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

LiDAR Surveys and Flood Mapping of Alubijid River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	AWLS¬ Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CMU	Central Mindanao University
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
UPC	University of the Philippines Cebu
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 ALUBIJID RIVER

Enrico C. Paringit, Dr. Eng., Dr. George Puno, and Eric Bruno

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) and the 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 Central Mindanao University (CMU). CMU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the thirteen (13) river systems in the Northern Mindanao Region. The university is located in Maramag Municipality, Bukidnon Province, Mindanao.

1.2 Overview of the Alubijid River Basin

The Alubijid River Basin is located in the western part of Misamis Oriental. Most of the river channels traverse the municipality of Alubijid with a total length of 88.10 kilometers. The Alubijid River Basin has a total land area of 12,206 hectares nested within the twenty-nine (29) barangay jurisdiction distributed in one (1) city and six (6) municipalities of Misamis Oriental. The municipality of Alubijid is bounded on the north by Macajalar Bay; on the east by El Salvador City; on the south by the Municipality of Manticao; and on the west by the Municipalities of Laguindingan, Gitagum, Libertad, Initao and Naawan (Figure 1).

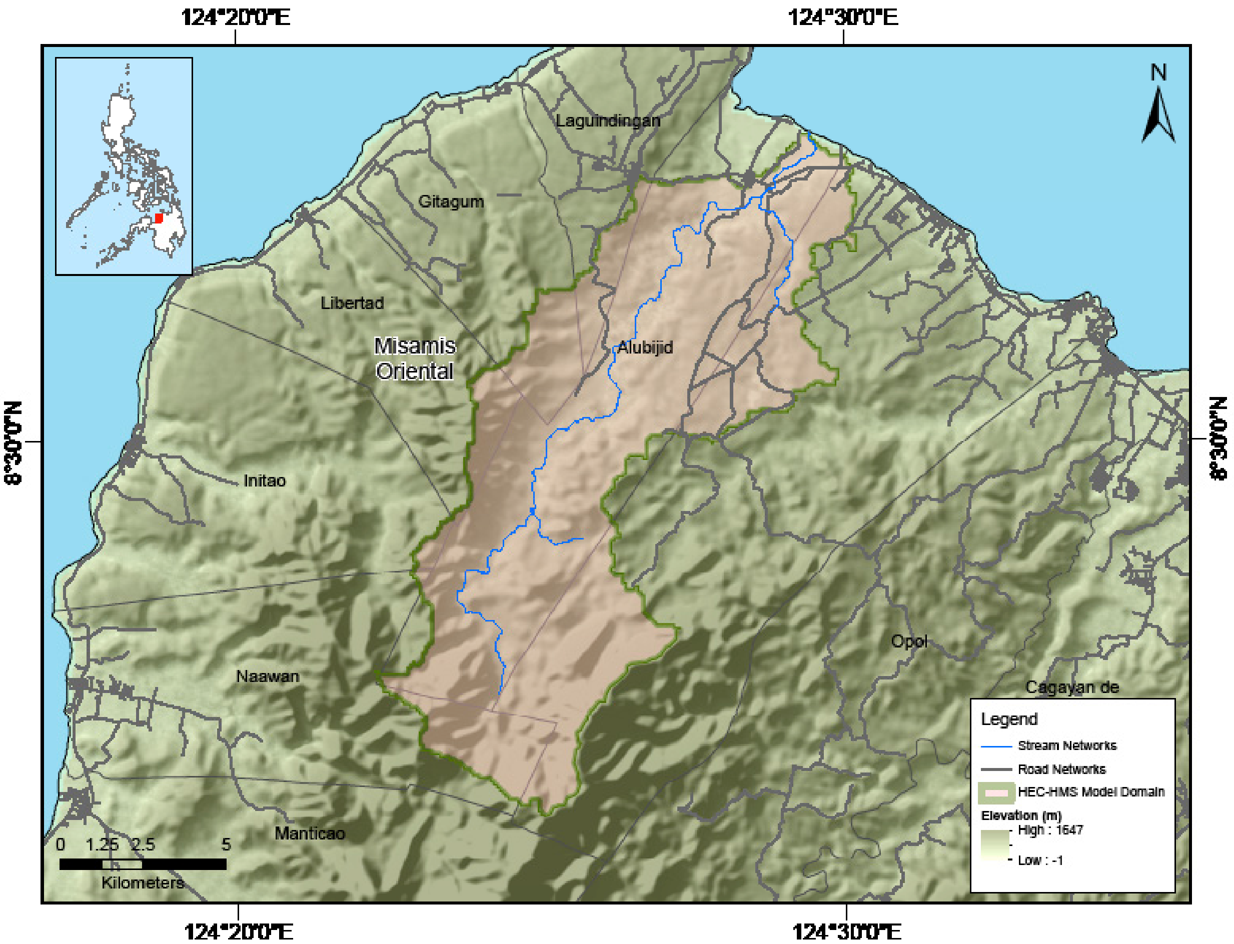

Figure 1. Location Map of the Alubijid River Basin (in brown)

The Alubijid River is classified as one of the eleven (11) major water resources in the province of Misamis Oriental, with its basin covering a total area of 12,206 hectares. It lies in the western portion of Northern Mindanao and covers the Municipalities of Alubijid, Manticao, Laguindingan, Gitagum, Libertad, Initao, Naawan and El Salvador City in the province of Misamis Oriental. It has a total area of 120 sq. km with an estimated total annual run-off of 516 (MCM).

The Alubijid Riveris part of the twelve (12) river systems in the Northern Mindanao Region. According to the 2010 national census of NSO, the total population ofresidents within the immediate vicinity of the river is 33,047, which is distributed among six (6) barangays of the Municipality of Alubijid namely: Baybay, Benigwayan, Calatcat, Lanao, Loguilo and Poblacion.Anthropogenic activities evident in the river basin include farming, animal raising, fishing, and shrimp and crabaquaculture. Some flat and low land plains are also utilized for salt production, especially during the dry season. One of the major tributaries of the Alubijid River, the Mahan-ob River, irrigates seventy (70) hectares of rice land along the national highway. The basin also contributes to eco-tourism with Mount Salumayagon, the headwater source of the river, as an excellent view point to the Macajalar Bay. However, some human activities upstream, such as charcoal production and small scale open-pit mining, are causing adverse environmental impact, especially in the communities downstream. The intensifying and increasing frequency of flood occurrences over the years has made Alubijid Riverone of the identified flood-prone rivers in the province of Misamis Oriental.

Focus group discussions and key informant interviews conducted in the floodplains of Alubijid revealed a flood incident as early as1990, during Typhoon Ruping. In 2009, three (3) of the visiting Typhoons in the country caused inundations in the area. These were Typhoons Auring (January 2009), Ondoy (September 2009), and Santi (November 2009). In 2010, a major flood took place along the national highways as Alubijid River overflowed. The flooding damaged the rice fields, and caused the Cagayan de Oro-Iligan Corridor to be impassable for hours. In December 2011, Typhoon Sendong left local residents with damaged agricultural crops, livestock, and infrastructure such as bridges and culverts, impedingtransportation to and from the rural barangays. Flooding also occurred during the December 2012 TyphoonPablo.

Under the Phil-LiDAR 1 Program, CMU was tasked to develop flood hazard maps in several rivers, including the Alubijid river, through flood Modeling and simulations using Hydrologic Engineering Center's – Hydrologic Modeling System (HEC-HMS), Hydrologic Engineering Center's – Hydrologic River Analysis System (HEC-RAS) and Light Detection and Ranging (LiDAR) technology. The generated basin model consists of forty-eight (48) sub basins, twenty-five (25) reaches, and twenty-six (26) junctions. It was calibrated using the actual climatic and hydrologic event on November 26, 2014, during Tropical Depression Queenie. Statistical tests for model efficiency revealed a satisfactory model performance. The model was subsequently used to simulate different river discharge scenarios using the Rainfall Intensity Duration Frequency (RIDF) data of Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) based on a 54-year record of Cagayan de Oro rain gauge. Flood inundation extent and depth were simulated using the hydraulic model for the three scenarios namely the 5-, 25-, and 100-year return periods.

The resulting analysis of the flood modelling of the Alubijid River Basin gives baseline information for the local government unit of the Municipality of Alubijid essential for the use of disaster preparedness. Furthermore, the simulations provide hydrologic details about quantity, variability and source of run-off in the river basin.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE ALUBIJID FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for the Alubijid floodplain in Misamis Oriental. These missions were planned for twelve (12) lines that 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

Table 1 . Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed (kts)	Average Turn Time (Minutes)
BLK67A	850	30	50	200	(Hz)	130	5
BLK67B	850	30	50	200	30	130	5
BLK67C	850	30	50	200	30	130	5
BLK67D	900	30	50	200	30	130	5
BLK67G	1200	30	50	200	30	130	5
BLK68A	1200	30	50	200	30	130	5

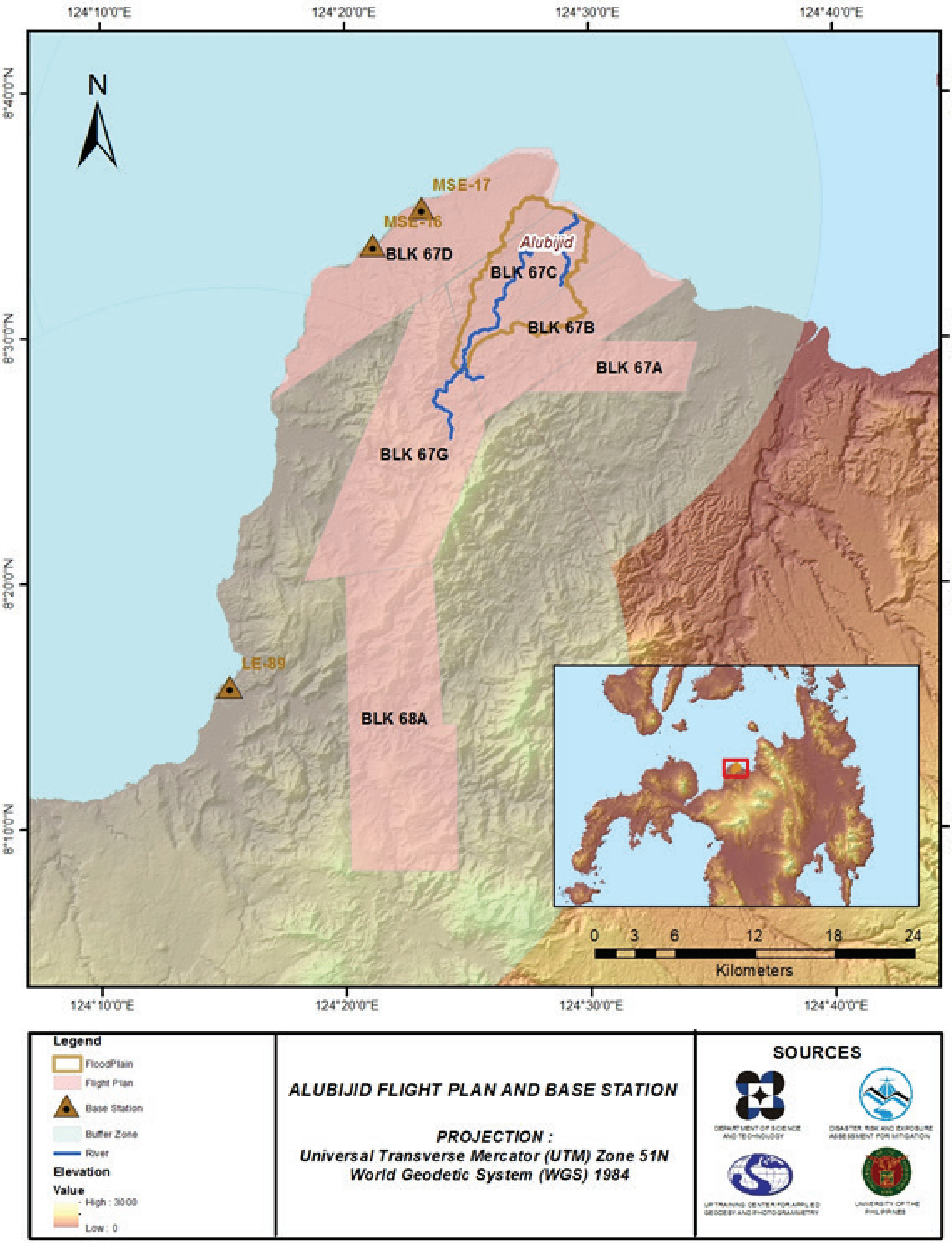

Figure 2. Flight plans and base stations used for Alubijid Floodplain.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points: MSE-16 and MSE-17, which areof second (2nd) order accuracy; and one(1) NAMRIA benchmark: LE-89, which is of first (1st) order accuracy. The benchmark was used as vertical reference point and was established as ground control point. The certifications for the NAMRIA reference points and benchmark are found in Annex2.These were used as base stations during flight operations for the entire duration of the survey, held on May 22 to June 27, 2014. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Alubijid floodplain are shown in Figure 2.

Figure 3to Figure 5show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 4show the details ofthe NAMRIA control stations,while Table 5 shows the list of all ground control points occupied during the acquisition, together with the corresponding dates of utilization.

Figure 3. GPS set-up over MSE-16 inside the school grounds of Libertad National High School, Brgy. Poblacion, Libertad, Misamis Oriental (a) and NAMRIA reference point MSE-16 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MSE-16 used as base station for the LiDAR acquisition.

Station Name	**MSE-16**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°33’51.6922” North 124°21’5.34868” East 1.34700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	428608.692 meters 947021.389 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°33’48.06049” North 124°21’10.74852” East 68.044 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	648735.65 meters 946891.04 meters

Figure 4. GPS set-up over MSE-17 inside the school grounds of Pangayawan Elementary School in Gitagum, Misamis Oriental (a) and NAMRIA reference point MSE-17 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MSE-17 used as base station for the LiDAR acquisition.

Station Name	**MSE-17**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°35’22.50573” North 124°23’6.85732” East 5.0100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	423328.91 meters 949805.1 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°35’18.86995” North 124°23’12.25471” East 71.73900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	610204.602 meters 884431.706 meters

Figure 5. GPS set-up over LE-89 in front of St. Peter Life Plan of Iligan City, Lanao del Norte (a) and NAMRIA benchmark AN-44 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point LE-89 used as base station for the LiDAR acquisition.

Station Name	LE-89	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°15'47.82322" North 124°15'17.37373" East 73.451 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 84)	Easting Northing	638201.305 meters 913622.047 meters
Elevation (mean sea level)	10.9546 m	

Table 5. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 22,2014	1497P	1BLK67B142A	MSE-16 & MSE-17
May 23,2014	1501P	1BLK67C143A	MSE-16 & MSE-17
May 24, 2014	1505P	1BLK67BC144A	MSE-16 & MSE-17
June 23, 2014	1625P	1BLK67BC174A	MSE-16 & MSE-17
June 27, 2014	1641P	1BLK68A178A	MSE-16 & LE-89

2.3 Flight Missions

Five (5) missions were conducted to complete the LiDAR data acquisition in the Alubijid floodplain, for a total of sixteen hours and twenty minutes (20+43) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 6shows the total area of actual coverage and the corresponding flying hours per mission,while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for LiDAR data acquisition in Alubijid floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed outside the Floodplain (km2)	No. of Images (Frames)	Flying Hour	
							Hr	Min
May 22,2014	1497P	130.55	190.38	12.97	177.41	435	3	41
May 23,2014	1501P	67.8	170.25	60.43	109.82	409	4	29
May 24, 2014	1505P	117.48	152.26	11.60	140.76	670	3	47
June 23, 2014	1625P	155.4	190.85	0.99	189.86	818	4	23
June 27, 2014	1641P	148.6	230.97	0	230.97	787	4	23
TOTAL		619.83	934.71	85.99	848.82	3119	20	43

Table 7. 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
1497P	900	30	50	200	30	130	5
1501P	800/700	30	50	200	30	130	5
1505P	850	30	50	200	30	130	5
1625P	1200	30	50	200	30	130	5
1641P	1200	30	50	200	30	130	5

2.4 Survey Coverage

The Alubijid floodplain is located in the province of Misamis Oriental with majority of the floodplain situated within the municipalities of Alubijid and Laguindingan. Municipalities of Alubijid, Gitagum, Laguindingan and Libertad are fully covered by the survey. The list of municipalities and cities surveyed,with at least one (1) square kilometer coverage, is shown in Table 8.The actual coverage of the LiDAR acquisition for the Alubijid floodplain is presented in Figure 6. See Annex 7 for the Flight Status Reports.

Table 8. List of municipalities and cities surveyed during Alubijid floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Misamis Oriental	Alubijid	80.16	80.16	100%
	Gitagum	41.48	41.41	100%
	Libertad	40.59	40.59	100%
	Laguindingan	37.87	37.87	100%
	Initao	68.01	59.07	87%
	El Salvador City	141.45	102.45	72%
	Naawan	69.78	47.35	68%
	Manticao	110.07	73.5	67%
	Opol	143.16	25.27	18%
	Cagayan de Oro City	440.17	15.06	3%
Lanao del Norte	Iligan City	650.87	175.7	27%
Lanao del Sur	Kapai	188.22	31.86	17%
	Tagoloan II	149.68	18.82	13%

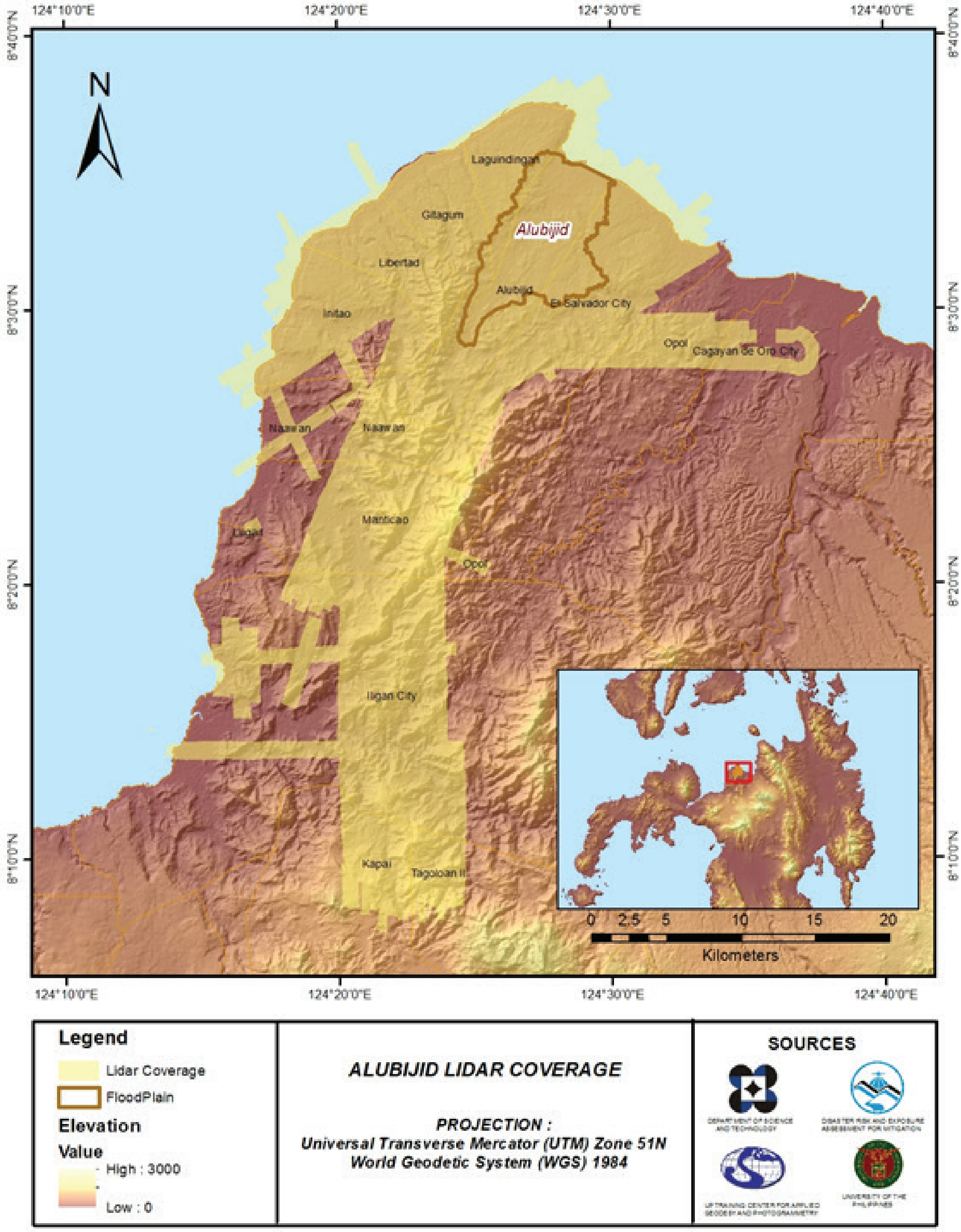

Figure 6. Actual LiDAR survey coverage for Alubijid floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE ALUBIJID FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

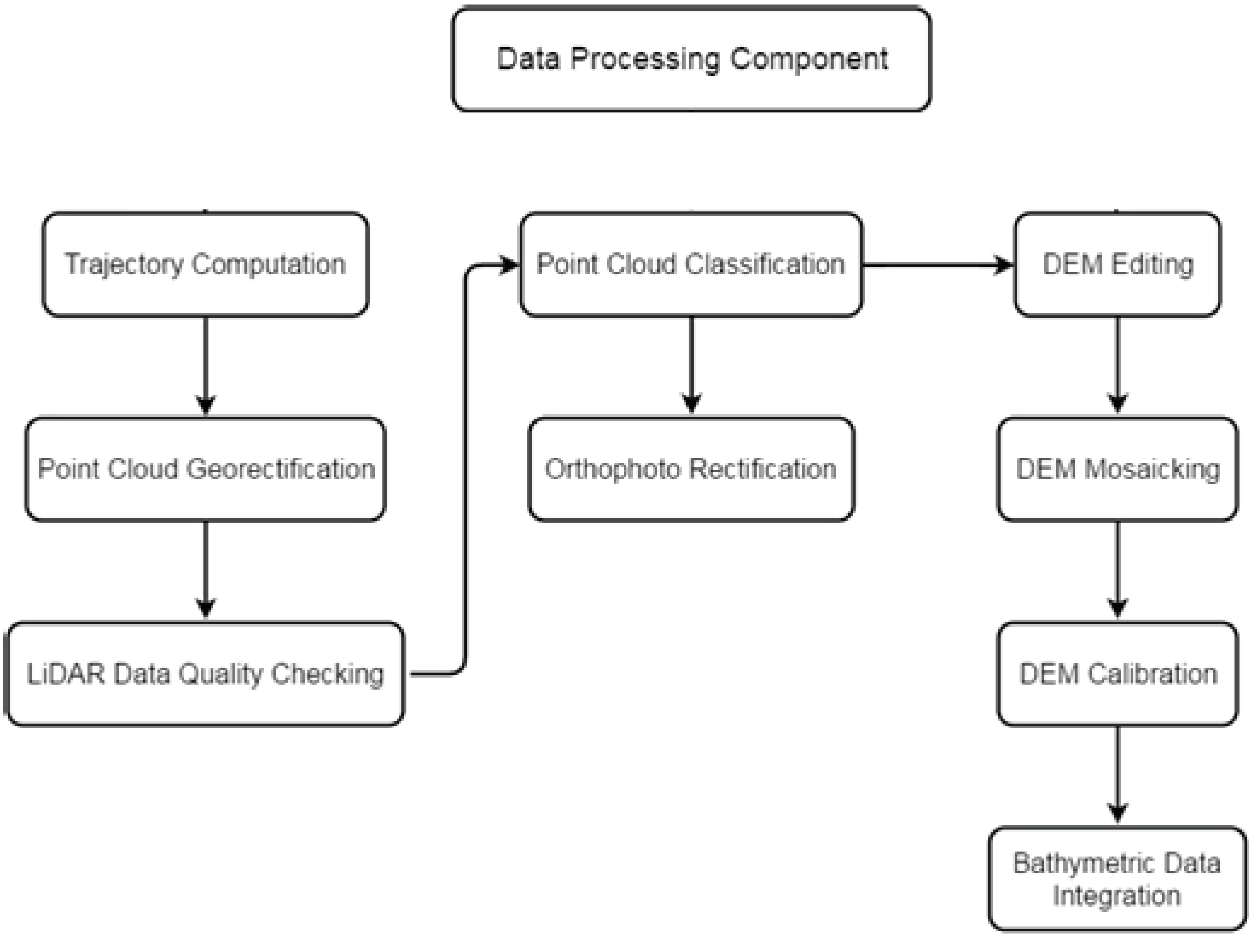

Figure 7. Schematic Diagram for Data Pre-Processing Component.

The data transmitted by the Data Acquisition Component (DAC) 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 (DVBC). 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 7.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Alubijid floodplain can be found in Annex 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Alubijid, Misamis Oriental. The DAC transferred a total of 168.80 Gigabytes of Range data, 1.417 Gigabytes of POS data, 43.10 Megabytes of GPS base station data, and 343.20 Gigabytes of raw image data, to the data server on August 1, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Alubijid was fully transferred on August 1, 2014 as indicated on the Data Transfer Sheets for Alubijid floodplain.

3.3 Trajectory Computation

TheSmoothed Performance Metric Parameters of the computed trajectory for flight 1505P, one of the Alubijidflights, which arethe North, East, and Down position RMSE values are shown in Figure8. 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 (May 24, 2014 00:00AM). The Y-axis is the RMSE value for that particular position.

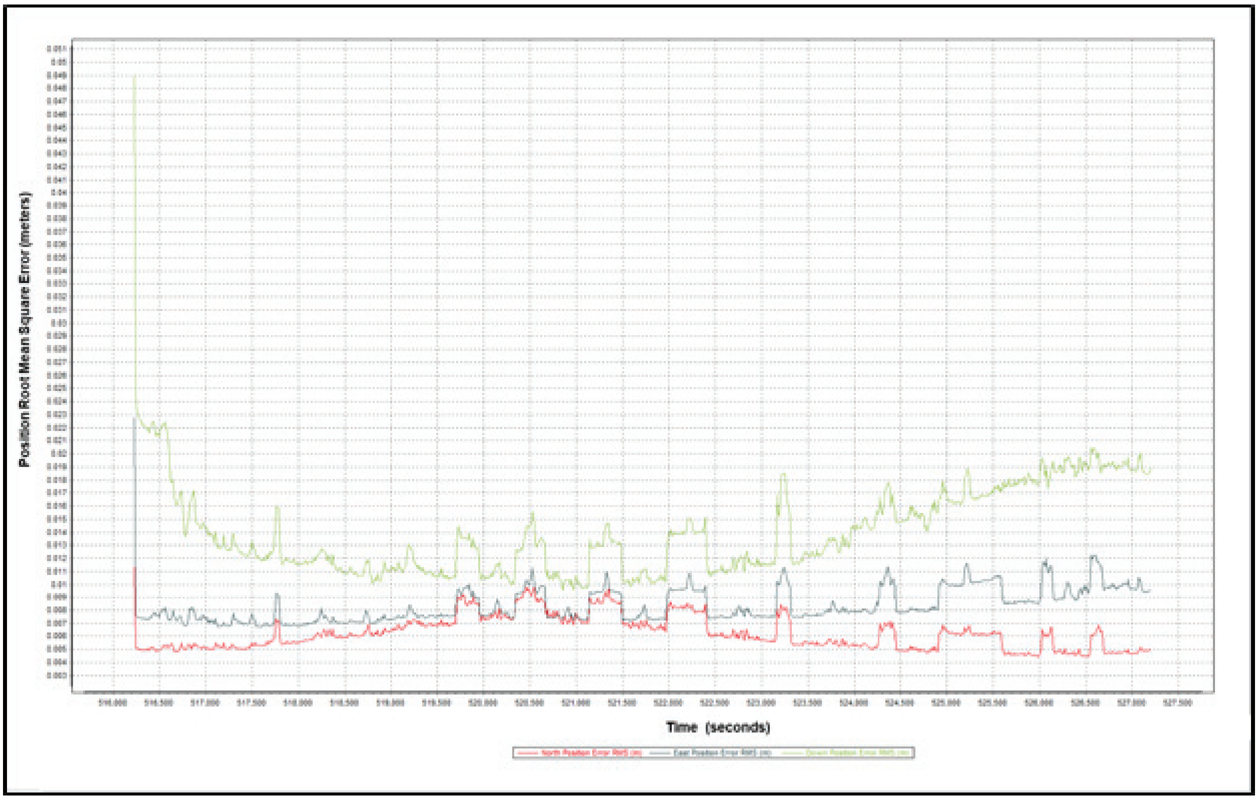

Figure 8. Smoothed Performance Metrics of Alubijid Flight 1505P.

The time of flight was from 516000 seconds to 527500 seconds, which corresponds to the morning of May 24, 2014. 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 was starting tocomputefor the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increases 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 8 shows that the North position RMSE peaks at 0.98 centimeters, the East position RMSE peaks at 1. 22 centimeters, and the Down position RMSE peaks at 2.05 centimeters, which are within the prescribed accuracies described in the methodology.

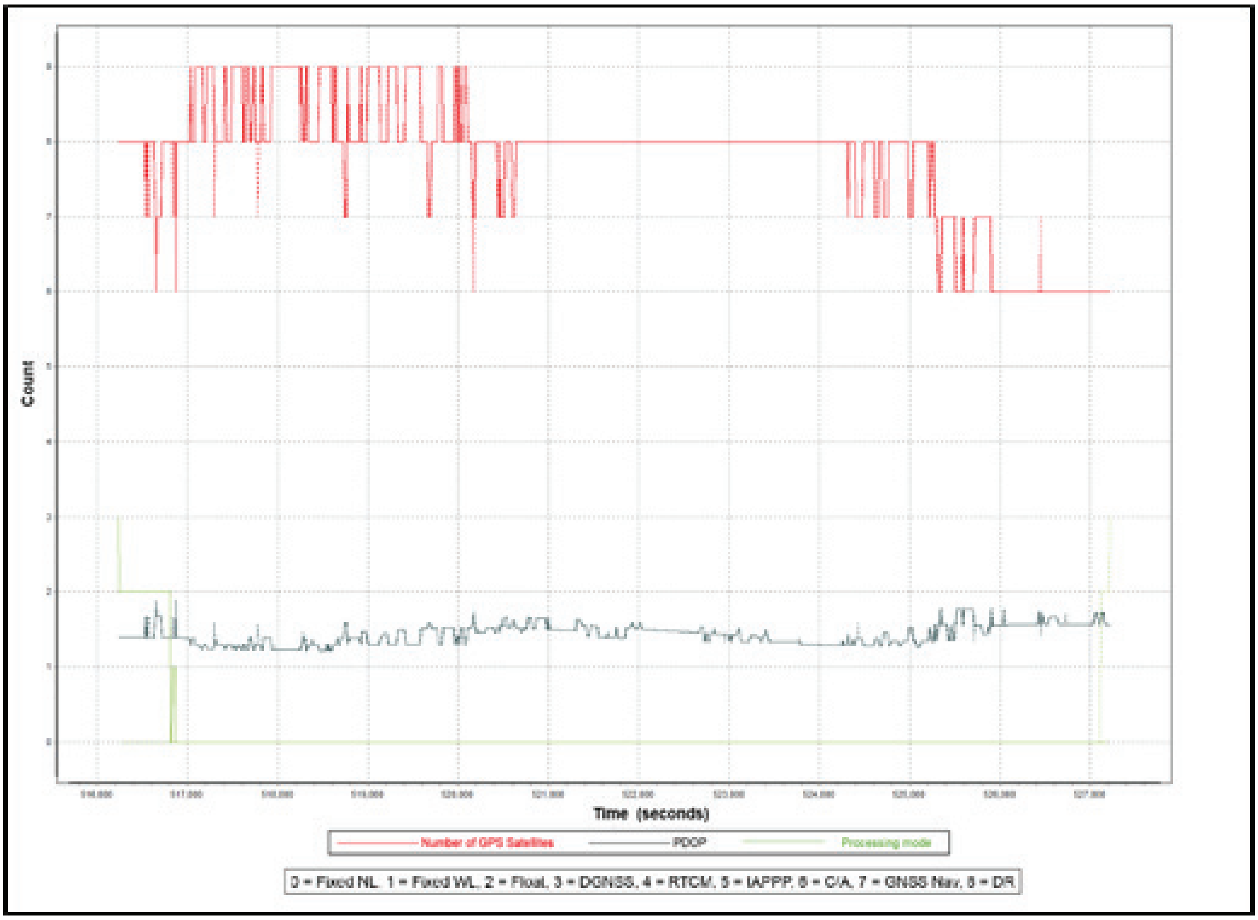

Figure 9. Solution Status Parameters of Alubijid Flight 1505P.

The Solution Statusparameters of flight 1505P, one of the Alubijidflights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down below six (6). Majority of the time, the number of satellites tracked was between six (6) and nine (9). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode stayed at the value of zero (0) for majority of the survey with some peaks up to one (1) attributed to the turns performed by the aircraft. The value of zero (0) corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Alubijid flights is shown in Figure 10.

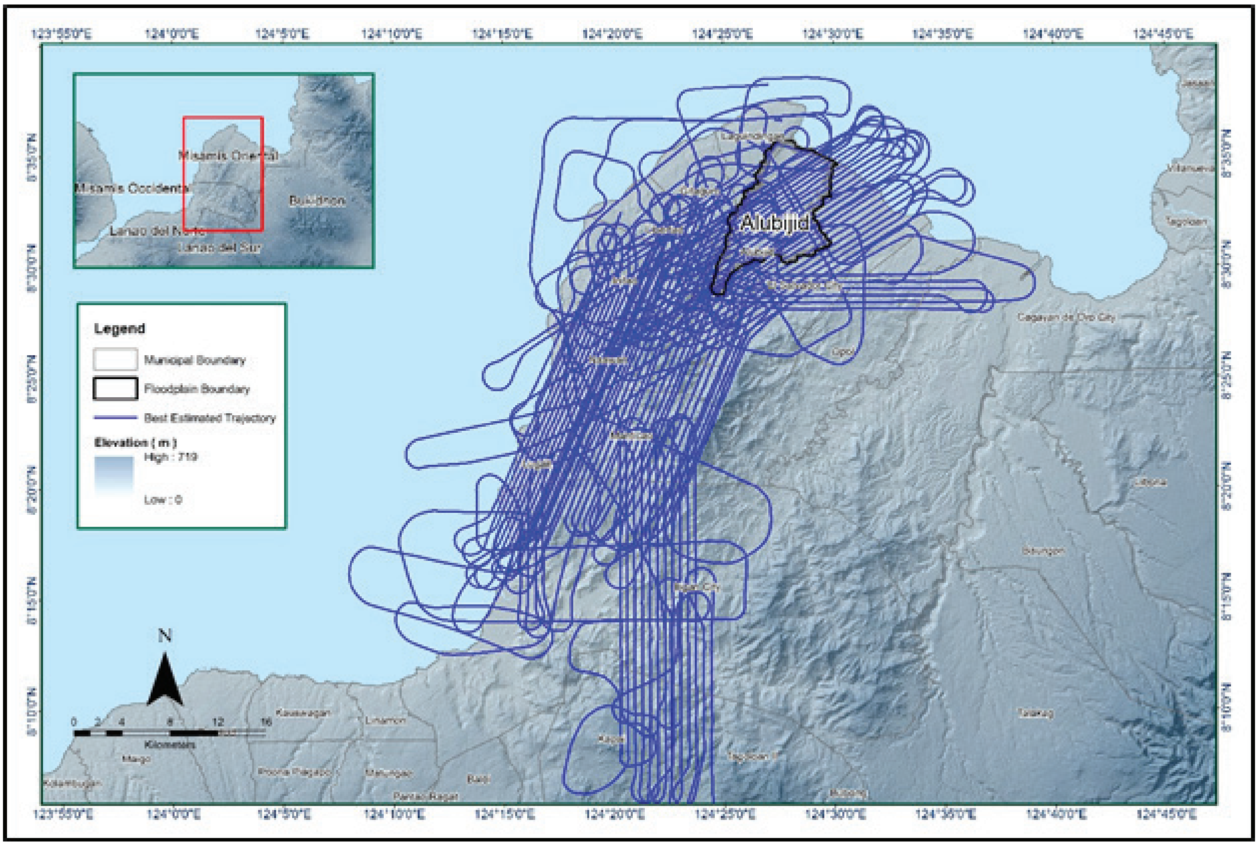

Figure 10. The best estimated trajectory of the LiDAR missions conducted over the Alubijid Floodplain.

3.4 LiDAR Point Cloud Computation

The generated LAS data contains 158 flight lines, with each flight line containing two (2) channels, since the Pegasus System contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Alubijid floodplain are given in Table 9.

Table 9. Self-Calibration Results values for Alubijid flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000165
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000472
GPS Position Z-correction stdev	(<0.01meters)	0.0063

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over the Alubijid Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

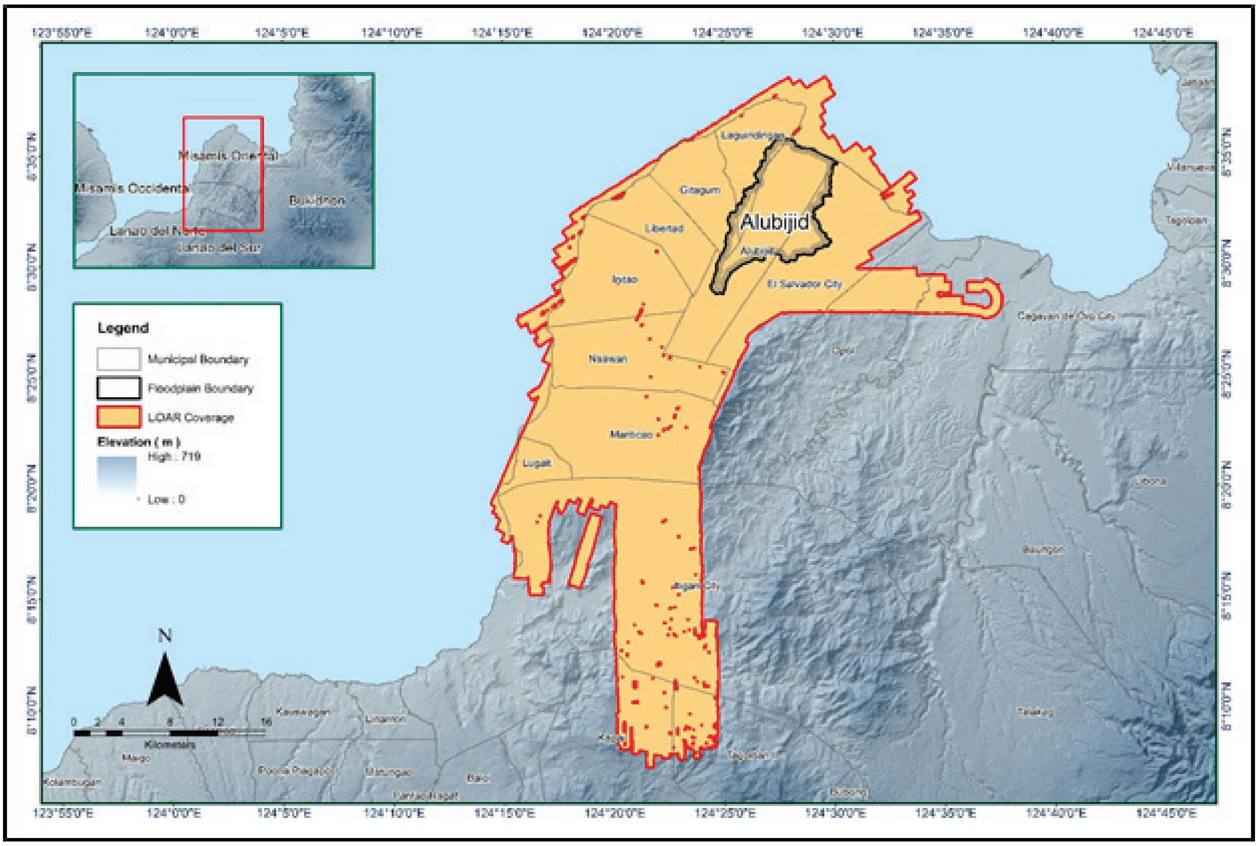

Figure 11. Boundary of the processed LiDAR data over Alubijid Floodplain.

The total area covered by the Alubijid missions is 1,002.53 sq.km, which is comprised of seven (7) flight acquisitions grouped and merged into five (5) blocks, as shown in Table 10.

Table 10. List of LiDAR blocks for Alubijid floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
NorthernMindanao_Blk67AB	1505P	140.04
NorthernMindanao_Blk67CD	1497P	332.58
	1501P	
NorthernMindanao_Blk67G	1625P	184.57
NorthernMindanao_Blk67E	1545P	137.95
	1641P	
NorthernMindanao_Blk68A	1641P	207.39
TOTAL		1,002.53 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 12. Since the Pegasus System employs two channels, it is expected to have an average value of two (blue) for areas where there is limited overlap, and a value of three (yellow) or more (red) for areas with three or more overlapping flight lines.

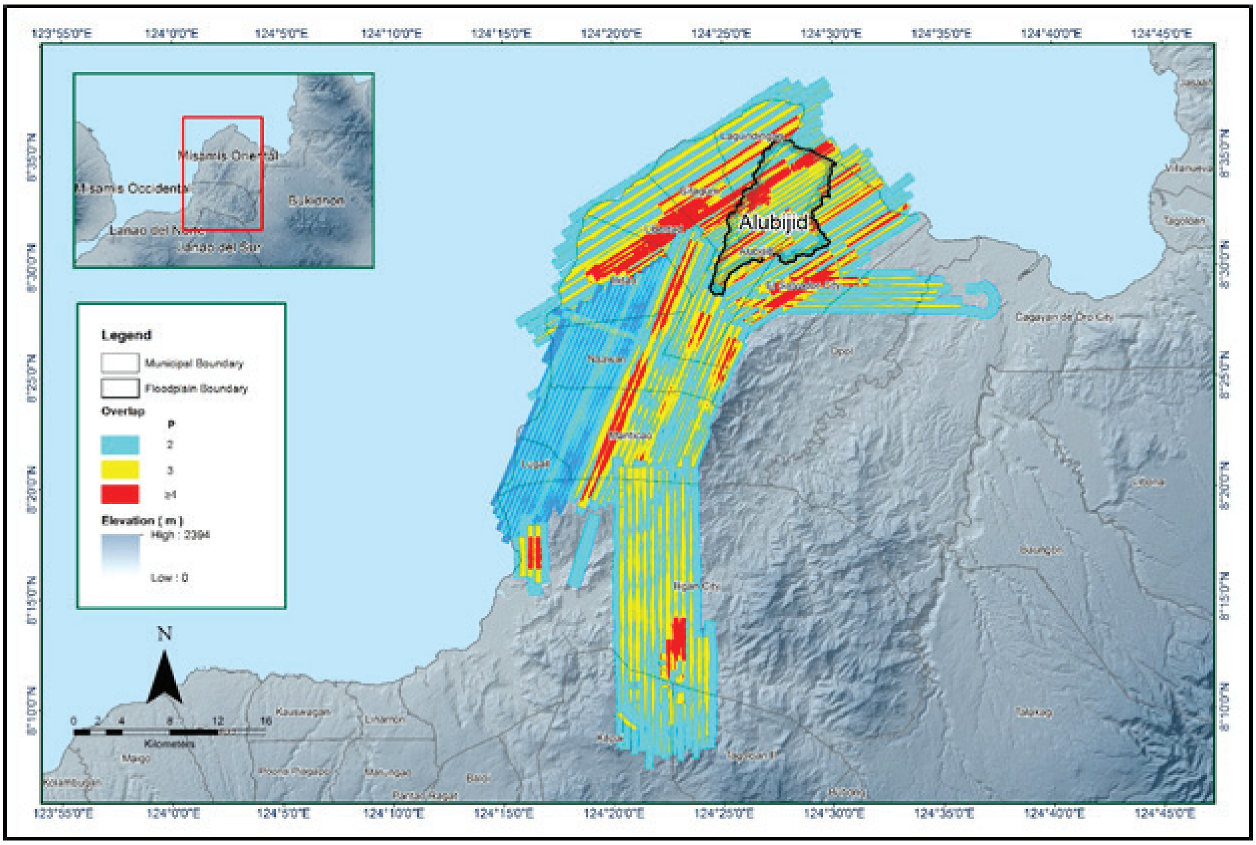

Figure 12. Image of data overlap for Alubijid floodplain.

The overlap statistics per block for the Alubijid 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 37.51% and 57.82% 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 two (2) points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for the Alubijid floodplain satisfy the point density requirement, and the average density for the entire survey area is 6.13 points per square meter.

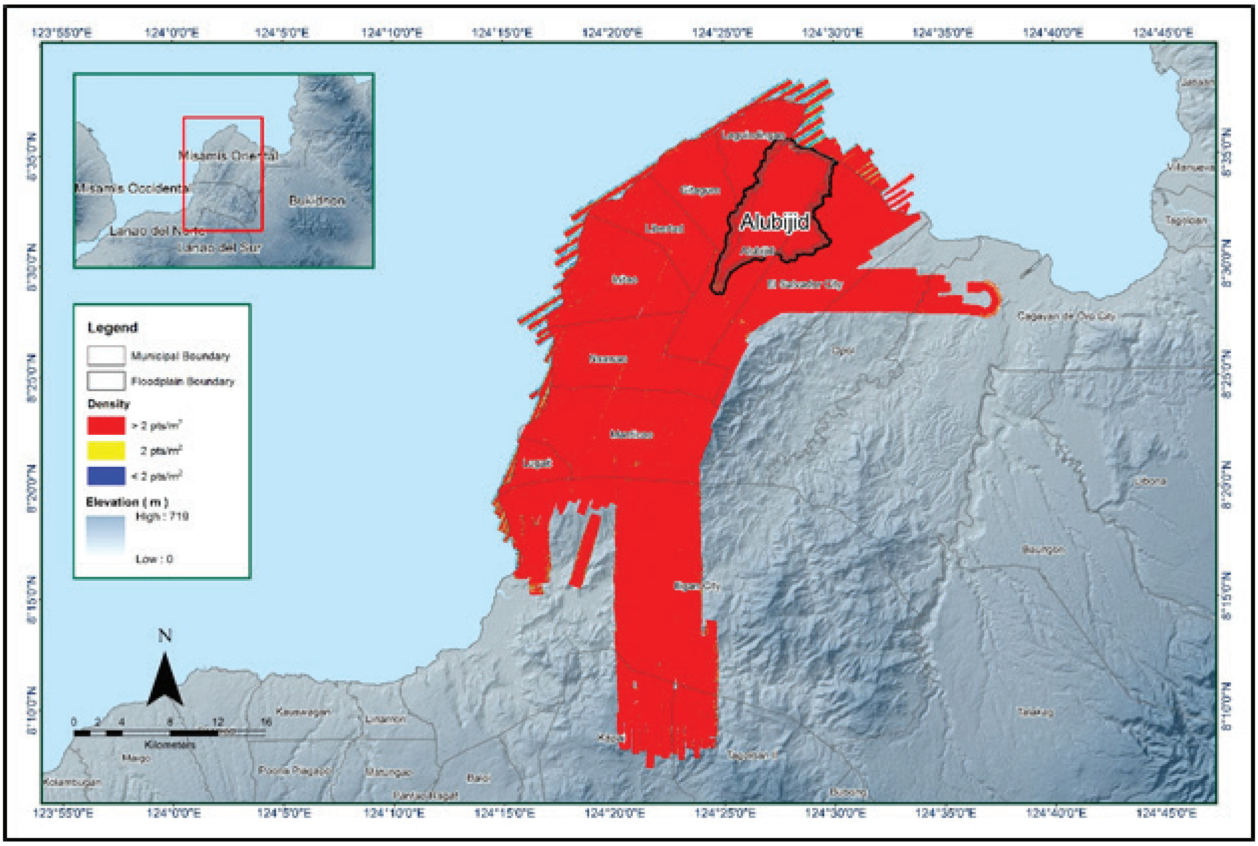

Figure 13. Density map of merged LiDAR data for Alubijid floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. 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 (QT) Modeler software.

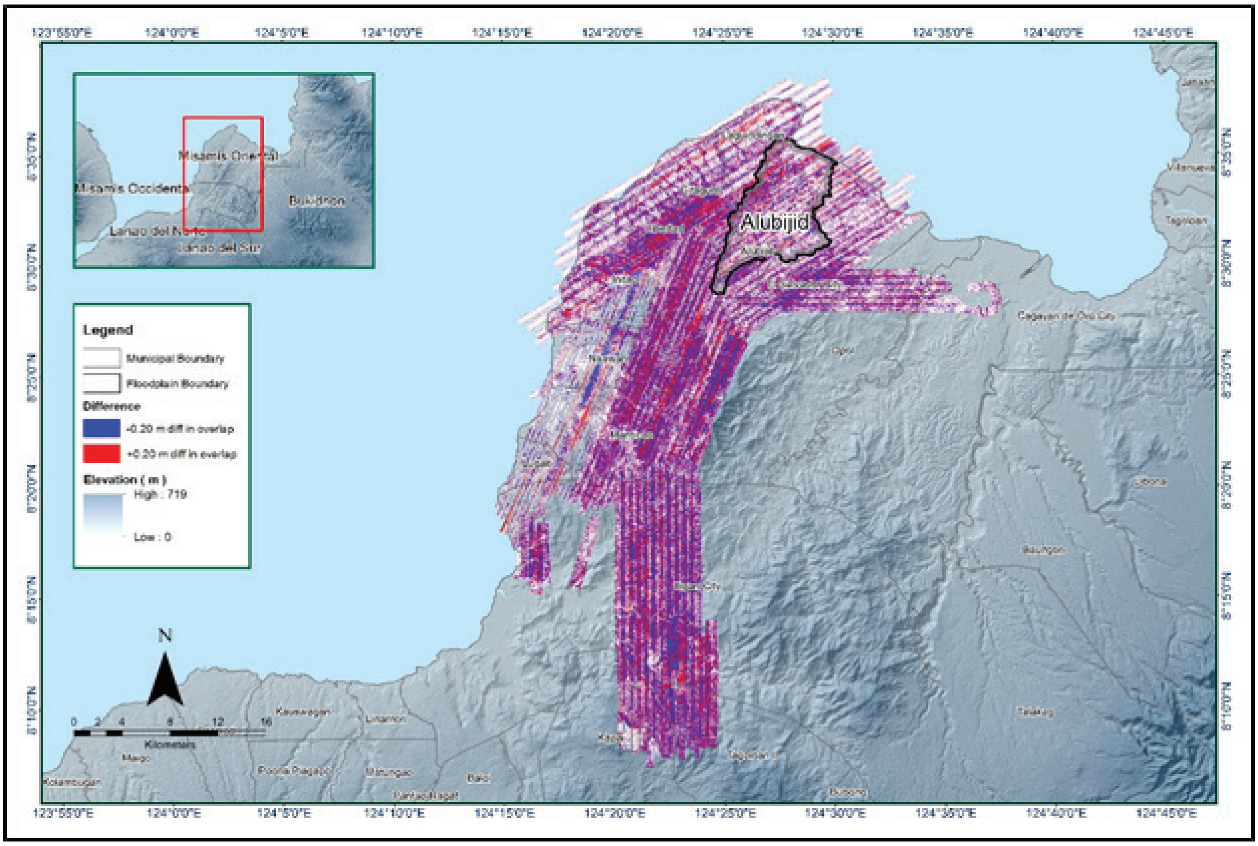

Figure 14. Elevation difference map between flight lines for Alubijid floodplain.

A screen capture of the processed LAS data from an Alubijid flight 1505P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The X-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data was satisfactory. No reprocessing was done for this LiDAR dataset.

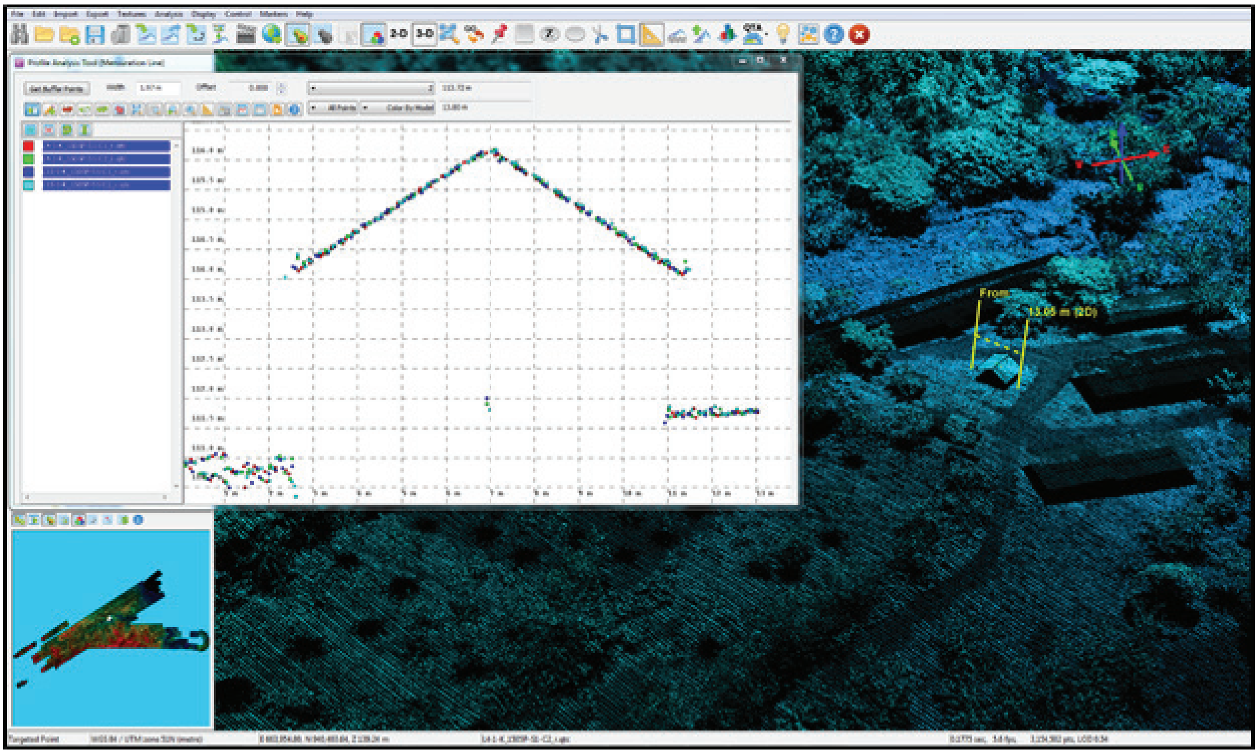

Figure 15. Quality checking for an Alubijid flight 1505P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Alubijid classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,143,449,288
Low Vegetation	1,159,029,334
Medium Vegetation	1,833,282,838
High Vegetation	1,483,877,104
Building	62,775,690

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Alubijid floodplain are shown in Figure 16. A total of 1,311 1km x 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 1,067.00 meters and 61.09 meters, respectively.

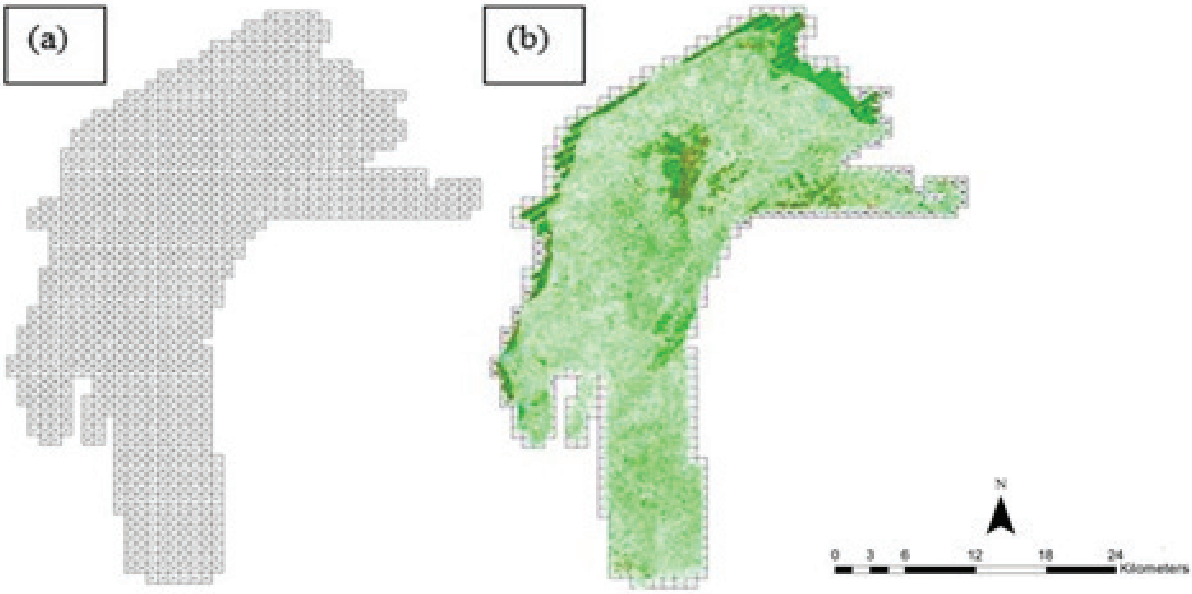

Figure 16 . Tiles for Alubijid floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. 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.

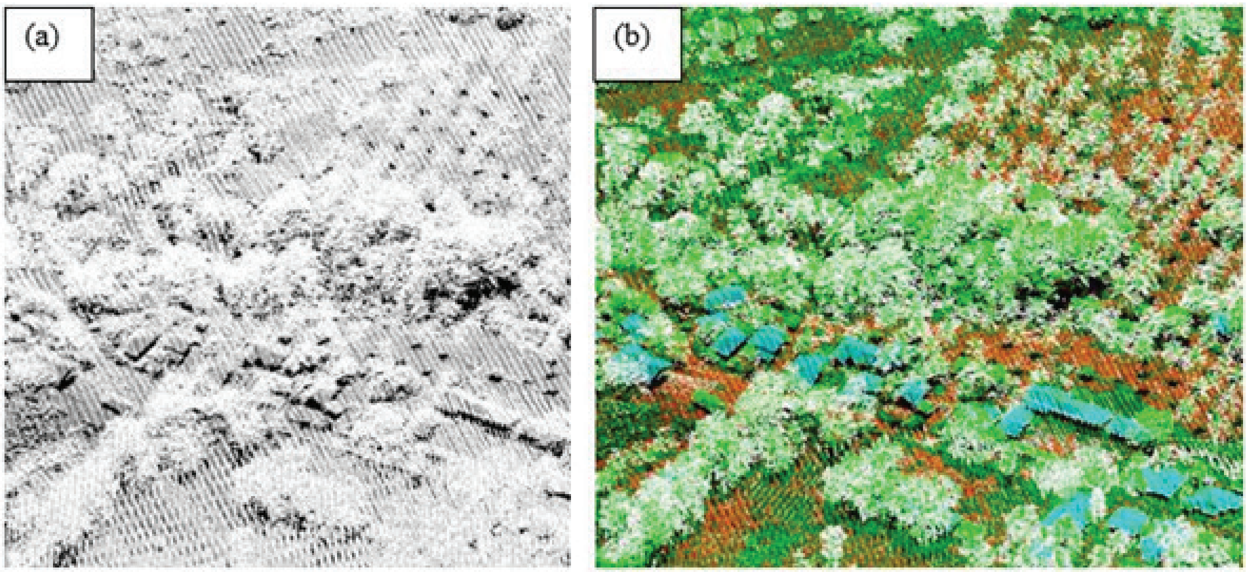

Figure 17. Point cloud before (a) and after (b) classification.

