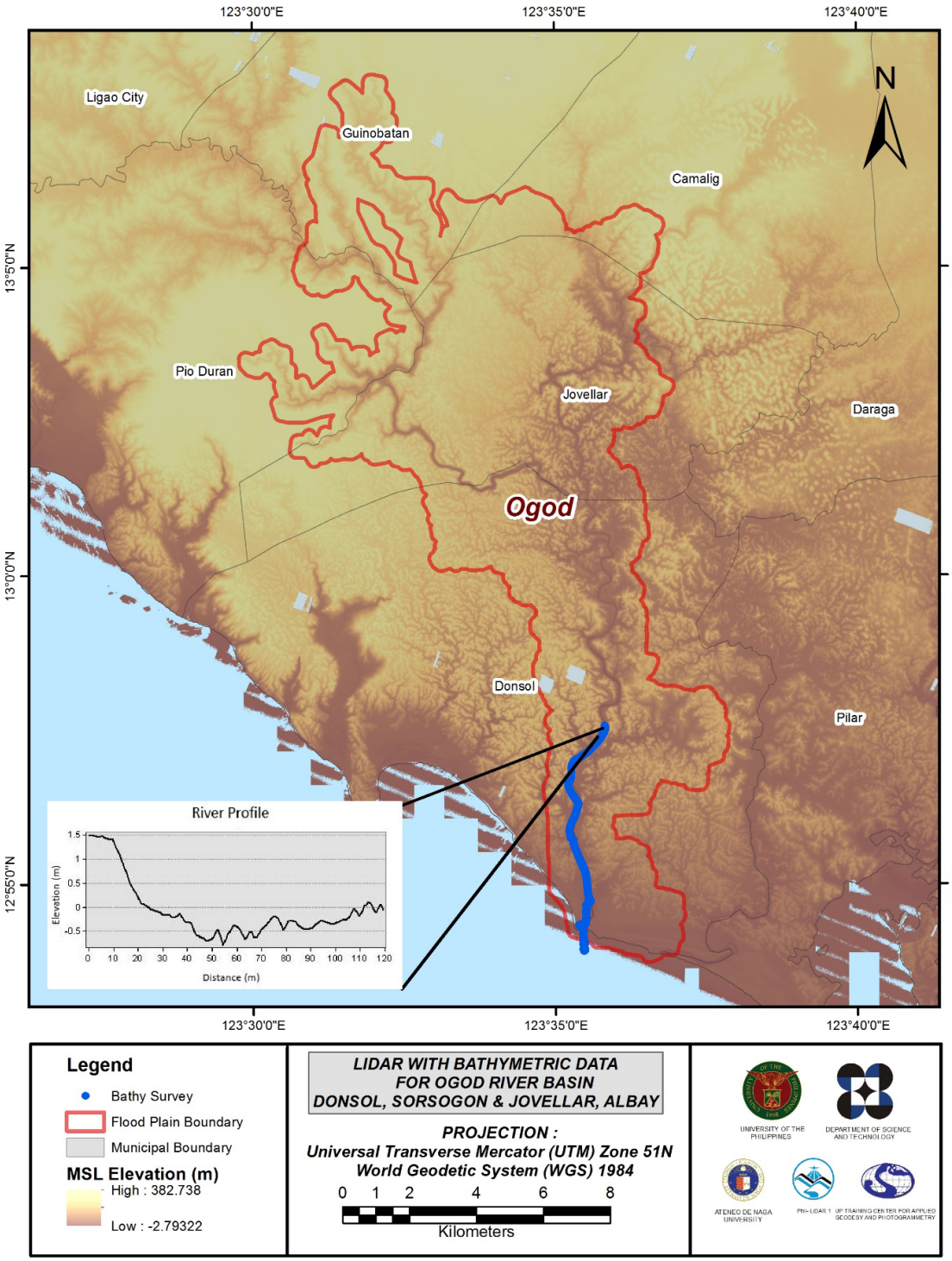


Figure 31. Map of Ogod Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Ogod floodplain, including its 200 m buffer, has a total area of 148.43 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1432 building features, are considered for QC. Figure 32 shows the QC points for Ogod floodplain.

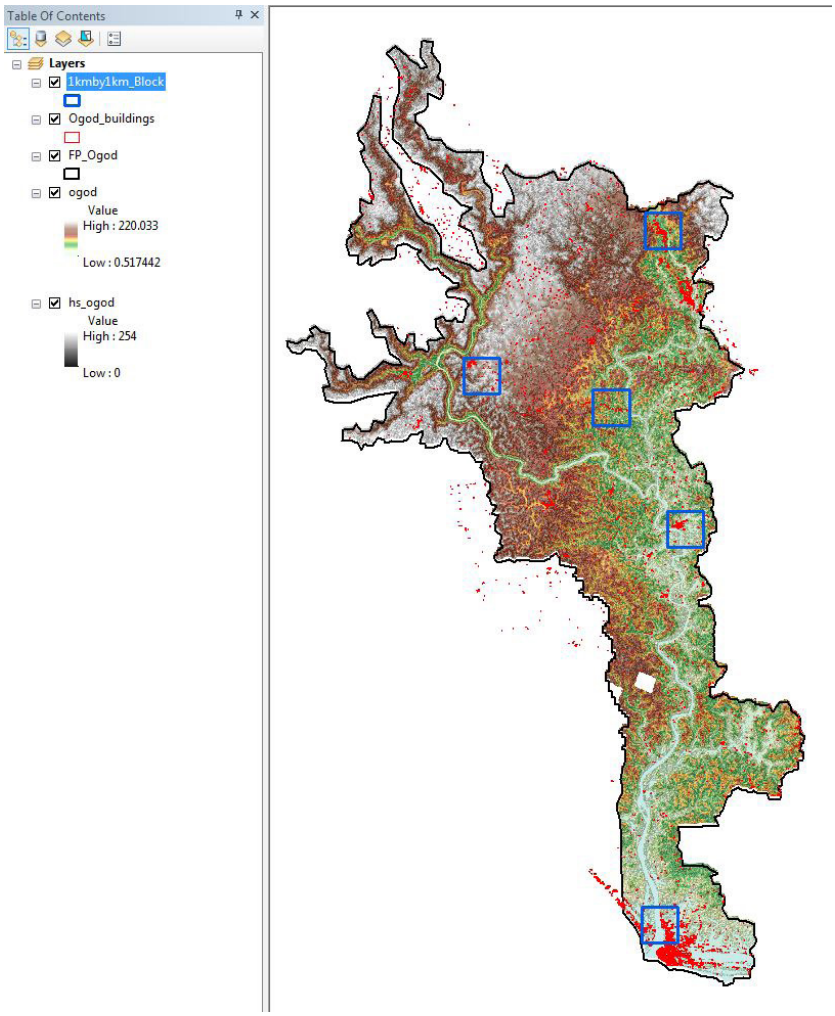


Figure 32. QC blocks for Ogod building features.

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

Table 21. Quality Checking Ratings for Ogod Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Ogod	99.94	100	99.84	PASSED

3.12.2 Height Extraction

Height extraction was done for 9,417 building features in Ogod floodplain. Of these building features, 93 were filtered out after height extraction, resulting to 9,324 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 21.23 m.

3.12.3 Feature Attribution

Feature Attribution was done for 9,324 building features in Ogod Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an android application called reGIS. The Resource Extraction for Geographic Information System (reGIS)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features. This effectively allows unified and standardized sets of data.

Table 22 summarizes the number of building features per type. On the other hand, Table 23 shows the total length of each road type, while Table 24 shows the number of water features extracted per type.

Table 22. Number of Building Features Extracted for Ogod Floodplain

Facility Type	No. of Features
Residential	8827
School	297
Market	8
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	11
Barangay Hall	37
Military Institution	0
Sports Center/Gymnasium/Covered Court	3
Telecommunication Facilities	1
Transport Terminal	3
Warehouse	2
Power Plant/Substation	1
NGO/CSO Offices	0
Police Station	4
Water Supply/Sewerage	0
Religious Institutions	47
Bank	1
Factory	0
Gas Station	3
Fire Station	1
Other Government Offices	25
Other Commercial Establishments	53
Total	9,324

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

Floodplain	Road Network Length (km)					Total
	BR	CM	PR	NA	Others	
Ogod	88.0800	18.0400	0	5.3100	0.00	**108.43**

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

Floodplain	Water Body Type					Total
	RS	LP	SE	DM	FP	
Ogod	1	10	1	0	0	**12**

A total of 13 bridges 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 33 shows the Digital Surface Model (DSM) of Ogod floodplain overlaid with its ground features.

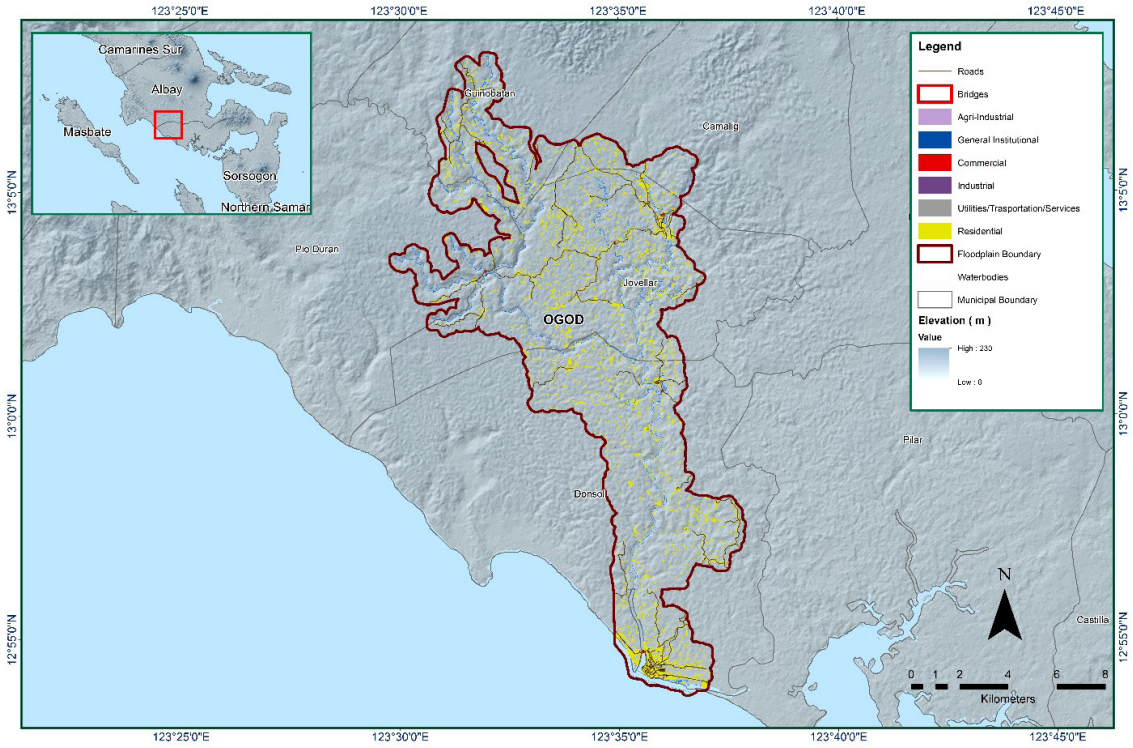


Figure 33. Extracted features for Ogod floodplain.

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

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Ogod River Basin on October 15 to 24, 2014 with the following scope of work: reconnaissance; control survey for the establishment of control points; cross-section and bridge as-built survey for Ilog Bridge in Brgy. Gura, Municipality if Donsol, Sorsogon; ground validation data acquisition of about 52.18 km; and bathymetric survey from Brgy. Gura to Brgy. Ogod both in Donsol, Sorsogon with an estimated length of 8 km using Ohmex™ Single Beam Echo Sounder and GNSS PPK survey technique. The extent of the bathymetric survey for the Ogod river basin is shown in Figure 34.

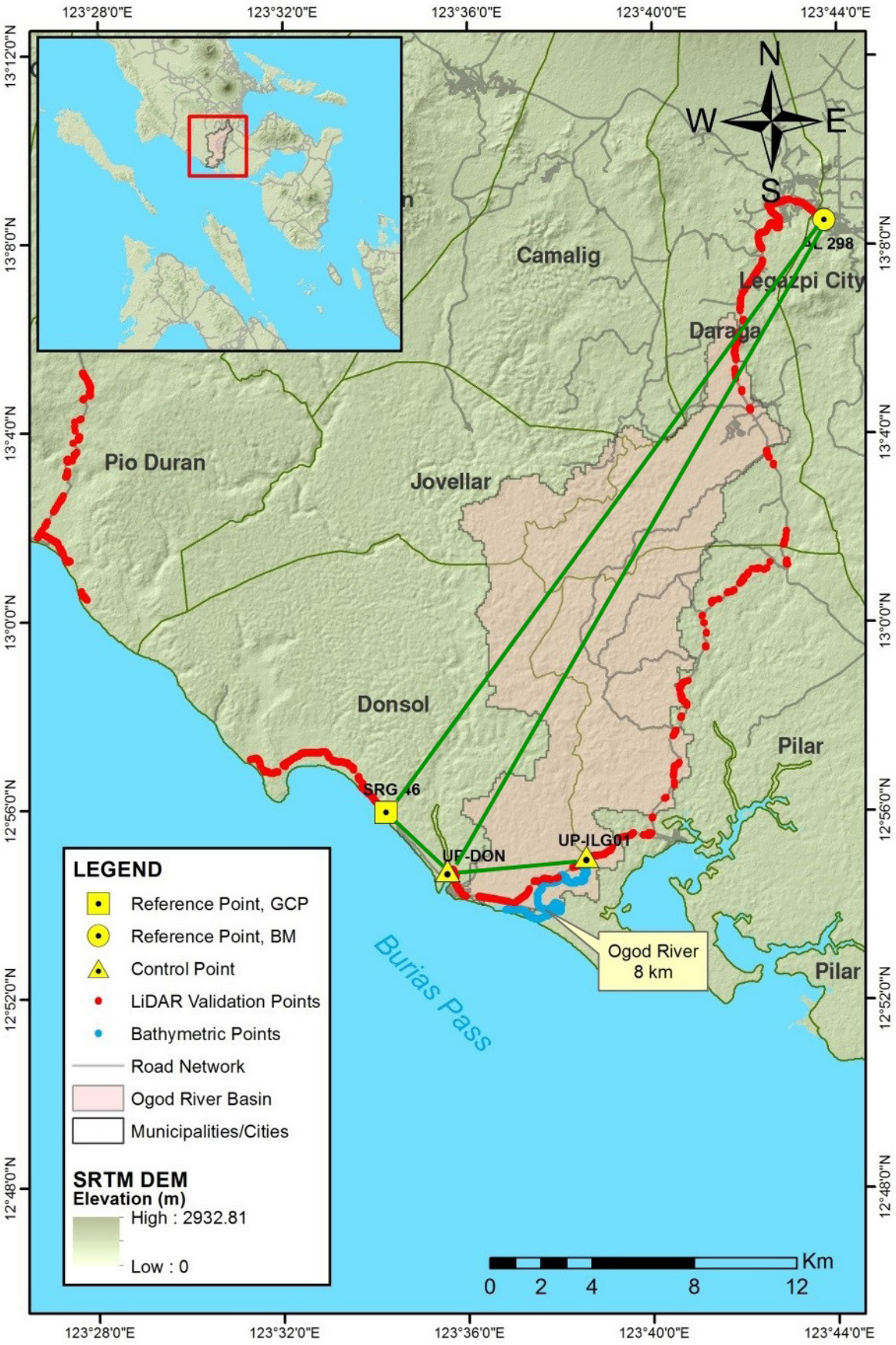


Figure 34. Survey extent for Ogod River Basin.

4.2 Control Survey

The GNSS Network used for Ogod River Basin is composed of a single loop and a baseline established on October 17 and 18, 2014 occupying the following reference points: SRG–46, a second-order GCP, in Brgy. Pangpang, Municipality of Donsol, Sorsogon.; and AL–298, a first-order BM, in Sagpon Bridge, Legazpi City, Albay.

Two (2) Control points were established along the approach of bridges, namely: UP-DON, located at the approach of Dankalan Bridge in Brgy. Dankalan, Municipality of Donsol; and UP-ILG01, located at Ilog Birdge in Brgy. Gura, also in Donsol, Sorsogon,

The summary of reference and control points and its location is summarized in Table 25 while the GNSS network established is illustrated in Figure 35 GNSS network of Ogod River field survey.

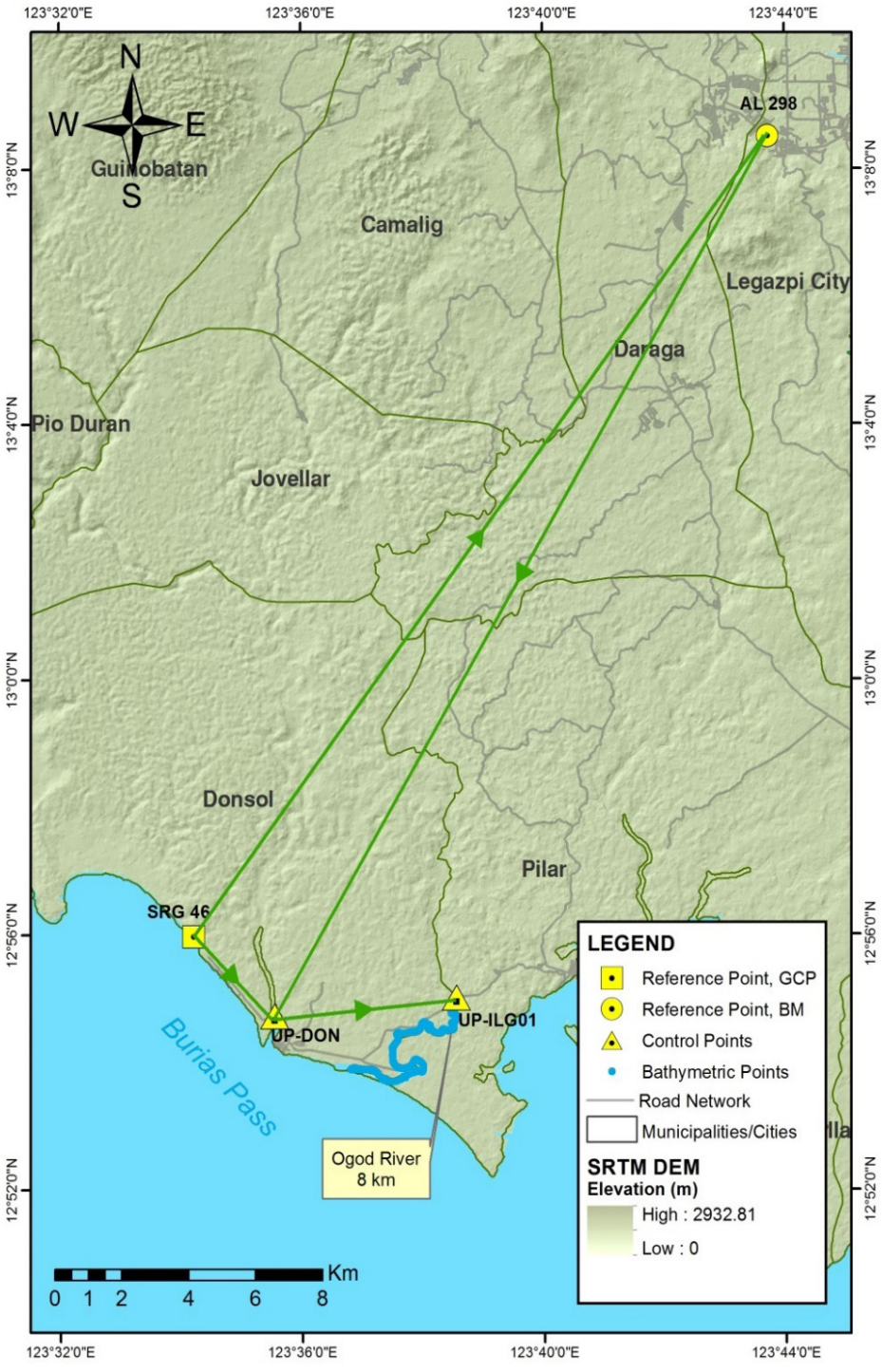


Figure 35. GNSS network of Ogod River field survey.

Table 25. List of Reference and Control points occupied in during Ogod River Basin survey (Source: NAMRIA and UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
AL-298	1st order, BM	-	-	65.916	11.6955	2009
SRG-46	2nd order, GCP	12°55'58.28467"N	123°34'12.66564"E	56.687	-	2007
UP-DON	UP Established	-	-	-	-	10-17-2014
UP-ILG 01	UP Established	-	-	-	-	10-17-2014

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 36 to Figure 39.

Figure 36. Trimble® SPS 852 setup at AL-298, Sagpon Bridge Brgy. Sagpon, Legazpi City, Albay

Figure 37. Trimble® SPS 882 at SRG-46, Pangpang Elementary School, Donsol Sorsogon.

Figure 38. Trimble® SPS 985 setup at UP-DON, Dankalan Bridge, Brgy. Dankalan, Donsol, Sorsogon

Figure 39. Trimble® SPS 852 setup at UP-ILG01 at the approach of Ilog Bridge, Brgy. Gura, Donsol, Sorsogon

4.3 Baseline Processing

The 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 is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. The baseline processing result of control points in the Ogod River Basin is summarized in Table 26 as generated by TBC software.

Table 26. Baseline Processing Report for Ogod River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
AL-298 – SRG-46	10-17-2014	Fixed	0.004	0.024	216°40'29"	28826.56	-8.314
AL-298 – UP-DON	10-18-2014	Fixed	0.004	0.019	210°20'38"	29502.778	-7.692
AL-298 – UP-DON	10-18-2014	Fixed	0.003	0.023	210°20'37"	29502.776	-7.727
UP-ILG01 – UP-DON	10-18-2014	Fixed	0.004	0.014	236°59'54"	5550.558	-5.457
SRG-46 – UP-DON	10-17-2014	Fixed	0.002	0.008	135°18'48"	3290.945	0.642
UP-ILG01 – SRG-46	10-17-2014	Fixed	0.005	0.017	102°38'48"	8029.084	6.145

As shown in Table 26, a total of six (6) baselines were processed and all of them passed the required accuracy set by the project.

4.4 Network Adjustment

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

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

where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

The four (4) control points, SRG-46, AL-298, UP-DON, and UP-ILG01 were occupied and observed simultaneously to form a GNSS loop. Coordinates of SRG-46 and elevation value of AL-298 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)
SRG-46	Global	Fixed	Fixed		
AL-298	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 28. All fixed control points have no values for grid and elevation errors.

Table 28. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
AL-298	578994.142	0.012	1452941.041	0.009	11.696	?	e
SRG-46	561849.132	?	1429779.512	?	2.948	0.080	LL
UP-DON	564167.815	0.008	1427445.746	0.007	3.659	0.074	
UP-ILG	569684.587	0.014	1428039.705	0.011	9.210	0.098	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 29.Using the equation for horizontal and for the vertical; below is the computation for accuracy that passed the required precision:

a. **SRG-46**

Horizontal accuracy = Fixed

Vertical accuracy = 8 cm < 10 cm

b. **AL-298**

Horizontal accuracy = $\sqrt{((1.2)^2 + (0.9)^2}$

= $\sqrt{(1.44 + 0.81)}$

= 1.5 cm < 20 cm

Vertical accuracy = Fixed

c. **UP-DON**

Horizontal accuracy = $\sqrt{((0.8)^2 + (0.7)^2}$

= $\sqrt{(0.64 + 0.49)}$

= 1.06 cm < 20 cm

Vertical accuracy = 7.4 cm < 10 cm

d. **UP-ILG01**

Horizontal accuracy = $\sqrt{((1.4)^2 + (1.1)^2}$

= $\sqrt{(1.96 + 1.21)}$

= 1.78 cm < 20 cm

Vertical accuracy = 9.8 cm < 10 cm

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

Table 29. Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
AL-298	N13°08'30.80115"	E123°43'43.85582"	65.015	?	e
SRG-46	N12°55'58.28467"	E123°34'12.66564"	56.687	0.080	LL
UP-DON	N12°54'42.14411"	E123°35'29.43706"	57.332	0.074	
UP-ILG	N12°55'01.04655"	E123°38'32.55519"	62.804	0.098	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 30.

Table 30. References 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	Ellipsoid Height (m)	Northing	Easting	BM Ortho
AL-298	1st order, BM	13°08'30.80115"	123°43'43.85582"	56.687	1429779.512	561849.132	2.948

SRG-46	2nd order, GCP	12°55'58.28467"	123°34'12.66564"	65.015	1452941.041	578994.142	11.696
UP-DON	UP Established	12°54'42.14411"	123°35'29.43706"	57.332	1427445.746	564167.815	3.659
UP-ILG 01	UP Established	12°55'01.04655"	123°38'32.55519"	62.804	1428039.705	569684.587	9.210

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

Cross-section and as-built survey were conducted on October 8, 2015 at the downstream side of Ilog Bridge in Brgy. Gura, Municipality if Donsol, Sorsogon as shown in Figure 40. The survey used a Trimble® SPS 882 in GNSS PPK technique with UP-ILG01 as the GNSS base station and a chain method as shown in Figure 41.

Figure 40. Ilog bridge facing downstream.

Figure 41. Water level marking on Ilog Bridge, Brgy. Gura, Donsol, Sorsogon.

The cross-sectional line of Ilog bridge is about 53.08 m with thirty-one (31) cross-sectional points. The location map, cross-section diagram, and accomplished data form for Ilog Bridge are presented in Figure 42 to Figure 44, respectively.

Water level elevation for Ilog Bridge was acquired on the same date at 4:13 PM using Trimble® SPS 882 in GNSS PPK survey technique with a value of -0.005 m in MSL. It was translated into marking on the bridge pier using chain method to be used as reference for flow measurement and depth gauge deployment of the HEI responsible for Ogod river, ADNU.

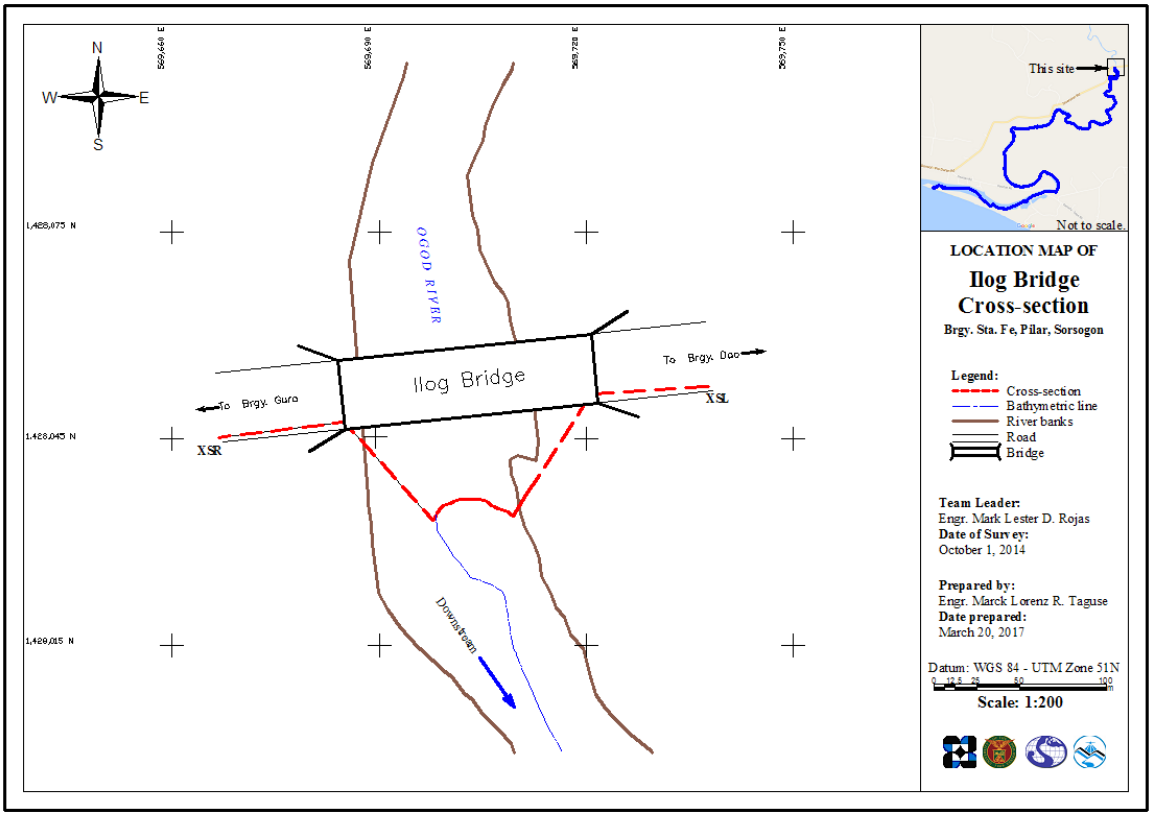


Figure 42. Ilog Bridge cross-section diagram.

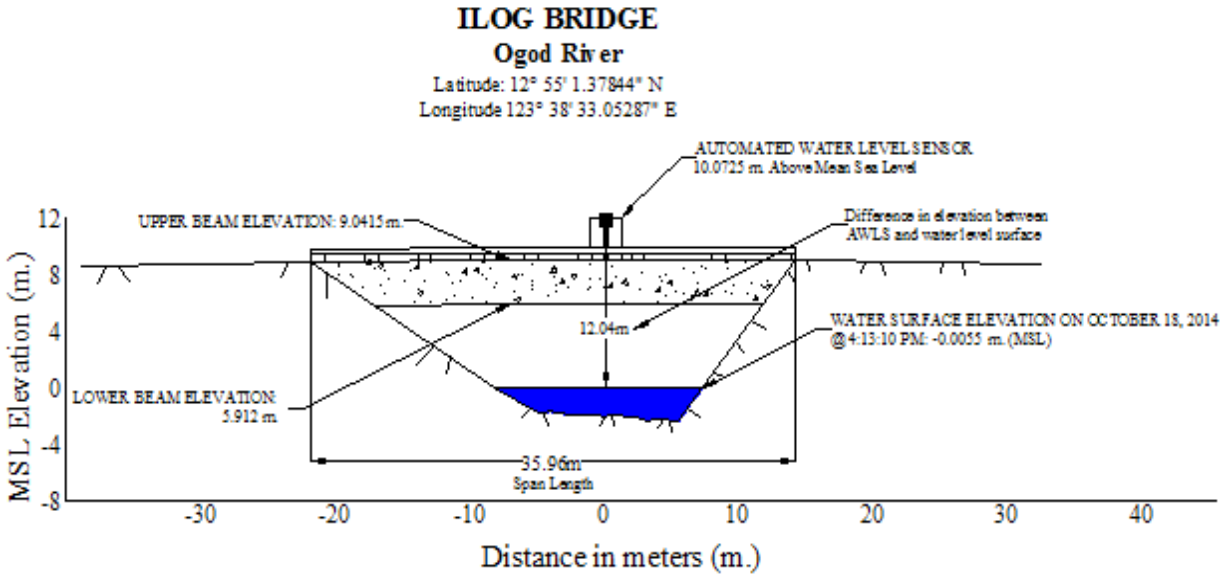


Figure 43. Ilog bridge cross-section location map.

Bridge Data Form

Bridge Name: ILOG Bridge **Date: October 1, 2014**

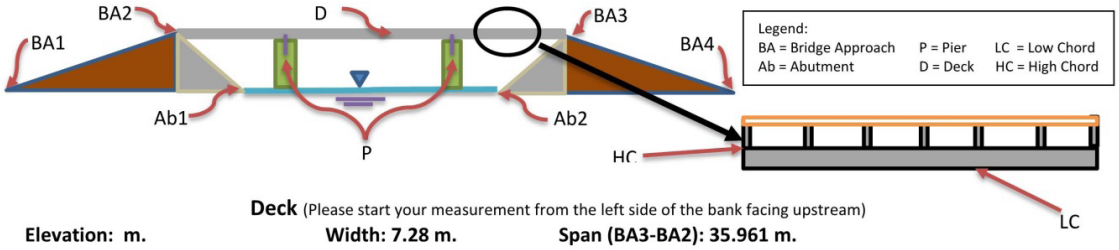
River Name: OGOD River **Time: 10:00 AM**

Location (Brgy, City,Region): Sta. Fe, Pilar, Sorsogon

Survey Team: Mark Lester D. Rojas, John Louis Gacad, Dona Rina Patricia Tajora, Nancy Dimayacyac

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

Latitude: 12°55'01.37844" N **Longitude: 123°38'33.05287" E**



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

Elevation: m. **Width: 7.28 m.** **Span (BA3-BA2): 35.961 m.**

	Station	High Chord Elevation	Low Chord Elevation
1	31.905	9.0415	5.912
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	8.594	BA3	53.082	9.0165
BA2	17.121	8.952	BA4	71.315	8.8205

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

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

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

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 44. Ilog Bridge Bridge Data Form.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted from October 17 to 19, 2014 using a survey grade GNSS rover receiver, Trimble® SPS 882, attached to a pole and installed on a van utilizing post process kinematic in topography mode as shown in Figure 45. The antenna height was measuring 2.57 m from the ground to the bottom of the notch of the GNSS rover receiver.

The first two (2) days started at Ilog Bridge in Pilar, Sorsogon and ended in Brgy. Sagpon, Legazpi City, Albay using AL-298 and UP-ILG01 as base stations. The survey was completed on the third day which covered Pio Duran going to Ligao City, Albay occupying SRG-46 as the base station. The total length is approximately 58.12 km with a total of 4,266 points covering the Municipality of Donsol, Sorsogon to Legaspi City, Albay.

Figure 45. Validation points acquisition survey setup.

Overall coverage of the validation points acquisition survey is illustrated in Figure 46. Gaps shown are due to canopy obstructions along the road.

Figure 46. Validation points acquisition survey along Ogod River Basin.

4.7 River Bathymetric Survey

Bathymetric survey was executed on October 20, 2014 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode. The survey started in the

upstream part of the river in Brgy. Santa Fe, Municipality of Pilar with coordinates 12°55'00.65529"N, 123°38'33.12008"E, and ended at the mouth of the river in Brgy. Ogod, with coordinates 12°53'53.37602"N, 123°36'48.08595"E as shown in Figure 47. The control point UP-ILG01 was used as the GNSS base station all throughout the entire survey.

The bathymetric survey for Ogod River gathered a total of 5,945 points covering 8 km of the river traversing barangays Santa Fe and Guiron in Mun. of Pilar, and barangyas Gura and Ogod in Mun. of Donsol. A CAD drawing was also produced to illustrate the riverbed profile of Ogod River. As shown in Figure 48, the highest and lowest elevation has a 4m difference. The highest elevation observed was -1.166 m below MSL located in Brgy. Guiron, Municipality of Pilar, while the lowest was -5.547 m below MSL located in Brgy. Gura, in Municipality of Donsol.

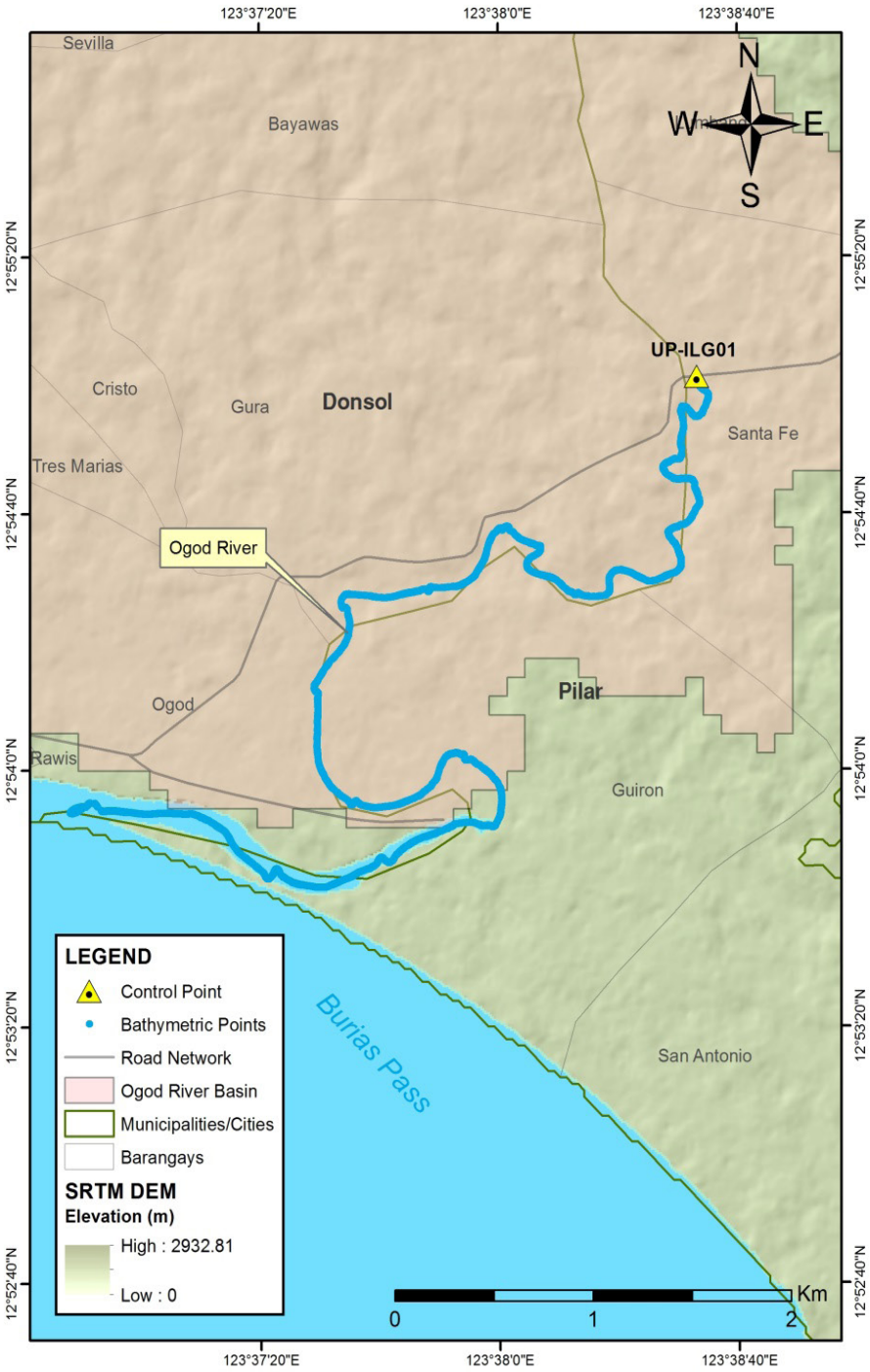


Figure 47. Bathymetric points gathered along Ogod River.

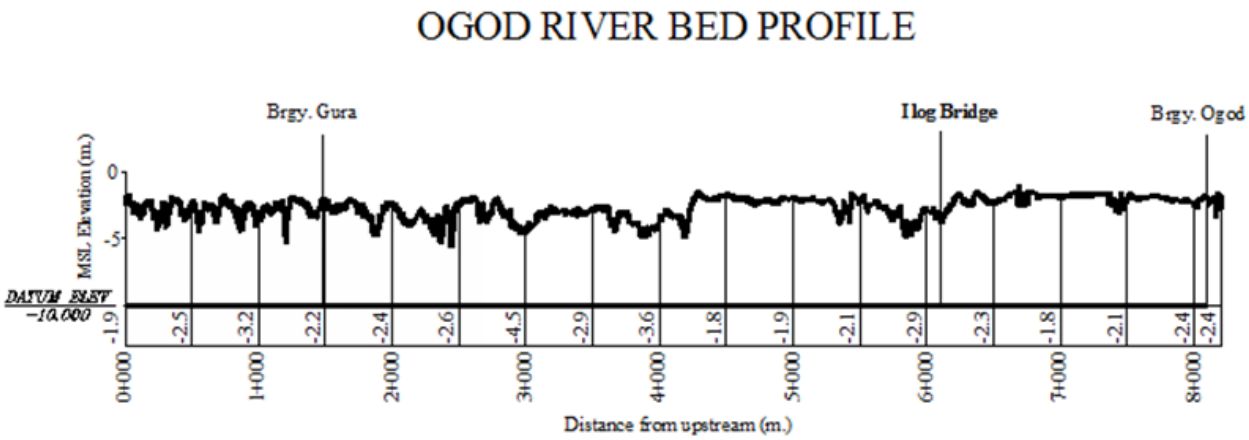


Figure 48. Riverbed Profile of Ogod River.

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, Gianni Sumajit, Engr. Ferdinand E. Bien, Engr. Francis Patray P. Bolaños, Engr. Jan Karl T. Ilarde, Engr. Lech Fidel C. Pante, Engr. Davy M. Jallores, Jan Carlo C. Plopenio, Christian Javier B. Arroyo, Juvylin B.Bismonte, Mark D. Delloro, Berlin Phil V. Garciano, Ruth R. Lumbera, Engr. Herminio A. Magpantay, Engr. Julius Hector S. Manchete, John Paul B. Obina, Razal, Ernesto F. Jr., Rox Harvey DP. Rosales, and Aaron P. San Andres

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Ogod 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 Ogod River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauge (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The rain gauge is the LGU Donsol ARG (Figure 49). The precipitation data collection started from December 07, 2014 at 5:30 AM to December 08, 2015 at 4:15 AM with a 15-minute recording interval.

The total precipitation for this event in LGU Donsol ARG is 50.8 mm. It has a peak rainfall of 2.8mm on December 07, 2014 at 6:45 PM. The lag time between the peak rainfall and discharge is 5 hours and 5 minutes.

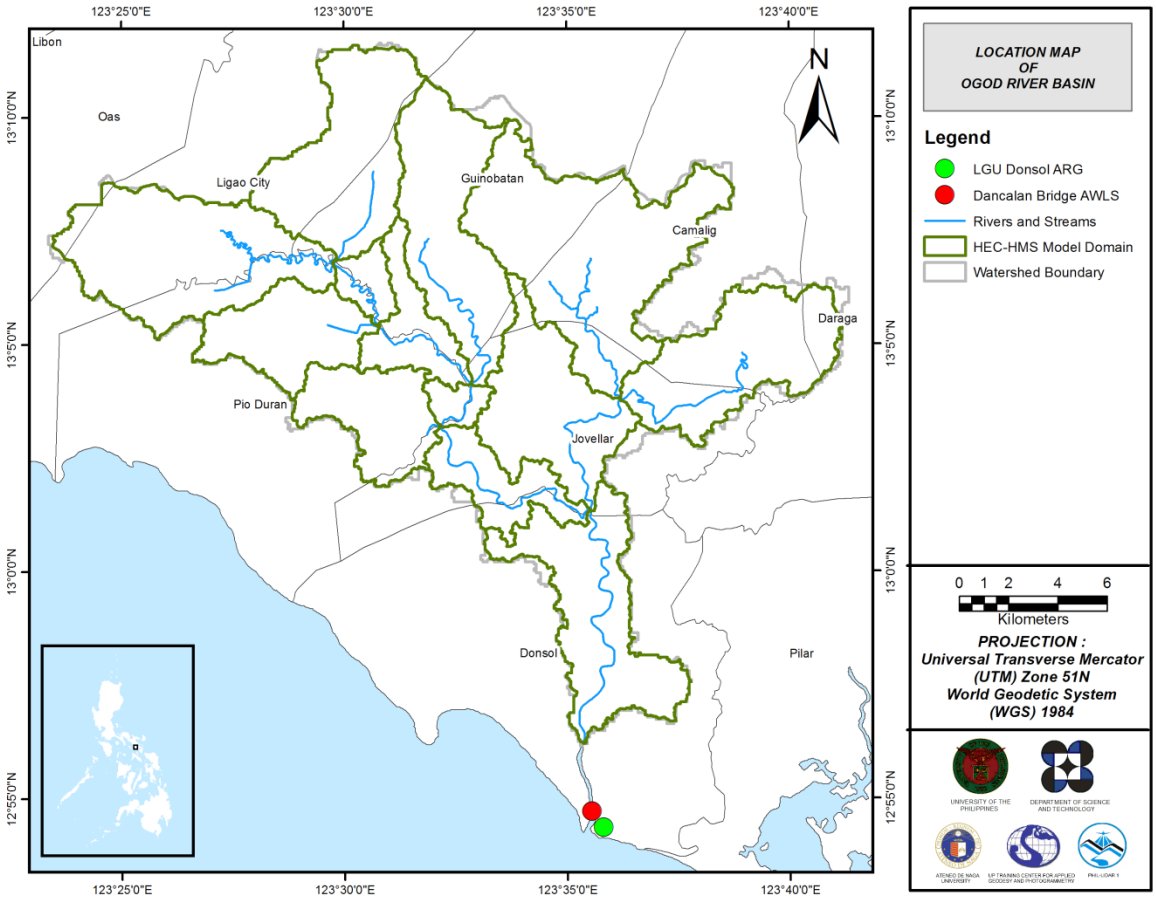


Figure 49. The location map of Ogod HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Dancalan Bridge, Donsol, Sorsogon (12°54'42.79"N, 123°35'32.43"E). It gives the relationship between the observed water levels at Dancalan Bridge and outflow of the watershed at this location.

For Dancalan Bridge, the rating curve is expressed as $Q = 96.76e^{0.5448h}$ as shown in Figure 51.

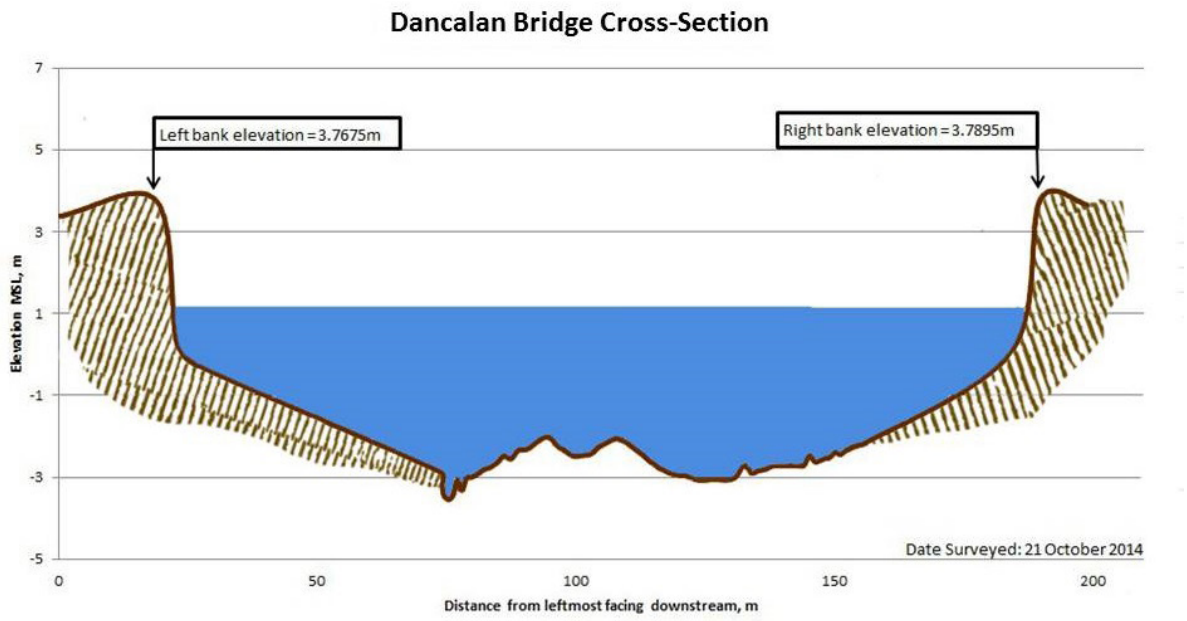


Figure 50. Cross-Section Plot of Dancalan Bridge.

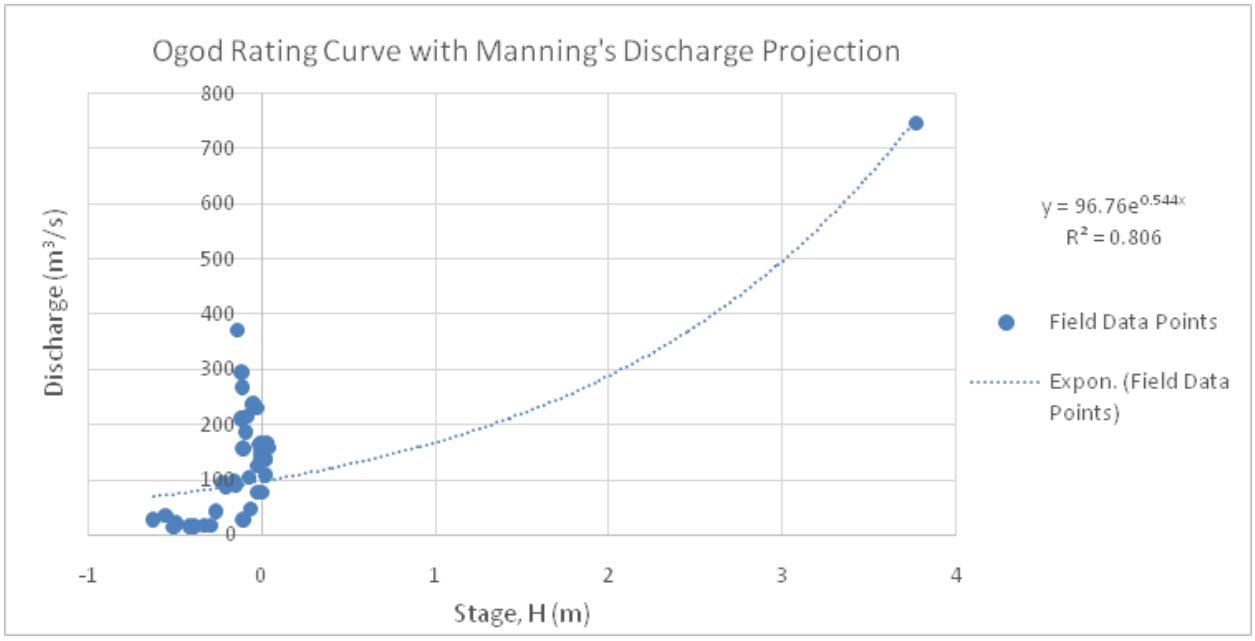


Figure 51. The rating curve of Dancalan Bridge at Donsol, Sorsogon.

This rating curve equation was used to compute the river outflow at Dancalan Bridge for the calibration of the HEC-HMS model shown in Figure 52. The total rainfall for this event is 50.8mm and the peak discharge is 159.6 m^3/s at 11:50 PM, December 07, 2014.

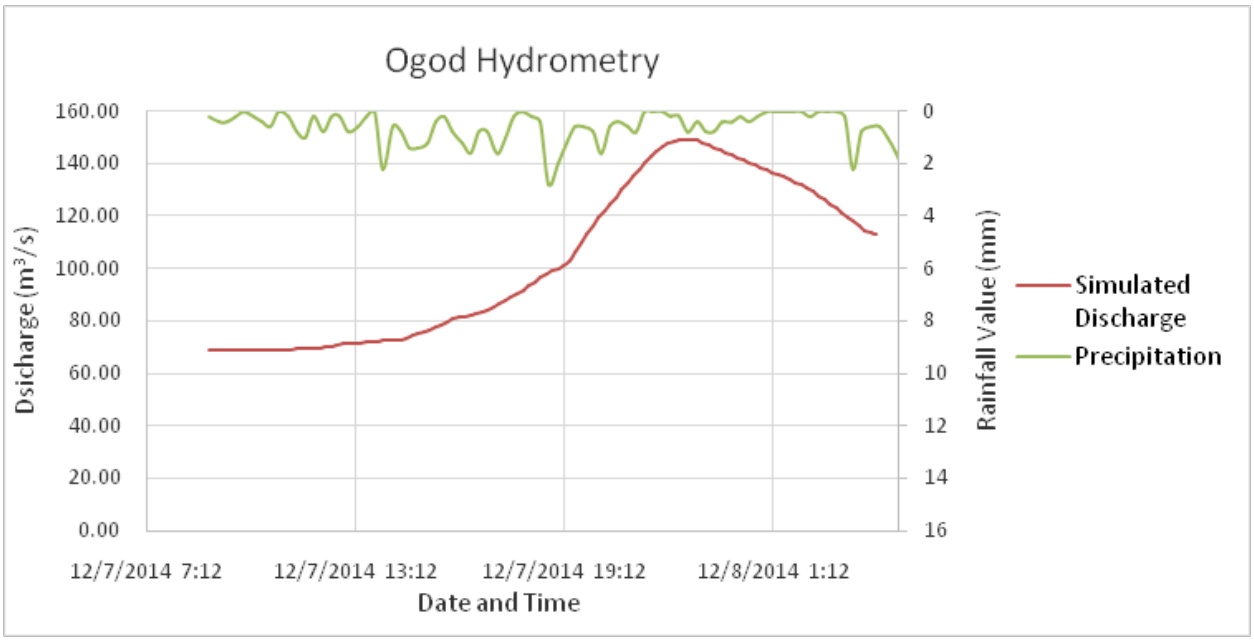


Figure 52. Rainfall and outflow data of the Ogod River Basin, which used for modeling.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Legazpi RIDF. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Ogod watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 31. RIDF values for Ogod Rain Gauge computed by PAG-ASA.

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	21	31.9	39.6	53.4	74.5	89.3	119.2	145.5	176.4
5	29.1	43.8	54.5	76.7	113.4	138.5	189.8	228.7	260.5
10	34.5	51.6	64.3	92.2	139.1	171.1	236.6	283.8	316.1
15	37.5	56	69.8	100.9	153.6	189.4	263	314.8	347.5
20	39.6	59.1	73.7	107	163.7	202.3	281.5	336.6	369.5
25	41.3	61.5	76.7	111.7	171.6	212.2	295.7	353.4	386.4
50	46.3	68.9	85.9	126.2	195.7	242.7	339.6	405	438.6
100	51.3	76.2	95.1	140.5	219.6	273.1	383.1	456.2	490.3

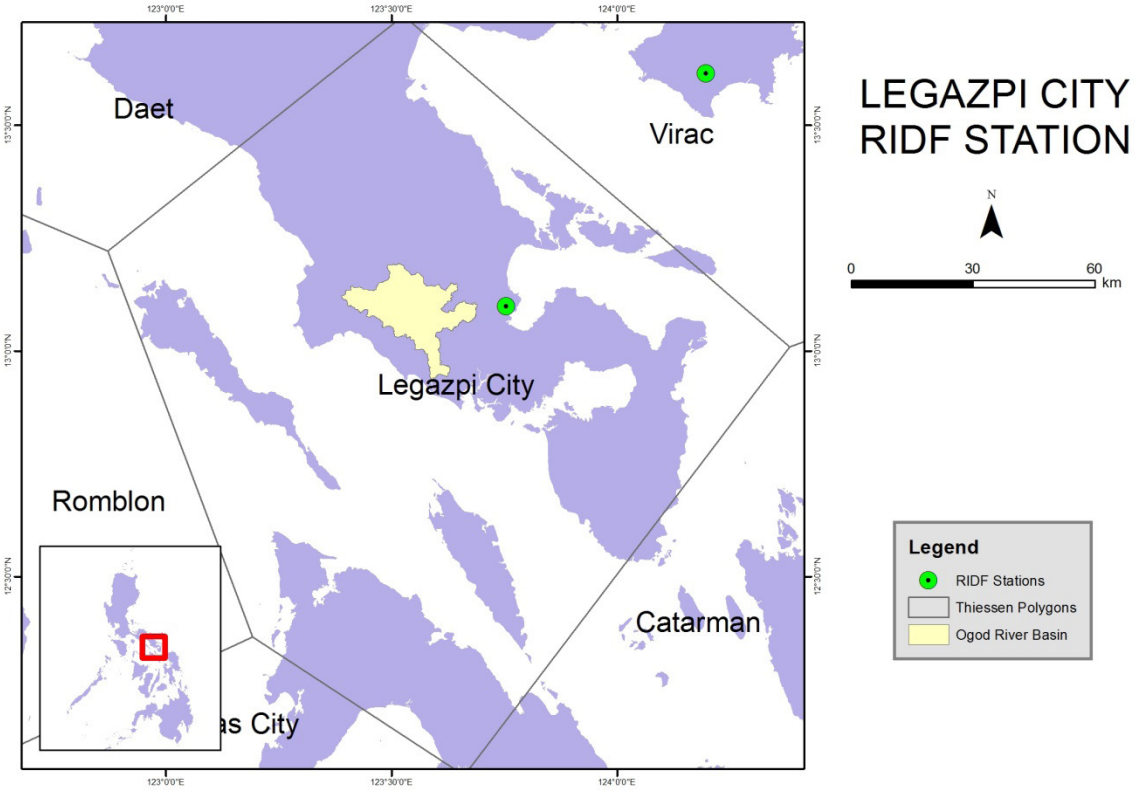


Figure 53. The location of the Legazpi City RIDF station relative to the Ogod River Basin

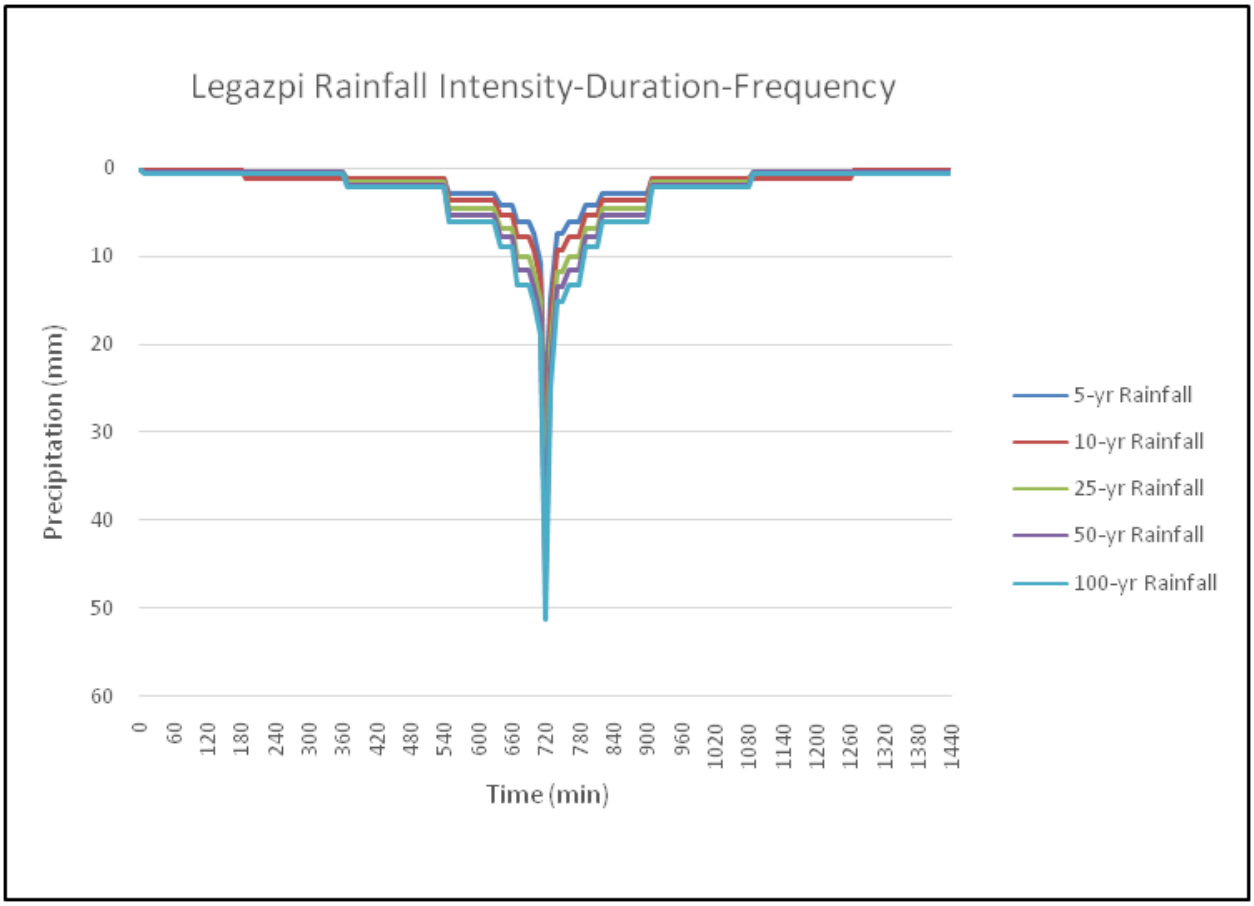


Figure 54. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soils and Water Management (BSWM); this is under the Department of Agriculture (DAR). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Ogod River Basin are shown in Figures 55 and 56, respectively.

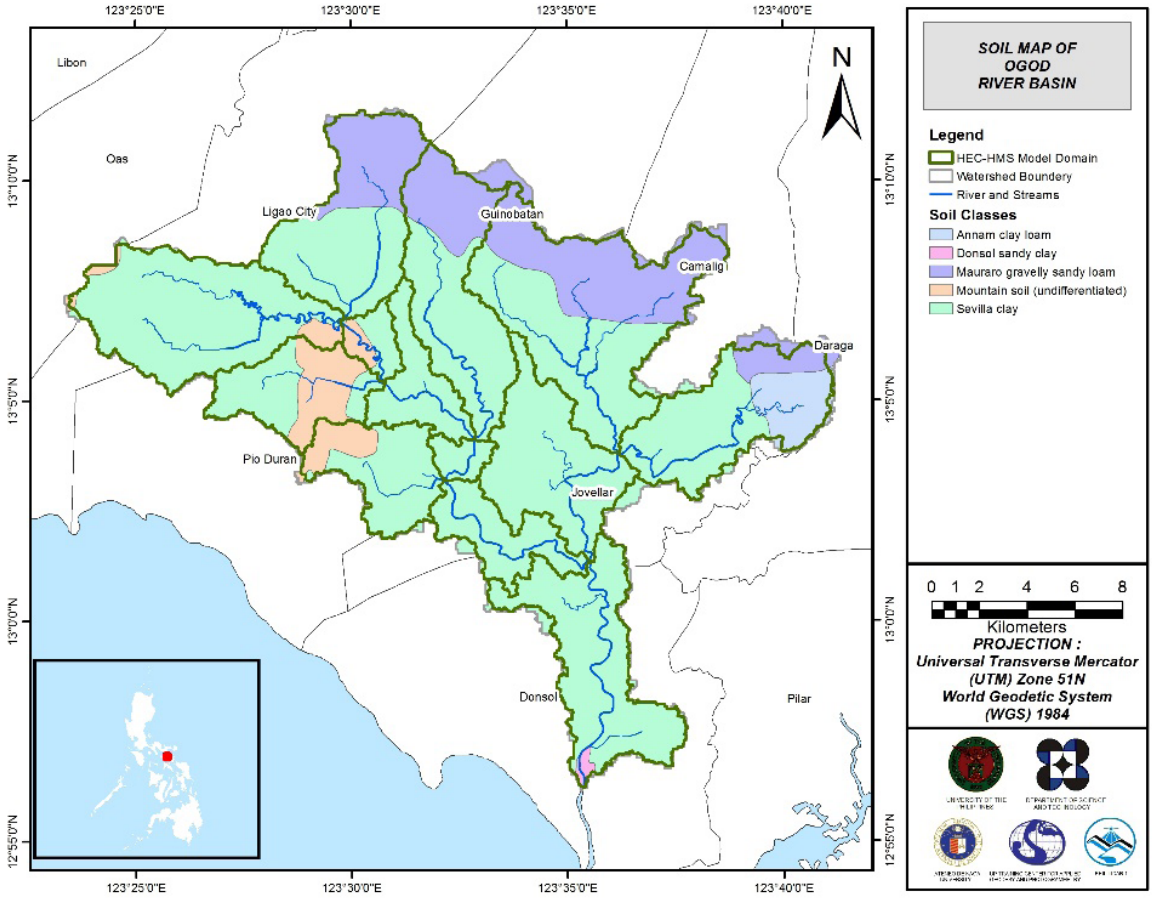


Figure 55. Soil map of Ogod River Basin.

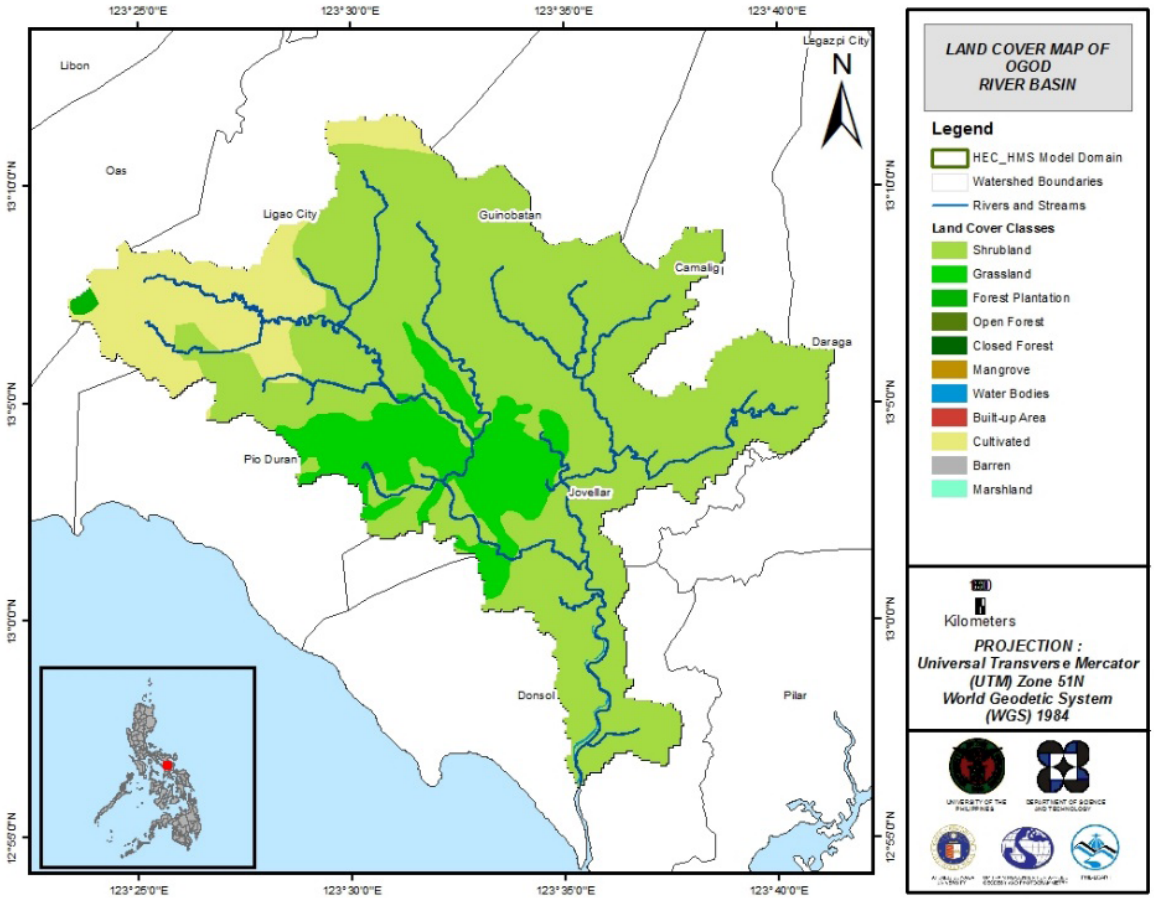


Figure 56. Land cover map of Ogod River Basin

For Ogod, five soil classes were identified. These are Annam clay loam, Donsol sandy clay, Mauraro gravelly sandy loam, Sevilla clay, and undifferentiated mountain soil. Moreover, three land cover classes were identified. These are shrubland, grassland, and cultivated areas.

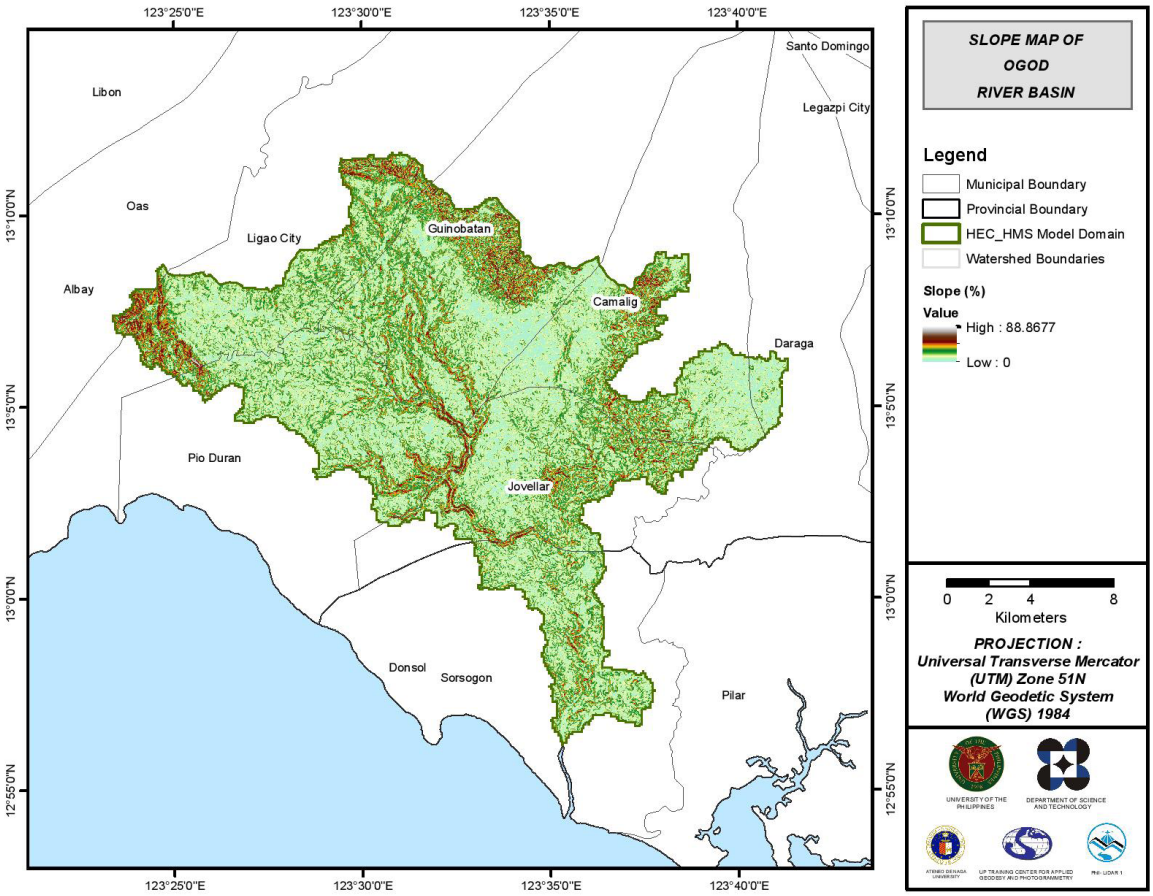


Figure 57. Slope map of Ogod River Basin.

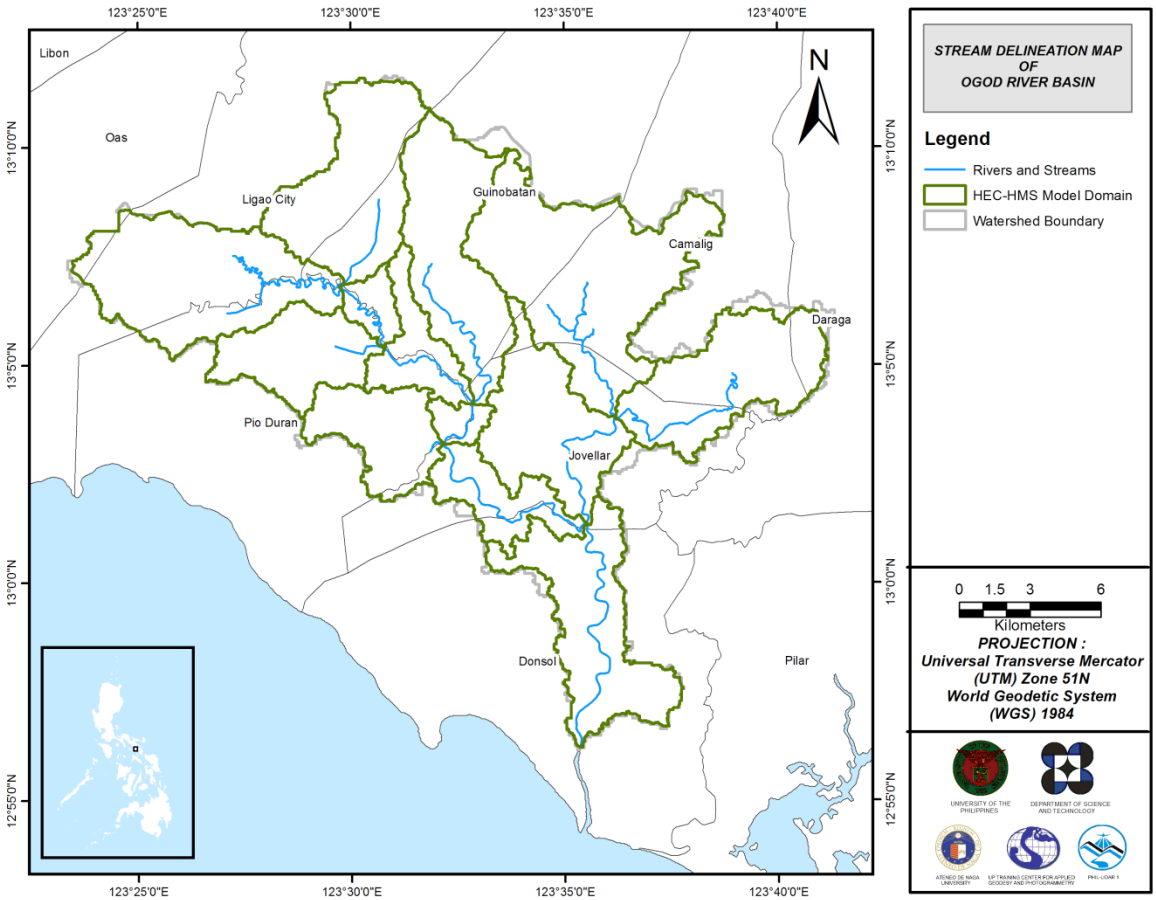


Figure 58. Stream delineation map of Ogod River Basin.

Using the SAR-based DEM, the Ogod basin was delineated and further divided into subbasins. The model consists of 13 sub basins, 6 reaches, and 7 junctions as shown in Figure 58. The main outlet is Dancalan Bridge.

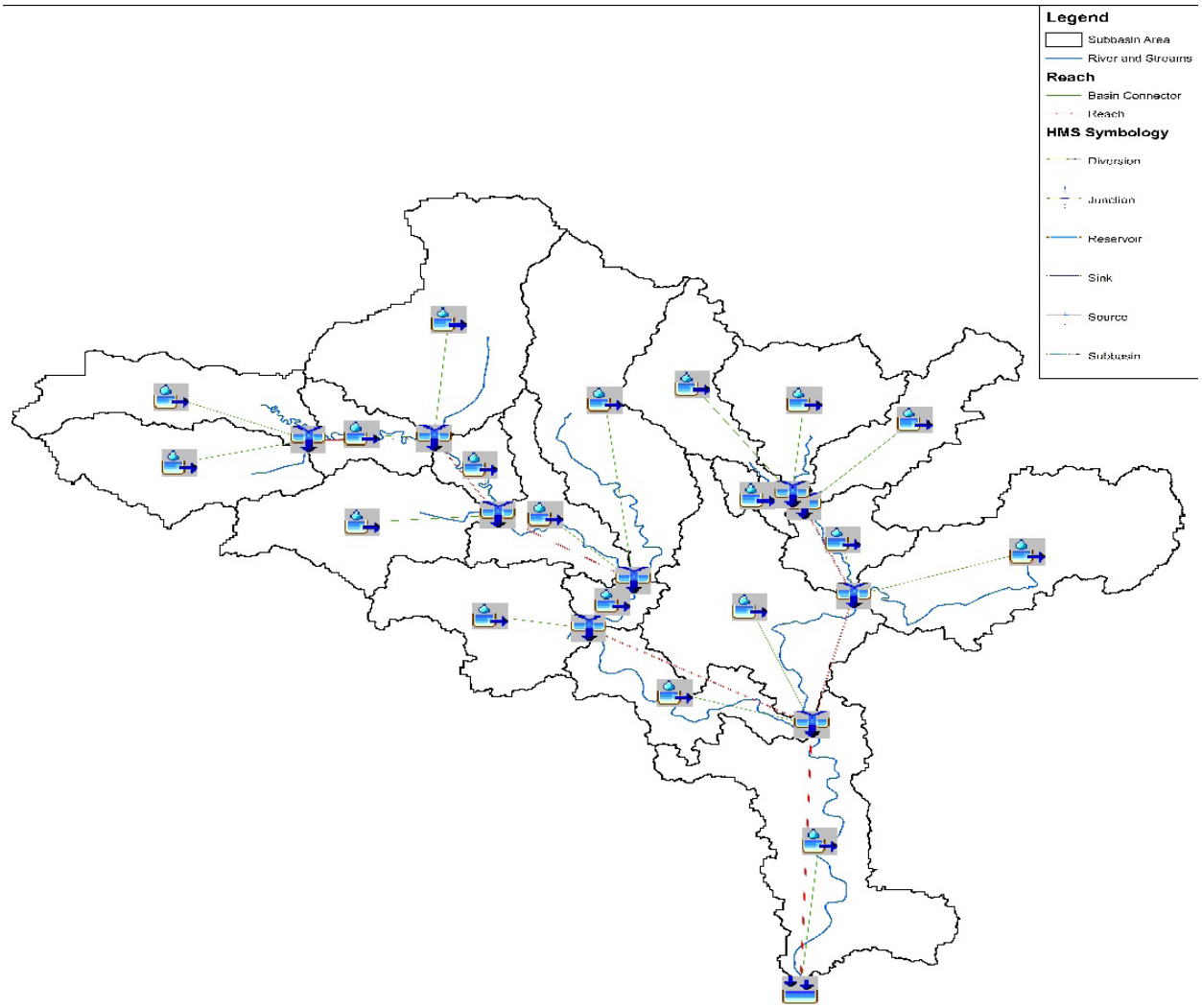


Figure 59. The Ogod river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

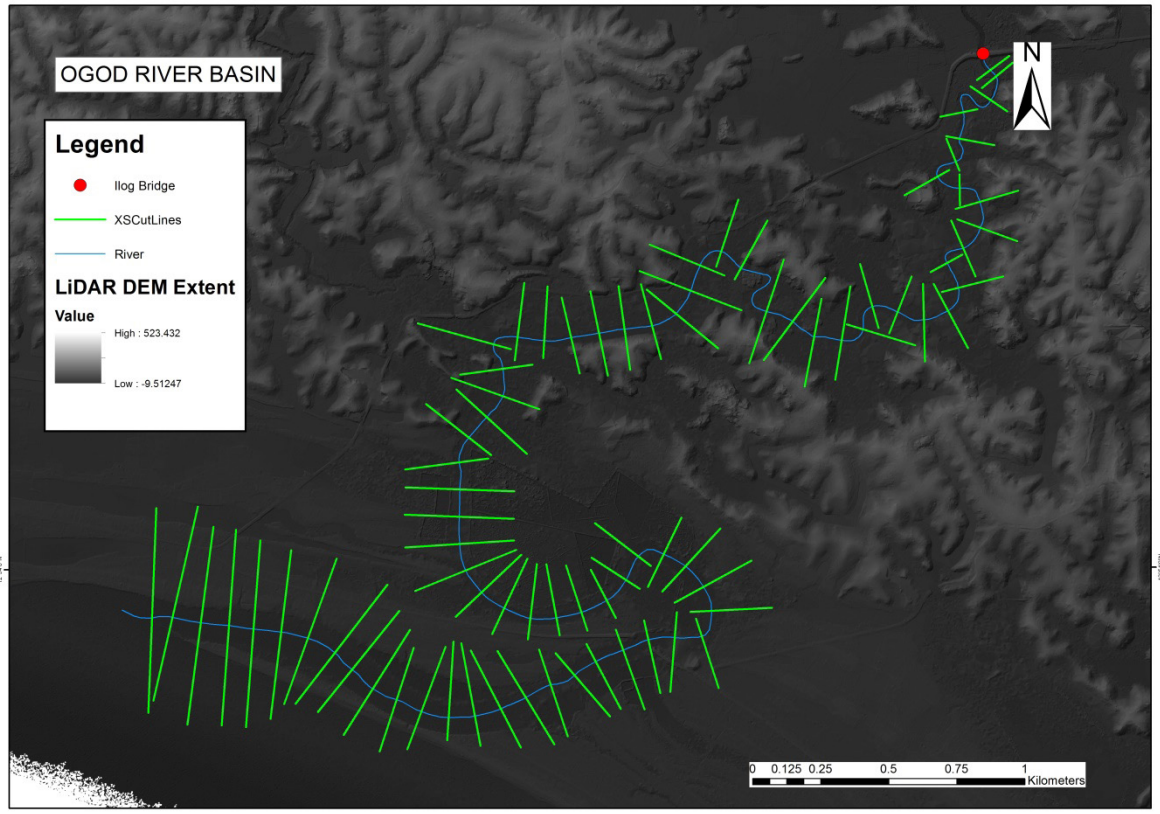


Figure 60. River cross-section of Donsol River generated through Arcmap HEC GeoRAS tool.

