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

LiDAR Surveys and Flood Mapping of Iraan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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
UPLB	University of the Philippines Los Baños
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND IRAAN RIVER

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1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) 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 implementing partner university for the Phil-LiDAR 1 Program is the University of the Phiippines Los Baños (UPLB). UPLB 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 45 river basins in the MIMAROPA region. The university is located in the municipality of Los Baños in the province of Laguna.

1.2 Overview of the Iraan River Basin

The Iraan River Basin covers two (2) municipalities in Palawan; namely, the municipalities of Rizal and Brooke's Point. The DENR River Basin Control Office (RBCO) states that the Iraan River Basin has a drainage area of 183 km² and an estimated 293 cubic meter (MCM) annual run-off (RBCO, 2015).

Iraan River Basin is a 157,400-hectare watershed located in Palawan. It covers the barangays of Aribungos, Mainit, Mambalot and Tubtub in the municipality of Brooke's Point; and Bunog, Iraan and Punta Baja in Rizal. The river basin is generally characterized by >50% slope. Iraan River Basin is comprised of two soil classes. Sibul clay soil type covers the river basin although unclassified area (rough mountainous land) can also be found. The river basin still has good forest cover of closed canopy (mature trees covering >50%). Other land cover types include cultivated area mixed with brushland/ grassland, cropland mixed with coconut plantation, mossy forest and open canopy (mature trees covering <50%).

Its main stem, Iraan River, is part of the forty-five (45) river systems under the PHIL-LIDAR 1 Program partner HEI, University of the Philippines Los Baños. The Iraan River passes through Aribungos, Mainit, Mambalot and Tubtub in Brooke's Point municipality; and, bunog, Iraan and Punta Baja in Rizal. According to the 2015 national census of PSA, a total of 6,780 persons reside in Brgy. Iraan in the Municipality of Rizal, which is within the immediate vicinity of the river. The economy of Palawan largely rests on agriculture particularly fishing, tourism, trade, commerce, and mineral extraction (Palawan Knowledge Platform for Biodiversity and Sustainable Development, 2007).

Based on the studies conducted by the Mines and Geosciences Bureau, only Iraan has a flood susceptibility range of low to high while other barangays have none. The field surveys conducted by the PHIL-LiDAR 1 validation team showed that a rainfall event in January 2013 caused flooding affecting barangay Iraan. In terms of landslide susceptibility, Punta Baja and and Iraan have a range of low to high risk while other barangays have a range of moderate to high risk. On August 22, 2016, an approximately 1-meter deep flooding incident was reported in Brgy. Iraan in the Municipality of Rizal due to heavy rains as per NDRRMC report (National Disaster Risk Reduction and Management Council, 2016).

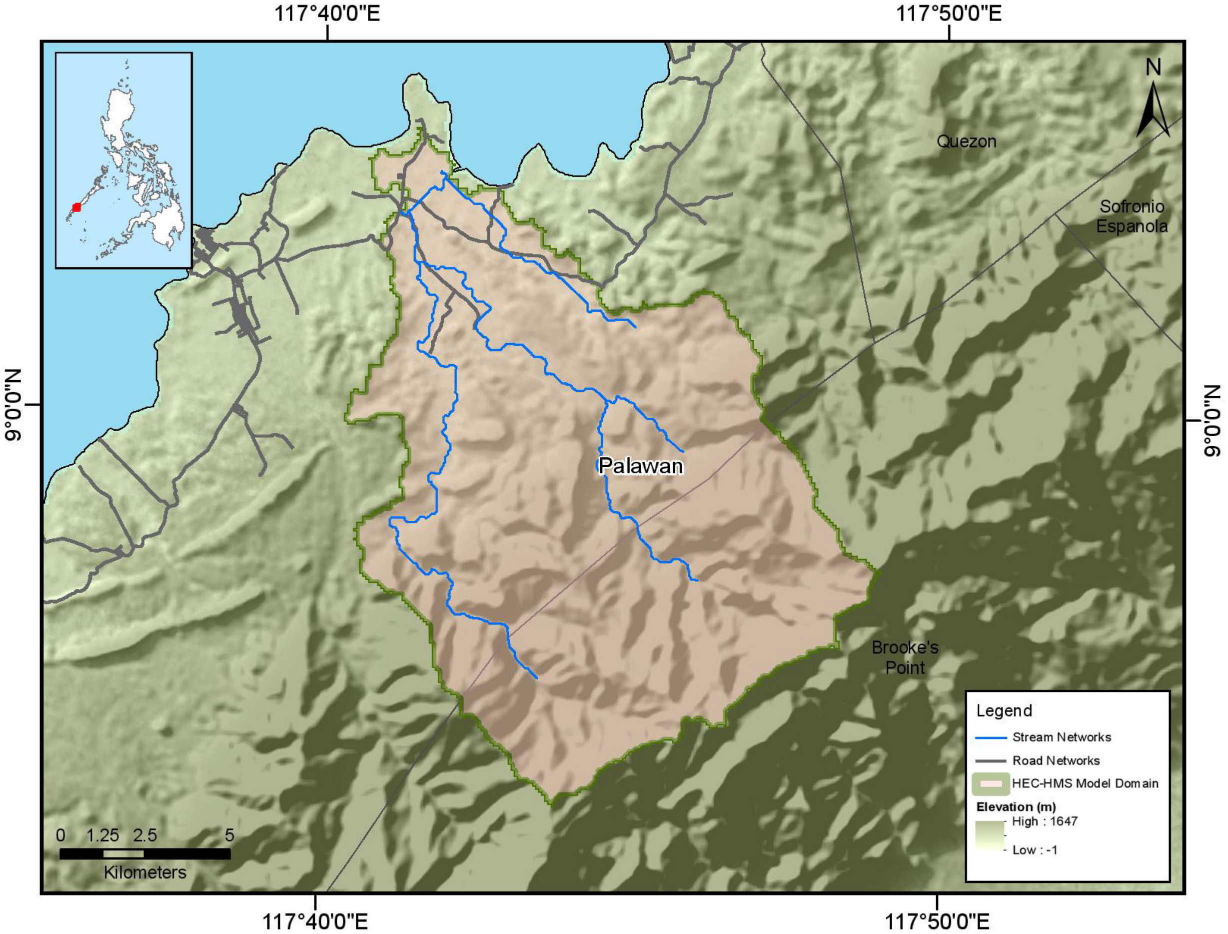

Figure 1. Map of the Iraan River Basin (in brown)

Climate Type I and III prevails in MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE IRAAN 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 Iraan Floodplain in Palawan. These missions were planned for 21 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 1 shows the flight plan for Iraan Floodplain.

Table 1. Parameters used in Pegasus LiDAR System during Flight Acquisition.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK42J	1200	30	50	200	30	130	5
BLK42L	1200	30	50	200	30	130	5
BLK42M	1200	30	50	200	30	130	5
BLK42N	1200	30	50	200	30	130	5
BLK42O	1200	30	50	200	30	130	5
BLK42P	1200	30	50	200	30	130	5
BLK42S	1200	30	50	200	30	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

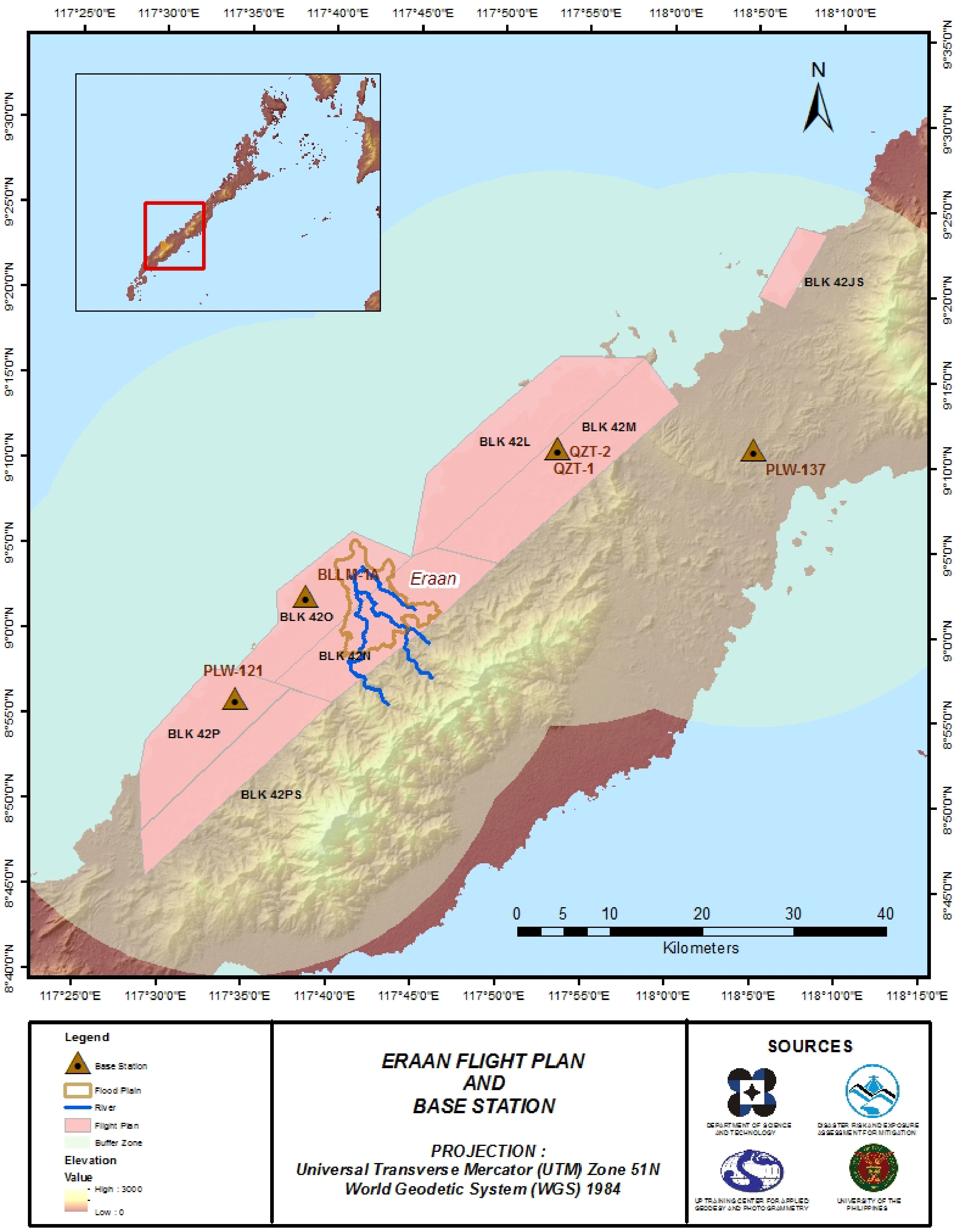

Figure 2. Flight Plan and base stations used for the Iraan Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points: PLW-121 and PLW-137which are of second (2nd) order accuracy order accuracy. The project team also established three (3) ground control points: BLLM-1A, QZT-1 and QZT-2. The certifications for the NAMRIA reference points are found in Annex 2, while the processing reports for the established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (May 25 to July, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS R8. Flight plans and location of base stations used during the aerial LiDAR acquisition in Iraan Floodplain are shown in Figure 2.

Figure 3 to Figure 4 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 6 show the details about the following NAMRIA control stations and established points while Table 7 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 3. GPS set-up over PLW-121as recovered within the vicinity of Cabkungan Elementary School in Brgy. Campong Ulay, Rizal, Palawan (a) and NAMRIA reference point PLW-121(b) as recovered by the field team.

Table 2 Details of the recovered NAMRIA horizontal control point PLW-121 used as base station for the LiDAR Acquisition.

Station Name	**PLW-121**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 56' 1.71426" North 117° 34' 23.99157" East 8.98036 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	398086.54 meters 987945.887 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 55' 57.38325" North 117° 34' 29.39124" East 58.05800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	563030.26 meters 987521.12 meters

Figure 4. GPS set-up over PLW-137as recovered at the top of the ridge along national highway in Brgy. Ipilan, Quezon, Palawan (a) and NAMRIA reference point PLW-137(b) as recovered by the field team.

Table 3 Details of the recovered NAMRIA horizontal control point PLW-137 used as base station for the LiDAR Acquisition.

Station Name	**PLW-137**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 11’ 2.95364” North 118° 4’ 48.04729” East 35.83359 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	453844.056 meters 1015530.347 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 10’ 58.60442” North 118° 4’ 53.42391” East 85.64700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	618656.03 meters 1015326.41 meters

Table 4. Details of the established horizontal control point BLLM-1A used as base station for the LiDAR Acquisition.

Station Name	BLLM-1A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 02' 07.68639" North 117° 38' 28.10618" East -2.0700 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 02' 03.33580" North 117° 38' 33.49665" East 46.965 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	570465.682 meters 998772.489 meters

Table 5. Details of the established horizontal control point QZT-1 used as base station for the LiDAR Acquisition.

Station Name	QZT-1	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 10' 58.89071" North 117° 53' 13.01663" East 9.33800 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 10' 54.52473" North 117° 53' 18.39361" East 85.64700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	597443.484 meters 1015143.507 meters

Table 6. Details of established horizontal control point QZT-2 used as base station for the LiDAR Acquisition.

Station Name	**QZT-2**	
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	9° 10' 57.93286" North 117° 53' 13.25970" East 6.86400 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 10' 53.56696" North 117° 53' 18.63670" East 56.200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	597450.975 meters 1015114.108 meters

Table 7. Ground control points that were used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
11-Jul-15	3157P	1BLK42PO192A	PLW-121, BLLM-1A
11-Jul-15	3159P	1BLK42PO192B	PLW-121, BLLM-1A
12-Jul-15	3161P	1BLK42LMN193A	QZT-1, QZT-2
13-Jul-15	3165P	1BLK42KLM194A	PLW-137, QZT-1, QZT-2
13-Jul-15	3167P	1BLK42KLM194B	PLW-137, QZT-1, QZT-2

2.3 Flight Missions

Five (5) missions were conducted to complete the LiDAR Data Acquisition in Iraan Floodplain, for a total of seventeen hours and forty minutes (17+40) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for the LiDAR data acquisition of the Iraan Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
11-Jul-15	3157P	546.67	447.70	38.05	409.65	536	4	23
11-Jul-15	3159P	385.73	231.17	47.19	183.98	1	3	12
12-Jul-15	3161P	347.69	291.21	1.86	289.35	710	3	33
13-Jul-15	3165P	347.69	251.76	NA	251.76	583	4	14
13-Jul-15	3167P	28.55	79.92	NA	79.92	103	2	18
TOTAL		1656.34	1301.76	87.1	1214.66	1933	17	40

Table 9. Actual parameters used during the LiDAR data acquisition of the Iraan Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3157P	1200	30	50	200	25	130	5
3159P	1200	30	50	200	25	130	5
3161P	1200, 1000	30	50	200	25	130	5
3165P	1200, 800	30	50	200	25	130	5
3167P	1200	30	50	200	25	130	5

2.4 Survey Coverage

Iraan Floodplain is located in the province of Palawan with majority of the floodplain situated within the municipality of Rizal. Municipalities of Rizal and Quezon were mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Iraan Floodplain is presented in Figure 5.

Table 10. List of municipalities and cities surveyed during Iraan Floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Palawan	Narra	831.19	1.84	0.22%
	Quezon	917.97	360.75	39.30%
	Rizal	980.59	480.86	49.04%
	Sofronio Espanola	477.50	84.93	17.79%
Total		**3207.25**	**928.38**	**26.59%**

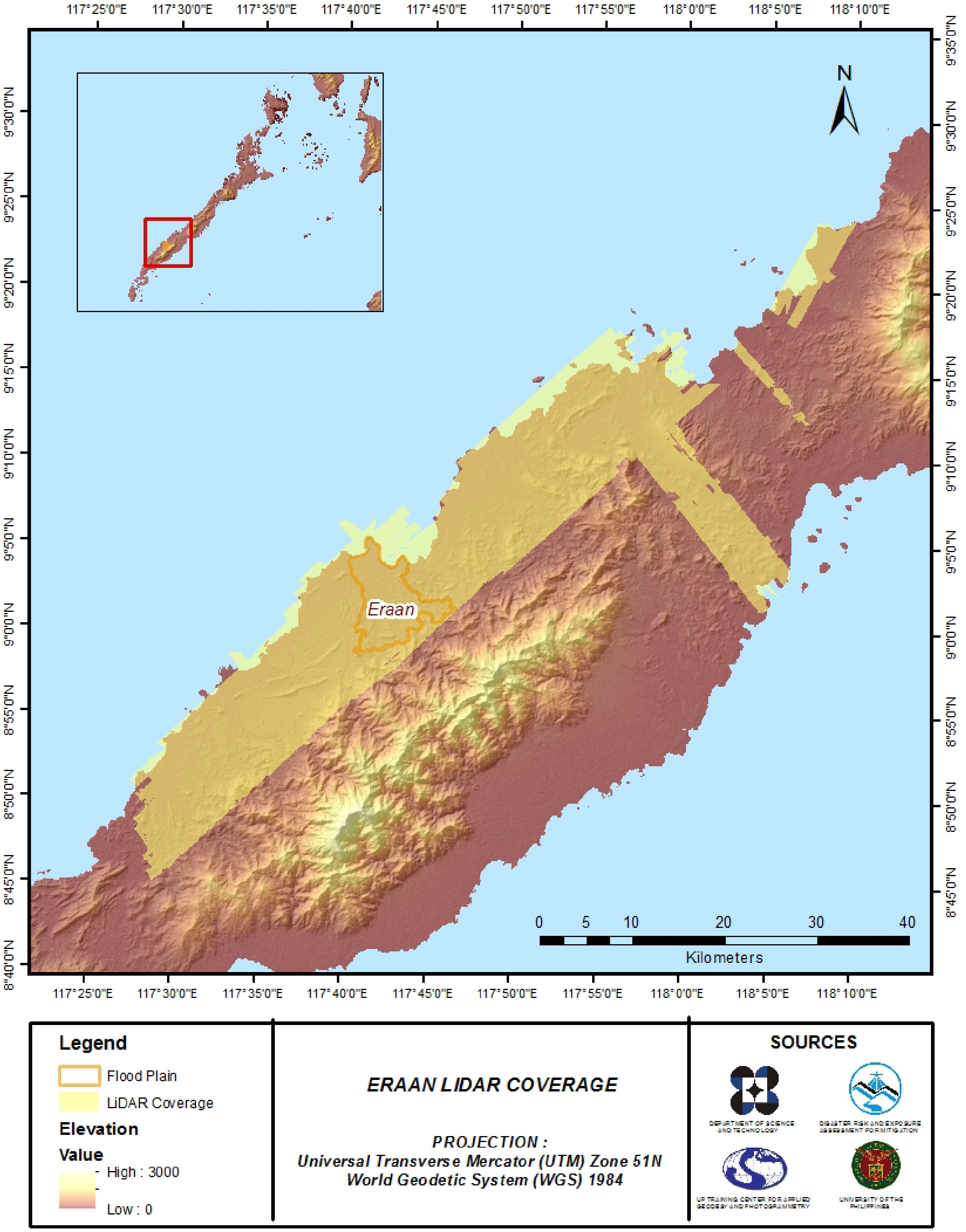

Figure 5. Actual LiDAR survey coverage for Iraan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE IRAAN 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

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 are the minimum point density, vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flow chart shown in Figure 6.

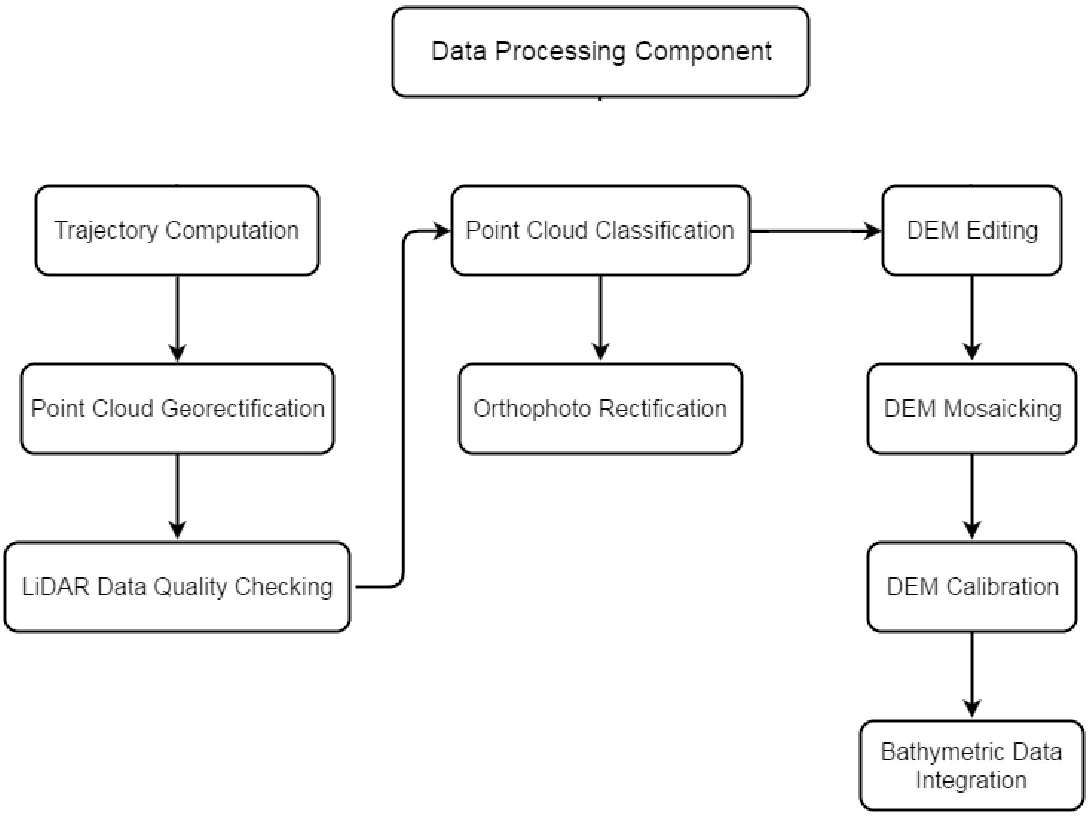

Figure 6. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Iraan Floodplain can be found in Annex 5. Missions flown during the first survey conducted on July 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Rizal, Palawan.

The Data Acquisition Component (DAC) transferred a total of 129.96 Gigabytes of Range data, 1.05 Gigabytes of POS data, 68.49 Megabytes of GPS base station data, and 173.73 Gigabytes of raw image data to the data server on July 13, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Iraan was fully transferred on August 5, 2015, as indicated on the Data Transfer Sheets for Iraan Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3159P, one of the Iraan flights, which is the North, East, and Down position RMSE values are shown in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on July 11, 2015 00:00AM on that week. The y-axis is the RMSE value for that particular position.

