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

LiDAR Surveys and Flood Mapping of Kipit River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Zamboanga University

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADZU	Ateneo de Zamboanga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord

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

CHAPTER 1: Overview of the program Kipit River

Enrico C. Paringit, Dr. Eng., Mr. Mario S. Rodriguez

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Zamboanga University (ADZU). ADZU 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 18 river basins in the Zamboanga Peninsula. The university is located in Zamboanga City in the province of Zamboanga Sibugay.

1.2 Overview of the Alubijid River Basin

Considered as one of the biggest river basins in the region, Kipit River Basin has a catchment area of 707.64 sq.km. It covers several areas of the municipalities of Gutalac, Labason, Baliguian, and Kalawit in Zamboanga del Norte and RT Lim and Titay in Zamboanga Sibugay. It is also one of the 3 rivers which lies within the jurisdiction of the municipality of Labason and serves as the political boundary between Labason and Gutalac. The DENR River Basin Control Office (RBCO) states that the Kipit River Basin has a drainage are of 633 sq.km and an estimated 475 cubic meter (MCM) annual run-off (RBCO, 2015). Its main stem, Kipit River, is part of the 18 river systems in Zamboanga Peninsula. According to the 2015 national census of PSA, a total of 3,952 persons are residing in Brgy. Antonio (Poblacion) in the Municipality of Labason, which is within the immediate vicinity of the river. The economy of the province Zamboanga del Norte largely rests on agriculture particularly fishing and mineral extraction (Island Properties, n.d.). On February 1, 2017, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Kipit River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Mindanao as per NDRRMC report (2017).

Kipit River was named after the oldest barangays of the Province. Long before Labason was an independent district from Sindangan, Kipit, or previously spelled as Quipit, has already existed as one of the Sitios of Sindangan. According to oral tradition, Kipit came from the word "kumpit" which means boat. It was said that the place used to be a hiding place of the pirates who were hiding from the authorities.

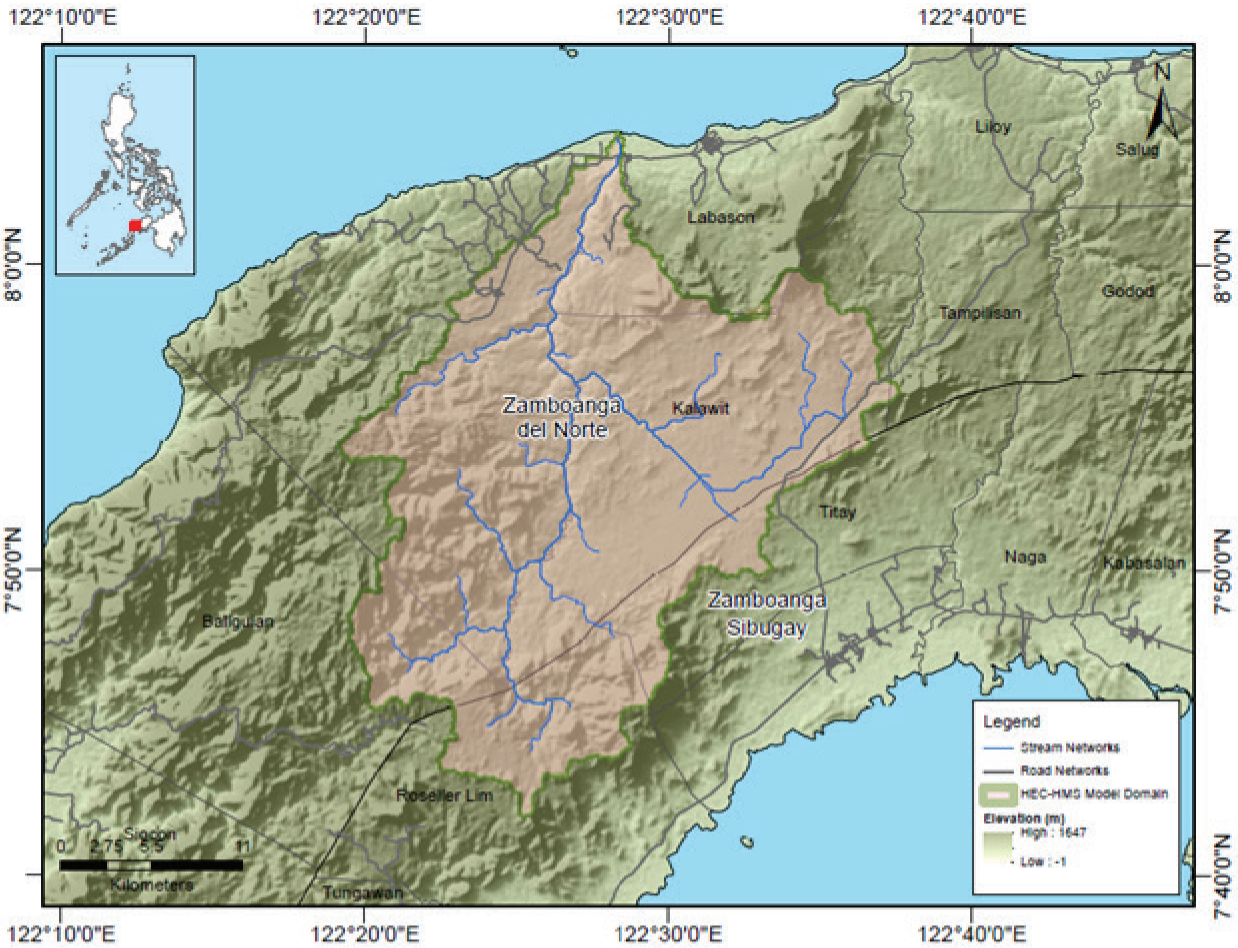

Figure 1. Map of the Kipit River Basin (in brown)

Figure 2. Kipit River, January 2017

As one of the rivers with a big catchment area, it is not surprising that Kipit River somehow causes flooding to the areas nearby. Based on the records of the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Labason, Kipit River overflowed twice: in 2000 and 2012. It was notable that during the flooding in 2012, several residents of Barangay Kipit were rescued and evacuated due to the rising level of the flood waters.

The Environmental Management Bureau Region 9 has classified the Kipit River as Class B River, which means it is a Recreational Water Class 1 and could primarily be used for recreation activities such as bathing, swimming or any other tourism purposes.

Kipit River is part of the Lituban-Quipit Watershed. In previous years, logging activities were present in the area. According to a research conducted by Lisa Paguntalan in 2010, timber companies such as TIMES, Curuan Timber, Zamboanga Wood Products, JOLAR and DACON Timber Company operated in the area in 2008.

Figure 3. Spring located along the Siocon-Labason road, covered by the Lituban-Quipit Watershed

In the same year, Lituban-Quipit Watershed was declared as part of the Philippine Indigenous Peoples and Protected Areas along with several watershed areas in Zamboanga Peninsula. With this, reforestation activities such as planting of several exotic plants were conducted.

CHAPTER 2: LiDAR Acquisition in Kipit 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 Kipit Floodplain in Zamboanga del Norte. These missions were planned for 12 lines that run for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 4 shows the flight plans for Kipit Floodplain survey.

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)
BLK73A	750, 850, 1000	20, 30	50	200	30	130	5
BLK73D	600, 700, 800, 1000, 1100, 1200	30	50	200	30	130	5
BLK73E	600, 700, 800, 1000, 1100, 1200	30	50	200	30	130	5
BLK73F	700, 800, 1000, 1100, 1200	30	50	200	30	130	5

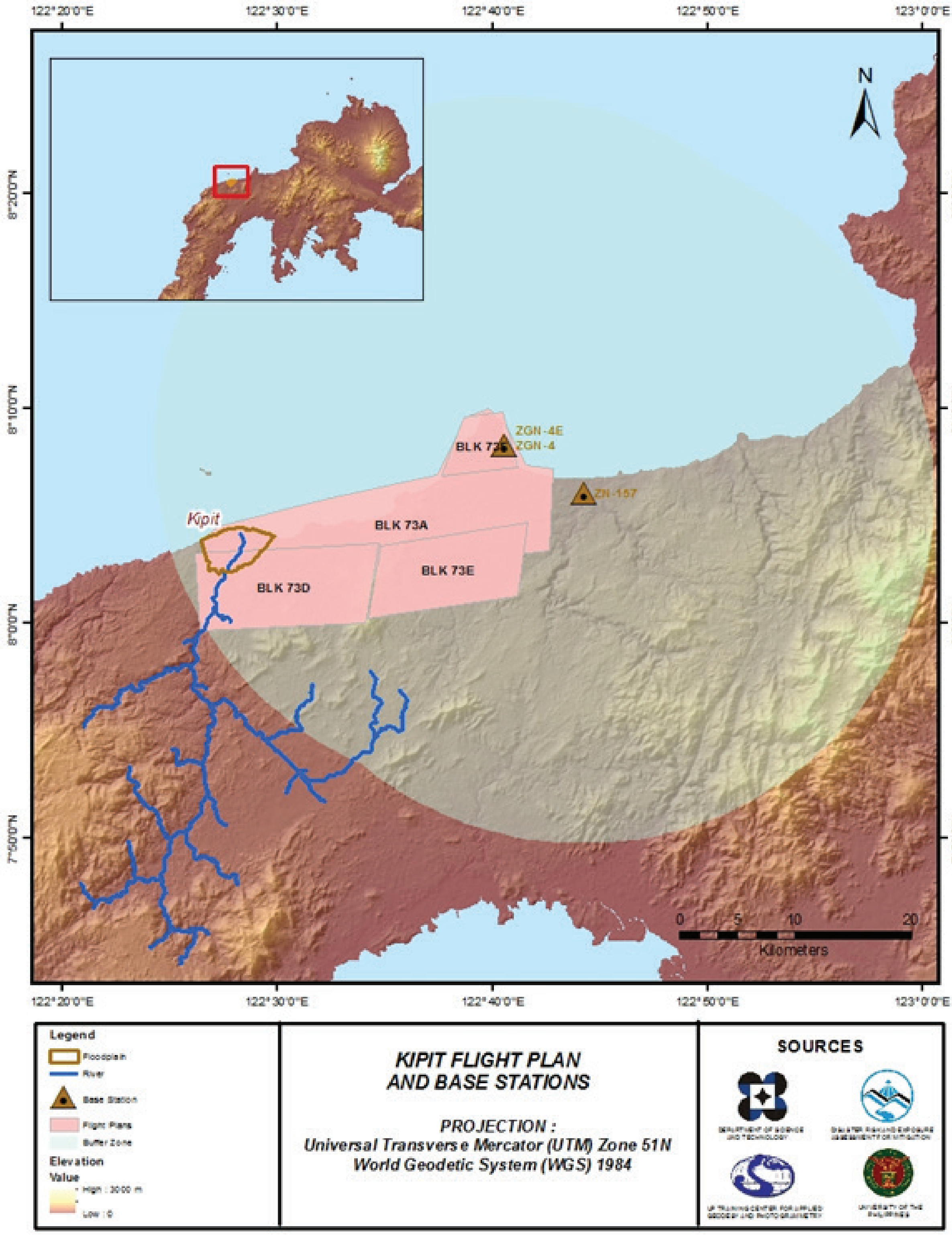

Figure 4. Flight plan and base stations used for Kipit Floodplain

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point, ZGN-4, which is of first (1st) order accuracy. The project team also recovered one (1) NAMRIA benchmark, ZN-157, and established one (1) ground control point, ZGN-4E. The certification for the NAMRIA reference point is found in Annex 2 while the baseline processing reports for the benchmark and established control points are found in Annex 3. These points were used as base stations during flight operations for the entire duration of the survey (October 8 to November 11, 2014 and November 20 to 26, 2016). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 852, TRIMBLE SPS 882, and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Kipit Floodplain are shown in Figure 4.

Figure 5 shows the recovered NAMRIA reference point within the area. In addition, Table 2 to Table 4 show the details about the following NAMRIA control stations and established point, while Table 5 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization. The data transfer sheets can be found in Annex 6.

Figure 5. GPS set-up over ZGN-4 at Barangay Lamao, Liloy, Zamboanga del Norte (a) and NAMRIA reference point ZGN-4 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point ZGN-4 used as base station for the LiDAR acquisition

Station Name	ZGN-4	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 8' 20.40827" North 122° 40' 28.89097" East 3.848 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	464,150.413 meters 899,937.404 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 8' 16.73719" North 122° 40' 34.34251" East 67.3513 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	464,162.96 meters 899,622.41 meters

Table 3. Details of the recovered NAMRIA horizontal control point ZN-157 used as base station for the LiDAR acquisition

Station Name	ZN-157	
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° 6' 5.34724" North 122° 44' 9.71575" East 7.394 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 6' 1.69150" North 122° 44' 15.17027" East 71.024 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	471,084.95 meters 895,414.31 meters

Table 4. Details of the established control point ZGN-4E used as base station for the LiDAR acquisition

Station Name	ZGN-4E	
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° 8' 16.81854" North 122° 40' 34.48473" East 67.351 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 8' 16.81854" North 122° 40' 34.48473" East 67.351 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	464,334.47 meters 899,568.85 meters

Table 5. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 6, 2014	2169P	1BLK73A310A	ZGN-4, ZN-157
November 10, 2014	2185P	1BLK73A314A	ZGN-4, ZGN-4E
November 11, 2014	2189P	1BLK73A315A	ZGN-4, ZN-157
November 26, 2016	23582P	1BLK73DE331A	ZGN-4, ZN-157
November 28, 2016	23590P	1BLK73DEF333A	ZGN-4, ZN-157

2.3 Flight Missions

Five (5) missions were conducted to complete the LiDAR data acquisition in Kipit Floodplain, for a total of twenty-one hours and two minutes (21+2) of flying time for RP-9122. The missions were acquired using the Pegasus LiDAR system. Table 6 shows the total area of actual coverage and the corresponding flying hours of the mission, while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for LiDAR data acquisition in Kipit 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
November 6, 2014	2169P	223.6	170.41	15.06	155.35	559	4	5
November 10, 2014	2185P	223.6	83.00	15.53	67.47	611	4	30
November 11, 2014	2189P	223.6	79.52	6.16	73.36	950	3	53
November 26, 2016	23582P	178.01	181.39	9.02	172.37	NA	4	23
November 28, 2016	23590P	202.03	130.22	0.12	130.1	NA	4	11
TOTAL		1,050.84	1,050.84	45.89	598.65	2,120	21	2

Table 7. Actual parameters used during LiDAR data acquisition of the Kipit Floodplain

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes
2169P	750	30	50	200	30	130	5
2185P	750, 850, 1000	20	50	200	30	130	5
2189P	750, 850, 1000	20	50	200	30	130	5
23582P	600, 700, 800, 1000, 1100, 1200	30	50	200	30	130	5
23590P	700, 800, 1000, 1100, 1200	30	50	200	30	130	5

2.4 Survey Coverage

Kipit Floodplain is located in the province of Zamboanga del Norte, with majority of the floodplain situated within the municipality of Gutalac and Labason. Municipalities of Liloy and Labason are mostly covered during 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 Kipit Floodplain is presented in Figure 6. Annex 7 shows 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
Zamboanga del Norte	Liloy	123.94	112.56	90.82%
	Labason	179.14	152.91	85.35%
	Tampilisan	103.05	11.57	11.23%
	Kalawit	329.51	27.96	8.48%
	Gutalac	449.87	27.17	6.04%
Total		1185.51	332.17	28.02%

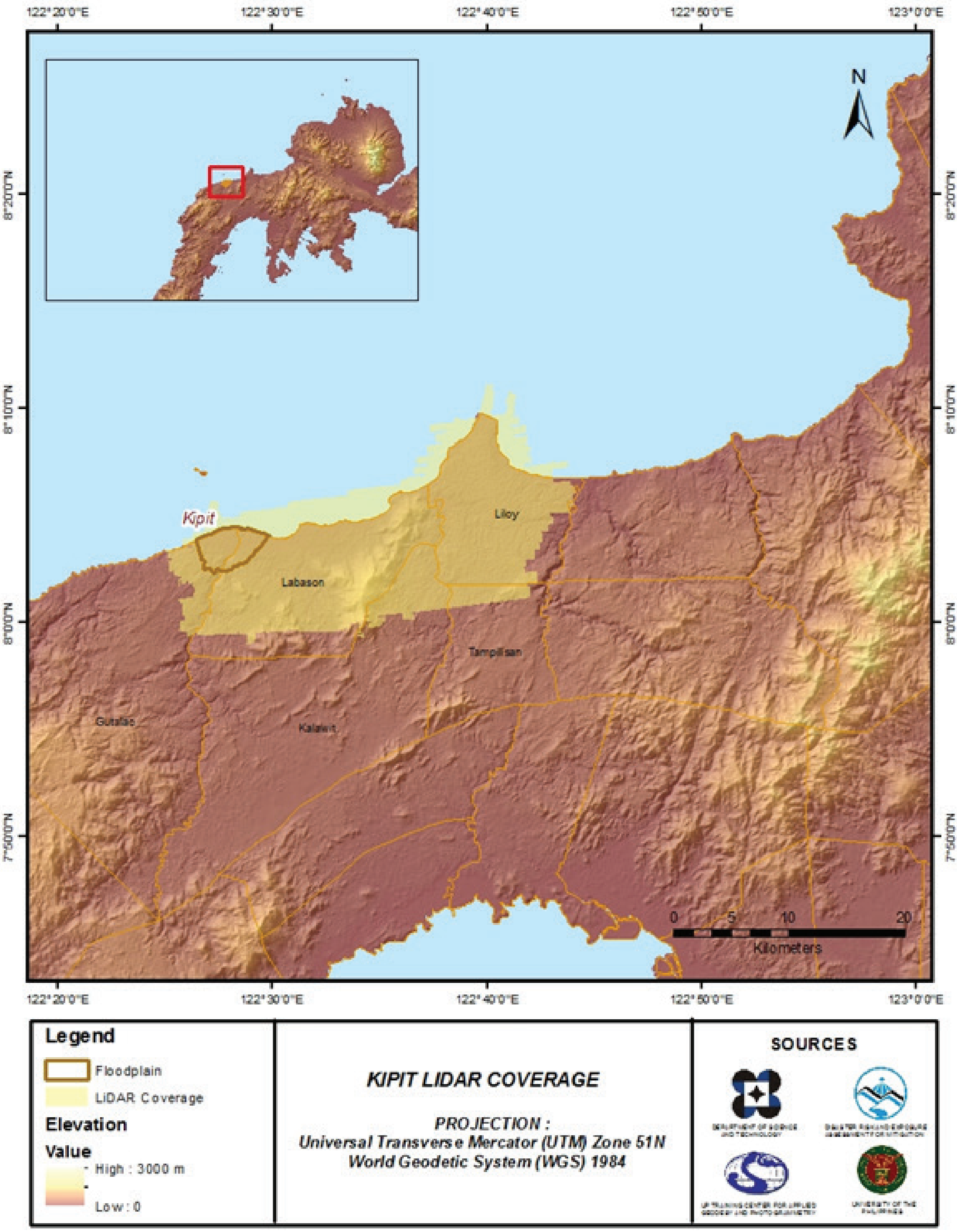

Figure 6. Actual LiDAR survey coverage for Kipit Floodplain.

Chapter 3: LiDAR Data Processing of the Kipit 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

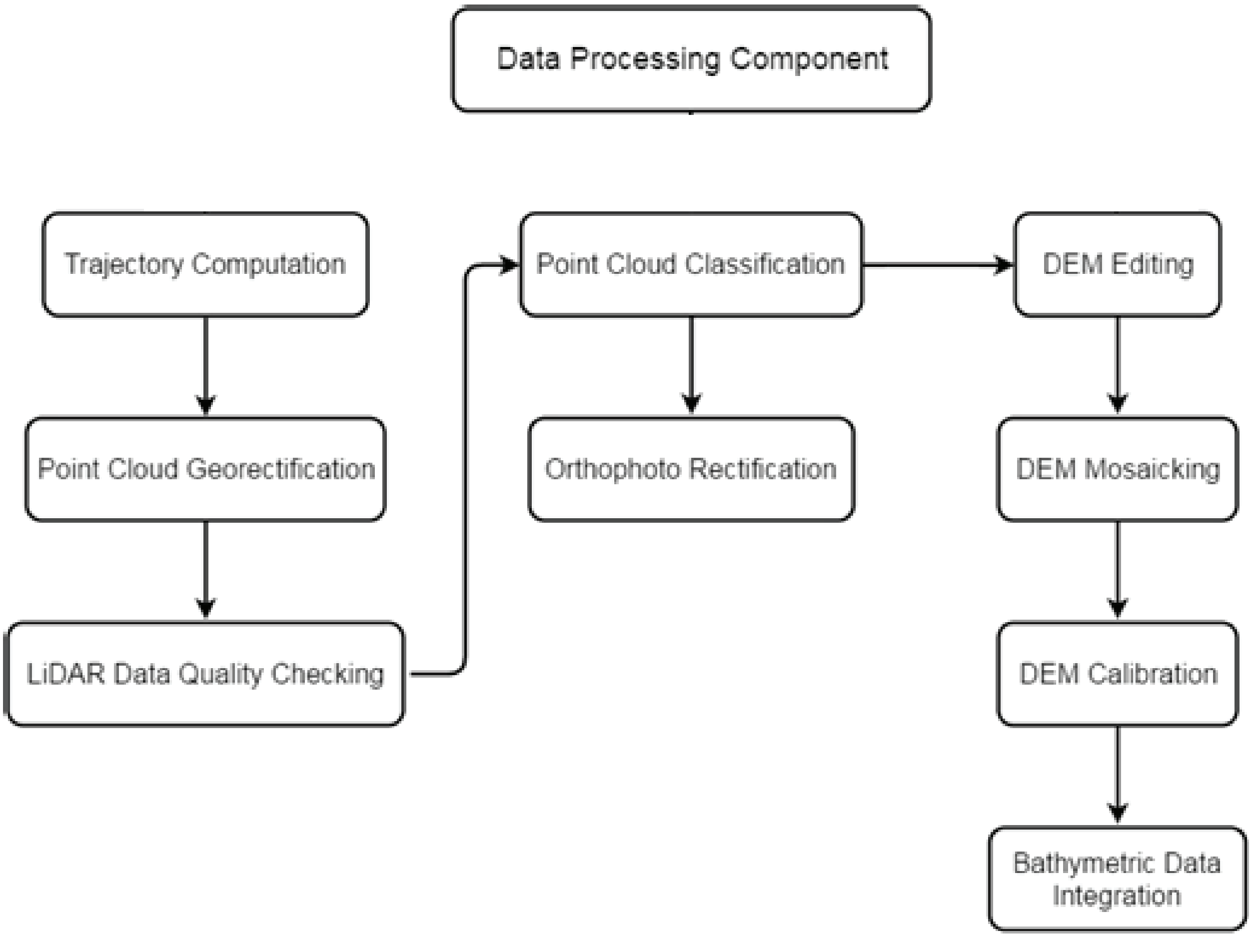


Figure 7. Schematic Diagram for Data Pre-Processing Component

The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, which included the minimum point density and vertical and horizontal accuracies, were 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 were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 7.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Kipit Floodplain can be found in Annex 5. Missions flown during the first survey conducted on November 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Municipality of Gutalac and Labason, Zamboanga del Norte. The Data Acquisition Component (DAC) transferred a total of 98.90 Gigabytes of Range data, 1,196 Megabytes of POS data, 274.60 Megabytes of GPS base station data, and 120.60 Gigabytes of raw image data to the data server on December 08, 2016. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Kipit was fully transferred on December 08, 2016 as indicated on the data transfer sheets for Kipit Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 2189P, one of the Kipit flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on November 09, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

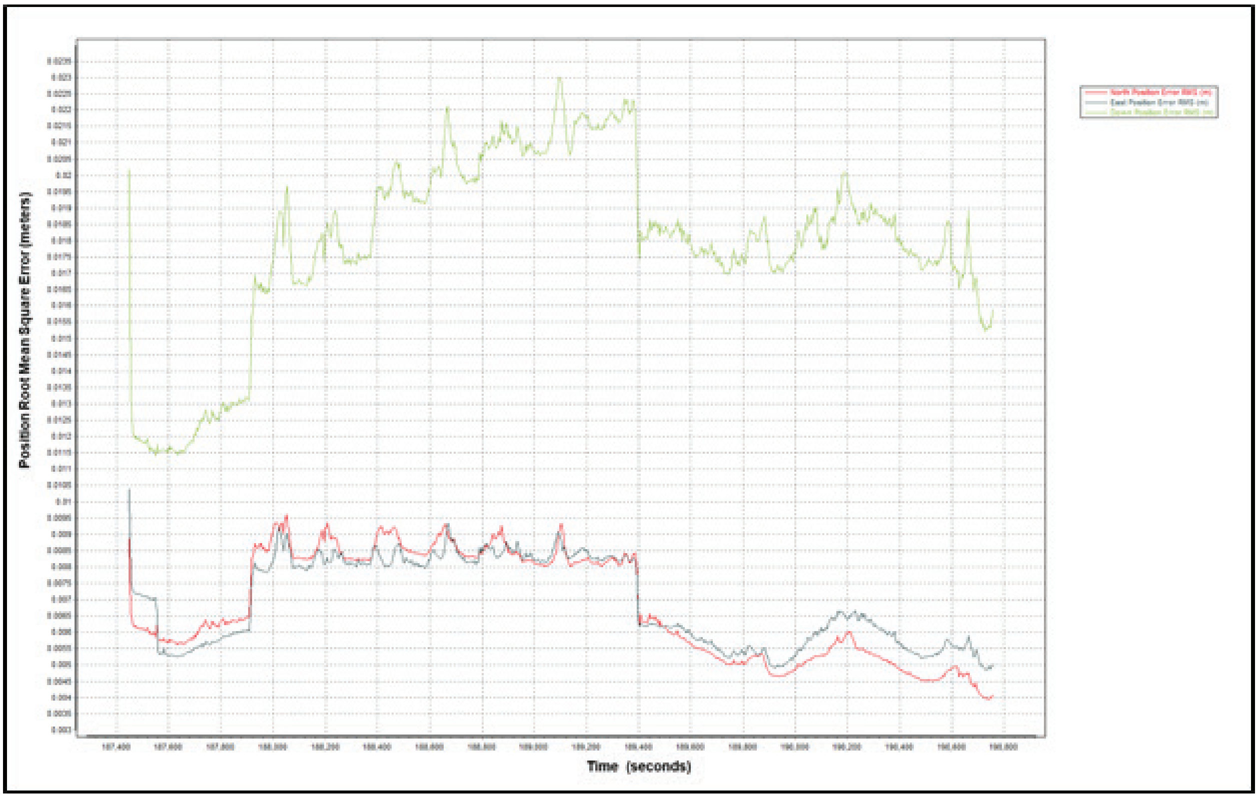


Figure 8. Smoothed Performance Metric parameters of a Kipit Flight 2189P

The time of flight was from 187,400 seconds to 190,800 seconds, which corresponds to morning of November 11, 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 starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 0.95 centimeters, the East position RMSE peaks at 0.97 centimeters, and the Down position RMSE peaks at 2.31 centimeters, which are within the prescribed accuracies described in the methodology.

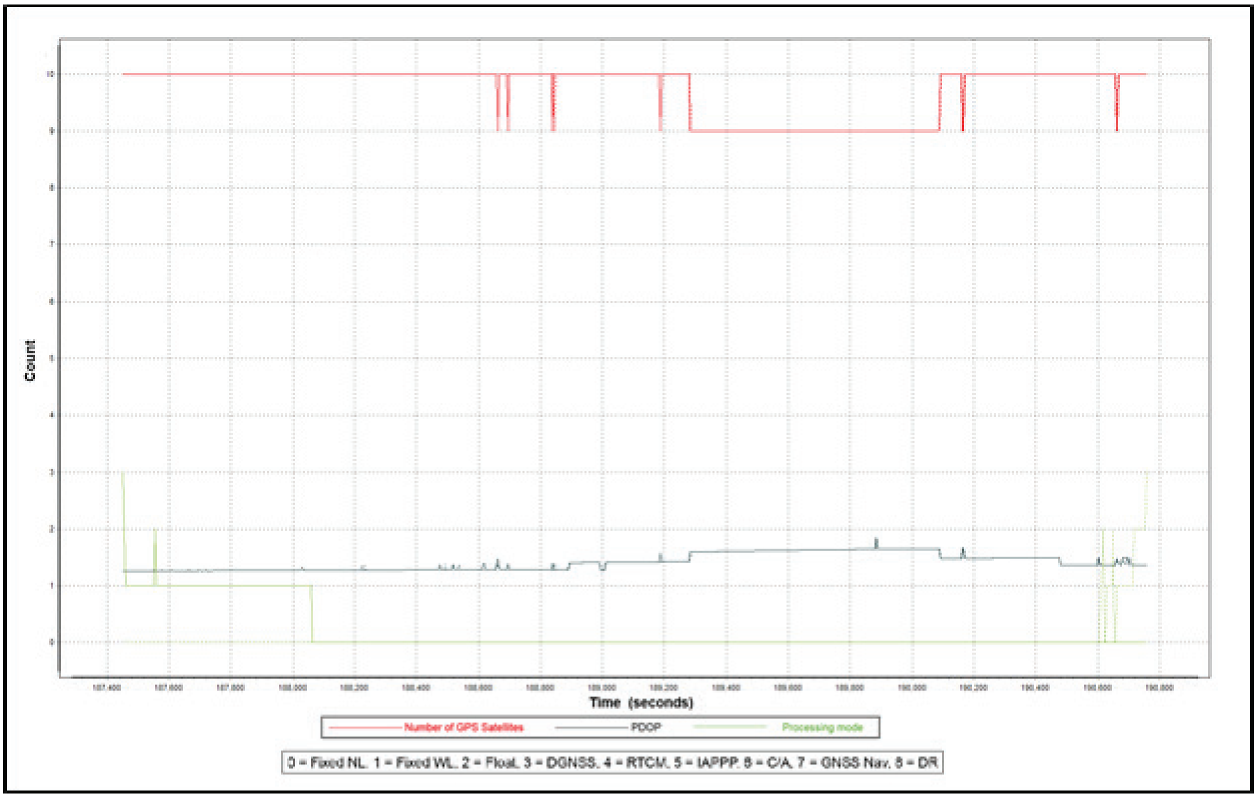


Figure 9. Solution Status Parameters of Kipit Flight 2189P

The Solution Status parameters of flight 2189P, one of the Kipit flights, which are the number of GPS satellites, Positional Dilution of Precision, 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 9. Majority of the time, the number of satellites tracked was between 9 and 10. The PDOP value also did not go above the value of 3, which still indicates optimal GPS geometry. The processing mode stayed at the value of 0 for almost the entire survey time with some parts go to 1 attributed to the turn performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Kipit flights is shown in Figure 10.

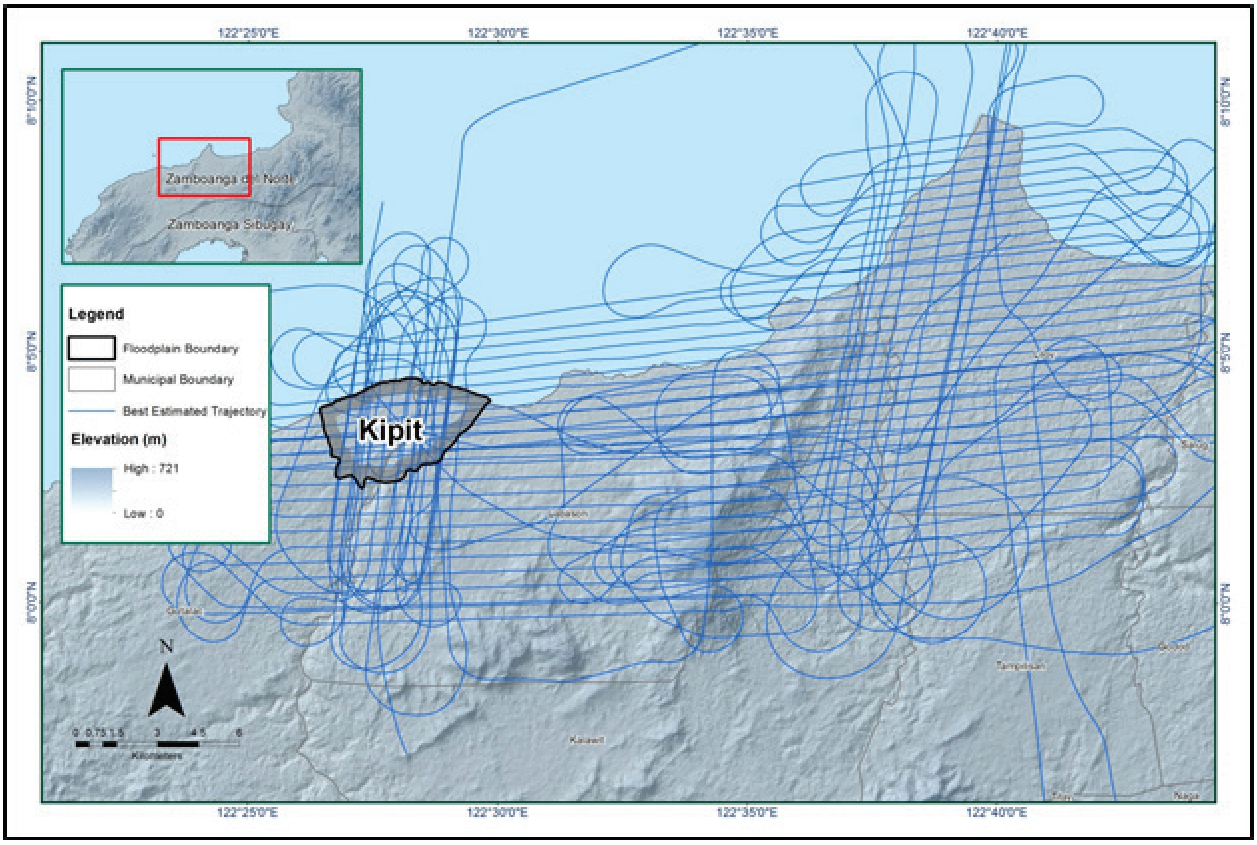


Figure 10. Best estimated trajectory of the LiDAR missions conducted over the Kipit Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 98 flight lines, with each flight line containing two 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 Kipit Floodplain is given in Table 9.

Table 9. Self-calibration results values for Kipit flights

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000281
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000827
GPS Position Z-correction stdev	(<0.01meters)	0.0058

The optimum accuracy is obtained for all Kipit 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.

3.5 LiDAR Data Quality Checking

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

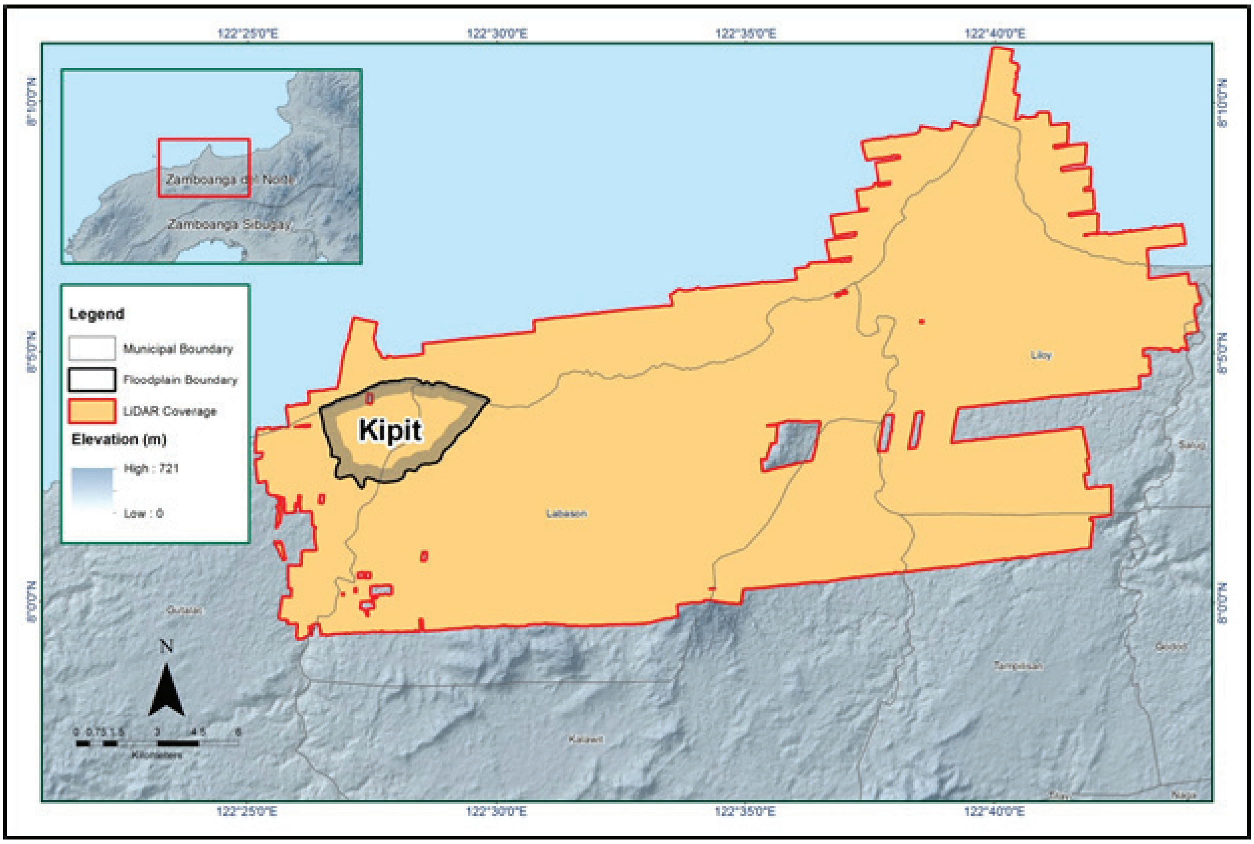


Figure 11. Boundary of the processed LiDAR data over Kipit Floodplain

The total area covered by the Kipit missions is 463.53 sq.km and comprised of 5 flight acquisitions grouped and merged into 4 blocks as shown in Table 10.

Table 10. List of LiDAR blocks for Kipit Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
	2169P	199.65
	2185P	
	2189P	
NorthernMindanao_Blk67G	2185P	11.77
NorthernMindanao_Blk67E	23582P	125.71
	23590P	126.40
TOTAL		463.53

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is shown in Figure 23. Since the Pegasus system employs two channels, an average value of 2 (blue) is expected for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

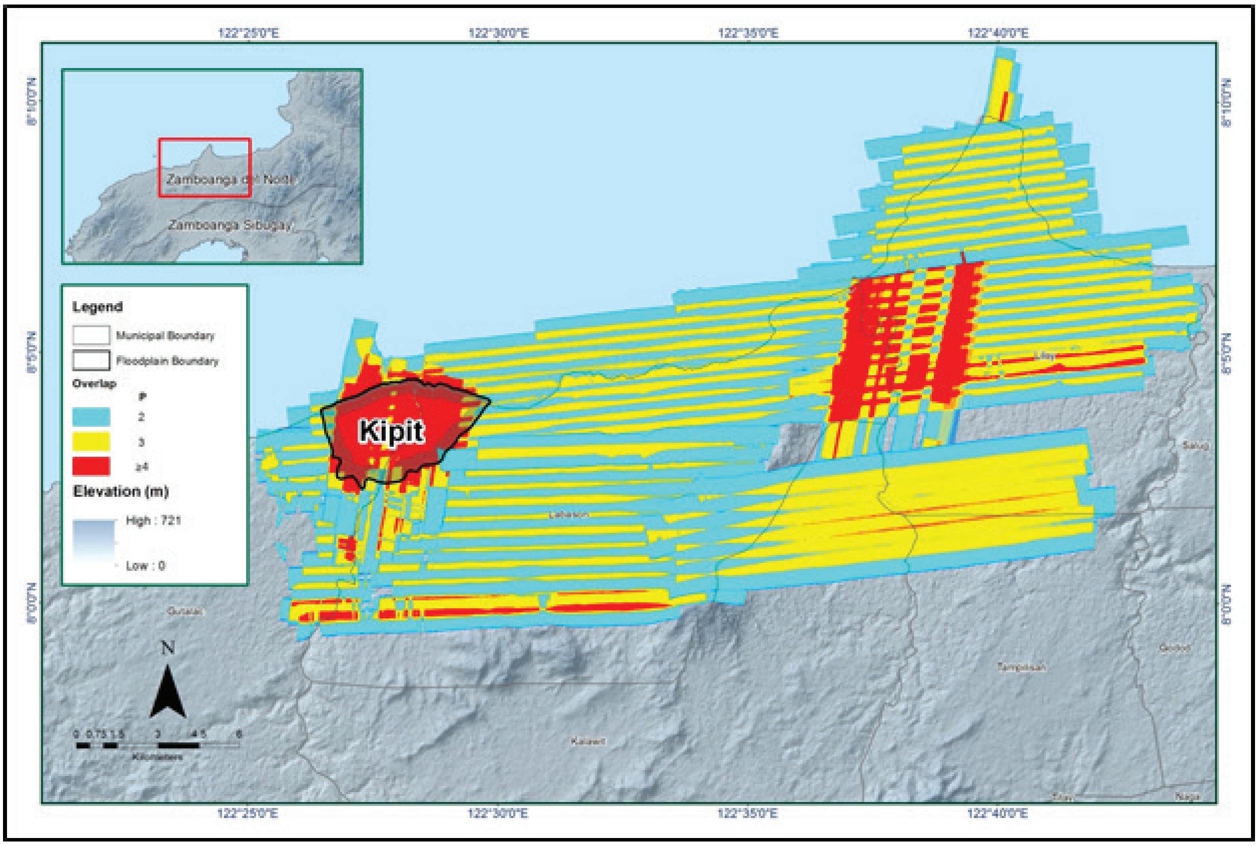


Figure 12. Image of data overlap for Kipit Floodplain

The overlap statistics per block for the Kipit Floodplain can be found in Annex 8. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 41.91% and 61.13%, respectively, which passed the 25% requirement.

The density map for the merged LiDAR data is shown in Figure 13, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion. It was determined that all LiDAR data for Kipit Floodplain satisfy the point density requirement, and the average density for the entire survey area is 5.17 points per square meter.

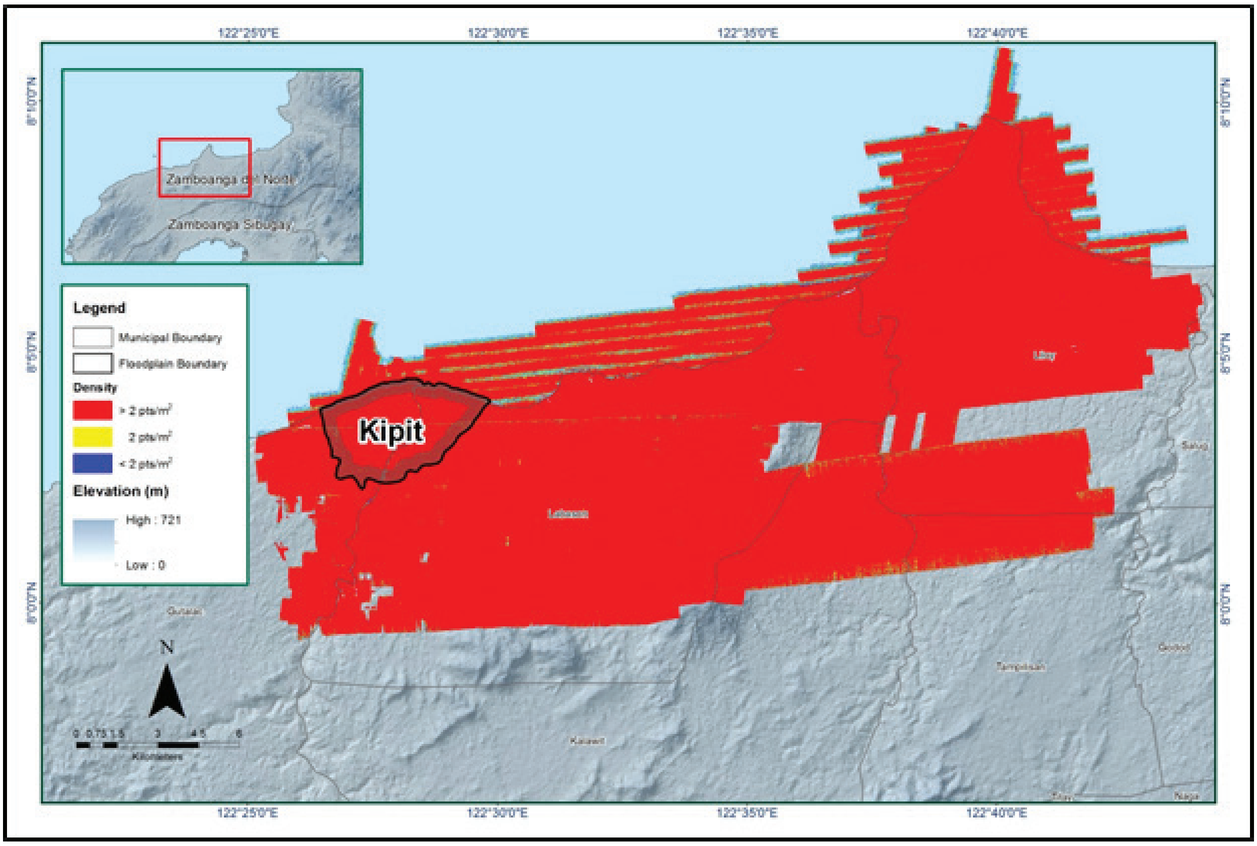


Figure 13. Density map of merged LiDAR data for Kipit Floodplain

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 Modeler software.

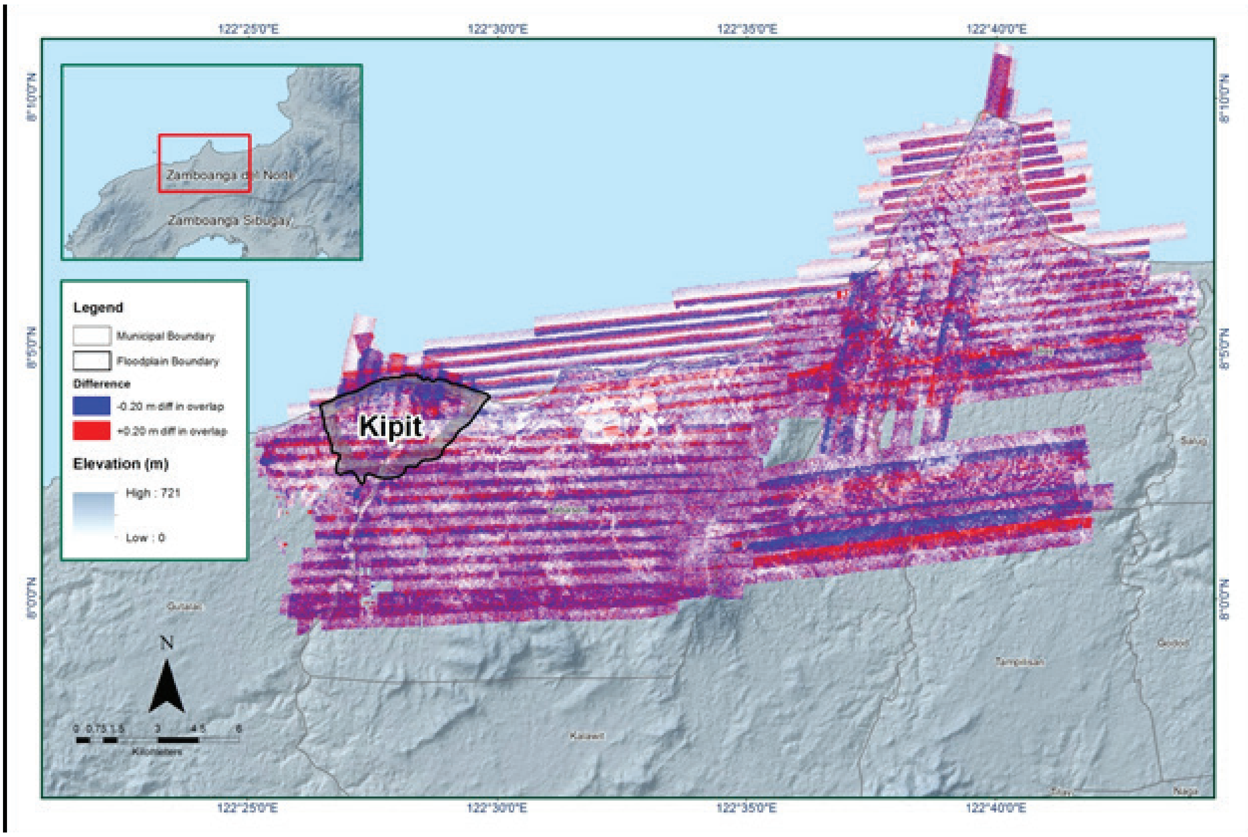


Figure 14. Elevation difference map between flight lines for Kipit Floodplain

A screen capture of the processed LAS data from a Kipit flight 2189P 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 red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

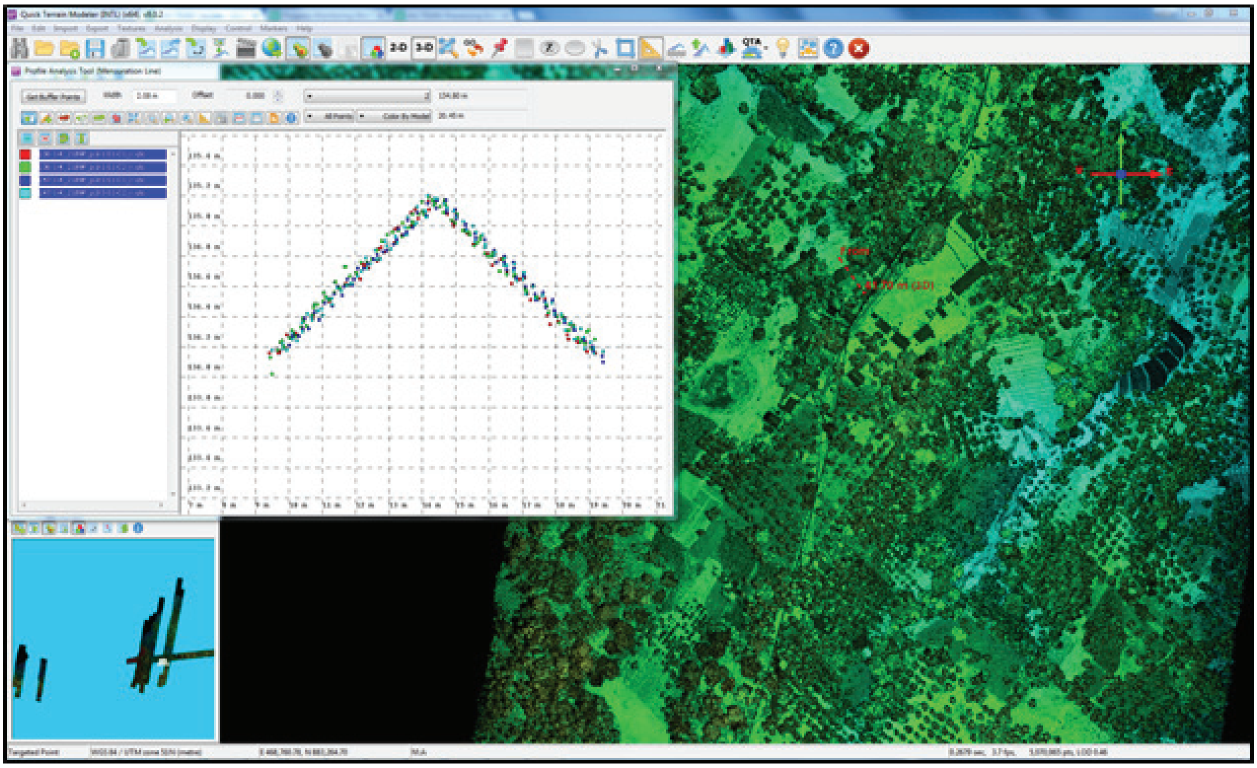


Figure 15. Quality checking for a Kipit flight 2189P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Alubijid classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	600,460,525
Low Vegetation	618,719,570
Medium Vegetation	1,056,994,637
High Vegetation	1,442,935,760
Building	30,435,912

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Kipit Floodplain is shown in Figure 16. A total of 653 1km by 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 845.30 meters and 53.96 meters, respectively.