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.

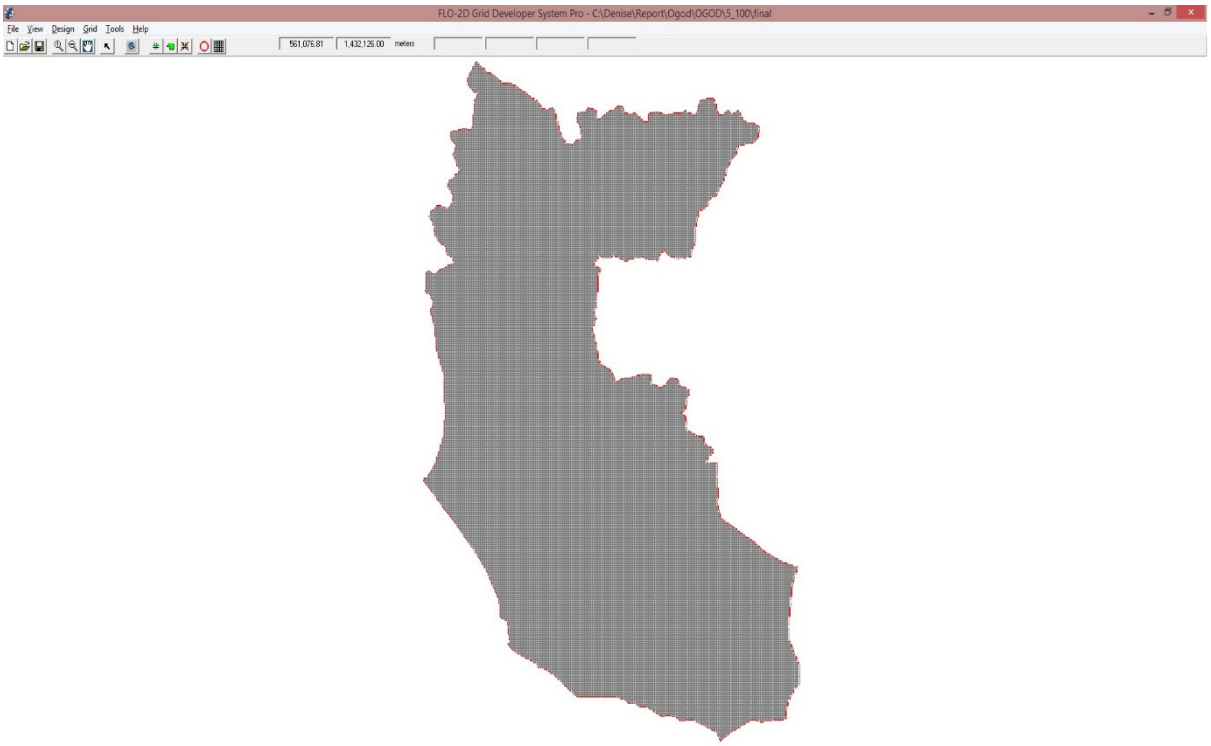


Figure 61. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 29.81 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 m^2/s. The generated hazard maps for Ogod 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 14,216,600.00 m^2. The generated flood depth maps for Ogod are in Figures 66, 68, and 70.

There is a total of 60,967,082.87m^3 of water entering the model, of which 6,951,872.95 m^3 is due to rainfall and 54,015,209.92m^3 is inflow from basins upstream. 1,947,474.38 m^3 of this water is lost to infiltration and interception, while 15,287,983.94m^3 is stored by the flood plain. The rest, amounting up to 43,731,617.31m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Ogod HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

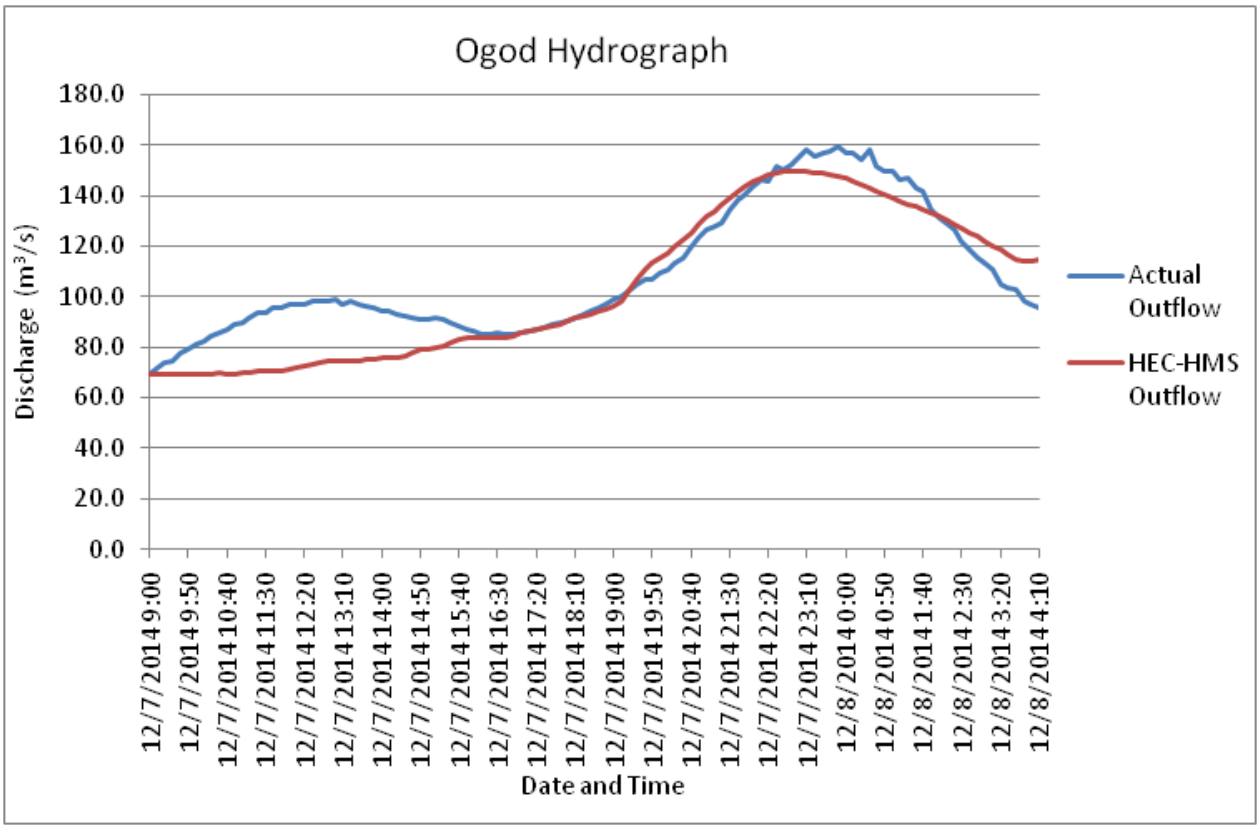


Figure 62. Outflow hydrograph of Ogod River Basin produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 32 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 32. Range of Calibrated Values for the Ogod River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.001-54
			Curve Number	35-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-8
			Storage Coefficient (hr)	0.02-17
	Baseflow	Recession	Recession Constant	0.00001-1
			Ratio to Peak	0.4-1
Reach	Routing	Muskingum-Cunge	Slope	0.0004-0.004
			Manning's n	0.0001-0.4

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.0001mm to 54mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35 to 99 for curve number is wider than the advisable for Philippine watersheds (70-80), depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Ogod, the basin mostly consists of shrubland and the soil consists of Sevilla clay, Mauraro gravelly sandy loam, and mountain soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 17 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. For Ogod, it will take 4 hours and 20 minutes from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.0001 corresponds to the common roughness of Philippine watersheds. Ogod river basin is determined to be built-up area that is concrete and float-finished (Brunner, 2010).

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

Accuracy Measure	Value
RMSE	12.3
r2	0.8065
NSE	0.77
PBIAS	5.66
RSR	0.48

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 12.3 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8065.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.77.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 5.66.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.48.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 63) shows the Ogod outflow using the synthetic storm events using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 1767.3m^3/s in a 5-year return period to 3761m^3/s in a 100-year return period.

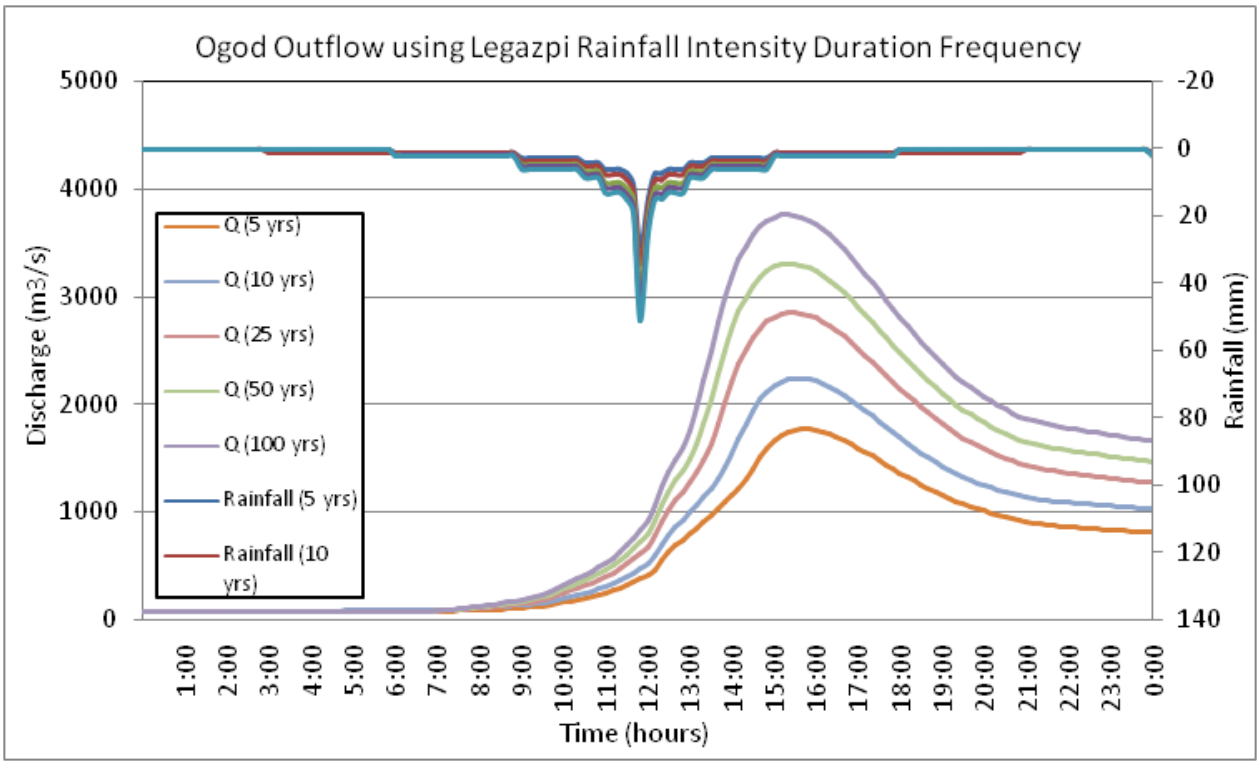


Figure 63. The outflow hydrograph at the Ogod Basin, generated using the simulated rain events for 24-hour period for Legazpi station.

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Ogod discharge using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 34.

Table 34. Peak values of the Ogod HECHMS Model outflow using the Legazpi RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	260.5	29.1	1767.3	3 hours, 40 minutes
10-Year	316.1	34.5	2240.2	3 hours, 30 minutes
25-Year	386.4	41.3	2851.9	3 hours, 30 minutes
50-Year	438.4	46.3	3307	3 hours, 20 minutes
100-Year	490.3	51.3	3761	hours, 20 minutes

5.8 River Analysis (RAS) Model Simulation

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

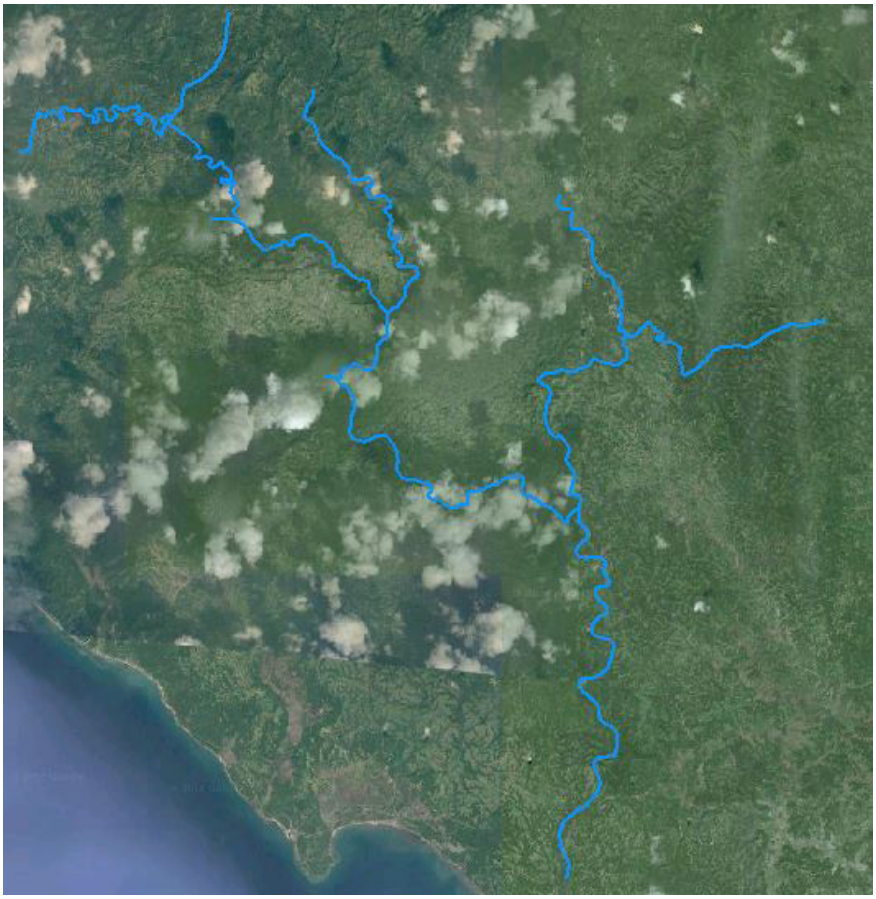


Figure 64. The sample output map of the Ogod RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 65 to 70 show the 5-, 25-, and 100-year rain return scenarios of the Ogod flood plain. The flood plain, with an area of 99.03km2, covers five (5) municipalities, namely Camalig, Guinobatan, Jovellar, Pio Duran, and Donsol. Table 35 shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Ogod floodplain.

Municipality	Total Area (km²)	Area Flooded (km²)	% Flooded
Camalig	136.54	1.56	1.15
Guinobatan	174.07	0.49	0.28
Jovellar	82.35	42.72	51.87
Pio Duran	133.24	6.09	4.57
Donsol	153	43.42	28.38

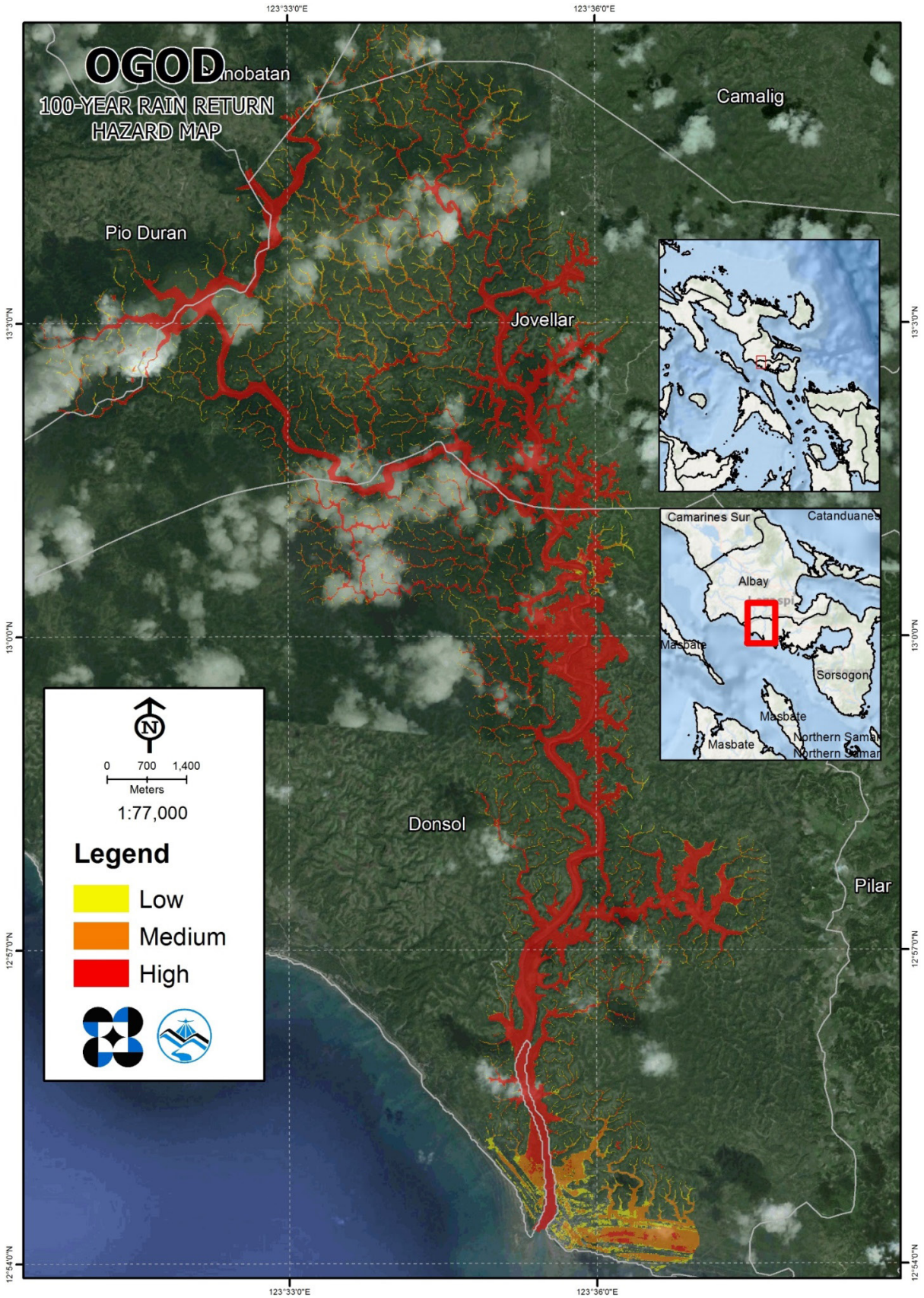


Figure 65. 100-year flood hazard map for the Ogod flood plain overlaid on Google Earth imagery

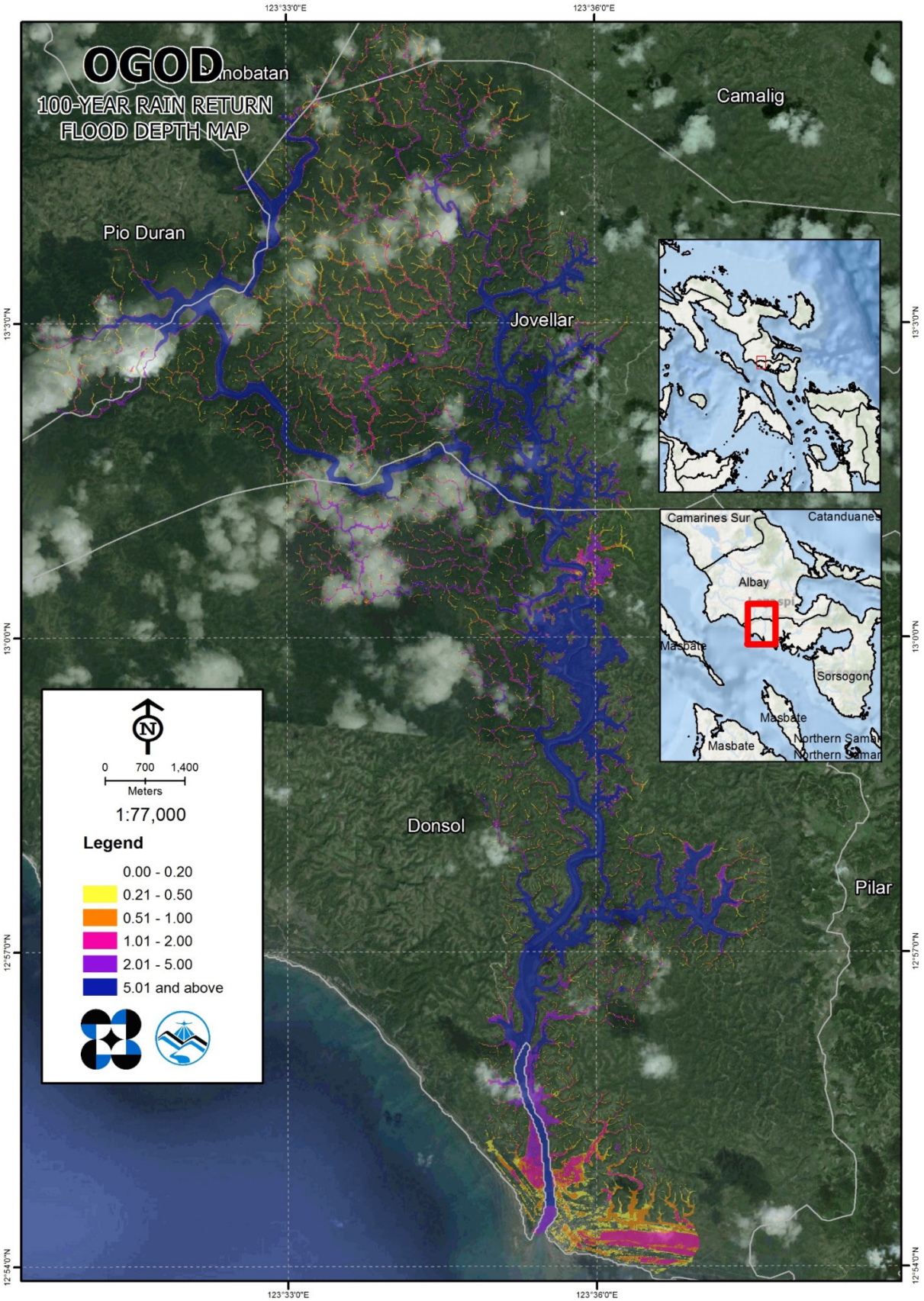


Figure 66. 100-year flow depth map for the Ogod flood plain overlaid on Google Earth imagery.

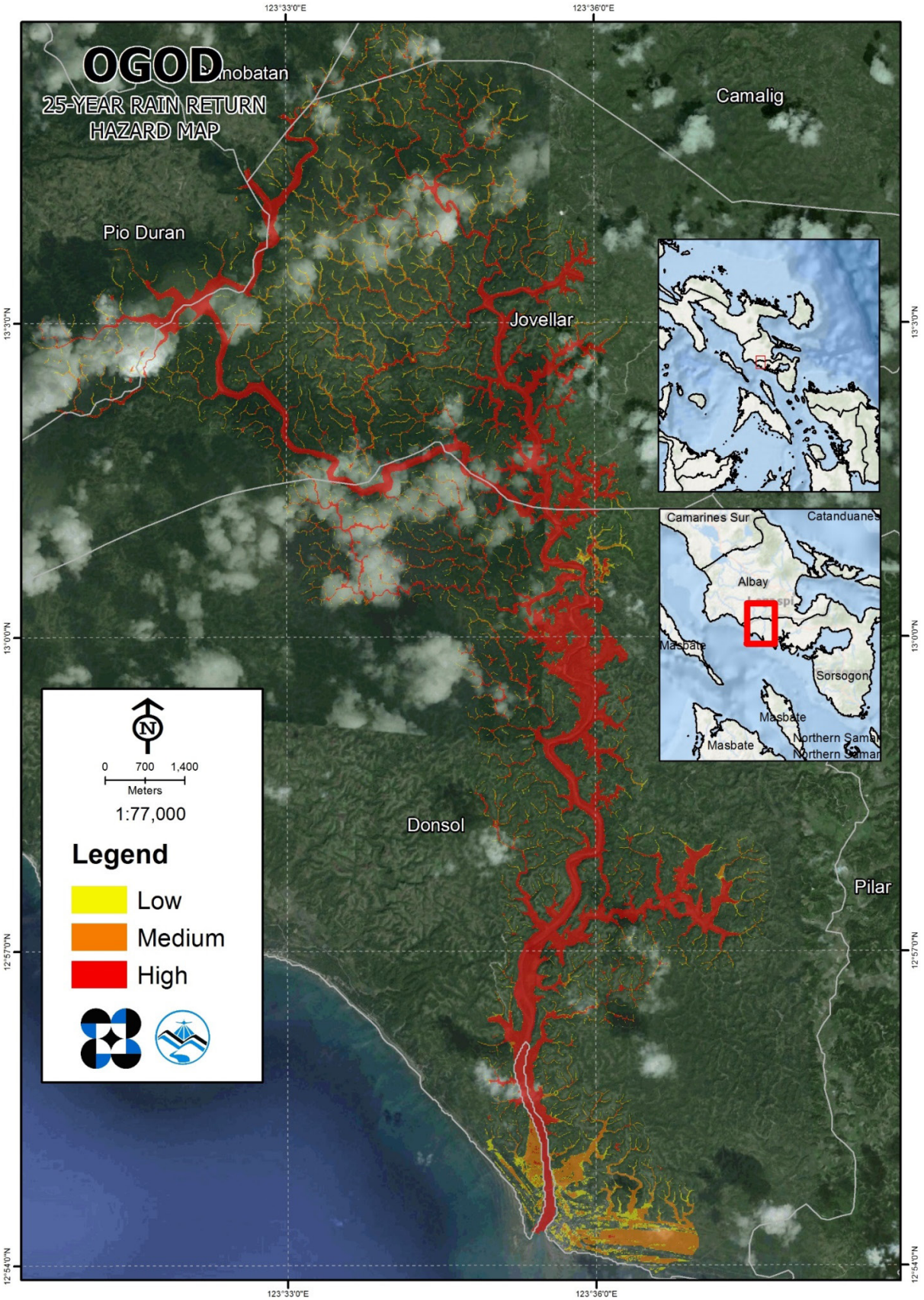


Figure 67. 25-year flood hazard map for the Ogod flood plain overlaid on Google Earth imagery.

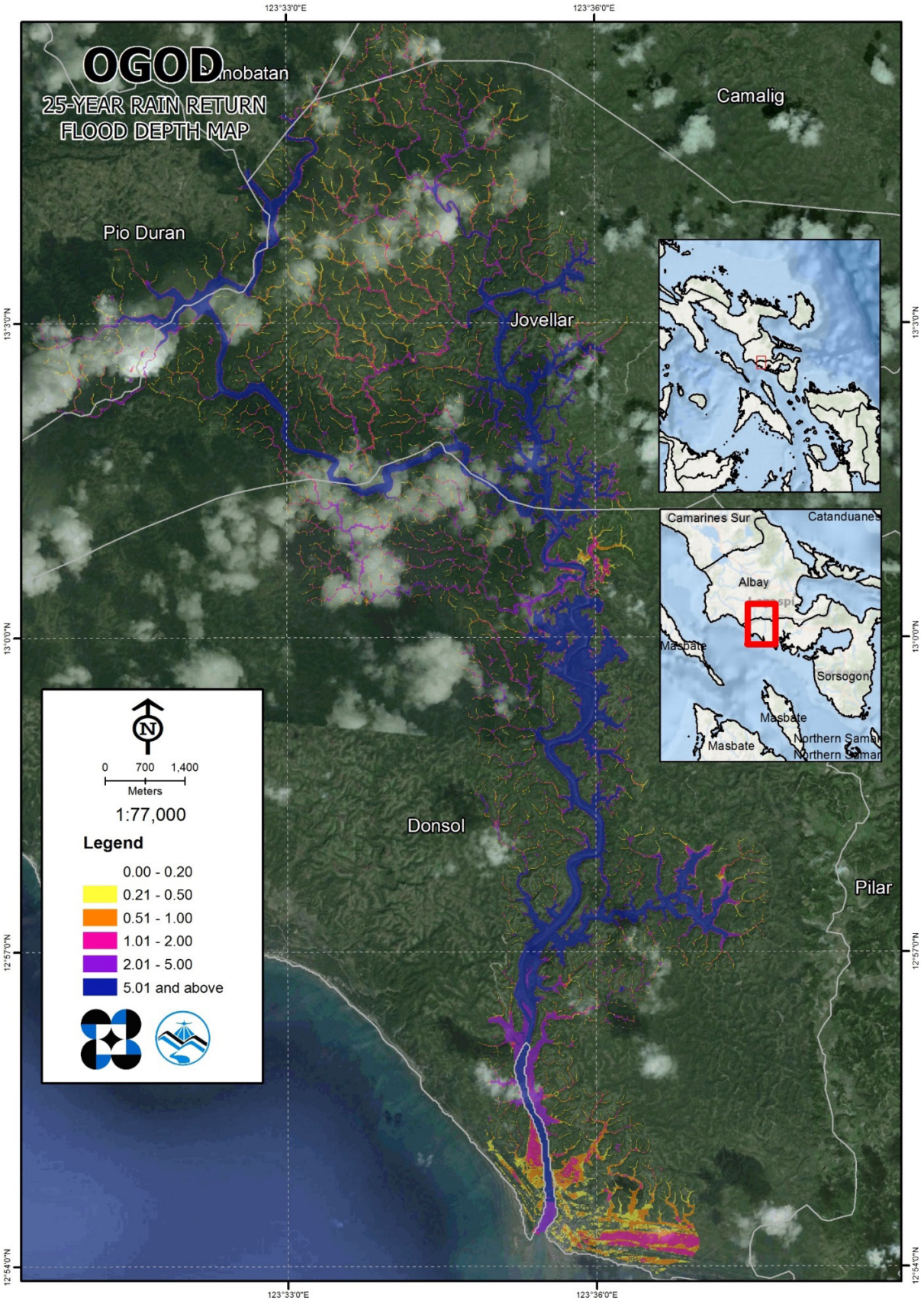


Figure 68. 25-year flow depth map for the Ogod flood plain overlaid on Google Earth imagery.

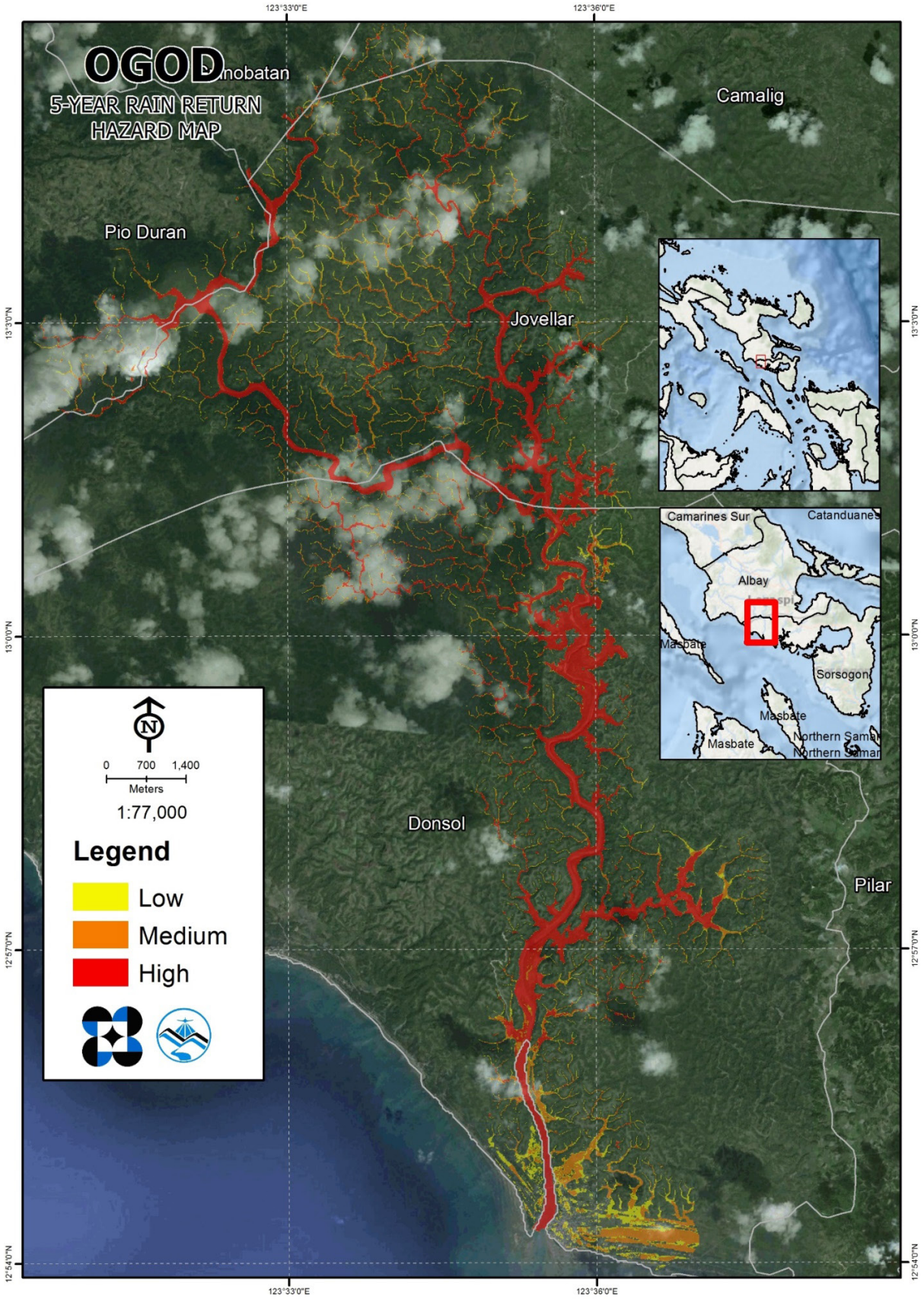


Figure 69. 5-year flood hazard map for the Ogod flood plain overlaid on Google Earth imagery.

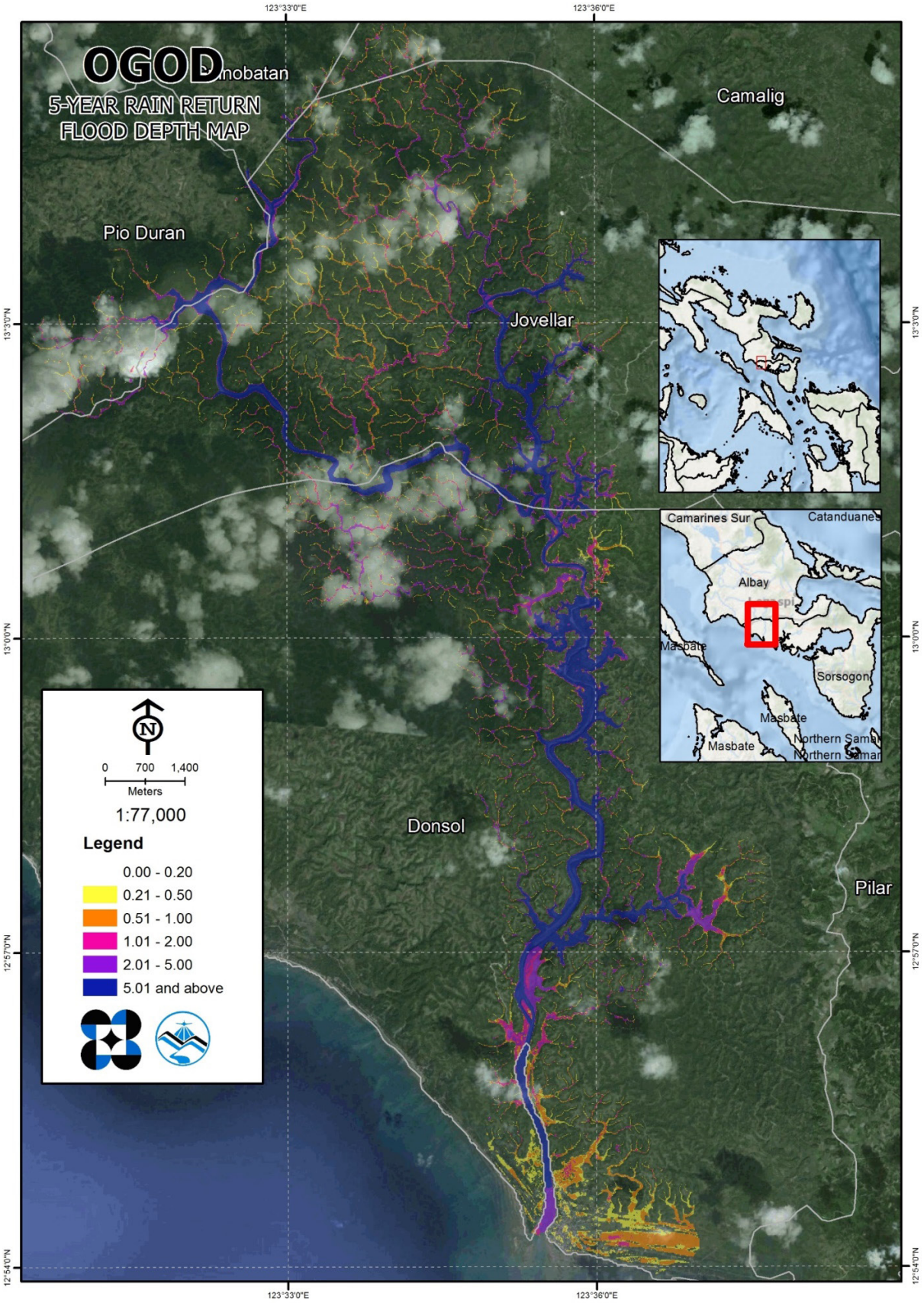


Figure 70. 5-year flow depth map for the Ogod flood plain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Ogod river basin, grouped by municipality, are listed below. For the said basin, five municipalities consisting of 54 barangays are expected to experience flooding when subjected to the three scenarios of rainfall return period.

For the 5-year rainfall return period, 1.05% of the municipality of Camalig with an area of 136.54 sq. km. will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.03%, 0.02%, 0.01%, and 0.0004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 36 depicts the areas affected in Camalig in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Camalig, Albay during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Camalig
	Quinartilan
0.03-0.20	1.43
0.21-0.50	0.047
0.51-1.00	0.04
1.01-2.00	0.034
2.01-5.00	0.014
>5.00	0.00049

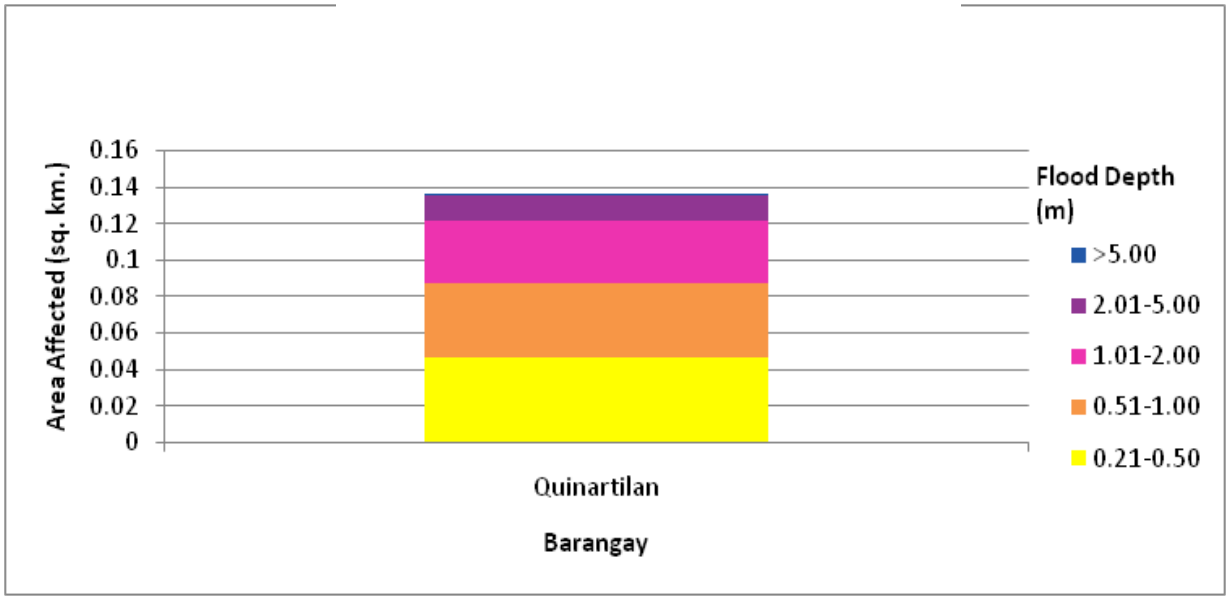


Figure 71. Affected Areas in Camalig, Albay during the 5-Year Rainfall Return Period.

For the municipality of Guinobatan with an area of 174.07 sq. km., 0.24% will experience flood levels of less than 0.20 meters. 0.008% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.005%, 0.006%, 0.007%, and 0.009% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 37 depicts the areas affected in Guinobatan in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Guinobatan, Albay during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinobatan	
	Balite	Malobago
0.03-0.20	0.077	0.35
0.21-0.50	0.00046	0.014
0.51-1.00	0.00051	0.0079
1.01-2.00	0.0008	0.01
2.01-5.00	0.0019	0.0099
>5.00	0.0087	0.0068

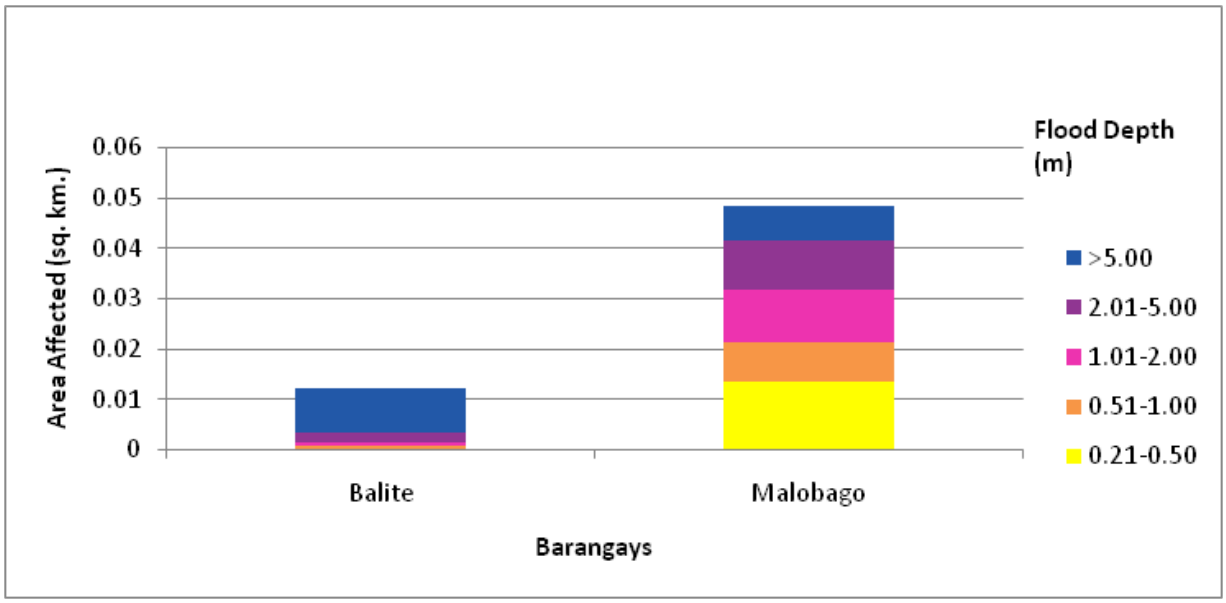


Figure 72. Affected Areas in Guinobatan, Albay during the 5-Year Rainfall Return Period.

For the municipality of Jovellar with an area of 82.35 sq. km., 44.28% will experience flood levels of less than 0.20 meters. 1.52% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.25%, 1.08%, 1.19%, and 2.56% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 38 depicts the areas affected in Jovellar in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Jovellar, Albay during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jovellar													
	Aurora Poblacion	Bagacay	Bautista	Cabraran	Del Rosario	Estrella	Mabini Pobla-cion	Maogog	Mercado Poblacion	Plaza Pobla-cion	San Roque	San Vicente	Sinaga-ran	Villa Paz
0.03-0.20	0.058	5.36	4.39	1.63	0.56	2.14	0.34	4.82	0.0031	0.0011	4.55	4.49	5.25	2.88
0.21-0.50	0.00072	0.19	0.12	0.072	0.017	0.05	0.01	0.18	0.0001	0	0.076	0.24	0.17	0.11
0.51-1.00	0	0.15	0.12	0.056	0.018	0.039	0.0058	0.12	0	0	0.077	0.21	0.16	0.074
1.01-2.00	0	0.14	0.13	0.045	0.029	0.04	0.0064	0.11	0	0	0.1	0.12	0.14	0.032
2.01-5.00	0	0.15	0.13	0.021	0.088	0.069	0.015	0.11	0	0	0.27	0.011	0.074	0.038
>5.00	0	0.039	0.25	0.0016	0.14	0.16	0.018	0.15	0	0	0.9	0	0.33	0.13

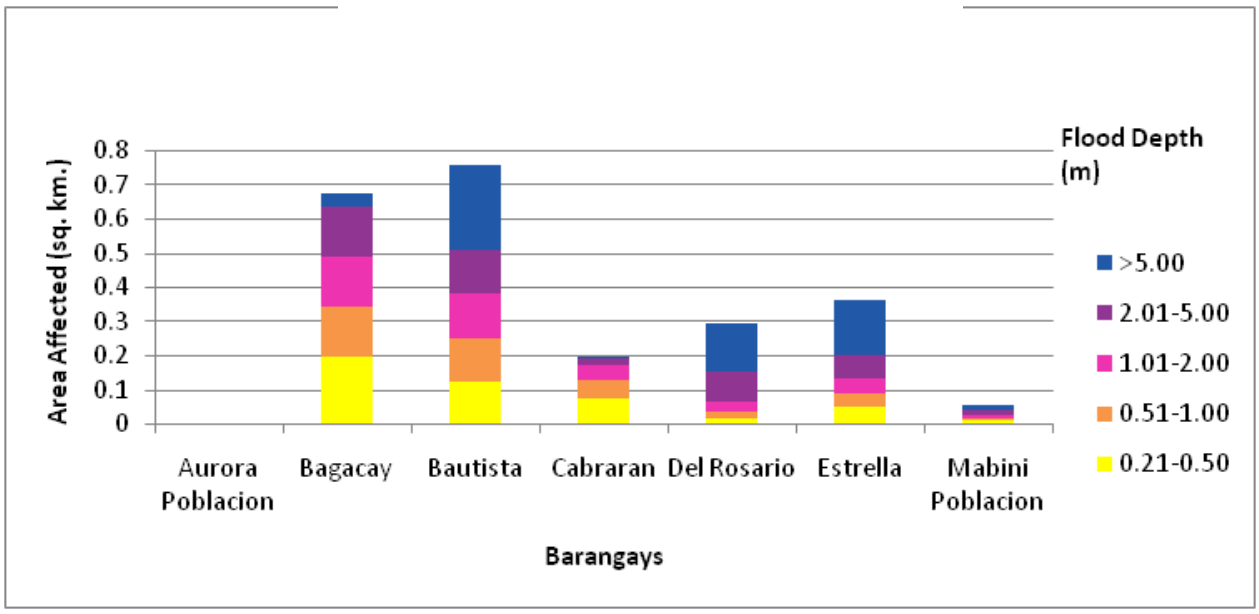


Figure 73. Affected Areas in Jovellar, Albay during the 5-Year Rainfall Return Period.

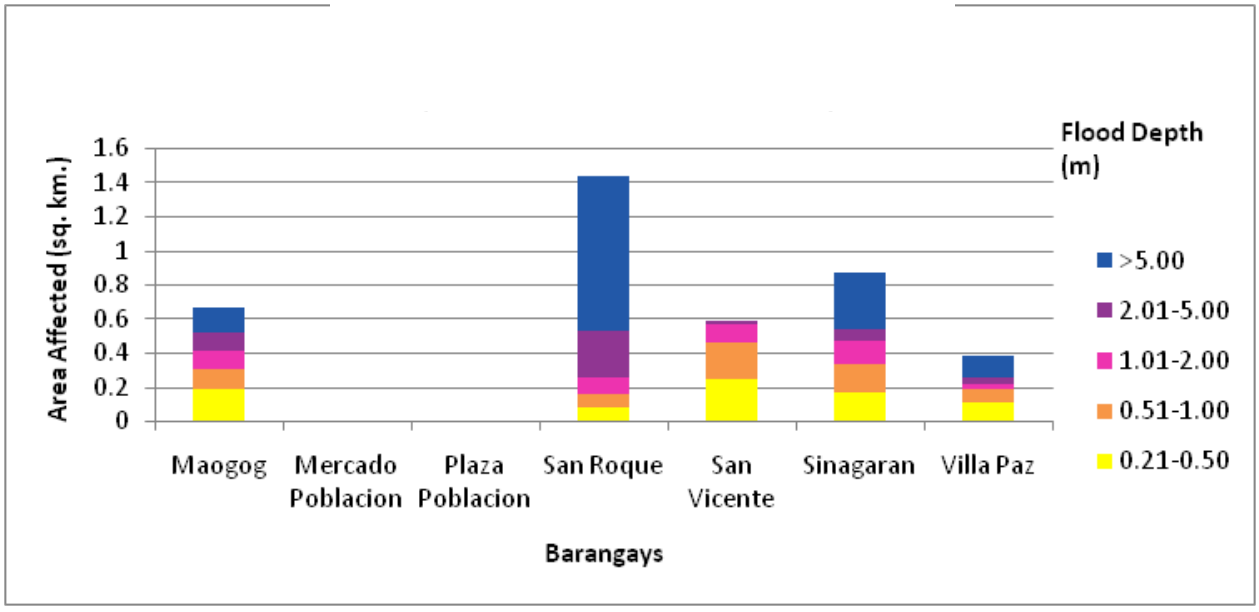


Figure 74. Affected Areas in Jovellar, Albay during the 5-Year Rainfall Return Period.

For the municipality of Pio Duran with an area of 133.24 sq. km., 4.09% will experience flood levels of less than 0.20 meters. 0.1% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.07%, 0.06%, 0.09%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 39 depicts the areas affected in Pio Duran in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Pio Duran, Albay during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pio Duran		
	Buyo	Rawis	Sukip
0.03-0.20	3.54	0.82	1.08
0.21-0.50	0.085	0.024	0.022
0.51-1.00	0.058	0.018	0.014
1.01-2.00	0.065	0.012	0.0088
2.01-5.00	0.096	0.0094	0.012
>5.00	0.2	0.00068	0.027

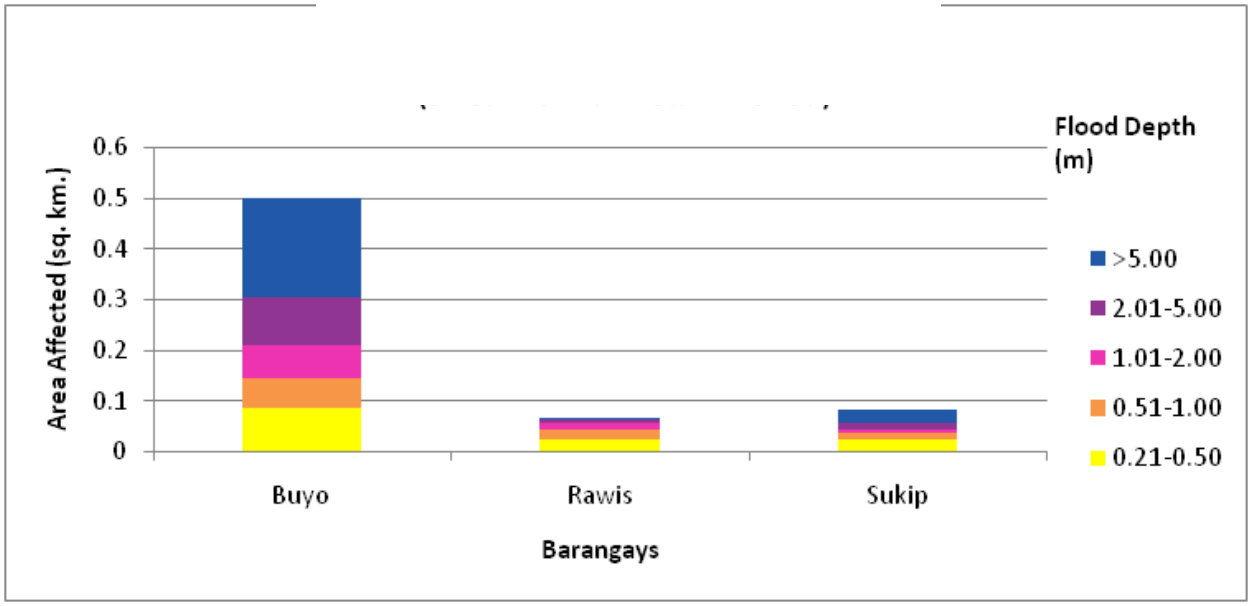


Figure 75. Affected Areas in Pio Duran, Albay during the 5-Year Rainfall Return Period.

For the municipality of Donsol with an area of 153 sq. km., 22.29% will experience flood levels of less than 0.20 meters. 1.05% of the area will experience flood levels of 0.21 to 0.50 meters, while 1%, 0.73%, 1.04%, and 2.28% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 40 depicts the areas affected in Donsol in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Donsol, Sorsogon during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol															
	Alin	Awai	Bandi	Banuang Gurang	Baras	Bororan Barangay 1	Cabugao	Central Barangay 2	Cristo	Dancalan	Girawan	Gogon	Juan Adre	Mabini	Market Site Barangay 3	New Maguisa	Ogod
0.03-0.20	1.21	0.036	2.23	1.61	0.32	0.088	4.99	0.03	0.07	1.55	0.82	0.03	1.08	2.43	0.093	0.26	1.12
0.21-0.50	0.025	0.011	0.049	0.088	0.0054	0.019	0.14	0.0076	0.0033	0.23	0.032	0.0002	0.028	0.066	0.032	0.006	0.36
0.51-1.00	0.02	0.012	0.051	0.068	0.007	0.0003	0.12	0.0075	0.001	0.085	0.042	0.0002	0.016	0.04	0.02	0.0051	0.56
1.01-2.00	0.026	0.0005	0.041	0.093	0.017	0.0011	0.17	0.0005	0.00042	0.034	0.1	0.0003	0.018	0.049	0.00064	0.0034	0.02
2.01-5.00	0.069	0	0.046	0.13	0.055	0.00016	0.15	0	0	0.011	0.046	0	0.041	0.096	0	0.0034	0
>5.00	0.51	0	0.013	0.2	0.34	0	0.2	0	0	0.0013	0.02	0	0.27	0.28	0	0.00071	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol															
	Old Maguisa	Orange	Parina	Pawala	Poso Poblacion	Punta Waling-Waling Poblacion	Rawis	San Antonio	San Isidro	San Jose	San Ramon	San Vicente	Suguian	Tagbac	Tongdol	Tres Marias
0.03-0.20	0.062	2.01	0.62	2.19	0.056	0.04	0.27	1.41	2.06	3.13	1.78	0.16	0.24	0.36	1.3	0.43
0.21-0.50	0.0014	0.055	0.011	0.053	0.014	0.004	0.062	0.043	0.04	0.07	0.058	0.0052	0.0053	0.0077	0.055	0.019
0.51-1.00	0.00022	0.05	0.0067	0.046	0.011	0.001	0.067	0.044	0.037	0.061	0.055	0.0025	0.0025	0.012	0.057	0.0091
1.01-2.00	0.00063	0.081	0.0042	0.058	0.00016	0	0.0087	0.034	0.073	0.087	0.11	0.0015	0.0033	0.028	0.05	0.0055
2.01-5.00	0.0001	0.11	0.0049	0.074	0	0	0	0.017	0.18	0.12	0.21	0.0003	0.018	0.089	0.12	0.00061
>5.00	0	0.023	0.002	0.17	0	0	0	0.002	0.65	0.33	0.14	0	0.079	0.26	0.00065	0

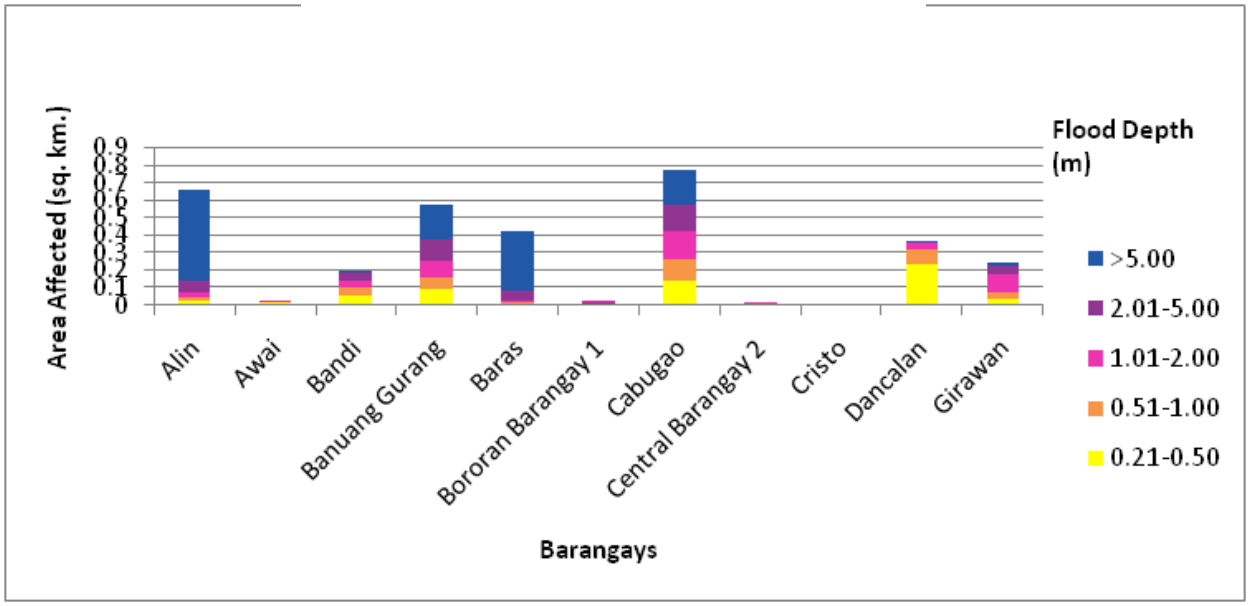


Figure 76. Affected Areas in Donsol, Sorsogon during the 5-Year Rainfall Return Period.

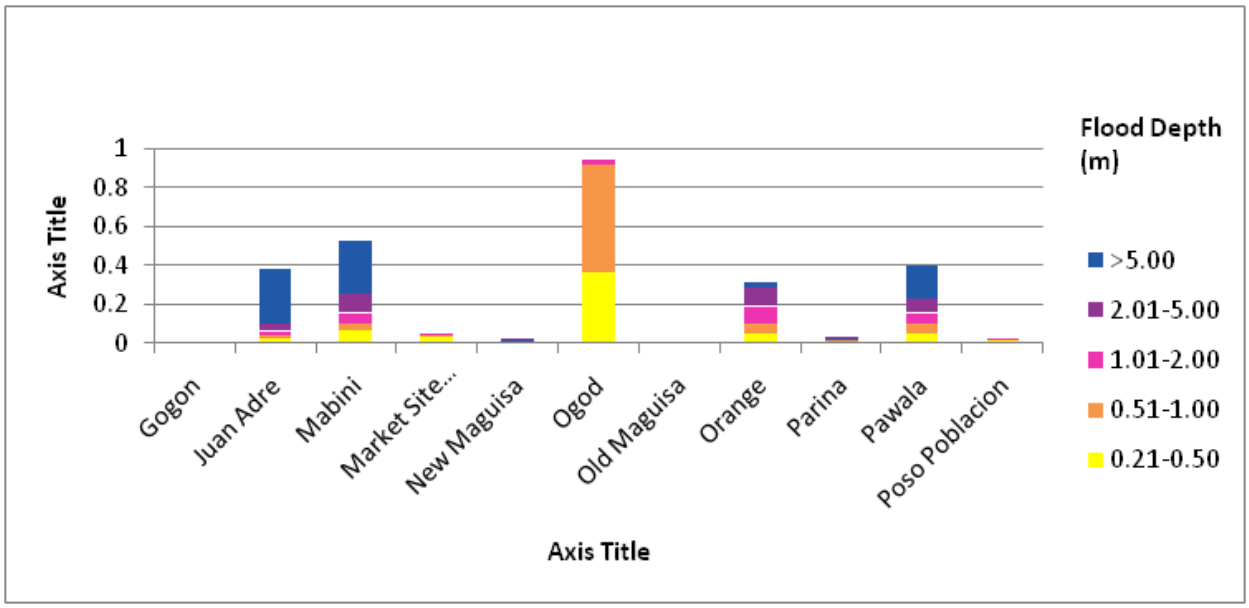


Figure 77. Affected Areas in Donsol, Sorsogon during the 5-Year Rainfall Return Period.

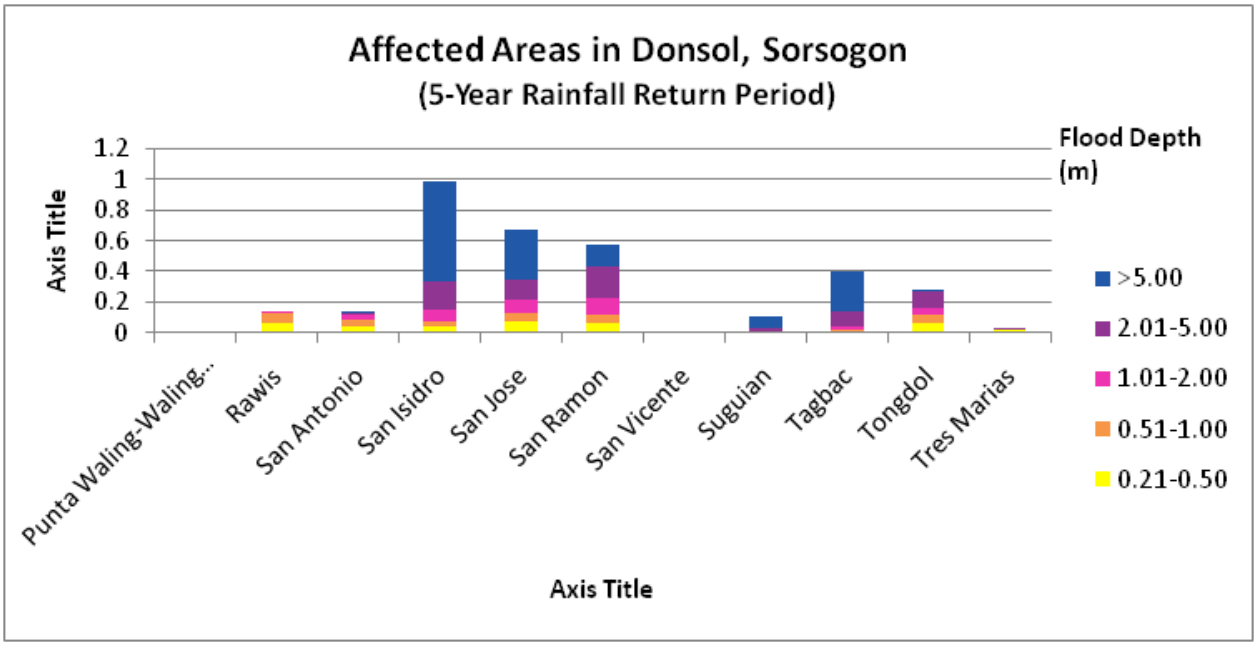


Figure 78. Affected Areas in Donsol, Sorsogon during the 5-Year Rainfall Return Period.

For the 25-year rainfall return period, 1.03% of the municipality of Camalig with an area of 136.54 sq. km. will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.03%, 0.03%, 0.02%, and 0.0007% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 41 depicts the areas affected in Camalig in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Camalig, Albay during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Camalig
	Quinartilan
0.03-0.20	1.41
0.21-0.50	0.047
0.51-1.00	0.045
1.01-2.00	0.042
2.01-5.00	0.021
>5.00	0.00089

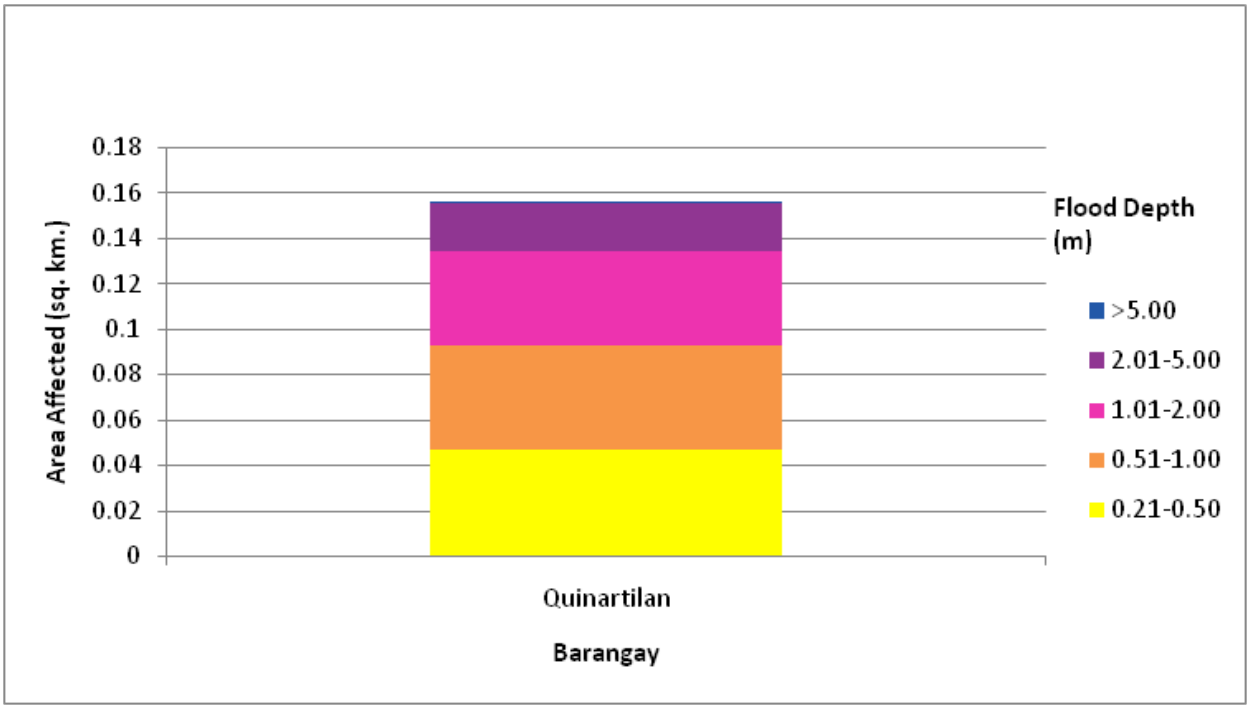


Figure 79. Affected Areas in Camalig, Albay during the 25-Year Rainfall Return Period.

For the municipality of Guinobatan with an area of 174.07 sq. km., 0.23% will experience flood levels of less than 0.20 meters. 0.009% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.006%, 0.007%, 0.01%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 42 depicts the areas affected in Guinobatan in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Guinobatan during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinobatan	
	Balite	Malobago
0.03-0.20	0.07	0.34
0.21-0.50	0.00084	0.014
0.51-1.00	0.00042	0.0093
1.01-2.00	0.0013	0.012
2.01-5.00	0.0028	0.015
>5.00	0.014	0.012

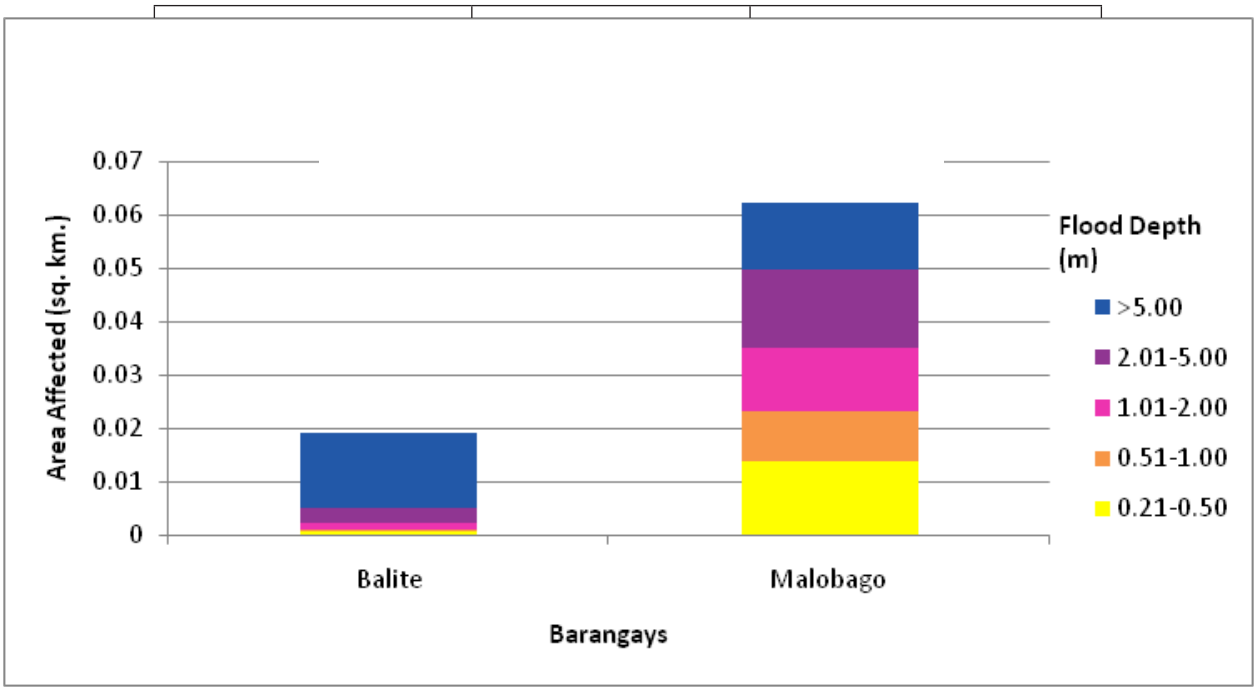


Figure 80. Affected Areas in Guinobatan, Albay during the 25-Year Rainfall Return Period.

For the municipality of Jovellar with an area of 82.35 sq. km., 44.34% will experience flood levels of less than 0.20 meters. 1.52% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.28%, 1.29%, 1.41%, and 4.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 43 depicts the areas affected in Jovellar in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Jovellar, Albay during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jovellar													
	Aurora Poblacion	Bagacay	Bautista	Cabraran	Del Rosario	Estrella	Mabini Poblacion	Maogog	Mercado Poblacion	Plaza Poblacion	San Roque	San Vicente	Sinagaran	Villa Paz
0.03-0.20	0.058	5.23	4.16	1.6	0.47	2.03	0.29	4.63	0.0031	0.0011	4.08	4.4	5.11	2.8
0.21-0.50	0.0013	0.21	0.11	0.075	0.011	0.053	0.0079	0.19	0.0001	0	0.064	0.24	0.17	0.12
0.51-1.00	0	0.16	0.11	0.06	0.015	0.039	0.0056	0.14	0	0	0.063	0.22	0.16	0.085
1.01-2.00	0	0.15	0.15	0.053	0.024	0.047	0.01	0.12	0	0	0.11	0.17	0.18	0.043
2.01-5.00	0	0.19	0.2	0.033	0.079	0.083	0.023	0.1	0	0	0.29	0.036	0.097	0.027
>5.00	0	0.098	0.41	0.0026	0.25	0.24	0.056	0.29	0	0	1.37	0	0.4	0.19

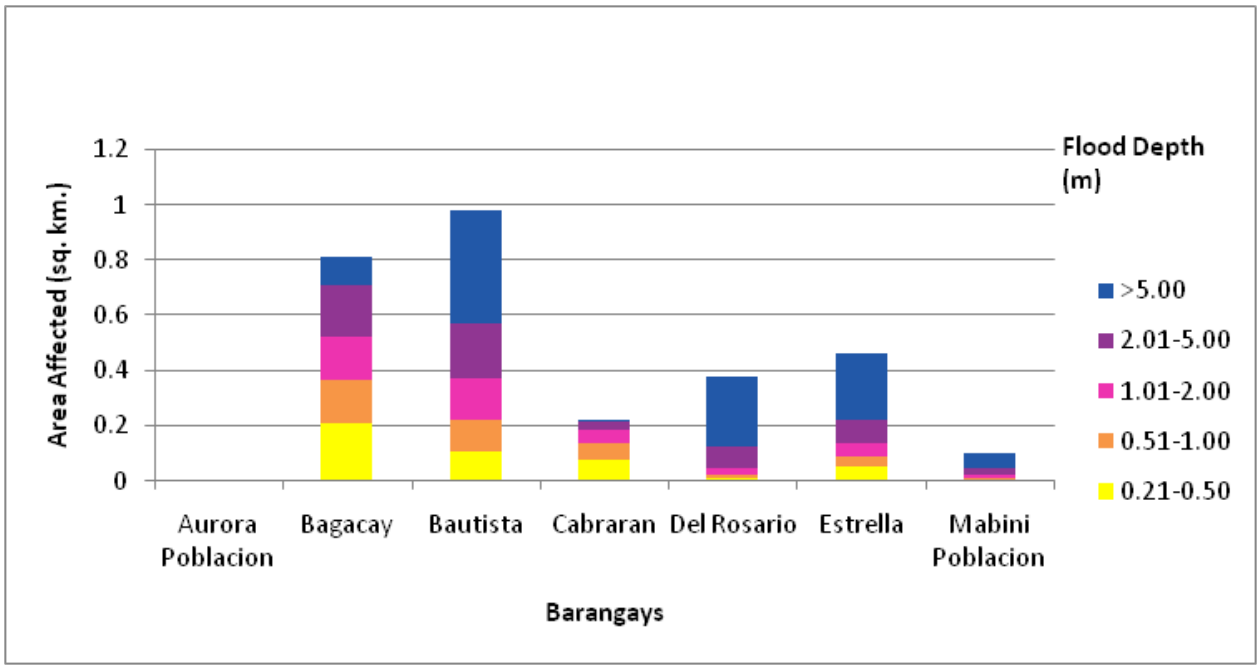


Figure 81. Affected Areas in Jovellar, Albay during the 25-Year Rainfall Return Period

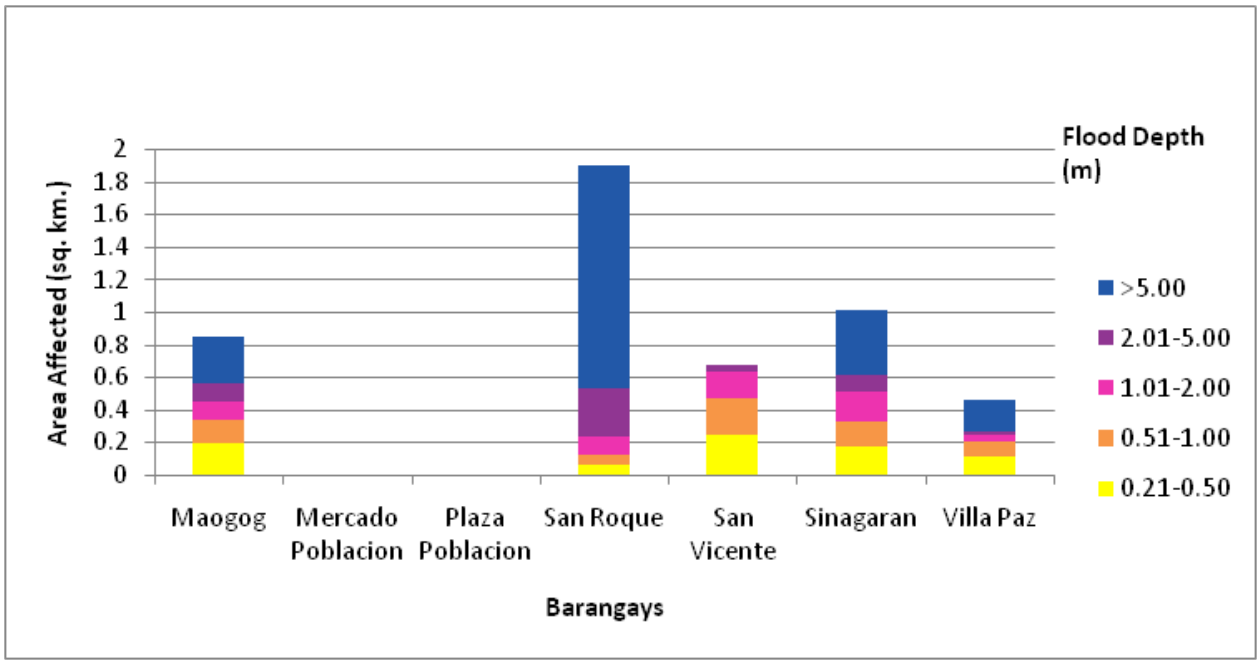


Figure 82. Affected Areas in Jovellar, Albay during the 25-Year Rainfall Return Period.

For the municipality of Pio Duran with an area of 133.24 sq. km., 3.93% will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.07%, 0.07%, 0.09%, and 0.31% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 44 depicts the areas affected in Pio Duran in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Pio Duran, Albay during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pio Duran		
	Buyo	Rawis	Sukip
0.03-0.20	3.37	0.81	1.05
0.21-0.50	0.098	0.025	0.024
0.51-1.00	0.055	0.02	0.017
1.01-2.00	0.061	0.014	0.011
2.01-5.00	0.097	0.013	0.013
>5.00	0.36	0.0019	0.047

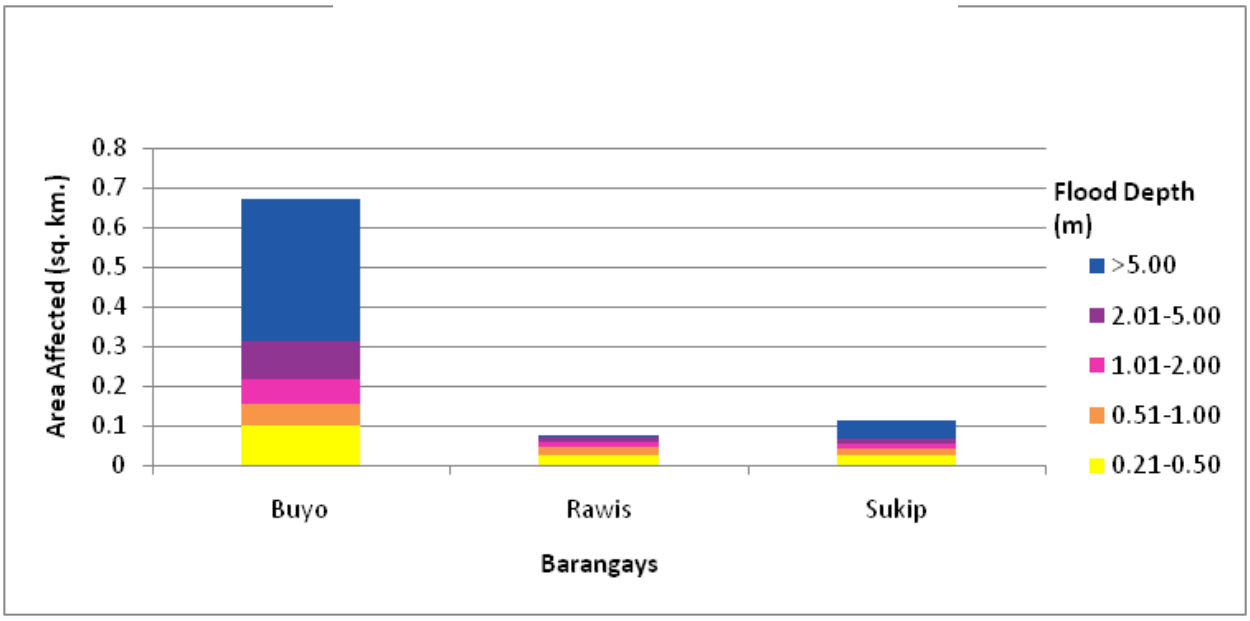


Figure 83. Affected Areas in Pio Duran, Albay during the 25-Year Rainfall Return Period.