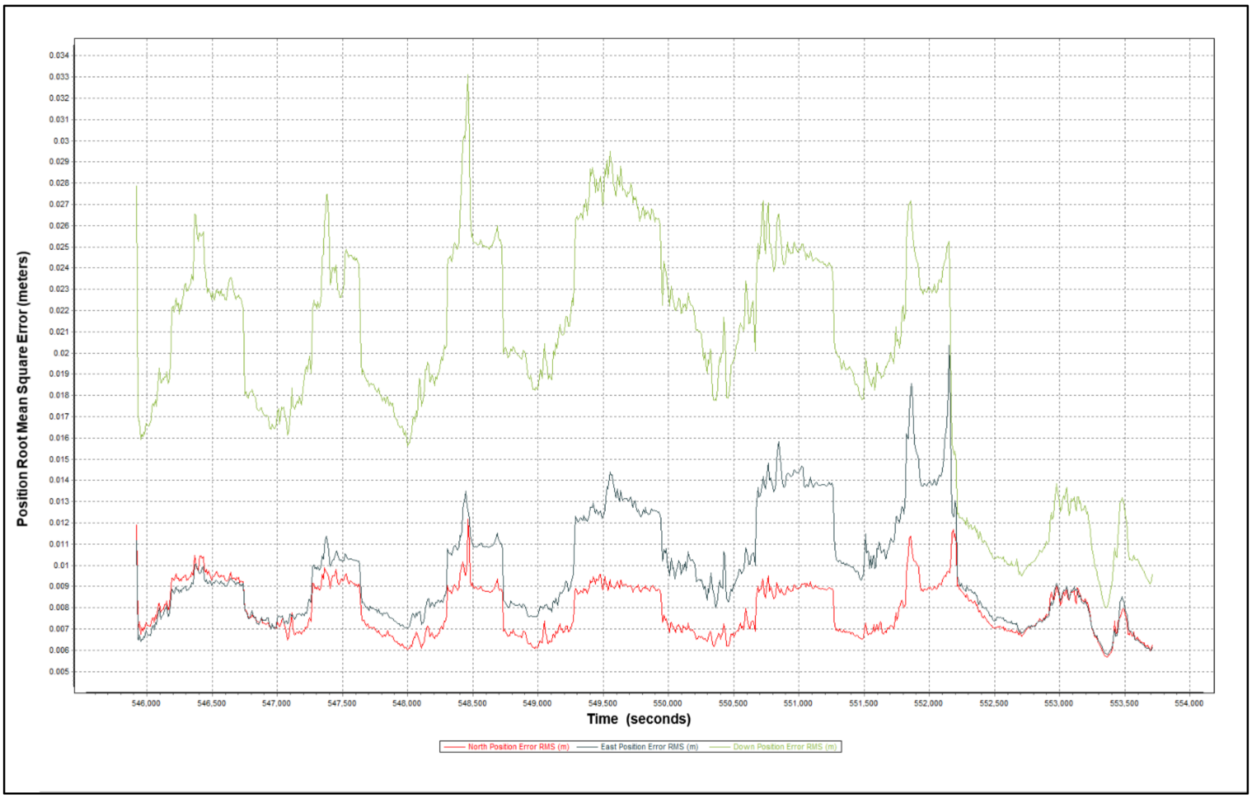

Figure 7. Smoothed Performance Metrics of an Iraan Flight 3159P.

The time of flight was from 545900 seconds to 553700 seconds, which corresponds to afternoon of July 11, 2015. 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 started computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 shows that the North position RMSE peaked at 1.20 centimeters, the East position RMSE peaked at 2.00 centimeters, and the Down position RMSE peaked at 3.30 centimeters, which are within the prescribed accuracies described in the methodology.

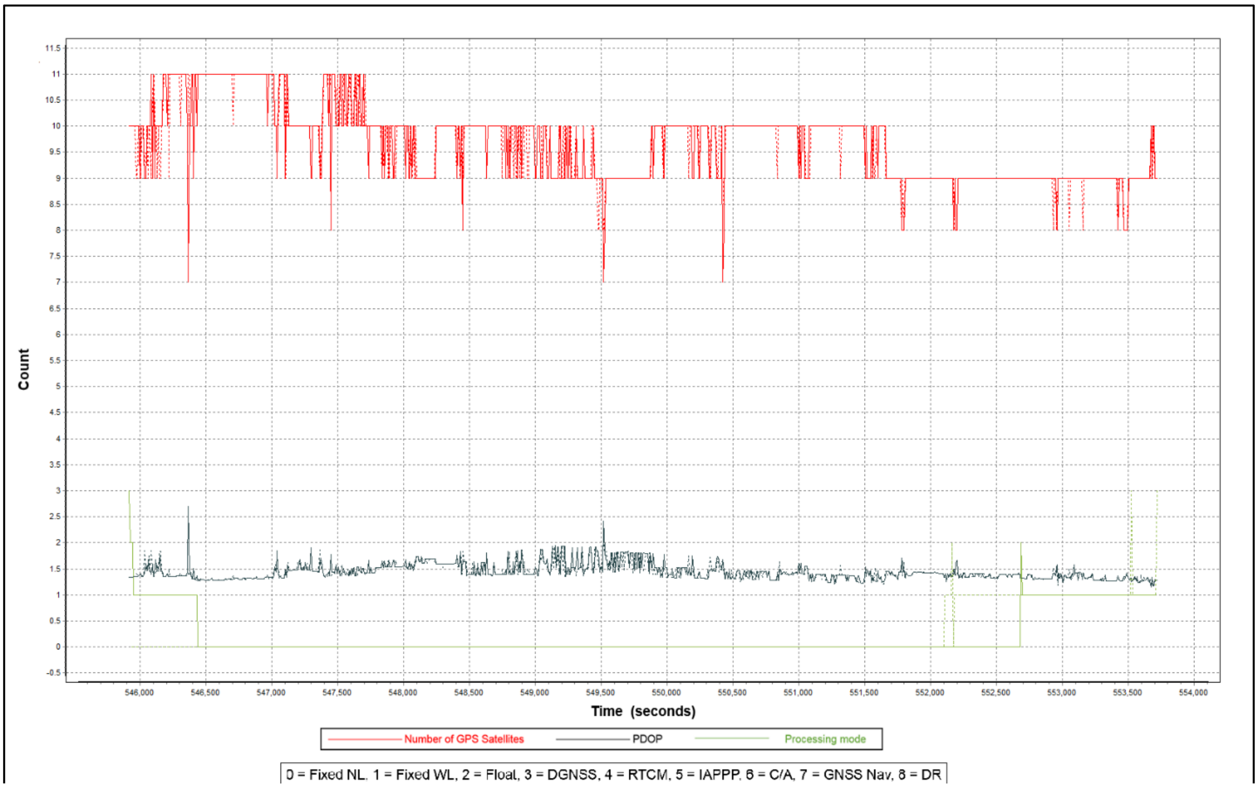

Figure 8. Solution Status Parameters of Iraan Flight 2842P.

The Solution Status parameters of flight 3159P, one of the Iraan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 11. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Iraan flights is shown in Figure 9.

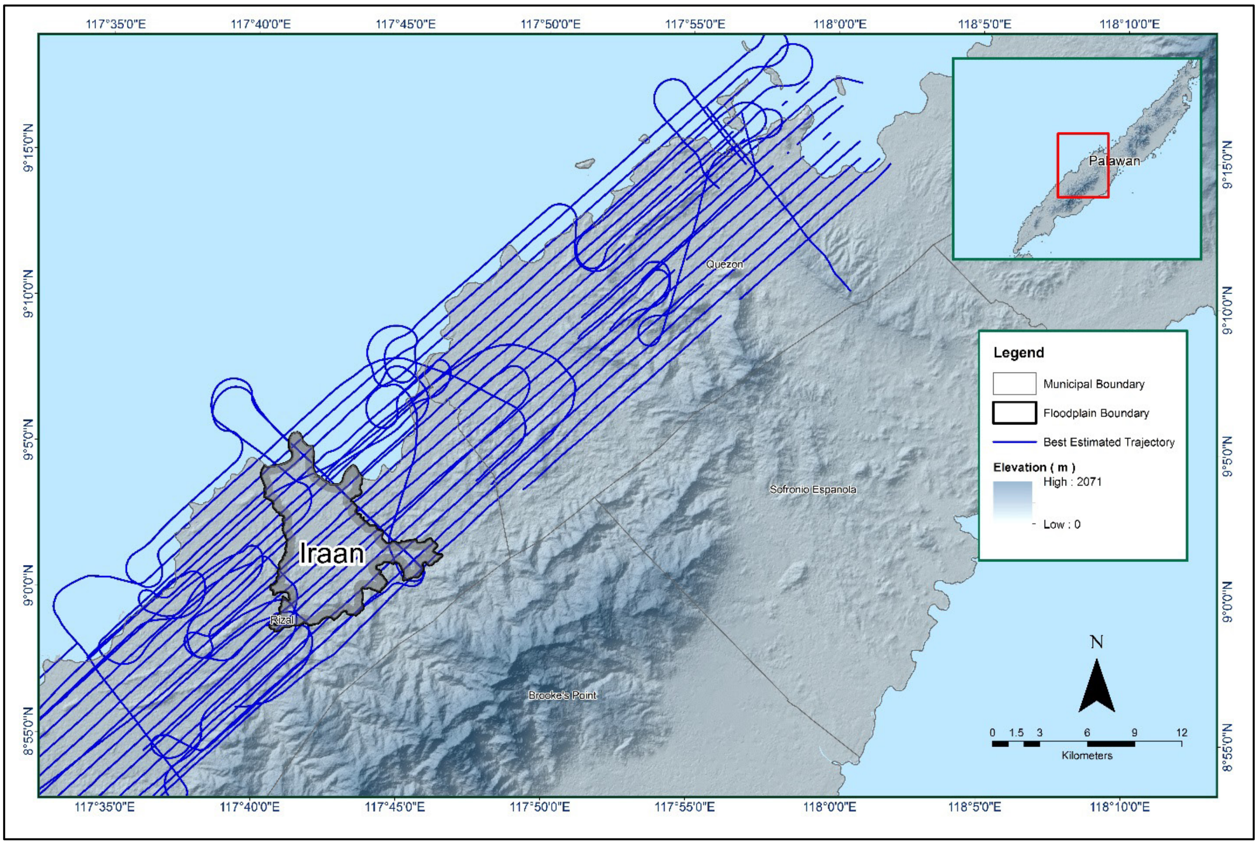

Figure 9. Best Estimated Trajectory for Iraan Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 44 flight lines, with each flight line containing one channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Iraan floodplain are given in Table 11.

Table 11 Self-Calibration Results values for Iraan flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000562
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000941
GPS Position Z-correction stdev	<0.01meters	0.0098

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Iraan Floodplain is shown in Figure B-5. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

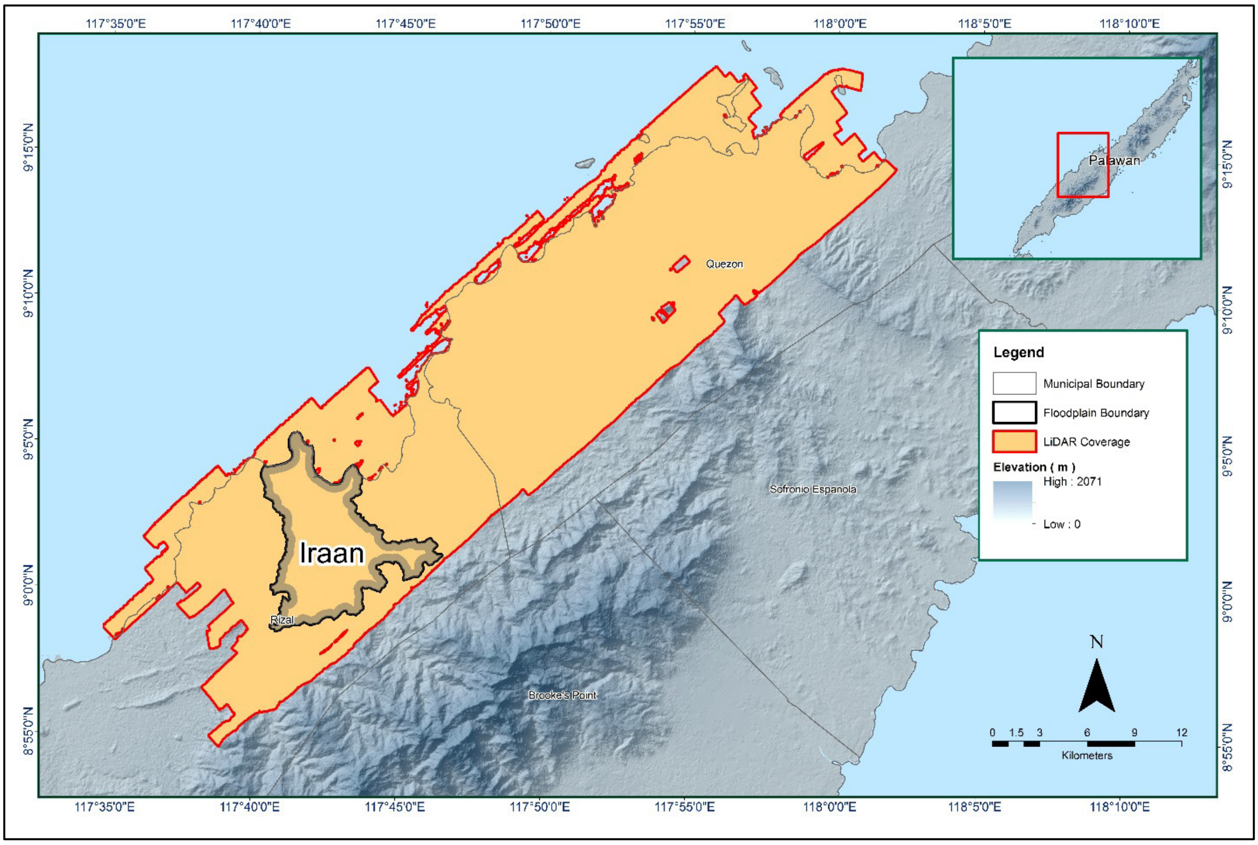

Figure 10. Boundary of the processed LiDAR data over Iraan Floodplain

The total area covered by the Iraan missions is 685.25 sq.km that is comprised of five (5) flight acquisitions grouped and merged into four (4) blocks as shown in Table 12

Table 12. List of LiDAR blocks for Iraan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_Blk42L	3161P	197.06
	3165P	
Palawan_Blk42M	3161P	184.09
	3165P	
	3167P	
Palawan_Blk42N	3157P	188.81
	3159P	
Palawan_Blk42O	3157P	115.29
TOTAL		685.25 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 11. Since the Pegasus system employs two channels an average value of 2 (blue) for areas where there was limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines is expected.

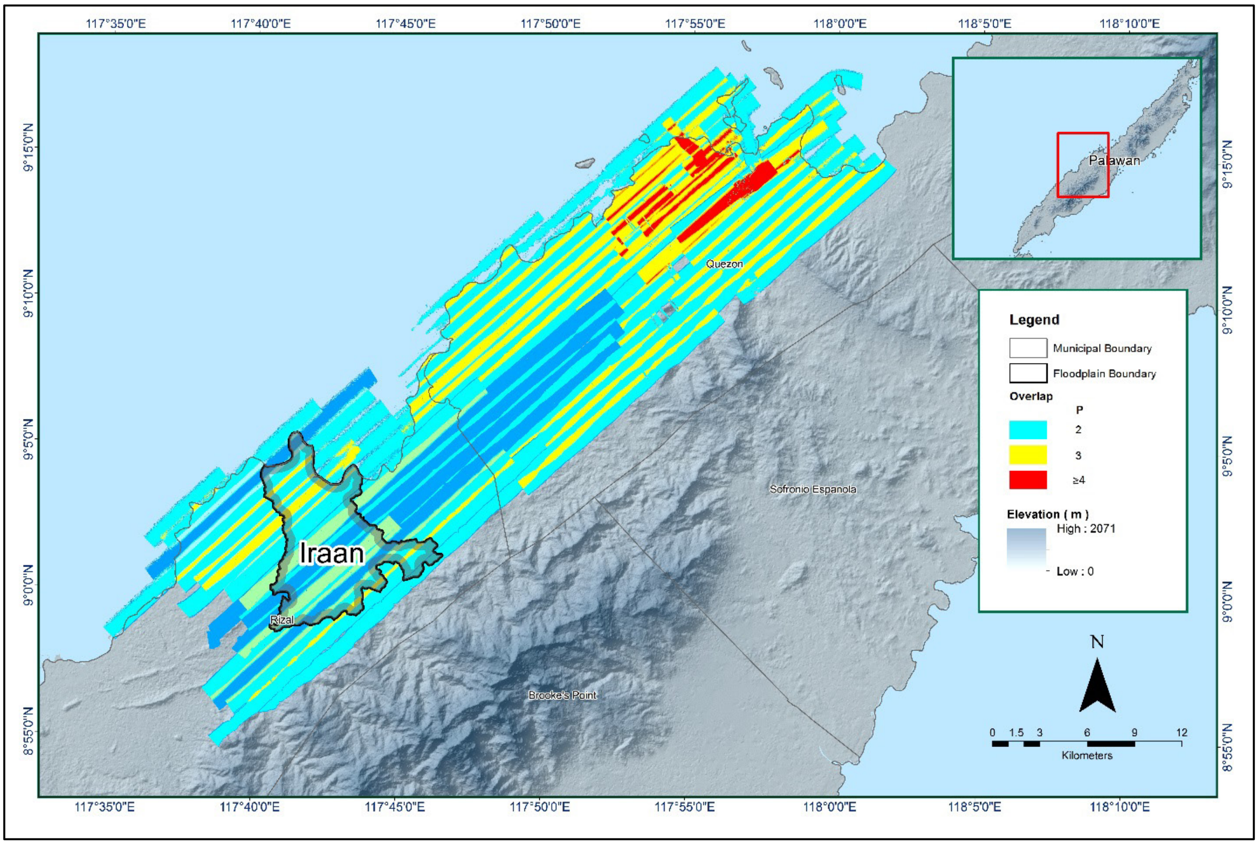

Figure 11. Image of data overlap for Iraan Floodplain.

The overlap statistics per block for the Iraan Floodplain can be found in Annex[Check annex number]. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 33.01% and 41.20% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 12. It was determined that all LiDAR data for Iraan Foodplain satisfy the point density requirement, and the average density for the entire survey area is 2.57 points per square meter.

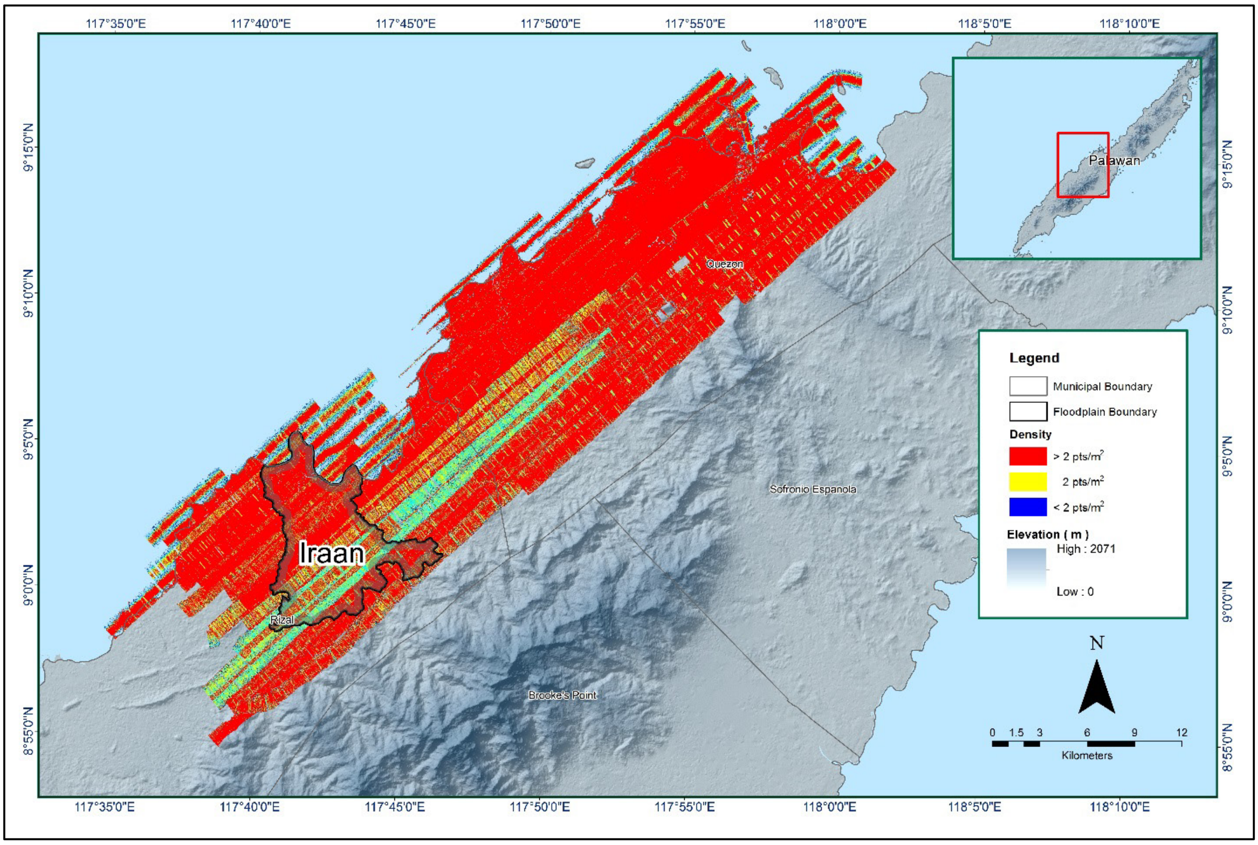

Figure 12. Pulse density map of merged LiDAR data for Iraan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. 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, were 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 were 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.

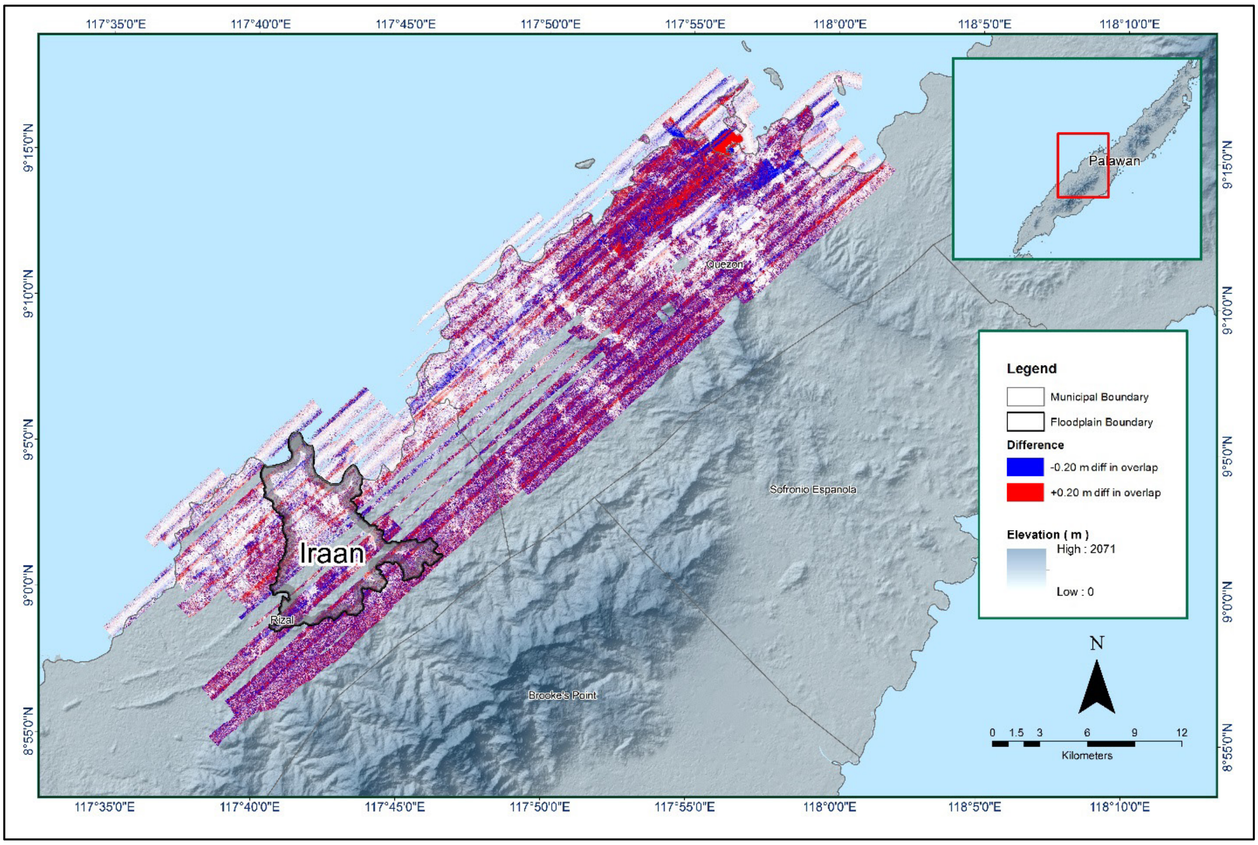

Figure 13. Elevation difference map between flight lines for Iraan Floodplain.