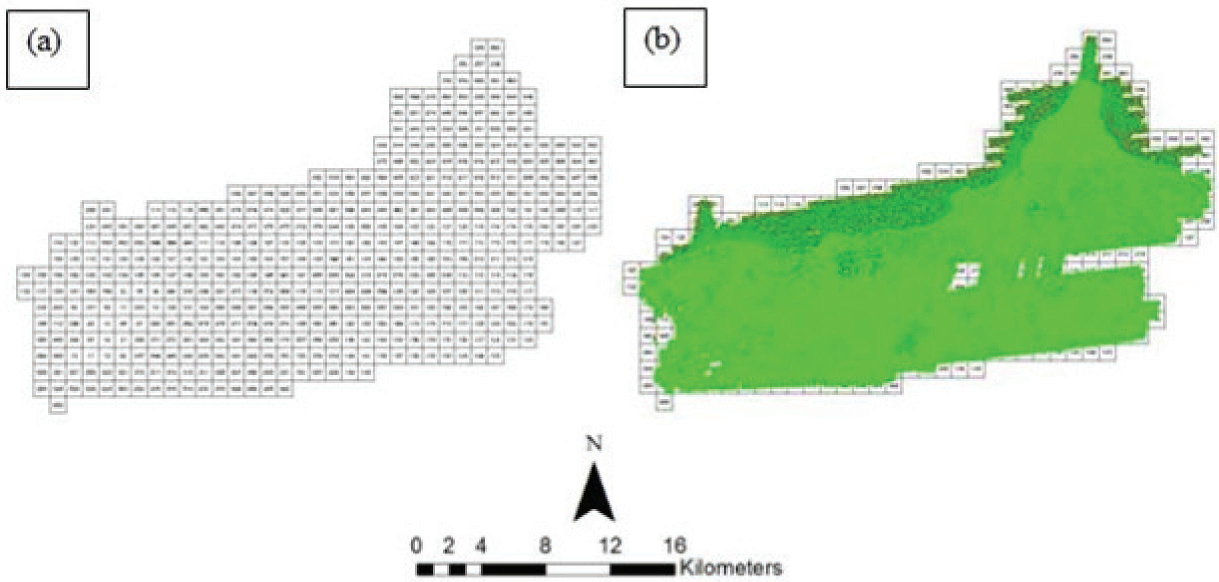


Figure 16. Tiles for Kipit Floodplain (a) and classification results (b) in TerraScan

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.

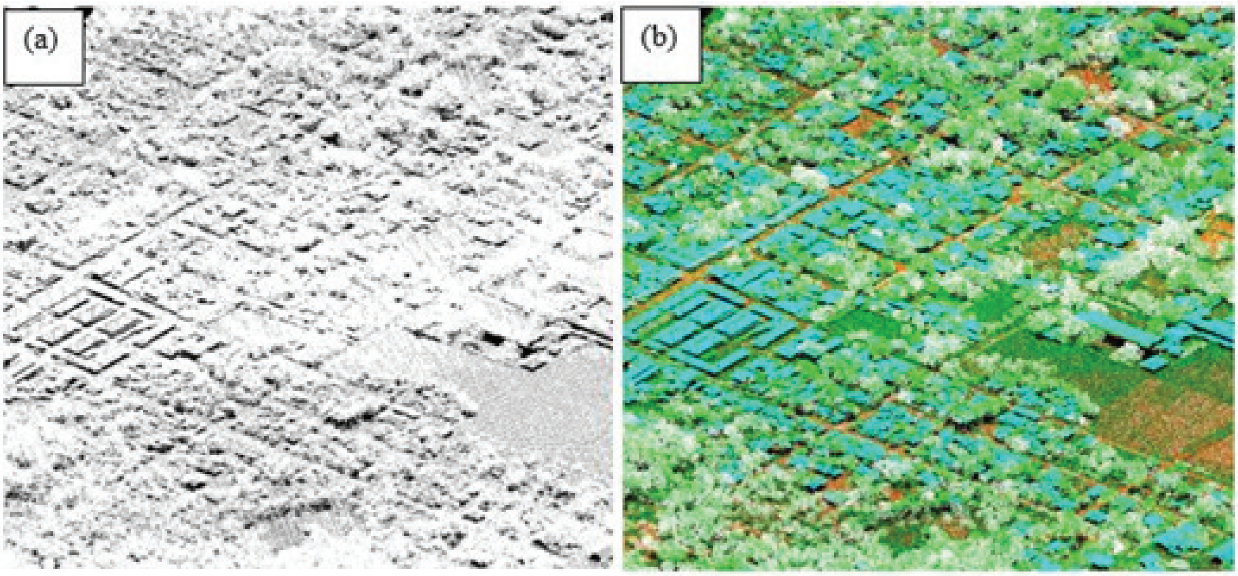


Figure 17. Point cloud before (a) and after (b) classification.

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.

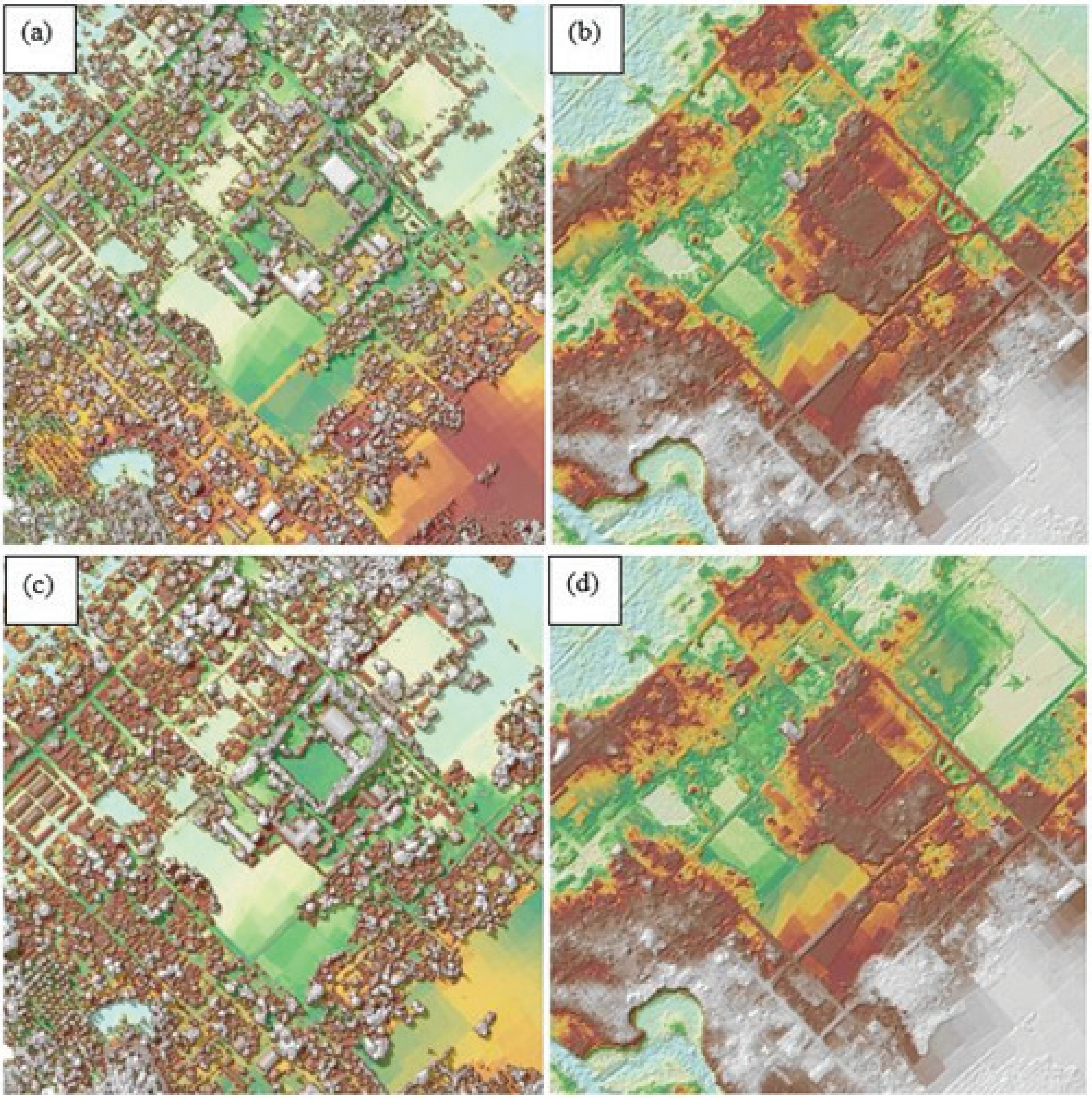


Figure 18. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Kipit Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Kipit Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Kipit floodplain. These blocks are composed of Dipolog blocks with a total area of 463.53 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Dipolog_Blk73A	199.65
Dipolog_Blk73A_additional	11.77
Dipolog_Reflights_Blk73A	125.71
Dipolog_Reflights_Blk73A_ additional	126.40
TOTAL	463.53 sq.km

Portions of DTM before and after manual editing are shown in Figure 19. The portion of the mountain (Figure 19a) has been removed during classification process and has to be retrieved to complete the surface (Figure 19b) to allow the correct flow of water. The bridge (Figure 19c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 19d) in order to hydrologically correct the river.

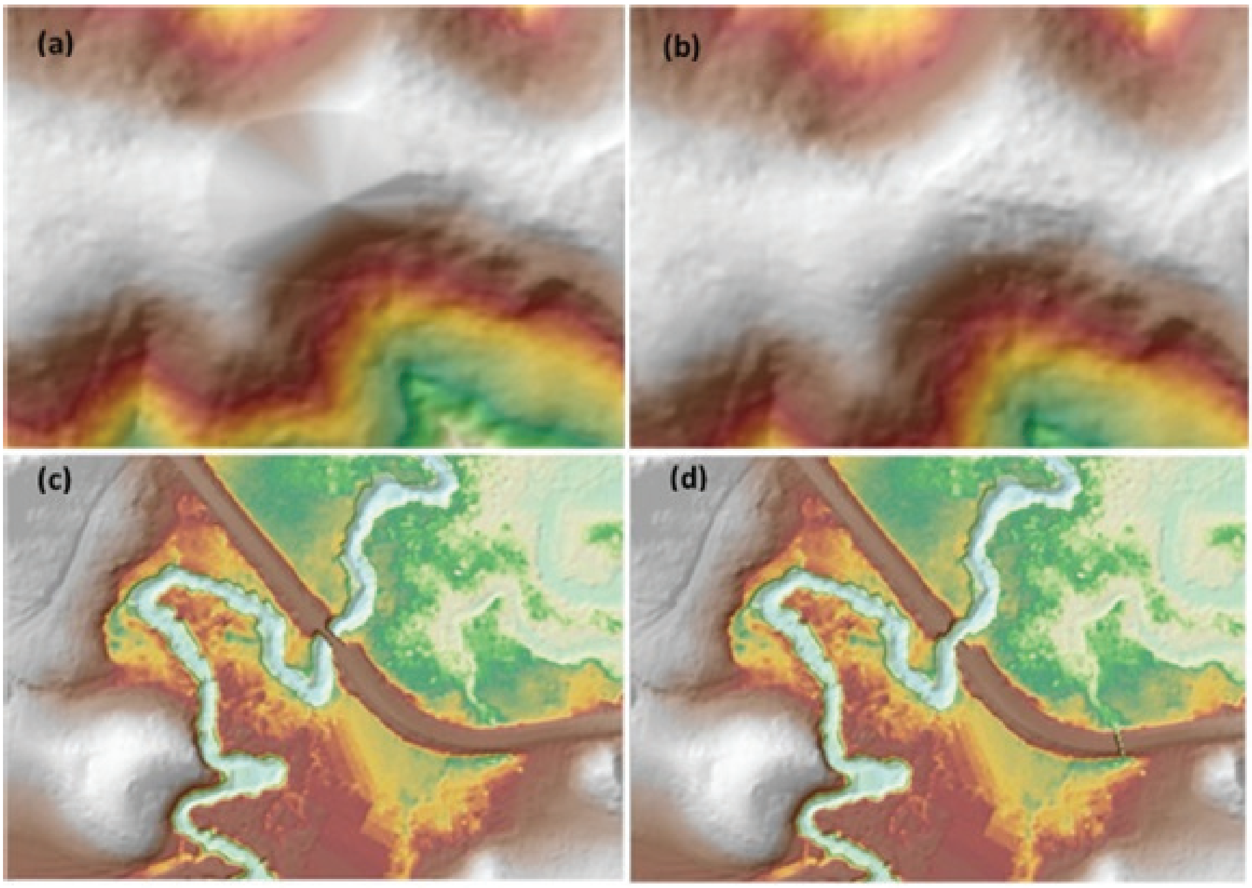


Figure 19. Portions in the DTM of Kipit Floodplain—a cut portion of the mountain before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

Dipolog_Blk73B was used as the reference block at the start of mosaicking because it was the first available data at that time. Table 13 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Kipit Floodplain is shown in Figure 20. It can be seen that the entire Kipit Floodplain is 99.00% covered by LiDAR data.

Table 13. Shift values of each LiDAR Block of Kipit Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Dipolog_Blk73A	0.00	0.00	0.43
Dipolog_Blk73A_additional	0.00	0.00	0.38
Dipolog_reflight_Blk73A	0.00	0.00	0.68
Dipolog_reflights_Blk73A_ additional(Upper)	0.85	0.39	0.58
Dipolog_reflights_Blk73A_ additional(Lower)	0.26	0.52	0.49

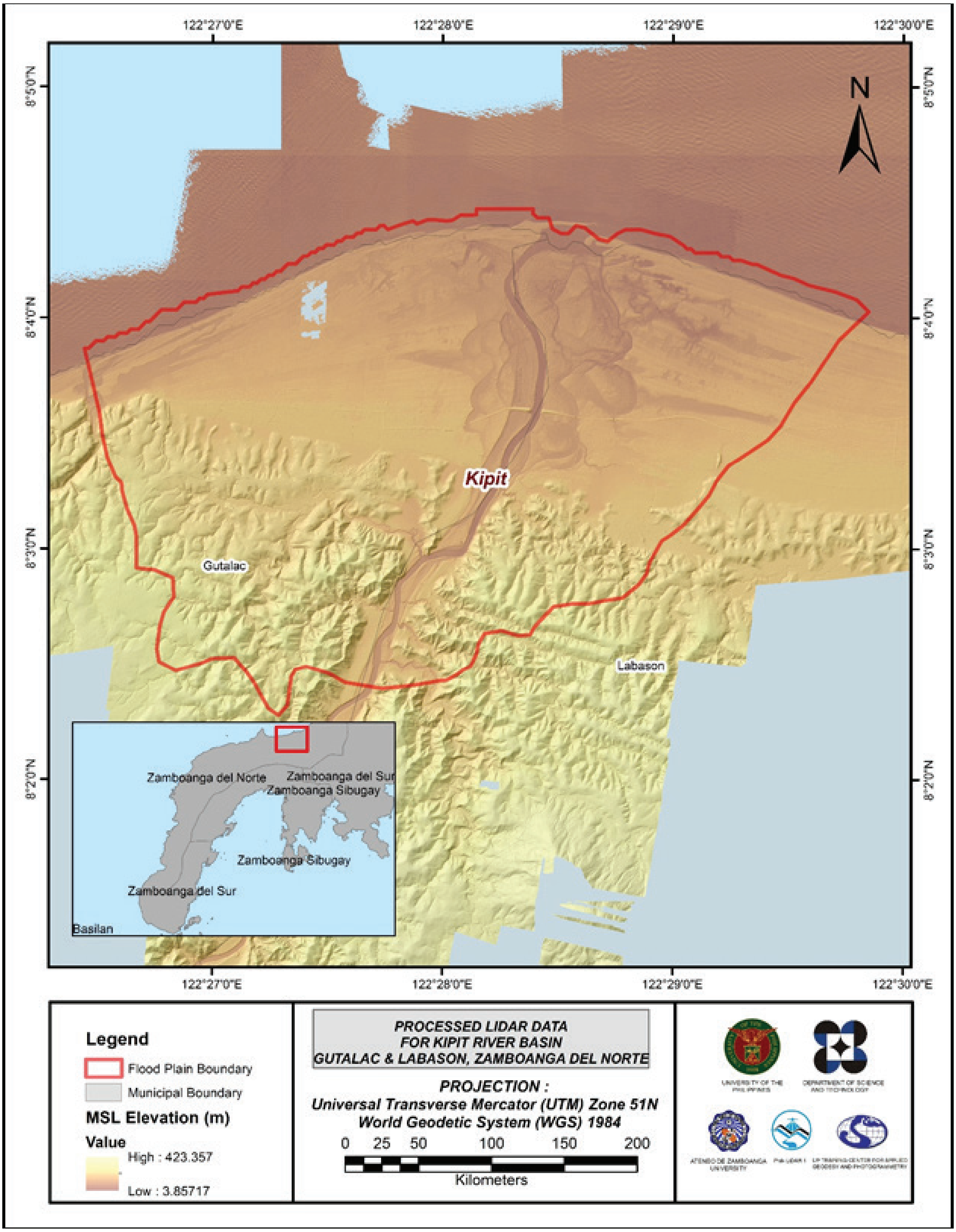


Figure 20. Map of processed LiDAR data for Kipit Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Kipit to collect points with which the LiDAR dataset was validated is shown in Figure 21. A total of 5,856 survey points were used for calibration and validation of Kipit LiDAR data. Random selection of 80% of the survey points, resulting in 4,685 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 22. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 4.62 meters with a standard deviation of 0.16 meters. Calibration of Kipit LiDAR data was done by adding the height difference value, 4.62 meters, to Kipit mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

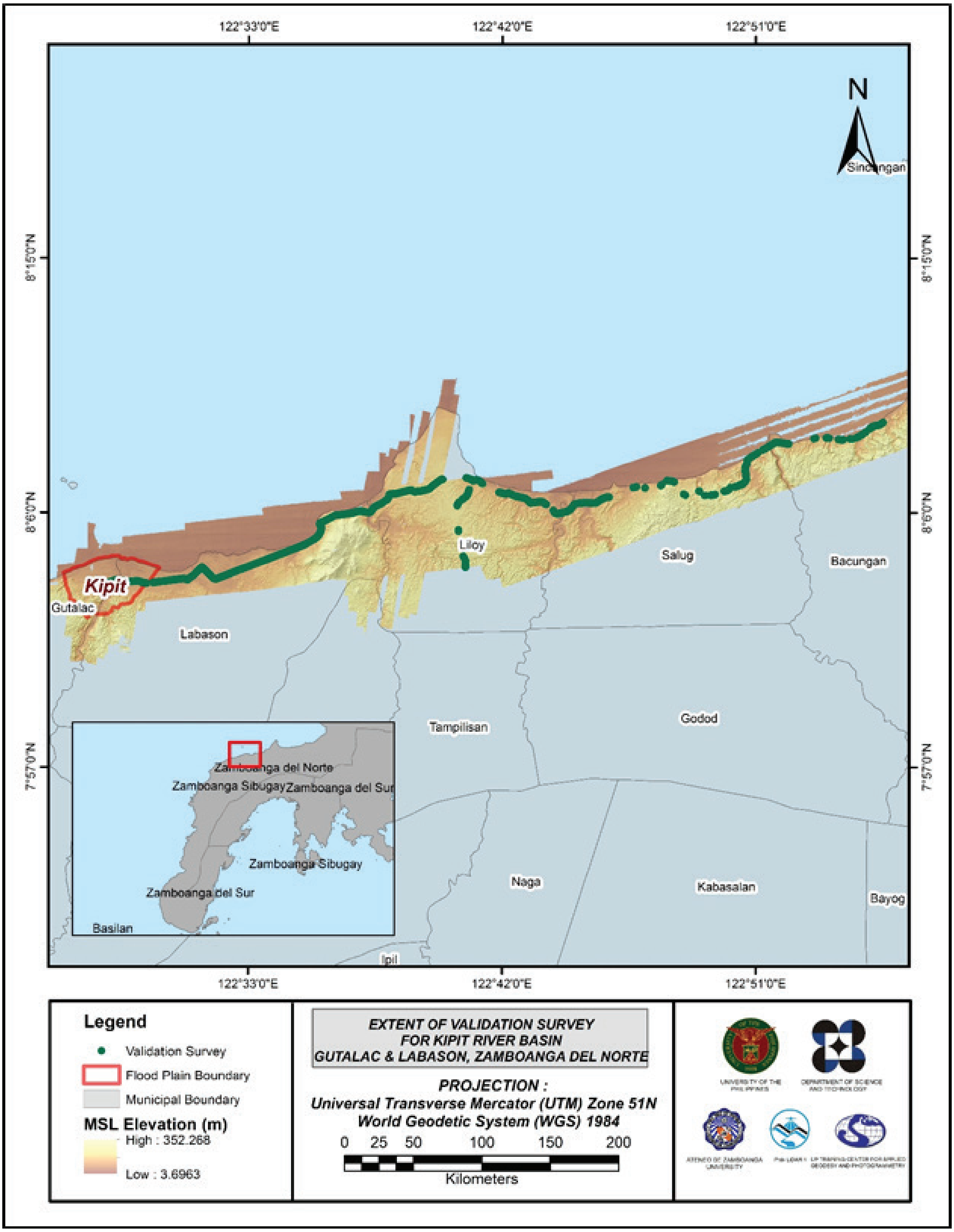


Figure 21. Map of Kipit Floodplain with validation survey points in green

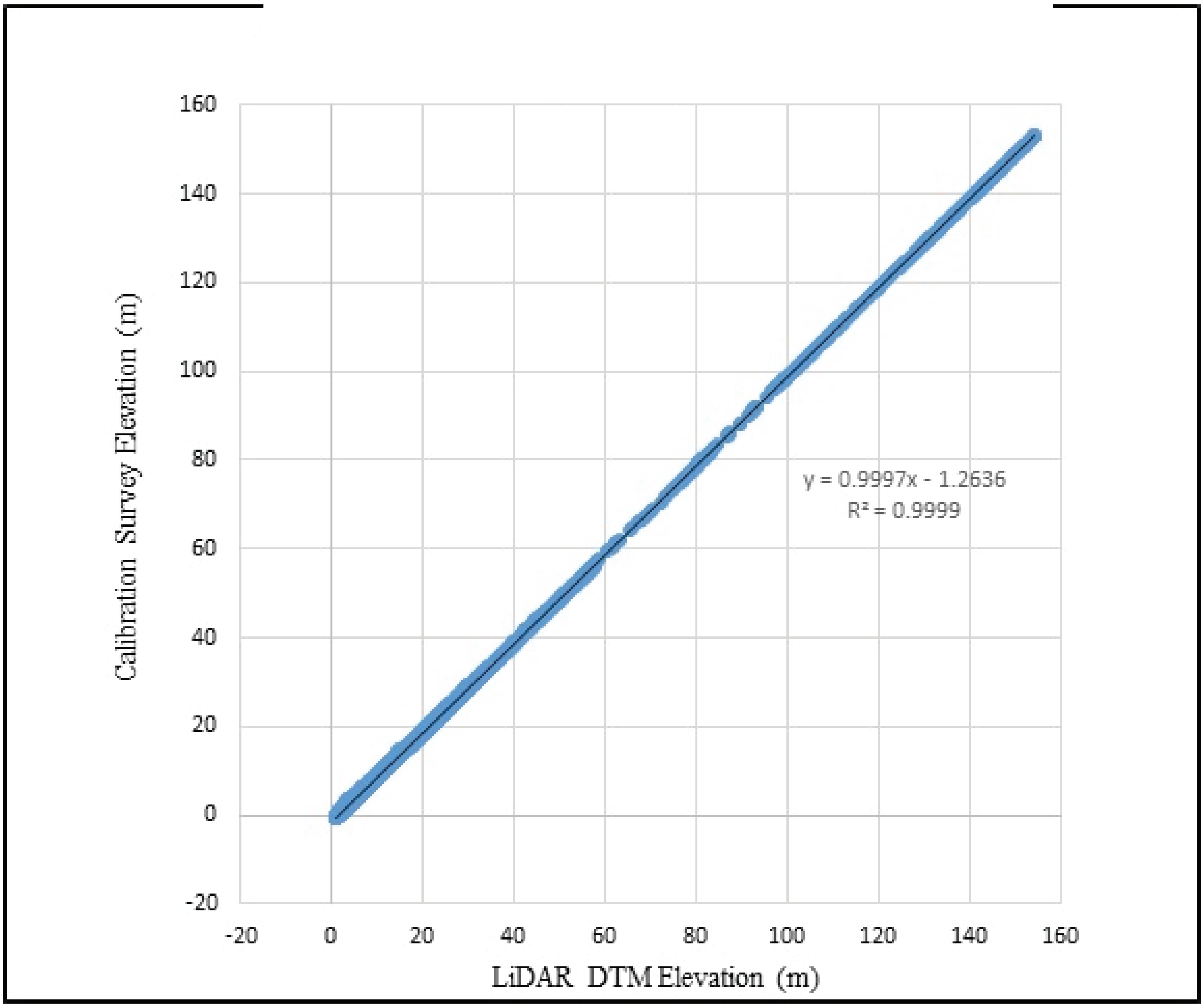


Figure 22. Correlation plot between calibration survey points and LiDAR data

Table 14. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	4.62
Standard Deviation	0.16
Average	4.62
Minimum	4.30
Maximum	4.93

The remaining 20% of the total survey points, equivalent to 1171.94 of the said points, lie within the Kipit Floodplain and were used for the validation of calibrated Kipit 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 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.05 meters, as shown in Table 15.

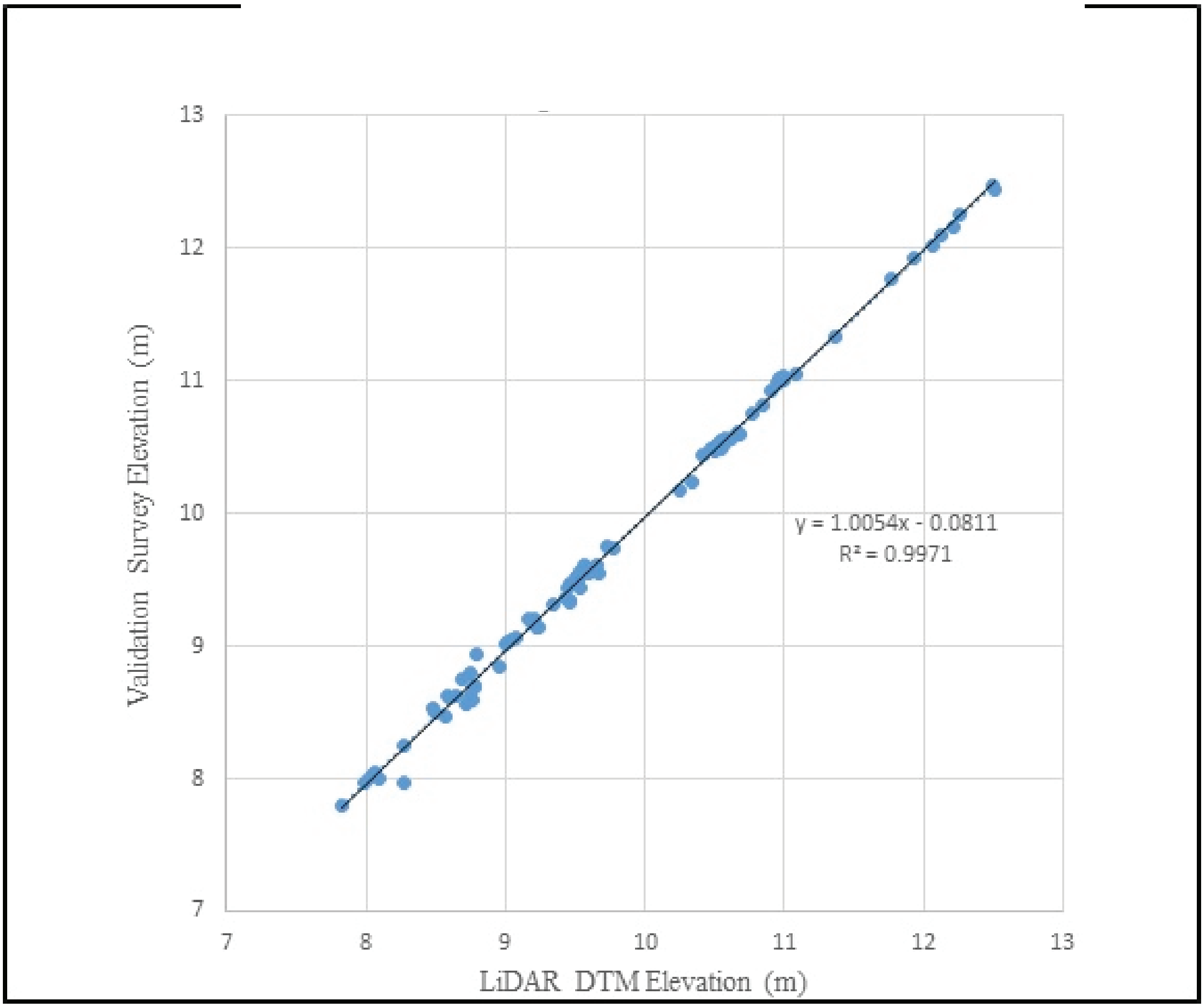


Figure 23. Correlation plot between validation survey points and LiDAR data

Table 15. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.06
Standard Deviation	0.06
Average	0.02
Minimum	-0.09
Maximum	0.14

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross section data was available for Kipit with 1,023 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.05 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Kipit integrated with the processed LiDAR DEM is shown in Figure 24.

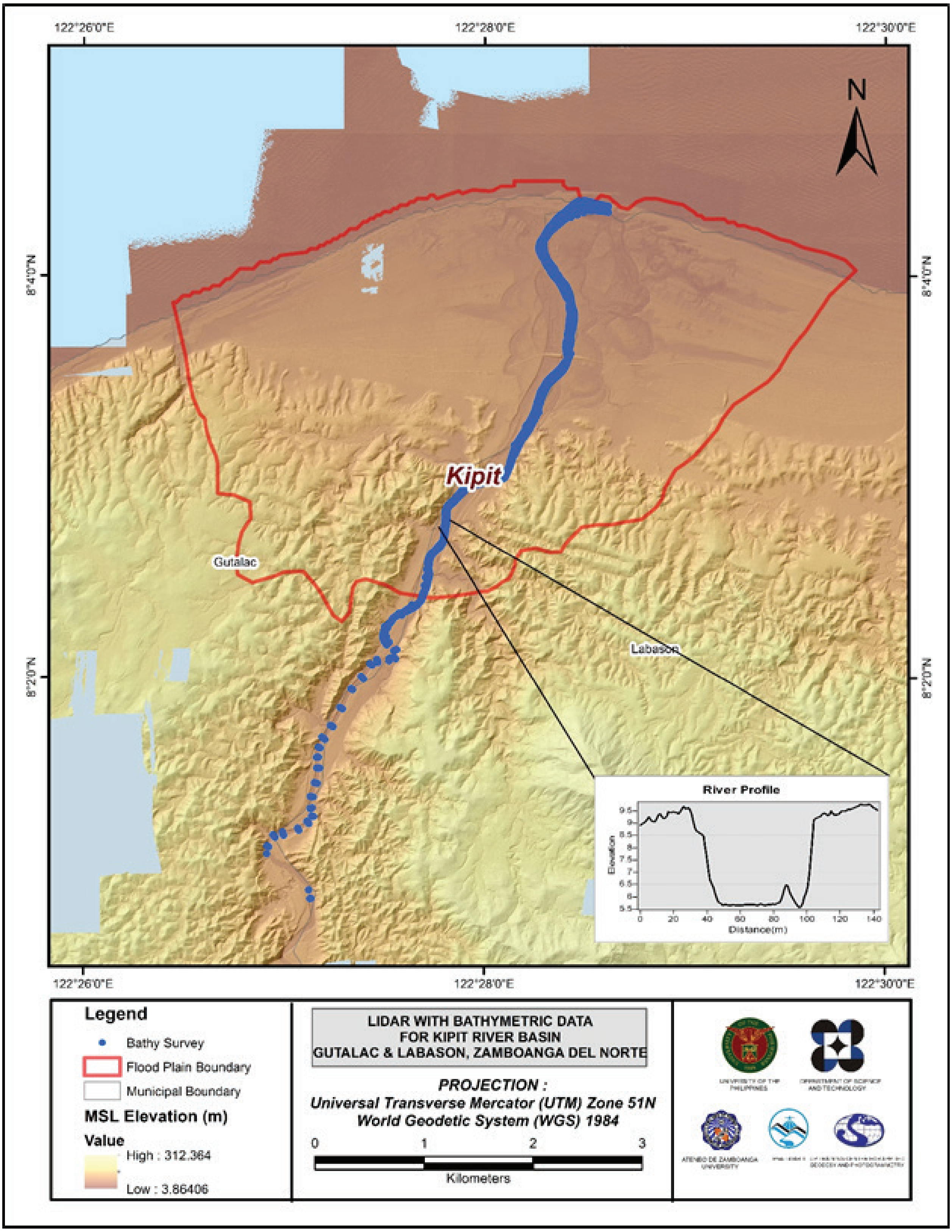


Figure 26. Extent of the bathymetric survey (in bluea Figure 24. Map of Kipit Floodplain with bathymetric survey points shown in blue line) in Alubijid River and the LiDAR data validation survey (red).

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Kipit Floodplain, including its 200m buffer, has a total area of 19.46 sq.km. For this area, a total of 5.00 sq.km, corresponding to a total of 534 building features, are considered for QC.

Figure 25 shows the QC blocks for Kipit Floodplain.

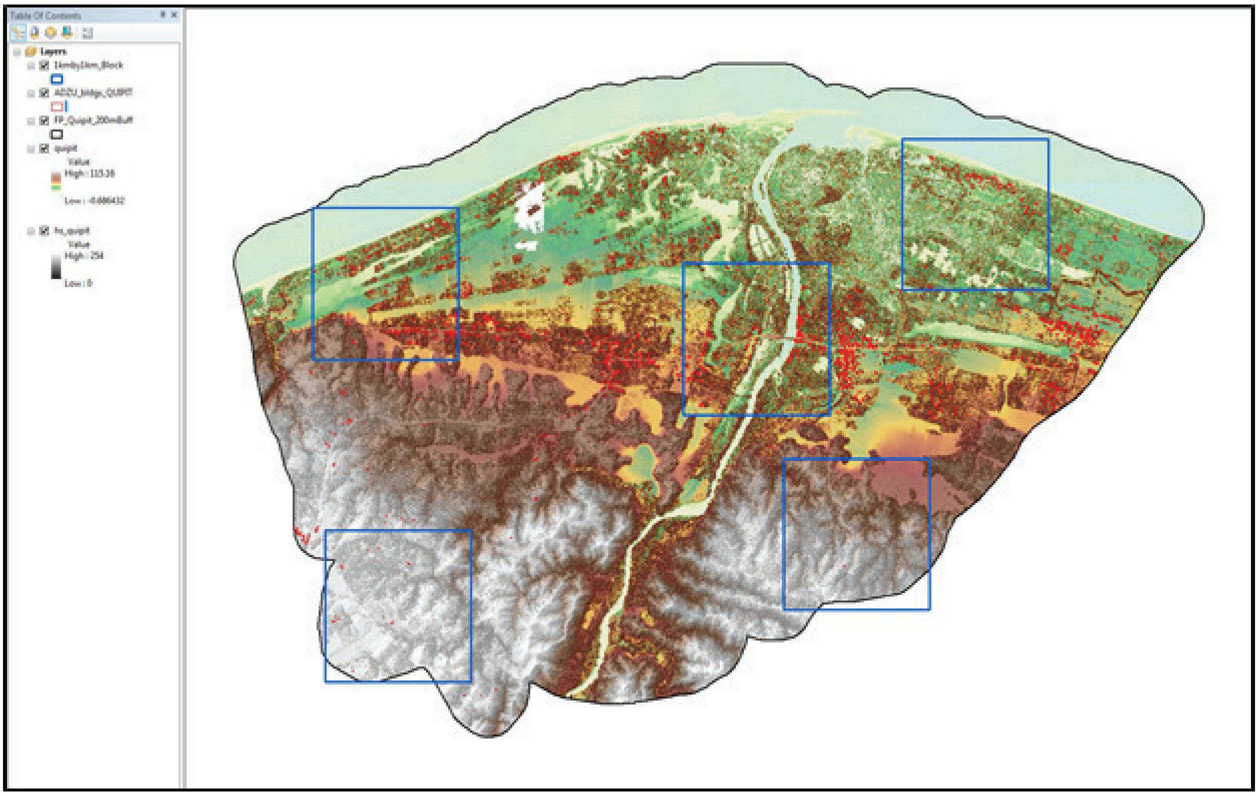


Figure 25. Blocks (in blue) of Kipit building features subjected to QC

Quality checking of Kipit building features resulted in the ratings shown in Table 16.

Table 16. Quality checking ratings for Kipit building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Kipit	100.00	89.43	99.46	PASSED

3.12.2 Height Extraction

Height extraction was done for 1,771 building features in Kipit Floodplain. Of these building features, none was filtered out after height extraction, resulting in 1,771 buildings with height attributes. The lowest building height is at 2.00m, while the highest building is at 7.81m.

3.12.3 Feature Attribution

One of the Research Associate of ADZU Phil-LiDAR 1 was able to develop GEONYT, an offline web-based application for feature attribution extracted from a LiDAR-based Digital Surface Model. The attribution is conducted by combining automatic data consolidation, geotagging, and offline navigation. The app is conveniently integrated in a smart phone/ tablet. The data collected are automatically stored in database and can be viewed as CSV (or excel) and KML (can viewed via google earth). The GEONYT App was the main tool used in all feature attribution activity of the team.

The team conducted a 2-day Feature Attribution through Community-based Mapping. With the help of the Mayor's Office and the Local Disaster Risk Reduction and Management Office, 2 to 3 representatives from the barangay identified as included in the river basin floodplain were invited in the said activity. The representatives aided in identifying the features in the floodplain through the use of GEONYT.

For the features which were not covered, the LGUs, through LDRRM, endorsed a number of enumerators and hired them to conduct the house-to-house survey of the features also using the GEONYT application. The team provided the enumerators smart tablets integrated with GEONYT. The number of days by which the survey was conducted depended on the number of the remaining features which is yet to be covered in floodplain of the river basin; likewise, the number of enumerators also depended on the availability of the tablet and the number of features of the floodplain.

Table 17 summarizes the number of building features per type. Table 18 shows the total length of each road type, while Table 19 presents the number of water features extracted per type.

Table 17. Number of building features extracted for Kipit Floodplain

Facility Type	No. of Features
Residential	1710
School	15
Market	11
Agricultural/Agro-Industrial Facilities	5
Medical Institutions	0
Barangay Hall	2
Military Institution	0
Sports Center/Gymnasium/Covered Court	3
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	0

Water Supply/Sewerage	0
Religious Institutions	12
Bank	1
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	5
Other Commercial Establishments	4
N/A	2
Total	1771

Table 18. Total length of extracted roads for Kipit Floodplain

Floodplain	**Road Network Length (km)**					**Total**
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Kipit	0.00	13.48	0.00	8.34	0.00	21.82

Table 19. Number of extracted water bodies for Kipit Floodplain

Floodplain	**Water Body Type**					**Total**
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Kipit	29	0	1	0	0	30

A total of 2 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 26 shows the Digital Surface Model (DSM) of Kipit Floodplain overlaid with its ground features.

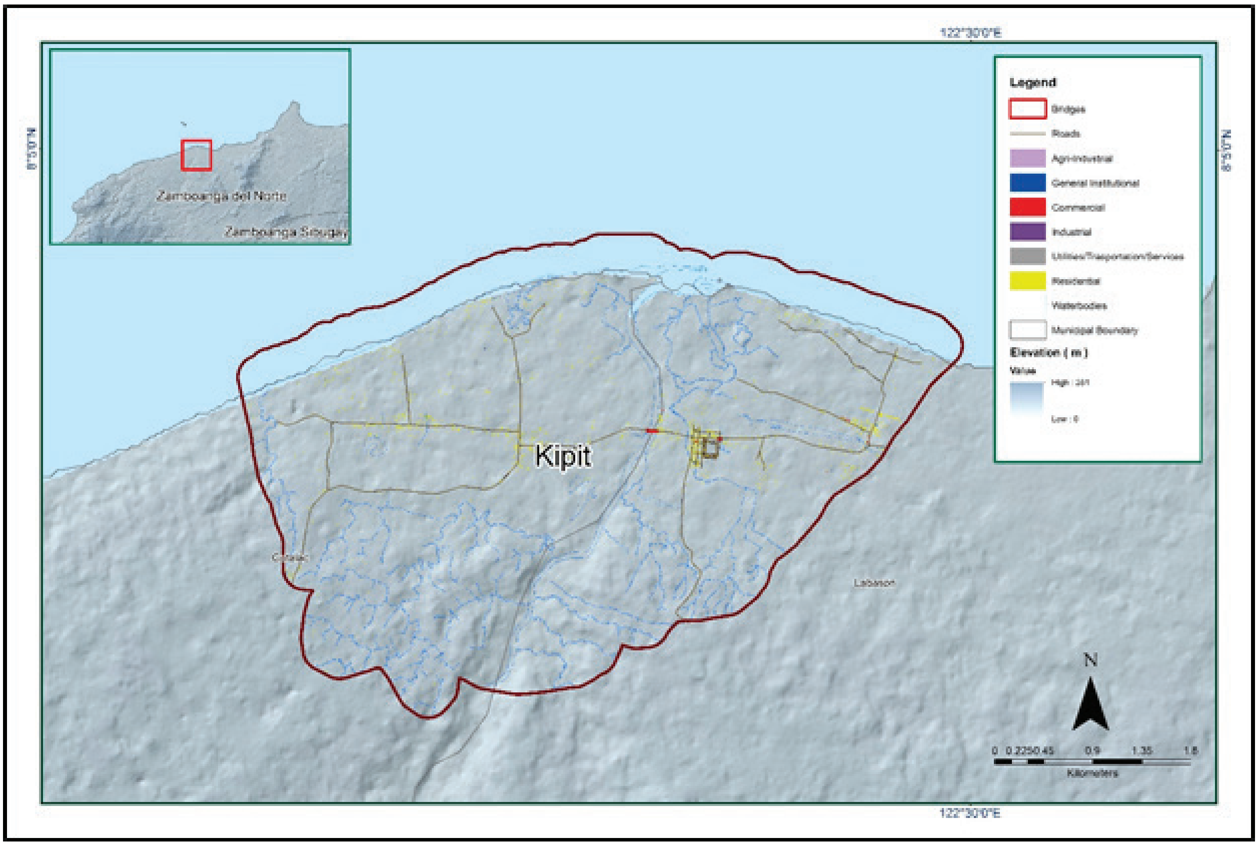


Figure 26. Extracted features for Kipit Floodplain

Chapter 4: LiDAR Validation Survey and Measurements of the Kipit River Basin

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, Vie Marie Paola M. Rivera

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

AB Surveying and Development (ABSD) conducted a field survey in Kipit River on April 3, 21, 22, 24, 25, 2016 with the following scope of work: cross-section, bridge as-built and water level marking in MSL of Kipit Bridge, bathymetric survey from the mouth of the river in Brgy. Kipit in the Municipality of Labason to the upstream in Brgy. Imelda in the Municipality of Gutalac, and manual bathymetric from downstream in Brgy. Imelda in the Municipality of Gutalac to the upstream in Brgy. New Salvacion in the Municipality of Labason using GNSS survey technique, Hi-Target™ echo sounder and total station and bathymetry data were gathered by DVC on August 21-31, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Kipit River Basin area. The entire survey extent is illustrated in Figure 27.

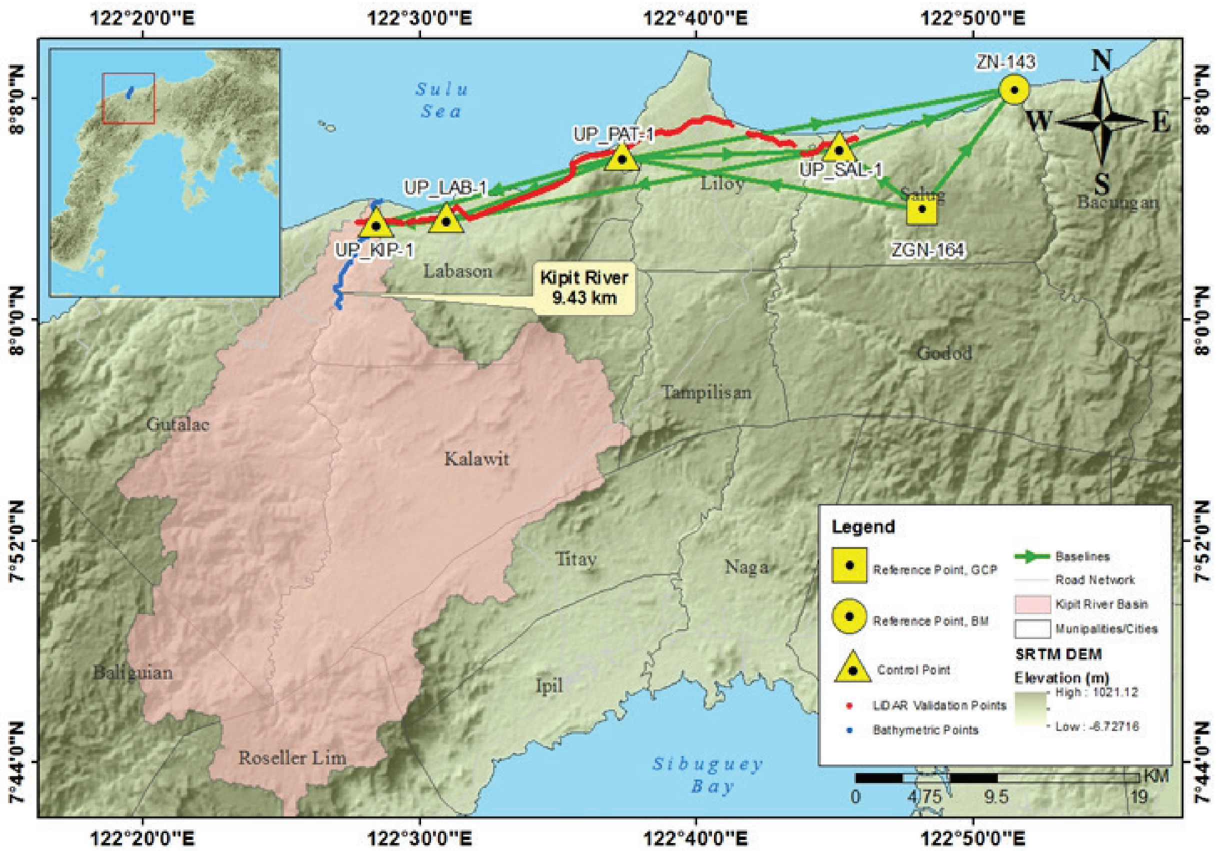


Figure 27. Extent of the bathymetric survey (in blue) in Kipit River and the LiDAR data validation survey (in red)

4.2 Control Survey

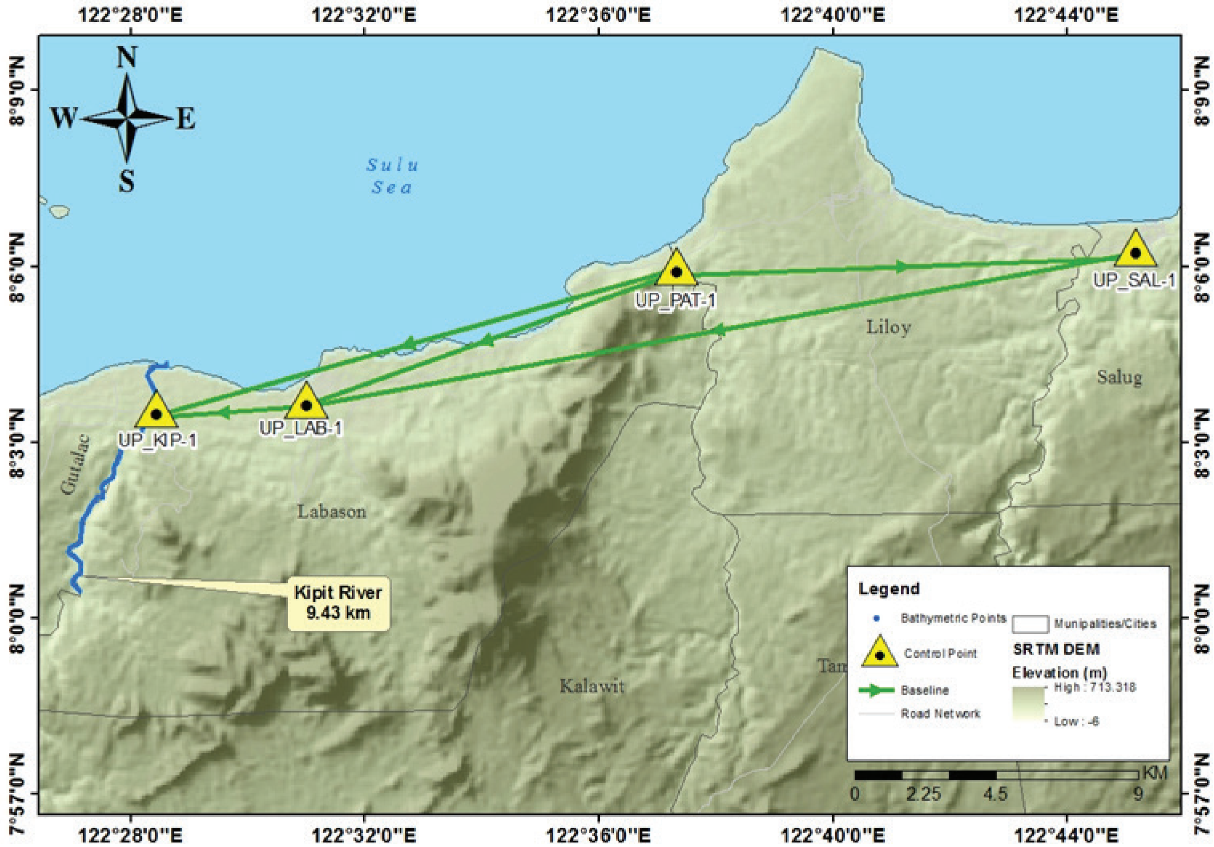
The GNSS network used for Kipit River is composed of 2 loops established on August 24, 2016 occupying the following control points established in the area by ABSD: UP_KIP-1 located at the approach of Kipit Bridge in Brgy. Kipit, Municipality of Labason, UP_LAB-1 at Labason Bridge in Brgy. Antonio, Municipality of Labason, UP_PAT-1 at the side of Labason-Liloy Road near Patawag Bridge in Brgy. Patawag, Municipality of Labason, and UP_SAL-1 located at the side of Ipil-Dipolog Highway near Salug Bridge in Brgy. La Libertad, Municipality of Gutalac.

The summary of reference and control points and its location is summarized in Table 20 while GNSS network established is illustrated in Figure 28.