For the municipality of Donsol with an area of 153 sq. km., 20.88% will experience flood levels of less than 0.20 meters. 0.92% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.97%, 0.95%, 1.19%, and 3.46% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 45 depicts the areas affected in Donsol in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Donsol, Sorsogon during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol														
	Alin	Awai	Bandi	Banuang Gurang	Baras	Bororan Barangay 1	Cabugao	Central Barangay 2	Cristo	Dancalan	Girawan	Gogon	Juan Adre	Mabini	Market Site Barangay 3
0.03-0.20	1.06	0.023	2.17	1.45	0.23	0.08	4.88	0.027	0.07	1.33	0.77	0.03	1.03	2.25	0.062
0.21-0.50	0.019	0.015	0.05	0.087	0.0045	0.026	0.14	0.0067	0.0024	0.19	0.022	0.0005	0.028	0.056	0.04
0.51-1.00	0.017	0.018	0.048	0.084	0.0051	0.001	0.13	0.011	0.0021	0.18	0.022	0.0001	0.018	0.037	0.035
1.01-2.00	0.028	0.0037	0.049	0.099	0.011	0.0001	0.17	0.00092	0.00052	0.16	0.029	0.0004	0.019	0.05	0.0084
2.01-5.00	0.074	0	0.07	0.12	0.038	0.0012	0.22	0	0	0.06	0.19	0	0.037	0.12	0
>5.00	0.67	0	0.044	0.34	0.46	0	0.23	0	0	0.0027	0.036	0	0.33	0.45	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol																	
	New Maguisa	Ogod	Old Maguisa	Orange	Parina	Pawala	Poso Poblacion	Punta Waling-Waling Poblacion	Rawis	San Antonio	San Isidro	San Jose	San Ramon	San Vicente	Suguian	Tagbac	Tongdol	Tres Marias
0.03-0.20	0.26	1.01	0.062	1.93	0.61	2.12	0.042	0.035	0.24	1.37	1.87	2.96	1.71	0.16	0.23	0.26	1.2	0.42
0.21-0.50	0.006	0.25	0.0016	0.05	0.012	0.052	0.018	0.0078	0.052	0.038	0.036	0.065	0.047	0.0058	0.0063	0.0071	0.044	0.021
0.51-1.00	0.0058	0.44	0.0004	0.044	0.0081	0.045	0.016	0.0024	0.076	0.031	0.033	0.066	0.047	0.0031	0.0032	0.0097	0.038	0.012
1.01-2.00	0.004	0.36	0.00065	0.063	0.0051	0.059	0.0044	0.0001	0.04	0.032	0.051	0.089	0.062	0.0016	0.0023	0.018	0.041	0.0087
2.01-5.00	0.0044	0	0.0001	0.17	0.0054	0.085	0	0	0	0.048	0.13	0.15	0.15	0.0003	0.0062	0.086	0.076	0.001
>5.00	0.00093	0	0	0.064	0.0076	0.23	0	0	0	0.033	0.93	0.47	0.33	0	0.098	0.38	0.18	0

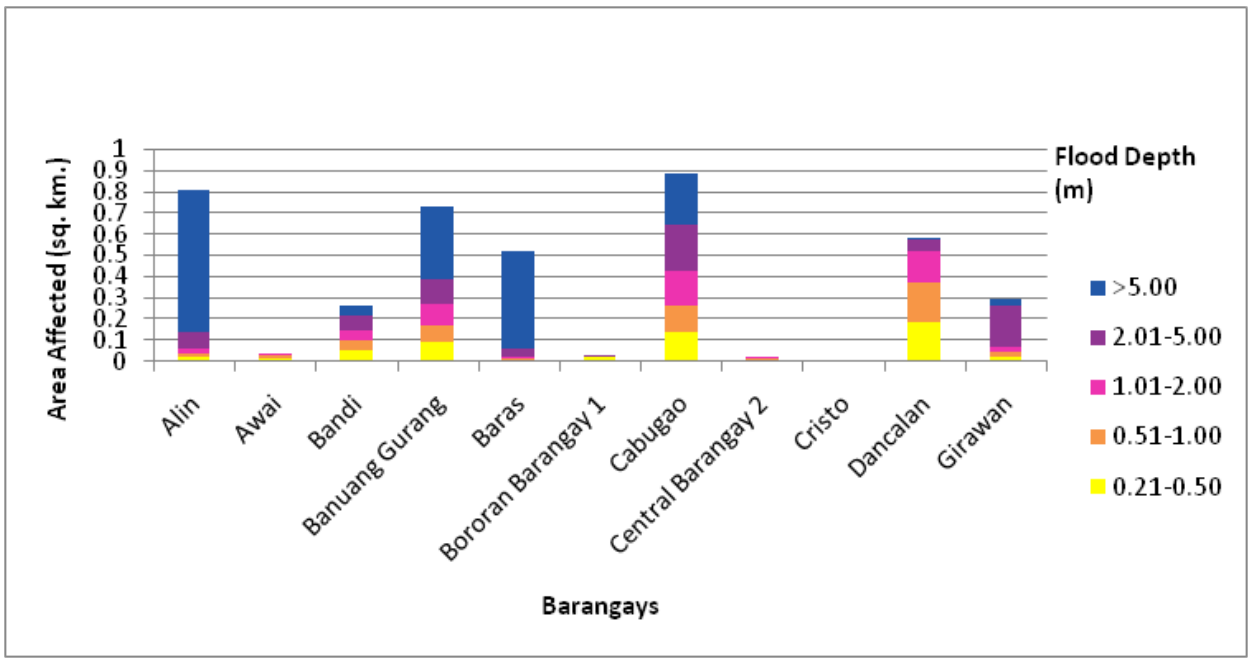


Figure 84. Affected Areas in Donsol, Sorsogon during the 25-Year Rainfall Return Period.

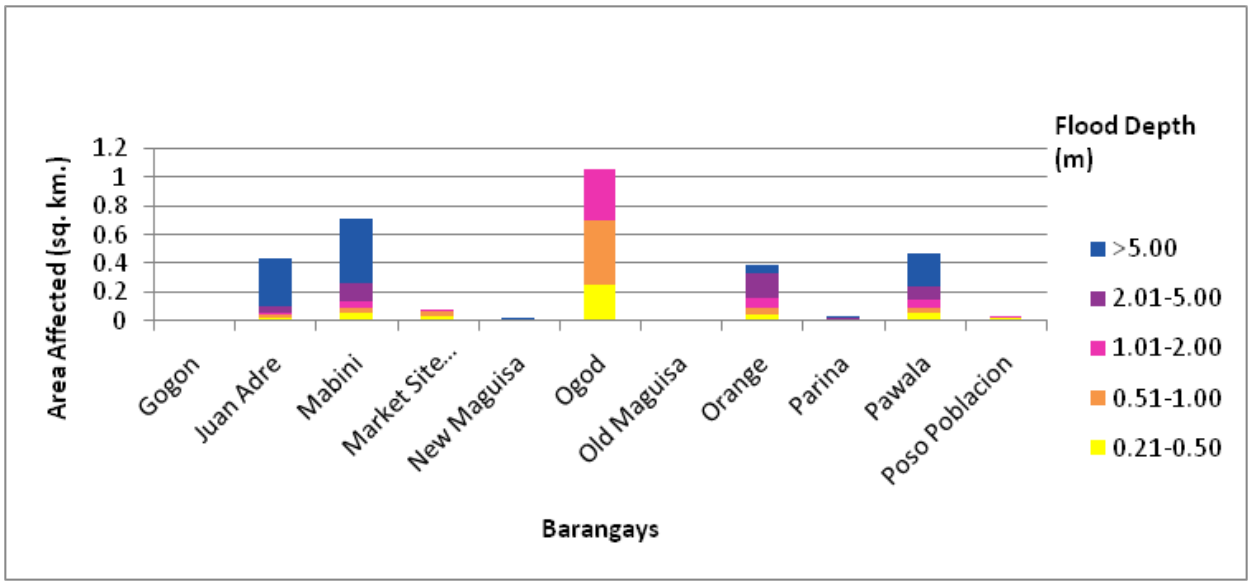


Figure 85. Affected Areas in Donsol, Sorsogon during the 25-Year Rainfall Return Period.

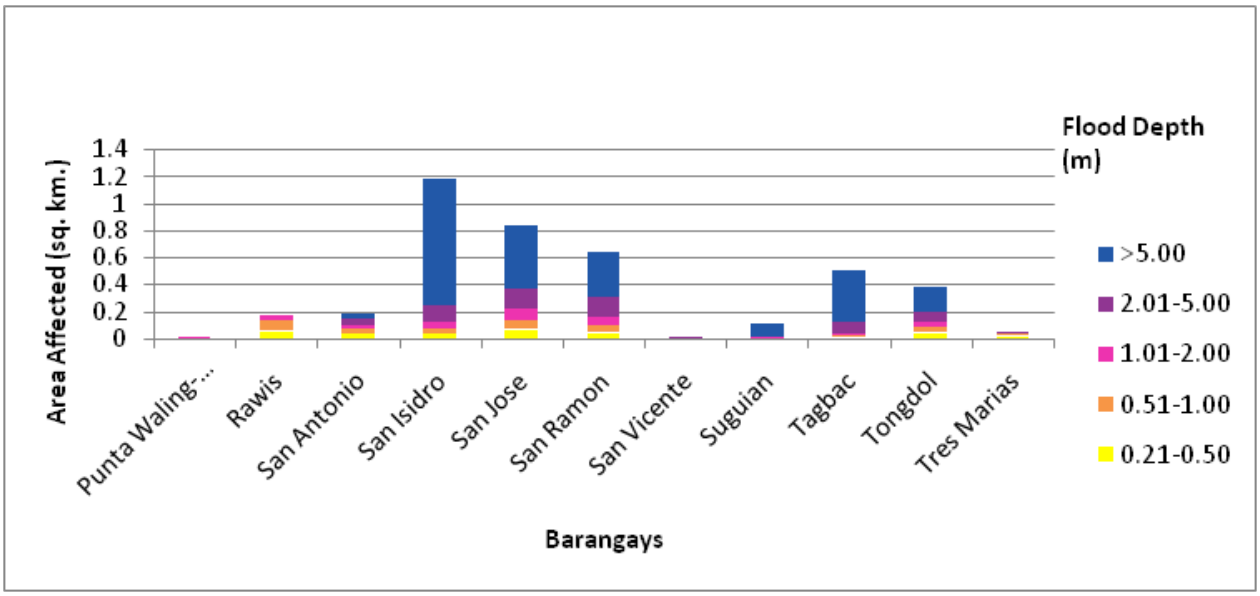


Figure 86. Affected Areas in Donsol, Sorsogon during the 25-Year Rainfall Return Period.

For the 100-year rainfall return period, 1.02% of the municipality of Camalig with an area of 136.54 sq. km. will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.03%, 0.03%, 0.02%, and 0.0008% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 46 depicts the areas affected in Camalig in square kilometers by flood depth per barangay.

Table 46. Affected Areas in Camalig, Albay during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Camalig
	Quinartilan
0.03-0.20	1.39
0.21-0.50	0.049
0.51-1.00	0.046
1.01-2.00	0.046
2.01-5.00	0.028
>5.00	0.0011

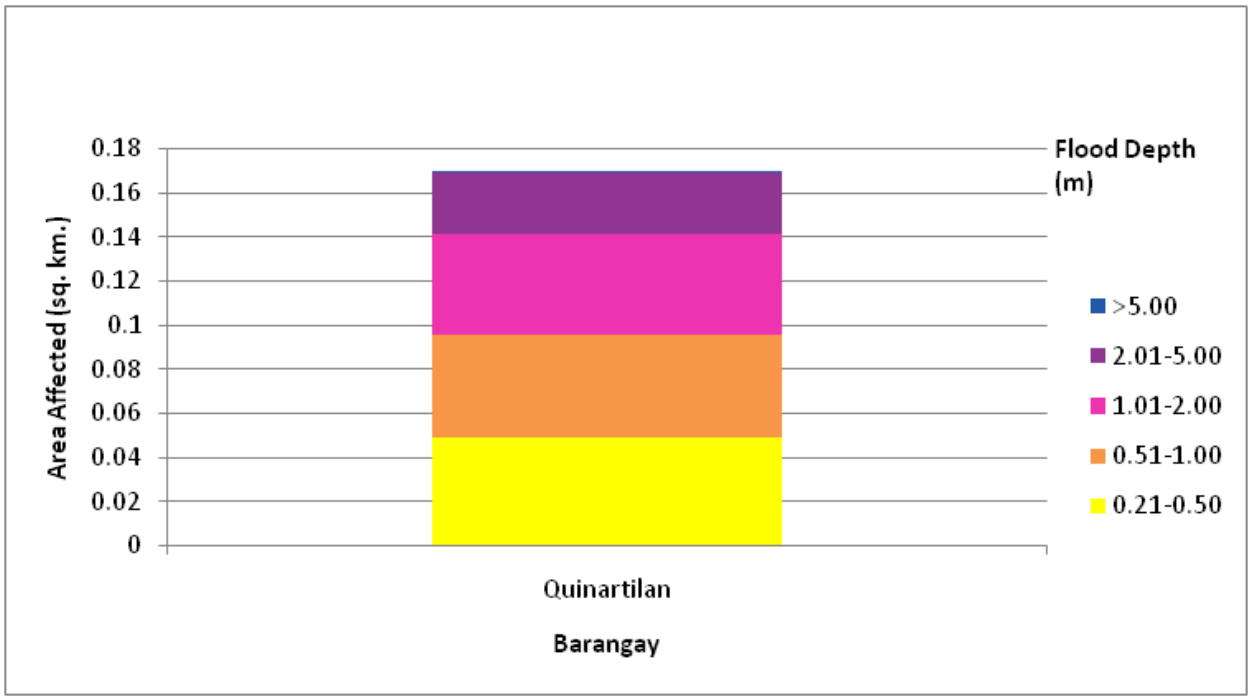


Figure 87. Affected Areas in Camalig, Albay during the 100-Year Rainfall Return Period.

For the municipality of Guinobatan with an area of 174.07 sq. km., 0.22% will experience flood levels of less than 0.20 meters. 0.009% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.006%, 0.008%, 0.01%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 47 depicts the areas affected in Guinobatan in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Guinobatan, Albay during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinobatan	
	Balite	Malobago
0.03-0.20	0.065	0.32
0.21-0.50	0.0013	0.015
0.51-1.00	0.0004	0.011
1.01-2.00	0.0014	0.012
2.01-5.00	0.0034	0.02
>5.00	0.018	0.02

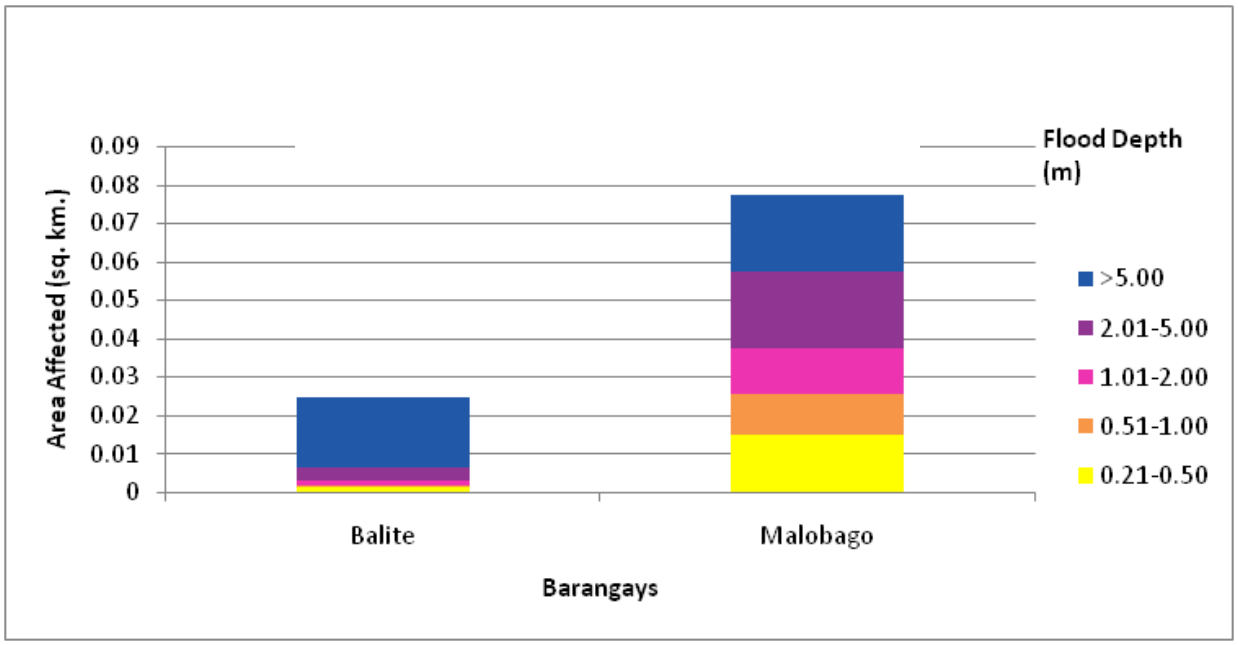


Figure 88. Affected Areas in Guinobatan, Albay during the 100-Year Rainfall Return Period

For the municipality of Jovellar with an area of 82.35 sq. km., 41.01% will experience flood levels of less than 0.20 meters. 1.51% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.32%, 1.36%, 1.61%, and 5.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 48 depicts the areas affected in Jovellar in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Jovellar, Albay during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jovellar													
	Aurora Poblacion	Bagacay	Bautista	Cabraran	Del Rosario	Estrella	Mabini Poblacion	Maogog	Mercado Poblacion	Plaza Poblacion	San Roque	San Vicente	Sinagaran	Villa Paz
0.03-0.20	0.057	5.14	3.99	1.58	0.43	1.96	0.24	4.51	0.0031	0.0011	3.75	4.35	5.01	2.75
0.21-0.50	0.0016	0.21	0.097	0.078	0.0097	0.058	0.0055	0.19	0.0001	0	0.058	0.24	0.18	0.12
0.51-1.00	0	0.16	0.11	0.064	0.01	0.038	0.0076	0.15	0	0	0.061	0.23	0.16	0.092
1.01-2.00	0	0.16	0.14	0.058	0.024	0.044	0.0089	0.14	0	0	0.1	0.2	0.2	0.052
2.01-5.00	0	0.2	0.24	0.04	0.07	0.089	0.034	0.12	0	0	0.31	0.065	0.13	0.029
>5.00	0	0.15	0.56	0.0059	0.31	0.31	0.092	0.38	0	0	1.69	0	0.45	0.22

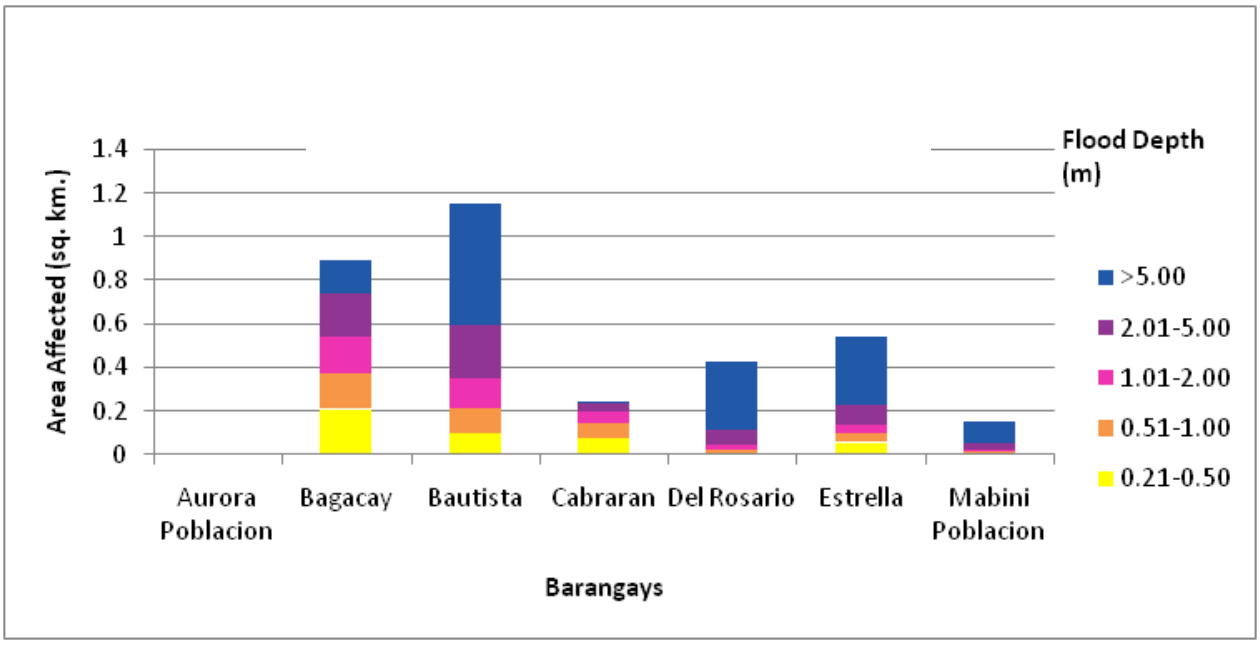


Figure 89. Affected Areas in Jovellar, Albay during the 100-Year Rainfall Return Period.

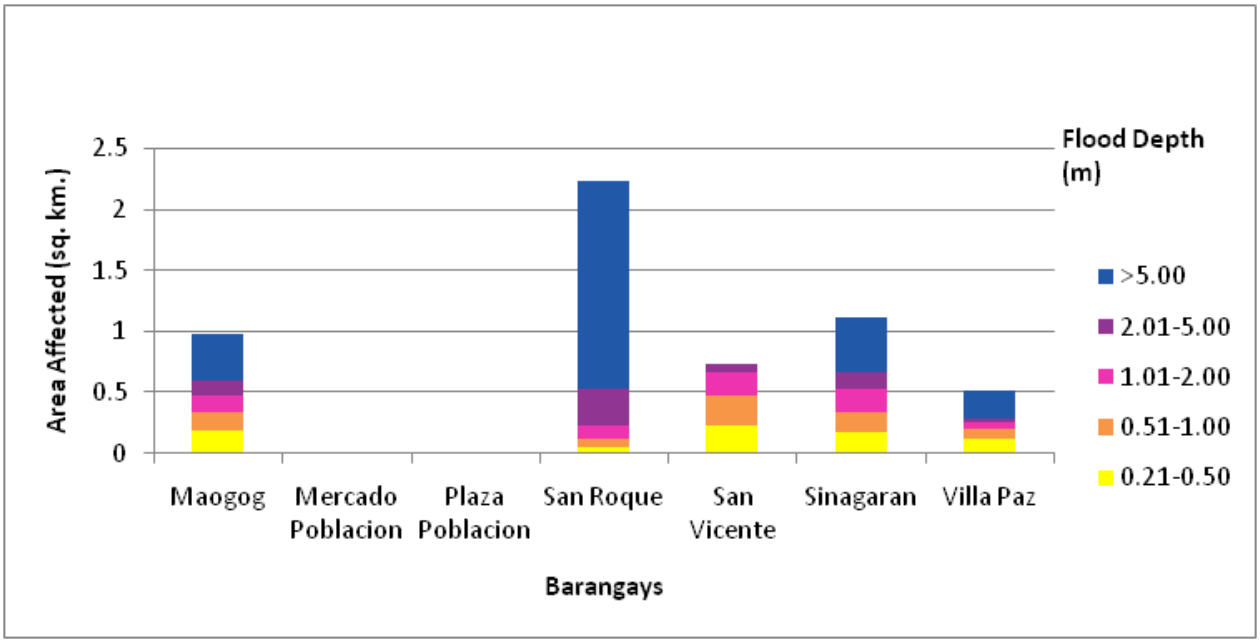


Figure 90. Affected Areas in Jovellar, Albay during the 100-Year Rainfall Return Period.

For the municipality of Pio Duran with an area of 133.24 sq. km., 3.82% will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.07%, 0.07%, 0.09%, and 0.4% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 49 depicts the areas affected in Pio Duran in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Pio Duran, Albay during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pio Duran		
	Buyo	Rawis	Sukip
0.03-0.20	3.26	0.81	1.03
0.21-0.50	0.1	0.025	0.024
0.51-1.00	0.057	0.021	0.019
1.01-2.00	0.064	0.017	0.014
2.01-5.00	0.089	0.014	0.017
>5.00	0.47	0.0035	0.064

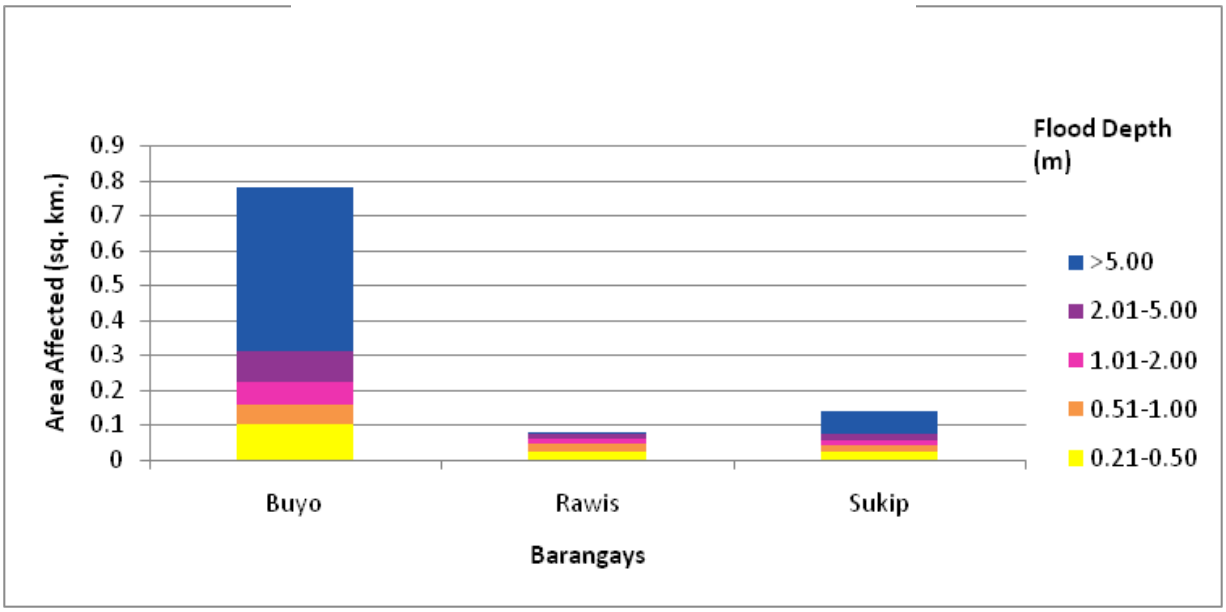


Figure 91. Affected Areas in Pio Duran, Albay during the 100-Year Rainfall Return Period.

For the municipality of Donsol with an area of 153 sq. km., 19.96% will experience flood levels of less than 0.20 meters. 0.85% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.9%, 1.11%, 1.28%, and 4.29% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 50 depicts the areas affected in Donsol in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Donsol, Sorsogon during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol														
	Alin	Awai	Bandi	Banuang Gurang	Baras	Bororan Baran-gay 1	Cabugao	Central Baran-gay 2	Cristo	Dan-calan	Girawan	Gogon	Juan Adre	Mabini	Market Site Baran-gay 3
0.03-0.20	0.95	0.019	2.12	1.3	0.18	0.074	4.81	0.026	0.069	1.25	0.74	0.03	1	2.1	0.051
0.21-0.50	0.017	0.0098	0.052	0.065	0.0033	0.031	0.14	0.0066	0.0022	0.14	0.019	0.0005	0.026	0.051	0.038
0.51-1.00	0.017	0.022	0.043	0.056	0.0034	0.0024	0.13	0.012	0.0024	0.13	0.016	0.0001	0.02	0.04	0.046
1.01-2.00	0.03	0.0087	0.055	0.093	0.0087	0	0.17	0.0013	0.00088	0.22	0.023	0.0004	0.017	0.055	0.012
2.01-5.00	0.077	0	0.08	0.26	0.032	0.0013	0.25	0	0.000032	0.16	0.082	0	0.041	0.13	0
>5.00	0.78	0	0.083	0.41	0.51	0	0.27	0	0	0.014	0.18	0	0.36	0.58	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Donsol																	
	New Maguisa	Ogod	Old Maguisa	Orange	Parina	Pawala	Poso Poblacion	Punta Waling-Waling Poblacion	Rawis	San Antonio	San Isidro	San Jose	San Ramon	San Vicente	Suguian	Tagbac	Tongdol	Tres Marias
0.03-0.20	0.26	0.92	0.061	1.88	0.6	2.07	0.034	0.031	0.21	1.34	1.76	2.86	1.67	0.16	0.23	0.21	1.13	0.41
0.21-0.50	0.0059	0.24	0.0015	0.052	0.012	0.048	0.022	0.01	0.057	0.039	0.033	0.064	0.042	0.0056	0.007	0.0059	0.04	0.021
0.51-1.00	0.0061	0.42	0.0008	0.043	0.0095	0.045	0.018	0.004	0.063	0.032	0.036	0.062	0.043	0.0039	0.0039	0.0092	0.032	0.015
1.01-2.00	0.0043	0.48	0.00052	0.059	0.0047	0.065	0.0076	0.0001	0.083	0.032	0.052	0.09	0.056	0.0019	0.0035	0.015	0.036	0.01
2.01-5.00	0.0049	0	0.00023	0.14	0.0065	0.095	0	0	0	0.042	0.11	0.15	0.13	0.0003	0.0057	0.057	0.084	0.0017
>5.00	0.0012	0	0	0.15	0.011	0.27	0	0	0	0.067	1.06	0.57	0.41	0	0.1	0.48	0.26	0.0001

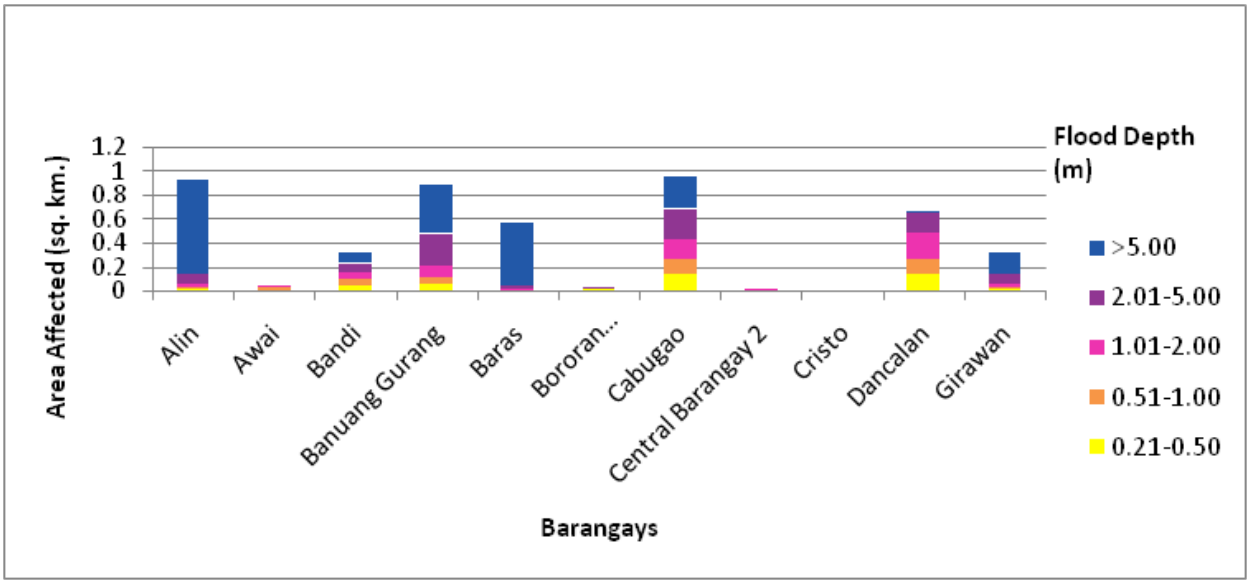


Figure 92. Affected Areas in Donsol, Sorsogon during the 100-Year Rainfall Return Period.

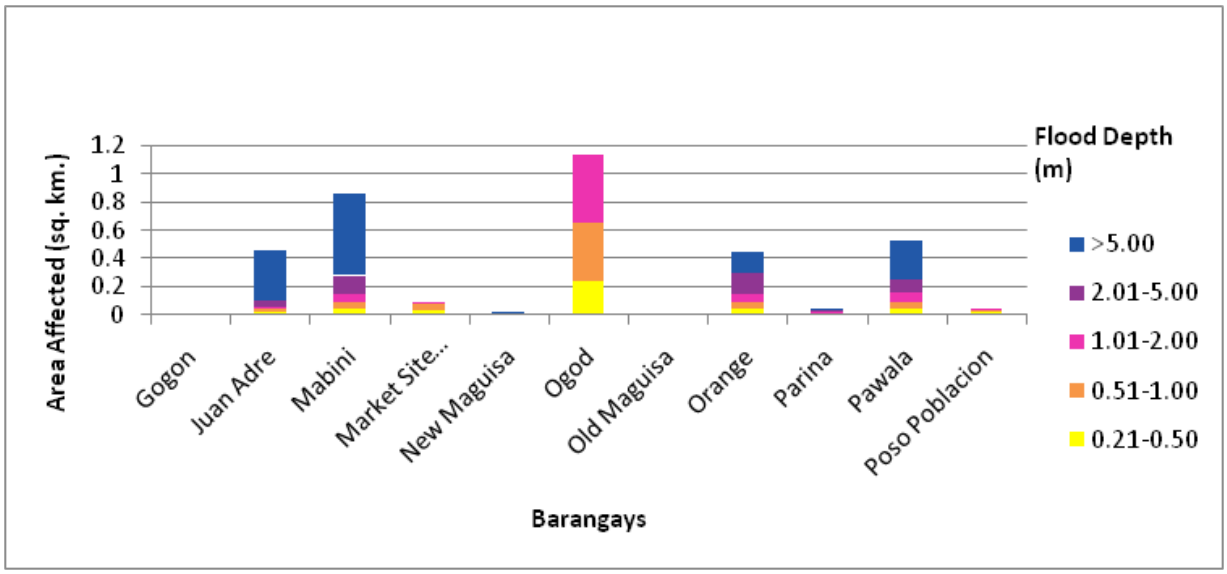


Figure 93. Affected Areas in Donsol, Sorsogon during the 100-Year Rainfall Return Period.

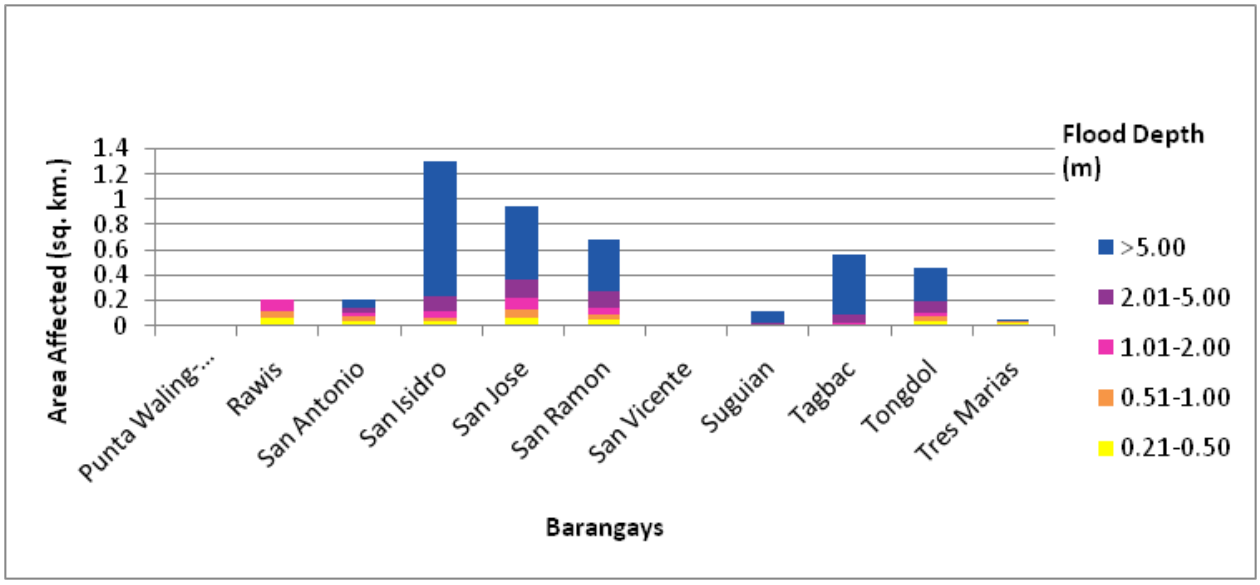


Figure 94. Affected Areas in Donsol, Sorsogon during the 100-Year Rainfall Return Period.

Among the barangays in Camalig, only Quinartilan will experience flood levels at 1.15%.

Among the barangays in Guinobatan, Malobago is projected to have the highest percentage of area that will experience flood levels at 0.23%. Meanwhile, Balite posted the second highest percentage of area that may be affected by flood depths at 0.05%.

Among the barangays in the municipality of Jovellar, Bagacay is projected to have the highest percentage of area that will experience flood levels of at 7.33%. Meanwhile, Bautista posted the second highest percentage of area that may be affected by flood depths of at 6.25%.

Among the barangays in Pio Duran, Buyi is projected to have the highest percentage of area that will experience flood levels at 3.03%. Meanwhile, Sukip posted the second highest percentage of area that may be affected by flood depths at 0.88%.

Among the barangays in Donsol, Cabugao is projected to have the highest percentage of area that will experience flood levels of at 3.77%. Meanwhile, San Vicente posted the second highest percentage of area that may be affected by flood depths of at 3.32%.

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

Table 51. Area covered by each warning level with respect to rainfall scenario.

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.41	3.16	3.06
Medium	4.31	4.81	4.88
High	10.19	14.18	17.02
Total	**17.91**	**22.15**	**24.96**

Of the 49 identified Educational Institutions in Ogod floodplain, 4 were assessed to be exposed to low, 5 to medium, and 10 to high level flooding during the 5-year scenario. In the 25-year scenario, 5 were assessed to be exposed to low, 4 to medium, and 14 to high level flooding. In the 100-year scenario, 8 were assessed to be exposed to low, 4 to medium, and 15 to high level flooding.

Of the 5 identified Medical Institutions in Ogod flood plain, none was assessed to be exposed to low, while 1 was assessed to be exposed to both medium and high level flooding in the 5-year scenario. In the 25-year scenario, none was assessed to be exposed to both low and medium, while 2 were assessed to be exposed to high level flooding. In the 100-year scenario, none was assessed to be exposed to low, 1 was assessed to be exposed to medium, and 2 were assessed to be exposed to high level flooding.

5.11 Flood Validation

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

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

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

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 182 points randomly selected all over the Ogod floodplain. It has an RMSE value of 1.720501563.

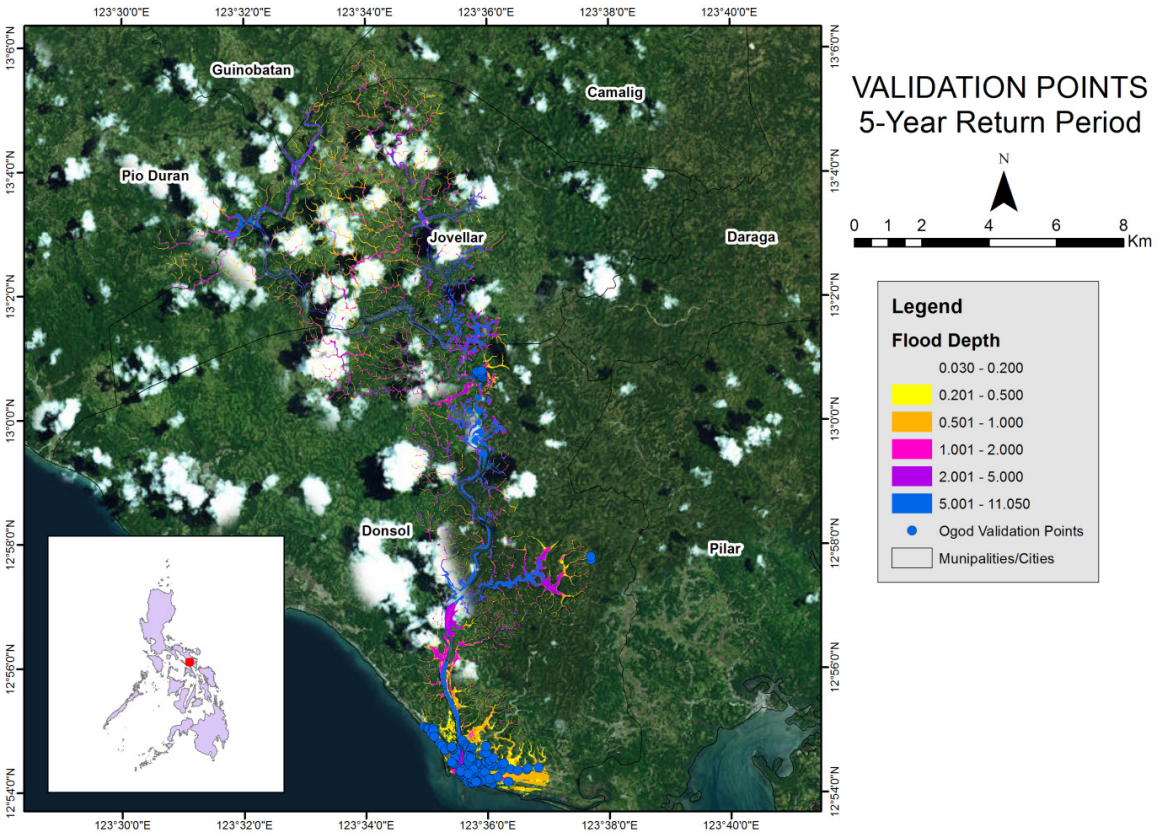


Figure 95. Ogod Floodplain Flood Validation Points.

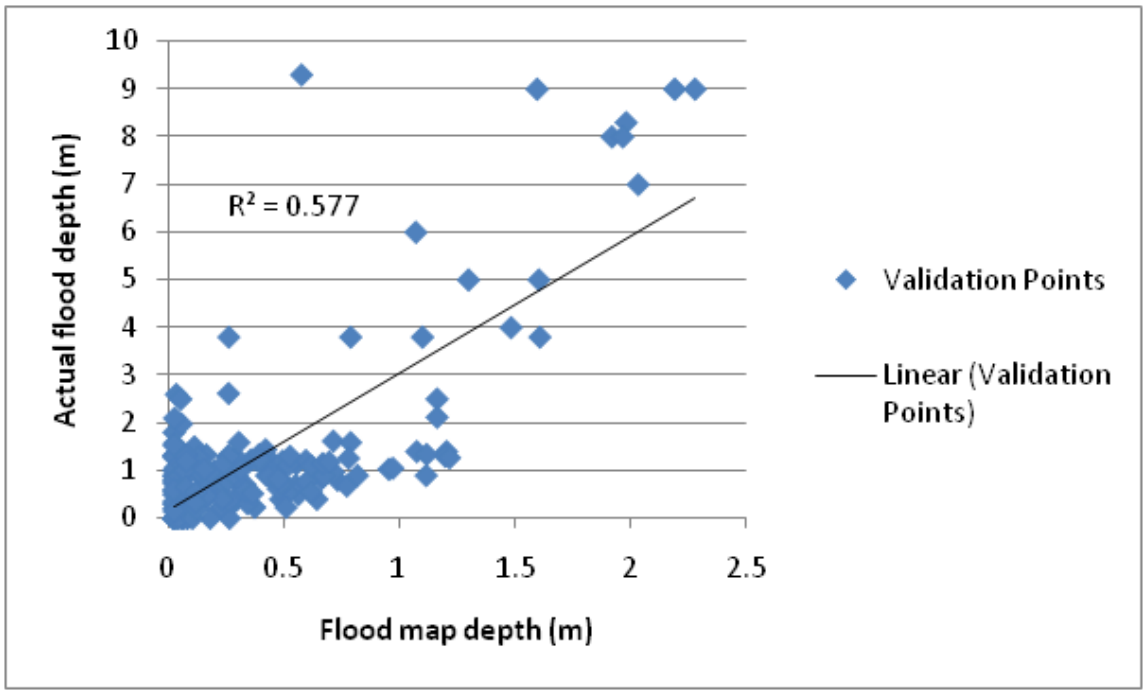


Figure 96. Flood map depth vs. Actual flood depth.

Table 52. Actual Flood Depth vs. Simulated Flood Depth in Ogod River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	27	3	0	0	0	0	30
0.21-0.50	16	9	3	0	0	0	28
0.51-1.00	25	12	11	1	0	0	49
1.01-2.00	17	17	12	5	0	0	51
2.01-5.00	3	2	1	7	0	0	13
> 5.00	0	0	1	5	3	0	9
Total	88	43	28	18	3	0	180

The overall accuracy generated by the flood model is estimated at 28.89%, with 52 points correctly matching the actual flood depths. In addition, there were 57 points estimated one level above and below the correct flood depths, 48 points estimated two levels above and below, and 23 points estimated three or more levels above and below the correct flood depths. A total of 7 points were overestimated while a total of 121 points were underestimated in the modelled flood depths of Ogod.

Table 53. Summary of Accuracy Assessment in Ogod River Basin Survey

OGOD	No. of Points	%
Correct	52	**28.89**
Overestimated	7	3.89
Underestimated	121	67.22
Total	180	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. OPTECH TECHNICAL SPECIFICATION OF THE GEMINI SENSOR

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

ANNEX 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

1. ABY-92

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

April 10, 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: **ALBAY**
Station Name: **ABY-92**
Order: **2nd**

Island: **LUZON**
Municipality: **CITY OF LIGAO**
Barangay: **ALLANG**

PRS92 Coordinates

Latitude: **13° 11' 56.27238"** Longitude: **123° 27' 47.60156"** Ellipsoidal Hgt: **127.30900 m.**

WGS84 Coordinates

Latitude: **13° 11' 51.38974"** Longitude: **123° 27' 52.59990"** Ellipsoidal Hgt: **180.74900 m.**

PTM Coordinates

Northing: **1459605.458 m.** Easting: **550210.89 m.** Zone: **4**

UTM Coordinates

Northing: **1,459,094.57** Easting: **550,193.31** Zone: **51**

Location Description

ABY-92
From Ligao City Hall, travel towards Brgy. Allang for about 13 km. Upon reaching Allang Brgy. Hall, walk for about 20 m. to reach the station. Station is located beside the baseline of the basketball court, about 19 m. from the said brgy. hall. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "ABY-92 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-833**

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

9904102014140410

CERTIFICATION INTERNATIONAL ISO 9001:2008 · ACCREDITED QMS Certification body Accreditation No.: MSA 001
CIP/4701/12/09/814

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

2. ABY-08

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

April 10, 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: **ALBAY**
Station Name: **ABY-8**
Order: **2nd**

Island: **LUZON**
Municipality: **LEGASPI CITY**
Barangay: **LIDONG**

PRS92 Coordinates

Latitude: **13° 12' 51.92876"** Longitude: **123° 45' 45.95336"** Ellipsoidal Hgt: **6.33900 m.**

WGS84 Coordinates

Latitude: **13° 12' 47.06720"** Longitude: **123° 45' 50.94829"** Ellipsoidal Hgt: **60.47000 m.**

PTM Coordinates

Northing: **1461395.121 m.** Easting: **582675.867 m.** Zone: **4**

UTM Coordinates

Northing: **1,460,883.61** Easting: **582,646.93** Zone: **51**

Location Description

ABY-8
From Legaspi Pier, Legaspi City, Travel towards Tabaco Albay for about 8.0 km. upon reaching Legaspi-Santo Domingo boundary post, travel for about 200 m. ahead, turn right to second T road intersection of Mayon Riviera Subdivision and travel about 0.90 km. The station is located at the center end of the island of Mayon Riviera Subdivision. Highest prominent mark is the electric timber post 9.50 m. SE of the station. Station mark is 12.50 mm. dia. steel bar centered on a triangle on a 0.30 m. x 0.30 m. concrete block protruding 0.05 m. above ground surface and mark with NAMRIA ABY-8, 1990. Reference mark is Electric Timber Post.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-831**

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

9904102014140311

CERTIFICATION INTERNATIONAL ISO 9001:2008 — ACCREDITED QMS Certification Body Accreditation No: MSA-001
CIP/4701/12/09/814

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. ABY-93

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

March 08, 2016

CERTIFICATION

To whom it may concern:

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

Province: **ALBAY**
Station Name: **ABY-93**
Order: **2nd**

Island: **LUZON**
Municipality: **LIBON**
Barangay: **BURABOD**
MSL Elevation:

PRS92 Coordinates

Latitude: **13° 16' 0.55893"** Longitude: **123° 25' 14.84177"** Ellipsoidal Hgt: **19.22500 m.**

WGS84 Coordinates

Latitude: **13° 15' 55.65621"** Longitude: **123° 25' 19.83465"** Ellipsoidal Hgt: **72.37800 m.**

PTM / PRS92 Coordinates

Northing: **1467103.957 m.** Easting: **545598.649 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **1,466,590.45** Easting: **545,582.69** Zone: **51**

Location Description

ABY-93
From Ligao City, travel NW going to Libon Town Proper. Upon reaching Libon, travel S passing through Brgys. San Isidro and Bacolod. Then continue traveling W to reach Brgy. Burabod. Total distance from Libon Town Proper to Brgy. Burabod is approx. 9 km. Station is located in front (about 10 m.) of Burabod Chapel, beside Burabod basketball court. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "ABY-93 2007 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089979 I**
T.N.: **2016-0565**

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

9903082016120911

4. ABY-9

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

April 10, 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: **ALBAY**
Station Name: **ABY-9**
Order: **3rd**

Island: **LUZON**
Municipality: **LEGASPI CITY**
Barangay:

PRS92 Coordinates

Latitude: **13° 9' 11.38733"** Longitude: **123° 43' 45.95874"** Ellipsoidal Hgt: **14.54010 m.**

WGS84 Coordinates

Latitude: **13° 9' 6.53800"** Longitude: **123° 43' 50.95900"** Ellipsoidal Hgt: **68.75400 m.**

PTM Coordinates

Northing: **1454607.115 m.** Easting: **579082.538 m.** Zone: **4**

UTM Coordinates

Northing: **1,454,097.98** Easting: **579,054.86** Zone: **51**

Location Description

ABY-9
From Albay Capitol Building, Legaspi City travel along Washington Drive about 2.0 km., turn left at road intersection and travel at about 1.0 km. to Legaspi Airport. Station is located at Legaspi Airport Compound, 52.0 m. SE of Legaspi Airport Flagpole, 35 m. NE of Legaspi Airport Welcome Post, 3.30 m. NW of Lamp. Station mark is 12.5 mm. dia. steel bar centered on a triangle on 0.30 m. x 0.30 m concrete block protruding 0.05 m. above the ground surface and mark with "NAMRIA ABY-9, 1990". Reference mark is Flagpole, Welcome Post, Lamp.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-832**

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

9904102014141548

CERTIFICATION INTERNATIONAL ISO 9001:2008 · ACCREDITED QMS Certification Body Accreditation No. MSA-001
CIP/4701/12/09/814

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

5. AL-298

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

April 10, 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: **ALBAY**
Station Name: **AL-298**

Island: **Luzon**	Municipality: **LEGAZPI CITY (CAPITAL)**	Barangay: **BGY. 4 - SAGPON**
Elevation: **11.6955 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM AL-298 is in the Province of Albay, City of Legaspi, Brgy. 4, Sagpon, along the Legaspi - Daraga national road.The station is located at the south west end of Sagpon Bridge at KM 528+166 and about 4.8 m SW of the centerline of the road.

A brass rod is det on a drilled hole and cemented flushed on top of a 15x15 cm cemnet putty with the inscripition "AL-298, 2009, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-842**

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3404 to 88
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

6. AL-191

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

March 08, 2016

CERTIFICATION

To whom it may concern:

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

Province: **ALBAY**
Station Name: **AL-191**

Island: **Luzon**	Municipality: **POLANGUI**	Barangay: **MATACON**
Elevation: **17.5055 +/- 0.0444 m.**	Accuracy Class at 95% C.L: **4 CM**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1988. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

AL-191
Along the Albay-Sorsogon National Road. The station is located at the edge of the center island is about 5 meters south of the centerline of the road. a brass rod is set on a drilled hole and cemented flushed on top of a 15cm x 15cm cement putty with the inscription AL-191 2008 NAMRIA.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089979 I**
T.N.: **2016-0563**

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

ANNEX 3. BASELINE PROCESSING REPORT

1. AL-298

ABY-92 - AL-298 (7:48:44 AM-10:10:34 AM) (S1)

Baseline observation:	ABY-92 --- AL-298 (B1)
Processed:	4/14/2014 9:29:25 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.008 m
Vertical precision:	0.030 m
RMS:	0.015 m
Maximum PDOP:	3.073
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	4/7/2014 7:49:04 AM (Local: UTC+8hr)
Processing stop time:	4/7/2014 10:10:34 AM (Local: UTC+8hr)
Processing duration:	02:21:30
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	ABY-92				
Grid		**Local**		**Global**	
Easting	550343.396 m	**Latitude**	N13°11'51.38974"	**Latitude**	N13°11'51.38974"
Northing	1459035.245 m	**Longitude**	E123°27'52.59990"	**Longitude**	E123°27'52.59990"
Elevation	127.447 m	**Height**	180.749 m	**Height**	180.749 m

To:	AL-298				
Grid		**Local**		**Global**	
Easting	578994.349 m	**Latitude**	N13°08'30.79294"	**Latitude**	N13°08'30.79294"
Northing	1452940.789 m	**Longitude**	E123°43'43.86268"	**Longitude**	E123°43'43.86268"
Elevation	12.595 m	**Height**	65.914 m	**Height**	65.914 m

Vector					
ΔEasting	28650.953 m	**NS Fwd Azimuth**	102°06'52"	**ΔX**	-24576.830 m
ΔNorthing	-6094.456 m	**Ellipsoid Dist.**	29302.150 m	**ΔY**	-14774.810 m
ΔElevation	-114.852 m	**ΔHeight**	-114.835 m	**ΔZ**	-6028.707 m

2. AL-191

ABY-93 - AL-191 (9:19:13 AM-1:48:42 PM) (S2)

Baseline observation:	ABY-93 --- AL-191 (B2)
Processed:	3/22/2016 11:03:07 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.018 m
RMS:	0.005 m
Maximum PDOP:	2.828
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/4/2016 9:19:13 AM (Local: UTC+8hr)
Processing stop time:	3/4/2016 1:48:42 PM (Local: UTC+8hr)
Processing duration:	04:29:29
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	ABY-93				
Grid		**Local**		**Global**	
Easting	545582.688 m	**Latitude**	N13°16'00.55893"	**Latitude**	N13°15'55.65621"
Northing	1466590.445 m	**Longitude**	E123°25'14.84177"	**Longitude**	E123°25'19.83465"
Elevation	19.407 m	**Height**	19.225 m	**Height**	72.378 m

To:	AL-191				
Grid		**Local**		**Global**	
Easting	546787.787 m	**Latitude**	N13°19'36.00214"	**Latitude**	N13°19'31.08584"
Northing	1473210.531 m	**Longitude**	E123°25'55.27136"	**Longitude**	E123°26'00.25899"
Elevation	19.328 m	**Height**	19.069 m	**Height**	72.087 m

Vector					
ΔEasting	1205.099 m	**NS Fwd Azimuth**	10°24'50"	**ΔX**	-176.563 m
ΔNorthing	6620.086 m	**Ellipsoid Dist.**	6731.393 m	**ΔY**	-1941.191 m
ΔElevation	-0.079 m	**ΔHeight**	-0.156 m	**ΔZ**	6443.014 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	**σ NS fwd Azimuth**	0°00'00"	**σ ΔX**	0.005 m
σ ΔNorthing	0.001 m	**σ Ellipsoid Dist.**	0.001 m	**σ ΔY**	0.008 m
σ ΔElevation	0.009 m	**σ ΔHeight**	0.009 m	**σ ΔZ**	0.003 m

3. LPH – 01

LPH-01 - ABY-09 (9:36:54 AM-12:39:19 PM) (S1)

Baseline observation:	LPH-01 — ABY-09 (B1)
Processed:	4/14/2014 8:54:10 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.003 m
RMS:	0.001 m
Maximum PDOP:	2.071
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	3/29/2014 9:37:04 AM (Local: UTC+8hr)
Processing stop time:	3/29/2014 12:39:19 PM (Local: UTC+8hr)
Processing duration:	03:02:15
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	ABY-09				
Grid		Local		Global	
Easting	579204.817 m	Latitude	N13°09'06.53800"	Latitude	N13°09'06.53800"
Northing	1454039.532 m	Longitude	E123°43'50.95900"	Longitude	E123°43'50.95900"
Elevation	15.448 m	Height	68.754 m	Height	68.754 m

To:	LPH-01				
Grid		Local		Global	
Easting	580467.016 m	Latitude	N13°09'08.50554"	Latitude	N13°09'08.50554"
Northing	1454103.670 m	Longitude	E123°44'32.88949"	Longitude	E123°44'32.88949"
Elevation	11.957 m	Height	65.236 m	Height	65.236 m

Vector					
ΔEasting	1262.199 m	NS Fwd Azimuth	87°15'26"	ΔX	-1040.600 m
ΔNorthing	64.138 m	Ellipsoid Dist.	1264.234 m	ΔY	-715.619 m
ΔElevation	-3.491 m	ΔHeight	-3.518 m	ΔZ	58.079 m

Standard Errors

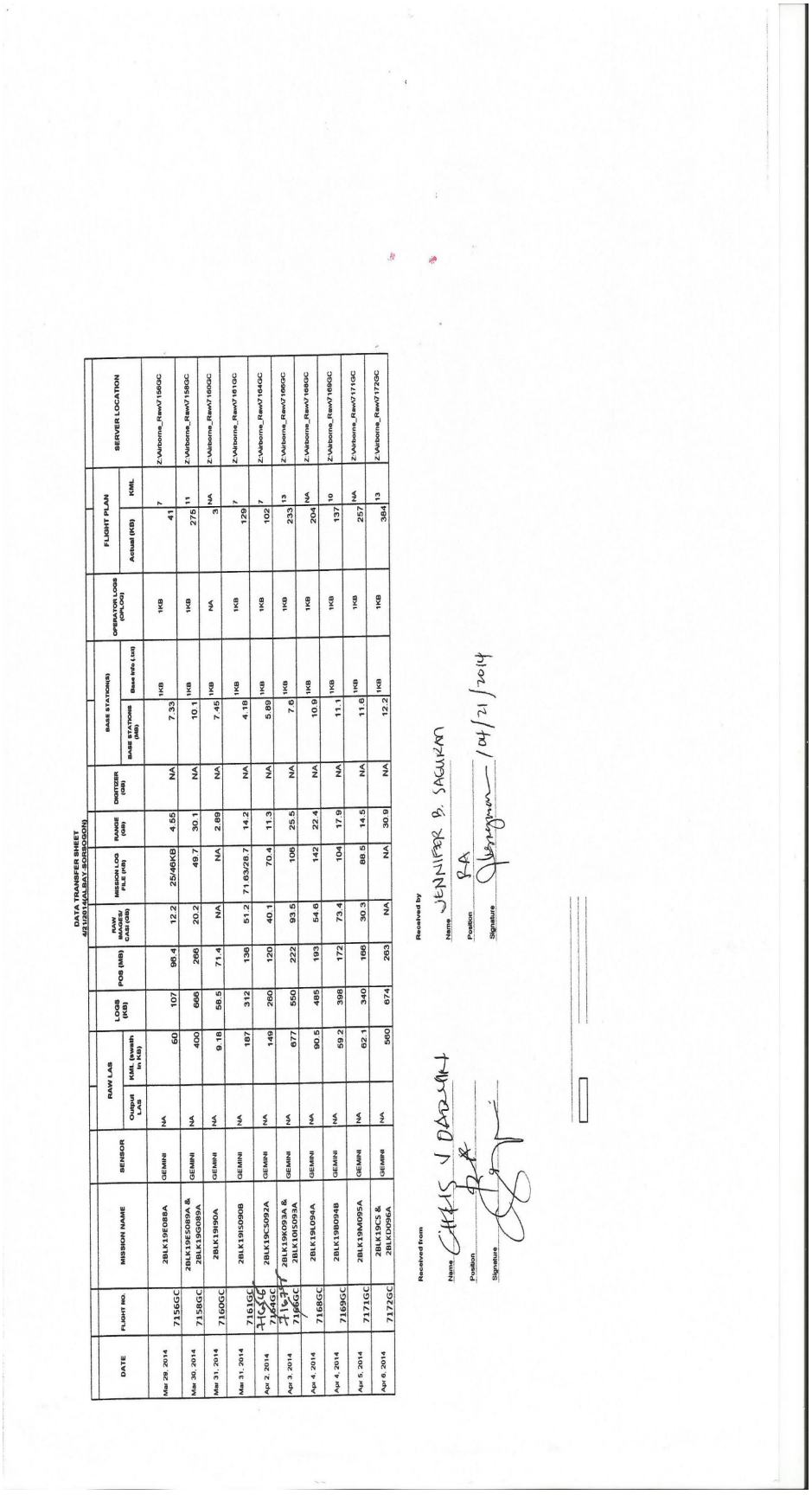
Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.001 m

2

ANNEX 4. THE LIDAR SURVEY TEAM COMPOSITION

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA-PAGADOR	UP-TCAGP
		CHRISTOPHER JOAQUIN	UP-TCAGP
LiDAR Operation	Research Associate (RA)	LARAH KRISELLE PARAGAS	UP-TCAGP
		MA. VERLINA E. TONGA	
		MILLIE SHANE REYES	
		IRO NIEL ROXAS	
		KRISTINE ANDAYA	
		JERIEL PAUL ALAMBAN	
Ground Survey, Data Download and Transfer	RA	KENNETH QUISADO	UP-TCAGP
		JASMIN DOMINGO	
		LANCE KERWIN CINCO	
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJIE CARBOLLEDO	
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
	Pilot	CAPT. CESAR ALFONSO III	
	Pilot	CAPT. RAUL CZ SAMAR II	

ANNEX 5. DATA TRANSFER SHEET FOR OGOD FLOODPLAIN FLIGHTS



DATA TRANSFER SHEET
4/21/2014(ALBAY-SORSOGON)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS (KB)	POS (MB)	RAW IMAGES/ CAM (GB)	MISSION LOG FILE (KB)	RANGE (KM)	DIGITIZER (m)	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath in KB)							BASE STATIONS (MB)	Base Info (.txt)		Actual (KB)	KML	
Mar 29, 2014	7156GC	2BLK19E088A	GEMINI	NA	60	107	90.4	12.2	25/46KB	4.55	NA	7.33	1KB	1KB	41	7	Z:\Alboine_Raw\7156GC
Mar 30, 2014	7158GC	2BLK19S0089A & 2BLK19S0089A	GEMINI	NA	400	666	266	20.2	49.7	30.1	NA	10.1	1KB	1KB	275	11	Z:\Alboine_Raw\7158GC
Mar 31, 2014	7160GC	2BLK19I90A	GEMINI	NA	9.18	58.5	71.4	NA	NA	2.89	NA	7.45	1KB	NA	3	NA	Z:\Alboine_Raw\7160GC
Mar 31, 2014	7161GC	2BLK19I5090B	GEMINI	NA	187	312	136	51.2	71.63/28.7	14.2	NA	4.18	1KB	1KB	129	7	Z:\Alboine_Raw\7161GC
Apr 2, 2014	7164GC	2BLK19C5092A	GEMINI	NA	149	260	120	40.1	70.4	11.3	NA	5.89	1KB	1KB	102	7	Z:\Alboine_Raw\7164GC
Apr 3, 2014	7166GC	2BLK19K0924 & 2BLK19S093A	GEMINI	NA	677	550	222	93.5	106	25.5	NA	7.6	1KB	1KB	233	13	Z:\Alboine_Raw\7166GC
Apr 4, 2014	7168GC	2BLK19L094A	GEMINI	NA	90.5	485	193	54.6	142	22.4	NA	10.9	1KB	1KB	204	NA	Z:\Alboine_Raw\7168GC
Apr 4, 2014	7169GC	2BLK19B094B	GEMINI	NA	59.2	398	172	73.4	104	17.9	NA	11.1	1KB	1KB	137	10	Z:\Alboine_Raw\7169GC
Apr 5, 2014	7171GC	2BLK19M095A	GEMINI	NA	62.1	340	166	30.3	88.5	14.5	NA	11.6	1KB	1KB	257	NA	Z:\Alboine_Raw\7171GC
Apr 6, 2014	7172GC	2BLK19C5 & 2BLK0096A	GEMINI	NA	560	674	263	NA	NA	30.9	NA	12.2	1KB	1KB	384	13	Z:\Alboine_Raw\7172GC

Received from

Name CHRIS V DADSON

Position RA

Signature

Received by

Name JENNIFER B. SACUZAN

Position RA

Signature 04/21/2014

DATA TRANSFER SHEET
4/28/2014(Albay sorsogon)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/ CASI	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/7/2014	7174GC	2BLK19F097A	GEMINI	N/A	309	496	205	62	N/A	23.4	N/A	12.1	158	471	214	NA	Z:\Airborne_Raw\7174GC
4/7/2014	7175GC	2BLK19H097B	GEMINI	N/A	522	353	145	52.3	N/A	14.1	N/A	12.4	158	300	361	7.89	Z:\Airborne_Raw\7175GC
4/8/2014	7176GC	2BLK19HS098A	GEMINI	N/A	17.7	110	84.1	N/A	N/A	4.83	N/A	1.97	100	248	868	NA	Z:\Airborne_Raw\7176GC
4/12/2014	7184GC	2BLK19J102A	GEMINI	N/A	136	222	129	29.3 GB N/A	N/A	10.5	N/A	9.75	130	380	99.5	NA	Z:\Airborne_Raw\7184GC

Received from

Name C. SOAMILI
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 4/28/14

DATA TRANSFER SHEET
5/5/2014(ALBAY Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	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	
4/20/2013	7200GC	2BLK19JS110A & 2BLK19N110A	GEMINI	NA	221KB	402KB	237MB	50.3	133	17.3	NA	7.61	1KB	1KB	151	24	Z:\Airborne_Raw\7200GC
4/22/2014	7204GC	2BLK19A112A	GEMINI	NA	130/20MB	359	206	NA	NA	15.1	N/A	1.14	1KB	1KB	384	7	Z:\Airborne_Raw\7204GC
4/26/2014	7212GC	2BLK19P116A & 2BLK19O116A	GEMINI	NA	125	431	126	N/A	N/A	17.7	N/A	1.66	1KB	1KB	244	11	Z:\Airborne_Raw\7212GC
4/26/2014	7213GC	2BLK19OS116B & VOIDS	GEMINI	NA	33.6	263	141	N/A	N/A	8.77	N/A	1.68	1KB	1KB	311	3	Z:\Airborne_Raw\7213GC
4/28/2014	7216GC	2BLK19AS118A & VOIDS	GEMINI	NA	46.2	311	184	41.5	N/A	12.1	N/A	7.36	1KB	1KB	191	5kb/2kb	Z:\Airborne_Raw\7216P

Received from

Name
Position
Signature

Received by

Name Benjamin magallon
Position SSRS
Signature 5/5/2014

DATA TRANSFER SHEET

ALBAY/SORSOGON 3/18/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
28-Feb-16	3825G	2BLK19JFS 059B	GEMINI	NA	233	13.3	176	4.37	37	19.1	NA	6.33	1KB	2KB	15/11	233	Z:\DAC\RAW DATA
29-Feb-16	3827G	2BLK19AB S060A	GEMINI	NA	NA	2.03	265	2.2	1	33.6	NA	11.7	1KB	3KB	36/29/30	376	Z:\DAC\RAW DATA
29-Feb-16	3829G	2BLK19FS 060B	GEMINI	NA	565	1.98	130	26.9	252	14	NA	11.7	1KB	1KB	36/32/29/30/3 0	NA	Z:\DAC\RAW DATA
4-Mar-16	3843G	2BLK19DS 064A	GEMINI	NA	942	5.18	274	88.1	735	39.2	NA	9.29	1KB	1KB	32/29	NA	Z:\DAC\RAW DATA
6-Mar-16	3851G	2BLK19aA B066A	GEMINI	NA	331	587	183	28.7	227	16	NA	4.19	1KB	1KB	30/28/27	331	Z:\DAC\RAW DATA

Received from

Name R. PUNTO

Position RA

Signature

Received by

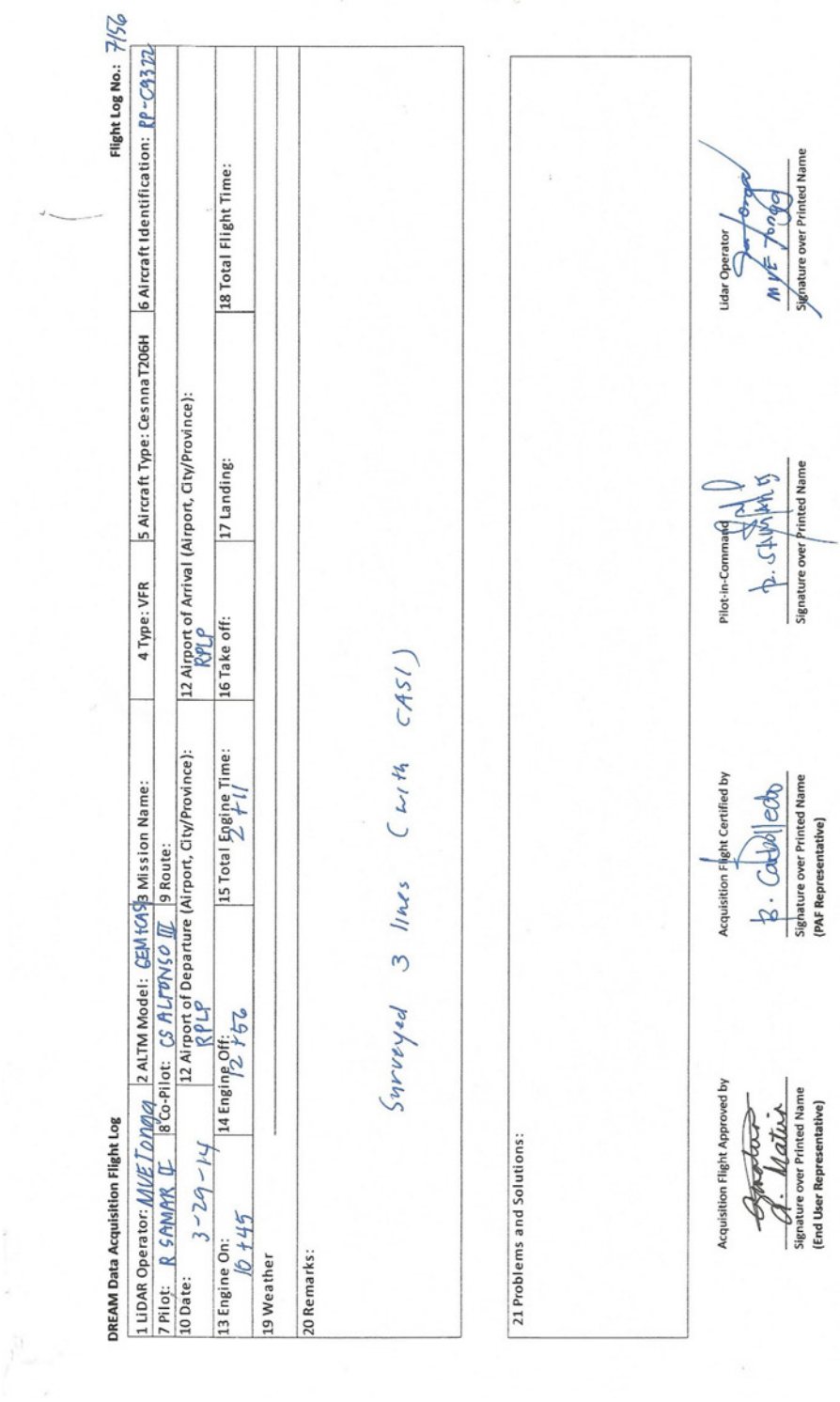
Name AC Bongat

Position ASSTRO

Signature Bongat 3/21/16

ANNEX 6. FLIGHT LOGS

Flight Log for 7156GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7156

1 LiDAR Operator: AIM Tonga	2 ALTM Model: GEMINI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C3322
7 Pilot: R. SAMAR II	8 Co-Pilot: CS ALFONSO III	9 Route:			
10 Date: 3-29-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 16+45	14 Engine Off: 12+52	15 Total Engine Time: 2+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed 3 lines (with CASI)					
21 Problems and Solutions:					

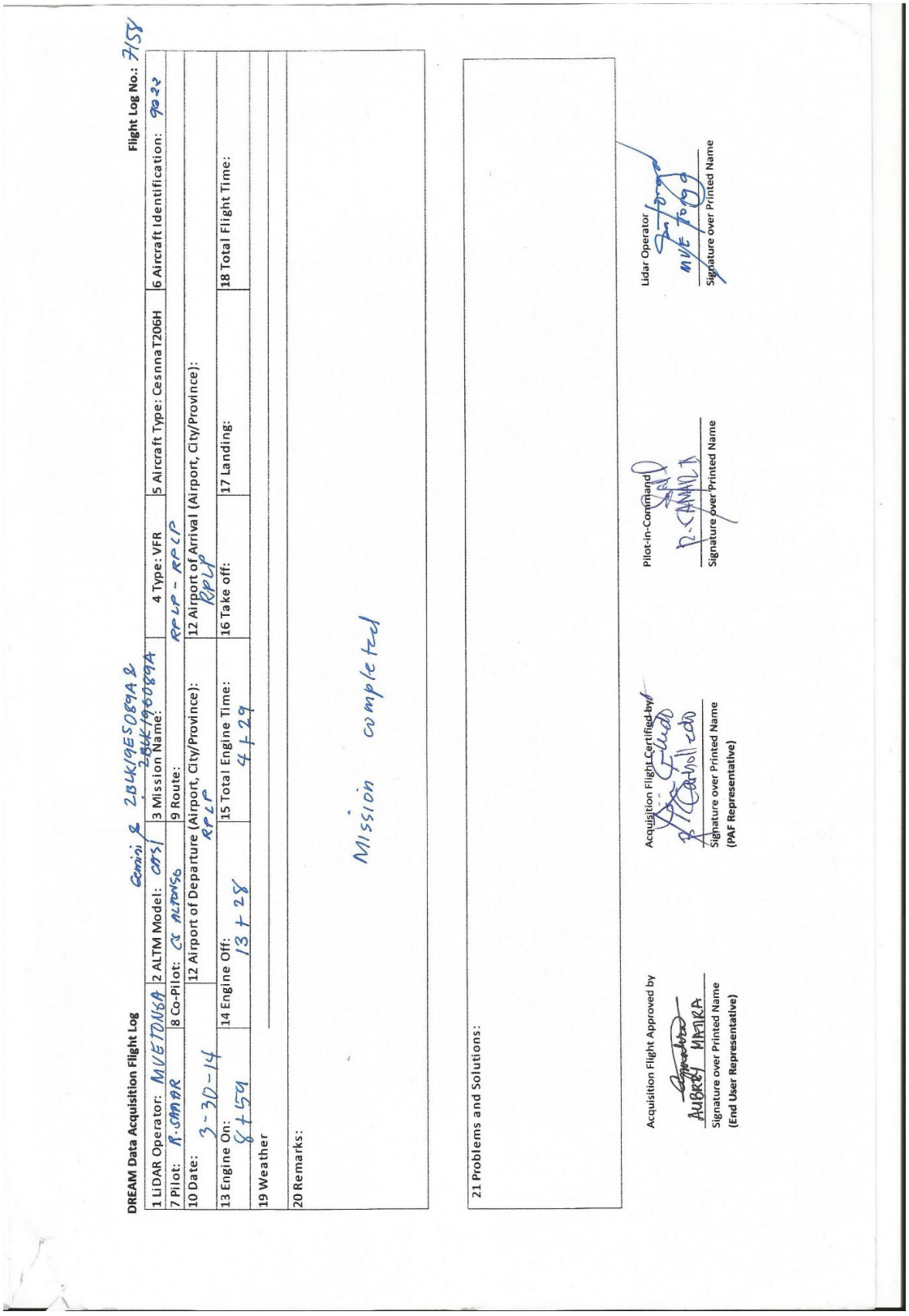
Acquisition Flight Approved by
Signature over Printed Name (End User Representative)

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

Pilot-in-Command
R. Samar II
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 7158GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7/SY

1 LiDAR Operator: MVE TONGA	2 ALTM Model: 08SI	3 Mission Name: 2BLK19E5089A2 ~~2BLK19E5089A~~	4 Type: VFR — RPLP - RPLP	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: R. SAMAR	8 Co-Pilot: CS ALTAMS6	9 Route:			
10 Date: 3-30-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 8:459	14 Engine Off: 13:28	15 Total Engine Time: 4:29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks: Mission completed

21 Problems and Solutions:

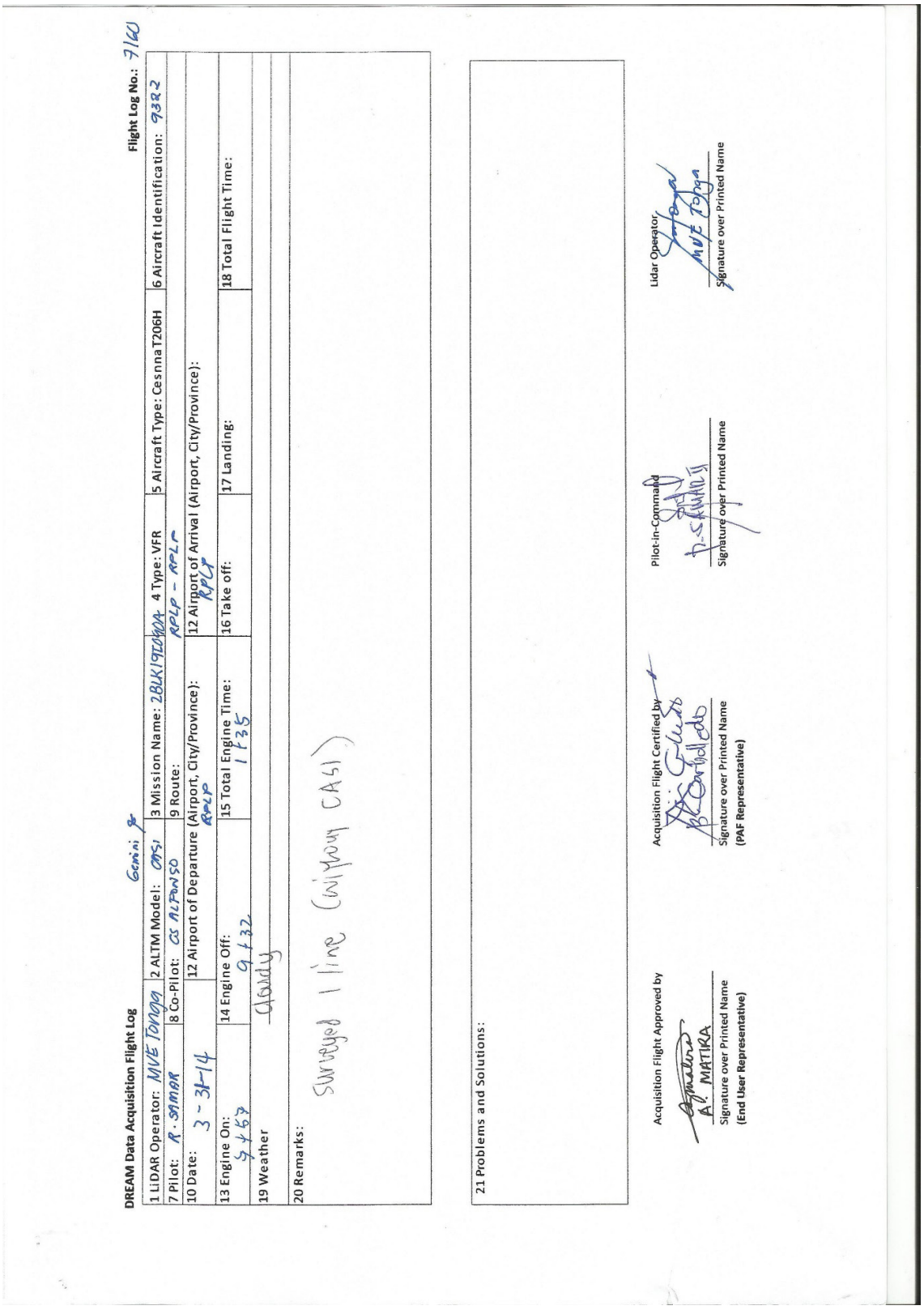
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)
AUBREY MANERA