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

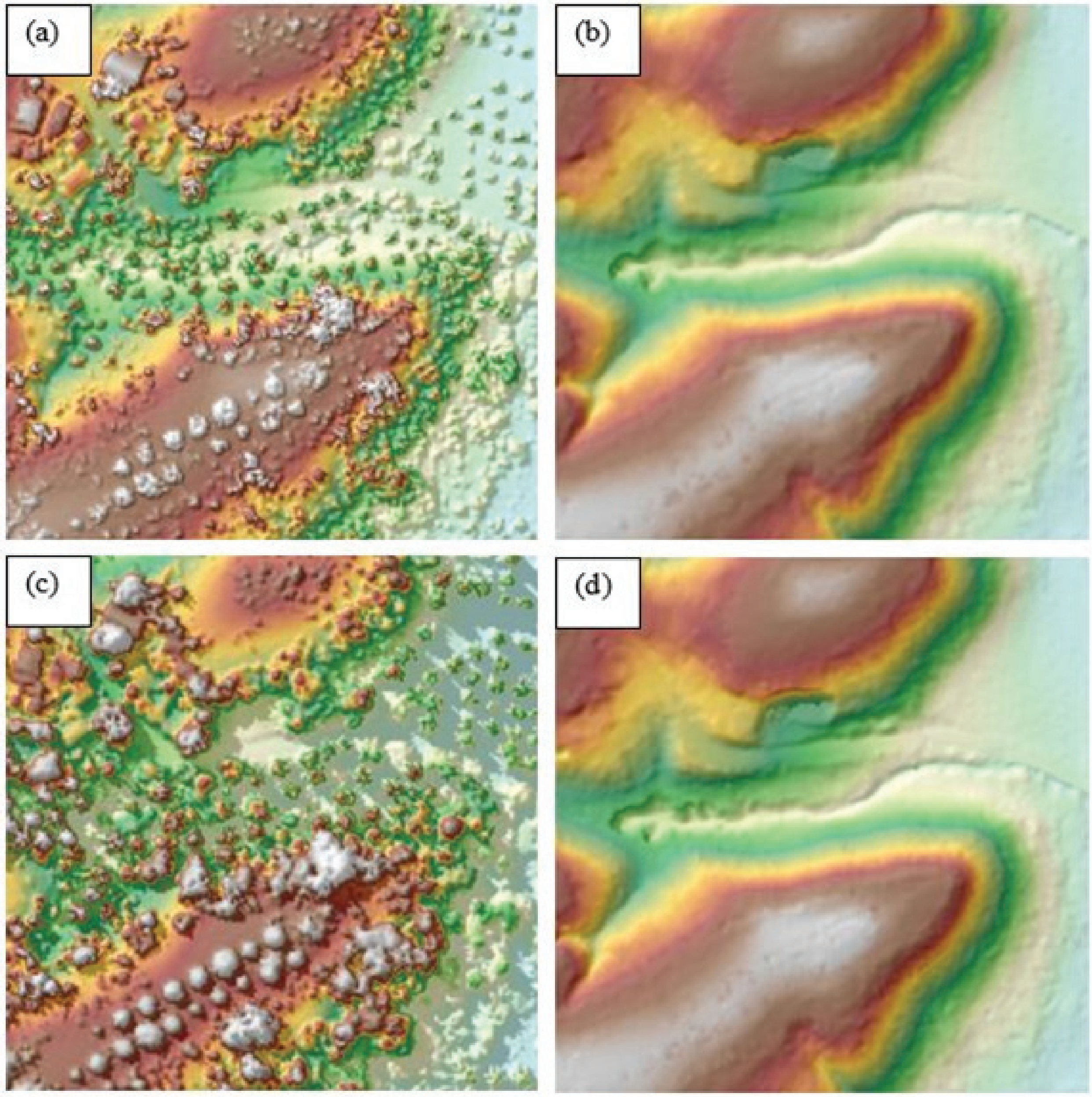

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Alubijid floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,273 1km x 1km tiles area covered by the Alubijid floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seam lines where photos overlap. The Alubijid Floodplain survey attained a total of 873.24 sq.km in orthophotogaph coverage comprised of 4,647 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

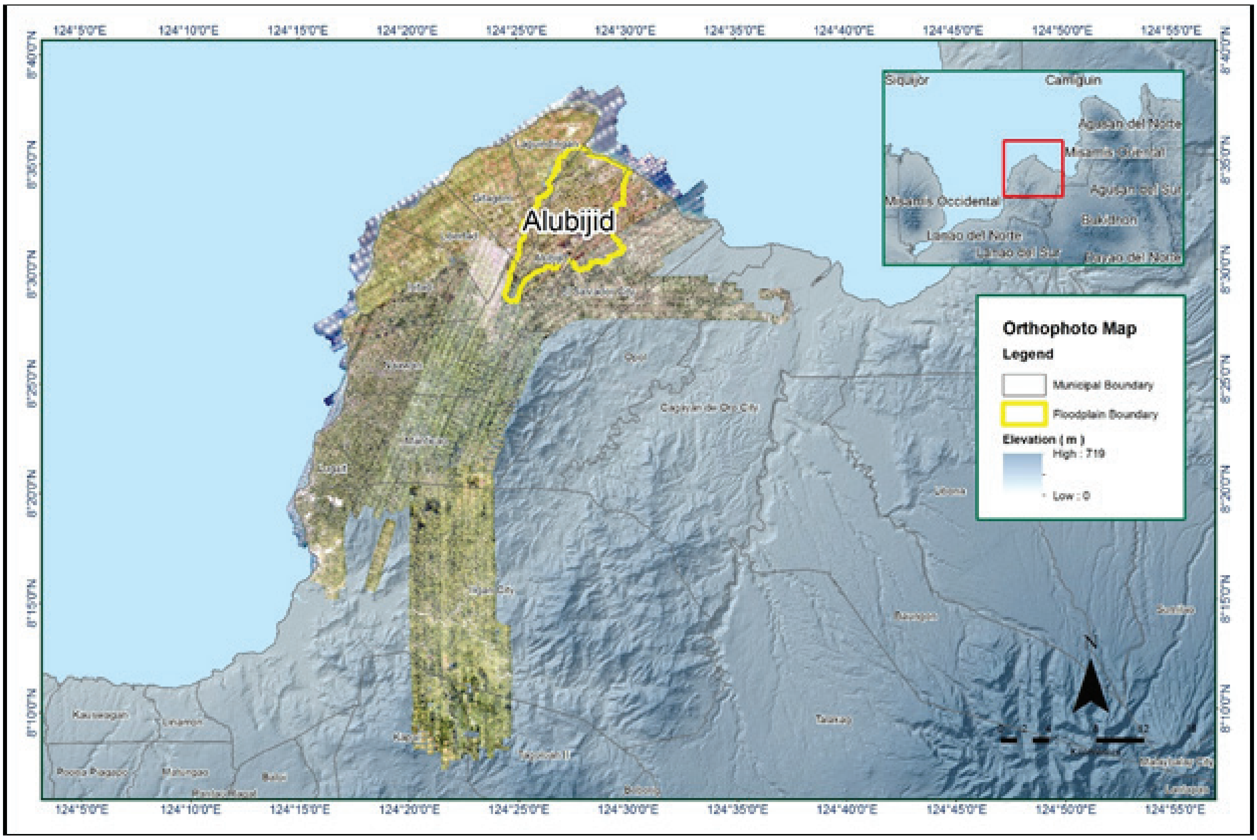

Figure 19. Alubijid floodplain with available orthophotographs.

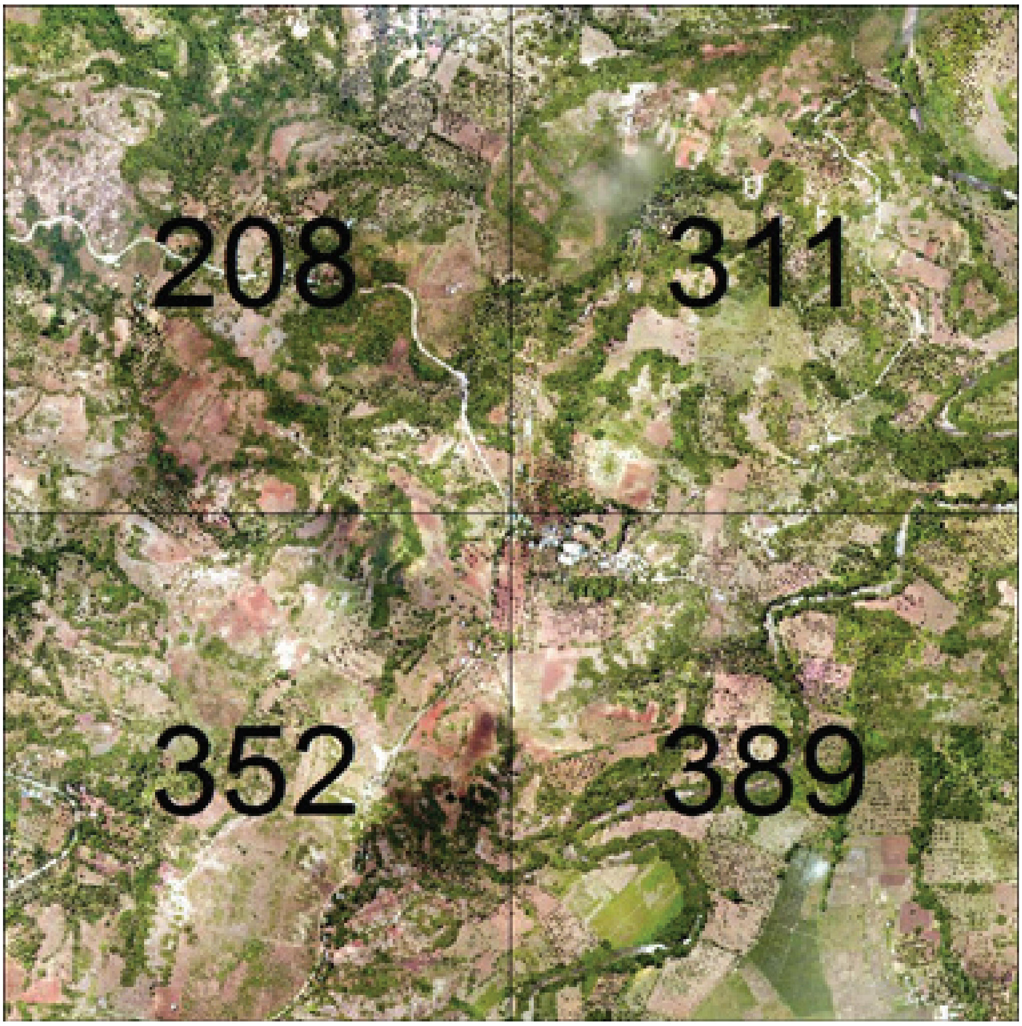

Figure 20. Sample orthophotograph tiles for Alubijid floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for the Alubijid floodplain. These blocks are composed of Northern Mindanao blocks with a total area of 1,002.53 km2. Table 12 shows the name and corresponding area of each block in km2.

Table 12. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
NorthernMindanao_Blk67CD	332.58
NorthernMindanao_Blk67AB	140.04
NorthernMindanao_Blk67E	137.95
NorthernMindanao_Blk67G	184.57
NorthernMindanao_Blk68A	207.39
TOTAL	1,002.53sq.km

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a.) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b.) in order to hydrologically correct the river. This was done through interpolation process wherein a specific polygon determines the upstream and downstream elevation values to generate an interpolated portion of a river and eventually remove the bridge footprint. Another example of interpolation is to manually enclose a building footprint by a polygon to interpolate ground elevation values from the edges. A building that is still present in the DTM after classification (Figure 21g.) has to be removed through manual editing (Figure 21h.). On the other hand, object retrieval was done in areas such as paddies (Figure 21c.) which have been removed during classification process and have to be retrieved to complete the surface (Figure 21d.). A portion of the ridge also (Figure 21e.) has been misclassified that needs to be retrieved to retain the correct terrain (Figure 21f.). Object retrieval uses the secondary DTM (t-layer) to fill in these areas.

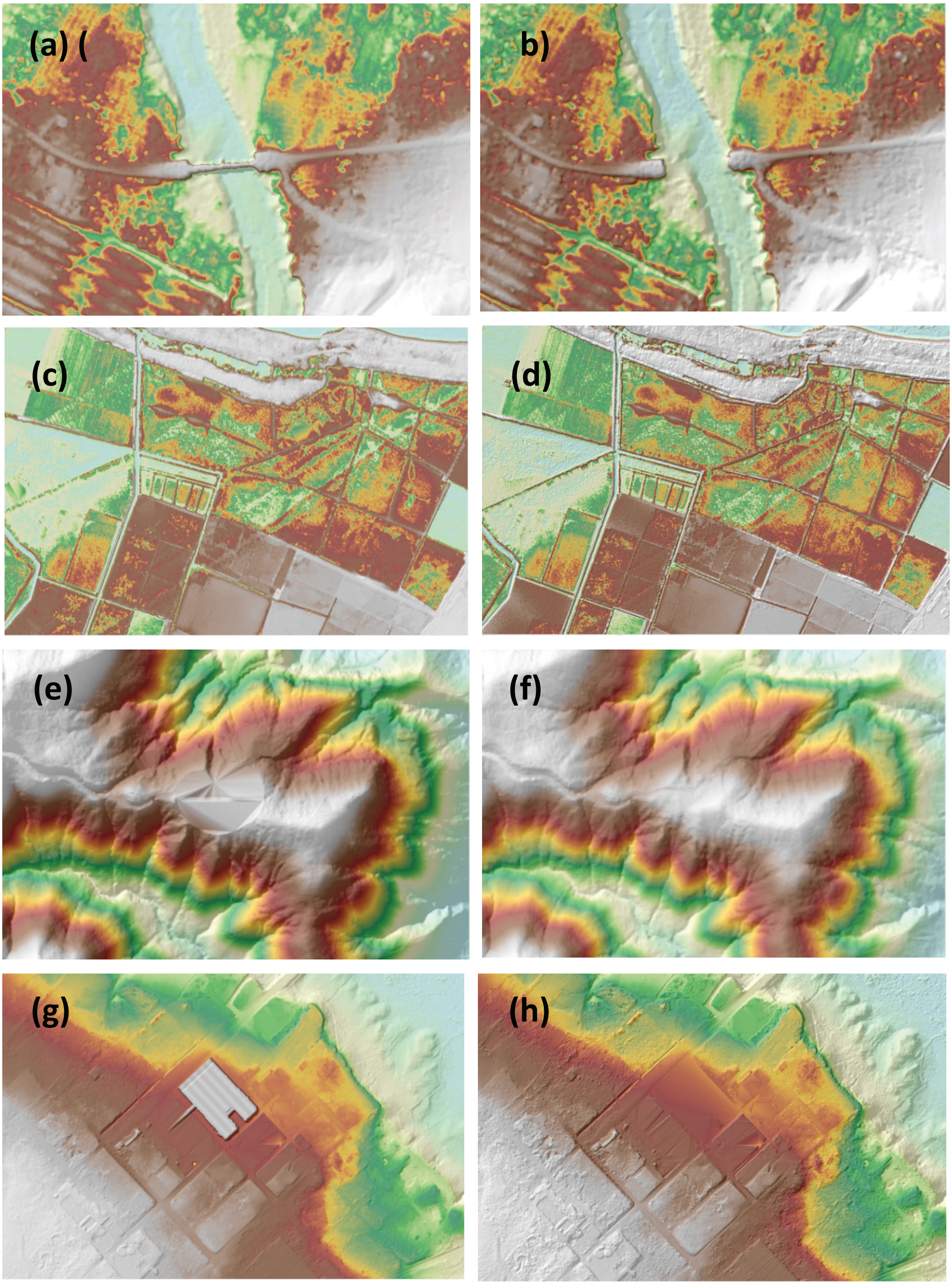

Figure 21. Portions in the DTM of Alubijid floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; a mountain ridge before (e) and after (f) data retrieval; and a building before (g) and after (h) manual editing.

3.9 Mosaicking of Blocks

The Alubijid floodplain lies within the NorthernMindanao_Blk67CD block. NorthernMindanao_Blk67CD was used as the reference block at the start of mosaicking due to the availability of validation points that was used to calibrate such block. Table 13 shows the area of each LiDAR blocks and the shift values applied during mosaicking. Shifting values were derived from the height difference of the calibrated block and the overlapping adjacent block.

Mosaicked LiDAR DTM for the Alubijid floodplain is shown in Figure 22. It can be seen that the entire Alubijid floodplain is 100% covered by LiDAR data.

Table 13. Shift Values of each LiDAR Block of Alubijid floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
NorthernMindanao_Blk67CD	0.00	0.00	0.00
NorthernMindanao_Blk67AB	0.00	0.00	0.08
NorthernMindanao_Blk67E	0.00	0.00	0.03
NorthernMindanao_Blk67G	0.00	0.00	-0.48
NorthernMindanao_Blk68A	0.00	0.00	0.44

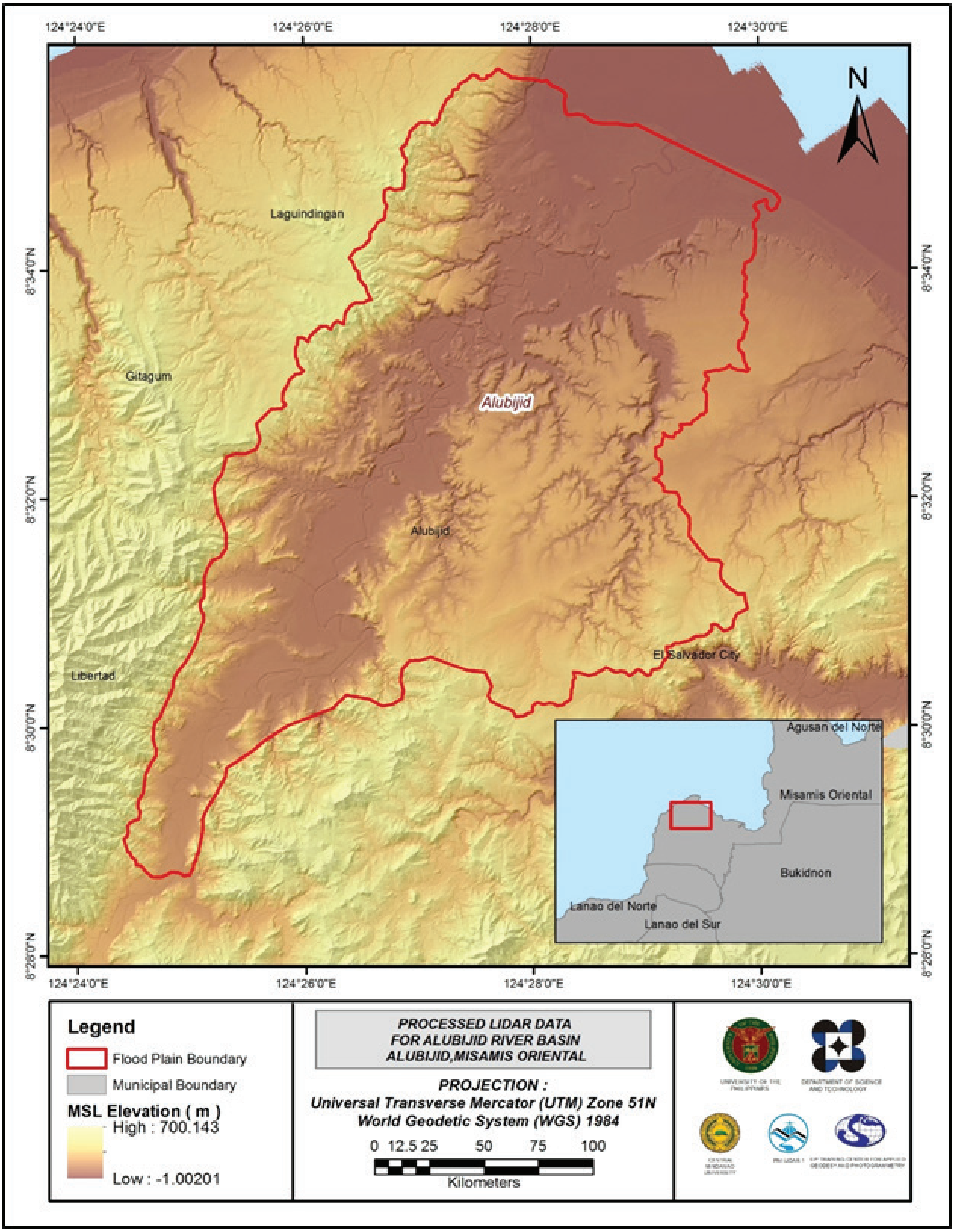

Figure 22. Map of Processed LiDAR Data for Alubijid Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Alubijid to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 1152 survey points were used for calibration and validation of NorthernMindanao_Blk67CD block (Alubijid LiDAR DTM). Eighty percent (80%) of the total survey points were extracted through equal selection at a certain interval, resulting to 921 points used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 24. 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 0.08 meters with a standard deviation of 0.08 meters. Calibration of Alubijid LiDAR data was done by subtracting the height difference value, 0.08 meters, to Alubijid mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

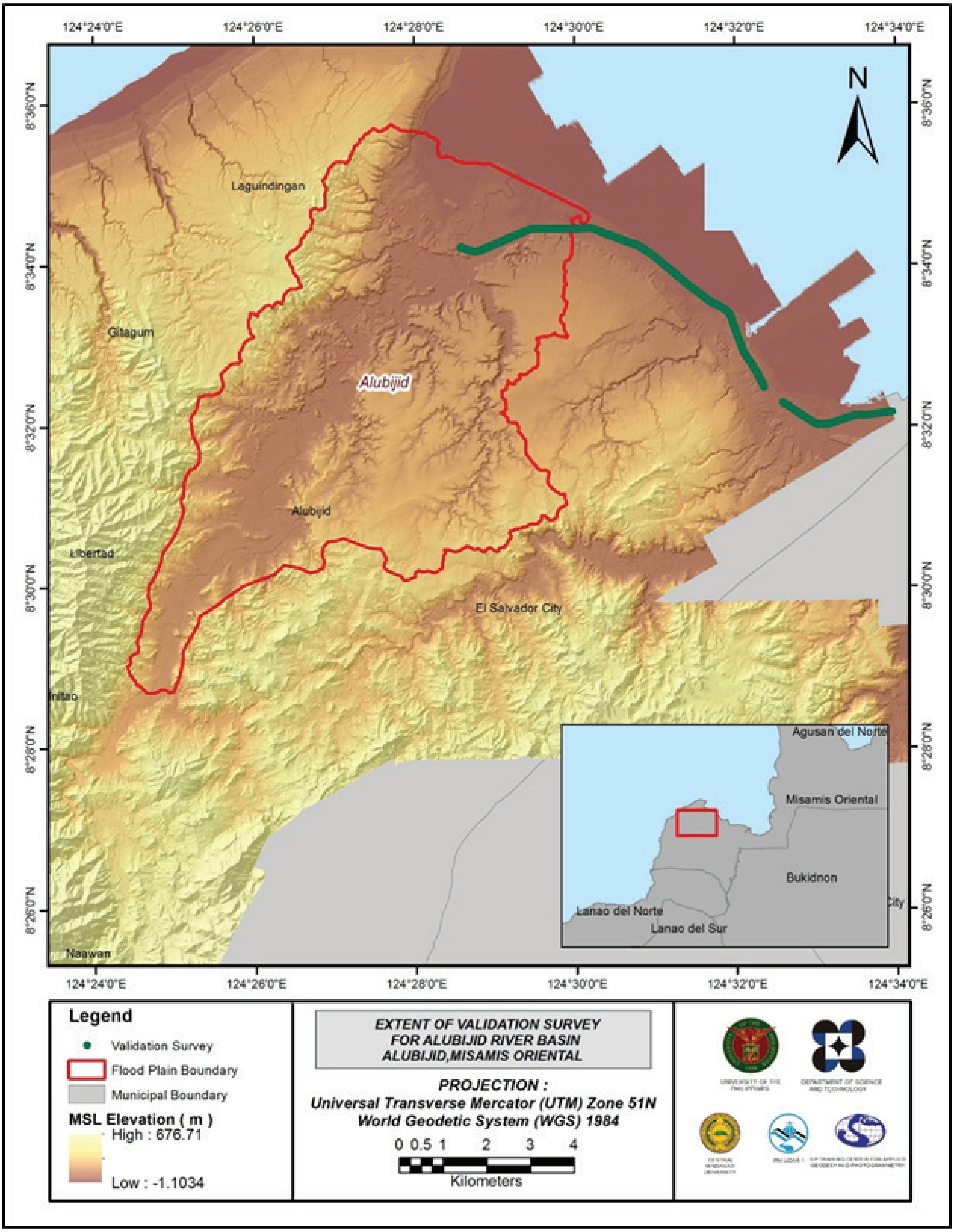

Figure 23. Map of Alubijid Flood Plain with validation survey points in green.

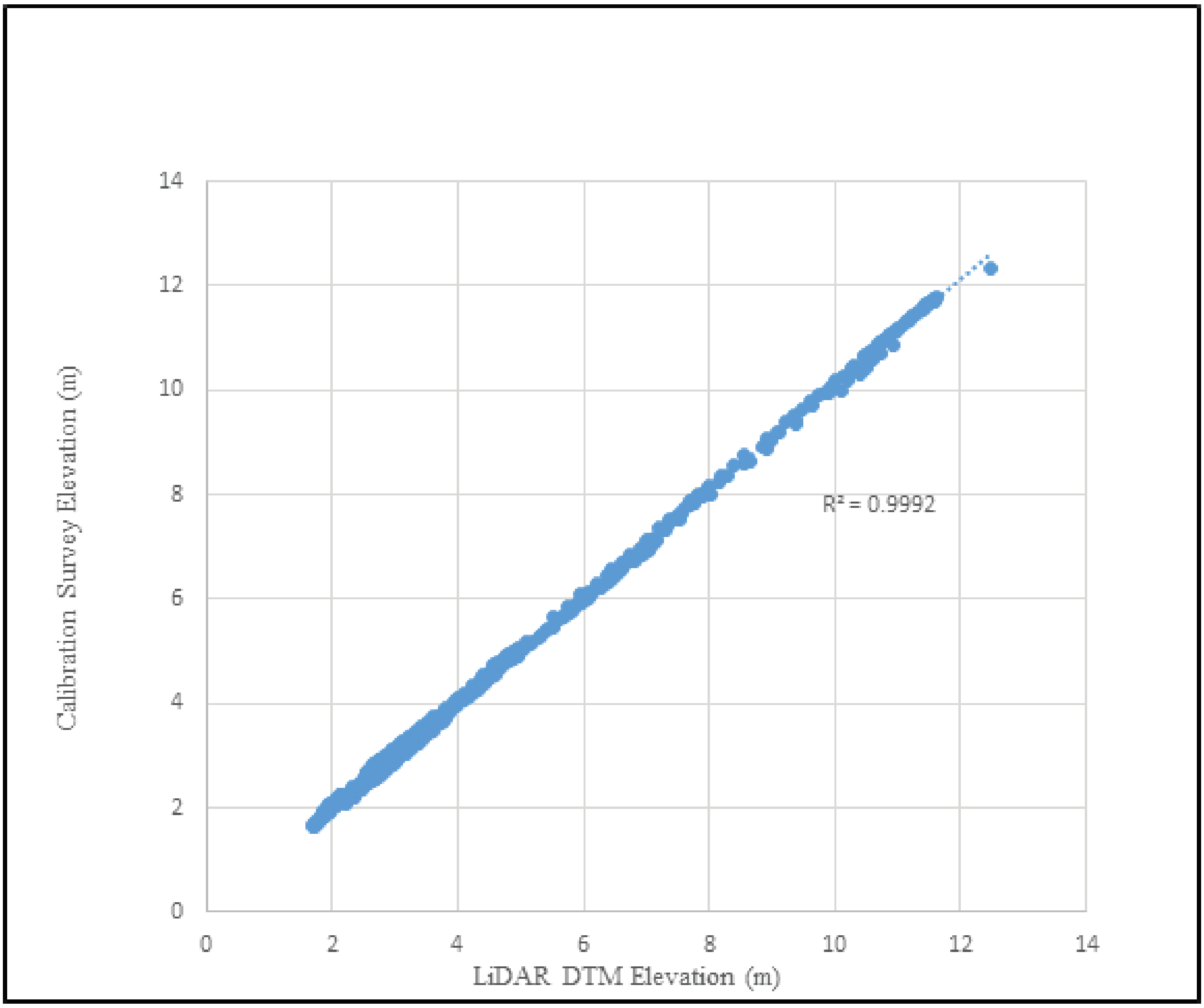

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.08
Standard Deviation	0.08
Average	-0.03
Minimum	0.15
Maximum	-0.19

The remaining twenty percent (20%) of the total survey points is equivalent to 230. Forty-six (46) of the said points lie within the Alubijid flood plain and were used for the validation of the calibrated Alubijid 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 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.08 meters with a standard deviation of 0.08 meters, as shown in Table 15.

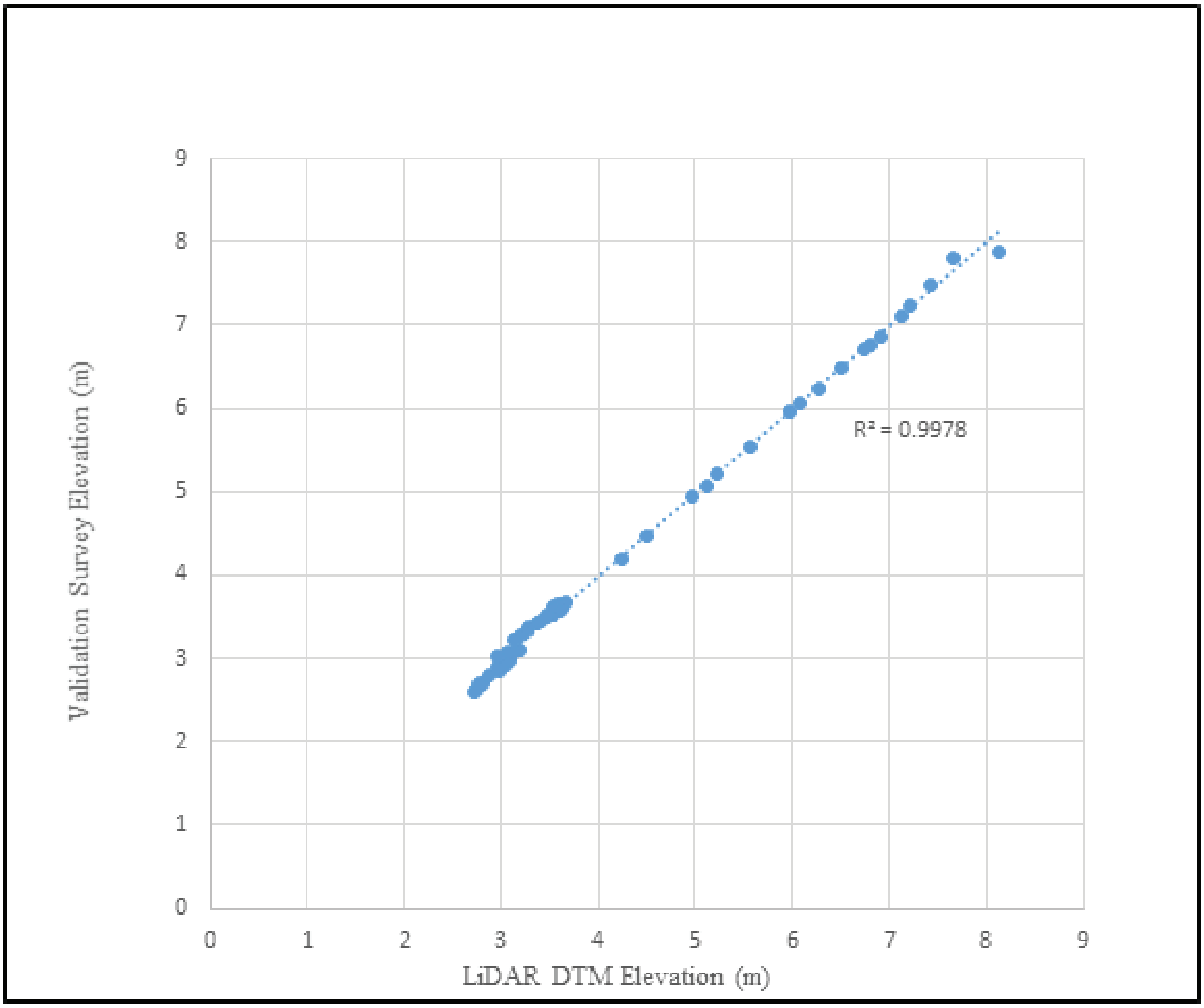

Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.08
Standard Deviation	0.08
Average	0.02
Minimum	-0.16
Maximum	0.25

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Alubijid, with 360 bathymetric survey points. The resulting raster surface produced was accomplished through the 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 0.08 meters. The extent of the bathymetric survey done by the DVBC in Alubijid integrated with the processed LiDAR DEM is shown in Figure 26.

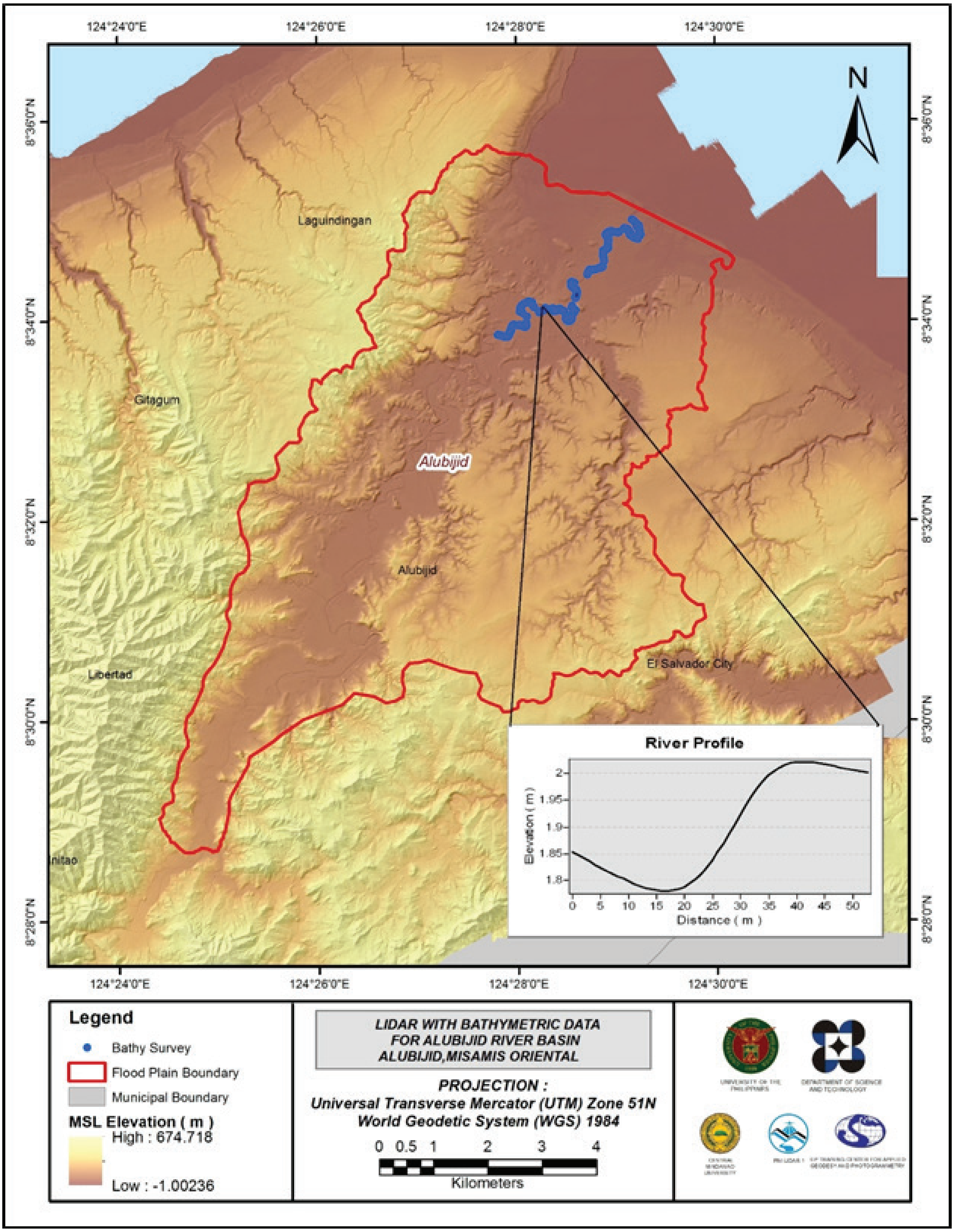

Figure 26. Extent of the bathymetric survey (in blue line) in Alubijid River and the LiDAR data validation survey (red).

3.12 Feature Extraction

The salient features in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area, with a 200-meter buffer zone. Mosaicked LiDAR DEM with one (1) meter 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

The Alubijid floodplain, including its 200-meter buffer, has a total area of 77.56 km2. For this area, a total of 5.0 km2, corresponding to a total of 827 building features, are considered for QC. Figure 27 shows the QC blocks for Alubijid floodplain.

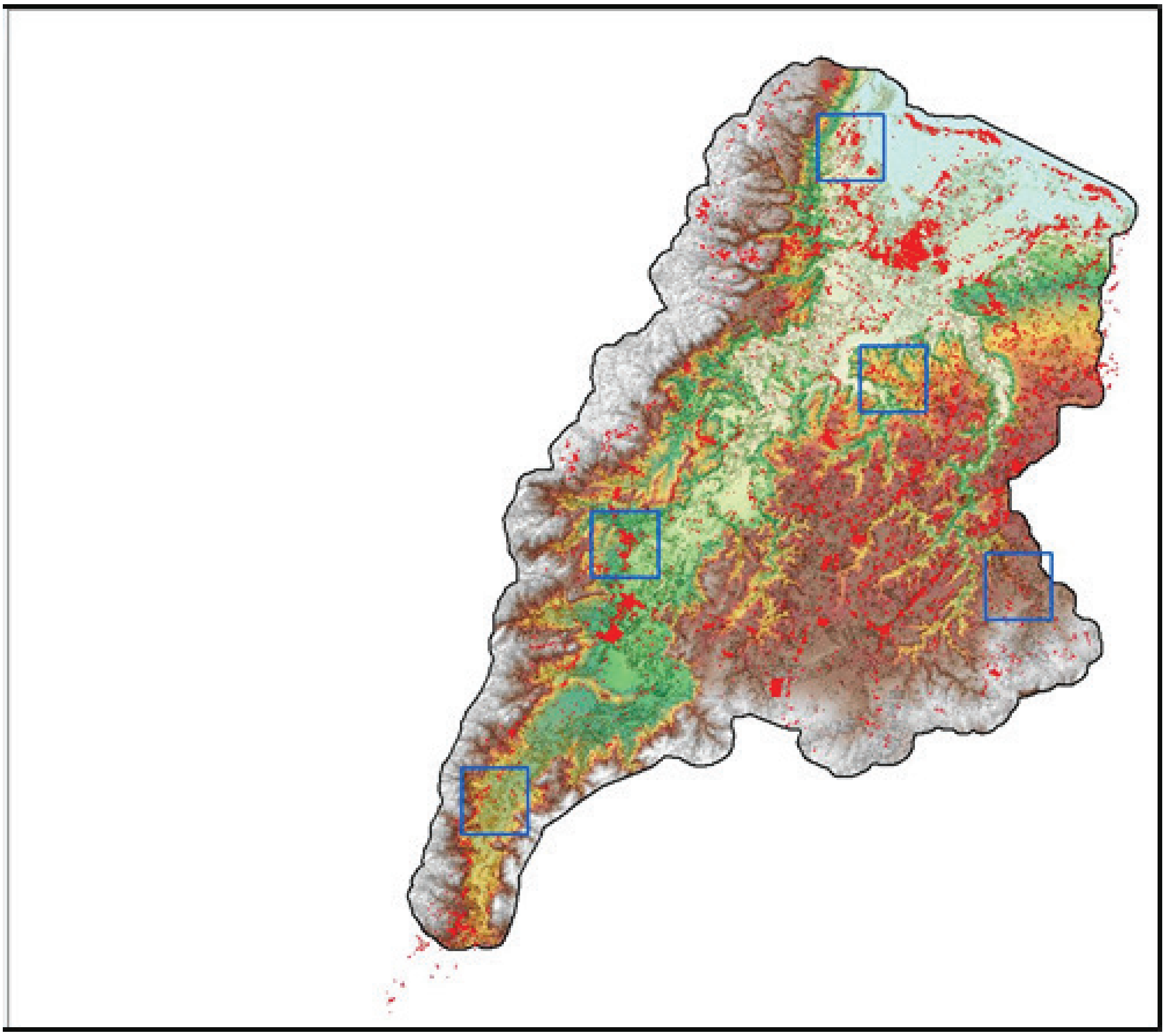

Figure 27. Blocks (in blue) of Alubijid building features that were subjected to QC

Quality Checking (QC) of Alubijid building features resulted in the ratings shown in Table 16.

Table 16. Quality Checking Ratings for Alubijid Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Alubijid	100.00	100.00	99.97	PASSED

3.12.2 Height Extraction

Height extraction was done for 11,248 building features in the Alubijid floodplain. Of these building features, 273 were filtered out after height extraction, resulting to 10,975 buildings with height attributes. Filtered features were the features with less than two (2) meters high. The lowest building height is at 2.00 meters, while the highest building is at 15.43 meters.

3.12.3 Feature Attribution

Field data collection for the attribution process was done through Geotagging (point to a specific feature and shoot method) using a handheld GPS with a built-in camera. The X,Y,Z and the viewing direction of the GPS in 0-359 degrees during the photo capture were the essential information in the process. Using Arcmap's tool "Geotagged Photos to Points", the symbology of the imported point shapefile was set as "Airfield" and the viewing angle was set as "Direction". The "Path" is automatically created in the points' attribute table wherein the photo's directory is linked every after the "Identify" button is clicked to a specific point.

Table 17 summarizes the number of building features per type. From the total features identified, approximately 10,615 of it are residential establishments while the commercial establishments and schools are the most common in non-residential features. On the other hand, Table 18 shows the total length of each road type. Road networks were classified based on the Comprehensive Land Use Plan (CLUP) Map of Alubijid. Table 19 shows the water feature (major river) which is the Alubijid River. Fish pens are convertible into salt plantation ponds. During the rainy season, fish pens are used to accumulate rainwater.Fish pens are utilized as salt plantation ponds in the dry season.

Table 17. Building Features Extracted for Alubijid Floodplain.

Facility Type	No. of Features
Residential	10, 615
School	131
Market	1
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	12
Barangay Hall	14
Military Institution	0
Sports Center/Gymnasium/Covered Court	12
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	14

Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	22
Bank	4
Factory	0
Gas Station	7
Fire Station	1
Other Government Offices	9
Other Commercial Establishments	144
Total	10,986

Table 18. Total Length of Extracted Roads for Alubijid Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Dalanas	97.92	0	31.45	7.13	0	136.50

Table 19. Number of Extracted Water Bodies for Alubijid Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Dalanas	1	0	0	0	78	79

A total of six (6) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 28 shows the Digital Surface Model (DSM) of Alubijid floodplain overlaid with its ground features.

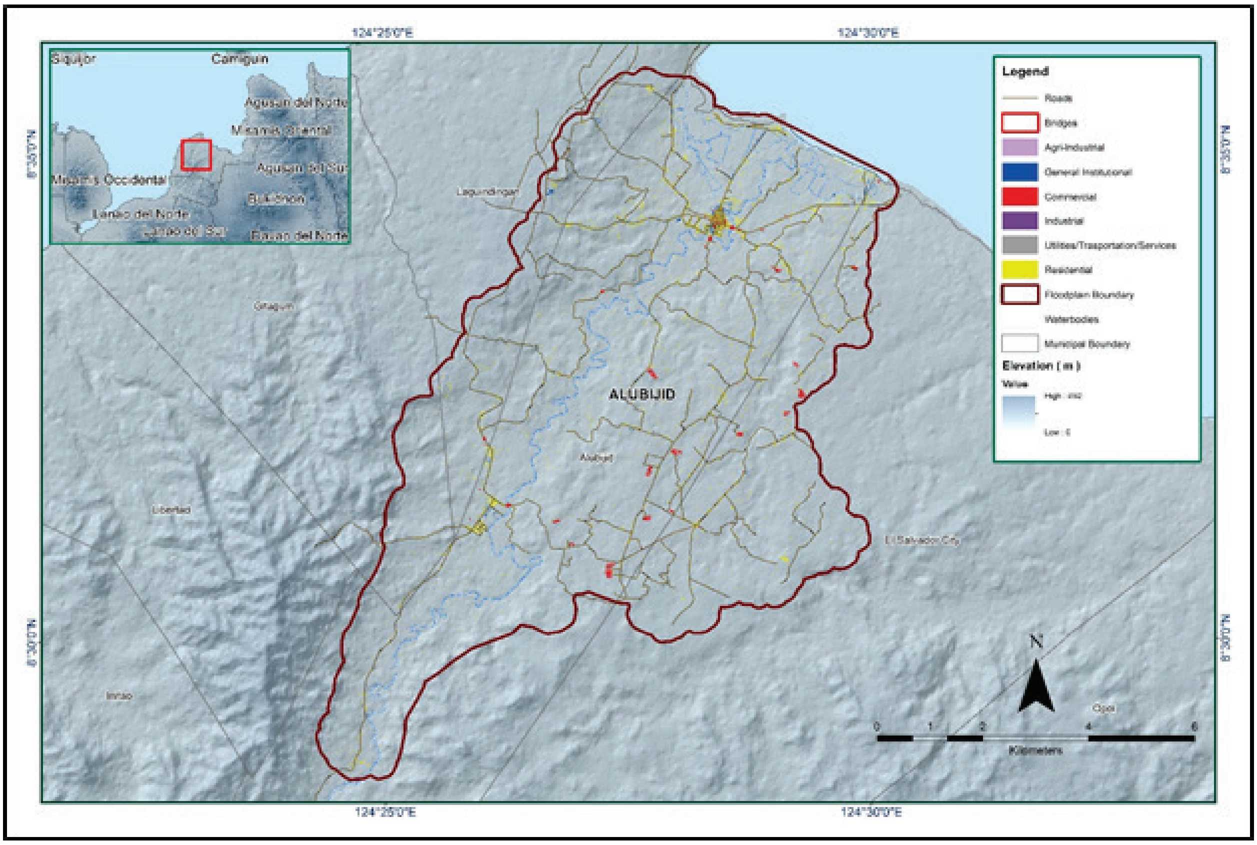

Figure 28. Extracted features for Alubijid floodplain.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) of PHIL-LiDAR1 together with its partner for the area, PHIL-LiDAR1 personnel of Central Mindanao University (CMU) conducted surveys for the Alubijid River Basin on September 25 to October 9, 2014, with the following scope of work: (i) reconnaissance; (ii) control survey for the establishment of an accessible control point to be used in other survey types; (iii) cross-section survey, determination of bridge as-built features and water-level marking with respect to MSL on the pier of Alubijid Bridge; (iv) LiDAR ground validation points acquisition with approximate length of 30 km; and (v) bathymetry survey using Trimble® GNSS PPK survey technique and OHMEX Echosounder covering an estimated 5.7 km.

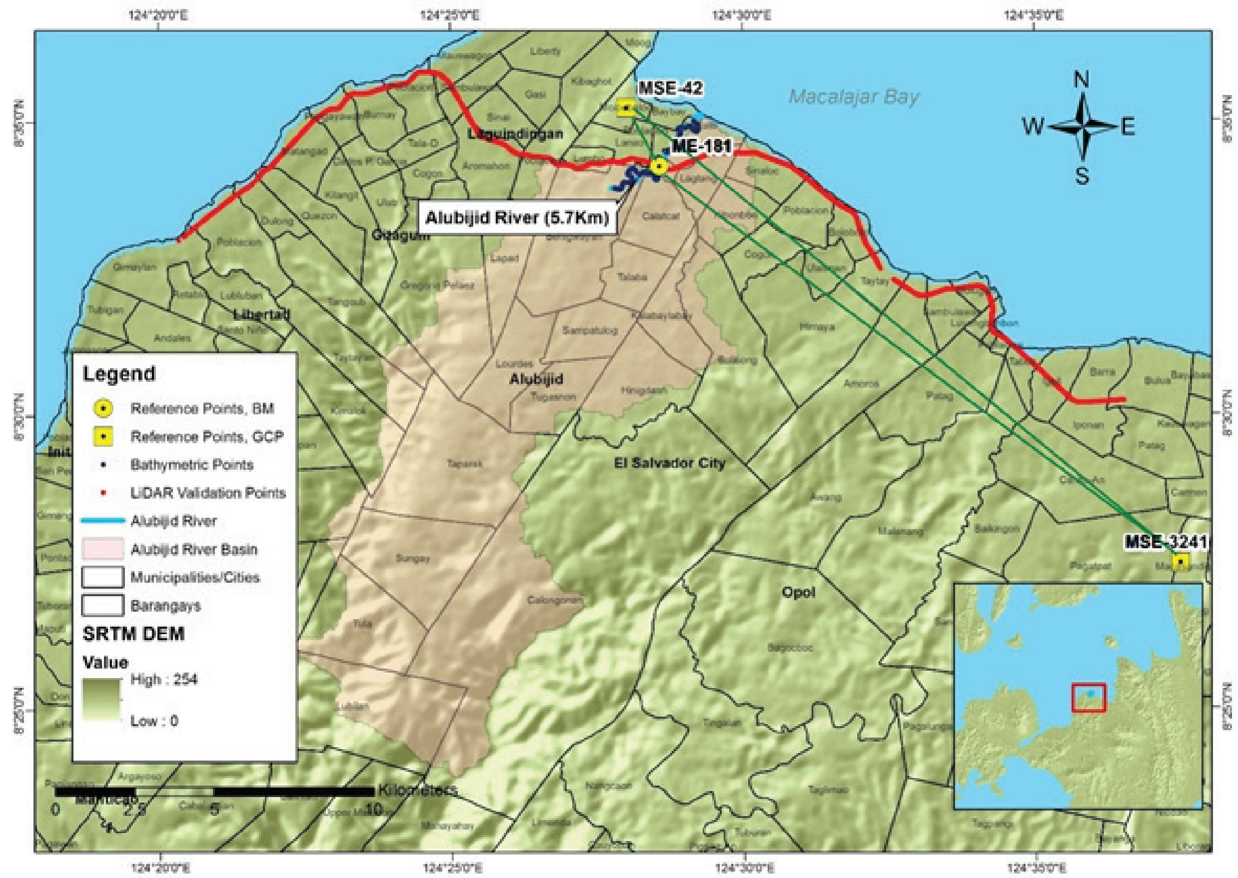


Figure 29. Extent of bathymetric survey in Alubijid River and the LiDAR data validation survey.

4.2 Control Survey

The GNSS network used for theAlubijid River Basin is composed of a single loop established on September 26, 2014, occupying the following reference points: MSE-42, a second-order GCP in Brgy. Molocboloc, Municipality of Alubijid; and ME-181, a first-order BM in Brgy. Poblacion, Municipality of Alubijid, Misamis Oriental.

A NAMRIA established control point,MSE-3241, a 3rd order GCP, located in Barangay 10 (POB.), Cagayan de Oro Citywas also occupied to use as marker in the survey.

The summary of reference and control points and theirlocations is summarized in Table 20 while the GNSS network established is illustrated in Figure 30.

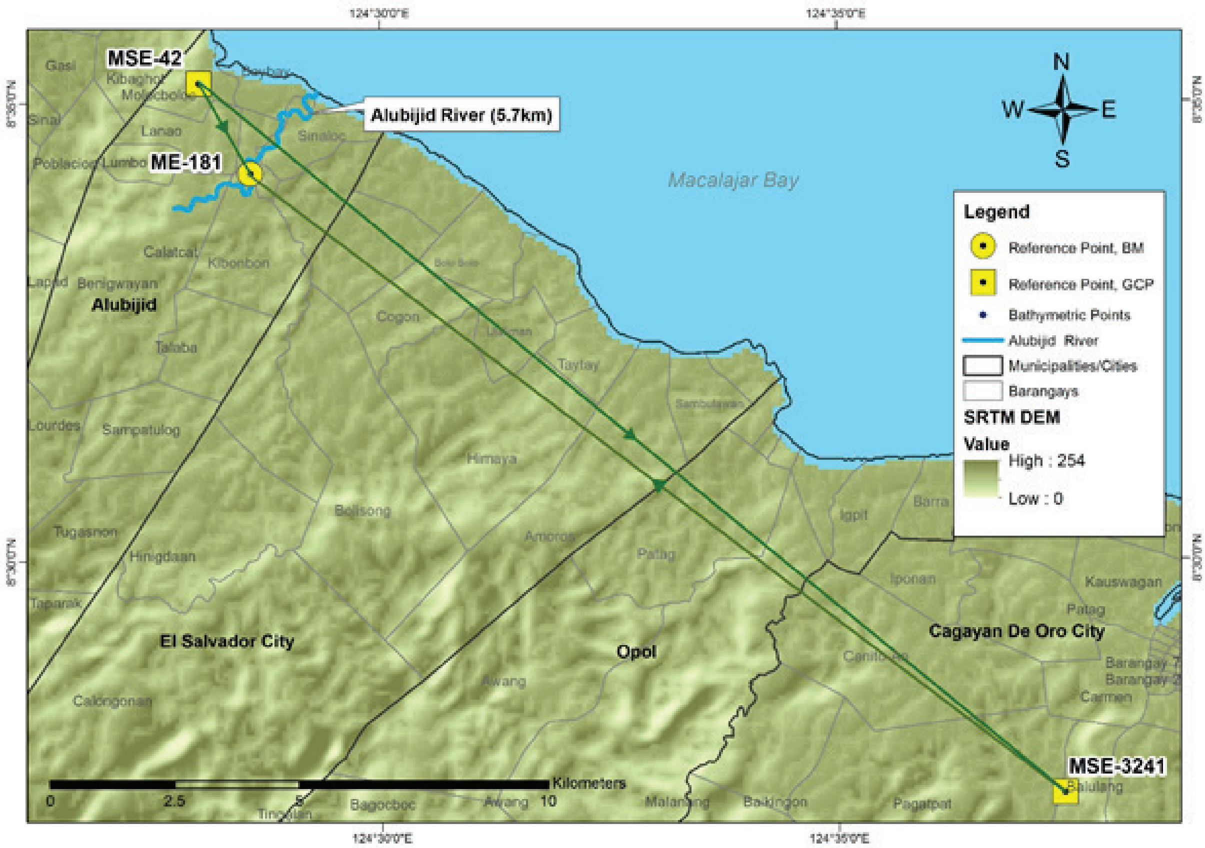


Figure 30. GNSS Network of Alubijid River field survey.

Table 20 List of References and Control Points occupied in Alubijid River Basin survey.

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
MSE-42	2nd Order, GCP	8°35'13.03914"	124°28'00.89489"	90.957	-	2003
ME-181	1st Order, BM	-	-	91.293	22.896	2007
MSE-3241	Used as Marker	-	-	188.462	-	2007

The GNSS set-ups on the recovered reference and control points in Alubijid River are shown in Figure 31 to Figure 33.

Figure 31. GNSS receiver, Trimble® SPS 852, setup at ME-181 in Alubijid Bridge, Brgy. Poblacion, Alubijid.

Figure 32. GNSS receiver Trimble® SPS 985 setup, at MSE-42 on the concrete water tank behind the Molocboloc Barangay Hall, Municipality of Alubijid.

Figure 33. GNSS receiver Trimble® SPS 852 setup at MSE-3241 in Brgy. 10 (POB.), Cagayan de Oro City.

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within+/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines do not meet all of these criteria, masking is performed. Masking is done by removing portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. The Baseline processing results of control points in the Alubijid River Basin is summarized in Table 21, generated by TBC software.

Table 21 Baseline processing report for Alubijid River Basin static survey.

Observation	Date of Observation	Solution Type	Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter	ΔHeight (Meter)
MSE-3241 --- MSE-42	09-26-2014	Fixed	0.003	0.013	129°28'10"	22494.351	97.525
MSE-3241 --- ME-181	09-26-2014	Fixed	0.004	0.027	307°23'52"	20550.228	-97.202

wqasMSE-3241 --- ME-181	09-26-2014	Fixed	0.004	0.031	307°23'52"	20550.220	-97.149
MSE-42 --- ME-181	09-26-2014	Fixed	0.008	0.018	307°23'52"	20550.248	-97.114
MSE-42 --- ME-181	09-26-2014	Fixed	0.003	0.014	150°27'39"	2097.031	0.364
MSE-42 --- ME-181	09-26-2014	Fixed	0.004	0.007	150°27'39"	2097.030	0.322
MSE-42 --- ME-181	09-26-2014	Fixed	0.004	0.010	150°27'39"	2097.023	0.333

As shown in Table 21, a total of seven (7) baselines were processed with coordinates of MSE-42 and elevation value of ME-181 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment wasperformed using TBC. Looking at the Adjusted Grid Coordinates in Table 23of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm, or in equation form:

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

Where:

x^e is the Easting Error,
y^e is the Northing Error, and
z^e is the Elevation Error

for each control point. See Table 22 for the complete details of the Network Adjustment Report for Alubijid River.

Table 22 . Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MSE-42	Local	Fixed	Fixed		
ME-181	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 inTable 23. All fixed control points have no values for grid and elevation errors.

Table 23 . Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ME-181	662470.950	0.005	947675.855	0.004	22.896	?	e
MSE-42	661430.196	?	949496.213	?	22.819	0.017	LL
MSE-241	678848.436	0.006	935263.900	0.005	118.361	0.033	

With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z^e<10$ cm for the vertical; the computation for the accuracy are as follows:

a. MSE-42
Horizontal Accuracy = Fixed
Vertical Accuracy = $1.7 < 10$ cm

b. ME-181
Horizontal Accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= $0.64 < 20$ cm
Vertical Accuracy = Fixed

c. MSE-3241
Horizontal Accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$
= $\sqrt{(0.36 + 0.25)}$
= $0.78 < 20$ cm
Vertical Accuracy = $3.3 < 10$ cm

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

Table 24 . Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
ME - 181	N8°34'13.65259"	E124°28'34.70466"	91.293	?	e
MSE - 42	N8°35'13.03914"	E124°28'00.89489"	90.957	0.017	LL
MSE-3241	N8°27'27.49300"	E124°37'28.59511"	188.462	0.033	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 24.

The summary of reference and control points used is indicated in Table 25.

Table 25 . Reference and control points used and its location.

(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MSE-42	2nd Order, GCP	8°35'13.03914"	124°28'00.89489"	90.957	949496.213	661430.196	22.819
ME-181	1st Order, BM	8°34'13.65259"	124°28'34.70466"	91.293	947675.855	662470.95	22.896
MSE-3241	Used as Marker	8°27'27.49300"	124°37'28.59511"	188.462	935263.9	678848.436	118.361

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

Cross section and bridge as-built survey was conducted on September 28, 2014 at the downstream side of the Alubijid Bridge in Brgy. Poblacion, Municipality of Alubijid using Trimble®SPS882 receiver in PPK survey technique, as shown in Figure 34.

Figure 34. Cross Section survey at Alubijid Bridge in the Municipality of Alubijid.

The cross-sectional line of Alubijid Bridge is about 147.41 m with twenty four (24) cross-sectional points using the control point ME-181 as the GNSS base station. The cross-section diagram, planimetric map and bridge data form are shown in Figure 35 to Figure 37, respectively.

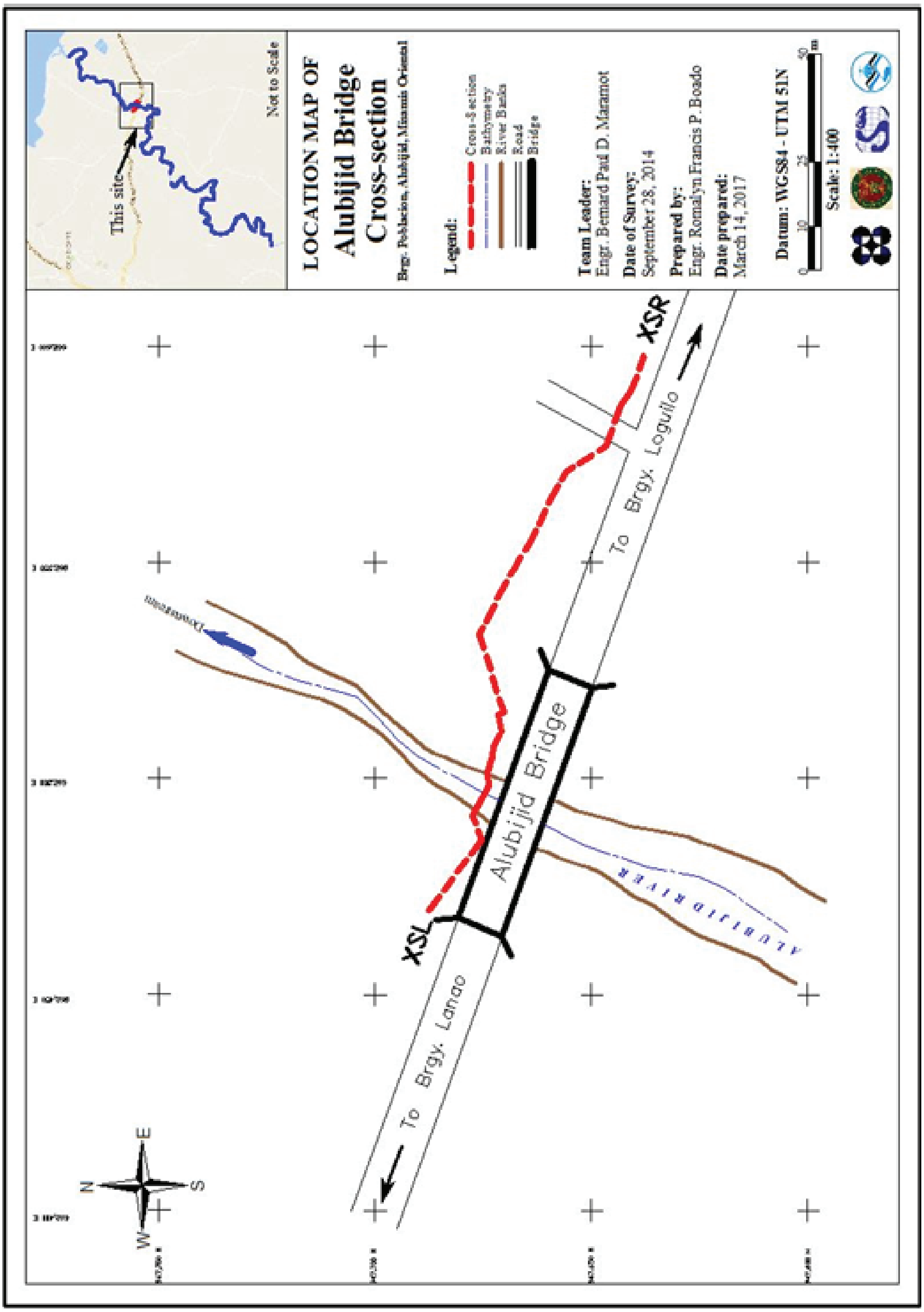


Figure 35. Alubijid Bridge location map.

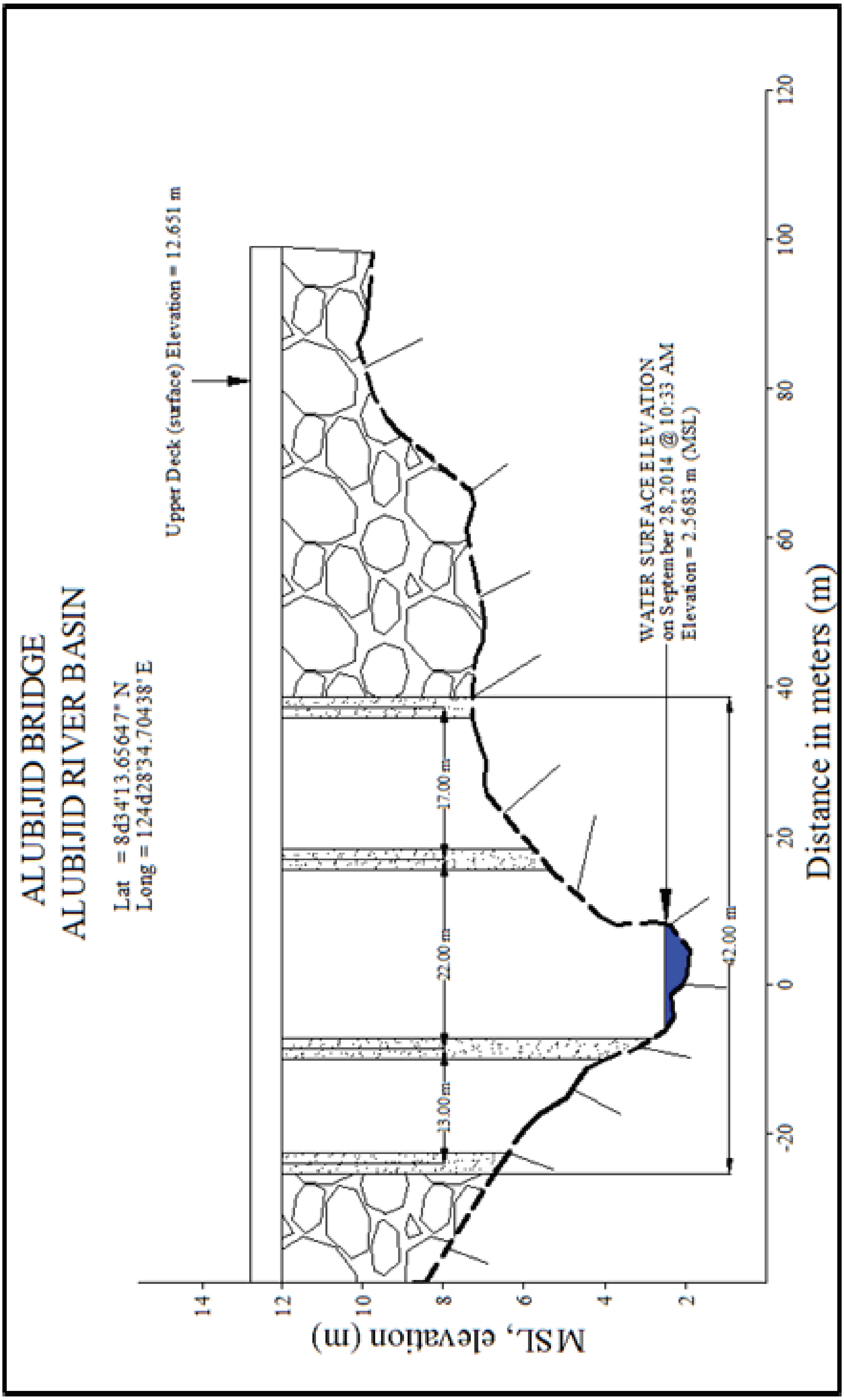


Figure 36. Alubijid Bridge cross-section diagram.