A screen capture of the processed LAS data from an Iraan flight 3159P loaded in QT Modeler is shown in Figure 14. 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 were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

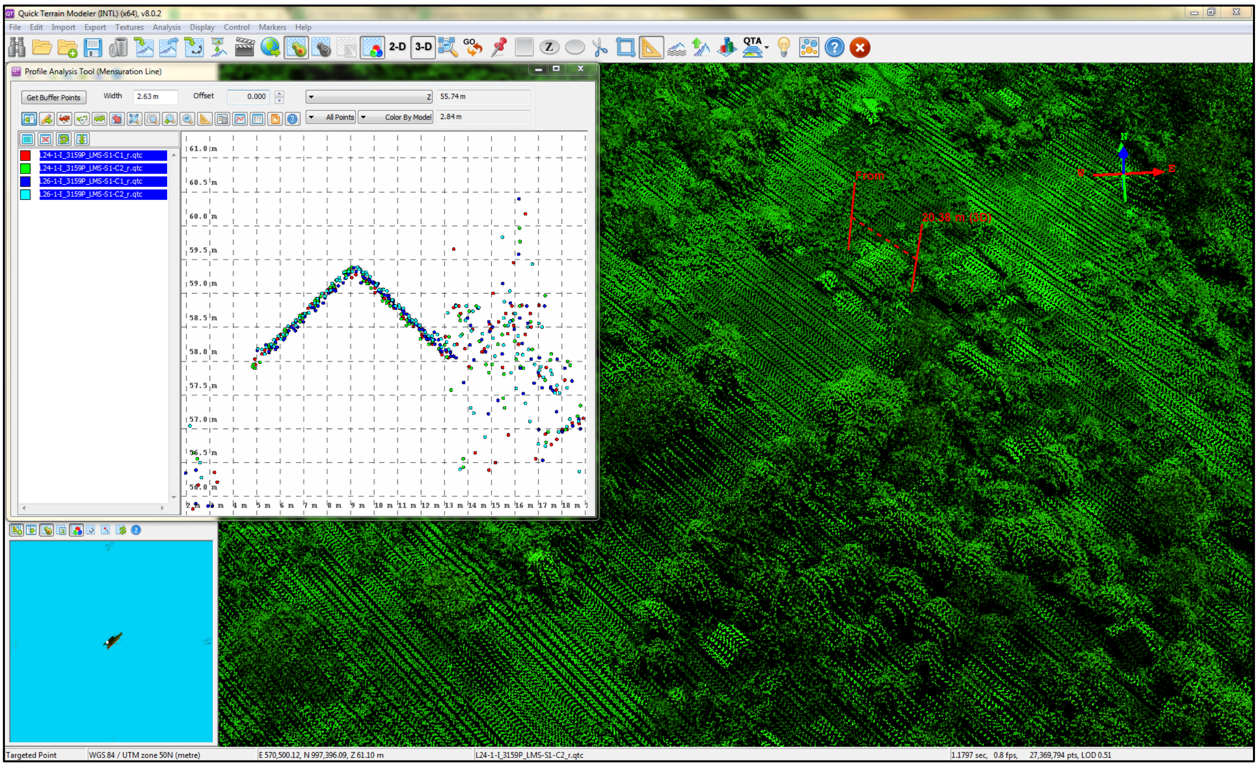

Figure 14. Quality checking for a Iraan flight 3159P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Iraan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	477,956,084
Low Vegetation	354,589,122
Medium Vegetation	585,031,437
High Vegetation	1,922,330,728
Building	31,537,795

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Iraan Floodplain is shown in Figure 15. A total of 984 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 658.32 meters and 35.92 meters respectively.

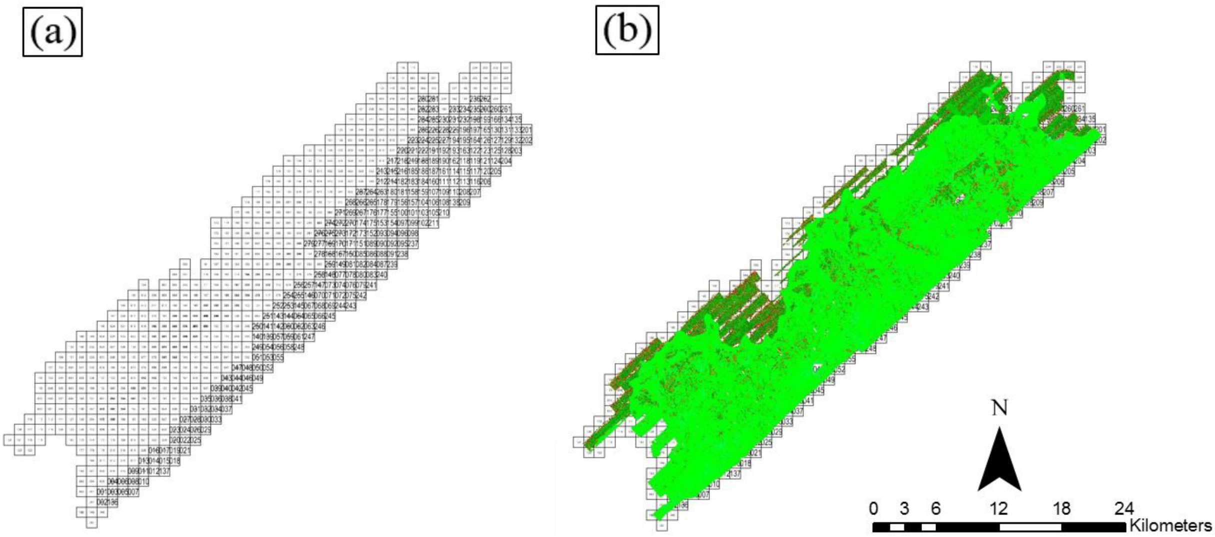

Figure 15. Tiles for Iraan Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 16. 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.

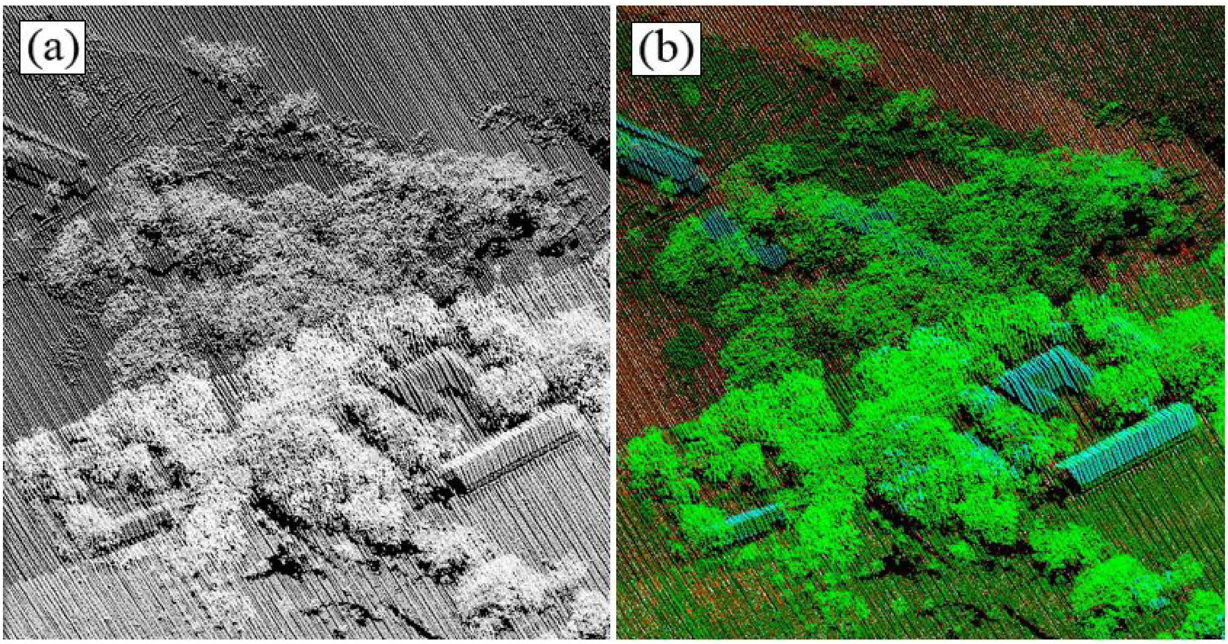

Figure 16. Point cloud before (a) and after (b) classification

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

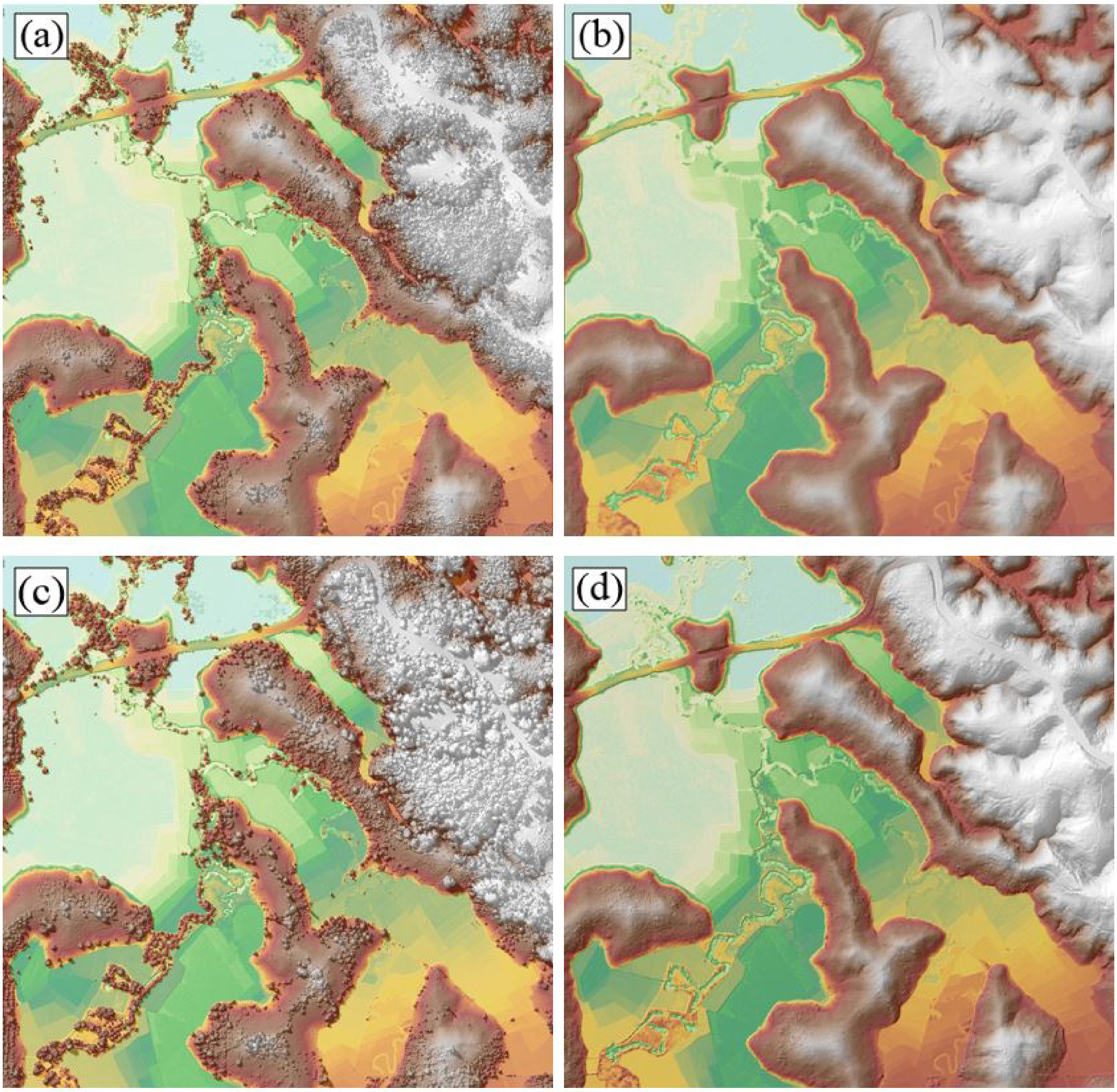

Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Iraan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 96 1km by 1km tiles area covered by Iraan Floodplain is shown in Figure 18. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Iraan Floodplain has a total of 41.16 sq.km orthophotogaph coverage comprised of 86 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 19.

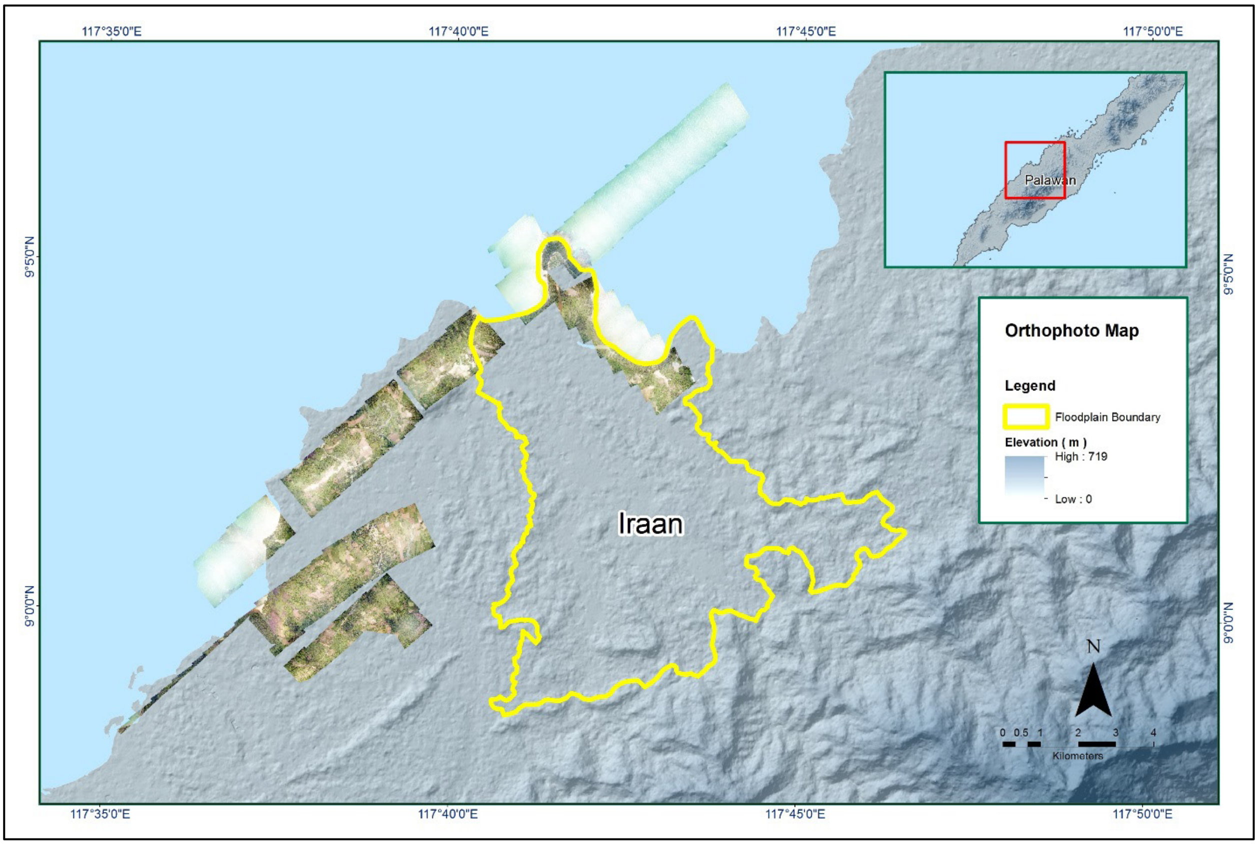

Figure 18. Iraan Floodplain with available orthophotographs.

Figure 19. Sample orthophotograph tiles for Iraan Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Iraan Floodplain. These blocks are composed of Palawan blocks with a total area of 685.25 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Palawan_Blk42L	197.06
Palawan_Blk42M	184.09
Palawan_Blk42N	188.81
Palawan_Blk42O	115.29
TOTAL	685.25sq.km

Portions of DTM before and after manual editing are shown in Figure 20. The bridge (Figure 20a) would be an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done (Figure 20b). Another portion of the DTM presented (Figure 20c) shows the part of the river which was previously interpolated to remove the barrier in the river. However, upon quality checking, it was determined that the area (Figure 20c) did not need removal as shown in the output in Figure 20d.

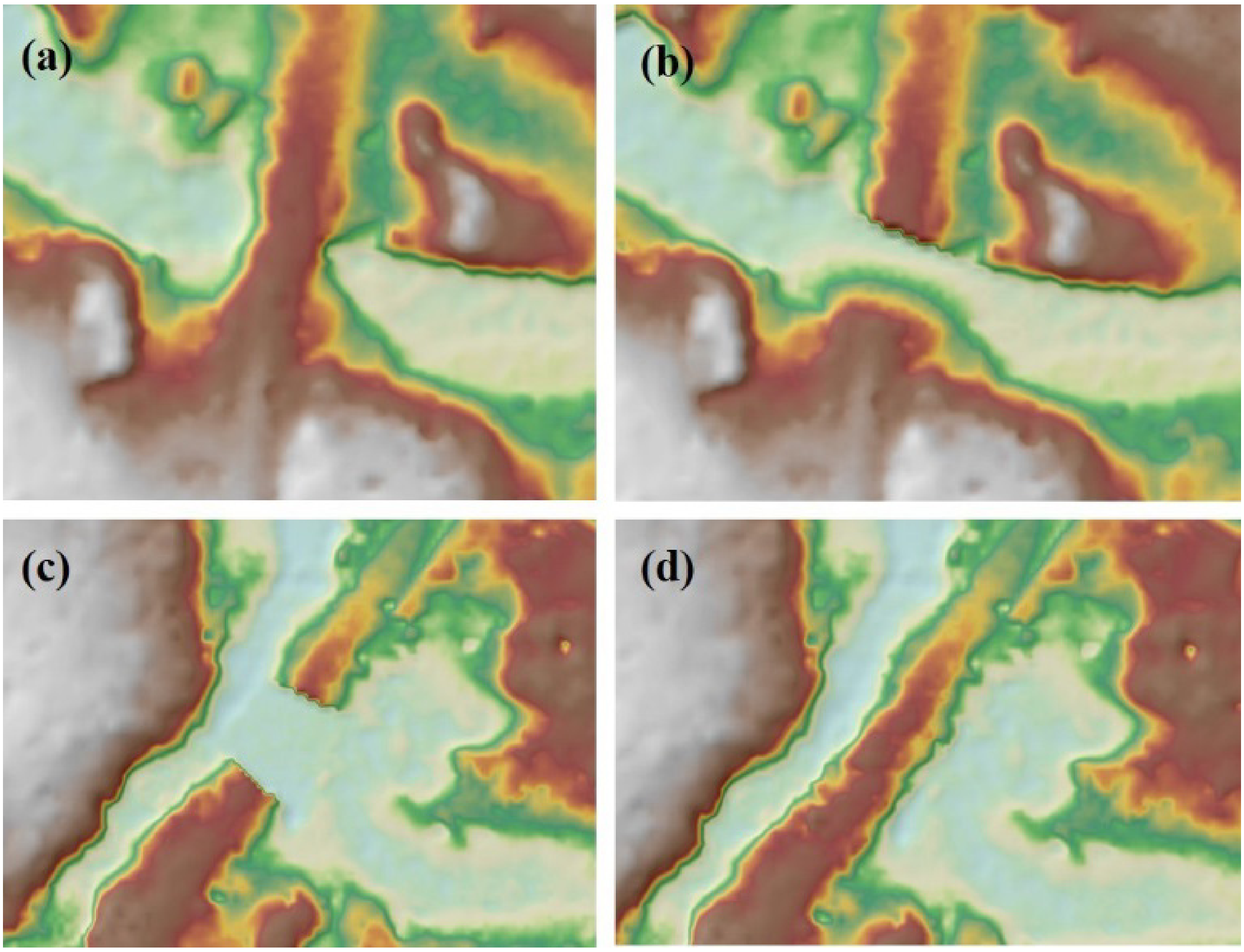

Figure 20. Portions in the DTM of Iraan Floodplain – a bridge before (a) and after (b) data interpolation and a barrier before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

Palawan_Blk42M was used as the reference block at the start of mosaicking because it was the first block mosaicked to the larger DTM of West Coast Palawan. This was followed by PWN42N, PWN42L and PWN42O, respectively. Given that Palawan block 42M was mosaicked to the other blocks of West Coast Palawan, the block was also inspected for elevation shifts that it might need. Table 15 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Iraan floodplain is shown in Figure 21. It can be seen that the entire Iraan Floodplain is 100% covered by LiDAR data.

Table 15. Shift values of each LiDAR block of Iraan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42L	0.00	0.00	7.01
Palawan_Blk42M	0.00	0.00	6.88
Palawan_Blk42N	0.00	0.00	6.55
Palawan_Blk42O	0.00	0.00	6.52

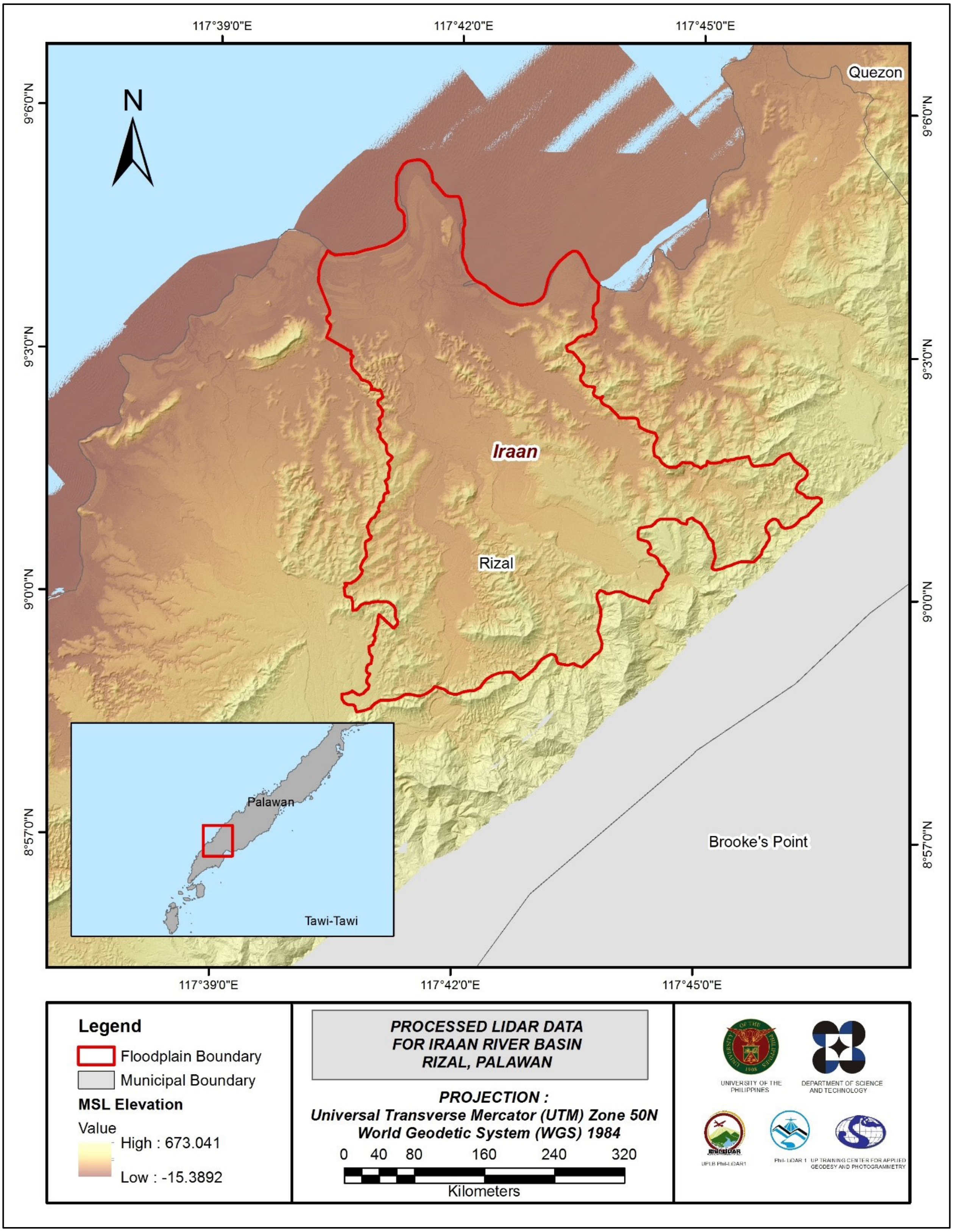

Figure 21 . Map of Processed LiDAR Data for Iraan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Iraan to collect points with which the LiDAR dataset was validated is shown in Figure 22. A total of 2,533 survey points were used for calibration and validation of Iraan LiDAR data. Random selection of 80% of the survey points, resulting to 2,027 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 23. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.20 meters with a standard deviation of 0.20 meters. Calibration of Iraan LiDAR data was done by adding the height difference value, 0.20 meters, to Iraan mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