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

Pilot-in-Command
Signature over Printed Name
R. CAMILLA

Lidar Operator
Signature over Printed Name
MVE Tonga

Flight Log for 7160GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7160

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 28JAN14TONGA	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9382
7 Pilot: R. SAMAR	8 Co-Pilot: CS ALFONSO	9 Route: RPLP – RPLC			
10 Date: 3-31-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 5463	14 Engine Off: 9432	15 Total Engine Time: 11.35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks: Surveyed 1 line (Wilpong CA51)

21 Problems and Solutions:

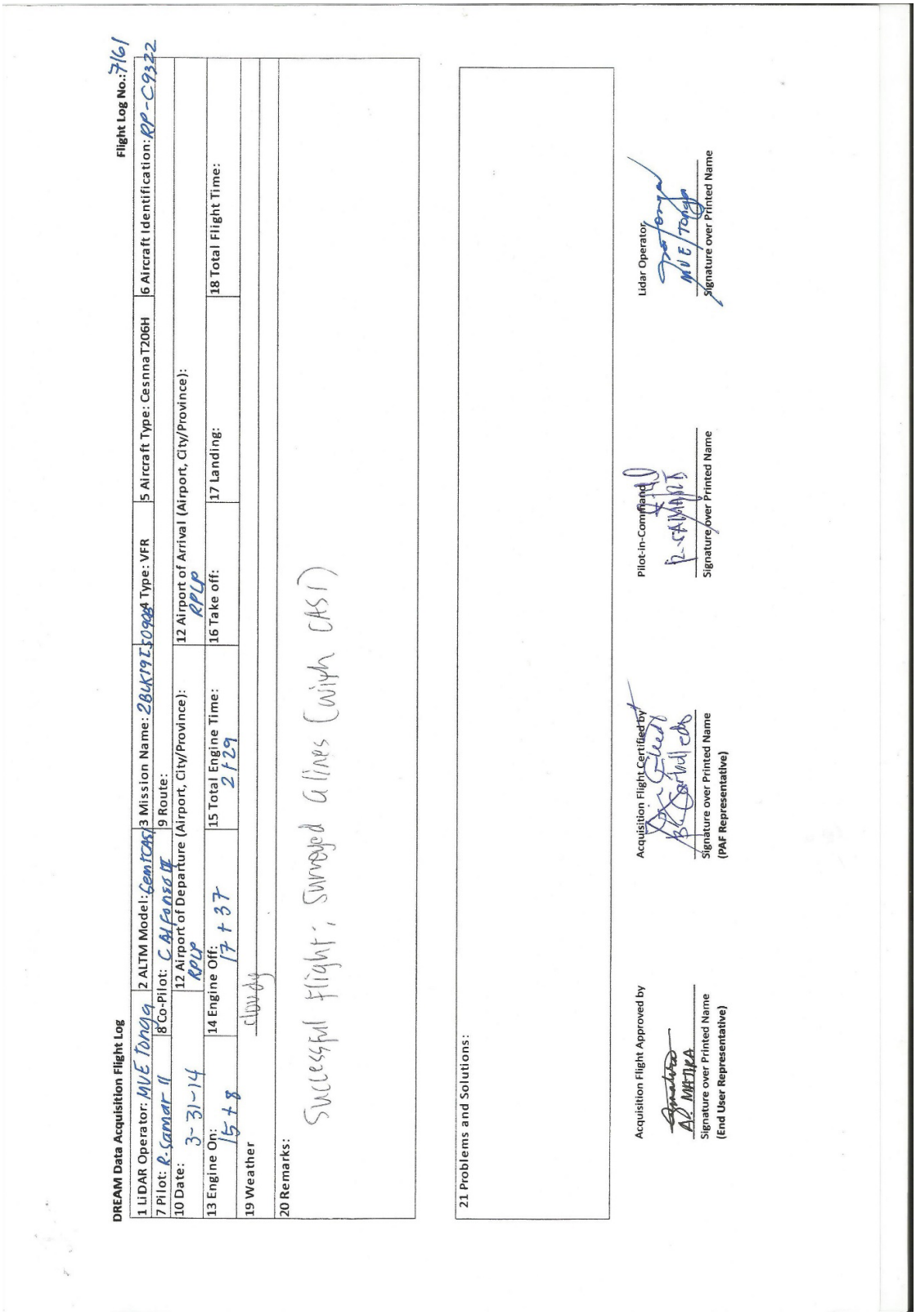
Acquisition Flight Approved by
A.I. MATIRA
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
MVE Tonga
Signature over Printed Name

Flight Log for 7161GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7161

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 28UK191T0922	4 Type: VFR
5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322		
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route:	
10 Date: 3-31-14	12 Airport of Departure (Airport, City/Province): RPLP	12 Airport of Arrival (Airport, City/Province): RPLP	
13 Engine On: 15+8	14 Engine Off: 17+37	15 Total Engine Time: 2+29	16 Take off:
17 Landing:	18 Total Flight Time:		
19 Weather: cloudy			

20 Remarks: Successful Flight; Surveyed 6 lines (with CAS1)

21 Problems and Solutions:

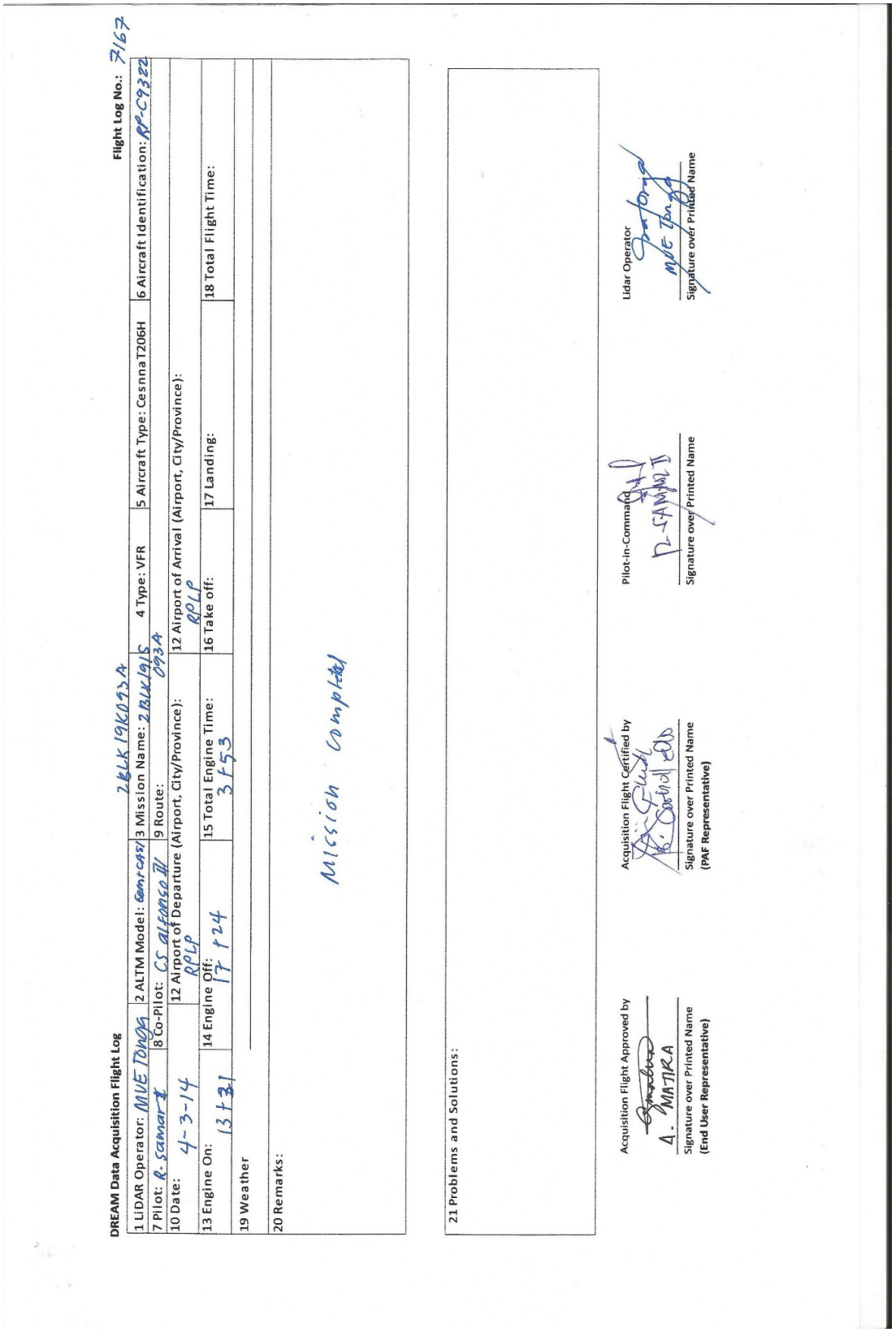
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 7167GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7167

1 LiDAR Operator: NUE TONGA	2 ALTM Model: Gemini 167	3 Mission Name: 2BLK19K093A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samart	8 Co-Pilot: CS Alfonso III	9 Route:			
10 Date: 4-3-14	11 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 13+31	14 Engine Off: 17+24	15 Total Engine Time: 3.53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					
21 Problems and Solutions:					

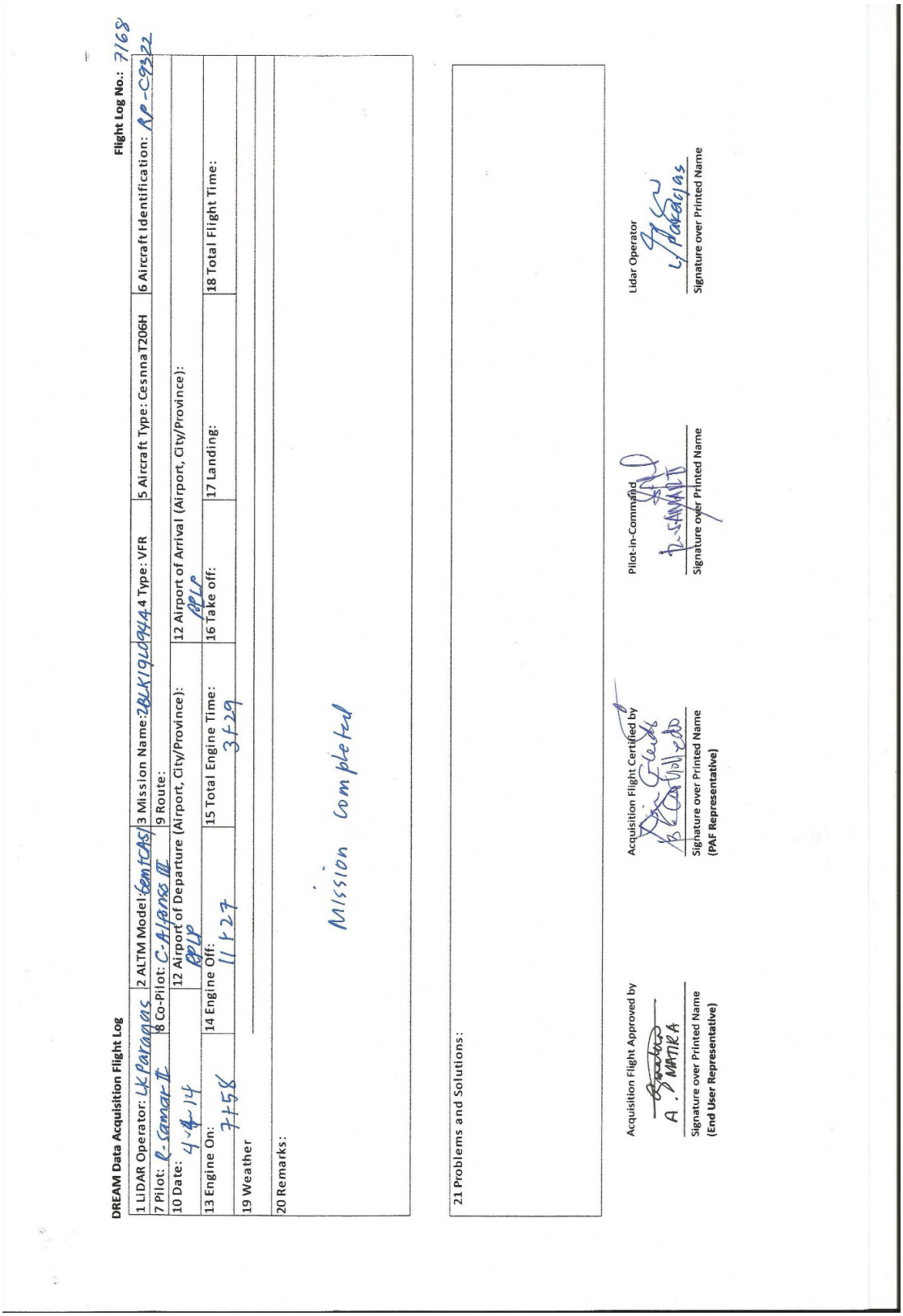
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)
A. MATIRA

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

Pilot-in-Command
Signature over Printed Name
R. SAMART II

Lidar Operator
Signature over Printed Name
NUE TONGA

Flight Log for 7168GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7168

1 LiDAR Operator: LK Paragas	2 ALTM Model: SentCAS	3 Mission Name: 2BLK19LOG414	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R-Samar II	8 Co-Pilot: C-Albos III	9 Route:			
10 Date: 4-4-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 7458	14 Engine Off: 11427	15 Total Engine Time: 3.29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission Completed

21 Problems and Solutions:

Acquisition Flight Approved by

A. P. MANTA

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

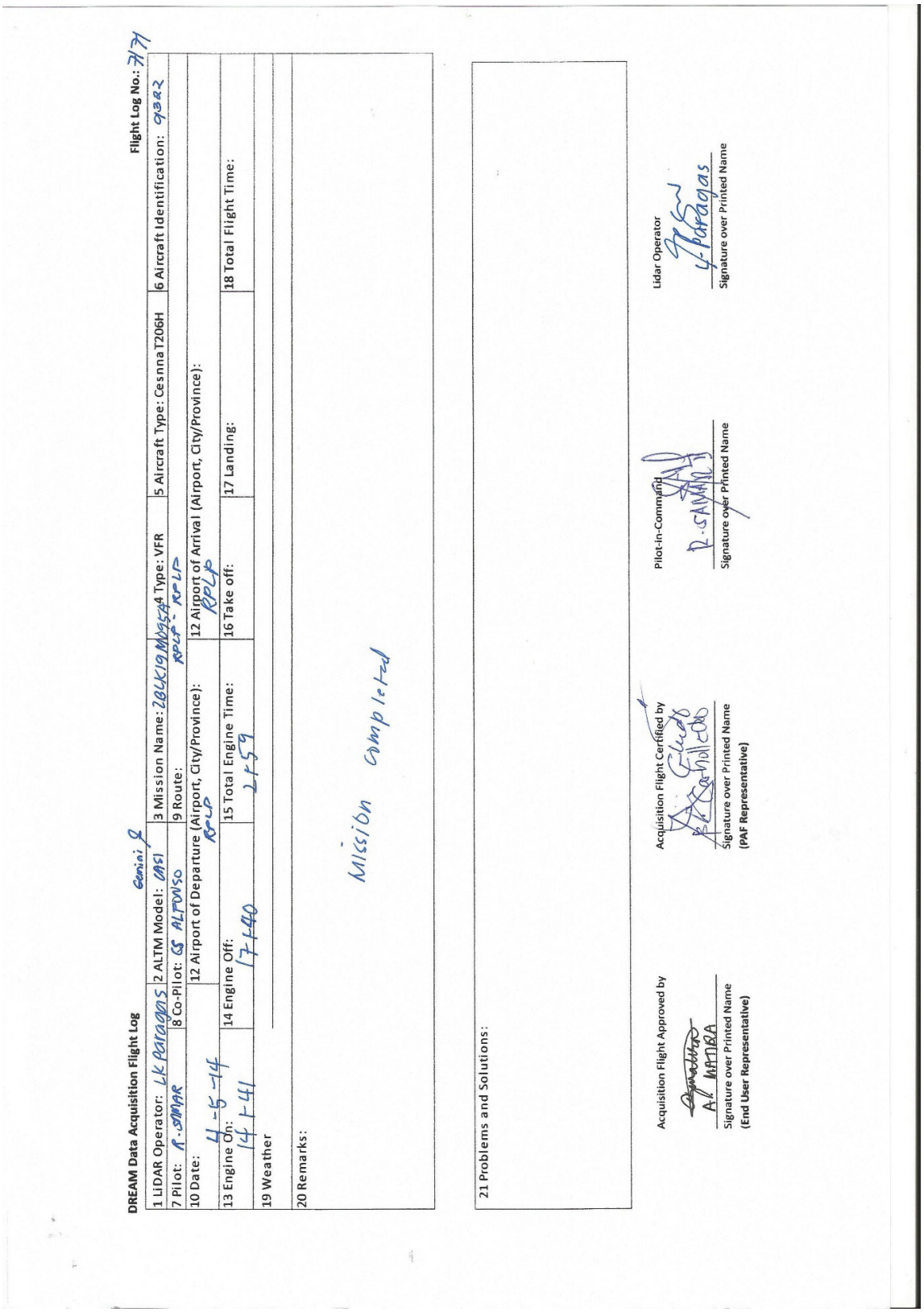
Signature over Printed Name

Lidar Operator

L. Makalias

Signature over Printed Name

Flight Log for 7171GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7171

1 LiDAR Operator: LK Paragas	2 ALTM Model: GM21	3 Mission Name: 28UK19M0524	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9382
7 Pilot: R. Samar	8 Co-Pilot: GS Alforso	9 Route: RPLP - RPLP			
10 Date: 4-5-14		12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP	
13 Engine On: 14:41	14 Engine Off: 17:40	15 Total Engine Time: 2.59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks: Mission Completed

21 Problems and Solutions:

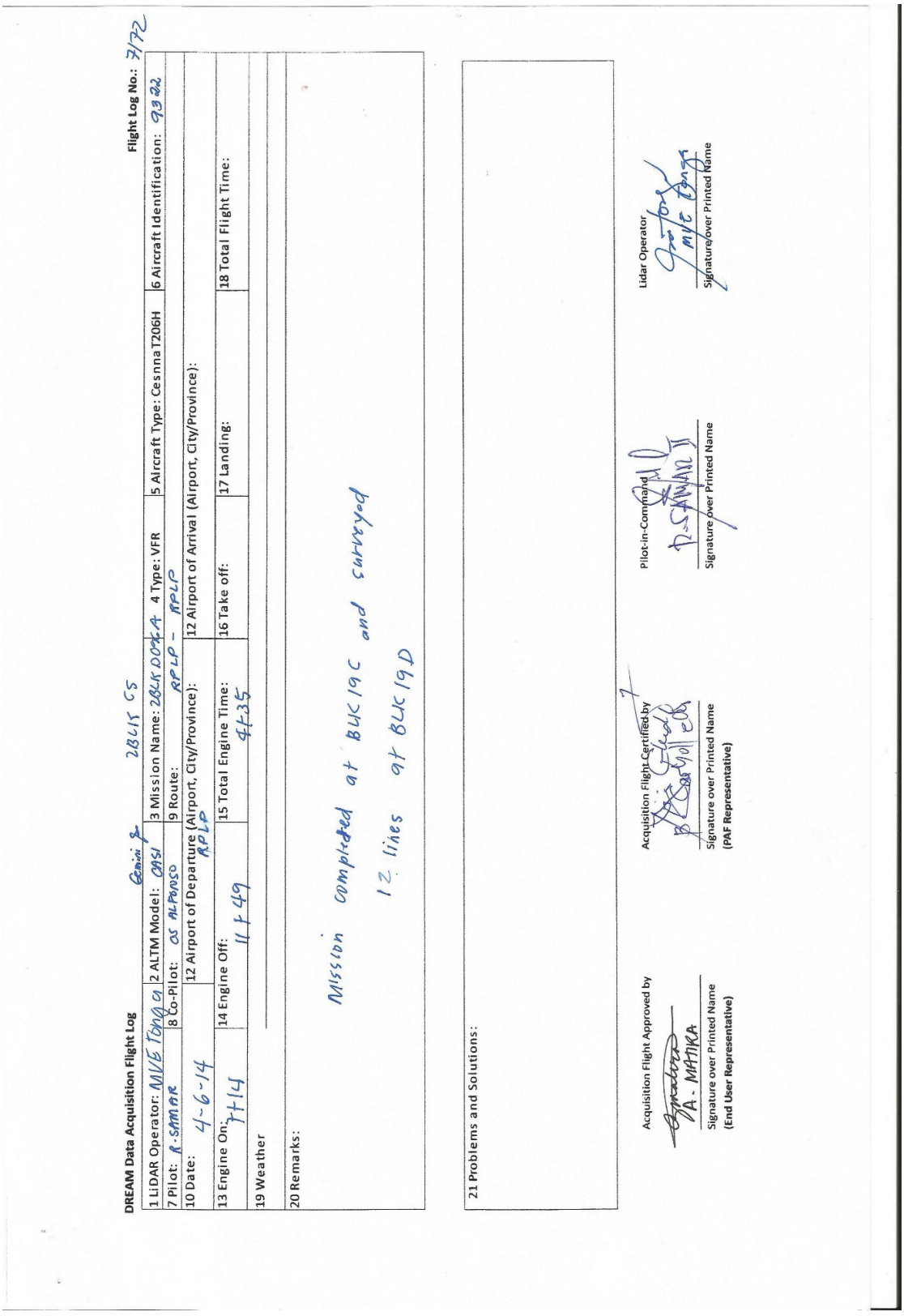
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 7172GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7/72

1 LiDAR Operator: MVE Tongco	2 ALTM Model: GEMINI 8 / 2BLK CS	3 Mission Name: 2BLK 007A	4 Type: VFR
5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9382		
7 Pilot: R. SAMAR	8 Co-Pilot: DS ALFONSO	9 Route: RPLP – RPLP	
10 Date: 4-6-14	11 Airport of Departure (Airport, City/Province): RPLP	12 Airport of Arrival (Airport, City/Province):	
13 Engine On: 7:14	14 Engine Off: 11:49	15 Total Engine Time: 4:35	16 Take off:
17 Landing:	18 Total Flight Time:		
19 Weather			

20 Remarks:

Mission completed at BLK 19C and surveyed 12 lines at BLK 19D

21 Problems and Solutions:

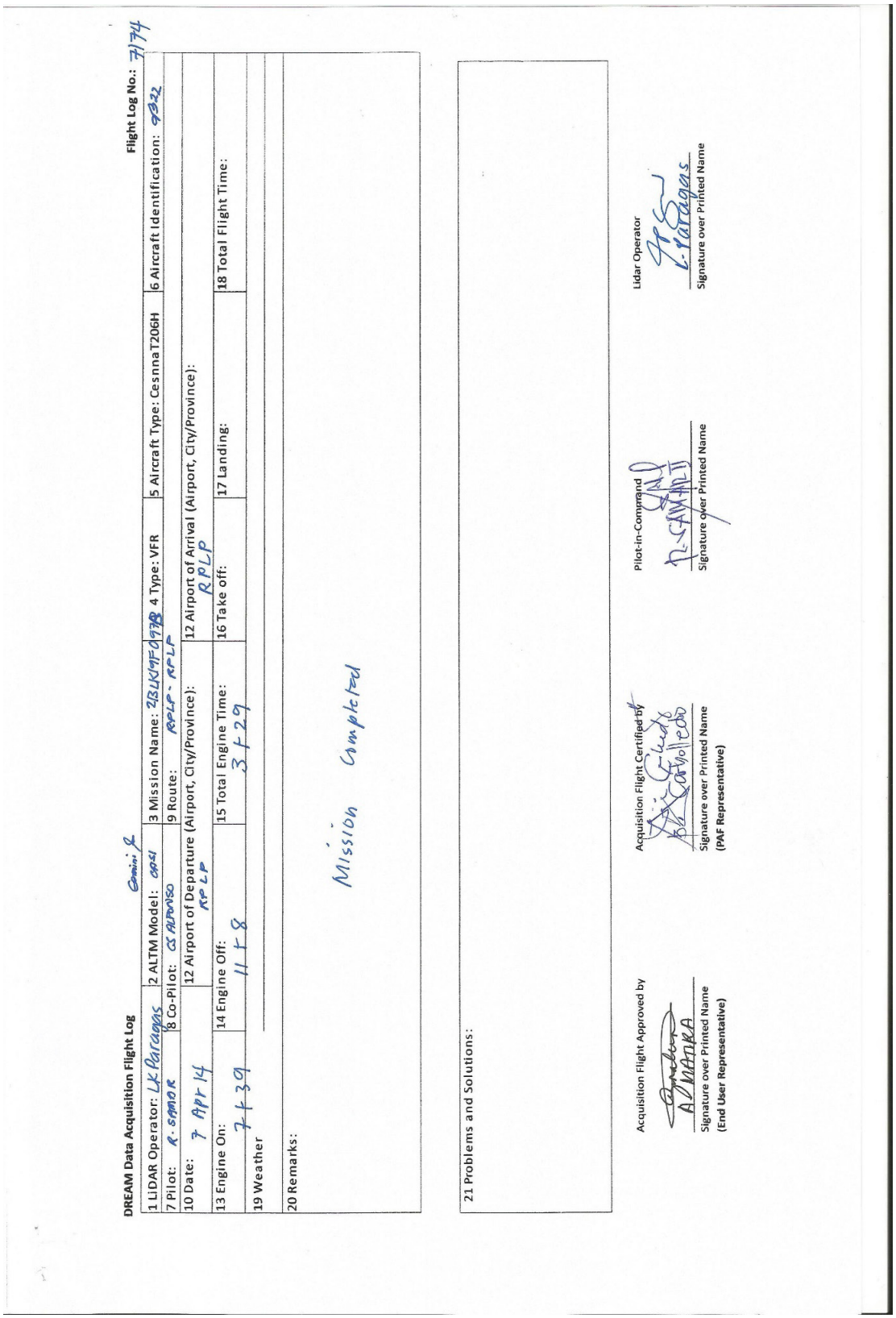
Acquisition Flight Approved by
A. MATIKA
Signature over Printed Name (End User Representative)

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

Pilot-in-Command
D. SAMAR II
Signature over Printed Name

Lidar Operator
MVE Tongco
Signature over Printed Name

Flight Log for 7174GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7174

1 LiDAR Operator: LK Paraguas	2 ALTM Model: 3021	3 Mission Name: 23JAN14FD078	4 Type: VFR
5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9332		
7 Pilot: R. Samar	8 Co-Pilot: CS Alonso	9 Route: RPLP - RPLP	
10 Date: 7 APR 14	11 Airport of Departure (Airport, City/Province): RPLP	12 Airport of Arrival (Airport, City/Province): RPLP	
13 Engine On: 7:39	14 Engine Off: 11:48	15 Total Engine Time: 3:29	16 Take off:
17 Landing:	18 Total Flight Time:		
19 Weather			
20 Remarks: Mission Completed			
21 Problems and Solutions:			

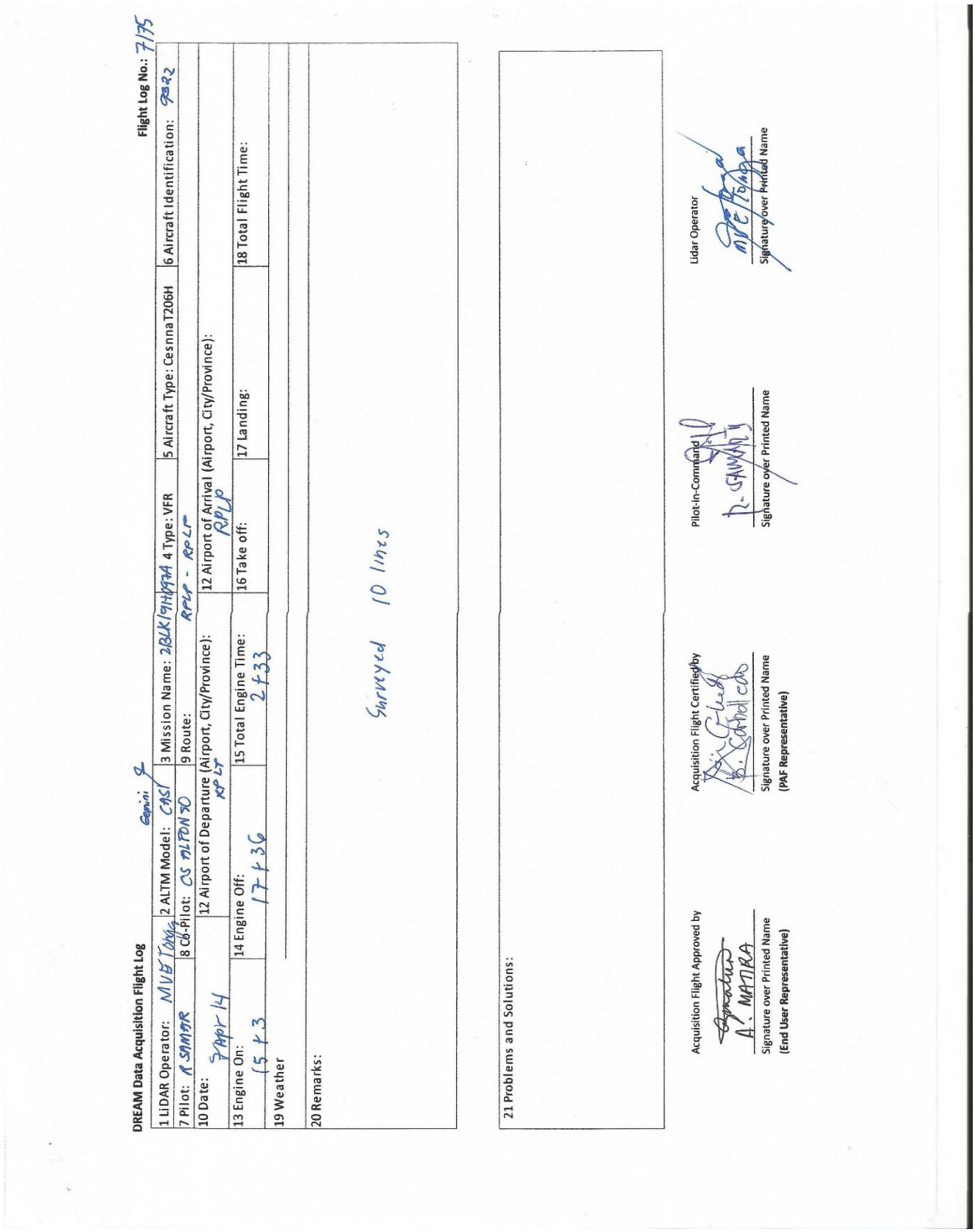
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 7175 Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7175

1 LiDAR Operator: MVB Tonga	2 ALTM Model: CASI Gemini 8	3 Mission Name: 2BLK19HAGA 4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMSAR	8 Co-Pilot: CS ALFONSO	9 Route: RPLP - RPLP		
10 Date: 7 APR 14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP	
13 Engine On: 1543	14 Engine Off: 1736	15 Total Engine Time: 2433	16 Take off:	17 Landing: 18 Total Flight Time:
19 Weather				
20 Remarks: Surveyed 10 lines				
21 Problems and Solutions:				

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

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

Pilot-in-Command — R. SAMSAR — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Flight Log for 7176GC Mission

DREAM Data Acquisition Flight Log Gemini 2 2BLK19HS098A — **Flight Log No.:** 7176

1 LiDAR Operator: LK Paragas	2 ALTM Model: OASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR	8 Co-Pilot: CS ALFONSO	9 Route: RPLP - RPLP			
10 Date: 4-8-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 7+23	14 Engine Off: 9+4	15 Total Engine Time: 1+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

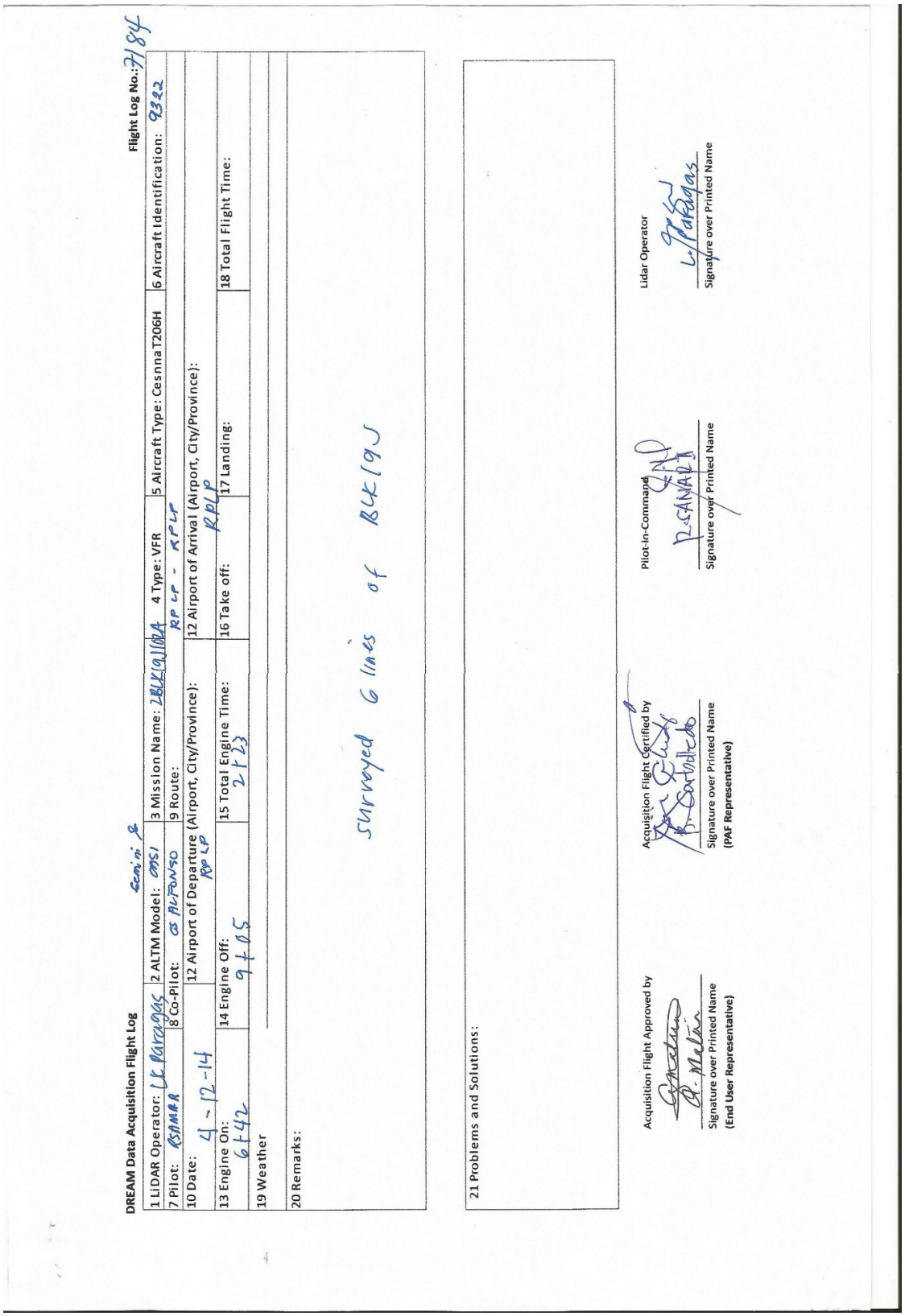
20 Remarks:

Flight aborted due to precipitation in the survey area

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. MATIRA	B. Corbolledo	R. SAMAR II	J. Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 7184GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7184GC

1 LiDAR Operator: Lt Parayas	2 ALTM Model: GM21	3 Mission Name: 2BLK19J1084	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9322
7 Pilot: RAMOS	8 Co-Pilot: CS ALFONSO	9 Route: RPLP - RPLP			
10 Date: 4-12-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 0642	14 Engine Off: 0705	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks: Surveyed 6 lines of BLK19J

21 Problems and Solutions:

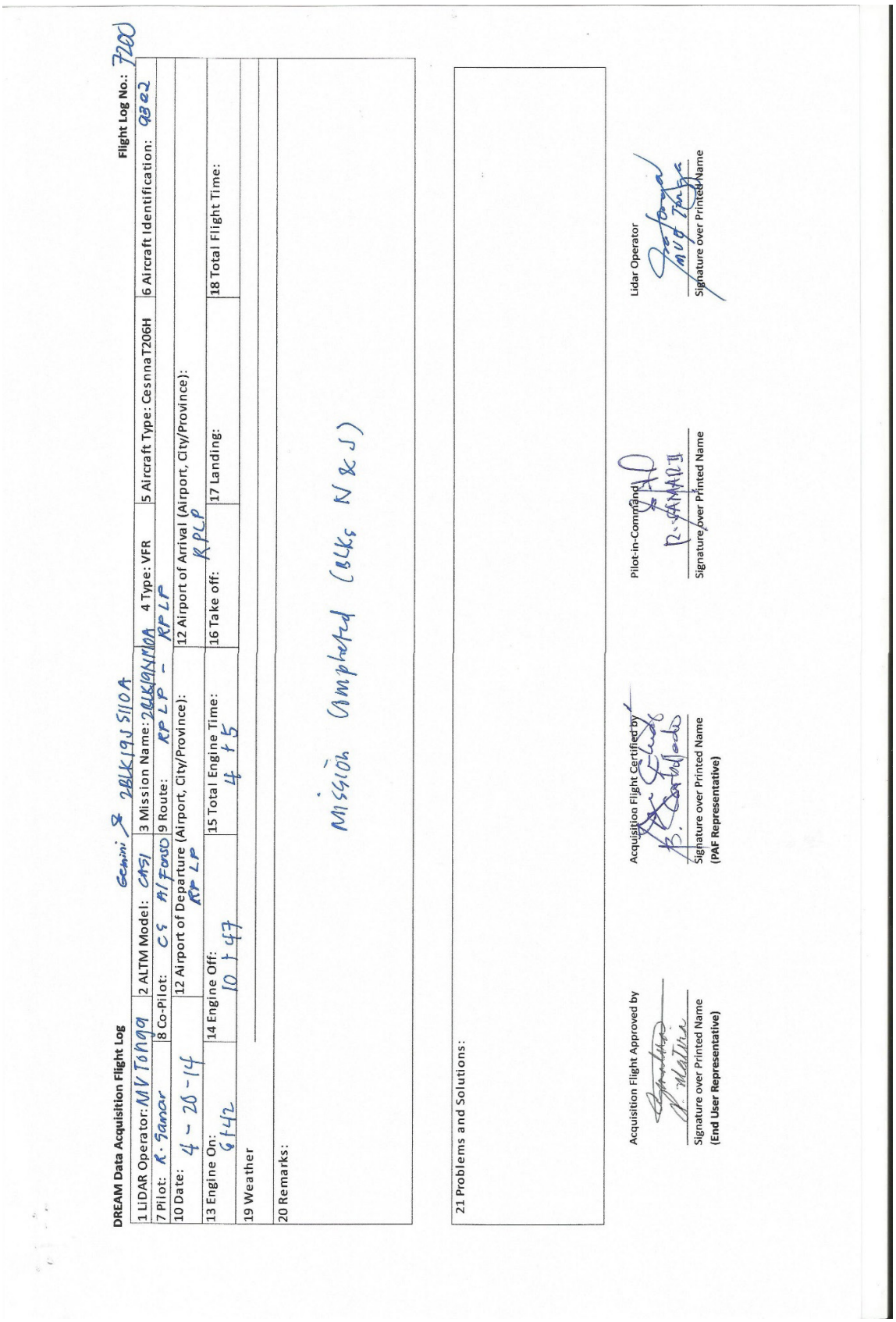
Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Flight Log for 7200GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7200

1 LiDAR Operator: MVTolnay	2 ALTM Model: Gemini 8	3 Mission Name: 28LK19J SIIOA	4 Type: VFR
5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9382		
7 Pilot: R. Tamor	8 Co-Pilot: C/S Alfordo	9 Route: RPLP - RPLP	
10 Date: 4 - 28 - 14	12 Airport of Departure (Airport, City/Province): RP LP	12 Airport of Arrival (Airport, City/Province): RPLP	
13 Engine On: 0642	14 Engine Off: 10 + 47	15 Total Engine Time: 4 + 5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather			
20 Remarks: Mission Completed (BLKs N & J)			
21 Problems and Solutions:			

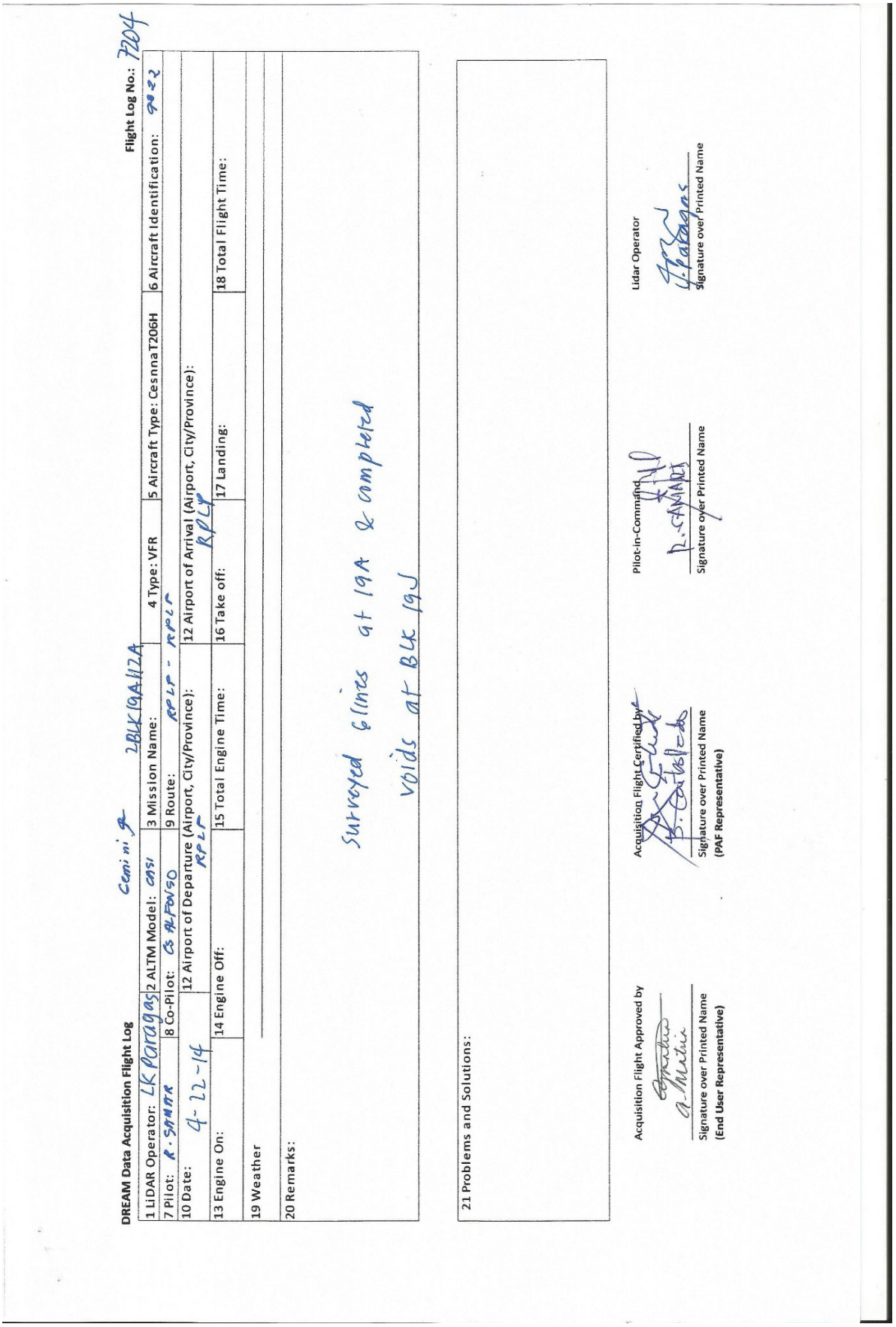
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 7204GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7204

Cessna — 2BLK19A&12A

1 LiDAR Operator: LK Paragas	2 ALTM Model: CASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9052
7 Pilot: R. Samar	8 Co-Pilot: CS Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-22-14	11 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Surveyed 6 lines at 19A & completed voids at BLK 19J

21 Problems and Solutions:

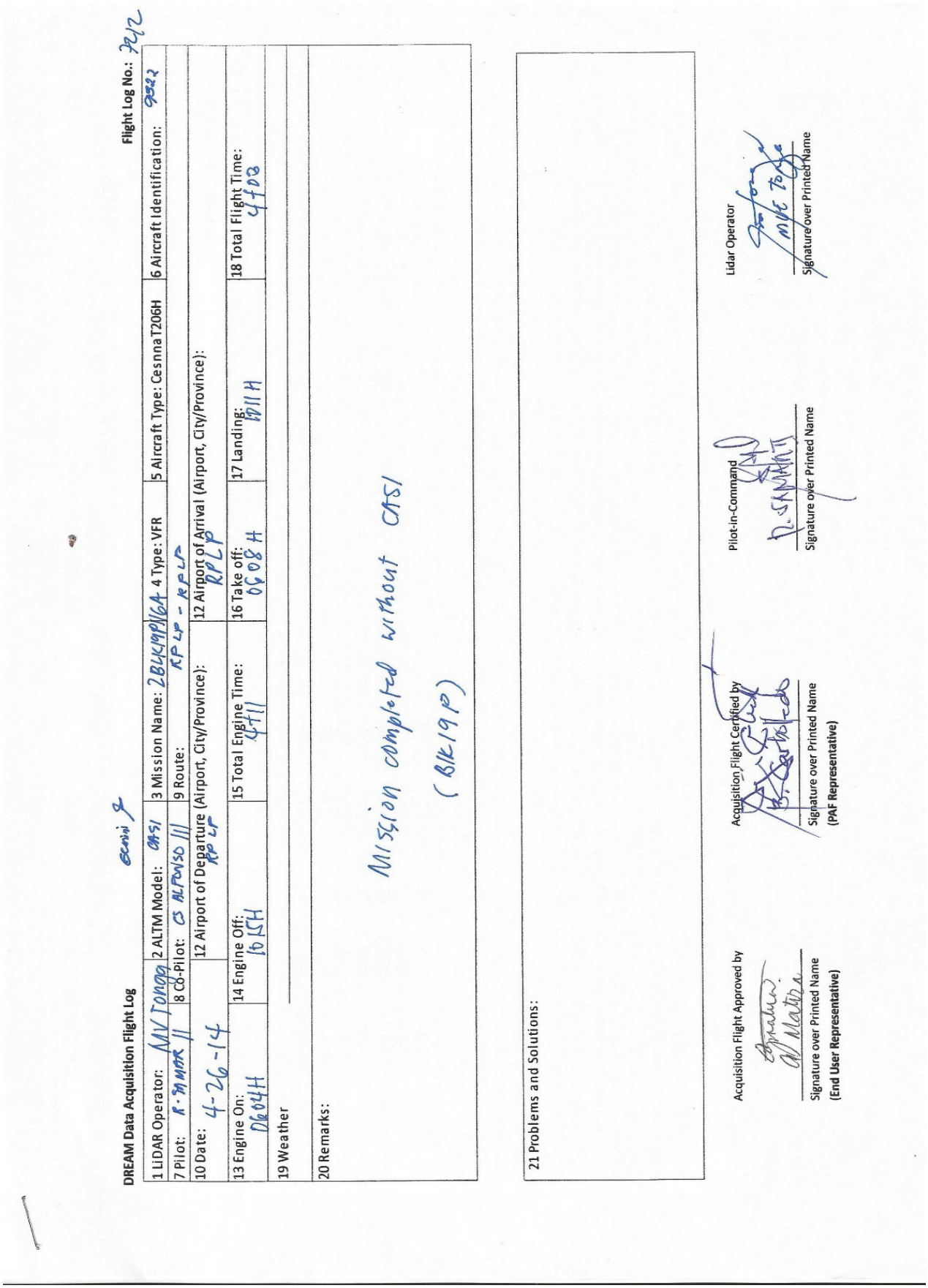
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 7212GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7212

1 LiDAR Operator: MV Tongo	2 ALTM Model: CHSI	3 Mission Name: 2BLK19P116A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9542
7 Pilot: R. Minor II	8 Co-Pilot: CS Alfonso III	9 Route: RPLP - RPLP			
10 Date: 4-26-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 0604H	14 Engine Off: 1015H	15 Total Engine Time: 4.11	16 Take off: 0608 H	17 Landing: 1911 H	18 Total Flight Time: 4.05

19 Weather

20 Remarks: Mission completed without CHSI (BLK19P)

21 Problems and Solutions:

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

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM Data Acquisition Flight Log Gemini 2 **Flight Log No.:** 7213

1 LiDAR Operator: LParagas	2 ALTM Model: CASI	3 Mission Name: BLK05116B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9307
7 Pilot: R. SAMAR	8 Co-Pilot: CJ ALFONSO	9 Route: RPLP - RPLP		
10 Date: 4-26-14	12 Airport of Departure (Airport, City/Province): RPLP	12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 1458H gr	14 Engine Off: 1733H gr	15 Total Engine Time: 2+35 gr	16 Take off: 1501H gr	17 Landing: 1729H. gr	18 Total Flight Time: 2+28 gr
19 Weather	Cloudy				

20 Remarks:

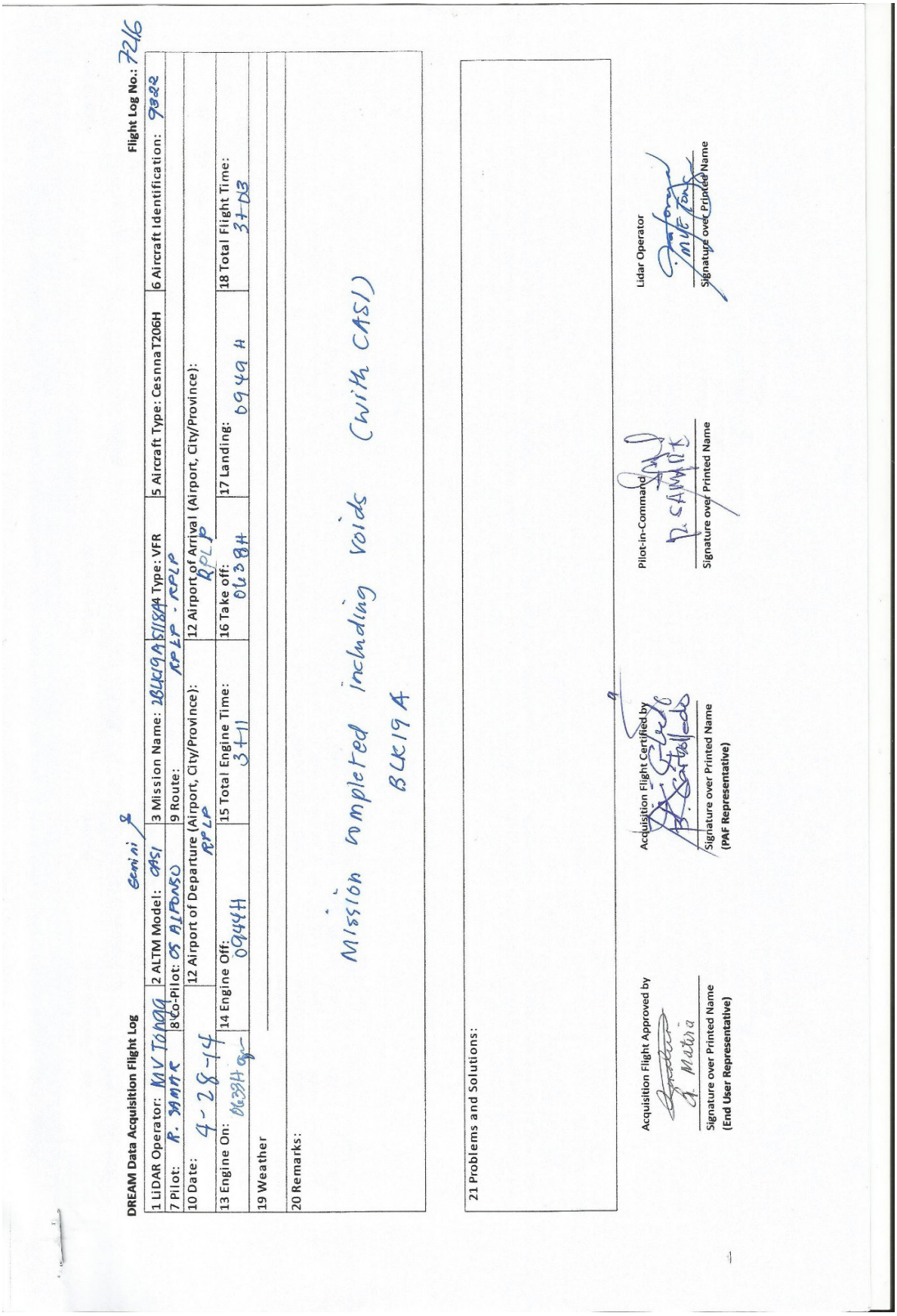
Mission Completed without CASI

(BLK 19 0)

21 Problems and Solutions:

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

Flight Log for 7216GC Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 7216

Gemini 8

1 LiDAR Operator: MV Tanga	2 ALTM Model: CASI	3 Mission Name: 2BLK19A	S1584 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: OS Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-28-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 0633H	14 Engine Off: 0944H	15 Total Engine Time: 3+11	16 Take off: 0638H	17 Landing: 0949 H	18 Total Flight Time: 3+03
19 Weather					

20 Remarks:

Mission completed including voids (with CASI)
BLK19A

21 Problems and Solutions:

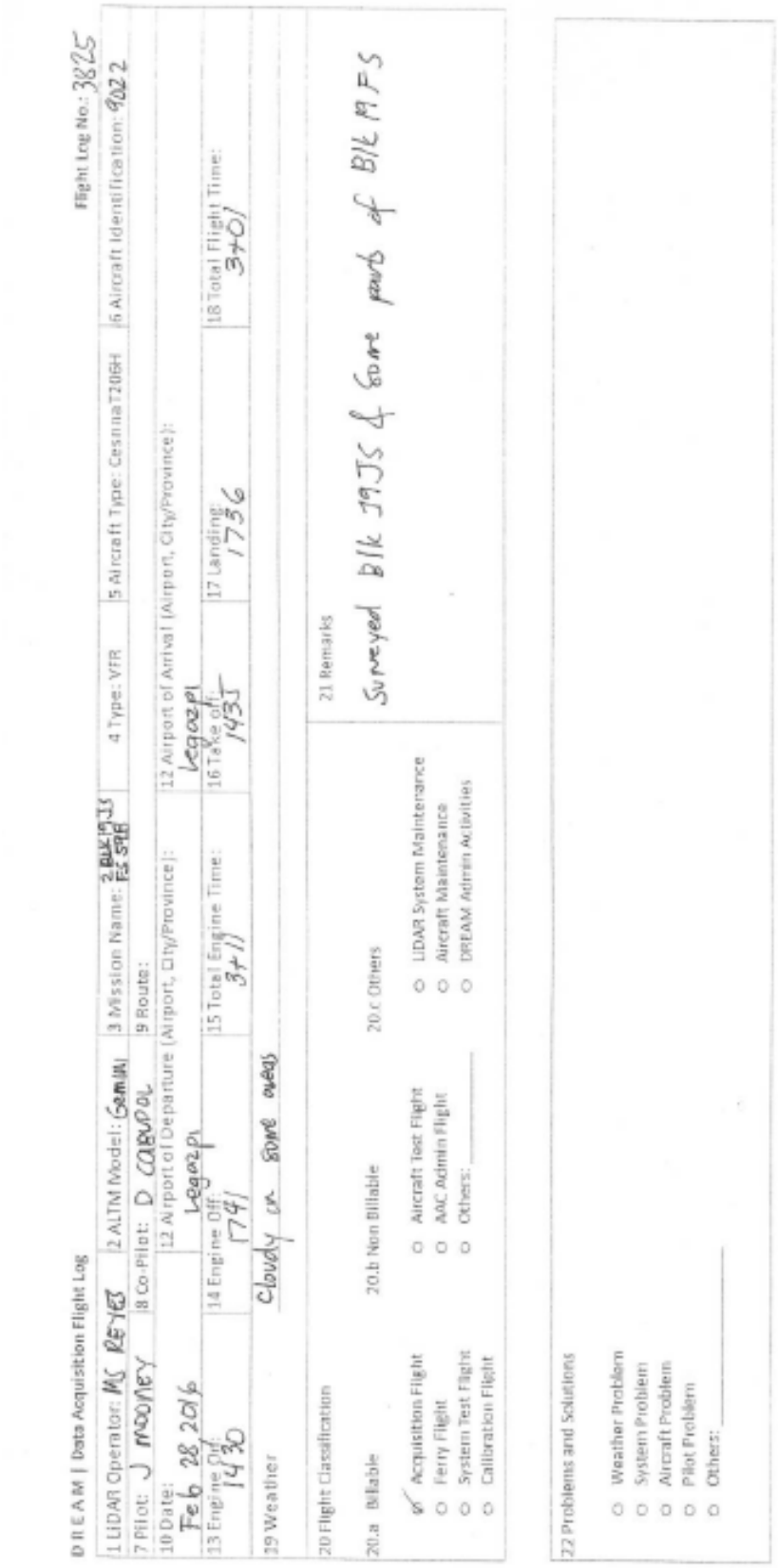
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 3825G Mission



DREAM | Data Acquisition Flight Log

Flight Log No.: 3825

1 LiDAR Operator: MS REYES	2 ALTM Model: GEMINI	3 Mission Name: 2 BLKS 19 JS FS 568	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 902 2
7 Pilot: J MOONEY	8 Co-Pilot: D CABUDOL	9 Route:			
10 Date: Feb 28 2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine Off: 1430	14 Engine Off: 1741	15 Total Engine Time: 3+11	16 Take off: 1931	17 Landing: 1736	18 Total Flight Time: 3+05

19 Weather: Cloudy on some areas

20 Flight Classification

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

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

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

21 Remarks: Surveyed Blk 19 JS & some parts of Blk 19 FS

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

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

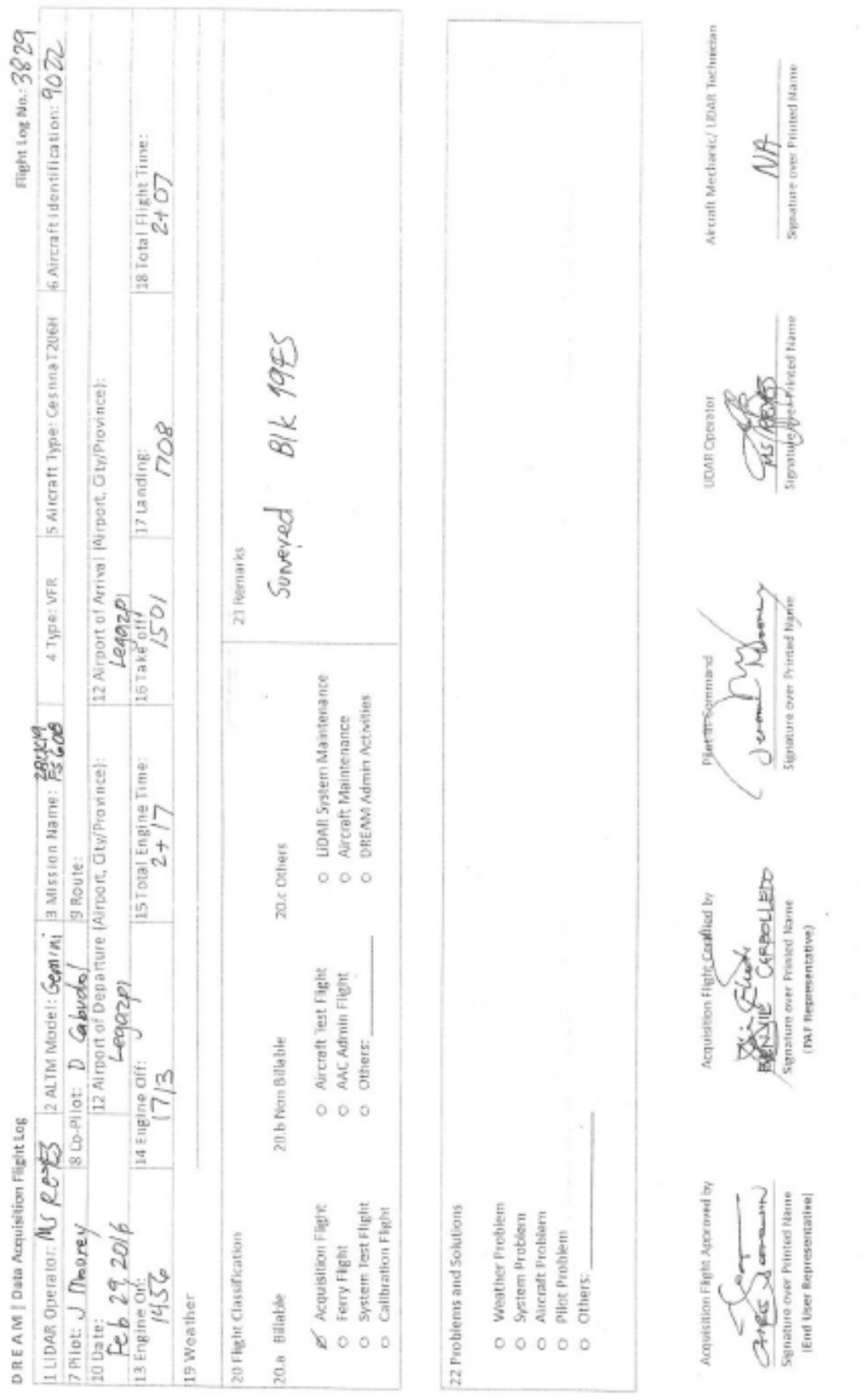
Acquisition Flight Certified by
Signature over Printed Name (NAF Representative)

Pilot-in-Command
Signature over Printed Name

LiDAR Operator
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
N/A
Signature over Printed Name

Flight Log for 3829G Mission



DREAM | Data Acquisition Flight Log

Flight Log No.: 3829

1 LIDAR Operator: NS Reyes	2 ALTM Model: Gemini	3 Mission Name: 3829G	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: J Monrey	8 Co-Pilot: D Gabuedo	9 Route:			
10 Date: Feb 29 2016	11 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 1436	14 Engine Off: 1713	15 Total Engine Time: 2+17	16 Take Off: 1501	17 Landing: 1708	18 Total Flight Time: 2+07
19 Weather					

20 Flight Classification

20.a Billable

- ☑ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ DREAMA Admin Activities

21 Remarks: Surveyed Blk 19ES

22 Problems and Solutions

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

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

LiDAR Operator

Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician

N/A

Signature over Printed Name

Flight Log for 3843G Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1197P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route:			
10 Date: MAR. 8, 2014	12 Airport of Departure (Airport, City/Province): LA UNION		12 Airport of Arrival (Airport, City/Province): LA UNION		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 2 + 59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION SUCCESSFUL					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	MARLON TORRE	M.L. TANGONAN	R. PUNTO
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 REPORT

ALBAY AND SORSOGON (March 26 – April 30, 2014 and February 24 – March 20, 2016)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7156GC	BLK19E	2BLK19E088A	MVE TONGA	03-29-14	Surveyed 3 lines (with CASI)
7158GC	BLK19EG	2BLK19ES089A & 2BLK19G089A	MVE TONGA	03-30-14	Mission completed (with CASI)
7160GC	BLK19I	2BLK19I90A	MVE TONGA	03-31-14	Surveyed 1 line (without CASI)
7161GC	BLK19I	2BLK19IS090B	MVE TONGA	03-31-14	Surveyed 6 lines (with CASI)
7167GC	BLK19KI	2BLK19K093A & 2BLK10IS093A	MVE TONGA	04-03-14	Mission completed (with CASI)
7168GC	BLK19L	2BLK19L094A	L. PARAGAS	04-04-14	Mission completed (with CASI)
7171GC	BLK19M	2BLK19M095A	L. PARAGAS	04-05-14	Mission completed (with CASI)
7172GC	BLK19CD	2BLK19CS096A & 2BLK19D096A	MVE TONGA	04-06-13	Mission completed at BLKC and surveyed 12 lines at BLK19D (with CASI-corrupted hard drive)
7174GC	BLK19F	2BLK19F097A	L. PARAGAS	04-07-14	Mission completed (with CASI except first 2 lines)
7175GC	BLK19H	2BLK19H097B	MVE TONGA	04-07-14	Surveyed 10 lines (with CASI)
7176GC	BLK19H	2BLK19HS098A	L. PARAGAS	04-08-14	Surveyed 2 lines (without CASI)
7184GC	BLK19J	2BLK19J102A	L. PARAGAS	04-12-14	Surveyed 6 lines (with CASI)
7200GC	BLK19JN	2BLK19JS110A & 2BLK19N110A	MVE TONGA	04-20-13	Mission completed (with CASI)
7204GC	BLK19A	2BLK19A112A	L. PARAGAS	04-22-14	Surveyed 6 lines at BLK19A and completed the voids at BLKJ (without CASI)
7212GC	BLK19PO	2BLK19P116A & 2BLK190116A	MVE TONGA	4-26-14	Mission completed at BLK19P and surveyed 2 lines of BLK19O (without CASI)
7213GC	BLK19O	2BLK19OS116B & VOIDS	L. PARAGAS	4-26-14	Completed the rest of BLK19O and rest of void data (NO CASI)
7216GC	BLK19A	2BLK19AS118A & VOIDS	MVE TONGA	4-28-14	Surveyed the rest of BLKA and the rest of void data (without CASI)
3825G	BLK19JF	2BLK19JFS059B	M. REYES	02-28-16	SURVEYED BLK19J AND SOME LINES OF BLK19FS

3829G	BLK19F	2BLK19FS060B	M. REYES	02-29-16	SURVEYED REST OF BLK19FS
3843G	BLK19D	2BLK19DS064A	J. ALAMBAN	03-04-16	SURVEYED BLK19DS

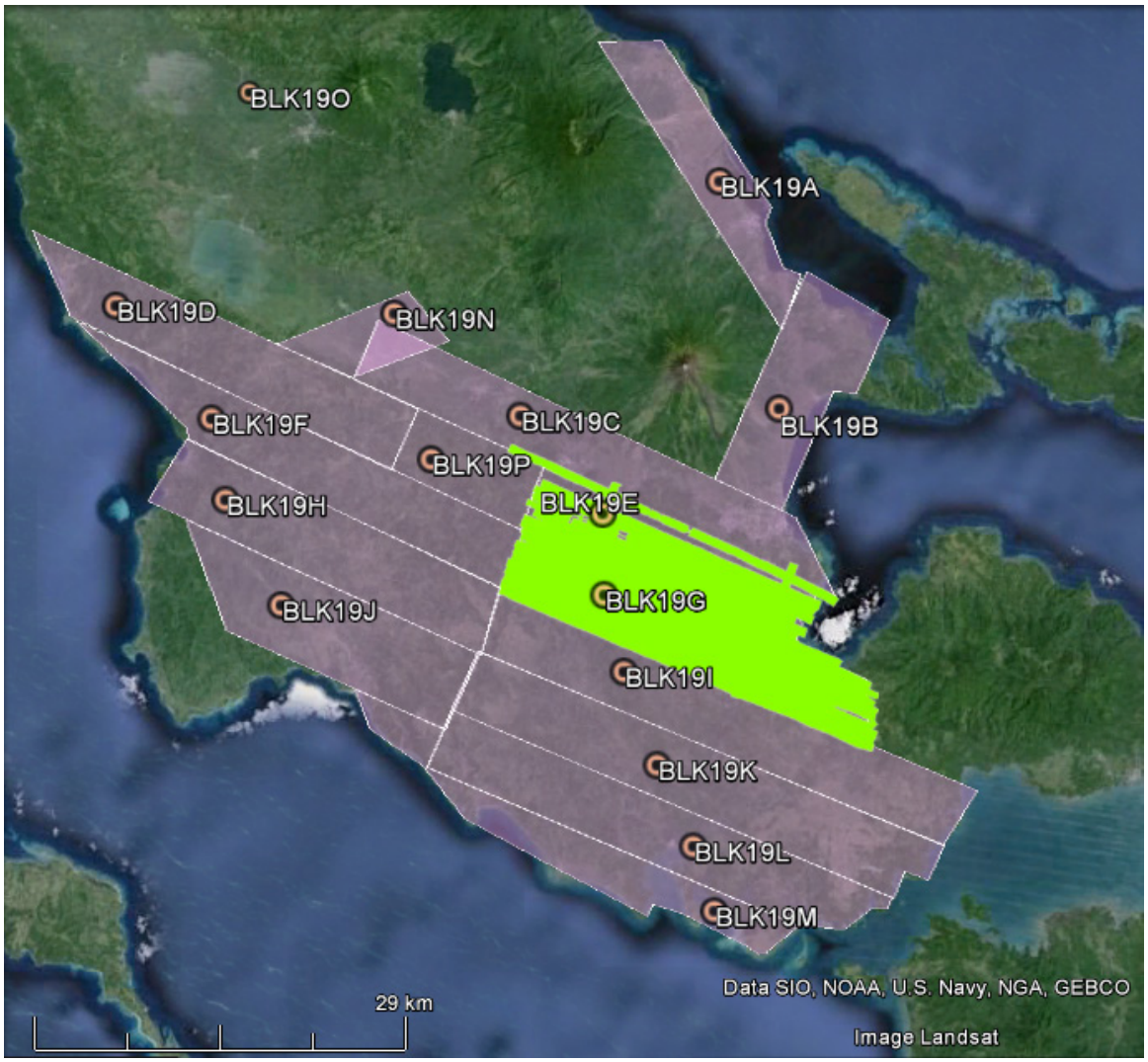
LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. : 7156 GC
Area: BLK19E
Mission name: 2BLK19E088A
Parameters: Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 35 %

LAS/SWATH

Flight No. : 7158 GC
Area: BLK19E AND BLK19G
Mission name: 2BLK19ES089A & 2BLK19G089A
Parameters: Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 35 %

LAS/SWATH



Flight No. : 7160 GC
Area: BLK19I
Mission name: 2BLK19IS090A
Parameters: Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 45 %

LAS/SWATH

Flight No. : 7161 GC
Area: BLK19I
Mission name: 2BLK19IS090B
Parameters: Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 45 %

LAS/SWATH

Flight No. : 7167 GC
Area: BLK19K AND BLK19I
Mission name: 2BLK19K093A & 2BLK19IS093B
Parameters: Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 40 %

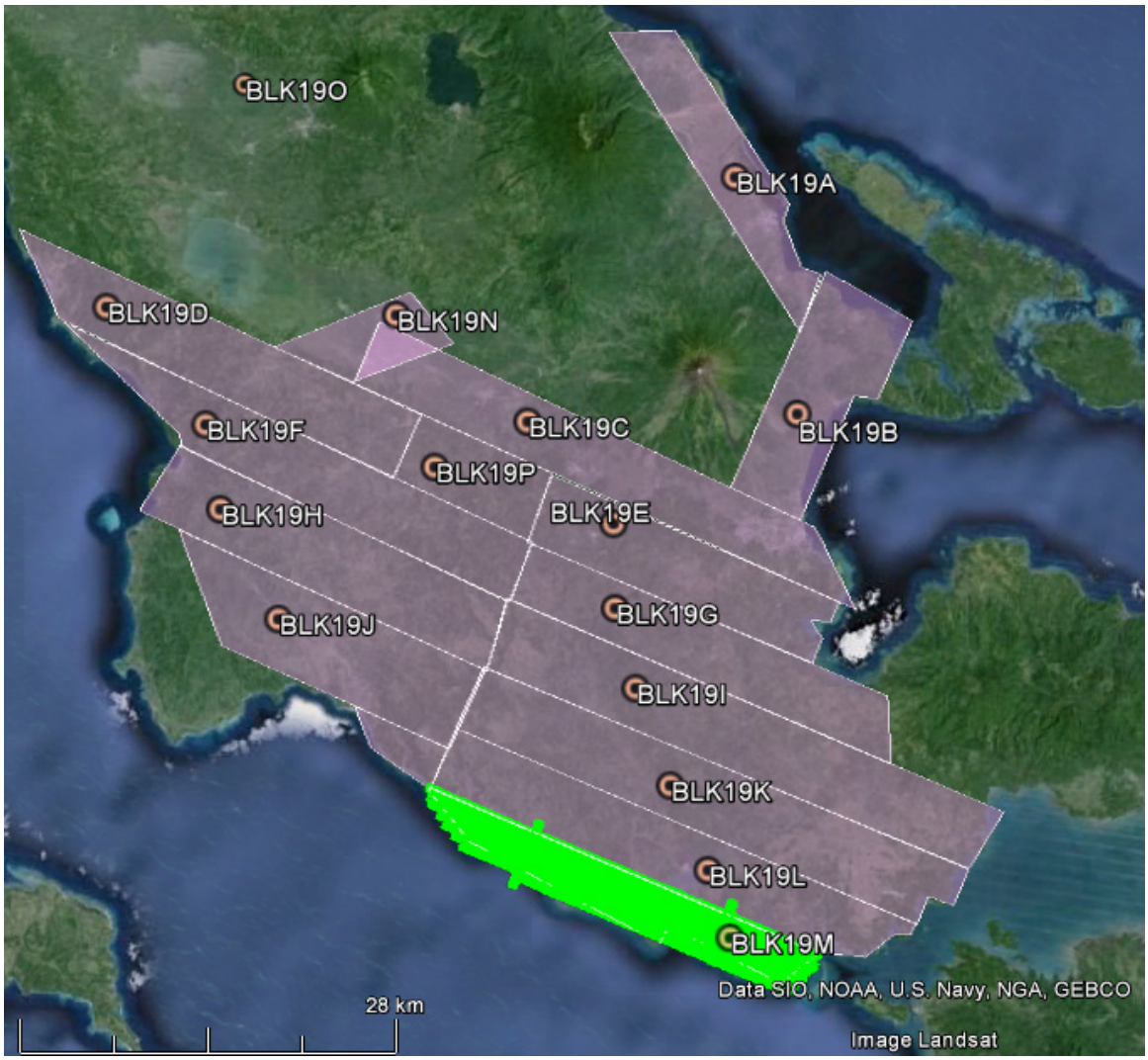
LAS/SWATH

Flight No. : 7168 GC
Area: BLK19L
Mission name: BLK19L
Parameters: Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 40 %

LAS/SWATH

Flight No. : 7171 GC
Area: BLK19M
Mission name: 2BLK19M095A
Parameters: Altitude: 900; Scan Frequency: 50; FOV: 40; Overlap: 20 %

LAS/SWATH



Flight No. : 7172 GC
Area: BLK19A
Mission name: 2BLK19AS118A & VOIDS
Parameters: Altitude: 1100; Scan Frequency: 50; FOV: 34; Overlap: 50 %

LAS/SWATH

Flight No. : 7174 GC
Area: BLK19F

Mission name: 2BLK19F097A
Parameters: Altitude: 1300; Scan Frequency: 50; Scan Angle: 34; Overlap: 30 %

Flight No. : 7175 GC
Area: BLK19H

Mission name: 2BLK19H097B
Parameters: Altitude: 1100; Scan Frequency: 50; Scan Angle: 40; Overlap: 50 %

Flight No. : 7176 GC
Area: BLK19HS

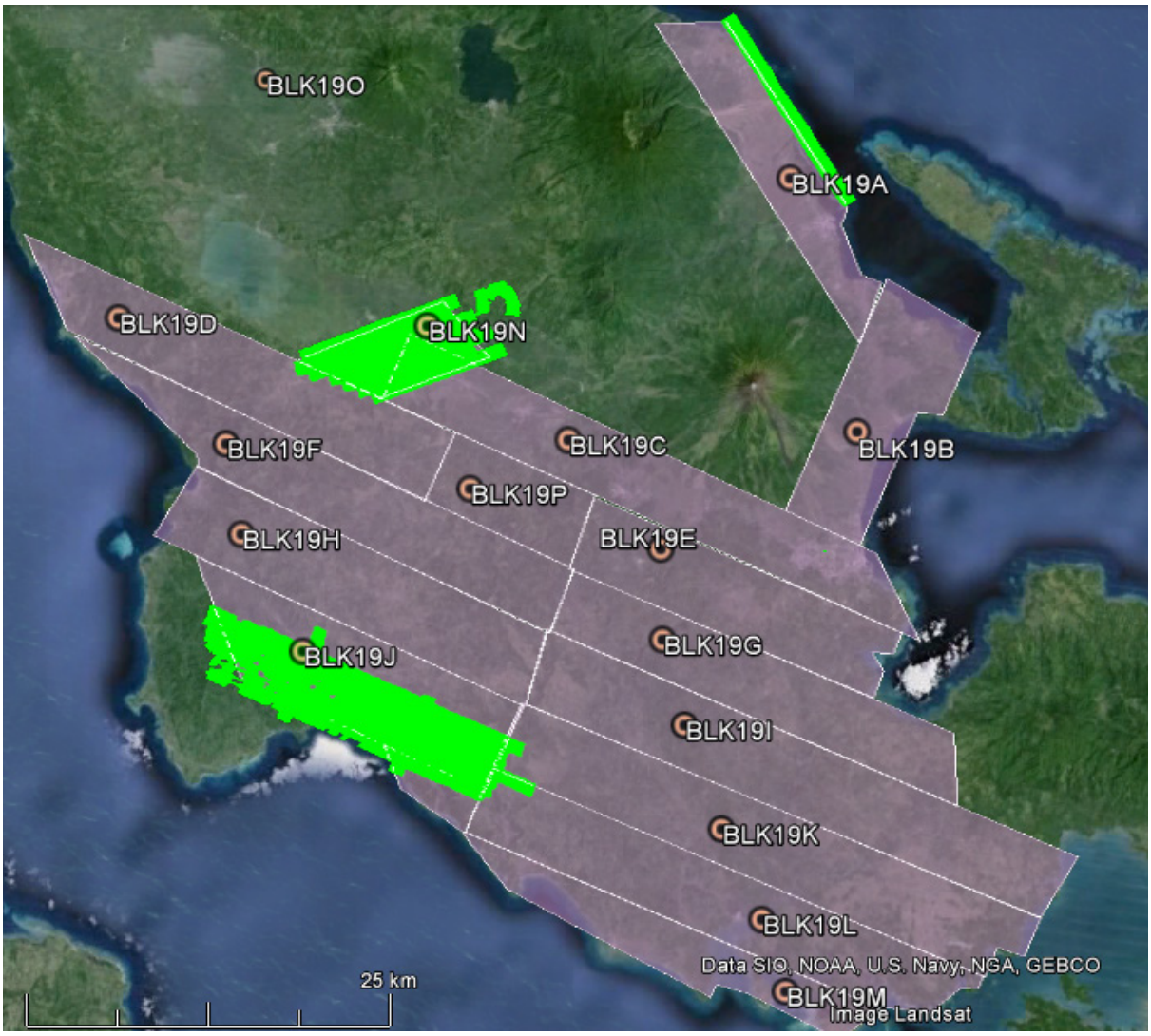
Mission name: 2BLK19HS098A
Parameters: Altitude: 1300; Scan Frequency: 50; Scan Angle: 34; Overlap: 35 %

Flight No. : 7184 GC
Area: BLK19J

Mission name: 2BLK19J102A
Parameters: Altitude: 1300; Scan Frequency: 50; Scan Angle: 34; Overlap: 30 %