Bridge Data Form

Bridge Name: ALUBIJID BRIDGE **Date:** September 28, 2014

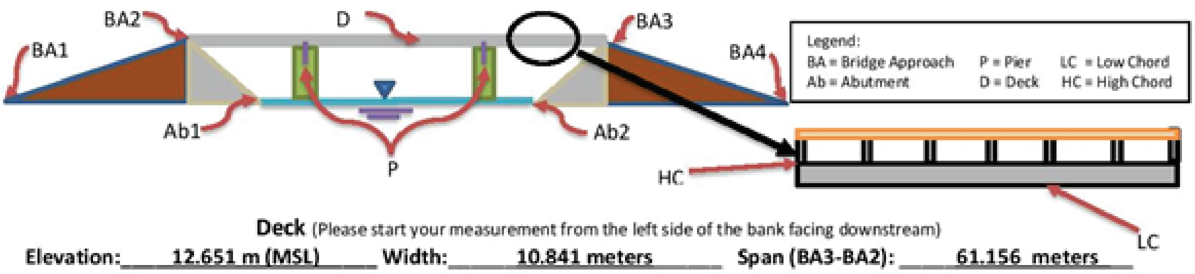
River Name: ALUBIJID RIVER **Time:** 10:33 am

Location (Brgy, City, Region): Brgy. Poblacion, Alubijid, Misamis Oriental

Survey Team: DVBC Misamis Oriental Survey Team

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

Latitude: 8°34'13.65238" N **Longitude:** 124°28'34.70479" E



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

Elevation: 12.651 m (MSL) **Width:** 10.841 meters **Span (BA3-BA2):** 61.156 meters

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	12.6663	11.0003 m
2			
3			
4			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	13.952	BA3	135.297	11.593
BA2	74.141	12.839	BA4	213.123	9.861

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: Cylindrical **Number of Piers:** 4 **Height of column footing:** ____

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	76.301	12.648	
Pier 2	92.692	12.387	
Pier 3	115.761	12.065	
Pier 4	132.947	11.586	

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

Figure 37. Alubijid Bridge Data Form.

The water surface elevation of the Alubijid River was acquired using Trimble®SPS882 in GNSS PPK survey technique on September 28, 2014 at 10:33 AM. The water surface elevation is 2.568 m above MSL. The elevation data was translated to the bridge's pier using a GNSS receiver Trimble™ SPS 882. The resulting data was used to mark the piers of Alubijid Bridge as shown in Figure 38. The markings on the bridge pier shall serve as elevation reference for flow data gathering and depth gauge deployment of Central Mindanao University PHIL-LiDAR 1.

Figure 38. Water level mark at the pier of Alubijid Bridge.

4.6 Validation Points Acquisition Survey

LiDAR validation points acquisition survey was conducted on September 27, 2014 using a survey GNSS rover receiverTrimble®SPS882 mounted on a pole which was attached at the side of the vehicle, as shown in Figure 39. It was secured with a cabletieto ensure that it was horizontally and vertically balanced. The antenna height of 2.52 meters was measured from the ground up to the bottom of notch of the GNSS rover receiver.

Figure 39. Trimble SPS®882 set-up in a vehicle in Alubijid River.

The survey started from Brgy. Gimaylan, Municipality of Libertad, going east through the major roads traversing the municipalities of Libertad, Gitagum, Laguindingan, Alubijid, Opol, El Salvador City and Cagayan De Oro City; and ended in Brgy. Bulua, Cagayan De Oro City. A total of 3,721 points were gathered with an approximate length of 30 km using ME-181 as GNSS base station for the entire extent of validation points acquisition survey, as illustrated in the map in Figure 40.

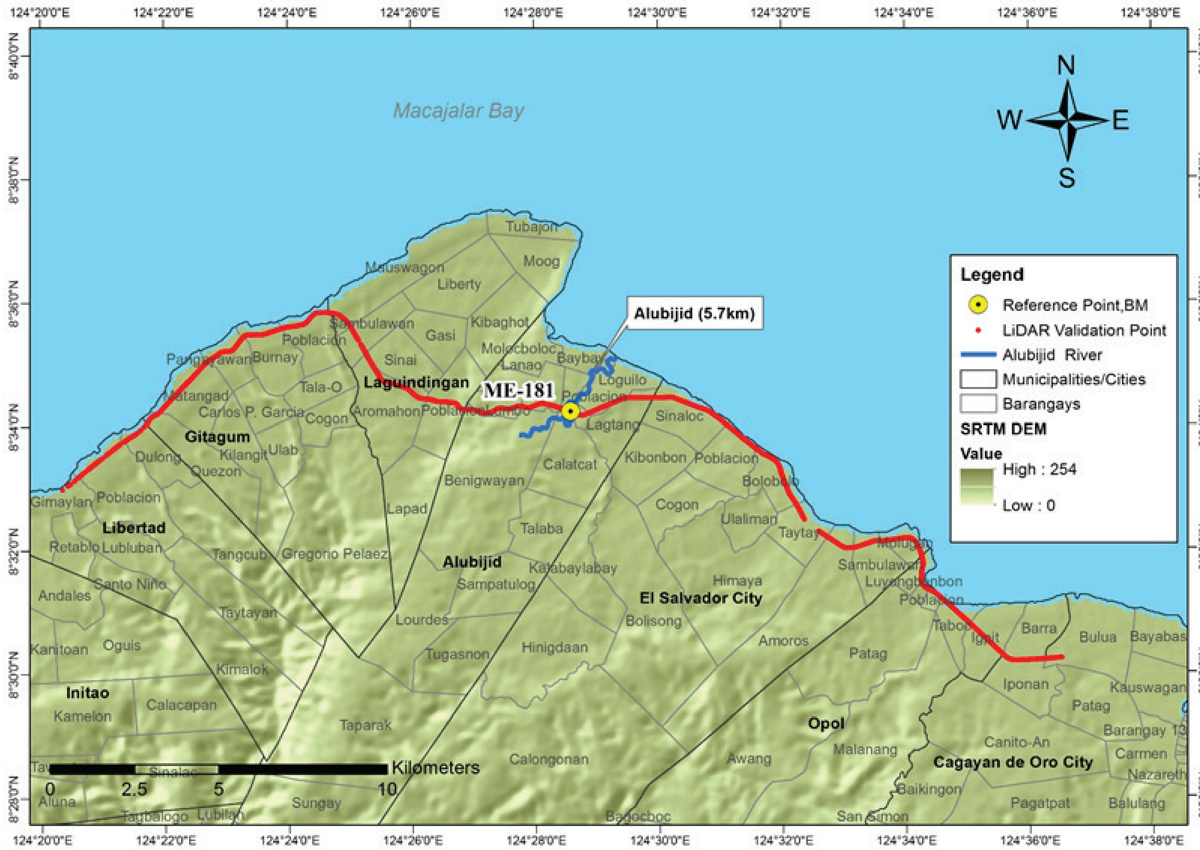


Figure 40. LiDAR ground validation survey coverage for Alubijid River Basin.

4.7 Bathymetric Survey

Bathymetric survey in the Alubijid River was conducted on September 27, 2014 using Trimble® SPS 882 in GNSS PPK survey technique (See Figure 41). The survey commenced onthe upstream portion in Brgy. Benigwayanwith coordinates 8°32'41.34130" 124°26'58.75098", then walked down to its mouth in Brgy. Baybay with coordinates 8°35'00.30104"124°29'10.04657".The reference point ME-181, located at Alubijid Bridge in Brgy. Poblacion, Alubijid, served as the GNSS base station. The bathymetry line length is about 5.7 kilometers, with a total of 406 bathymetric points gathered, as presented in Figure 42.

Figure 41. Manual bathymetry in the shallow portion of Alubijid River.

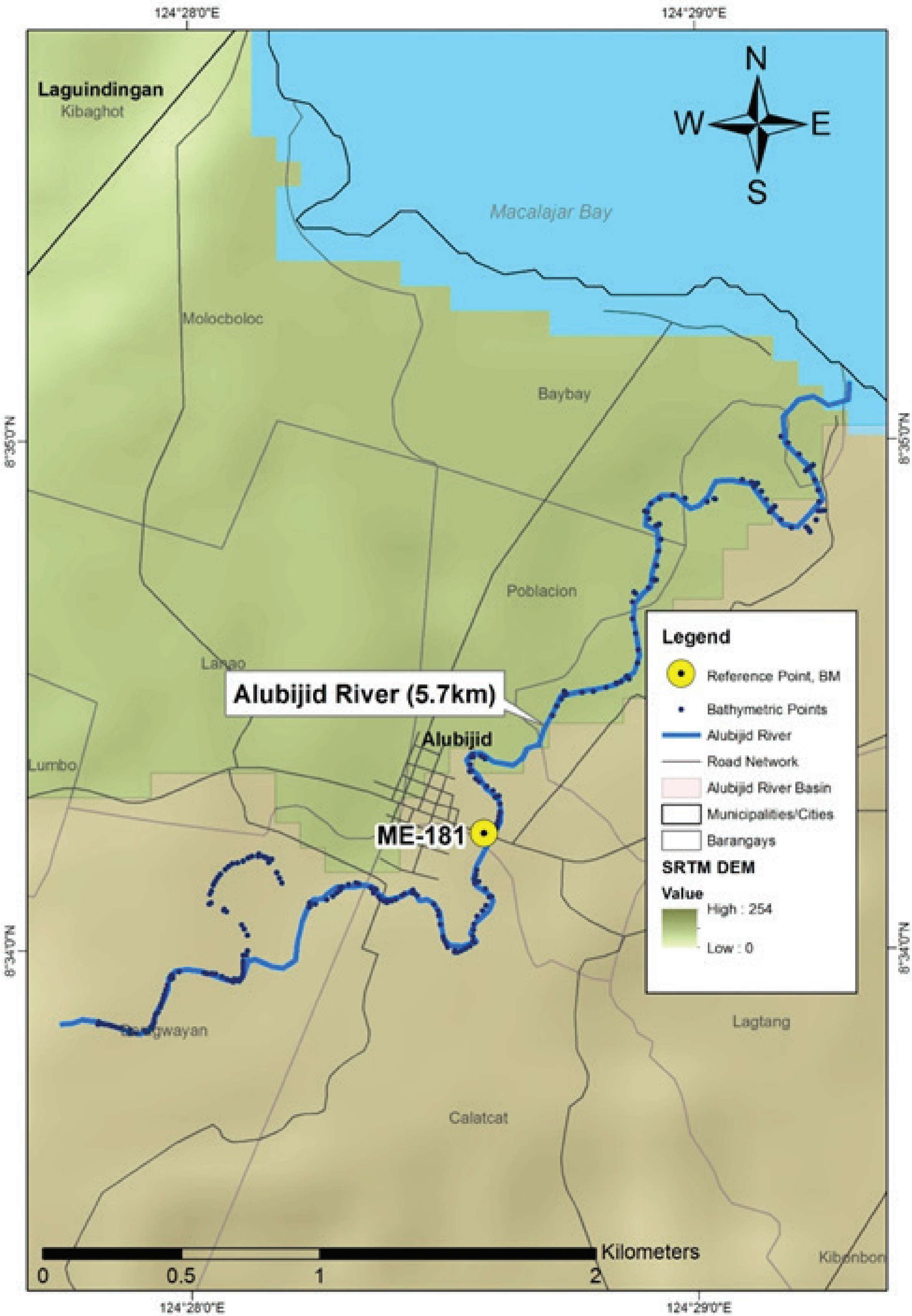


Figure 42. Bathymetric survey of Alubijid River.

A CAD drawing was produced to illustrate the riverbed profile of the Alubijid River, as shown in Figure 43. An elevation drop of 5.15 meters was observed within the approximate distance of 5.7 kilometers from Brgy. Benigwayan down to its mouth in Brgy. Baybay.

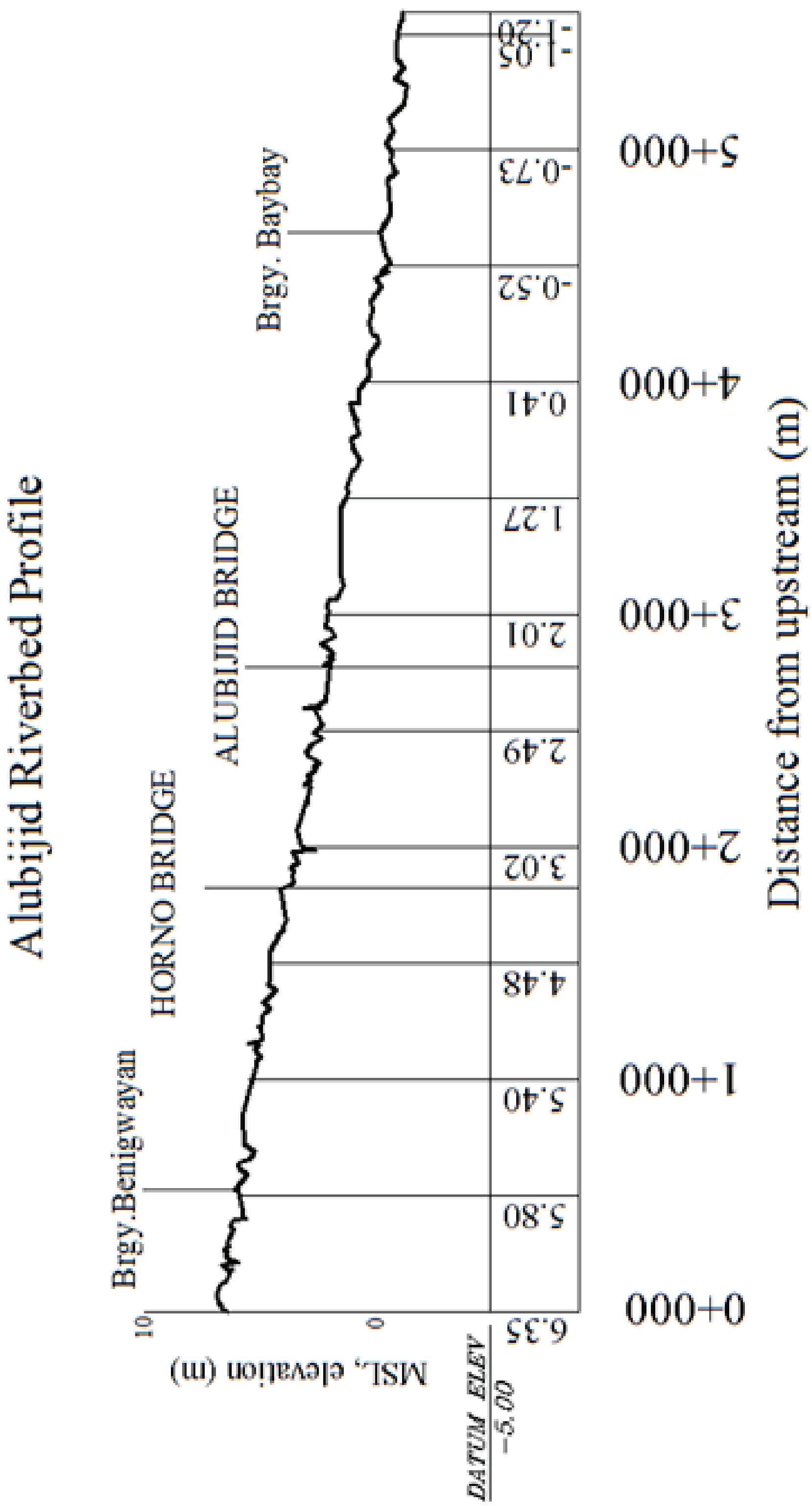


Figure 43. Riverbed profile of Alubijid River.

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 and Mariel Monteclaro

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Misamis Oriental, including the Alubijid River basin, was under Signal No. 1 during the landfall of Tropical Depression Queenie onNovember27, 2014. The hydrologic data collection covered the period 1020 hrs on November 26, 2014 until1610 hrs onNovember 27, 2014. Hydrologic data include the river velocity, water depth and rain collected from data logging sensors (mechanical velocity meter, depth gauge and rain gauges) in a specific time period. Precipitation data was taken from three (3) automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). These were the Pigsag-an, Pugaan and San Simon ARGs. The location map of the rain gauges is seen in Figure 44. Rainfall data were downloaded from the web portal of Philippine E-Science Grid-ASTI (http://repo.pscigrid.gov.ph).

Total precipitation for this event inPigsag-an rain gauge is 6.2mm. It peaked to 5.6mm on 26 November 2014, 22:30. For Pugaan, total rain for this event is 58.7mm. Peak rain of 8.9mm was recorded on 26 November 2014, 23:30. For San Simon, total rain is 21.8mm. It peaked to 2.2mm at 26 November 2014, 22:15. The lag time between the peak rainfall and discharge is two hours and fifty minutes.

The DOST-ASTI Region X had successfully installed two ARGs inNovember 2015after the occurrence of Typhoon Queenie. ARGs are located in the barangays of Taparak (8° 29’20”N, 124°24’43”E) and Tula (8° 26’10”N, 124°25’10”E). The two (2) ARGs are within the Alubijid River Basin,as shown inFigure 44.

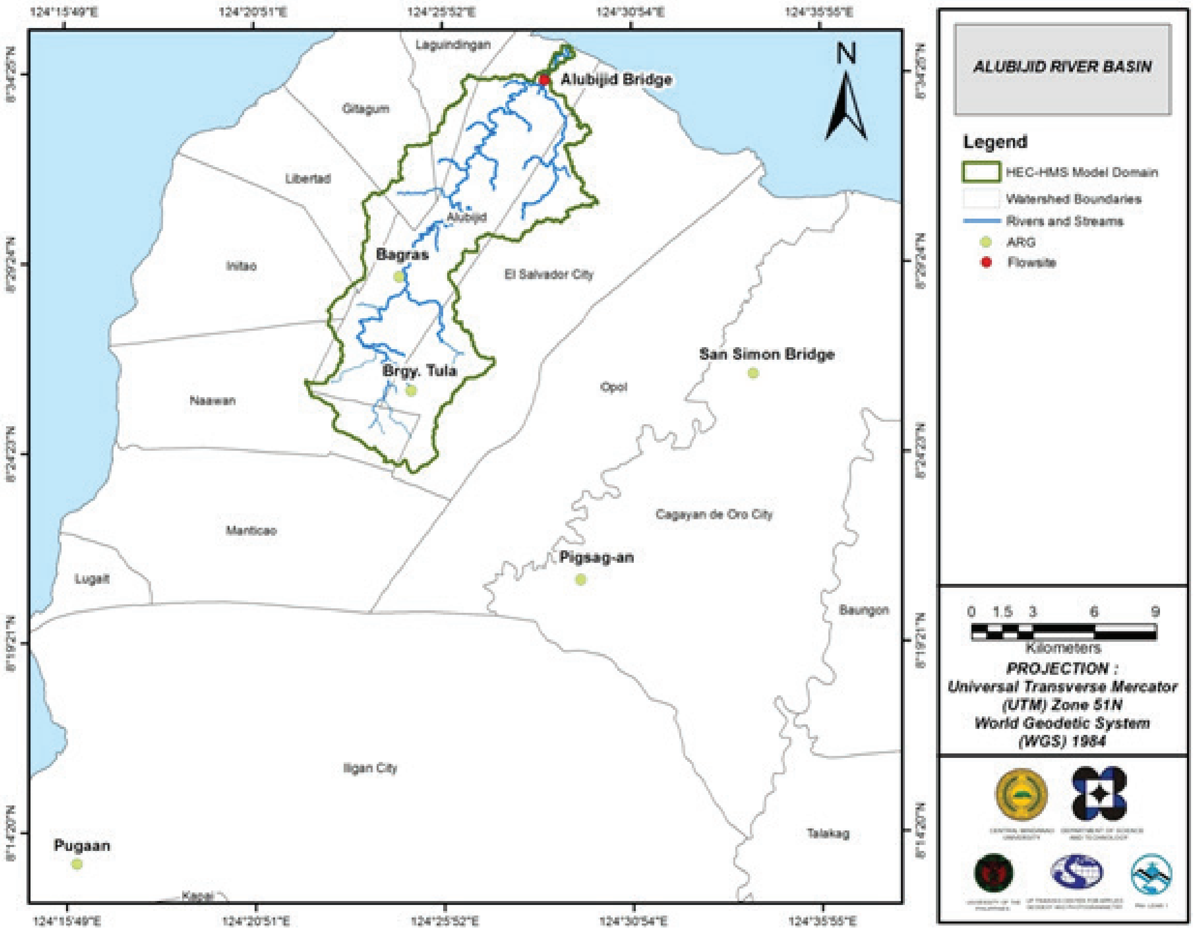


Figure 44. The location map of Alubijid HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

Tropical Depression Queenie,which occurred on November26-27, 2014 contributed to a 1.04 meter water level rise with peak discharge of 18.668 m3/s recorded at 0220 hrs on November 27, 2014, with accumulated rainfall 86.7 mm. These hydrologic data are actual eventsin theAlubijid River, and inputted to the hydrologic modeling. Hydrologic measurements were taken from Alubijid Bridge, Poblacion, Alubijid, Misamis Oriental.Figure 45 and Figure 46 illustrate the cross-section plot of the Alubijid Bridge and the Alubijid Hydrometry, respectively.

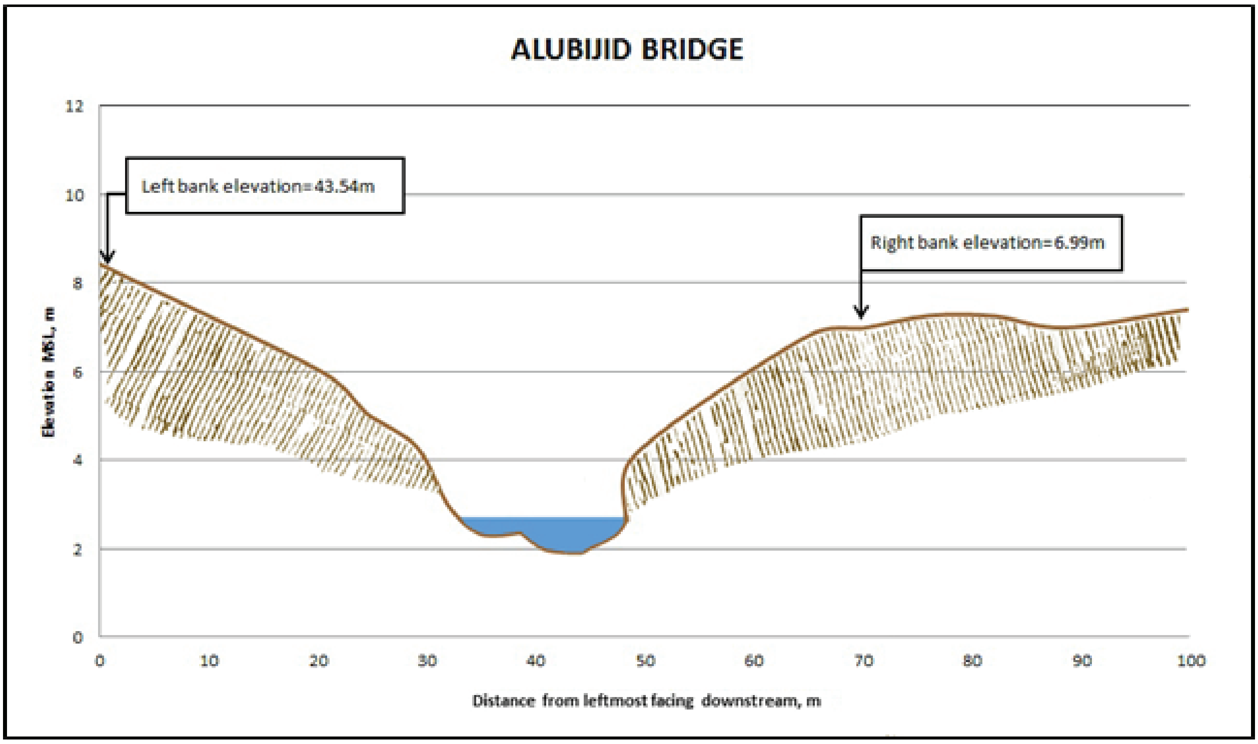


Figure 45. Cross-Section Plot of Alubijid Bridge.

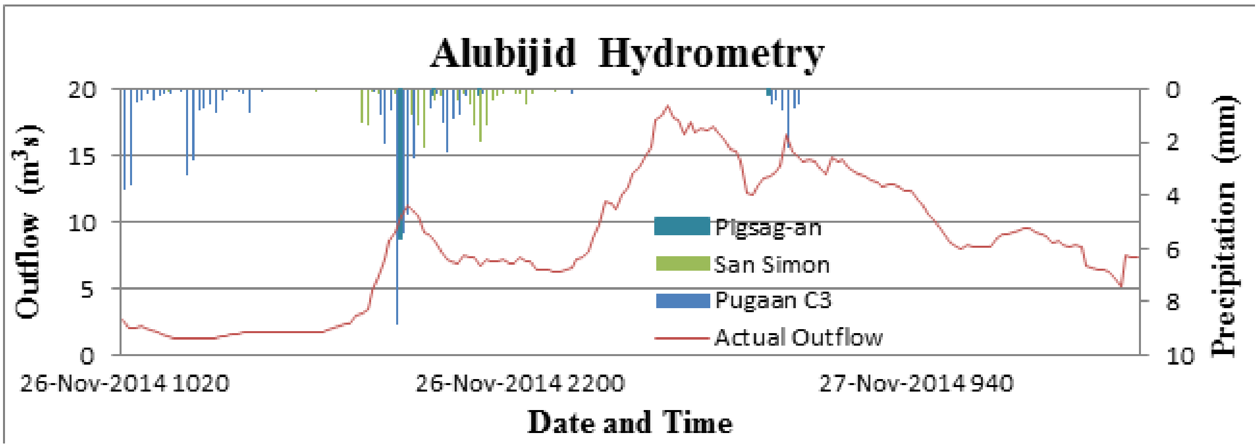


Figure 46. Rainfall and outflow data used for modeling.

A rating curve was generated for the observed flow and water level. It shows the relationship of the two hydrologic data. It is expressed in the form of the following equation:

Q=a nh

where, Q : Discharge (m3/s),

h : Gauge height (reading from Alubijid Bridge depth gauge sensor), and

a and n : Constants.

The Alubijid River Rating Curve measured at Alubijid Bridge is expressed as Q = 0.0065e2.4574x (Figure 47).

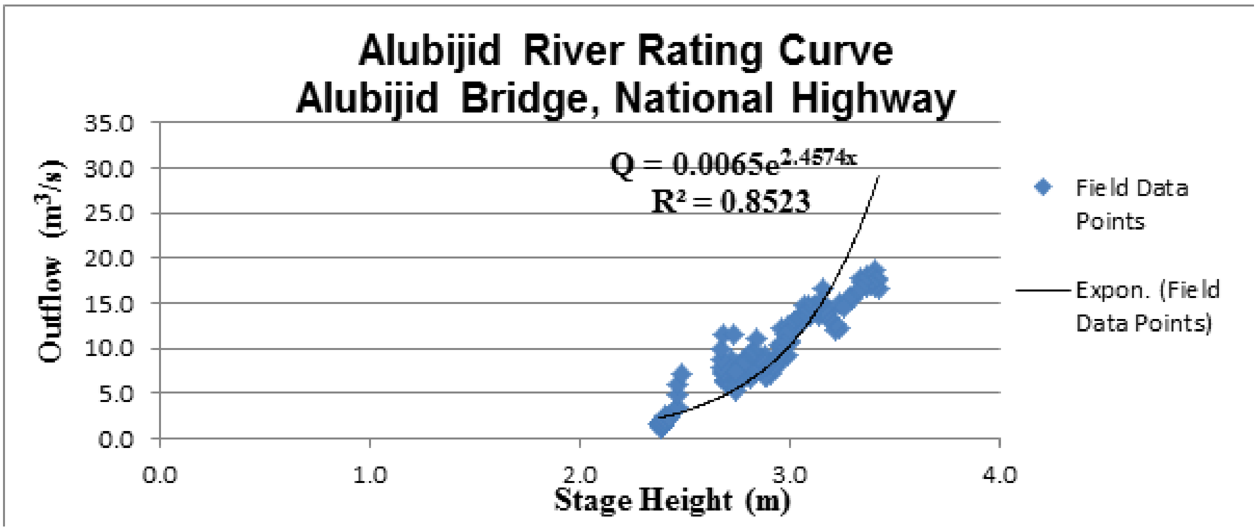


Figure 47. HQ Curve of HEC-HMS model.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Cagayan de Oro City Rain Gauge, presented in Table 26. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way that a certain peak value will be attained at a certain time. This station was selected based on its proximity to the Alubijid watershed (Figure 48). The extreme values for this watershed were computed based on a 54-year record.

Table 26. RIDF values for Cagayan de Oro Rain Gauge computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	18.6	29.5	37	48.3	62.3	69.4	81.6	91.8	100.1
5	24.5	38.4	48.2	63.7	84.3	92.6	109.9	128.1	141.7
10	28.4	44.3	55.6	73.9	98.8	107.9	128.7	152.1	169.2
15	30.6	47.7	59.8	79.6	107.1	116.6	139.3	165.6	184.7
20	32.2	50	62.8	83.7	112.8	122.7	146.7	175.1	195.6
25	33.3	51.8	65	86.8	117.3	127.4	152.4	182.4	204
50	37	57.3	72	96.3	130.9	141.8	170	204.9	229.8
100	40.6	62.8	78.9	105.8	144.5	156.1	187.4	227.3	255.5

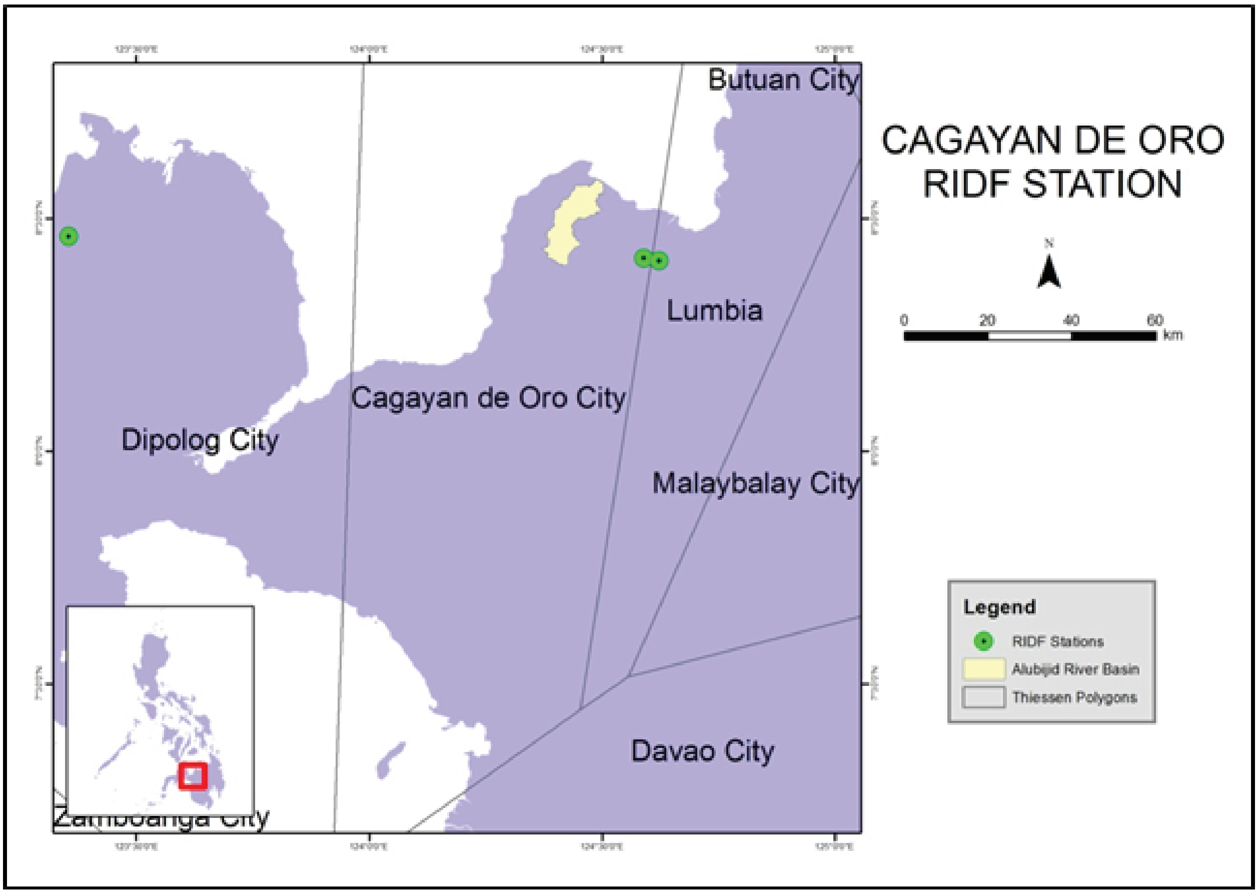


Figure 48. Location of Cagayan de Oro RIDF Station relative to Alubijid River Basin.

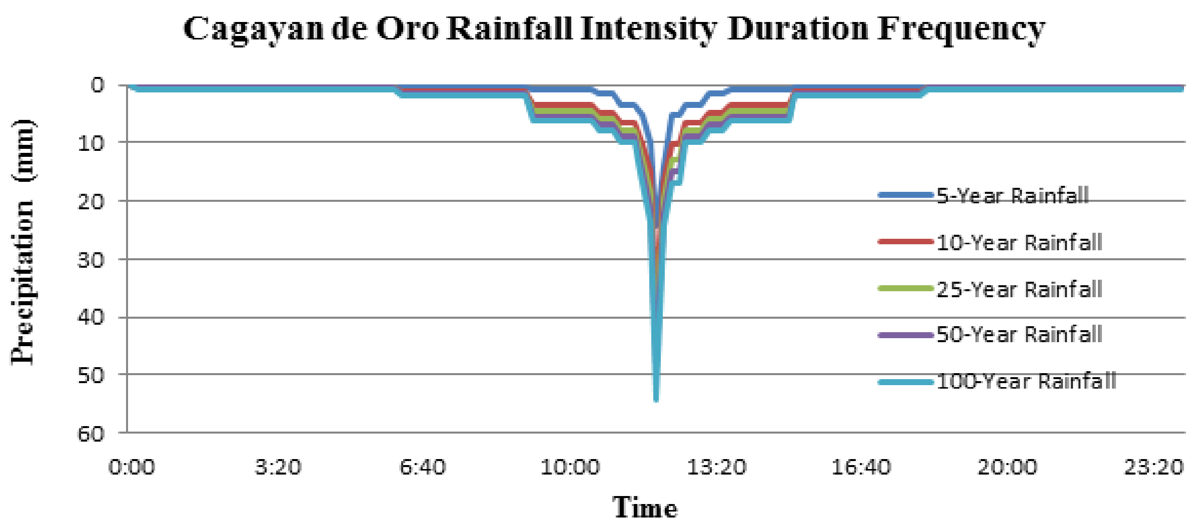


Figure 49. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil shapefile was taken in 2004 from the Bureau of Soils and Water Management (BSWM), under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Alubijid River Basin are shown in Figures 50 and 51, respectively.

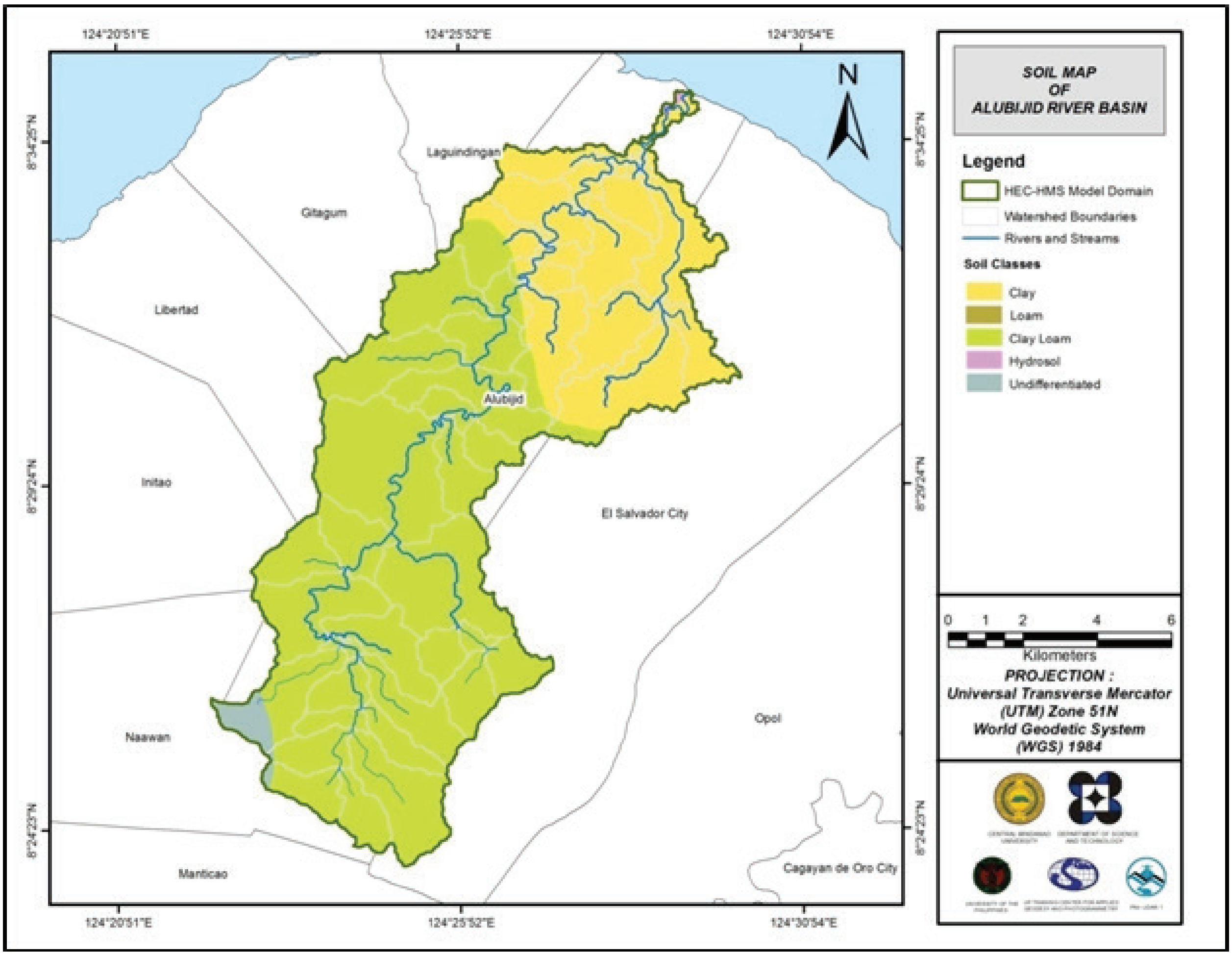


Figure 50. The soil map of the Alubijid River Basin.

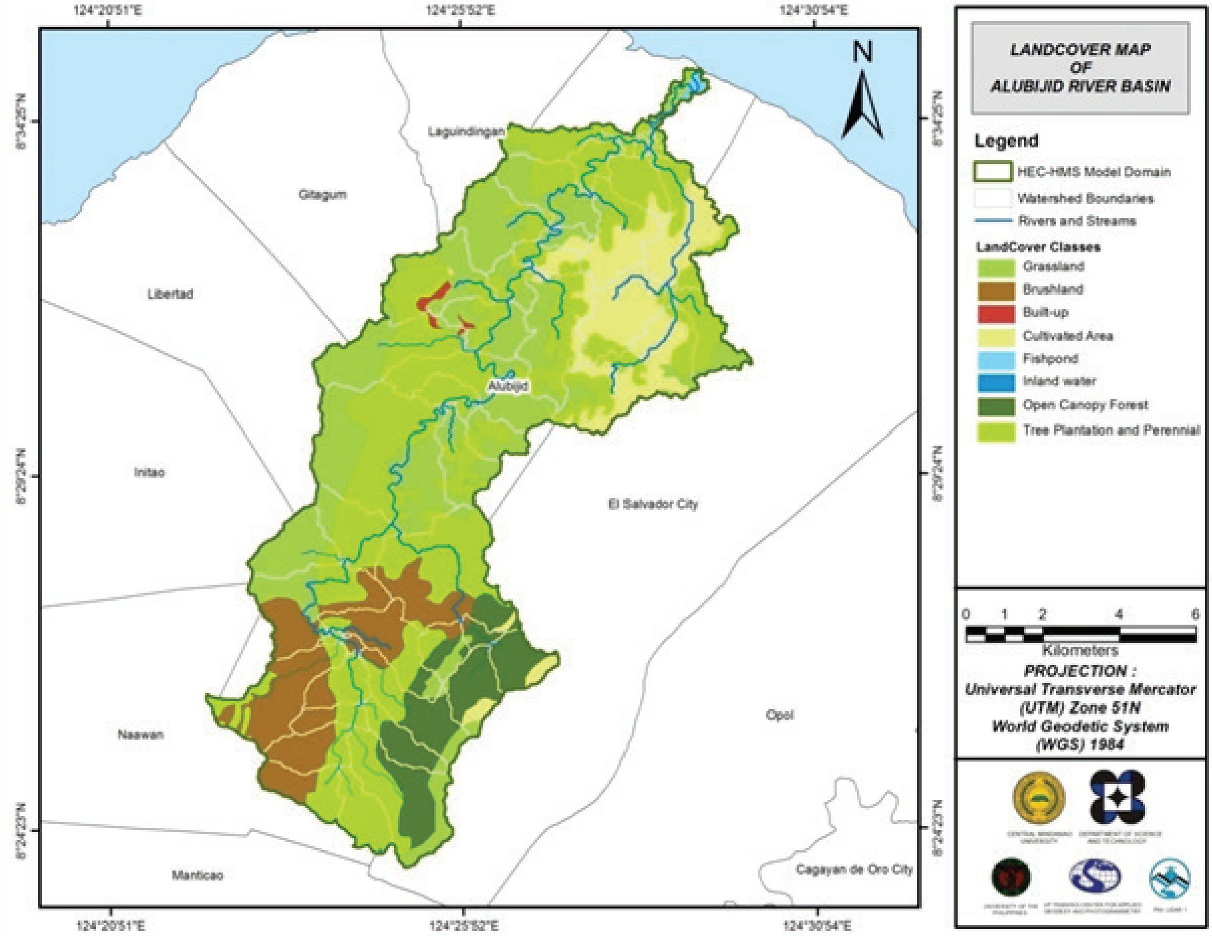


Figure 51. The land cover map of the Alubijid River Basin. (Source: NAMRIA)

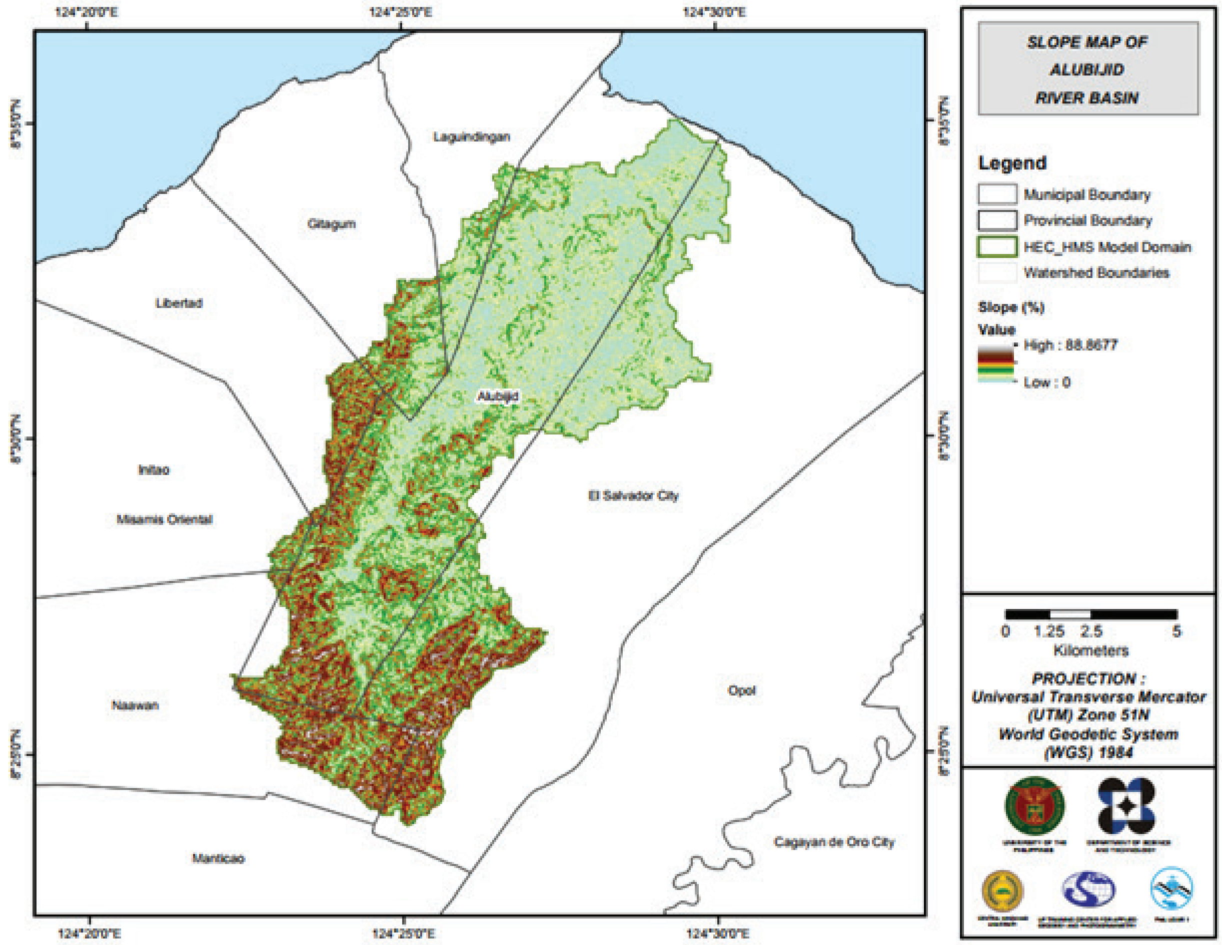


Figure 52 . Slope Map of Alubijid River Basin.

A drainage system includes the basin boundary, subbasin and the stream networks of the basin. Using ArcMap 10.1 with HEC-GeoHMS version 10.1 extension, the Alubijid River centerline and SAR-DEM 10m resolution served as primary data, delineating the drainage system of the Alubijid river basin. The river centerline was digitized starting from upstream towards downstream in Google Earth (2014). Default threshold area used is 140 hectares.

Using the SAR-based DEM, the LunMasla basin was delineated and further subdivided into subbasins. The Alubijid basin model consists of forty-eight (48) sub basins, twenty-five (25) reaches, and twenty-six (26) junctions. The main outlet is EstuaryCopy1. This basin model is illustrated in Figure 53. The basins were identified based on soil and land cover characteristics of the area. Precipitation fromNovember 26-27,2014 (Tropical Depression Queenie) was taken from DOST rain gauges. Finally, it was calibrated using data from the Alubijid Bridge using depth gauge sensor.

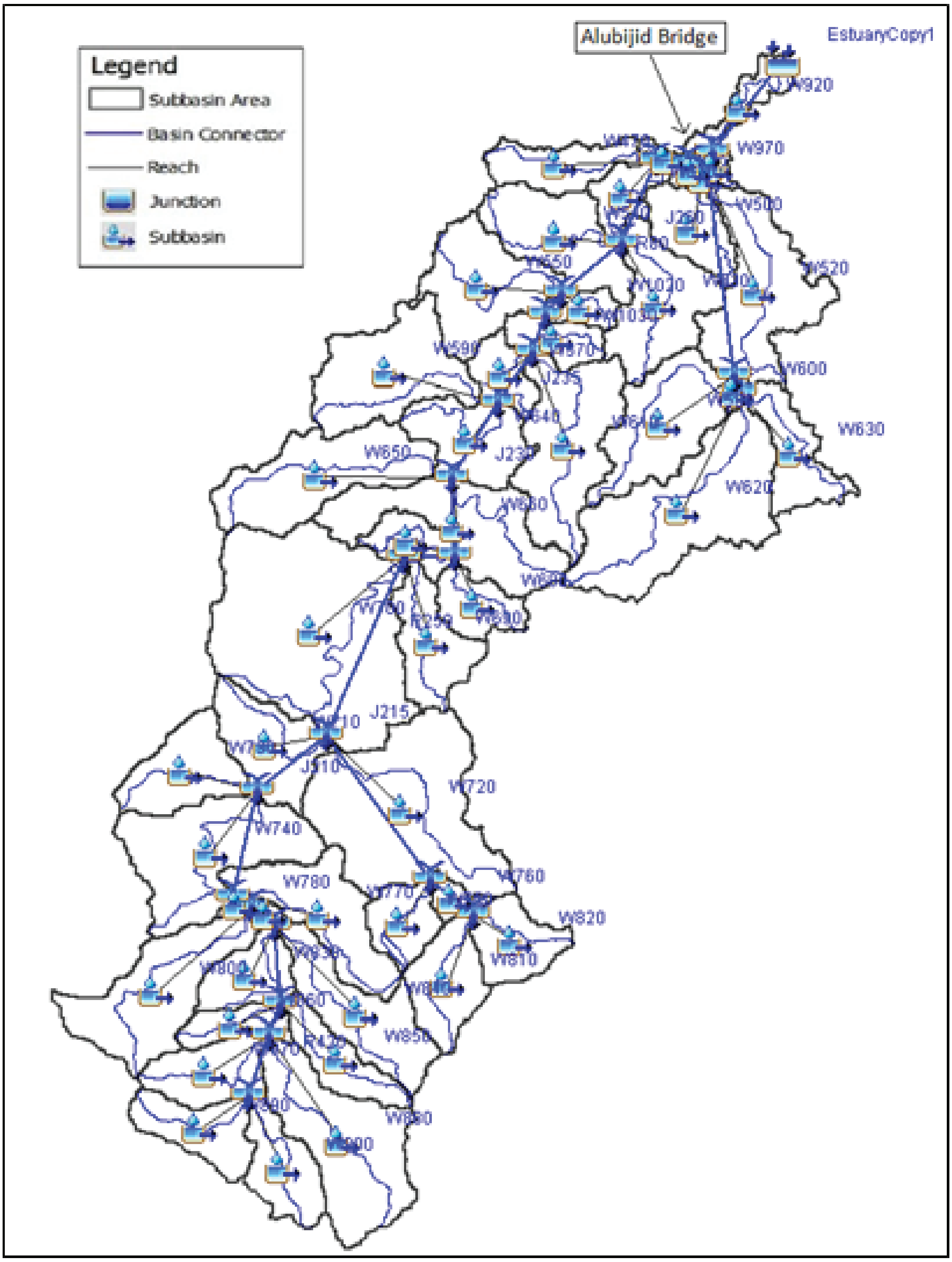


Figure 53 . HEC-HMS generated Alubijid River Basin Model.

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 54).

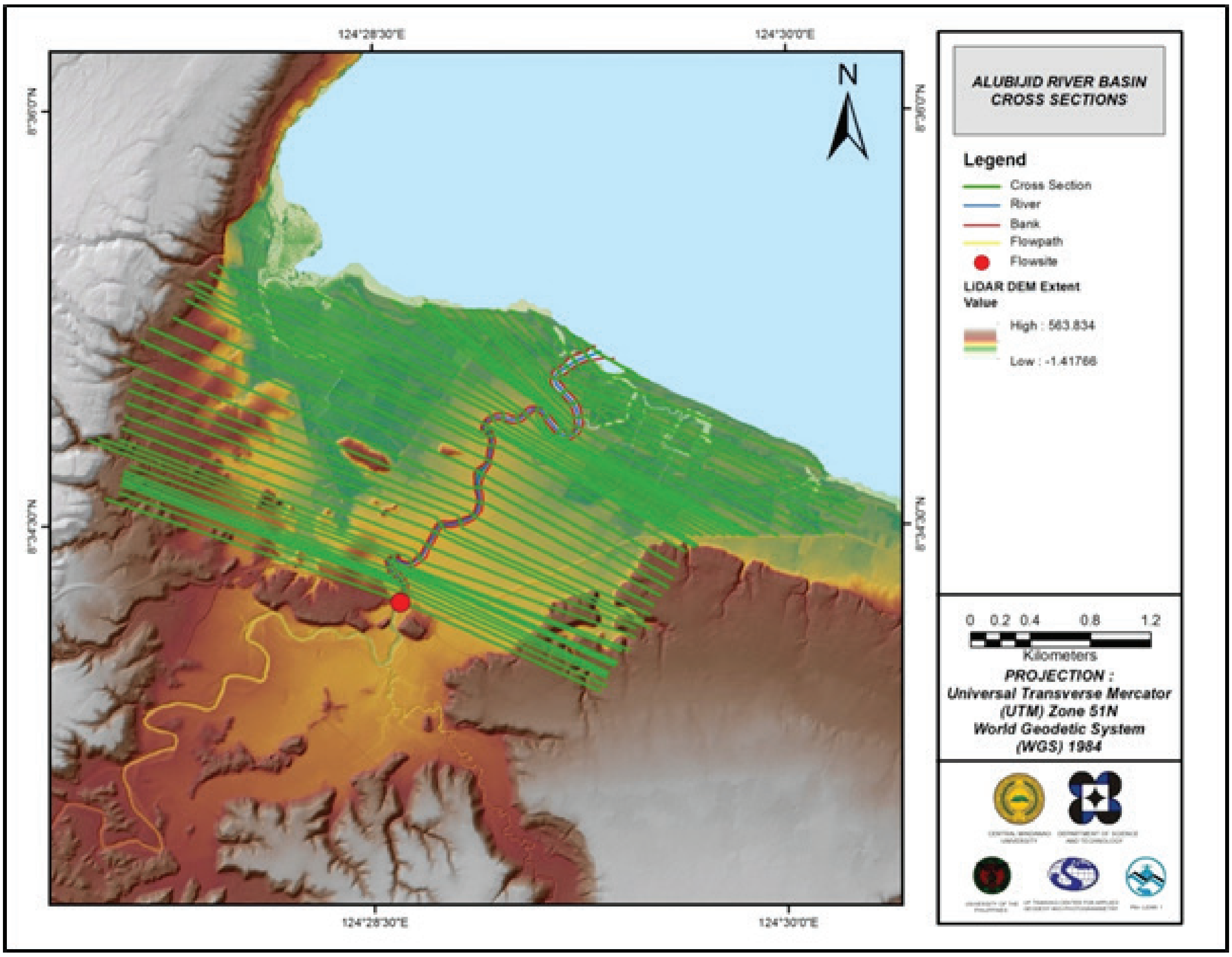


Figure 54 . Alubijid River Cross-section generated using HEC GeoRAS tool.

5.5 Flo 2D Model

The automated modeling 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 wasdivided into square grid elements, 10 meters by 10 meters in size. Each element wasassigned a unique grid element number which served as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinates of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were 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 south of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements, respectively.

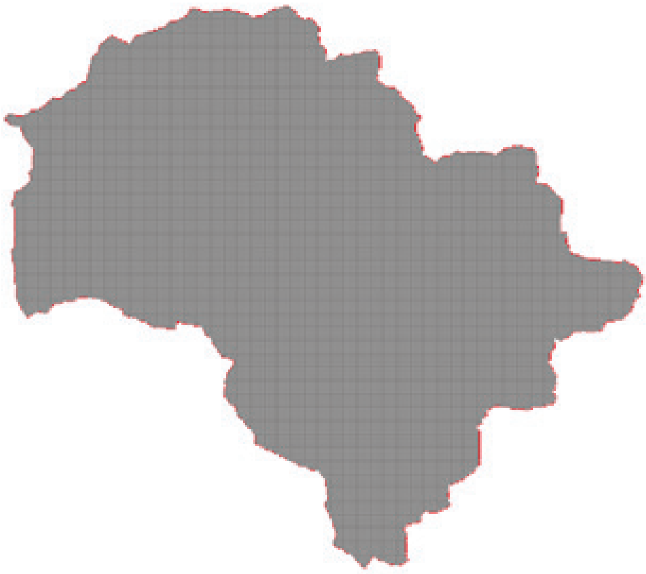


Figure 55. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro.

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 39.55225 hours. After the simulation, FLO-2D Mapper Pro was 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 flood hazard maps. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h) is set at 0 m2/s.

Figure 56. Generated 100-year rain return hazard map from FLO-2D Mapper.

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 39 385 900.00 m2.

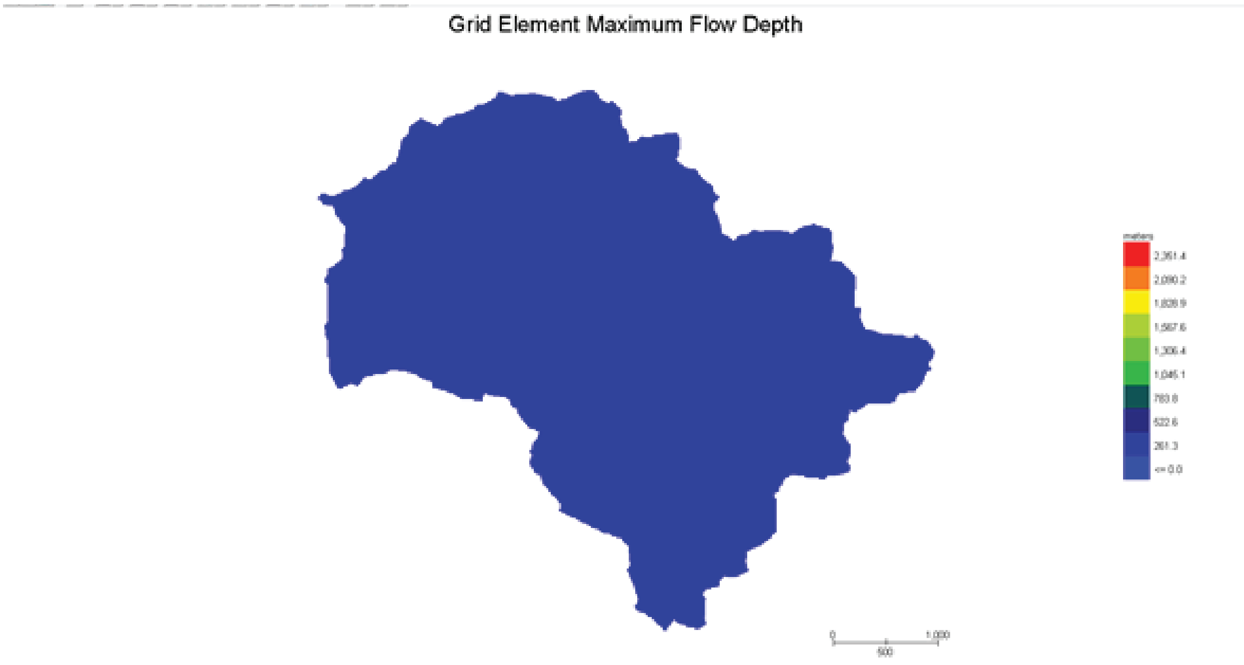


Figure 57. Generated 100-year rain return flow depth map from FLO-2D Mapper.

There is a total of 18 419 757.72 m3 of water entering the model. Of this amount, 10 725 727.85 m3 is due to rainfall while 7 694 029.87 m3 is inflow from other areas outside the model. 3 960 626.75 m3 of this water is lost to infiltration and interception, while 12 447 417.07 m3 is stored by the flood plain. The rest, amounting up to 2 011 714.06 m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Alubijid HEC-HMS river basin model, its accuracy was measured against the observed values (See Annex 9 for the Alubijid Model Basin Parameters). Figure 58 shows the comparison between the two (2) discharge data.