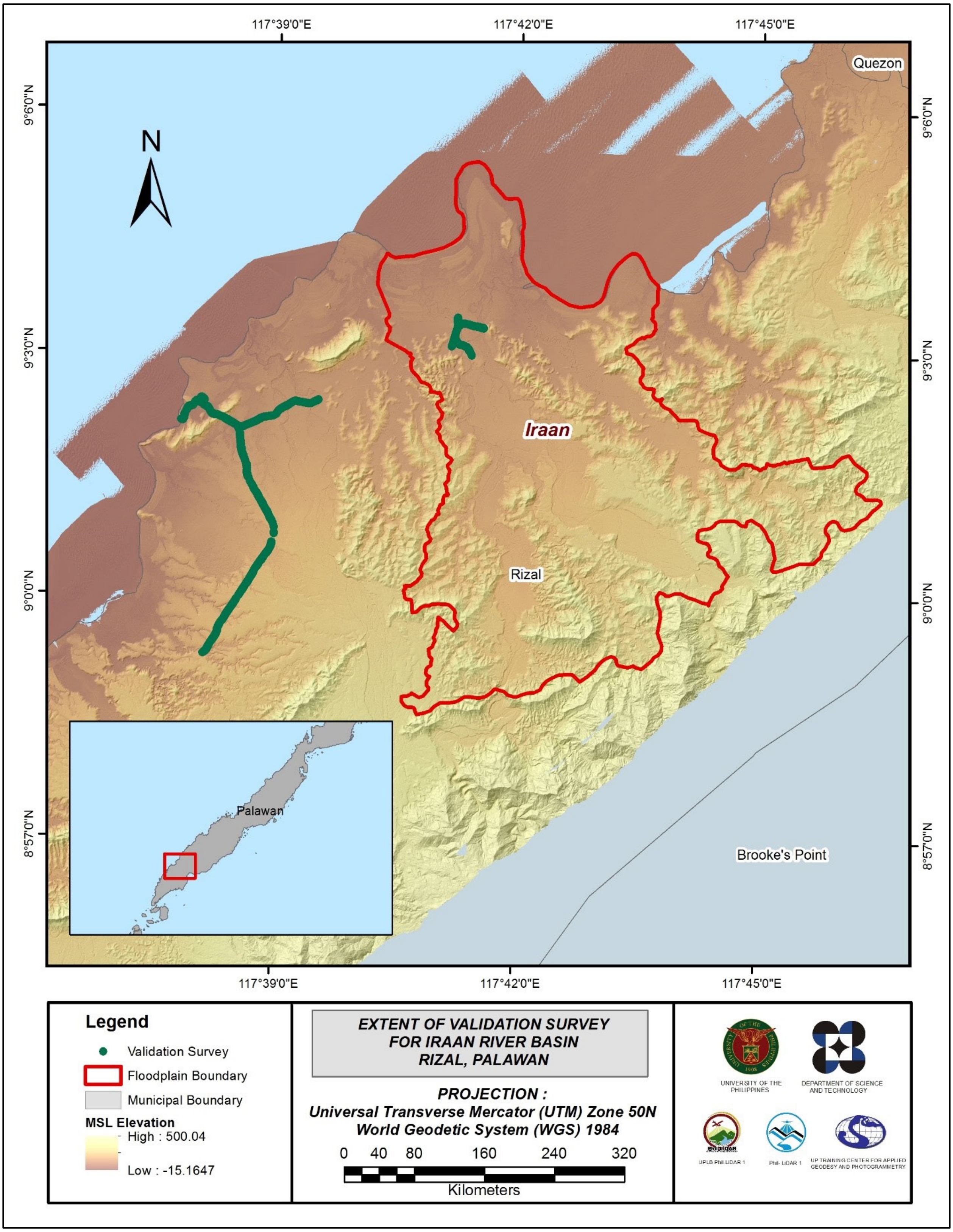

Figure 22. Map of Iraan Floodplain with validation survey points in green.

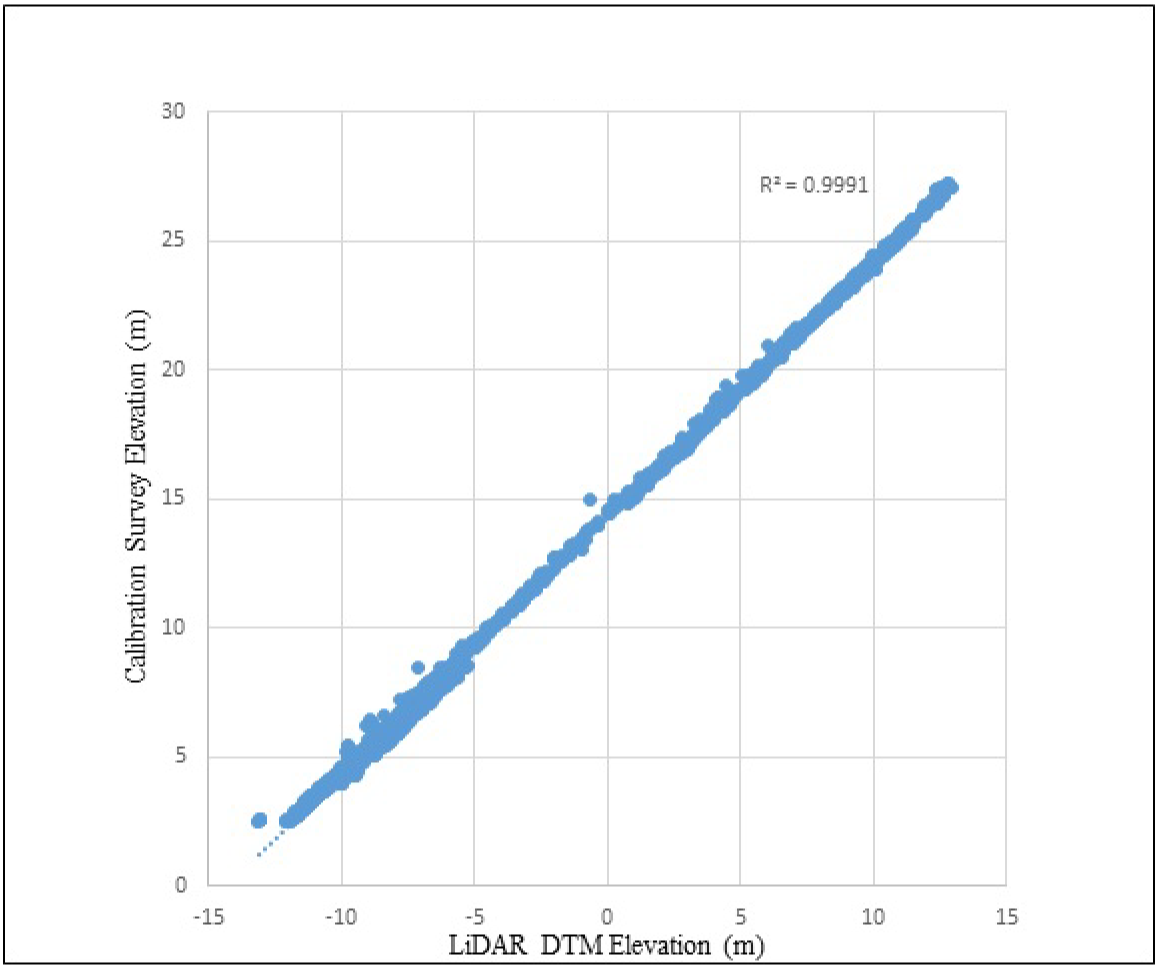

Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	14.31
Standard Deviation	0.23
Average	14.31
Minimum	13.84
Maximum	14.78

The remaining 20% of the total survey points, which was 506 points, were used for the validation of the calibrated Iraan 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 24. The computed RMSE between the calibrated LiDAR DTM and elevation values is 0.29 meters with a standard deviation of 0.19 meters, as shown in Table 17.

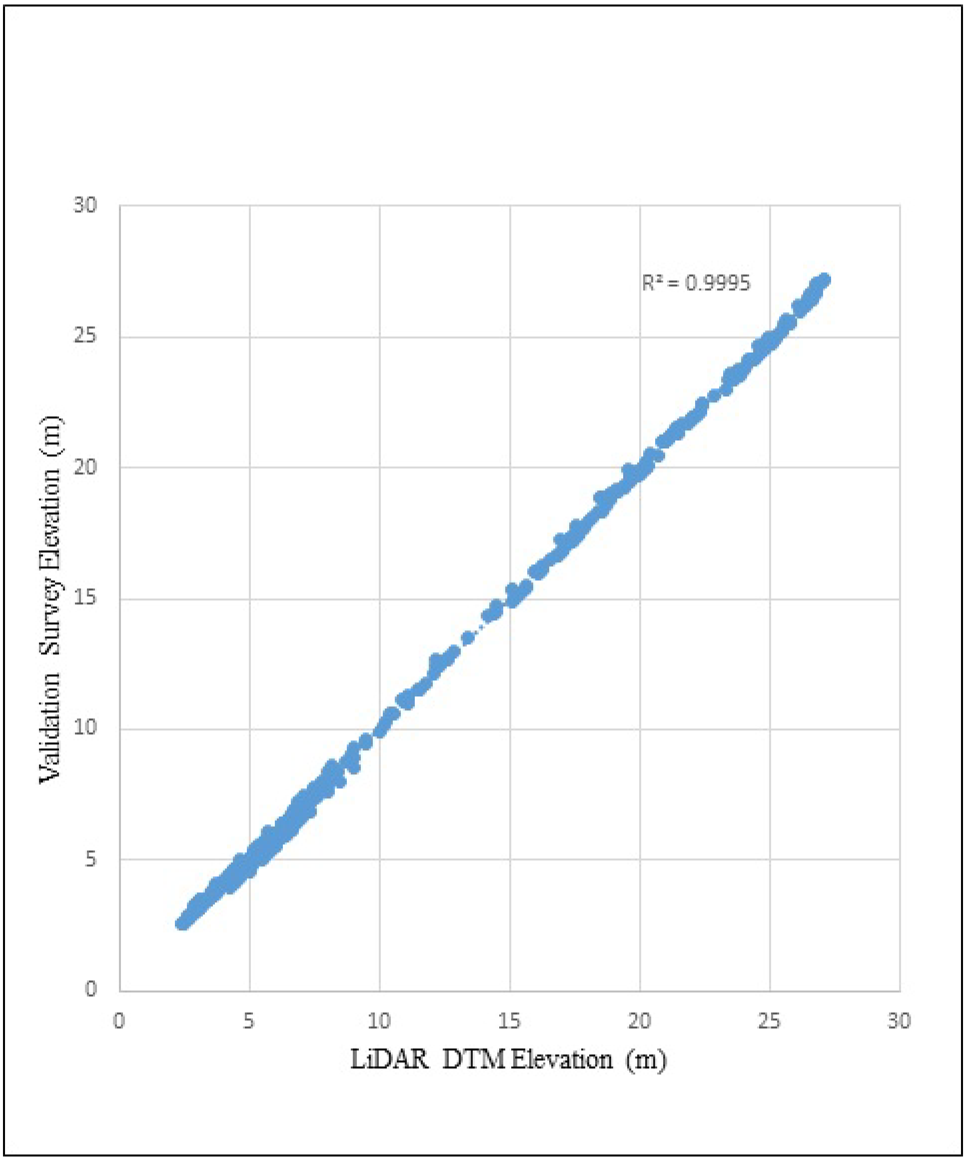

Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.19
Average	0.002
Minimum	-0.37
Maximum	0.37

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For the bathymetric data integration, data for centerline, cross-section, and zigzag points were used for Iraan Floodplain. The bathy points, which is a total of 4,129 points, is comprised of 1,867 centerline points, 41 and 2,221 points for cross-section and zigzag, respectively. Using Kernel interpolation method, the desired part of the river was given elevation values. The computed RMSE value for the interpolated river surface was 0.30. The extent of the bathymetric survey integrated with the processed LiDAR DEM is shown in Figure 25.

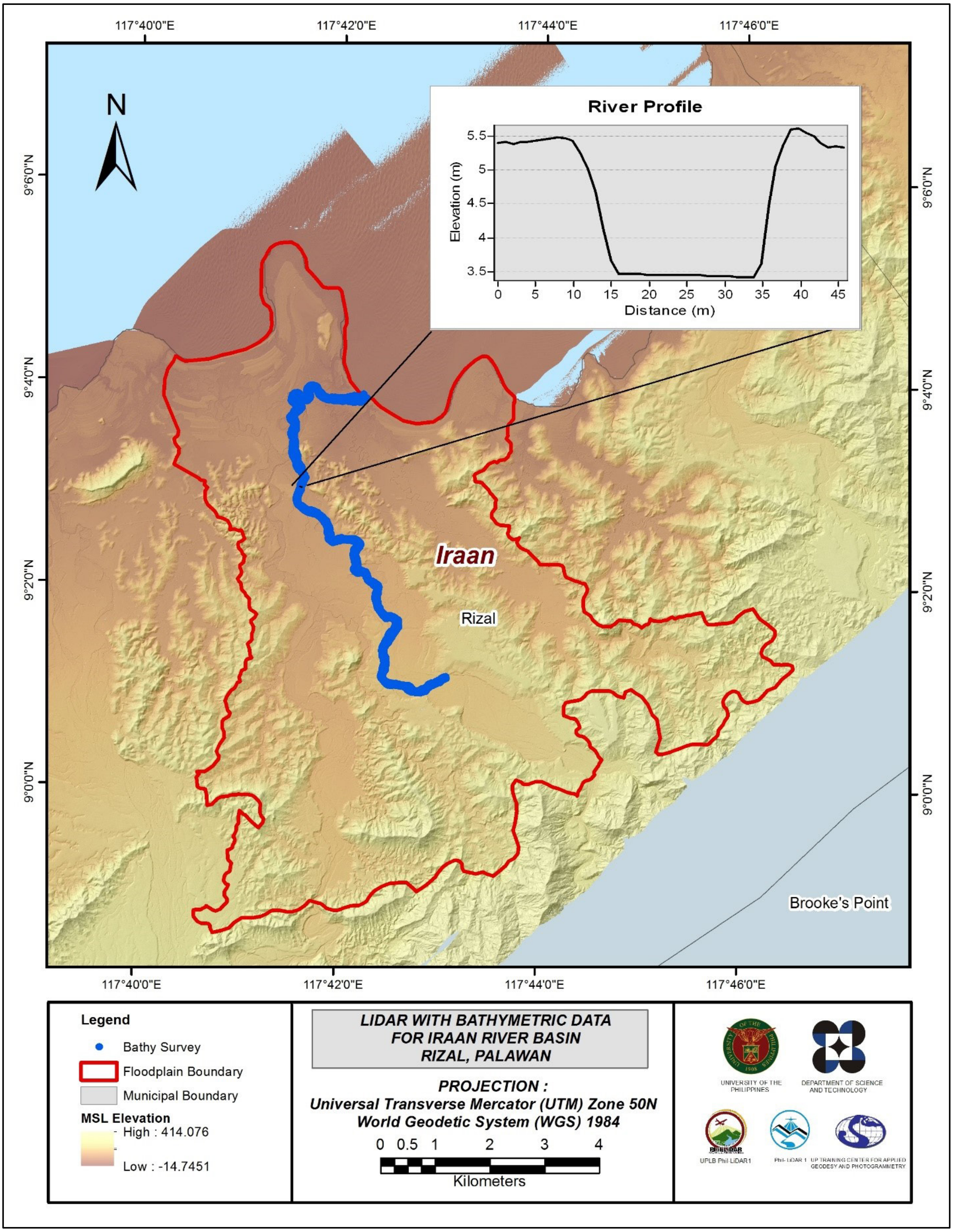

Figure 25. Map of Iraan Floodplain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

AB Surveying and Development (ABSD) conducted a field survey in Iraan River on December 3-4, 2015 and January 22-26, 2016 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Iraan Bridge in Brgy. Iraan, Municipality of Rizal, Palawan. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on August 16-28, 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 Iraan River Basin area. The entire survey extent is illustrated in Figure 26.

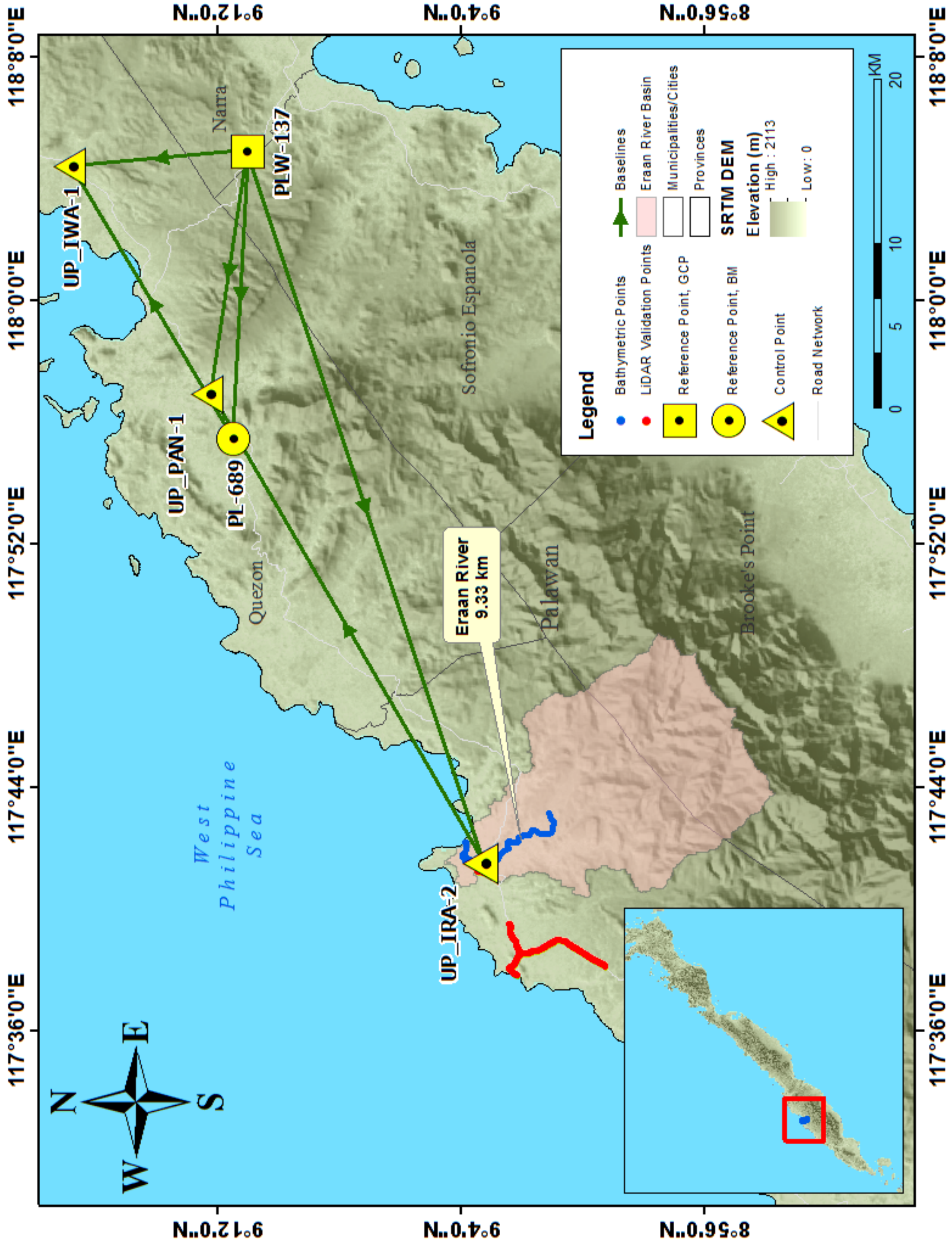


Figure 26. Extent of the bathymetric survey (in blue line) in Iraan River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Iraan River is composed of two (2) loops established on August 20, 2016 occupying the following reference points: PLW-121 a second-order GCP, in Brgy. Ransang, Rizal, Palawan and UP_MAL-1, an established control point that was referred from the static survey of Malabangan River on August 16-28, 2016 in Brgy. Punta Baja, Rizal, Palawan.

Three (3) control points established in the area by ABSD were also occupied: UP_ILO-1 at the side of the railings near Ilog Bridge in Brgy. Campong Ulay, Rizal, Province of Palawan, UP_RAN-2 located on a riprap near Ransang Bridge in Brgy. Ransang, Rizal, Palawan, and UP_IRA-2 at the side of Iraan Bridge in Brgy. Iraan, Rizal, Palawan.

The summary of reference and control points and its location is summarized in Table 18 while GNSS network established is illustrated in Figure 27.

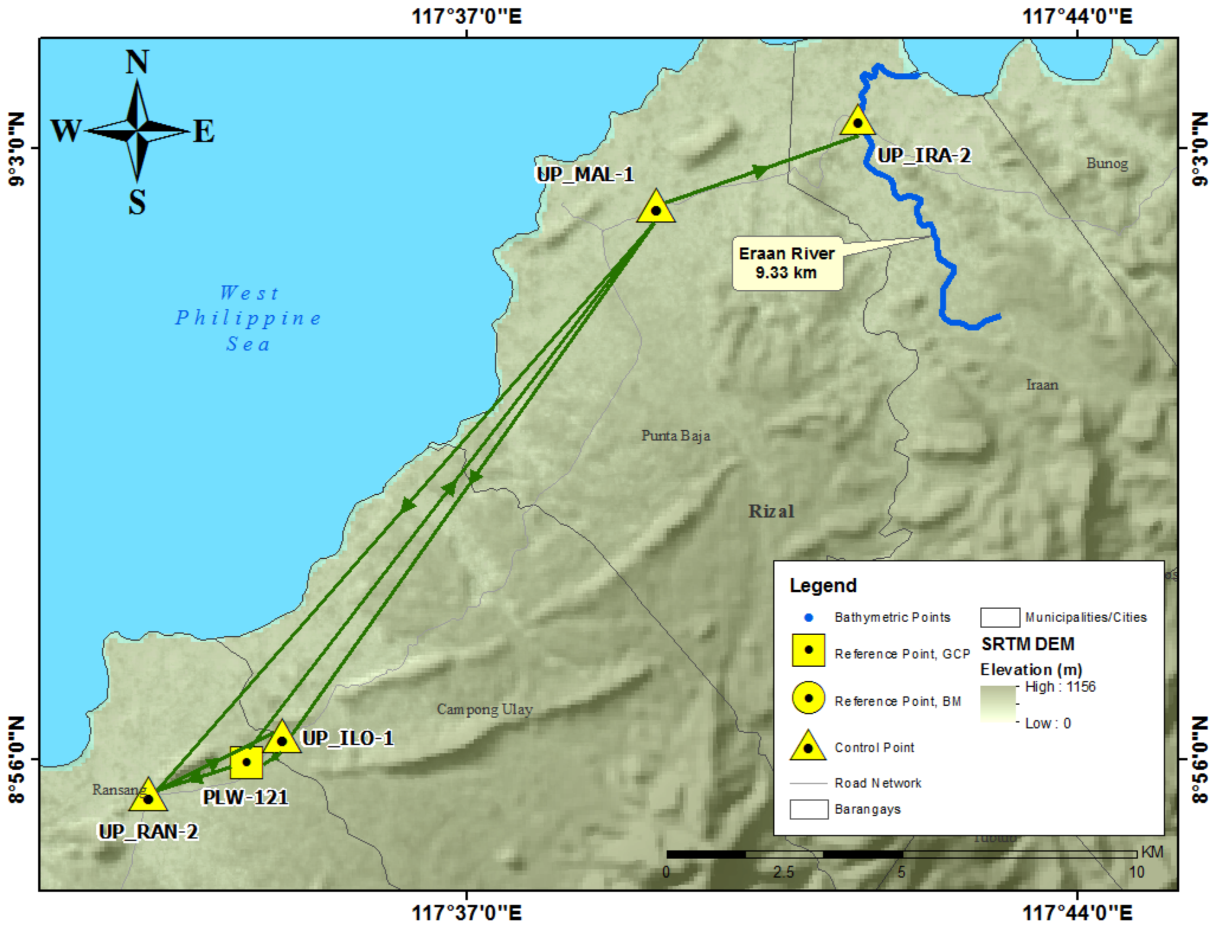


Figure 27. Iraan River Basin Control Survey Extent

Table 18. List of Reference and Control Points occupied for Iraan River Survey
(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
PLW-121	2nd order, GCP	8°55'57.38325"N	117°34'29.39124"E	58.058	16.172	2007
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	10.881	11-27-15
UP_ILO-1	Established	8°56'16.64151"N	117°34'53.41157"E	62.242	20.326	12-05-15
UP_RAN-2	Established	8°55'36.22496"N	117°33'21.55666"E	47.181	5.431	12-05-15
UP_IRA-2	Established	9°03'19.99012"N	117°41'29.98496"E	48.684	6.581	12-04-15

The GNSS set-ups on recovered reference points and established control points in Iraan River are shown from Figure 28 to Figure 32.