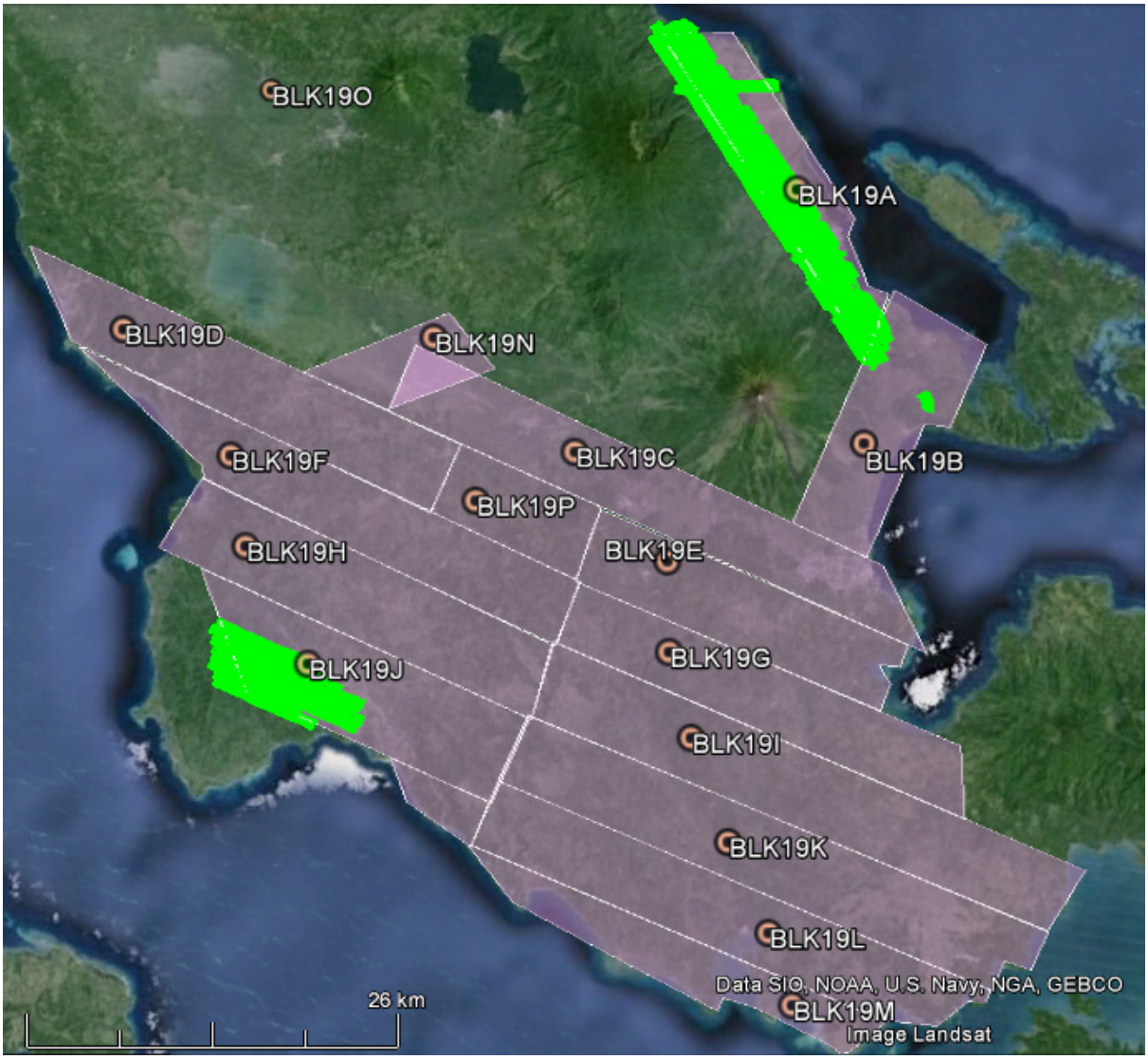
Flight No. : 7200 GC
Area: BLK19JS & BLK19N

Mission name: 2BLK19JS110A & 2BLK19N110A
Parameters: Altitude: 1300; Scan Frequency: 50; Scan Angle: 40; Overlap: 50 %



Flight No. : 7204 GC
Area: BLK19A

Mission name: 2BLK19A112A
Parameters: Altitude: 1300; Scan Frequency: 50; Scan Angle: 34; Overlap: 40 %

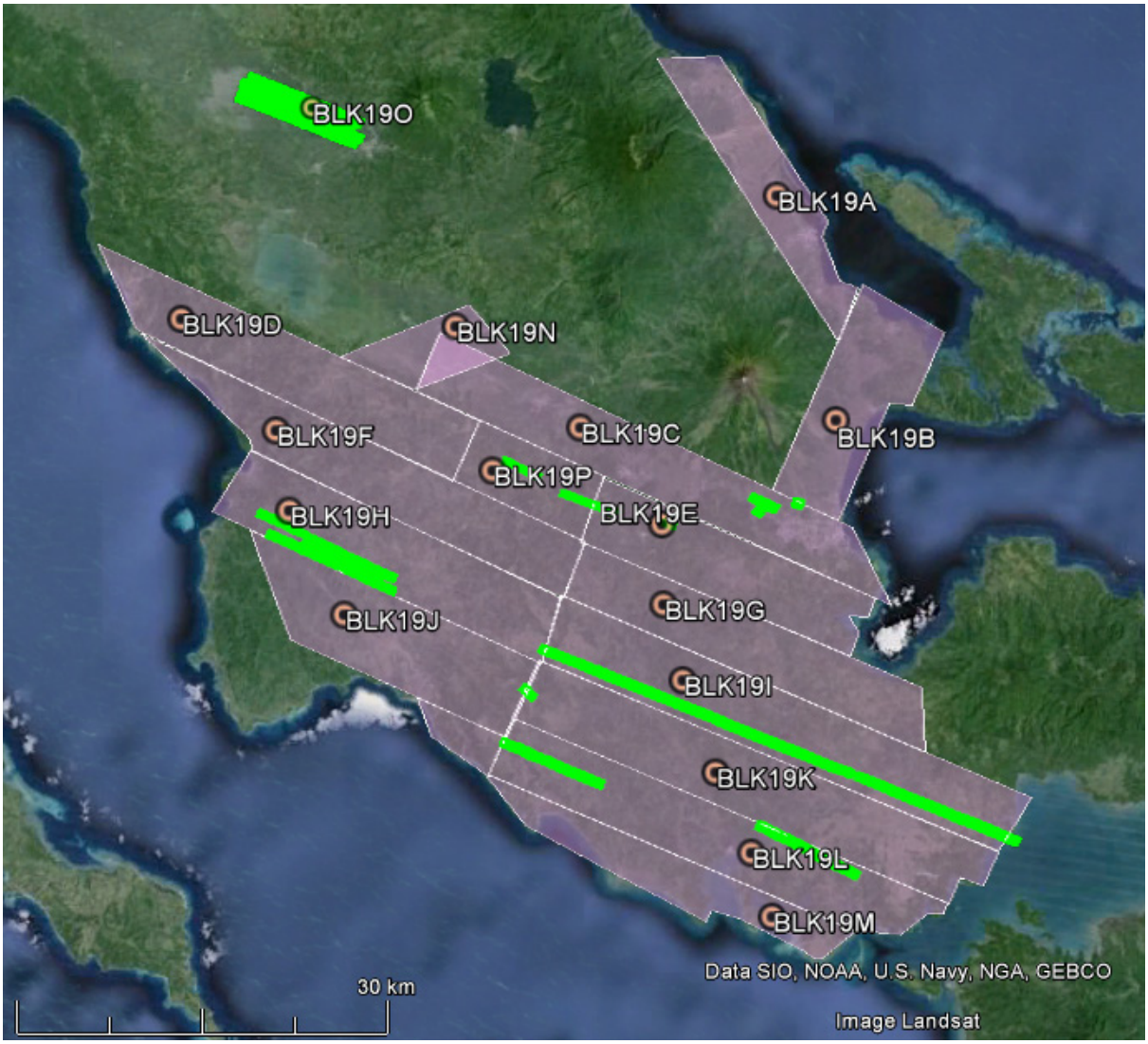


Flight No. : 7212 GC
Area: BLK19P

Mission name: 2BLKP116A & 2BLK19P116A
Parameters: Altitude: 1300; Scan Frequency: 50; Scan Angle: 34 and 40; Overlap: 50 %

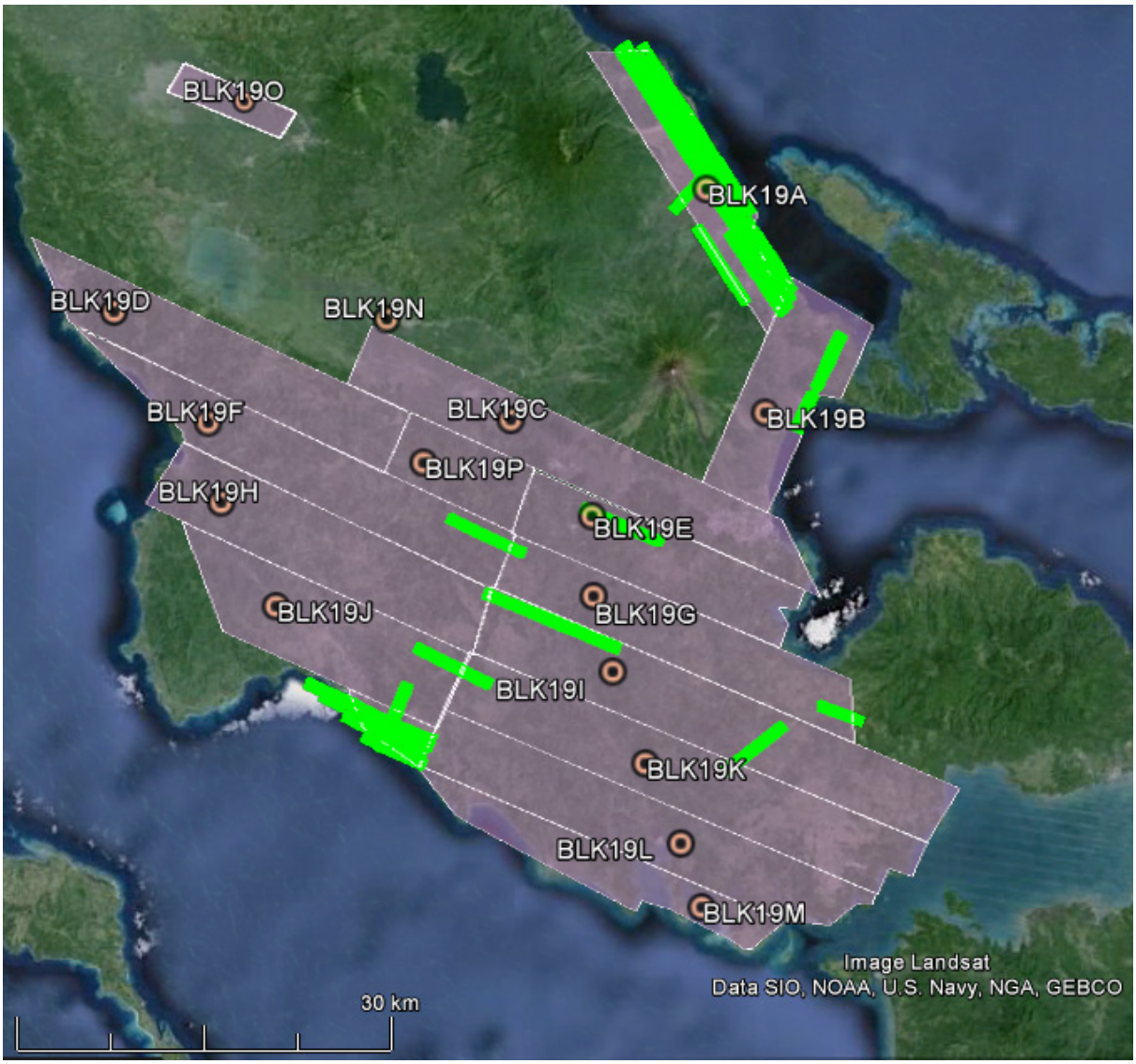
Flight No. : 7213 GC
Area: BLK190

Mission name: 2BLK19OS116B & VOIDS
Parameters: Altitude: 1100; Scan Frequency: 50; Scan Angle: 40; Overlap: 30 %



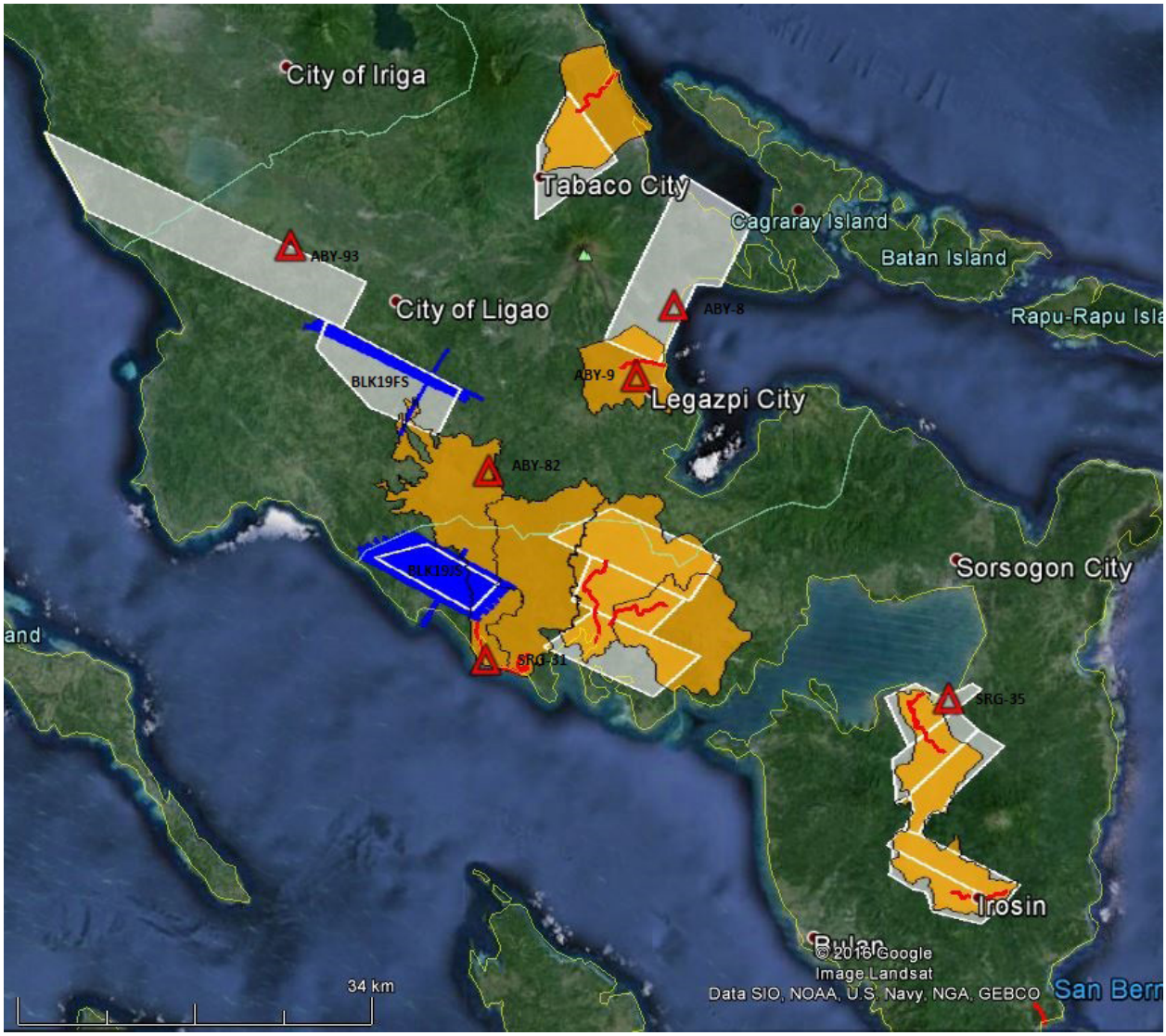
Flight No. : 7216 GC
Area: BLK19A

Mission name: 2BLK19AS118A & VOIDS
Parameters: Altitude: 1300; Scan Frequency: 50; Scan Angle: 34 and 40; Overlap: 50 %



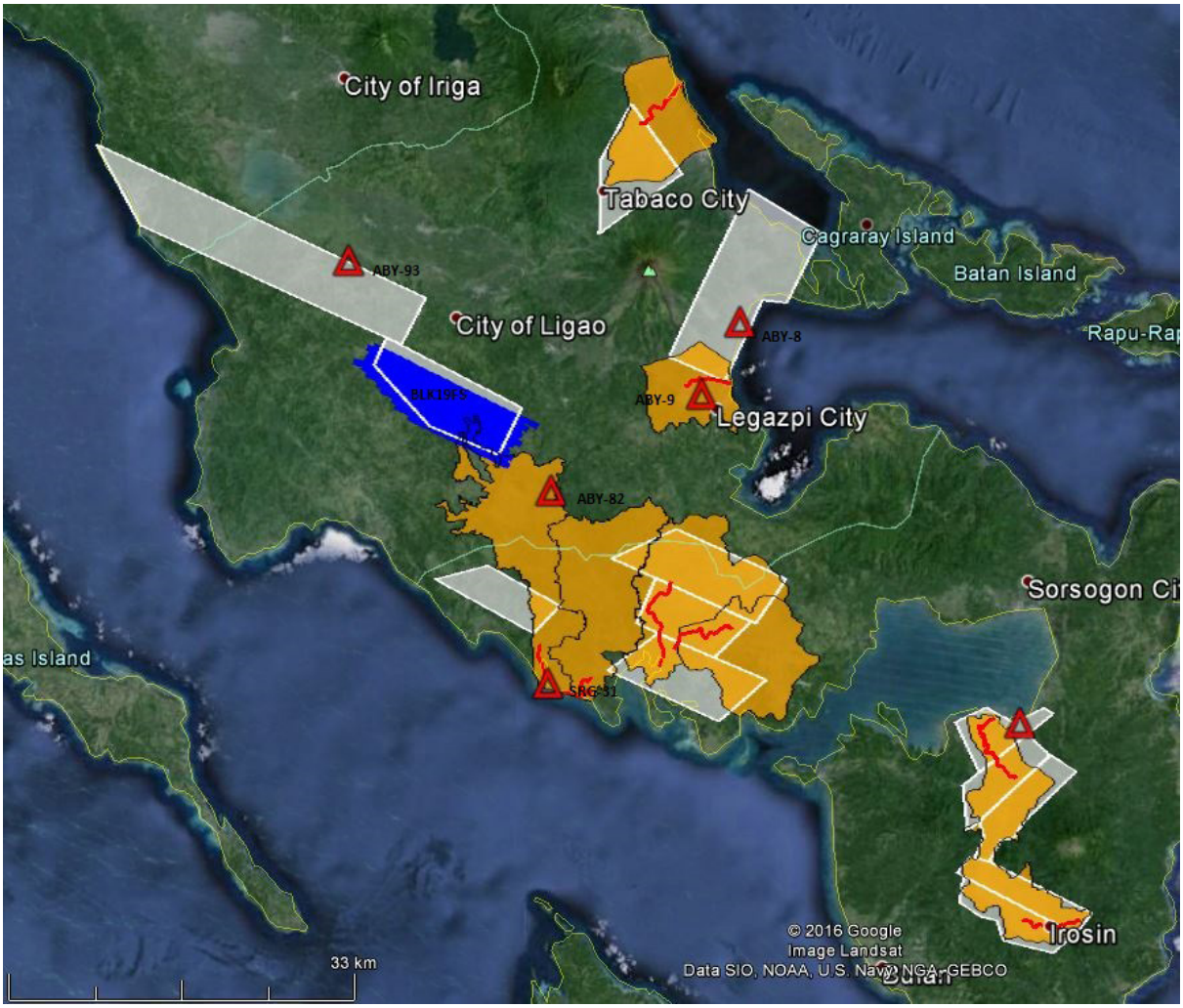
Flight No. : 3825G
Area: BLK19JS, BLK19FS
Mission Name: 2BLK19JFS059B
Parameters: Altitude: 650; Scan Frequency: 40; FOV: 50; Overlap: 40 %

LAS/SWATH



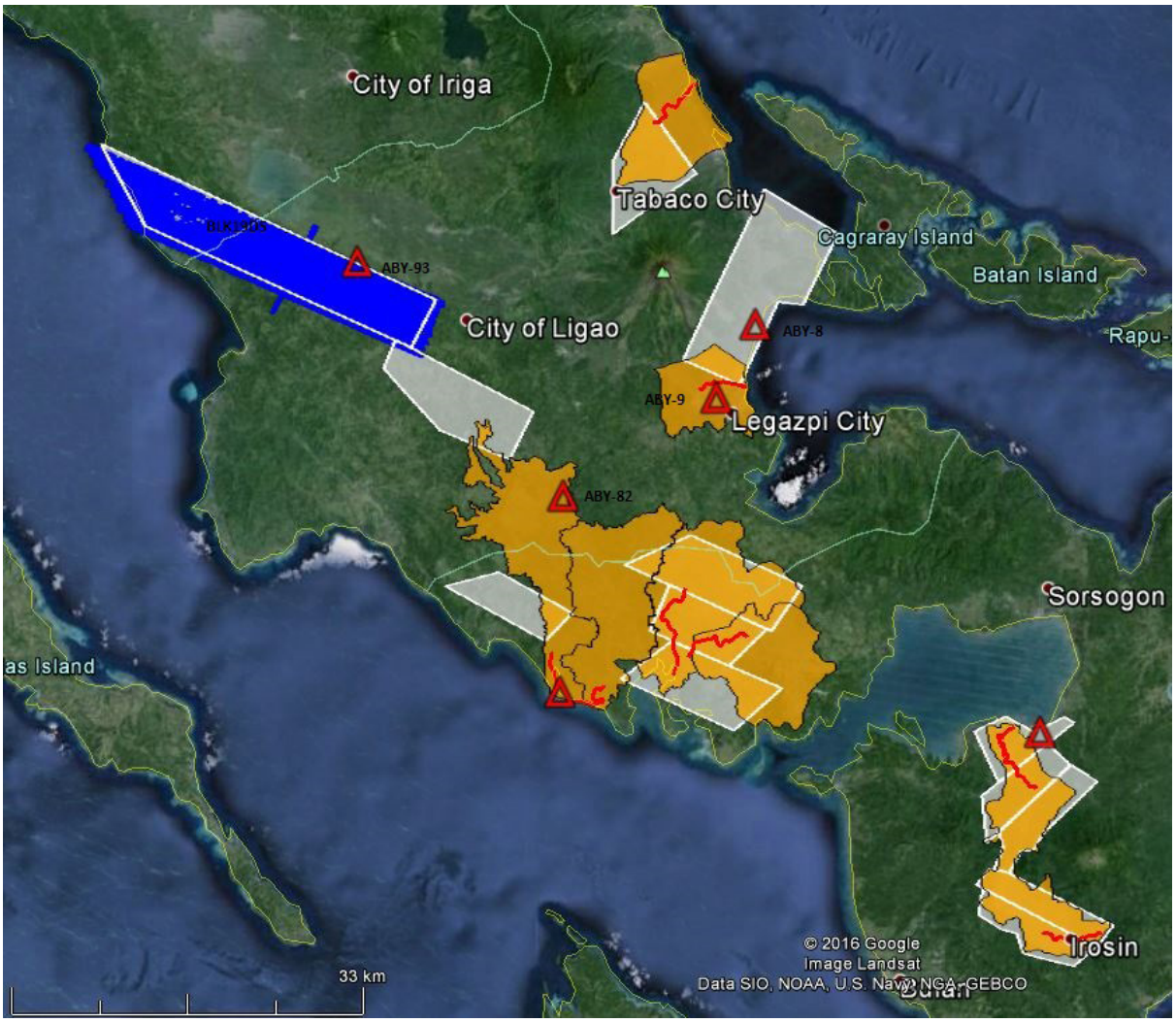
Flight No. : 3829G
Area: BLK19FS
Mission Name: 2BLK19FS060B
Parameters: Altitude: 750; Scan Frequency: 40; FOV: 50; Overlap: 40 %

LAS/SWATH



Flight No. : 3843G
Area: BLK19DS
Mission Name: 2BLK19DS064A
Parameters: Altitude: 750m; Scan Frequency: 40; FOV: 50; Overlap: 40 %

LAS/SWATH



ANNEX 8. Mission Summary Report

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19J**
Inclusive Flights	7184GC, 7200GC, 7204GC, 7216GC
Range data size	55.0 GB
POS	755 MB
Base data size	25.86 MB
Image	---
Transfer date	May 05, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.36
RMSE for East Position (<4.0 cm)	1.80
RMSE for Down Position (<8.0 cm)	3.96
Boresight correction stdev (<0.001deg)	0.000161
IMU attitude correction stdev (<0.001deg)	0.014344
GPS position stdev (<0.01m)	0.0316
Minimum % overlap (>25)	45.30 %
Ave point cloud density per sq.m. (>2.0)	3.84
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	311
Maximum Height	500.50
Minimum Height	54.39
Classification (# of points)	
Ground	57,540,257
Low vegetation	48,269,163
Medium vegetation	125,189,197
High vegetation	414,118,176
Building	5,074,553
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Christy Lubiano, Engr. Melissa Fernandez

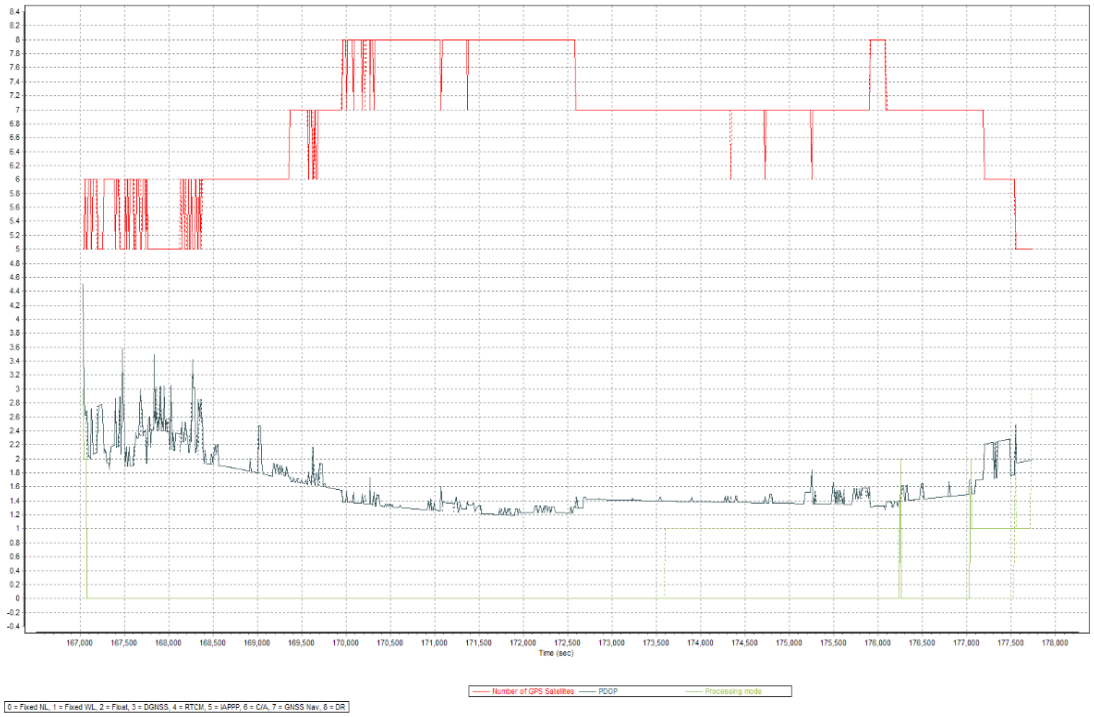


Figure 1.1.1 Solution Status

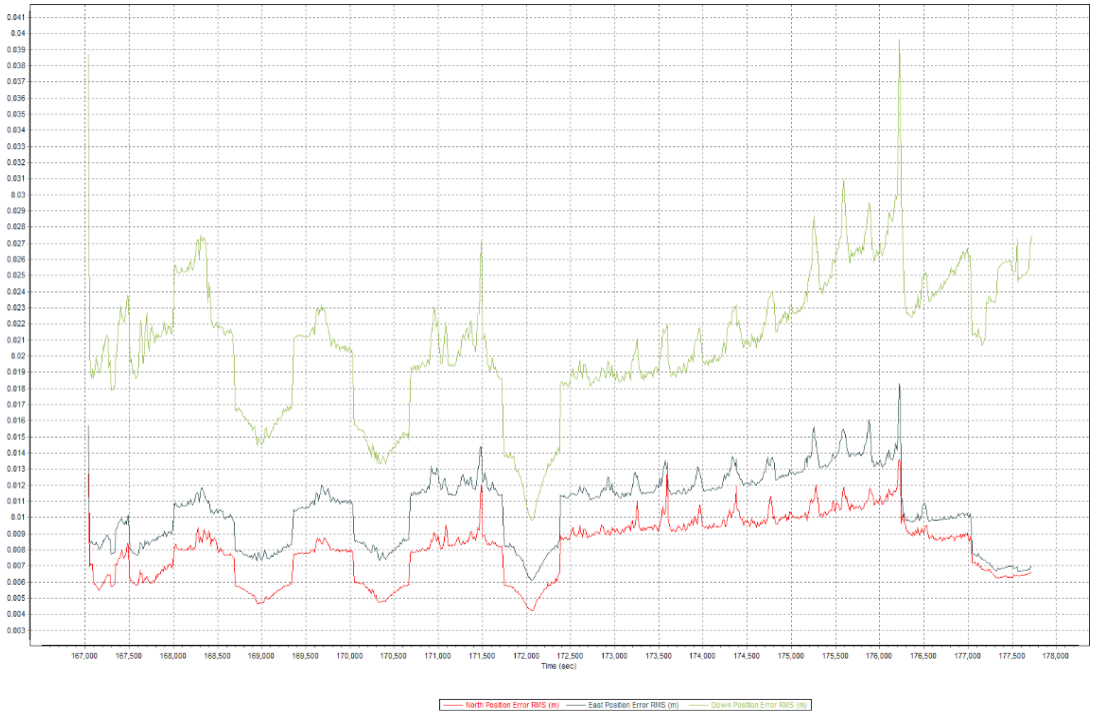


Figure 1.1.2 Smoothed Performance Metric Parameters

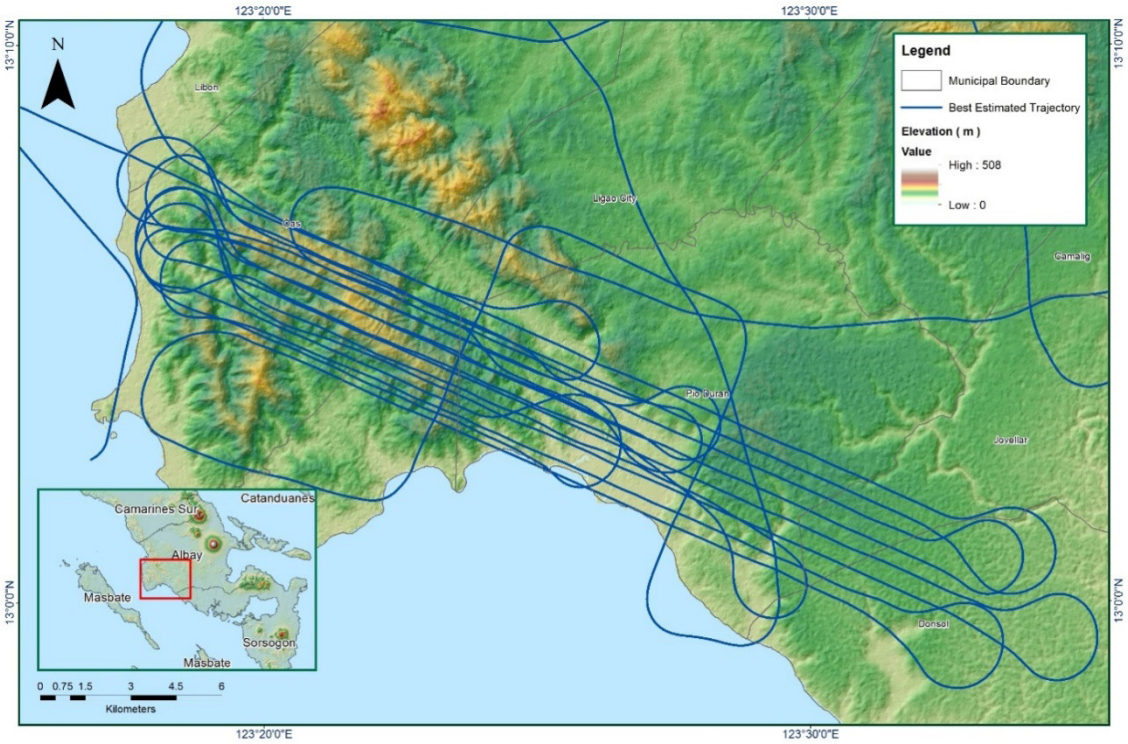


Figure 1.1.3 Best Estimated Trajectory

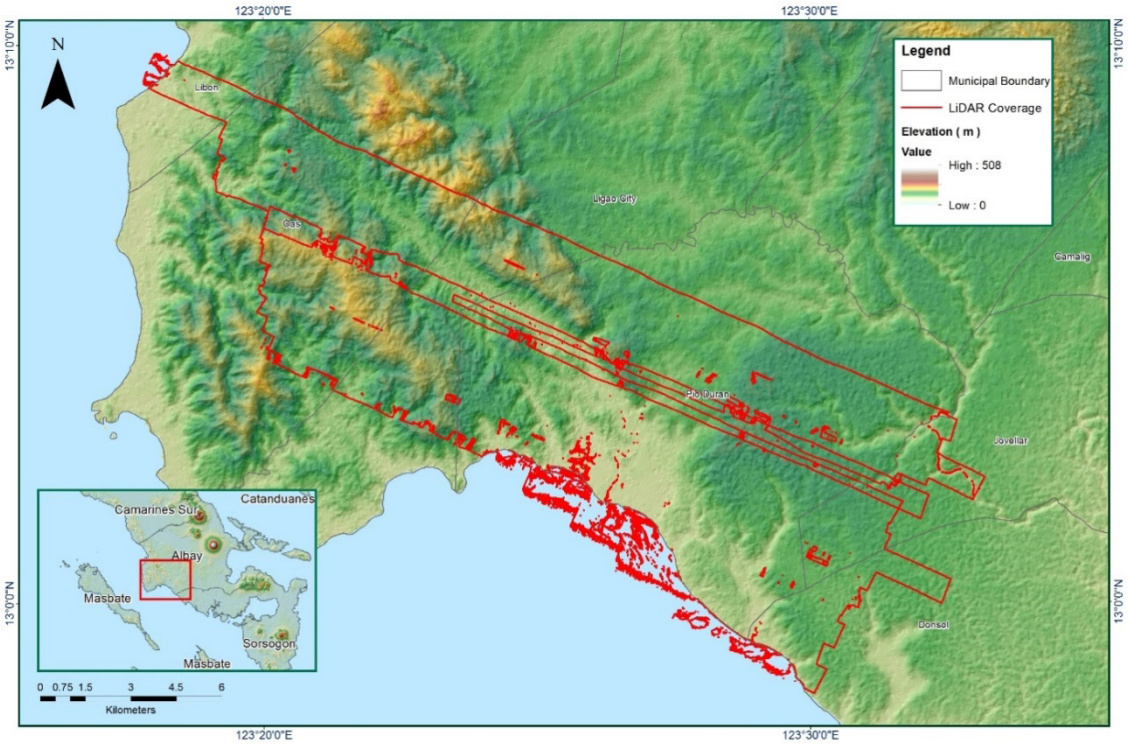


Figure 1.1.4 Coverage of LiDAR data

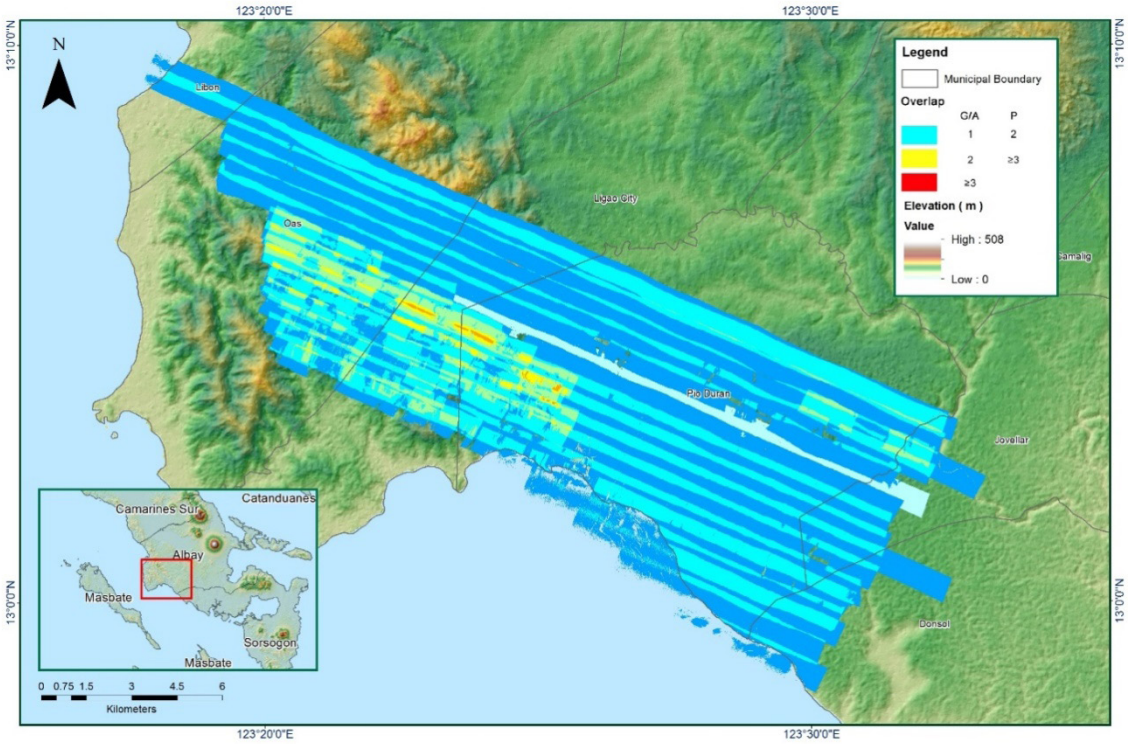


Figure 1.1.5 Image of Data Overlap

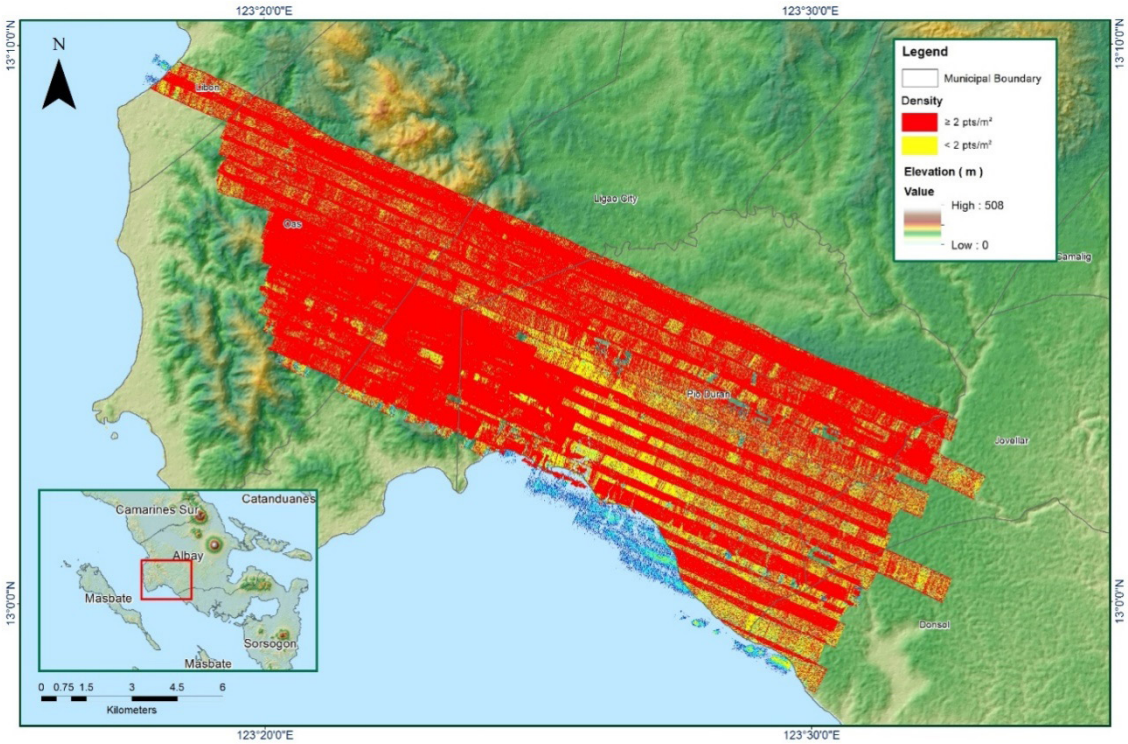


Figure 1.1.6 Density Map

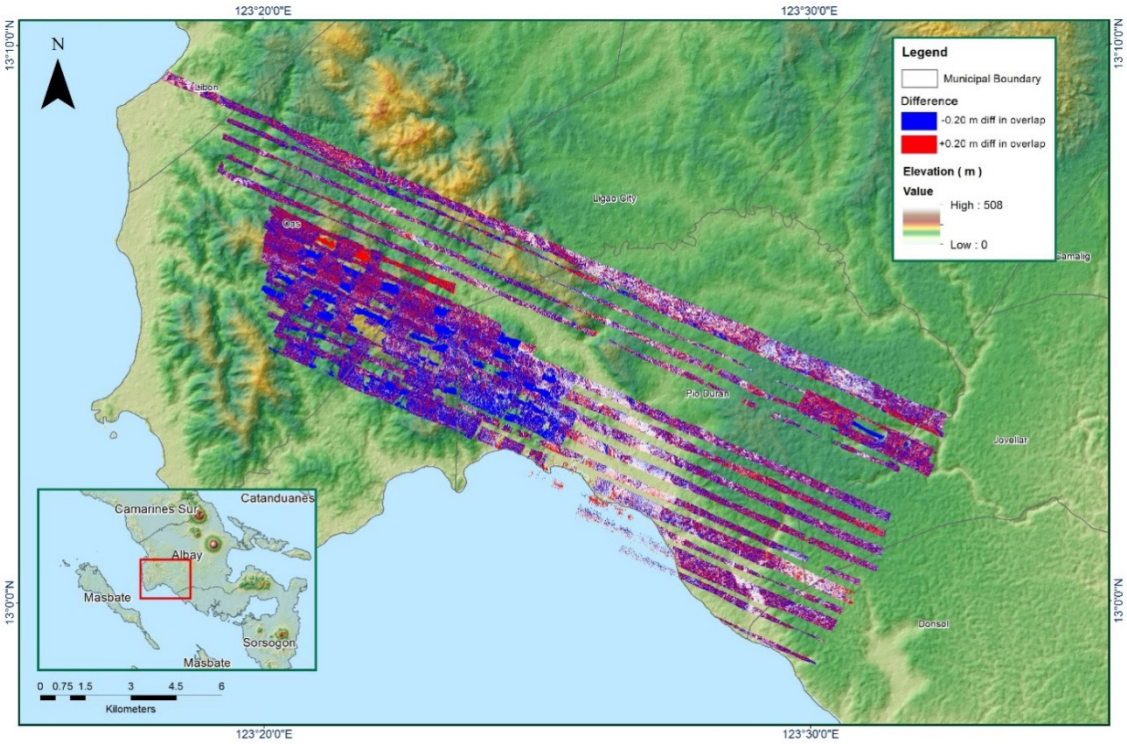


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Albay/Sorsogon
Mission Name	**Blk 19I**
Inclusive Flights	7160GC, 7161GC, 7167GC, 7213GC
Range data size	51.36 GB
POS	570.4 MB
Base data image	20.91 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.95
RMSE for East Position (<4.0 cm)	2.13
RMSE for Down Position (<8.0 cm)	7.4
Boresight correction stdev (<0.001deg)	0.000140
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0058
Minimum % overlap (>25)	27.42 %
Ave point cloud density per sq.m. (>2.0)	3.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks Maximum Height Minimum Height *Classification (# of points)* Ground Low vegetation Medium vegetation High vegetation Building Orthophoto	479 314.54 53.68 161,483,905 147,862,292 219,358,011 579,999,947 6,587,455 No
Processed by	Victoria Rejuso, Engr. Mark Joshua Salvacion, Engr. Elainne Lopez, Engr. Ma. Ailyn Olanda

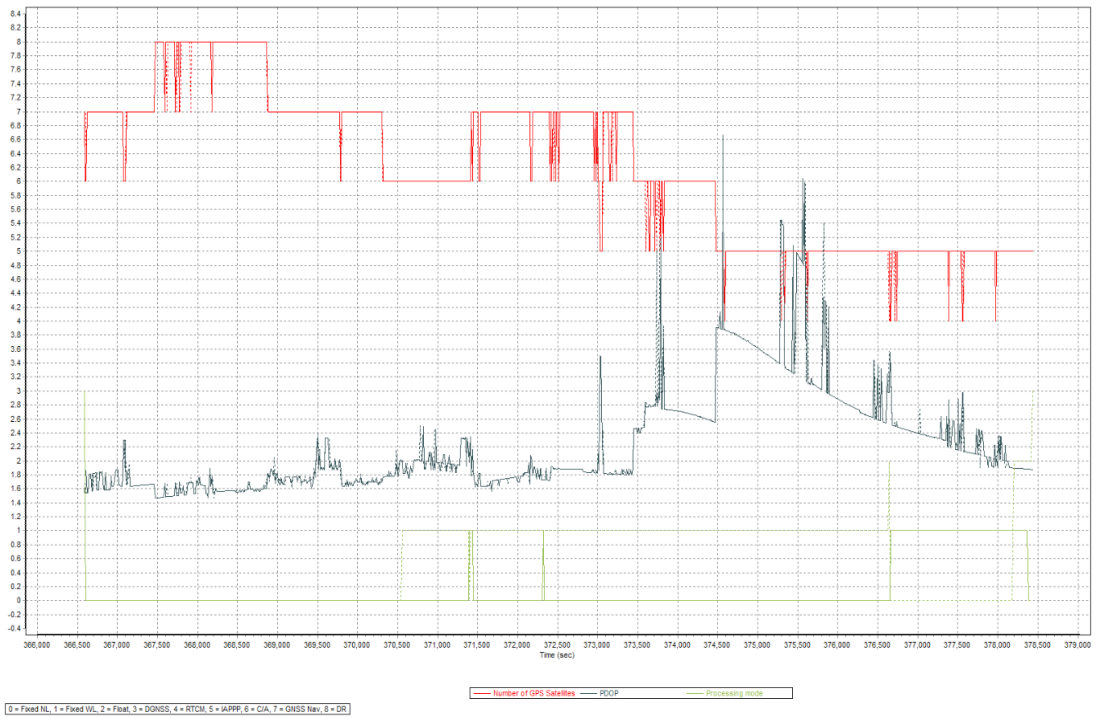


Figure 1.2.1 Solution Status

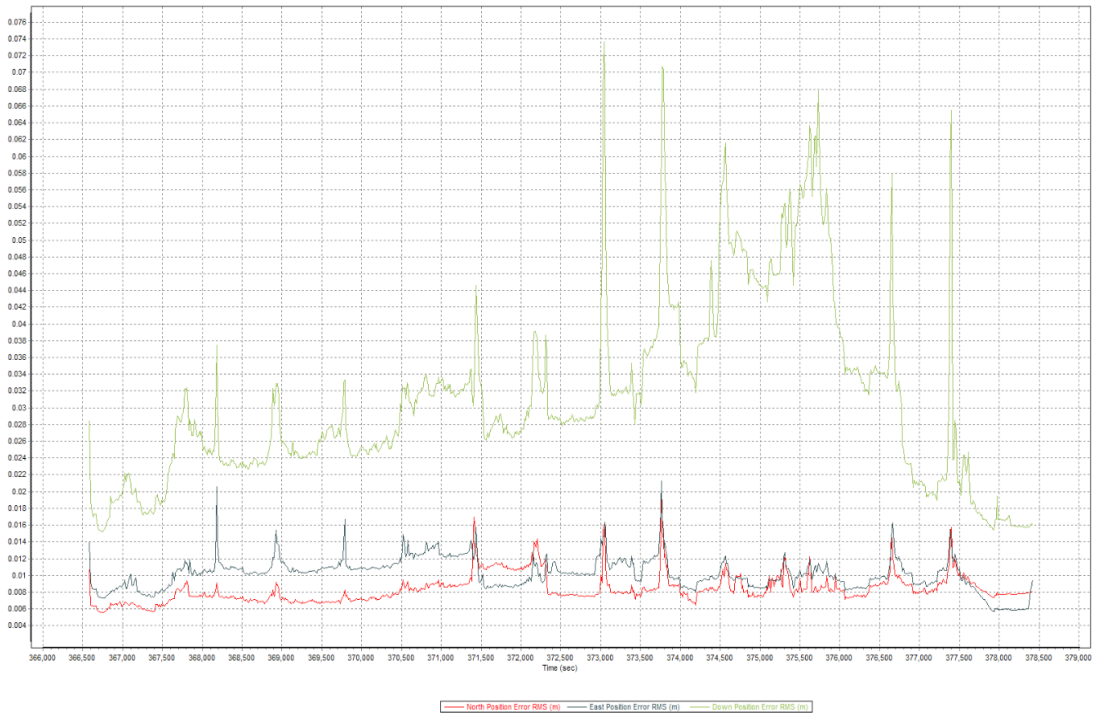


Figure 1.2.2 Smoothed Performance Metric Parameters

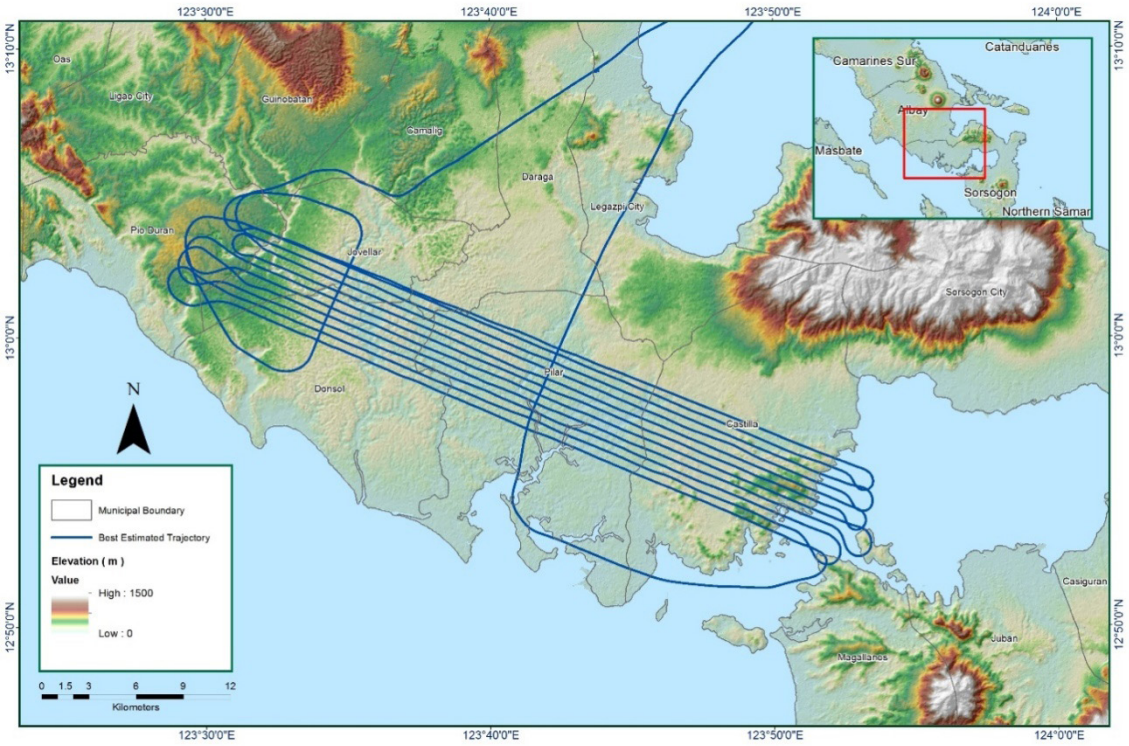


Figure 1.2.3 Best Estimated Trajectory

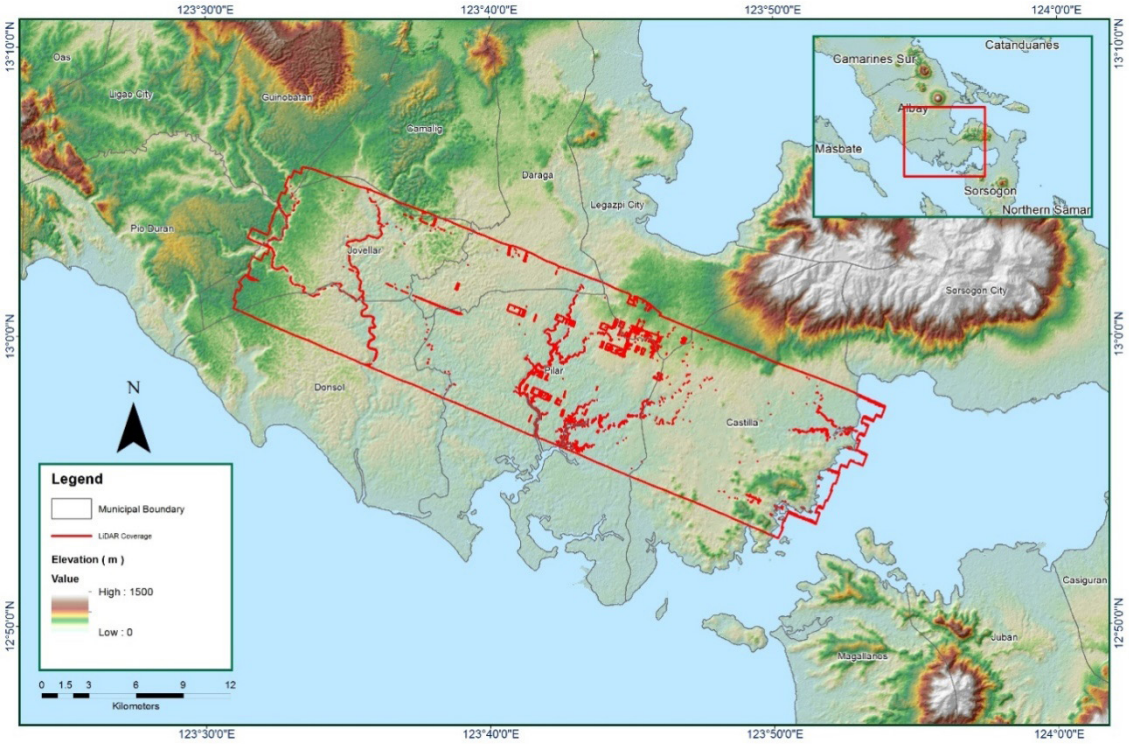


Figure 1.2.4 Coverage of LiDAR data

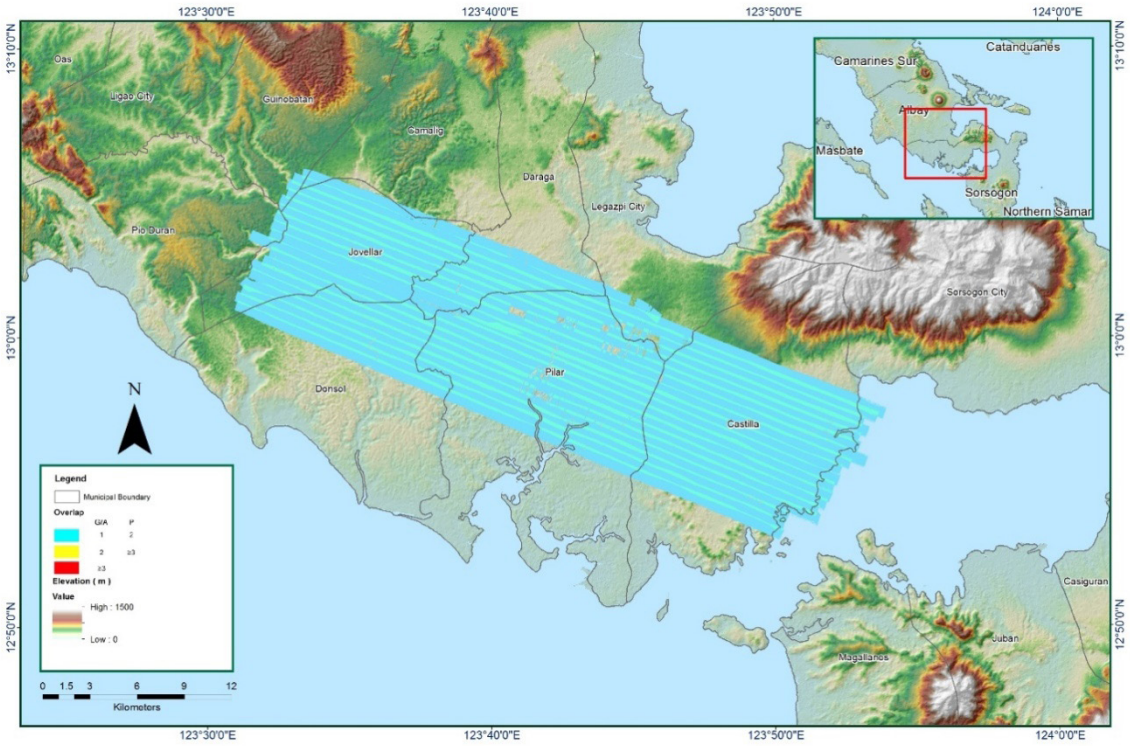


Figure 1.2.5 Image of Data Overlap

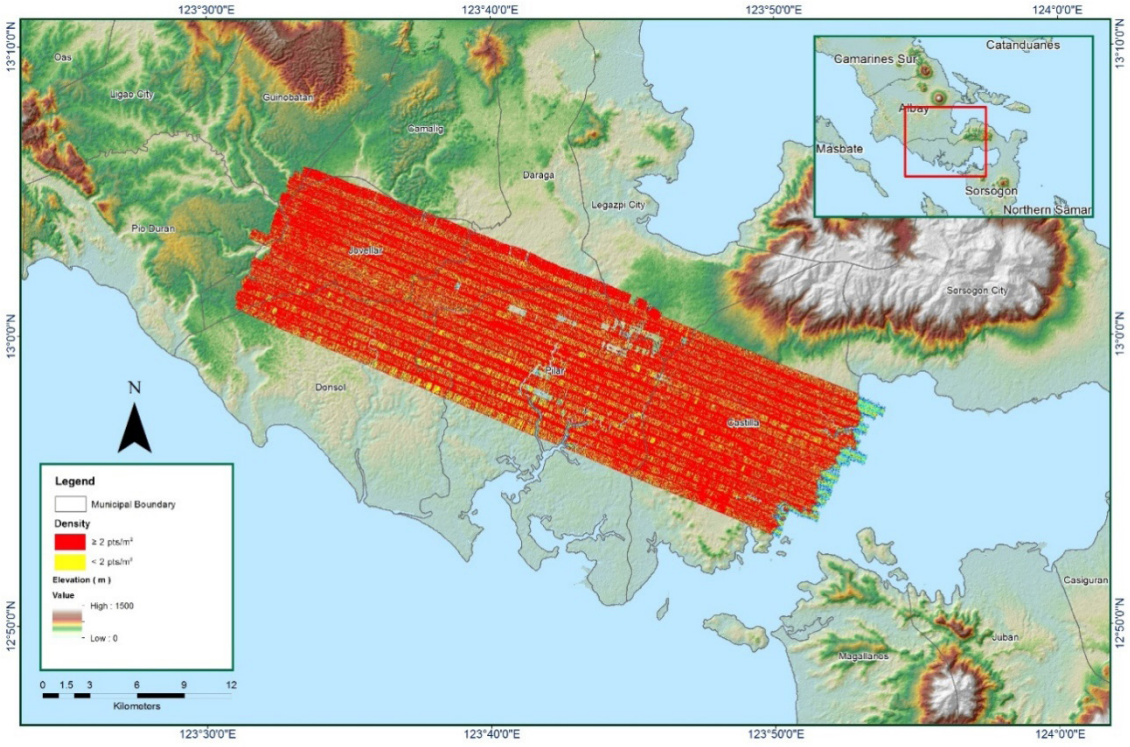


Figure 1.2.6 Density Map

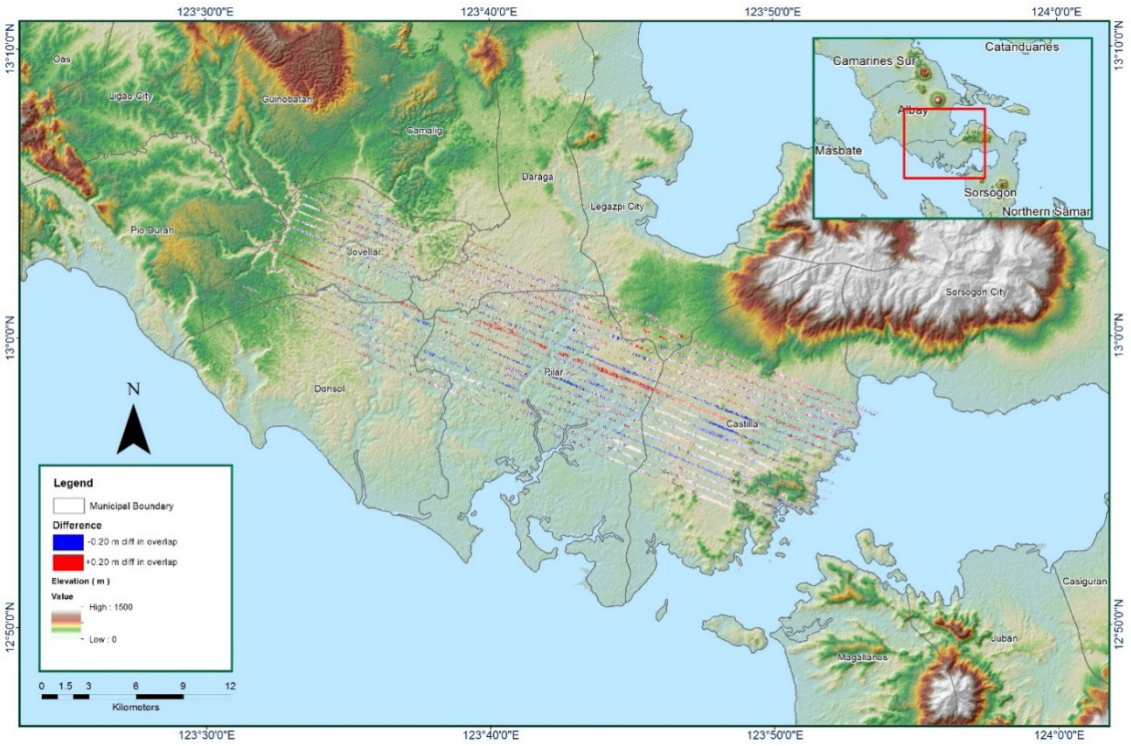


Figure 1.2.7 Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19H**
Inclusive Flights	7175GC, 7176GC, 7213GC
Range data size	27.7 GB
POS	370.2 MB
Base data size	16.05 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.4
RMSE for East Position (<4.0 cm)	7.4
RMSE for Down Position (<8.0 cm)	21.5
Boresight correction stdev (<0.001deg)	0.000415
IMU attitude correction stdev (<0.001deg)	0.001579
GPS position stdev (<0.01m)	0.0114
Minimum % overlap (>25)	36.83 %
Ave point cloud density per sq.m. (>2.0)	3.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	201
Maximum Height	583.66
Minimum Height	53.88
Classification (# of points)	
Ground	57,591,857
Low vegetation	50,633,799
Medium vegetation	92,847,123
High vegetation	295,936,710
Building	3,313,359
Orthophoto	No
Processed by	Engr. Benjamin Jonah Magallon, Engr. Mark Joshua Salvacion, Engr. Gladys Mae Apat

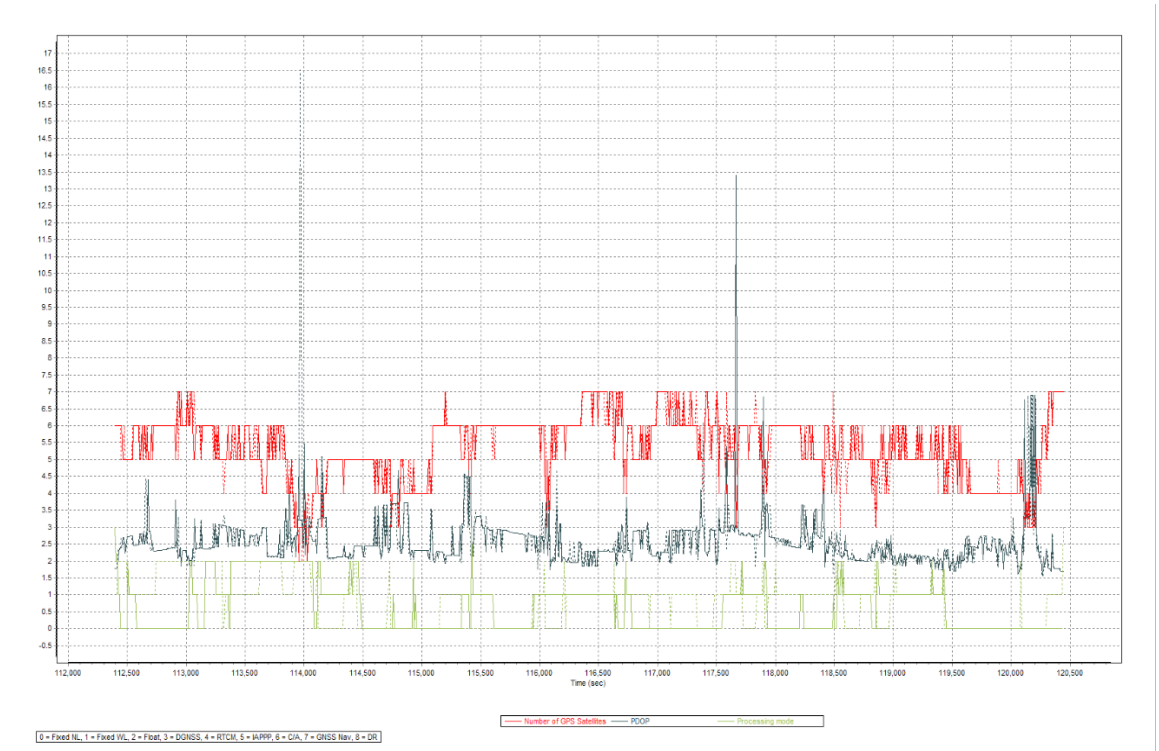


Figure 1.3.1 Solution Status

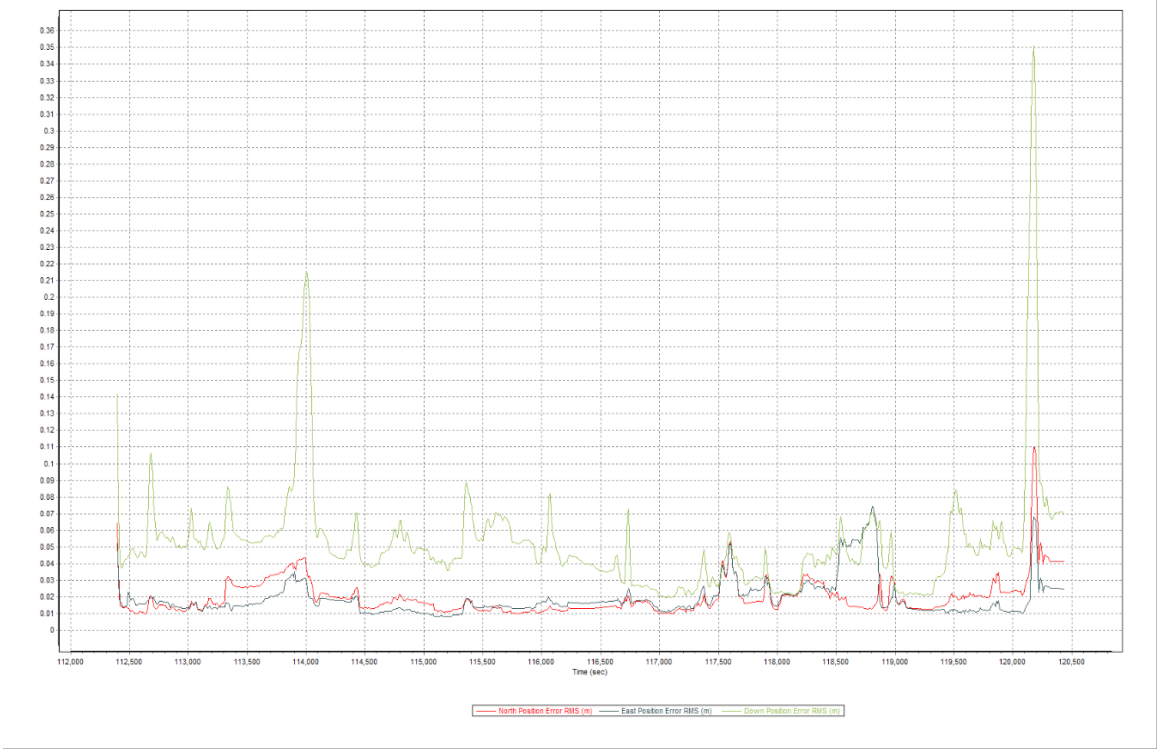


Figure 1.3.2 Smoothed Performance Metric Parameters

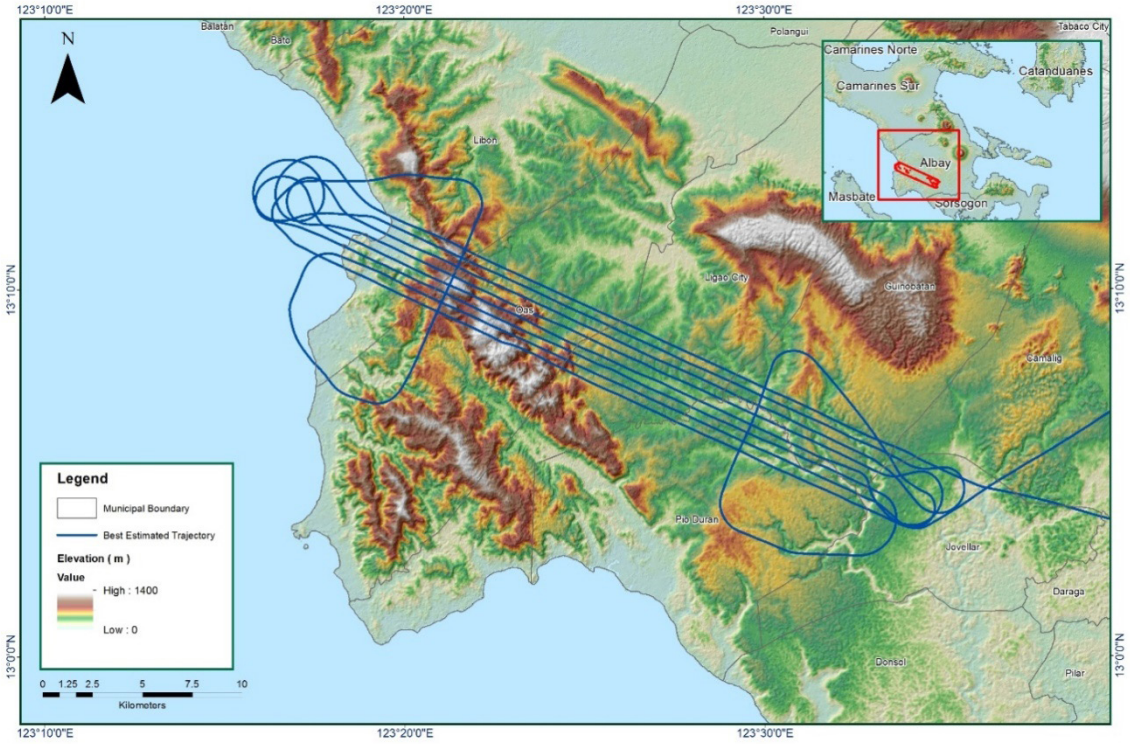


Figure 1.3.3 Best Estimated Trajectory

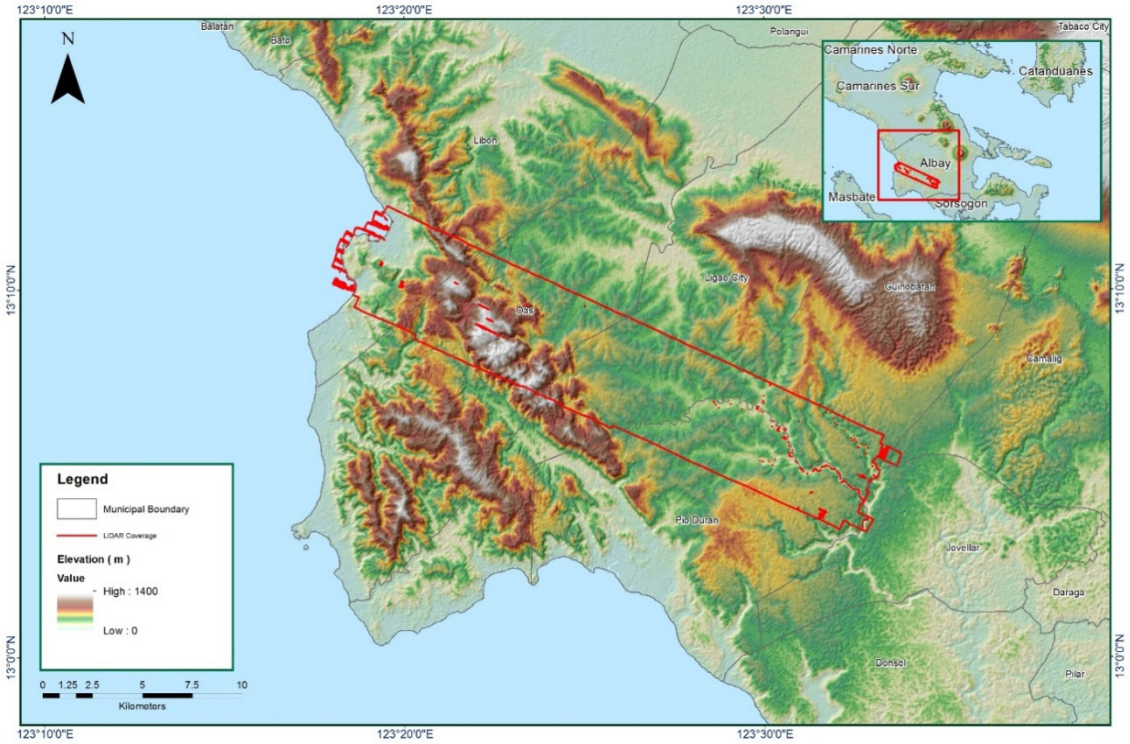


Figure 1.3.4 Coverage of LiDAR data

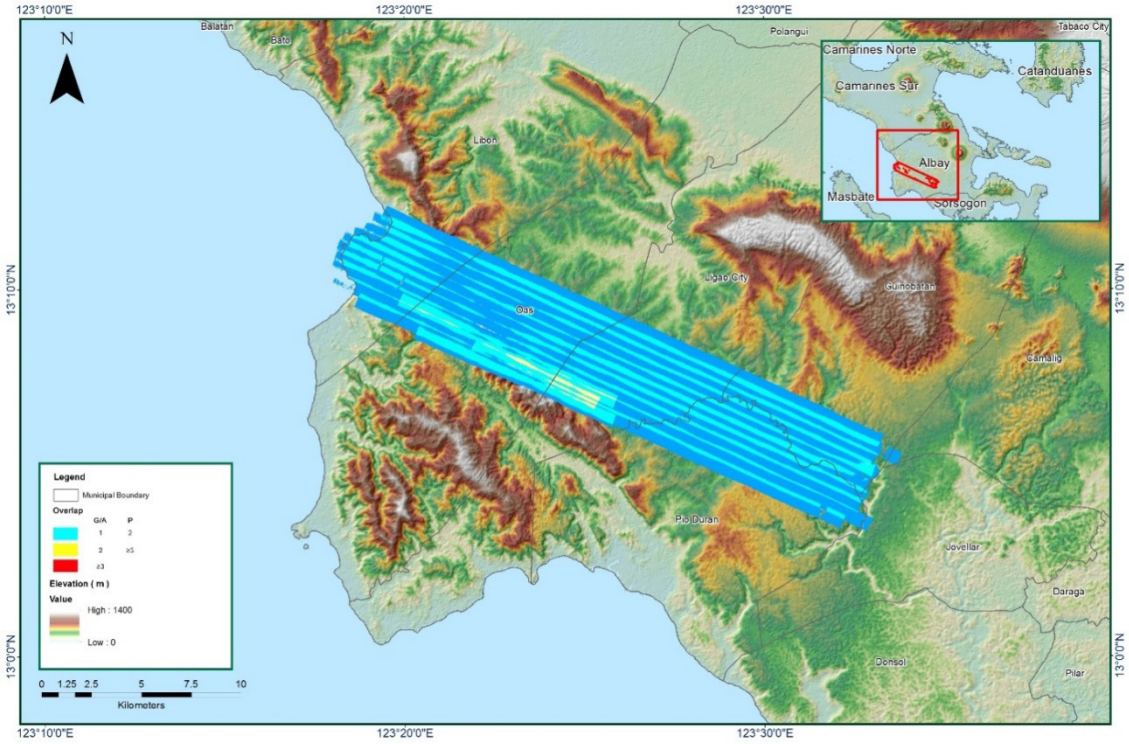


Figure 1.3.5 Image of Data Overlap

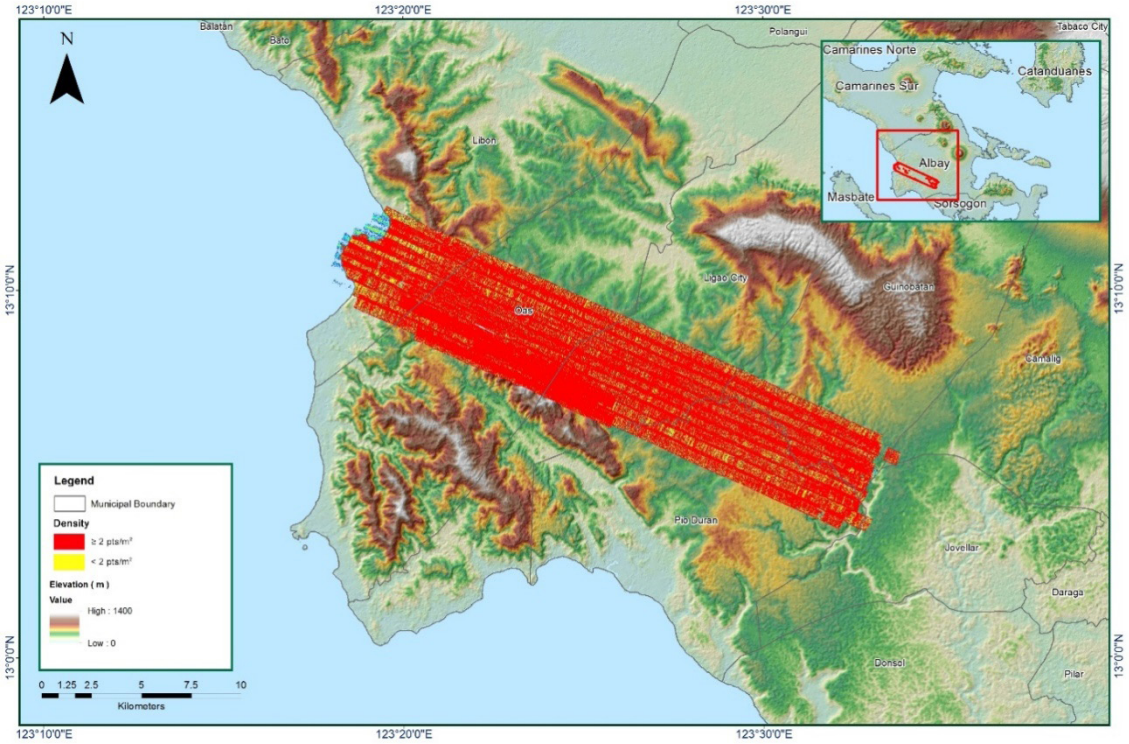


Figure 1.3.6 Density Map

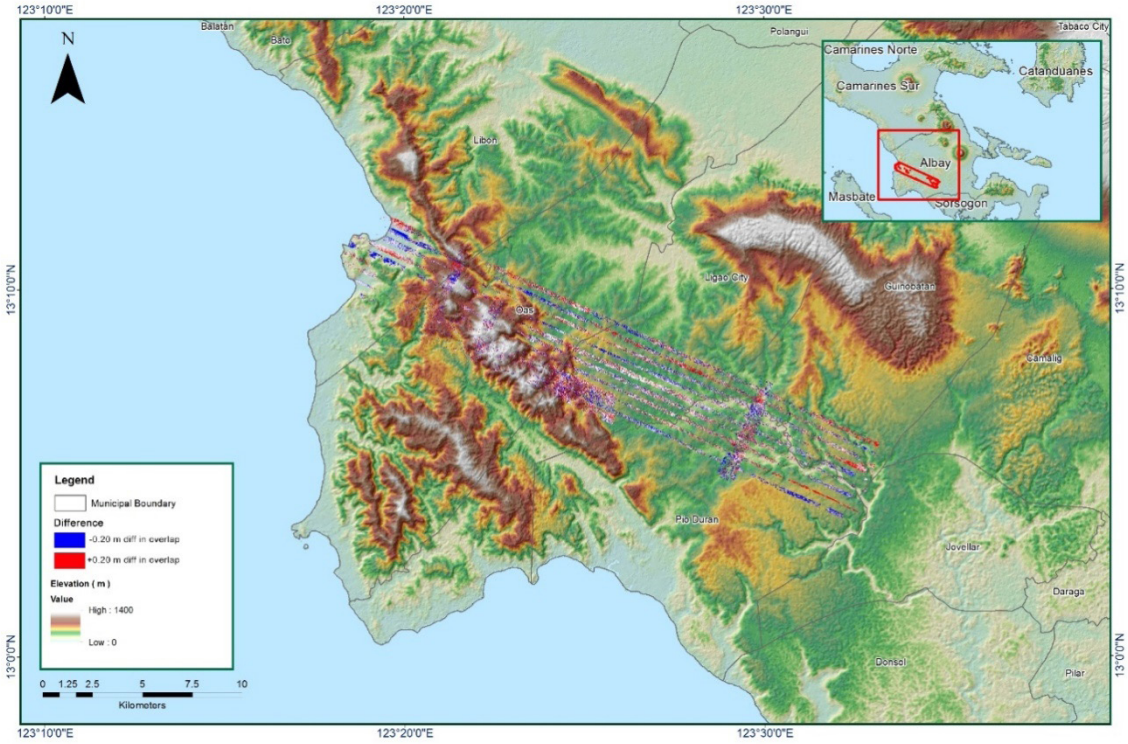


Figure 1.3.7 Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19F**
Inclusive Flights	7174GC, 7216GC
Range data size	35.5 GB
POS	389 MB
Base data size	19.46 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	10.5
RMSE for East Position (<4.0 cm)	4.9
RMSE for Down Position (<8.0 cm)	22.5
Boresight correction stdev (<0.001deg)	0.000244
IMU attitude correction stdev (<0.001deg)	0.000495
GPS position stdev (<0.01m)	0.0084
Minimum % overlap (>25)	31.86 %
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	268
Maximum Height	502.48
Minimum Height	53.28
Classification (# of points)	
Ground	73,395,293
Low vegetation	65,323,778
Medium vegetation	114,032,966
High vegetation	349,680,648
Building	3,647,665
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. Gladys Mae Apat