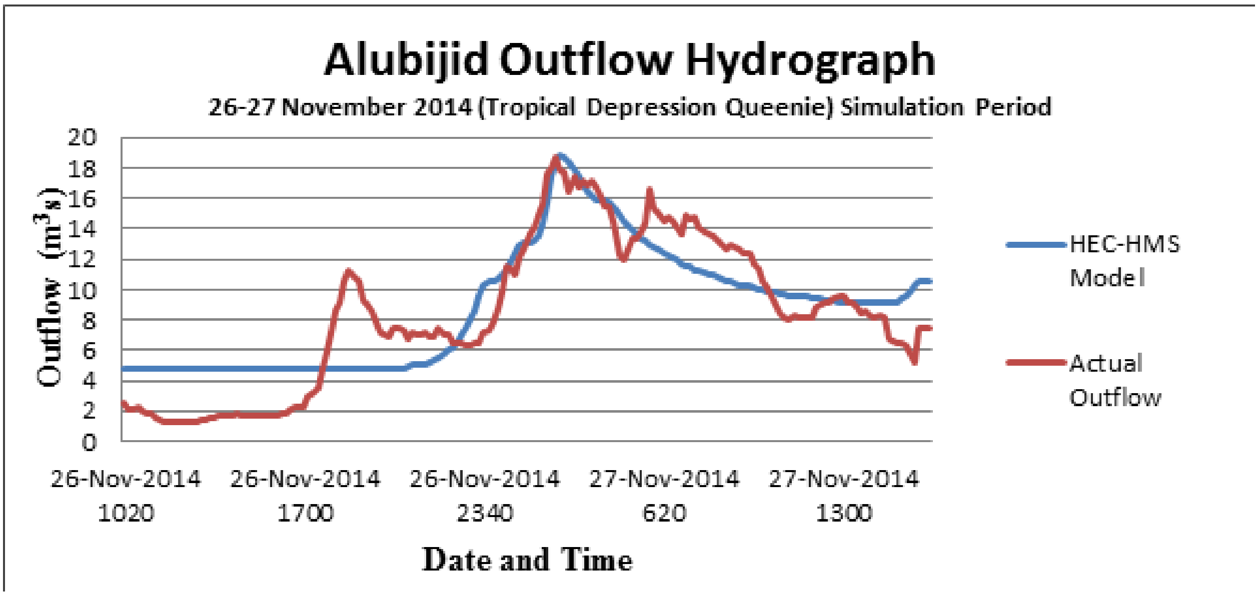


Figure 58. Outflow Hydrograph of Alubijid produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 27 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of Calibrated Values for Alubijid.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.94 - 36.89
			Curve Number	45.96 -99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.022 - 0.31
			Storage Coefficient (hr)	0.34 - 4.93
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.35
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001

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 0.94mm to 36.89mm 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 45.96 to 90 for curve number has values lower and higher than the advisable range for Philippine watersheds (70—80) depending on the soil and land cover of the area. For Alubijid, the basin mostly consists of grasslands, tree plantation, and perennial plants; and the soil consists of clay and clay loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.022 to 0.31 of an hour determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1.0 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.35 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0001for the Alubijid river basin is lower than the usual Manning's n value in the Philippines

Table 28. Summary of the Efficiency Test of Alubijid HMS Model.

Accuracy Measure	Value
r2	0.74
NSE	0.75
PBIAS	24.74
RSR	0.5
PBIAS	.40

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed at 2.5 (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 0.74.

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 0.75.

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 24.74.

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 0.5.

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 59) shows the Alubijid River outflow using the Cagayan de Oro Rainfall Intensity-Duration-Frequency curves (RIDF) in five (5) different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

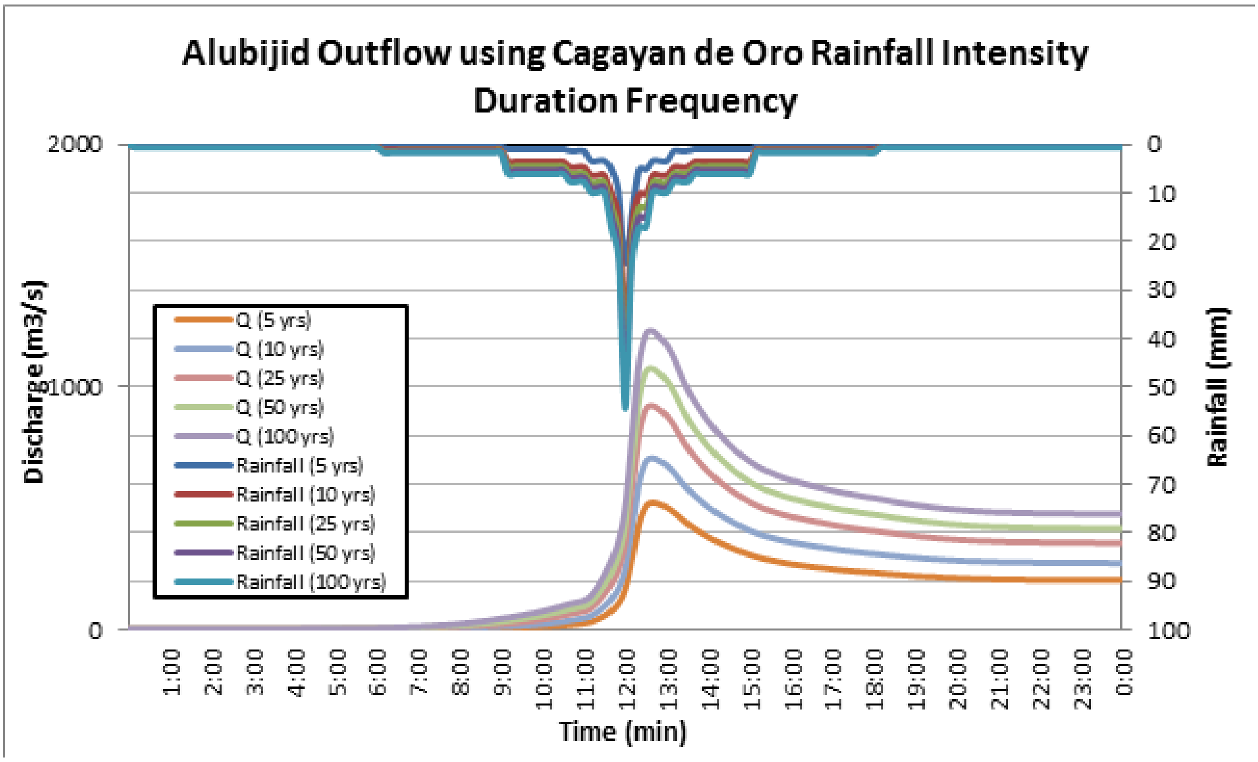


Figure 59. Outflow hydrograph at AlubijidStation generated using Cagayan de Oro RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Alubijid discharge using the Cagayan de Oro Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 29.

Table 29. Peak values of the Alubijid HECHMS Model outflow using the Cagayan de Oro RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m3s)	Time to Peak
5-Year	141.7	24.5	525.5	40 minutes
10-Year	300.7	37	707.6	40 minutes
25-Year	373.6	44	922.6	40 minutes
50-Year	427.6	49.2	1075.8	40 minutes
100-Year	481.2	54.4	1229.8	40 minutes

5.7.2 Discharge data using Dr. Horritts' recommended hydrologic method

The river discharge for the river entering the floodplainis shown in Figure 60 and the peak values are summarized in Table 30.

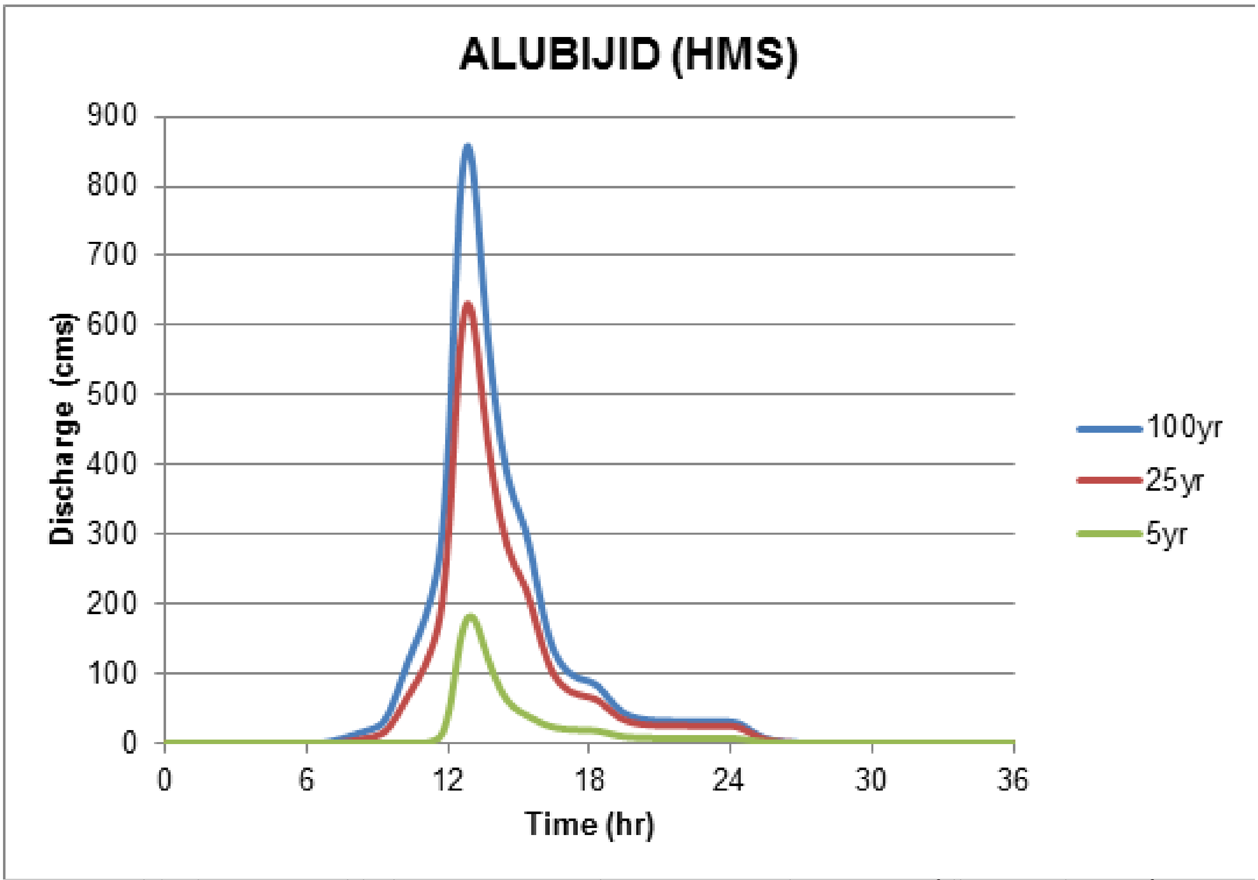


Figure 60. Alubijid River generated discharge using 5-, 25-, and 100-year Cagayan de Oro City rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

Table 30. Summary of Alubijid river (1) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	857.9	12 hours, 50 minutes
25-Year	631.4	12 hours, 50 minutes
5-Year	181.9	13 hours

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 31.

Table 31. Validation of river discharge estimates.

VALIDATION					
Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	Bankful Discharge	Specific Discharge
Alubijid (1)	160.072	308.790	144.528	Pass	Pass

The value from the HEC-HMS river discharge estimates was able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated value is based on theory but is supported by other discharge computation methods, so they were acceptable for use in flood modeling. This value will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river will be presented. The sample generated map of Alubijid River using the calibrated HMS base flow is shown in Figure 61.

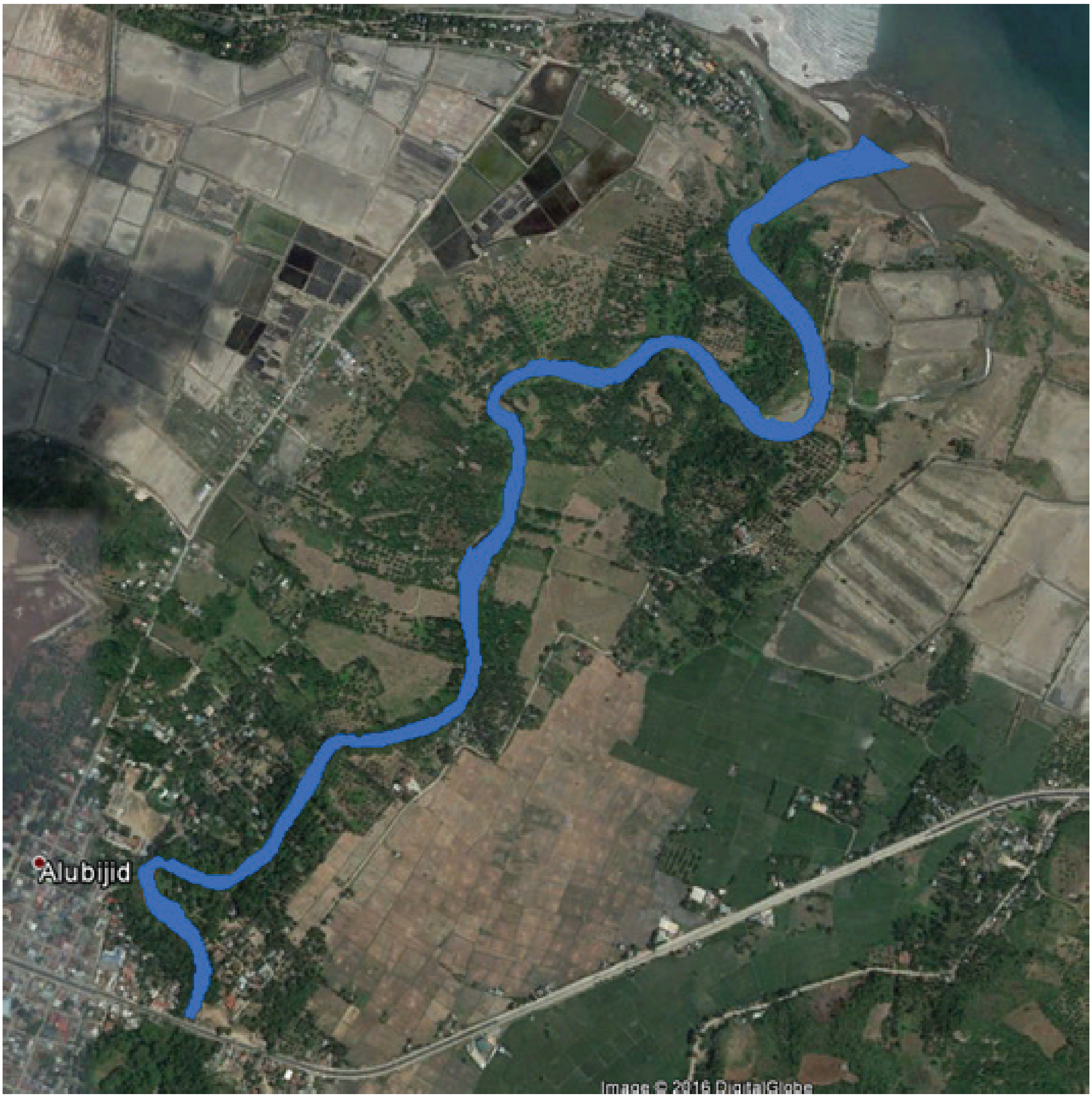


Figure 61. Sample output of Alubijid RAS Model.

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Alubijid floodplain are shown in Figure 62 to Figure 67.

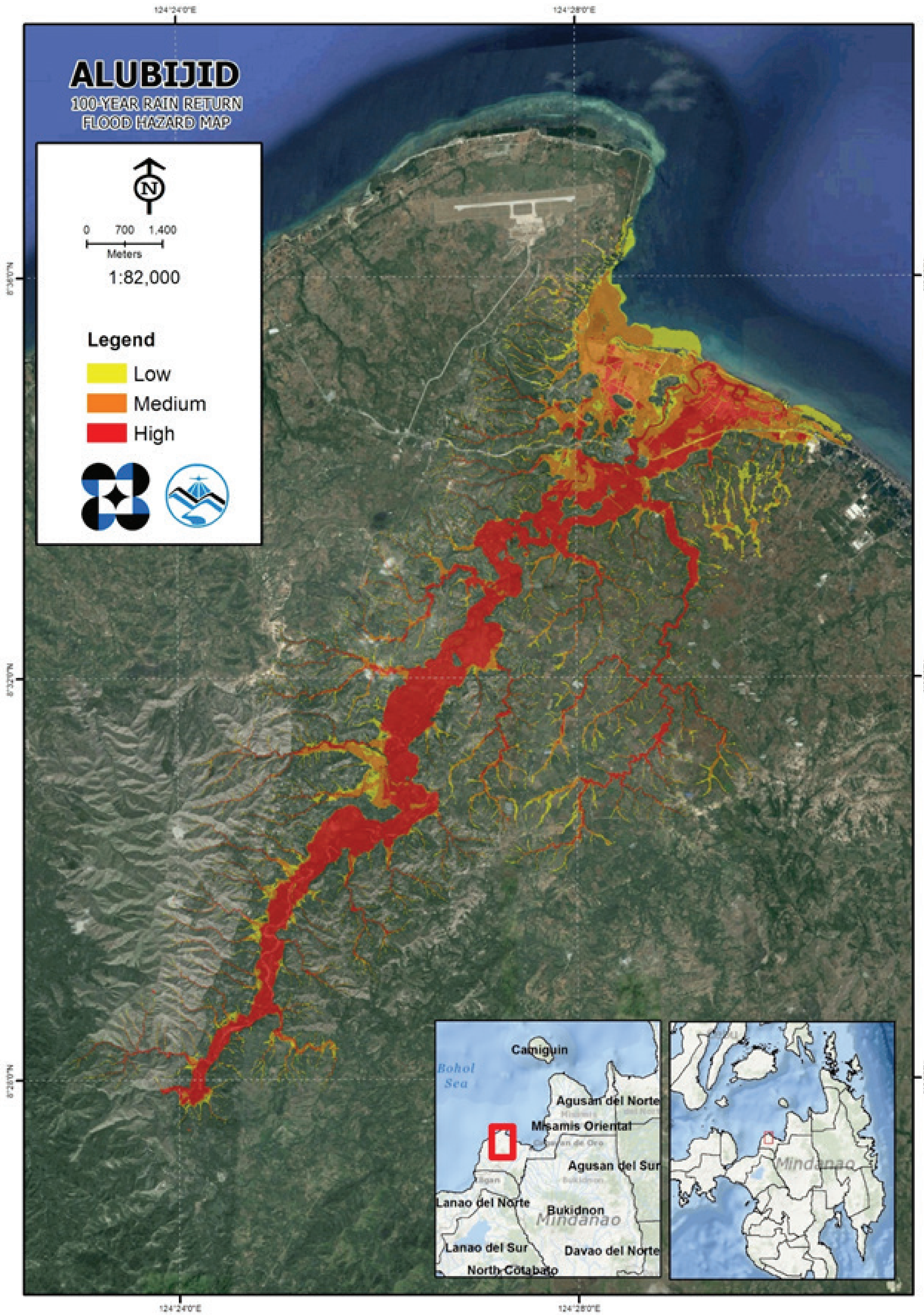


Figure 62. 100-year Flood Hazard Map for Alubijid Floodplain.

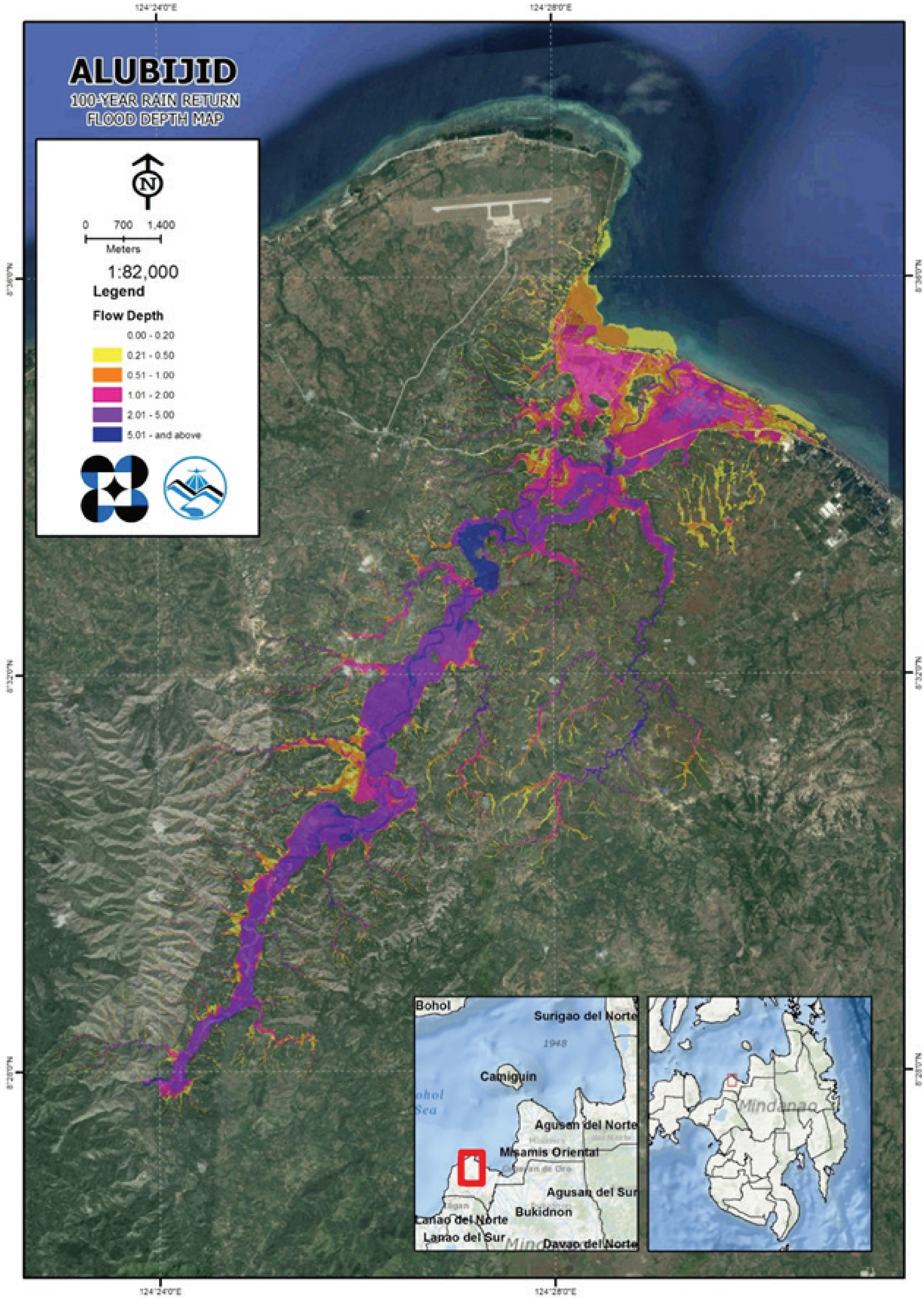


Figure 63. 100-year Flow Depth Map for Alubijid Floodplain.

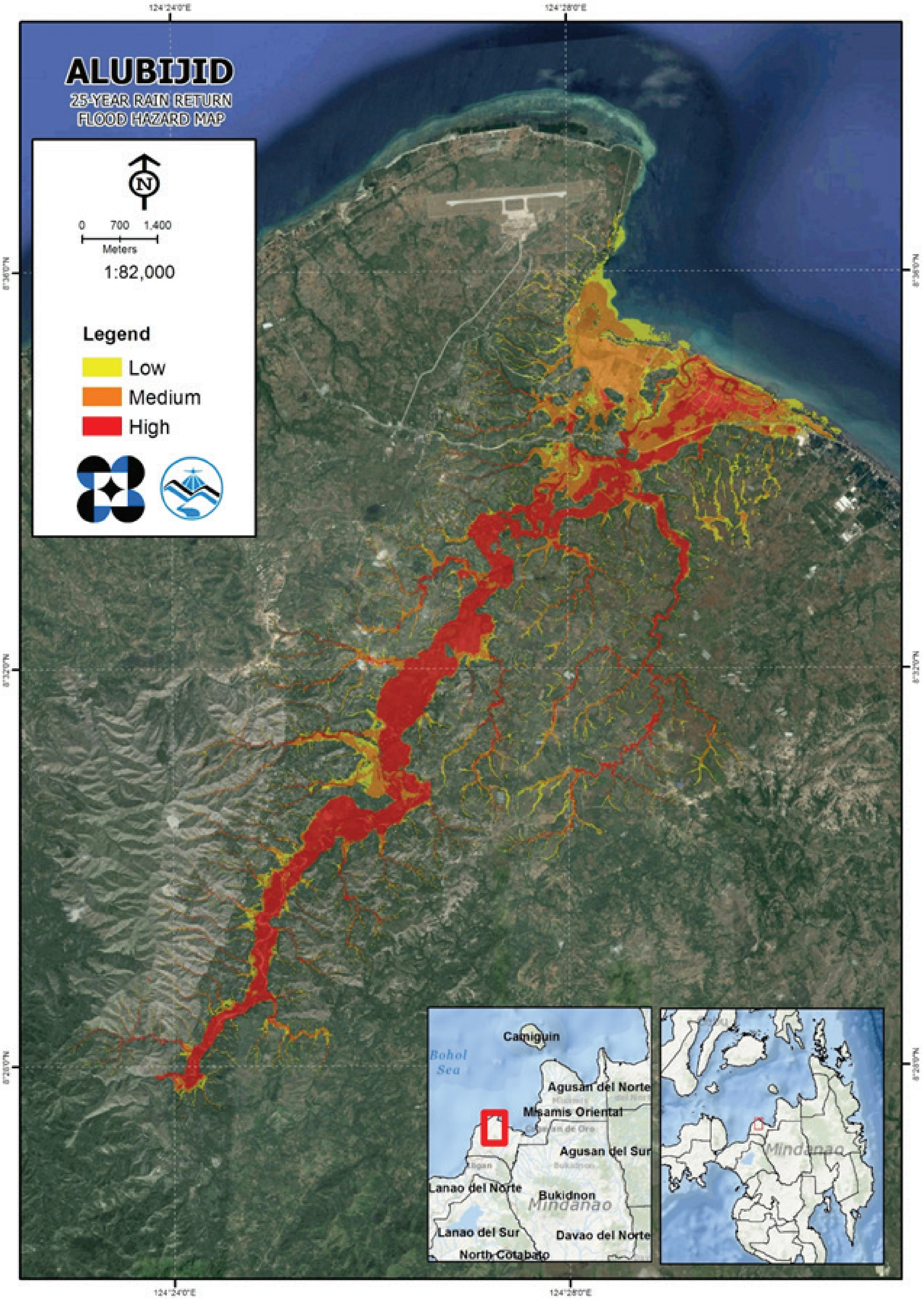


Figure 64. 25-year Flood Hazard Map for Alubijid Floodplain.

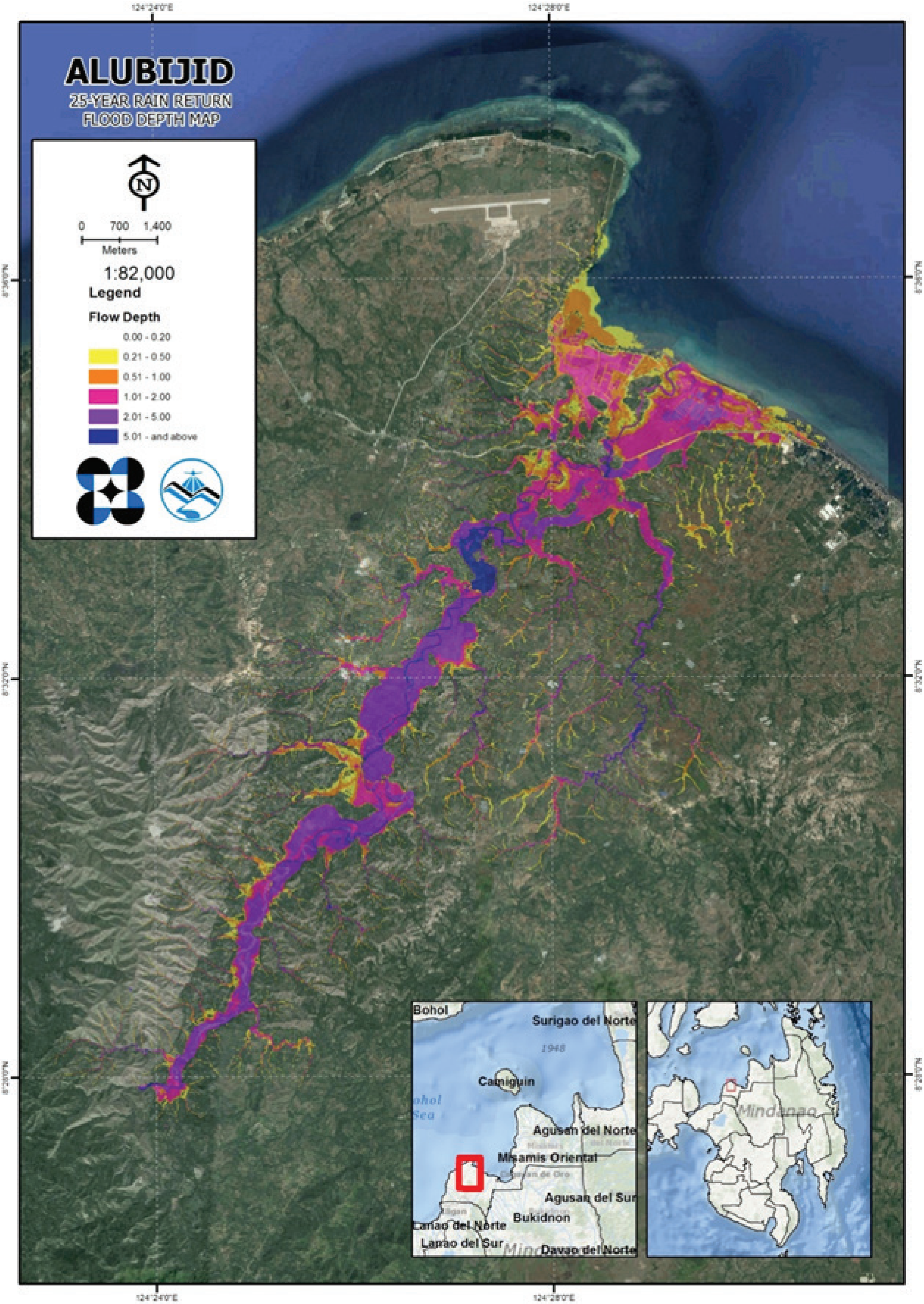


Figure 65. 25-year Flow Depth Map for Alubijid Floodplain.

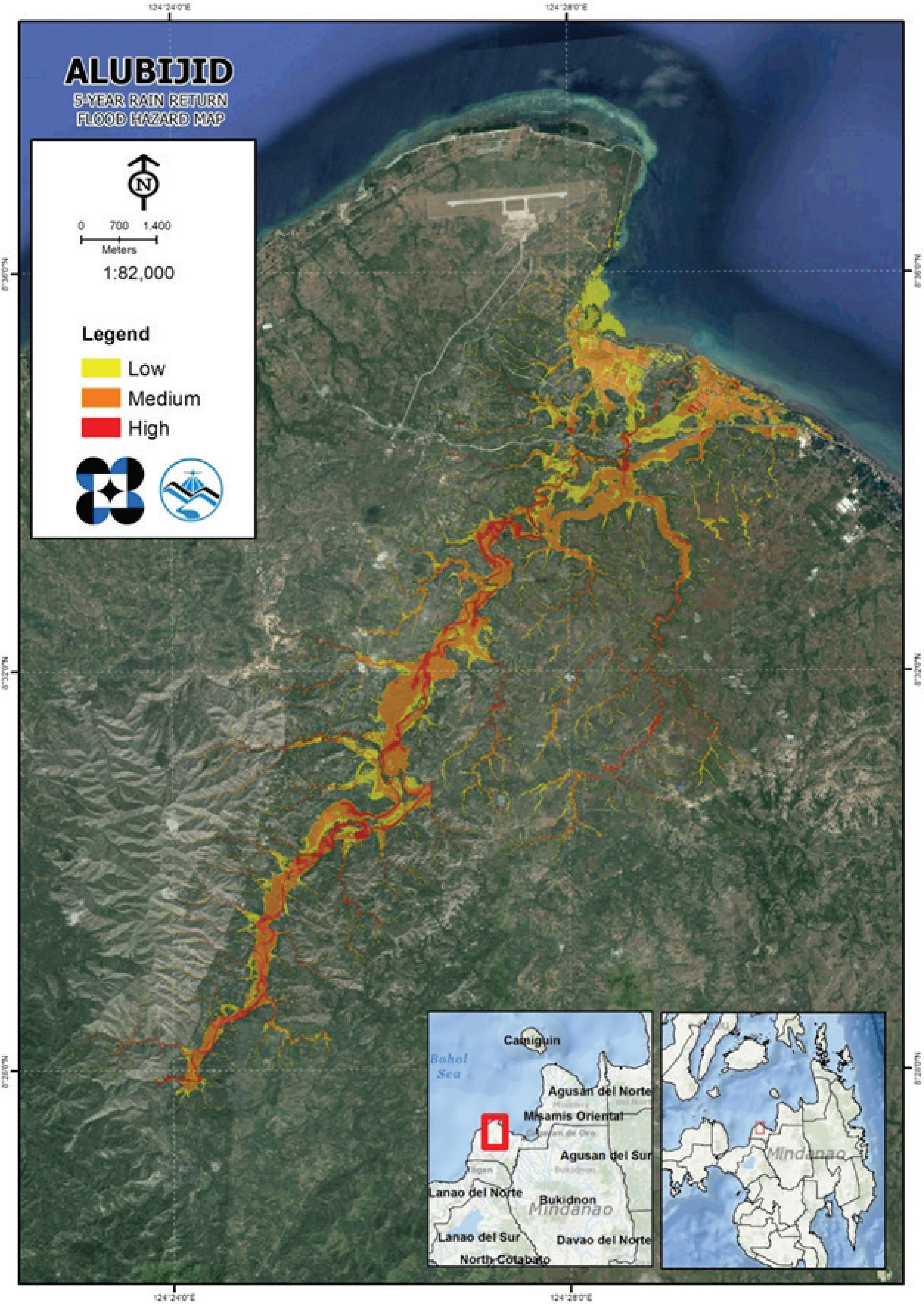


Figure 66. 5-year Flood Hazard Map for Alubijid Floodplain.

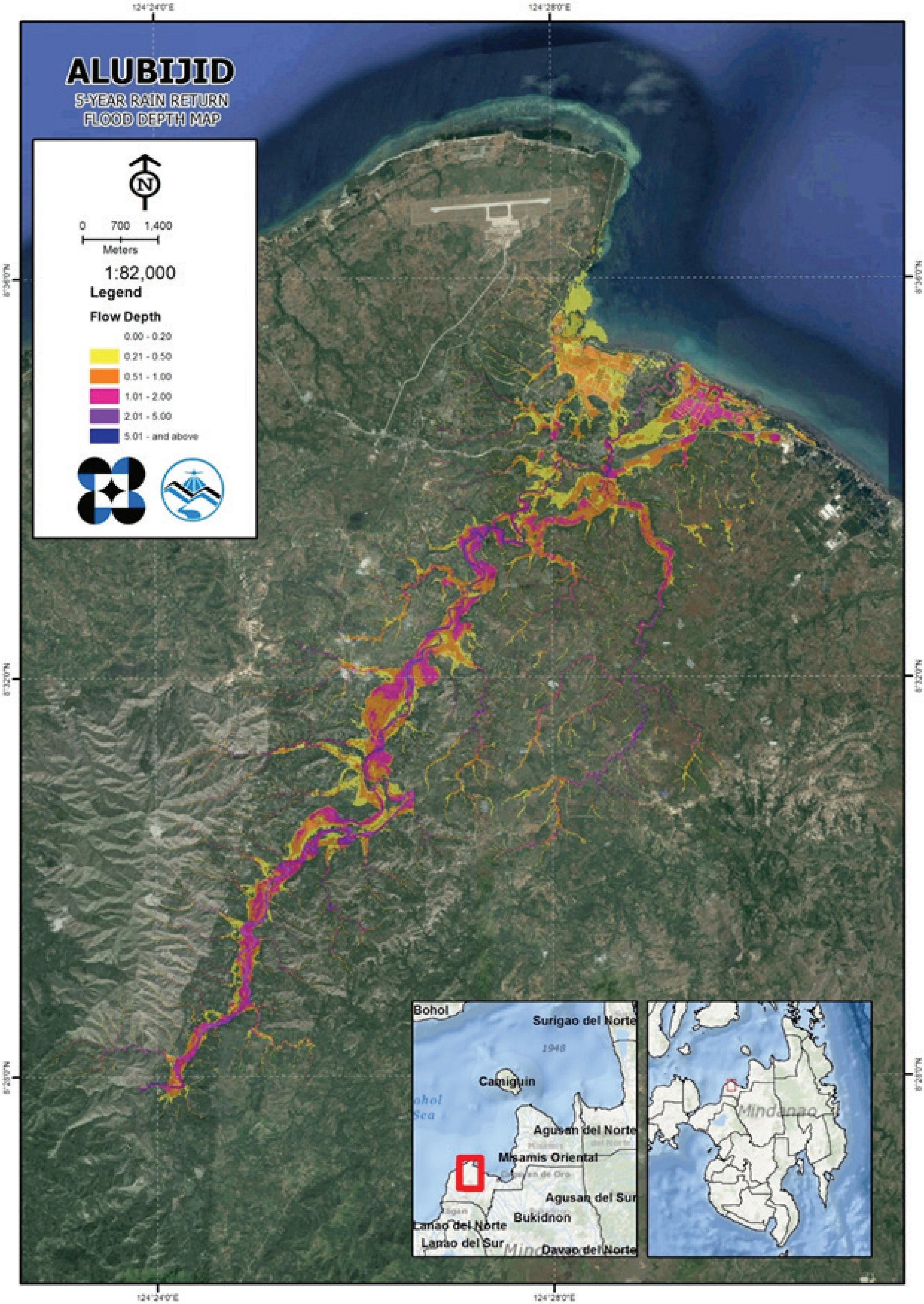


Figure 67. 5-year Flood Depth Map for Alubijid Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Alubijid river basin, grouped by municipality, are listed below. For the said basin, six (6) municipalities consisting of twenty-nine (29) barangays are expected to experience flooding when subjected to the 5-yr rainfall return period.

For the 5-year return period, 58.42% of the municipality of Alubijid, with an area of 80.1592 sq. km., will experience flood levels of less 0.20 meters. 6.11% of the area will experience flood levels of 0.21 to 0.50 meters; while 7.01%, 4.32%, 1.33%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Tables 32 and 33 are the affected areas, in square kilometers, by flood depth per barangay.

Table 32. Affected Areas in Alubijid, Misamis Oriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Alubijid (in sq. km.)							
	Baybay	Benigwayan	Calatcat	Lagtang	Lanao	Loguilo	Lourdes	Lumbo
0.03-0.20	**0.63**	8.14	2.95	1.95	1.62	0.93	2.92	0.97
0.21-0.50	**0.32**	0.99	0.25	0.15	0.28	0.5	0.79	0.038
0.51-1.00	**0.26**	1.29	0.64	0.15	0.32	0.43	0.98	0.03
1.01-2.00	**0.016**	1.04	0.27	0.071	0.056	0.39	0.61	0.016
2.01-5.00	**0.0041**	0.32	0.031	0.00098	0.0033	0.022	0.27	0.0052
> 5.00	**0**	0.068	0.0062	0	0	0	0.0071	0

Table 33. Affected Areas in Alubijid, Misamis Oriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Alubijid						
	Molocboloc	Poblacion	Sampatulog	Sungay	Talaba	Taparak	Tugasnon
0.03-0.20	**1.08**	0.56	3.79	3.14	3.11	11.14	3.91
0.21-0.50	**0.3**	0.2	0.15	0.12	0.084	0.6	0.14
0.51-1.00	**0.39**	0.16	0.11	0.14	0.052	0.59	0.072
1.01-2.00	**0.016**	0.03	0.053	0.12	0.061	0.66	0.043
2.01-5.00	**0.0002**	0.023	0.034	0.063	0.017	0.25	0.021
> 5.00	**0**	0.0017	0.0011	0.004	0	0.0014	0.0005

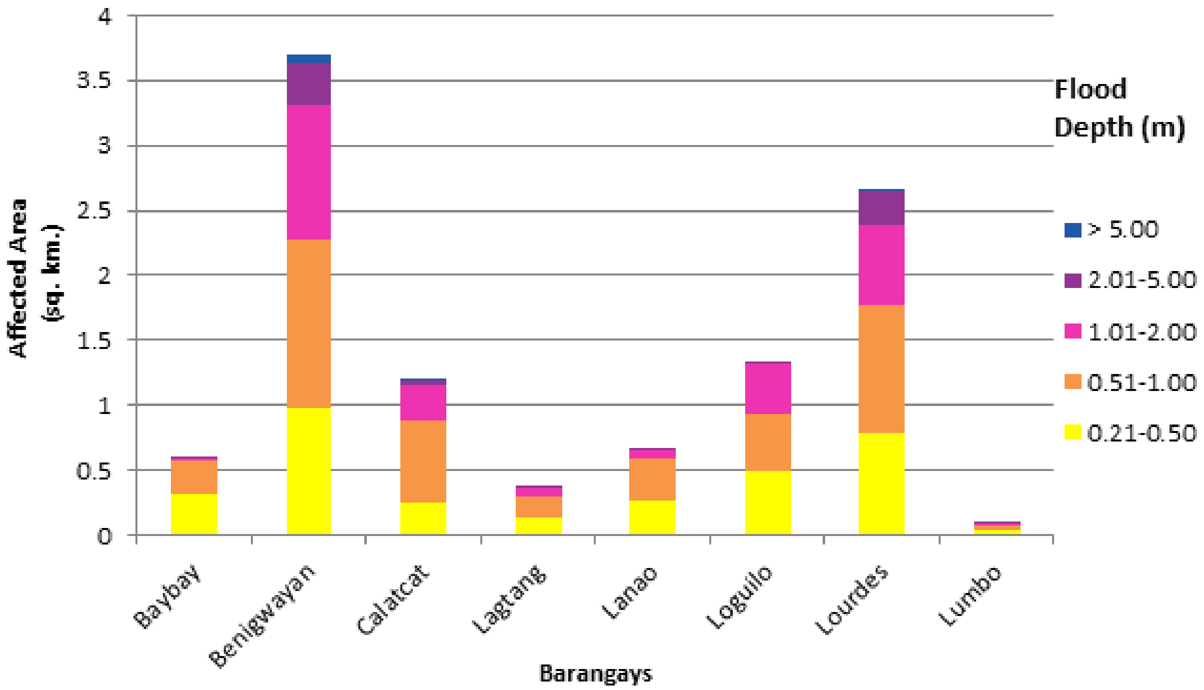


Figure 68. Affected Areas in Alubijid, Misamis Oriental during 5-Year Rainfall Return Period.

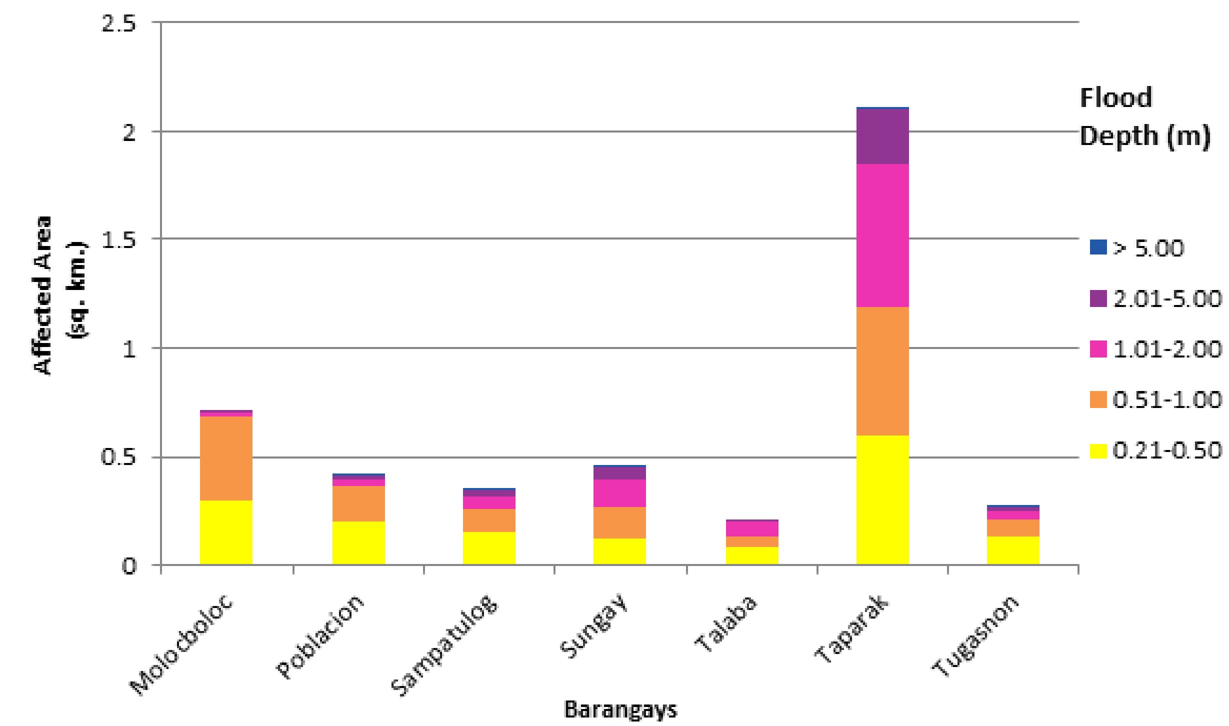


Figure 69 . Affected Areas in Alubijid, Misamis Oriental during 5-Year Rainfall Return Period.

For the city of El Salvador, with an area of 141.446 sq. km., 9.09% will experience flood levels of less 0.20 meters. 0.41% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.28%, 0.20%, 0.13%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively.Listed in Table 34 are the affected areas, in square kilometers, by flood depth per barangay.

Table 34. Affected Areas in El Salvador City, MisamisOriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in El Salvador City				
	Bolisong	Hinigdaan	Kalabaylabay	Kibonbon	Sinaloc
0.03-0.20	2.07	4.27	3.62	1.81	1.09
0.21-0.50	0.053	0.17	0.11	0.12	0.13
0.51-1.00	0.038	0.1	0.11	0.024	0.13
1.01-2.00	0.034	0.06	0.14	0.0032	0.053
2.01-5.00	0.034	0.043	0.11	0	0.00041
> 5.00	0.0006	0	0.0069	0	0

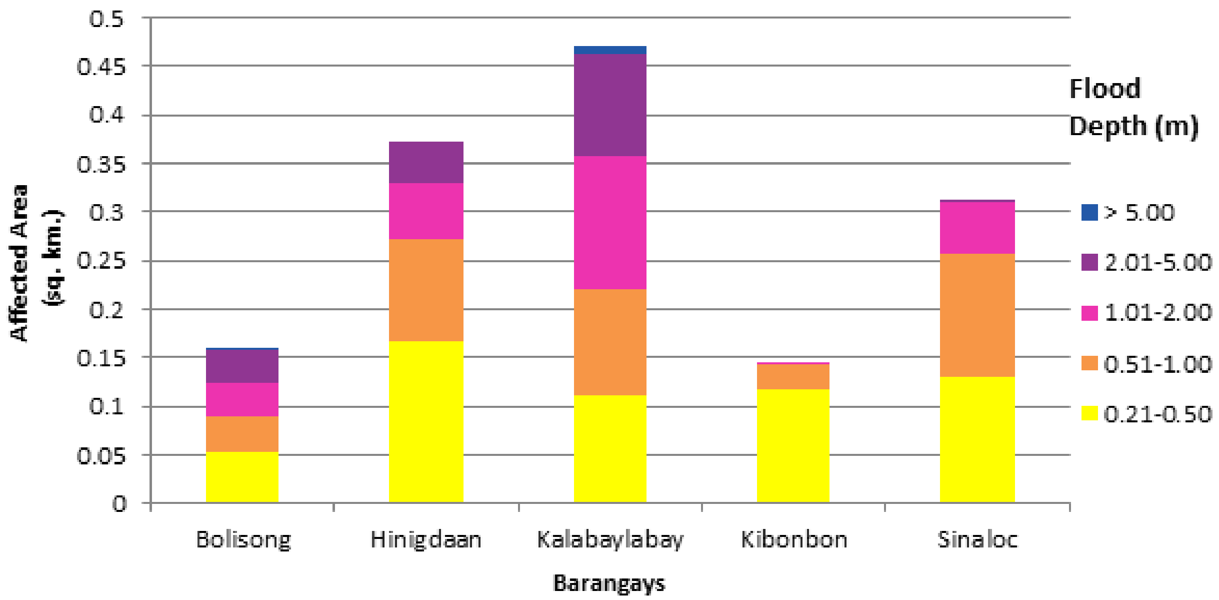


Figure 70 . Affected Areas in El Salvador City, MisamisOriental during 5-Year Rainfall Return Period.

For the municipality of Gitagum, with an area of 41.4755 sq. km., 14.71% will experience flood levels of less 0.20 meters. 0.43% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.26%, 0.22%, 0.12%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 35 are the affected areas, in square kilometers, by flood depth per barangay.

Table 35. Affected Areas in Gitagum, Misamis Oriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Gitagum
	Gregorio Pelaez
0.03-0.20	6.1
0.21-0.50	0.18
0.51-1.00	0.11
1.01-2.00	0.092
2.01-5.00	0.049
> 5.00	0.0009

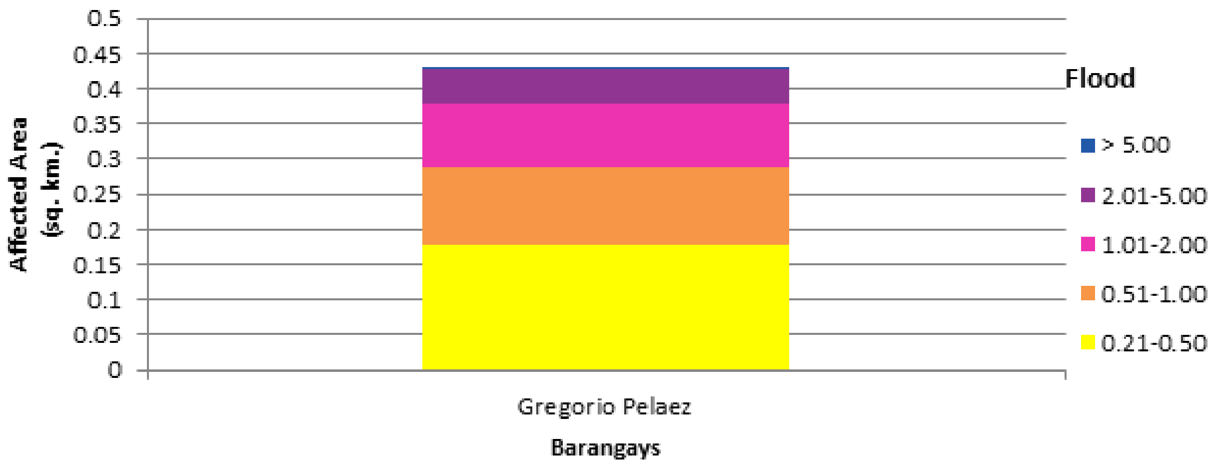


Figure 71 . Affected Areas in Gitagum, Samar during 5-Year Rainfall Return Period.

For the municipality of Initao, with an area of 68.0114 sq. km., 1.38% will experience flood levels of less 0.20 meters. 0.026% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.012%, 0.007%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters respectively. Listed in Table 36are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected Areas in Initao, Misamis Oriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Initao
	Sinalac
0.03-0.20	0.94
0.21-0.50	0.018
0.51-1.00	0.0081
1.01-2.00	0.0045
2.01-5.00	0.0025
> 5.00	0

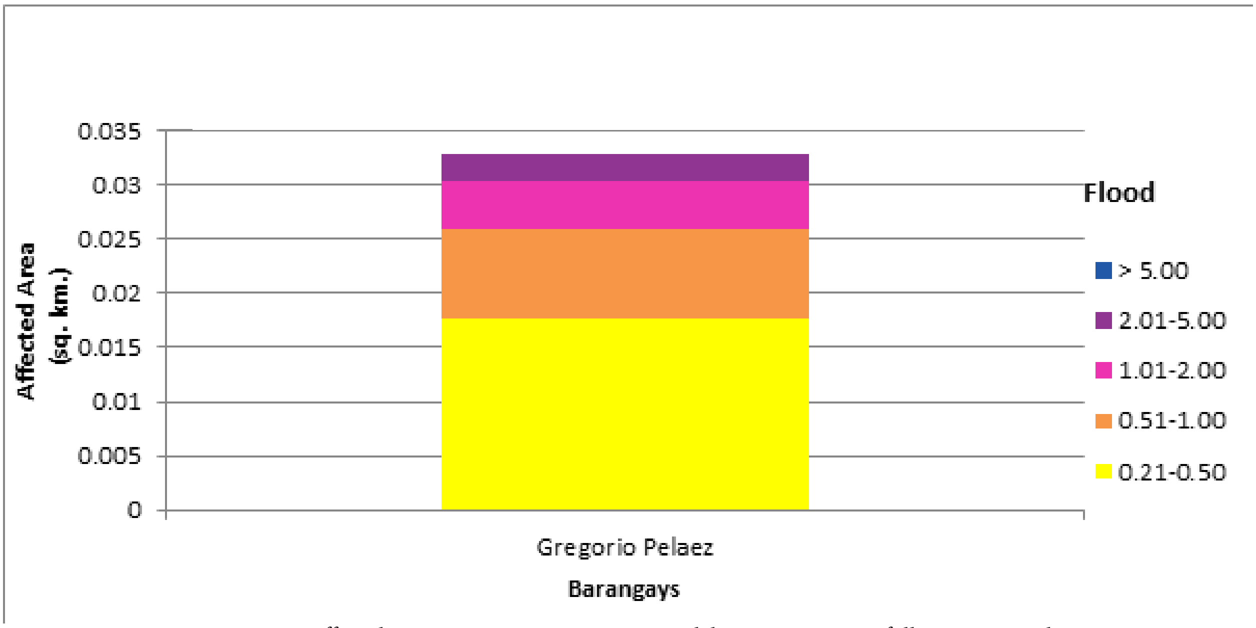


Figure 72 . Affected Areas in Initao, Misamis Oriental during 5-Year Rainfall Return Period.

For the municipality of Laguindingan, with an area of 37.8738 sq. km., 20.34% will experience flood levels of less 0.20 meters. 0.82% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.43%, 0.16%, 0.09%, and 0.0005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively.Listed in Table 37 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected Areas in Laguindingan, MisamisOriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Laguindingan			
	Kibaghot	Lapad	Moog	Poblacion
0.03-0.20	2.18	3.47	0.64	1.41
0.21-0.50	0.082	0.16	0.026	0.038
0.51-1.00	0.032	0.11	0.0027	0.013
1.01-2.00	0.011	0.043	0	0.0076
2.01-5.00	0.0035	0.028	0	0.0043

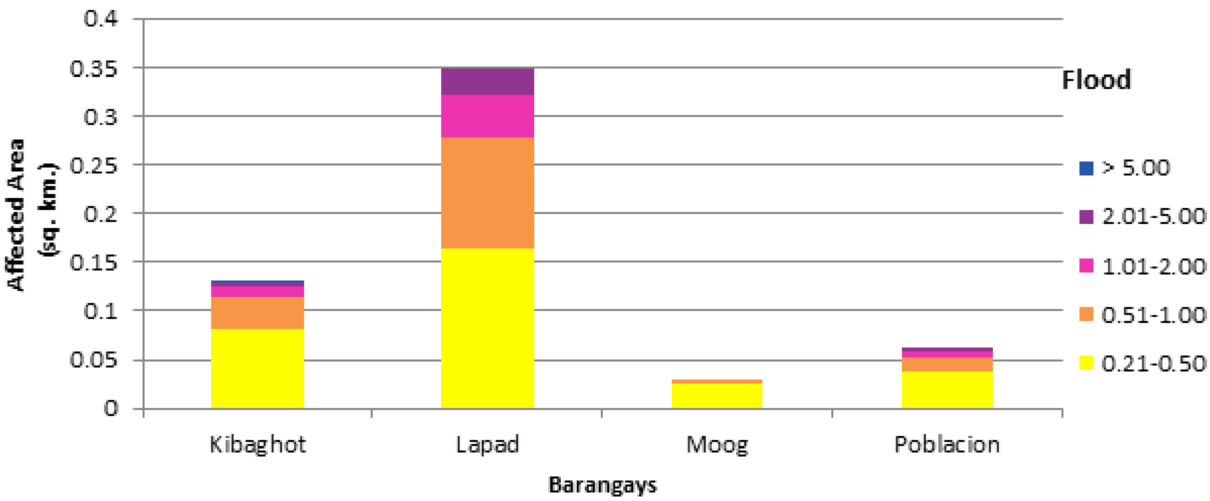


Figure 73 . Affected Areas in Laguindingan, Misamis Oriental during 5-Year Rainfall Return Period.

For the municipality of Libertad, with an area of 40.5917 sq. km., 6.88% will experience flood levels of less 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.072%, 0.022%, 0.005%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected Areas in Libertad, Misamis Oriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Libertad		
	Kimalok	Tangcub	Taytayan
0.03-0.20	0.97	0.86	0.96
0.21-0.50	0.018	0.014	0.019
0.51-1.00	0.0054	0.011	0.013
1.01-2.00	0.001	0.0047	0.0035
2.01-5.00	0.0006	0.00037	0.0009
> 5.00	0.0005	0	0

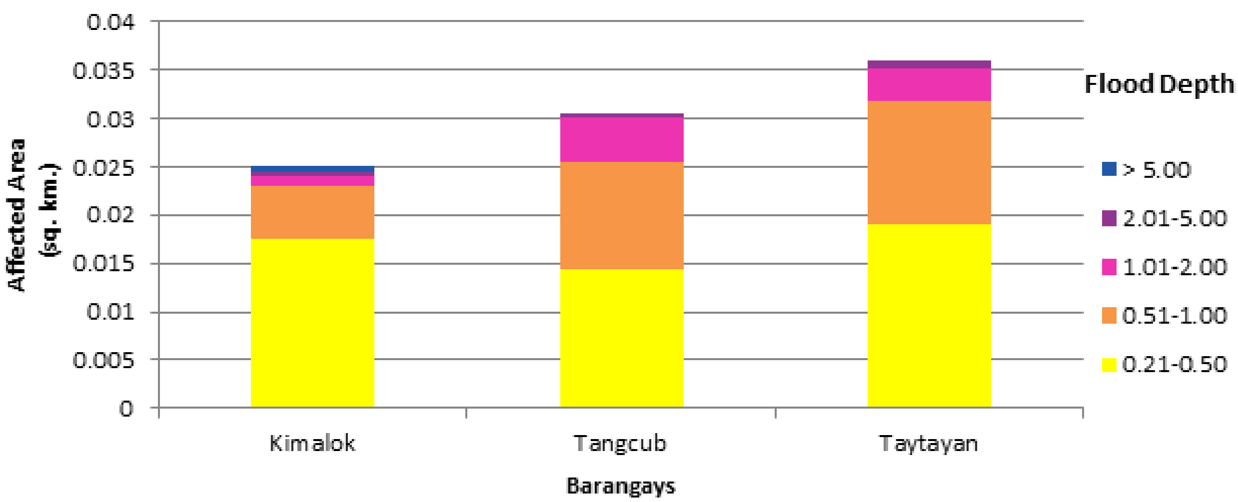


Figure 74 . Affected Areas in Libertad, Samar during 5-Year Rainfall Return Period.

For the 25-year return period, 52.09% of the municipality of Alubijid, with an area of 80.159203 sq. km., will experience flood levels of less than 0.20 meters. 3.80% of the area will experience flood levels of 0.21 to 0.50 meters; while 4.69%, 7.94%, 7.87%, and 0.91% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 39-40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected Areas in Alubijid, Misamis Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Alubijid							
	Baybay	Benigwayan	Calatcat	Lagtang	Lanao	Loguilo	Lourdes	Lumbo
0.03-0.20	**0.27**	7.06	2.75	1.74	1.35	0.096	2.24	0.93
0.21-0.50	**0.2**	0.43	0.12	0.16	0.16	0.19	0.33	0.046
0.51-1.00	**0.4**	0.61	0.17	0.13	0.3	0.38	0.38	0.03
1.01-2.00	**0.34**	1.17	0.8	0.23	0.43	1.17	0.68	0.035
2.01-5.00	**0.019**	2.04	0.3	0.057	0.025	0.43	1.87	0.016
> 5.00	**0**	0.55	0.024	0	0.0002	0	0.091	0

Table 40. Affected Areas in Alubijid, Misamis Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Alubijid						
	Molocboloc	Poblacion	Sampatulog	Sungay	Talaba	Taparak	Tugasnon
0.03-0.20	**0.93**	0.31	3.67	2.99	3.03	10.6	3.79
0.21-0.50	**0.17**	0.094	0.17	0.13	0.11	0.58	0.17
0.51-1.00	**0.34**	0.23	0.13	0.094	0.068	0.41	0.11
1.01-2.00	**0.34**	0.24	0.094	0.16	0.053	0.55	0.07
2.01-5.00	**0.0016**	0.1	0.064	0.2	0.068	1.09	0.041
> 5.00	**0**	0.0066	0.014	0.021	0	0.021	0.0026

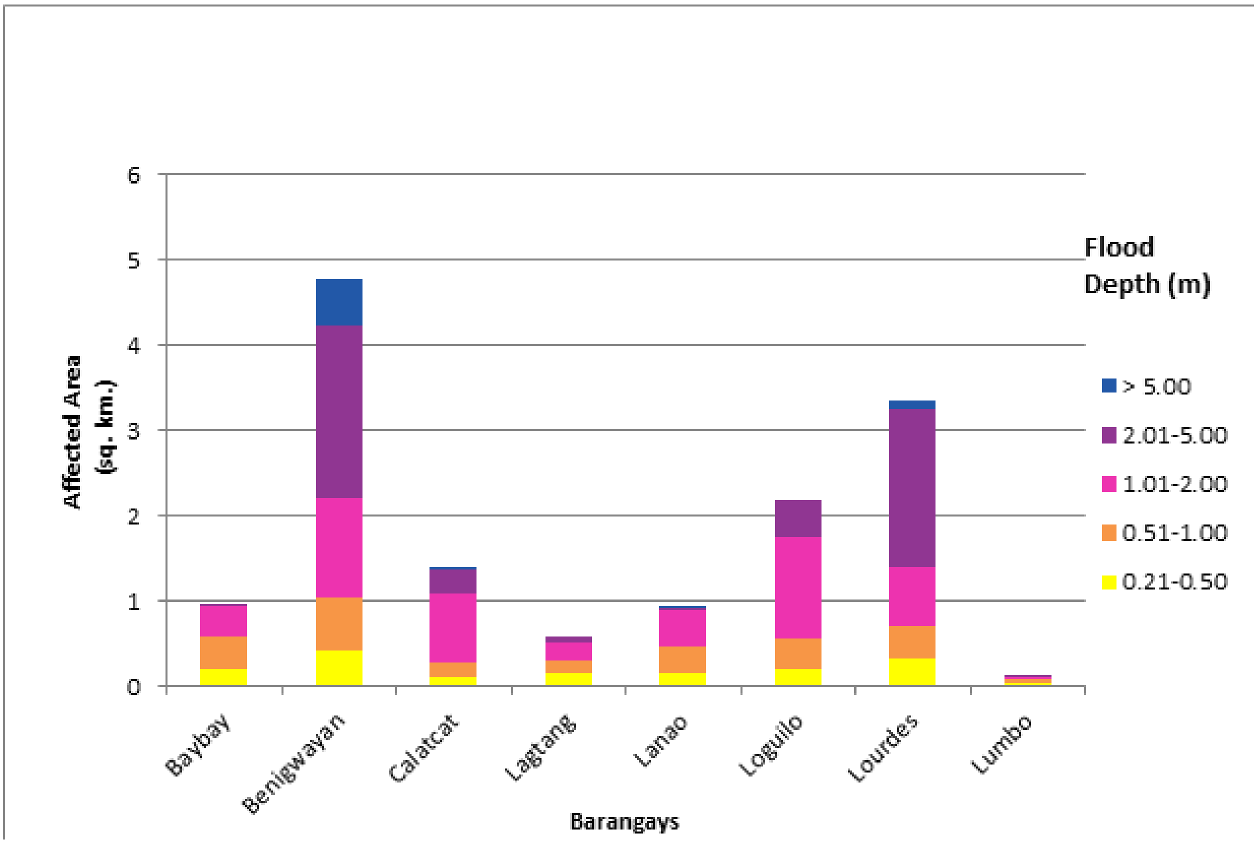


Figure 75 . Affected Areas in Alubijid, Misamis during 25-Year Rainfall Return Period.