Table 20. List of reference and control points used during the survey in Kipit River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
UP_KIP-1	Established	8°03'35.83524"N	122°28'26.48383"E	78.022	12.435	08-24-16
UP_LAB-1	Established	8°03'44.29109" N	122°30'59.74333"E	75.708	9.889	08-24-16
UP_PAT-1	Established	8°06'00.79142" N	122°37'19.54470"E	76.488	10.835	08-24-16
UP_SAL-1	Established	8°06'20.46964"N	122°45'09.85390"E	76.124	10.080	08-24-16

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



River Basin Control Survey Extent

Figure 29. UP_KIP-1 located at the approach of Kipit Bridge in Brgy. Kipit, Municipality of Labason, Province of Zamboanga del Norte

Figure 30. GNSS base set up, Trimble® SPS 882, at UP_LAB-1 at Labason Bridge in Brgy. Antonio, Municipality of Labason, Province of Zamboanga del Norte

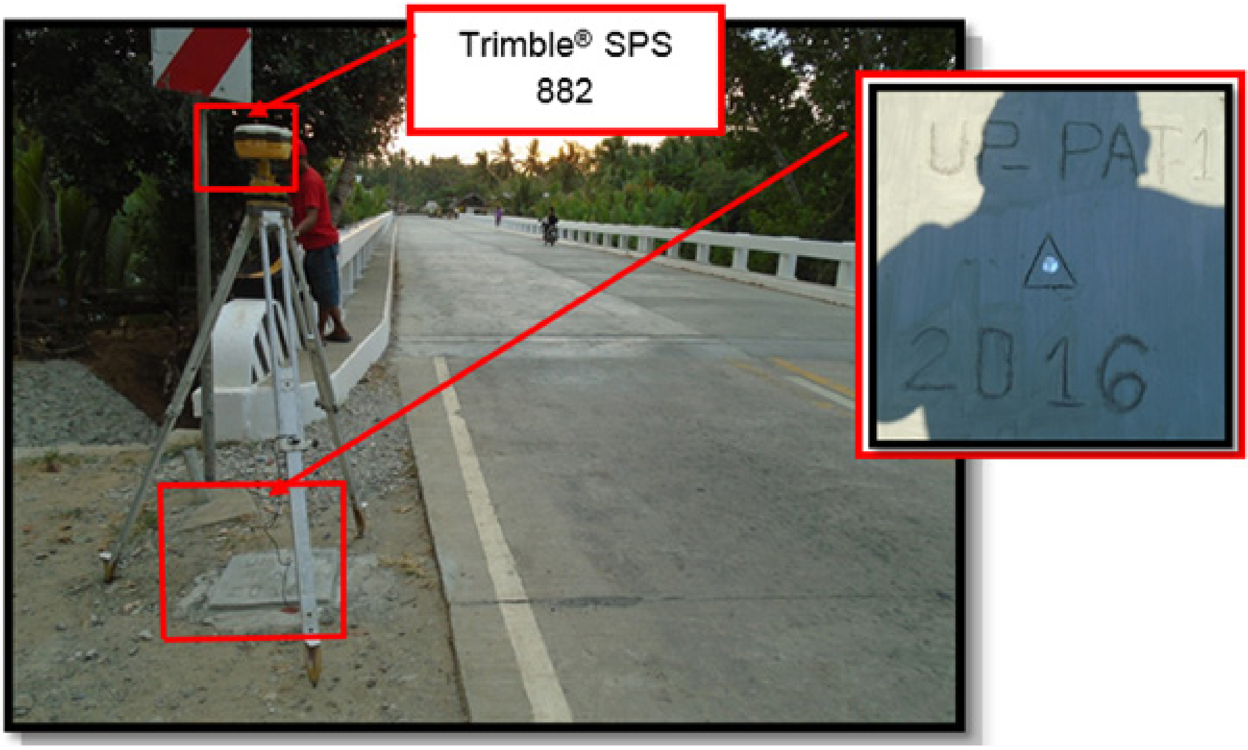


Figure 31. GNSS receiver set up, Trimble® SPS 882, UP_PAT-1 at the side of Labason-Liloy Road near Patawag Bridge in Brgy. Patawag, Municipality of Labason, Province of Zamboanga del Norte

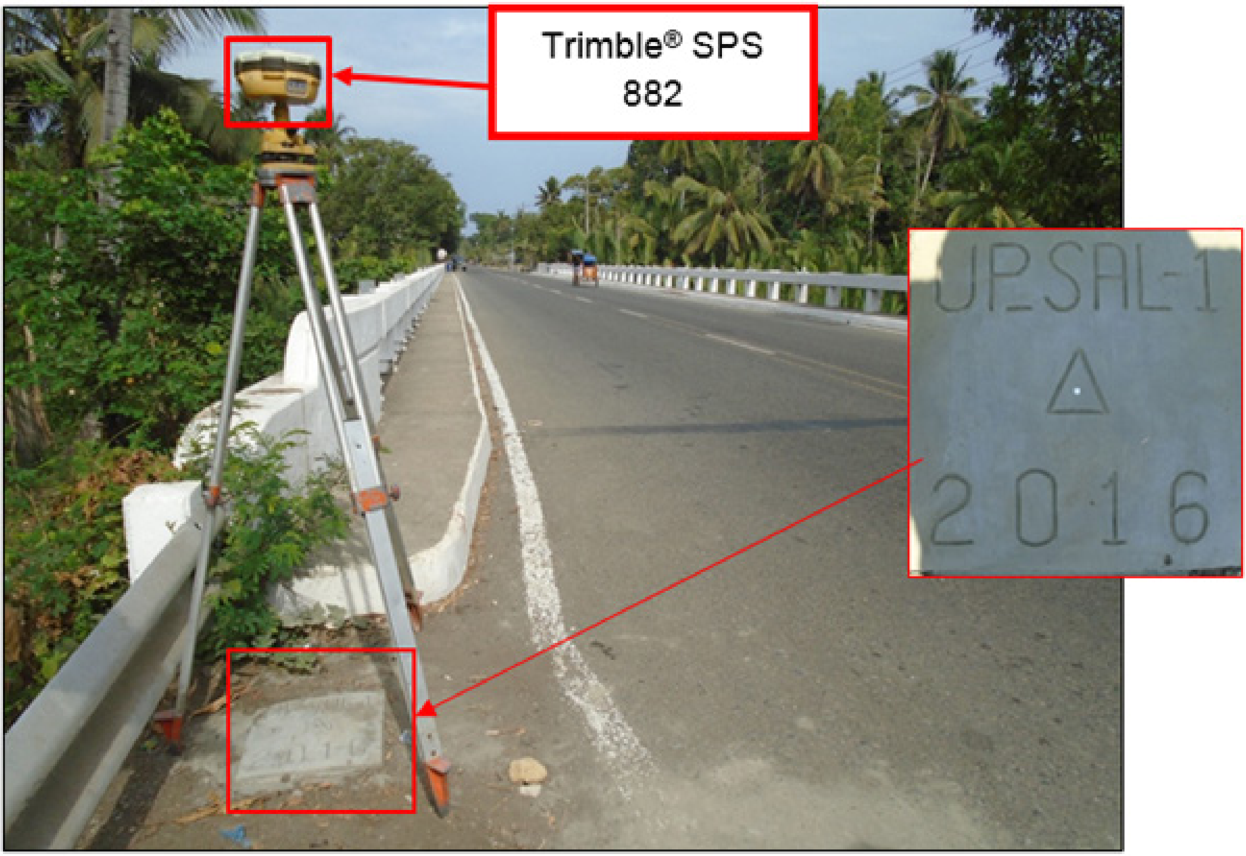


Figure 32. GNSS receiver set up, Trimble® SPS 882, UP_SAL-1 located at the side of Ipil-Dipolog Highway near Salug Bridge in Brgy. La Libertad, Municipality of Gutalac, Province of Zamboanga del Norte

4.3 Baseline Processing

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

Table 21. Baseline processing report for Kipit River static survey

Observation	Date of Observation	Solution Type	Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter	ΔHeight (Meter)
UP_KIP-1 --- UP_PAT-1	10-24-2016	Fixed	0.006	0.035	254°44'54"	16917.407	1.523
UP_LAB-1 --- UP_SAL-1	10-24-2016	Fixed	0.005	0.054	259°34'18"	26466.198	-0.410
UP_LAB-1 --- UP_KIP-1	10-24-2016	Fixed	0.006	0.033	266°50'03"	4699.763	2.326
UP_SAL-1 --- UPPAT1	10-24-2016	Fixed	0.006	0.040	87°35'11"	14411.370	-0.290
UP_LAB-1 --- UP_PAT-1	10-24-2016	Fixed	0.013	0.081	250°10'37"	12361.399	-0.729

As shown Table 21, a total of 5 baselines were processed with coordinate and ellipsoidal height values of UP_PAT-1 and UP_SAL-1 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

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 the Network Adjustment Report shown from Table 22 to Table 24 for the complete details. Refer to Annex 1 for the computation for the accuracy of ABSD.

The 4 control points, UP_KIP-1, UP_LAB-1, UP_PAT-1, and UP_SAL-1 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of UP_PAT-1 and UP_SAL-1 were held fixed during the processing of the control points as presented in Table 22. Through this reference point, the coordinates and ellipsoidal height of the unknown control points were computed.

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	Fixed	
ME-181	Local	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network is indicated in Table 23. All fixed control points have no values for grid errors and elevation error.

Table 23. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
UP_KIP-1	442045.506	0.011	890963.192	0.011	12.435	0.053	
UP_LAB-1	446736.710	0.011	891217.077	0.011	9.889	0.058	
UP_PAT-1	458365.200	?	895396.684	?	10.835	?	LLh
UP_SAL-1	472758.821	?	895989.921	?	10.080	?	LLh

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:

UP_KIP-1

horizontal accuracy = $\sqrt{((0.1)^2 + (1.1)^2}$
= $\sqrt{(0.01 + 1.21)}$
= $1.10 < 20$ cm

vertical accuracy = $5.3 < 10$ cm

UP_LAB-1

horizontal accuracy = $\sqrt{((0.1)^2 + (1.1)^2}$
= $\sqrt{(0.01 + 1.21)}$
= $1.10 < 20$ cm

vertical accuracy = $5.8 < 10$ cm

UP_PAT-1

horizontal accuracy = Fixed

vertical accuracy = Fixed

UP_SAL-1

horizontal accuracy = Fixed

vertical accuracy = Fixed

Following the given formula, the horizontal and vertical accuracy result of the 4 occupied control points are within the required precision.

Table 24. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
UP_KIP-1	8°03'35.83524"N	122°28'26.48383"E	78.022	0.053	
UP_LAB-1	8°03'44.29109" N	122°30'59.74333"E	75.708	0.058	
UP_PAT-1	8°06'00.79142" N	122°37'19.54470" E	76.488	?	LLh
UP_SAL-1	8°06'20.46964"N	122°45'09.85390"E	76.124	?	LLh

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 24. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference 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)
UP_KIP-1	Established	8°03'35.83524"N	122°28’26.48383”E	78.022	890963.192	442045.506	12.435
UP_LAB-1	Established	8°03’44.29109”N	122°30’59.74333”E	75.708	891217.077	446736.710	9.889
UP_PAT-1	Established	122°37’19.54470”E	122°37’19.54470”E	76.488	895396.684	458365.200	10.835
UP_SAL-1	Established	122°45’09.85390”E	122°45’09.85390”E	76.124	895989.921	472758.821	10.080

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

Cross-section and as-built surveys were conducted on April 3, 2016 at the upstream side of Kipit Bridge in Brgy. Kipit, Municipality of Labason, Province of Zamboanga del Norte as shown in Figure 33. A Nikon® Total Station was utilized for this survey as shown in Figure 34.

Figure 33. Kipit Bridge facing upstream

Figure 34. As-built survey of Kipit Bridge

The cross-sectional line of Kipit Bridge is about 233.699m with 133 cross-sectional points using the control points UP_KIP-1 and UP_KIP-2 as the GNSS base stations. The cross-section diagram, location map and the bridge data form are shown in Figure 35 to Figure 37.
No bridge cross-section or bridge points checking data were gathered for Kipit Bridge because the contractor's data passed the quality assessment.

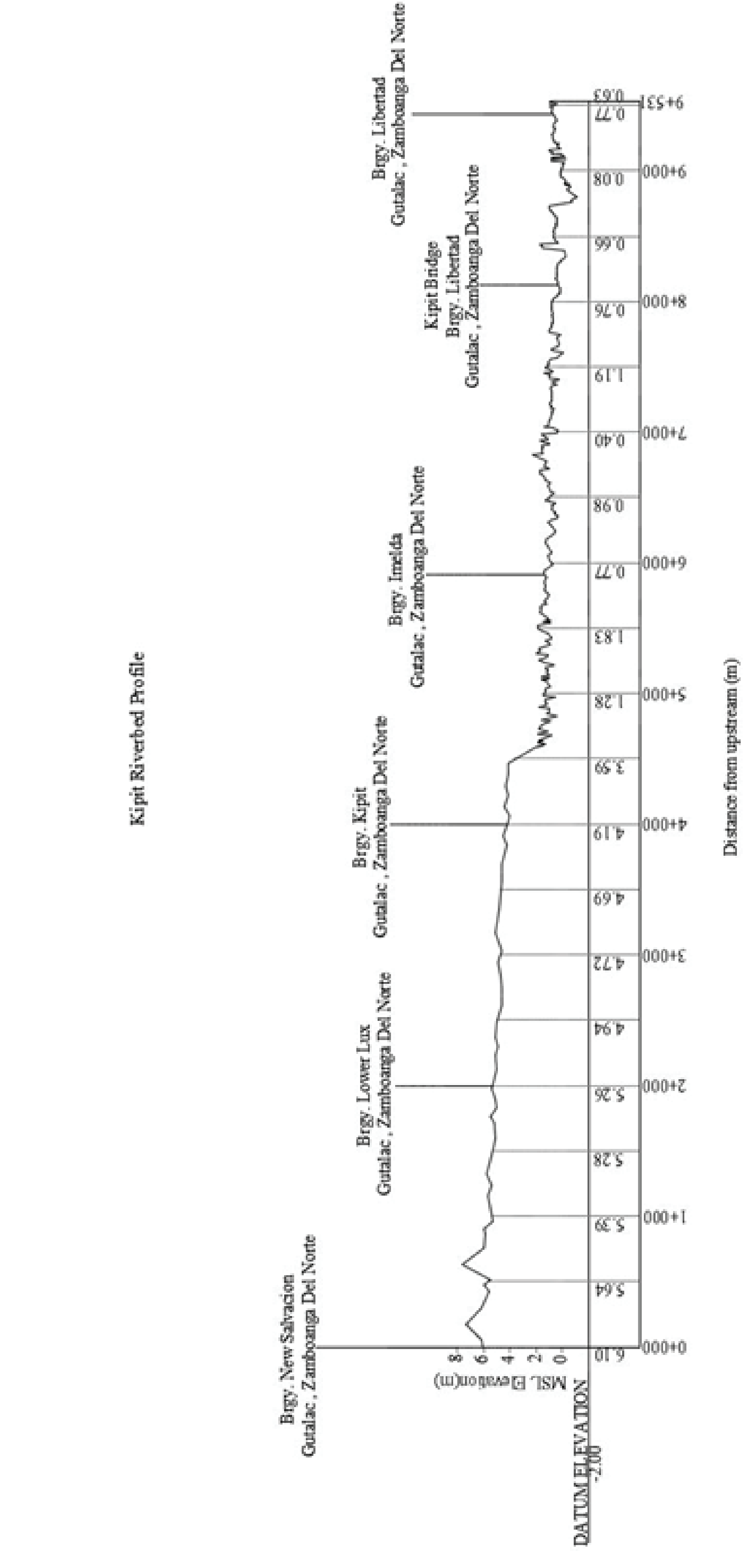


Figure 35. Kipit Bridge Cross-section Diagram

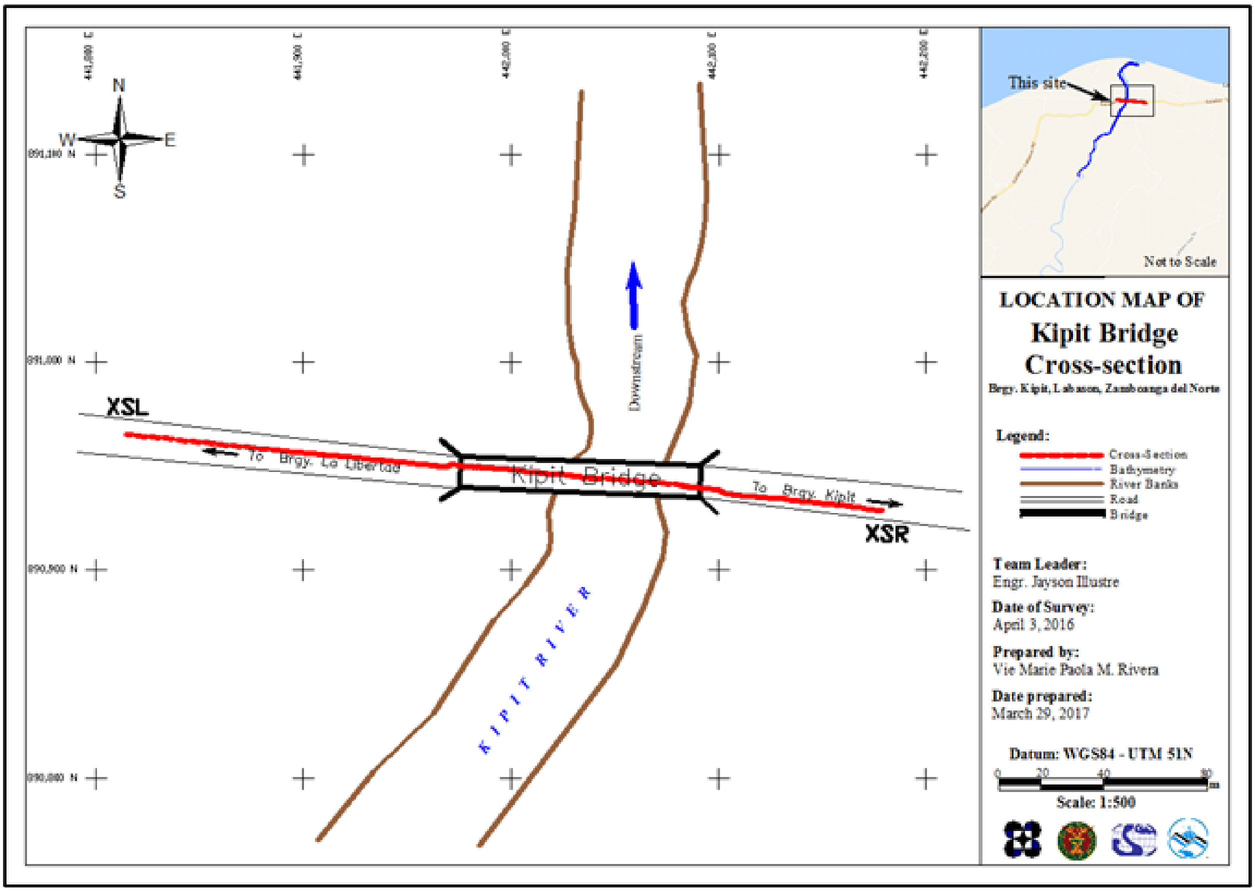


Figure 36. Kipit bridge cross-section location map

Bridge Data Form

Bridge Name: KIPIT BRIDGE

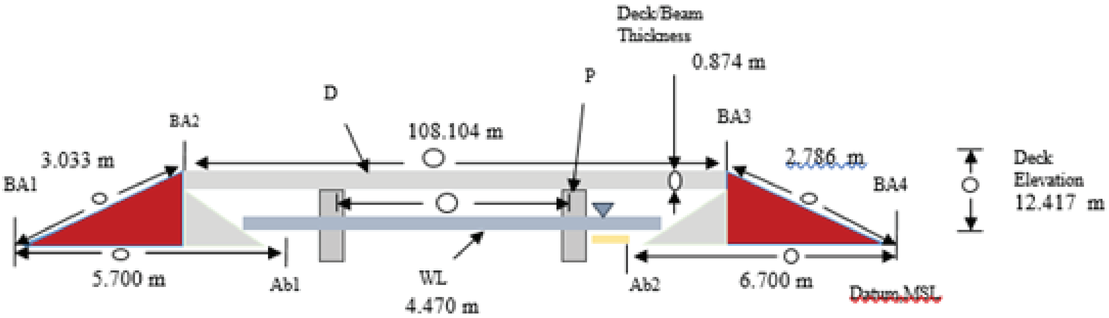
River Name: KIPIT RIVER
Location (Brgy.City.Region): Labason, Zamboanga Del Norte

Survey Team: Jayson Illustre, Ryan Antonio, Agripito Cinco
Date and Time: April 3, 2016, 1:52 PM

Flow Condition: low ✔normal high

Weather Condition: ✔fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	3.033 m	
2. BA2-BA3	108.104 m	
3. BA3-BA4	2.786 m	
4. BA1-Ab1	5.700 m	
5. Ab2-BA4	6.700 m	
6. Deck/beam thickness	0.874 m	
7. Deck elevation	12.417 m	

Note: Observer should be facing downstream

Figure 37. Kipit Bridge Data Sheet

Water surface elevation of Kipit River was determined by a Nikon® Total Station on April 3, 2016 at 1:52 PM at Kipit Bridge area with a value of 4.470 m in MSL. This was translated into marking on the bridge's pier as shown in Figure 38. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Kipit River, the Ateneo de Zamboanga University.

Figure 38. Water-level markings on Kipit Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 24, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 39. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.278 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with ZGS-99 occupied as the GNSS base station in the conduct of the survey.

Figure 39. Validation points acquisition survey set-up for Kipit River

The survey started from Brgy. La Libertad, Municipality of Gutalac, Zamboanga del Norte going west along national high way covering six (19) barangays in 4 municipalities, namely the municipalities of Gutalac, Labason, Liloy, and Salug, and ending in Brgy. Poblacion, Municipality of Salug, Zamboanga del Norte. The survey gathered a total of 6,266 points with approximate length of 36.9 km using UP_PAT-1 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 40.

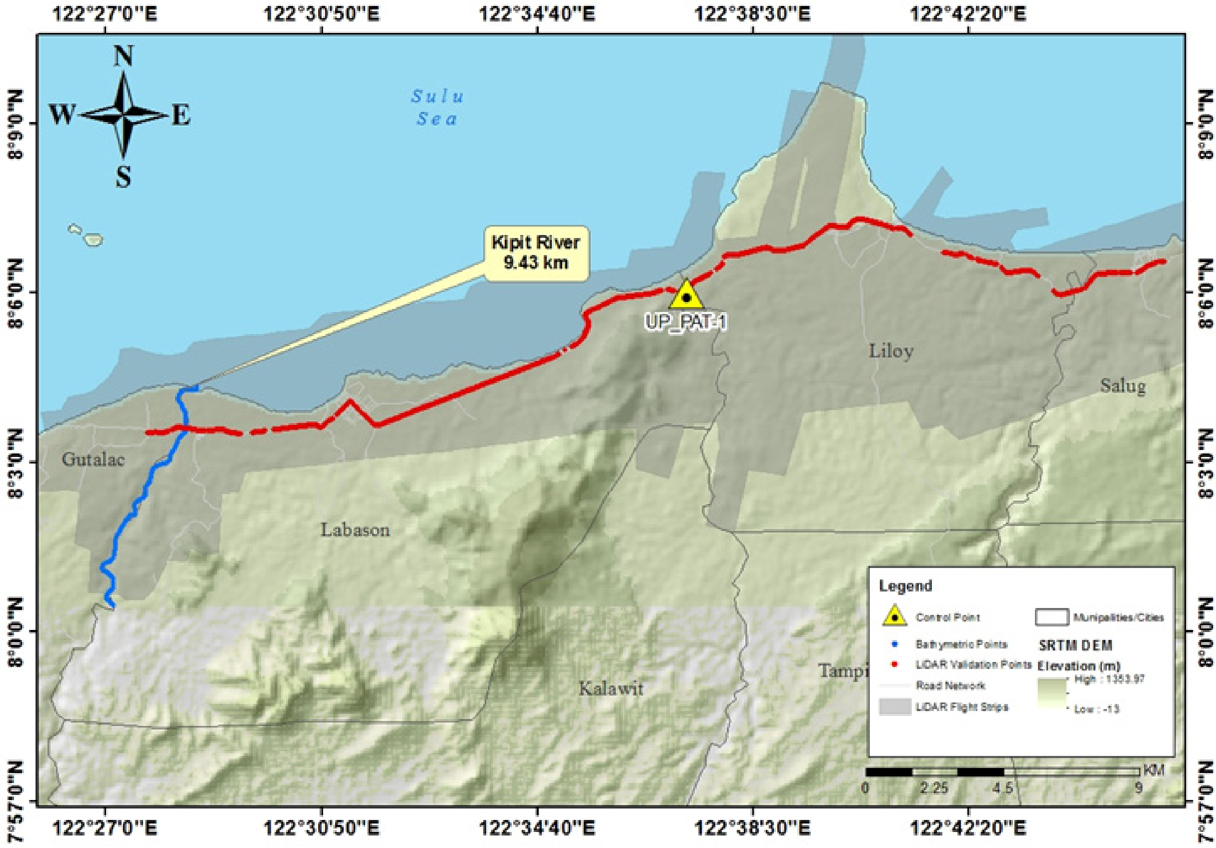


Figure 40. Validation points acquisition covering the Kipit River basin area

4.7 Bathymetric Survey

Bathymetric survey was executed on April 22, 24, and 25, 2016 at Kipit River using a Hi-Target™ Echo Sounder and a Nikon® Total Station as illustrated in Figure 41 and Figure 42. The survey started from Brgy. Imelda, Gutalac, Zamboanga del Norte with coordinates 8°2'10.08531"N, 122°27'30.29868"E and ended at the mouth of the river in Brgy. Kipit, Labason, Zamboanga del Norte, with coordinates 8°0'24.63893"N, 122°27'9.03173"E. The control point UP_KIP-1 was used as GNSS base station all throughout the entire survey.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 21 to 31, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. A map showing the DVC bathymetric checking points is shown in Figure 43.

Figure 41. Bathymetric survey of ABSD at Kipit River using Hi-Target™ Echo Sounder (upstream)

Figure 42. Cross-section survey at Kipit River using Nikon® Total Station

The bathymetric survey for Kipit River gathered a total of 16,760 points covering 5.10 km of the river traversing the barangays of La Libertad and Imelda in the Municipality of Gutalac, and Brgy. Kipit in the Municipality of Labason. The manual bathymetric survey for Kipit River gathered a total of 3,327 points covering 4.47 km of the river traversing the barangays of Imelda and Lower Luz in the Municipality of Gutalac, and the barangays of New Salvacion and Kipit in the Municipality of Labason. A CAD drawing was also produced to illustrate the riverbed profile of Kipit River. As shown in Figure 45, an elevation drop of -1.19 m was observed within the distance of approximately 8.793 km.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets. The computed R2value of 0.86 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.057 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

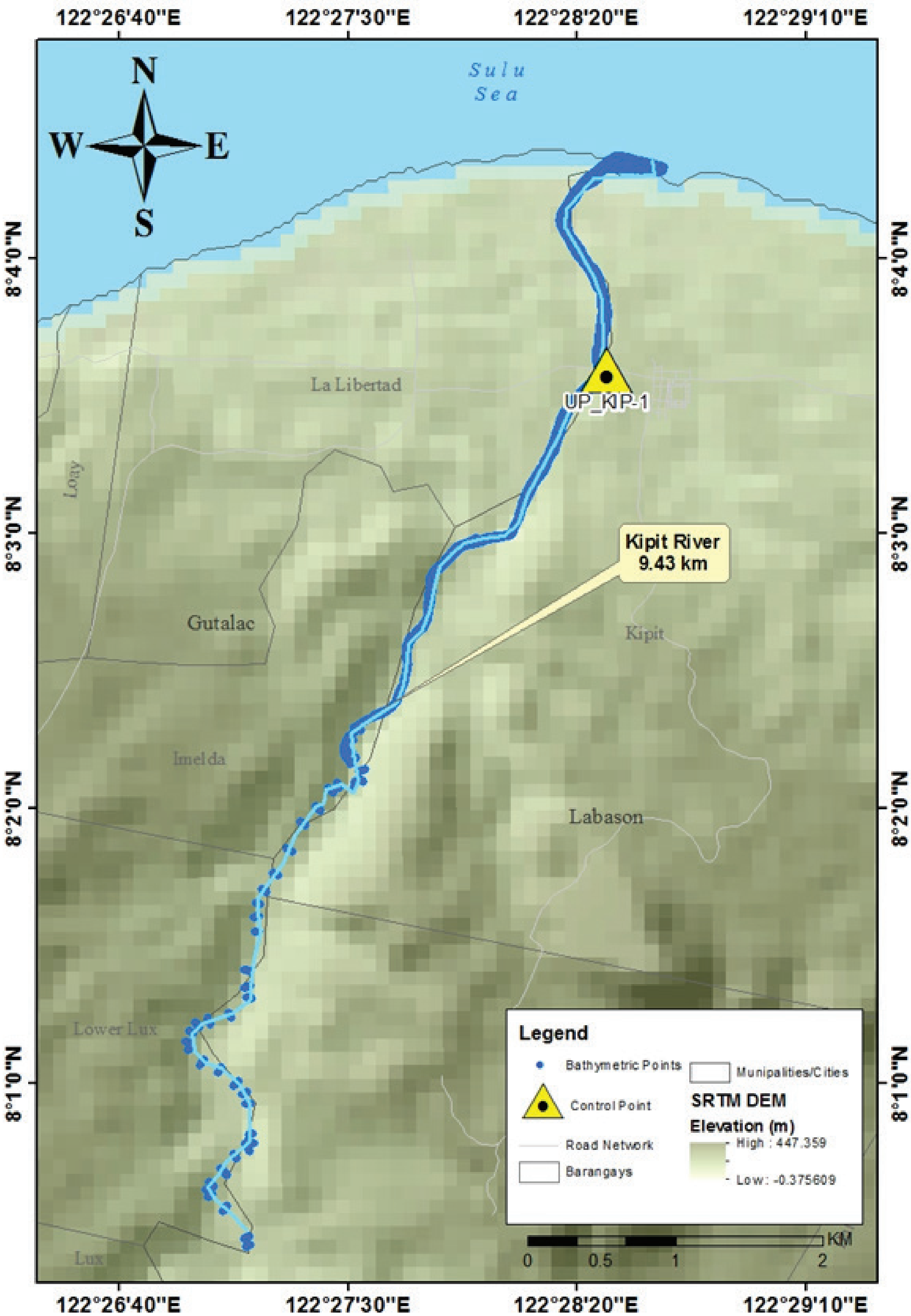


Figure 43. Bathymetric survey of Kipit River

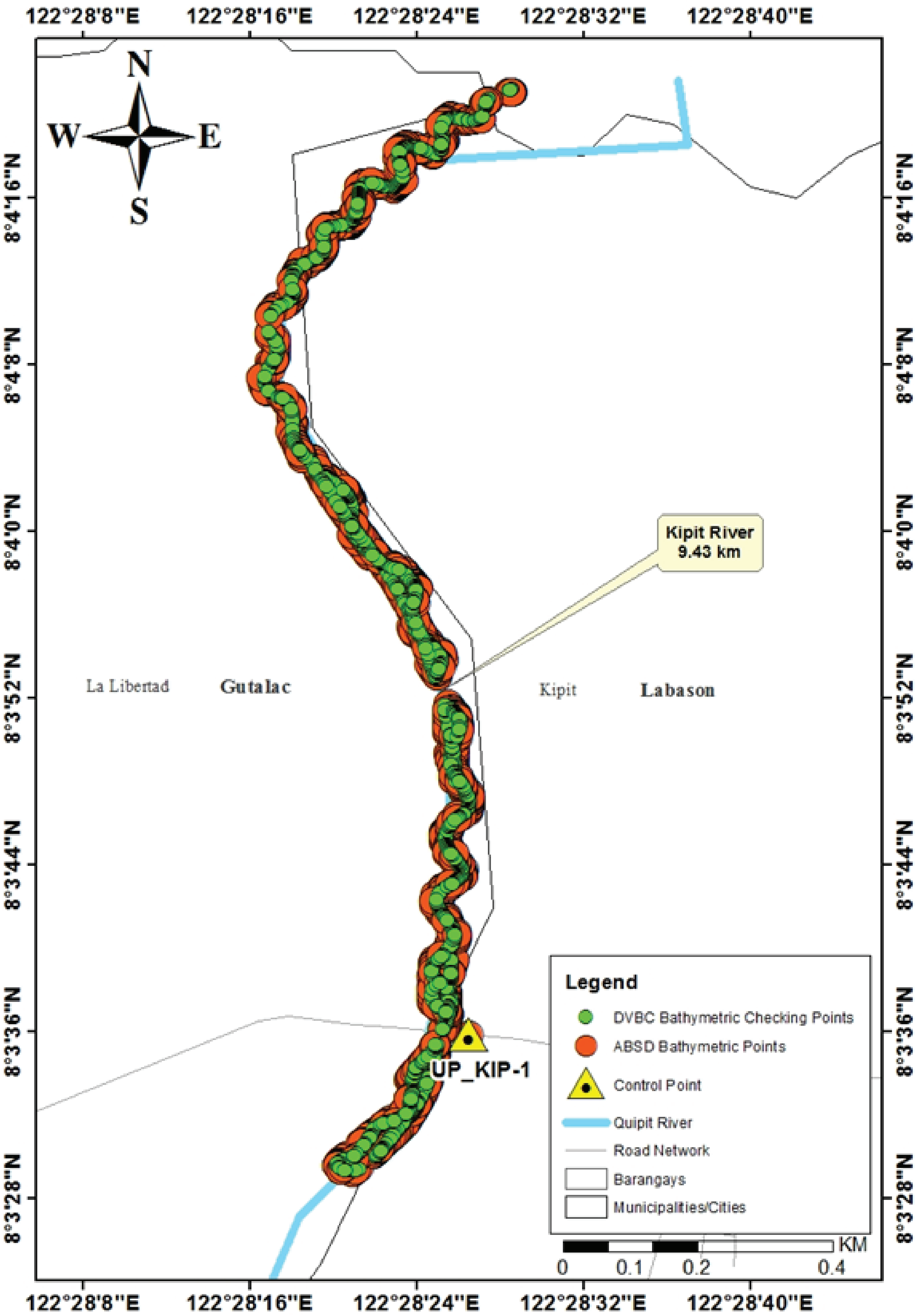


Figure 44. Quality checking points gathered along Kipit River by DVBC

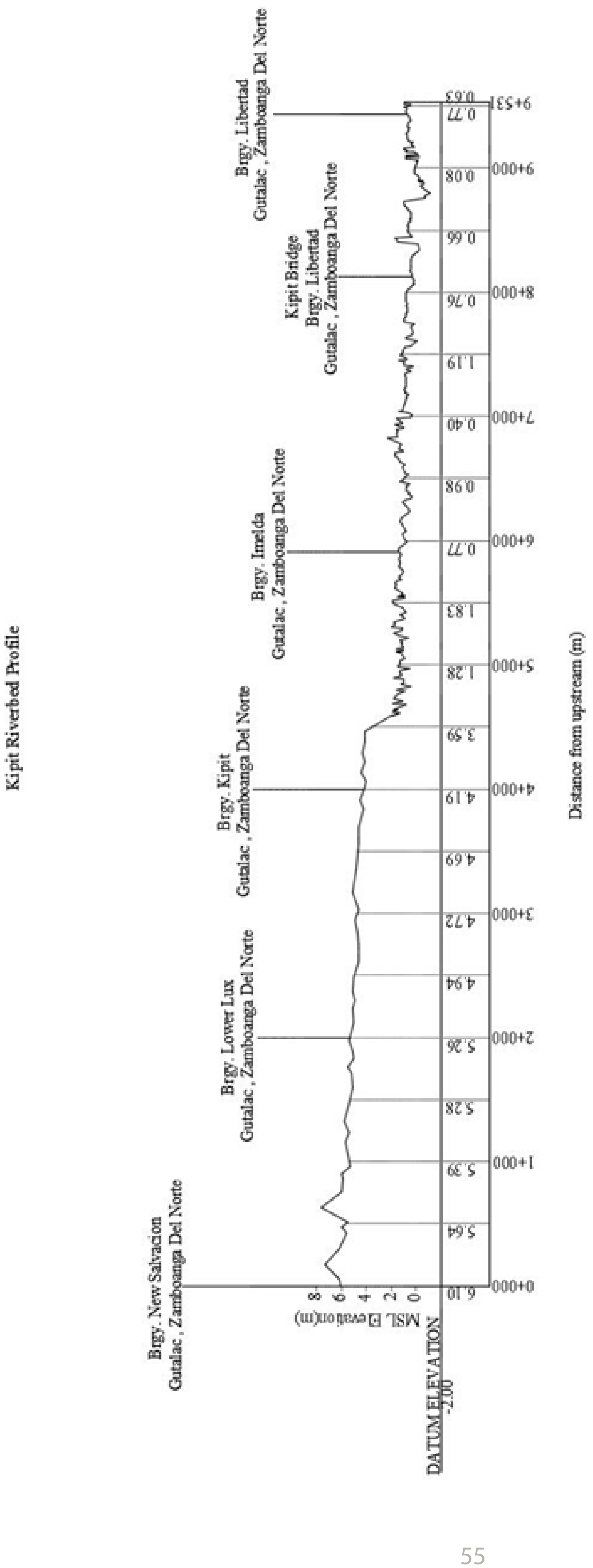


Figure 45. Kipit riverbed profile

Chapter 5: Flood Modeling and Mapping

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a manually read rain gauge at Brgy. Kipit, Labason, Zamboanga del Norte (8°1’44.43”N, 122° 27’ 16.94”E) (Figure 46). The precipitation data collection started from June 27, 2016 at 6:00 PM to June 28, 2016 at 8:00 PM with 10 minutes recording interval.

The total precipitation for this event in Brgy. Kipit was 13.4 mm. It has a peak rainfall of 3.2 mm. on June 27, 2016 at 07:40 AM. The lag time between the peak rainfall and discharge is 6 hours and 50 minutes.

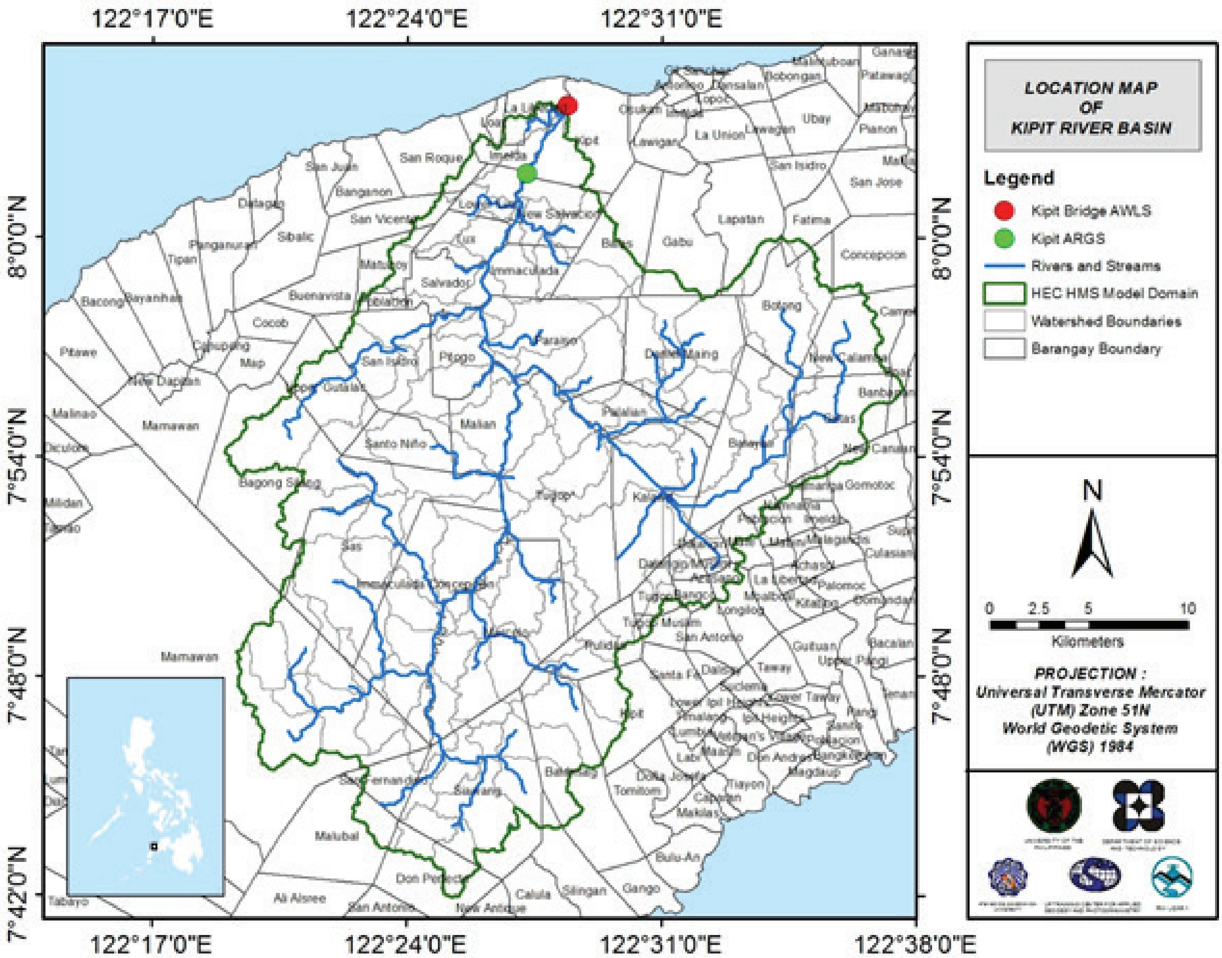


Figure 46. The location map of Kipit HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Kipit Bridge, Brgy. Kipit, Labason, Zamboanga del Norte (7°51’24.33”N, 122° 26’30.35”E). It gives the relationship between the observed water levels at Kipit Bridge and outflow of the watershed at this location.

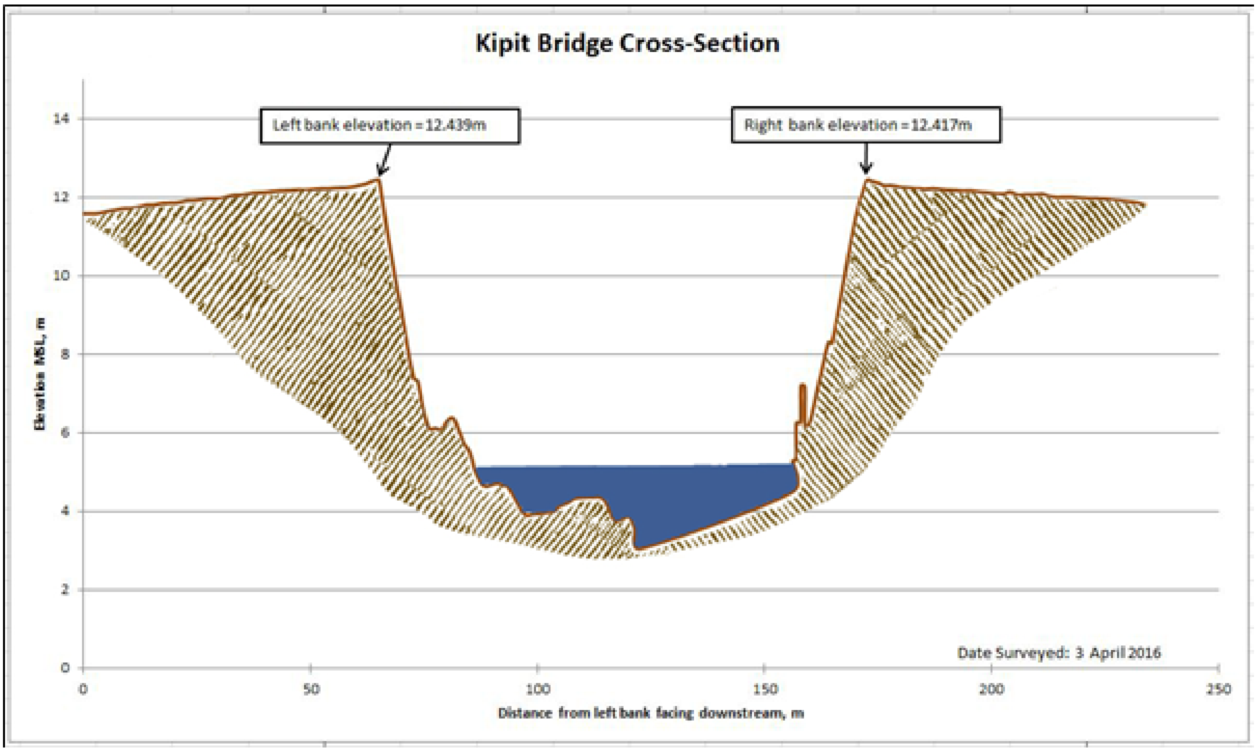


Figure 47. Cross-section plot of Kipit Bridge

For Kipit Bridge, the rating curve is expressed as $Q = 2E\text{-}85e^{2.9611h}$ as shown in Figure 48.

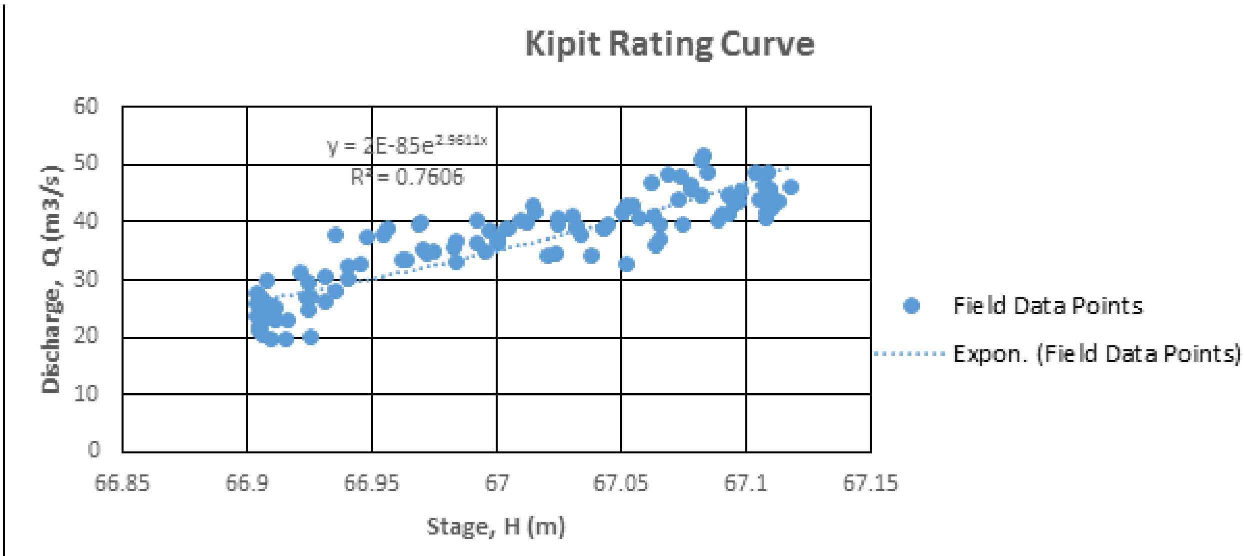


Figure 48. Rating curve at Kipit Bridge, Brgy. Kipit, Labason, Zamboanga del Norte

This rating curve equation was used to compute the river outflow at Kipit Bridge for the calibration of the HEC-HMS model shown in Figure 49. Peak discharge is 51.8 cubic meters per second at 2:30 AM, June 28, 2016.

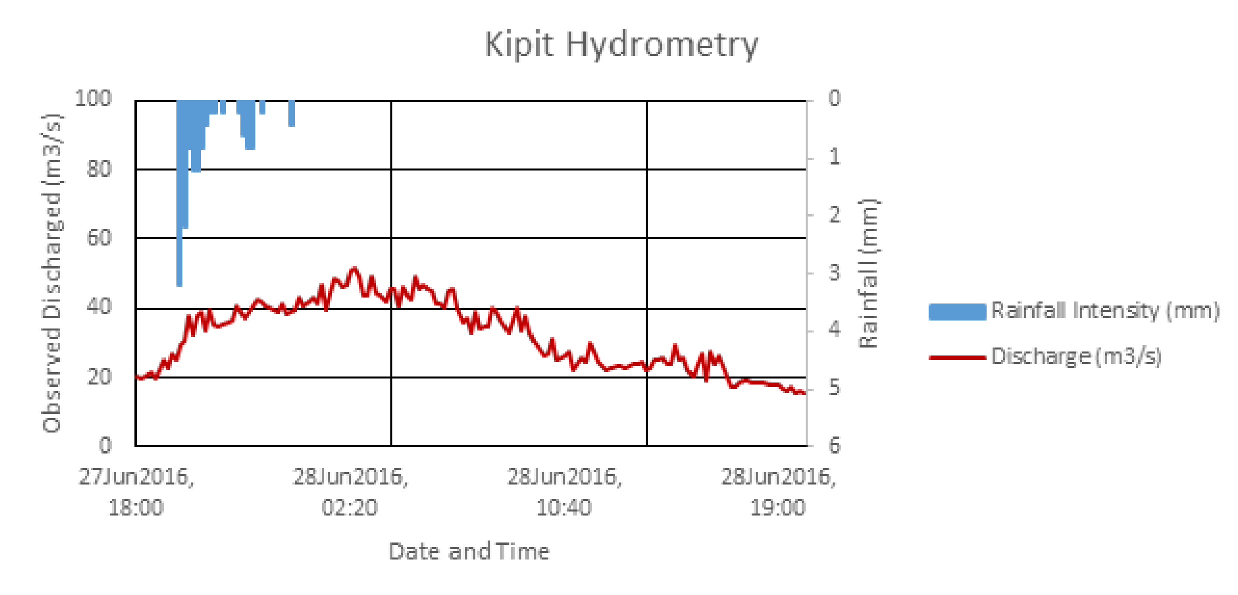


Figure 49. Rainfall and outflow data at Kipit used for modeling

5.2 RIDF Station

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

Table 26. RIDF values for Zamboanga City 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	15.5	23.3	28.4	36.9	45.6	50.7	60	66.1	77.3
5	21.4	31.6	38.3	50.4	61.2	38.2	82.5	91.5	107.8
10	25.3	37.1	44.8	59.4	71.6	79.8	97.5	108.3	127.9
15	27.5	40.2	48.5	64.4	77.4	86.4	105.9	117.8	139.3
20	29	42.3	51.1	68	81.5	91	111.8	124.4	147.3
25	30.2	44	53.1	70.7	84.7	94.5	116.3	129.5	153.4
50	33.9	49.1	59.2	79.1	94.4	105.4	130.4	145.3	172.3
100	37.5	54.2	65.3	87.4	104	116.2	144.3	161	191.1

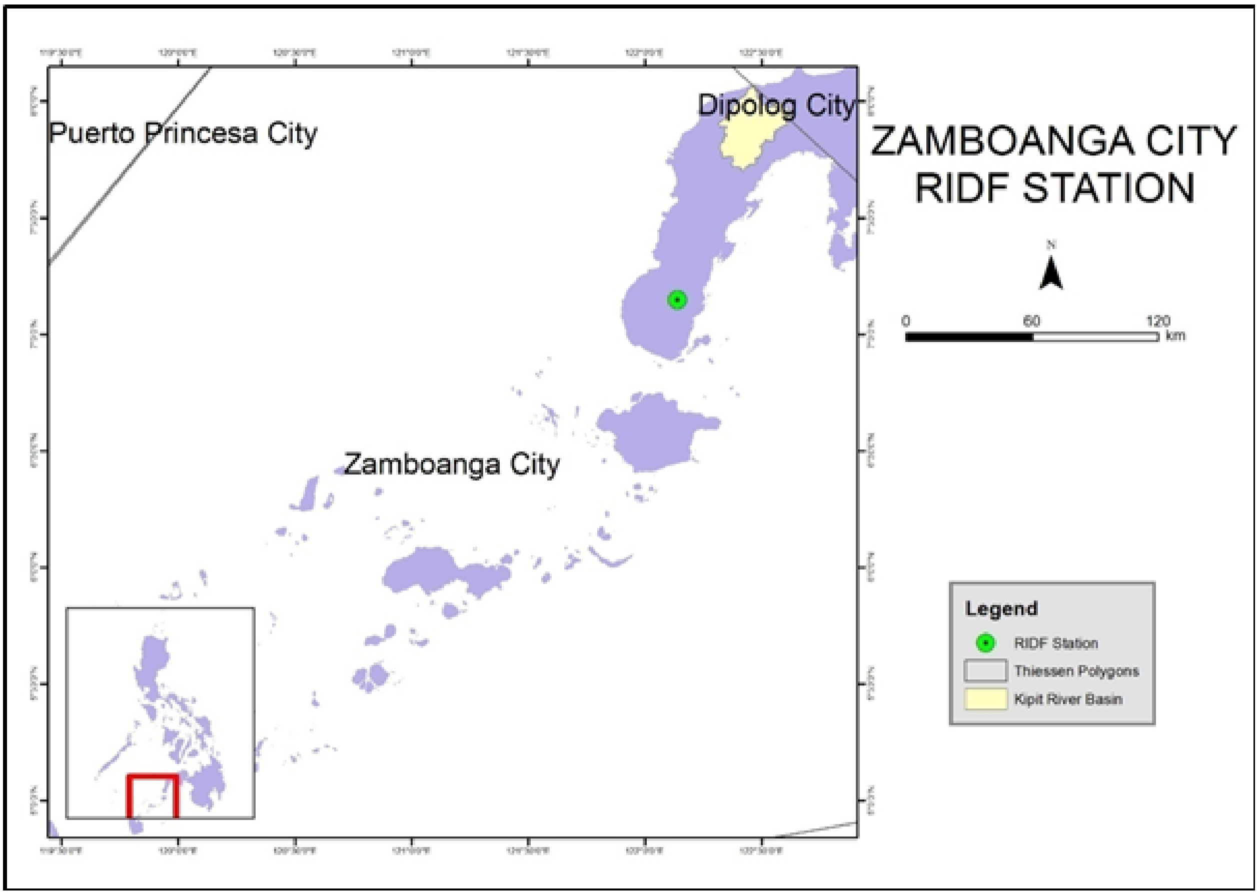


Figure 50. Zamboanga City RIDF location relative to Kipit River Basin

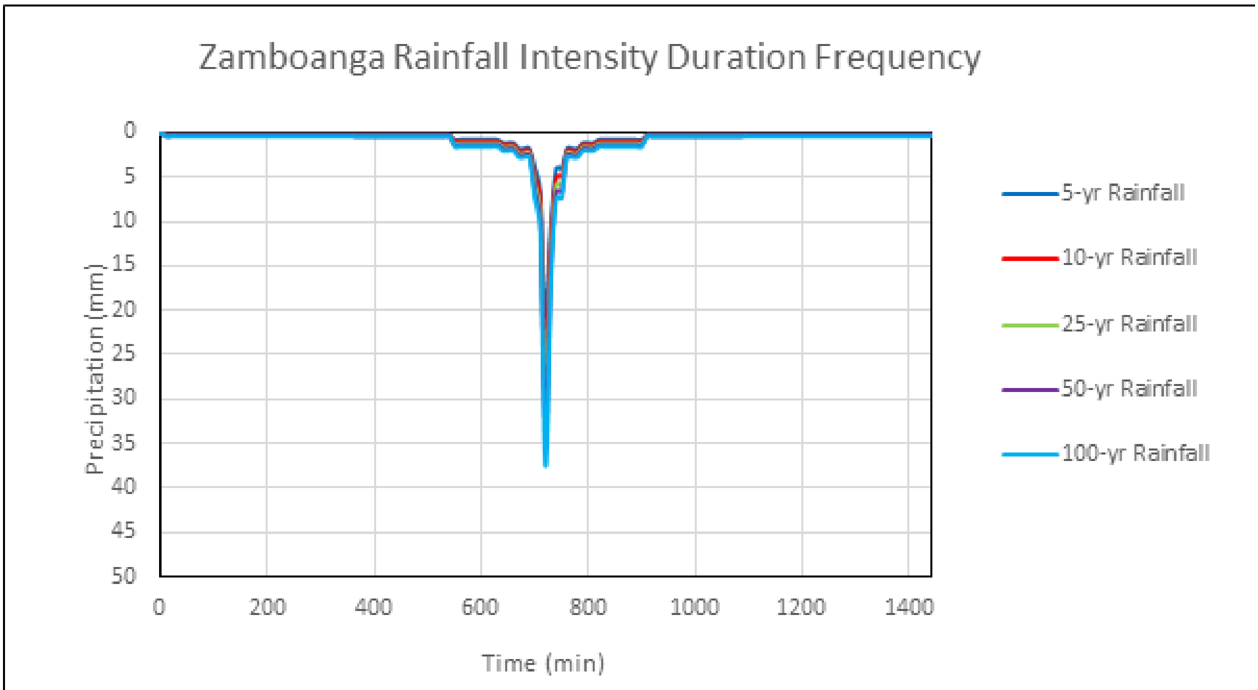


Figure 51. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Kipit River Basin are shown in Figure 52 Figure and 53, respectively.