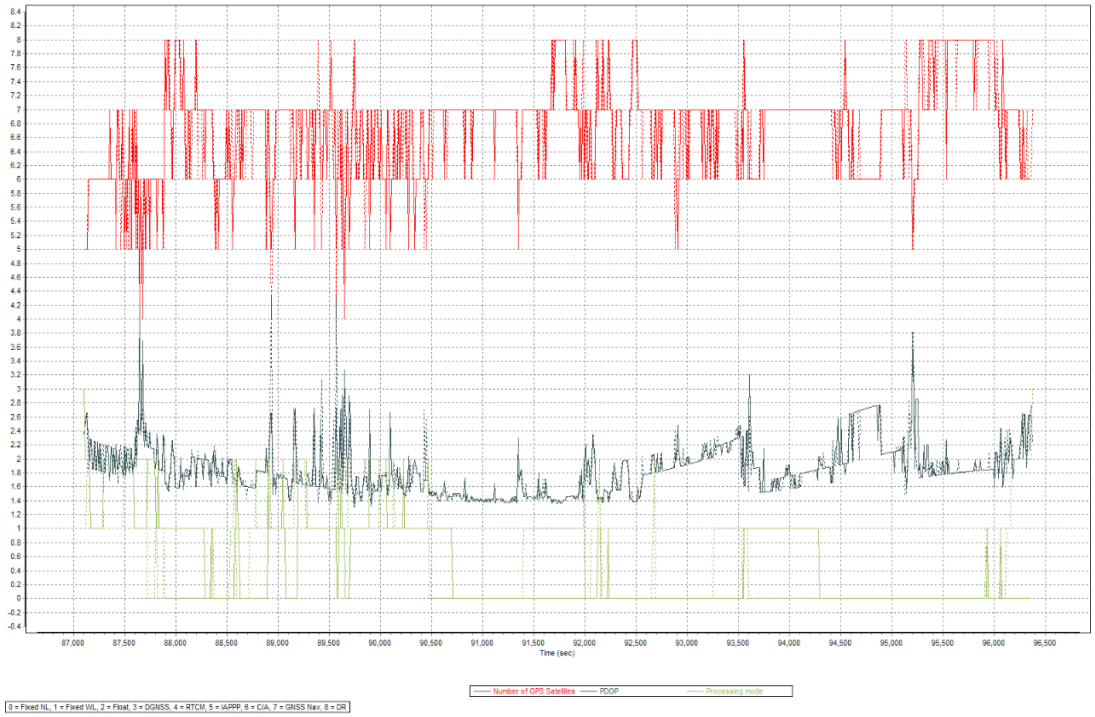


Figure 1.4.1 Solution Status

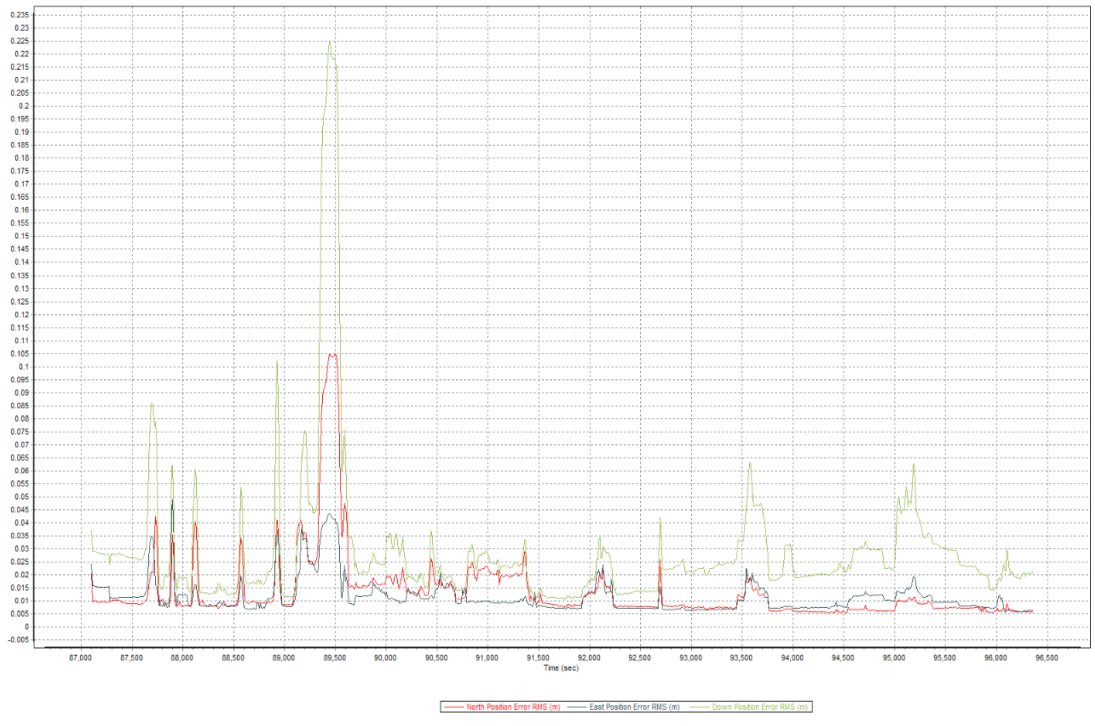


Figure 1.4.2 Smoothed Performance Metric Parameters

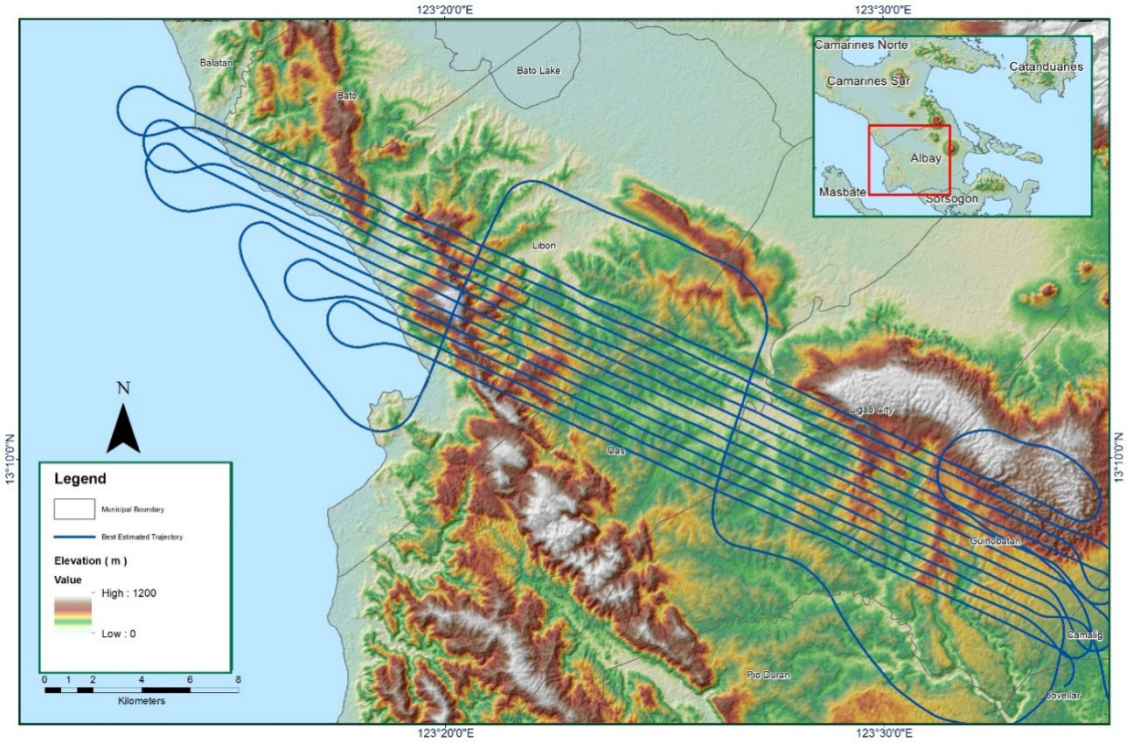


Figure 1.4.3 Best Estimated Trajectory

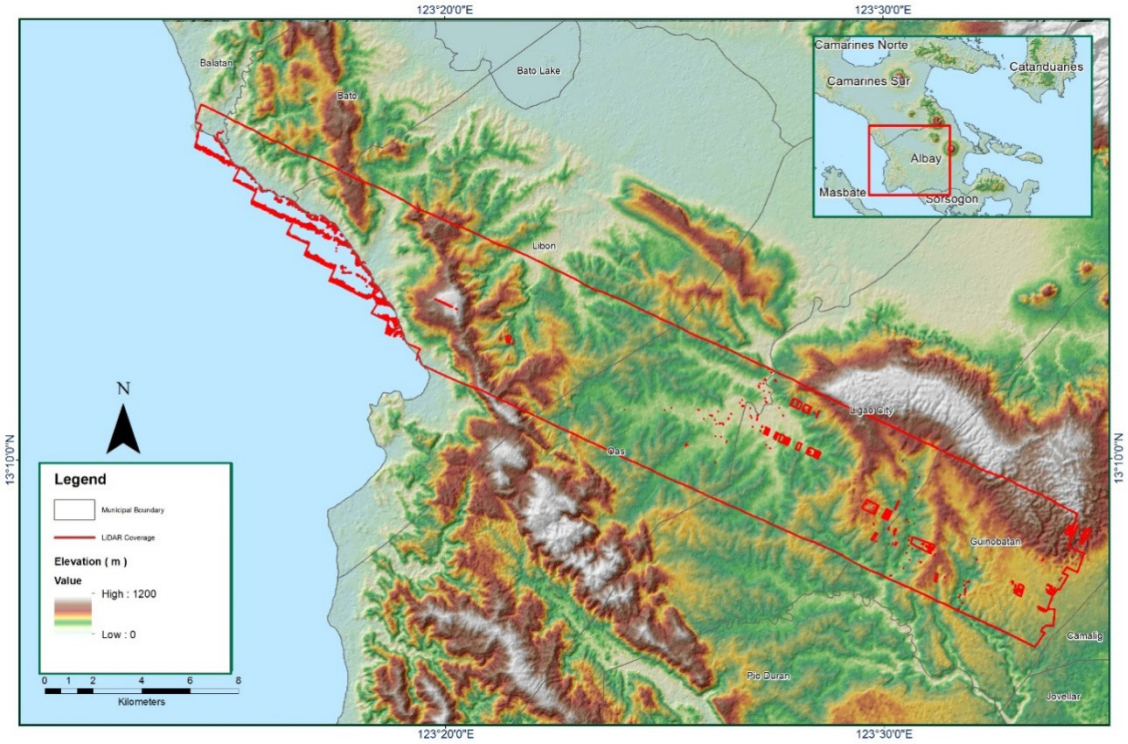


Figure 1.4.4 Coverage of LiDAR data

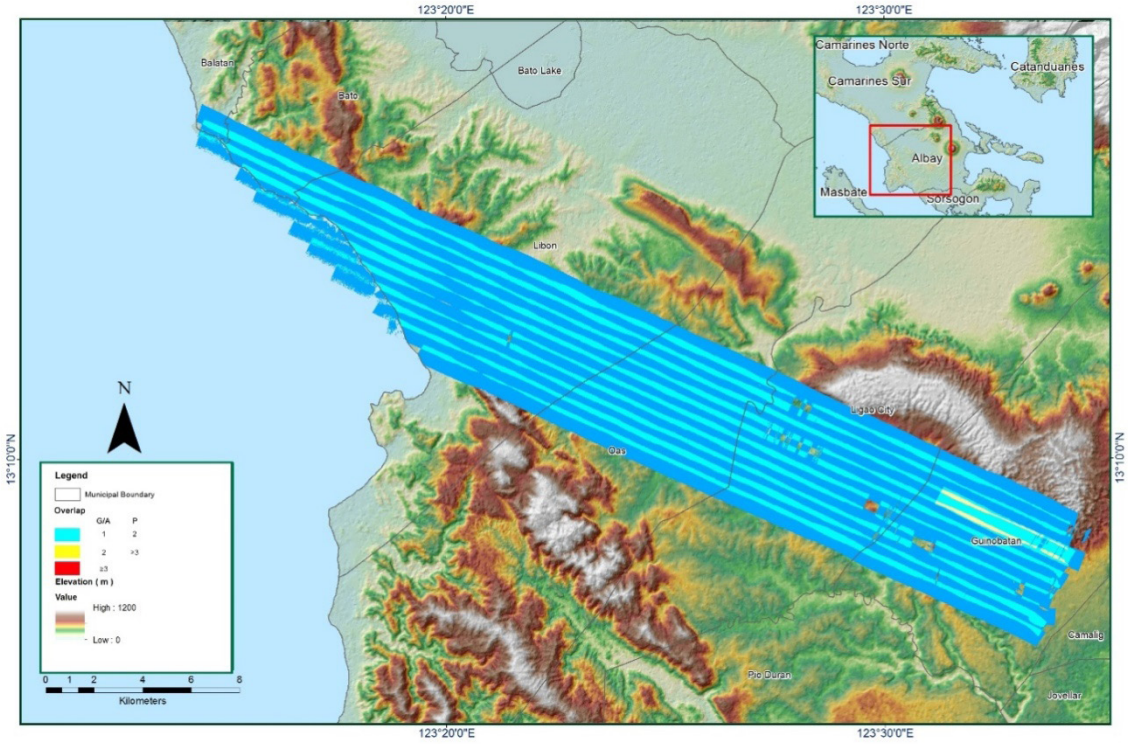


Figure 1.4.5 Image of Data Overlap

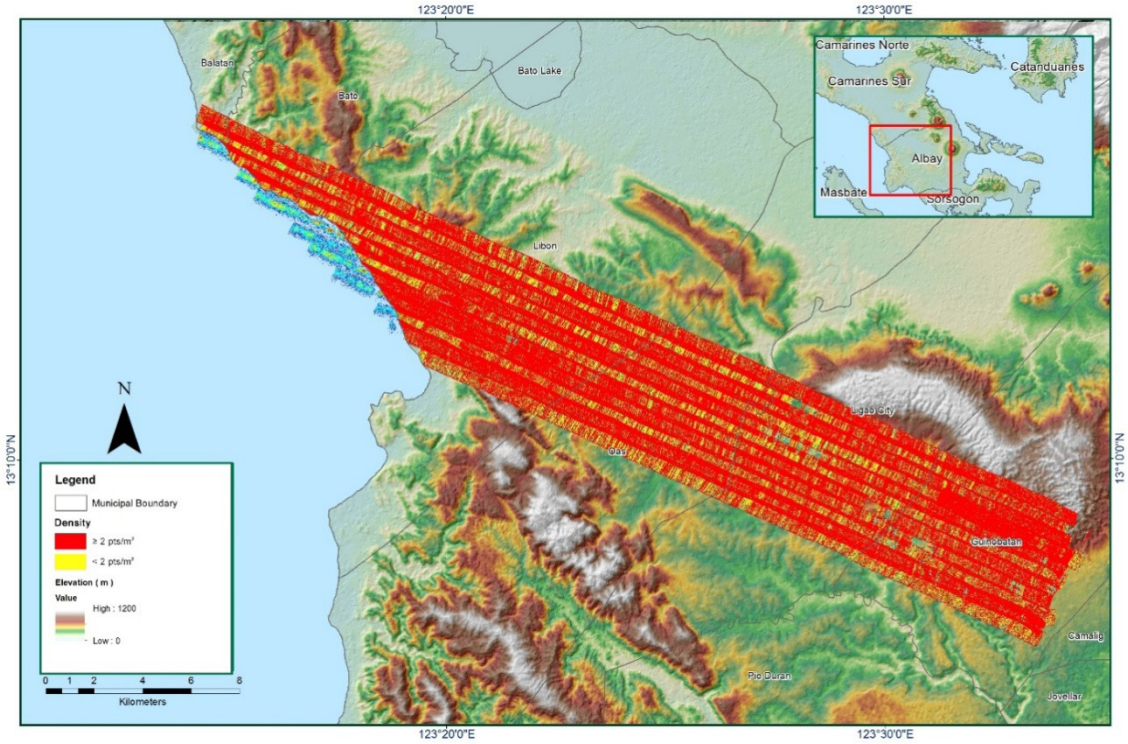


Figure 1.4.6 Density Map

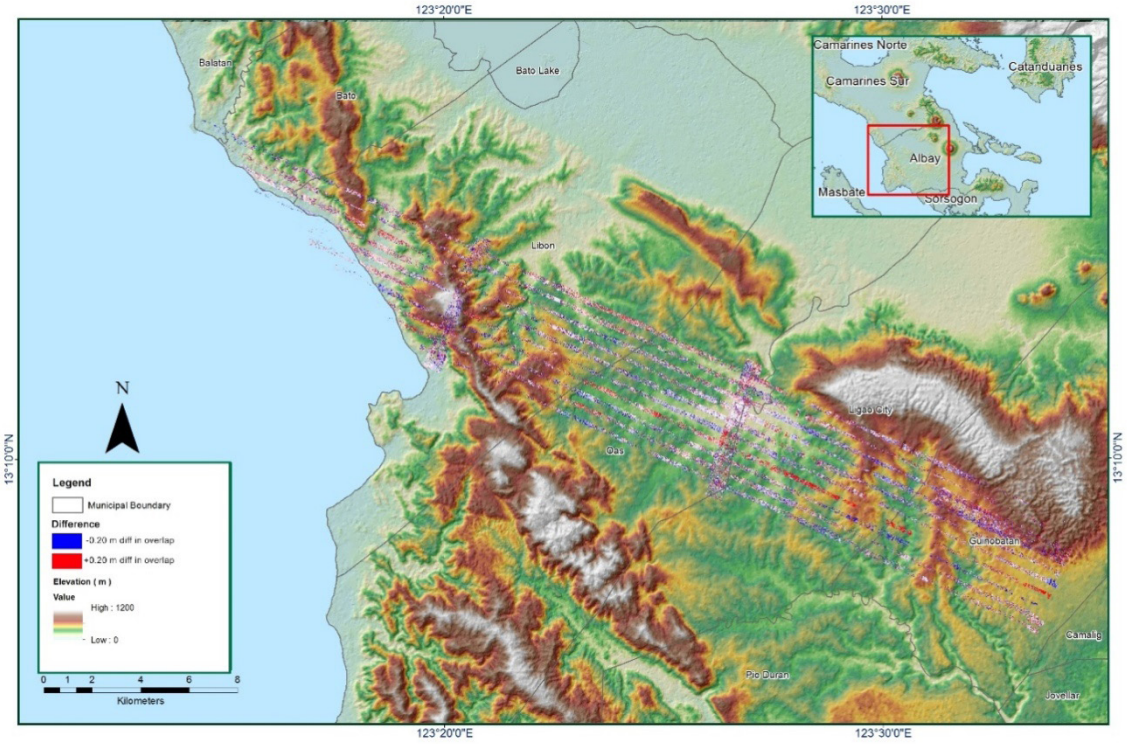


Figure 1.4.7 Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19EG**
Inclusive Flights	7156GC, 7158GC, 7216GC
Range data size	46.75 GB
POS	547.4 MB
Base data size	24.79 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	7.0
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	10.2
Boresight correction stdev (<0.001deg)	0.000224
IMU attitude correction stdev (<0.001deg)	0.001635
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	30.62 %
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	373
Maximum Height	447.71
Minimum Height	53.24
Classification (# of points)	
Ground	145,515,827
Low vegetation	130,178,426
Medium vegetation	147,064,919
High vegetation	462,980,087
Building	7,156,764
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Aljon Rie Araneta, Engr. Gladys Mae Apat

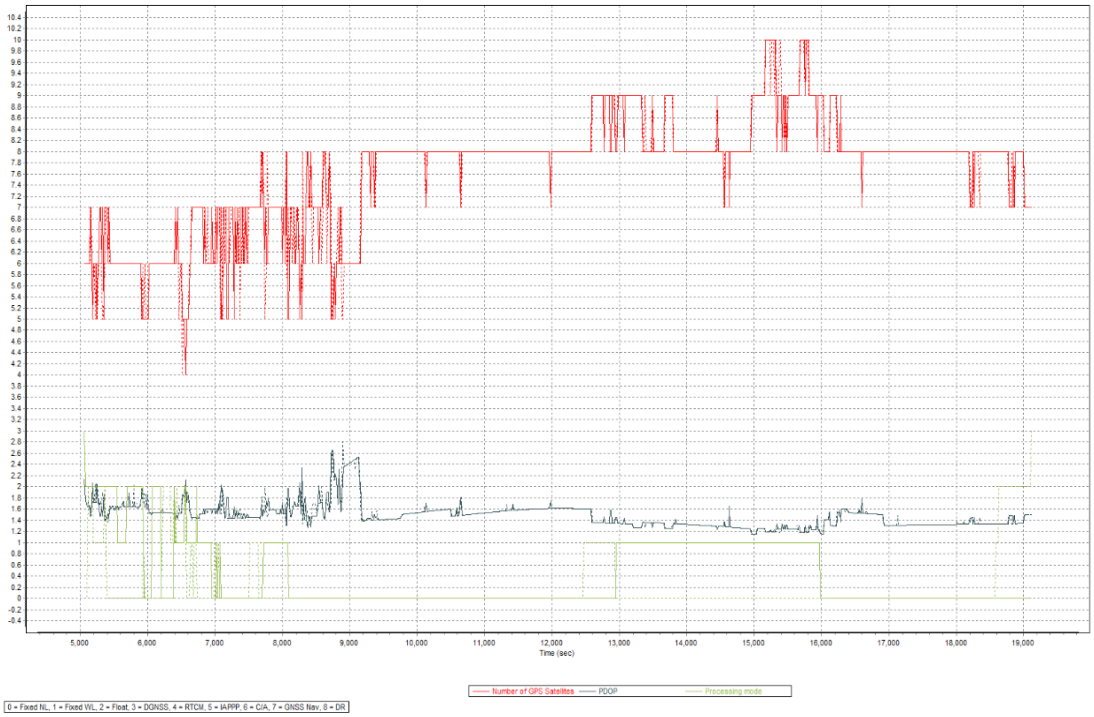


Figure 1.5.1 Solution Status

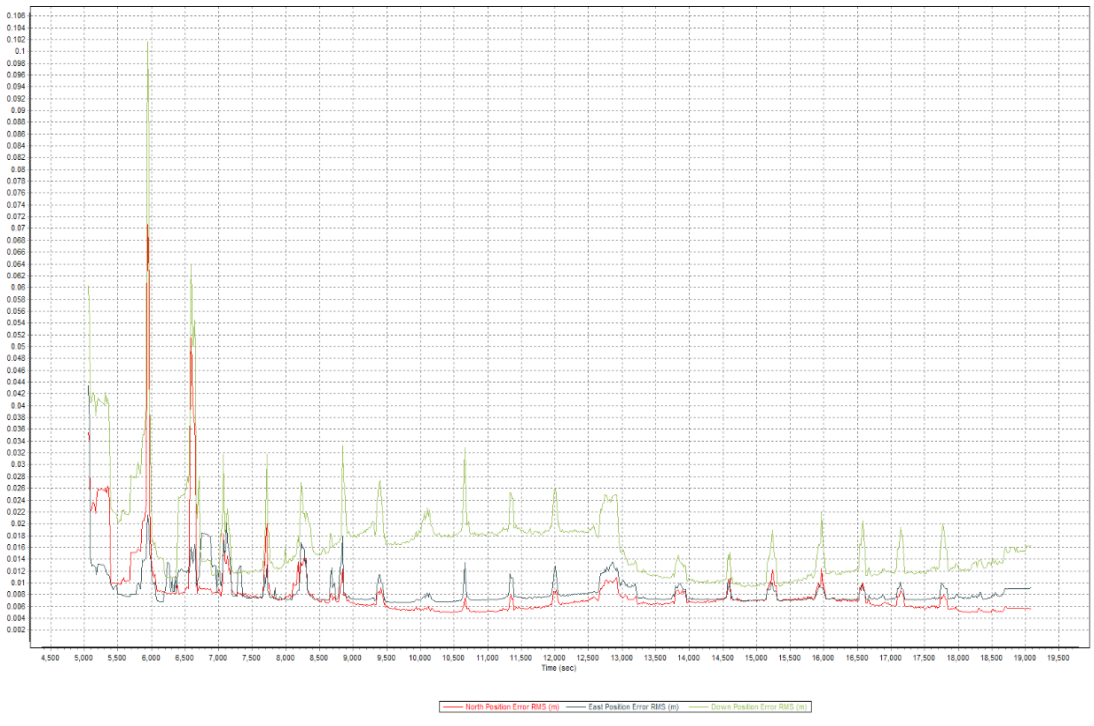


Figure 1.5.2 Smoothed Performance Metric Parameters

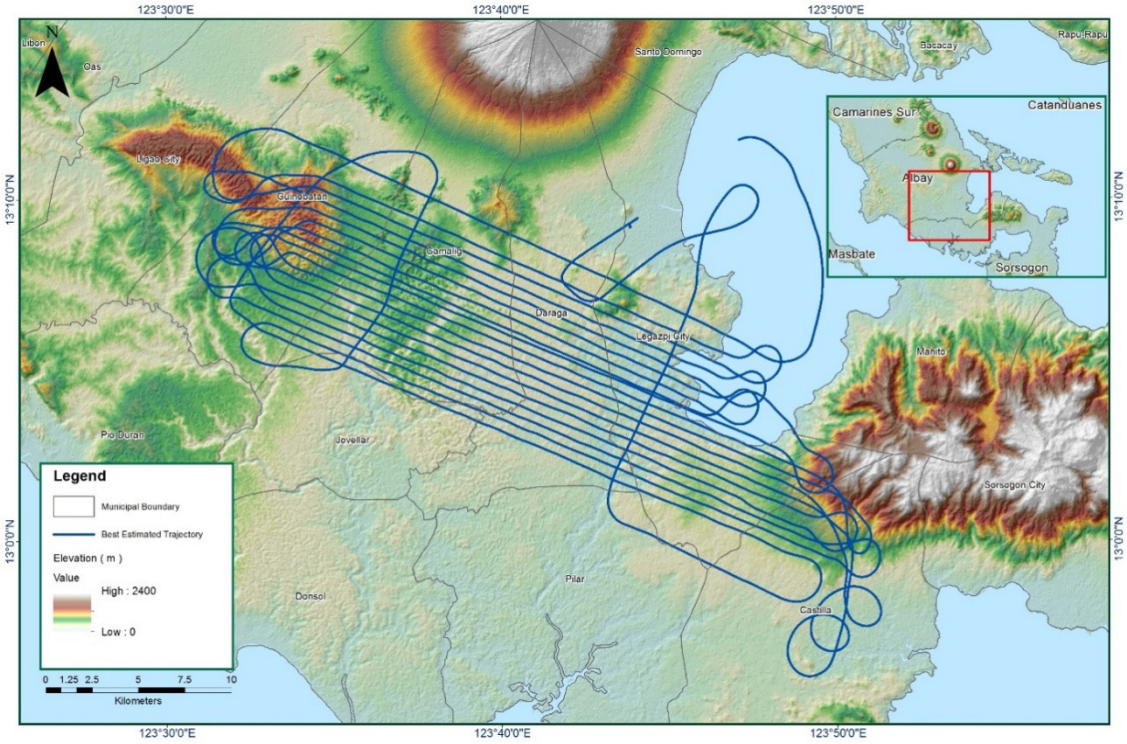


Figure 1.5.3 Best Estimated Trajectory

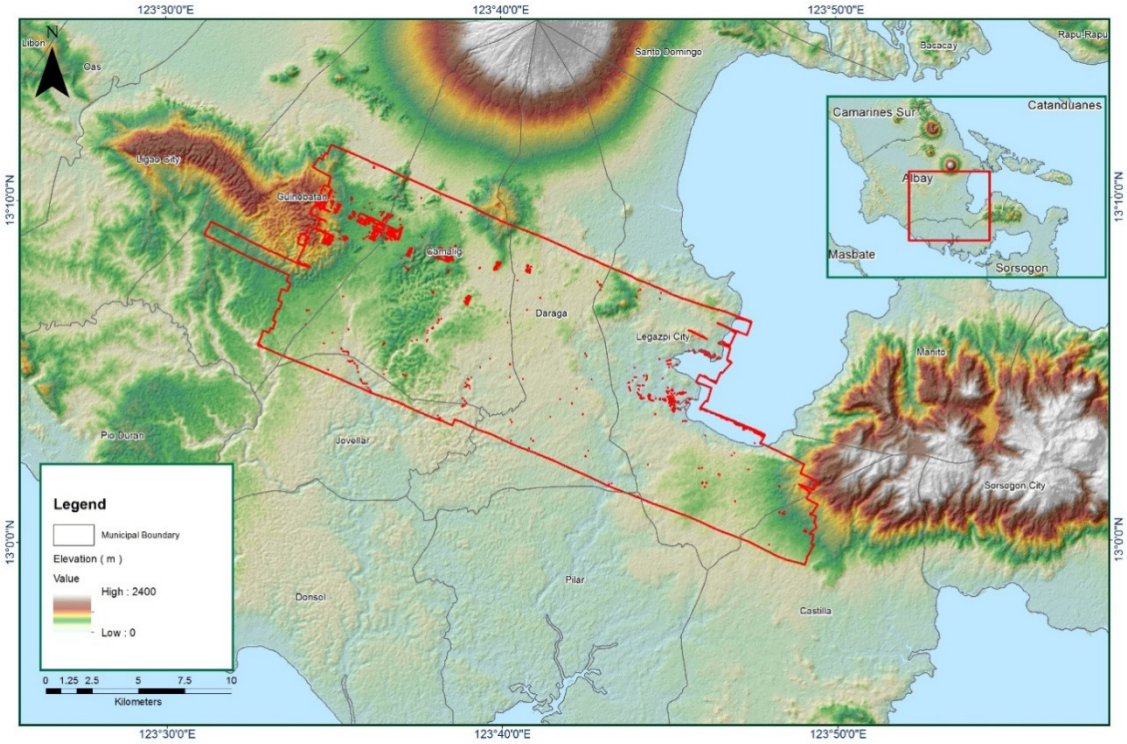


Figure 1.5.4 Coverage of LiDAR data

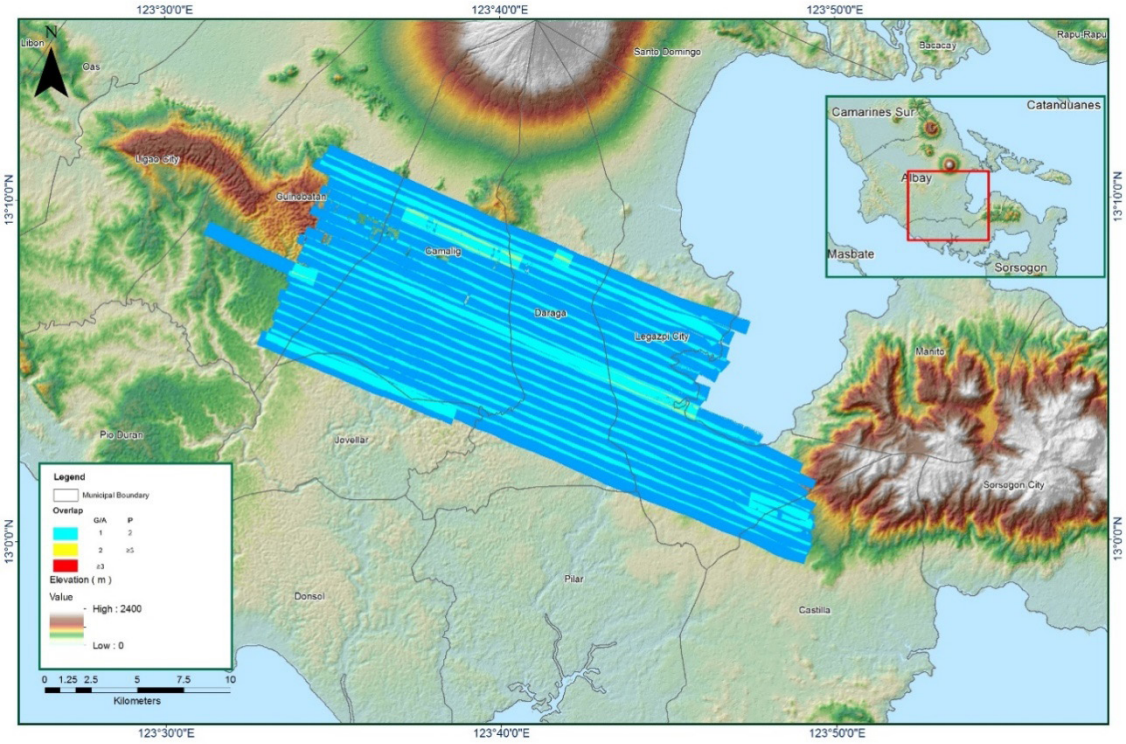


Figure 1.5.5 Image of Data Overlap

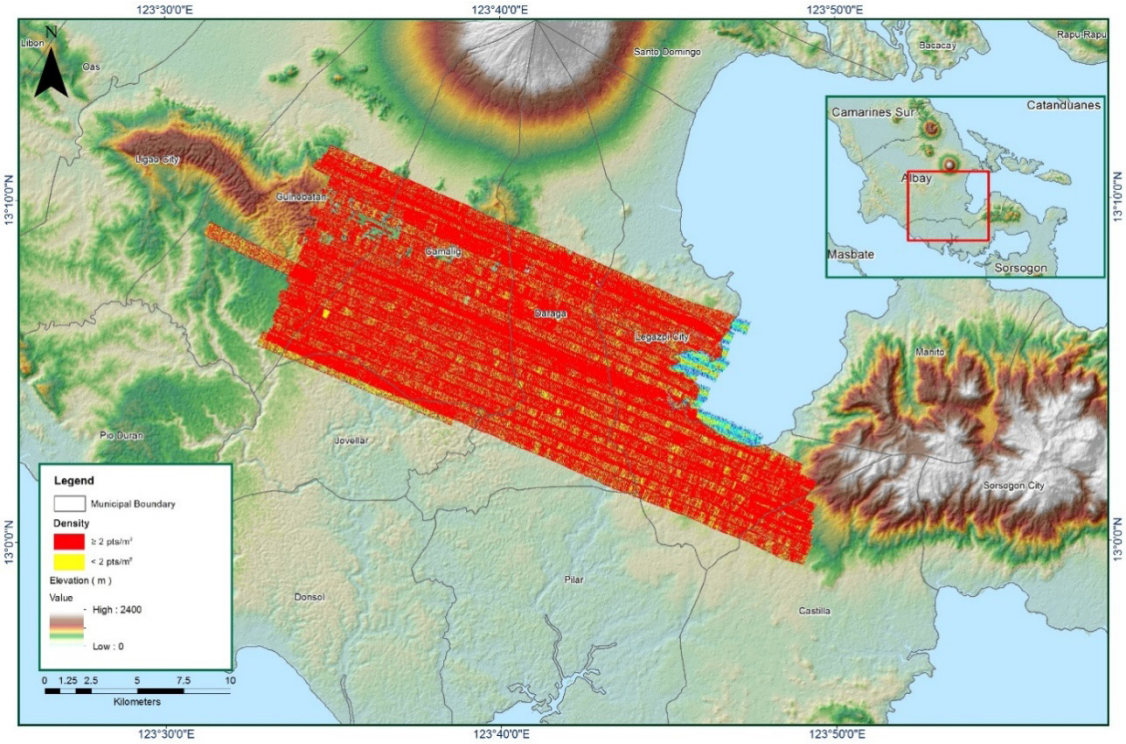


Figure 1.5.6 Density Map

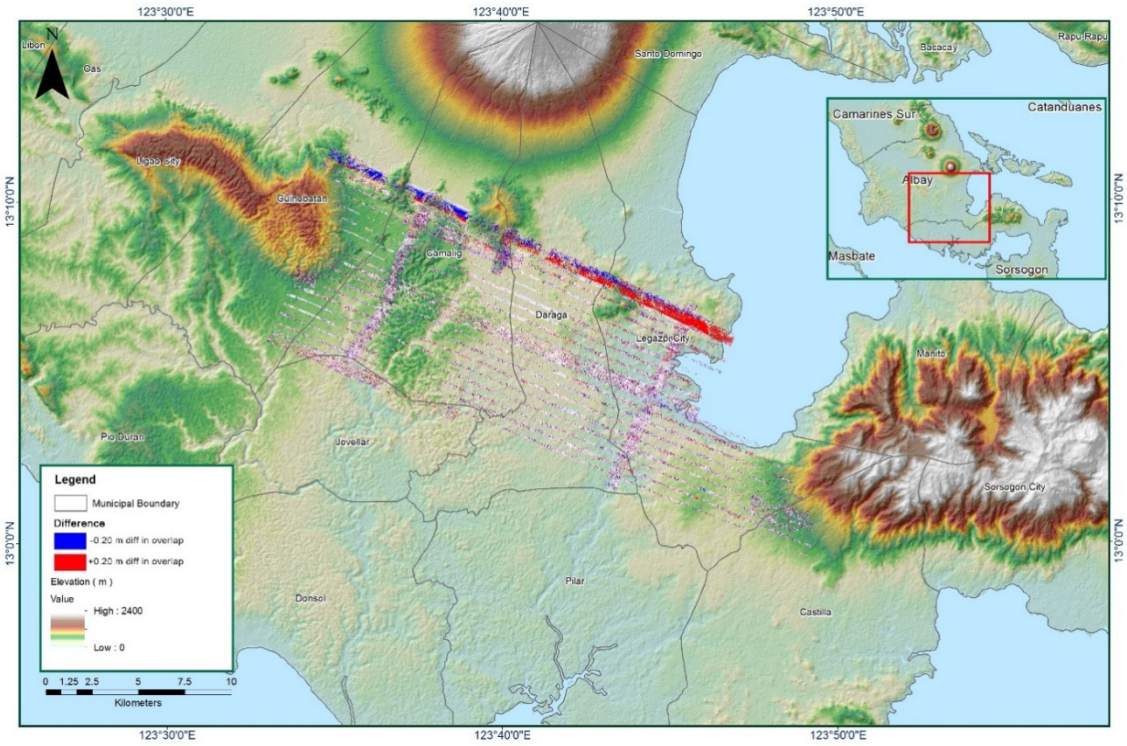


Figure 1.5.7 Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19P**
Inclusive Flights	7212GC, 7213GC
Range data size	26.47 GB
POS	267 MB
Base data size	3.36 MB
Image	---
Transfer date	May 05, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.26
RMSE for East Position (<4.0 cm)	1.58
RMSE for Down Position (<8.0 cm)	4.35
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	18.93 %
Ave point cloud density per sq.m. (>2.0)	2.94
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	123
Maximum Height	533.14
Minimum Height	75.62
Classification (# of points)	
Ground	31,656,437
Low vegetation	23,751,574
Medium vegetation	37,009,663
High vegetation	126,126,722
Building	2,189,856
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Charmaine Cruz, Ailyn Biñas

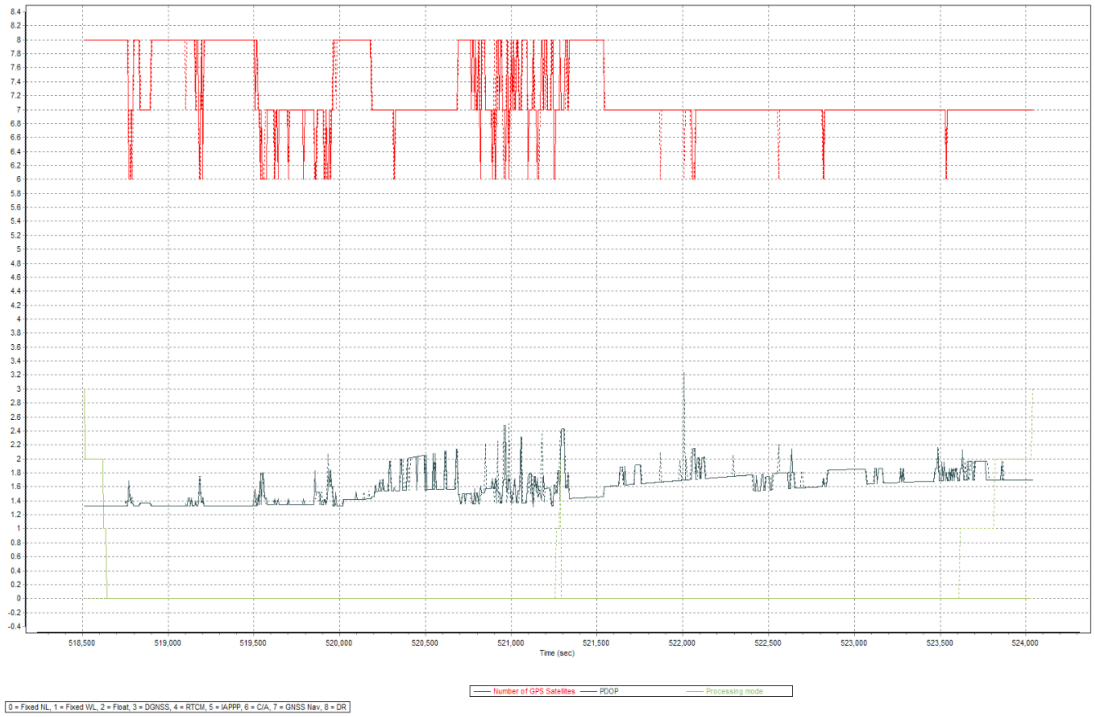


Figure 1.6.1 Solution Status

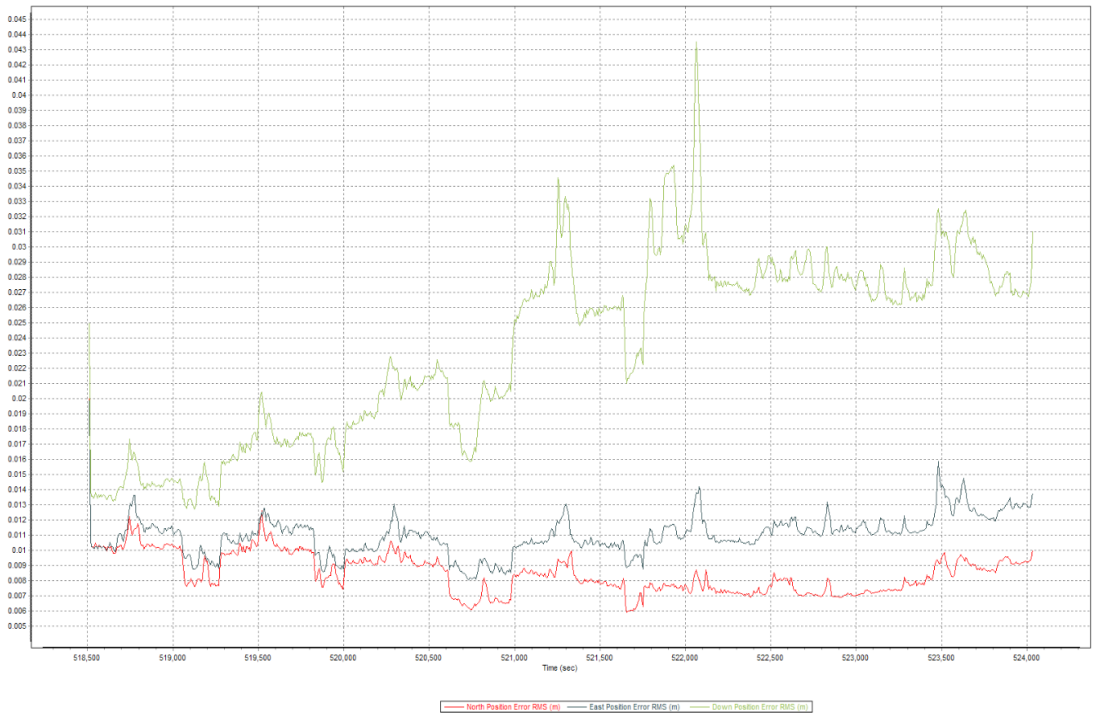


Figure 1.6.2 Smoothed Performance Metric Parameters

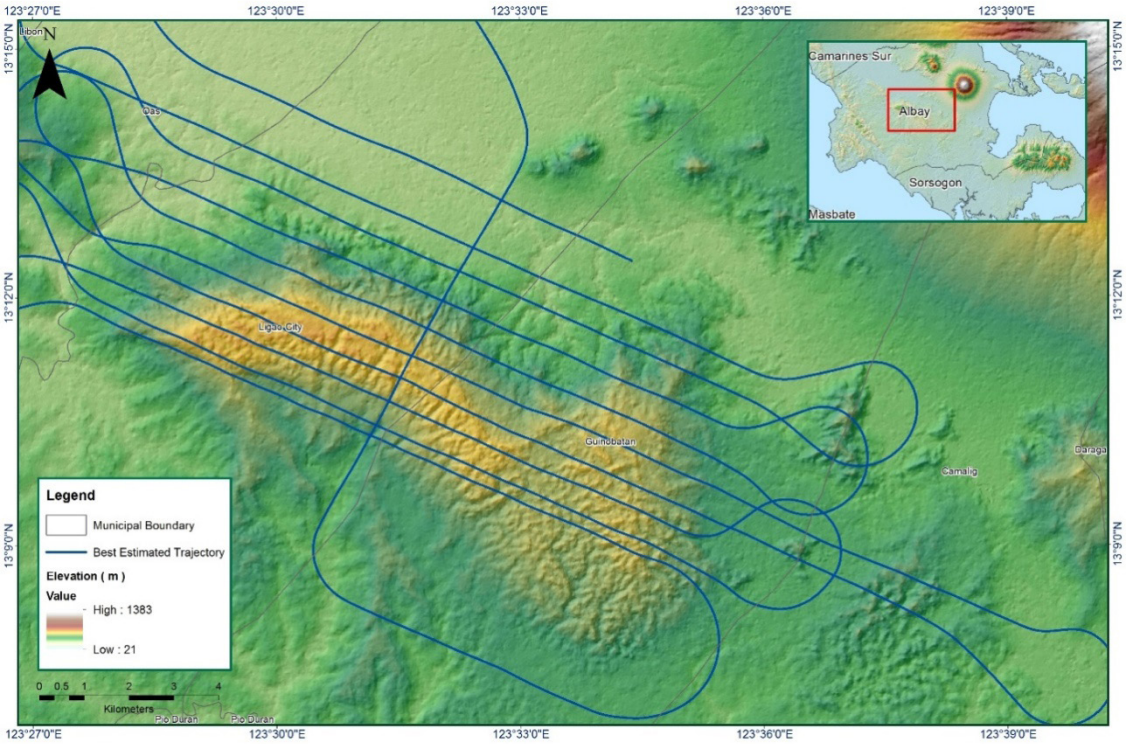


Figure 1.6.3 Best Estimated Trajectory

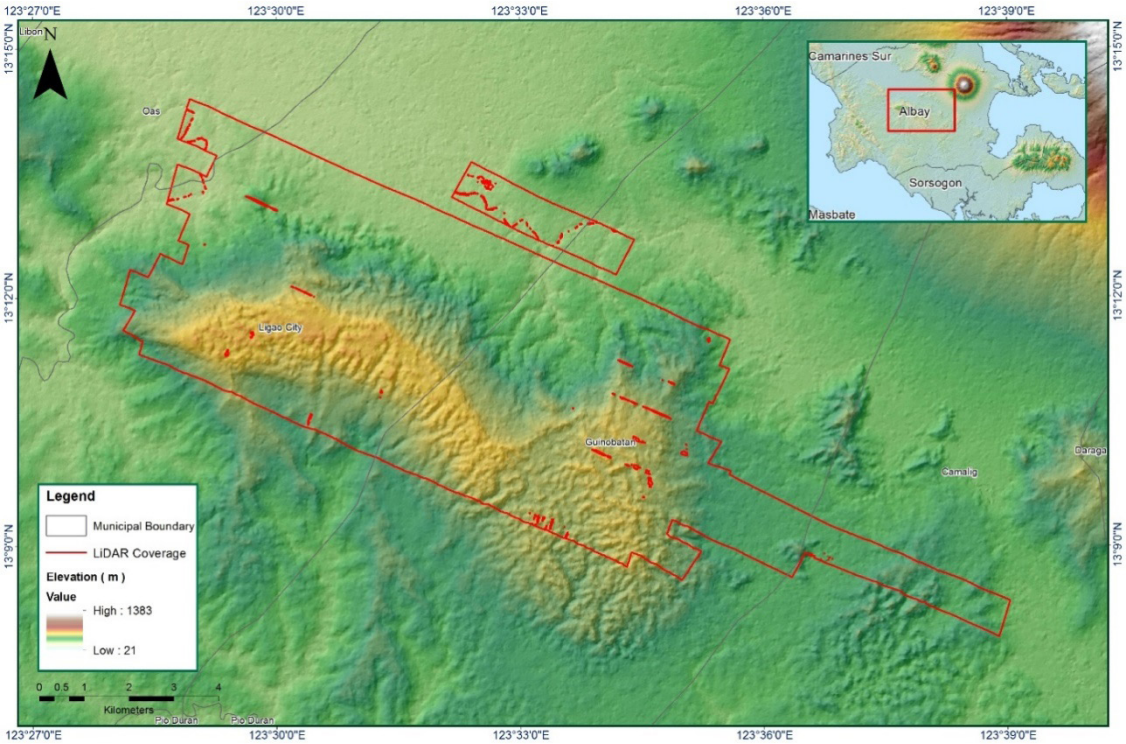


Figure 1.6.4 Coverage of LiDAR data

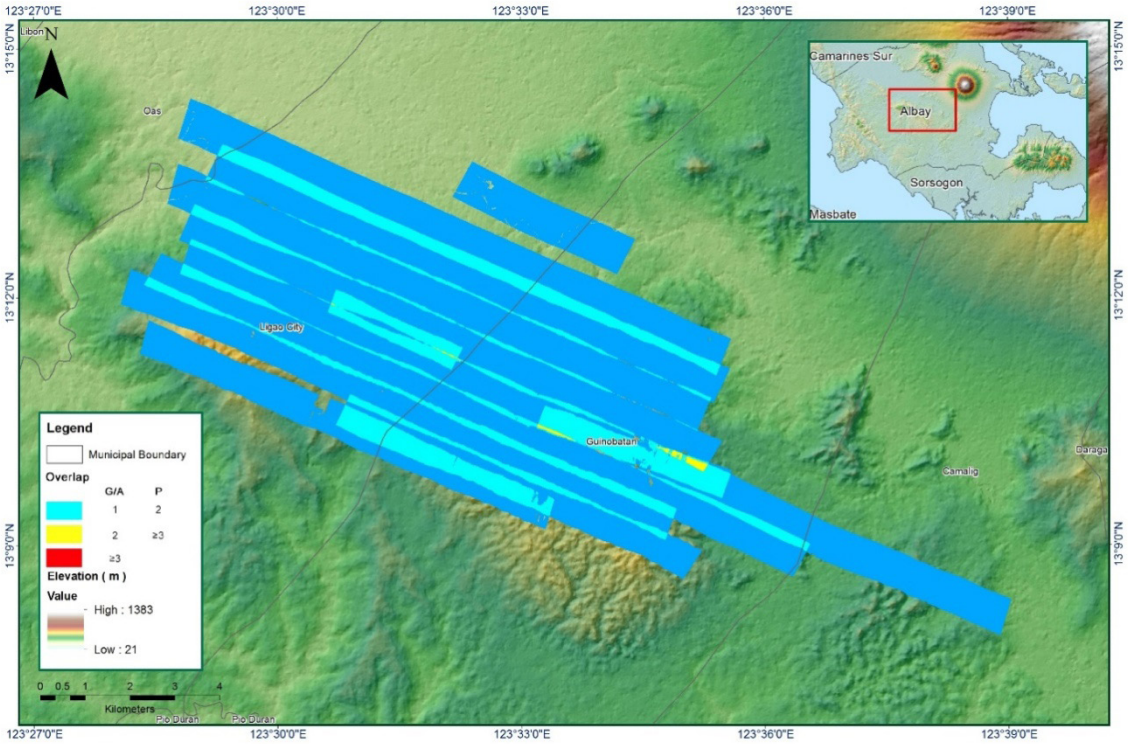


Figure 1.6.5 Image of Data Overlap

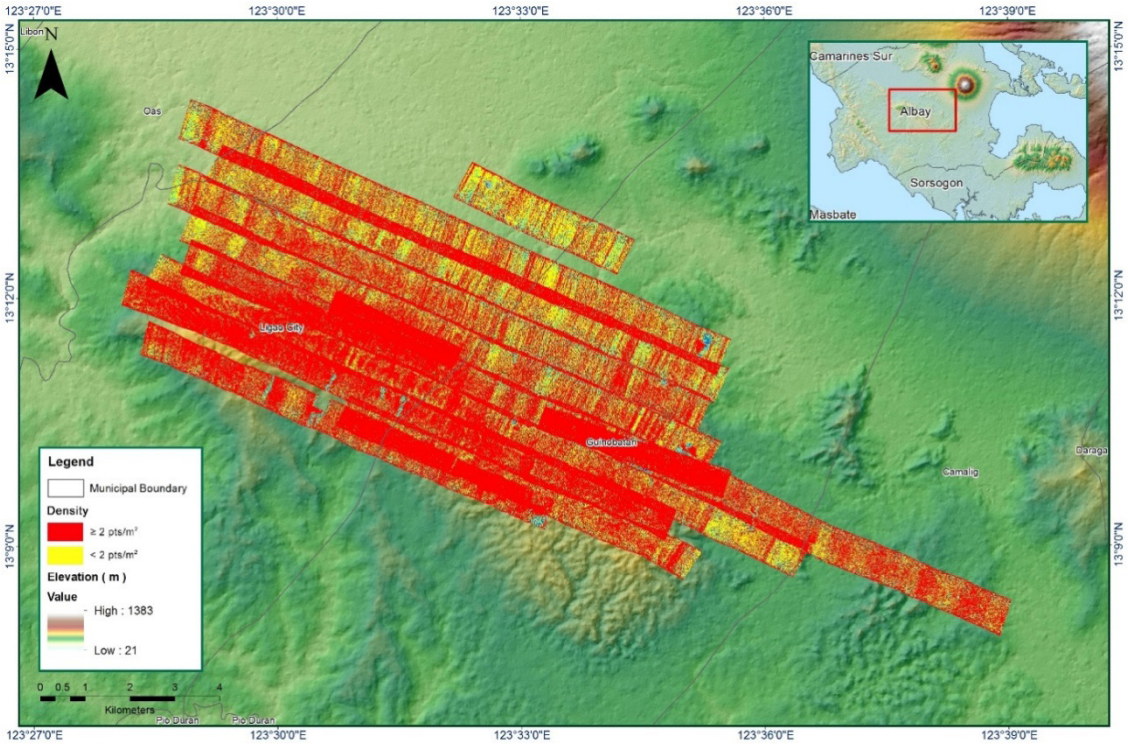


Figure 1.6.6 Density Map

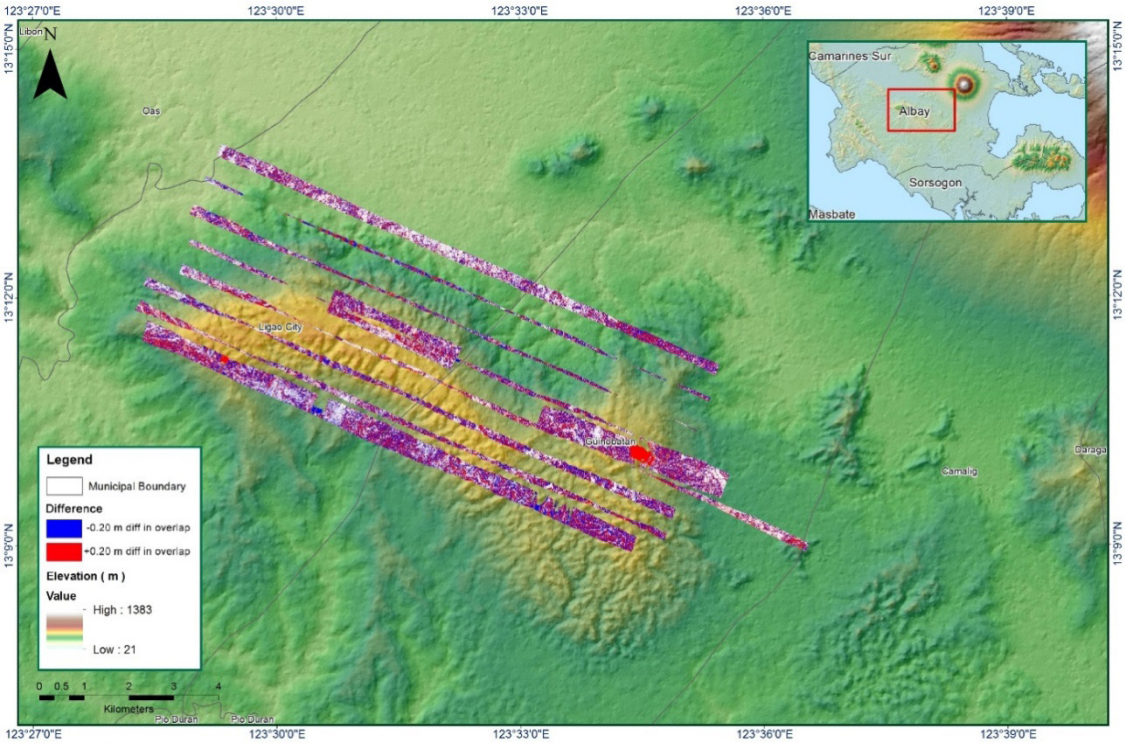


Figure 1.6.7 Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19M**
Inclusive Flights	7171GC
Range data size	14.5 GB
POS	166 MB
Base data image	11.6 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.2
RMSE for East Position (<4.0 cm)	4.4
RMSE for Down Position (<8.0 cm)	22.5
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.000456
GPS position stdev (<0.01m)	0.0067
Minimum % overlap (>25)	15.07 %
Ave point cloud density per sq.m. (>2.0)	2.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	165
Maximum Height	179.86
Minimum Height	52.66
Classification (# of points)	
Ground	40578668
Low vegetation	35563429
Medium vegetation	48648596
High vegetation	105602789
Building	2349495
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Engr. Gladys Mae Apat

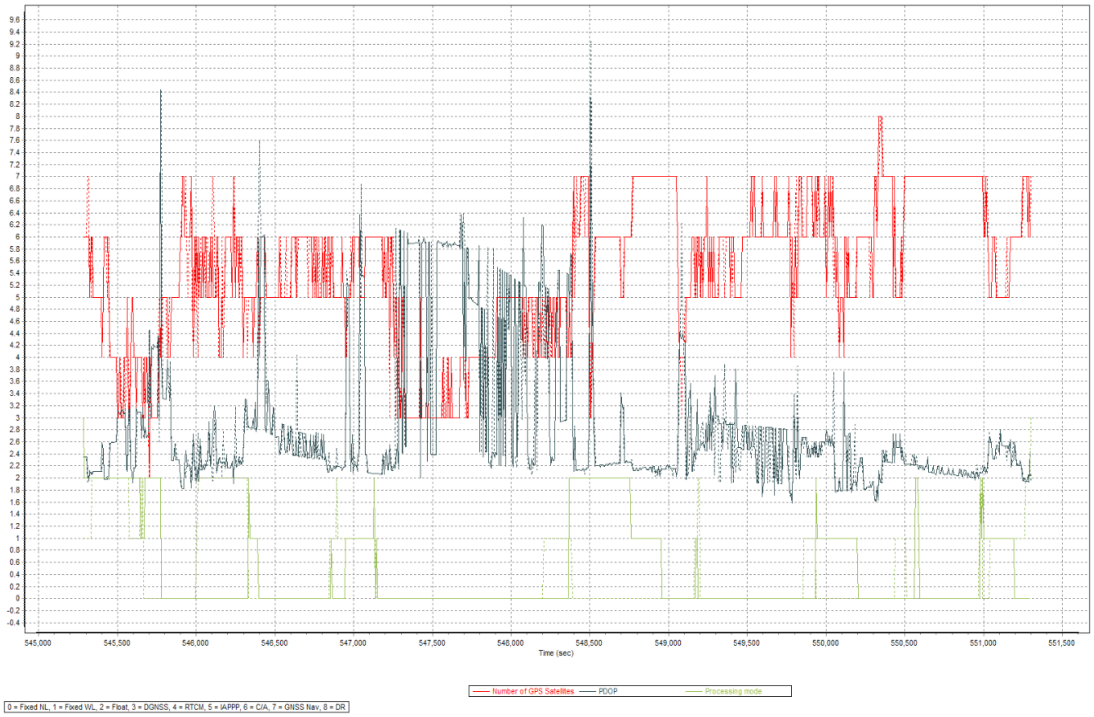


Figure 1.7.1 Solution Status

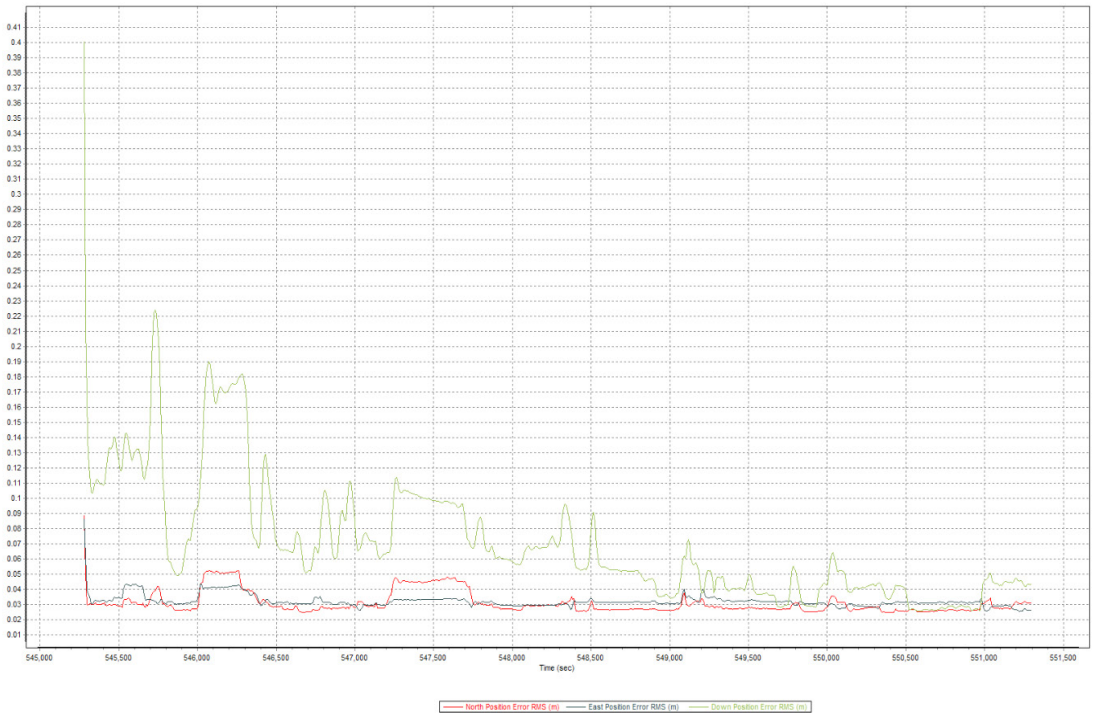


Figure 1.7.2 Smoothed Performance Metric Parameters

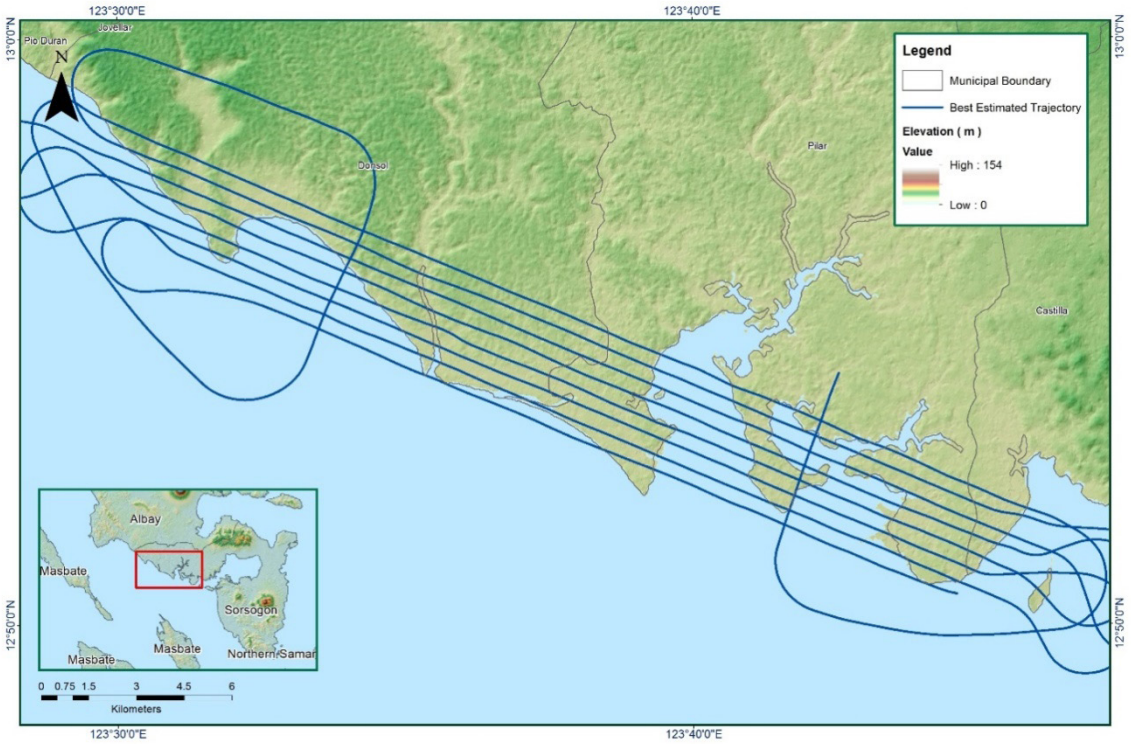


Figure 1.7.3 Best Estimated Trajectory

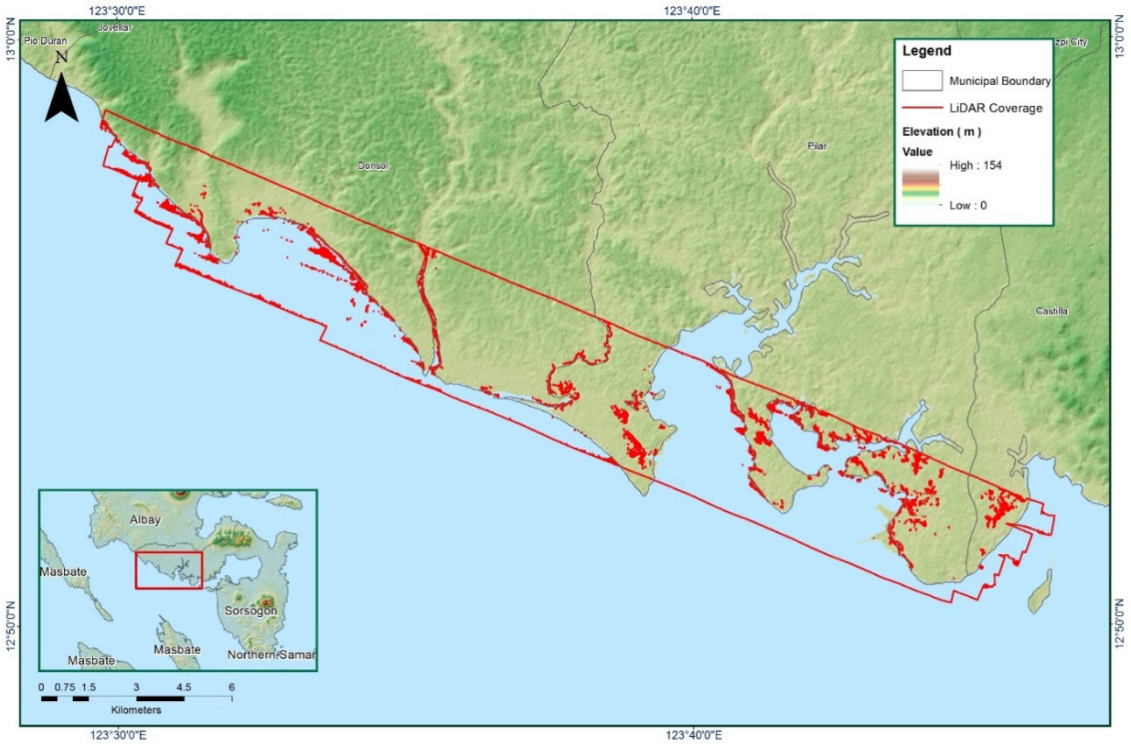


Figure 1.7.4 Coverage of LiDAR data

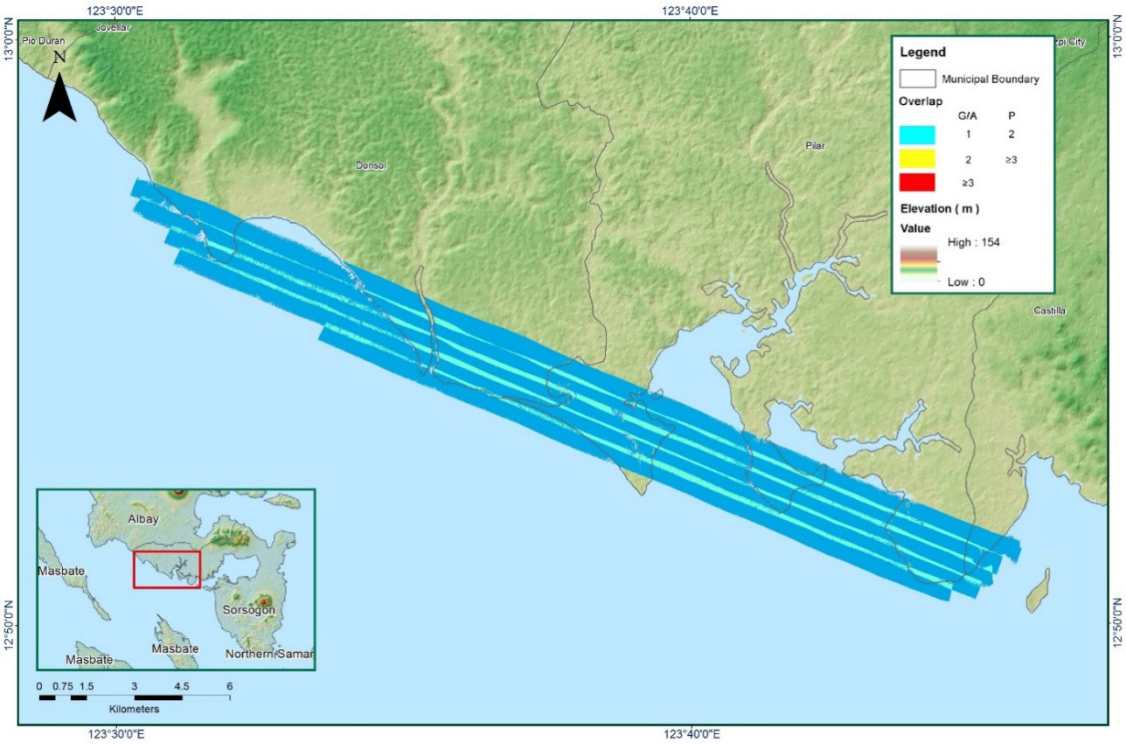


Figure 1.7.5 Image of Data Overlap

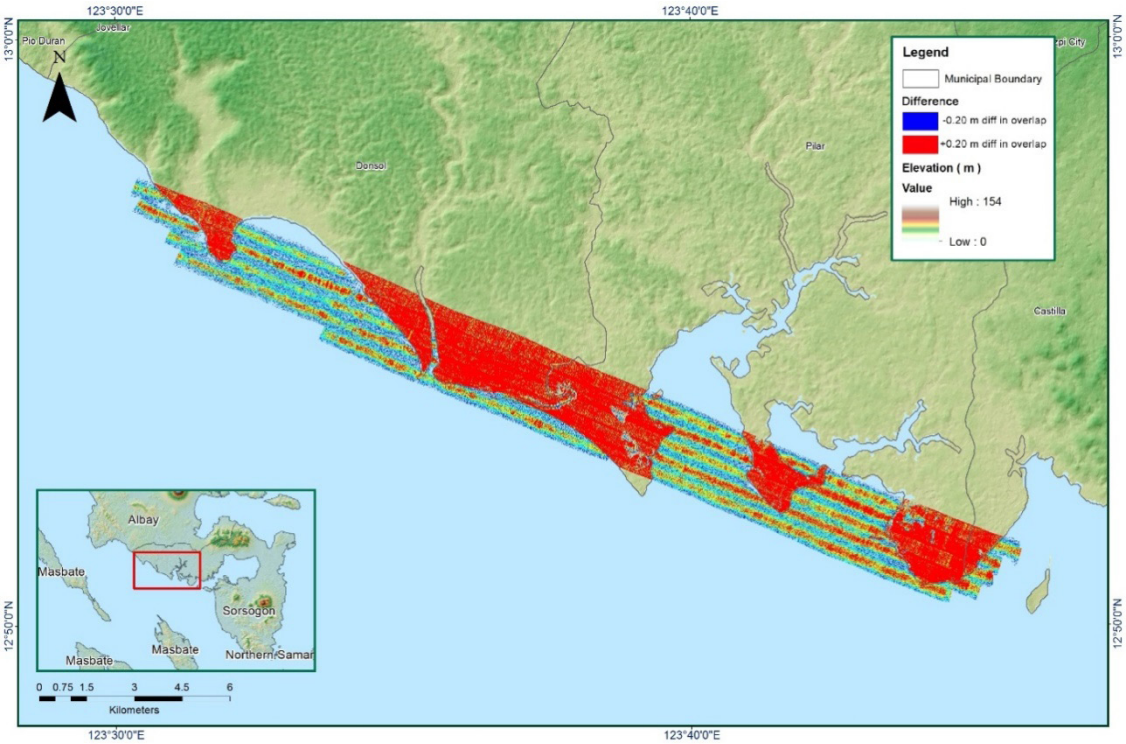


Figure 1.7.6 Density Map

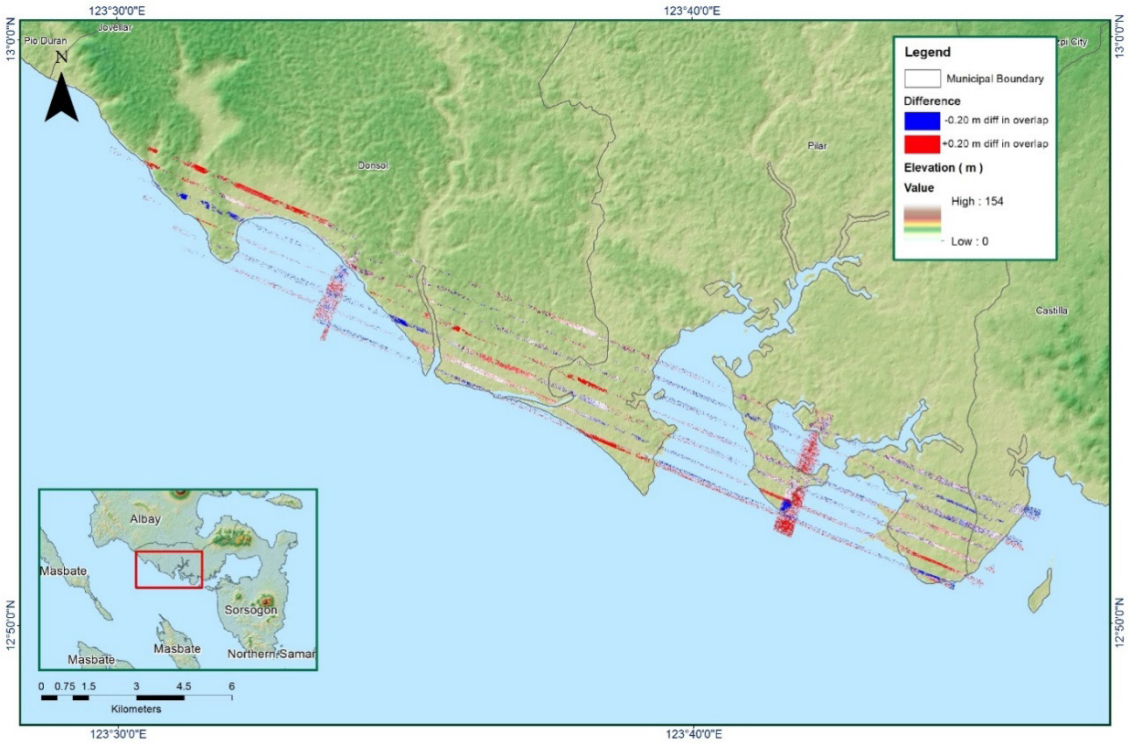


Figure 1.7.7 Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19M_Additional**
Inclusive Flights	7171GC
Range data size	14.5 GB
POS	166 MB
Base data size	11.6 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.2
RMSE for East Position (<4.0 cm)	4.4
RMSE for Down Position (<8.0 cm)	22.5
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.000456
GPS position stdev (<0.01m)	0.0067
Minimum % overlap (>25)	13.70 %
Ave point cloud density per sq.m. (>2.0)	2.93
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	95
Maximum Height	179.81
Minimum Height	54.08
Classification (# of points)	
Ground	15934374
Low vegetation	13968667
Medium vegetation	20218656
High vegetation	68566425
Building	1117461
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Alex John Escobido