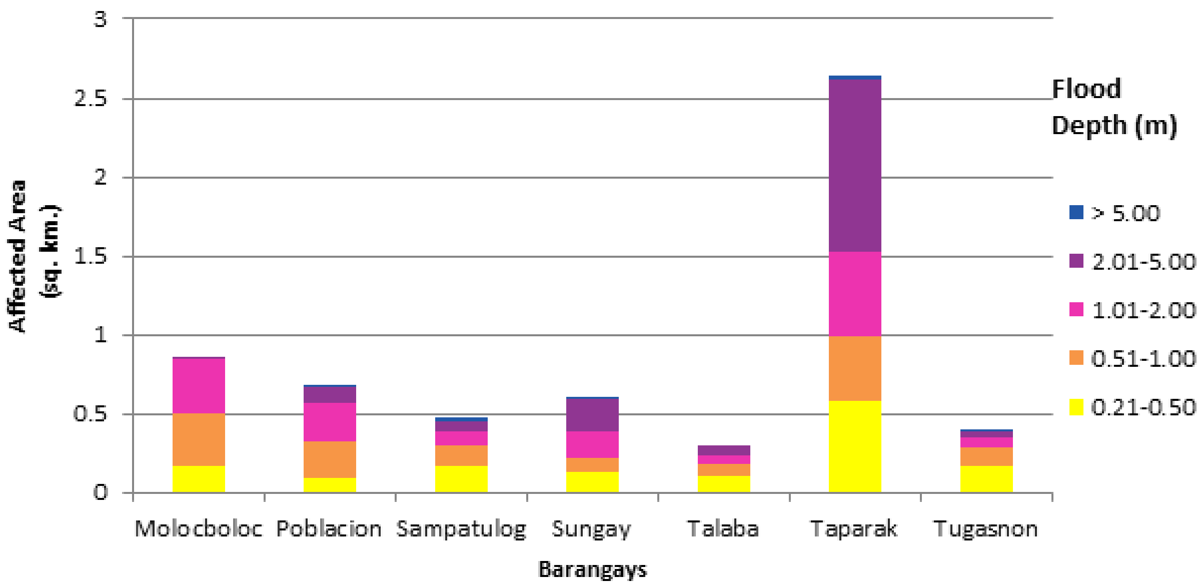


Figure 76 . Affected Areas in Alubijid, Misamis during 25-Year Rainfall Return Period.

For the 25-year return period, 8.49% of the city of El Salvador, with an area of 141.446 sq. km., will experience flood levels of less than 0.20 meters. 0.62% of the area will experience flood levels of 0.21 to 0.50 meters ;while 0.37%, 0.31%, 0.24%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed inTable 41are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected Areas in El Salvador City, Misamis Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in El Salvador City				
	Bolisong	Hinigdaan	Kalabaylabay	Kibonbon	Sinaloc
0.03-0.20	2.01	4.12	3.46	1.63	0.79
0.21-0.50	0.064	0.21	0.12	0.25	0.23
0.51-1.00	0.049	0.12	0.081	0.06	0.22
1.01-2.00	0.042	0.1	0.12	0.0098	0.16
2.01-5.00	0.054	0.074	0.21	0.00092	0.0016
> 5.00	0.011	0.02	0.096	0	0

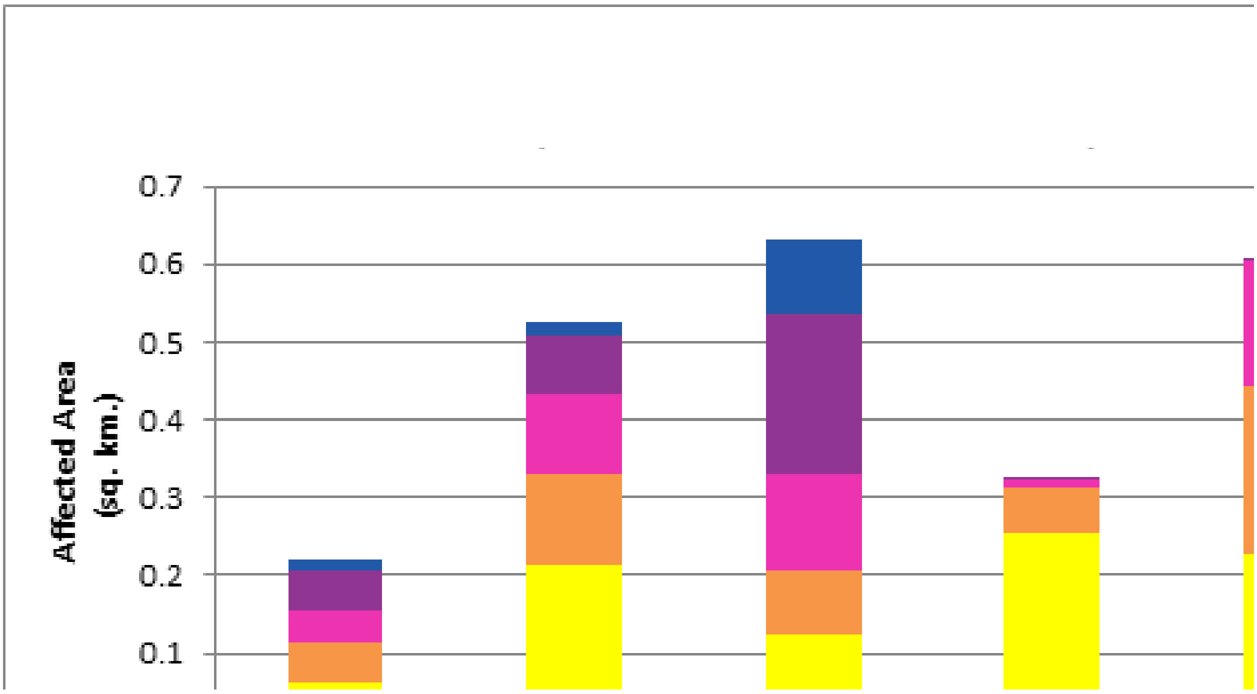


Figure 77 . Affected Areas in El Salvador City, Misamis Oriental during 25-Year Rainfall Return Period.

For the 25-year return period, 14.26% of the municipality of Gitagum, with an area of 41.475498 sq. km., will experience flood levels of less than 0.20 meters. 0.59% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.39%, 0.27%, 0.23%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected Areas in Gitagum, Misamis Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Gitagum
	Gregorio Pelaez
0.03-0.20	5.91
0.21-0.50	0.25
0.51-1.00	0.16
1.01-2.00	0.11
2.01-5.00	0.095
> 5.00	0.0039

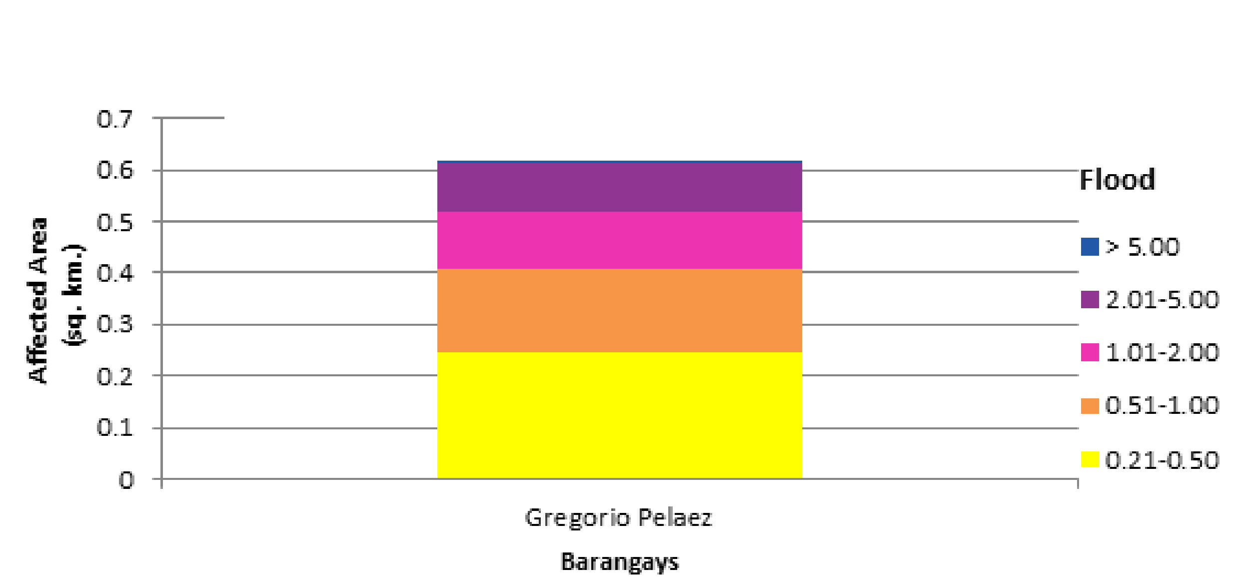


Figure 78 . Affected Areas in Gitagum, Misamis Oriental during 25-Year Rainfall Return Period.

For the 25-year return period, 1.37% of the municipality of Initao, with an area of 68.011398 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 0.02%, 0.01%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected Areas in Initao, Misamis Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Initao
	Sinalac
0.03-0.20	0.93
0.21-0.50	0.023
0.51-1.00	0.011
1.01-2.00	0.0068
2.01-5.00	0.0039
> 5.00	0

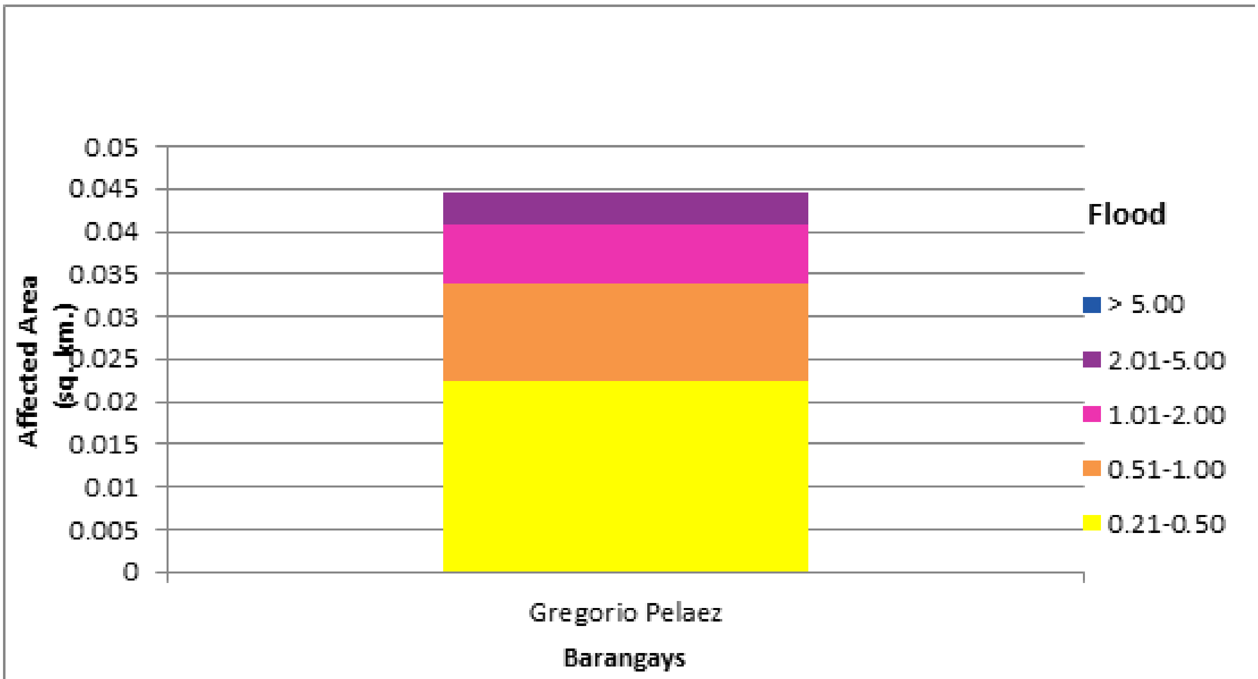


Figure 79 . Affected Areas in Initao, Misamis Oriental during 25-Year Rainfall Return Period.

For the 25-year return period, 16.78% of the municipality of Laguindingan, with an area of 37.873798 sq. km., will experience flood levels of less than 0.20 meters. 1.19% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.15%, 0.98%, 0.41%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected Areas in Laguindingan, Misamis Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Laguindingan			
	Kibaghot	Lapad	Moog	Poblacion
0.03-0.20	2.1	3.34	0.61	0.31
0.21-0.50	0.13	0.16	0.06	0.094
0.51-1.00	0.048	0.15	0.0068	0.23
1.01-2.00	0.023	0.11	0	0.24
2.01-5.00	0.0077	0.048	0	0.1
> 5.00	0.0004	0.0016	0	0.0066

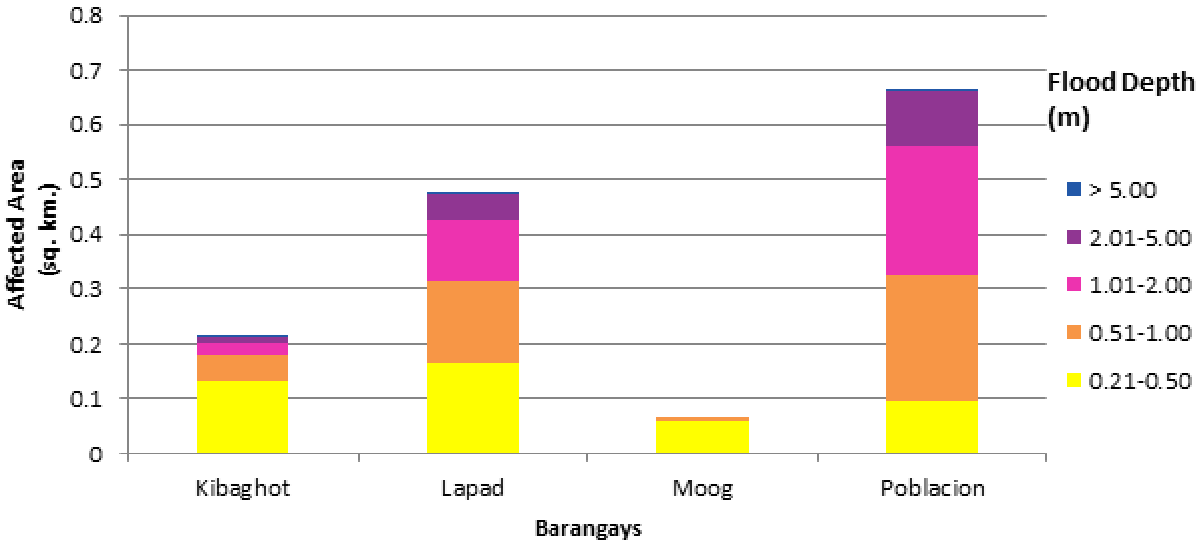


Figure 80 . Affected Areas in Laguindingan, Misamis Oriental during 25-Year Rainfall Return Period.

For the 25-year return period, 6.80% of the municipality of Libertad, with an area of 40.591702 sq. km., will experience flood levels of less than 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.09%, 0.04%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed inTable 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected Areas in Libertad, Misamis Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Libertad		
	Kimalok	Tangcub	Taytayan
0.03-0.20	0.96	0.85	0.95
0.21-0.50	0.023	0.018	0.022
0.51-1.00	0.0075	0.014	0.016
1.01-2.00	0.003	0.0075	0.007
2.01-5.00	0.0018	0.0014	0.0017
> 5.00	0.0015	0	0.000099

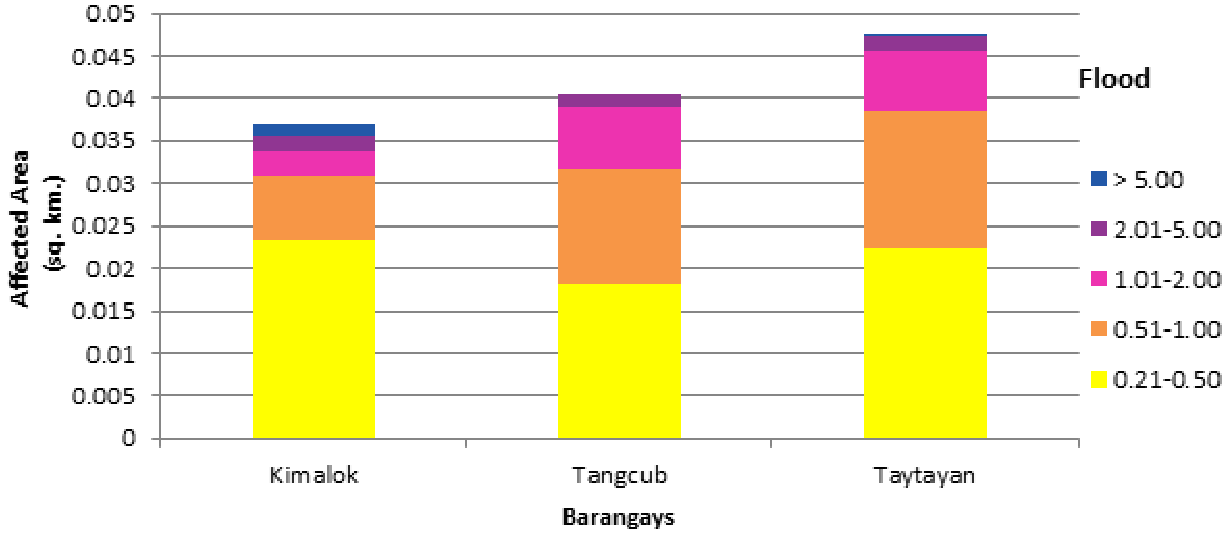


Figure 81 . Affected Areas in Libertad, Misamis Oriental during 25-Year Rainfall Return Period.

For the 100-year return period, 50.79% of the municipality of Alubijid, with an area of 80.159203 sq. km., will experience flood levels of less than 0.20 meters. 3.61% of the area will experience flood levels of 0.21 to 0.50 meters; while 4.31%, 7.64%, 9.58%, and 1.38% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46-47are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected Areas in Alubijid, Misamis Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Alubijid							
	Baybay	Benigwayan	Calatcat	Lagtang	Lanao	Loguilo	Lourdes	Lumbo
0.03-0.20	**0.16**	6.88	2.71	1.69	1.31	0.04	2.12	0.92
0.21-0.50	**0.18**	0.35	0.11	0.18	0.13	0.15	0.29	0.05
0.51-1.00	**0.37**	0.5	0.14	0.13	0.26	0.37	0.36	0.031
1.01-2.00	**0.5**	1.04	0.53	0.24	0.53	1.17	0.47	0.037
2.01-5.00	**0.021**	2.32	0.64	0.074	0.049	0.53	2.14	0.023
> 5.00	**0**	0.75	0.033	0	0.0002	0.00015	0.2	0.000099

Table 47. Affected Areas in Alubijid, Misamis Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Alubijid						
	Molocboloc	**Poblacion**	**Sampatulog**	**Sungay**	**Talaba**	**Taparak**	**Tugasnon**
0.03-0.20	**0.88**	0.27	3.62	2.94	2.99	10.45	3.75
0.21-0.50	**0.16**	0.081	0.18	0.14	0.12	0.58	0.19
0.51-1.00	**0.24**	0.22	0.13	0.084	0.073	0.42	0.12
1.01-2.00	**0.49**	0.29	0.11	0.12	0.059	0.46	0.079
2.01-5.00	**0.002**	0.11	0.076	0.27	0.082	1.27	0.053
> 5.00	**0**	0.0074	0.022	0.029	0.0003	0.067	0.0034

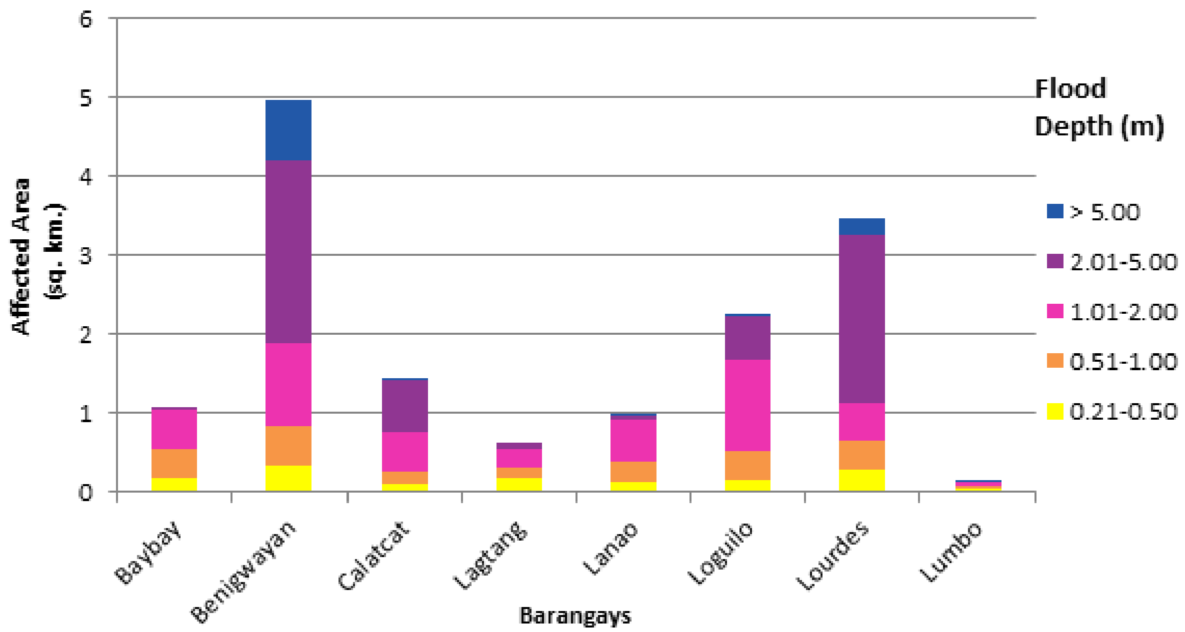


Figure 82 . Affected Areas in Alubijid, Misamis Oriental during 100-Year Rainfall Return Period.

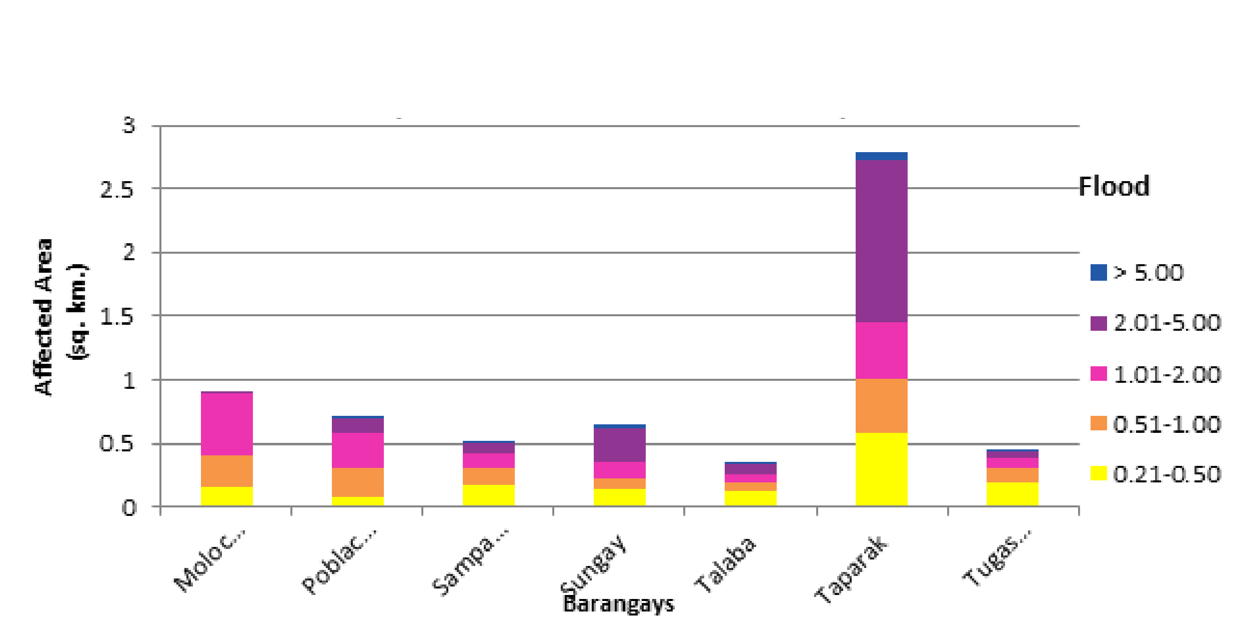


Figure 83 . Affected Areas in Alubijid, Misamis Oriental during 100-Year Rainfall Return Period.

For the 100-year return period, 8.27% of the city of El Salvador, with an area of 141.446 sq. km. will experience flood levels of less than 0.20 meters. 0.72% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.41%, 0.33%, 0.27%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected Areas in El Salvador, Misamis Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in El Salvador City				
	Bolisong	Hinigdaan	Kalabaylabay	Kibonbon	Sinaloc
0.03-0.20	1.99	4.04	3.4	1.54	0.72
0.21-0.50	0.067	0.24	0.13	0.33	0.25
0.51-1.00	0.052	0.12	0.089	0.08	0.23
1.01-2.00	0.048	0.12	0.099	0.012	0.19
2.01-5.00	0.058	0.085	0.24	0.0013	0.003
> 5.00	0.018	0.031	0.13	0	0

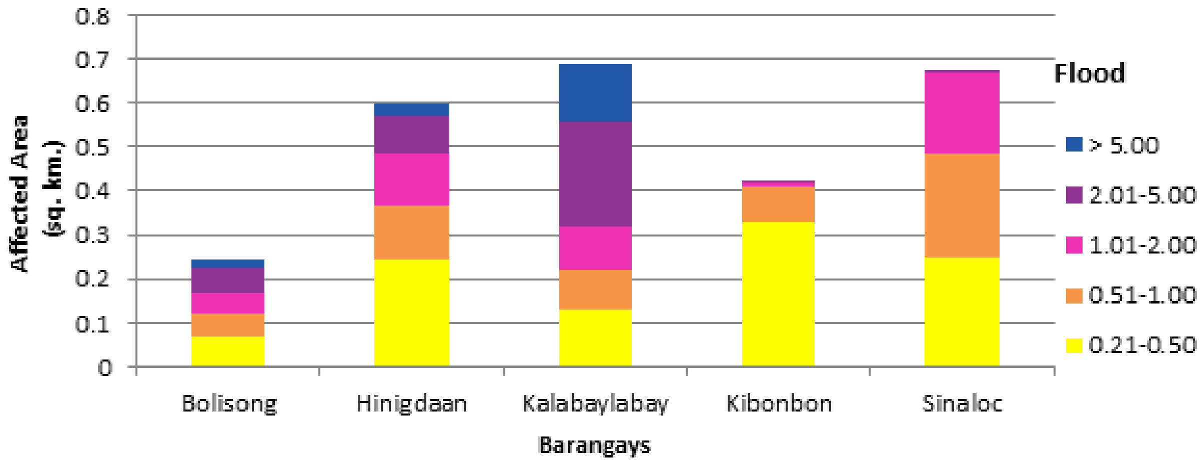


Figure 84 . Affected Areas in El Salvador, Misamis Oriental during 100-Year Rainfall Return Period.

For the 100-year return period, 14.07% of the municipality of Gitagum, with an area of 41.475498 sq. km., will experience flood levels of less than 0.20 meters. 0.65% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.42%, 0.32%, 0.27%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 49are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected Areas in Gitabum.Misamis Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Gitagum
	Gregorio Pelaez
0.03-0.20	5.84
0.21-0.50	0.27
0.51-1.00	0.18
1.01-2.00	0.13
2.01-5.00	0.11
> 5.00	0.0054

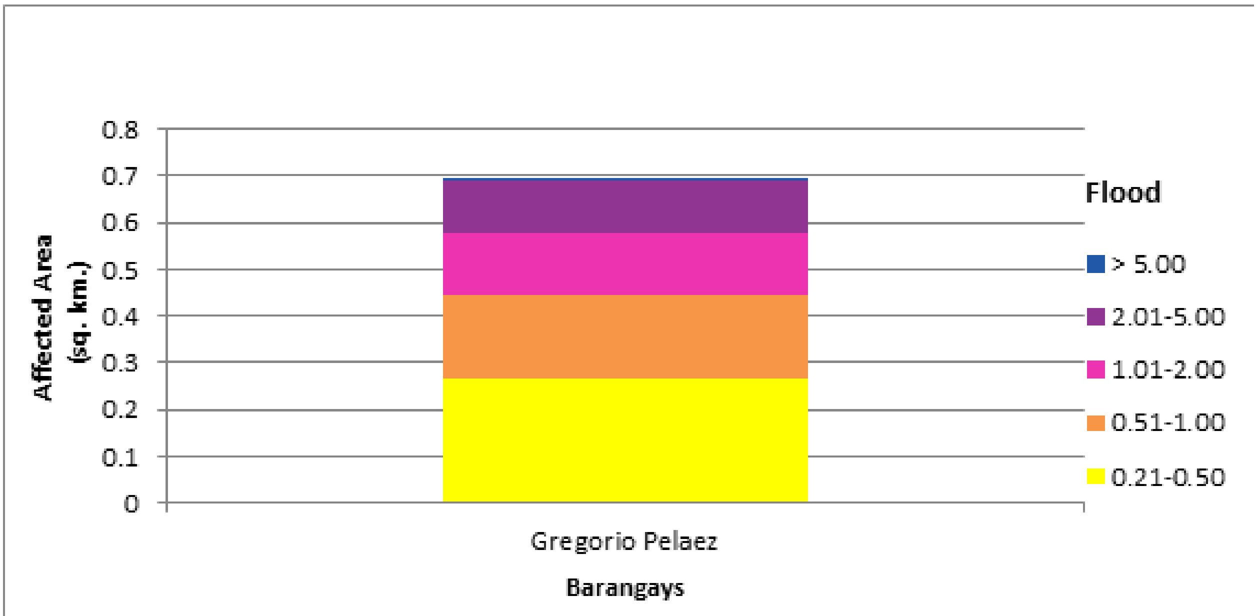


Figure 85 . Affected Areas in Gitagum, Misamis Oriental during 100-Year Rainfall Return Period.

For the 100-year return period, 1.36% of the municipality of Initao, with an area of 68.011398 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 0.02%, 0.01%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected Areas in Initao, Misamis Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Initao
	Sinalac
0.03-0.20	0.93
0.21-0.50	0.024
0.51-1.00	0.013
1.01-2.00	0.0075
2.01-5.00	0.0046
> 5.00	0

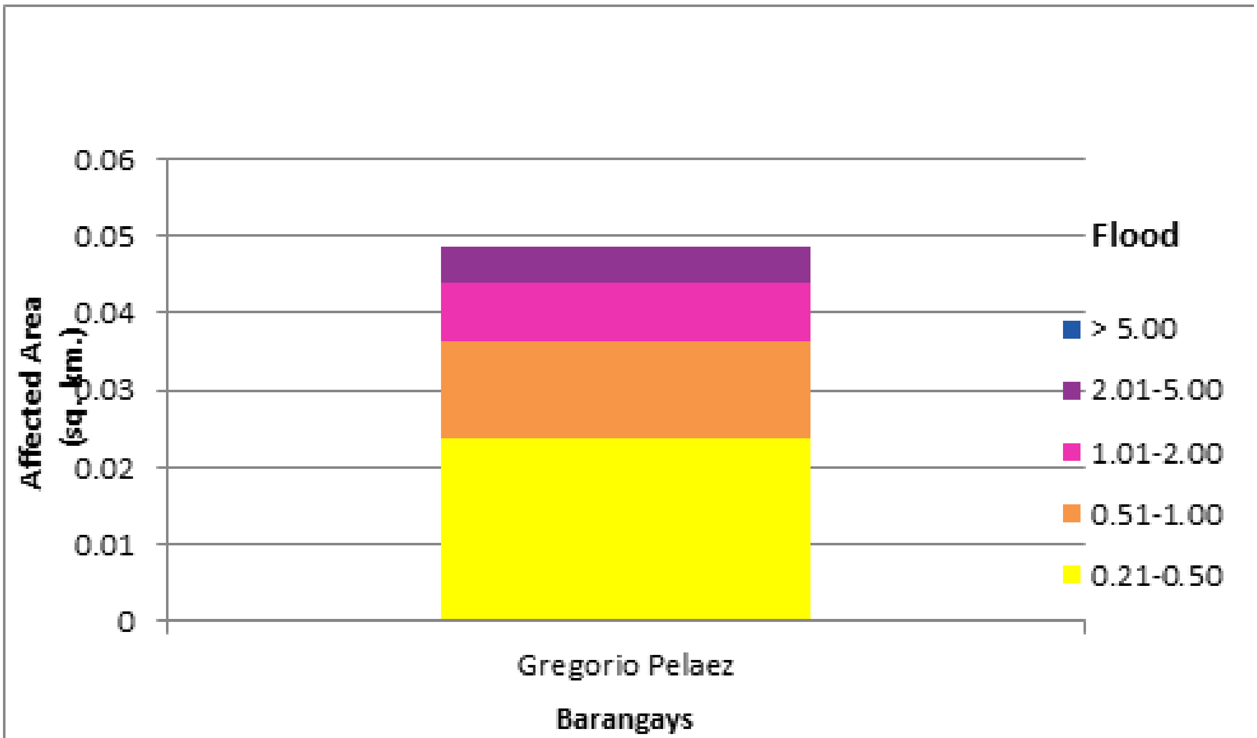


Figure 86 . Affected Areas in Initao, Misamis Oriental during 100-Year Rainfall Return Period.

For the 100-year return period, 16.37% of the municipality of Laguindingan, with an area of 37.873798 sq. km., will experience flood levels of less than 0.20 meters. 1.30% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.16%, 1.20%, 0.47%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51 . Affected Areas in Laguindingan, Misamis Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Laguindingan			
	Kibaghot	Lapad	Moog	Poblacion
0.03-0.20	2.05	3.29	0.58	0.27
0.21-0.50	0.16	0.17	0.084	0.081
0.51-1.00	0.057	0.16	0.01	0.22
1.01-2.00	0.029	0.14	0	0.29
2.01-5.00	0.0093	0.056	0	0.11
> 5.00	0.0007	0.0024	0	0.0074

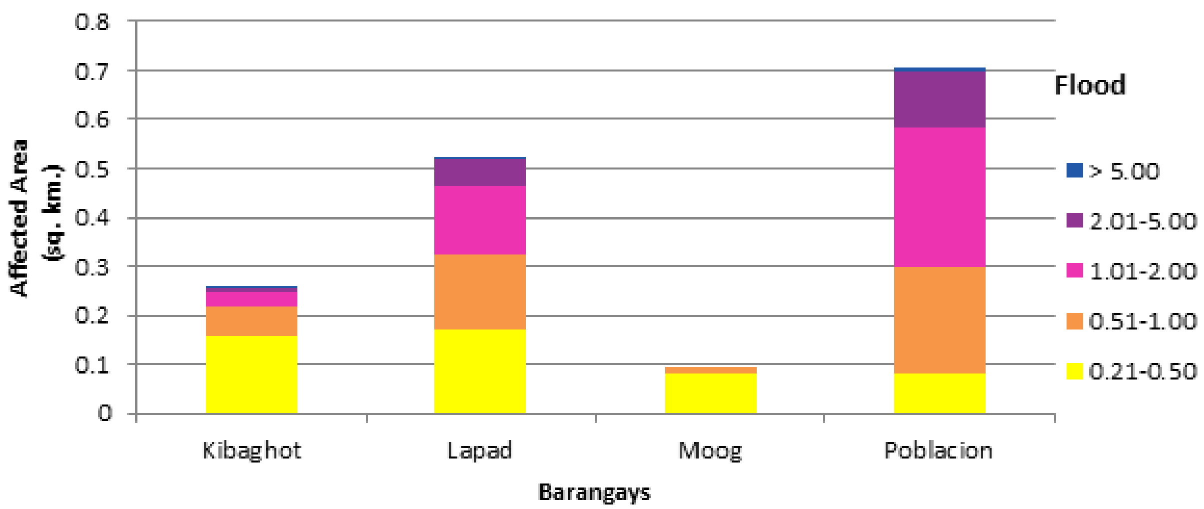


Figure 87 . Affected Areas in Laguindingan, Misamis Oriental during 100-Year Rainfall Return Period.

For the 100-year return period, 6.77% of the municipality of Libertad, with an area of 40.591702 sq. km. will experience flood levels of less than 0.20 meters. 0.17% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.10%, 0.06%, 0.02%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected Areas in Libertad, Misamis Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Libertad		
	Kimalok	Tangcub	Taytayan
0.03-0.20	0.95	0.84	0.95
0.21-0.50	0.024	0.021	0.025
0.51-1.00	0.0092	0.013	0.016
1.01-2.00	0.0041	0.0087	0.0098
2.01-5.00	0.0018	0.0024	0.0019
> 5.00	0.0018	0	0.000099

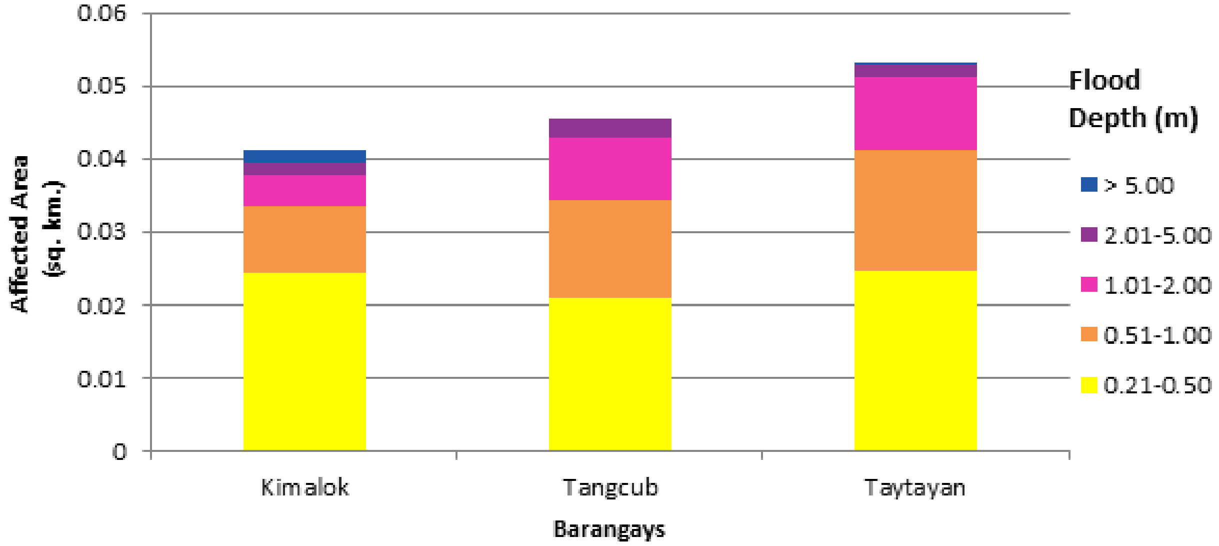


Figure 88 . Affected Areas in Libertad, Misamis Oriental during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Alubijid, Taparak is projected to have the highest percentage of area that will experience flood levels at 16.52%. Meanwhile, Benigwayan posted the second highest percentage of area that may be affected by flood depths at 14.77%.

Among the barangays in the city of El Salvador, Hinigdaan is projected to have the highest percentage of area that will experience flood levels at 3.28%. Meanwhile, Kalabaylabay posted the second highest percentage of area that may be affected by flood depths at 2.89%.

For the municipality of Gitagum, only Gregorio Pelaez is projected to experience flood levels at a percentage of 15. 74%.

For the municipality of Initao, only Sinalac is projected to experience flood levels at a percentage of 1.43%. Among the barangays in the municipality of Laguindingan, Lapad is projected to have the highest percentage of area that will experience flood levels of at 10.08%. Meanwhile, Kibaghot posted the percentage of area that may be affected by flood depths of at 6.09%.

Among the barangays in the municipality of Libertad, Taytayan is projected to have the highest percentage of area that will experience flood levels at 2.47%. Meanwhile, Kimalok posted the second highest percentage of area that may be affected by flood depths of at 2.45%.

The generated flood hazard maps for the Alubijid Floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps – "Low", "Medium", and "High" – the affected institutions were given individual assessments for each Flood Hazard Scenario (5-yr., 25-yr., and 100-yr.). See Annex 12 and 13 for Educational Institutions and Health Institutions affected by flooding in the Alubijid floodplain.

Table 53 . Area covered by each warning level with respect to the rainfall scenario.

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	6.39	5.18	5.37
Medium	9.23	9.02	8.66
High	2.73	11.09	13.15
Total	**18.35**	**25.29**	**27.18**

Of the twenty-eight (28) identified Education Institutes in the Alubijid Floodplain, four (4) schools were assessed to be exposed to Low level flooding during a 5-year scenario, while one(1) school was assessed to be exposed to Medium level flooding in the same scenario. In the 25-year scenario, three (3) schools were assessed to be exposed to Low level flooding, while four(4) schools were assessed to be exposed to Medium level flooding. In the same scenario, one (1) school is exposed to High level flooding. For the 100-year scenario, four (4) schools were assessed to be exposed to Low level flooding and five (5) schools toMedium level flooding. In the same scenario, one (1) school was assessed to be exposed to High level flooding. The school exposed to high level flooding is located in Barangay Lourdes, Alubijid.

Five (5) Medical Institutions were identified in the AlubijidFloodplain.Only one (1) was assessed to be exposed to Low level flooding in the 5-year scenario and is exposed to Medium level flooding in the 25- and 100-year scenarios in Barangay Lourdes, Alubijid.

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 onflood occurrence in the area within the major river systems in the Philippines.

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

The validation personnel went to the specified points identified in a river basin and will gather data onthe actual flood level in each location. Data gathering was done through the assistance of local DRRM offices in obtaining maps or situation reports about the past flooding events, or through the conduct of interviews with some residents with knowledge or experience of flooding in the particular area.

The actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map.
The flood validation consists of 202 points randomly selected all over the Alubijid floodplain. It has an RMSE value of 1.33. The validation points are found in Annex 11.

The validation data were obtained on November 15-25,2016

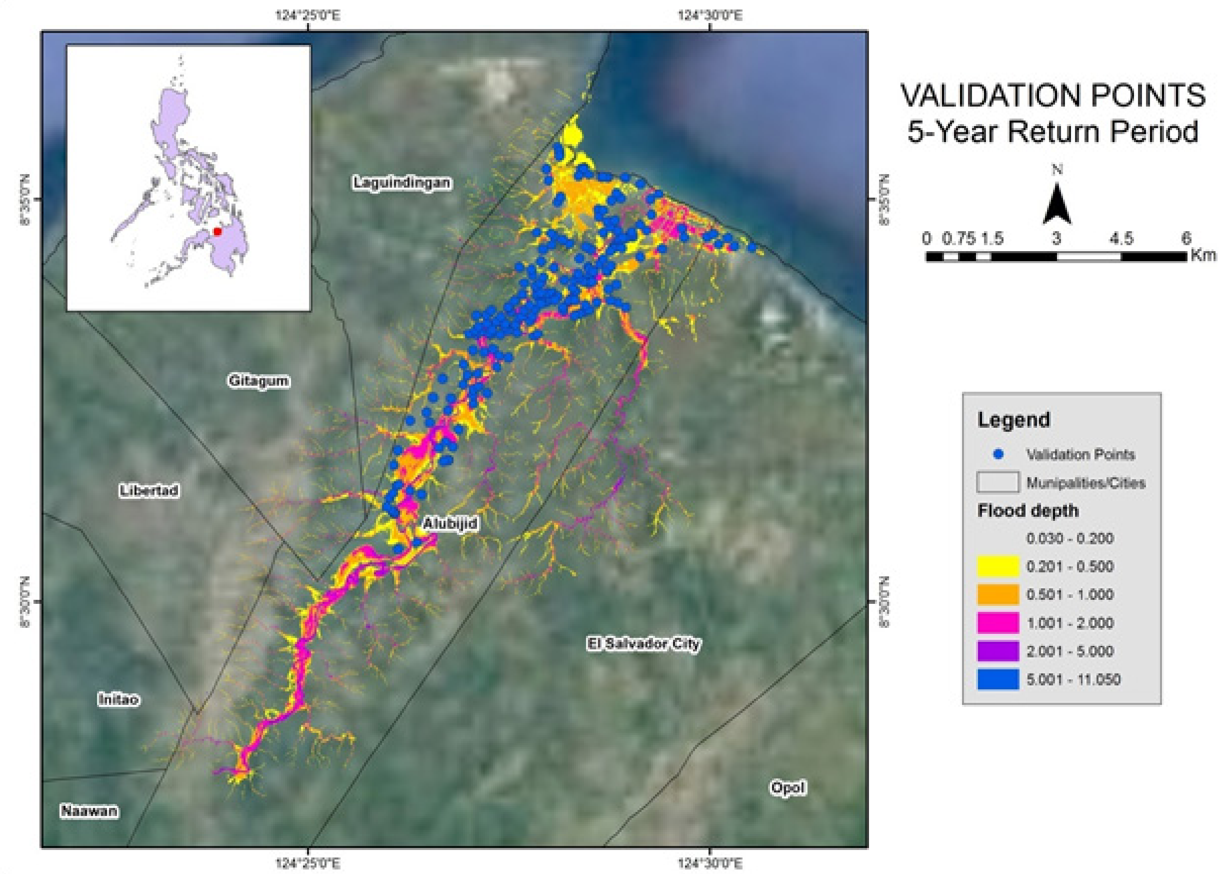


Figure 89 . Alubijid Flood Validation Points.

Table 54 . Actual Flood Depth vs Simulated Flood Depth in Alubijid.

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	57	15	15	15	3	0	105
0.21-0.50	7	4	1	0	0	0	12
0.51-1.00	19	4	2	1	0	0	26
1.01-2.00	8	7	6	6	2	0	29
2.01-5.00	2	3	5	4	9	0	23
> 5.00	1	0	2	2	2	0	7
Total	94	33	31	28	16	0	202

The overall accuracy generated by the flood model is estimated at 38.61%, with 78 points correctly matching the actual flood depths. In addition, there were 42 points estimated one level above and below the correct flood depths, while there were 48 points and 34 points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood. A total of 52 points were overestimated, while a total of 72 points were underestimated in the modeled flood depths of Alubijid.

Table 55 . Summary of Accuracy Assessment in Alubijid.

	No. of Points	%
Correct	78	38.61
Overestimated	52	25.74
Underestimated	72	35.64
Total	202	100.00

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.

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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.

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

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

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

ANNEXES

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

Table A-1.1. Technical specifications of the Pegasus sensor

1. PEGASUS SENSOR

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

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

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

1. MSE-16

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

July 25, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MISAMIS ORIENTAL**
Station Name: **MSE-16**
Order: **2nd**

Island: **Mindanao**		Barangay: **POBLACION**
Municipality: **LIBERTAD**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **8° 33' 51.69220"**	Longitude: **124° 21' 5.34868"**	Ellipsoidal Hgt: **1.34700 m.**
	WGS84 Coordinates	
Latitude: **8° 33' 48.06049"**	Longitude: **124° 21' 10.74852"**	Ellipsoidal Hgt: **68.04400 m.**
	PTM / PRS92 Coordinates	
Northing: **947021.389 m.**	Easting: **428608.692 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **946,891.04**	Easting: **648,735.65**	Zone: **51**

Location Description

From Cagayan de Oro travel W for about 40 Km. to the Municipality of Libertad. At Brgy. Poblacion, turn right for about 200m towards the municipal town hall. E of the municipal hall is Libertad National High School. Station is located on the S corner of a concrete pavement used as a volleyball court. It is about 15m S of the flagpole and about 50m N of the main gate. The istation is leveled flush with the pavement surface. Station mark iis the head of a copper nail, top-centered on a 30cm x 30cm x 60cm concrete block, leveled flush with a nearby concrete pavement with inscriptions, MSE-16 2003, NAMRIA.

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1721**

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

9 9 0 7 2 5 2 0 1 4 1 3 1 4 3 8

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. MSE-16

2. MSE-17

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

June 06, 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: **MISAMIS ORIENTAL**
Station Name: **MSE-17**
Order: **2nd**

Island: **MINDANAO**		Barangay: **PANGAYAWAN**
Municipality: **GITAGUM**		
	PRS92 Coordinates	
Latitude: **8° 35' 22.50573"**	Longitude: **124° 23' 6.86732"**	Ellipsoidal Hgt: **5.01000 m.**
	WGS84 Coordinates	
Latitude: **8° 35' 18.86995"**	Longitude: **124° 23' 12.25471"**	Ellipsoidal Hgt: **71.73900 m.**
	PTM Coordinates	
Northing: **949805.1 m.**	Easting: **432328.91 m.**	Zone: **5**
	UTM Coordinates	
Northing:	Easting:	Zone:

Location Description

MSE-17
From Cagayan de Oro, travel W for about 40km towards the municipality of Gitagum. At brgy. Pangayawan, visible from the provincial road on the left side (SE side), is Pangayawan Elementary School. Station is located near the edge of a corn field, about 20m NW of the flagpole, about 30m ESE of the school gate, and about 30m Se from the highway. Station mark is the head of a 4" copper nail, top-centered on a 30cm x 30cm x 60cm concrete block protruding by about 20cm above the ground, with inscriptions, MSE-17 2003, NAMRIA.

Requesting Party:	UP-TCAGP
Pupose:	Reference
OR Number:	8796290 A
T.N.:	2014-1288

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

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Figure A-2.2. MSE-17

3. LE-89

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

July 25, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LANAO DEL NORTE**
Station Name: LE-89

Island: **Mindanao**	Municipality: **LALA**	Barangay:
Elevation: **10.8140 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LE-89
Is in the Province of Lanao del Norte, Municipality of Lala, Brgy. Panguil, along the Iligan - Zamboanga National Road. The station is located on top of a riprap, about 6 meters North West of KM post 1600 and about 8 meters West of centerline of the highway.

A brass rod is set on a drilled hole and cemented flushed on top of a 15cm x 15cm cement putty with inscription "LE-89, 2007 NAMRIA".

Requesting Party: **UP-TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8799582 A**
T.N.: **2014-1724**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.23 LE-89

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

Table A-3.1. Baseline Processing Repors of Control Points used in the LiDAR Survey

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Processing Start Time	Processing Stop Time	Satellite Available
LDN01 — LE89 PM (B1)	LDN01	LE89 PM	6/27/2014 1:59:14 PM	6/27/2014 4:08:49 PM	Fixed	0.003	0.015	-1621.590	-1696.938	3341.597	34°12'00"	4083.501	-5.499	6/27/2014 1:59:14 PM	6/27/2014 4:08:49 PM	GPS: 15 GLONASS: 8 Galileo: 0 QZSS: 0
LDN01 — LE89 AM (B2)	LDN01	LE89 AM	6/27/2014 8:08:24 AM	6/27/2014 12:39:54 PM	Fixed	0.003	0.012	-1621.627	-1696.894	3341.611	34°12'00"	4083.509	-5.471	6/27/2014 8:08:34 AM	6/27/2014 12:39:54 PM	GPS: 15 GLONASS: 13 Galileo: 0 QZSS: 0

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

1

LDN01 - LE89 PM (1:59:14 PM-4:08:49 PM) (S1)

Baseline observation:	LDN01 --- LE89 PM (B1)
Processed:	7/27/2014 10:37:49 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.015 m
RMS:	0.002 m
Maximum PDOP:	1.981
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	6/27/2014 1:59:14 PM (Local: UTC+8hr)
Processing stop time:	6/27/2014 4:08:49 PM (Local: UTC+8hr)
Processing duration:	02:09:35
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	LDN01				
Grid		Local		Global	
Easting	635916.865 m	Latitude	N8°13'57.88944"	Latitude	N8°13'57.88944"
Northing	910238.155 m	Longitude	E124°14'02.37264"	Longitude	E124°14'02.37264"
Elevation	9.384 m	Height	78.950 m	Height	78.950 m

To:	LE89 PM				
Grid		Local		Global	
Easting	638201.305 m	Latitude	N8°15'47.82322"	Latitude	N8°15'47.82322"
Northing	913622.047 m	Longitude	E124°15'17.37373"	Longitude	E124°15'17.37373"
Elevation	3.968 m	Height	73.451 m	Height	73.451 m

Vector					
ΔEasting	2284.440 m	NS Fwd Azimuth	34°12'00"	ΔX	-1621.760 m
ΔNorthing	3383.892 m	Ellipsoid Dist.	4083.501 m	ΔY	-1696.687 m
ΔElevation	-5.416 m	ΔHeight	-5.499 m	ΔZ	3341.640 m

2

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader – I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3"></td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="3">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>JASMINE ALVIAR</td><td>UP-TCAGP</td></tr>
<tr><td>Research Associate (RA)</td><td>GRACE SINADJAN</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. IRO NIEL ROXAS</td><td>UP-TCAGP</td></tr>
<tr><td>Ground Survey, Data Download and Transfer</td><td>RA</td><td>LANCE KERWIN CINCO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">LiDAR Operation</td><td>Airborne Security</td><td>SSG. LEE JAY PUNZALAN</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="2">Pilot</td><td>CAPT. JEFFREY JEREMY ALAJAR</td><td>ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. CESAR ALFONSO III</td><td>AAC</td></tr>
</table>

Annex 5. Data Transfer Sheets for the Alubijid Floodplain Flights

DATA TRANSFER SHEET
07/28/2014(Northern Mindanao - ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6/8/2014	1565P	1BLK71B159A	Pegasus	NA	16	6.93	168	NA	NA	13.3	NA	7.75	1KB	1KB	36	NA	Z:\Airborne_Raw
6/9/2014	1569P	1BLKRXE160A	Pegasus	4.16	832	16.5	290	8.86	62	38.5	NA	10	1KB	1KB	85	NA	Z:\Airborne_Raw
6/16/2014	1597P	1BLKRXE167A	Pegasus	2.18	332	10.5	237	NA	NA	21.3	NA	7.52	1KB	1KB	68	NA	Z:\Airborne_Raw
6/19/2014	1609P	1RXS170A	Pegasus	2.16	526	11.2	259	45.3	309	22.1	NA	7.07	1KB	1KB	77/76	NA	Z:\Airborne_Raw
6/20/2014	1613P	1BLK71G171A	Pegasus	3.44	177	13.7	258	67.3	437	33.2	NA	5.92	1KB	1KB	46	NA	Z:\Airborne_Raw
6/23/2014	1625P	1BLK67BC174A	Pegasus	3.09	1112	11.7	212	60.3	415	29.4	86.6	4.97	1KB	1KB	52/56	NA	Z:\Airborne_Raw
6/24/2014	1629P	1BLKRXES175A	Pegasus	2.79	370	10.7	187	36.3	268	26.1	NA	4.45	1KB	1KB	73	NA	Z:\Airborne_Raw
6/27/2014	1641P	1BLK68A178A	Pegasus	2.94	1995	12.6	268	57.4	398	28.9	57.2	7.7	1KB	1KB	65/65/60/58	NA	Z:\Airborne_Raw
6/27/2014	1643P	1BLK67ABS178S	Pegasus	532	95	4.33	119	NA	NA	5.65	NA	7.7	1KB	1KB	48	NA	Z:\Airborne_Raw
6/28/2014	1645P	1BLK71C179A	Pegasus	2.84	NA	11.4	242	51.8	375	27.4	NA	6.25	1KB	1KB	59/68	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

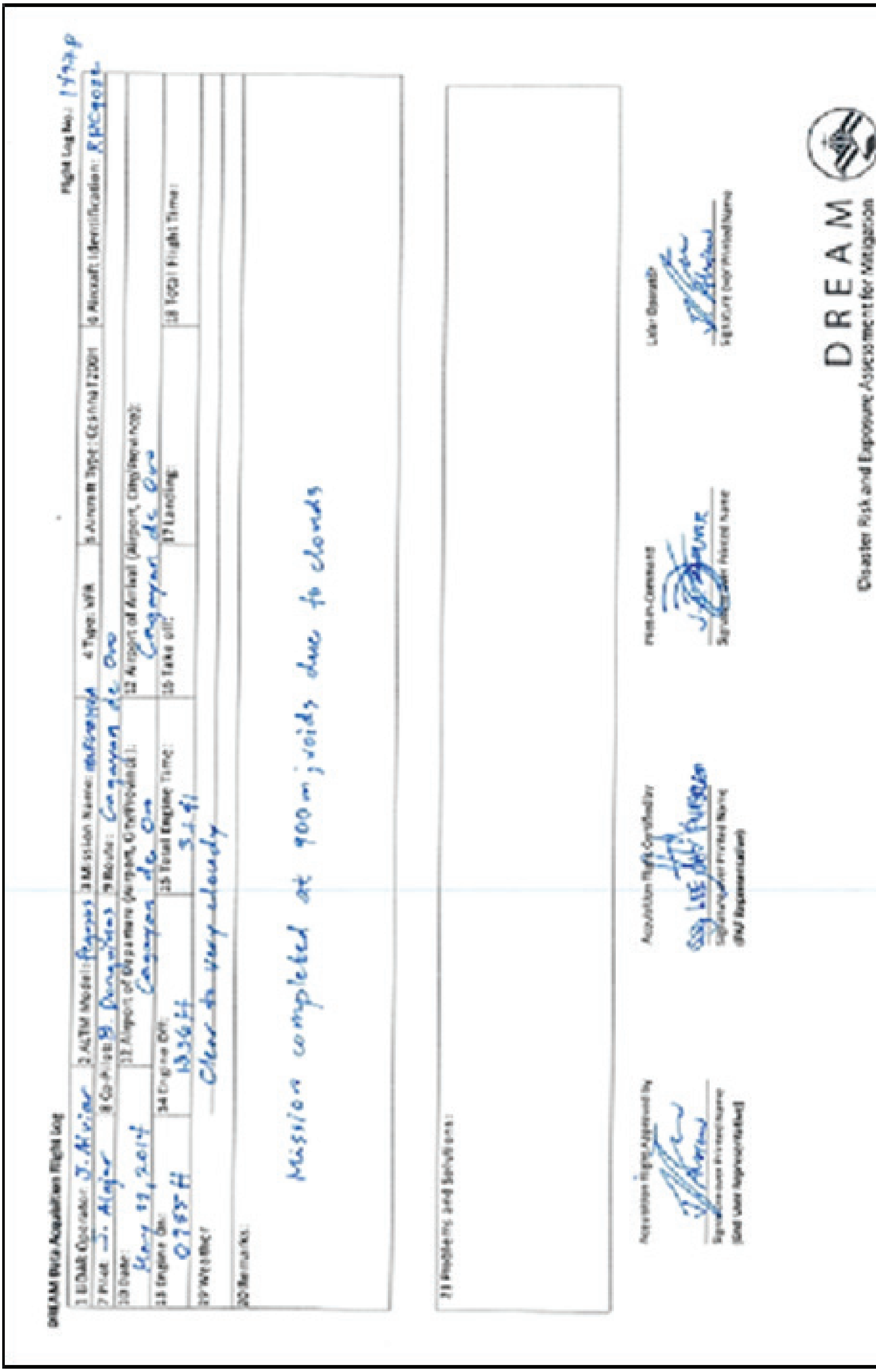
Received by

Name JOIDA PRIETO
Position SRS
Signature 7/28/14

Figure A-5.1. Data Transfer Sheet for Sibalom Floodplain – A

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1497P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1497P

1 LiDAR Operator: J. Alviar
2 ALTM Model: Pegasus
3 Mission Name:
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar
8 Co-Pilot: B. Dongallo
9 Route: Cagayan de Oro
10 Date: May 17, 2014
12 Airport of Departure (Airport, City/Province): Cagayan de Oro
12 Airport of Arrival (Airport, City/Province): Cagayan de Oro
13 Engine On: 0955H
14 Engine Off: 1336H
15 Total Engine Time: 3+41
16 Take off:
17 Landing:
18 Total Flight Time:
19 Weather: Clear to very cloudy
20 Remarks:
Mission completed at 900m; voids due to clouds
21 Problems and Solutions:

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

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

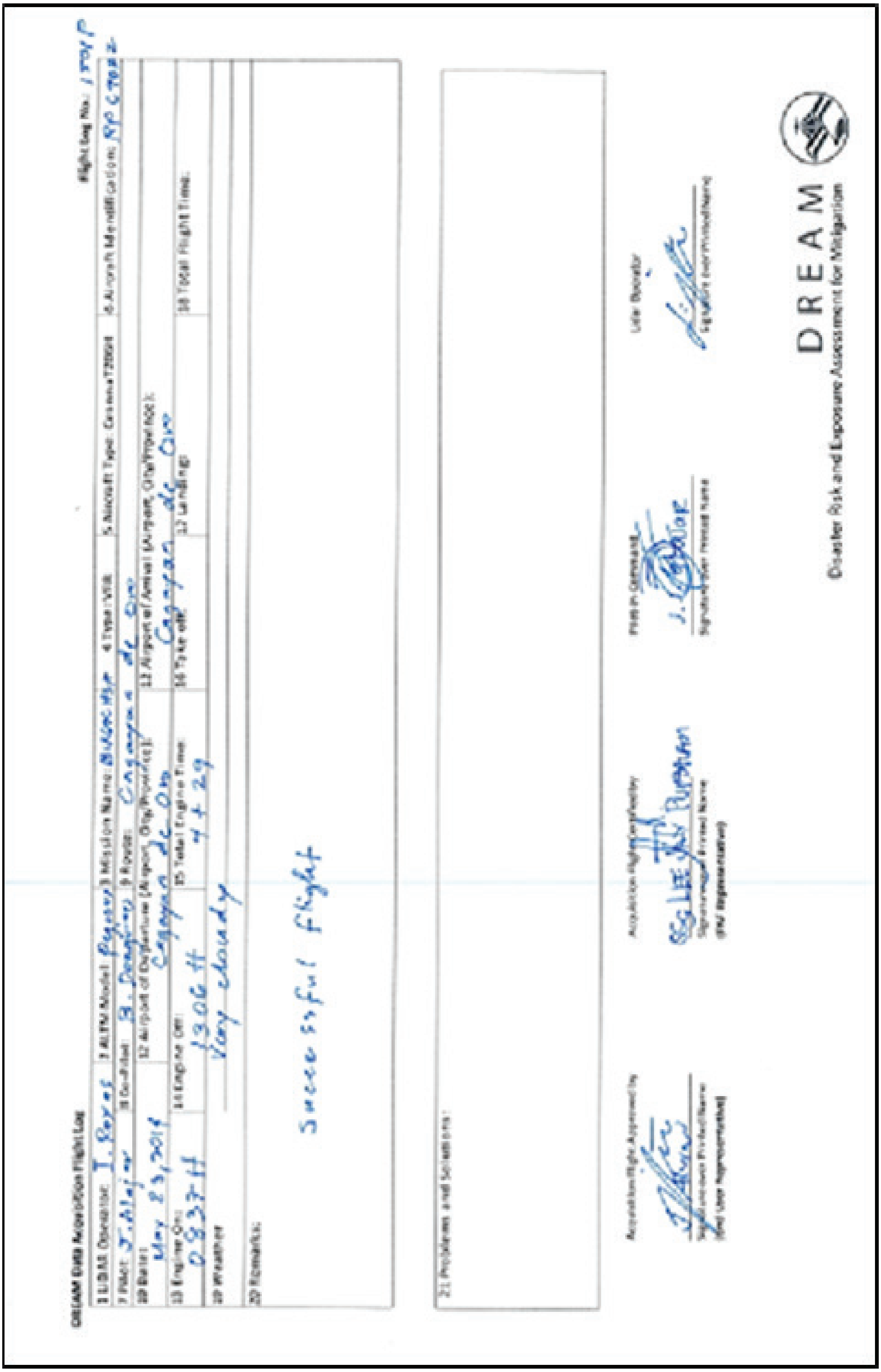
Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1497P

2. Flight Log for 1501P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1501P

1 LiDAR Operator: I. Reyes	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Dongallo	9 Route: Cagayan de Oro			
10 Date: May 23, 2014	12 Airport of Departure (Airport, City/Province): Cagayan de Oro		12 Airport of Arrival (Airport, City/Province): Cagayan de Oro		
13 Engine On: 0837H	14 Engine Off: 1306H	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Very cloudy				

20 Remarks:

Successful flight

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

SSG LEE JAY PUNSALAN
Signature over Printed Name
(PAF Representative)

Pilot-in-Command

J. ALAJAR
Signature over Printed Name

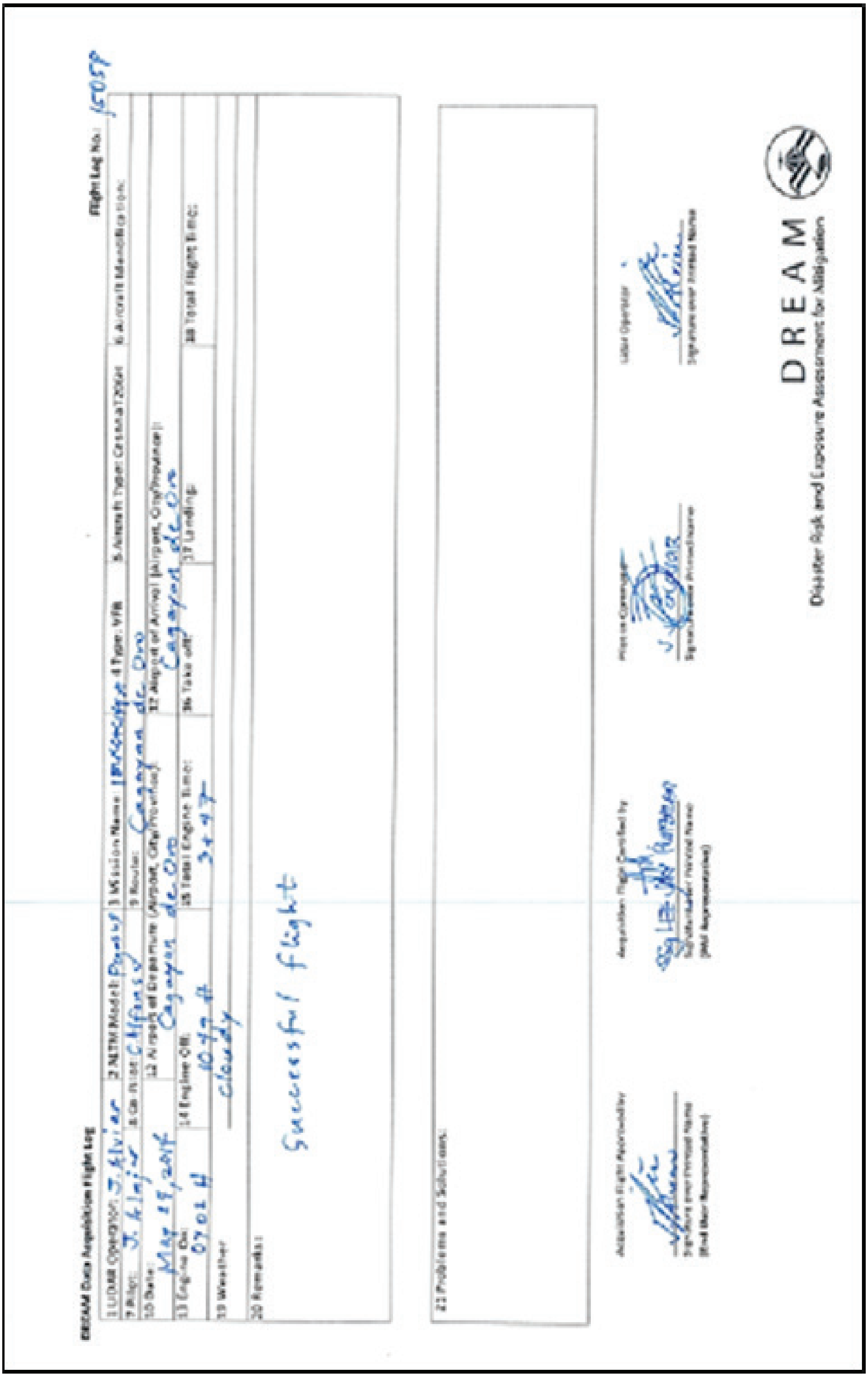
Lidar Operator

Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2. Flight Log for Mission 1501P

3. Flight Log for 1505P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1505P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK60Ggs	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Alajar	8 Co-Pilot: C. Alfonso	9 Route: Cagayan de Oro			
10 Date: May 19, 2014	12 Airport of Departure (Airport, City/Province): Cagayan de Oro		12 Airport of Arrival (Airport, City/Province): Cagayan de Oro		
13 Engine On: 0702 H	14 Engine Off: 1049 H	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks: Successful flight

21 Problems and Solutions:

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

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

Pilot-in-Command — J. Alajar — Signature over Printed Name

Lidar Operator — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 1505P

4. Flight Log for 1625P Mission

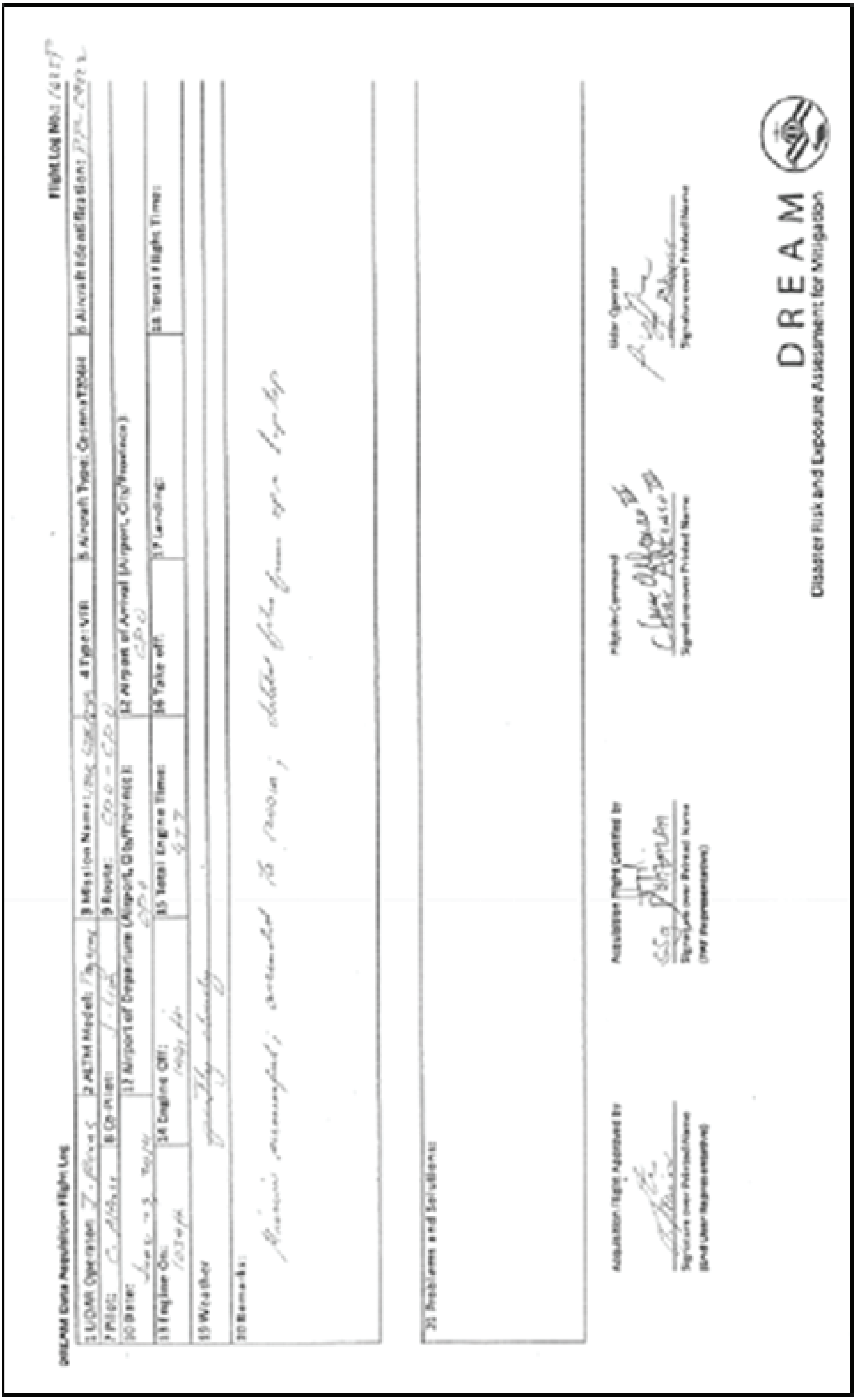
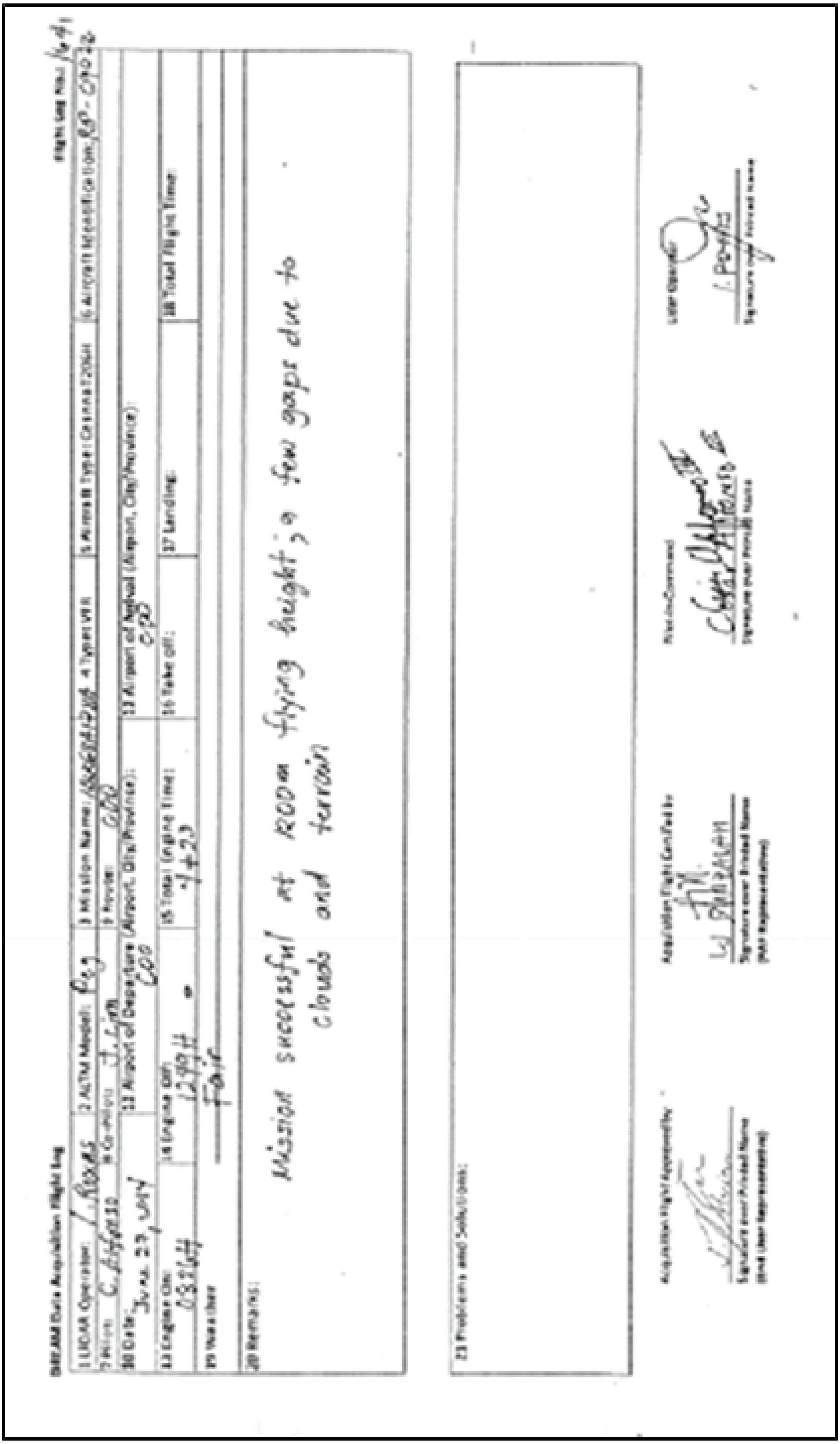


Figure A-6.4. Flight Log for Mission 1625P

5. Flight Log for 1641P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1641

1 LiDAR Operator: L. Rosas
2 ALTM Model: Peg
3 Mission Name:
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification: RP-C9022

7 Pilot: C. Alfonso
8 Co-Pilot: J. Lim
9 Route: CDO

10 Date: June 23, 2014
12 Airport of Departure (Airport, City/Province): CDO
13 Airport of Arrival (Airport, City/Province): CDO

14 Engine On: 0831H
14 Engine Off: 1259H
15 Total Engine Time: 4+29
16 Take off:
17 Landing:
18 Total Flight Time:

19 Weather: Fair

20 Remarks:

Mission successful at 1200m flying height; a few gaps due to clouds and terrain

21 Problems and Solutions:

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

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

Pilot-in-Command
C. Alfonso
Signature over Printed Name

LiDAR Operator
L. Rosas
Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1641P

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

NORTHERN MINDANAO
(May 22-July 10, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1497P	BLK 67D	1BLK67B142A	J.Alviar	May 22, 2014	Mission completed at 900m; voids due to clouds
1501P	BLK 67C,67DS	1BLK67C143A	I. Roxas	May 23, 2014	Original flight plan block cut due to clouds and terrain; mission completed at 800m and 700m flying height
1505P	BLK 67A,67B	1BLK67C144A	J.Alviar	May 24, 2014	Surveyed at 850m
1625P	BLK 67G	1BLK67BC174A	I. Roxas	June 23, 2014	Mission successful; ascended to 1200m
1641P	BLK68A	1BLK68A178A	I. Roxas	June 27, 2014	Mission successful at 1200m flying height; a few gaps due to clouds and terrain

LAS BOUNDARIES PER FLIGHT

Flight No. : 1497P
Area: BLK 67D
Mission Name: 1BLK67B142A
Parameters: Altitude: 900m;
Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

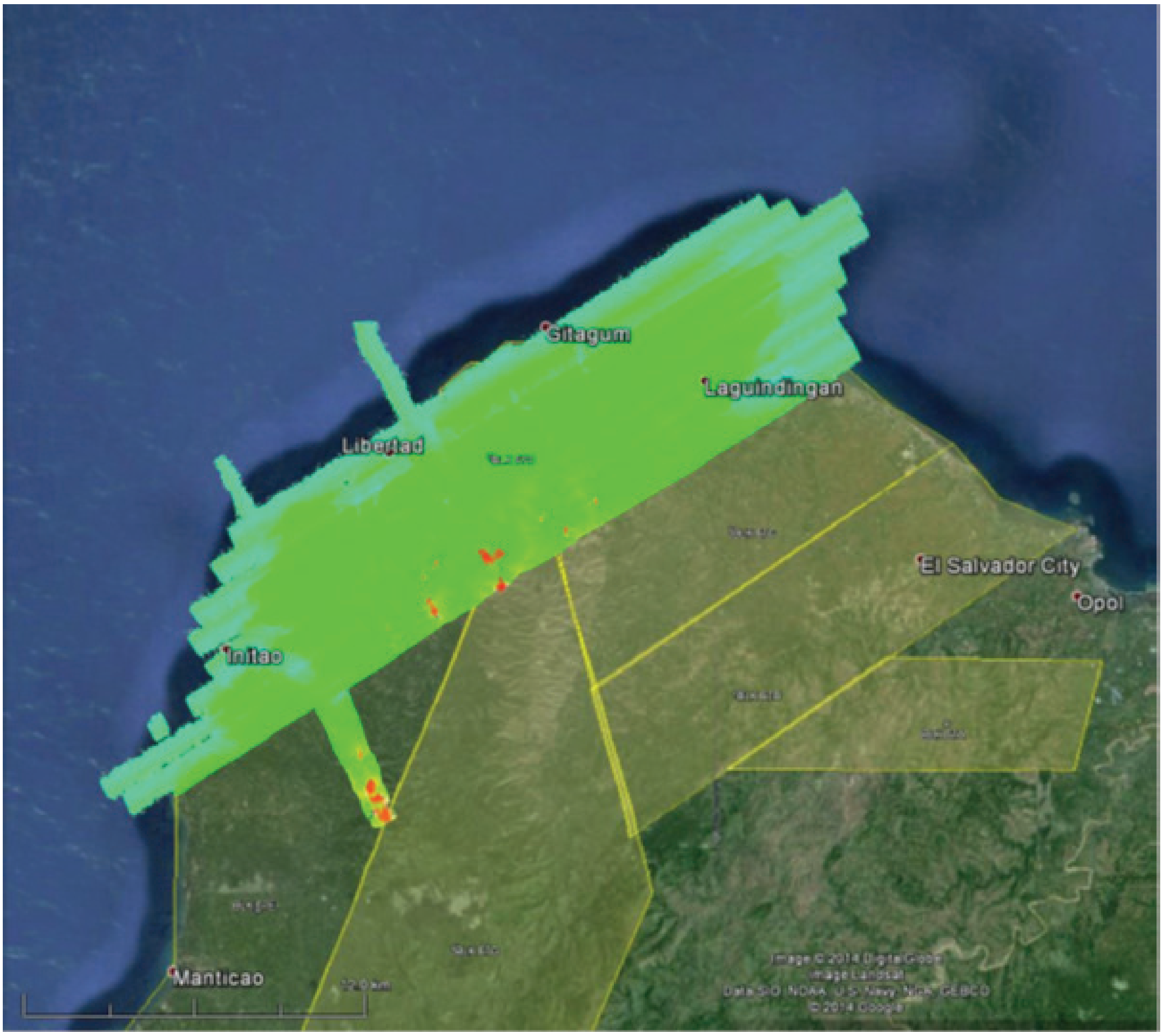


Figure A-7.1. Swath for Flight No. 1497P

4. Flight Log for 1625P Mission

Flight No. : 1501P
Area: BLK 67C, 67DS
Mission Name: 1BLK67C143A
Parameters: Altitude: 900m;
Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

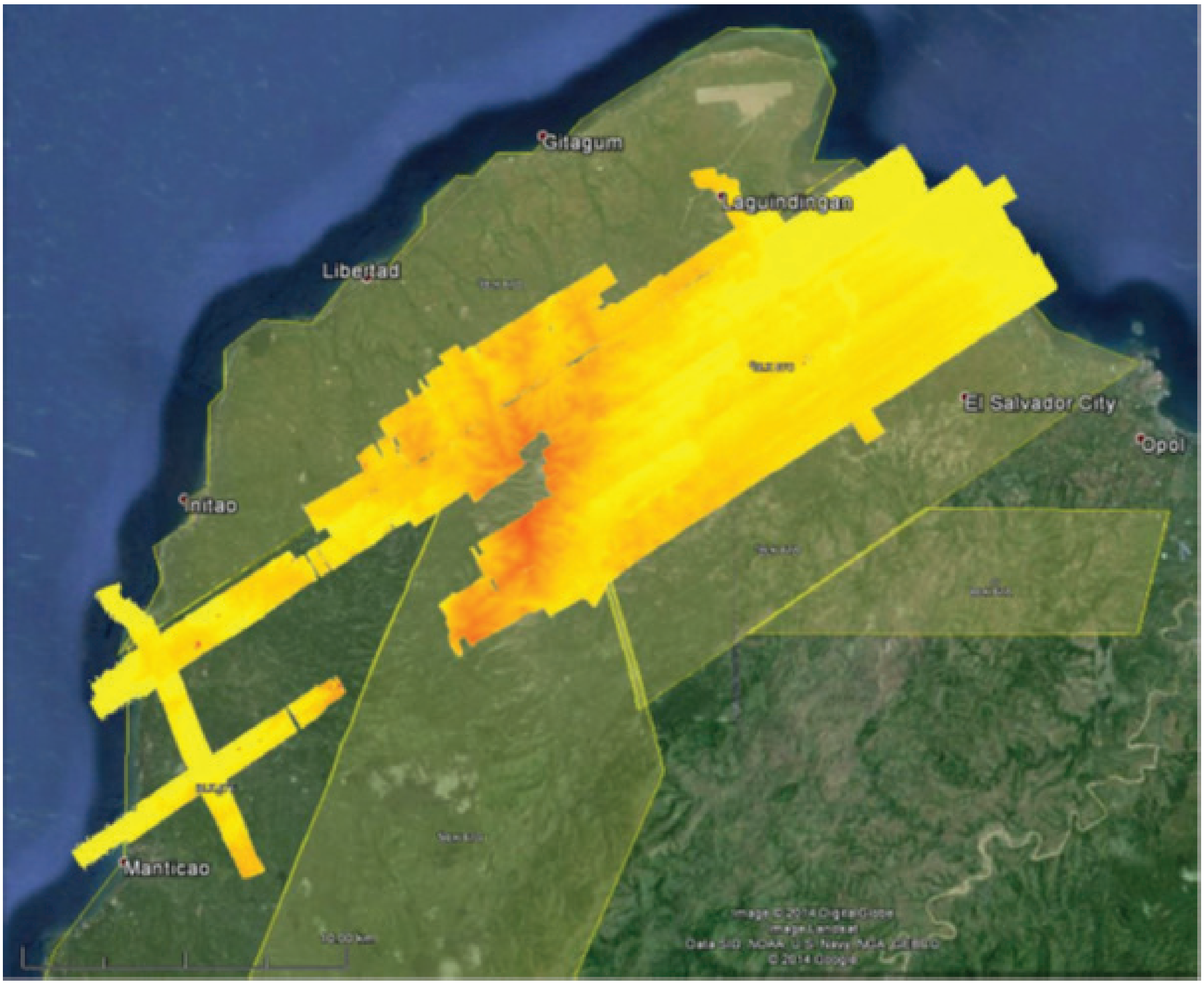


Figure A-7.2. Swath for Flight No. 1501P

Flight No. : 1505P
Area: BLK 67C, 67DS
Mission Name: 1BLK67BC144A
Parameters: Altitude: 850 m;
Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

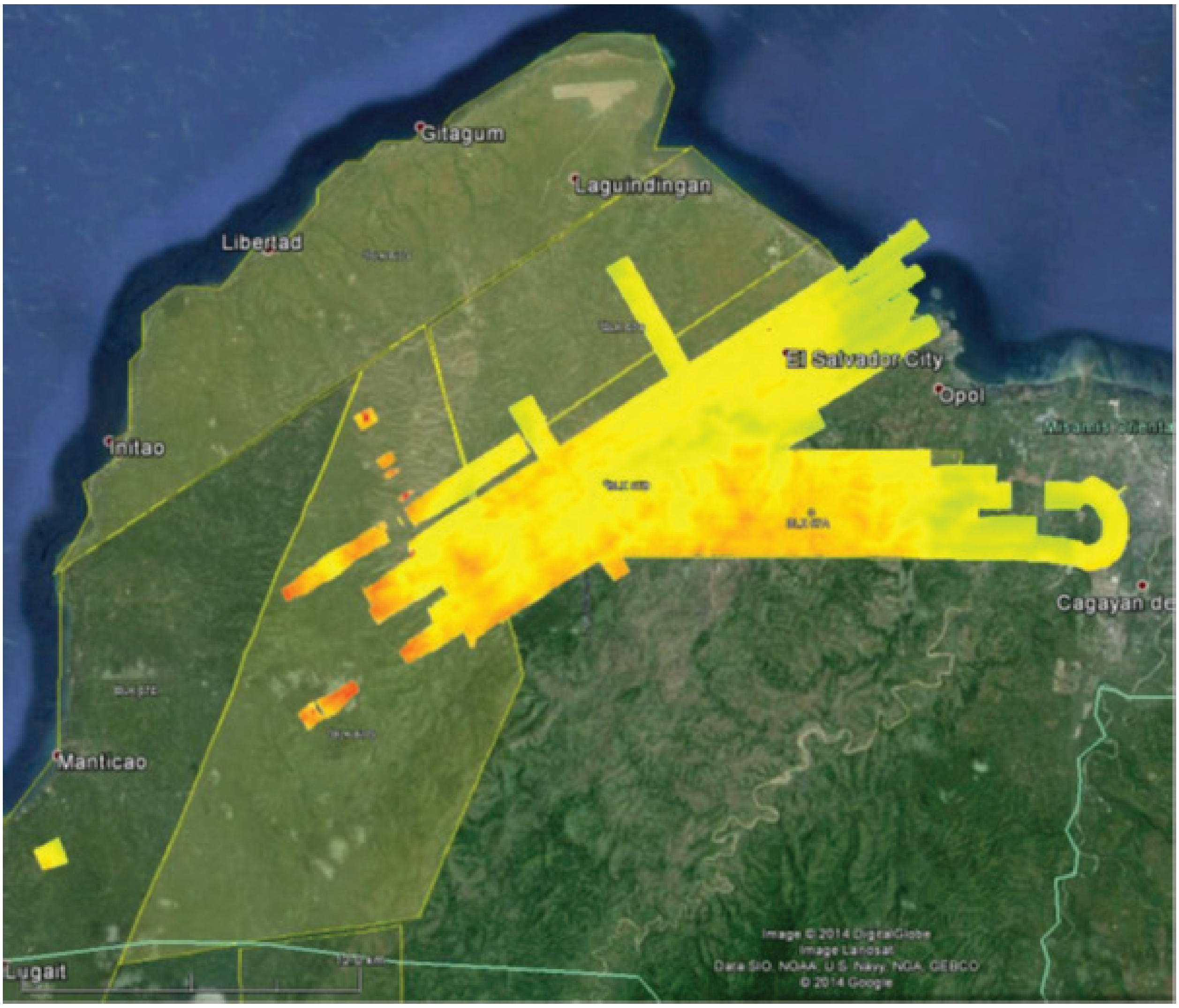


Figure A-7.3. Swath for Flight No. 1505P

Flight No. : 1625P
Area: BLK 67G
Mission Name: 1BLK67BC174A
Parameters: Altitude: 1200m;
Scan Frequency: 30Hz;
Scan Angle: 25 deg; Overlap: 30%

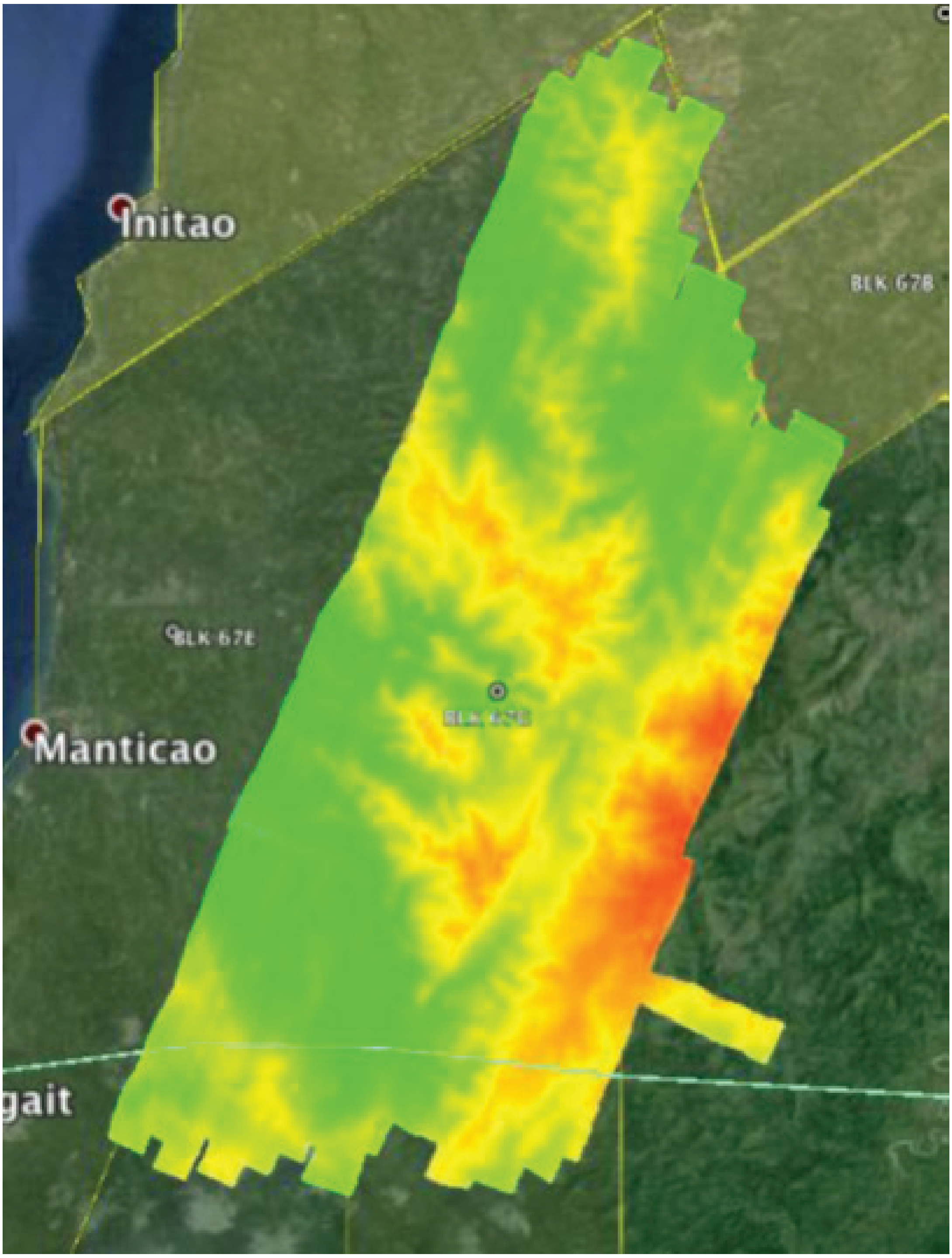


Figure A-7.4. Swath for Flight No. 1505P

Flight No. : 1641P
Area: BLK 68A
Mission Name: 1BLK68A178A
Parameters: Altitude:1200m;
Scan Frequency: 30 kHz;
Scan Angle: 25 deg Overlap: 30%

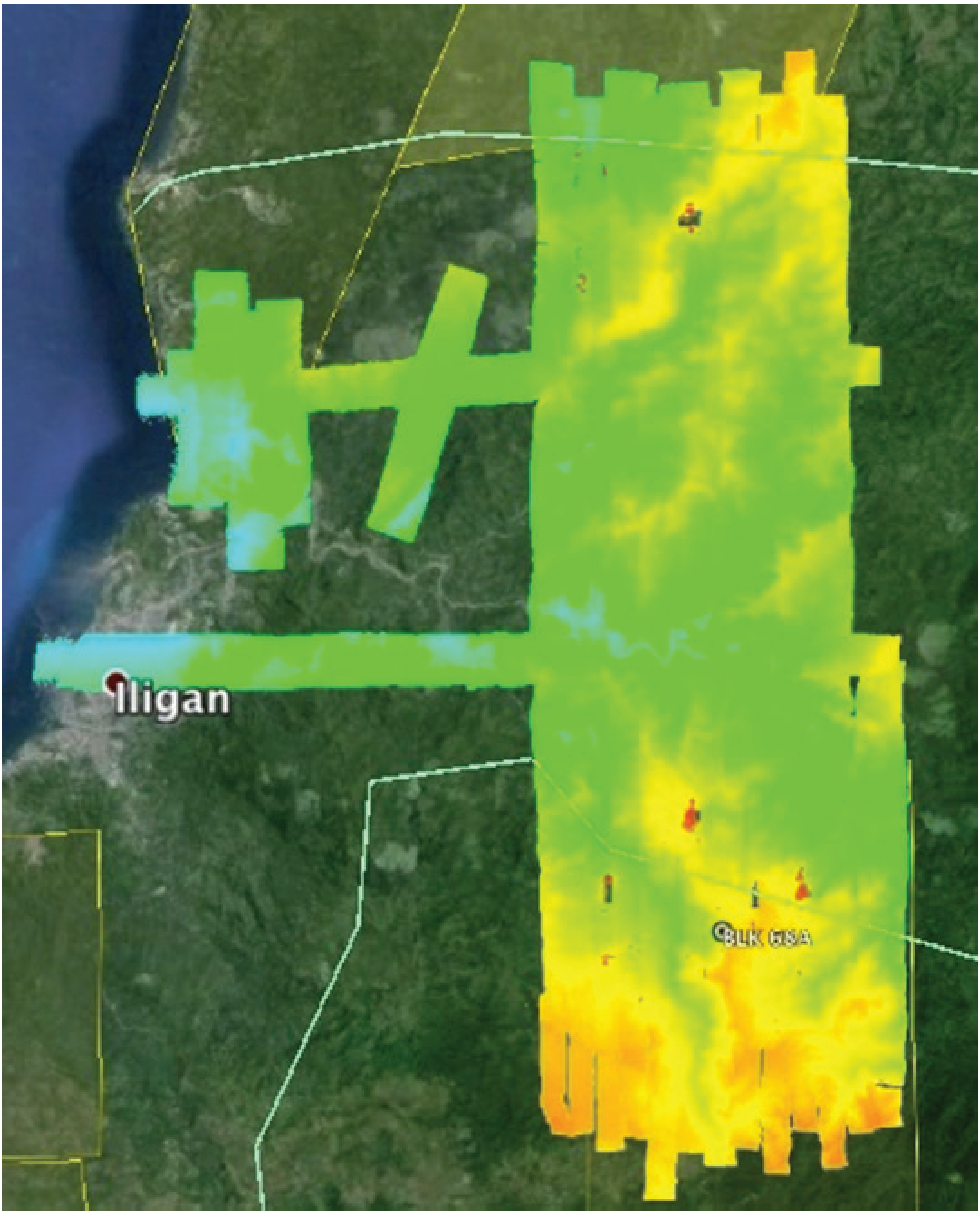


Figure A-7.5. Swath for Flight No. 1641P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk43J

Flight Area	Northern Mindanao
Mission Name	Blk67CD
Inclusive Flights	1497P ,1501P
Range data size	48.6 GB
Base data size	12.8 MB
POS	472 MB
Image	109.1 GB
Transfer date	June 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	0.9
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000329
IMU attitude correction stdev (<0.001deg)	0.003593
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	54.95%
Ave point cloud density per sq.m. (>2.0)	4.39
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	398
Maximum Height	563.64 m
Minimum Height	61.09 m
Classification (# of points)	
Ground	444,340,071
Low vegetation	418,432,205
Medium vegetation	524,039,451
High vegetation	335,166,168
Building	19,152,772
Orthophoto	YES
Processed by	Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Engr. Gladys Apat

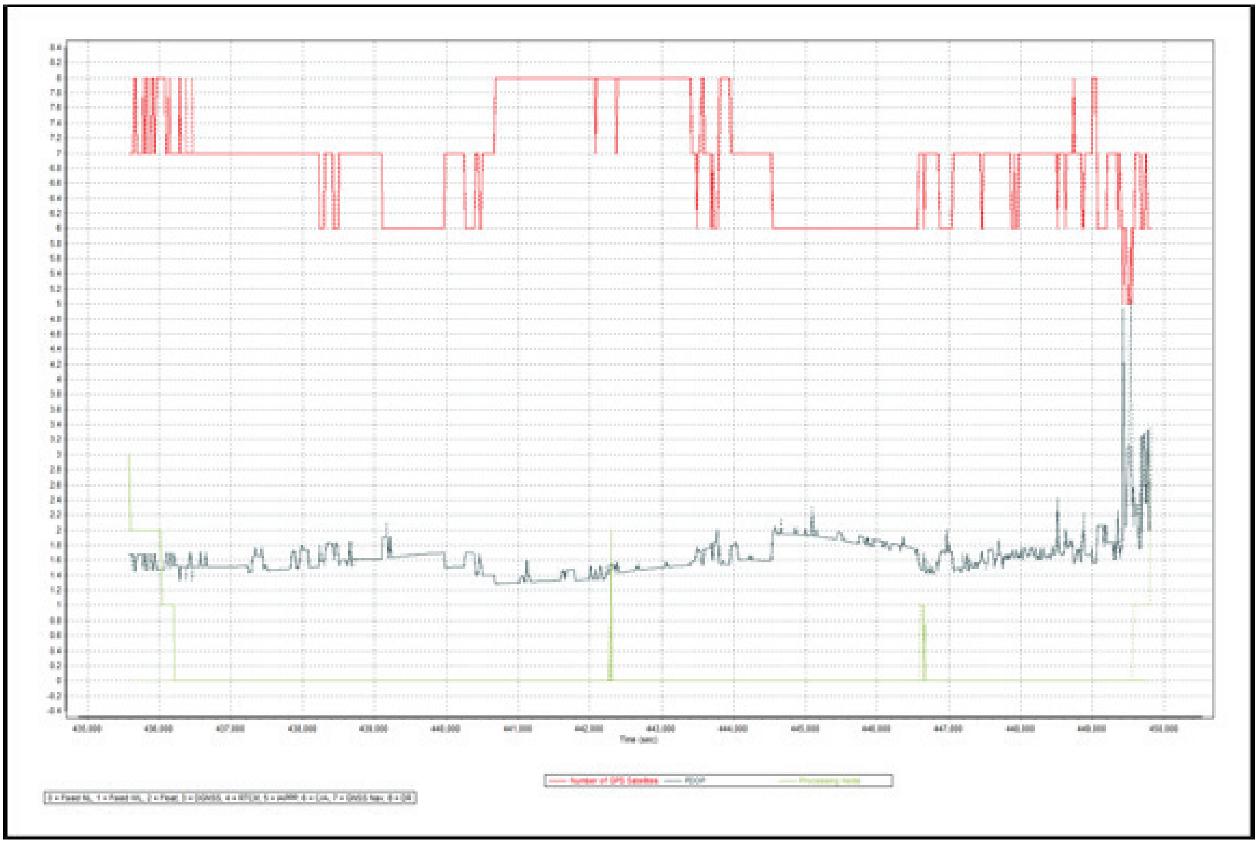


Figure A-8.1. Solution Status for Blk67CD.

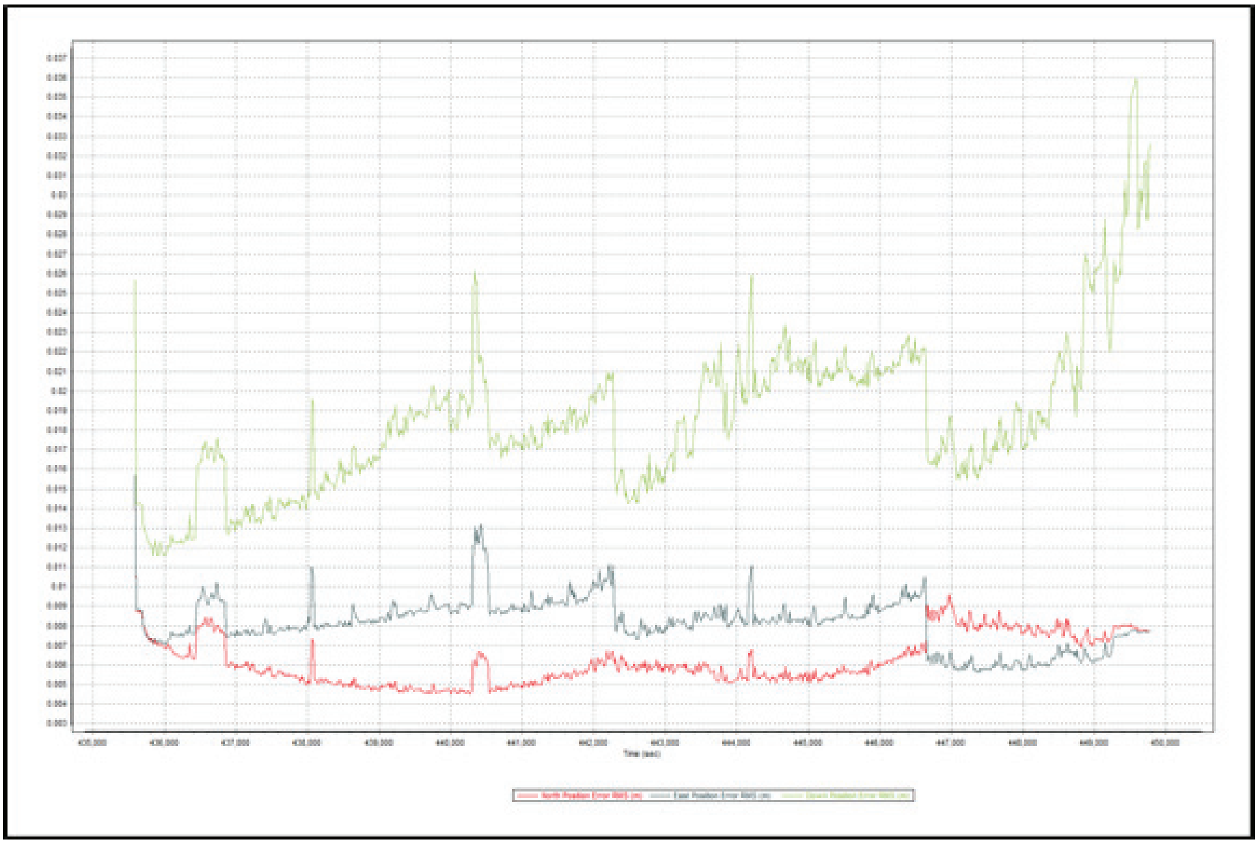


Figure A-8.2 . Smoothed Performance Metric Parameters for Blk67CD.

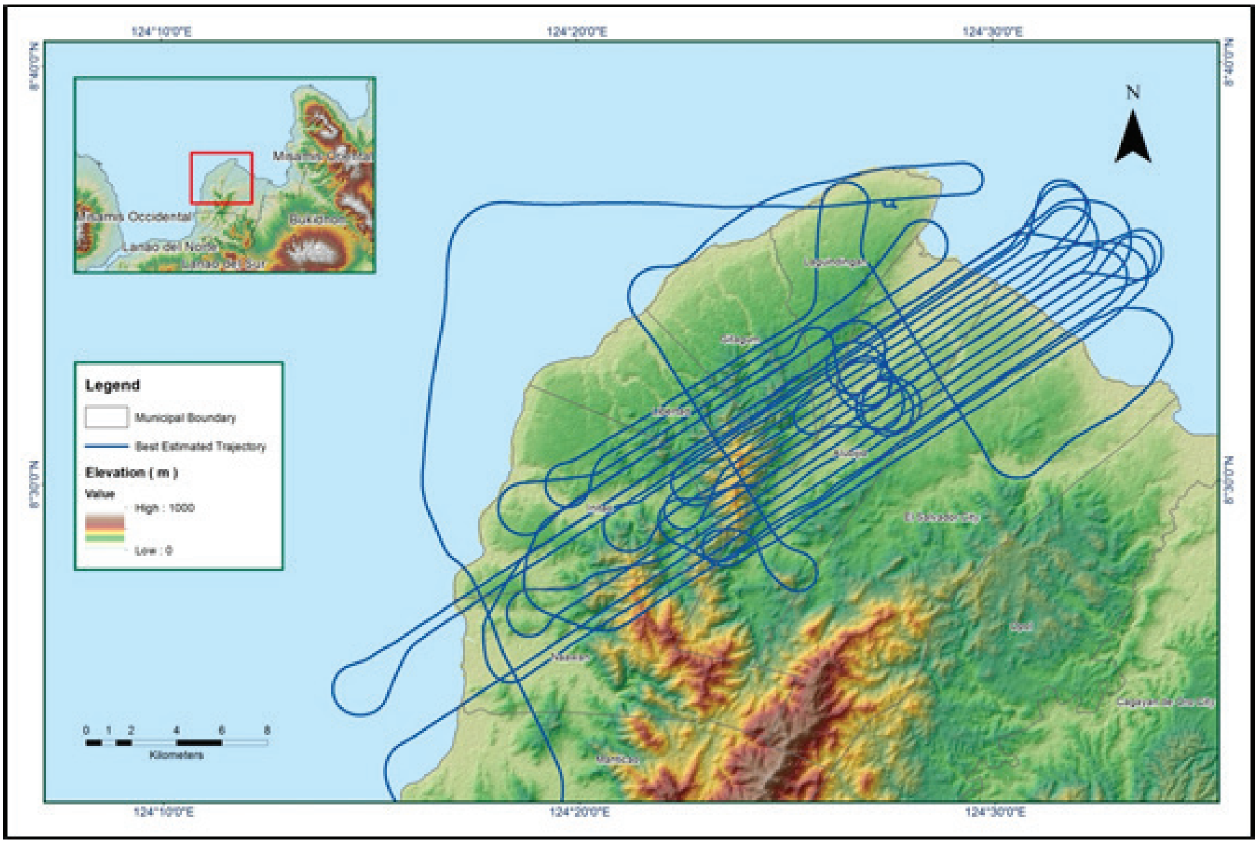


Figure A-8.3. Best Estimated Trajectory for Blk67CD.

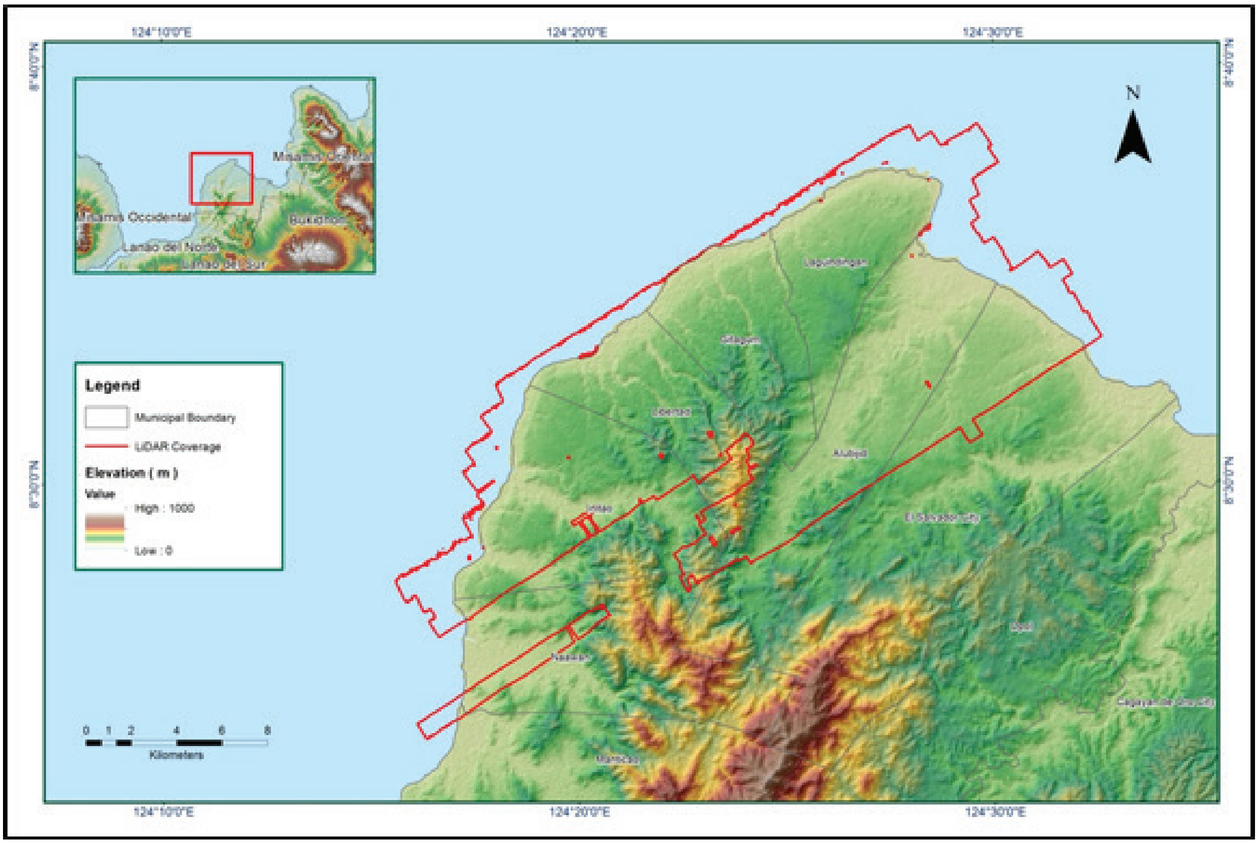


Figure A- 8.4. Coverage of LiDAR data for Blk67CD.

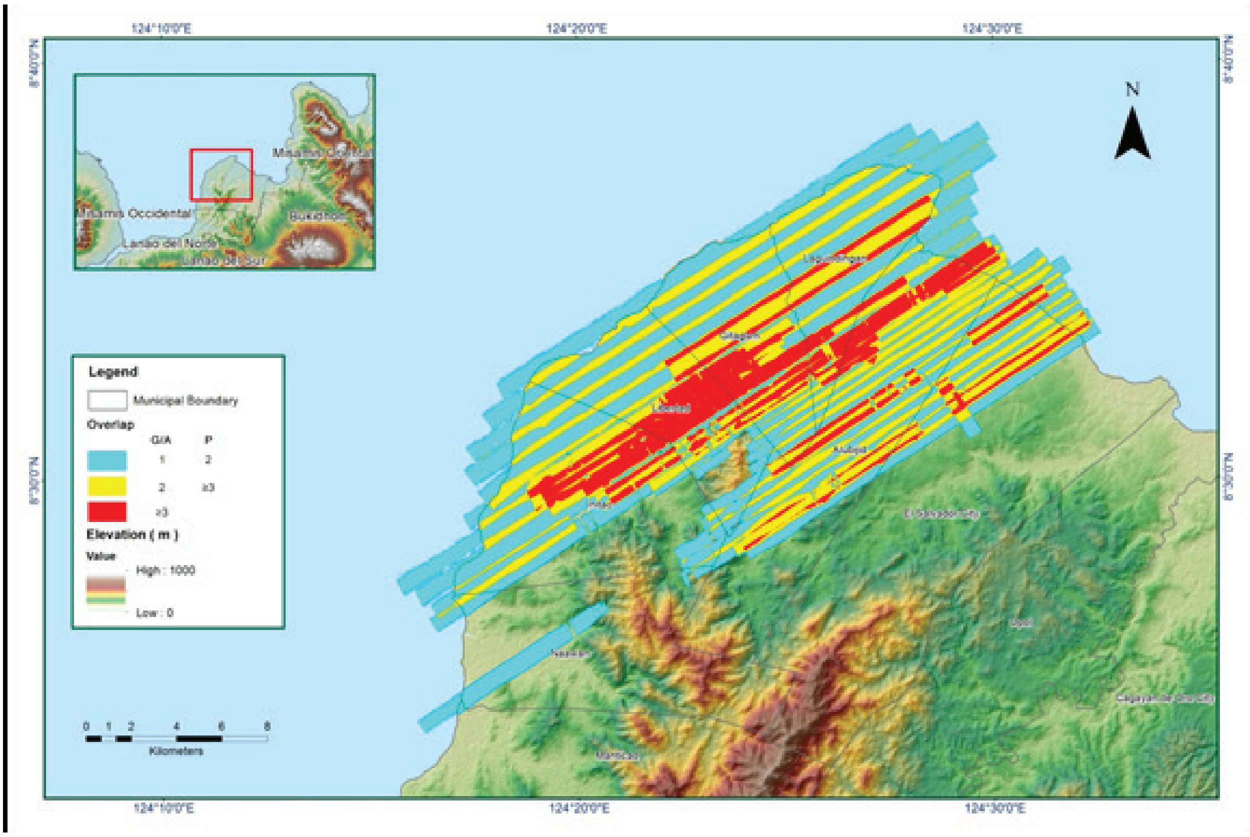


Figure A- 8.5 . Image of data overlap for Blk67CD.

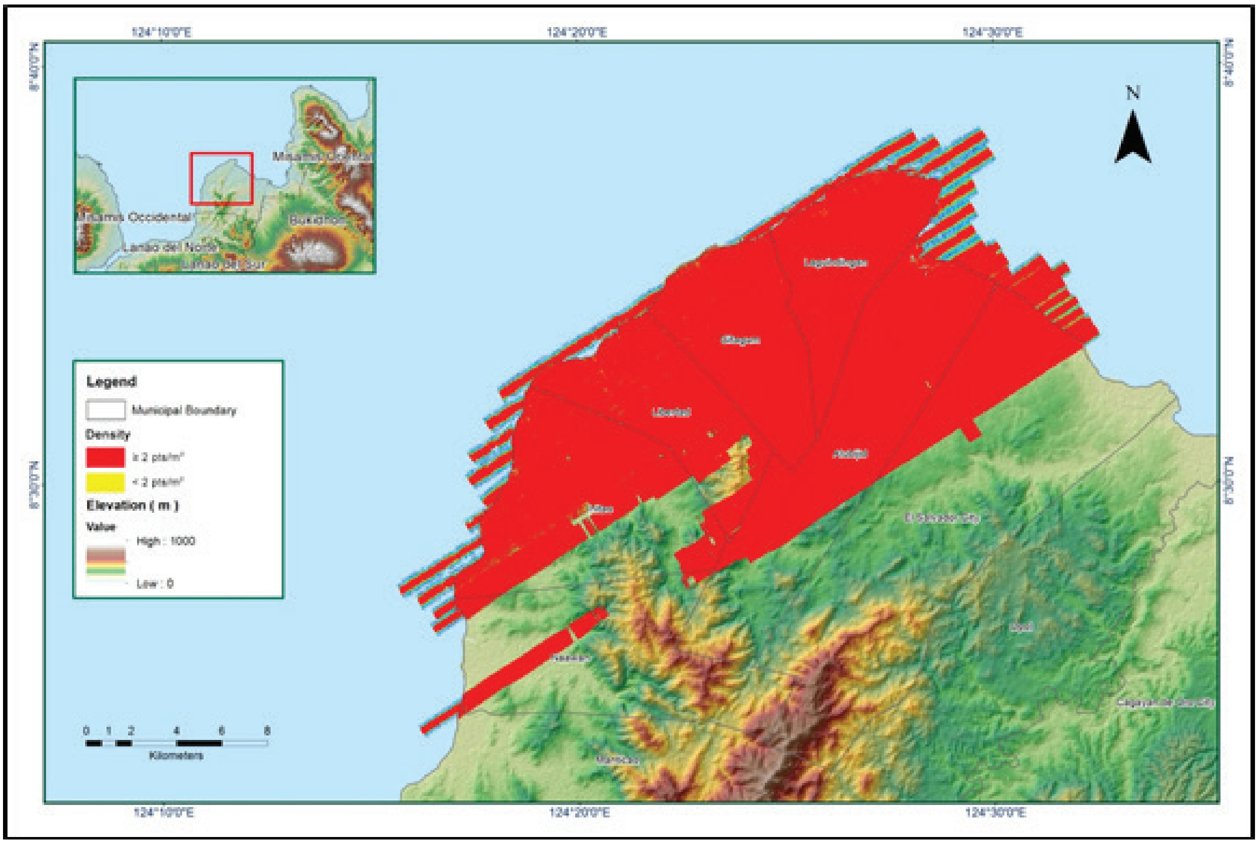


Figure A-8.6 . Density map of merged LiDAR data for Blk67CD.

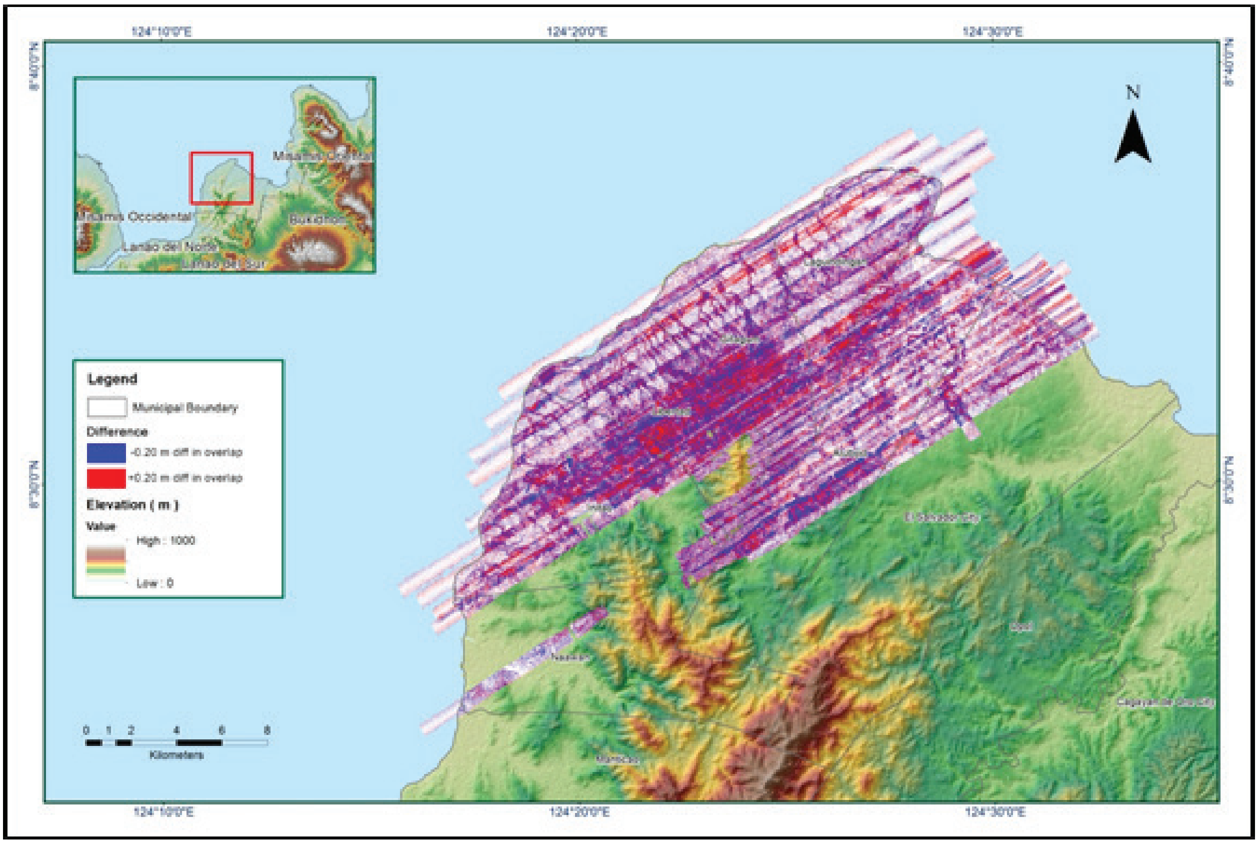


Figure A-8.7 . Elevation difference between flight lines for Blk67CD.