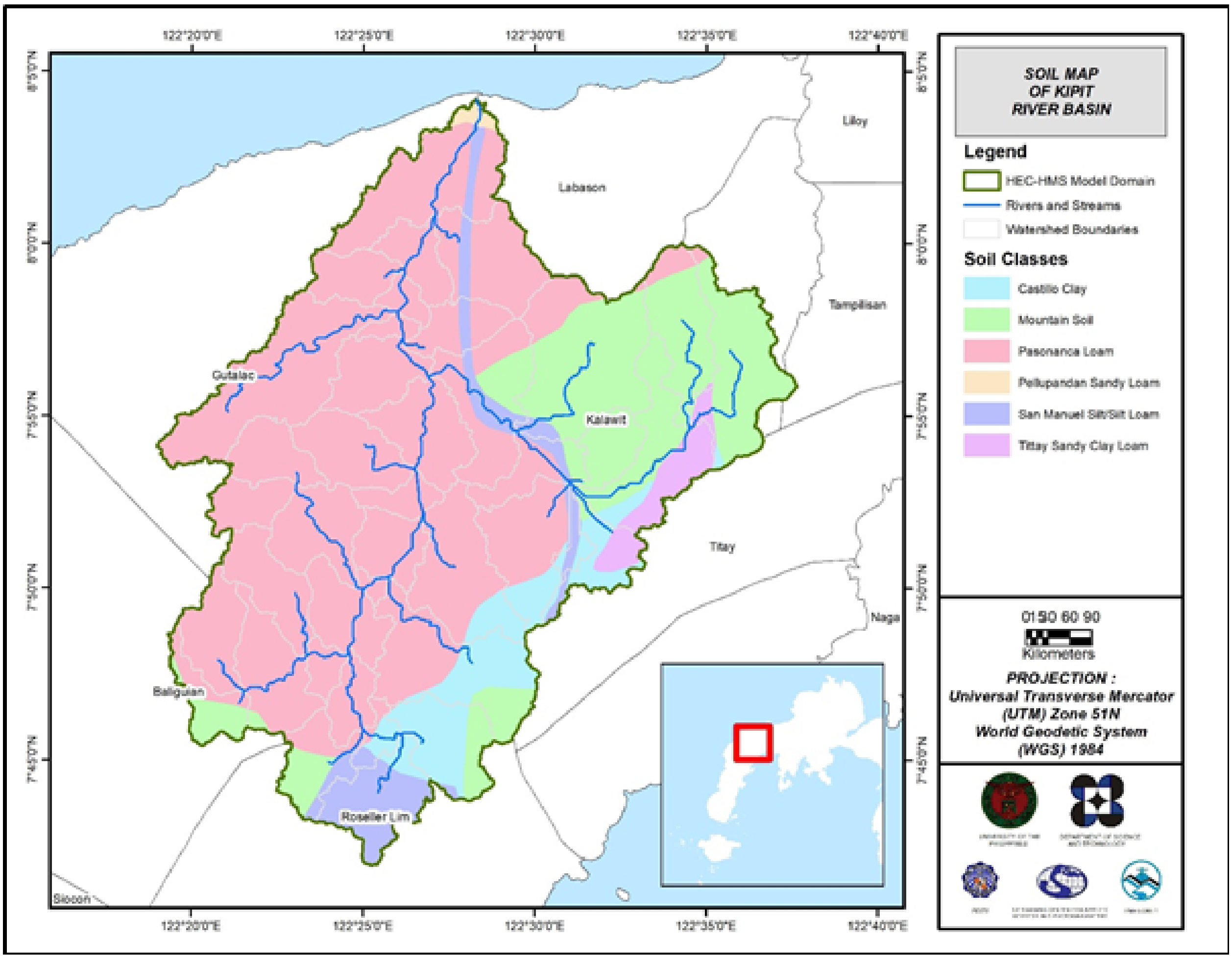


Figure 52. Soil map of Kipit River Basin

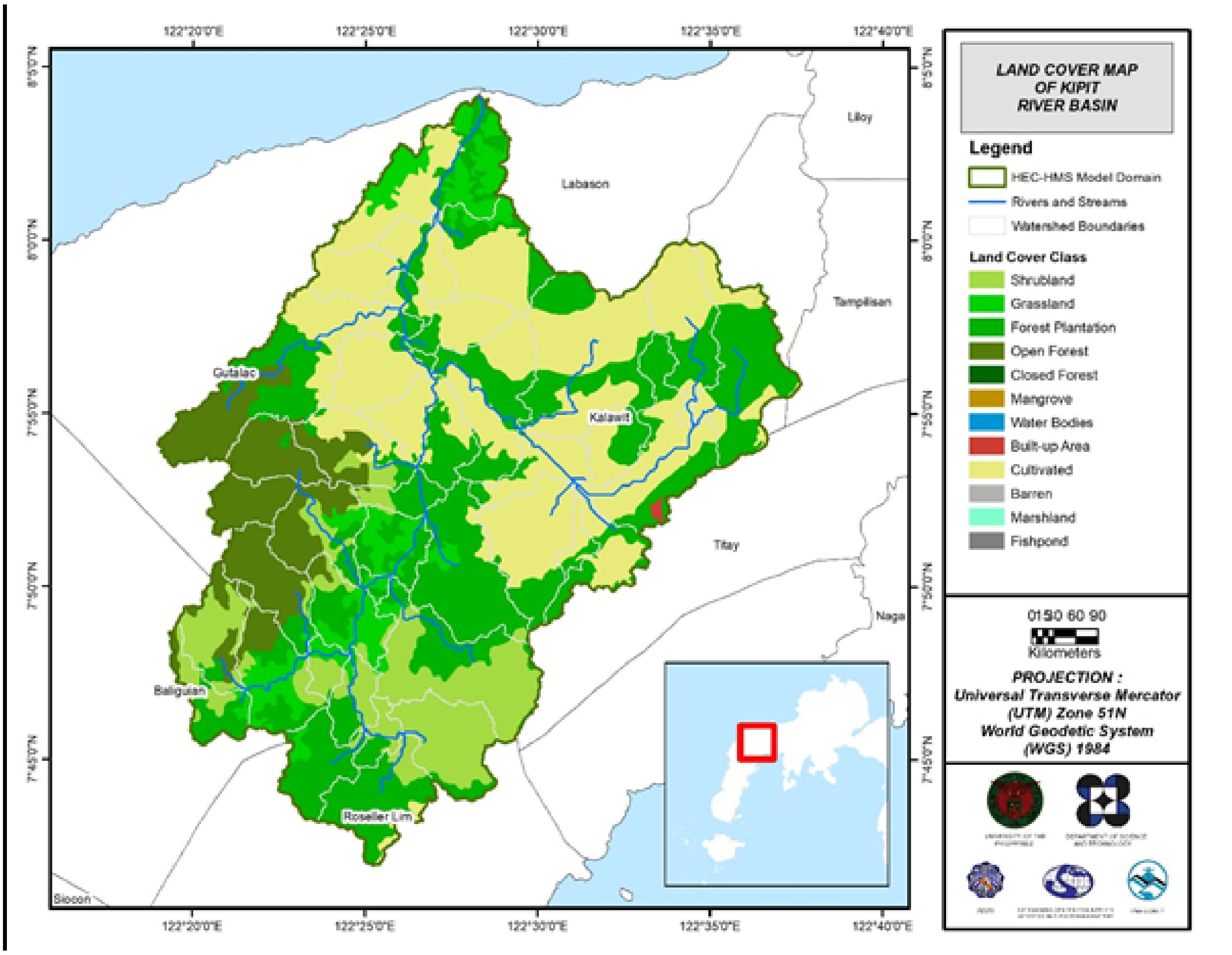


Figure 53. Land cover map of Kipit River Basin (Source: NAMRIA)

For Kipit, the soil classes identified were clay, loam, sandy loam, silt loam, sandy clay loam, and mountain soil. The land cover types identified were brushland, cultivated areas, built-up areas, tree plantations, open canopy forests, and grassland.

Table 27.

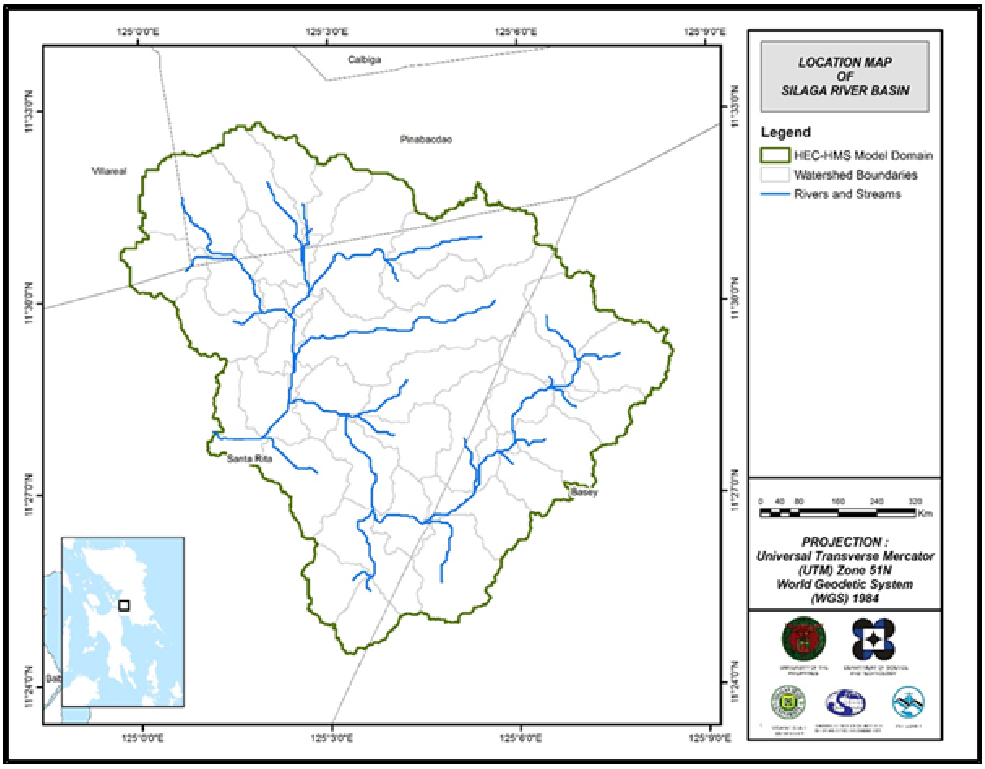


Figure 54. Stream delineation map of Kipit river basin

Using the SAR-based DEM, the Kipit basin was delineated and further subdivided into subbasins. The model consists of 83 sub basins, 41 reaches, and 41 junctions as shown in Figure 55. The main outlet is at Kipit Bridge, Brgy. Kipit, Labason.

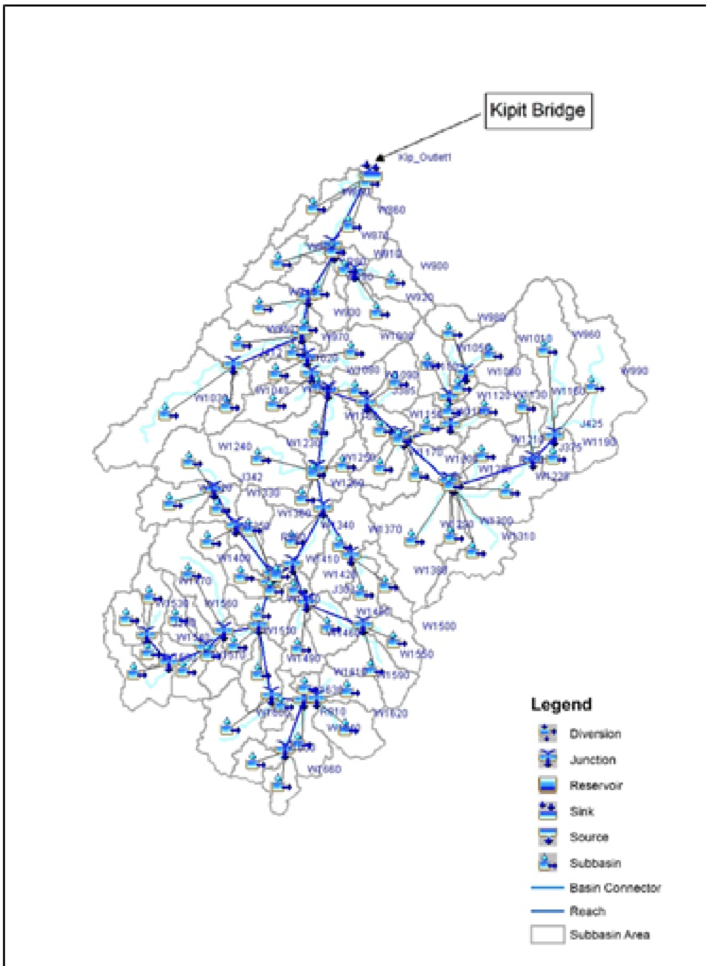


Figure 55. The Kipit River Basin model generated using HEC-HMS

5.4 Cross-section Data

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

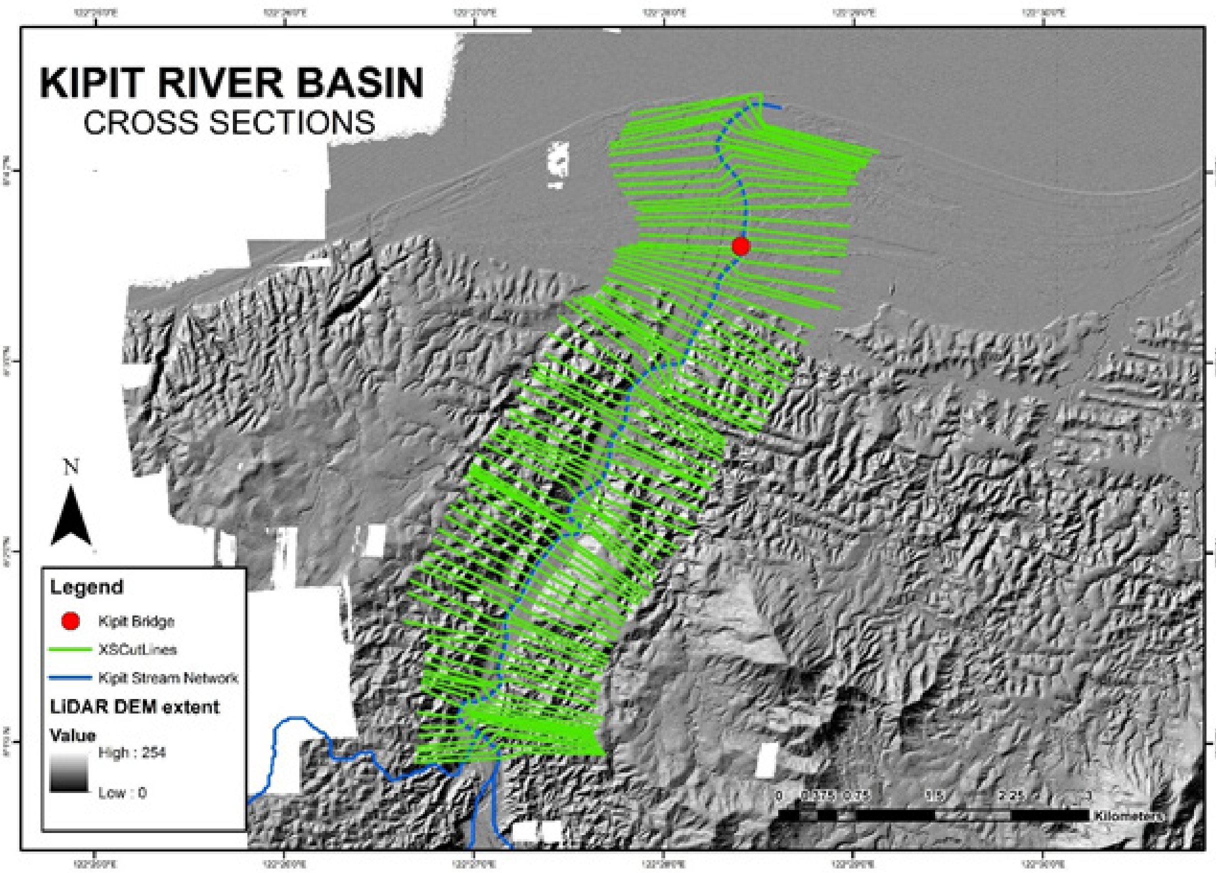


Figure 56. River cross-section of Kipit River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

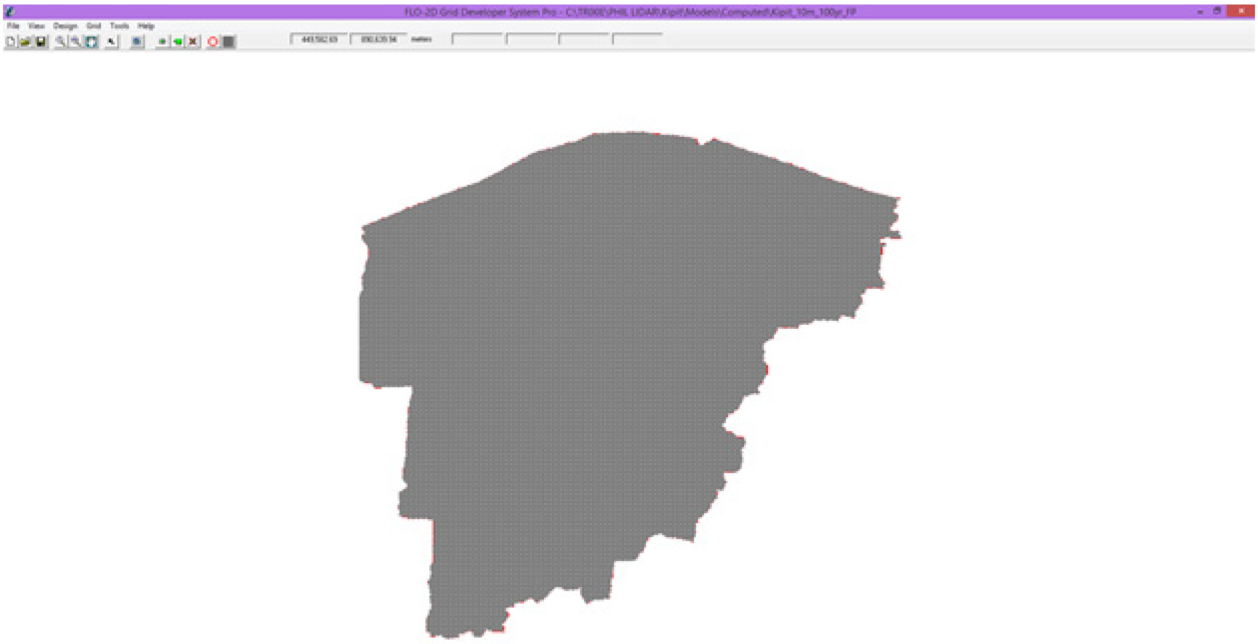


Figure 57. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 41.57031 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

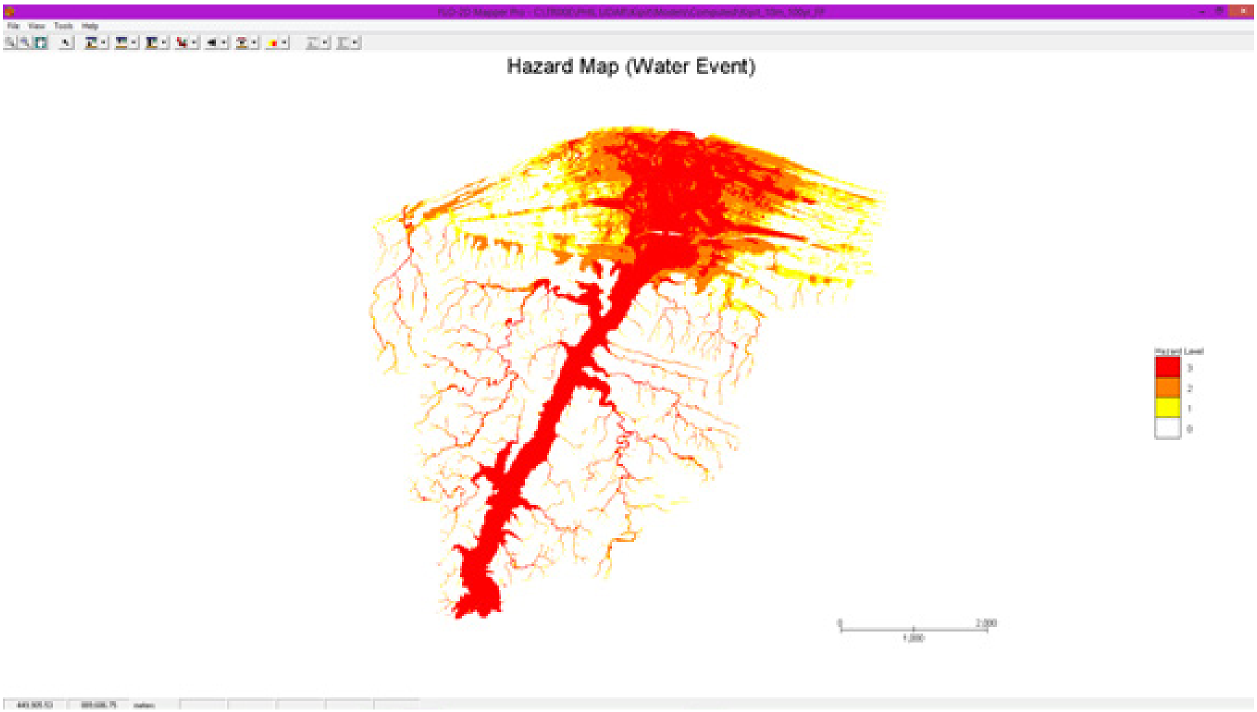


Figure 58. Generated 100-year rain return hazard map from FLO-2D Mapper

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 29999700.00 m2.

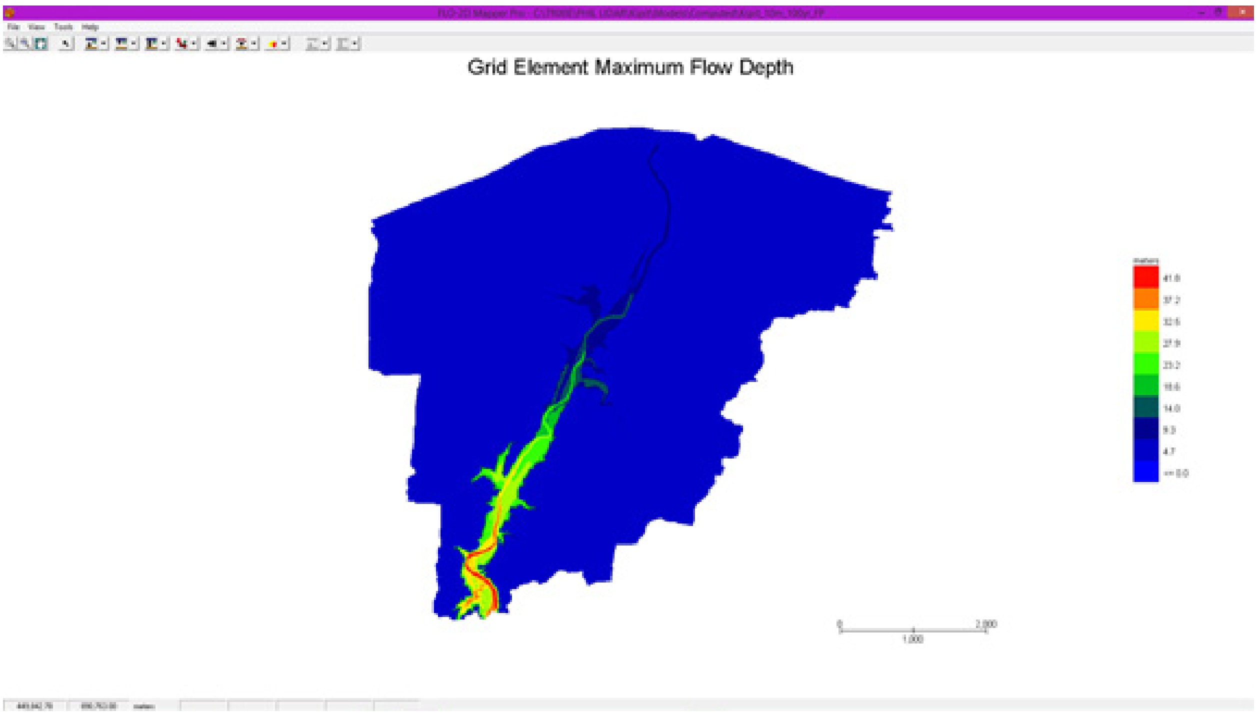


Figure 59. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 88,065,520.75 m3 of water entering the model. Of this amount, 5,759,441.92 m3 is due to rainfall while 82,306,078.83 m3 is inflow from other areas outside the model. 4,837,247.00 m3 of this water is lost to infiltration and interception, while 9,334,316.91 m3 is stored by the floodplain. The rest, amounting up to 73,893,961.02 m3, is outflow.

5.5.1 Discharge data using Dr. Horritts's recommended hydrologic method

The river discharge for the river entering the floodplain are shown in Figure 60 and the peak values are summarized in Table 28.

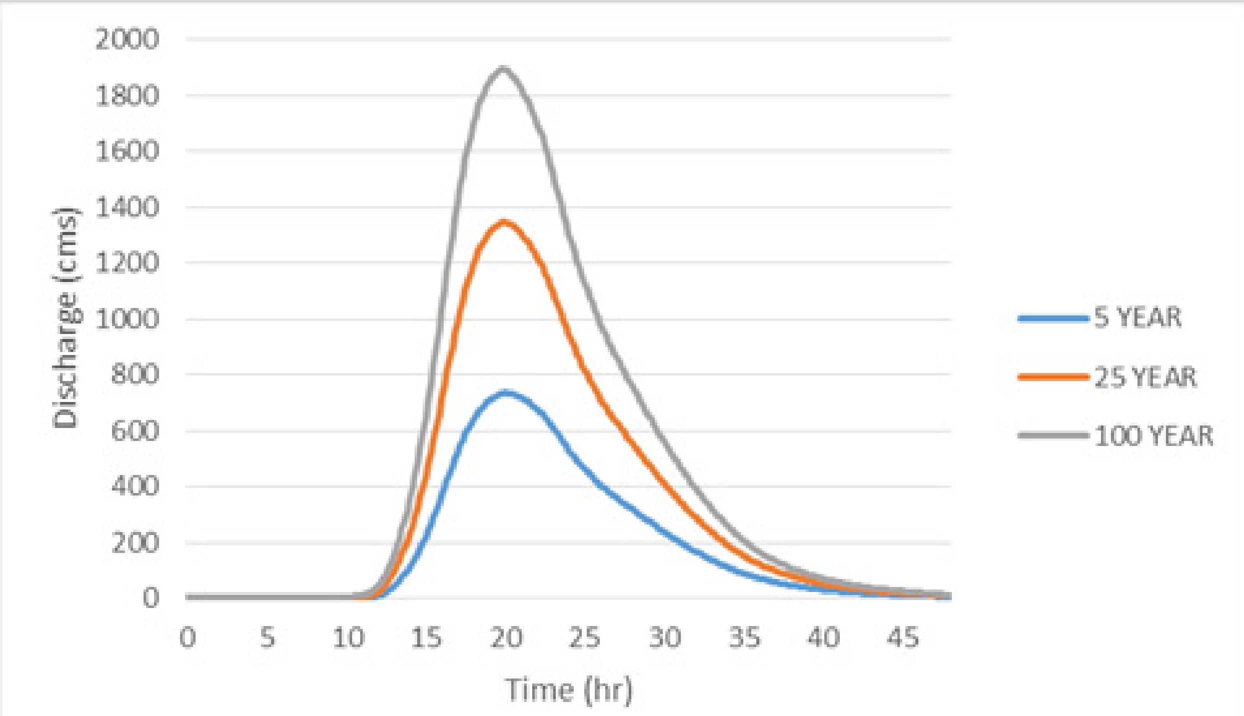


Figure 60. Kipit River generated discharge using interpolated 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 27. Summary of Kipit river discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	857.9	443.26
25-Year	631.4	443.26
5-Year	181.9	443.26

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 29.

Table 28. Validation of river discharge estimates

				VALIDATION	
Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	Bankful Discharge	Specific Discharge
Kipit	647.416	411.434	946.262	Fail	Pass

The HEC-HMS river discharge estimate was able to satisfy the conditions for validation using the specific discharge method. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use for flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.6 Results of HMS Calibration

After calibrating the Kipit HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 61 shows the comparison between the two discharge data.

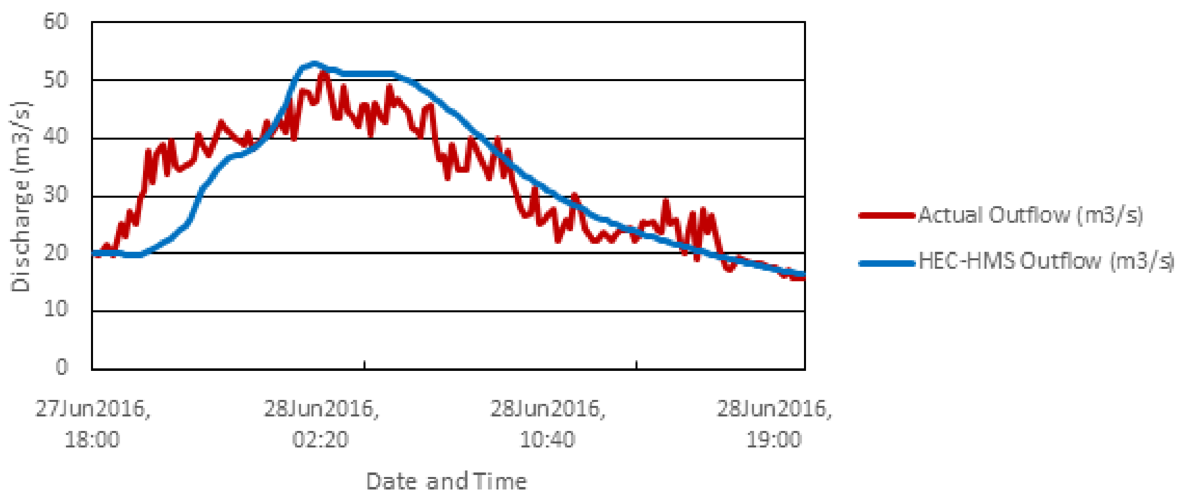


Figure 61. Outflow hydrograph of Kipit produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 30 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of calibrated values for Kipit

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.0025 – 0.0051
			Curve Number	50.53 – 83.95
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 – 1.49
			Storage Coefficient (hr)	0.02 – 1.22
	Baseflow	Recession	Recession Constant	0.19
			Ratio to Peak	0.25
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.05

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 0.0025 mm to 0.0051 mm means that there is a minimal 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 the curve number increases. The range of 50.53 to 83.95 for curve number is reasonable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Kipit, the basin mostly consists of tree plantations and the soil consists of loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 1.49 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.19 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.25 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.05 corresponds to the common roughness of Philippine watersheds (Brunner, 2010).

Table 30. Summary of the efficiency test of Kipit HMS Model

RMSE	73.6679
r2	0.7606
NSE	0.650122
PBIAS	-1.2552
RSR	0.591505

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 73.6679 (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 0.7606.

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 0.650122.

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 -1.2552.

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 0.591505.

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

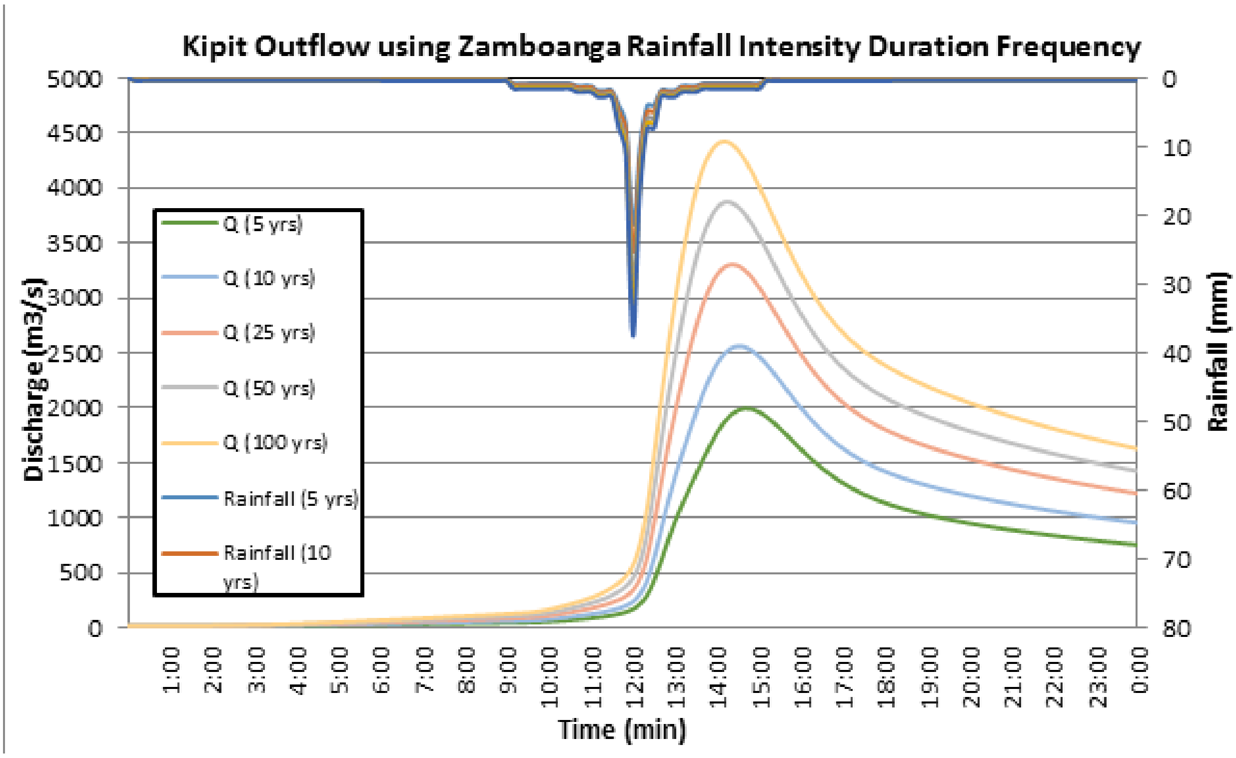


Figure 62. Outflow hydrograph at Kipit Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Kipit discharge using the Zamboanga City RIDF in five different return periods is shown in Table 32.

Table 31. Peak values of the Kipit HEC-HMS Model outflow using the Zamboanga City RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m3s)	Time to Peak
5-Year	107.8	21.4	1996.96	14 hours 40 minutes
10-Year	127.9	25.3	2562.29	14 hours 30 minutes
25-Year	153.4	30.2	3302.93	14 hours 20 minutes
50-Year	172.3	33.9	3869.54	14 hours 10 minutes
100-Year	191.1	37.5	4424.57	14 hours 10 minutes

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 was used in determining the flooded areas within the model. The simulated model is an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Kipit River using the calibrated HMS base flow is shown in Figure 63.

Figure 63. Sample output of Kipit RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 64 to Figure 69 show the 5-, 25-, and 100-year rain return scenarios of the Kipit Floodplain. The floodplain covers two municipalites namely Gutalac and Labason. Table 33 shows the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Kipit Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Gutalac	398.41	14.22	4%
Labason	159.43	15.56	10%