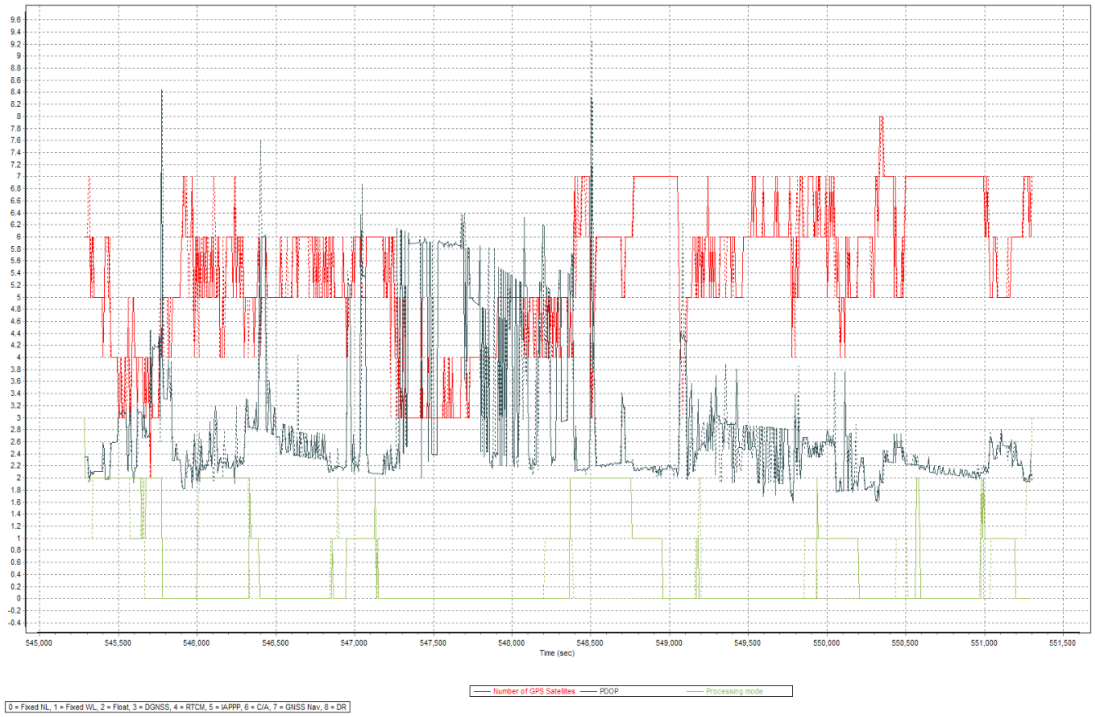


Figure 1.8.1 Solution Status

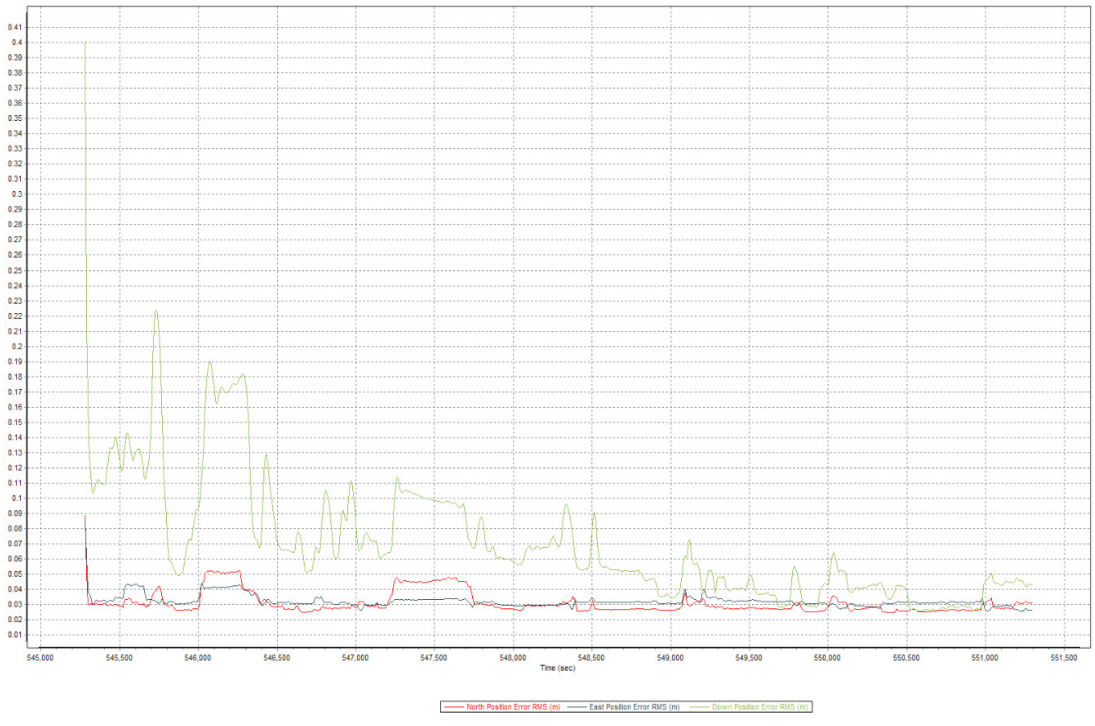


Figure 1.8.2 Smoothed Performance Metric Parameters

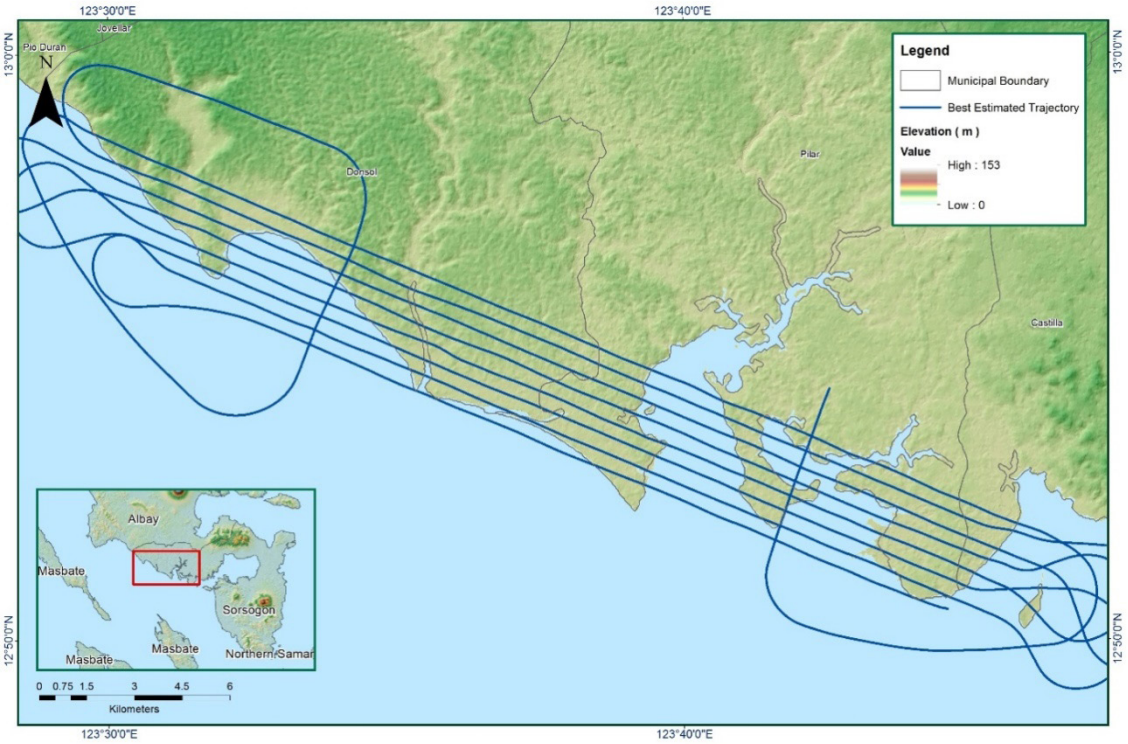


Figure 1.8.3 Best Estimated Trajectory

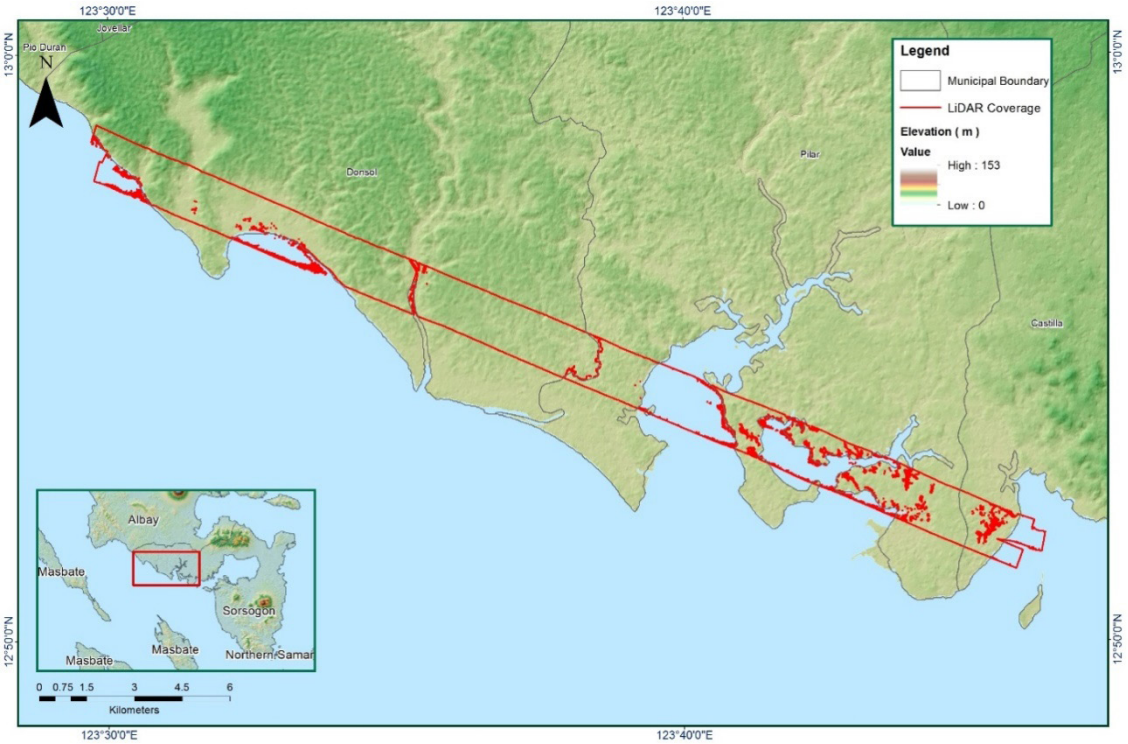


Figure 1.8.4 Coverage of LiDAR data

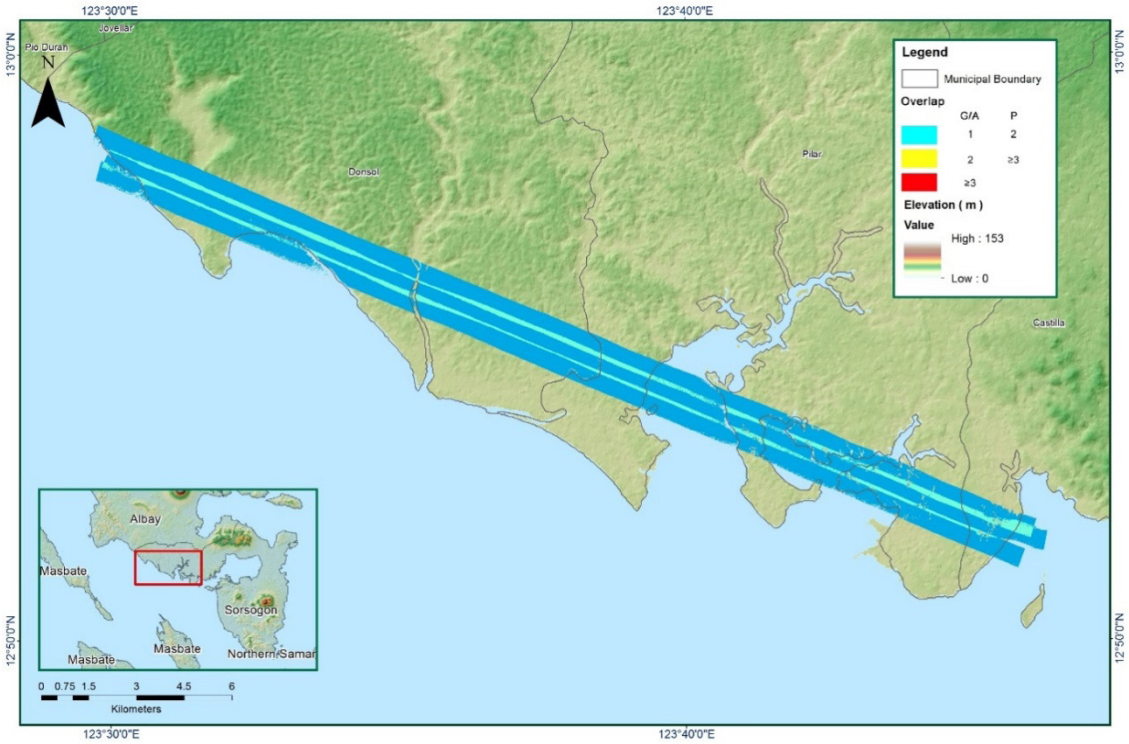


Figure 1.8.5 Image of Data Overlap

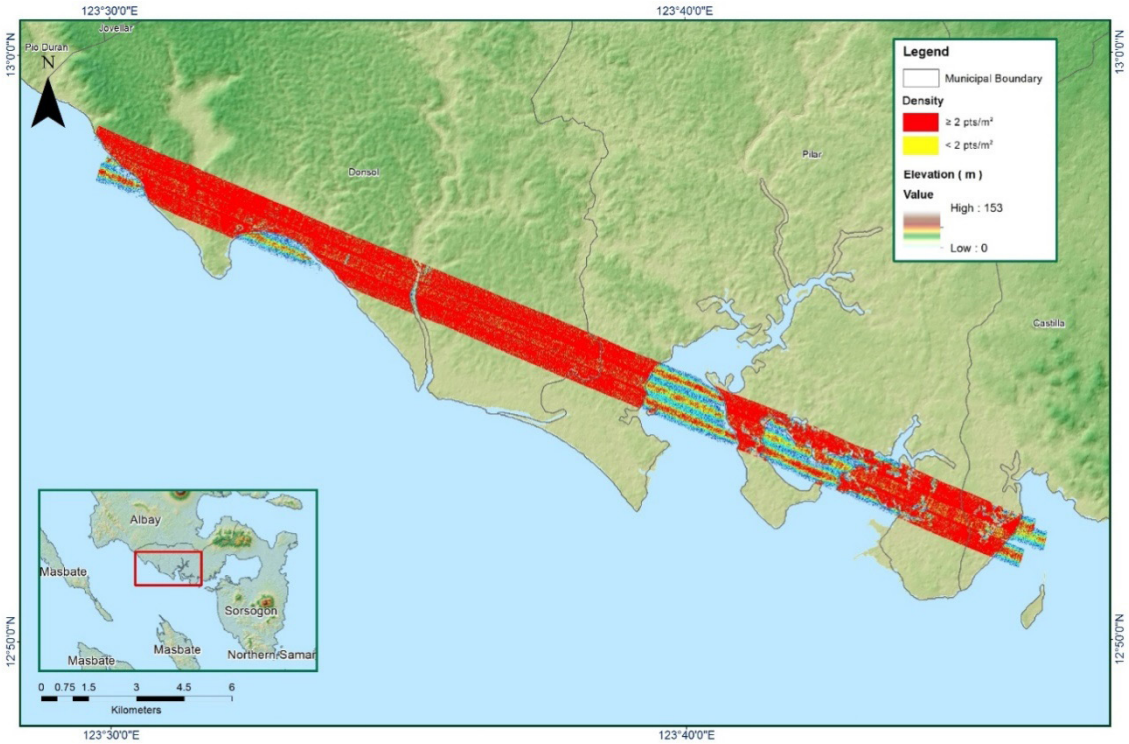


Figure 1.8.6 Density Map

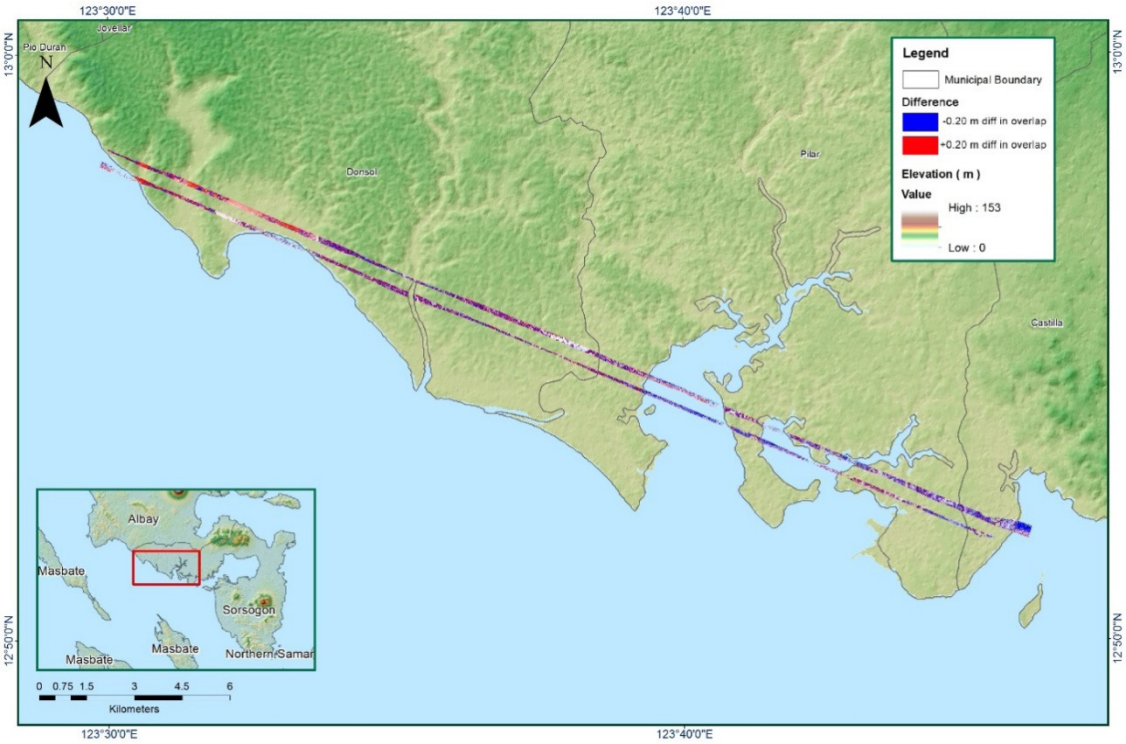


Figure 1.8.7 Elevation difference between flight lines

Flight Area	Albay_Sorsogon
Mission Name	**Blk19L_additional**
Inclusive Flights	7168G
Range data size	22.4 GB
POS data size	193 MB
Base data size	10.9 MB
Image	n/a
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	7.7
RMSE for East Position (<4.0 cm)	5.6
RMSE for Down Position (<8.0 cm)	17.4
Boresight correction stdev (<0.001deg)	0.000200
IMU attitude correction stdev (<0.001deg)	0.003237
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	21.81
Ave point cloud density per sq.m. (>2.0)	2.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	9
Maximum Height	172.19 m
Minimum Height	53.72 m
Classification (# of points)	
Ground	350,380
Low vegetation	101,547
Medium vegetation	344,518
High vegetation	1,729,486
Building	1,216
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Melissa Fernandez

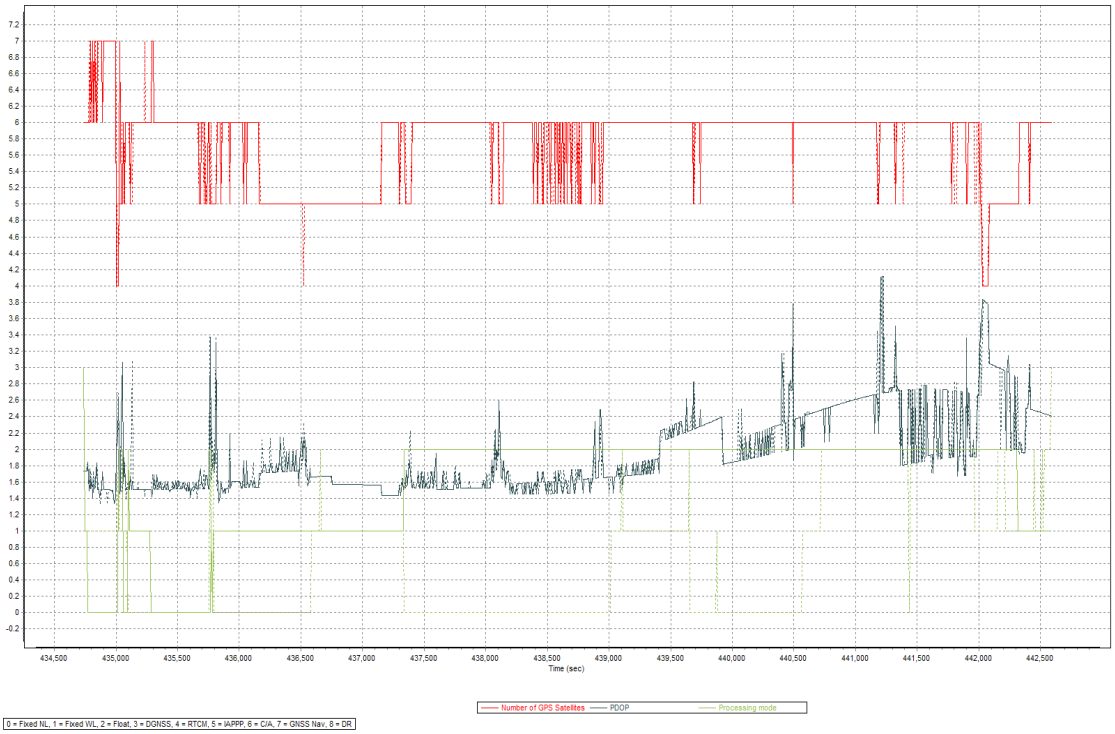


Figure 1.9.1. Solution Status

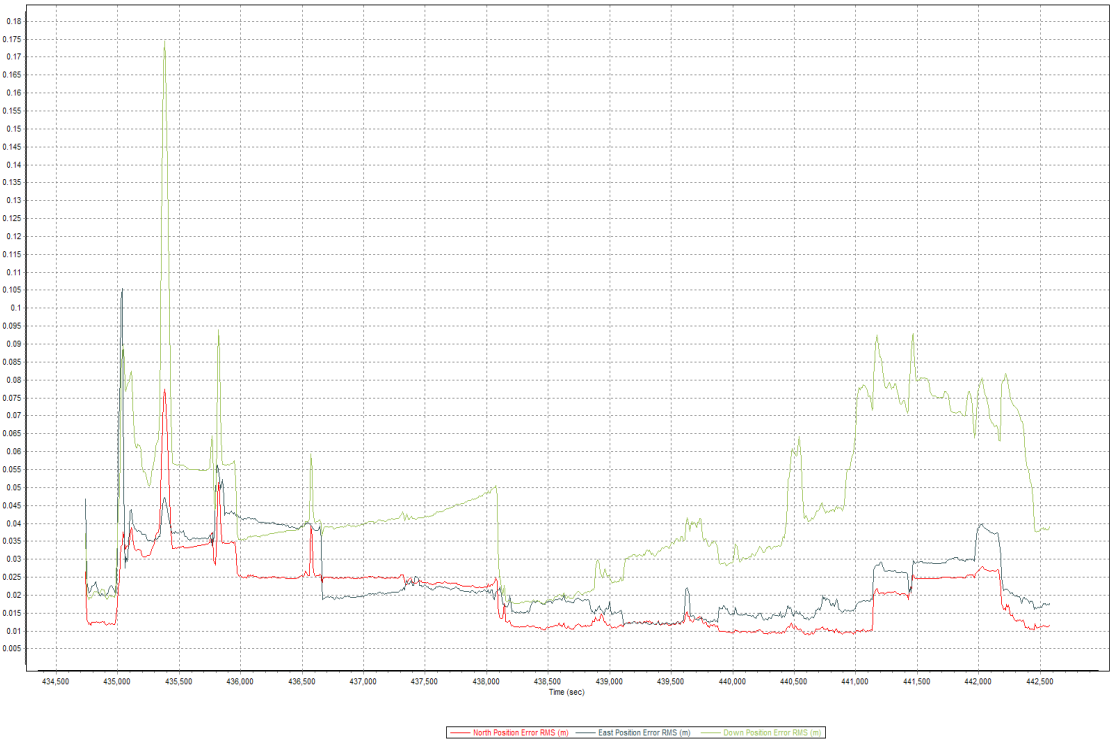


Figure 1.9.2. Smoothed Performance Metric Parameters

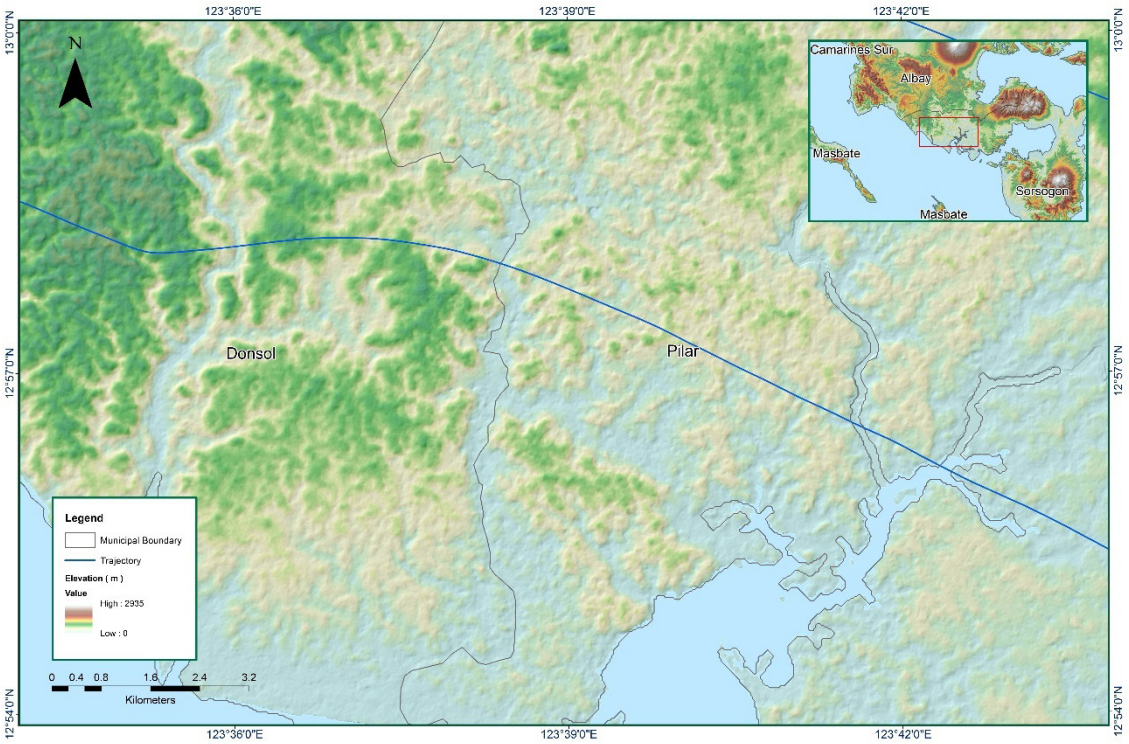


Figure 1.9.3. Best Estimated Trajectory

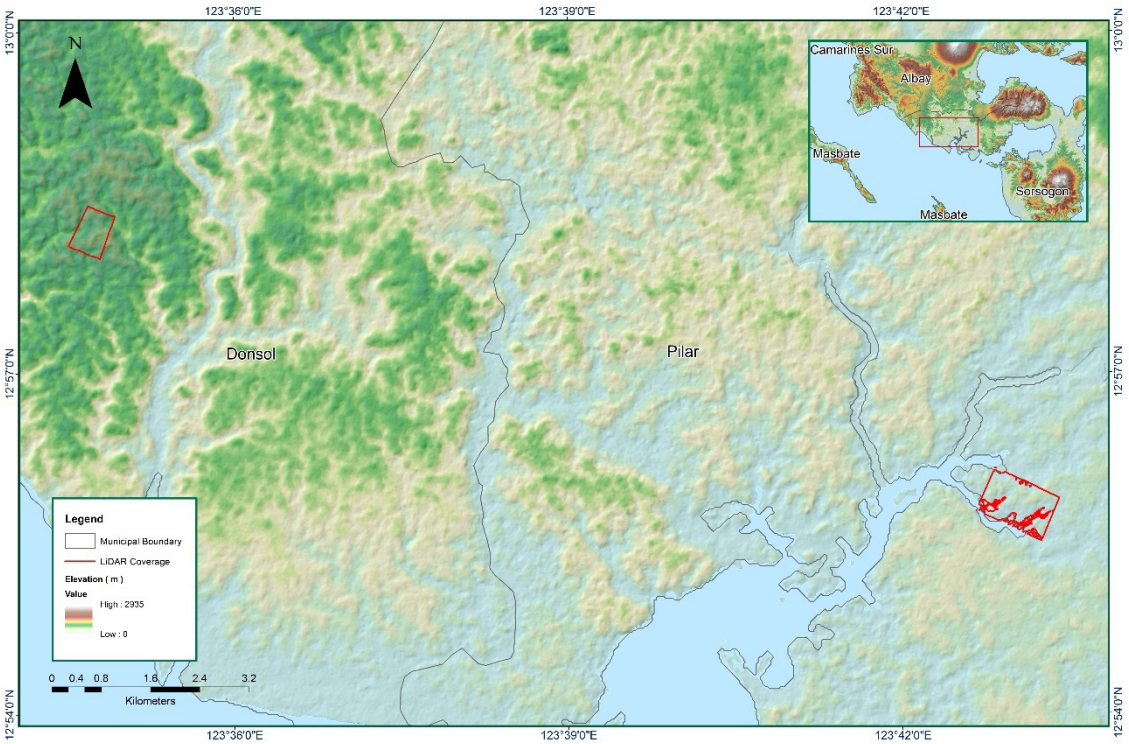


Figure 1.9.4. Coverage of LiDAR Data

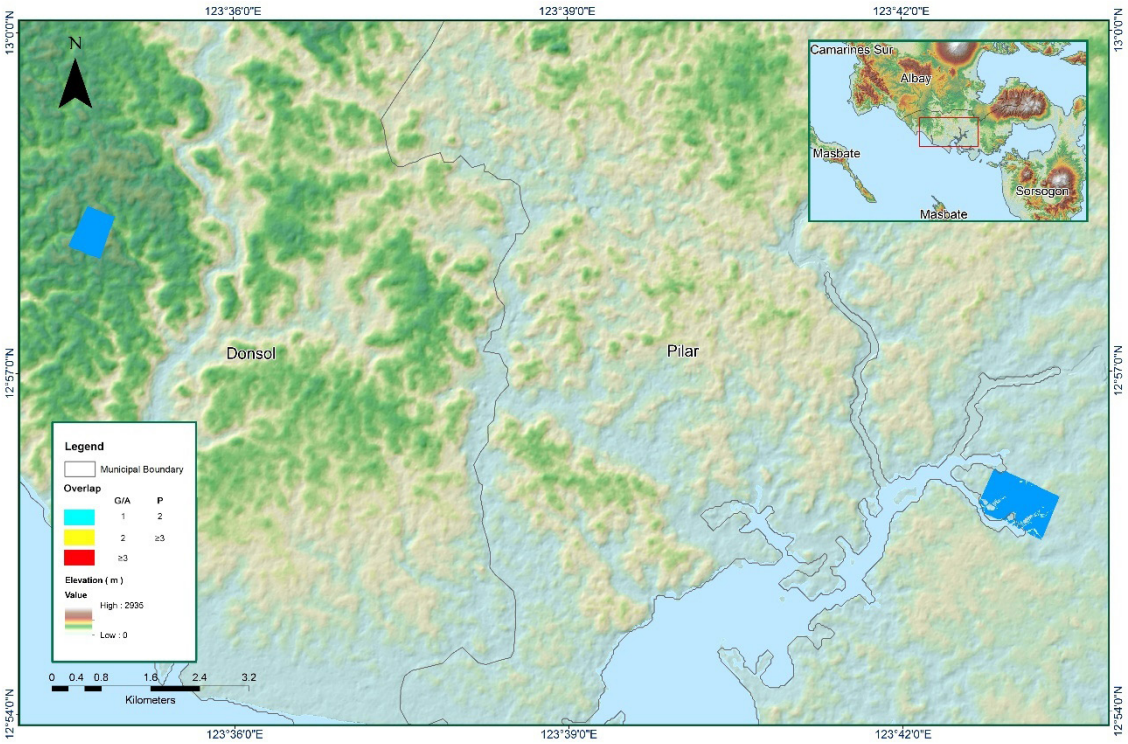


Figure 1.9.5. Image of data overlap

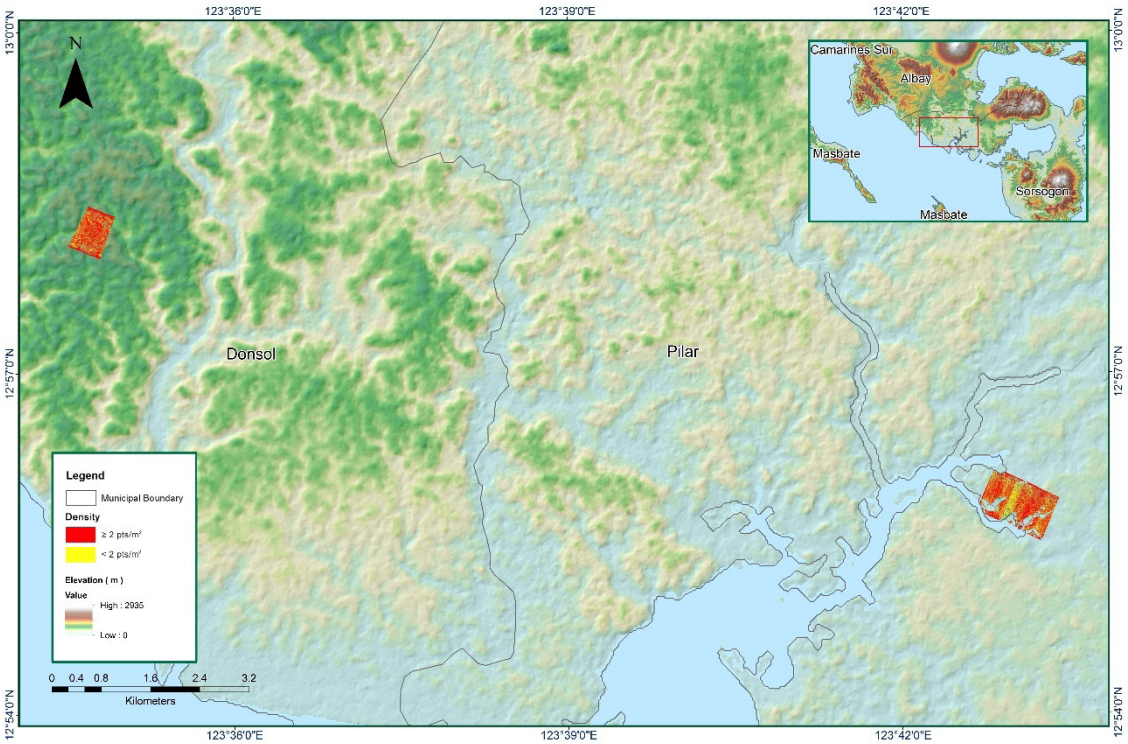


Figure 1.9.6. Density map of merged LiDAR data

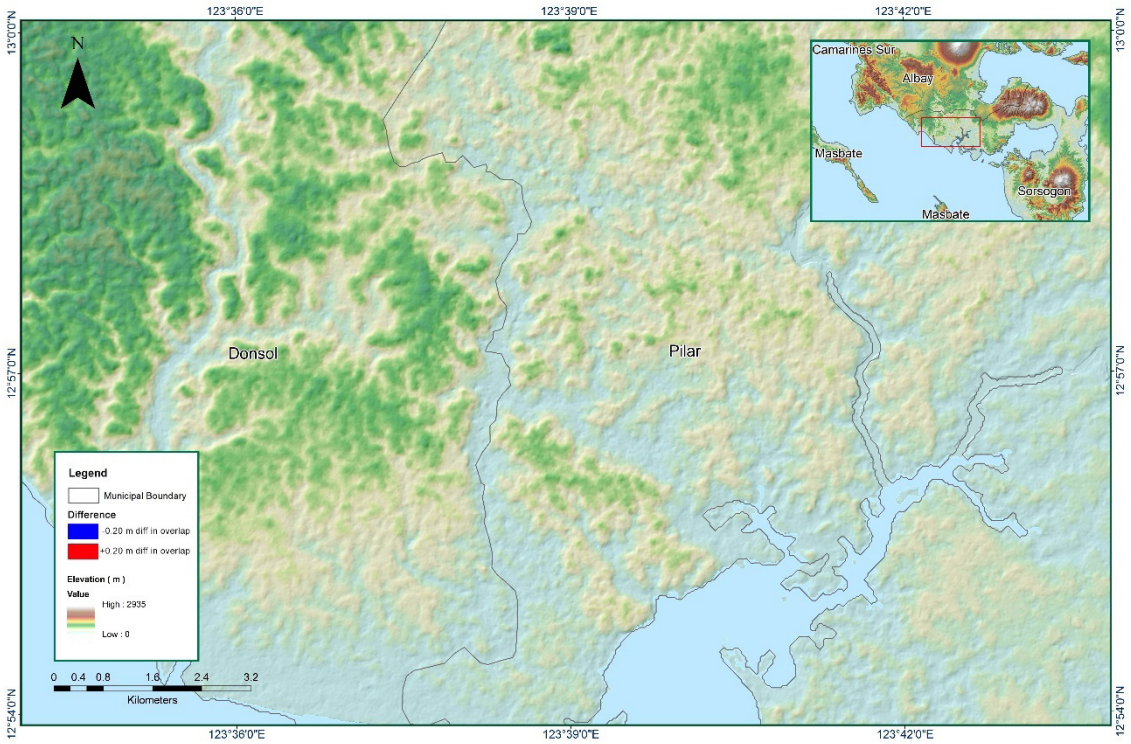


Figure 1.9.7. Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19L**
Inclusive Flights	7168GC
Range data size	22.4 GB
POS	193 MB
Base data size	10.9 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	7.7
RMSE for East Position (<4.0 cm)	10.6
RMSE for Down Position (<8.0 cm)	17.5
Boresight correction stdev (<0.001deg)	0.000200
IMU attitude correction stdev (<0.001deg)	0.001959
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	21.81 %
Ave point cloud density per sq.m. (>2.0)	2.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	265
Maximum Height	238.97
Minimum Height	52.76
Classification (# of points)	
Ground	58020284
Low vegetation	46865776
Medium vegetation	84917293
High vegetation	266182218
Building	2788874
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Antonio Chua, Jr., Ailyn Biñas

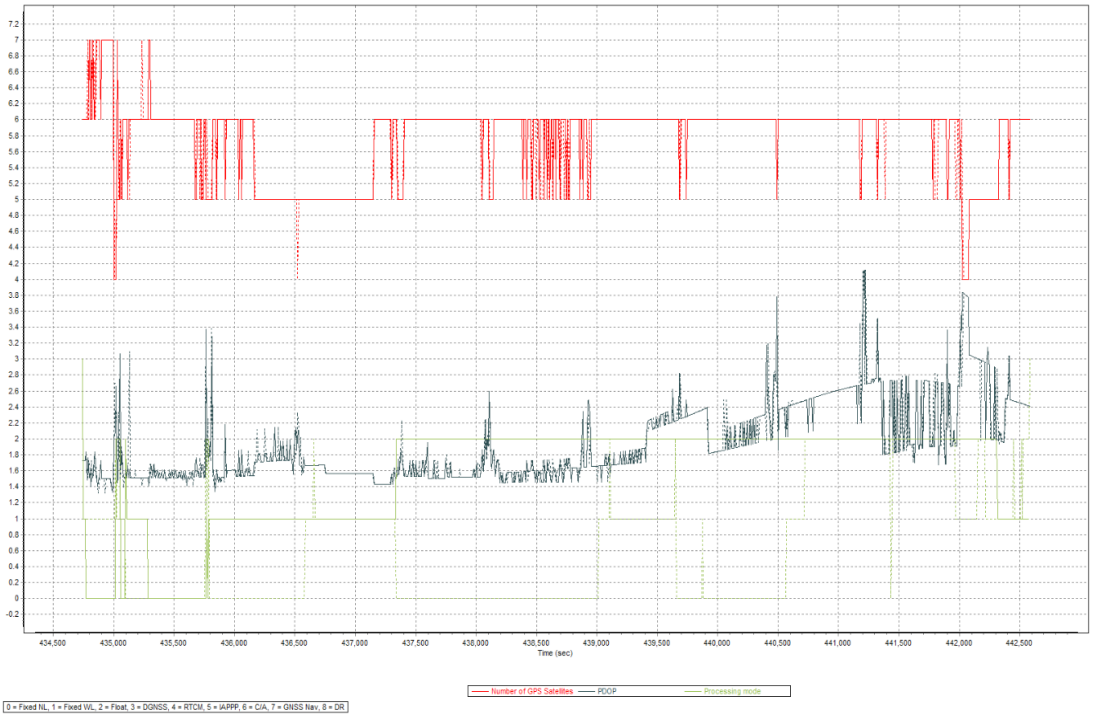


Figure 1.10.1 Solution Status

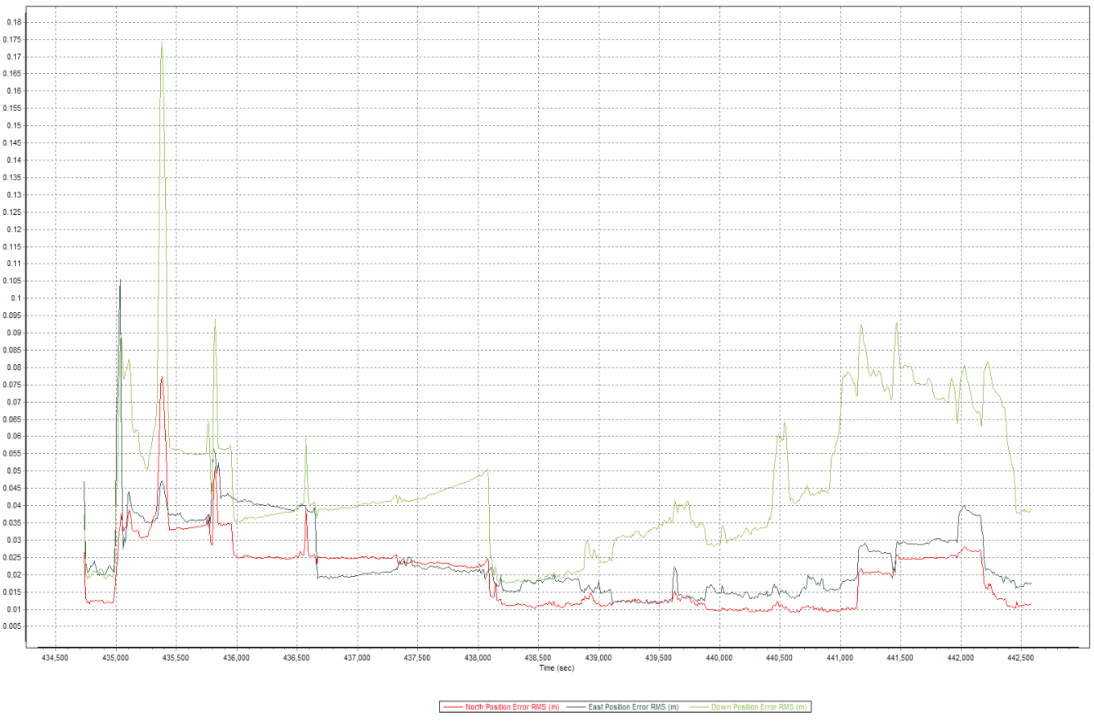


Figure 1.10.2 Smoothed Performance Metric Parameters

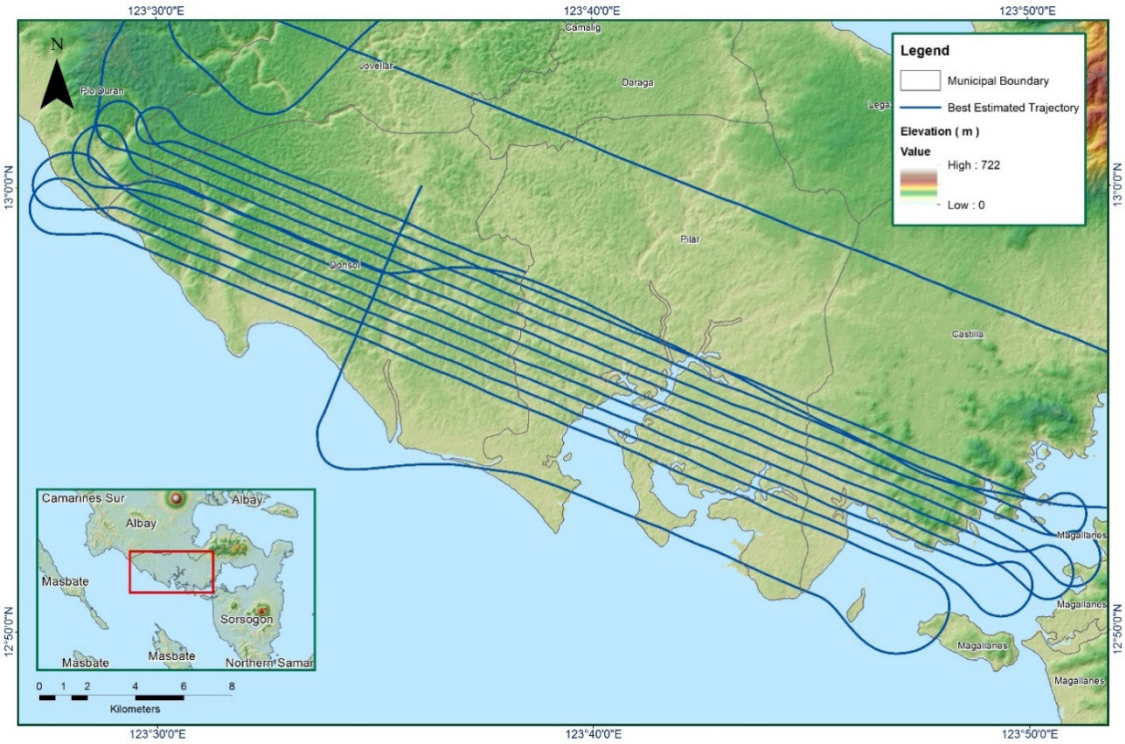


Figure 1.10.3 Best Estimated Trajectory

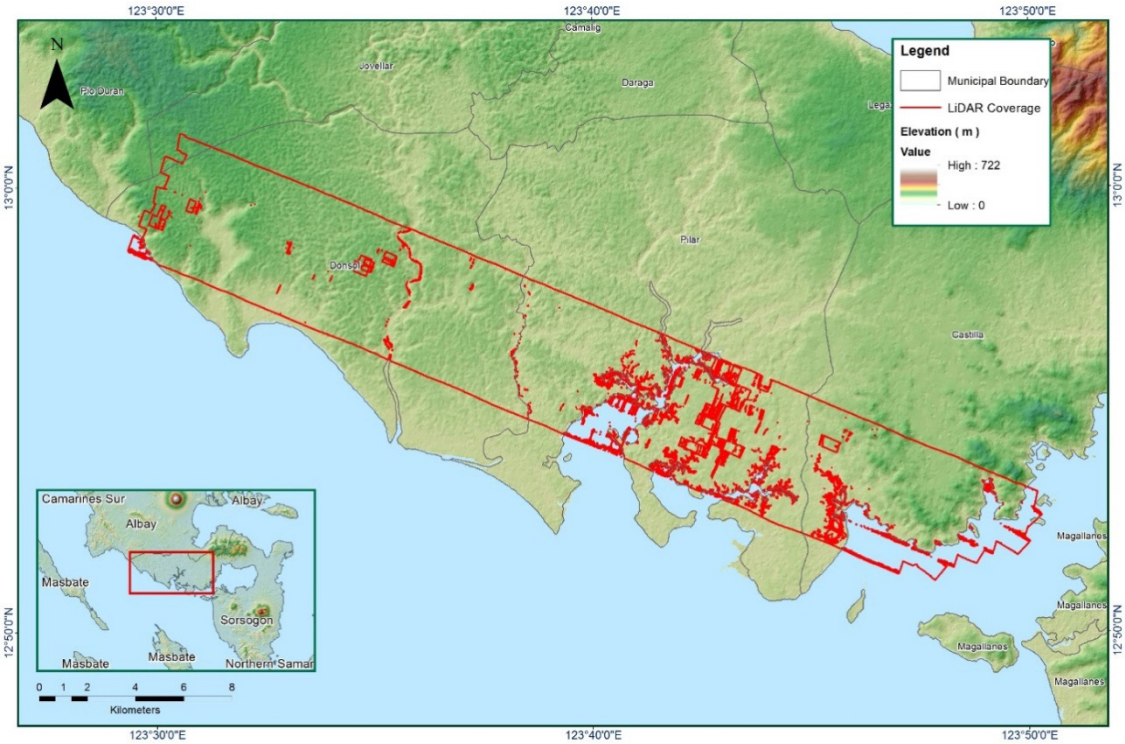


Figure 1.10.4 Coverage of LiDAR data

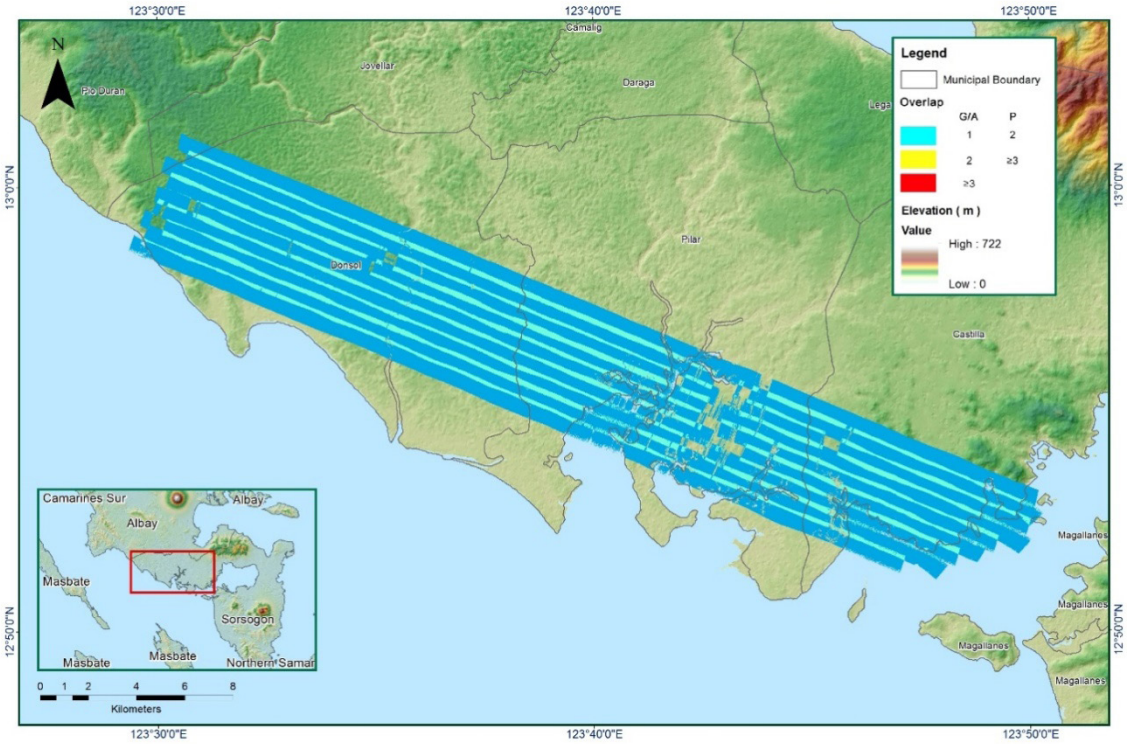


Figure 1.10.5 Image of Data Overlap

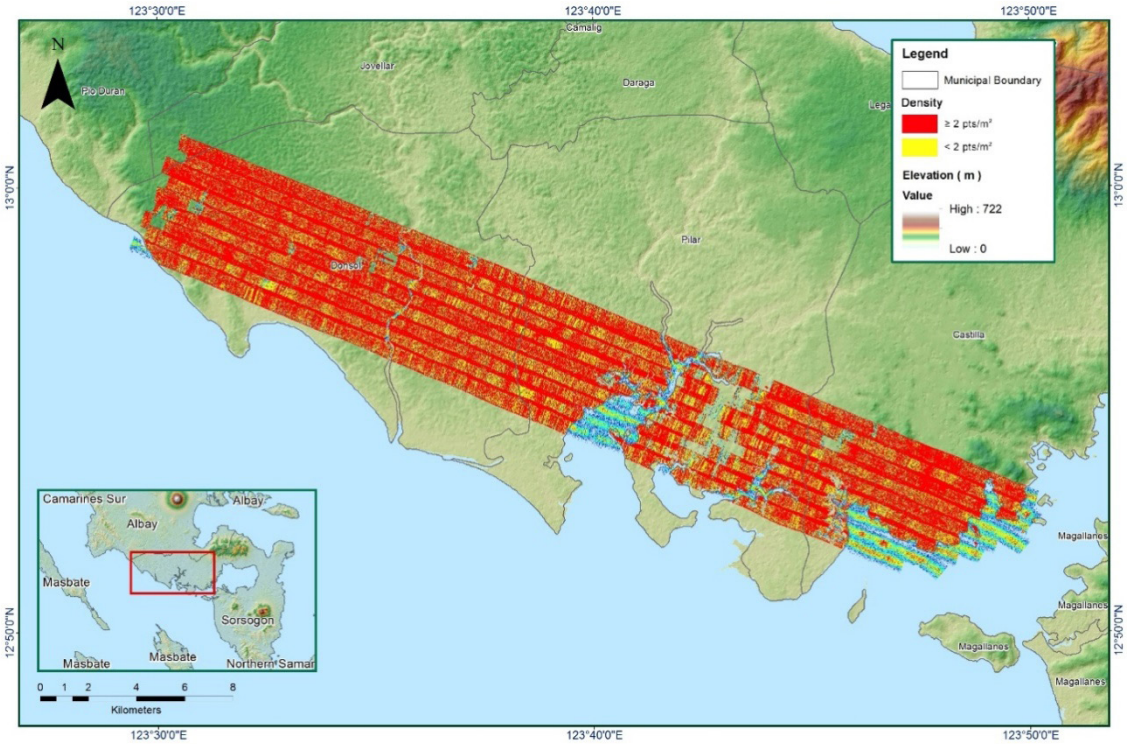


Figure 1.10.6 Density Map

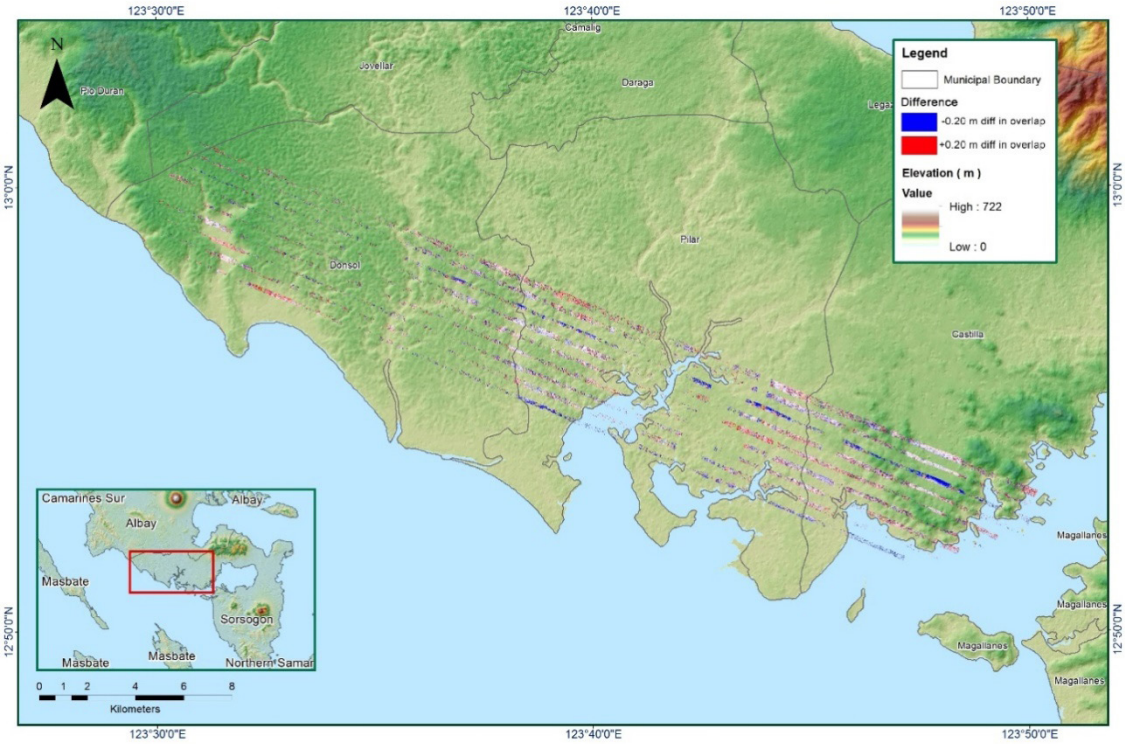


Figure 1.10.7 Elevation difference between flight lines

Flight Area	ALBAY/SORSOGON
Mission Name	**Blk 19K**
Inclusive Flights	7167GC
Range data size	25.5 GB
POS	222 MB
Base data size	7.6 MB
Image	---
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.95
RMSE for East Position (<4.0 cm)	2.13
RMSE for Down Position (<8.0 cm)	7.4
Boresight correction stdev (<0.001deg)	0.000214
IMU attitude correction stdev (<0.001deg)	0.000503
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	30.10 %
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	308
Maximum Height	314.54
Minimum Height	54.37
Classification (# of points)	
Ground	95392016
Low vegetation	93507131
Medium vegetation	131188293
High vegetation	342412034
Building	3934510
Orthophoto	No
Processed by	Victoria Rejuso, Engr. Mark Joshua Salvacion, Engr. Jeffrey Delica

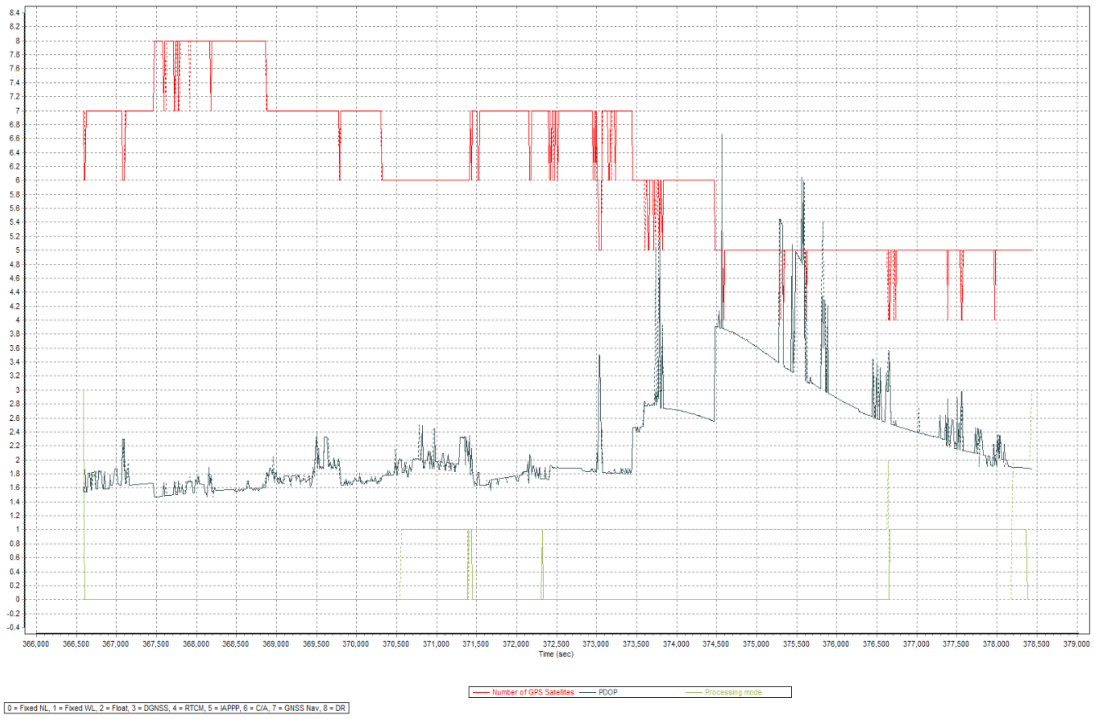


Figure 1.11.1 Solution Status

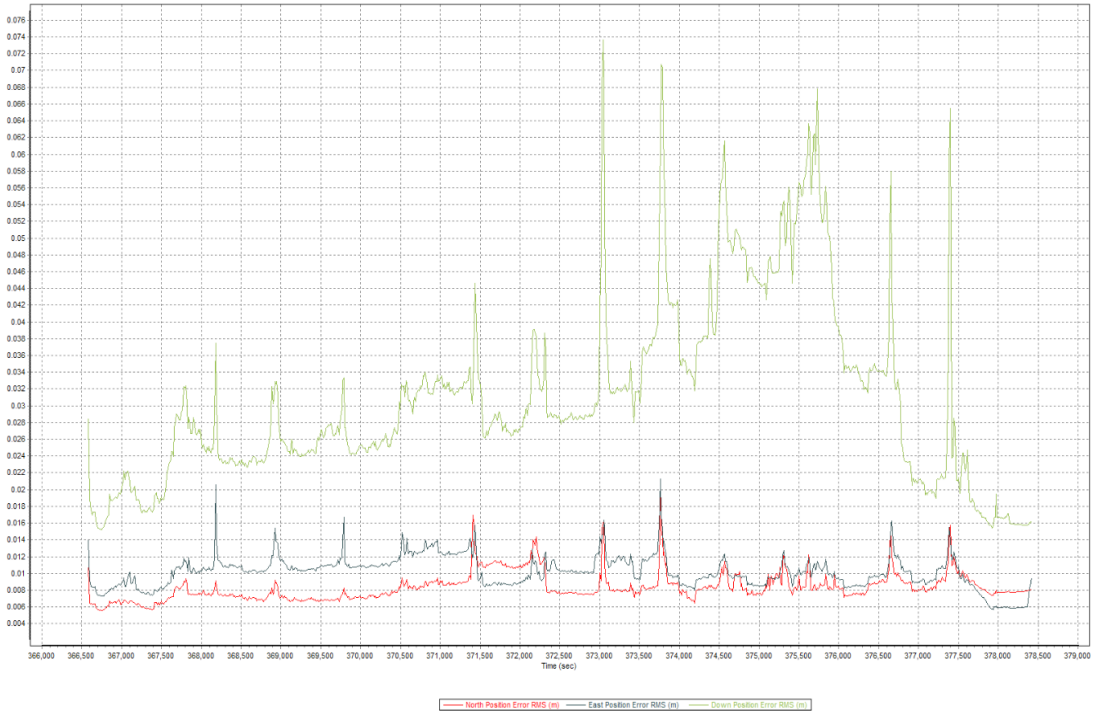


Figure 1.11.2 Smoothed Performance Metric Parameters

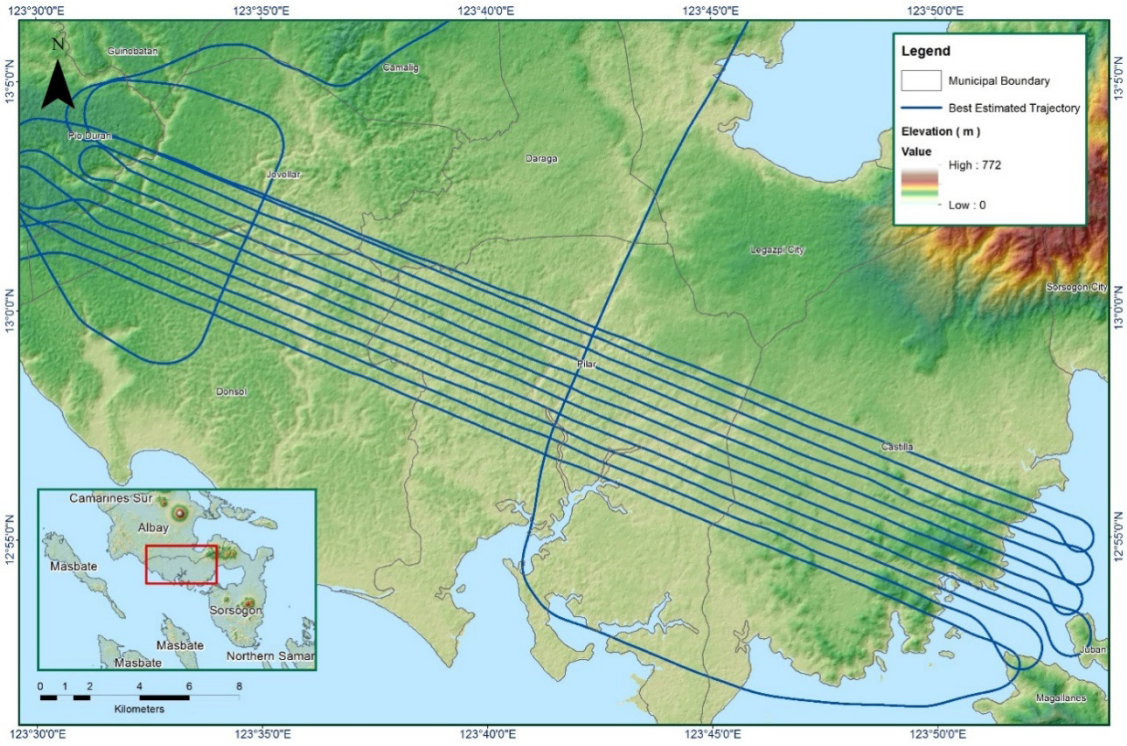


Figure 1.11.3 Best Estimated Trajectory

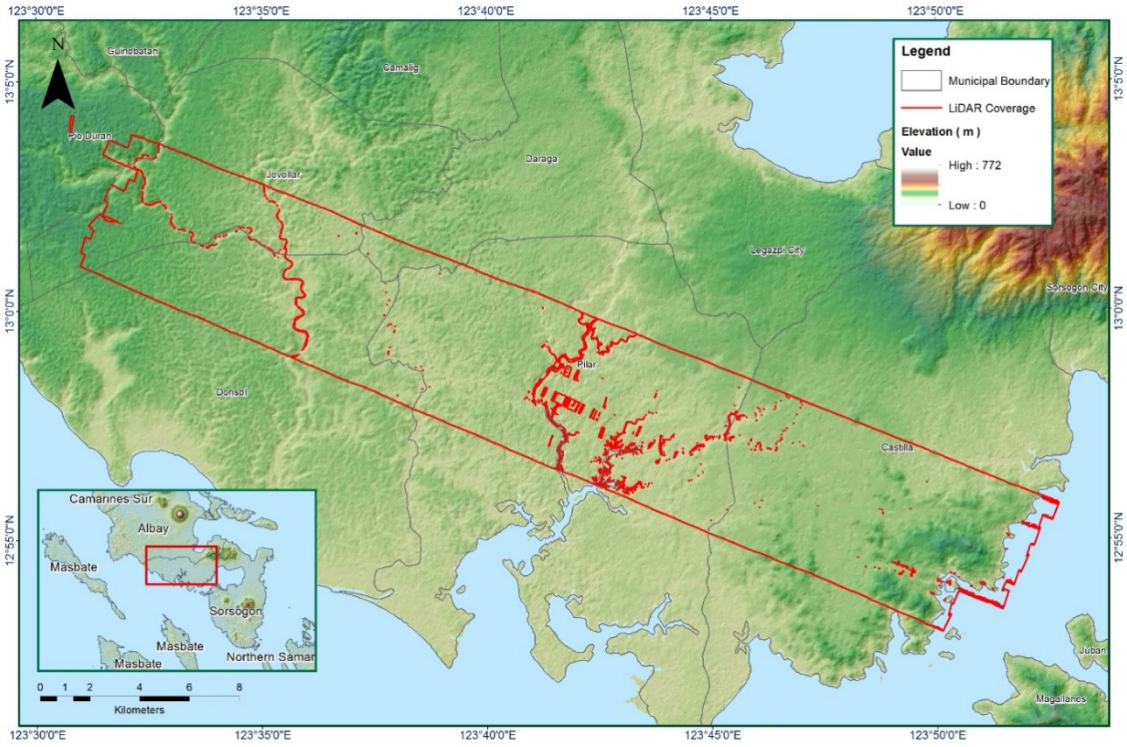


Figure 1.11.4 Coverage of LiDAR data

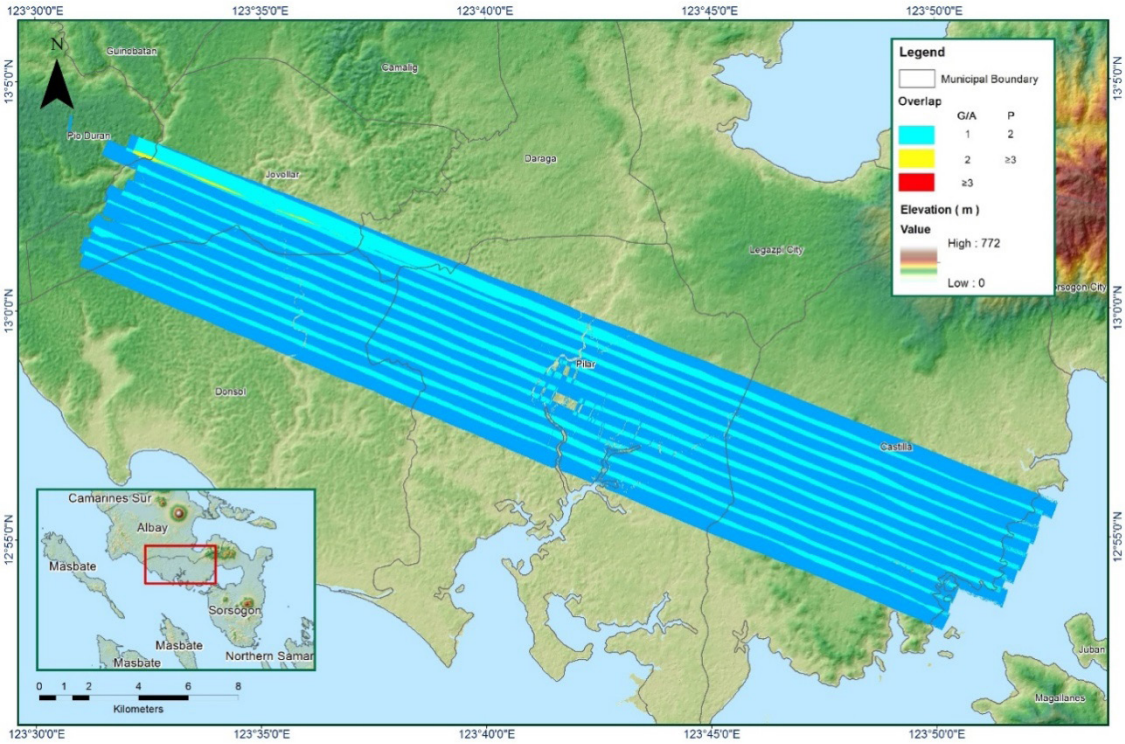


Figure 1.11.5 Image of Data Overlap

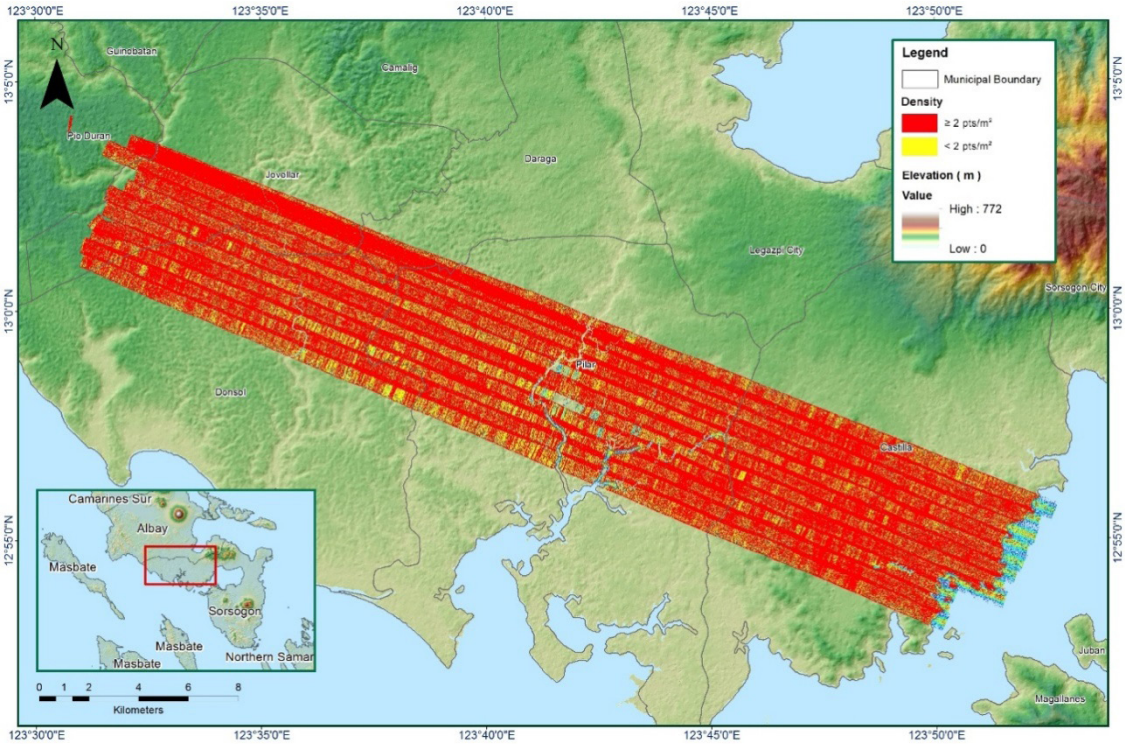


Figure 1.11.6 Density Map

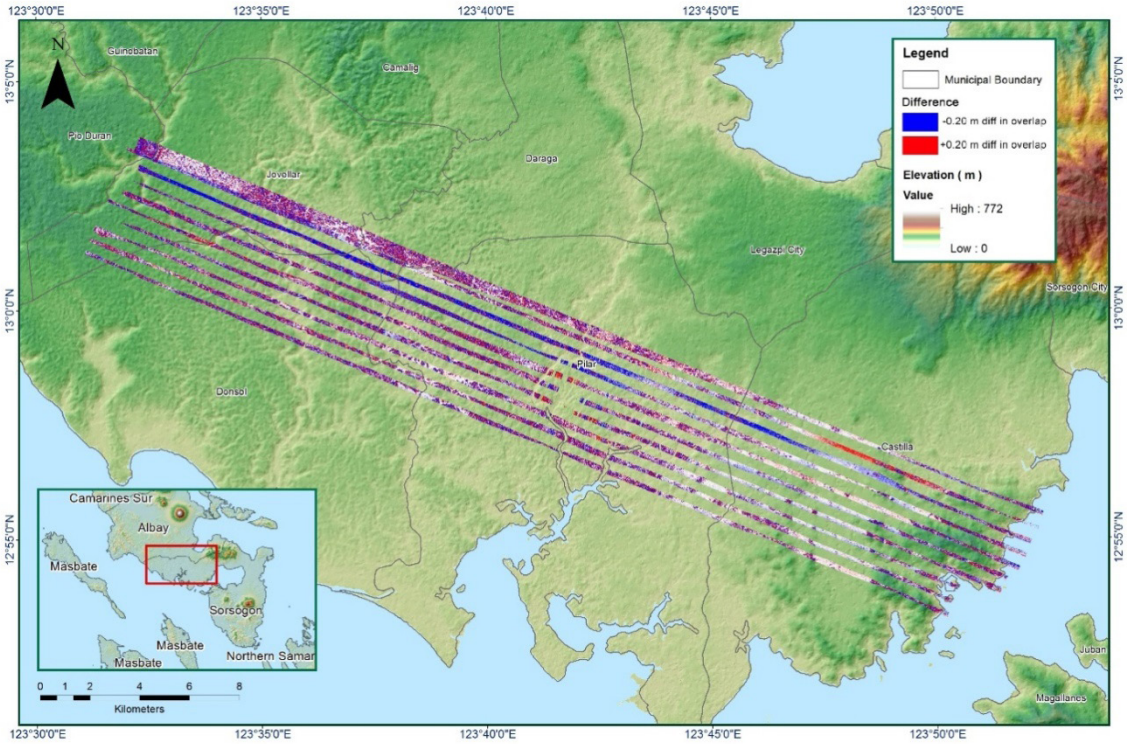


Figure 1.11.7 Elevation difference between flight lines

Flight Area	Albay_Sorsogon
Mission Name	**Blk19J_additional**
Inclusive Flights	7184G
Range data size	10.5 GB
POS data size	128 MB
Base data size	9.75 MB
Image	n/a
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.000479
IMU attitude correction stdev (<0.001deg)	0.004047
GPS position stdev (<0.01m)	0.0153
Minimum % overlap (>25)	45.30
Ave point cloud density per sq.m. (>2.0)	3.84
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	52
Maximum Height	436.95 m
Minimum Height	73.94 m
Classification (# of points)	
Ground	4,231,548
Low vegetation	2,621,692
Medium vegetation	5,286,639
High vegetation	23,047,731
Building	126,531
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Christy Lubiano, Engr. Melissa Fernandez