Table A-8.2. Mission Summary Report for Mission Blk67AB

Flight Area	Northern Mindanao
Mission Name	Blk67AB
Inclusive Flights	1505P
Range data size	21.8 GB
Base data size	7.68 MB
POS	212 MB
Image	46.7 GB
Transfer date	June 10, 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)	1.0
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.0
Boresight correction stdev (<0.001deg)	0.000165
IMU attitude correction stdev (<0.001deg)	0.000472
GPS position stdev (<0.01m)	0.0065
Minimum % overlap (>25)	37.51%
Ave point cloud density per sq.m. (>2.0)	4.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	217
Maximum Height	645.43 m
Minimum Height	67.41 m
Classification (# of points)	
Ground	216,730,281
Low vegetation	173,975,518
Medium vegetation	246,142,374
High vegetation	166,562,458
Building	9,373,891
Orthophoto	YES
Processed by	Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. Gladys Apat

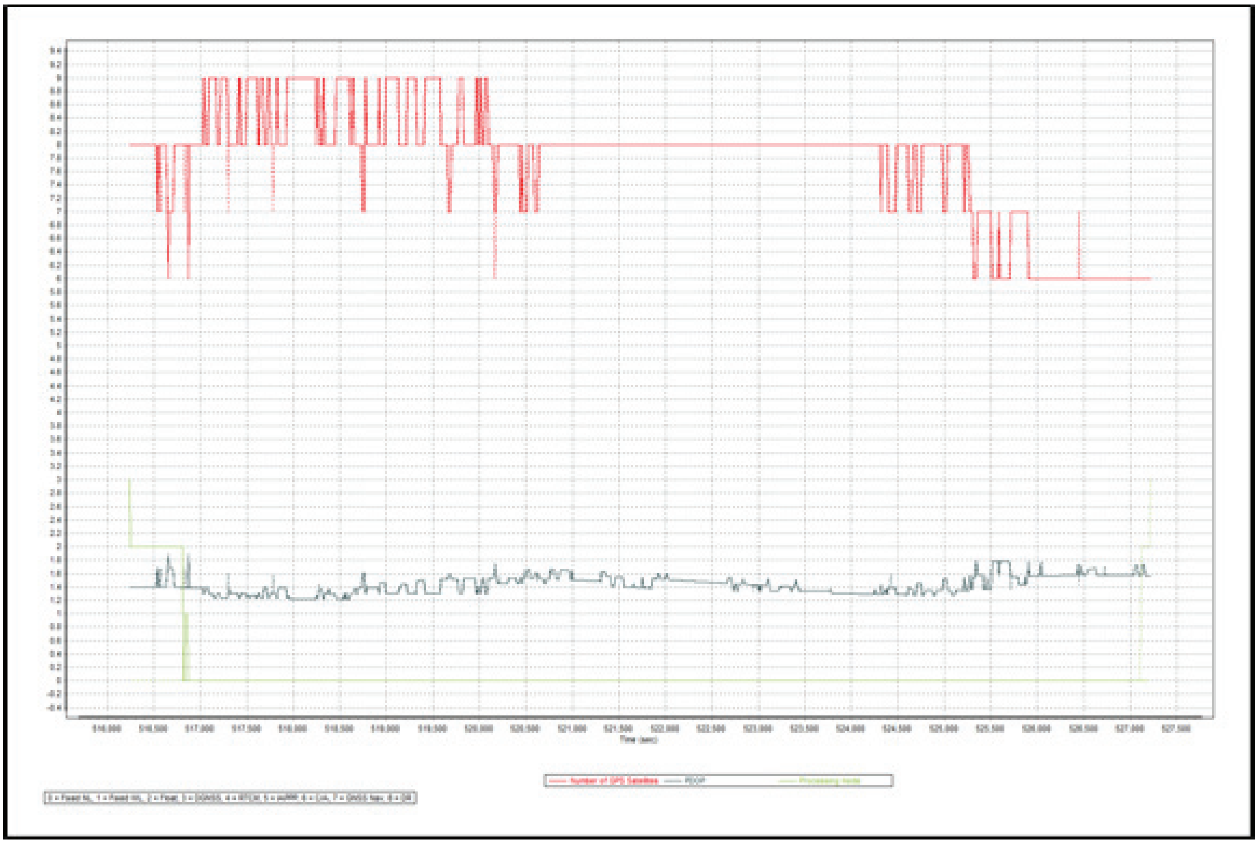


Figure A- 8.9 . Solution Status for Blk67AB.

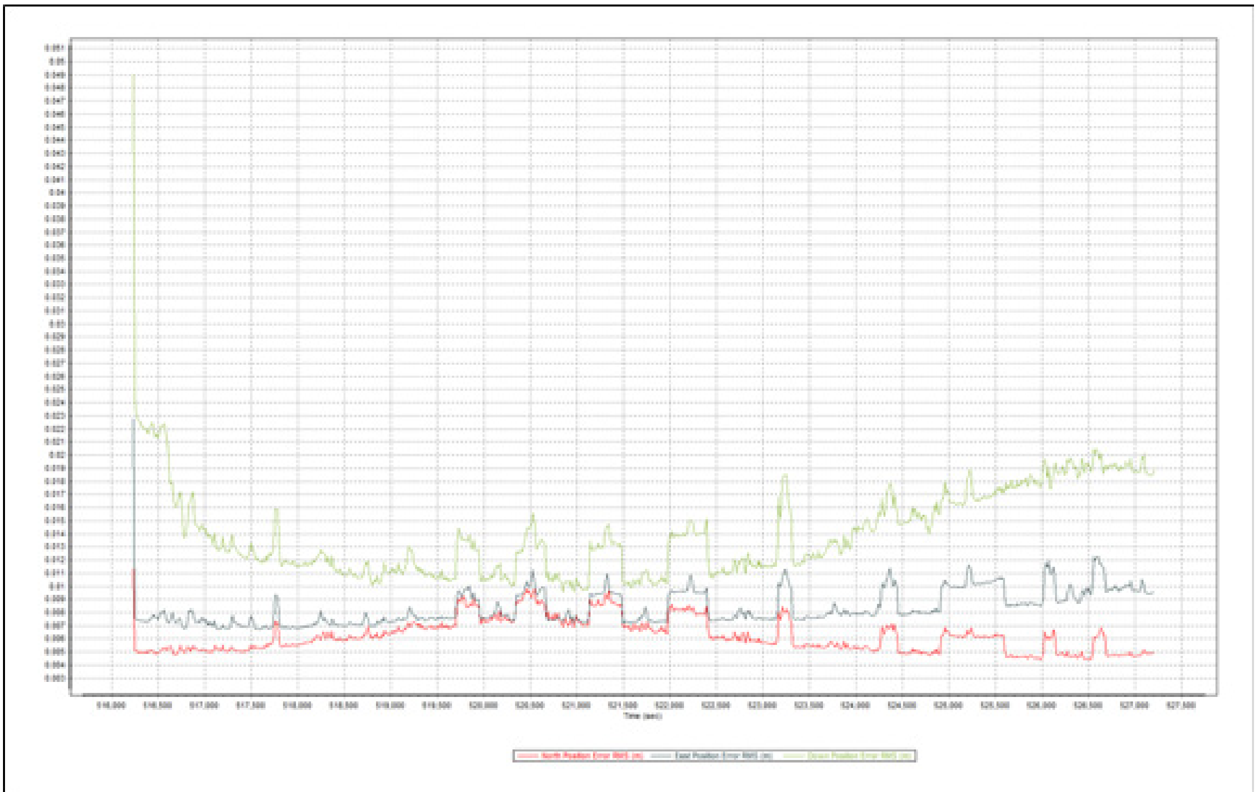


Figure A- 8.10. Smoothed Performance Metric Parameters for Blk67AB.

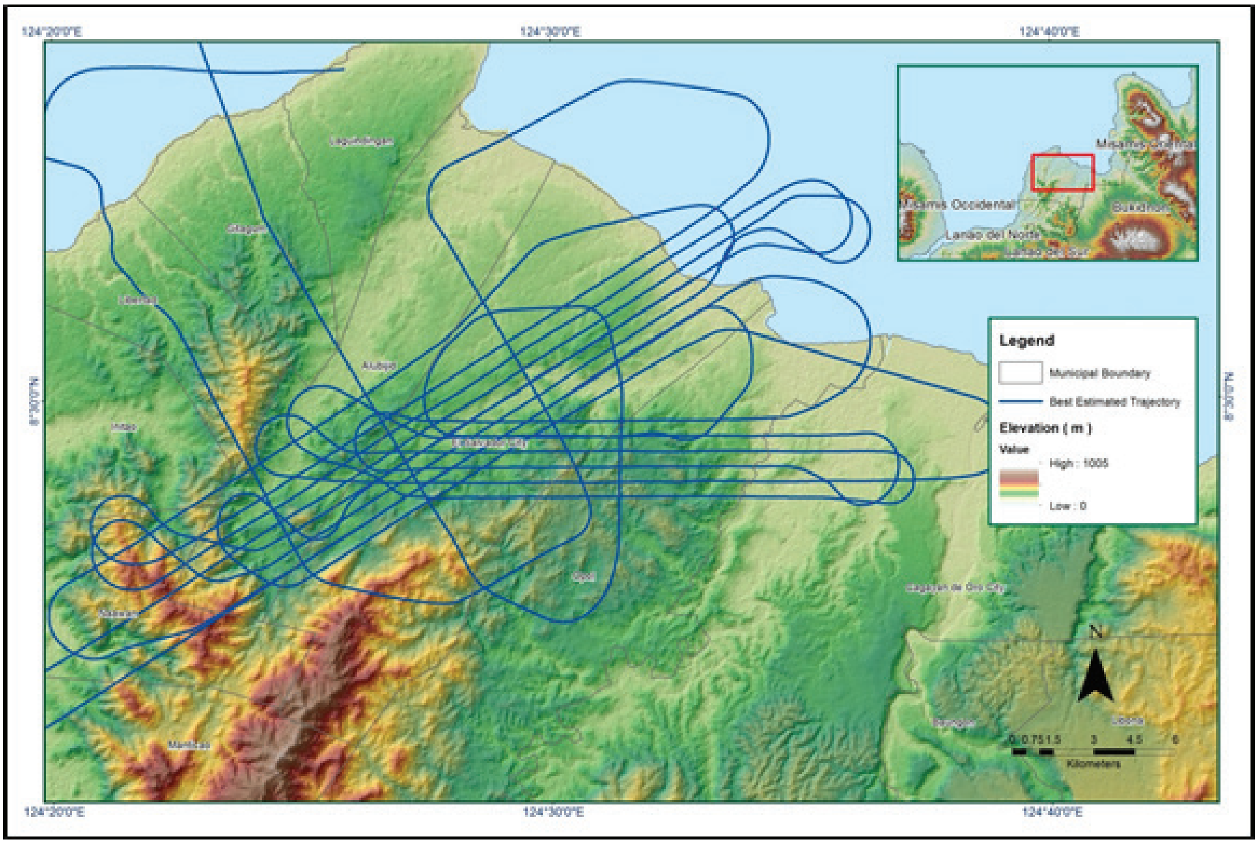


Figure A- 8.12 . Best Estimated Trajectory for Blk67AB.

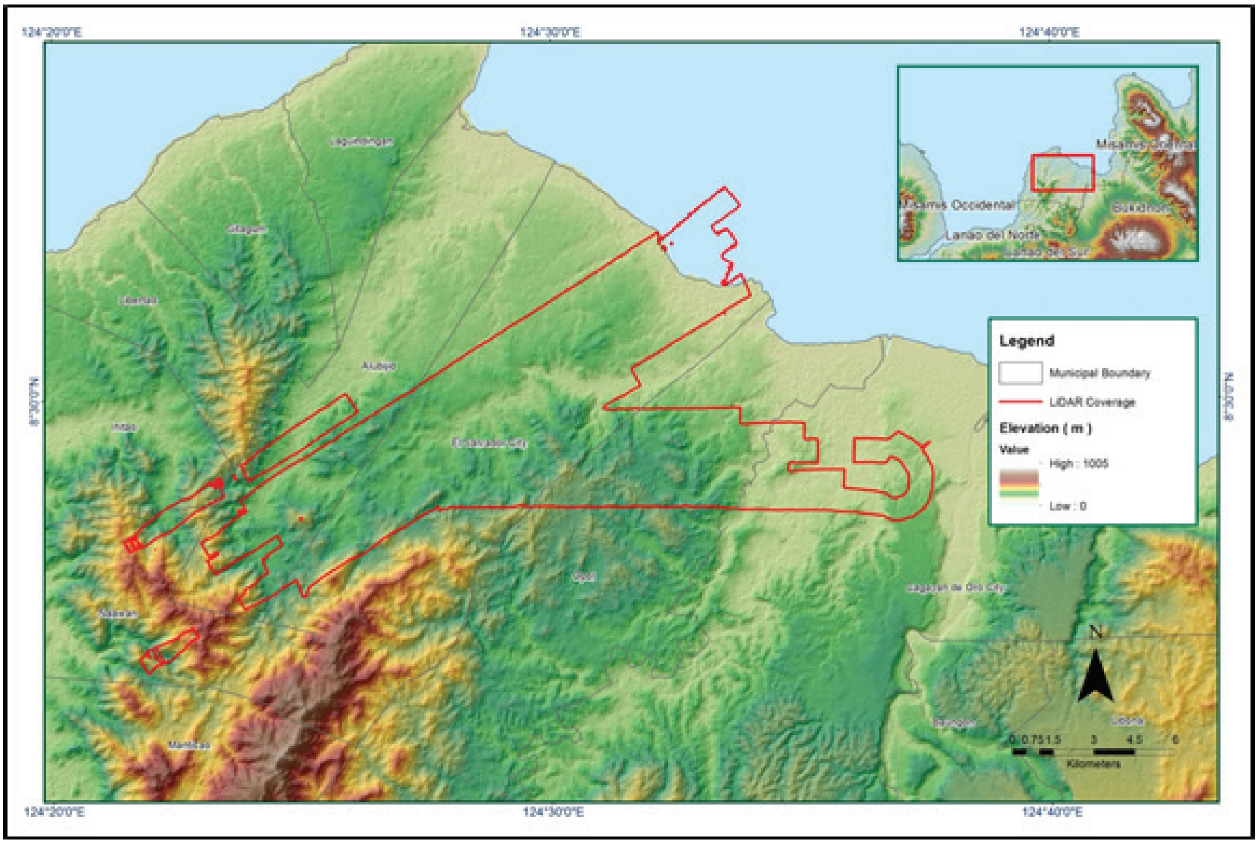


Figure A -8.13 . Coverage of LiDAR data for Blk67AB.

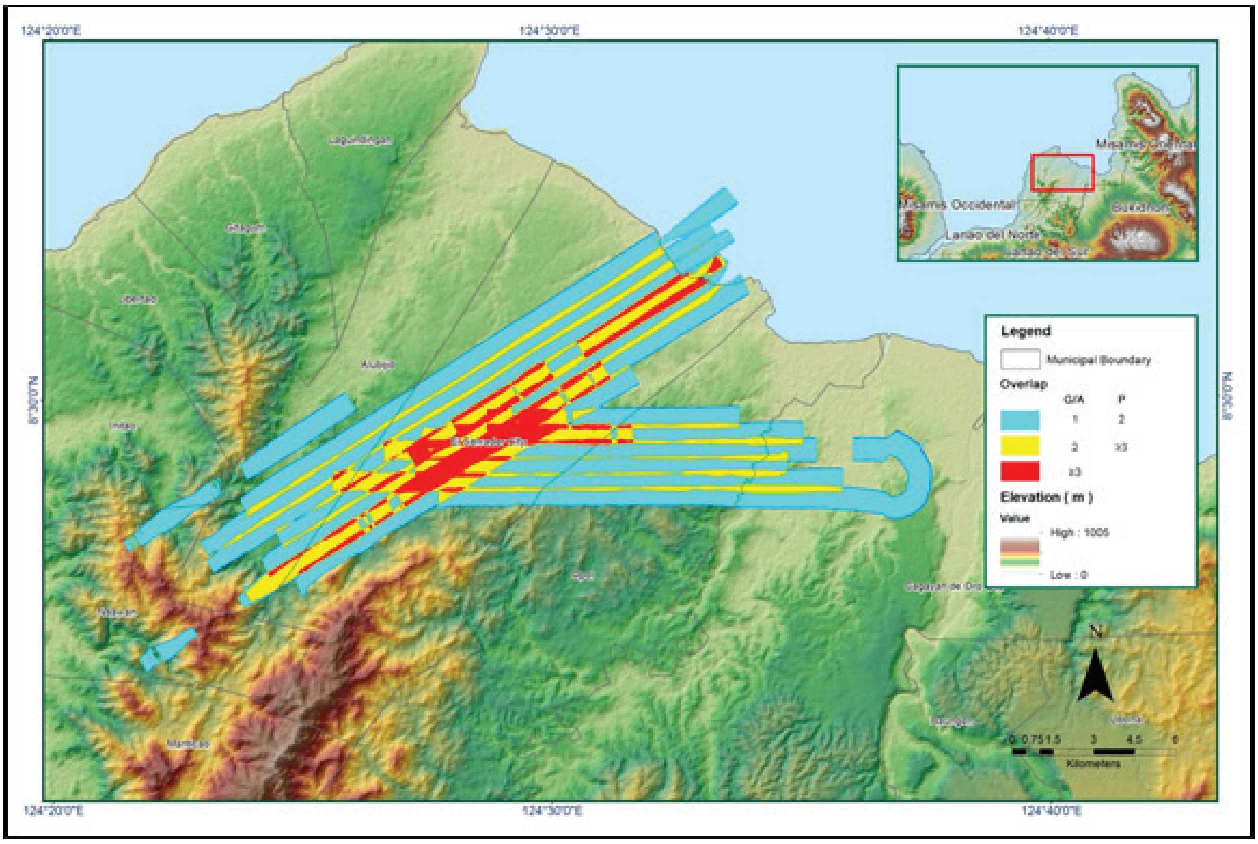


Figure A- 8.14 . Image of data overlap for Blk67AB.

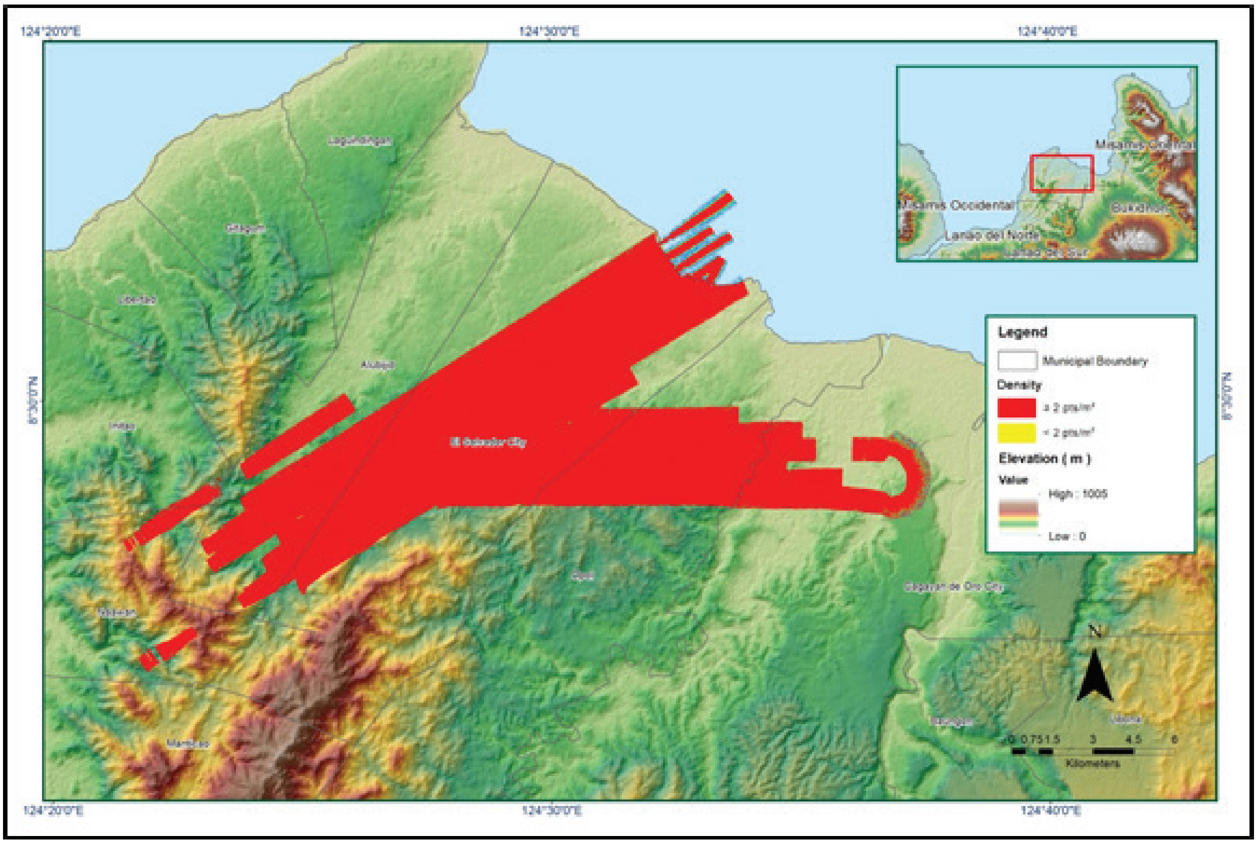


Figure A- 8.15. Density map of merged LiDAR data for Blk67AB.

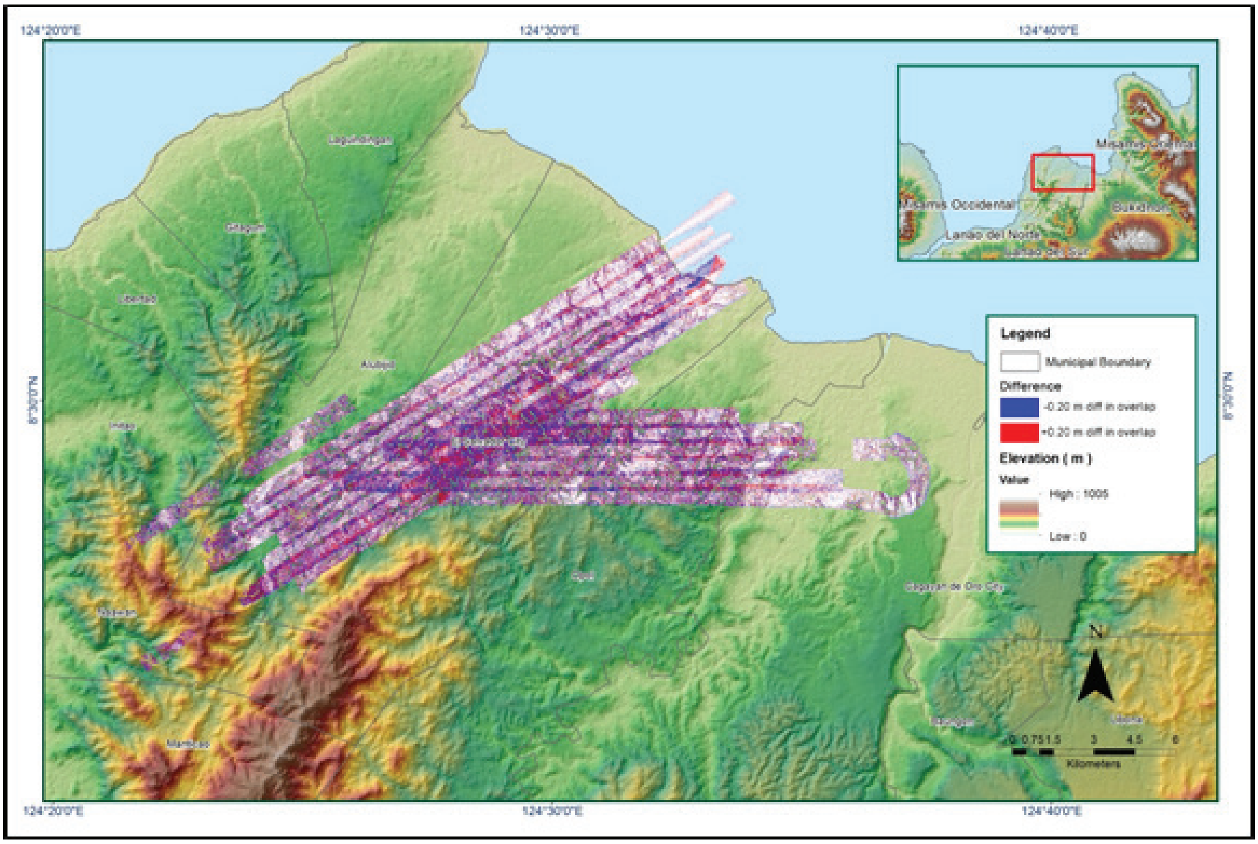


Figure A-8.17. Elevation difference between flight lines for Blk67AB.

Table A-8.3. Mission Summary Report for Mission Blk67G

Flight Area	Northern Mindanao
Mission Name	Blk67G
Inclusive Flights	1625P
Range data size	29.4 GB
Base data size	4.97 MB
POS	258 MB
Image	60.3 GB
Transfer date	August 01, 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)	1.5
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000157
IMU attitude correction stdev (<0.001deg)	0.000735
GPS position stdev (<0.01m)	0.0062
Minimum % overlap (>25)	56.61%
Ave point cloud density per sq.m. (>2.0)	5.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	232
Maximum Height	1067 m
Minimum Height	89.42 m
Classification (# of points)	
Ground	178,631,315
Low vegetation	159,869,678
Medium vegetation	466,647,080
High vegetation	400,753,213
Building	11,454,907
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Mark Joshua Salvacion, Engr. Gladys Apat

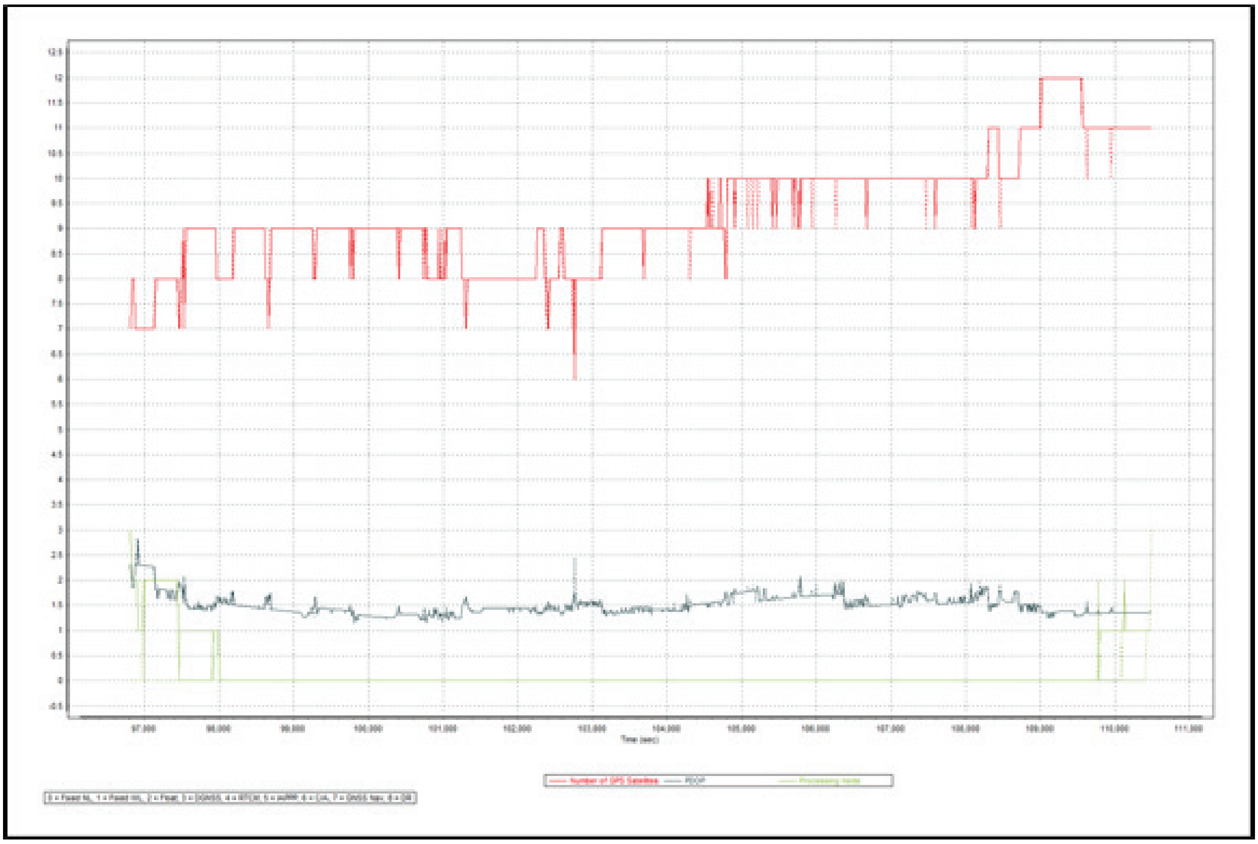


Figure A- 8.18. Solution Status for Blk67G.

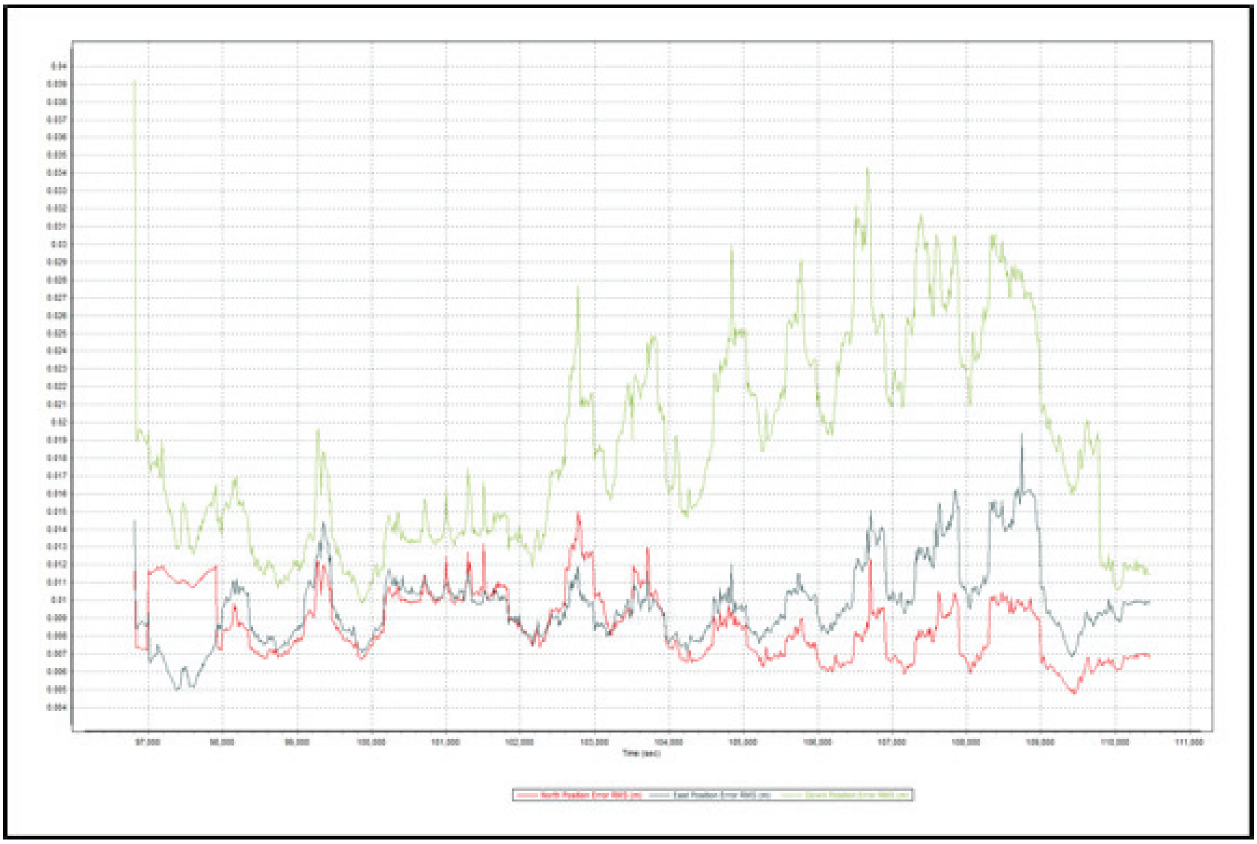


Figure A- 8.19. Smoothed Performance Metric Parameters for Blk67G.

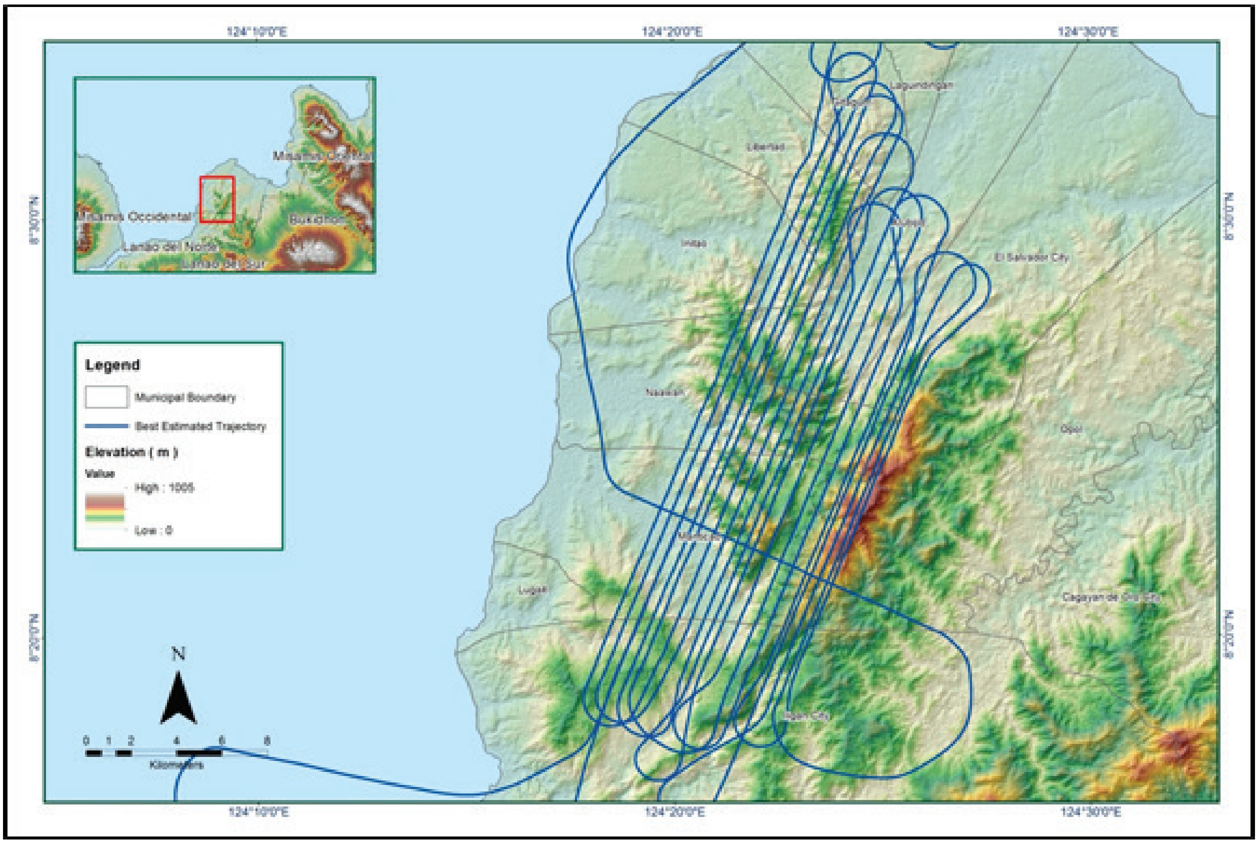


Figure A- 8.20 . Best Estimated Trajectory for Blk67G.

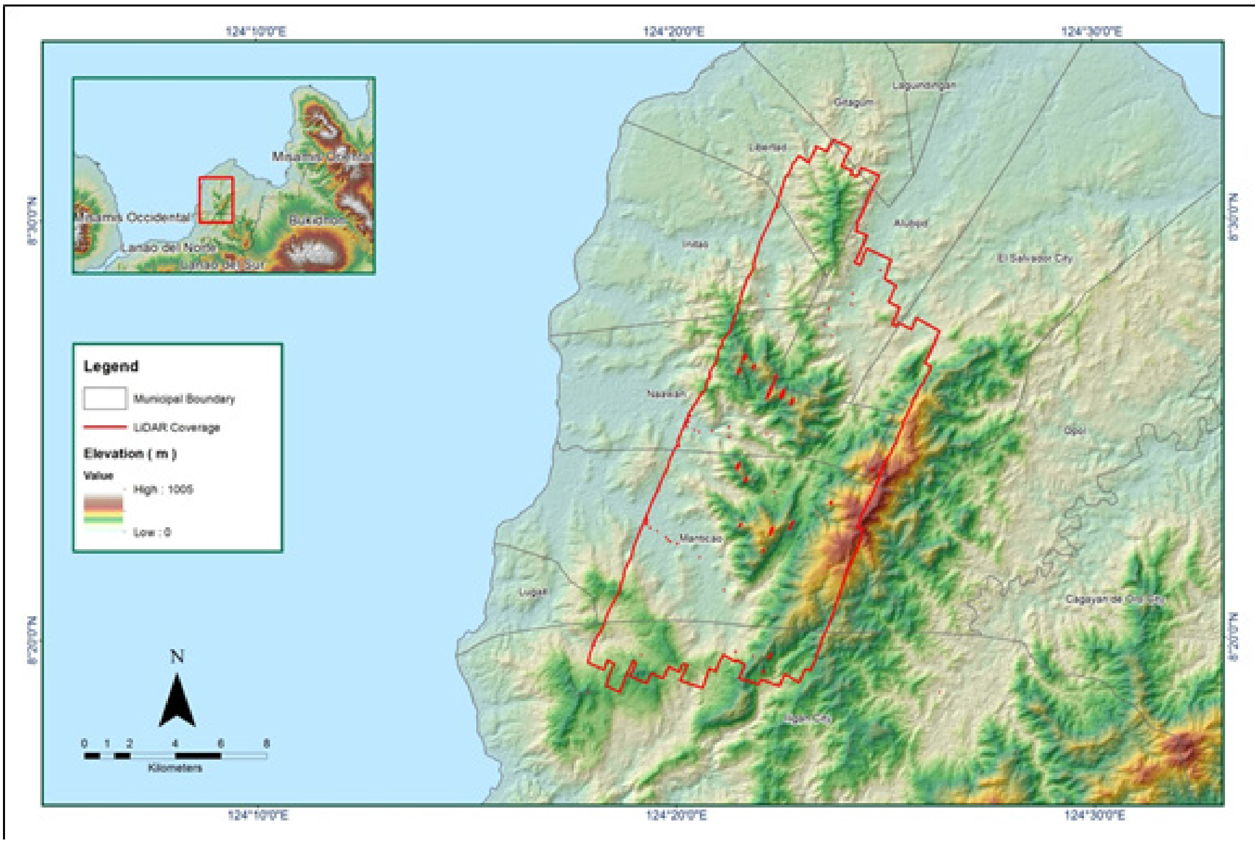


Figure A- 8.21. Coverage of LiDAR data for Blk67G.

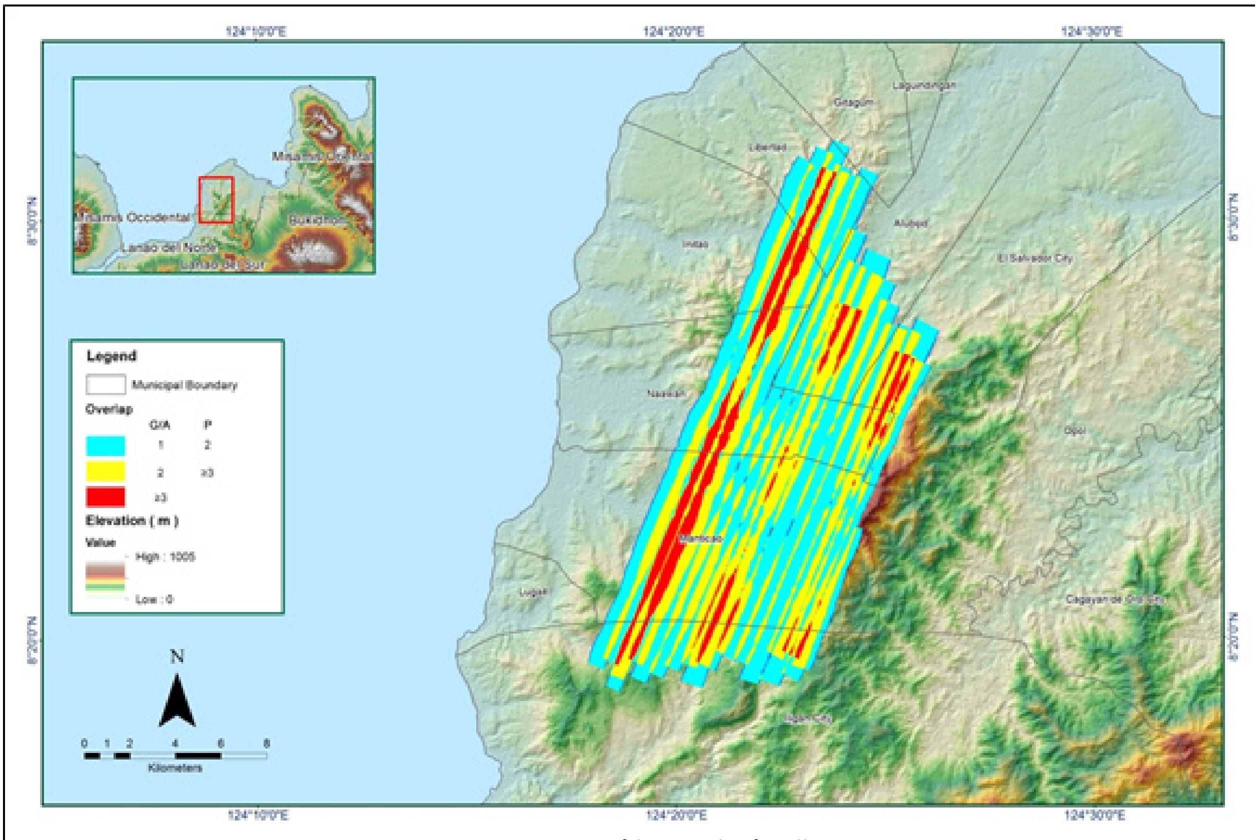


Figure A- 8.23 . Image of data overlap for Blk67G.

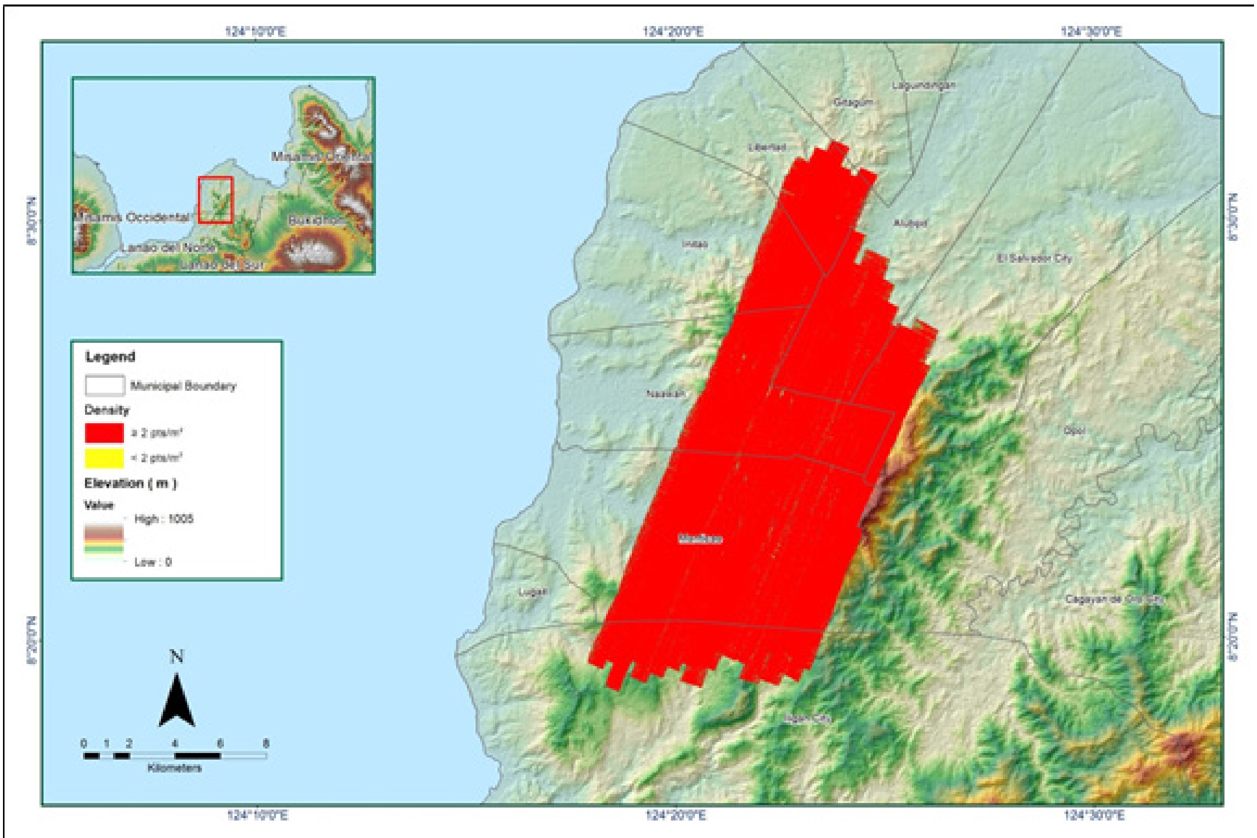


Figure A- 8.24 . Density map of merged LiDAR data for Blk67G.

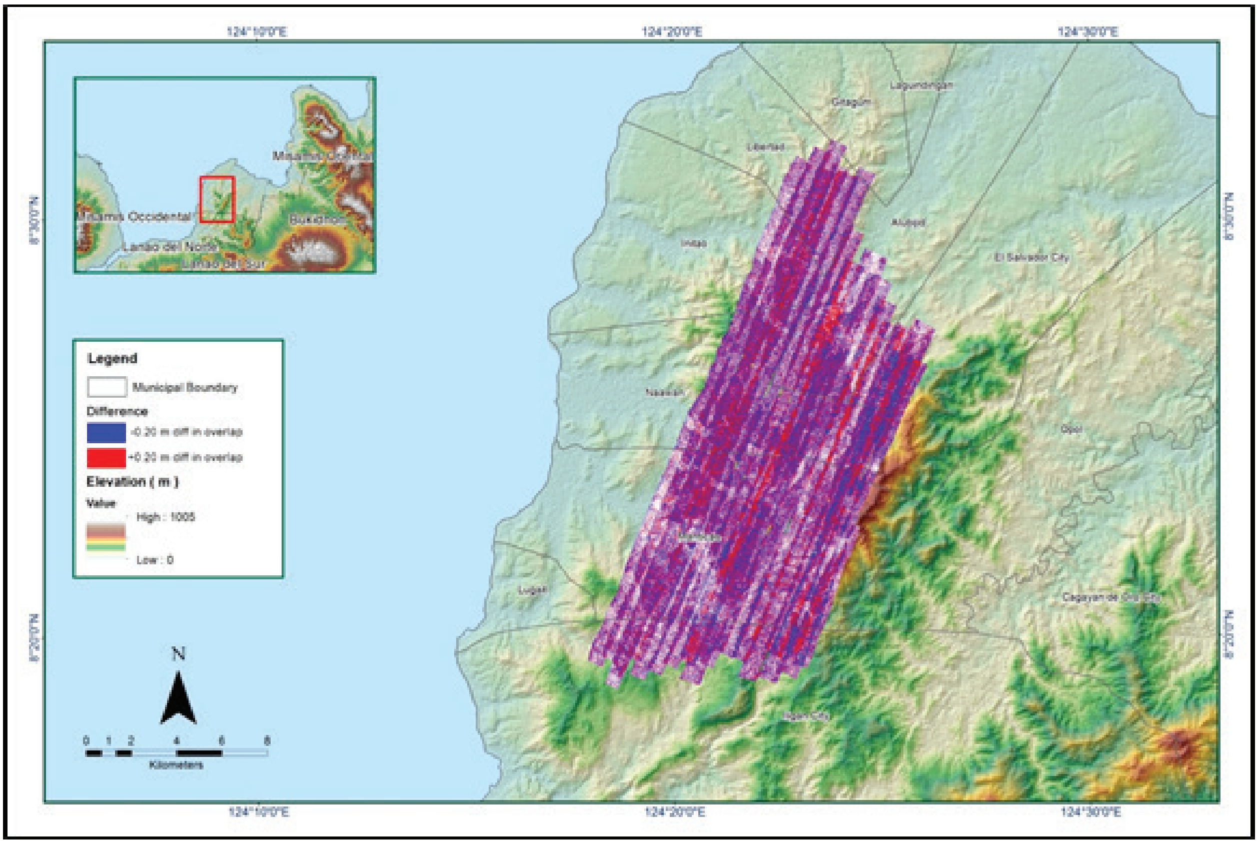


Figure A- 8.24 . Elevation difference between flight lines for Blk67G.

Table A-8.4. Mission Summary Report for Mission Blk43H_Additional

Flight Area	Northern Mindanao
Mission Name	Blk67E
Inclusive Flights	1545P
Mission Name	1BLK71C154A
Range data size	40.1 GB
POS	253 MB
Image	69.7 GB
Transfer date	June 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	8.0
Boresight correction stdev (<0.001deg)	0.000548
IMU attitude correction stdev (<0.001deg)	0.001101
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	57.82%
Ave point cloud density per sq.m. (>2.0)	9.22
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	182
Maximum Height	589.93 m
Minimum Height	62.29 m
Classification (# of points)	
Ground	159,665,332
Low vegetation	117,352,334
Medium vegetation	207,785,534
High vegetation	244,112,573
Building	8,516,950
Orthophoto	Yes

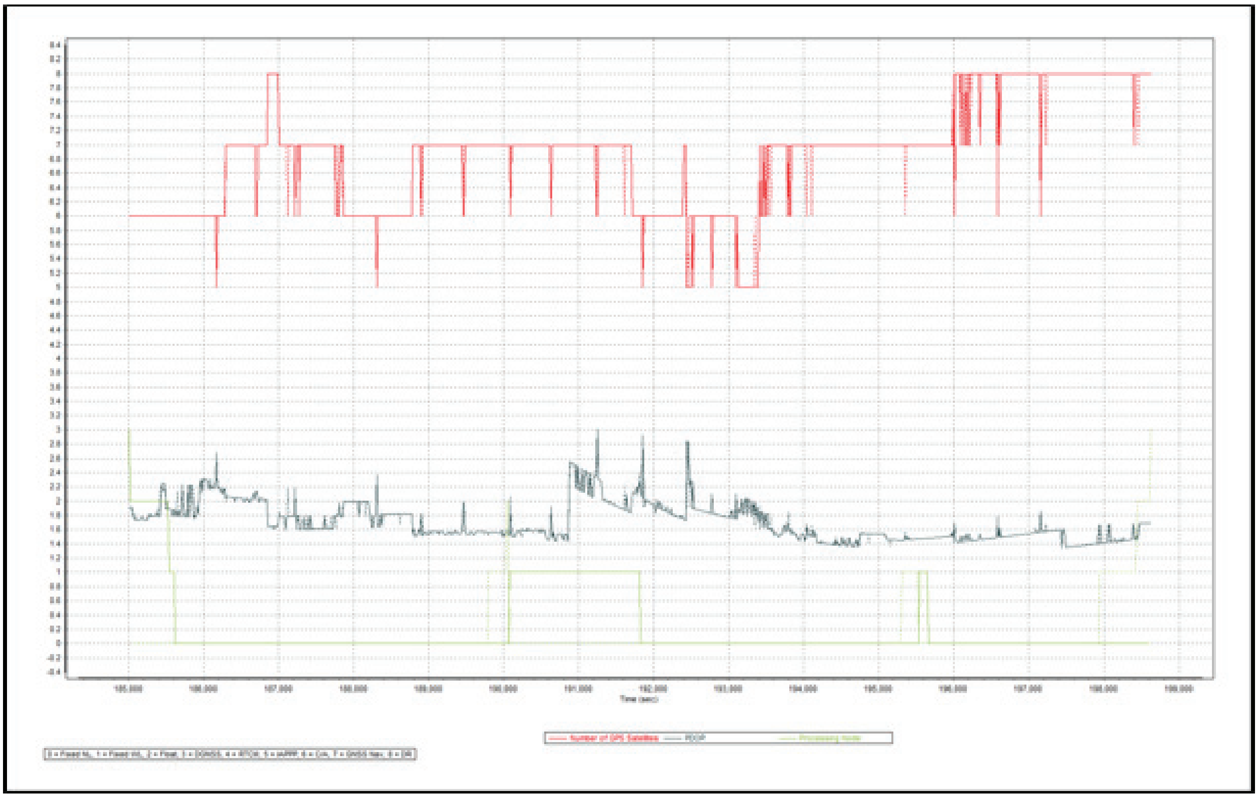


Figure A-8.25. Solution Status for Blk67E.

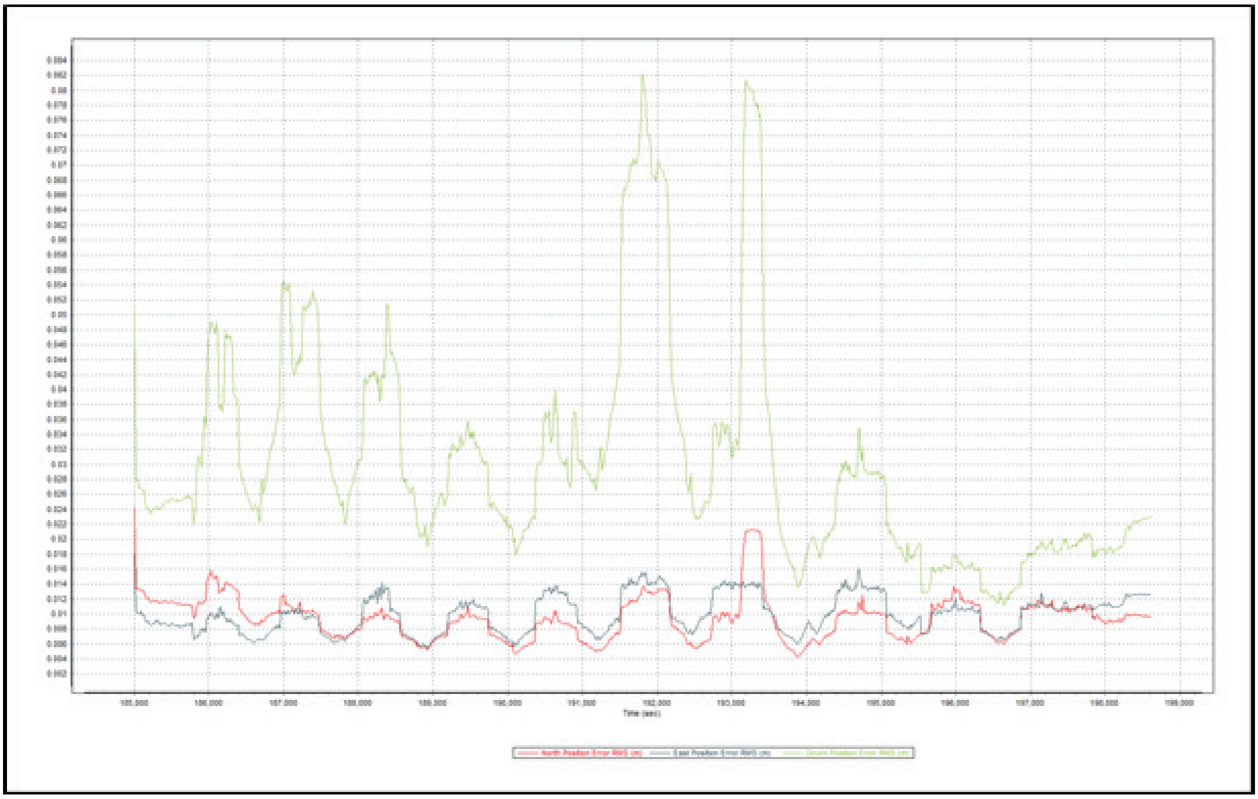


Figure A-8.26. Smoothed Performance Metric Parameters for Blk67E.

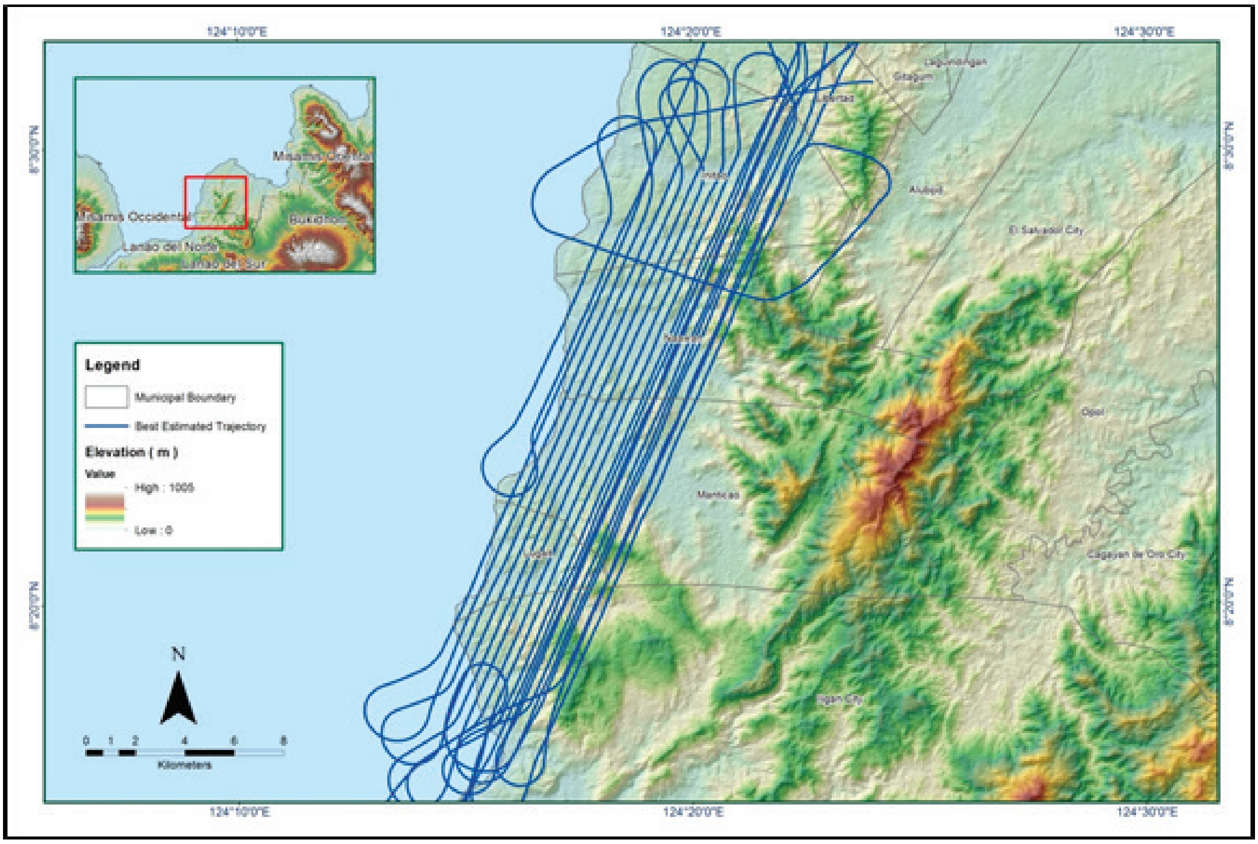


Figure A-5.27. Best Estimated Trajectory for 3 Blk67E.

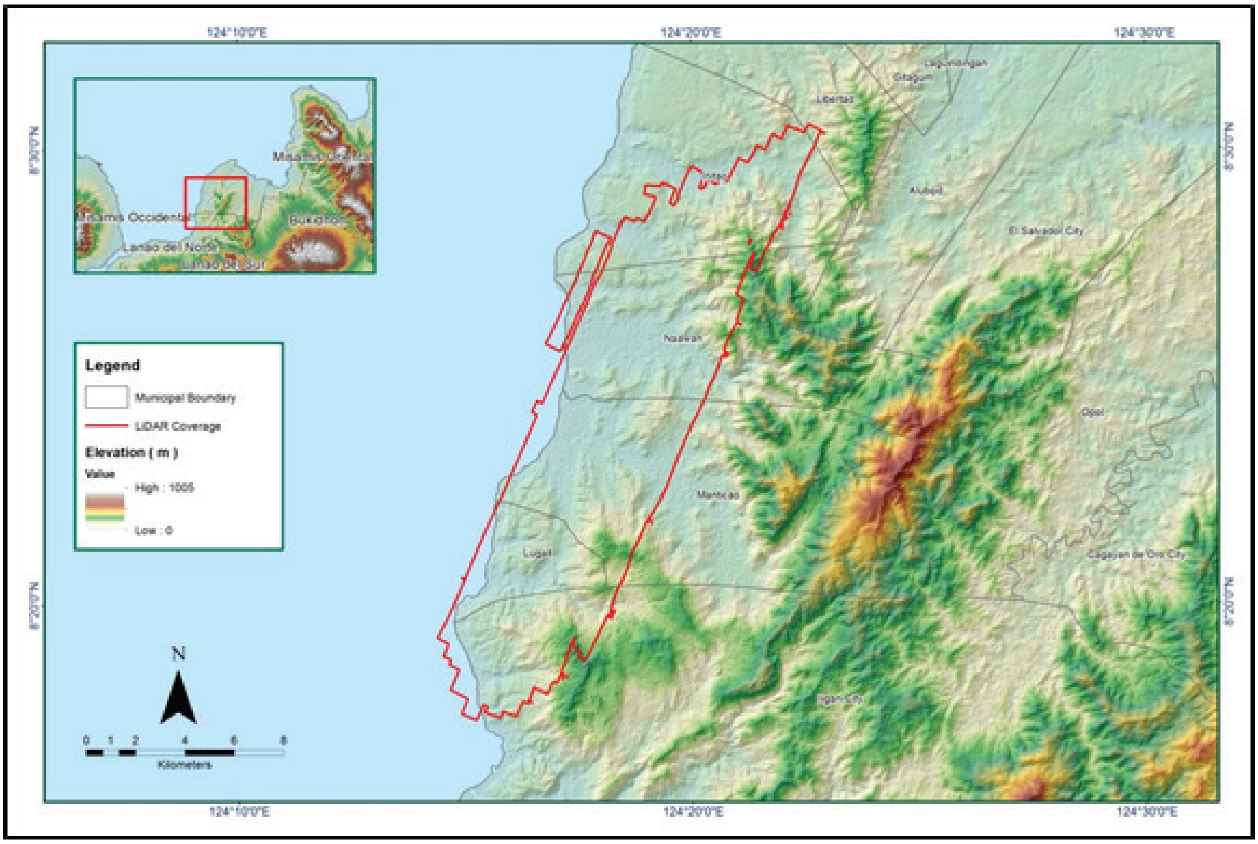


Figure A-8.28 . Coverage of LiDAR data for Blk67E.