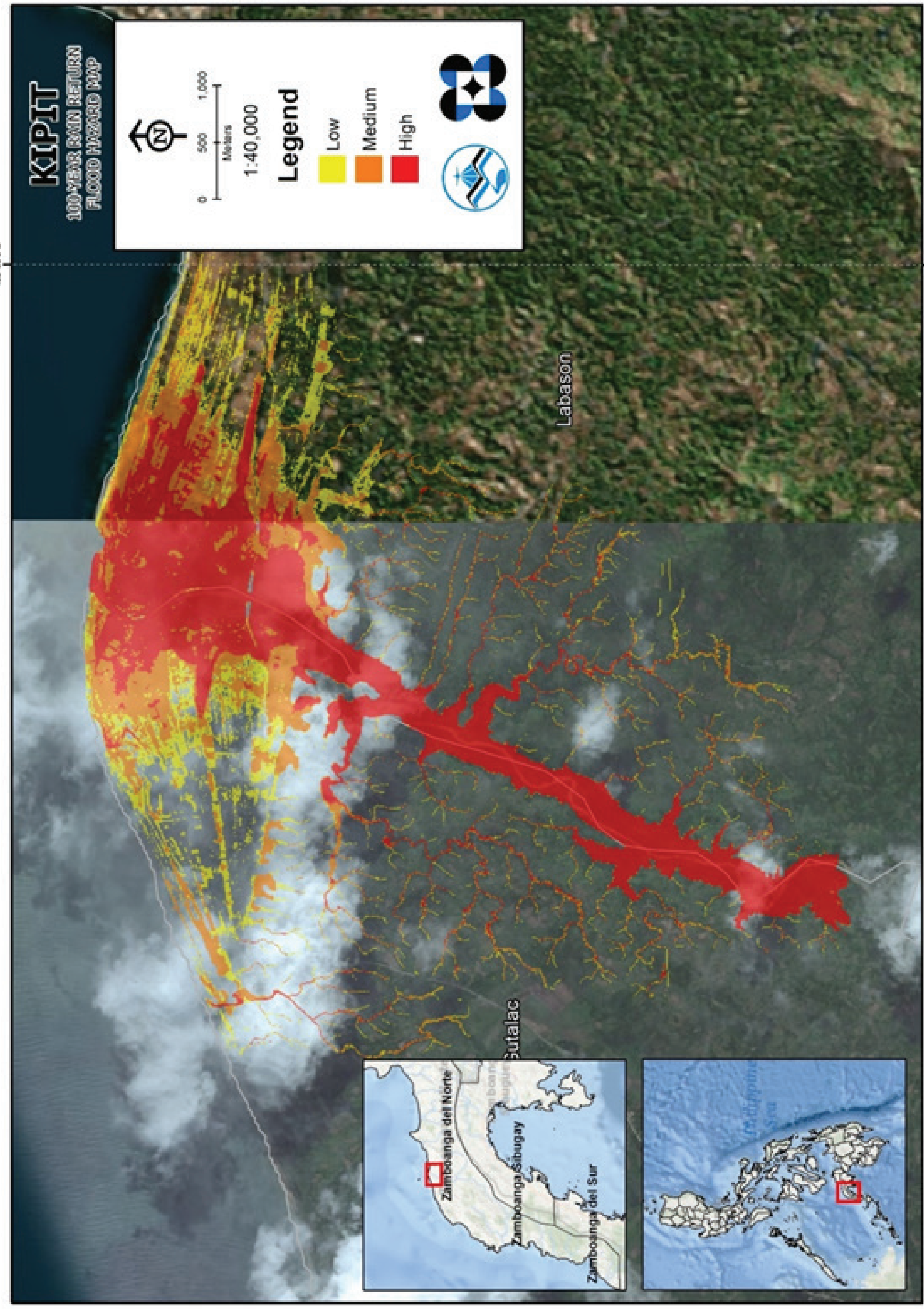


Figure 64. 100-year flood hazard map for Kipit Floodplain

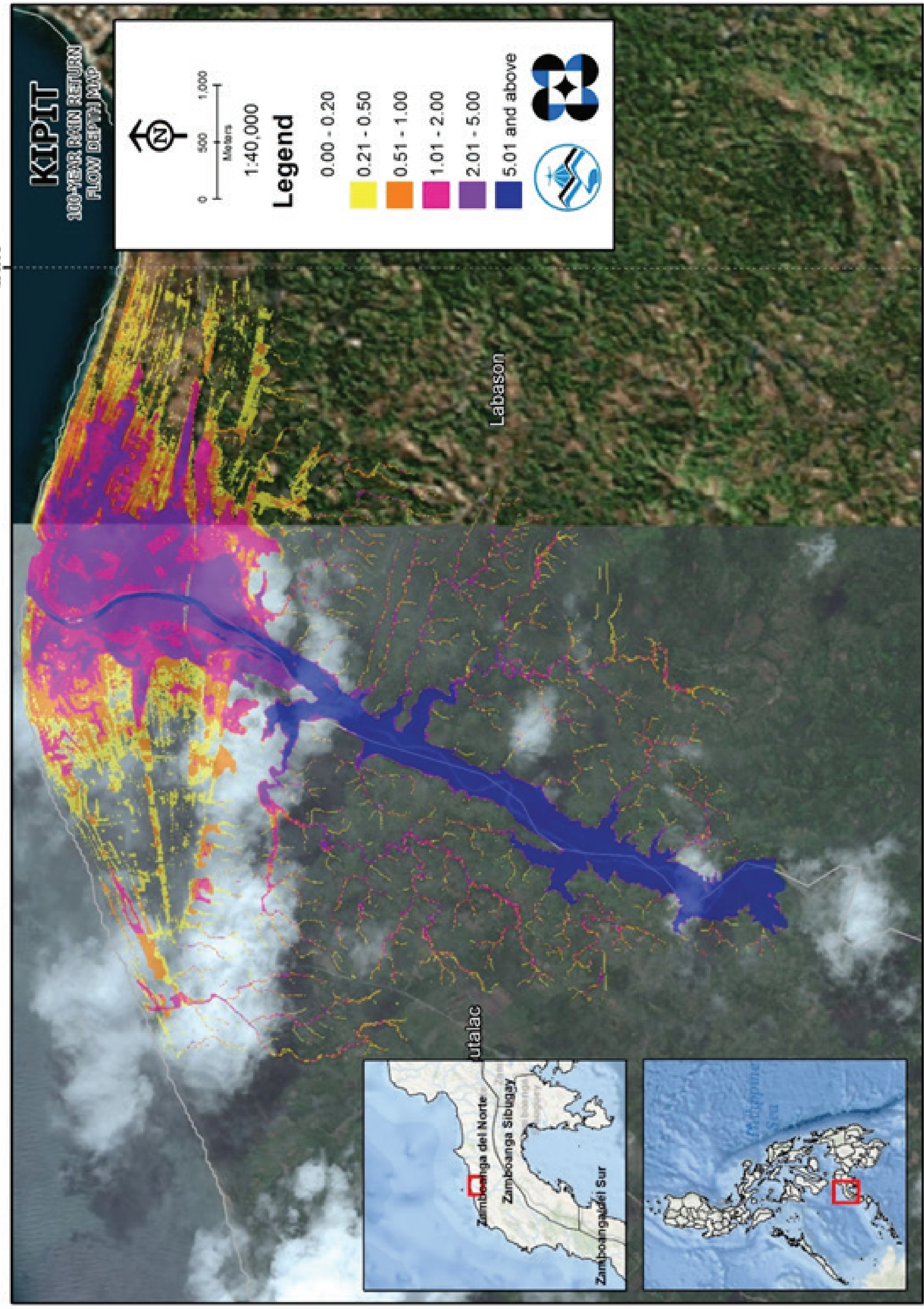


Figure 65. 100-year flow depth map for Kipit Floodplain

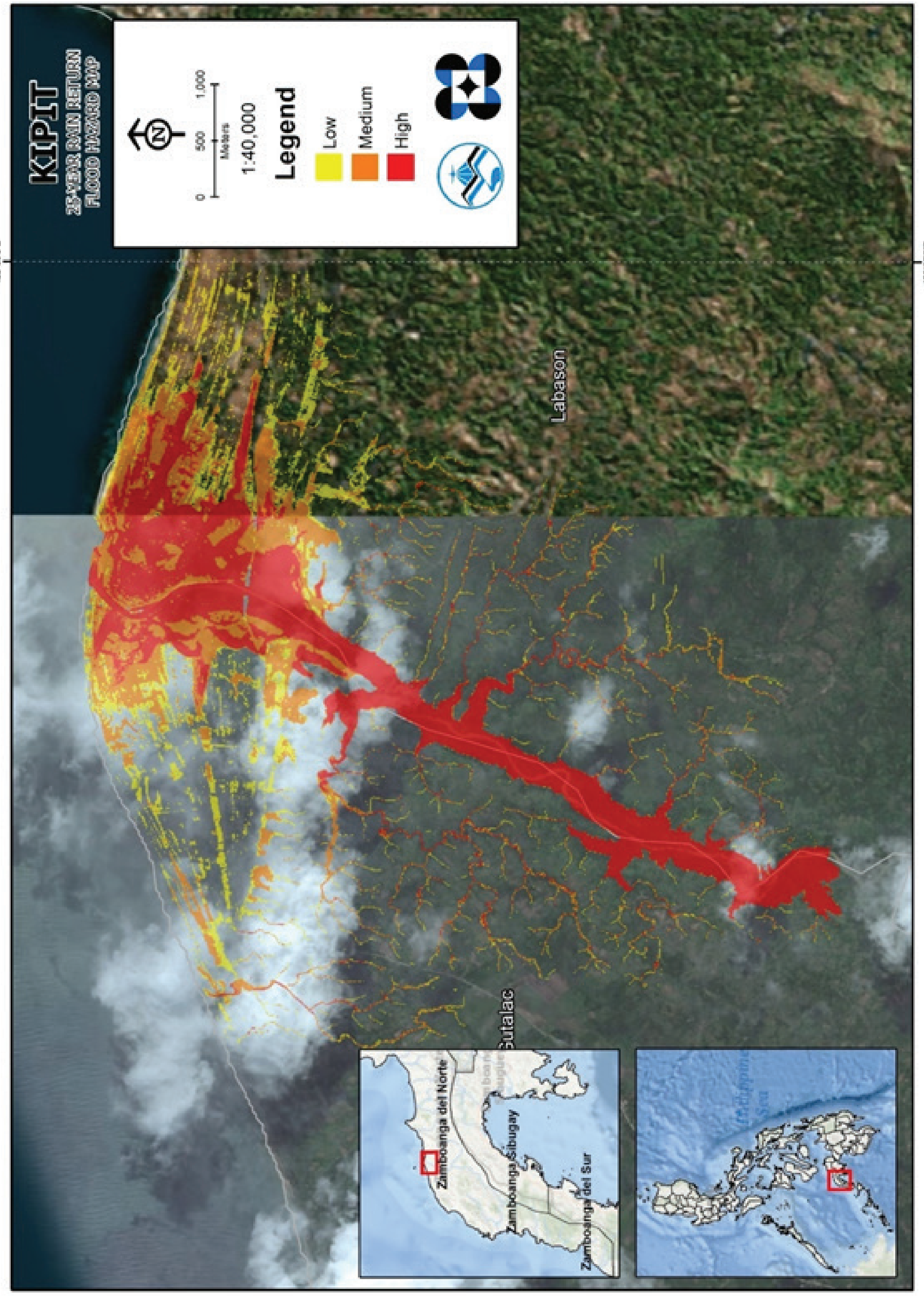


Figure 66. 25-year flood hazard map for Kipit Floodplain

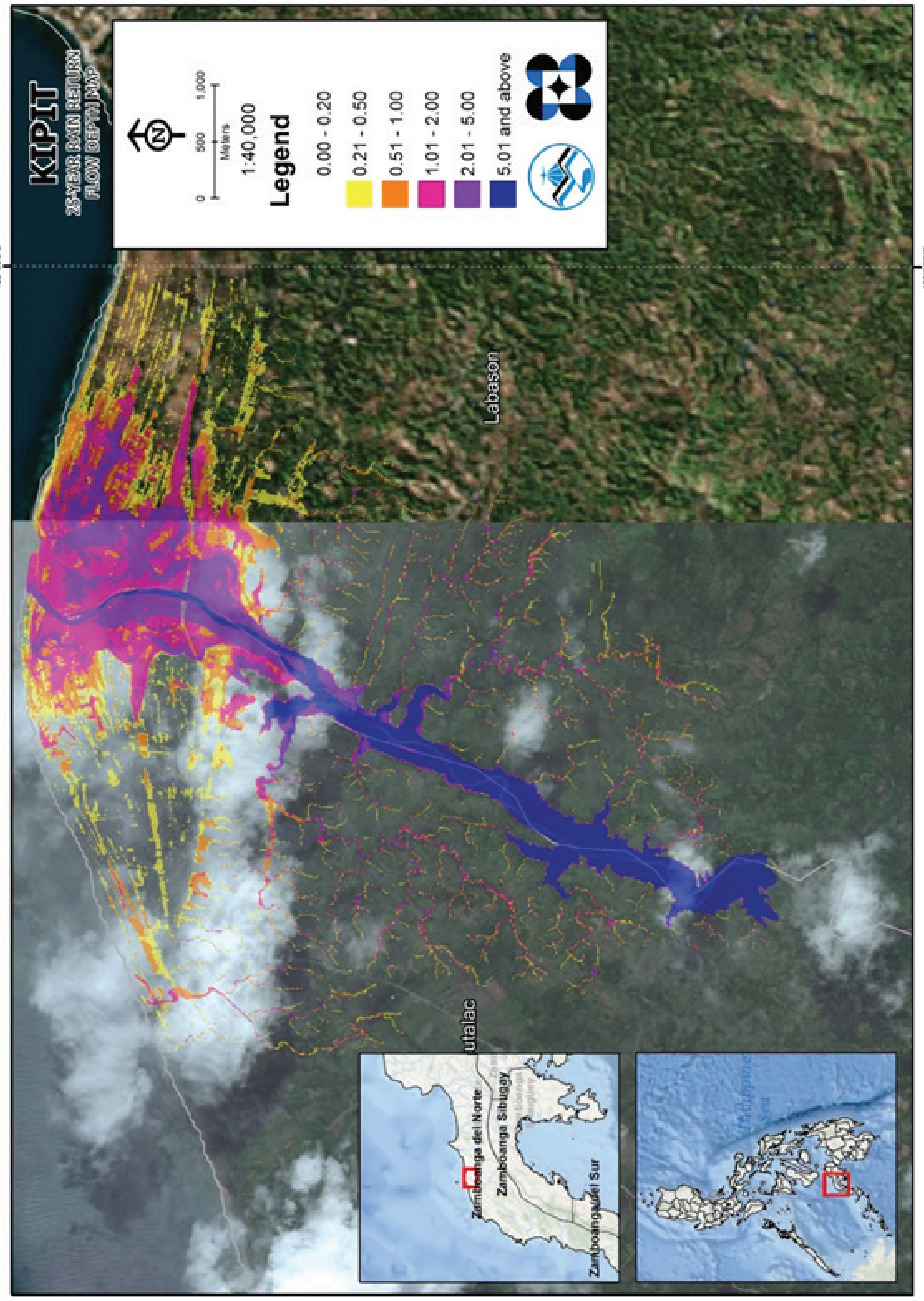


Figure 67. 25-year flow depth map for Kipit Floodplain

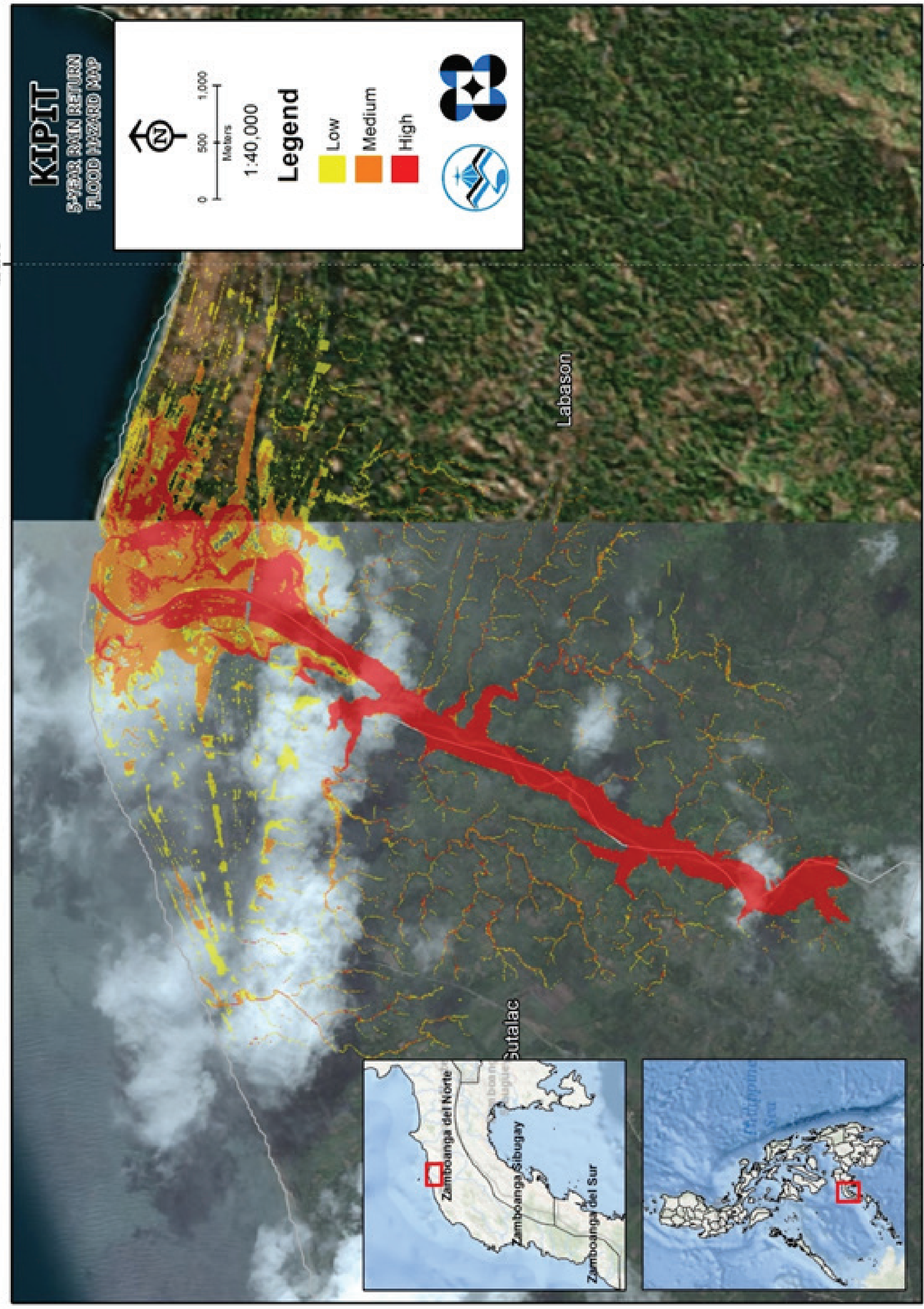


Figure 68. 5-year flood hazard map for Kipit Floodplain

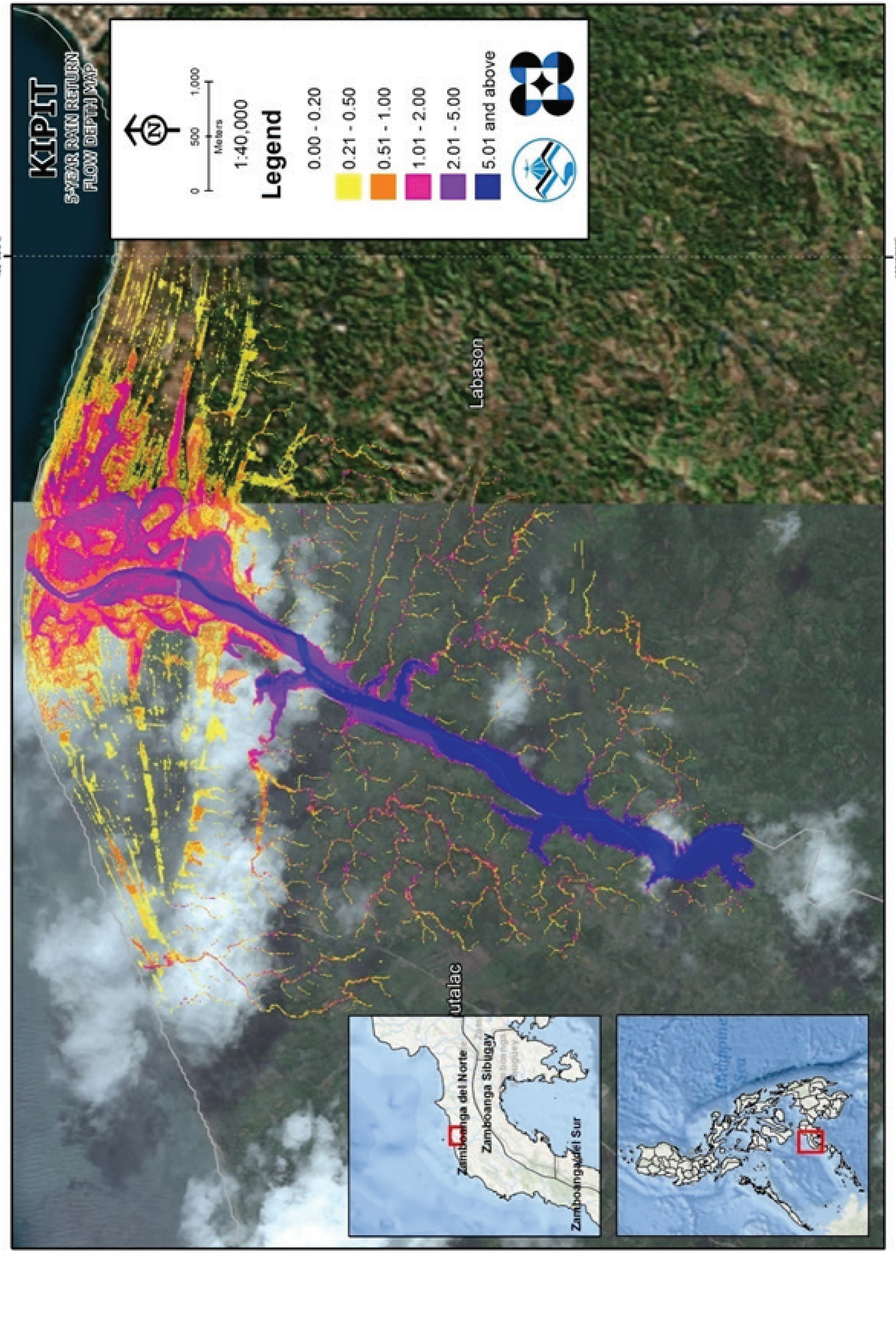


Figure 69. 5-year flood depth map for Kipit Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Kipit river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 35 barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 2.84% of the municipality of Gutalac with an area of 398.4112 sq. km will experience flood levels of less than 0.20 meters; 0.20% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.14%, 0.13%, 0.12%, and 0.14% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected areas in Gutalac, Zamboanga del Norte during 5-year rainfall return period

KIPIT BASIN		**Affected Barangays in Gutalac**			
		Imelda	**La Libertad**	**Loay**	**Lower Lux**
Affected Area (sq. km.)	1	**3.251093**	5.451003	1.330137	1.290413
	2	**0.097771**	0.604157	0.073111	0.033548
	3	**0.069347**	0.442952	0.040269	0.022081
	4	**0.074126**	0.387804	0.017417	0.023195
	5	**0.143805**	0.283088	0.003	0.032554
	6	**0.135456**	0.036566	0	0.379116

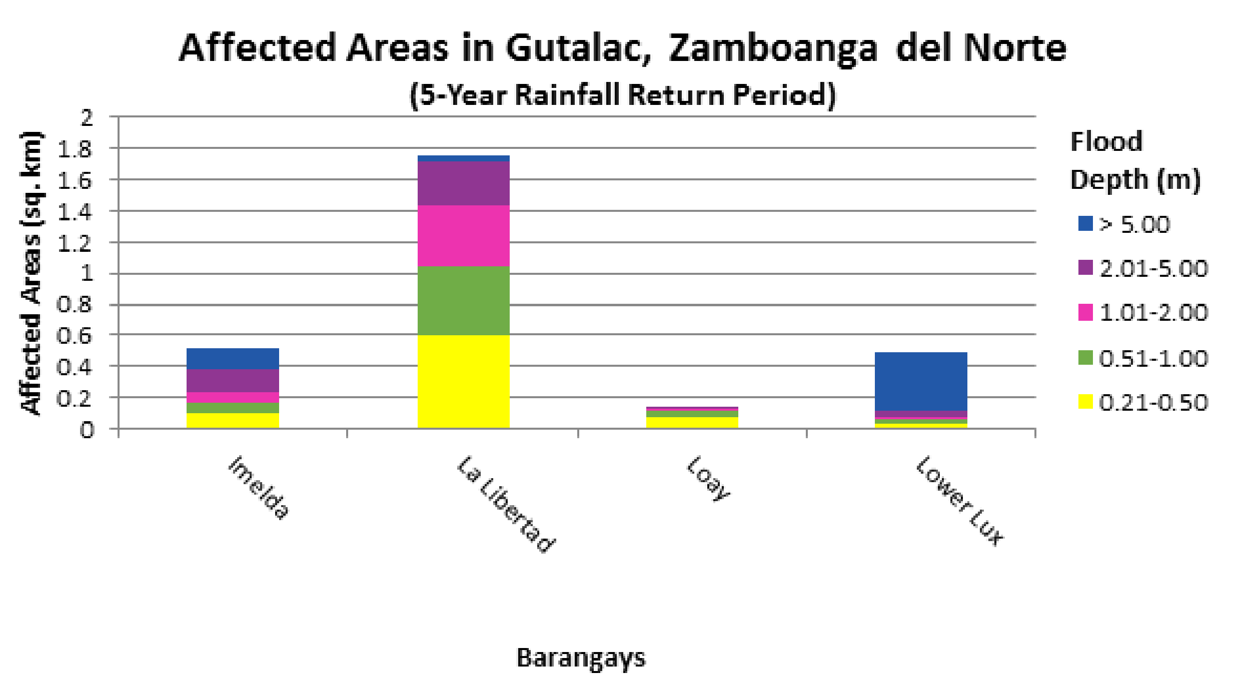


Figure 70. Affected areas in Gutalac, Zamboanga del Norte during a 5-year rainfall return period

For the 5-year return period, 7.26% of the municipality of Labason with an area of 159.4316 sq.km will experience flood levels of less than 0.20 meters; 0.54% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.48%, 0.72%, 0.36%, and 0.40% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected areas in Labason, Zamboanga del Norte during a 5-year rainfall return period

KIPIT BASIN		Affected Barangays in Labason		
		Kipit	New Salvacion	Osukan
Affected Area (sq. km.)	1	**9.829433**	1.747139	0.003288
	2	**0.819054**	0.0437	0
	3	**0.72547**	0.036249	0
	4	**1.11865**	0.023837	0
	5	**0.551205**	0.021395	0
	6	**0.457312**	0.184259	0

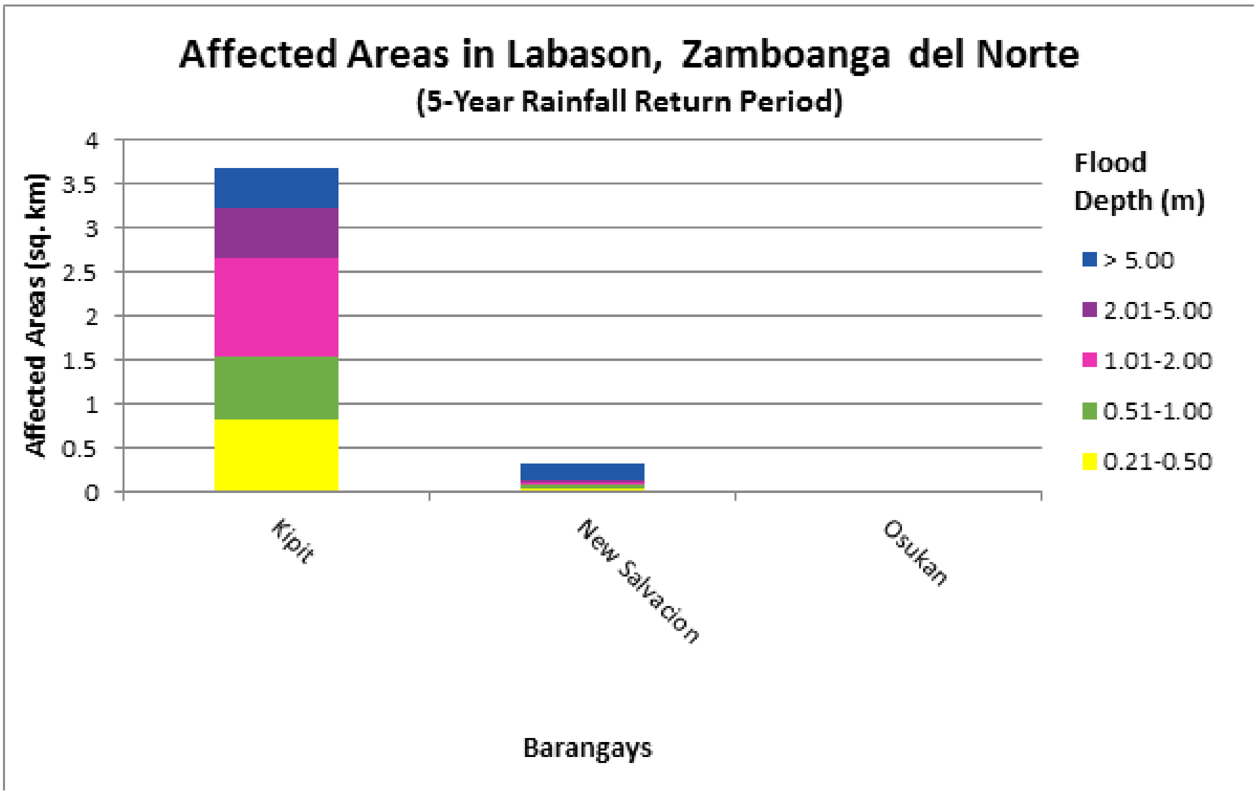


Figure 71. Affected areas in Labason, Zamboanga del Norte during a 5-year rainfall return period

For the 25-year return period, 2.59% of the municipality of Gutalac with an area of 398.4112 sq.km will experience flood levels of less than 0.20 meters; 0.23% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.19%, 0.21%, 0.14%, and 0.20% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Gutalac, Zamboanga del Norte during a 25-year rainfall return period

KIPIT BASIN		Affected Barangays in Gutalac			
		Imelda	La Libertad	Loay	Lower Lux
Affected Area (sq. km.)	1	**3.155597**	4.690939	1.285189	1.202971
	2	**0.09659**	0.722993	0.073355	0.035201
	3	**0.082177**	0.567101	0.063991	0.025597
	4	**0.08922**	0.698486	0.034405	0.026722
	5	**0.102457**	0.436554	0.006993	0.029804
	6	**0.245556**	0.089497	0	0.460613

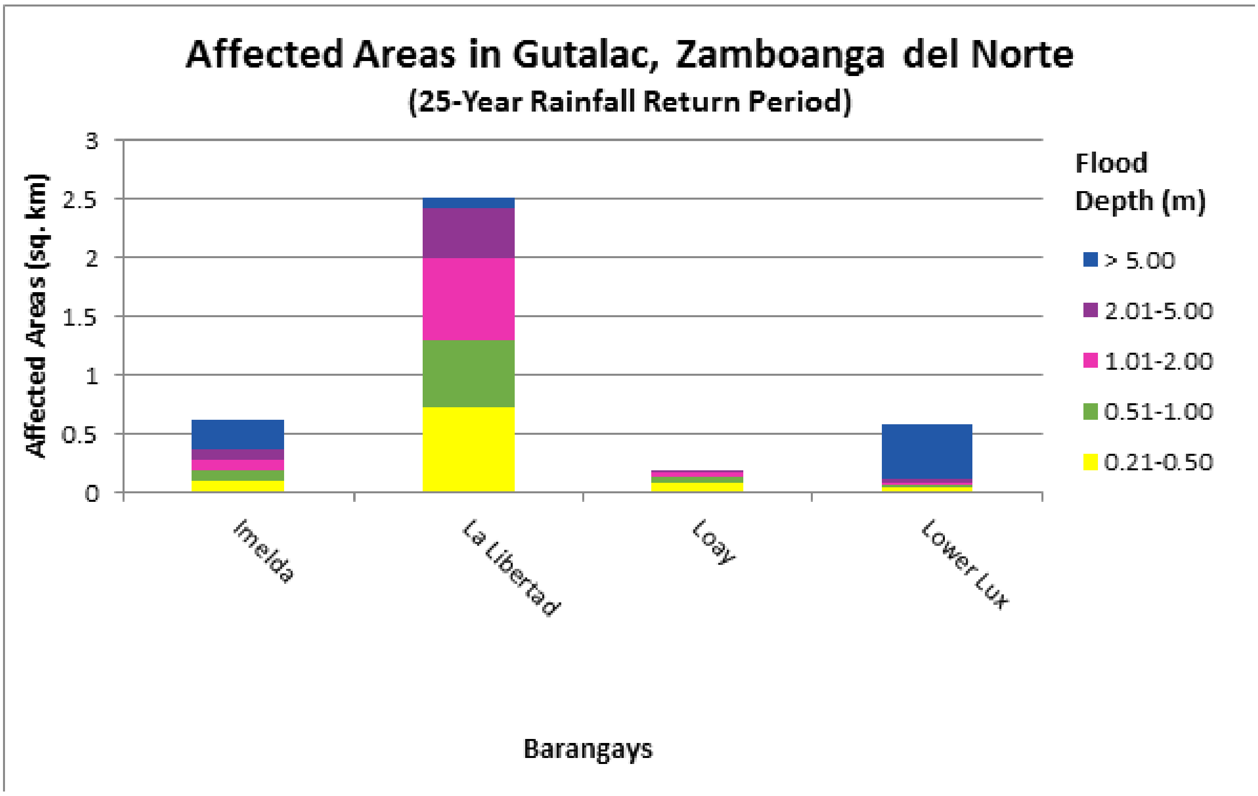


Figure 72. Affected areas in Gutalac, Zamboanga del Norte during a 25-year rainfall return period

For the 25-year return period, 6.63% of the municipality of Labason with an area of 159.4316 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 0.51%, 0.80%, 0.67%, and 0.52% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected areas in Labason, Zamboanga del Norte during a 25-year rainfall return period

KIPIT BASIN		Affected Barangays in Labason		
		Kipit	New Salvacion	Osukan
Affected Area (sq. km.)	1	**8.896986**	1.676252	0.003288
	2	**0.948738**	0.045395	0
	3	**0.775027**	0.040777	0
	4	**1.242858**	0.03488	0
	5	**1.047552**	0.025304	0
	6	**0.589964**	0.23397	0

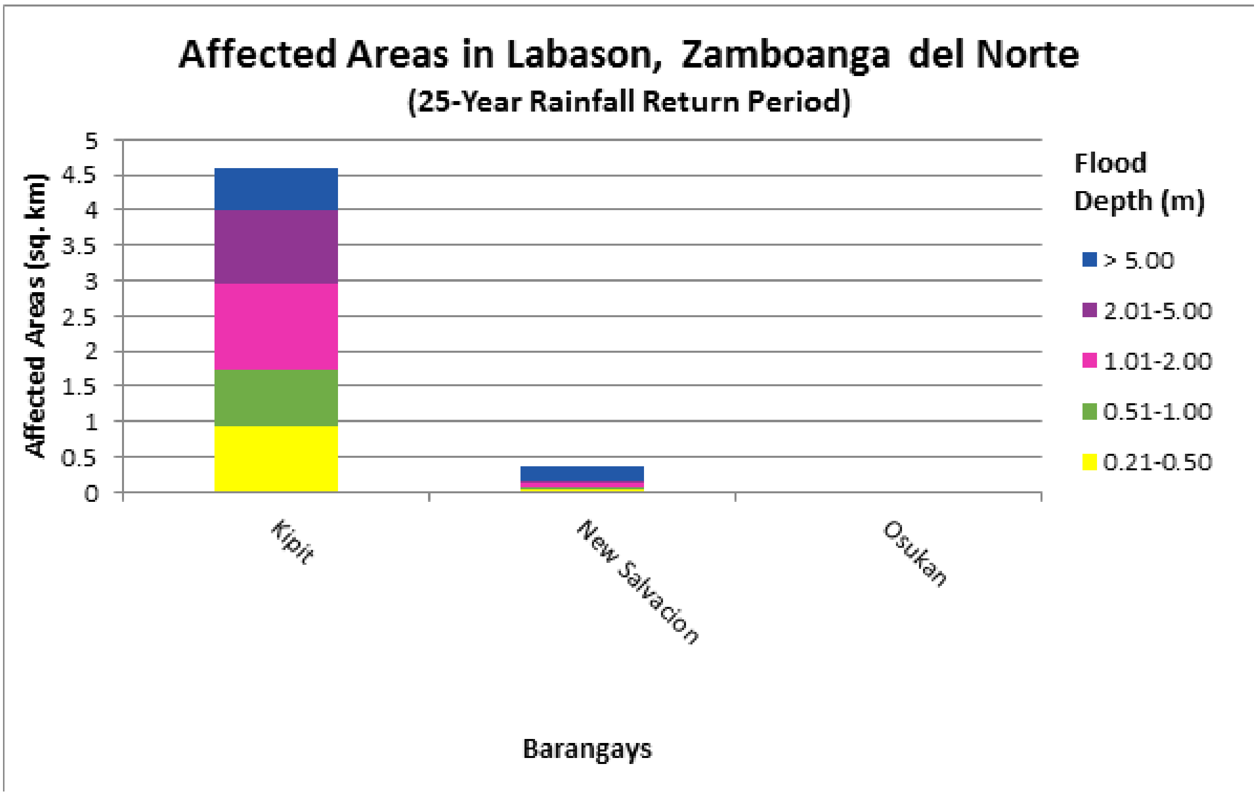


Figure 73. Affected areas in Labason, Zamboanga del Norte during a 25-year rainfall return period

For the 100-year return period, 2.38% of the municipality of Gutalac with an area of 398.4112 sq.km will experience flood levels of less than 0.20 meters; 0.28% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.24%, 0.24%, 0.20%, and 0.24% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 387 Affected areas in Gutalac, Zamboanga del Norte during a 100-year rainfall return period

KIPIT BASIN		Affected Barangays in Gutalac			
		Imelda	La Libertad	Loay	Lower Lux
Affected Area (sq. km.)	1	**3.080756**	3.98422	1.254601	1.150259
	2	**0.099106**	0.893696	0.072444	0.036543
	3	**0.079339**	0.781157	0.077335	0.029342
	4	**0.092984**	0.775087	0.048962	0.030184
	5	**0.107661**	0.644557	0.010593	0.031915
	6	**0.311752**	0.126853	0	0.502665

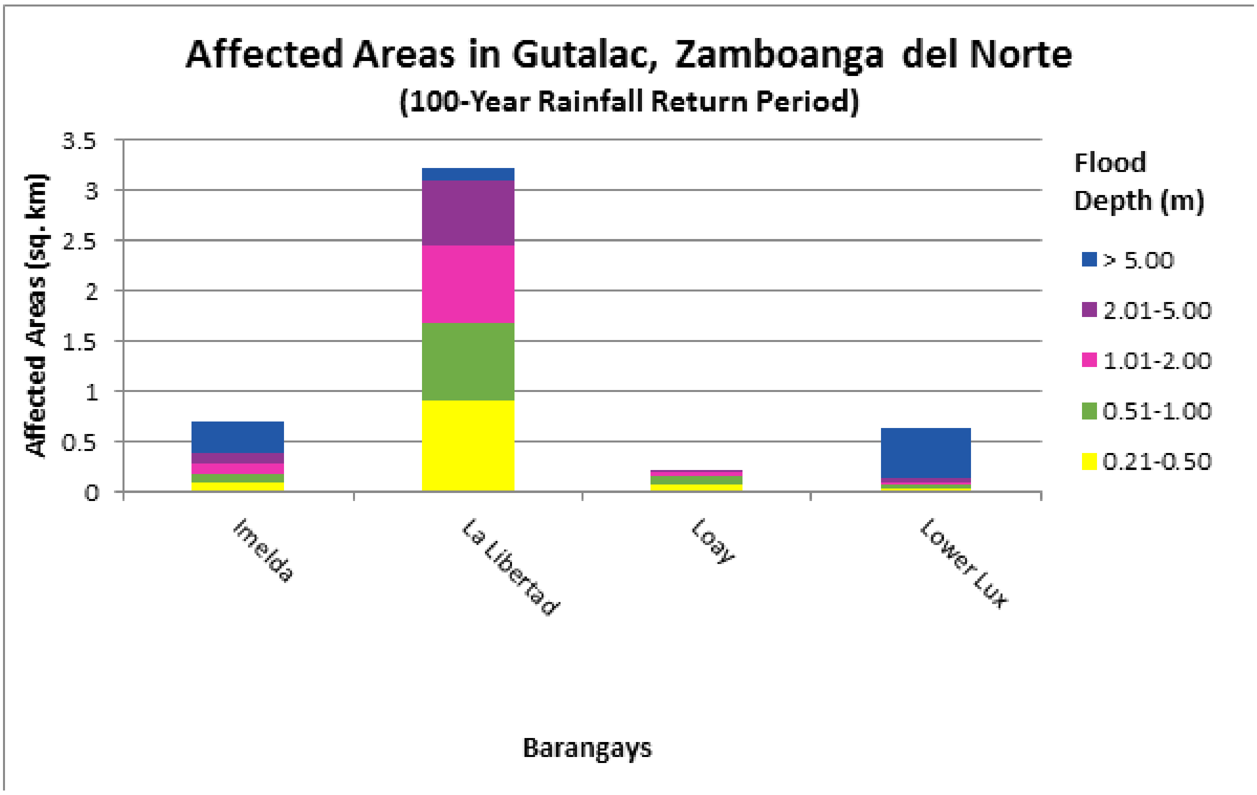


Figure 74. Affected areas in Gutalac, Zamboanga del Norte during a 100-year rainfall return period

For the 100-year return period, 6.26% of the municipality of Labason with an area of 159.4316 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 0.53%, 0.81%, 0.88%, and 0.63% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 398 Affected areas in Labason, Zamboanga del Norte during a 100-year rainfall return period

KIPIT BASIN		Affected Barangays in Labason		
		Kipit	New Salvacion	Osukan
Affected Area (sq. km.)	1	**8.351853**	1.629203	0.003288
	2	**0.989787**	0.047271	0
	3	**0.797623**	0.04067	0
	4	**1.258412**	0.04055	0
	5	**1.371165**	0.033698	0
	6	**0.732285**	0.265186	0

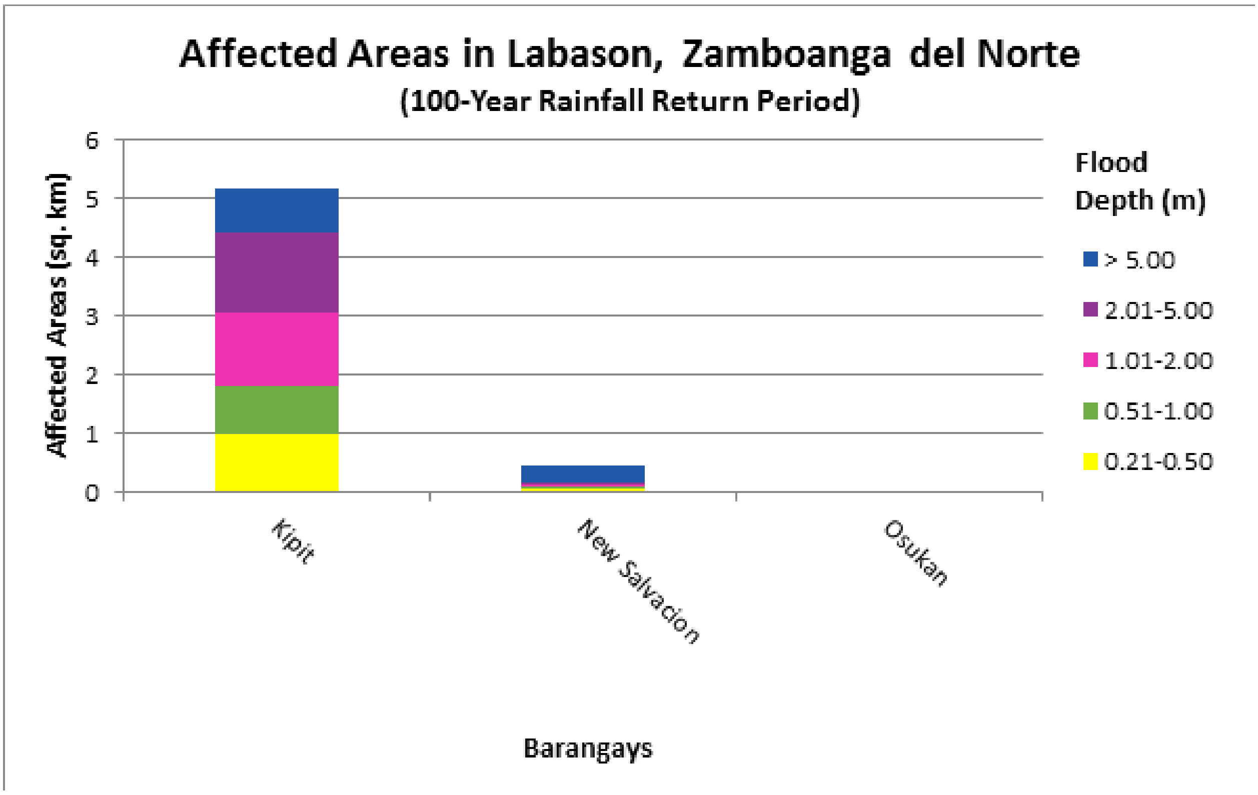


Figure 75. Affected areas in Labason, Zamboanga del Norte during a 100-year rainfall return period

The generated flood hazard maps for the Kipit Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps—"Low," "Medium," and "High"—the affected institutions were given their individual assessment for each flood hazard scenario (5-year, 25-year, and 100-year).

Table 39. 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	1.7183	1.9821	2.1836
Medium	2.3184	2.7363	2.9888
High	2.9601	4.2975	5.2993

Of the 6 identified educational institutions in Kipit Floodplain, 1 school was assessed to be exposed to the low-level flooding during a 5-year scenario while 2 schools were assessed to be exposed to medium-level flooding in the same scenario. 1 school was exposed to high-level flooding for the same scenario. In the 25-year scenario, 3 schools were assessed to be exposed to the medium-level flooding while 1 school was assessed to be exposed to high-level flooding. For the 100-year scenario, 3 schools were assessed for medium-level flooding. In the same scenario, 1 school was assessed to be exposed to high-level flooding (See Annex 12).

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the flood depth maps produced and to improve on what is needed.

The flood validation consists of 128 points randomly selected all over the Kipit Floodplain. It has an RMSE value of 0.7. The validation points are found in Annex 11.

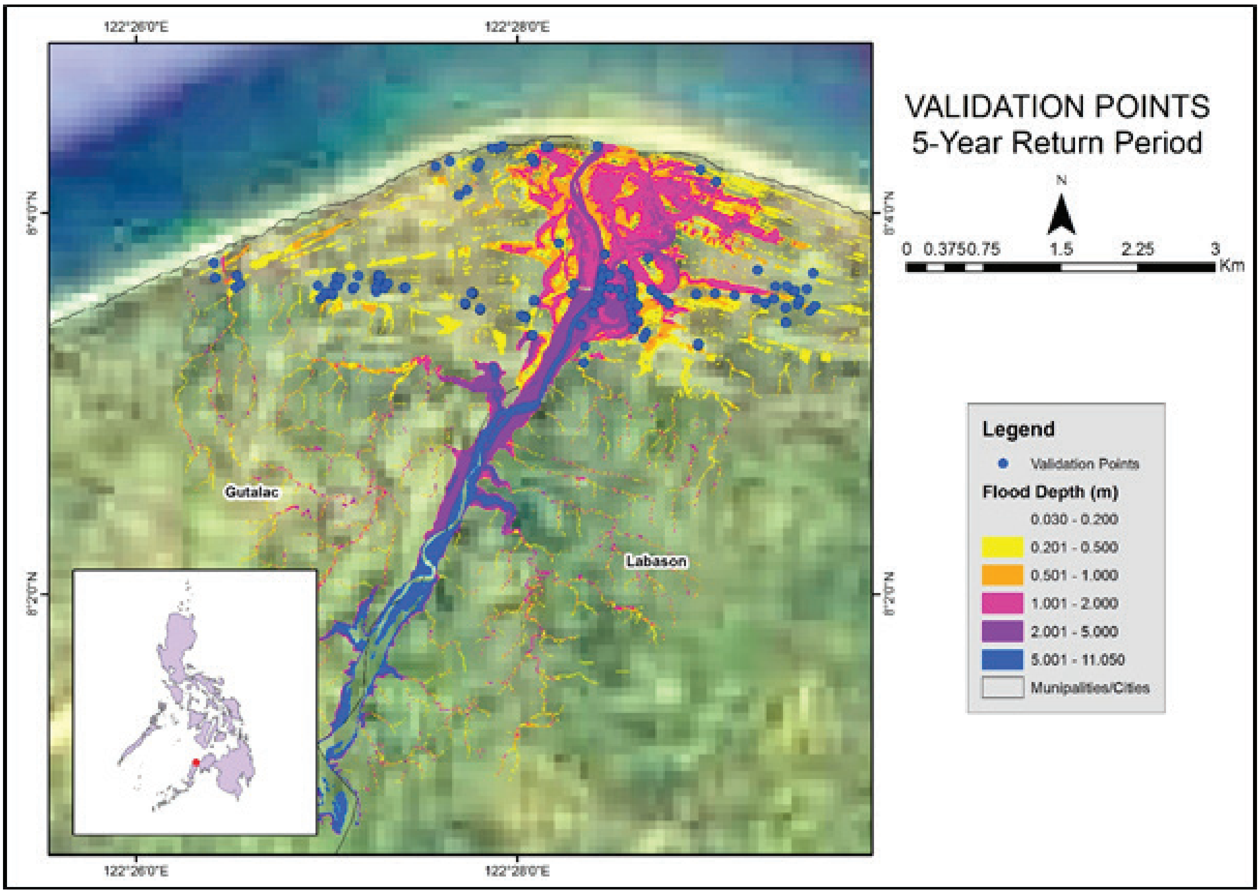


Figure 76. Validation points for 5-year flood depth map of Kipit Floodplain

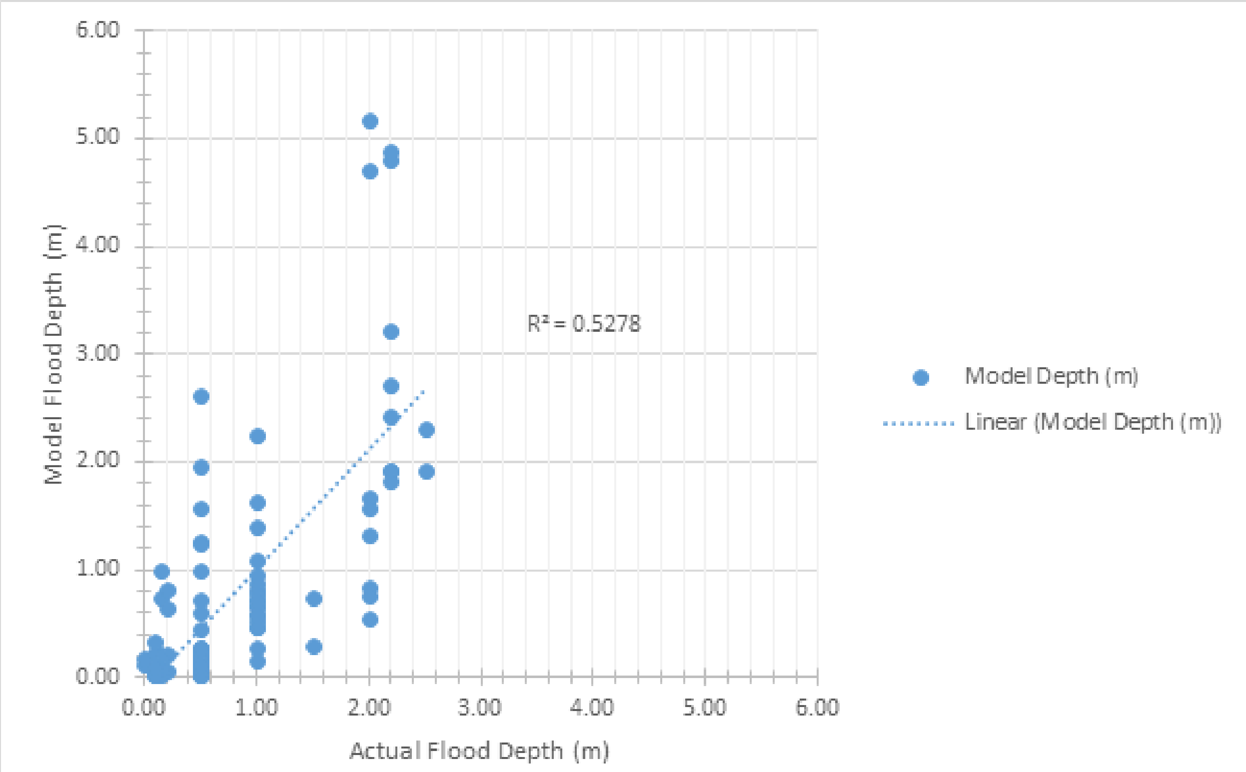


Figure 77. Flood map depth vs actual flood depth

Table 40. Actual flood depth vs simulated flood depth in Kipit

KIPIT BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	30	5	4	0	0	0	39
	0.21-0.50	35	7	3	4	1	0	50
	0.51-1.00	1	3	11	3	1	0	19
	1.01-2.00	0	1	4	3	1	1	10
	2.01-5.00	0	0	0	4	6	0	10
	> 5.00	0	0	0	0	0	0	0
	Total	66	16	22	14	9	1	128

The overall accuracy generated by the flood model was estimated at 44.53%, with 57 points correctly matching the actual flood depths. In addition, there were 55 points estimated one level above and below the correct flood depths while there were 12 points and 1 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 23 points were overestimated while a total of 48 points were underestimated in the modelled flood depths of Kipit.

Table 41. Summary of accuracy assessment in Kipit

	No. of Points	%
Correct	57	44.53
Overestimated	23	17.97
Underestimated	48	37.50
Total	128	100.00

REFERENCES

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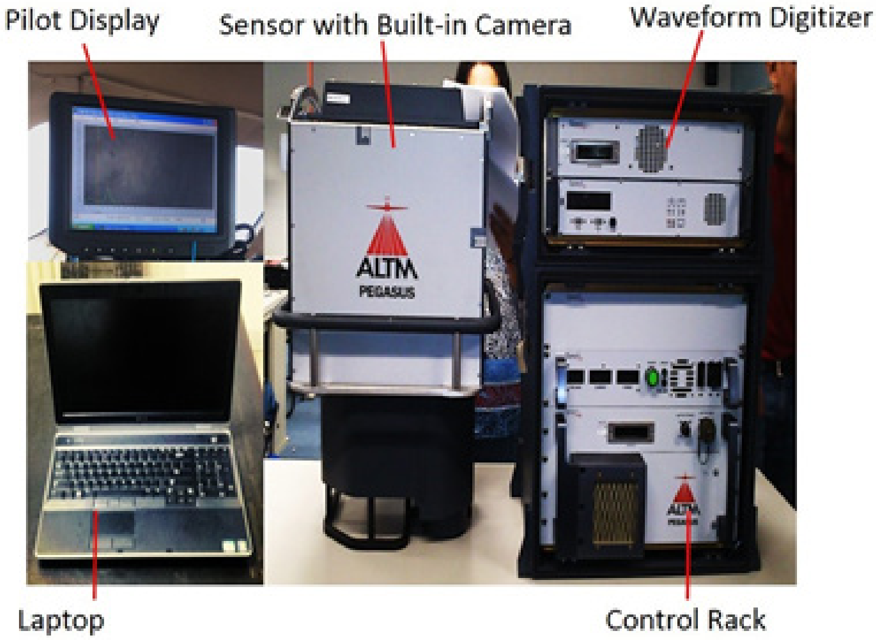
Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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.

Municipal Profile, LGU Labason
Municipal DRRM Plan, LGU Labason
Historical Data of Flood Events, LGU Labason
Environmental Management Bureau
Forestpeoples.org
Bird observations on the Zamboanga Peninsula, Mindanao, Philippines by Lisa Marie Paguntalan, et al.

ANNEXES

Annex 1. OPTECH Technical Specification of the Pegasus Sensor



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

Annex 2. NAMRIA Certificate of Reference Point Used

ZGN-4

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

December 09, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL NORTE**
Station Name: **ZGN-4**
Order: **1st**

Island:	**MINDANAO**	Barangay:	**LAMAO**		
Municipality:	**LILOY**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**8° 8' 20.40827"**	Longitude:	**122° 40' 28.89097"**	Ellipsoidal Hgt:	**3.84800 m.**
		WGS84 Coordinates			
Latitude:	**8° 8' 16.73719"**	Longitude:	**122° 40' 34.34251"**	Ellipsoidal Hgt:	**67.35130 m.**
		PTM / PRS92 Coordinates			
Northing:	**899937.404 m.**	Easting:	**464150.413 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**899,622.41**	Easting:	**464,162.96**	Zone:	**51**

Location Description

ZGN-4
From Dipolog city, travel SW along the natl. highway for 131 km. or 4-3/4 hrs. drive up to Liloy town proper. Upon reaching Liloy town proper, turn right and travel N for 2 km. on the road leading to Liloy Port in Brgy. Lamao. Station is located at the concrete pavement of the wharf; at the E corner of the intersection of the concrete curbs; it is 42.9 m. SE from the end of the wharf; 87.4 m. SW of the gate of the pier; 8.1 m. SE to the concrete stairway. Mark is a crosscut on top of a 0.15 m. x 0.01 m. in dia. brass rod, set in a drilled hole, centered in a 0.3 m. x 0.3 m. cement putty with inscription of the station name. Reference marks (RM); RM 1, RM 2 and RM 3 are 0.15 m. x 0.01 m. in dia. brass rod centered in a 0.25 m. x 0.25 m. cement putty; set on top of the concrete curb of the pier and inscribed on top with the RM no. and the arrow pointing to the station.

Requesting Party: **Christopher Cruz**
Purpose: **Reference**
OR Number: **8077396 I**
T.N.: **2014-2979**

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

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

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

Annex 3. Baseline Processing Reports of Reference Points Used

ZN-157

Vector Components (Mark to Mark)

From:	ZGN-4				
Grid		Local		Global	
Easting	464162.960 m	Latitude	N8°08'20.40828"	Latitude	N8°08'16.73719"
Northing	899622.410 m	Longitude	E122°40'28.89097"	Longitude	E122°40'34.34251"
Elevation	2.145 m	Height	3.948 m	Height	67.351 m

To:	ZN-157				
Grid		Local		Global	
Easting	470917.760 m	Latitude	N8°06'05.34724"	Latitude	N8°06'01.69150"
Northing	895470.122 m	Longitude	E122°44'09.71575"	Longitude	E122°44'15.17027"
Elevation	4.934 m	Height	7.394 m	Height	71.024 m

Vector					
ΔEasting	6754.799 m	NS Fwd Azimuth	121°32'02"	ΔX	-6007.200 m
ΔNorthing	-4152.288 m	Ellipsoid Dist.	7932.054 m	ΔY	-3156.889 m
ΔElevation	2.789 m	ΔHeight	3.445 m	ΔZ	-4106.710 m

Standard Errors

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

ZGN-4E

Vector Components (Mark to Mark)

From:	ZGN-4				
Grid		Local		Global	
Easting	464330.109 m	Latitude	N8°08'16.73719"	Latitude	N8°08'16.73719"
Northing	899566.355 m	Longitude	E122°40'34.34251"	Longitude	E122°40'34.34251"
Elevation	2.145 m	Height	67.351 m	Height	67.351 m

To:	ZGN-4E				
Grid		Local		Global	
Easting	464334.463 m	Latitude	N8°08'16.81854"	Latitude	N8°08'16.81854"
Northing	899568.850 m	Longitude	E122°40'34.48473"	Longitude	E122°40'34.48473"
Elevation	2.145 m	Height	67.351 m	Height	67.351 m

Vector					
ΔEasting	4.354 m	NS Fwd Azimuth	60°08'28"	ΔX	-3.473 m
ΔNorthing	2.495 m	Ellipsoid Dist.	5.020 m	ΔY	-2.649 m
ΔElevation	0.000 m	ΔHeight	0.000 m	ΔZ	2.474 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'13"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000003395		
Y	-0.0000002924	0.0000006451	
Z	-0.0000000919	0.0000000865	0.0000001375

Annex 4. The Survey Team

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LiDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		ENGR. GRACE SINADJAN	UP-TCAGP
		KRISTINE JOY ANDAYA	UP-TCAGP
		ENGR. GEF SORIANO	UP-TCAGP
		JERIEL PAUL ALAMBAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. RENAN PUNTO	UP-TCAGP
		MERLIN FERNANDO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RONALD MONTENEGRO	PHILIPPINE AIR FORCE (PAF)
		SSG. GERONIMO BALICAO III	PAF
	Pilot	CAPT. JOHN BRYAN DONGUINES	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. ANTON RETSE DAYO	AAC
		CAPT. FERDINAND DE OCAMPO	AAC
		CAPT. ERNESTO SAYSAY JR.	AAC

Annex 5. Data Transfer Sheets for Kipit Floodplain

DATA TRANSFER SHEET

11/17/2014(dipolog)

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	
19-Oct	2099P	1BLK69CALIB292A	PEGASUS	106	na	3.84	113	9.11	83	3.84	na	4.08	1KB	1KB	47/23	na	Z:\DAC\RAW DATA
22-Oct	2111P	1BLK69B295A	PEGASUS	2.01	453	12.4	236	29.5	292	22.2	na	7.59	1KB	1KB	292/48/58	na	Z:\DAC\RAW DATA
23-Oct	2113P	1BLK69B296A	PEGASUS	1.62	394	10	216	36.4	260	19.4	na	15.1	1KB	1KB	48/51/44/61	na	Z:\DAC\RAW DATA
23-Oct	2115P	1BLK6970A296B	PEGASUS	754	171	6.26	105	13.6	115	8.18	na	15.1	1KB	1KB	40/51/25	na	Z:\DAC\RAW DATA
24-Oct	2117P	1BLK69B297A	PEGASUS	1.24	237	5.73	113	18.6	164	12.4	na	7.64	1KB	1KB	48/51/50	na	Z:\DAC\RAW DATA
26-Oct	2125P	1BLK69C299A	PEGASUS	1.5	267	8.41	211	32	239	15.4	na	37.4	1KB	1KB	48/51/50/41/ 56/43/22	na	Z:\DAC\RAW DATA
26-Oct	2127P	1BLK6970A299B	PEGASUS	2.54	na	5.91	114	16	1	12.9	na	37.4	1KB	1KB	27/1	na	Z:\DAC\RAW DATA
28-Oct	2133P	1BLK69FE301A	PEGASUS	2.05	244/454	10.2	225	57.4	343	na	na	37.3	1KB	1KB	73/51/81/39	na	Z:\DAC\RAW DATA
28-Oct	2135P	1BLK69F301B	PEGASUS	266	170/87	3.42	94.6	na	na	5.4	na	37.3	1KB	1KB	92	na	Z:\DAC\RAW DATA
29-Oct	2137P	1BLK70D302A	PEGASUS	1.05	453/220	7.37	190	28.3	181	11.2	na	19.4	1KB	1KB	106/93/82/75	na	Z:\DAC\RAW DATA
31-Oct	2145P	1BLK69C304A	PEGASUS	2.33	1118/434	9.11	182	48.6	342	22.8	na	6.52	1KB	1KB	74	na	Z:\DAC\RAW DATA
1-Nov	2149P	1BLK70B305A	PEGASUS	1.79	338	7.39	192	32.1	227	20.3	na	29.2	1KB	1KB	54/79	na	Z:\DAC\RAW DATA
3-Nov	2157P	1BLK70C307A	PEGASUS	2.26	198	11.3	240	40.6	295	25.1	na	35.5	1KB	1KB	33	na	Z:\DAC\RAW DATA
6-Nov	2169P	1BLK73A310A	PEGASUS	3.01	523	12.1	240	62.9	na	26.9	na	21.3	1KB	1KB	80	na	Z:\DAC\RAW DATA
8-Nov	2177P	1BLK70C312A	PEGASUS	1.75	327	8.89	199	23.1	na	17.5	na	17.8	1KB	1KB	60/53/57	na	Z:\DAC\RAW DATA
9-Nov	2181P	1BLK69F313A	PEGASUS	1.46	291	8.11	182	22.4	182	15.2	na	17	1KB	1KB	65/62/51	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin

Position RA

Signature

Received by

Name Angelo Carlo Bongat

Position SSRS

Signature 11/19/2014

DATA TRANSFER SHEET
12/09/2014(dipolog)

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	
10-Nov	2185P	1BLK73A314A	PEGASUS	1.15	na	9.84	253	na	na	13.1	na	19.5	1KB	1KB	56/49/45/58	na	Z:\DAC\RAW DATA
11-Nov	2189P	1BLK73S315A	PEGASUS	1.6	na	7.23	219	na	na	16.8	na	29.5	1KB	1KB	56/49/45/59	na	Z:\DAC\RAW DATA

Received from

Name C.JOAQUIN
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SUPSRS
Signature 12/9/14

14-77

DATA TRANSFER SHEET
DIPOLOG 12/6/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
November 20, 2016	23558P	1BLK69BC325A	PEGASUS	249	NA	11.2	274	NA	NA	24.8	NA	175	1KB	1KB	234	NA	Z:\DAC\RAW DATA
November 21, 2016	23562P	1BLK69BD326A	PEGASUS	2.64	NA	12.2	289	NA	NA	29.5	NA	165	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA
November 22, 2016	23566P	1BLK69E327A	PEGASUS	1.65	NA	9.58	267	NA	NA	18	NA	188	1KB	1KB	652	NA	Z:\DAC\RAW DATA
November 24, 2016	23574P	1BLK69AD329A	PEGASUS	1.92	NA	10	264	NA	NA	21.7	NA	126	1KB	1KB	421	NA	Z:\DAC\RAW DATA
November 26, 2016	23582P	1BLK73DE331A	PEGASUS	2.46	NA	11.6	281	25.1	274	25.5	NA	162	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 12/6/16

DATA TRANSFER SHEET
DIPOLOG 12/8/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
November 28, 2016	23590P	1BLK73DEF333A	PEGASUS	1.56	NA	7.69	203	32.6	298	16.6	NA	42.3	1KB	1KB	1.19	NA	Z:\DAC\RAW DATA
November 30, 2016	23598P	1BLK76A335A	PEGASUS	600	NA	6.93	239	NA	NA	7.85	NA	48.2	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA
December 01, 2016	23602P	1BLK76AB336A	PEGASUS	1.56	NA	9.08	287	NA	NA	16.5	NA	53.9	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA

Received from

Name: R. PUNTO
Position: RA
Signature: [signature]

Received by

Name: AC Bongat
Position: SSRS
Signature: [signature] 12/8/16

Annex 6. Flight Logs fo the Flight Missions

Flight Log for 1BLK73A310A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2169P

1 LiDAR Operator: K. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK73A310A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: B. Donguines	8 Co-Pilot: P. De Ocampo	9 Route:			
10 Date: Nov. 6, 2014	12 Airport of Departure (Airport, City/Province): Pitogo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 10:23	14 Engine Off: 14:28	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Successful flight					

21 Problems and Solutions:

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

Flight Log for 1BLK73A314A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2185P

1 LiDAR Operator: KL ANVAYA	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK73A314A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: B. DONGUINES	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: Nov. 10, 2014	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 12:40	14 Engine Off: 17:10	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: CLOUDY					

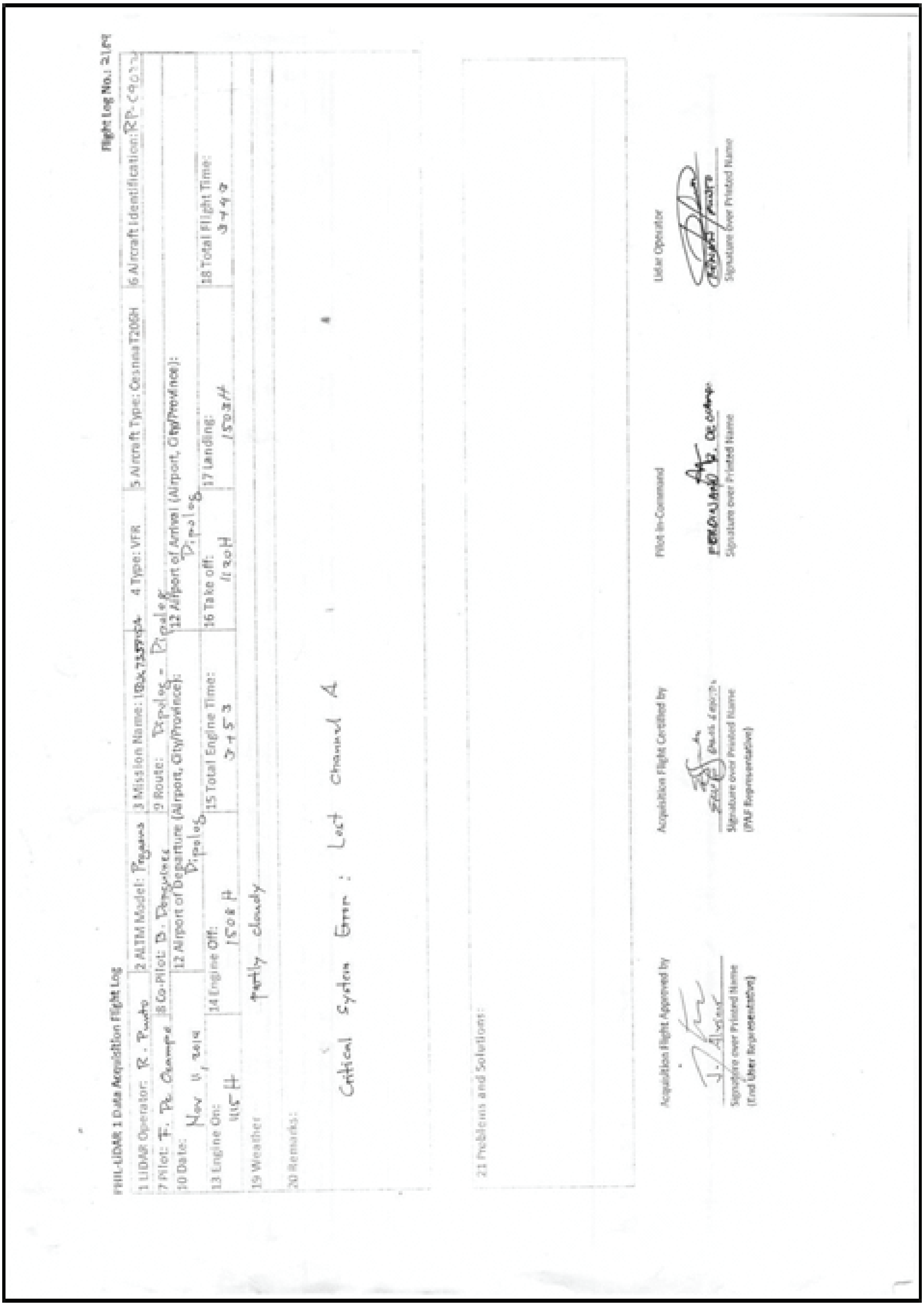
20 Remarks:

SUCCESSFUL FLIGHT.