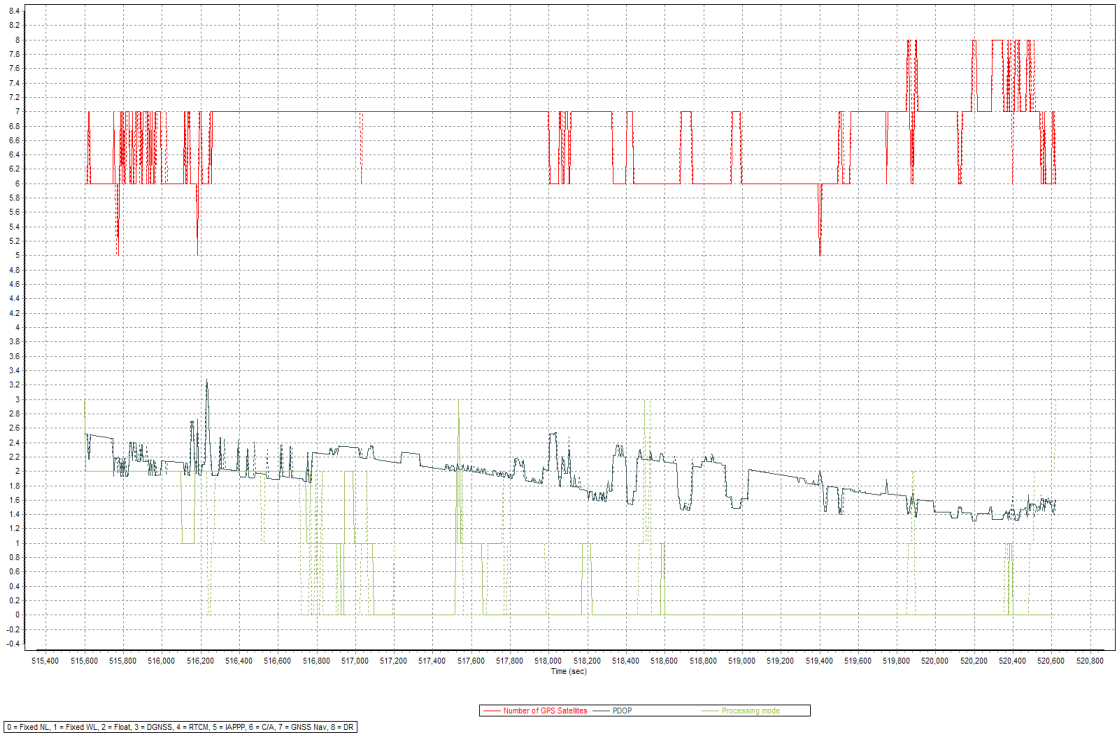


Figure 1.12.1. Solution Status

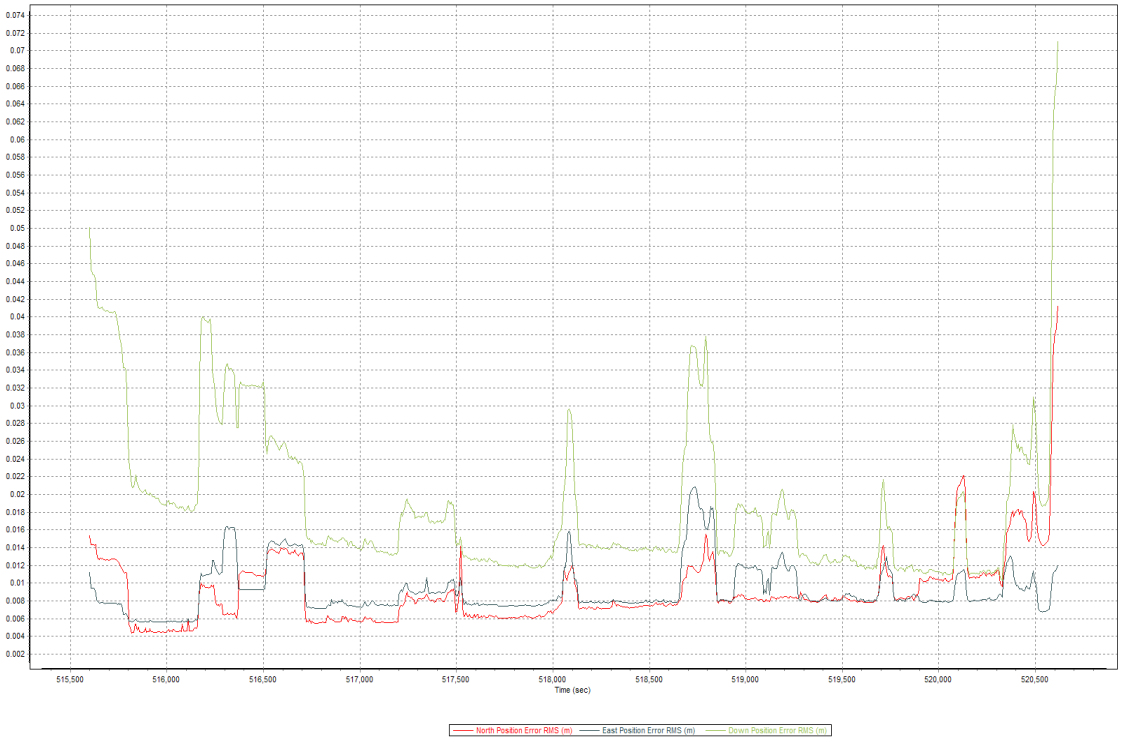


Figure 1.12.2. Smoothed Performance Metric Parameters

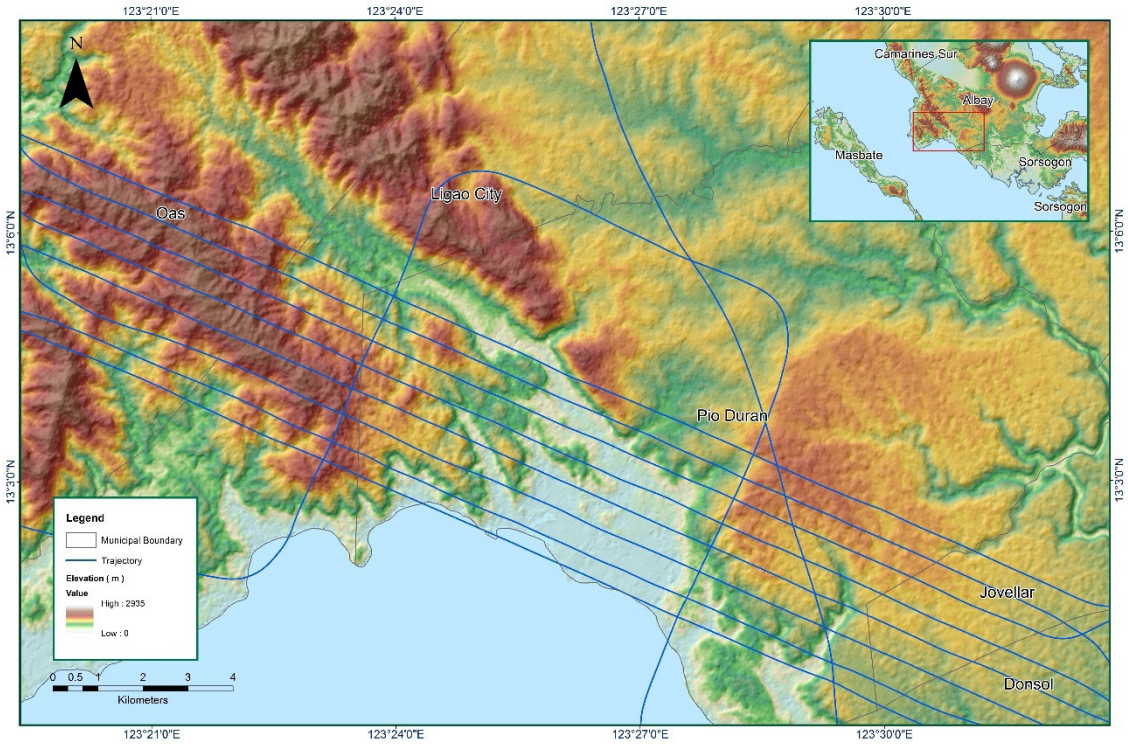


Figure 1.12.3. Best Estimated Trajectory

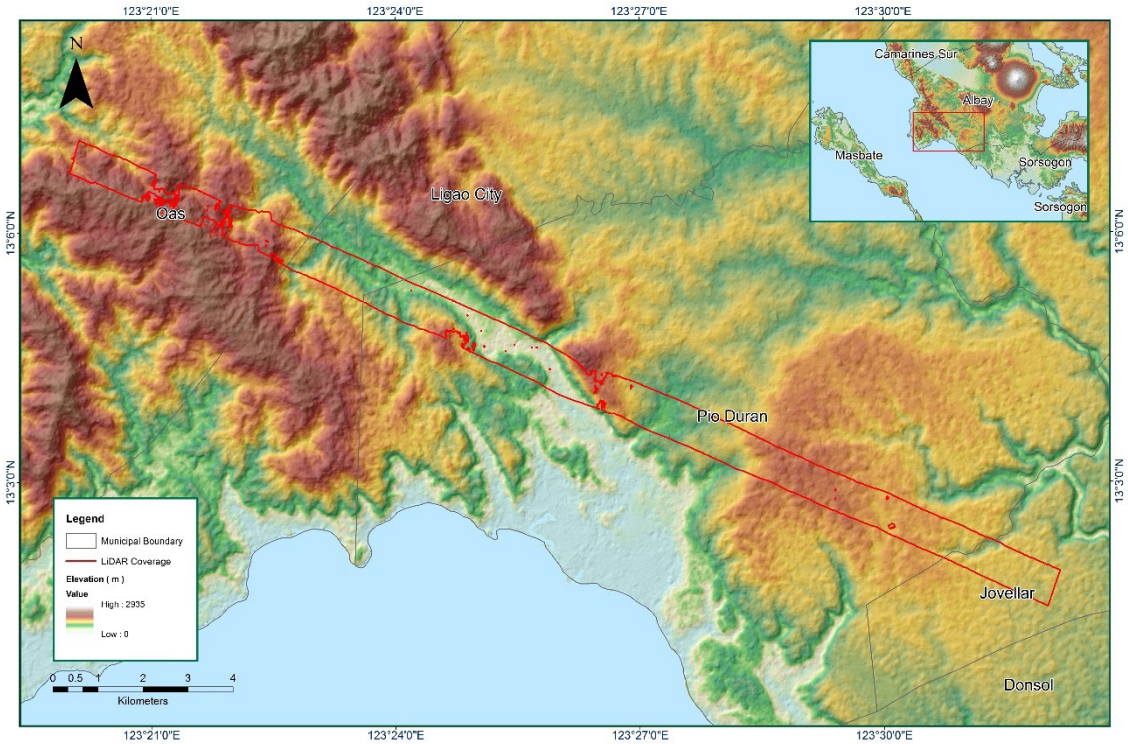


Figure 1.12.4. Coverage of LiDAR Data

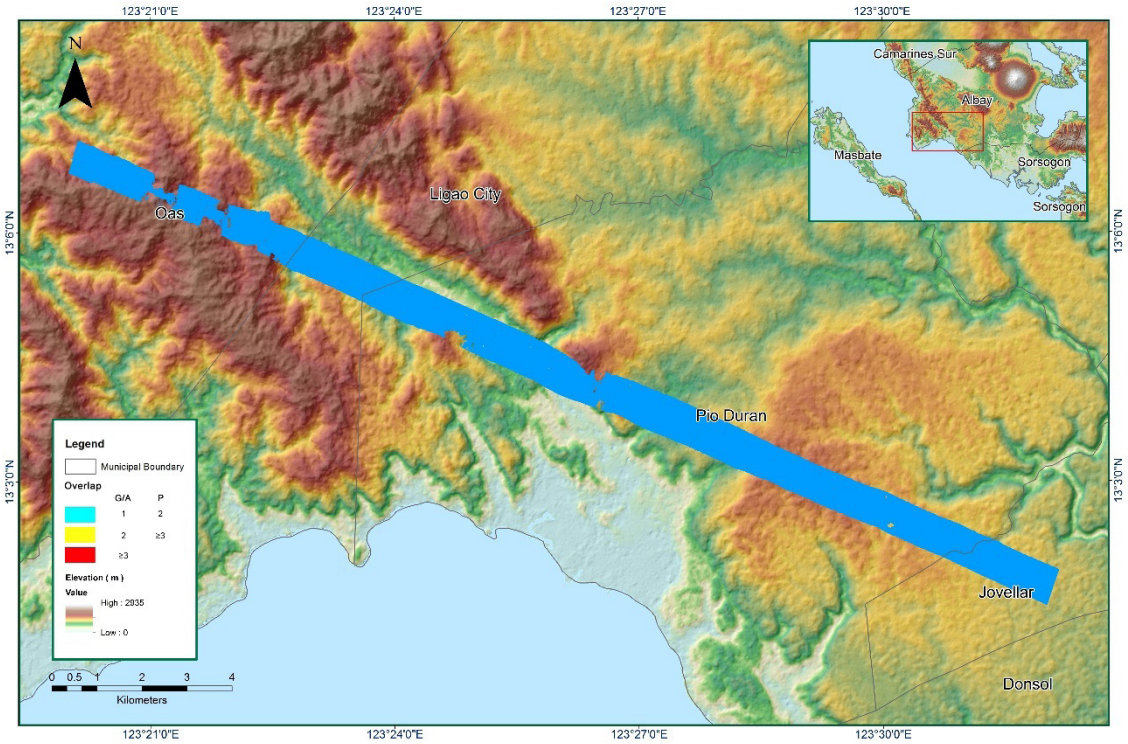


Figure 1.12.5. Image of data overlap

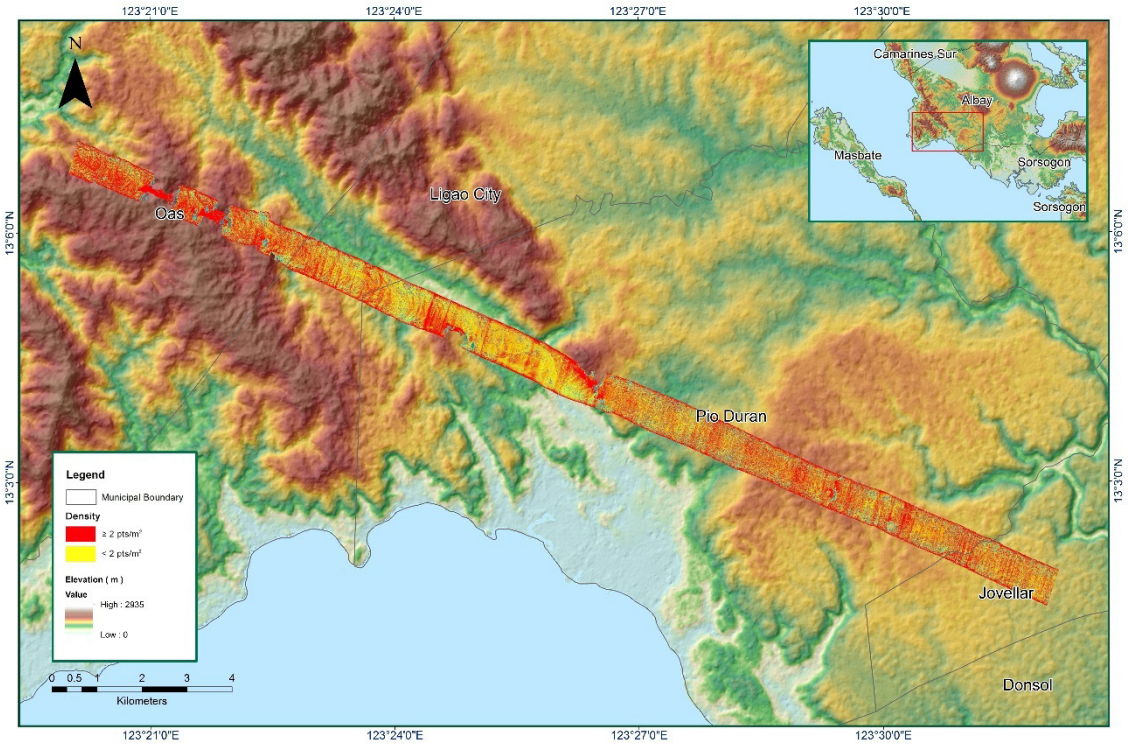


Figure 1.12.6. Density map of merged LiDAR data

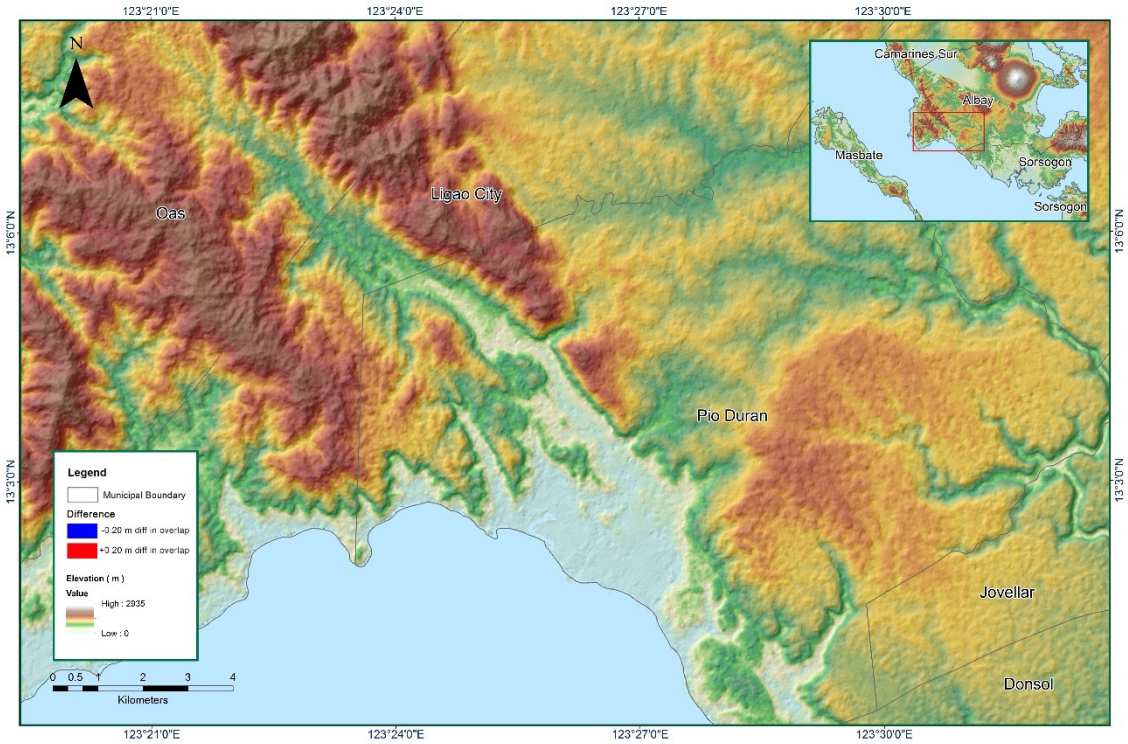


Figure 1.12.7. Elevation difference between flight lines

Flight Area	Albay-Sorsogon Reflights
Mission Name	Blk 19Q
Inclusive Flights	3825G
Range data size	19.1 GB
POS data size	176 MB
Base data size	6.33 MB
Image	4.37 MB
Transfer date	March 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.925
RMSE for East Position (<4.0 cm)	1.005
RMSE for Down Position (<8.0 cm)	4.500
Boresight correction stdev (<0.001deg)	0.000491
IMU attitude correction stdev (<0.001deg)	0.002958
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	47.44 %
Ave point cloud density per sq.m. (>2.0)	7.42
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	89
Maximum Height	224.93 m
Minimum Height	53.78 m
Classification (# of points)	
Ground	44,126,598
Low vegetation	26,703,296
Medium vegetation	147,927,046
High vegetation	2377,320,296
Building	320,912
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Engr. Krisha Marie Bautista

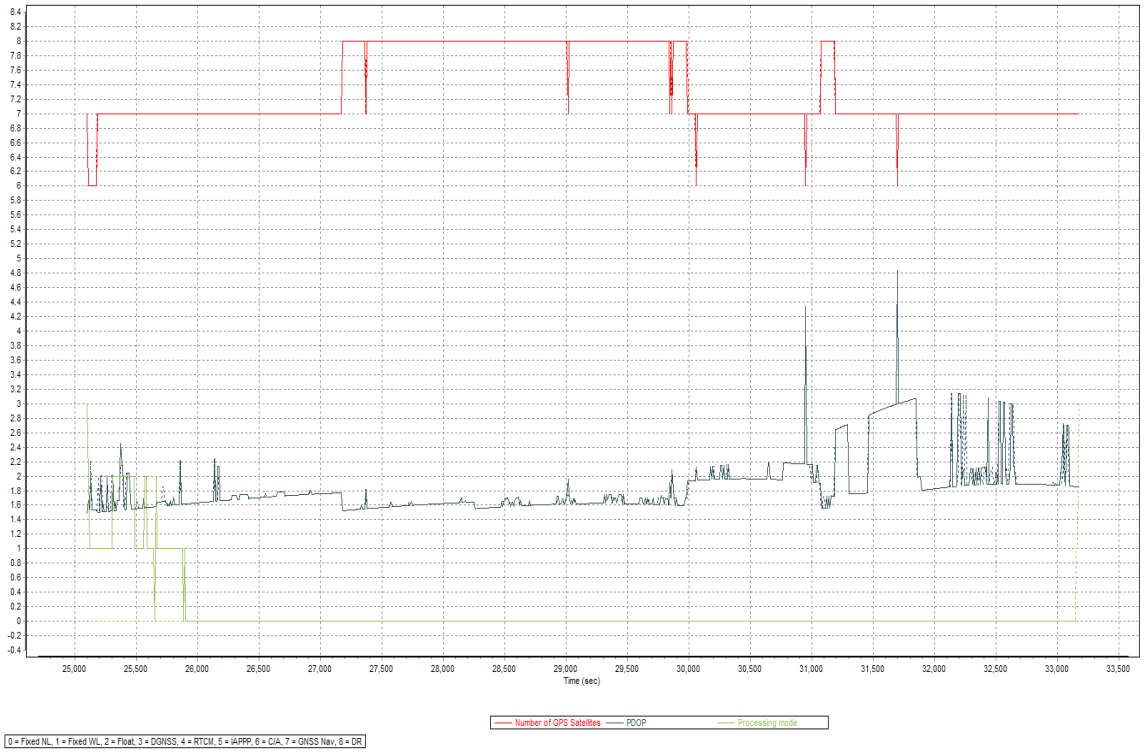


Figure 1.13.1. Solution Status

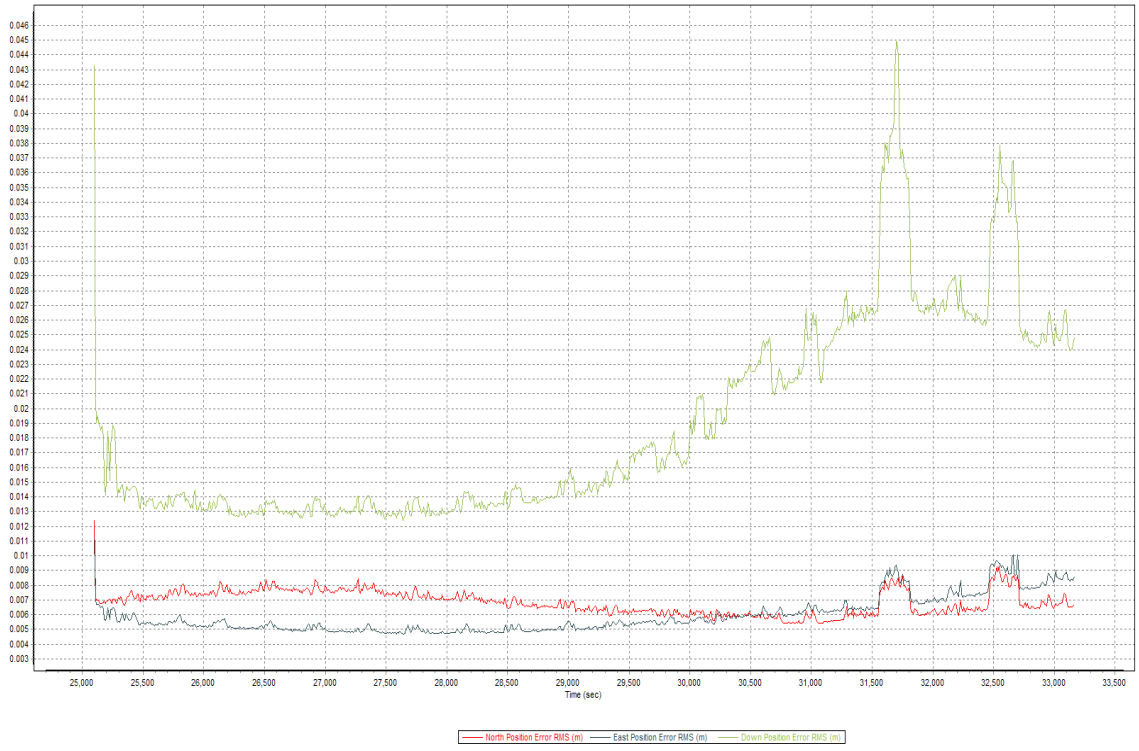


Figure 1.13.2. Smoothed Performance Metric Parameters

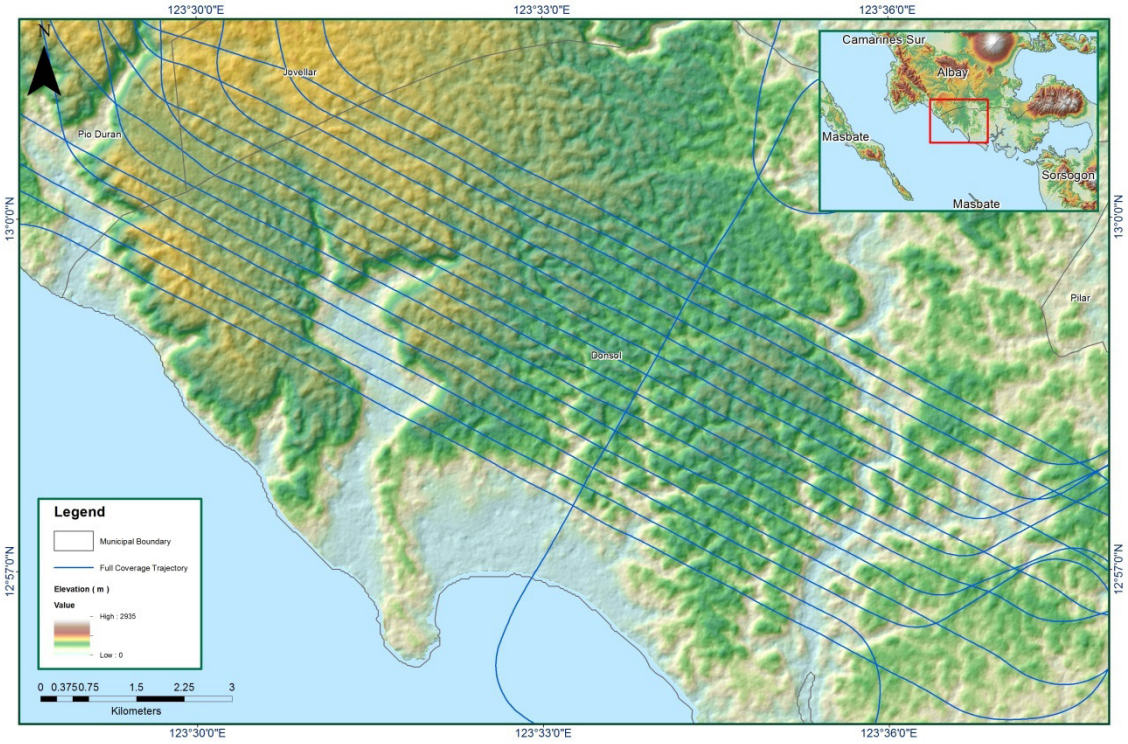


Figure 1.13.3. Best Estimated Trajectory

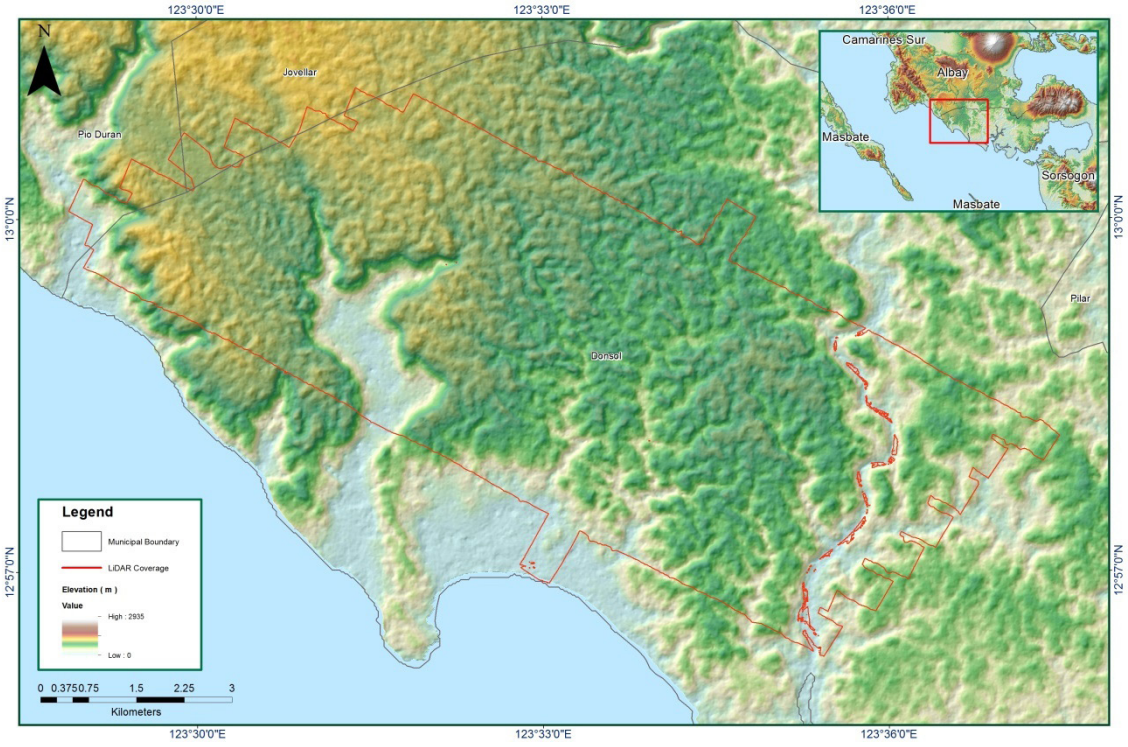


Figure 1.13.4. Coverage of LiDAR Data

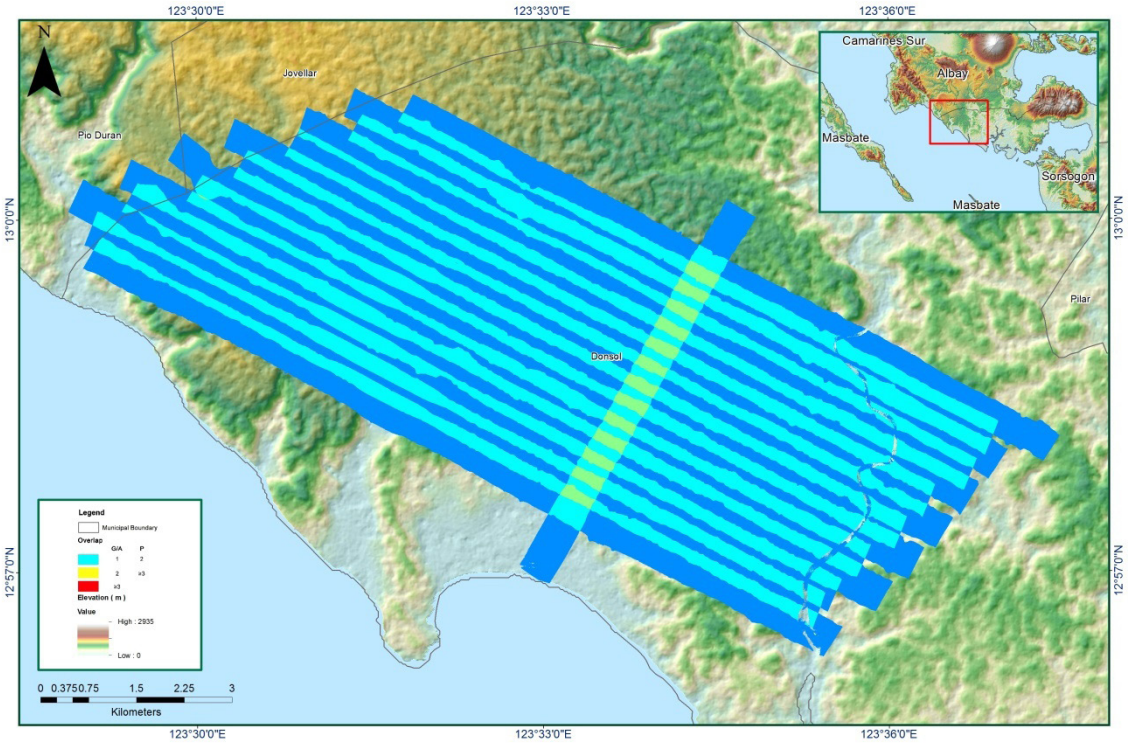


Figure 1.13.5. Image of data overlap

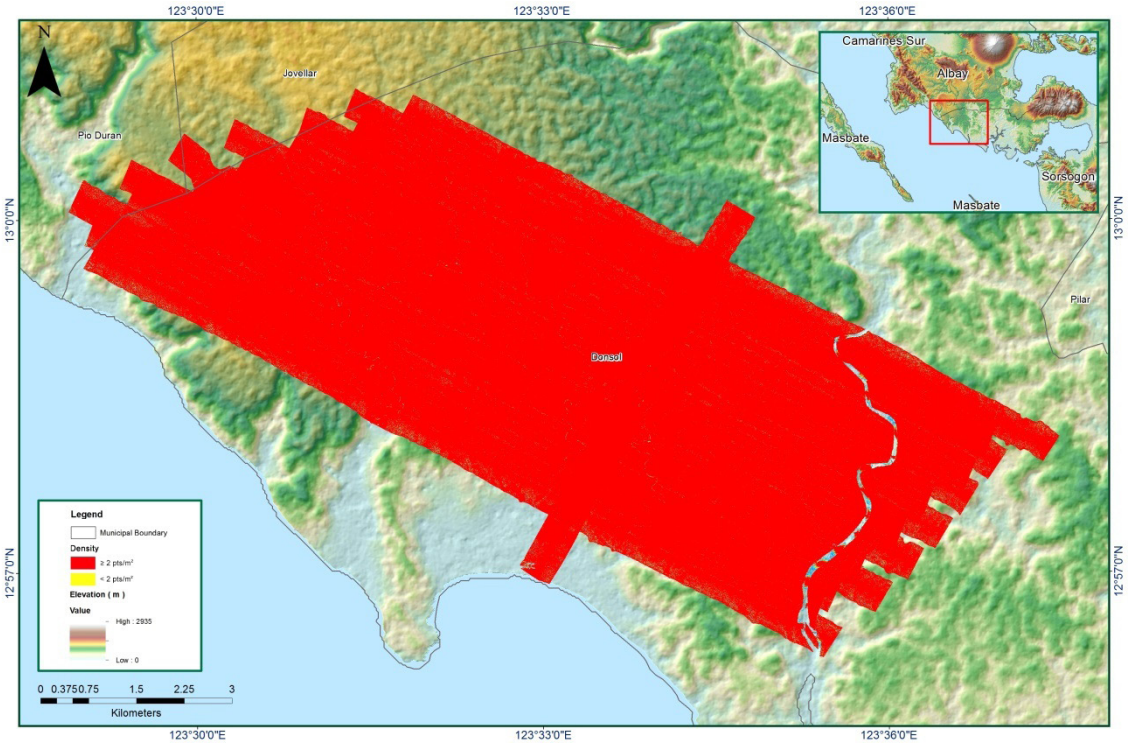


Figure 1.13.6. Density map of merged LiDAR data

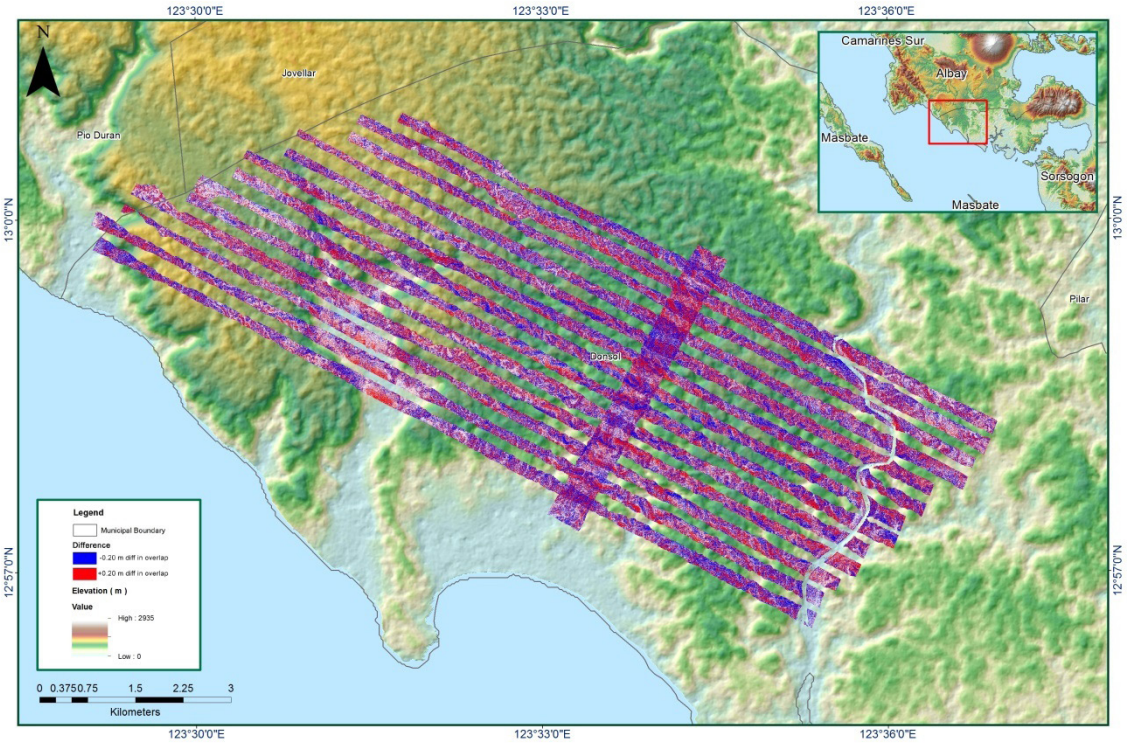


Figure 1.13.7. Elevation difference between flight lines

Flight Area	Albay-Sorsogon Reflights
Mission Name	Blk 19F
Inclusive Flights	3829G
Range data size	14 GB
POS data size	130 MB
Base data size	11.7 MB
Image	26.9 MB
Transfer date	March 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.200
RMSE for East Position (<4.0 cm)	0.935
RMSE for Down Position (<8.0 cm)	3.850
Boresight correction stdev (<0.001deg)	0.000304
IMU attitude correction stdev (<0.001deg)	0.001298
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	43.21 %
Ave point cloud density per sq.m. (>2.0)	6.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	129
Maximum Height	420.06 m
Minimum Height	92.20 m
Classification (# of points)	
Ground	68,358,091
Low vegetation	53,663,200
Medium vegetation	194,700,552
High vegetation	322,271,950
Building	1,037,318
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Edgardo Gubatanga, Jr., Maria Tamsyn Mala-banan, Ryan James Nicholai Dizon

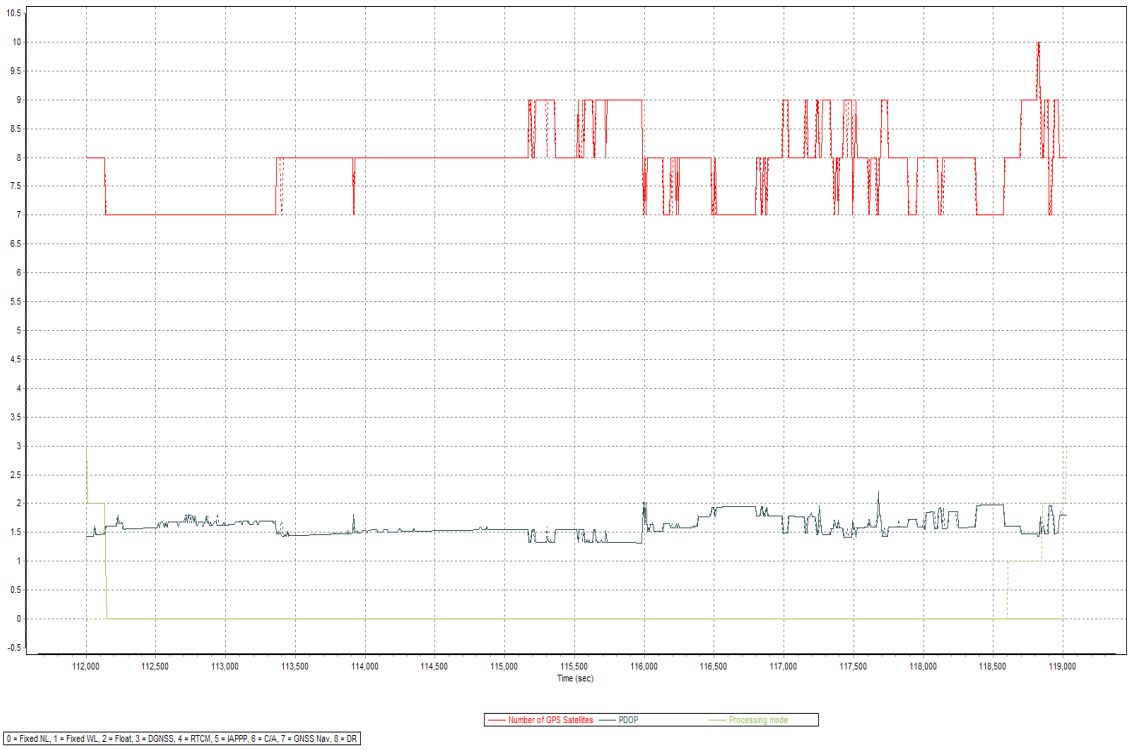


Figure 1.14.1. Solution Status

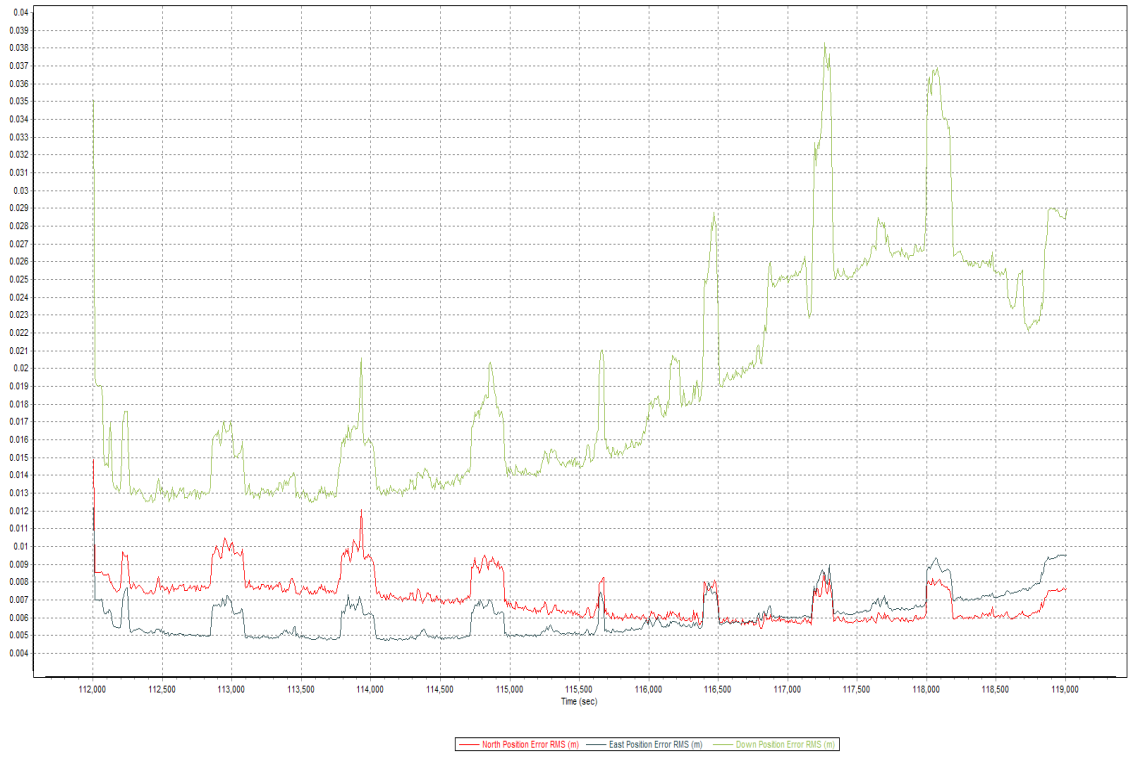


Figure 1.14.2. Smoothed Performance Metric Parameters

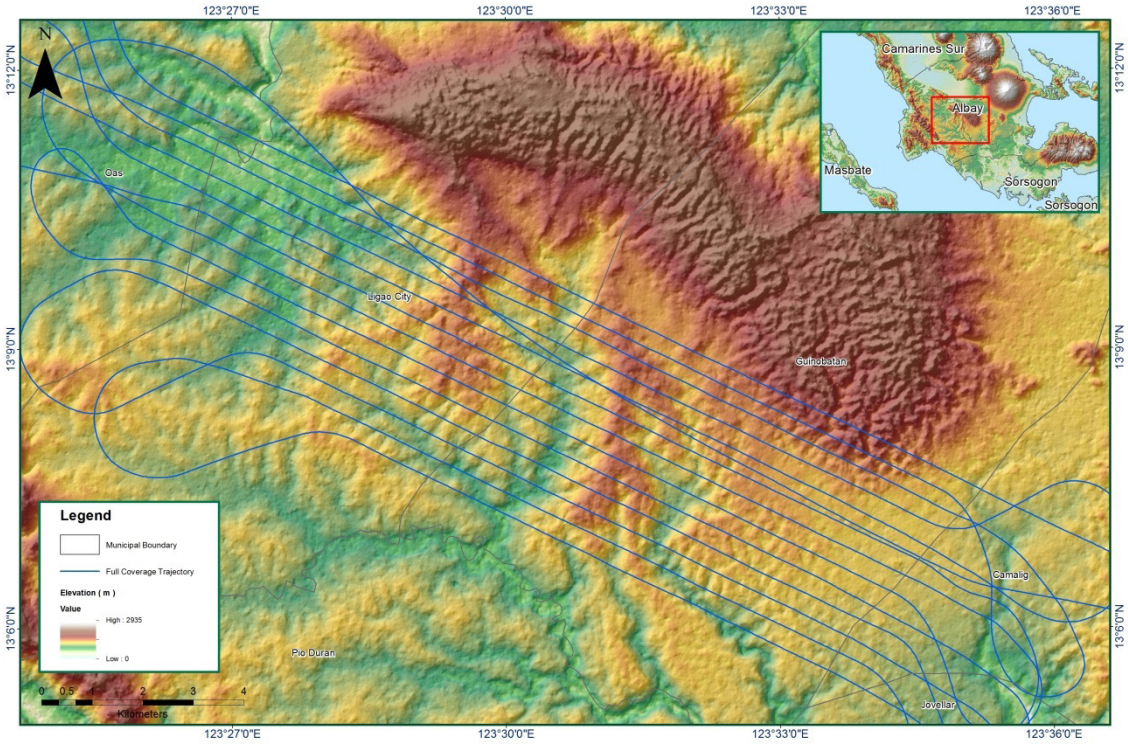


Figure 1.14.3. Best Estimated Trajectory

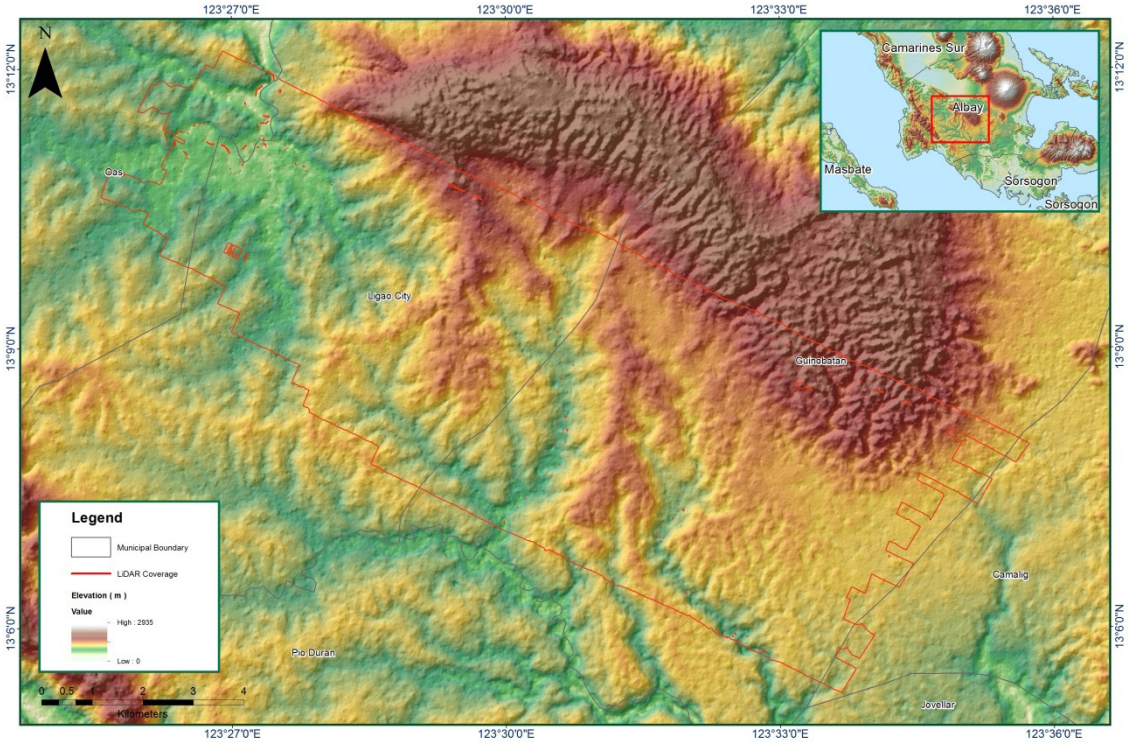


Figure 1.14.4. Coverage of LiDAR Data

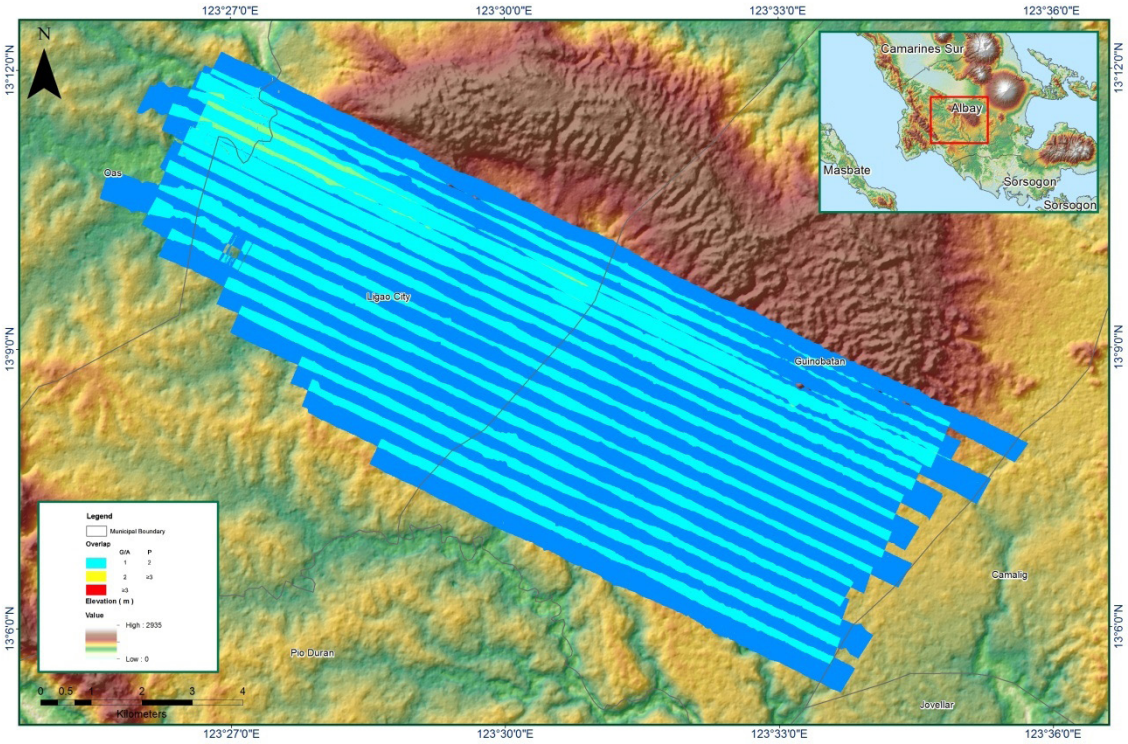


Figure 1.14.5. Image of data overlap

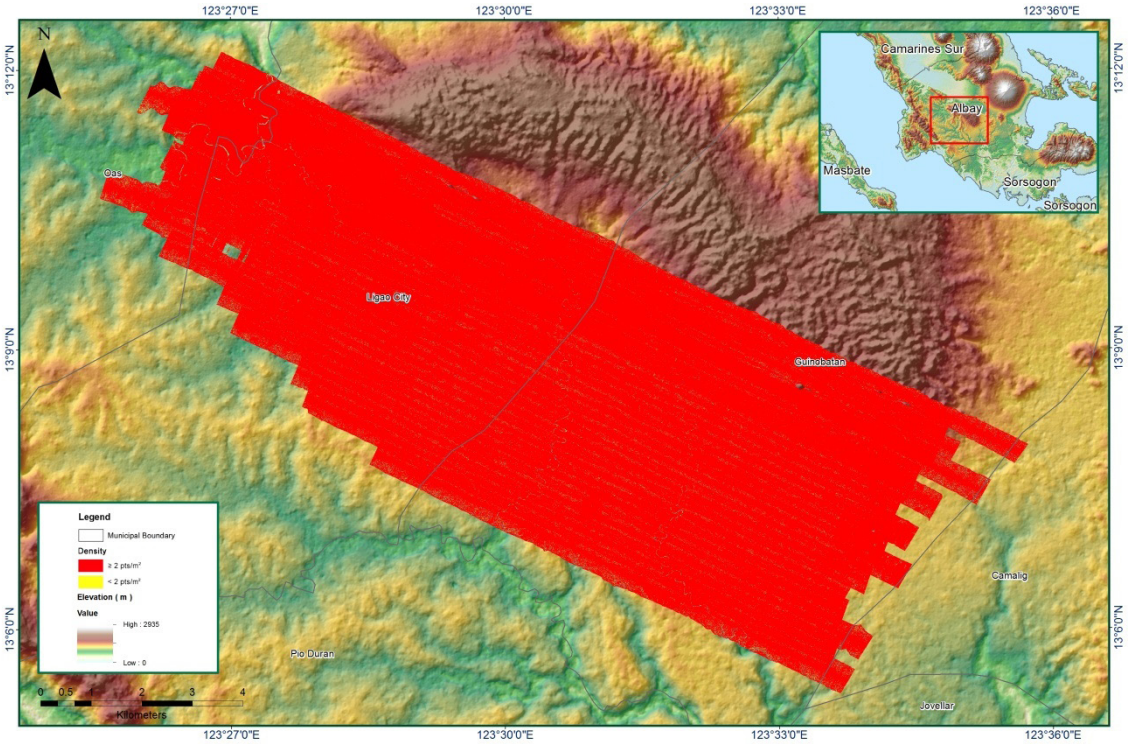


Figure 1.14.6. Density map of merged LiDAR data

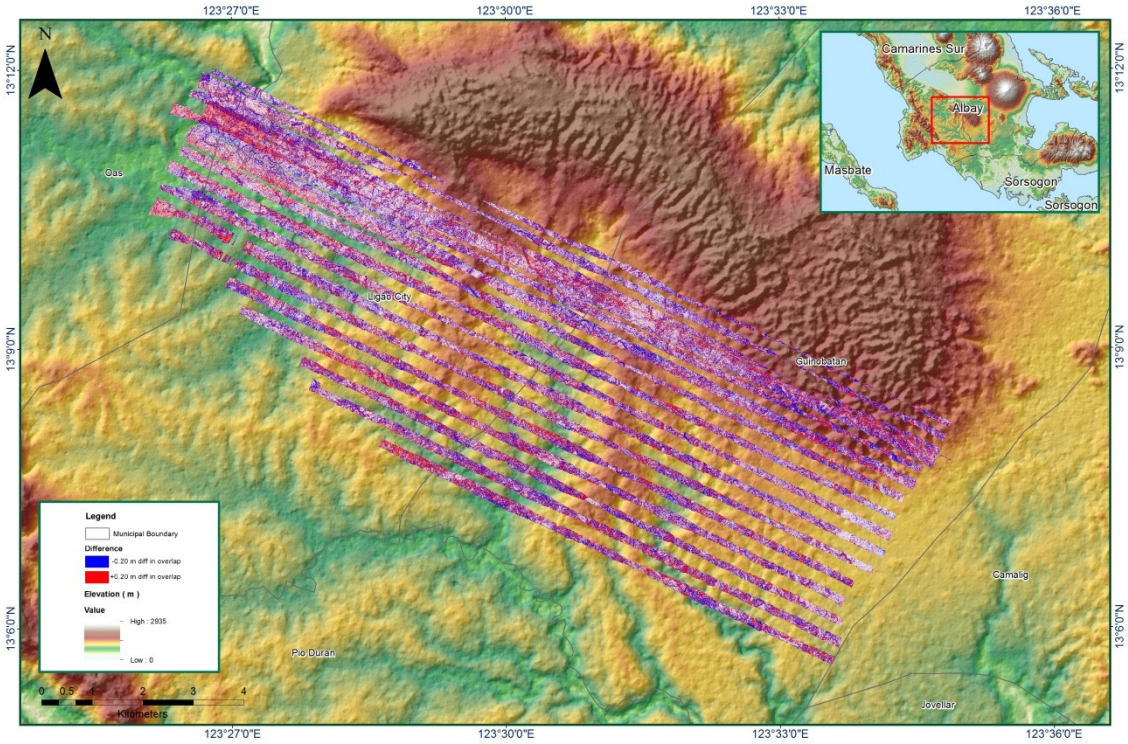


Figure 1.14.7. Elevation difference between flight lines

Flight Area	Albay-Sorsogon Reflights
Mission Name	Blk 19D
Inclusive Flights	3843G
Range data size	39.2 GB
POS data size	274 MB
Base data size	9.29 MB
Image	88.1 MB
Transfer date	March 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.680
RMSE for East Position (<4.0 cm)	1.420
RMSE for Down Position (<8.0 cm)	4.950
Boresight correction stdev (<0.001deg)	0.002121
IMU attitude correction stdev (<0.001deg)	0.005422
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	58.61 %
Ave point cloud density per sq.m. (>2.0)	7.13
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	247
Maximum Height	492.34 m
Minimum Height	50.88 m
Classification (# of points)	
Ground	99,373,196
Low vegetation	71,006,486
Medium vegetation	329,312,805
High vegetation	556,635,815
Building	1,563,670
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Edgardo Gubatanga, Jr., Maria Tamsyn Malabanan, Ryan James Nicholai Dizon

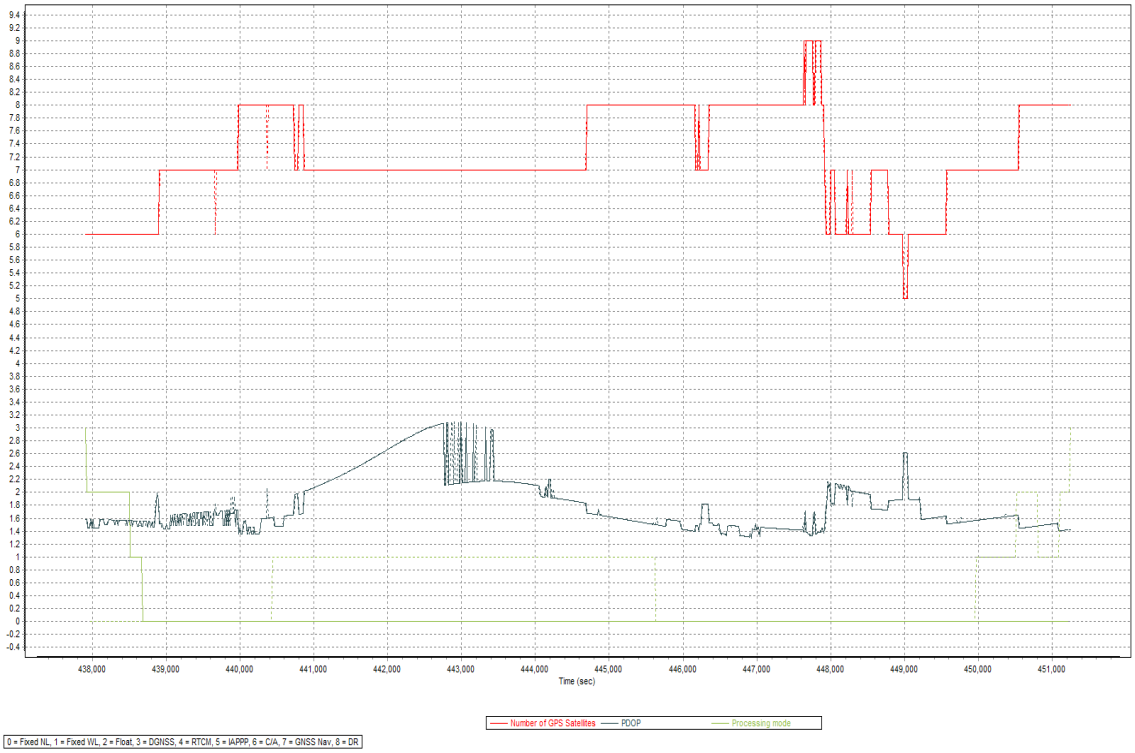


Figure 1.15.1. Solution Status

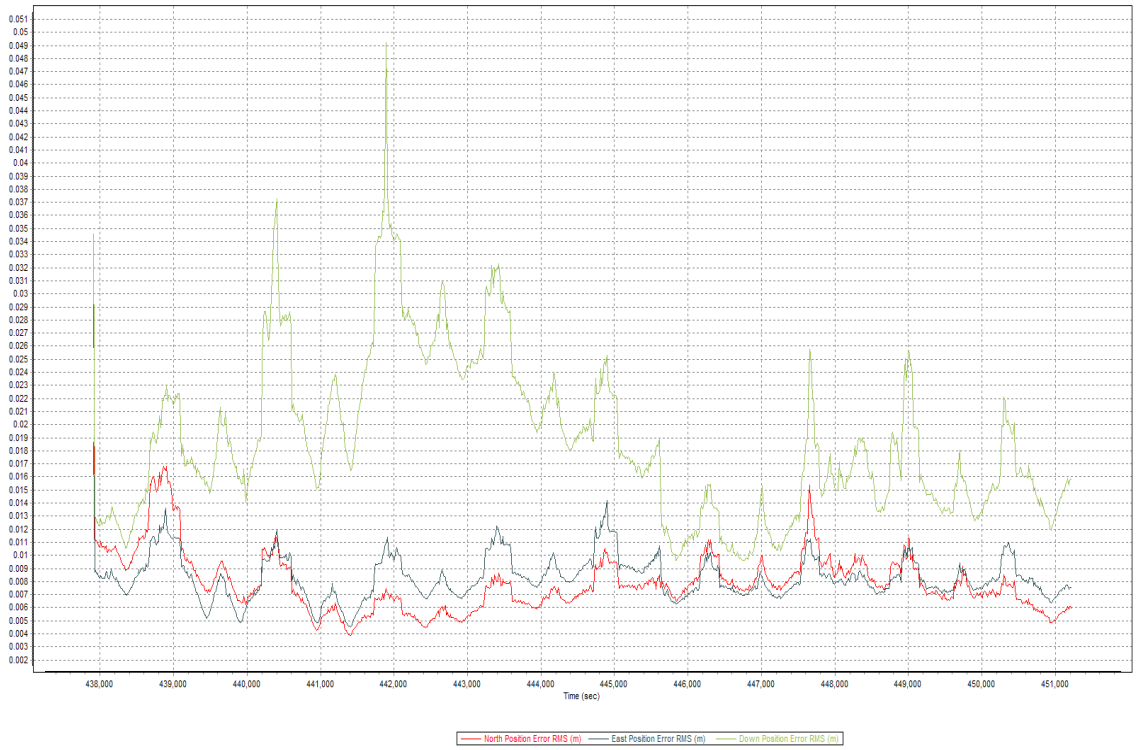


Figure 1.15.2. Smoothed Performance Metric Parameters

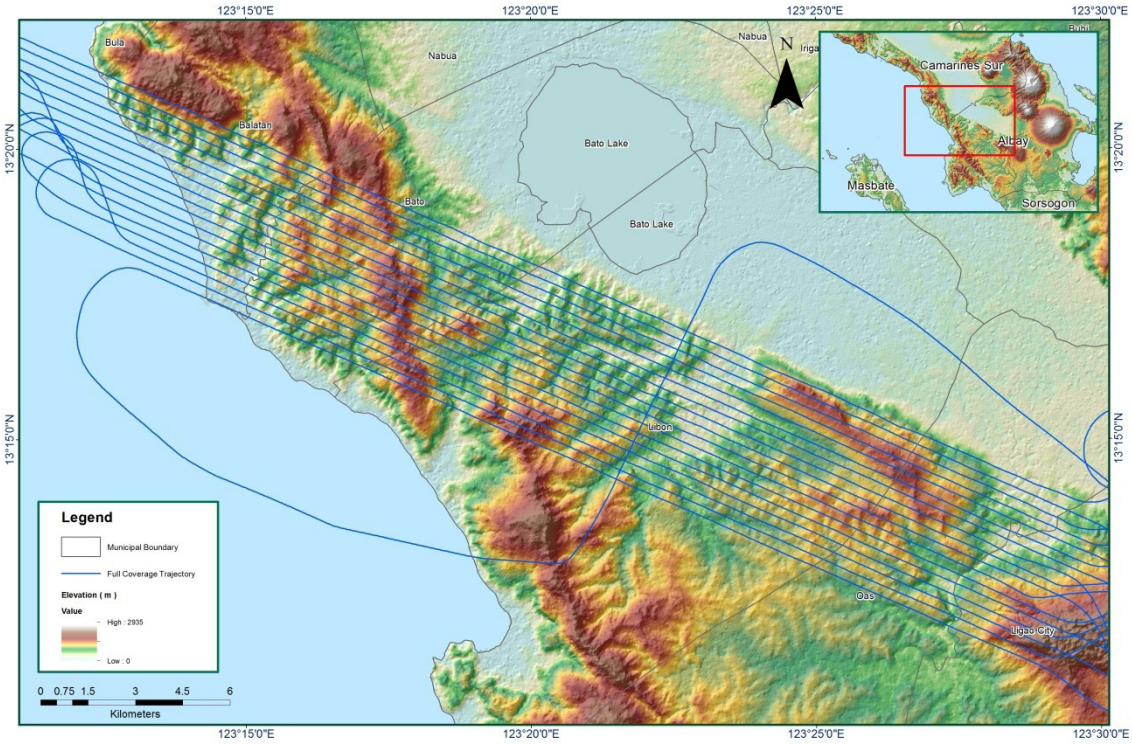


Figure 1.15.3. Best Estimated Trajectory

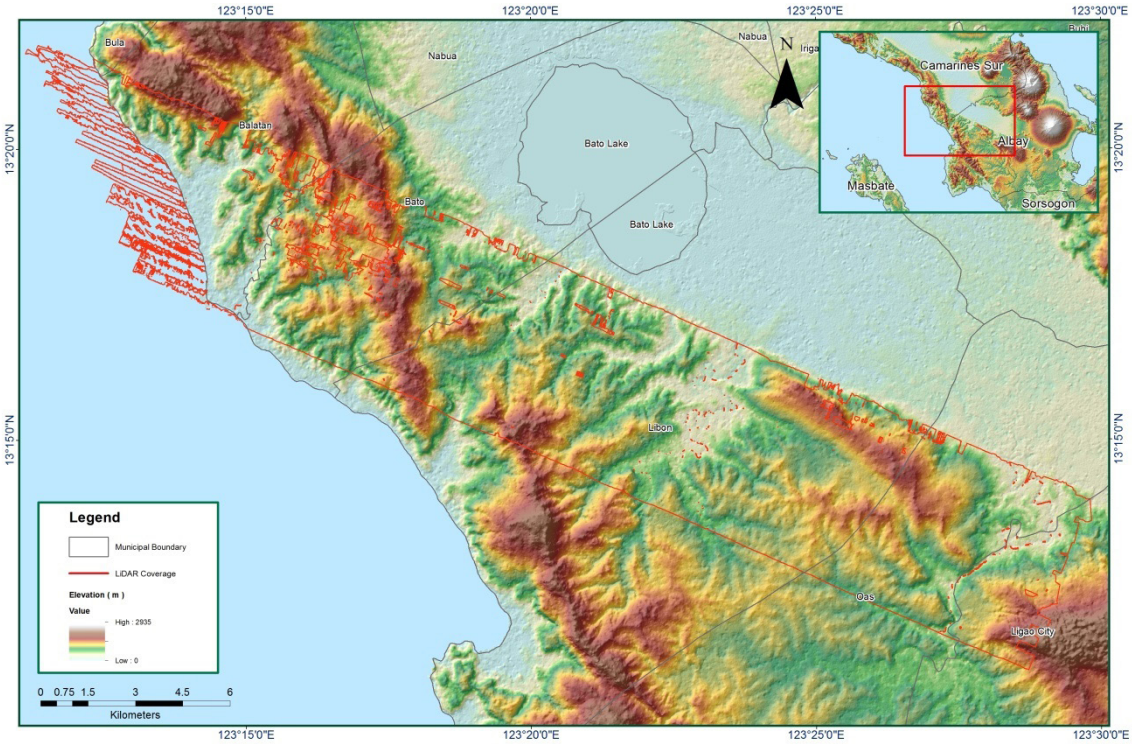


Figure 1.15.4. Coverage of LiDAR Data

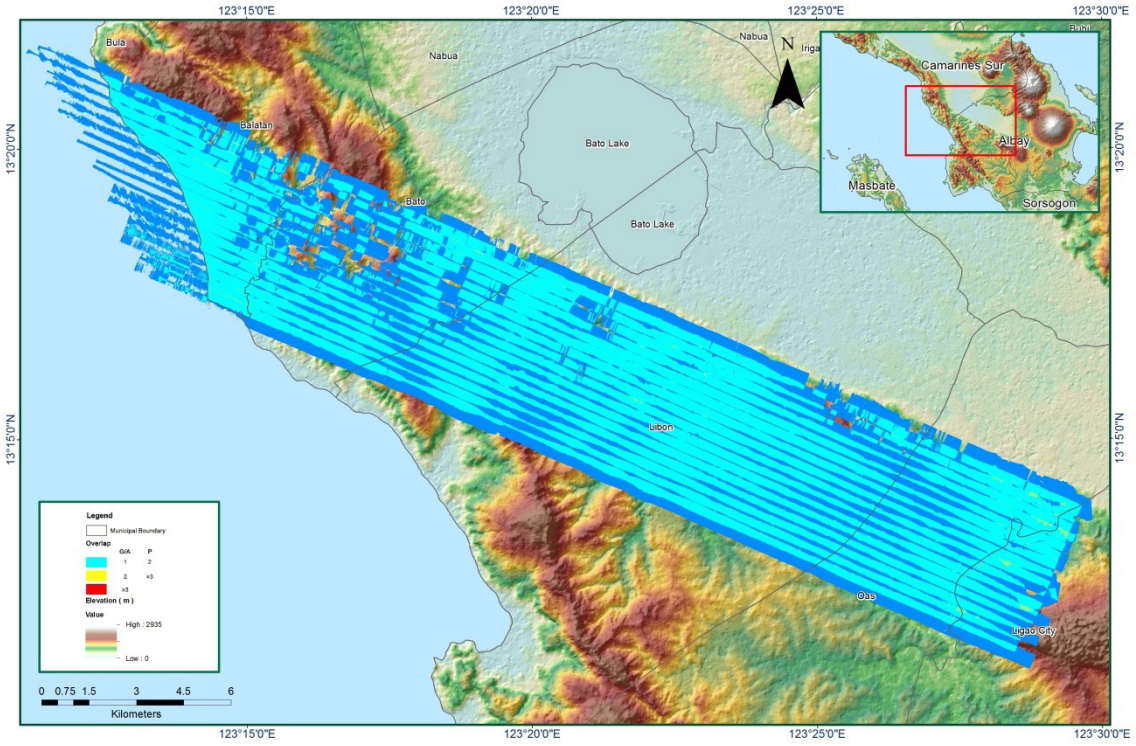


Figure 1.15.5. Image of data overlap

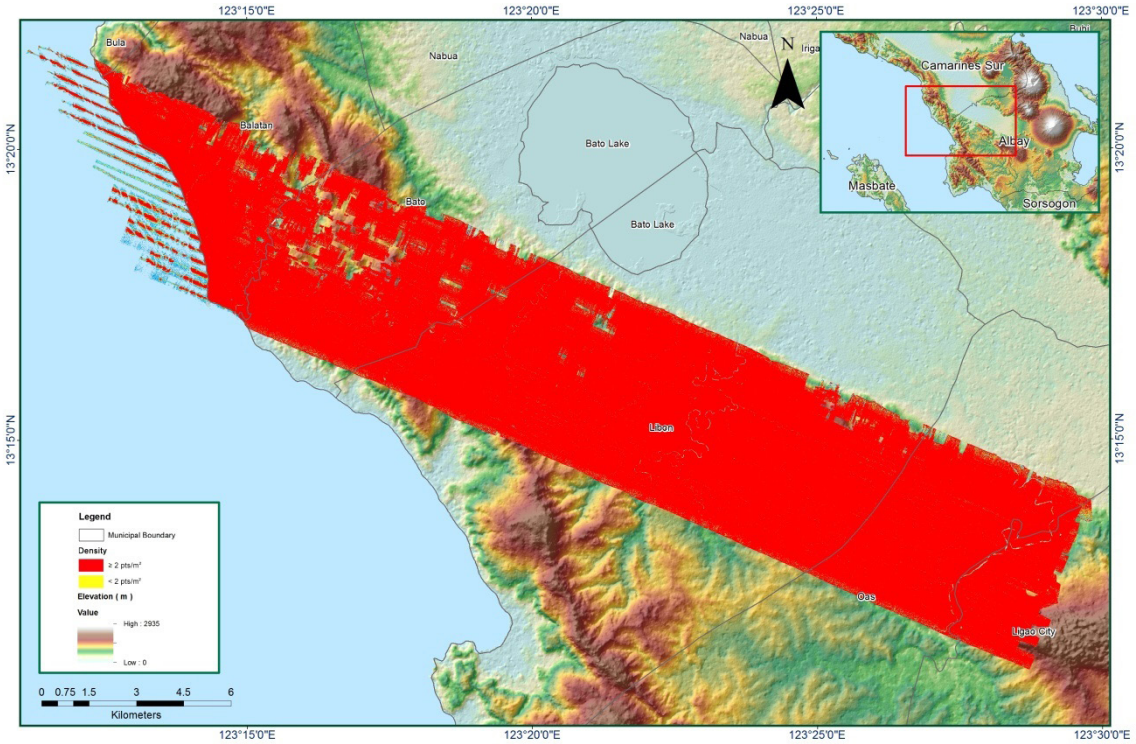


Figure 1.15.6. Density map of merged LiDAR data

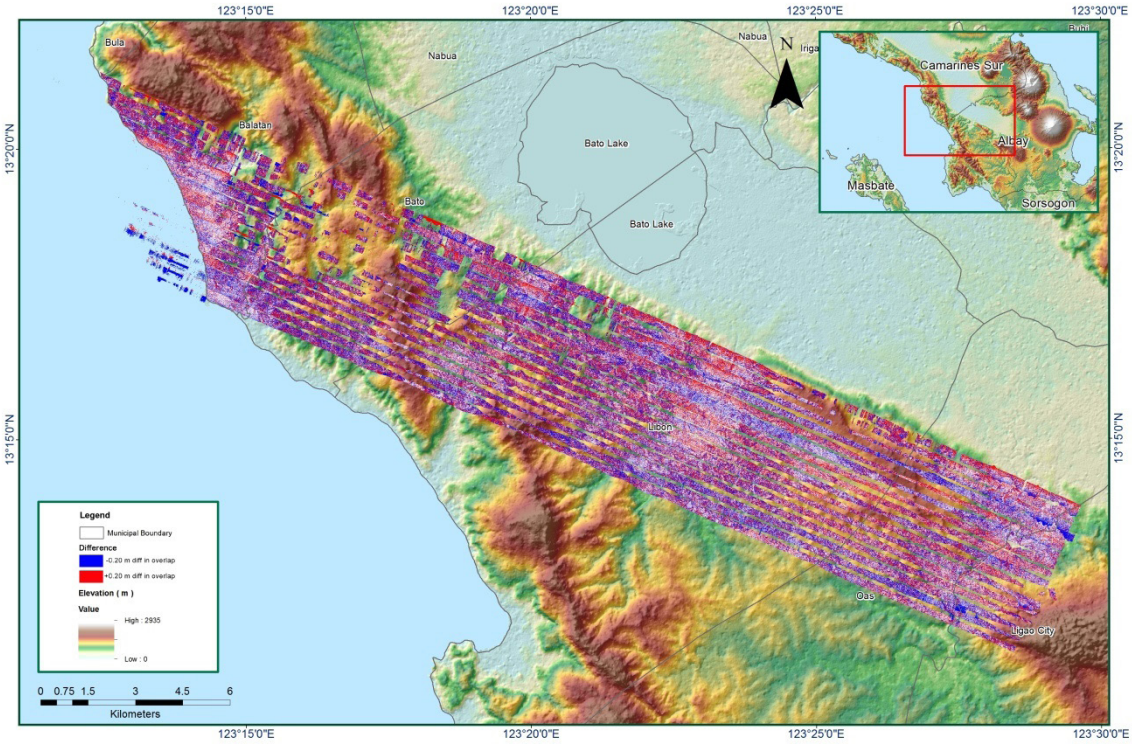


Figure 1.15.7. Elevation difference between flight lines

ANNEX 9. Ogod Model Basin Parameters

Basin Number	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
W140	26.945	35.867	0	86.181	0.01667	Discharge	7.0639	0.00001	Ratio to Peak	1.00000
W150	9.747	35.285	0	0.01667	0.01667	Discharge	8.7593	0.00001	Ratio to Peak	1.00000
W160	49.154	37.006	0	6.9067	17.42700	Discharge	1.1069	0.00001	Ratio to Peak	1.00000
W170	48.712	56.145	0	7.7764	12.75400	Discharge	7.0401	0.00001	Ratio to Peak	1.00000
W180	53.824	52.688	0	7.9485	109.2000	Discharge	4.0562	0.00001	Ratio to Peak	1.00000
W190	1.308	88.591	0	4.2437	3.01110	Discharge	11.467	1.00000	Ratio to Peak	0.43044
W200	1.068	49.881	0	5.0128	16.51700	Discharge	2.57	0.00001	Ratio to Peak	1.00000
W210	18.346	98.170	0	3.0015	2.69910	Discharge	6.6188	1.00000	Ratio to Peak	0.44304
W220	15.435	86.905	0	4.542	2.95220	Discharge	5.9702	1.00000	Ratio to Peak	0.40147
W230	22.352	99.000	0	5.1873	0.82974	Discharge	0.78562	0.26572	Ratio to Peak	0.43778
W240	0.001	99.000	0	0.12861	1.47450	Discharge	3.7646	1.00000	Ratio to Peak	1.00000
W250	19.272	98.942	0	5.2274	1.49570	Discharge	2.8626	0.49536	Ratio to Peak	0.40994
W260	14.521	82.063	0	2.378	11.58400	Discharge	6.8346	1.00000	Ratio to Peak	0.66667

ANNEX 10. Ogod Model Reach Parameters

Muskingum-Cunge Channel Routing							
Reach Number	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	Side Slope
R40	Automatic Fixed Interval	10804.0	0.00060	0.00010	Trapezoid	171.14	1
R50	Automatic Fixed Interval	13513.0	0.00366	0.02114	Trapezoid	171.14	1
R100	Automatic Fixed Interval	5357.5	0.00237	0.40967	Trapezoid	171.14	1
R110	Automatic Fixed Interval	5708.0	0.00104	0.00010	Trapezoid	171.14	1
R120	Automatic Fixed Interval	2848.7	0.00133	0.00010	Trapezoid	171.14	1
R130	Automatic Fixed Interval	7847.7	0.00040	0.00353	Trapezoid	171.14	1

ANNEX 11. Educational Institutions Affected in Ogod Floodplain

Albay				
Jovellar				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Bautista Elementary School	Bautista			Medium
Daycare Center Bautista	Bautista			
Estrella Elementary School	Estrella		Low	Low
Lilibdon Elementary School	Maogog			
Maogog Elementary School	Maogog			
Old Day Care Center Maogog	Maogog			
Daycare Center Sitio Medalla	San Vicente			
San Vicente School	San Vicente			
Daycare Center San Vicente	Sinagaran	High	High	High
San Vicente School	Sinagaran			
Daycare Center Villa Paz	Villa Paz			
Villa Paz Elementary School	Villa Paz			
Pio Duran				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Buyo Daycare center	Buyo		High	High
Buyo Elementary School	Buyo	High	High	High

Sorsogon				
Donsol				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Juan Adre Elementary School	Bandi			
Cabugao Elementary School	Cabugao	Medium	Medium	Medium
Cabugao National High School	Cabugao			
Daycare Center Rawis	Central Barangay 2	Low	Low	Low
Dancalan Elementary School	Dancalan			
Guirawan elementary	Girawan	Medium	High	High
Suguian Daycare Center	Juan Adre	High	High	High
Suguian School	Juan Adre	High	High	High
Donsol East Central School	Market Site Barangay 3			Low
New Building Awaii School	Market Site Barangay 3			
Rawis Elementary School	Market Site Barangay 3	Medium	Medium	Medium
Donsol National Comprehensive School	Ogod			
Ogod Elementary School	Ogod			Low
Orange Daycare Center	Orange			
Orange Elementary School	Orange		High	High
daycare.tagbac	Pawala			Low
Pawala Day Care Center	Pawala			
Pawala Elementary School	Pawala	Low	Medium	High
tagbac elementary school	Pawala	Medium	High	High
Donsol National Comprehensive School	Poso Poblacion	Low	Low	Low

New Building Awaii School	Poso Poblacion			
Daycare Center San isidro	San Isidro	High	High	High
San Isidro Elementary School	San Isidro	High	High	High
Bandi Elementary School	San Jose			
daycare.bandi	San Jose	High	High	High
San Jose Elementary School	San Jose	High	High	High
San Ramon Daycare Center	San Ramon	High	High	High
San Ramon Elementary School	San Ramon	High	High	High
Donsol Vocational School	Tongdol			
Gogon Elementary School	Tongdol			
Donsol East Central School	Tupas	Low	Low	Low
Donsol National Comprehensive School	Tupas			
Donsol Vocational High School	Tupas			
Donsol West Central School	Tupas	Medium	Medium	Medium
Tres Marias Elementary School	Tupas		Low	Low

ANNEX 12. Health Institutions Affected in Ogod Floodplain

Albay				
Jovellar				
Building Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Health Center	Bagacay			
Health Center	Bautista			Medium
Barangay Health Center	Estrella			

Sorsogon				
Donsol				
Building Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Cabugao Health Center	Cabugao	High	High	High
health center,bandi	San Jose	Medium	High	High