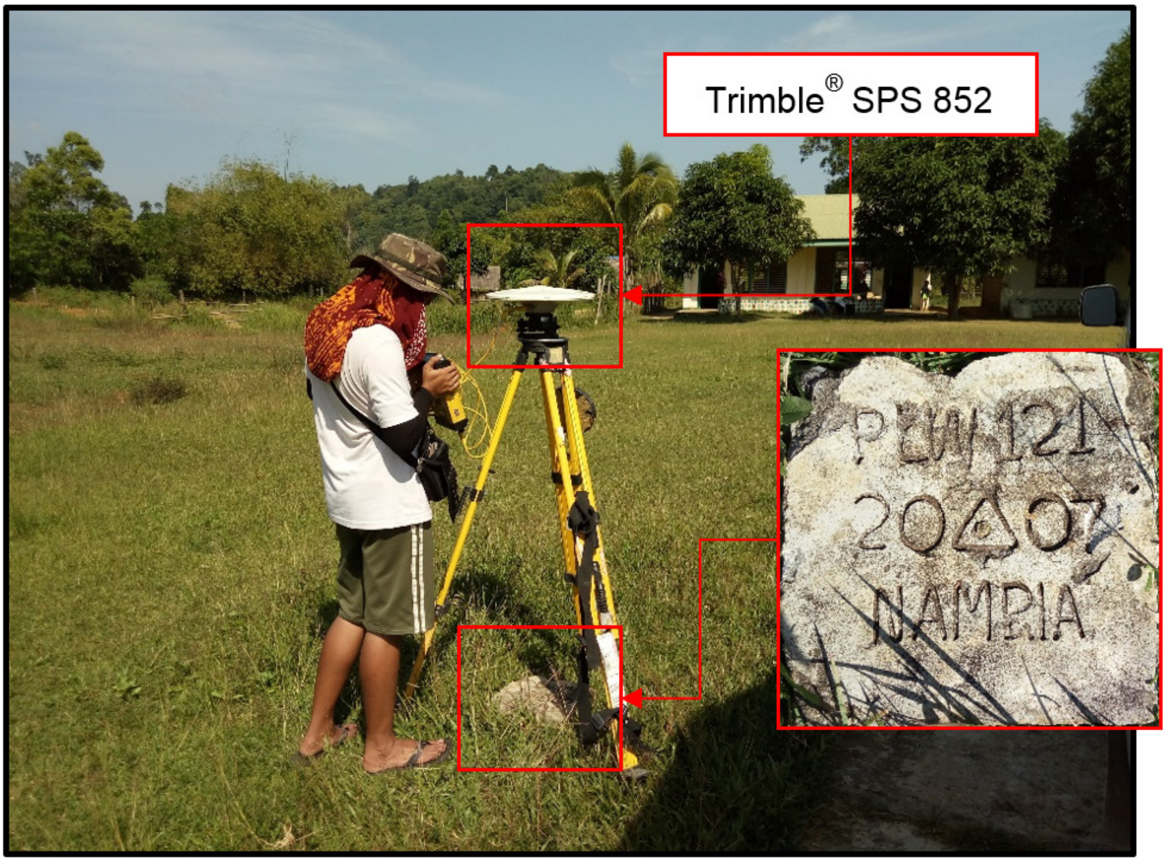


Figure 28. GNSS base set-up, Trimble® SPS 852, at PLW-121, located along the basketball court inside Cabcungan Elementary School in Brgy. Ransang, Rizal, Province of Palawan

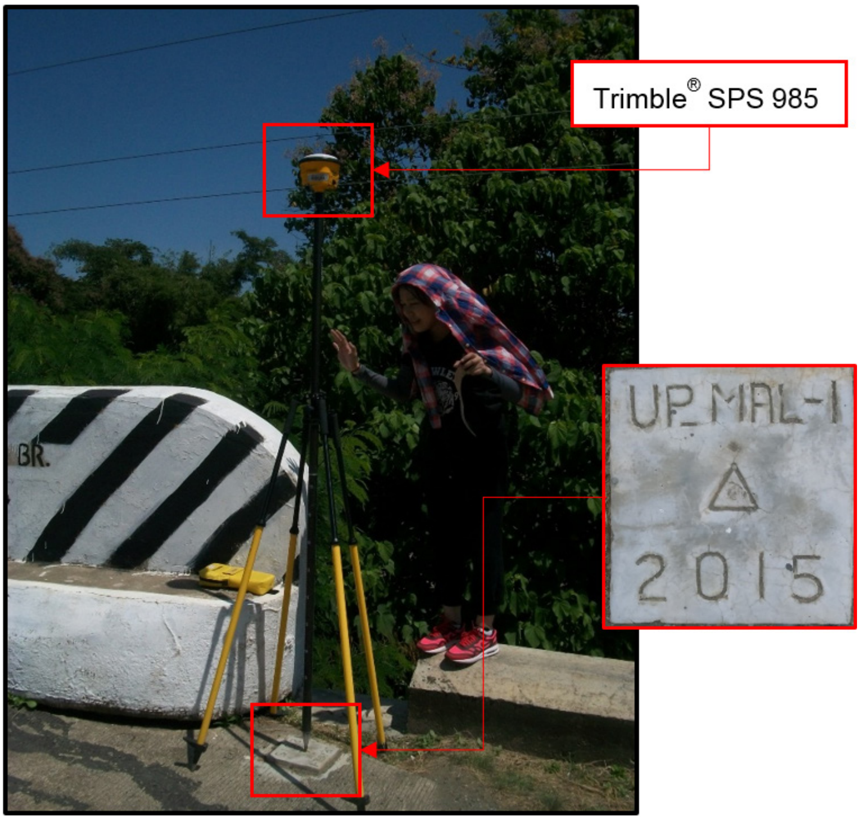


Figure 29. GNSS receiver set-up, Trimble® SPS 985, at UP_MAL-1, located beside the approach of Malambunga Bridge in Brgy. Punta Baja, Rizal, Province of Palawan

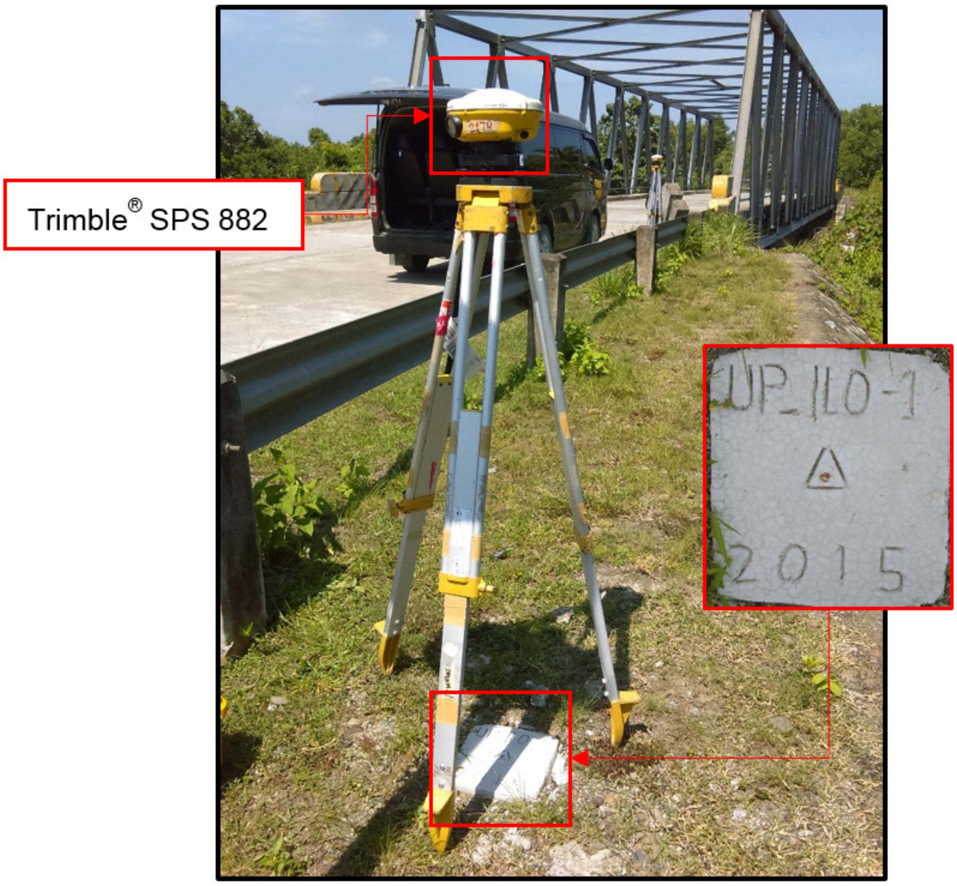


Figure 30. GNSS receiver set-up, Trimble® SPS 882, at UP_ILO-1, located at the side of the railings near Ilog Bridge in Brgy. Campong Ulay, Rizal, Province of Palawan

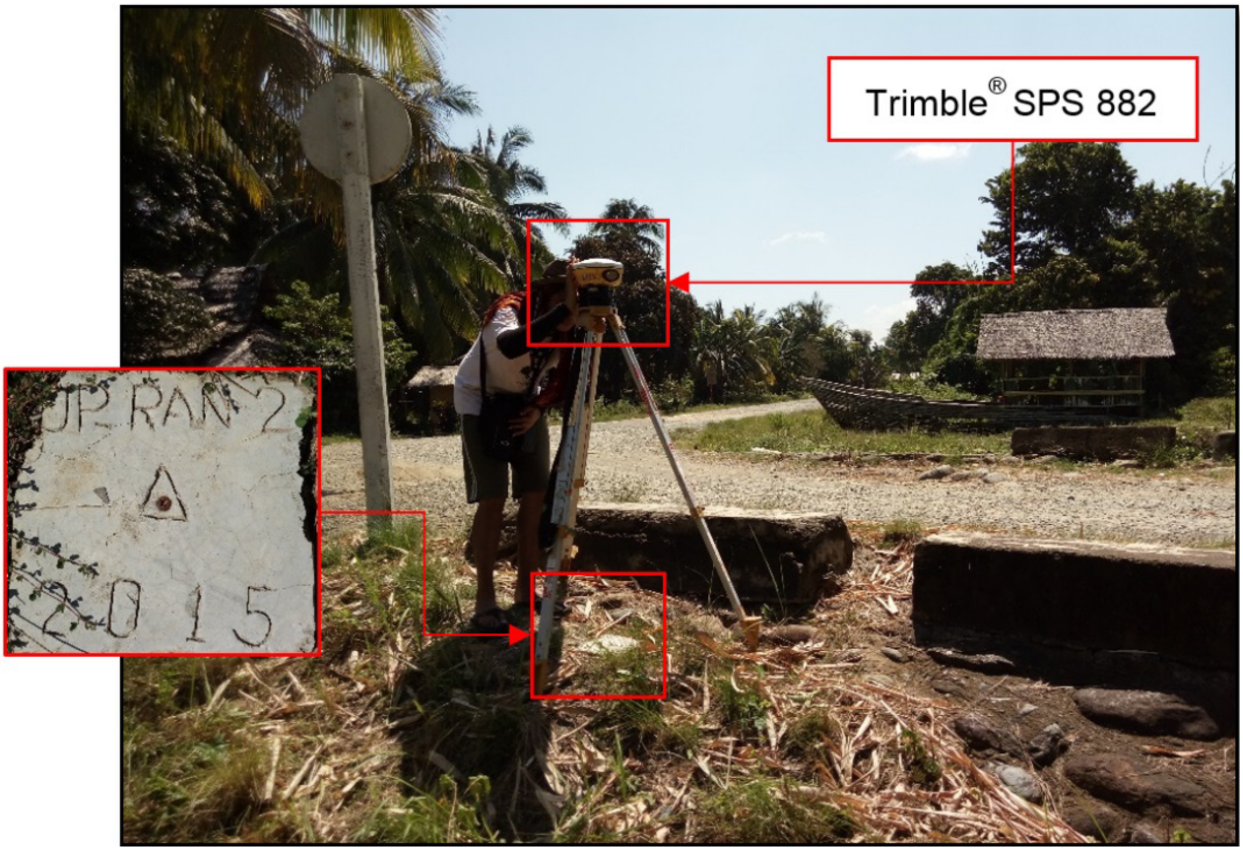


Figure 31 GNSS receiver set-up, Trimble® SPS 882, at UP_RAN-2, located on a riprap near Ransang Bridge in Brgy. Ransang, Rizal, Province of Palawan

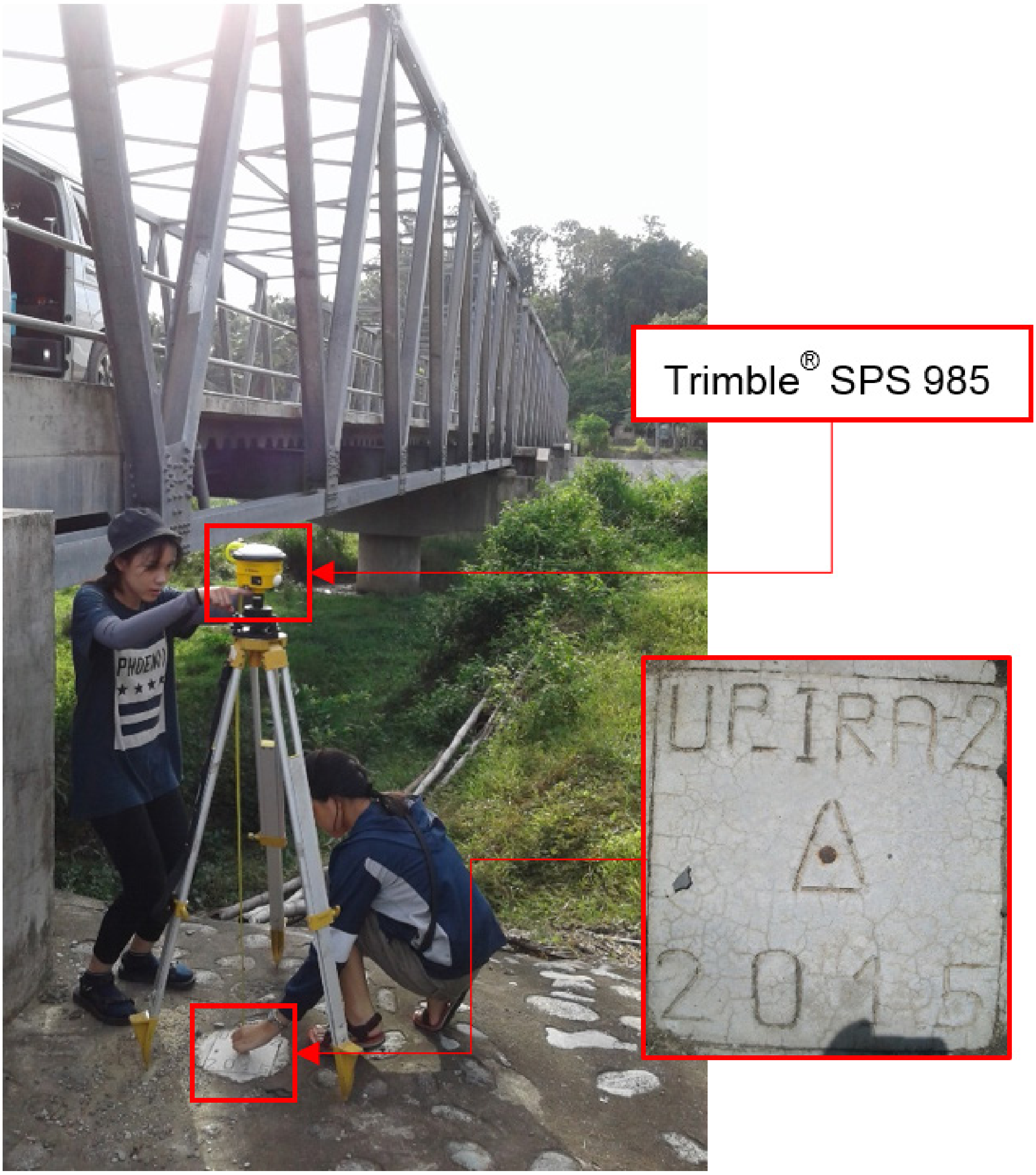


Figure 32. GNSS receiver set-up, Trimble® SPS 985, at UP_IRA-2, located on the side of Iraan Bridge in Brgy. Iraan, Rizal, Province of Palawan

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 Iraan River Basin is summarized in Table 19 generated by TBC software.

Table 19. Baseline Processing Report for Iraan River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_ILO-1 --- UP_MAL-1	8-20-2016	Fixed	0.004	0.013	215°01'35"	13676.838	9.465
UP_MAL-1 --- UP_IRA-2	8-20-2016	Fixed	0.009	0.023	67°02'36"	4630.420	-4.093
PLW-121 --- UP_ILO-1	8-20-2016	Fixed	0.002	0.002	231°07'17"	942.619	-4.184
PLW-121 --- UP_RAN-2	8-20-2016	Fixed	0.005	0.013	252°35'10"	2171.885	-10.878
PLW-121 --- UP_MAL-1	8-20-2016	Fixed	0.004	0.013	36°02'29"	14584.805	-5.289
UP_RAN-2 --- UP_ILO-1	8-20-2016	Fixed	0.005	0.015	66°07'44"	3068.568	15.065
UP_RAN-2 --- UP_MAL-1	8-20-2016	Fixed	0.005	0.018	40°34'00"	16380.815	5.587

As shown Table 23 a total of seven (7) baselines were processed with coordinates and ellipsoidal height values of PLW-121 and UP_MAL-1 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was 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 sum of the squares of x and y must be less than 20cm and z less than 10cm in equation from:

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

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 20 to Table 22 for the complete details. Refer to Appendix C[Check this..what's appendix c?] for the computation for the accuracy of ABSD.

The five (5) control points, PLW-121, UP_MAL-1, UP-ILO-1, UP_RAN-2, and UP-IRA-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height values of PLW-121 and UP_MAL-1 were held fixed during the processing of the control points as presented in Table 20 Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

The control point UP_IRA-2 was only connected via baseline; hence, it is not reflected in the Network Adjustment.

Table 20. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PLW-121	Global	Fixed	Fixed	Fixed	
UP_MAL-1	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Table 21. Adjusted grid coordinates for the control points used in the Iraan River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PLW-121	563194.622	?	987450.572	?	10.335	?	LLh
UP_ILO-1	563927.242	0.001	988043.176	0.001	14.489	0.002	
UP_MAL-1	571754.477	?	999253.104	?	5.044	?	LLh
UP_RAN-2	561124.020	0.003	986797.593	0.002	-0.406	0.010	

With the mentioned equation, for horizontal and for the vertical; the computation for the accuracy are as follows:

a.PLW-121

horizontal accuracy = Fixed

vertical accuracy = Fixed

b.UP_ILO-1

horizontal accuracy = $\sqrt{(0.1)^2 + (0.1)^2}$

= $\sqrt{(0.1 + 0.1)}$

= 0.02< 20 cm

vertical accuracy = 0.2< 10 cm

c.UP_MAL-1

horizontal accuracy = Fixed

vertical accuracy = Fixed

d.UP_RAN-2

horizontal accuracy = $\sqrt{(0.3)^2 + (0.2)^2}$

= $\sqrt{(0.9 + 0.4)}$

= 1.3< 20 cm

vertical accuracy = 1.0< 10 cm

Following the given formula, the horizontal and vertical accuracy result of the two (2) occupied control points are within the required precision.

Table 22. Adjusted geodetic coordinates for control points used in the Iraan River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
PLW-121	N8°55'57.38325"	E117°34'29.39124"	58.058	?	LLh
UP_ILO-1	N8°56'16.64151"	E117°34'53.41157"	62.242	0.002	
UP_MAL-1	N9°02'21.21274"	E117°39'10.37109"	52.776	?	LLh
UP_RAN-2	N8°55'36.22496"	E117°33'21.55666"	47.181	0.010	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown inTable 26. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 23.

Table 23. The reference and control points utilized in the Iraan River Static Survey, with their corresponding locations (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)
PLW-121	2nd order, GCP	8°55'57.38325"N	117°34'29.39124"E	58.058	987450.572	563194.622	16.172
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	999253.104	571754.477	10.881
UP_ILO-1	Established	8°56'16.64151"N	117°34'53.41157"E	62.242	988043.176	563927.242	20.326
UP_RAN-2	Established	8°55'36.22496"N	117°33'21.55666"E	47.181	986797.593	561124.02	5.431
UP_IRA-2	Established	9°03'19.99012"N	117°41'29.98496"E	48.684	1001066.17	576013.515	6.581

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

Cross-section and as-built surveys were conducted on December 3, 2015 at the downstream side of Iraan Bridge in Brgy. Iraan, Municipality of Rizal as shown in Figure 33 and Figure 34. A Horizon®Total Station was utilized for this survey as shown in Figure 35.

Figure 33. Iraan Bridge facing upstream

Figure 34. Iraan Bridge facing downstream

Figure 35. As-built survey of Iraan Bridge

The cross-sectional line of Iraan Bridge is about 187 m with forty-four (44) cross-sectional points using the control points UP_IRA-1 and UP_IRA-2 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown in Figure 37 to Figure 39. Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 20, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Figure 36.

Figure 36. Gathering of random cross-section points along the approach of Iraan Bridge

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range was determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. The computed R2values of 0.958 and 0.922 for the cross-section data via manual topographic survey and cross-section data via validation, respectively, were obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets. Additionally, a computed R2 value of 0.879 for the bridge points data of Iraan Bridge was also obtained.

In addition to the Linear Square Correlation, Root Mean Square (RMSE) analysis was also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the cross-section data via manual topographic survey and cross-section data via validation, the computed values were0.135 and 0.188, respectively. The computed RMSE value for the bridge points data was 0.174. The computed R2 and RMSE values are within the accuracy requirement of the program.