21 Problems and Solutions:

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

Flight Log for 1BLK73A315A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2184

1 LIDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK73A315A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: F. De Ocampo	8 Co-Pilot: B. Dongulnes	9 Route: Dipolog - Dipolog			
10 Date: Nov 11, 2014	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 1115 H	14 Engine Off: 1508 H	15 Total Engine Time: 3+53	16 Take off: 1120 H	17 Landing: 1503 H	18 Total Flight Time: 3+43
19 Weather: partly cloudy					

20 Remarks:

Critical System Error : Lost Channel A

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	[illegible]	FERDINAND F. DE OCAMPO	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 1BLK73DE331A Mission

Phil-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23582P

1 LIDAR Operator: JP MAMBAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK73DE331A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A DAYO	8 Co-Pilot: E CAYSAY JR	9 Route:			
10 Date: 11/26/16	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 1117H	14 Engine Off: 1540H	15 Total Engine Time: 4+23	16 Take off: 1122H	17 Landing: 1535H	18 Total Flight Time: 4+13
19 Weather: CLOUDY					

20 Flight Classification

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

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

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

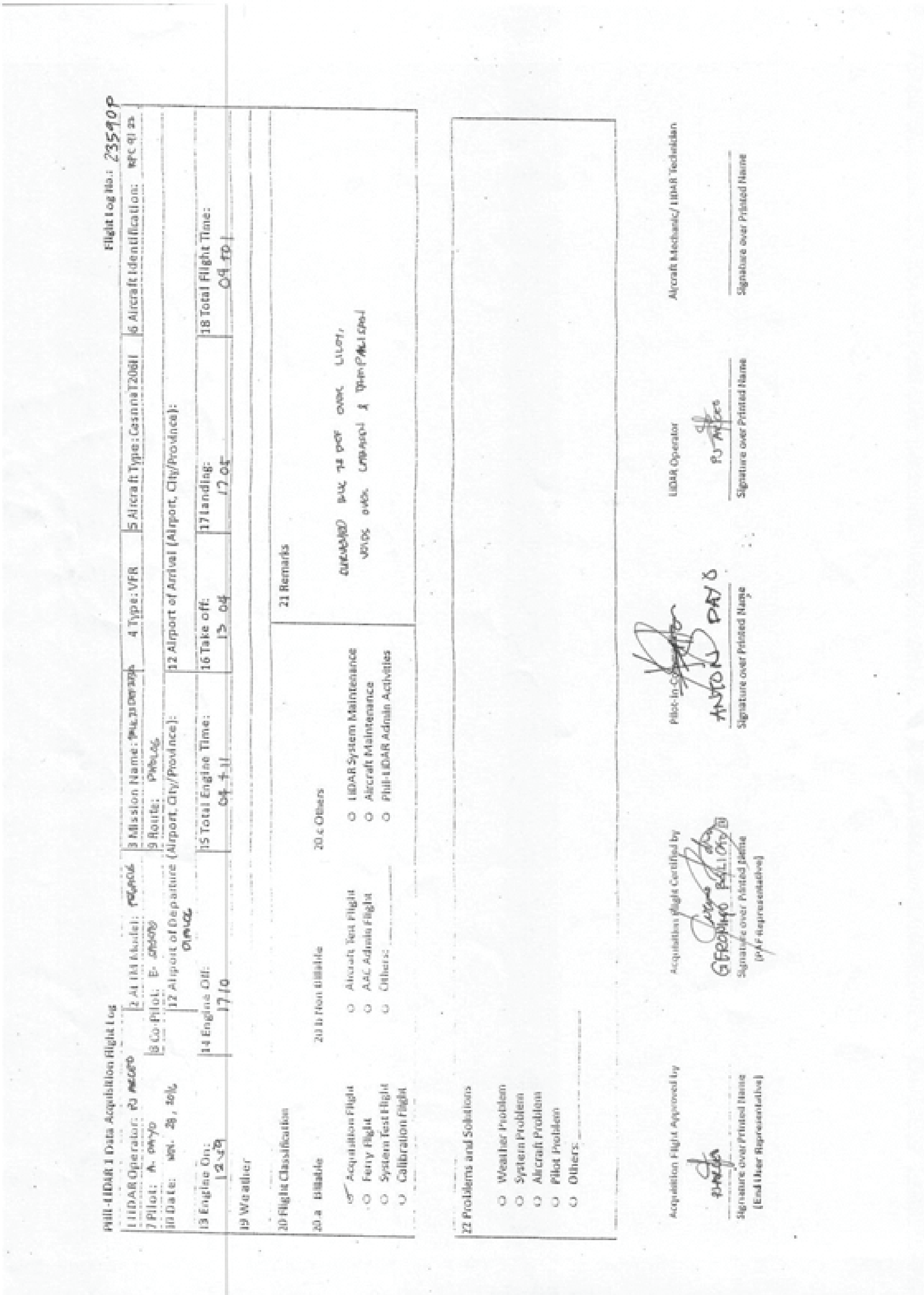
21 Remarks

SURVEYED BLK 73 D & E WITH VOIDS

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
[signature]	GERONIMO BALICANO III	ANTON DAYO	JP MAMBAN	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 1BLK73DEF333A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23590P

1 LIDAR Operator: PJ ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK73DEF333A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC 9122
7 Pilot: A. DAYO	8 Co-Pilot: E. GASOPO	9 Route: PHILOG			
10 Date: NOV. 28, 2016	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 12:59	14 Engine Off: 17:10	15 Total Engine Time: 04+11	16 Take off: 13:04	17 Landing: 17:05	18 Total Flight Time: 04+01

19 Weather

20 Flight Classification

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

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

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

21 Remarks

SURVEYED BLK 73 DEF OVER LILOY, VOIDS OVER LABASON & TAMPILISAN

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

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

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

Pilot-in-Command: ANTON DAYO — Signature over Printed Name

LIDAR Operator: PJ ARCEO — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Annex 7. Flight Status Reports

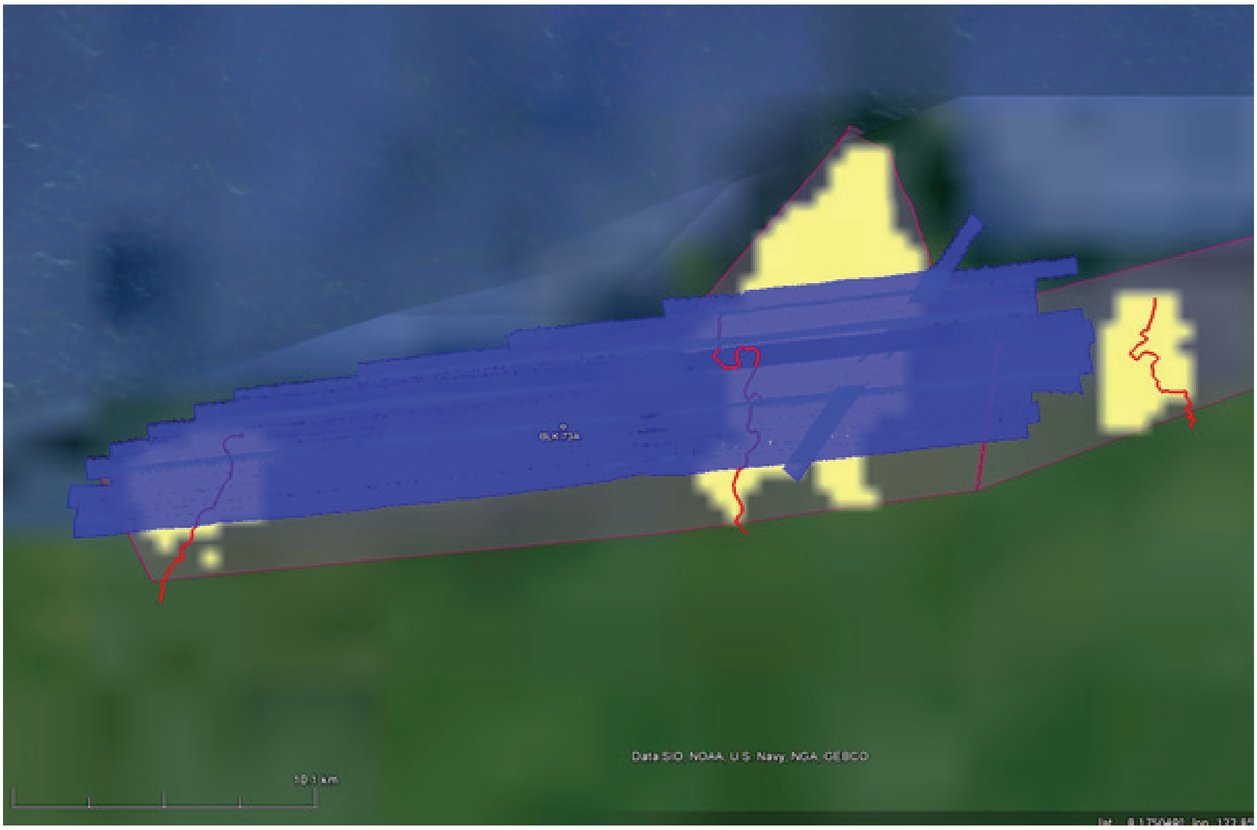
DIPOLOG-ZAMBOANGA DEL NORTE
(October 8 to November 11, 2014 and November 20 to 26, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2169P	BLK 73A	1BLK73A310A	R PUNTO	November 6, 2014	Successful flight over BLK 73A
2185P	BLK 73A	1BLK73A314A	KJ ANDAYA	November 10, 2014	Surveyed BLK 73A
2189P	BLK73A	1BLK73A315A	R PUNTO	November 11, 2014	Successful flight over BLK 73A
23582P	BLK 73D, 73E	1BLK73DE331A	JP ALAMBAN	November 26, 2016	Surveyed BLK 73D and 73D over Kipit and Patawag floodplain
23590P	BLK 73D, 73E, 73F	1BLK73DEF333A	PJ ARCEO	November 28, 2016	Surveyed Dipolog and Paro Dapitan floodplain with voids due to build up and strong winds

LAS BOUNDARIES PER FLIGHT

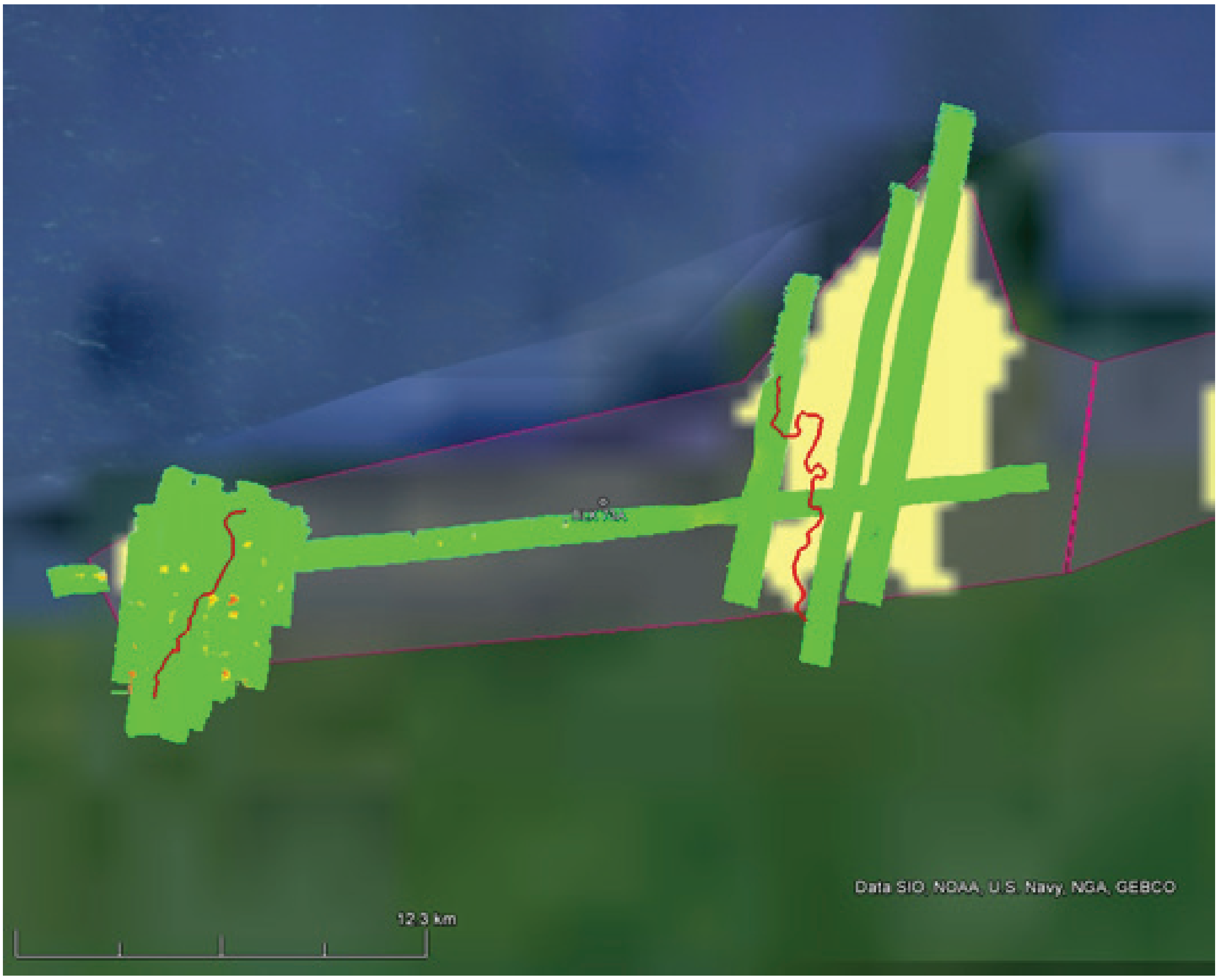
Flight No.: 2169P
Area: BLK 73A
Mission Name: 1BLK73A310A
Parameters: Altitude: 750 m;
Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS



Flight No.: 2185P
Area: BLK 73A
Mission Name: 1BLK73A314A
Parameters:
Altitude: 750/850/1000 m;
Scan Frequency: 30 Hz;
Scan Angle: 25 deg;
Overlap: 20%

LAS

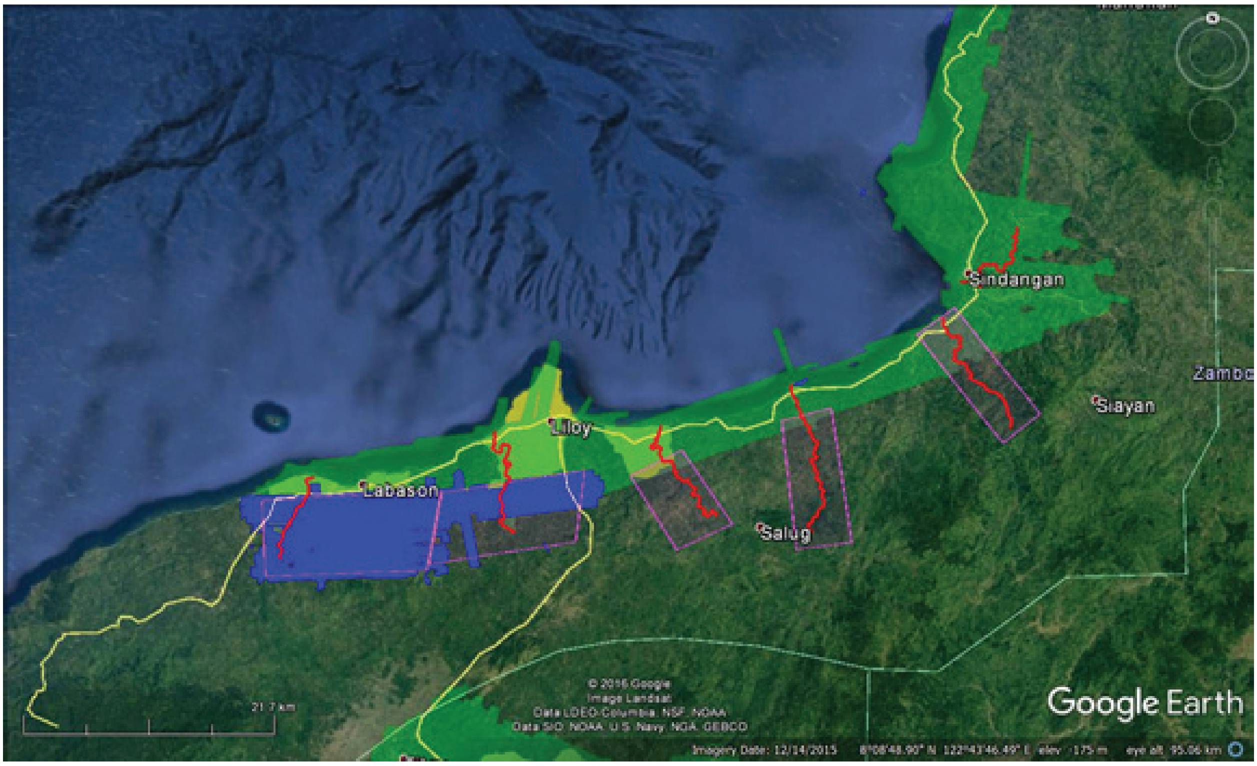


Flight No.: 2189P
Area: BLK 73A
Mission Name: 1BLK73A315A
Parameters:
Altitude: 750/850/1000 m;
Scan Frequency: 30 Hz;
Scan Angle: 25 deg;
Overlap: 20%

LAS

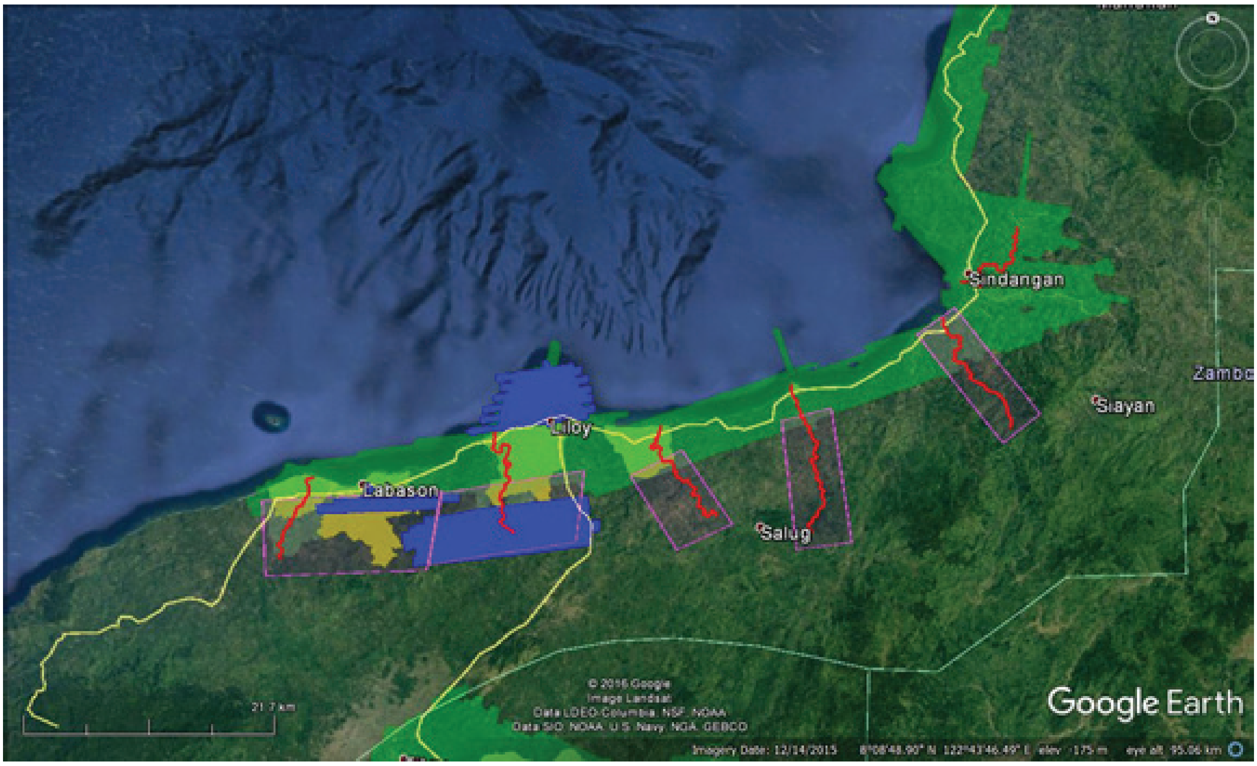
Flight No.: 23582P
Area: BLK 73D, BLK 73E
Mission Name: 1BLK73DE331A
Parameters: Altitude: 600/700/800/1000/1100/1200 m;
Scan Frequency: 30 Hz;
Scan Angle: 20 deg;
Overlap: 30%

LAS



Flight No.: 23590P
Area: BLK 73D, BLK 73E, BLK 73F
Mission Name: 1BLK73DEF333A
Parameters: Altitude: 700/800/1000/1100/1200 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg;
Overlap: 30%

LAS



Annex 8. Mission Summary Reports

Flight Area	Dipolog
Mission Name	Blk73A
Inclusive Flights	2169P, 2185P, 2189P
Mission Name	1BLK73A314A
Range data size	13.1 GB
POS	253 MB
Base data size	70.3 MB
Image	NONE
Transfer date	December 9, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.14
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.45
Boresight correction stdev (<0.001deg)	0.000281
IMU attitude correction stdev (<0.001deg)	0.002285
GPS position stdev (<0.01m)	0.0058
Minimum % overlap (>25)	59.36%
Ave point cloud density per sq.m. (>2.0)	6.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	281
Maximum Height	432.78 m
Minimum Height	62.42 m
Classification (# of points)	
Ground	316,257,459
Low vegetation	393,916,474
Medium vegetation	547,399,563
High vegetation	356,827,606
Building	11,617,652
Orthophoto	No
Processed by	Engr. Kenneth Solidum, AljonRieAraneta, Engr. Jeffrey Delica

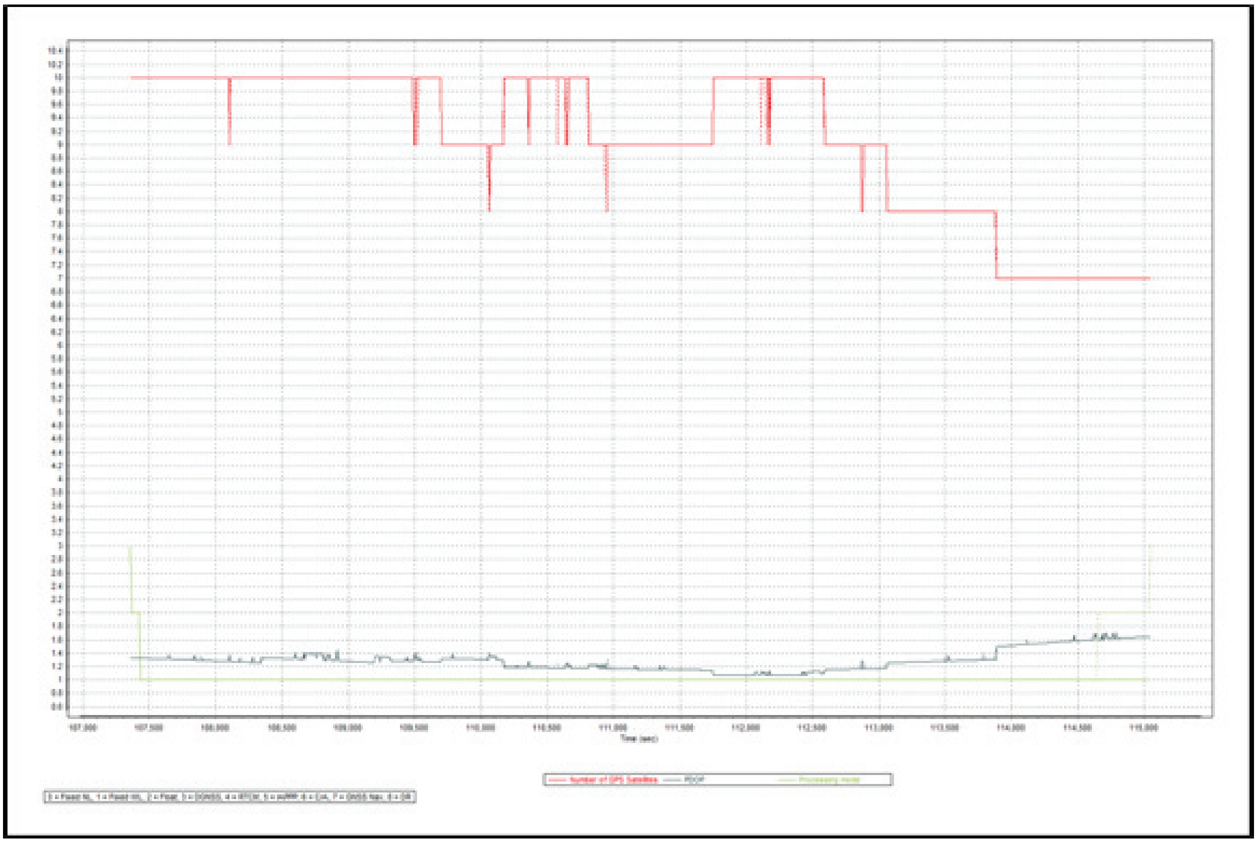


Figure 78. Solution Status

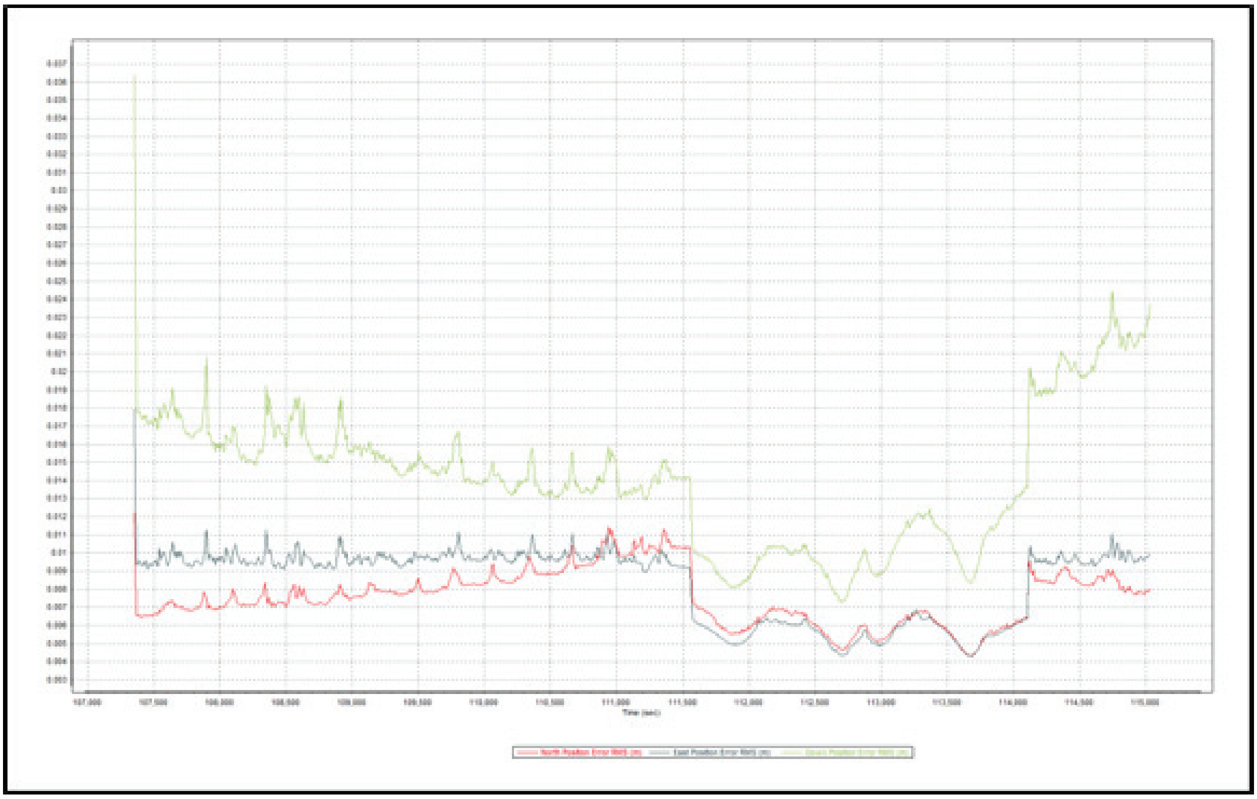


Figure 79. Smoothed Performance Metric Parameters

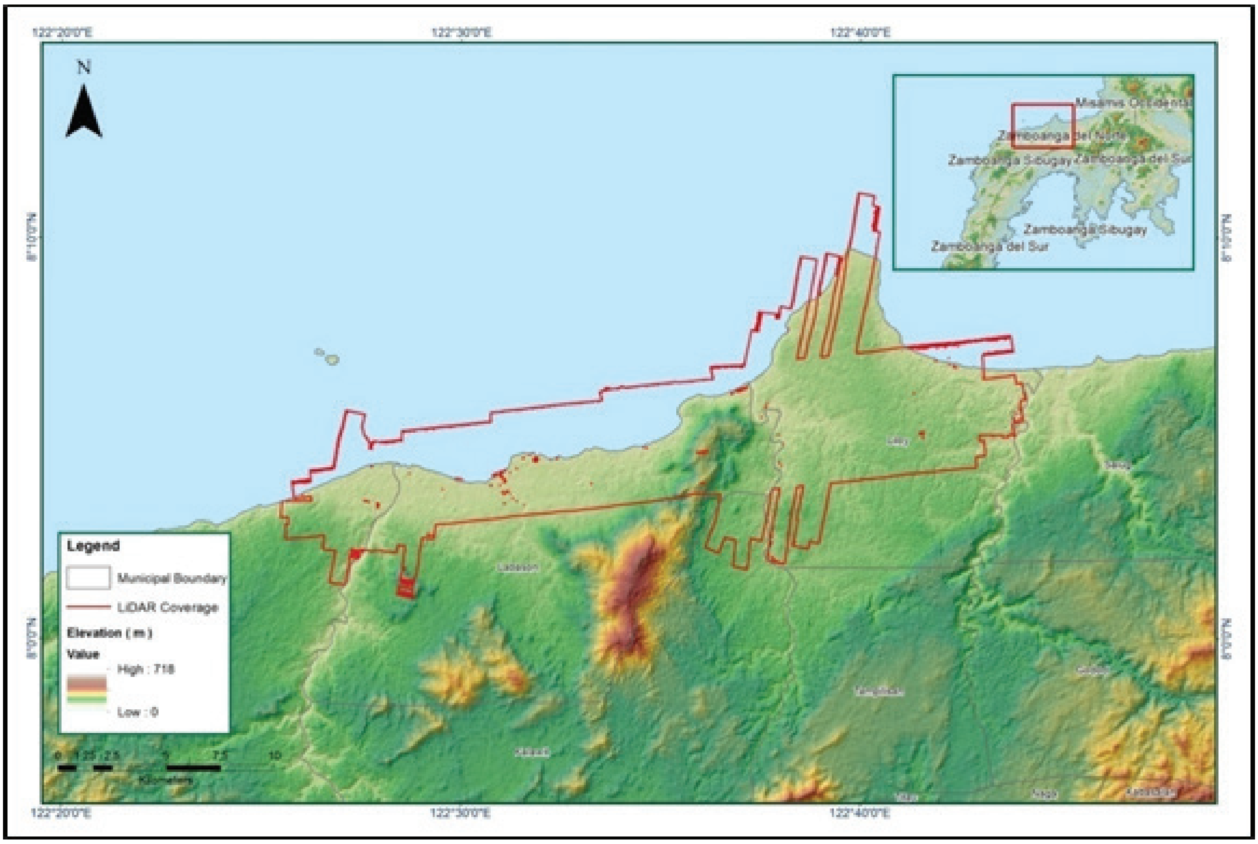


Figure 80. Best Estimated Trajectory

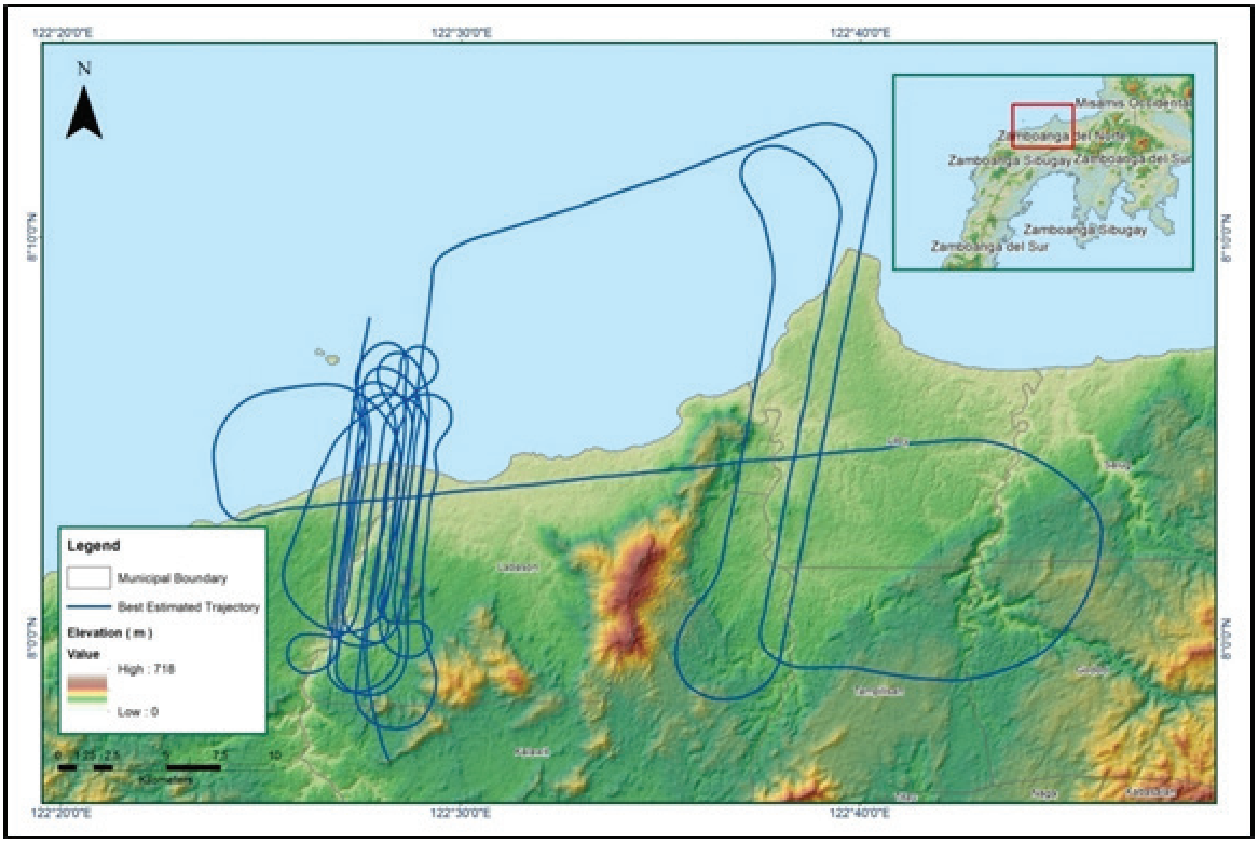


Figure 81. Coverage of LiDAR Data

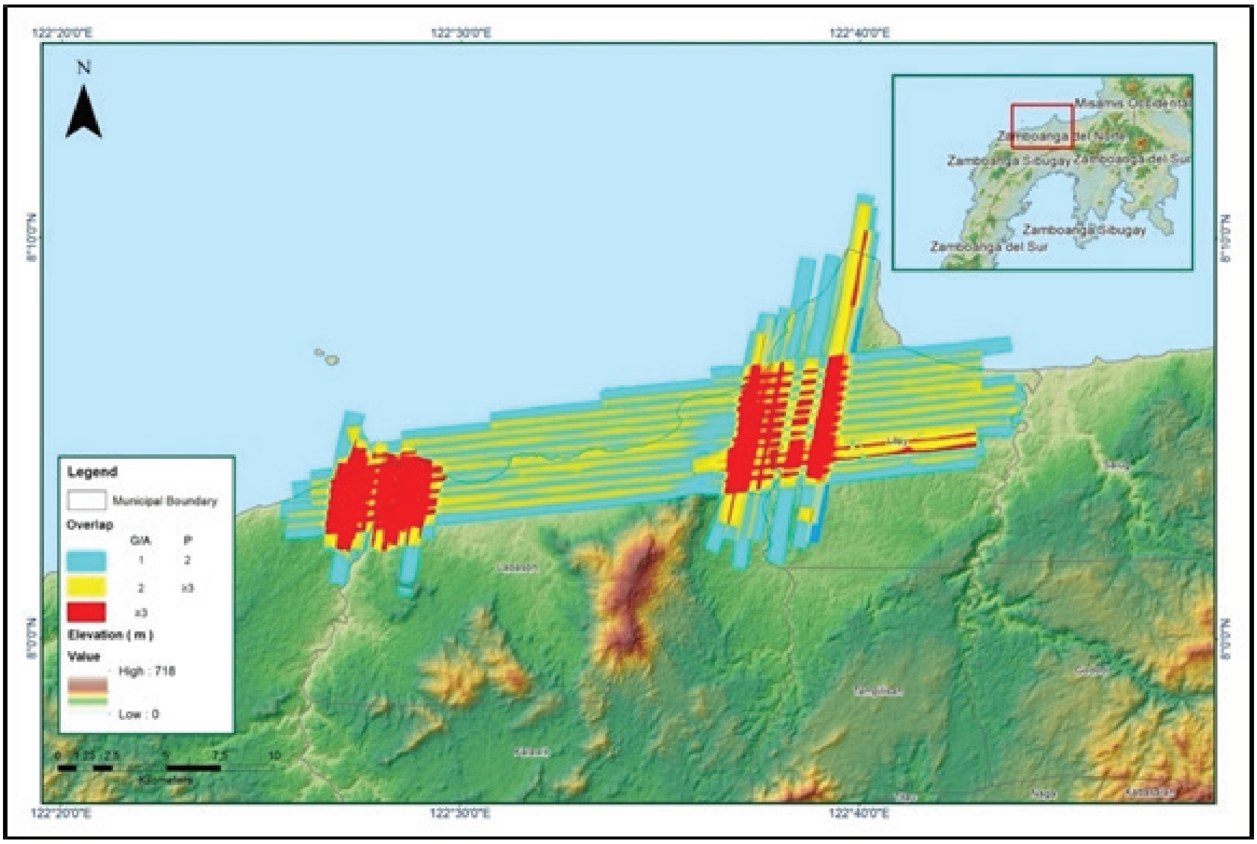


Figure 82. Image of Data Overlap

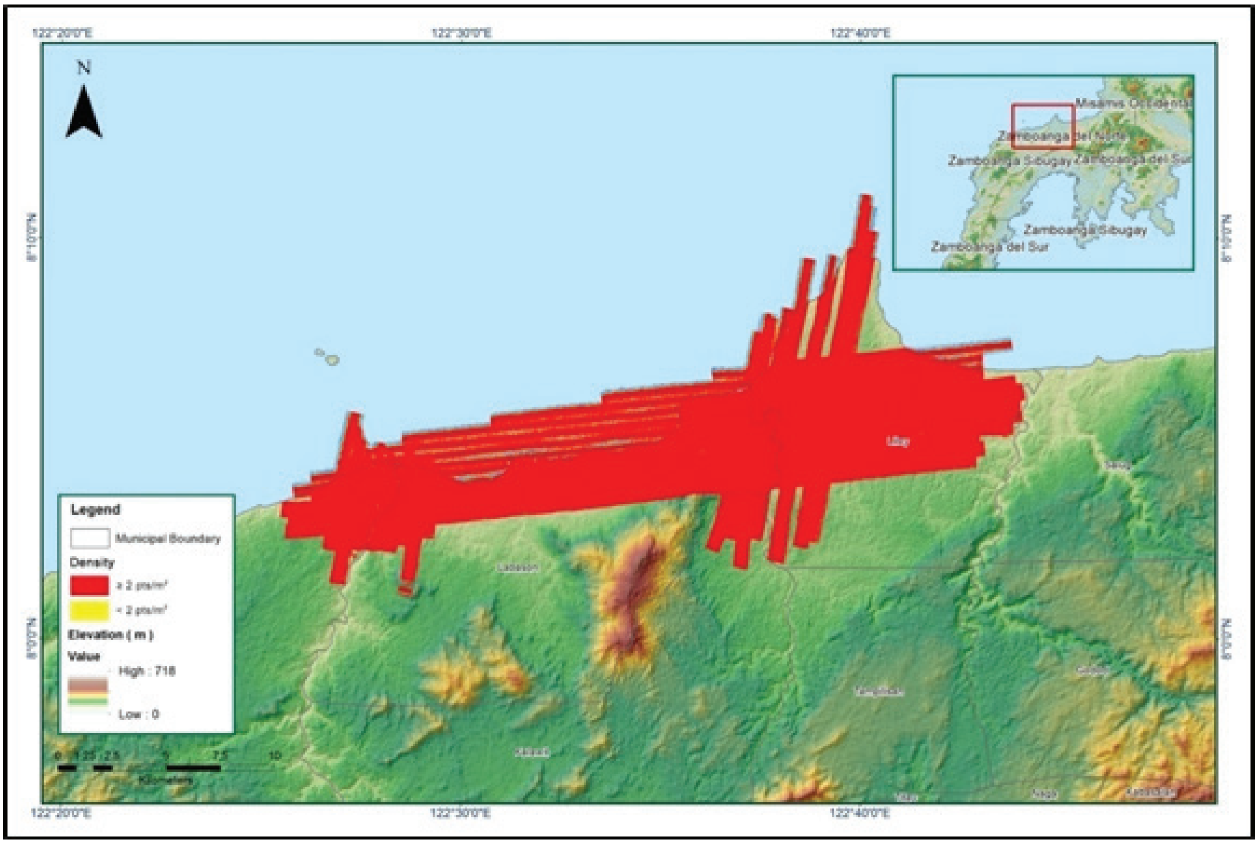


Figure 83. Density Map

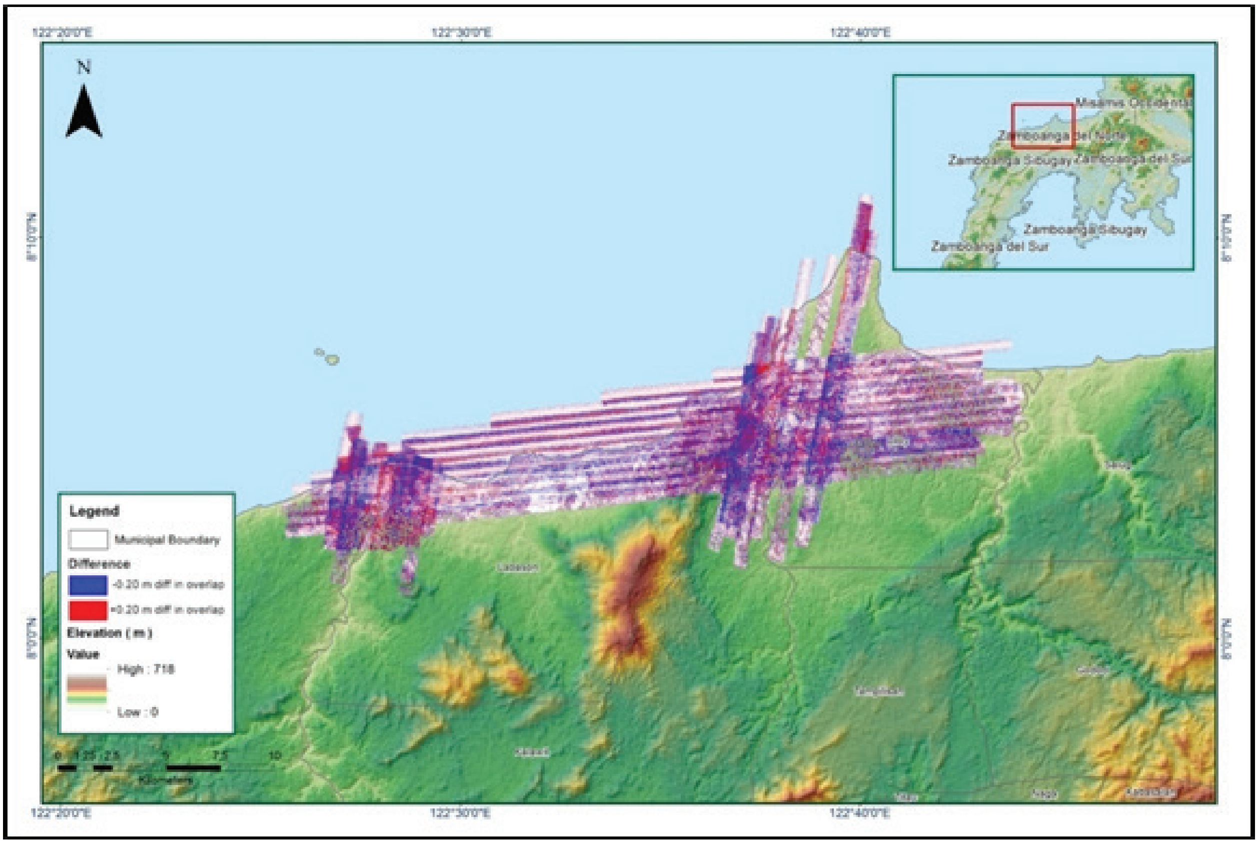


Figure 84. Elevation difference between flight lines

Flight Area	Dipolog
Mission Name	Blk73A_Additional
Inclusive Flights	2185P
Mission Name	1BLK73A314A
Range data size	13.1 GB
POS	253 MB
Base data size	19.5 MB
Image	NA
Transfer date	December 9, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.14
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.45
Boresight correction stdev (<0.001deg)	0.000236
IMU attitude correction stdev (<0.001deg)	0.002572
GPS position stdev (<0.01m)	0.0088
Minimum % overlap (>25)	61.13
Ave point cloud density per sq.m. (>2.0)	6.075
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	25
Maximum Height	300 m
Minimum Height	65.91 m
Classification (# of points)	
Ground	13,149,001
Low vegetation	13,403,807
Medium vegetation	36,628,573
High vegetation	72,067,315
Building	1,991,455
Orthophoto	No
Processed by	Engr. Kenneth Solidum, AljonRieAraneta, Maria Tamsyn Malabanan