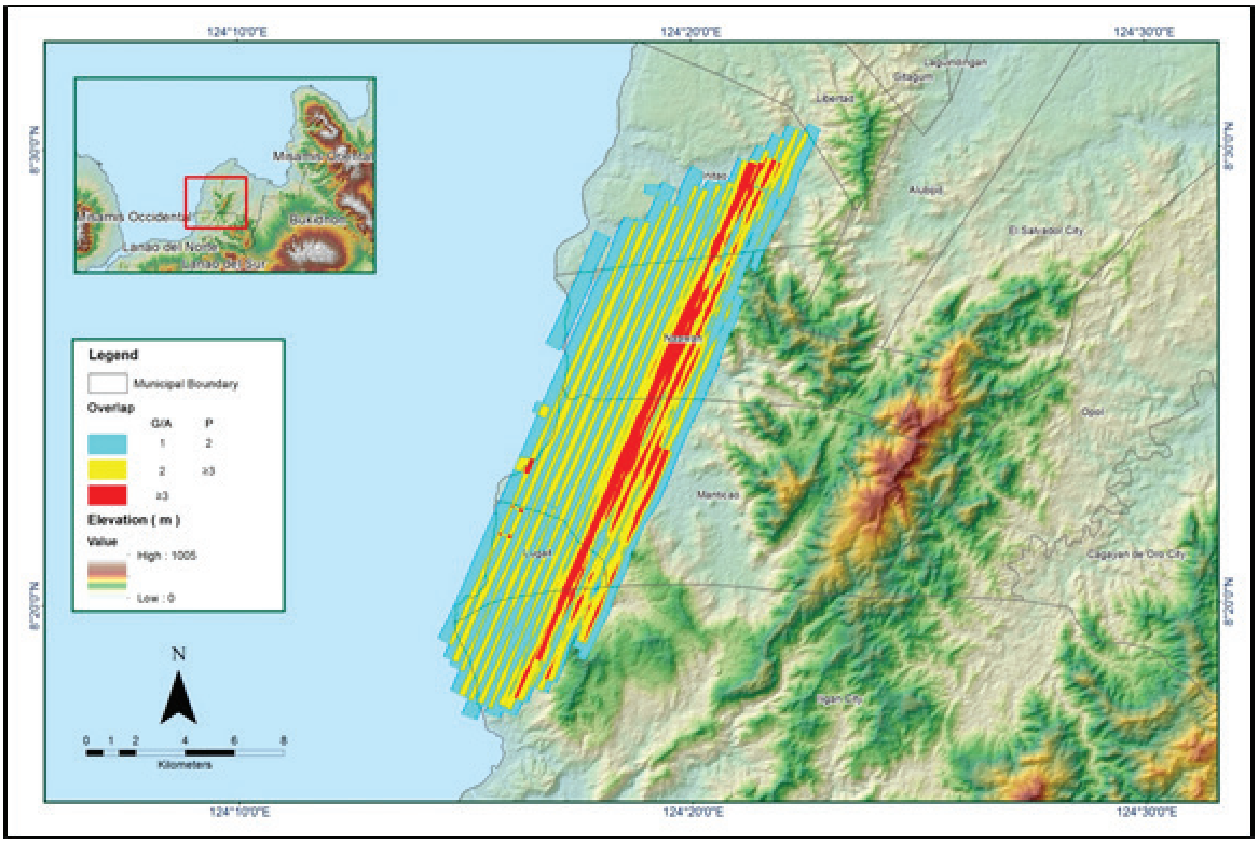


Figure A-8.29 . Image of data overlap for Blk67E.

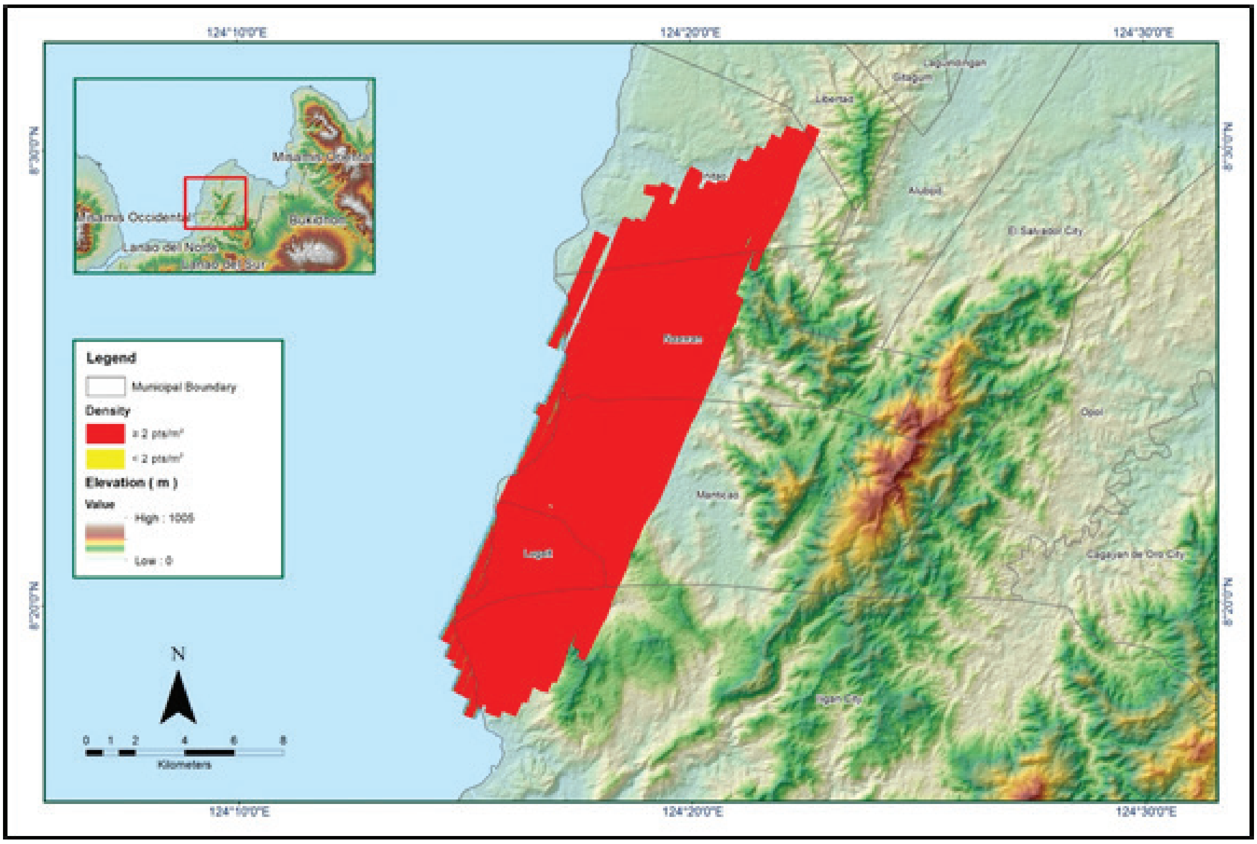


Figure A-8.30. Density map of merged LiDAR data for Blk67E.

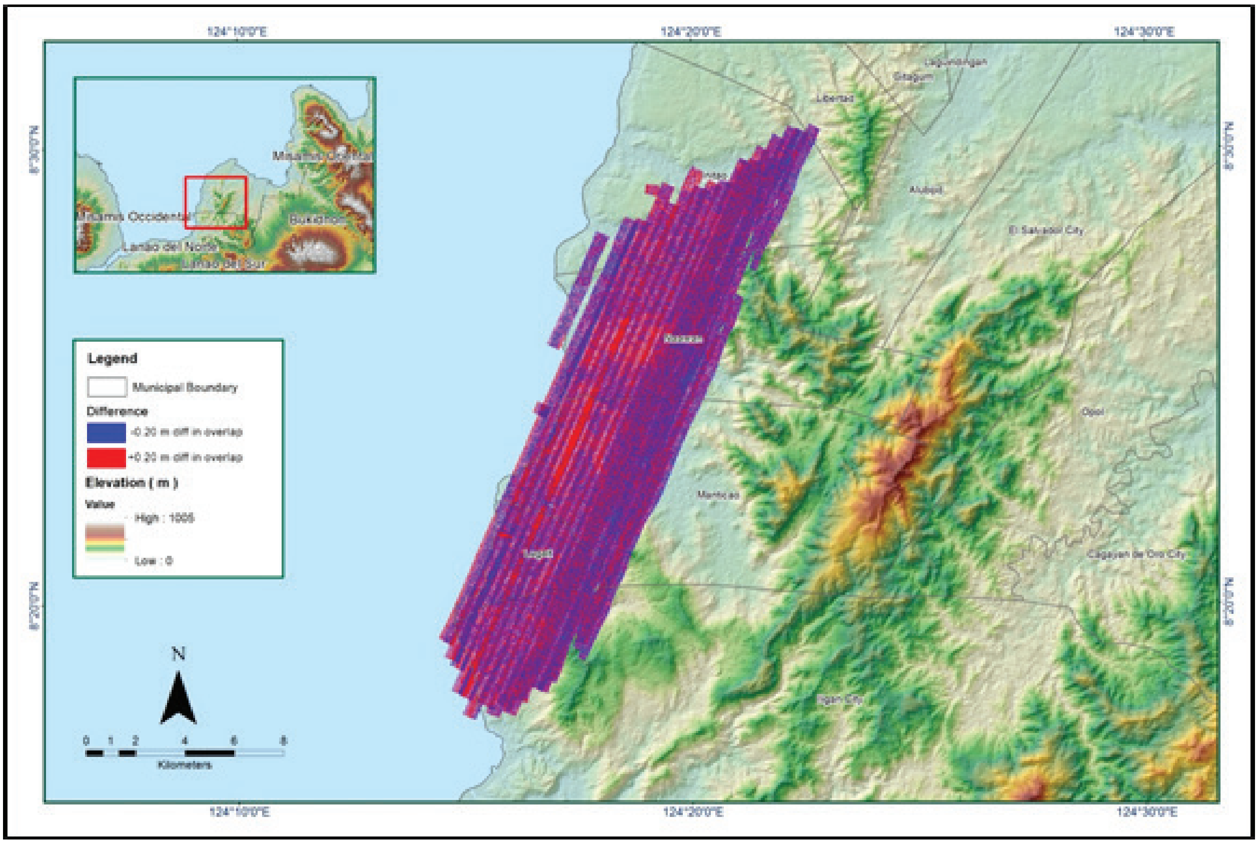


Figure A-8.31 . Elevation difference between flight lines for Blk67E.

Table A-8.5. Mission Summary Report for Mission Blk43I

Flight Area	Northern Mindanao
Mission Name	Blk68A
Inclusive Flights	1641P
Range data size	28.9 GB
POS	268 MB
Image	57.4 GB
Transfer date	July 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.0
RMSE for East Position (<4.0 cm)	2.5
RMSE for Down Position (<8.0 cm)	10
Boresight correction stdev (<0.001deg)	0.000155
IMU attitude correction stdev (<0.001deg)	0.001515
GPS position stdev (<0.01m)	0.0062
Minimum % overlap (>25)	42.46%
Ave point cloud density per sq.m. (>2.0)	4.25
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	282
Maximum Height	977.29 m
Minimum Height	67.52 m
Classification (# of points)	
Ground	144,082,289
Low vegetation	289,399,599
Medium vegetation	388,668,399
High vegetation	337,282,692
Building	142,77,170
Orthophoto	Yes

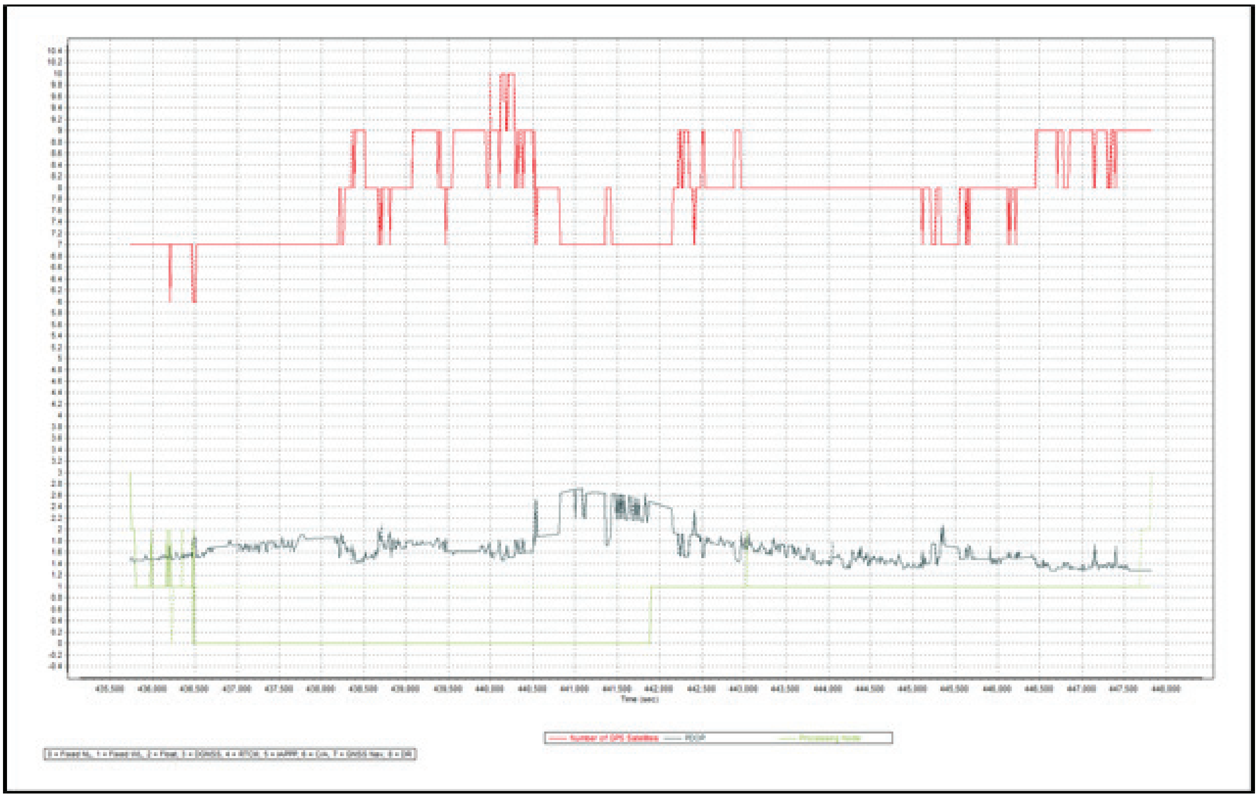


Figure A-8.32 . Solution Status for Blk68A.

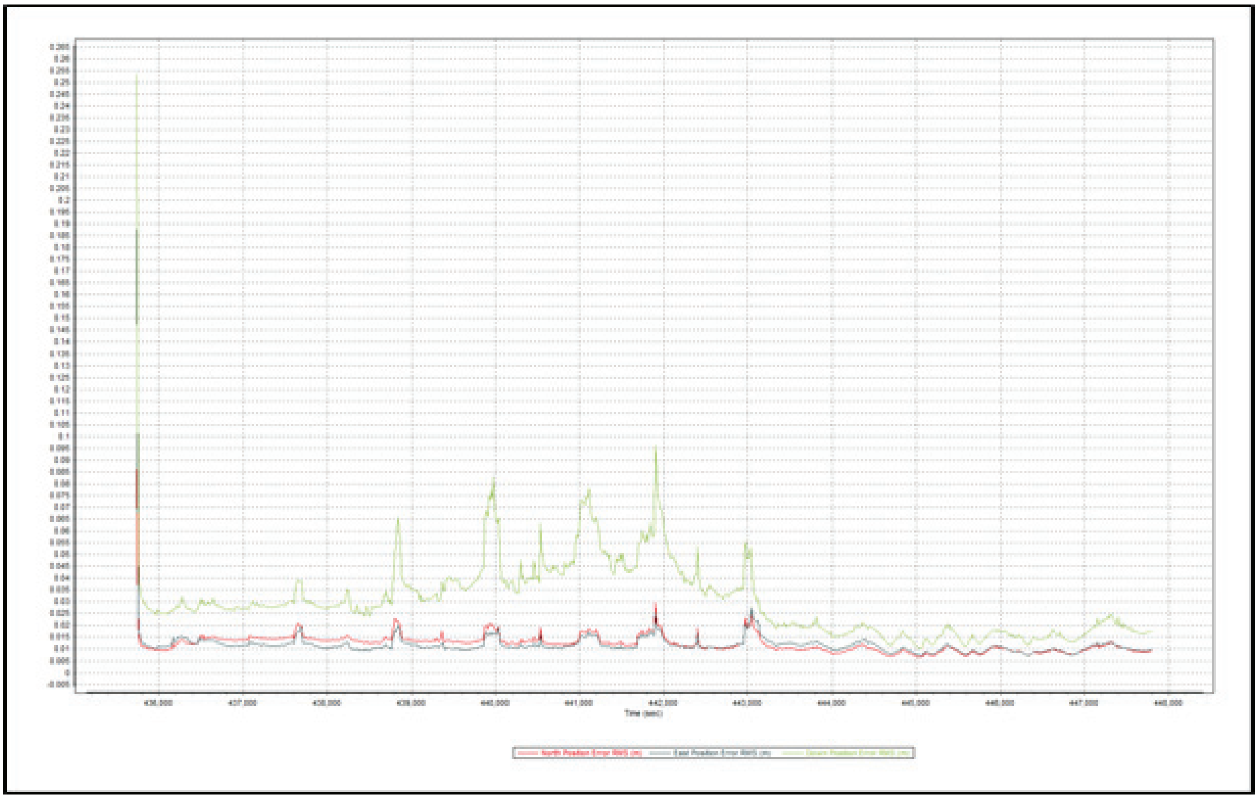


Figure A-8.33 . Smoothed Performance Metric Parameters for Blk68A.

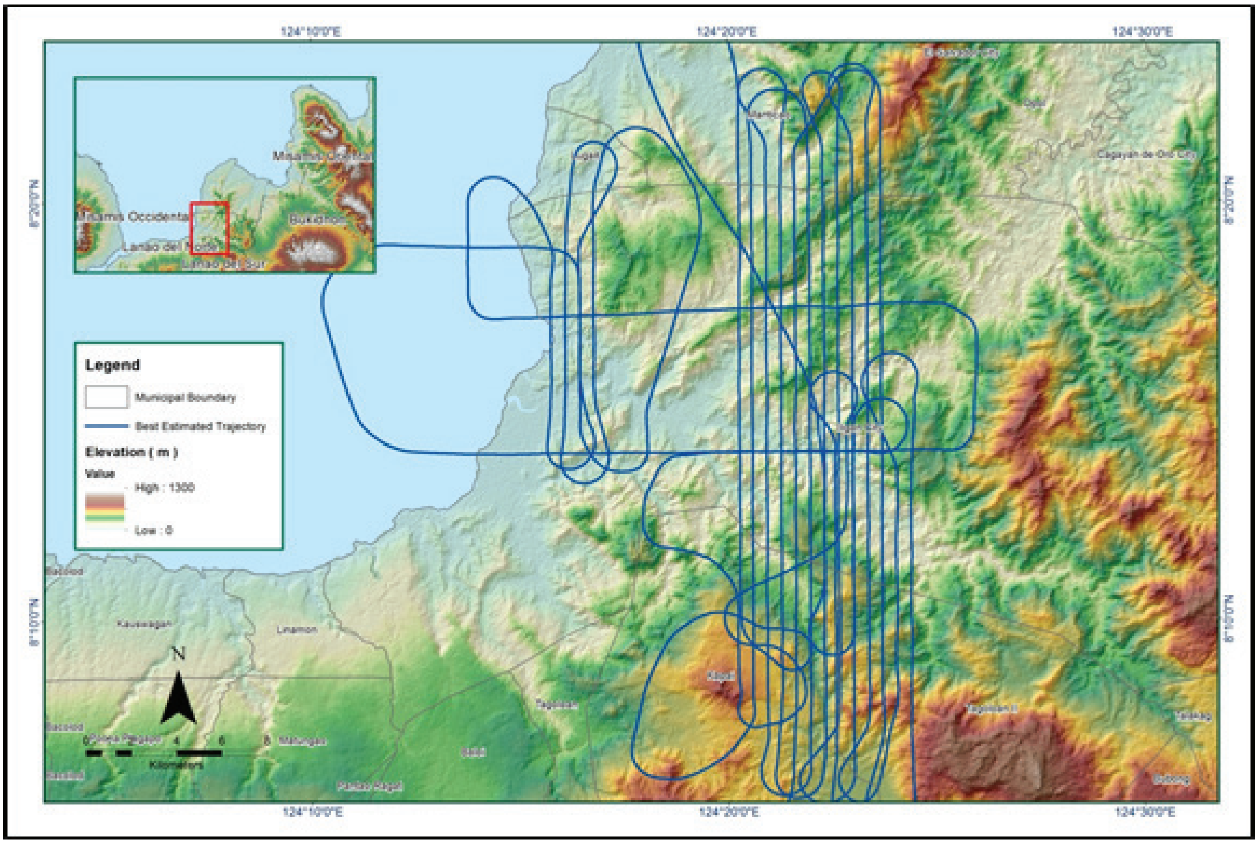


Figure A-8.34 . Best Estimated Trajectory for Blk68A.

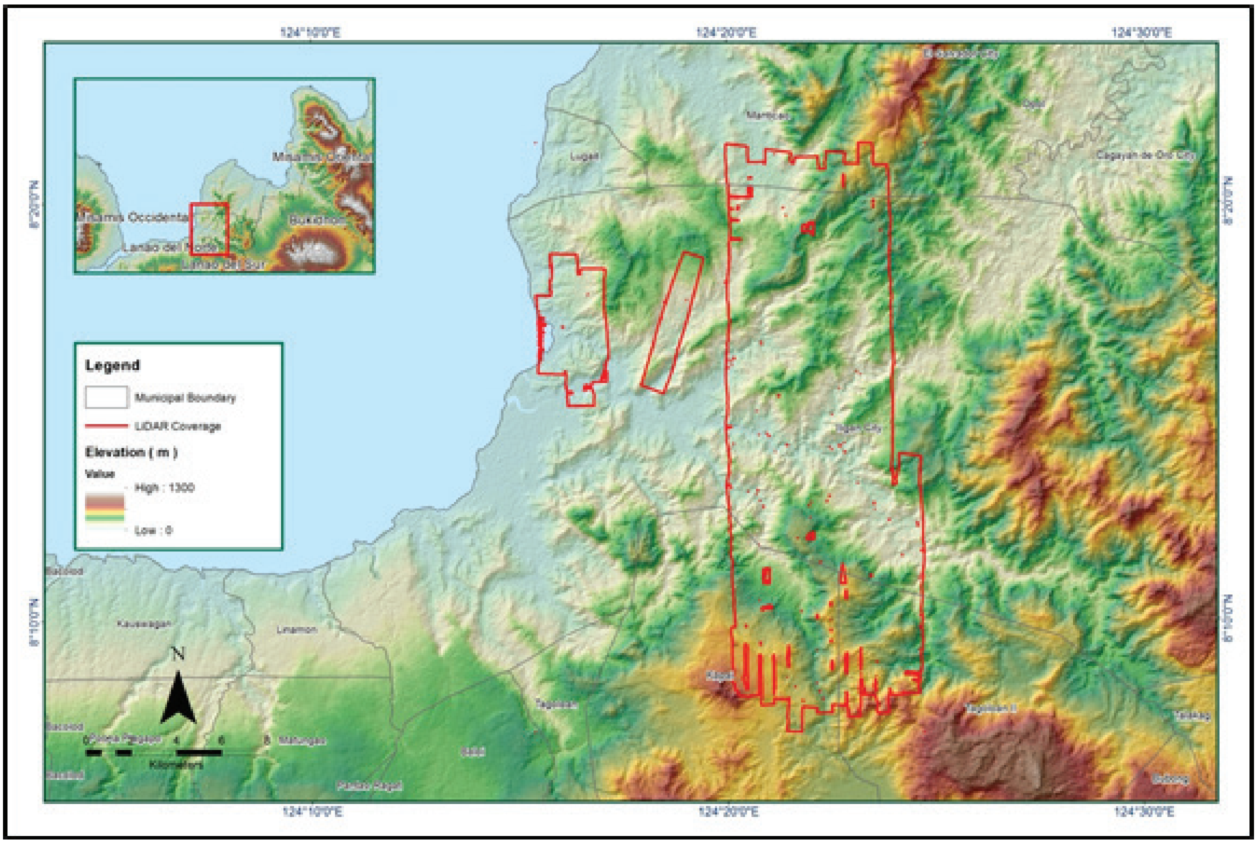


Figure A-8.35 . Coverage of LiDAR data for Blk68A.

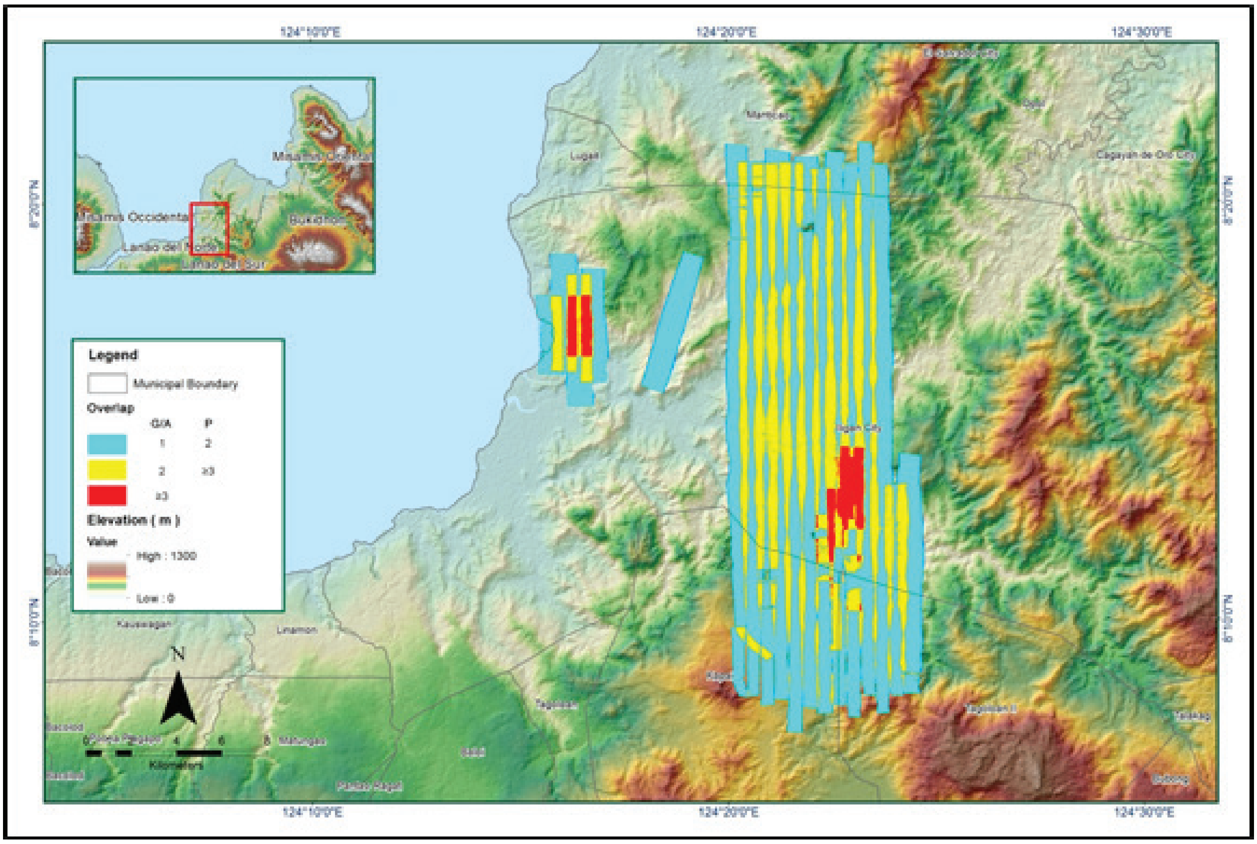


Figure A-8.36 . Image of data overlap for Blk68A.

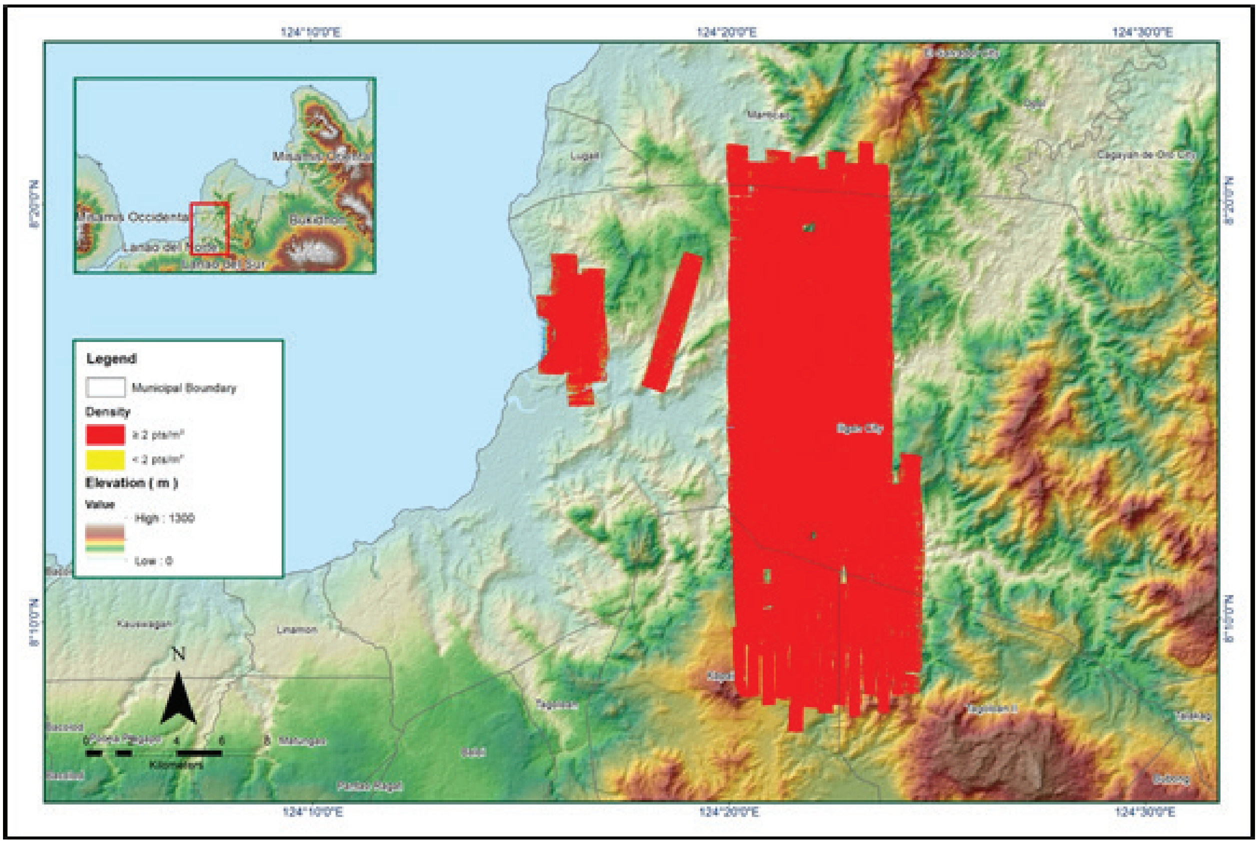


Figure A-8.37. Density map of merged LiDAR data for Blk68A.

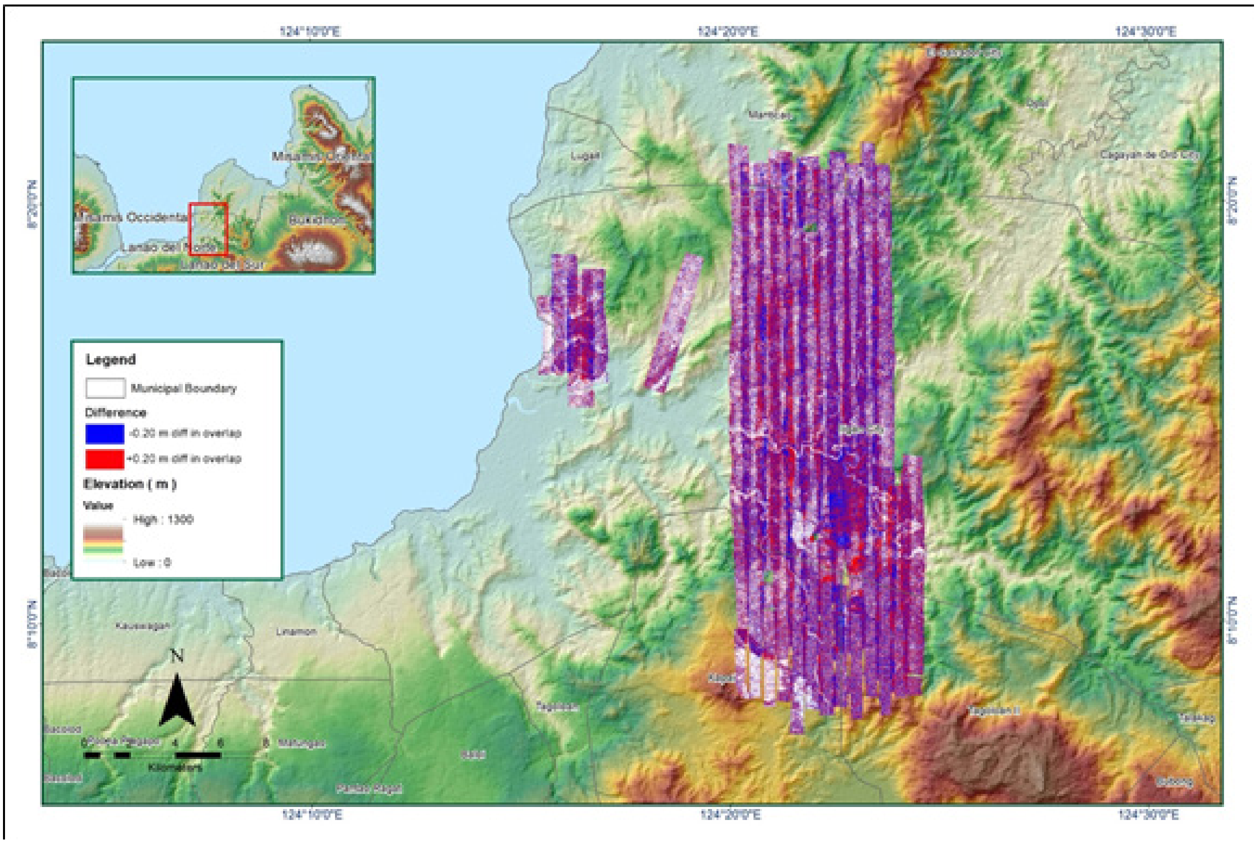


Figure A-8.38 . Elevation difference between flight lines for Blk68A.

Annex 9. Alubijid Model Basin Parameters

Table A-9.1. Alubijid Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1020	2.6365	83.808	0	0.065551	4.660684	Discharge	0.0269758	1	Ratio to Peak	0.35
W1030	6.3015	85.075	0	0.079154	2.052806	Discharge	0.0470735	1	Ratio to Peak	0.35
W470	1.1554	78.174	0	0.12835	1.42394	Discharge	0.0040461	1	Ratio to Peak	0.35
W490	0.93852	99	0	0.021571	0.3449894	Discharge	0.000396013	1	Ratio to Peak	0.35
W500	3.5334	53.43	0	0.13435	2.148748	Discharge	0.0467869	1	Ratio to Peak	0.35
W510	3.4986	99	0	0.30838	4.932144	Discharge	0.0291851	1	Ratio to Peak	0.35
W520	3.1875	81.71	0	0.27537	4.404218	Discharge	0.11738	1	Ratio to Peak	0.35
W530	3.5532	79.346	0	0.17012	2.720872	Discharge	0.0866826	1	Ratio to Peak	0.35

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W540	6.8211	75.411	0	0.14241	2.277716	Discharge	0.085096	1	Ratio to Peak	0.35
W550	7.4881	76.109	0	0.15583	2.492238	Discharge	0.0915338	1	Ratio to Peak	0.35
W570	5.0657	74.989	0	0.099471	1.048404	Discharge	0.0184433	1	Ratio to Peak	0.35
W580	2.3174	84.993	0	0.28342	1.590932	Discharge	0.0301908	1	Ratio to Peak	0.35
W590	3.1923	78.197	0	0.13031	4.532892	Discharge	0.0940558	1	Ratio to Peak	0.35
W600	5.2298	83.411	0	0.04558	2.084166	Discharge	0.10668	1	Ratio to Peak	0.35
W610	5.3261	77.68	0	0.19913	0.7289828	Discharge	0.003486	1	Ratio to Peak	0.35
W620	3.4075	81.5	0	0.26548	3.184902	Discharge	0.118	1	Ratio to Peak	0.35
W630	4.083	79.903	0	0.16831	4.246046	Discharge	0.16889	1	Ratio to Peak	0.35
W640	3.9216	77.679	0	0.15564	2.691864	Discharge	0.0523676	1	Ratio to Peak	0.35
W650	5.1018	75.64	0	0.13414	2.4892	Discharge	0.0660925	1	Ratio to Peak	0.35

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W660	14.887	77.757	0	0.1602	2.145416	Discharge	0.11434	1	Ratio to Peak	0.35
W670	6.0375	80.071	0	0.14701	2.562112	Discharge	0.11489	1	Ratio to Peak	0.35
W680	4.5712	52.407	0	0.077953	2.351314	Discharge	0.029034	1	Ratio to Peak	0.35
W690	10.5543527	75.713	0	0.12766	1.246756	Discharge	0.0364645	1	Ratio to Peak	0.35
W700	10.917	76.444	0	0.19606	2.041732	Discharge	0.0598006	1	Ratio to Peak	0.35
W710	13.578	84.168	0	0.074845	3.135706	Discharge	0.27441	1	Ratio to Peak	0.35
W720	13.803	75.101	0	0.1665	1.19707	Discharge	0.0698833	1	Ratio to Peak	0.35
W730	13.461	45.961	0	0.088286	2.663052	Discharge	0.19886	1	Ratio to Peak	0.35
W740	21.497	74.5	0	0.14511	1.411984	Discharge	0.0662489	1	Ratio to Peak	0.35
W750	19.09	82.844	0	0.050473	2.320934	Discharge	0.13122	1	Ratio to Peak	0.35

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W760	25.342	71.146	0	0.052966	0.8072358	Discharge	0.0373946	1	Ratio to Peak	0.35
W770	20.617	71.397	0	0.12786	0.8471218	Discharge	0.0138136	1	Ratio to Peak	0.35
W780	13.9306013	74.215	0	0.026091	2.044966	Discharge	0.0861954	1	Ratio to Peak	0.35
W790	6.7743	99	0	0.043233	0.417284	Discharge	0.0045099	1	Ratio to Peak	0.35
W800	10.855	67.895	0	0.16256	0.69146	Discharge	0.0054764	1	Ratio to Peak	0.35
W810	24.409	99	0	0.065888	2.59994	Discharge	0.1105	1	Ratio to Peak	0.35
W820	28.416	74.702	0	0.047878	1.053794	Discharge	0.0568878	1	Ratio to Peak	0.35
W830	25.306	74.933	0	0.073465	0.7657426	Discharge	0.0475138	1	Ratio to Peak	0.35
W840	18.841	74.994	0	0.093282	1.174922	Discharge	0.044132	1	Ratio to Peak	0.35
W850	20.19	75.852	0	0.066729	1.491952	Discharge	0.0838272	1	Ratio to Peak	0.35

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W860	29.974	99	0	0.052813	1.06722	Discharge	0.043835	1	Ratio to Peak	0.35
W870	36.886	68.894	0	0.085977	0.8446718	Discharge	0.0264313	1	Ratio to Peak	0.35
W880	24.624	51.967	0	0.095183	1.375038	Discharge	0.0541626	1	Ratio to Peak	0.35
W890	35.595	46.831	0	0.080413	1.522332	Discharge	0.13001	1	Ratio to Peak	0.35
W900	20.644	78.119	0	0.058507	1.2861	Discharge	0.0520758	1	Ratio to Peak	0.35
W920	22.822	79.487	0	0.29141	0.9357334	Discharge	0.050932	1	Ratio to Peak	0.35
W930	2.4294	99	0	0.064044	1.024296	Discharge	0.0046688	1	Ratio to Peak	0.35
W970	2.5073	78.411	0	0.089033	1.868076	Discharge	0.0082642	1	Ratio to Peak	0.35
W980	3.9647	83.31	0	0.1168	1.265964	Discharge	0.03085	1	Ratio to Peak	0.35

Annex 10. Alubijid Model Reach Parameters

Table A-10.1. Alubijid Model Reach Parameters

Reach Number	MuskingumCunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	1119.4	0.0001	0.0001	Trapezoid	46.11	1
R1000	Automatic Fixed Interval	732.55	0.0001	0.0001	Trapezoid	46.11	1
R1050	Automatic Fixed Interval	1362.3	0.0008	0.0001	Trapezoid	46.11	1
R110	Automatic Fixed Interval	4741.4	0.0077	0.0001	Trapezoid	46.11	1
R120	Automatic Fixed Interval	321.42	0.0001	0.0001	Trapezoid	46.11	1
R140	Automatic Fixed Interval	1552	0.0021	0.0001	Trapezoid	46.11	1
R190	Automatic Fixed Interval	1988.9	0.0034	0.0001	Trapezoid	46.11	1
R20	Automatic Fixed Interval	3367.6	0.0001	0.0001	Trapezoid	46.11	1
R210	Automatic Fixed Interval	3362.3	0.0013	0.0001	Trapezoid	46.11	1
R230	Automatic Fixed Interval	1462.3	0.0049	0.0001	Trapezoid	46.11	1
R250	Automatic Fixed Interval	5621.6	0.0034	0.0001	Trapezoid	46.11	1
R270	Automatic Fixed Interval	1956.9	0.0037	0.0001	Trapezoid	46.11	1
R280	Automatic Fixed Interval	4693.2	0.0118	0.0001	Trapezoid	46.11	1
R30	Automatic Fixed Interval	432.13	0.0001	0.0001	Trapezoid	46.11	1
R300	Automatic Fixed Interval	4237.5	0.0116	0.0001	Trapezoid	46.11	1
R310	Automatic Fixed Interval	406.27	0.0001	0.0001	Trapezoid	46.11	1
R320	Automatic Fixed Interval	1027.8	0.0553	0.0001	Trapezoid	46.11	1
R350	Automatic Fixed Interval	640.42	0.0084	0.0001	Trapezoid	46.11	1
R380	Automatic Fixed Interval	1780.5	0.0214	0.0001	Trapezoid	46.11	1
R40	Automatic Fixed Interval	78.284	0.0001	0.0001	Trapezoid	46.11	1
R410	Automatic Fixed Interval	691.13	0.031	0.0001	Trapezoid	46.11	1
R420	Automatic Fixed Interval	1581.2	0.0431	0.0001	Trapezoid	46.11	1
R60	Automatic Fixed Interval	2810.1	0.0012	0.0001	Trapezoid	46.11	1
R80	Automatic Fixed Interval	3072.9	0.0033	0.0001	Trapezoid	46.11	1
R940	Automatic Fixed Interval	460.42	0.0028	0.0001	Trapezoid	46.11	1

Annex 11. Alubijid Field Validation Points

Table A-11.1. Sibalom Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	8.510848525	124.435297278	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
2	8.512294991	124.439254123	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
3	8.516109427	124.441074757	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
4	8.518891000	124.434086999	0.34	0.50	0.16	Ondoy/25Nov2009	5YR
5	8.518969999	124.433839000	0.67	0.50	-0.17	Ondoy/25Nov2009	5YR
6	8.521616000	124.433596000	0.20	0.50	0.30	Ondoy/25Nov2009	5YR
7	8.522198796	124.440307393	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
8	8.522490999	124.434282000	0.50	1.00	0.50	Ondoy/25Nov2009	5YR
9	8.524058573	124.435103992	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
10	8.524310999	124.435431999	0.05	1.00	0.95	Ondoy/25Nov2009	5YR
11	8.528258999	124.434445000	0.31	1.00	0.69	Ondoy/25Nov2009	5YR
12	8.529125768	124.444787353	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
13	8.531336076	124.435299206	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
14	8.535649403	124.447881448	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
15	8.537102658	124.441897189	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
16	8.537491000	124.437823000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
17	8.539205999	124.441247000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
18	8.539572889	124.445625124	1.68	0.00	-1.68	Ondoy/25Nov2009	5YR
19	8.540997393	124.450950734	1.72	0.00	-1.72	Ondoy/25Nov2009	5YR
20	8.542094836	124.446228621	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
21	8.542258999	124.442645000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
22	8.542730184	124.450813438	2.08	0.00	-2.08	Ondoy/25Nov2009	5YR
23	8.543139808	124.453779626	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
24	8.543899375	124.450914440	2.01	0.00	-2.01	Ondoy/25Nov2009	5YR
25	8.544603958	124.452092936	1.53	0.00	-1.53	Ondoy/25Nov2009	5YR
26	8.544976000	124.448885999	0.05	1.00	0.95	Ondoy/25Nov2009	5YR
27	8.546195514	124.444579063	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
28	8.546970924	124.449721025	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
29	8.547276361	124.451860673	3.86	1.40	-2.46	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
30	8.548644119	124.455736297	0.71	0.00	-0.71	Ondoy/25Nov2009	5YR
31	8.549189446	124.448966402	1.40	0.00	-1.40	Ondoy/25Nov2009	5YR
32	8.550570509	124.458284843	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
33	8.550927182	124.456308698	1.44	0.00	-1.44	Ondoy/25Nov2009	5YR
34	8.551668143	124.453149475	1.06	1.80	0.74	Ondoy/25Nov2009	5YR
35	8.552052202	124.450922655	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
36	8.552356129	124.455037499	2.26	1.80	-0.46	Ondoy/25Nov2009	5YR
37	8.554954854	124.463500287	0.57	4.50	3.93	Ondoy/25Nov2009	5YR
38	8.555267080	124.454471050	1.48	1.30	-0.18	Ondoy/25Nov2009	5YR
39	8.555291891	124.456523191	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
40	8.555313013	124.451639139	2.65	3.20	0.55	Ondoy/25Nov2009	5YR
41	8.555406974	124.464280139	1.14	5.00	3.86	Ondoy/25Nov2009	5YR
42	8.555499175	124.450016068	0.34	0.00	-0.34	Ondoy/25Nov2009	5YR
43	8.555569248	124.454160919	2.21	2.20	-0.01	Ondoy/25Nov2009	5YR
44	8.555708723	124.460008386	2.26	4.20	1.94	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
45	8.555811904	124.452412118	2.74	2.90	0.16	Ondoy/25Nov2009	5YR
46	8.556115245	124.458107287	2.24	3.80	1.56	Ondoy/25Nov2009	5YR
47	8.556241477	124.451411487	1.67	1.70	0.03	Ondoy/25Nov2009	5YR
48	8.556322446	124.454827615	2.46	2.60	0.14	Ondoy/25Nov2009	5YR
49	8.556940611	124.457540670	1.38	2.60	1.22	Ondoy/25Nov2009	5YR
50	8.557084528	124.452059660	0.82	0.90	0.08	Ondoy/25Nov2009	5YR
51	8.557413854	124.459719043	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
52	8.557591717	124.457625663	2.13	3.10	0.97	Ondoy/25Nov2009	5YR
53	8.557696491	124.453664795	2.70	0.00	-2.70	Ondoy/25Nov2009	5YR
54	8.558075018	124.462693529	0.65	5.60	4.95	Ondoy/25Nov2009	5YR
55	8.558102091	124.455712661	2.24	2.70	0.46	Ondoy/25Nov2009	5YR
56	8.558817990	124.460426643	2.19	6.00	3.81	Ondoy/25Nov2009	5YR
57	8.559030220	124.456661911	0.99	2.40	1.41	Ondoy/25Nov2009	5YR
58	8.559097274	124.461029218	0.34	4.30	3.96	Ondoy/25Nov2009	5YR
59	8.559166006	124.463192084	1.57	6.20	4.63	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
60	8.559242366	124.451624388	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
61	8.559444620	124.453665213	0.34	0.00	-0.34	Ondoy/25Nov2009	5YR
62	8.560029426	124.458650937	0.66	4.00	3.34	Ondoy/25Nov2009	5YR
63	8.560286080	124.454615134	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
64	8.560342071	124.461518469	0.32	0.00	-0.32	Ondoy/25Nov2009	5YR
65	8.560673659	124.463728778	0.77	5.60	4.83	Ondoy/25Nov2009	5YR
66	8.560889999	124.458159999	0.07	2.50	2.43	Ondoy/25Nov2009	5YR
67	8.560974000	124.458176000	0.05	0.10	0.05	Ondoy/25Nov2009	5YR
68	8.560995356	124.482435006	0.81	0.00	-0.81	Ondoy/25Nov2009	5YR
69	8.561073141	124.469532910	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
70	8.561427024	124.462627898	1.91	6.30	4.39	Ondoy/25Nov2009	5YR
71	8.561676303	124.464912721	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
72	8.561861543	124.480916457	1.25	0.00	-1.25	Ondoy/25Nov2009	5YR
73	8.561958999	124.476511999	0.17	1.50	1.33	Ondoy/25Nov2009	5YR
74	8.562255999	124.470818000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
75	8.562317015	124.459482924	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
76	8.562294999	124.479348000	0.81	0.20	-0.61	Ondoy/25Nov2009	5YR
77	8.562343999	124.470769999	0.05	1.20	1.15	Ondoy/25Nov2009	5YR
78	8.562340401	124.472051672	1.11	2.50	1.39	Ondoy/25Nov2009	5YR
79	8.563613779	124.461166765	1.36	0.00	-1.36	Ondoy/25Nov2009	5YR
80	8.563683349	124.463996579	0.66	0.00	-0.66	Ondoy/25Nov2009	5YR
81	8.563933214	124.464906184	2.39	3.60	1.21	Ondoy/25Nov2009	5YR
82	8.564360000	124.472233000	0.05	0.20	0.15	Ondoy/25Nov2009	5YR
83	8.564649999	124.478890999	0.12	1.50	1.38	Ondoy/25Nov2009	5YR
84	8.564956309	124.471439877	0.65	0.00	-0.65	Ondoy/25Nov2009	5YR
85	8.565328968	124.463819386	0.31	0.00	-0.31	Ondoy/25Nov2009	5YR
86	8.565634555	124.480637231	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
87	8.565925508	124.464825466	0.60	0.00	-0.60	Ondoy/25Nov2009	5YR
88	8.565955767	124.461483266	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
89	8.566175959	124.473669715	0.70	3.60	2.90	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
90	8.566468000	124.471910999	0.56	2.00	1.44	Ondoy/25Nov2009	5YR
91	8.566593378	124.469806244	0.05	0.80	0.75	Ondoy/25Nov2009	5YR
92	8.567142141	124.472816688	0.38	2.20	1.82	Ondoy/25Nov2009	5YR
93	8.567235851	124.465428292	0.36	0.00	-0.36	Ondoy/25Nov2009	5YR
94	8.567632399	124.463250338	0.76	0.00	-0.76	Ondoy/25Nov2009	5YR
95	8.567948000	124.472633000	0.05	2.00	1.95	Ondoy/25Nov2009	5YR
96	8.568317000	124.478793000	0.34	1.50	1.16	Ondoy/25Nov2009	5YR
97	8.568607000	124.478593999	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
98	8.568871915	124.462986057	0.36	0.00	-0.36	Ondoy/25Nov2009	5YR
99	8.569234768	124.467607671	4.92	5.20	0.28	Ondoy/25Nov2009	5YR
100	8.569275504	124.460552036	0.70	0.00	-0.70	Ondoy/25Nov2009	5YR
101	8.569536999	124.479491999	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
102	8.569942999	124.477104000	0.05	1.00	0.95	Ondoy/25Nov2009	5YR
103	8.570473445	124.464928312	1.25	0.00	-1.25	Ondoy/25Nov2009	5YR
104	8.571013000	124.477842000	0.05	0.53	0.48	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
105	8.571056999	124.472923999	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
106	8.571352999	124.485483000	1.01	1.00	-0.01	Ondoy/25Nov2009	5YR
107	8.572522999	124.479243000	0.49	1.00	0.51	Ondoy/25Nov2009	5YR
108	8.572884416	124.465375906	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
109	8.572886000	124.475217000	0.22	1.52	1.30	Ondoy/25Nov2009	5YR
110	8.573069999	124.490074999	1.28	1.80	0.52	Ondoy/25Nov2009	5YR
111	8.573197999	124.481685000	0.64	1.80	1.16	Ondoy/25Nov2009	5YR
112	8.573390000	124.474235999	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
113	8.573327000	124.508699999	0.53	0.86	0.33	Ondoy/25Nov2009	5YR
114	8.573592000	124.505026999	0.78	1.20	0.42	Ondoy/25Nov2009	5YR
115	8.573899548	124.467203579	1.51	0.00	-1.51	Ondoy/25Nov2009	5YR
116	8.574085291	124.470893544	0.60	0.00	-0.60	Ondoy/25Nov2009	5YR
117	8.574012999	124.501738000	0.06	0.00	-0.06	Ondoy/25Nov2009	5YR
118	8.574893977	124.469486139	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
119	8.575104000	124.481303000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
120	8.575272999	124.481921999	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
121	8.575237000	124.503635999	0.09	0.00	-0.09	Ondoy/25Nov2009	5YR
122	8.575441999	124.494538999	0.05	1.00	0.95	Ondoy/25Nov2009	5YR
123	8.575507000	124.499348000	0.05	0.47	0.42	Ondoy/25Nov2009	5YR
124	8.575648851	124.467638181	1.19	0.00	-1.19	Ondoy/25Nov2009	5YR
125	8.576051999	124.500717999	0.80	0.00	-0.80	Ondoy/25Nov2009	5YR
126	8.576232064	124.467002330	0.66	0.00	-0.66	Ondoy/25Nov2009	5YR
127	8.576422920	124.464107975	0.32	0.00	-0.32	Ondoy/25Nov2009	5YR
128	8.576372999	124.477768999	0.20	0.00	-0.20	Ondoy/25Nov2009	5YR
129	8.576523000	124.483764999	0.05	0.86	0.81	Ondoy/25Nov2009	5YR
130	8.576784000	124.480816000	0.05	0.70	0.65	Ondoy/25Nov2009	5YR
131	8.576846000	124.486770999	1.51	1.80	0.29	Ondoy/25Nov2009	5YR
132	8.577275000	124.494130999	1.33	0.00	-1.33	Ondoy/25Nov2009	5YR
133	8.577492000	124.479297999	0.24	0.47	0.23	Ondoy/25Nov2009	5YR
134	8.578082999	124.485486000	0.20	0.86	0.66	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
135	8.578842000	124.478665999	0.17	0.47	0.30	Ondoy/25Nov2009	5YR
136	8.578992000	124.480290000	0.05	0.20	0.15	Ondoy/25Nov2009	5YR
137	8.579684000	124.476954000	0.65	1.30	0.65	Ondoy/25Nov2009	5YR
138	8.580102000	124.487800000	0.05	0.80	0.75	Ondoy/25Nov2009	5YR
139	8.580988000	124.477951999	0.33	0.47	0.14	Ondoy/25Nov2009	5YR
140	8.583294000	124.487689000	0.05	0.86	0.81	Ondoy/25Nov2009	5YR
141	8.583520999	124.481499000	0.09	0.67	0.58	Ondoy/25Nov2009	5YR
142	8.584399000	124.489346000	0.63	1.20	0.57	Ondoy/25Nov2009	5YR
143	8.584559000	124.480590000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
144	8.586381000	124.485559000	0.05	0.70	0.65	Ondoy/25Nov2009	5YR
145	8.587757999	124.482352000	0.06	1.00	0.94	Ondoy/25Nov2009	5YR
146	8.587777000	124.478602000	0.05	0.47	0.42	Ondoy/25Nov2009	5YR
147	8.587775999	124.482381999	0.06	1.80	1.74	Ondoy/25Nov2009	5YR
148	8.587857000	124.477541000	0.05	1.80	1.75	Ondoy/25Nov2009	5YR
149	8.587926999	124.477759000	0.05	1.00	0.95	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
150	8.588068000	124.472737000	0.81	1.80	0.99	Ondoy/25Nov2009	5YR
151	8.588445000	124.474780999	0.05	0.86	0.81	Ondoy/25Nov2009	5YR
152	8.589693999	124.473824000	0.05	0.47	0.42	Ondoy/25Nov2009	5YR
153	8.523087000	124.437839000	1.68	0.00	-1.68	Ondoy/25Nov2009	5YR
154	8.529306000	124.445692000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
155	8.529301000	124.445620000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
156	8.532048000	124.446661000	0.07	0.00	-0.07	Ondoy/25Nov2009	5YR
157	8.531837000	124.443824000	0.62	3.00	2.38	Ondoy/25Nov2009	5YR
158	8.533108000	124.445174000	1.01	3.00	1.99	Ondoy/25Nov2009	5YR
159	8.557752000	124.456815000	1.60	0.05	-1.55	Ondoy/25Nov2009	5YR
160	8.557790000	124.455319000	1.77	1.57	-0.20	Ondoy/25Nov2009	5YR
161	8.562826000	124.464283000	0.38	0.00	-0.38	Ondoy/25Nov2009	5YR
162	8.562027000	124.466003000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
163	8.562586000	124.466862000	0.34	3.00	2.66	Ondoy/25Nov2009	5YR
164	8.563938000	124.466308000	0.48	0.00	-0.48	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
165	8.563951000	124.467301000	0.36	1.58	1.22	Ondoy/25Nov2009	5YR
166	8.563007000	124.468338000	0.32	1.52	1.20	Ondoy/25Nov2009	5YR
167	8.563125000	124.468568000	0.33	0.00	-0.33	Ondoy/25Nov2009	5YR
168	8.562382000	124.467848000	0.41	0.00	-0.41	Ondoy/25Nov2009	5YR
169	8.580856000	124.476951000	0.20	1.20	1.00	Ondoy/25Nov2009	5YR
170	8.581222000	124.476773000	0.34	1.20	0.86	Ondoy/25Nov2009	5YR
171	8.583046000	124.479476000	0.05	0.50	0.45	Ondoy/25Nov2009	5YR
172	8.576172000	124.483780000	0.24	0.25	0.01	Ondoy/25Nov2009	5YR
173	8.575478000	124.483980000	0.29	0.00	-0.29	Ondoy/25Nov2009	5YR
174	8.575532000	124.483220000	0.32	0.00	-0.32	Ondoy/25Nov2009	5YR
175	8.575227000	124.482518000	0.17	0.60	0.43	Ondoy/25Nov2009	5YR
176	8.574929000	124.481179000	0.05	0.60	0.55	Ondoy/25Nov2009	5YR
177	8.574368000	124.480737000	0.05	0.60	0.55	Ondoy/25Nov2009	5YR
178	8.573301000	124.479892000	0.34	0.60	0.26	Ondoy/25Nov2009	5YR
179	8.573128000	124.480033000	0.38	1.20	0.82	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
180	8.594046000	124.468489000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
181	8.593120000	124.468750000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
182	8.592255000	124.468806000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
183	8.589677000	124.466109000	0.10	0.00	-0.10	Ondoy/25Nov2009	5YR
184	8.587179000	124.466491000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
185	8.582814000	124.468451000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
186	8.583831000	124.469035000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
187	8.589719000	124.473328000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
188	8.587780000	124.478869000	0.10	0.00	-0.10	Ondoy/25Nov2009	5YR
189	8.560081000	124.473811000	0.65	0.00	-0.65	Ondoy/25Nov2009	5YR
190	8.559581000	124.472889000	0.71	0.00	-0.71	Ondoy/25Nov2009	5YR
191	8.559265000	124.471911000	0.05	3.00	2.95	Ondoy/25Nov2009	5YR
192	8.560419000	124.474921000	0.05	0.00	-0.05	Ondoy/25Nov2009	5YR
193	8.561483000	124.474112000	0.49	1.50	1.01	Ondoy/25Nov2009	5YR
194	8.562858000	124.471290000	0.29	0.00	-0.29	Ondoy/25Nov2009	5YR

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
195	8.560218000	124.469597000	0.29	0.00	-0.29	Ondoy/25Nov2009	5YR
196	8.567137000	124.474723000	0.20	6.00	5.80	Ondoy/25Nov2009	5YR
197	8.566098000	124.474671000	0.90	0.00	-0.90	Ondoy/25Nov2009	5YR
198	8.566007000	124.474993000	1.14	0.00	-1.14	Ondoy/25Nov2009	5YR
199	8.566227000	124.475572000	0.65	0.00	-0.65	Ondoy/25Nov2009	5YR
200	8.569359000	124.474715000	0.05	1.20	1.15	Ondoy/25Nov2009	5YR
201	8.568866000	124.474985000	0.05	0.50	0.45	Ondoy/25Nov2009	5YR
202	8.568349000	124.475828000	1.54	0.00	-1.54	Ondoy/25Nov2009	5YR

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Annex 12. Educational Institutions Affected by Flooding in Alubijid Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Alubijid Floodplain

Misamis Oriental				
Alubijid				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Baybay Day Care Center	Baybay		Low	Medium
Baybay Elem School	Baybay			Low
Benigwayan Elem School	Benigwayan			
Catholic Learning Center	Benigwayan			
Day Care Center	Benigwayan			
Sampatutlog Integrated School	Benigwayan			
School	Calatcat			
Day Care Center	Lagtang	Low	Low	Low
Lagtang Day Care Center	Lagtang			
Lagtang Elem School	Lagtang			
Loguilo Elem School	Lagtang	Low	Medium	Medium
Alubijid Elem School	Lanao			
Catholic Learning Center	Lanao			
Elementary School	Lanao			
Loguilo Day Care Center	Loguilo		Medium	Medium
Covered Stage	Lourdes	Low	Medium	Medium
Lourdes Day Care Center	Lourdes			Low
Lourdes School	Lourdes	Medium	High	High
Lumbo Elem School	Lumbo		Low	Low
Alubijid National High School	Poblacion			
Bukidnon State University Annex	Poblacion	Low	Medium	Medium
Elementary School	Poblacion			
Day Care Center	Talaba			
Talaba Elem School	Talaba			

El Salvador City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Elem School	Bolisong			
Kalabaylabay Elem School	Kalabaylabay			

Laguindingan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
School	Kibaghot			
Laguindingan Elem School	Poblacion			

Annex 13. Medical Institutions Affected by Flooding in Alubijid Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Alubijid Floodplain

Misamis Oriental				
Alubijid				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy Health Center	Benigwayan			
Lagtang Health Center	Lagtang			
Alubijid Health Center	Lanao			
Alubijid Provincial Hospital	Lanao			
Lourdes Health Center	Lourdes	Low	Medium	Medium