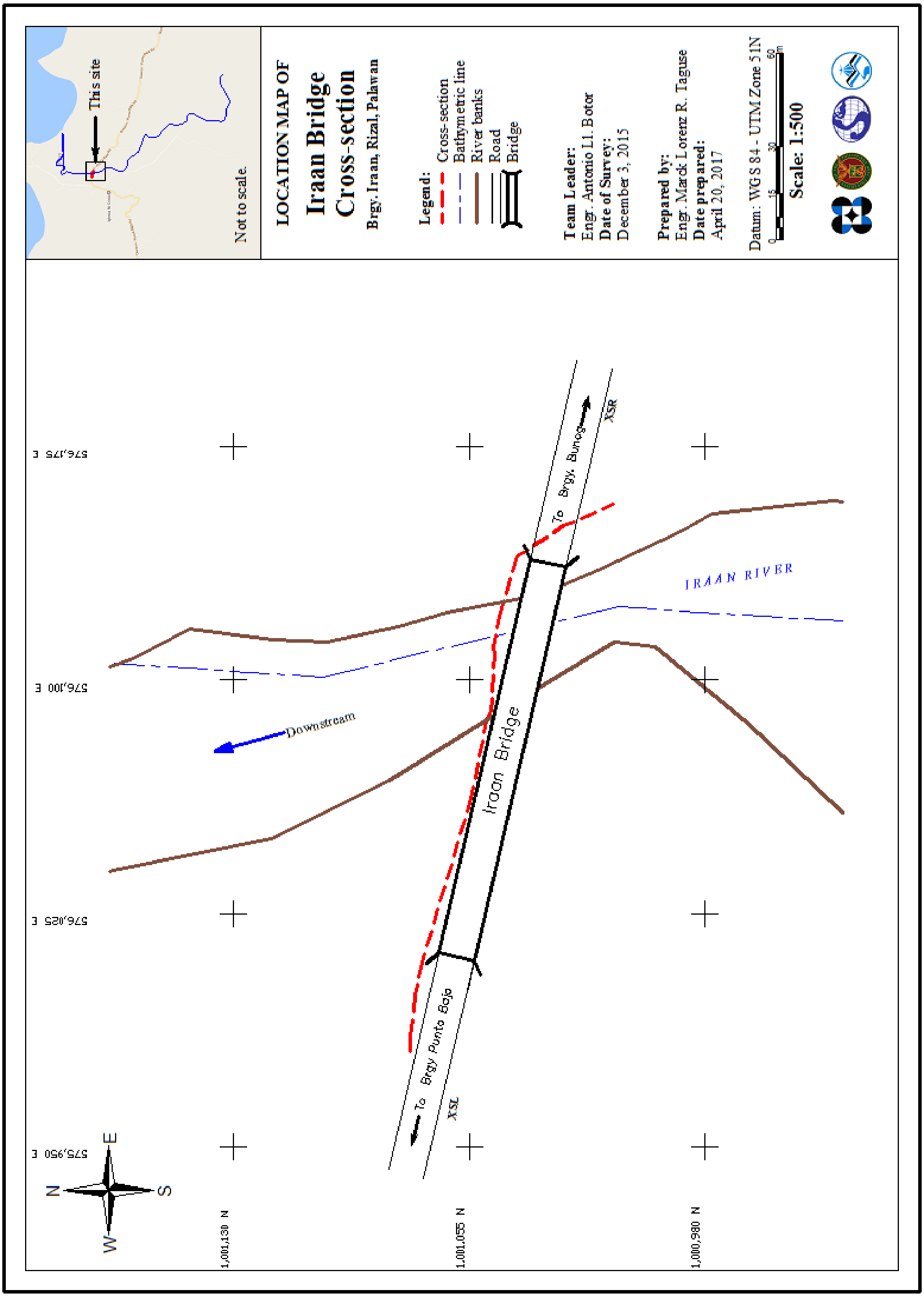


Figure 37. Location Map of Iraan Bridge Cross-section

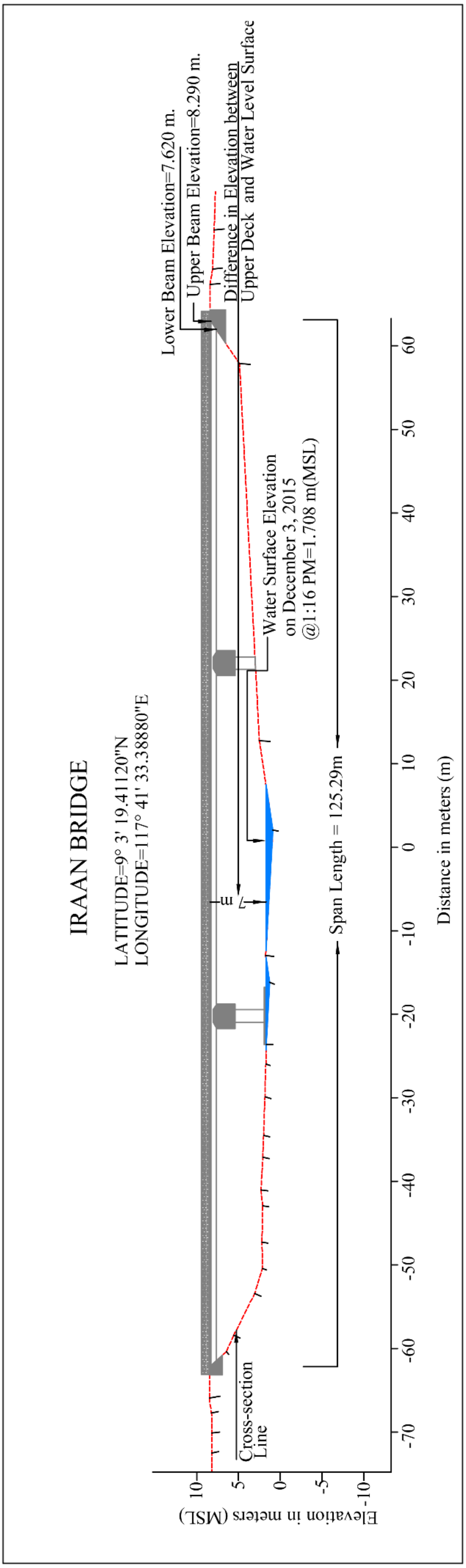


Figure 38. Iraan Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: Iraan Bridge

River Name: Eraan River

Location (Brgy, City, Region): Brgy. Iraan, Rizal, Palawan

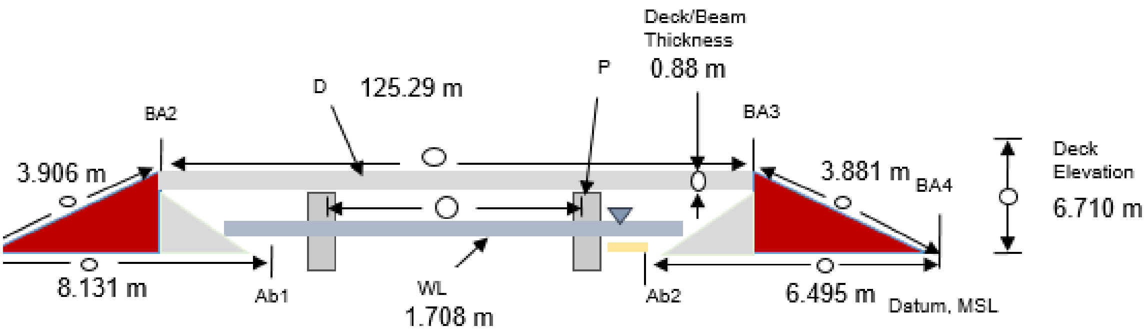
Survey Team: Nilo Alpas, Christorey dela Peña

Date and Time: December 3, 2015; 1:16 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	3.906 m	
2. BA2-BA3	125.29 m	
3. BA3-BA4	3.881m	
4. BA1-Ab1	8.131 m	
5. Ab2-BA4	6.495 m	
6. Deck/beam thickness	0.88 m	
7. Deck elevation	6.710 m	

Note: Observer should be facing downstream

Figure 39. Iraan Bridge Data Sheet

Water surface elevation of Iraan River was determined by a Horizon® Total Station on December 3, 2015 at 1:16 PM at Iraan Bridge area with a value of 1.708 m in MSL as shown inFigure 38. This was translated into marking on the bridge's pier as shown in Figure 40. The marking served [Pls check if this should be past tense or future tense. Will serve or served]as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Iraan River, the University of the Philippines Los Baños.

Figure 40. Water-level markings on Iraan Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC onAugust 19, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 41. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.560 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 UP_PAN-1 occupied as the GNSS base station in the conduct of the survey.

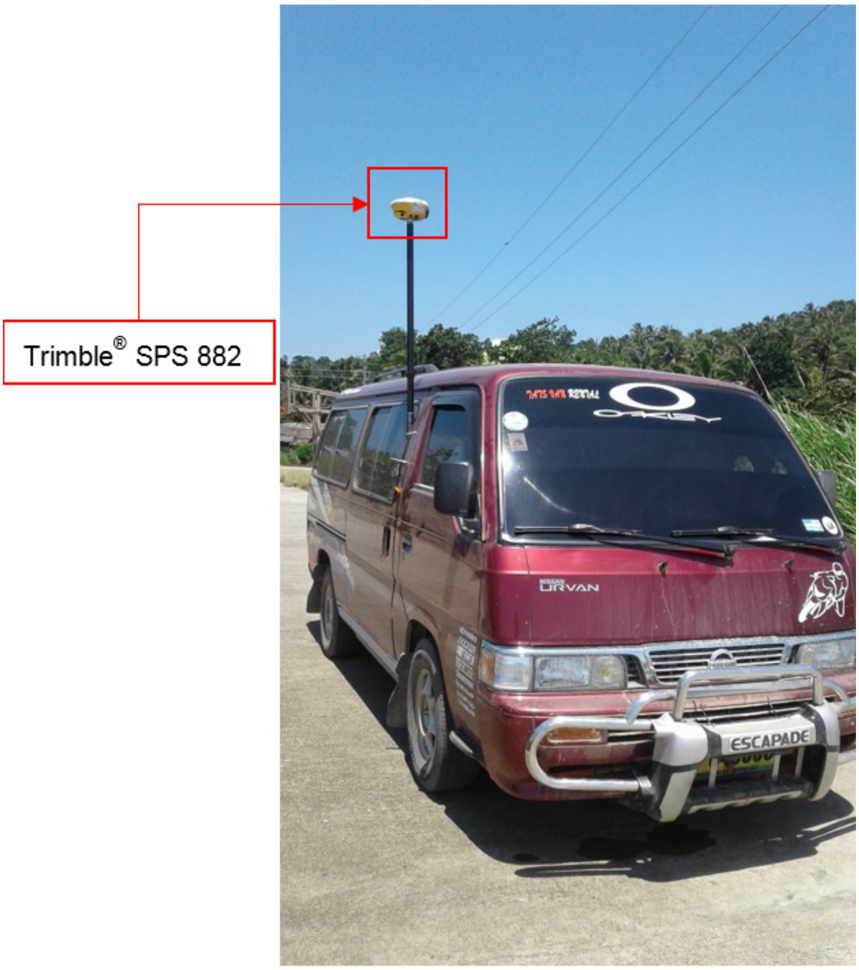


Figure 41. Validation points acquisition survey set up along Iraan River

The survey started from Brgy. Iraan, Municipality of Rizal, Palawan going south west along national highway and ended in Brgy. Punta Baja, Municipality of Rizal, Palawan. The survey gathered a total of 346 points with approximate length of 15.71 km using UP_MAL-1 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 42. Approximately 50% of roads traversed are unpaved, hence no data was acquired along it.

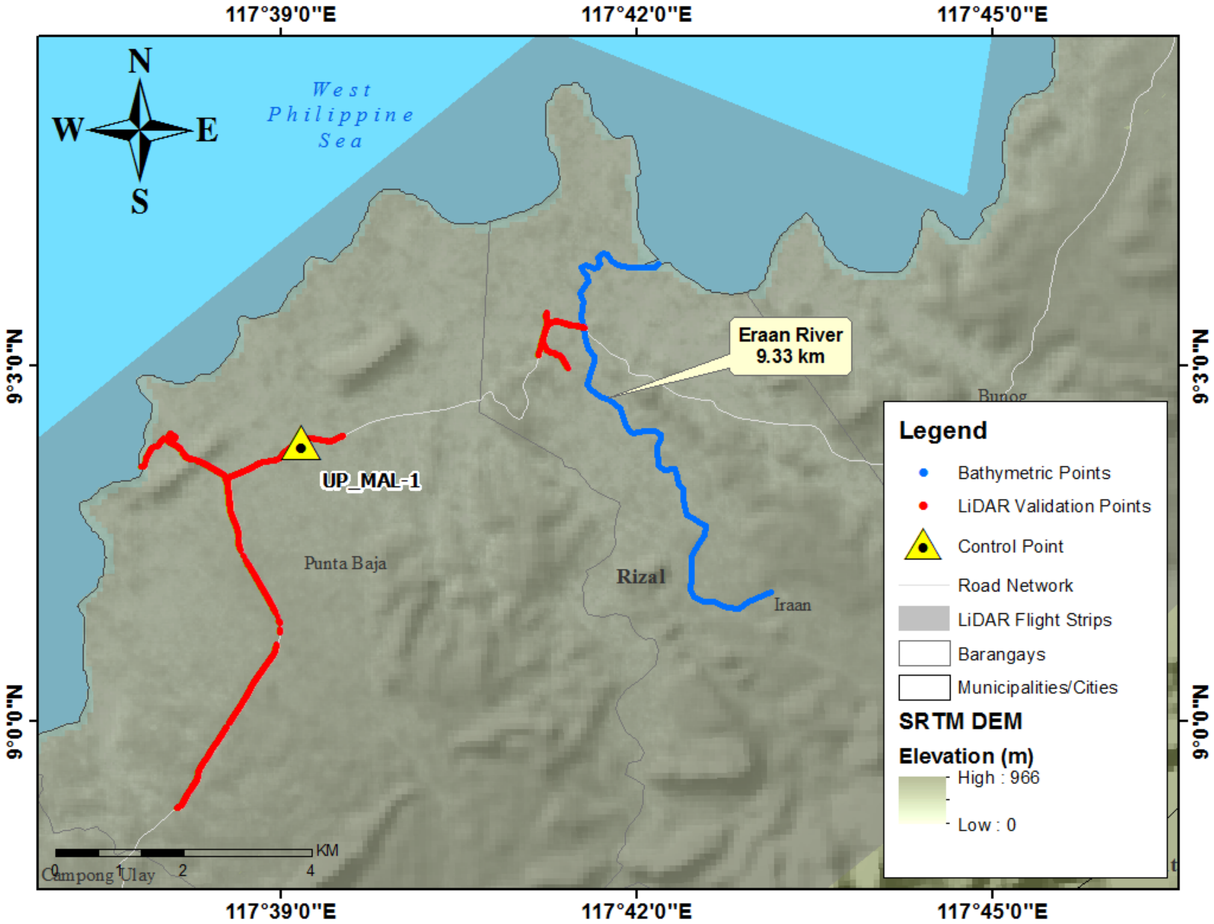


Figure 42. Validation points acquisition covering the Iraan River Basin Area

4.7 River Bathymetric Survey

Bathymetric survey was executed on January 22, 2016 using a Hi-Target™ Echo Sounder as illustrated in Figure 43. The survey started in Brgy. Iraan, Municipality of Rizal, Palawan with coordinates 9° 3' 49.69818"N, 117° 41' 36.62323"E and ended at the mouth of the river in Brgy. Iraan, Municipality of Rizal as well, with coordinates 9° 3' 50.58497"N, 117° 42' 15.22008"E.

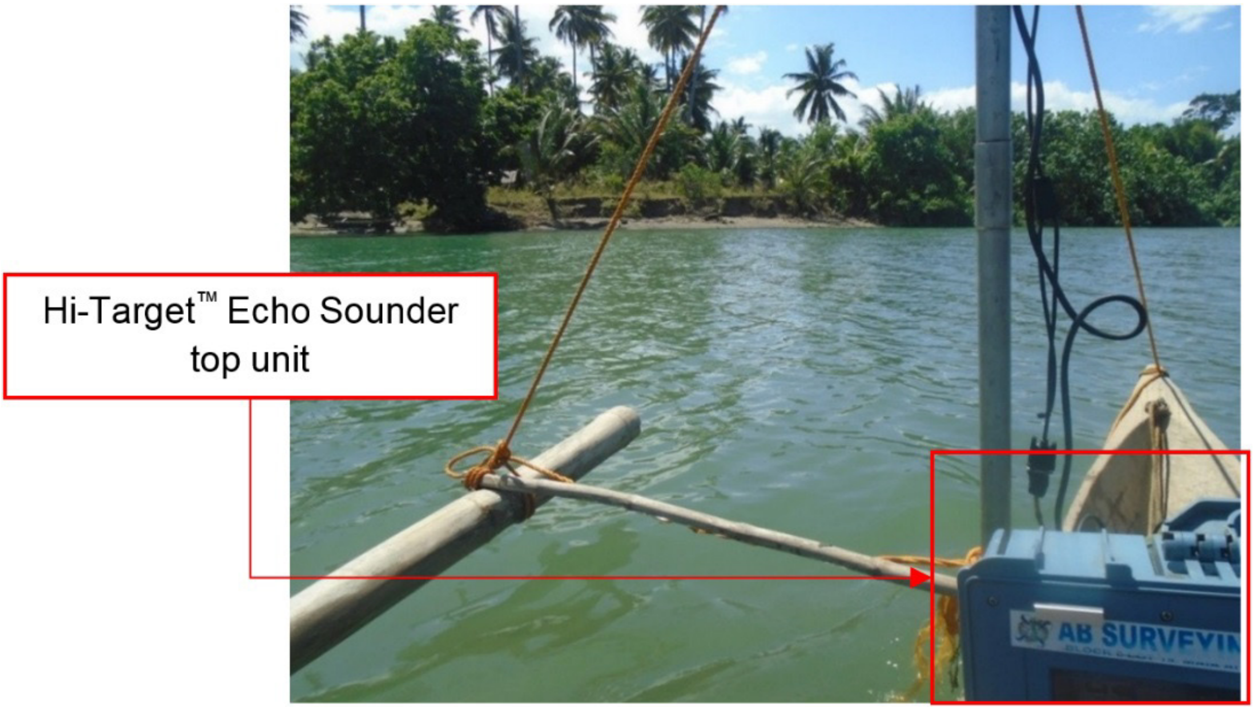


Figure 43. Bathymetric survey of ABSD at Iraan River using a Hi-Target™ Echo Sounder

Manual bathymetric survey on the other hand was executed from January 23-26, 2016 using a Nikon® Total Station as illustrated in Figure 44. The survey started in Brgy. Iraan, Municipality of Rizal with coordinates9° 1' 4.37241"N, 117° 43' 16.31070"E, traversing down the river and ended at the starting point of bathymetric survey using a boat in Brgy. Iraan, Municipality of Rizal as well. The control points UP_IRA-1 and UP_IRA-2 were used as GNSS base stations all throughout the entire survey.

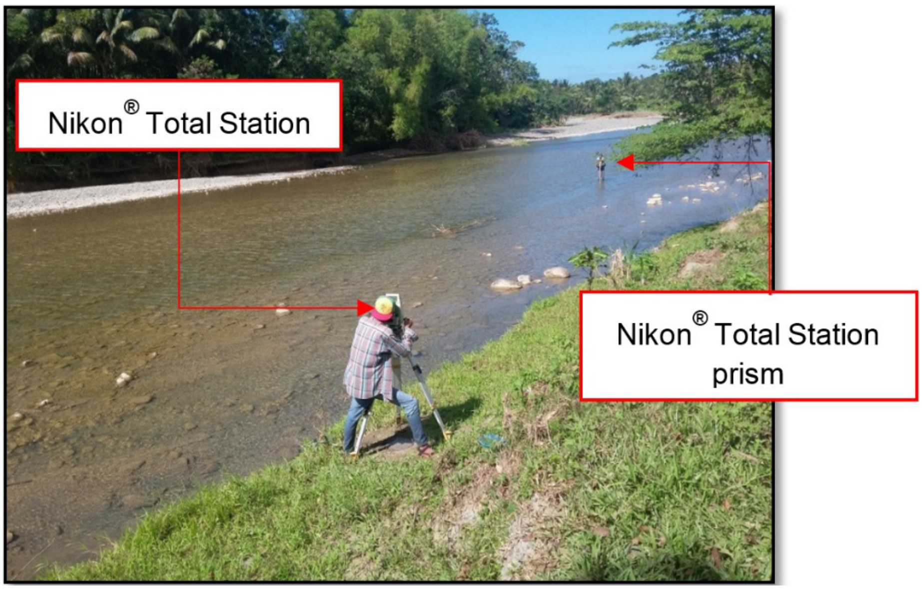


Figure 44. Manual bathymetric survey of ABSD along Iraan River using a Nikon® Total Station

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 20, 2016 using a GNSS Rover receiver, Trimble® SPS 882 attached to a 2-m pole (see Figure 45). A map showing the DVBC bathymetric checking points is shown in Figure 47.

Figure 45. Gathering of bathymetric checking points along Iraan River

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2value of 0.927 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.218 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Iraan River gathered a total of 6,424 points covering 9.33 km of the river traversing Brgy. Iraan in the Municipality of Rizal, as illustrated in Figure 46. A CAD drawing was also produced to illustrate the riverbed profile of Iraan River. As shown in Figure 48, the highest and lowest elevation has a 35-m difference. The highest elevation observed was 30.242 m below MSL while the lowest was -5.142 m below MSL, both located in Brgy. Iraan, Municipality of Rizal.