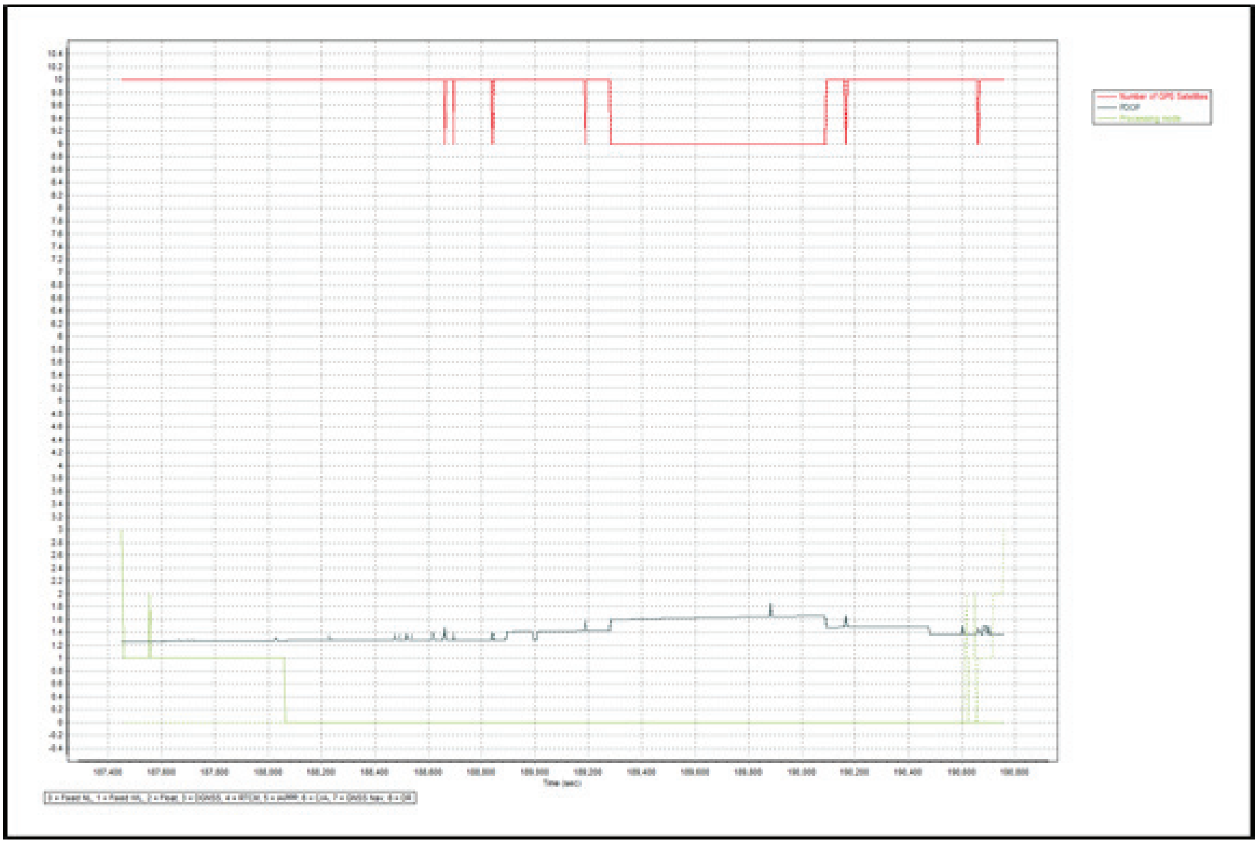


Figure 85. Solution Status

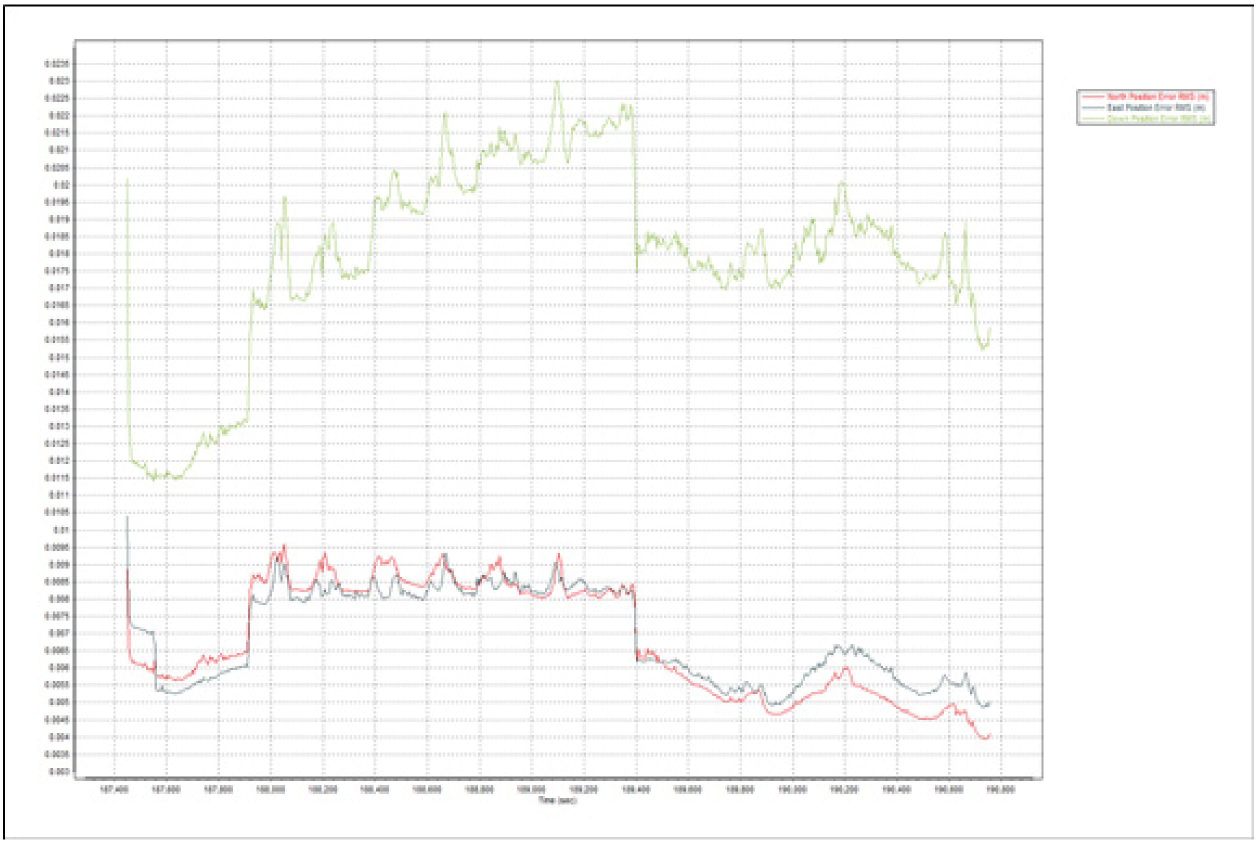


Figure 86. Smoothed Performance Metric Parameters

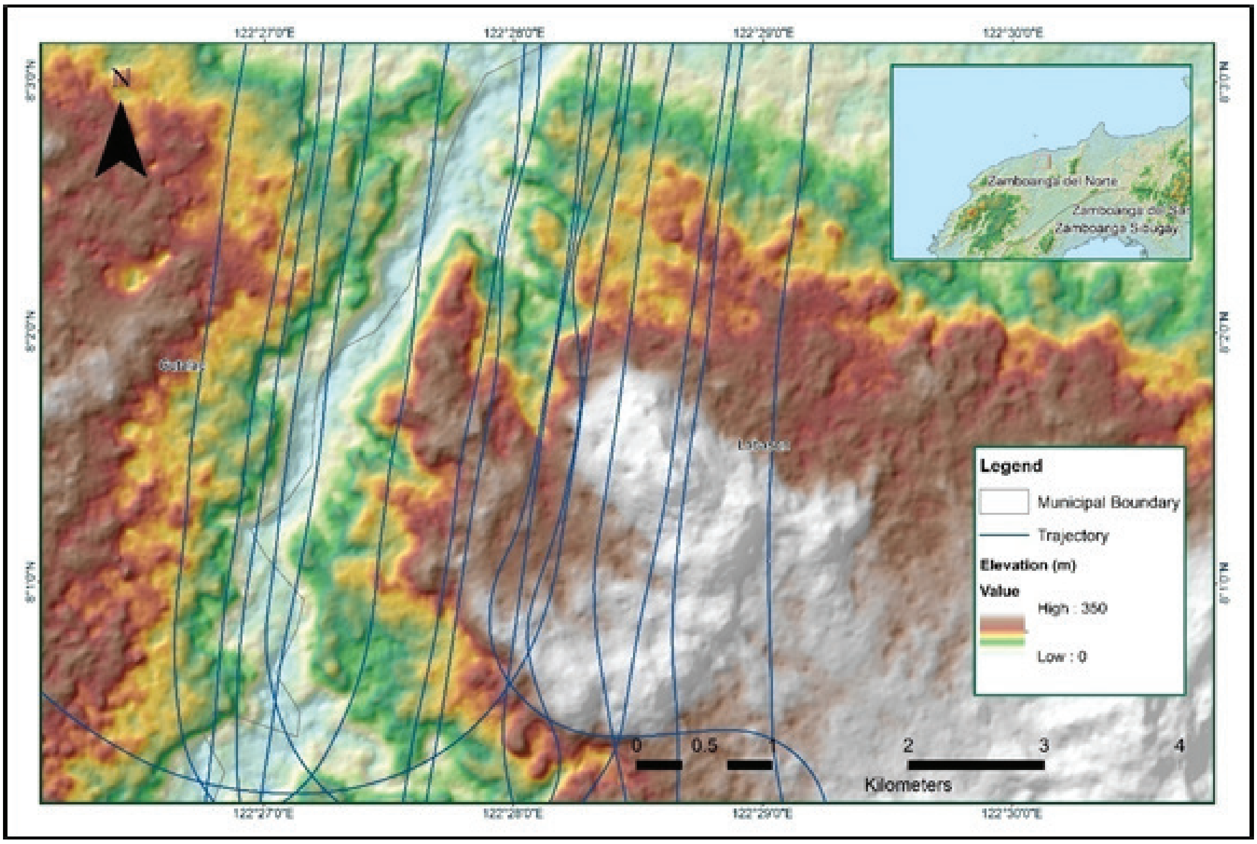


Figure 87. Best Estimated Trajectory

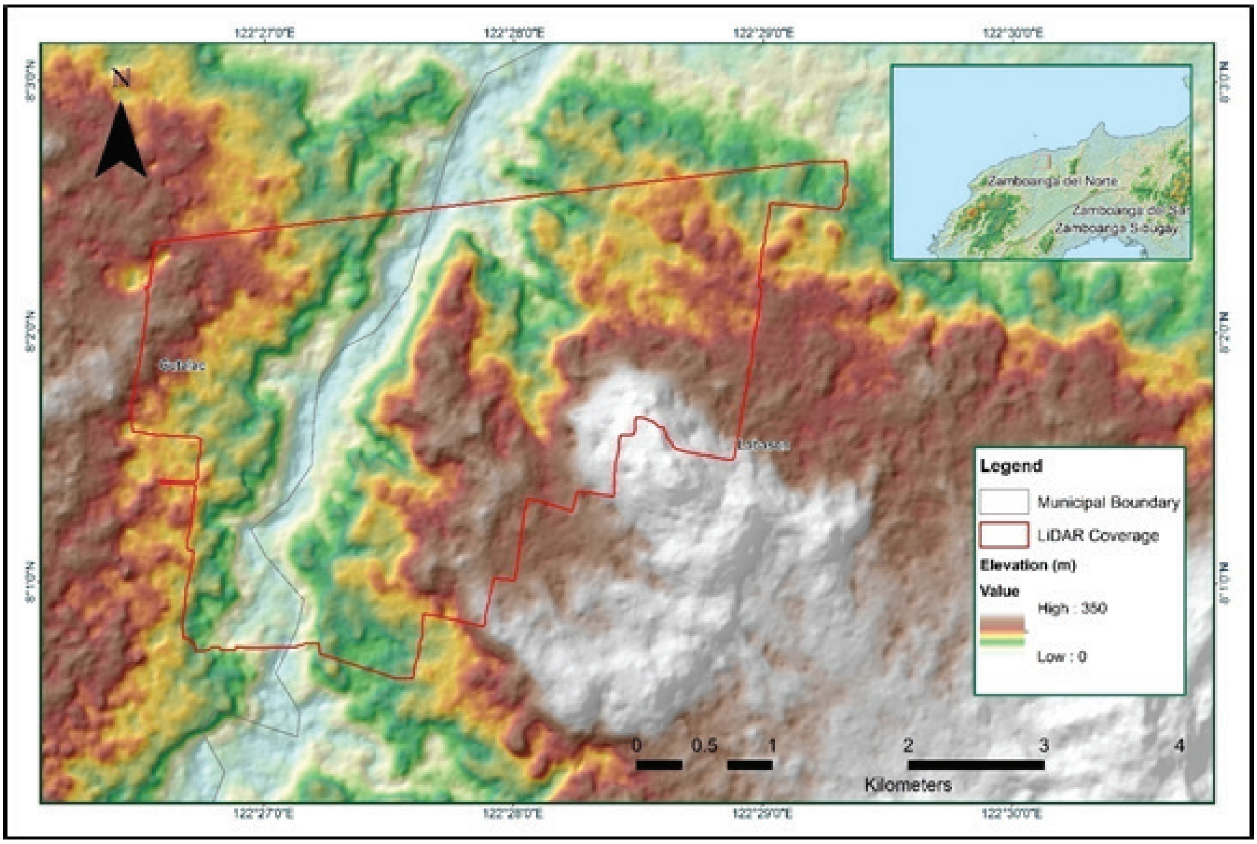


Figure 88. Coverage of LiDAR Data

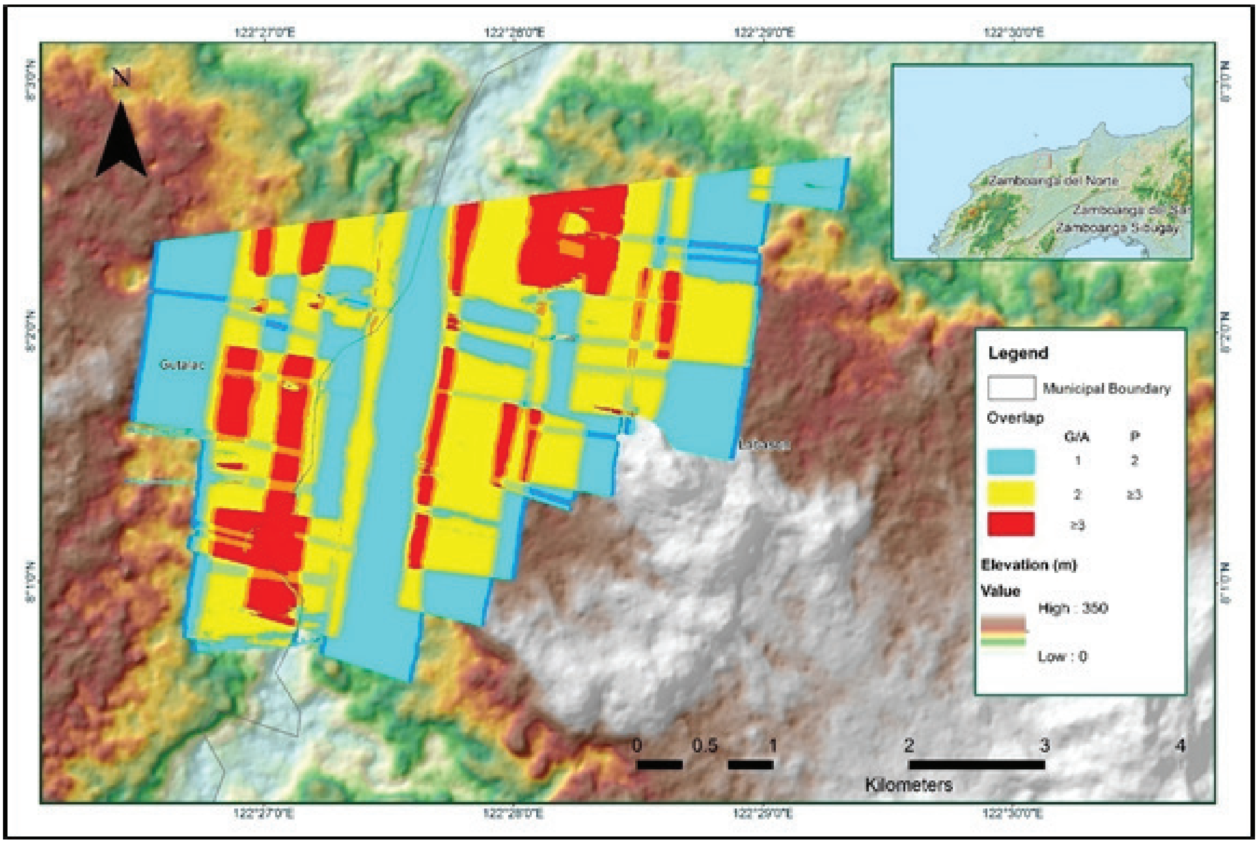


Figure 89. Image of Data Overlap

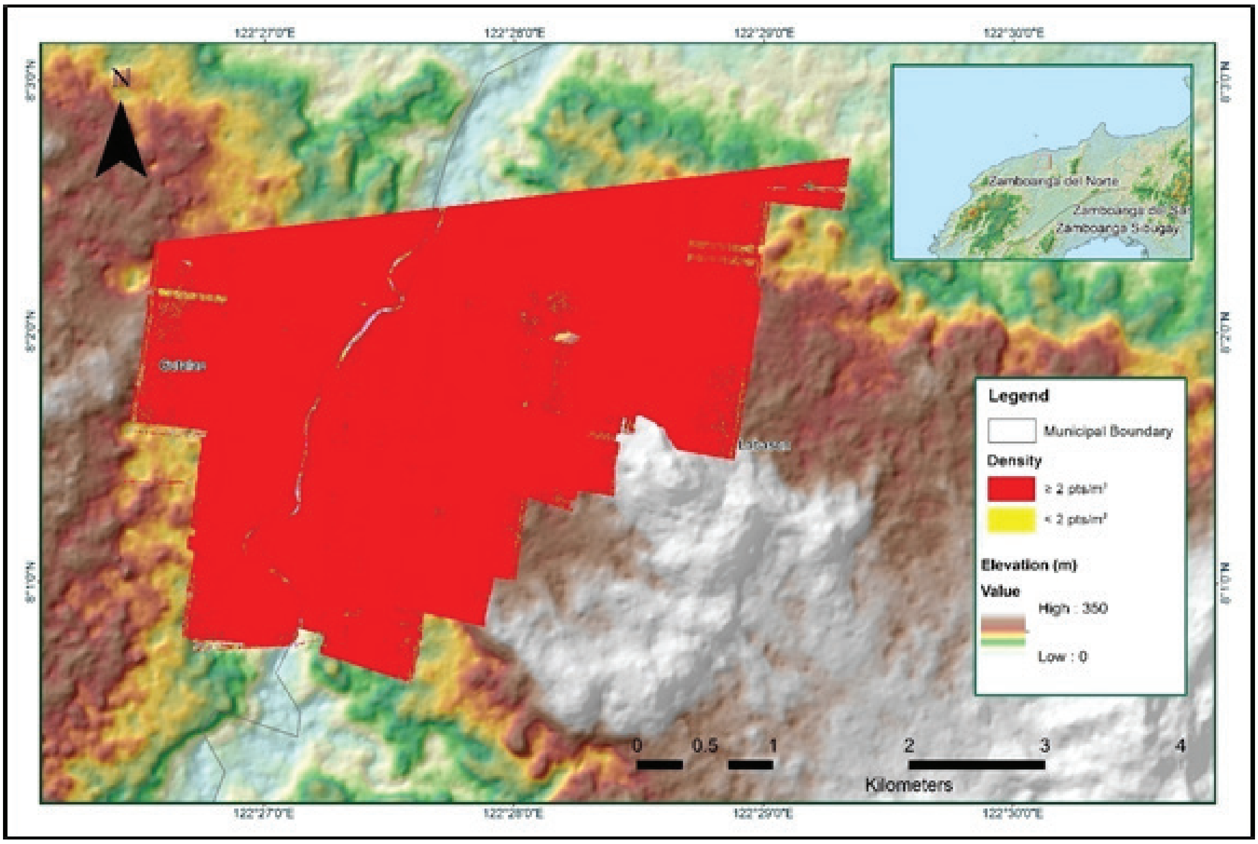


Figure 90. Density Map

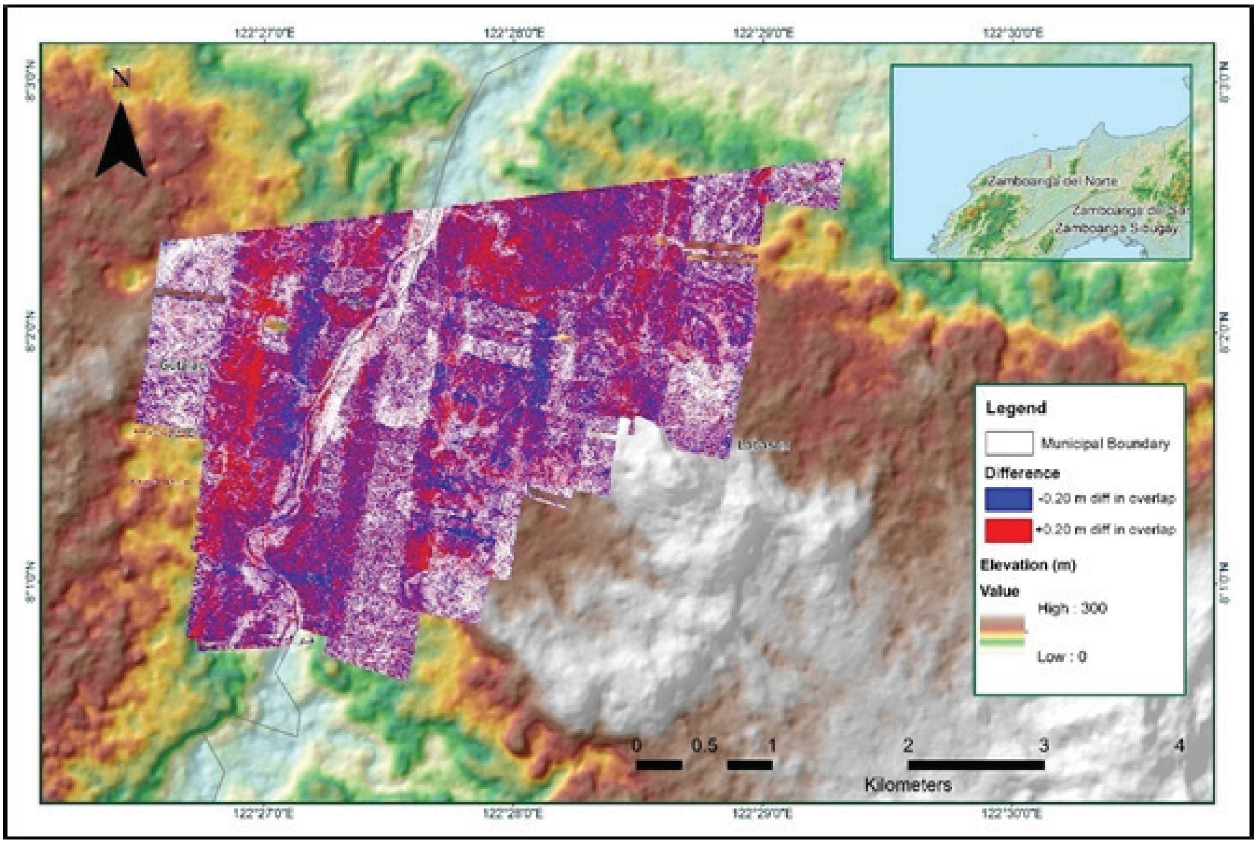


Figure 91. Elevation difference between flight lines

Flight Area	DipologReflights
Mission Name	Blk73A
Inclusive Flights	23582P
Range data size	25.5 GB
POS data size	281 MB
Base data size	162 MB
Image	25.1 GB
Transfer date	December 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.425
RMSE for East Position (<4.0 cm)	1.519
RMSE for Down Position (<8.0 cm)	4.281
Boresight correction stdev (<0.001deg)	0.000147
IMU attitude correction stdev (<0.001deg)	0.000270
GPS position stdev (<0.01m)	0.0008
Minimum % overlap (>25)	41.91 %
Ave point cloud density per sq.m. (>2.0)	4.62
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	165
Maximum Height	845.05 m
Minimum Height	845.05 m
Classification (# of points)	
Ground	117,262,301
Low vegetation	97,052,511
Medium vegetation	270,037,707
High vegetation	570,486,603
Building	9,958,195
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Mark Joshua Salvacion, Alex John Escobido

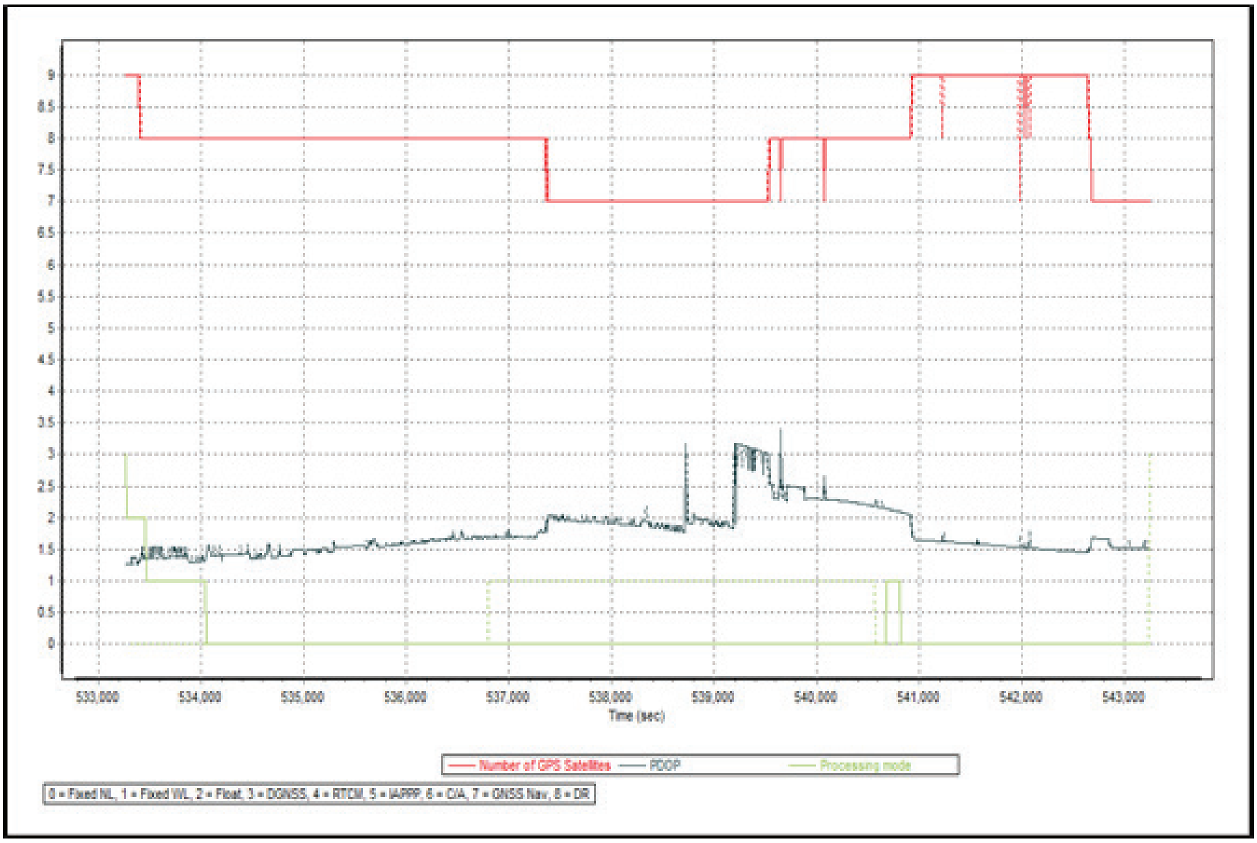


Figure 92. Solution Status

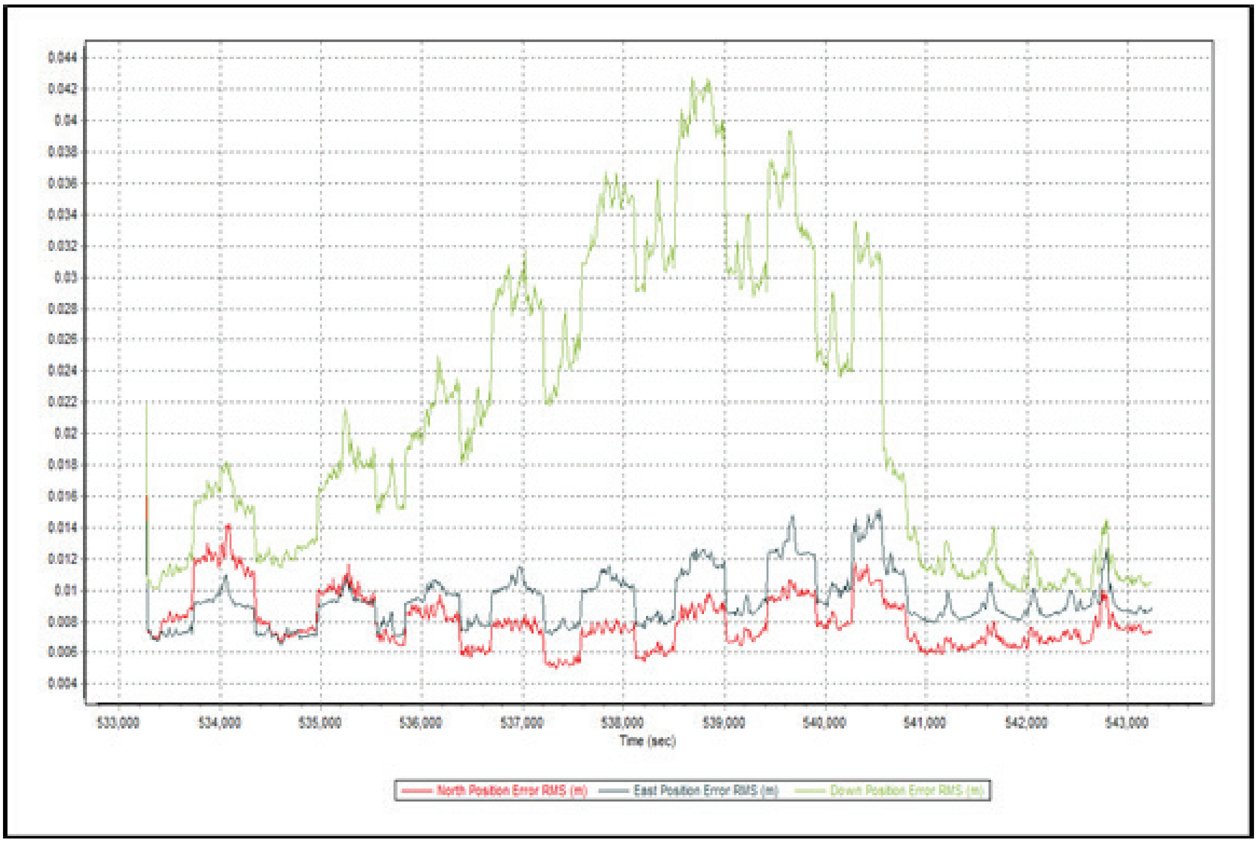


Figure 93. Smoothed Performance Metric Parameters

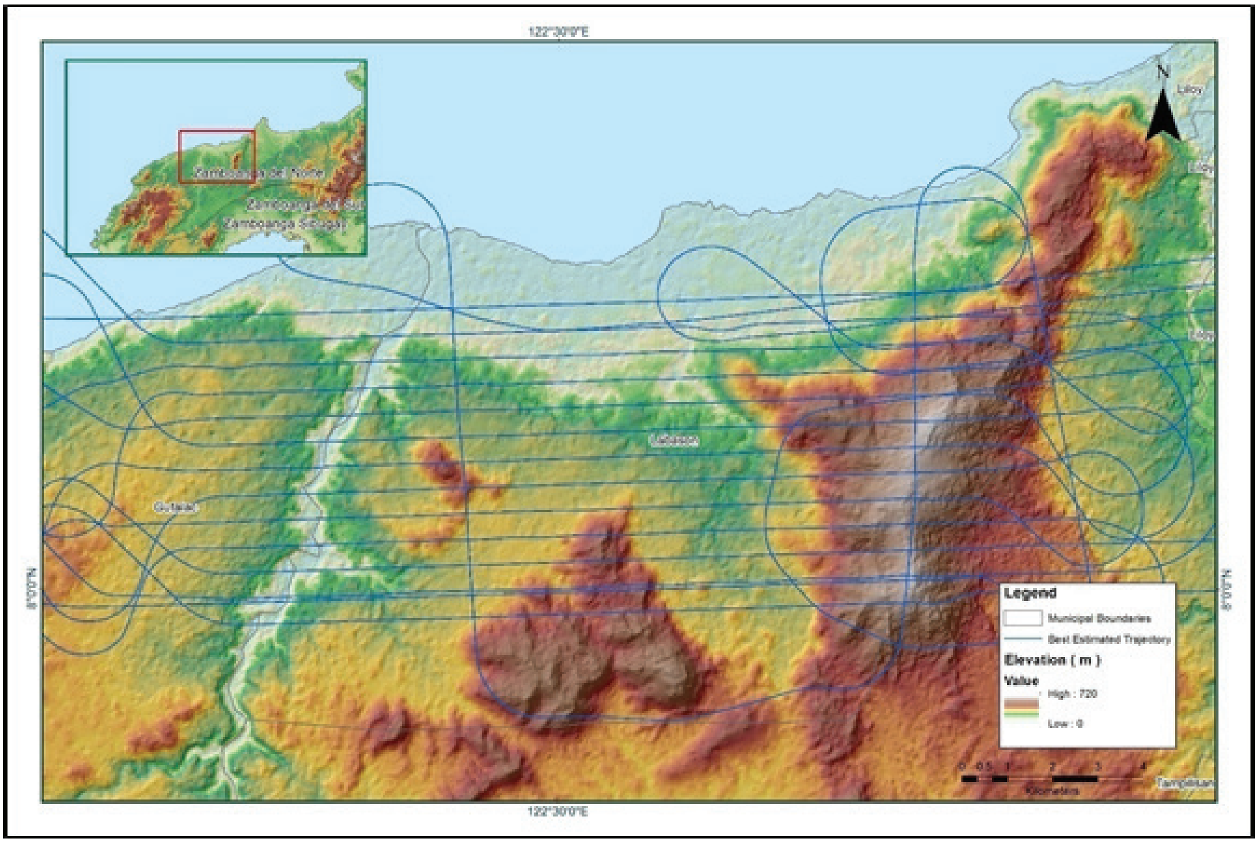


Figure 94. Best Estimated Trajectory

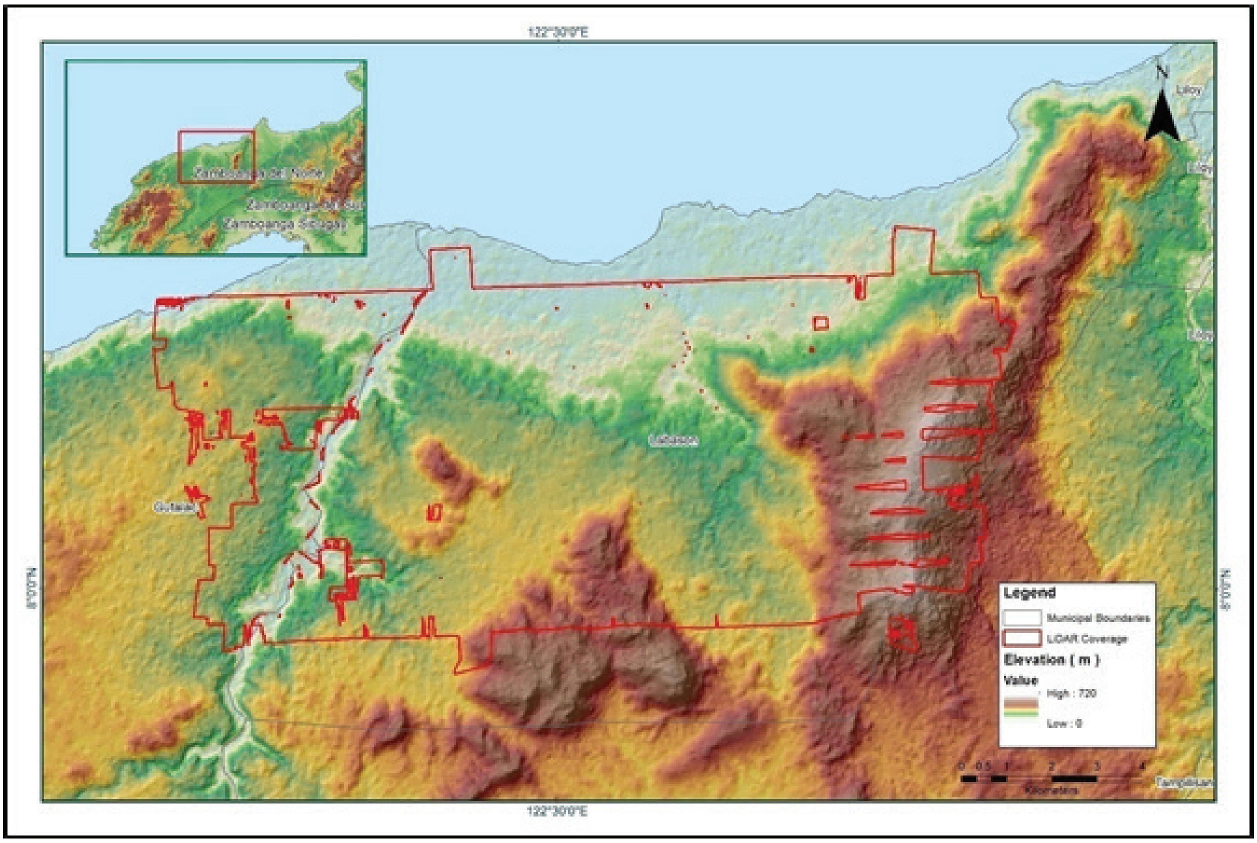


Figure 95. Coverage of LiDAR Data

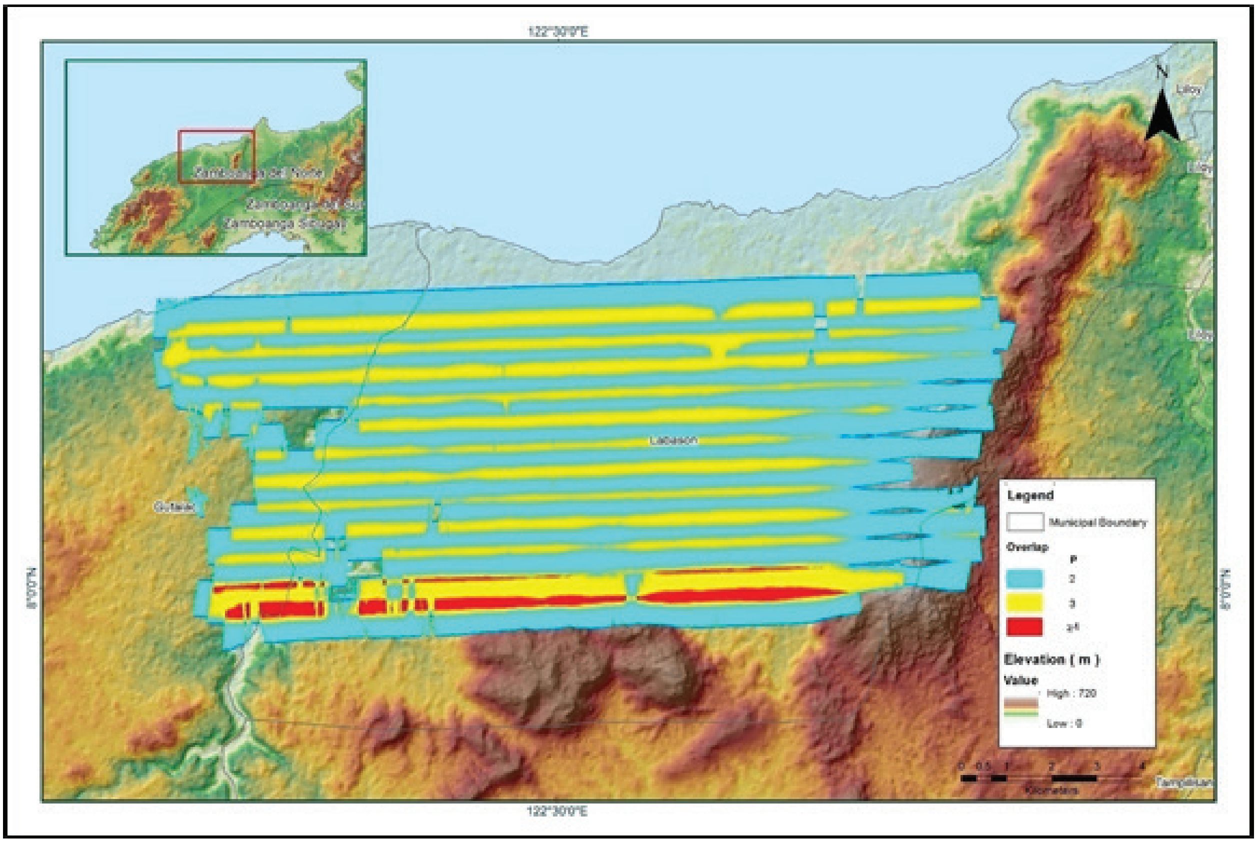


Figure 96. Image of data overlap

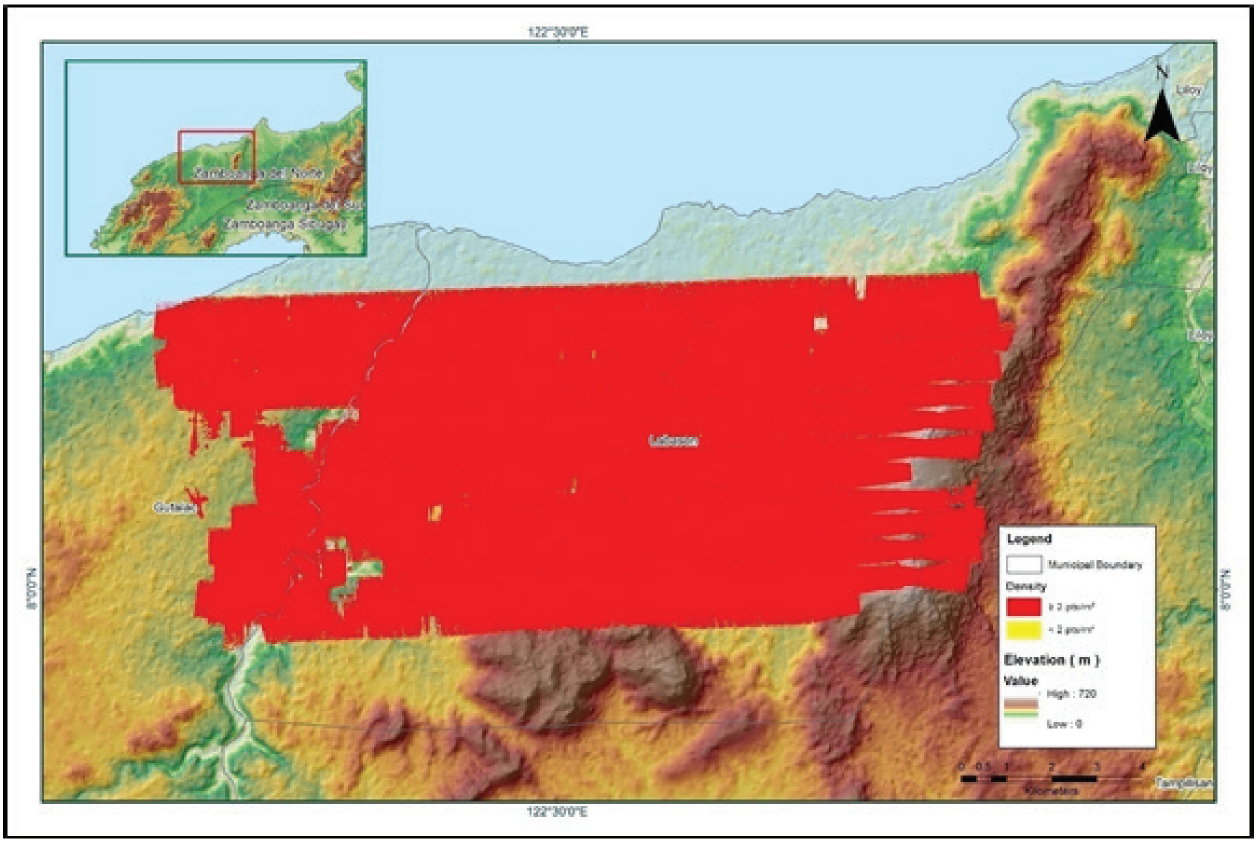


Figure 97. Density map of merged LiDAR data

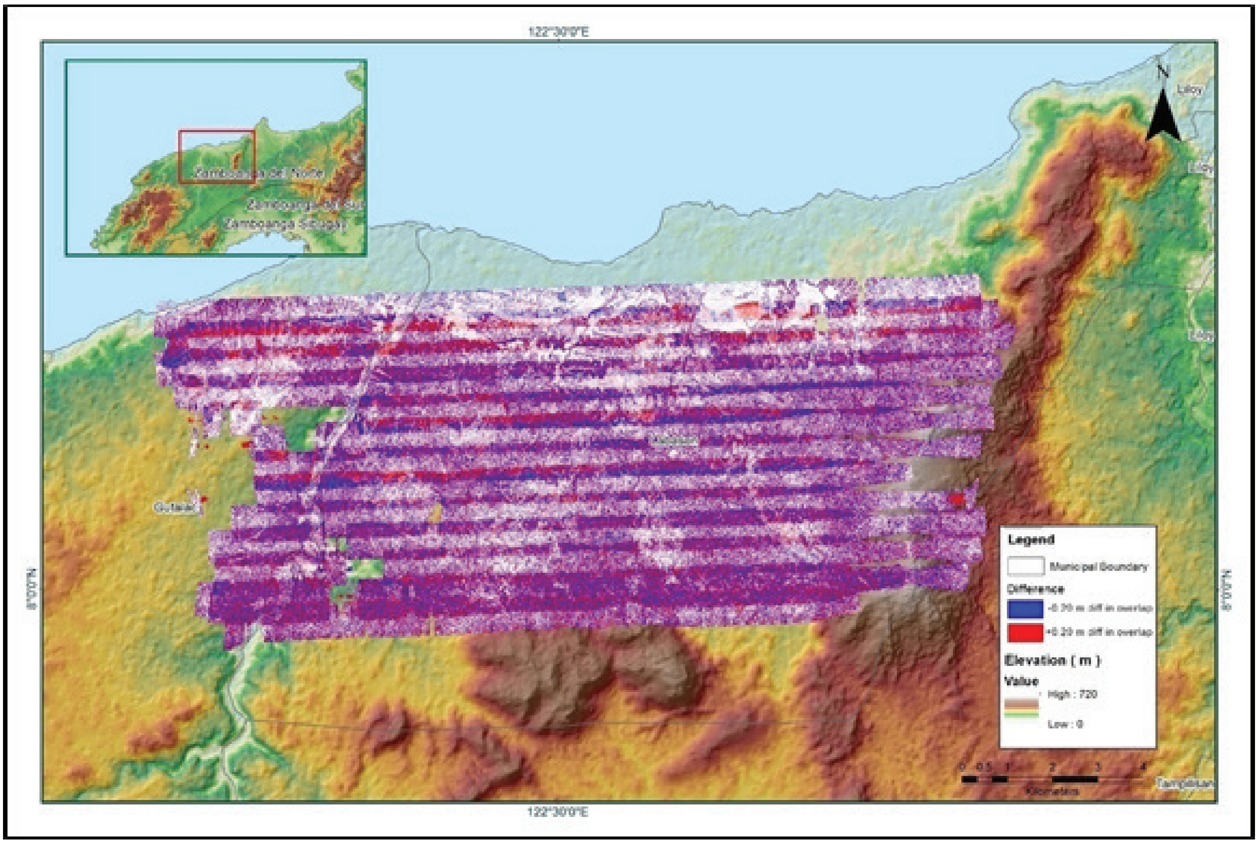


Figure 98. Elevation difference between flight lines

Flight Area	DipologReflights
Mission Name	Blk73A_additional
Inclusive Flights	23590P
Range data size	16.6 GB
POS data size	203 MB
Base data size	42.3 MB
Image	32.6 GB
Transfer date	December 8, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.304
RMSE for East Position (<4.0 cm)	1.277
RMSE for Down Position (<8.0 cm)	3.261
Boresight correction stdev (<0.001deg)	0.000127
IMU attitude correction stdev (<0.001deg)	0.006477
GPS position stdev (<0.01m)	0.0248
Minimum % overlap (>25)	52.29 %
Ave point cloud density per sq.m. (>2.0)	3.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	182
Maximum Height	845.3 m
Minimum Height	61.35 m
Classification (# of points)	
Ground	153,461,764
Low vegetation	114,346,778
Medium vegetation	202,928,794
High vegetation	443,554,236
Building	6,868,610
Orthophoto	No
Processed by	Engr. AnalynNaldo, EngrMerven Matthew Natino, Engr. Vincent Louise Azucena