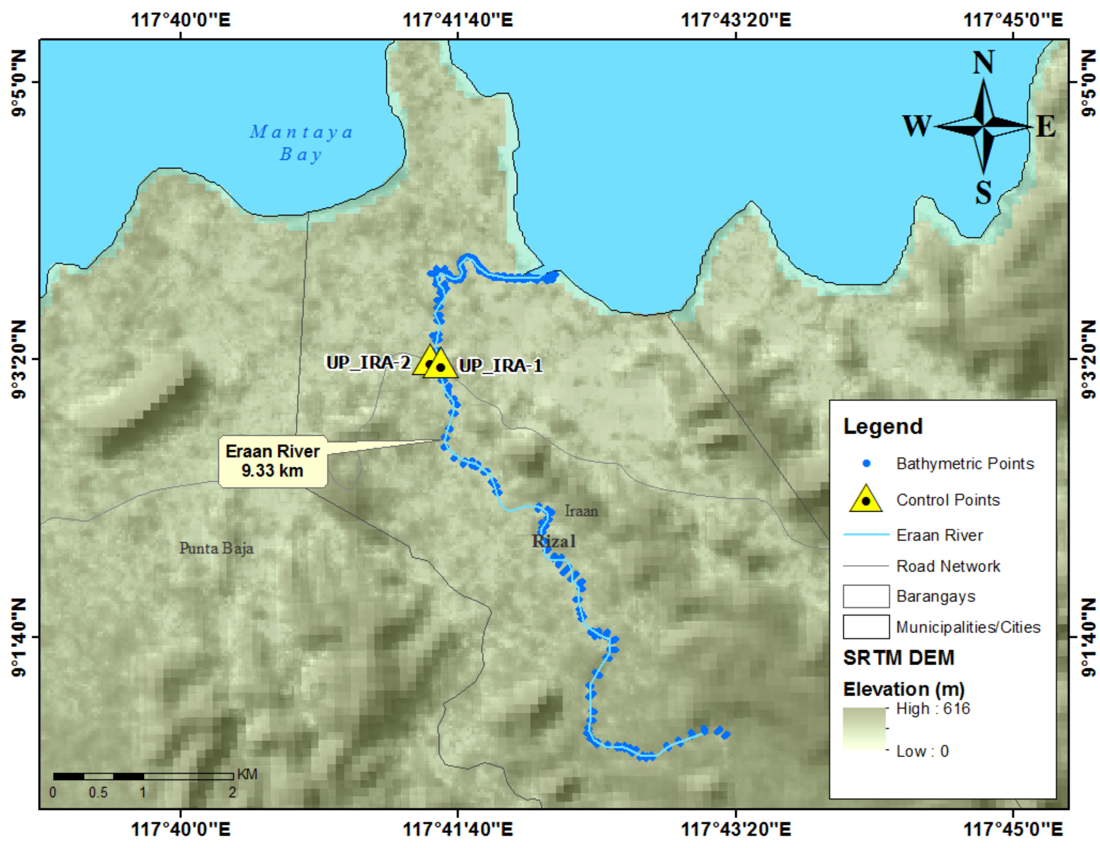


Figure 46. Bathymetric survey of Iraan River

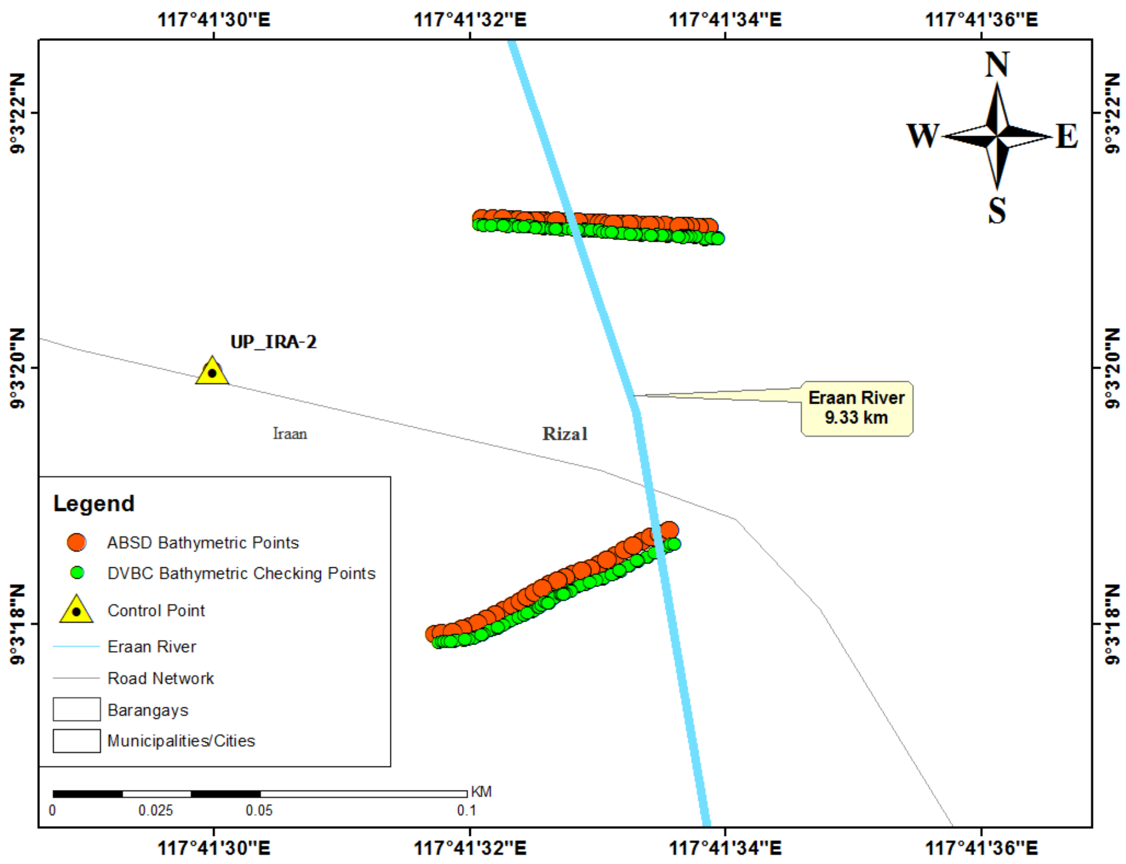


Figure 47. Quality checking points gathered along Iraan River by DVBC

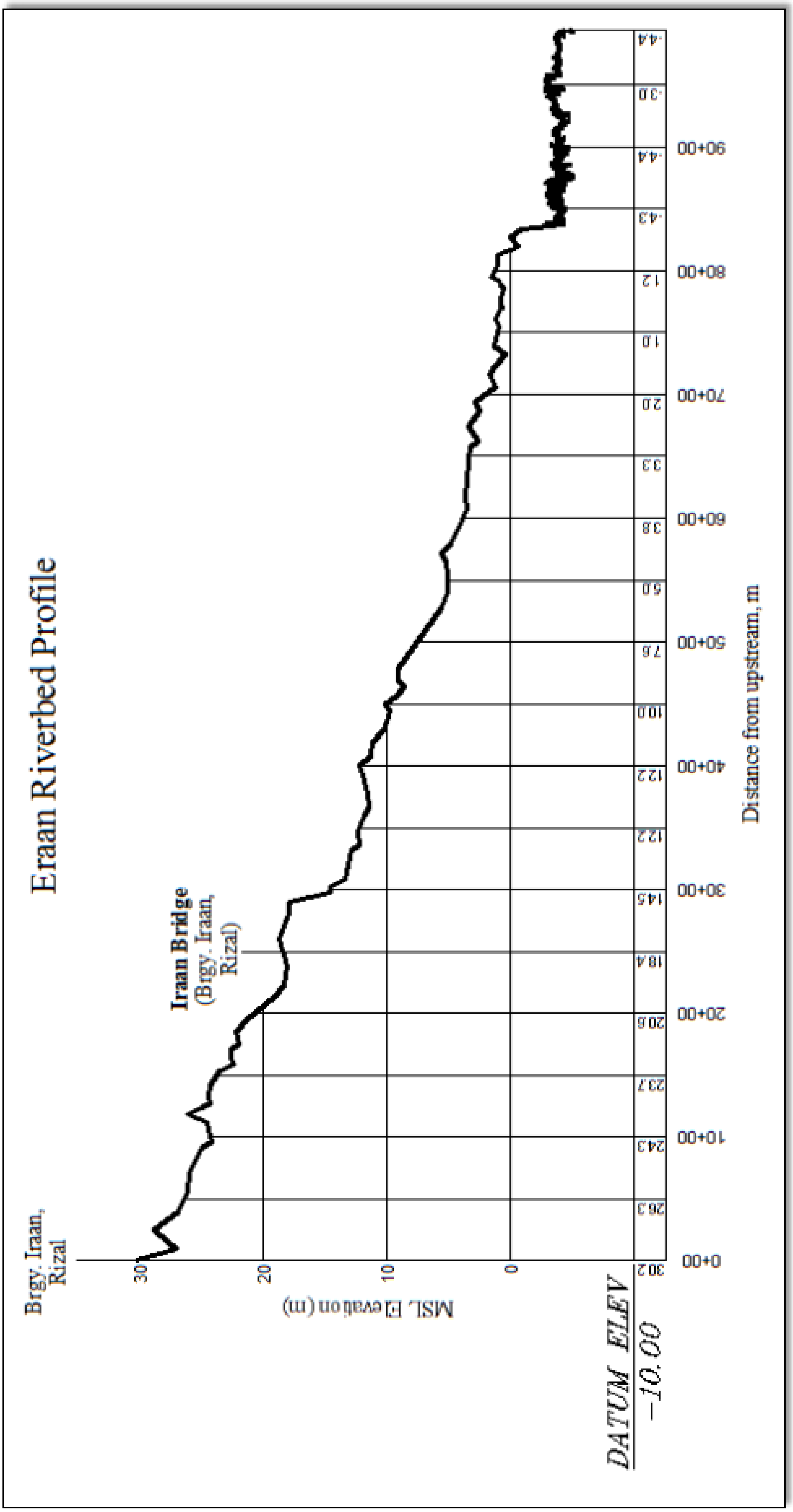


Figure 48 Iraan Riverbed Profile

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, Khristoffer Quinton, and John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, and Kevin M. Manalo

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a portable rain gauge deployed on a strategic location within the river basin (9.056689˚ N, 117.678720˚ E). The location of the rain gauge is seen in Figure 49.

The total precipitation for this event was 144.0 mm. It had a peak rainfall of 8.60 mm on January 11, 2017 at 2:10 am. The lag time between the peak rainfall and discharge was 5 hour and 20 minutes, as seen in Figure 52.

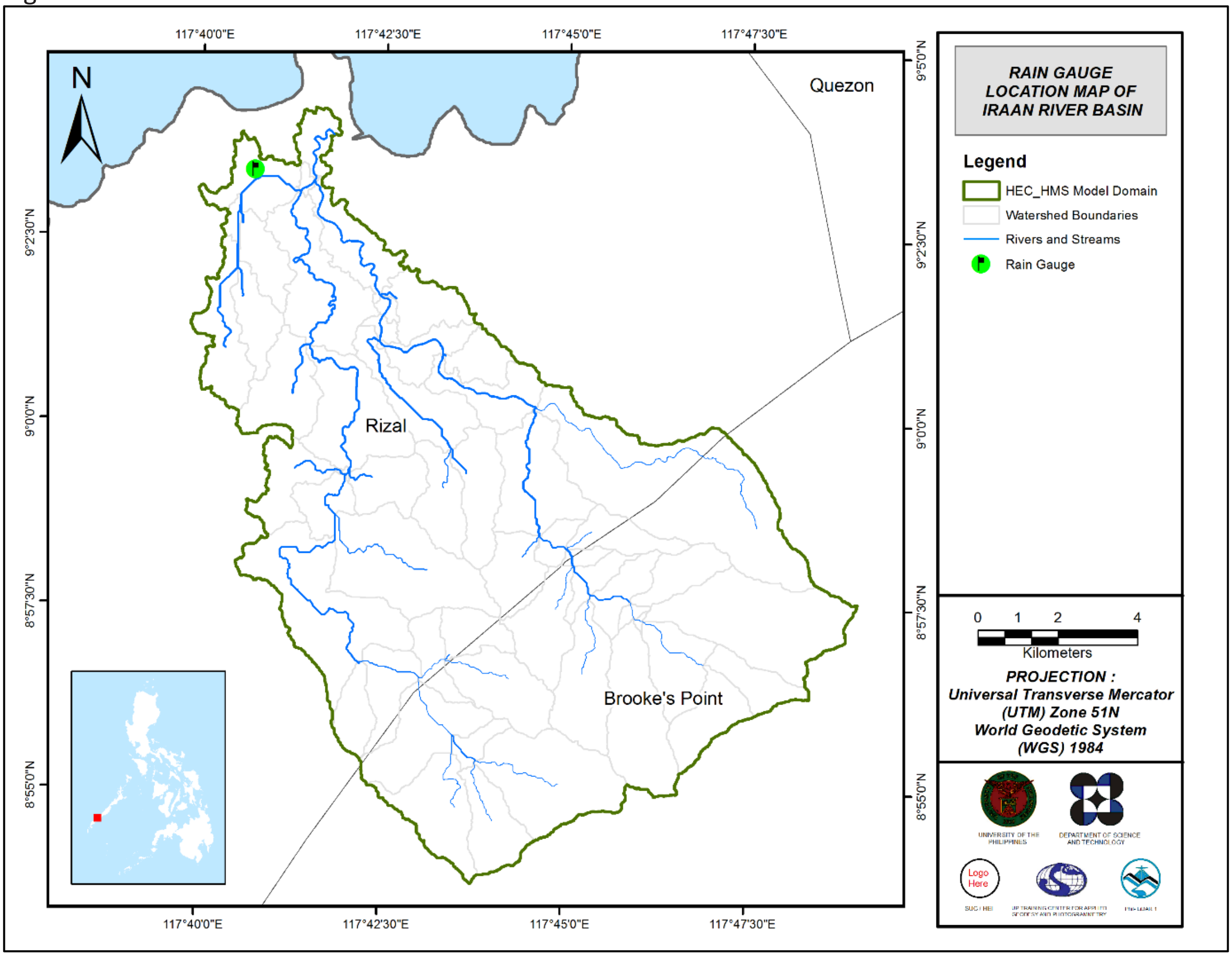


Figure 49. The location map of Iraan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Iraan Bridge, Rizal, Palawan (9.055361° N, 117.692553° E). It gives the relationship between the observed water levels from the Iraan Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Iraan Bridge, the rating curve is expressed as $Q = 1.8835^{0.8369x}$ as shown in Figure 51.

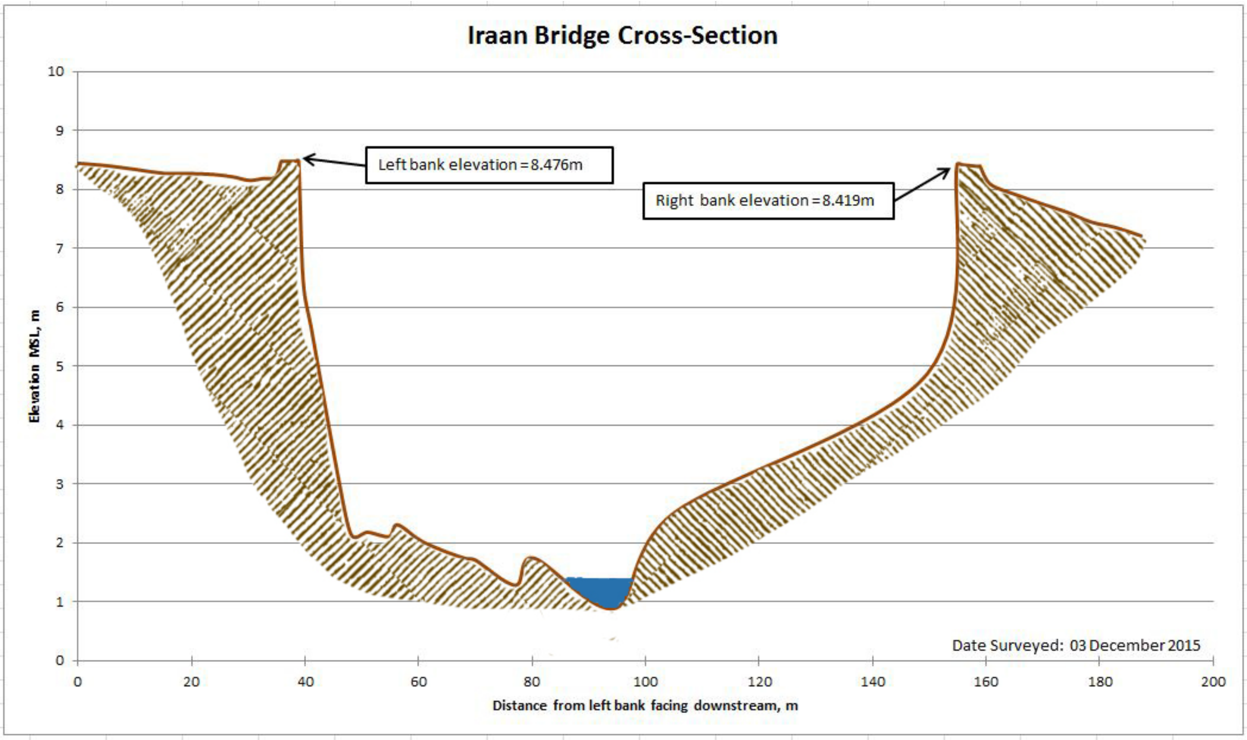


Figure 50. Cross-section plot of Iraan Bridge

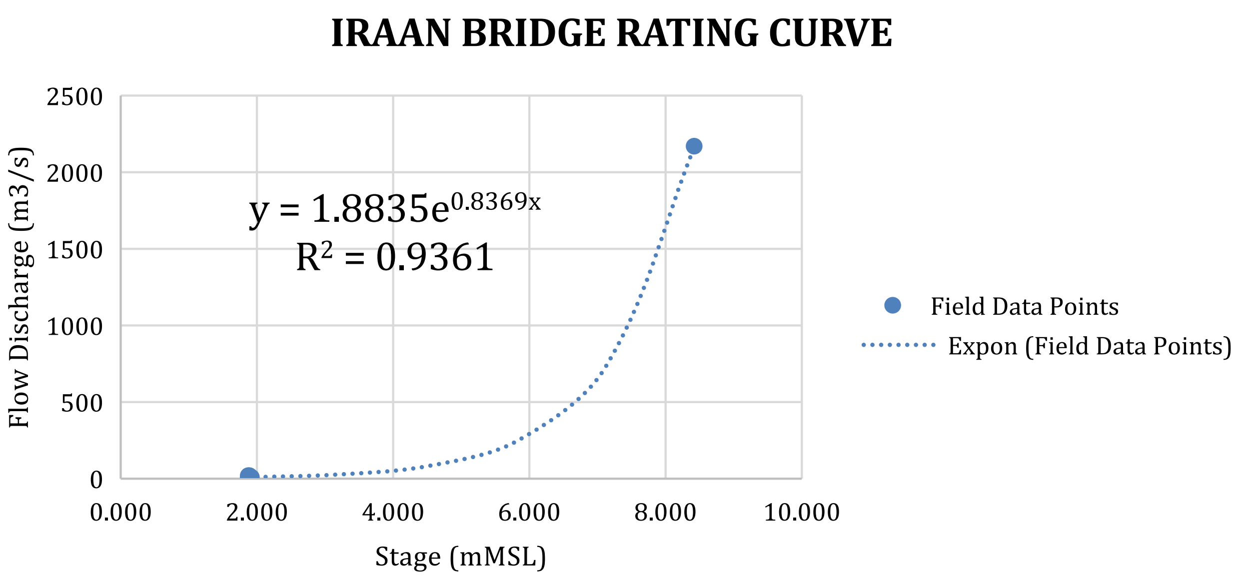


Figure 51. Rating Curve at Iraan Bridge, Rizal,Palawan

For the calibration of the HEC-HMS model, shown in Figure 52, actual flow discharge during a rainfall event was collected in the Iraan bridge. Peak discharge was 12.670 cu.m/s on January 11, 2017 at 7:30 am.

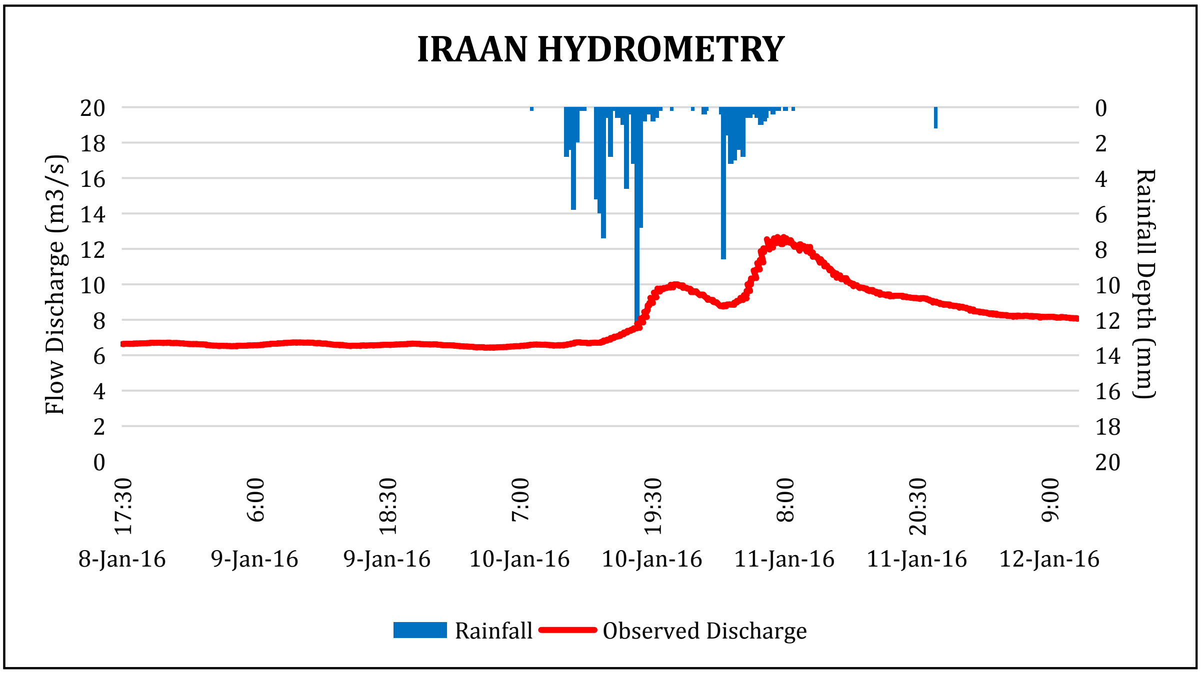


Figure 52. Rainfall and outflow data of Iraan River Basin, which was used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Puerto Princesa Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value is attained at a certain time. This station chosen based on its proximity to the Iraan watershed. The extreme values for this watershed were computed based on a 58-year record.

Table 24. RIDF values for Puerto Princesa 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	14.8	22	27.3	36.2	49.8	58.8	75.1	88	104.1
5	21.3	31.9	39.7	52.3	73	86.9	112.8	135.4	156.4
10	25.6	38.5	48	63	88.4	105.5	137.8	166.8	191.1
15	28.1	42.2	52.6	69	97	116	151.9	184.5	210.6
20	29.8	44.7	55.9	73.3	103.1	123.4	161.7	196.8	224.3
25	31.1	46.7	58.4	76.5	107.8	129.1	169.3	206.4	234.9
50	35.2	52.9	66.1	86.5	122.2	146.5	192.7	235.8	267.3
100	39.2	59	73.7	96.4	136.5	163.8	216	265	299.6

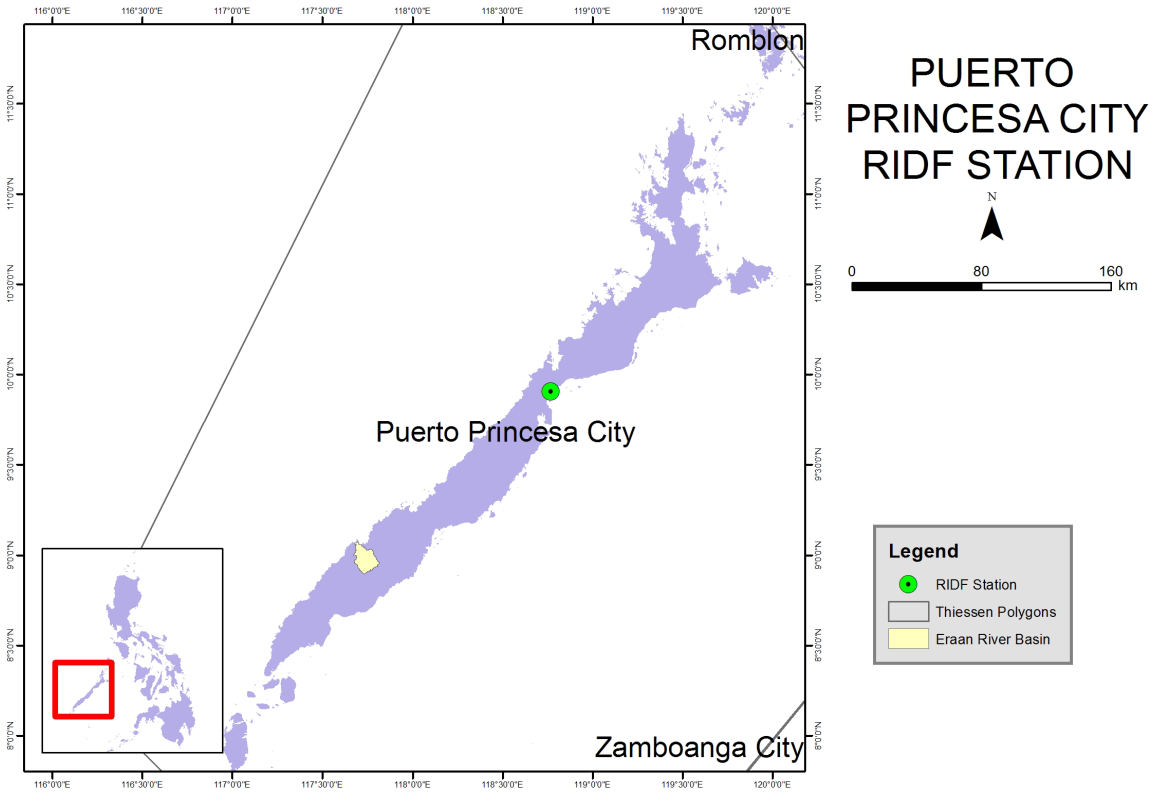


Figure 53. Location of Puerto Princesa RIDF relative to Iraan River Basin

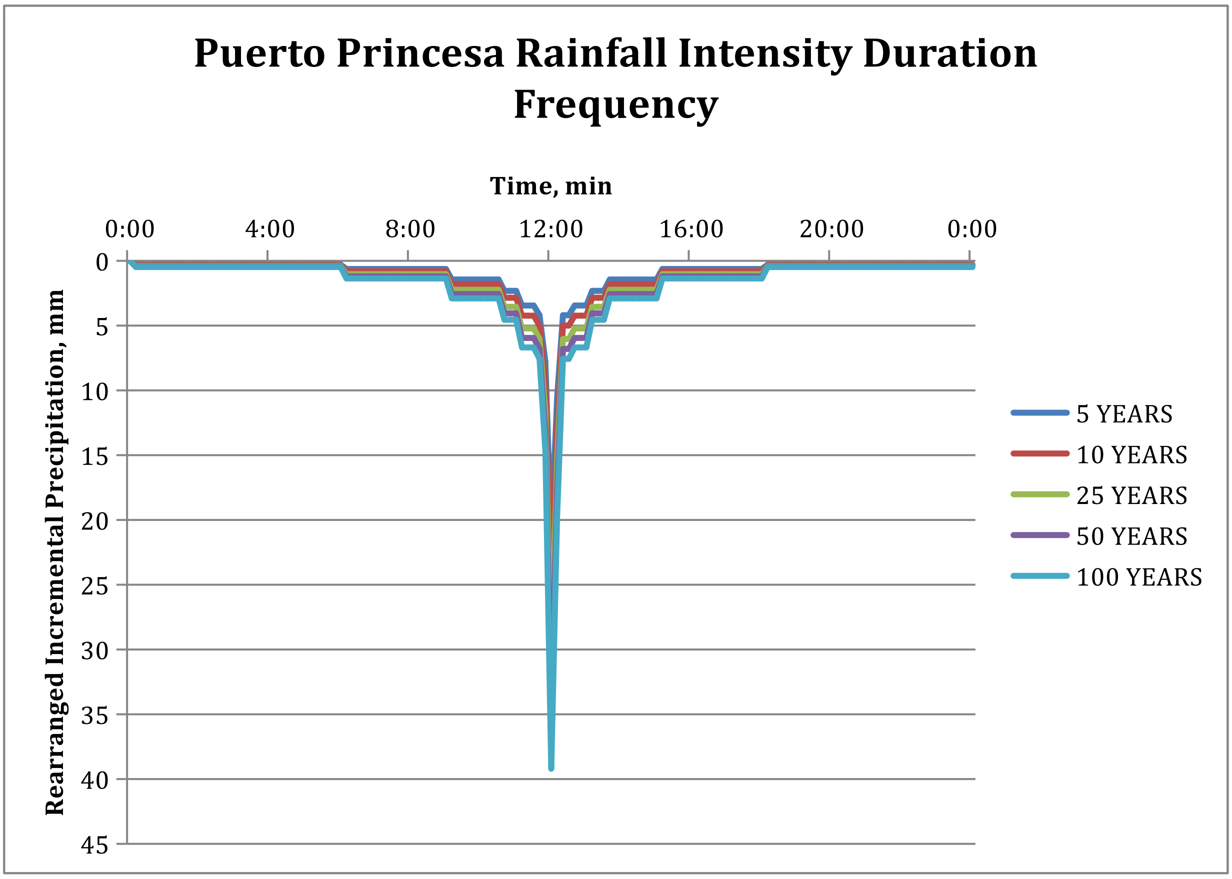


Figure 54. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Kotkot River Basin are shown in Figure 55 and Figure 56, respectively.