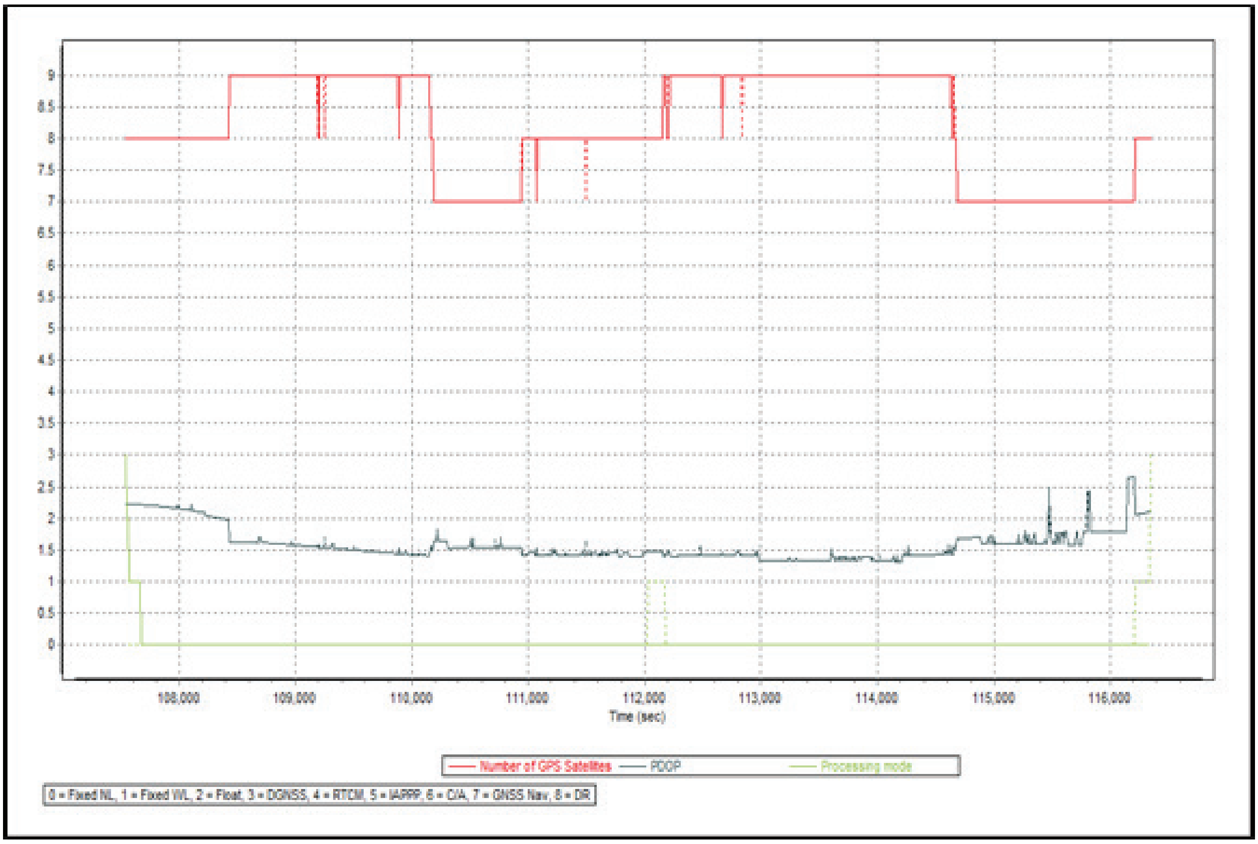


Figure 99. Solution Status

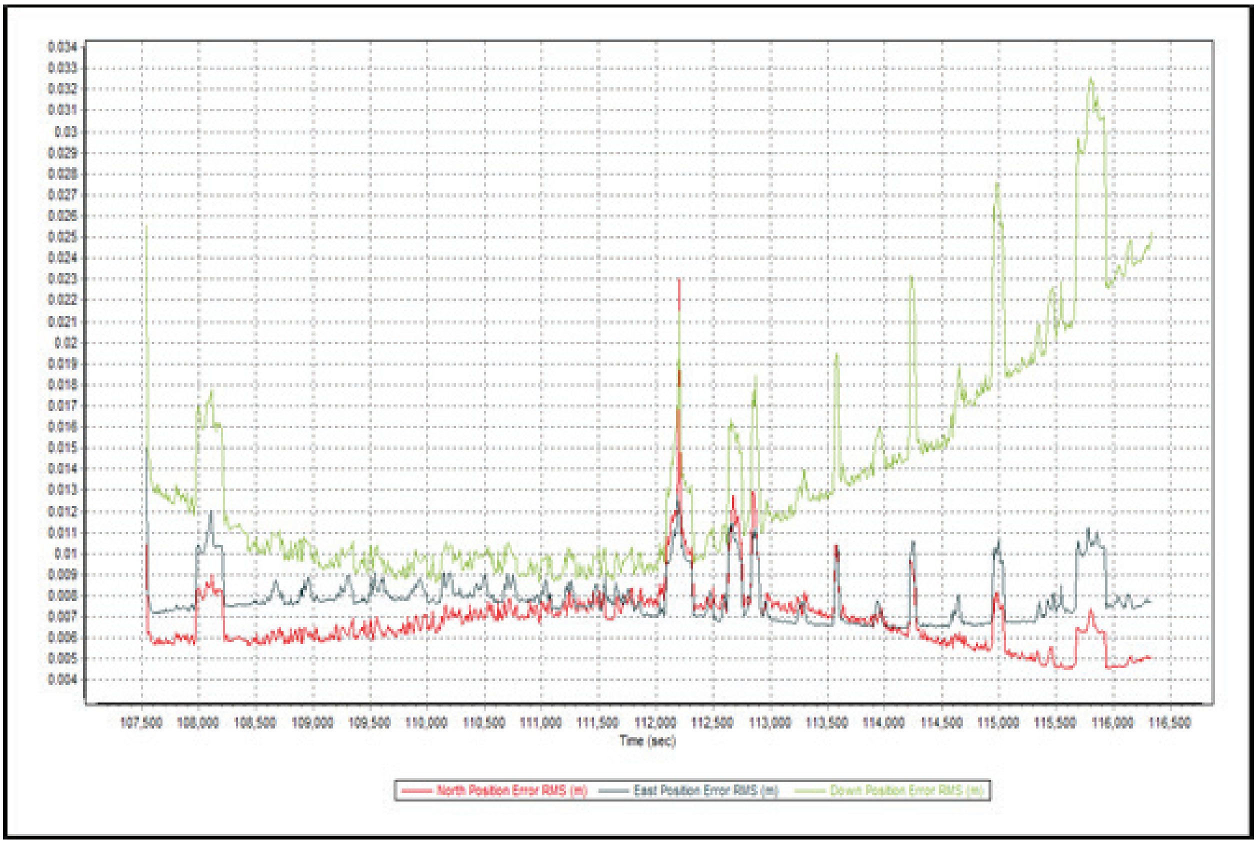


Figure 100. Smoothed Performance Metric Parameters

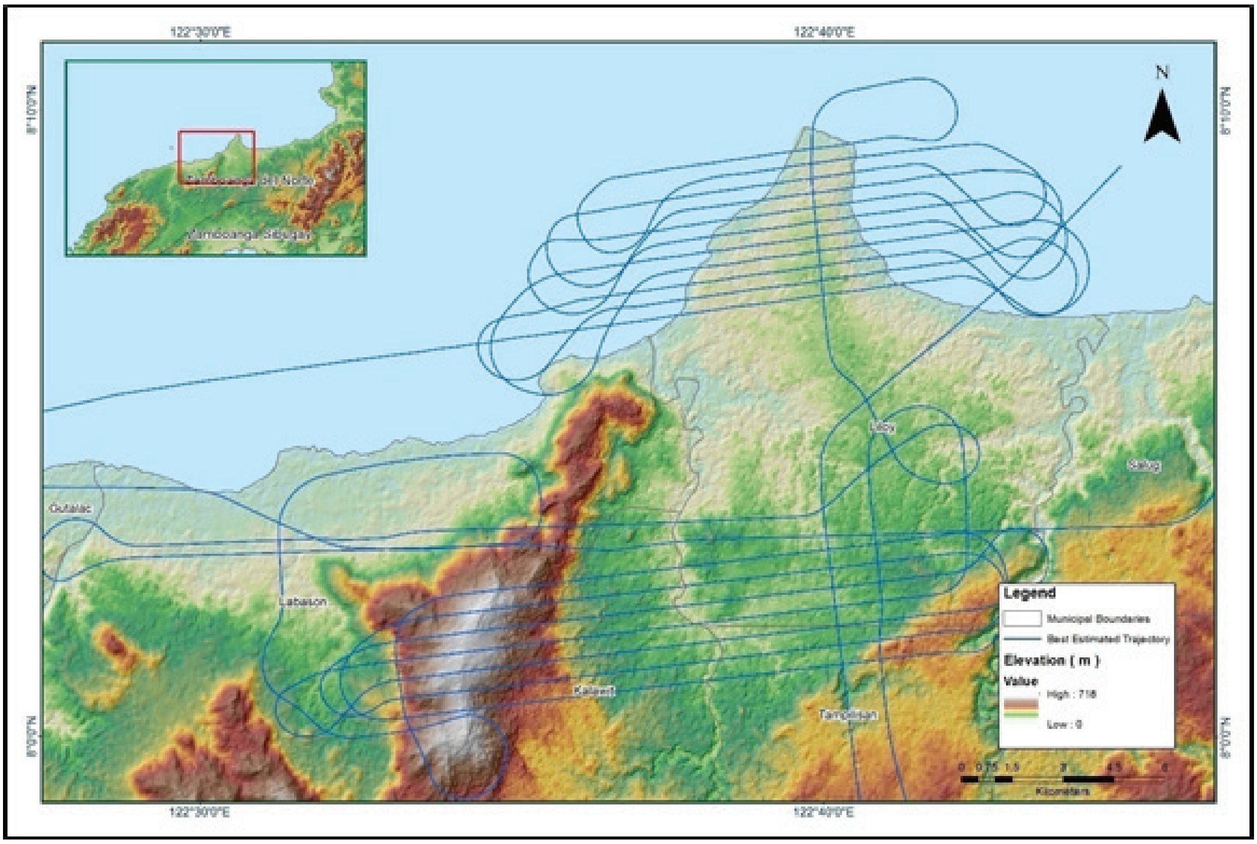


Figure 101. Best Estimated Trajectory

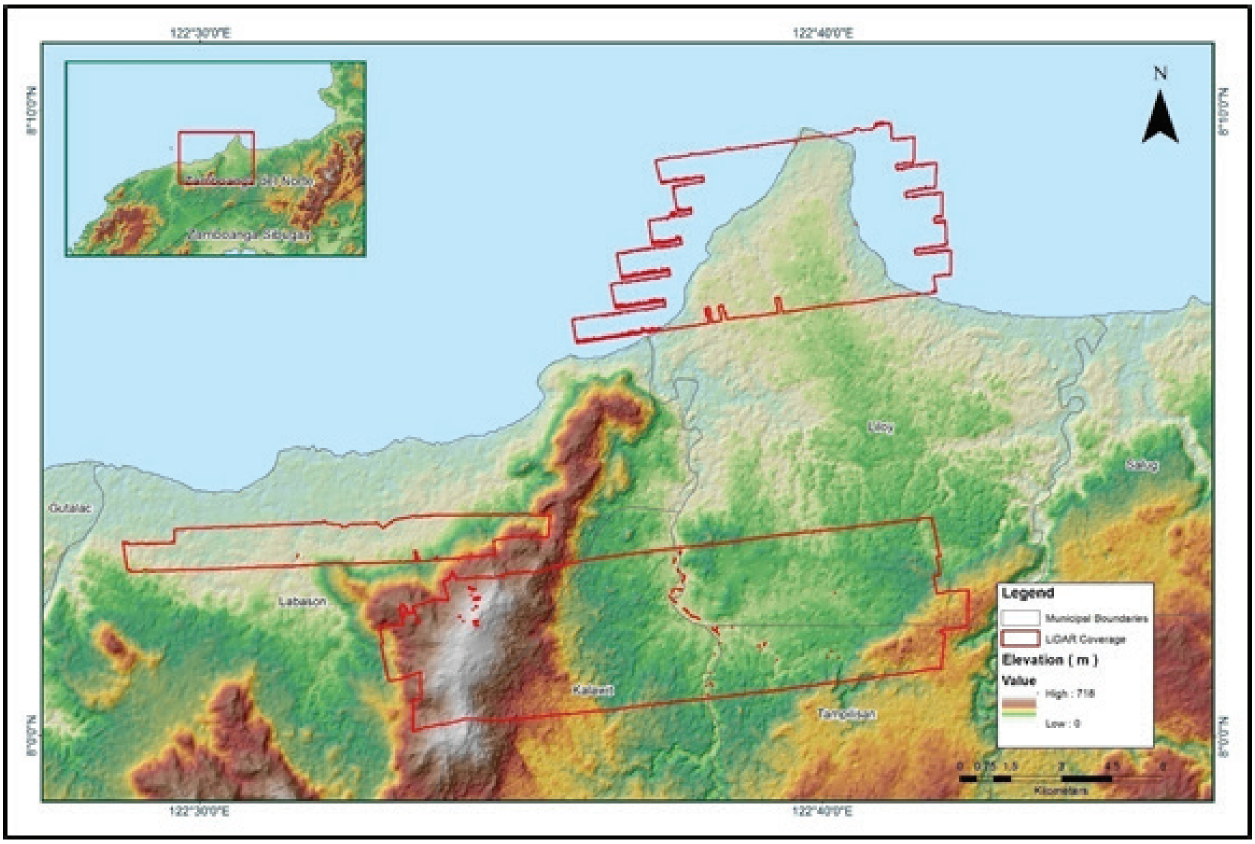


Figure 102. Coverage of LiDAR Data

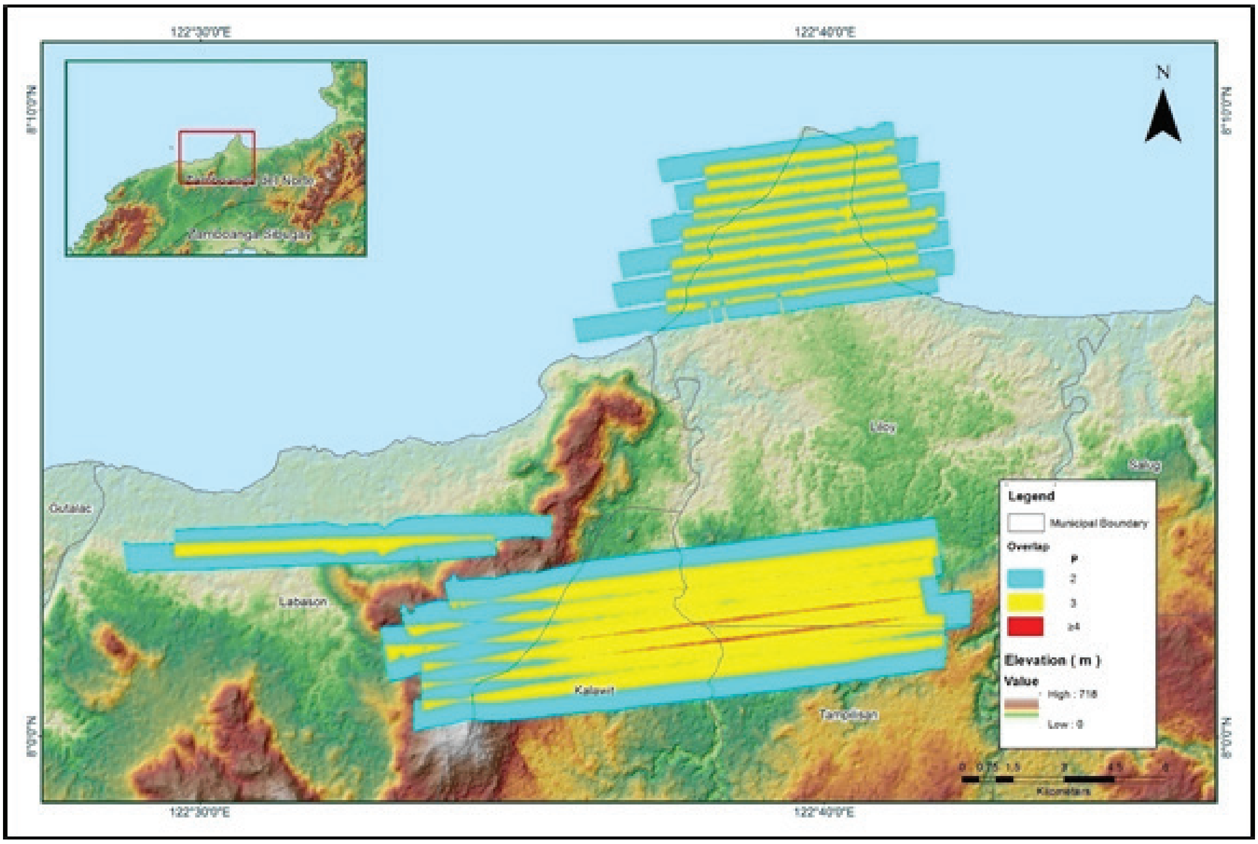


Figure 103. Image of data overlap

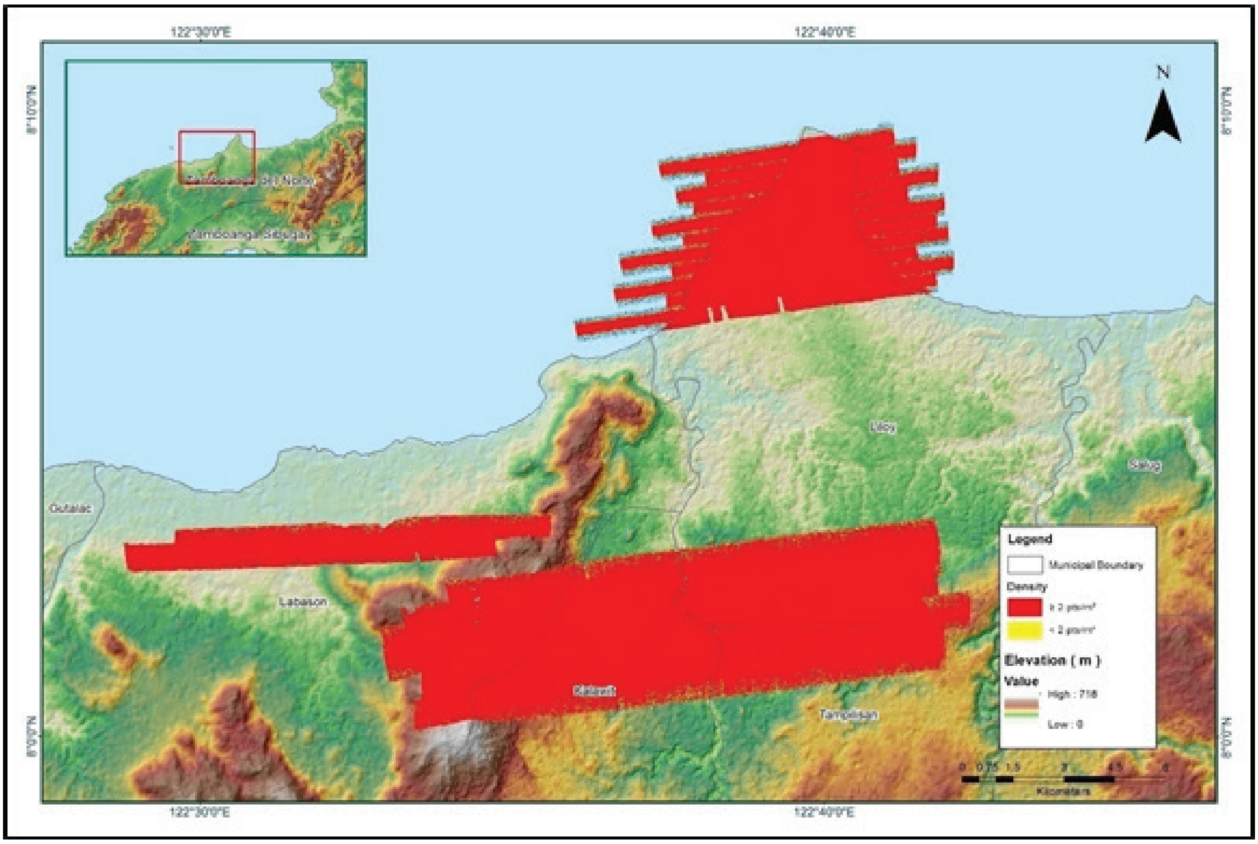


Figure 104. Elevation difference between flight lines

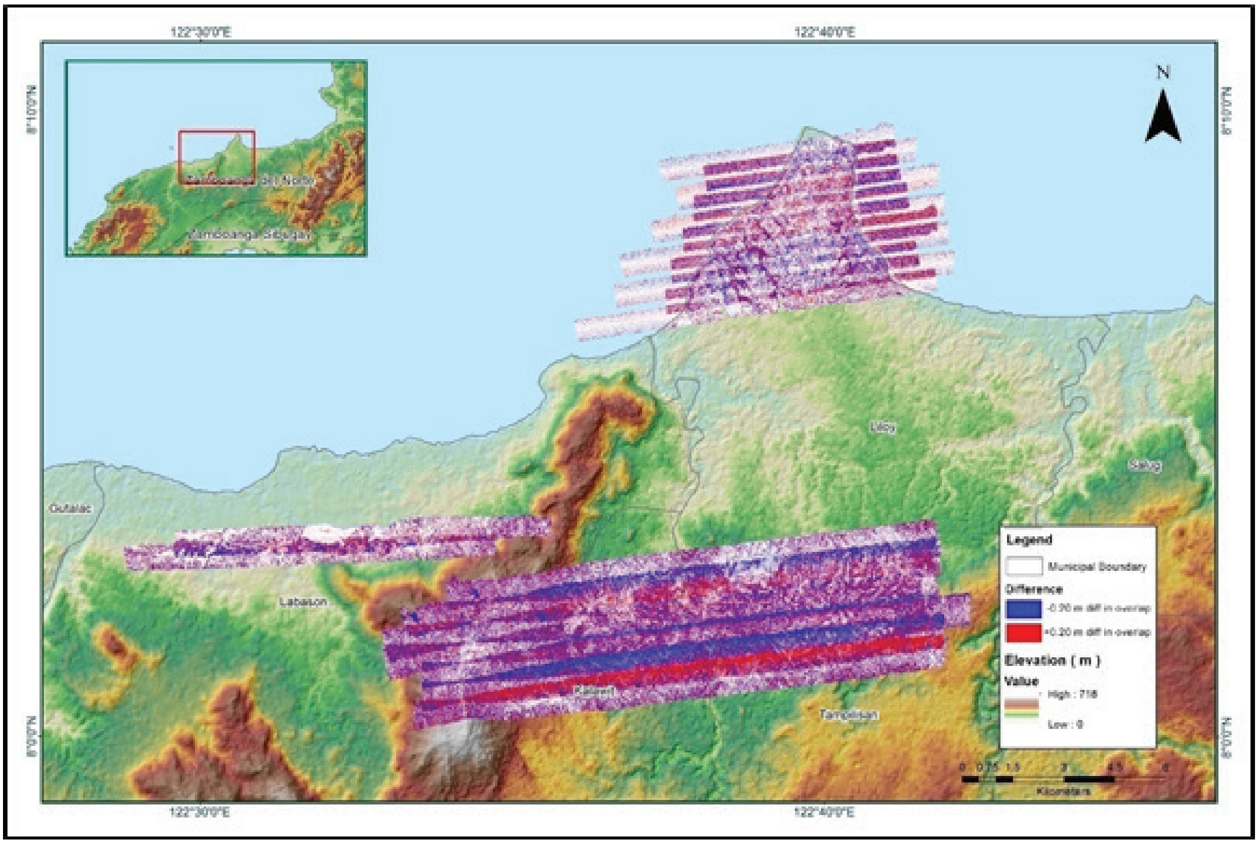


Figure 105. Elevation difference between flight lines

Annex 9. KipitModel 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
W1660	0.0026053	67.2237	0.0	0.40942	0.33409	Discharge	0.15016	0.19	Ratio to Peak	0.25
W1650	0.0026170	67.122	0.0	0.47144	0.38469	Discharge	0.15494	0.19	Ratio to Peak	0.25
W1640	0.0024690	68.437998	0.0	0.55388	0.45197	Discharge	0.29135	0.19	Ratio to Peak	0.25
W1630	0.0026261	67.042674	0.0	0.36322	0.29639	Discharge	0.14475	0.19	Ratio to Peak	0.25
W1620	0.0026350	66.965382	0.0	0.51786	0.42258	Discharge	0.30250	0.19	Ratio to Peak	0.25
W1610	0.0019853	73.123317	0.0	0.26368	0.21516	Discharge	0.0610997	0.19	Ratio to Peak	0.25
W1600	0.0027703	65.811087	0.0	0.9053	0.73873	Discharge	0.40962	0.19	Ratio to Peak	0.25
W1590	0.0027991	65.570058	0.0	0.49378	0.40292	Discharge	0.21325	0.19	Ratio to Peak	0.25
W1580	0.0038047	58.149009	0.0	0.81298	0.66339	Discharge	0.31213	0.19	Ratio to Peak	0.25
W1570	0.0035612	59.787396	0.0	0.58546	0.47774	Discharge	0.22208	0.19	Ratio to Peak	0.25
W1560	0.0036370	59.267709	0.0	0.60164	0.49093	Discharge	0.16257	0.19	Ratio to Peak	0.25
W1550	0.0031314	62.916705	0.0	0.5093	0.41559	Discharge	0.32716	0.19	Ratio to Peak	0.25
W1540	0.0035966	59.543316	0.0	0.3005	0.24521	Discharge	0.0863415	0.19	Ratio to Peak	0.25
W1530	0.0051434	50.53473	0.0	0.4534	0.36998	Discharge	0.16214	0.19	Ratio to Peak	0.25
W1520	0.0035993	59.52501	0.0	0.55166	0.45015	Discharge	0.20437	0.19	Ratio to Peak	0.25
W1510	0.0044892	53.989479	0.0	0.6019	0.49115	Discharge	0.14081	0.19	Ratio to Peak	0.25
W1500	0.0018109	74.97324	0.0	0.36232	0.29566	Discharge	0.22079	0.19	Ratio to Peak	0.25
W1490	0.0039587	57.158451	0.0	0.76882	0.62735	Discharge	0.25235	0.19	Ratio to Peak	0.25
W1480	0.0032056	62.353287	0.0	0.63964	0.52195	Discharge	0.25112	0.19	Ratio to Peak	0.25
W1470	0.0044492	54.21627	0.0	0.70632	0.57635	Discharge	0.19177	0.19	Ratio to Peak	0.25
W1460	0.0048898	51.820218	0.0	0.8054	0.65720	Discharge	0.20700	0.19	Ratio to Peak	0.25
W1450	0.0033612	61.204077	0.0	0.64588	0.52704	Discharge	0.25607	0.19	Ratio to Peak	0.25

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
W1440	0.0037063	58.799889	0.0	0.43698	0.35657	Discharge	0.15423	0.19	Ratio to Peak	0.25
W1430	0.0035565	59.81994	0.0	0.56048	0.45735	Discharge	0.0280801	0.19	Ratio to Peak	0.25
W1420	0.0032186	62.255655	0.0	0.59206	0.48311	Discharge	0.0796156	0.19	Ratio to Peak	0.25
W1410	0.0030919	63.220788	0.0	0.65022	0.53058	Discharge	0.0525676	0.19	Ratio to Peak	0.25
W1400	0.0033225	61.485786	0.0	0.85214	0.69534	Discharge	0.47502	0.19	Ratio to Peak	0.25
W1390	0.0021445	71.511372	0.0	0.78596	0.64134	Discharge	0.21147	0.19	Ratio to Peak	0.25
W1380	0.0015710	77.677443	0.0	0.4763	0.38866	Discharge	0.16579	0.19	Ratio to Peak	0.25
W1370	0.0026916	66.477222	0.0	1.34564	1.0980	Discharge	0.47130	0.19	Ratio to Peak	0.25
W1360	0.0036832	58.95549	0.0	0.74066	0.60438	Discharge	0.25397	0.19	Ratio to Peak	0.25
W1350	0.0034333	60.685407	0.0	0.3512	0.28657	Discharge	0.14439	0.19	Ratio to Peak	0.25
W1340	0.0032401	62.094969	0.0	0.77104	0.62916	Discharge	0.35262	0.19	Ratio to Peak	0.25
W1330	0.0038100	58.114431	0.0	0.4463	0.36419	Discharge	0.14151	0.19	Ratio to Peak	0.25
W1320	0.0033867	61.02	0.0	0.65314	0.53296	Discharge	0.28413	0.19	Ratio to Peak	0.25
W1310	0.0010738	83.95335	0.0	0.91498	0.74662	Discharge	0.36569	0.19	Ratio to Peak	0.25
W1300	0.0011594	82.802106	0.0	0.4507	0.36777	Discharge	0.11281	0.19	Ratio to Peak	0.25
W1290	0.0013375	80.504703	0.0	0.7022	0.57300	Discharge	0.71428	0.19	Ratio to Peak	0.25
W1280	0.0014328	79.326	0.0	0.165834	0.13532	Discharge	0.0018629	0.19	Ratio to Peak	0.25
W1270	0.0022266	70.707942	0.0	0.46658	0.38074	Discharge	0.16758	0.19	Ratio to Peak	0.25
W1260	0.0033266	61.456293	0.0	0.63426	0.51756	Discharge	0.18584	0.19	Ratio to Peak	0.25
W1250	0.0017267	75.900744	0.0	0.021748	0.0177464	Discharge	.000484873	0.19	Ratio to Peak	0.25
W1240	0.0033153	61.53867	0.0	0.72468	0.59134	Discharge	0.35885	0.19	Ratio to Peak	0.25
W1230	0.0026742	66.626721	0.0	0.93332	0.76159	Discharge	0.51996	0.19	Ratio to Peak	0.25
W1220	0.0012467	81.660015	0.0	0.76682	0.62573	Discharge	0.43975	0.19	Ratio to Peak	0.25
W1210	0.0017823	75.286476	0.0	0.7412	0.60481	Discharge	0.29243	0.19	Ratio to Peak	0.25
W1200	0.0016946	76.260762	0.0	0.9527	0.77740	Discharge	0.33900	0.19	Ratio to Peak	0.25

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
W1190	0.0011160	83.381796	0.0	0.32434	0.26467	Discharge	0.16317	0.19	Ratio to Peak	0.25
W1180	0.0026170	67.122	0.0	0.064388	0.0525400	Discharge	0.0027391	0.19	Ratio to Peak	0.25
W1170	0.0021192	71.762571	0.0	0.8304	0.67761	Discharge	0.17322	0.19	Ratio to Peak	0.25
W1160	0.0022754	70.239105	0.0	0.81594	0.66581	Discharge	0.23898	0.19	Ratio to Peak	0.25
W1150	0.0019077	73.934883	0.0	0.51178	0.41761	Discharge	0.17262	0.19	Ratio to Peak	0.25
W1140	0.0021519	71.438148	0.0	0.81146	0.66216	Discharge	0.19985	0.19	Ratio to Peak	0.25
W1130	0.0019426	73.567746	0.0	0.51796	0.42266	Discharge	0.22584	0.19	Ratio to Peak	0.25
W1120	0.0021130	71.824608	0.0	0.31262	0.25510	Discharge	0.0731705	0.19	Ratio to Peak	0.25
W1110	0.0017008	76.190589	0.0	0.4513	0.36827	Discharge	0.24819	0.19	Ratio to Peak	0.25
W1100	0.0015899	77.457771	0.0	0.53564	0.43709	Discharge	0.40681	0.19	Ratio to Peak	0.25
W1090	0.0019624	73.360278	0.0	0.4399	0.35895	Discharge	0.21067	0.19	Ratio to Peak	0.25
W1080	0.0019007	74.009124	0.0	0.191592	0.15634	Discharge	0.0455497	0.19	Ratio to Peak	0.25
W1070	0.0014349	79.300575	0.0	0.41544	0.33899	Discharge	0.25598	0.19	Ratio to Peak	0.25
W1060	0.0015214	78.261201	0.0	0.25632	0.20916	Discharge	0.0684409	0.19	Ratio to Peak	0.25
W1050	0.0016321	76.970628	0.0	0.43224	0.35271	Discharge	0.23219	0.19	Ratio to Peak	0.25
W1040	0.0020637	72.320904	0.0	0.5739	0.46830	Discharge	0.15074	0.19	Ratio to Peak	0.25
W1030	0.0030150	63.821835	0.0	1.31002	1.0690	Discharge	0.79440	0.19	Ratio to Peak	0.25
W1020	0.0015690	77.701851	0.0	0.46382	0.37848	Discharge	0.15941	0.19	Ratio to Peak	0.25
W1010	0.0014503	79.113447	0.0	0.46598	0.38024	Discharge	0.32576	0.19	Ratio to Peak	0.25
W1000	0.0016649	76.596372	0.0	0.61616	0.50279	Discharge	0.31631	0.19	Ratio to Peak	0.25
W990	0.0021541	71.416791	0.0	1.19732	0.97702	Discharge	0.91537	0.19	Ratio to Peak	0.25
W980	0.0022679	70.310295	0.0	0.4522	0.36899	Discharge	0.20500	0.19	Ratio to Peak	0.25
W970	0.0018590	74.453553	0.0	0.3151	0.25713	Discharge	0.0876628	0.19	Ratio to Peak	0.25
W960	0.0017518	75.622086	0.0	0.8661	0.70673	Discharge	0.63282	0.19	Ratio to Peak	0.25
W950	0.0014663	78.920217	0.0	0.70462	0.57497	Discharge	0.31742	0.19	Ratio to Peak	0.25

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
W1190	0.0011160	83.381796	0.0	0.32434	0.26467	Discharge	0.16317	0.19	Ratio to Peak	0.25
W1180	0.0026170	67.122	0.0	0.064388	0.0525400	Discharge	0.0027391	0.19	Ratio to Peak	0.25
W1170	0.0021192	71.762571	0.0	0.8304	0.67761	Discharge	0.17322	0.19	Ratio to Peak	0.25
W1160	0.0022754	70.239105	0.0	0.81594	0.66581	Discharge	0.23898	0.19	Ratio to Peak	0.25
W1150	0.0019077	73.934883	0.0	0.51178	0.41761	Discharge	0.17262	0.19	Ratio to Peak	0.25
W1140	0.0021519	71.438148	0.0	0.81146	0.66216	Discharge	0.19985	0.19	Ratio to Peak	0.25
W1130	0.0019426	73.567746	0.0	0.51796	0.42266	Discharge	0.22584	0.19	Ratio to Peak	0.25
W1120	0.0021130	71.824608	0.0	0.31262	0.25510	Discharge	0.0731705	0.19	Ratio to Peak	0.25
W1110	0.0017008	76.190589	0.0	0.4513	0.36827	Discharge	0.24819	0.19	Ratio to Peak	0.25
W1100	0.0015899	77.457771	0.0	0.53564	0.43709	Discharge	0.40681	0.19	Ratio to Peak	0.25
W1090	0.0019624	73.360278	0.0	0.4399	0.35895	Discharge	0.21067	0.19	Ratio to Peak	0.25
W1080	0.0019007	74.009124	0.0	0.191592	0.15634	Discharge	0.0455497	0.19	Ratio to Peak	0.25
W1070	0.0014349	79.300575	0.0	0.41544	0.33899	Discharge	0.25598	0.19	Ratio to Peak	0.25
W1060	0.0015214	78.261201	0.0	0.25632	0.20916	Discharge	0.0684409	0.19	Ratio to Peak	0.25
W1050	0.0016321	76.970628	0.0	0.43224	0.35271	Discharge	0.23219	0.19	Ratio to Peak	0.25
W1040	0.0020637	72.320904	0.0	0.5739	0.46830	Discharge	0.15074	0.19	Ratio to Peak	0.25
W1030	0.0030150	63.821835	0.0	1.31002	1.0690	Discharge	0.79440	0.19	Ratio to Peak	0.25
W1020	0.0015690	77.701851	0.0	0.46382	0.37848	Discharge	0.15941	0.19	Ratio to Peak	0.25
W1010	0.0014503	79.113447	0.0	0.46598	0.38024	Discharge	0.32576	0.19	Ratio to Peak	0.25
W1000	0.0016649	76.596372	0.0	0.61616	0.50279	Discharge	0.31631	0.19	Ratio to Peak	0.25
W990	0.0021541	71.416791	0.0	1.19732	0.97702	Discharge	0.91537	0.19	Ratio to Peak	0.25
W980	0.0022679	70.310295	0.0	0.4522	0.36899	Discharge	0.20500	0.19	Ratio to Peak	0.25
W970	0.0018590	74.453553	0.0	0.3151	0.25713	Discharge	0.0876628	0.19	Ratio to Peak	0.25
W960	0.0017518	75.622086	0.0	0.8661	0.70673	Discharge	0.63282	0.19	Ratio to Peak	0.25
W950	0.0014663	78.920217	0.0	0.70462	0.57497	Discharge	0.31742	0.19	Ratio to Peak	0.25

Annex 10. Alubijid Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	335.42	0.0274614	0.05	Trapezoid	30	0.01
R30	Automatic Fixed Interval	5552.7	0.0026331	0.05	Trapezoid	30	0.01
R40	Automatic Fixed Interval	552.84	0.0017771	0.05	Trapezoid	30	0.01
R60	Automatic Fixed Interval	2351.4	0.0107110	0.05	Trapezoid	30	0.01
R80	Automatic Fixed Interval	3588.9	0.0017771	0.05	Trapezoid	30	0.01
R110	Automatic Fixed Interval	2850.2	0.0032716	0.05	Trapezoid	30	0.01
R120	Automatic Fixed Interval	1552.5	0.0021337	0.05	Trapezoid	30	0.01
R130	Automatic Fixed Interval	6306.1	0.0120101	0.05	Trapezoid	30	0.01
R180	Automatic Fixed Interval	1419.7	0.0017771	0.05	Trapezoid	30	0.01
R190	Automatic Fixed Interval	1605.5	.0008585891315925033	0.05	Trapezoid	30	0.01
R210	Automatic Fixed Interval	2281.4	0.0025261	0.05	Trapezoid	30	0.01
R240	Automatic Fixed Interval	3639.3	0.0125564	0.05	Trapezoid	30	0.01
R250	Automatic Fixed Interval	2150.7	0.0062933	0.05	Trapezoid	30	0.01
R270	Automatic Fixed Interval	3550.3	0.0016983	0.05	Trapezoid	30	0.01
R300	Automatic Fixed Interval	402.84	0.0045324	0.05	Trapezoid	30	0.01
R310	Automatic Fixed Interval	3371.1	0.0071741	0.05	Trapezoid	30	0.01
R350	Automatic Fixed Interval	2459.2	0.0010474	0.05	Trapezoid	30	0.01
R360	Automatic Fixed Interval	5954.3	0.0071499	0.05	Trapezoid	30	0.01
R370	Automatic Fixed Interval	70.711	0.0017771	0.05	Trapezoid	30	0.01
R400	Automatic Fixed Interval	4056.8	0.0045149	0.05	Trapezoid	30	0.01
R420	Automatic Fixed Interval	141.42	0.0017771	0.05	Trapezoid	30	0.01
R430	Automatic Fixed Interval	268.70	0.0017771	0.05	Trapezoid	30	0.01
R450	Automatic Fixed Interval	6465.1	0.0013880	0.05	Trapezoid	30	0.01
R470	Automatic Fixed Interval	2554.0	0.0020025	0.05	Trapezoid	30	0.01
R480	Automatic Fixed Interval	3496.2	0.0233189	0.05	Trapezoid	30	0.01
R520	Automatic Fixed Interval	4023.3	0.0054346	0.05	Trapezoid	30	0.01
R540	Automatic Fixed Interval	4333.2	0.0017771	0.05	Trapezoid	30	0.01
R560	Automatic Fixed Interval	4550.7	0.0170701	0.05	Trapezoid	30	0.01
R570	Automatic Fixed Interval	1533.7	0.0017771	0.05	Trapezoid	30	0.01
R580	Automatic Fixed Interval	641.13	0.0017771	0.05	Trapezoid	30	0.01
R600	Automatic Fixed Interval	2889.7	0.0018477	0.05	Trapezoid	30	0.01
R610	Automatic Fixed Interval	3041.0	.0005034721754957777	0.05	Trapezoid	30	0.01
R630	Automatic Fixed Interval	5093.7	0.0117841	0.05	Trapezoid	30	0.01
R660	Automatic Fixed Interval	2912.1	0.0049344	0.05	Trapezoid	30	0.01
R700	Automatic Fixed Interval	1878.5	0.0027977	0.05	Trapezoid	30	0.01
R720	Automatic Fixed Interval	2427.4	0.0310195	0.05	Trapezoid	30	0.01
R730	Automatic Fixed Interval	3207.4	0.0111678	0.05	Trapezoid	30	0.01
R750	Automatic Fixed Interval	5281.7	0.0088419	0.05	Trapezoid	30	0.01
R770	Automatic Fixed Interval	817.28	0.0017771	0.05	Trapezoid	30	0.01
R780	Automatic Fixed Interval	2662.1	0.0144530	0.05	Trapezoid	30	0.01
R810	Automatic Fixed Interval	4062.9	0.0135599	0.05	Trapezoid	30	0.01

Annex 11. Kipit Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	8.059631	122.462745	0.18	0.50	-0.32	Not Defined	5 -Year
2	8.058167	122.463409	0.04	0.50	-0.46	Not Defined	5 -Year
3	8.058677	122.462143	0.17	0.50	-0.33	Not Defined	5 -Year
4	8.060164	122.442069	0.47	1.00	-0.53	Not Defined	5 -Year
5	8.060286	122.449232	0.06	0.10	-0.04	Not Defined	5 -Year
6	8.059127	122.449474	0.75	1.50	-0.75	Not Defined	5 -Year
7	8.05951	122.450053	0.07	0.15	-0.08	Not Defined	5 -Year
8	8.059425	122.450525	0.29	1.50	-1.21	Not Defined	5 -Year
9	8.060037	122.452261	0.12	0.10	0.02	Not Defined	5 -Year
10	8.059761	122.454364	0.13	0.50	-0.37	Not Defined	5 -Year
11	8.060099	122.456783	0.08	0.50	-0.42	Not Defined	5 -Year
12	8.057674	122.467035	0.05	0.10	-0.05	Not Defined	5 -Year
13	8.058948	122.468108	0.07	0.10	-0.03	Not Defined	5 -Year
14	8.055971	122.46794	0.72	1.00	-0.28	Not Defined	5 -Year
15	8.072471	122.465369	0.10	0.12	-0.02	Not Defined	5 -Year
16	8.072309	122.464895	0.24	0.12	0.12	Not Defined	5 -Year
17	8.072291	122.464448	0.04	0.12	-0.08	Not Defined	5 -Year
18	8.071152	122.46074	0.03	0.12	-0.09	Not Defined	5 -Year
19	8.070731	122.459518	0.03	0.12	-0.09	Not Defined	5 -Year
20	8.072414	122.469389	0.21	0.12	0.09	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
21	8.072396	122.46909	0.18	0.12	0.06	Not Defined	5 -Year
22	8.071101	122.468135	0.09	0.12	-0.03	Not Defined	5 -Year
23	8.071473	122.46789	0.03	0.12	-0.09	Not Defined	5 -Year
24	8.069385	122.48403	0.66	1.00	-0.34	Not Defined	5 -Year
25	8.070405	122.482656	0.16	1.00	-0.84	Not Defined	5 -Year
26	8.059423	122.485626	0.03	0.50	-0.47	Not Defined	5 -Year
27	8.058337	122.490092	0.04	0.50	-0.46	Not Defined	5 -Year
28	8.059828	122.490752	0.04	0.50	-0.46	Not Defined	5 -Year
29	8.059998	122.491944	0.12	0.50	-0.38	Not Defined	5 -Year
30	8.063038	122.474325	2.71	2.20	0.51	Not Defined	5 -Year
31	8.061763	122.474132	2.43	2.20	0.23	Not Defined	5 -Year
32	8.061335	122.474046	4.80	2.20	2.60	Not Defined	5 -Year
33	8.061051	122.474052	4.88	2.20	2.68	Not Defined	5 -Year
34	8.058678	122.473393	1.93	2.20	-0.27	Not Defined	5 -Year
35	8.05684	122.472211	3.21	2.20	1.01	Not Defined	5 -Year
36	8.05999	122.475537	1.33	2.00	-0.67	Not Defined	5 -Year
37	8.061276	122.4764	0.81	1.00	-0.19	Not Defined	5 -Year
38	8.060488	122.476577	0.13	0.10	0.03	Not Defined	5 -Year
39	8.05847	122.476461	1.64	1.00	0.64	Not Defined	5 -Year
40	8.057184	122.477216	2.25	1.00	1.25	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
41	8.056486	122.476814	1.39	1.00	0.39	Not Defined	5 -Year
42	8.056166	122.477922	0.13	0.10	0.03	Not Defined	5 -Year
43	8.055718	122.477681	0.33	0.10	0.23	Not Defined	5 -Year
44	8.055023	122.482431	0.10	0.10	0.00	Not Defined	5 -Year
45	8.058982	122.473952	1.93	2.20	-0.27	Not Defined	5 -Year
46	8.057853	122.473271	1.82	2.20	-0.38	Not Defined	5 -Year
47	8.054933	122.47255	0.83	2.00	-1.17	Not Defined	5 -Year
48	8.053532	122.472436	0.27	1.00	-0.73	Not Defined	5 -Year
49	8.058691	122.491153	0.27	0.50	-0.23	Not Defined	5 -Year
50	8.059038	122.479459	1.08	1.00	0.08	Not Defined	5 -Year
51	8.058725	122.479888	0.87	1.00	-0.13	Not Defined	5 -Year
52	8.059644	122.46274	0.18	0.50	-0.32	Not Defined	5 -Year
53	8.058722	122.46207	0.12	0.00	0.12	Not Defined	5 -Year
54	8.058235	122.463432	0.08	0.50	-0.42	Not Defined	5 -Year
55	8.058688	122.4734	1.93	2.50	-0.57	Not Defined	5 -Year
56	8.059308	122.473736	2.31	2.50	-0.19	Not Defined	5 -Year
57	8.059843	122.473837	5.18	2.00	3.18	Not Defined	5 -Year
58	8.060124	122.473985	1.66	2.00	-0.34	Not Defined	5 -Year
59	8.060763	122.47405	4.70	2.00	2.70	Not Defined	5 -Year
60	8.061065	122.474071	1.58	2.00	-0.42	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
61	8.061243	122.474686	0.99	0.15	0.84	Not Defined	5 -Year
62	8.061773	122.47589	0.75	0.15	0.60	Not Defined	5 -Year
63	8.059946	122.476729	1.00	0.50	0.50	Not Defined	5 -Year
64	8.060095	122.474762	0.95	1.00	-0.05	Not Defined	5 -Year
65	8.059358	122.475768	1.57	0.50	1.07	Not Defined	5 -Year
66	8.059526	122.476643	1.26	0.50	0.76	Not Defined	5 -Year
67	8.059088	122.476728	1.25	0.50	0.75	Not Defined	5 -Year
68	8.05858	122.47715	0.60	0.50	0.10	Not Defined	5 -Year
69	8.057786	122.47666	2.62	0.50	2.12	Not Defined	5 -Year
70	8.057401	122.476737	1.96	0.50	1.46	Not Defined	5 -Year
71	8.062705	122.478082	0.55	2.00	-1.45	Not Defined	5 -Year
72	8.059936	122.478368	0.46	0.50	-0.04	Not Defined	5 -Year
73	8.059527	122.47889	0.23	0.50	-0.27	Not Defined	5 -Year
74	8.059659	122.462737	0.18	0.00	0.18	Not Defined	5 -Year
75	8.058199	122.463377	0.19	0.50	-0.31	Not Defined	5 -Year
76	8.058741	122.462062	0.06	0.50	-0.44	Not Defined	5 -Year
77	8.068176	122.461538	0.47	1.00	-0.53	Not Defined	5 -Year
78	8.068649	122.462264	0.58	1.00	-0.42	Not Defined	5 -Year
79	8.070633	122.463169	0.66	1.00	-0.34	Not Defined	5 -Year
80	8.071009	122.463339	0.53	1.00	-0.47	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
61	8.061243	122.474686	0.99	0.15	0.84	Not Defined	5 -Year
62	8.061773	122.47589	0.75	0.15	0.60	Not Defined	5 -Year
63	8.059946	122.476729	1.00	0.50	0.50	Not Defined	5 -Year
64	8.060095	122.474762	0.95	1.00	-0.05	Not Defined	5 -Year
65	8.059358	122.475768	1.57	0.50	1.07	Not Defined	5 -Year
66	8.059526	122.476643	1.26	0.50	0.76	Not Defined	5 -Year
67	8.059088	122.476728	1.25	0.50	0.75	Not Defined	5 -Year
68	8.05858	122.47715	0.60	0.50	0.10	Not Defined	5 -Year
69	8.057786	122.47666	2.62	0.50	2.12	Not Defined	5 -Year
70	8.057401	122.476737	1.96	0.50	1.46	Not Defined	5 -Year
71	8.062705	122.478082	0.55	2.00	-1.45	Not Defined	5 -Year
72	8.059936	122.478368	0.46	0.50	-0.04	Not Defined	5 -Year
73	8.059527	122.47889	0.23	0.50	-0.27	Not Defined	5 -Year
74	8.059659	122.462737	0.18	0.00	0.18	Not Defined	5 -Year
75	8.058199	122.463377	0.19	0.50	-0.31	Not Defined	5 -Year
76	8.058741	122.462062	0.06	0.50	-0.44	Not Defined	5 -Year
77	8.068176	122.461538	0.47	1.00	-0.53	Not Defined	5 -Year
78	8.068649	122.462264	0.58	1.00	-0.42	Not Defined	5 -Year
79	8.070633	122.463169	0.66	1.00	-0.34	Not Defined	5 -Year
80	8.071009	122.463339	0.53	1.00	-0.47	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
81	8.055947	122.467958	0.72	0.50	0.22	Not Defined	5 -Year
82	8.057519	122.4674	0.22	0.20	0.02	Not Defined	5 -Year
83	8.059017	122.468129	0.07	0.20	-0.13	Not Defined	5 -Year
84	8.060447	122.471627	0.64	0.20	0.44	Not Defined	5 -Year
85	8.072476	122.473639	0.16	0.15	0.01	Not Defined	5 -Year
86	8.059541	122.482296	0.18	0.50	-0.32	Not Defined	5 -Year
87	8.05521	122.482469	0.03	0.50	-0.47	Not Defined	5 -Year
88	8.059593	122.483924	0.15	0.50	-0.35	Not Defined	5 -Year
89	8.059141	122.487508	0.04	0.50	-0.46	Not Defined	5 -Year
90	8.058745	122.48831	0.05	0.50	-0.45	Not Defined	5 -Year
91	8.057049	122.490116	0.17	0.50	-0.33	Not Defined	5 -Year
92	8.059146	122.489078	0.09	0.50	-0.41	Not Defined	5 -Year
93	8.061625	122.487657	0.04	0.50	-0.46	Not Defined	5 -Year
94	8.060199	122.489212	0.14	0.50	-0.36	Not Defined	5 -Year
95	8.060236	122.490191	0.22	0.50	-0.28	Not Defined	5 -Year
96	8.058108	122.492205	0.15	0.50	-0.35	Not Defined	5 -Year
97	8.059025	122.491275	0.27	0.50	-0.23	Not Defined	5 -Year
98	8.059834	122.490909	0.03	0.50	-0.47	Not Defined	5 -Year
99	8.05851	122.492688	0.22	0.10	0.12	Not Defined	5 -Year
100	8.061378	122.492485	0.16	0.50	-0.34	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
101	8.059654	122.462669	0.18	0.50	-0.32	Not Defined	5 -Year
102	8.058744	122.462078	0.12	0.50	-0.38	Not Defined	5 -Year
103	8.058248	122.463402	0.03	0.50	-0.47	Not Defined	5 -Year
104	8.060433	122.44246	0.58	1.00	-0.42	Not Defined	5 -Year
105	8.061141	122.442169	0.77	1.00	-0.23	Not Defined	5 -Year
106	8.062255	122.440154	0.10	0.15	-0.05	Not Defined	5 -Year
107	8.061002	122.440278	0.03	0.15	-0.12	Not Defined	5 -Year
108	8.059342	122.449649	0.18	0.15	0.03	Not Defined	5 -Year
109	8.059696	122.449952	0.05	0.15	-0.10	Not Defined	5 -Year
110	8.059646	122.450495	0.08	0.15	-0.07	Not Defined	5 -Year
111	8.060344	122.45066	0.11	0.10	0.01	Not Defined	5 -Year
112	8.060288	122.450942	0.03	0.10	-0.07	Not Defined	5 -Year
113	8.060976	122.450892	0.13	0.10	0.03	Not Defined	5 -Year
114	8.060922	122.451224	0.09	0.10	-0.01	Not Defined	5 -Year
115	8.060191	122.452447	0.09	0.50	-0.41	Not Defined	5 -Year
116	8.061147	122.452762	0.06	0.50	-0.44	Not Defined	5 -Year
117	8.060078	122.454285	0.26	0.50	-0.24	Not Defined	5 -Year
118	8.060785	122.454503	0.10	0.50	-0.40	Not Defined	5 -Year
119	8.061165	122.454501	0.13	0.50	-0.37	Not Defined	5 -Year
120	8.061134	122.454678	0.10	0.50	-0.40	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
121	8.060092	122.45508	0.27	0.50	-0.23	Not Defined	5 -Year
122	8.060483	122.455336	0.06	0.50	-0.44	Not Defined	5 -Year
123	8.060108	122.456896	0.12	0.50	-0.38	Not Defined	5 -Year
124	8.059	122.468129	0.03	0.10	-0.07	Not Defined	5 -Year
125	8.057514	122.467346	0.10	0.10	0.00	Not Defined	5 -Year
126	8.055972	122.467988	0.72	1.00	-0.28	Not Defined	5 -Year
127	8.059622	122.471401	0.82	0.20	0.62	Not Defined	5 -Year
128	8.064005	122.470298	0.76	2.00	-1.24	Not Defined	5 -Year

Annex 12. Educational Institutions Affected in Kipit Floodplain

Name	Municipality	Barangay	Rainfall Scenario		
			5-year	25-year	100-year
Kipit Elementary School	Gutalac	La Libertad	Medium	Medium	Medium
Kipit Agro Fishery High School	Gutalac	La Libertad	Medium	Medium	Medium
La Libertad Elementary School	Labason	Kipit	High	High	High
Riverside Community School	Labason	Kipit	Low	Medium	Medium
Rosalina M. Carloto Memorial ES	Labason	Kipit	None	None	None
Daycare Center	Labason	Kipit	None	None	None