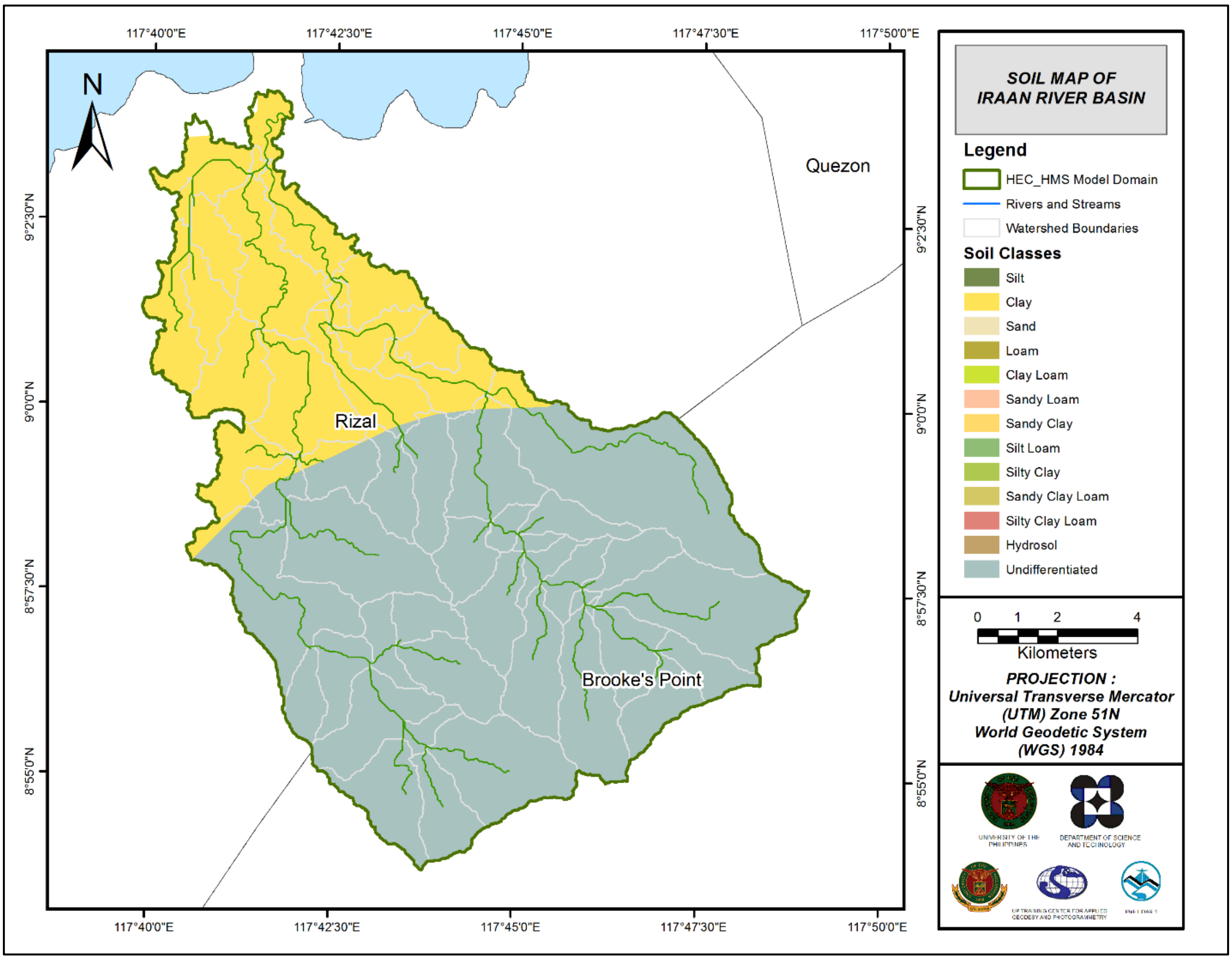


Figure 55. The soil map of the Iraan River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

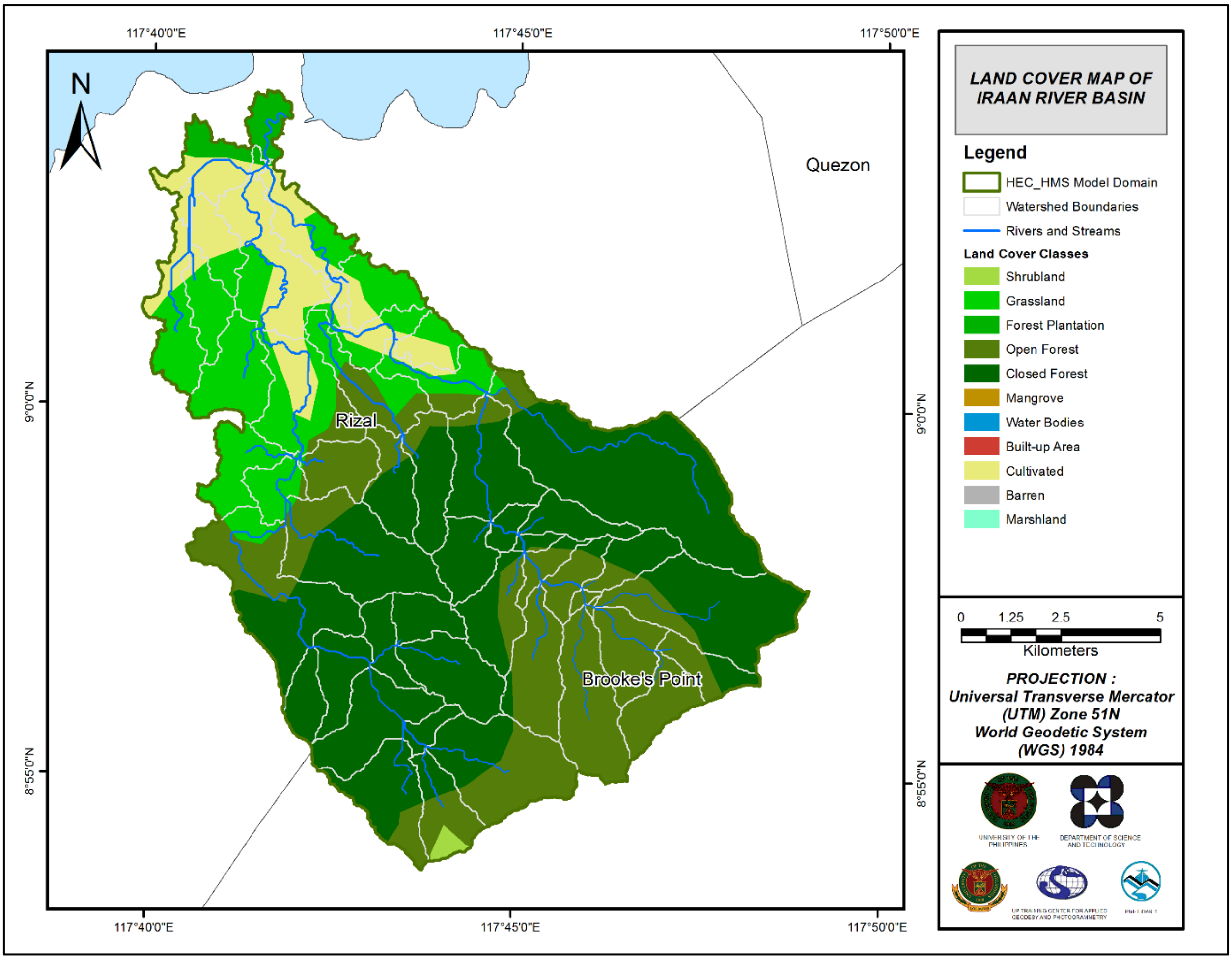


Figure 56. The land cover map of the Iraan River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

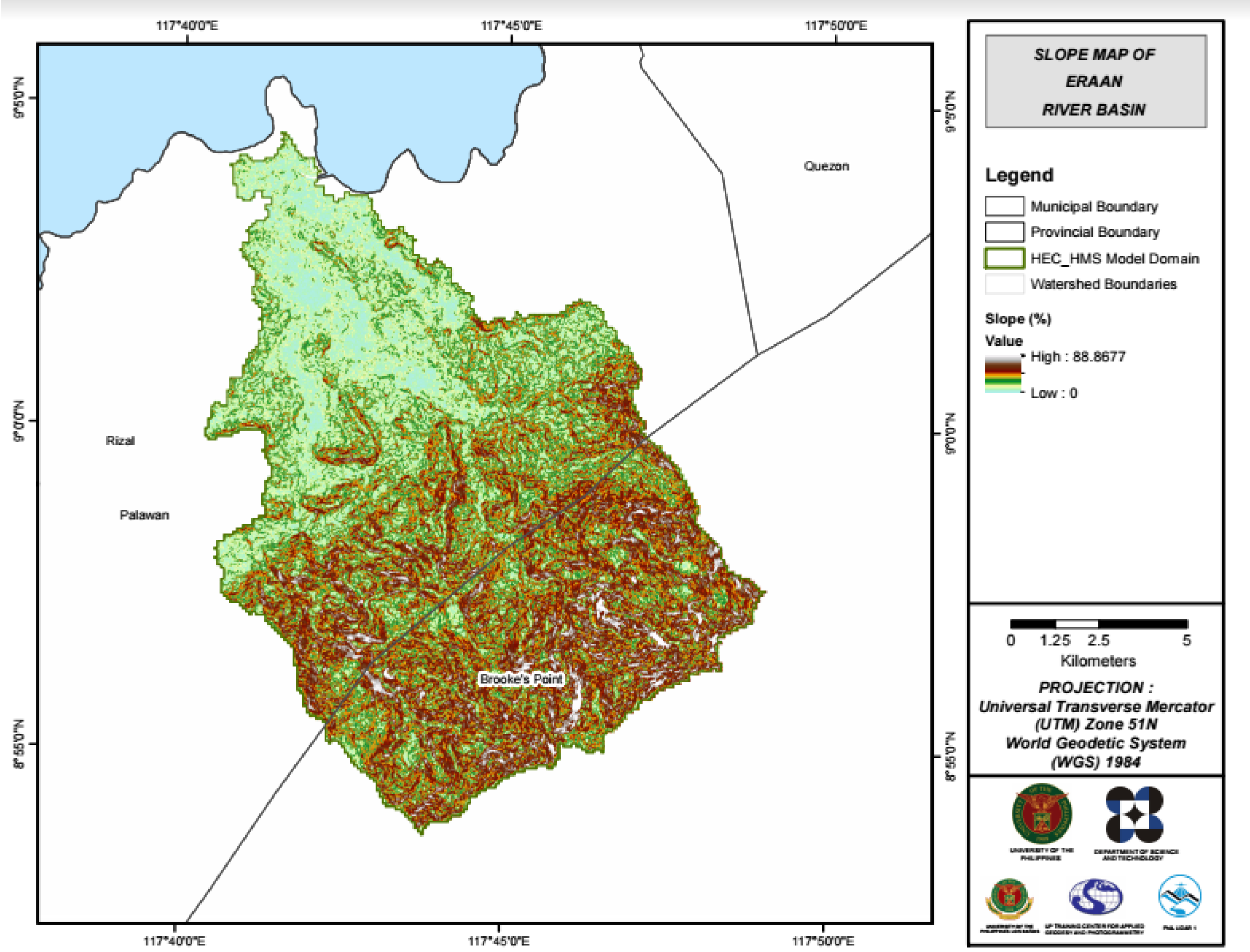


Figure 57. Slope Map of the Iraan River Basin

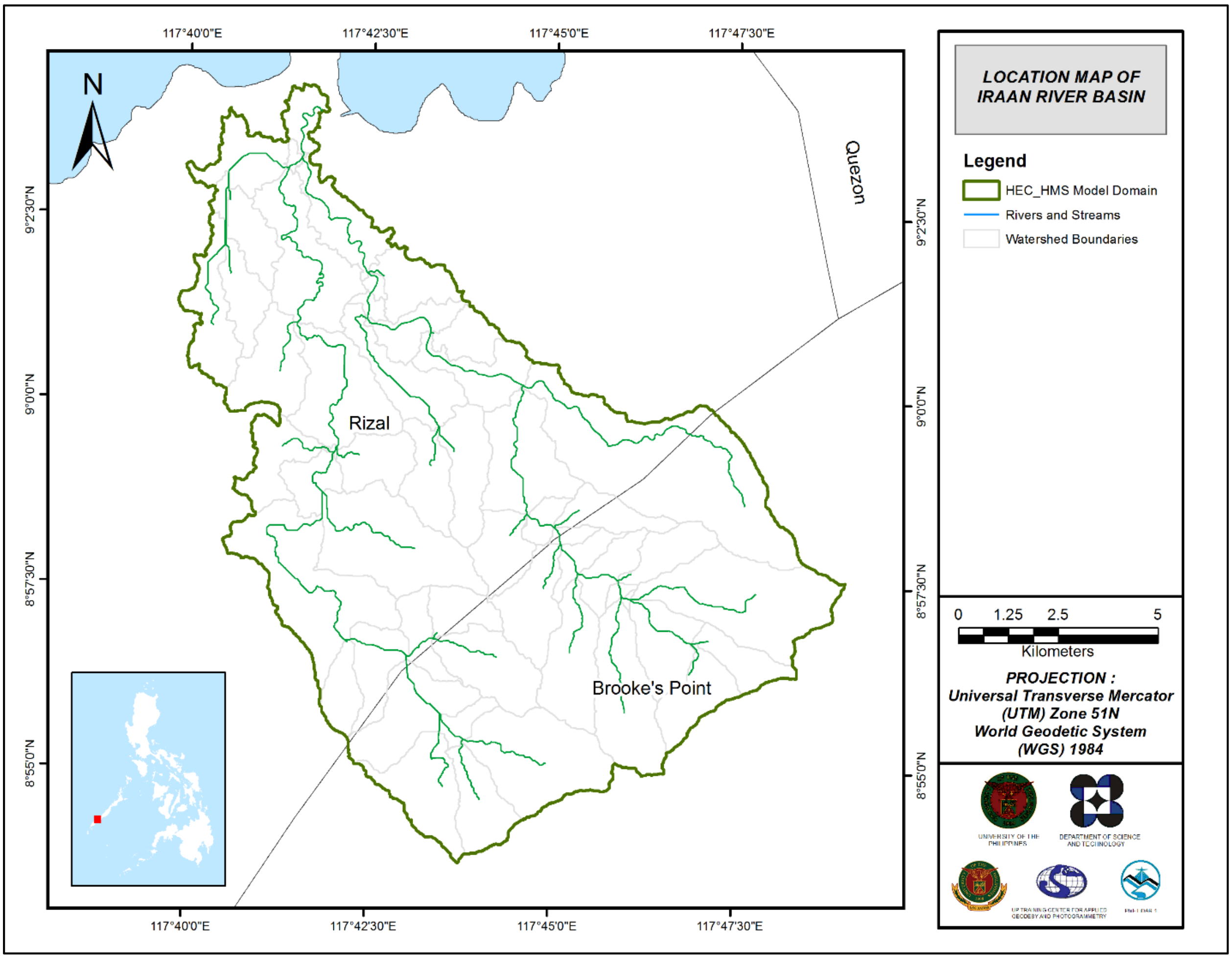


Figure 58. Stream Delineation Map of the Iraan River Basin

Using SAR-based DEM, the Iraan basin was delineated and further subdivided into subbasins. The model consists of 56 sub basins, 29 reaches, and 29 junctions. The main outlet is at Iraan Bridge.

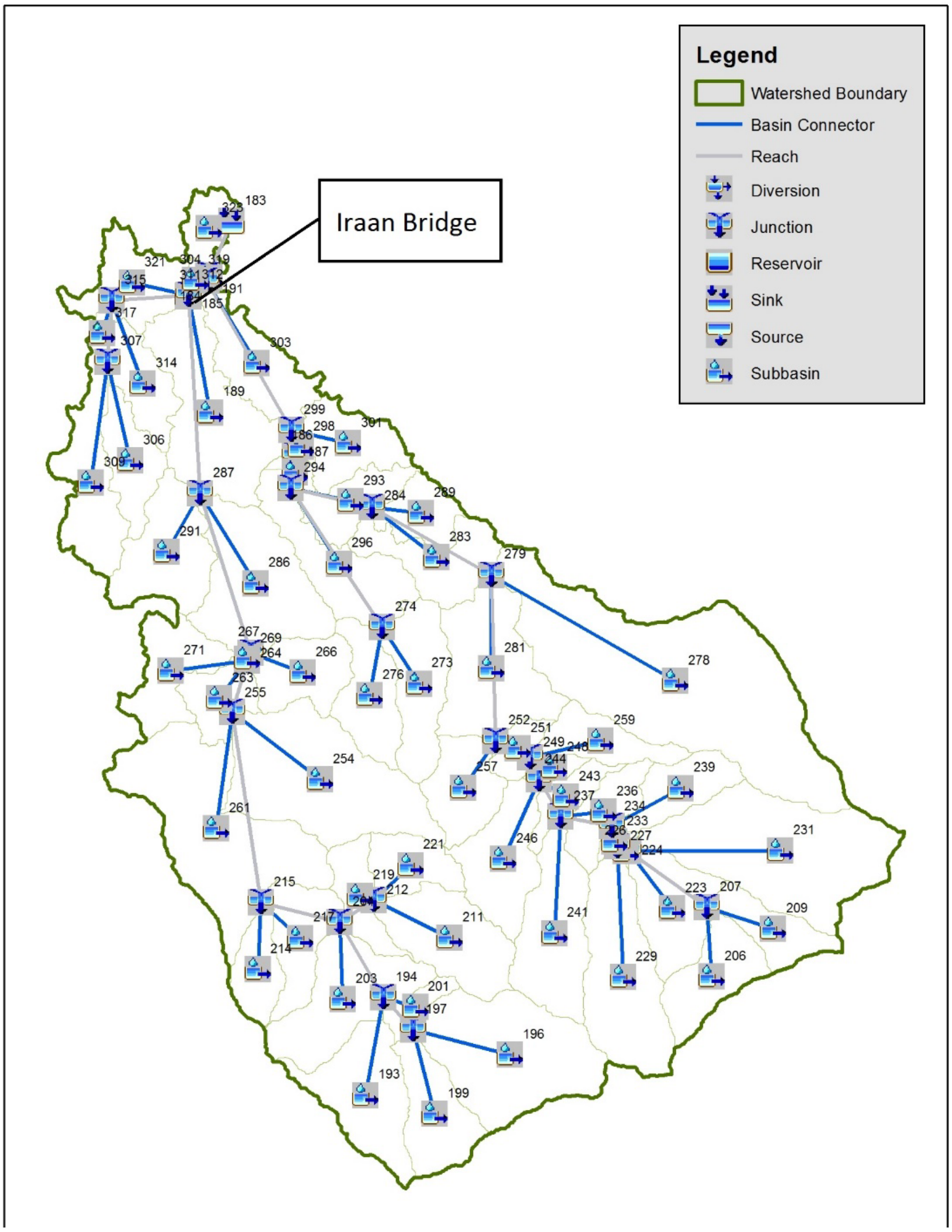


Figure 59. The Iraan river basin model generated using HEC-HMS

5.4 Cross-section Data

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

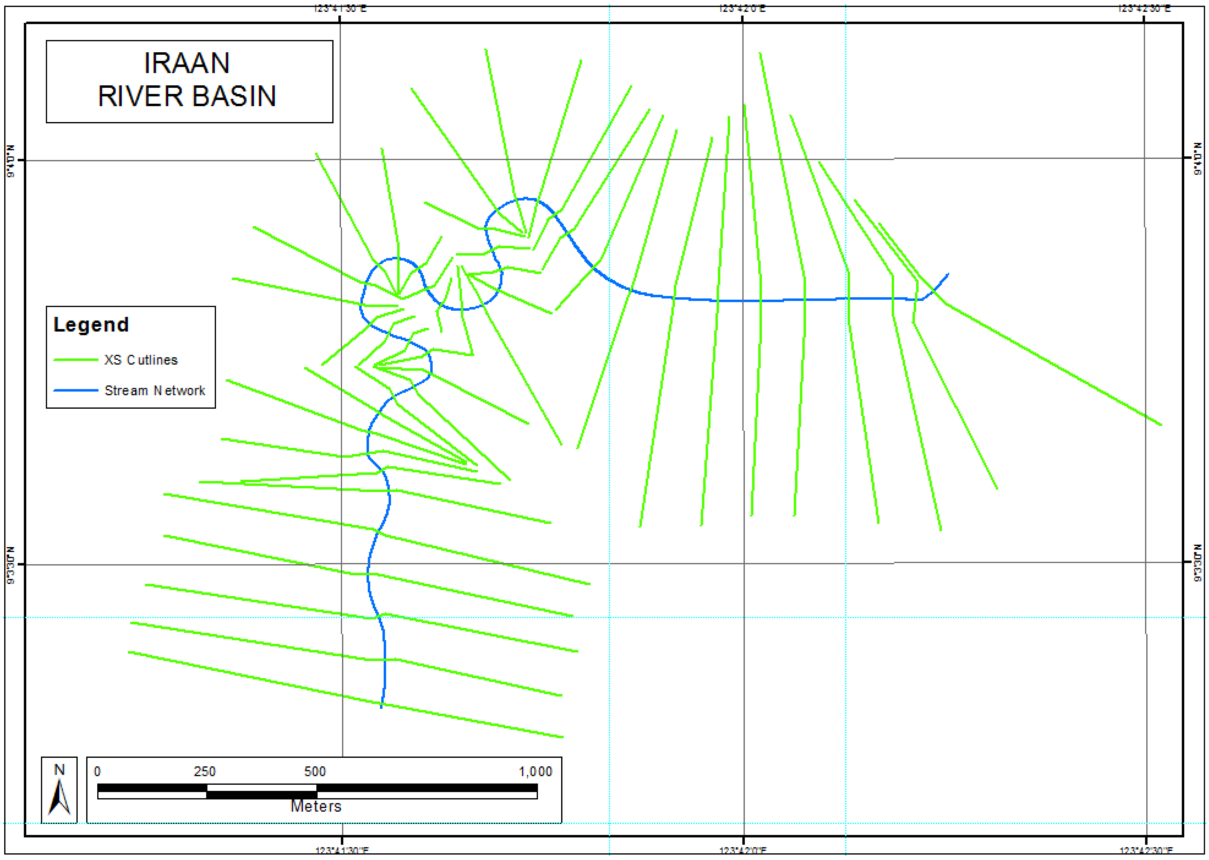


Figure 60. River cross-section of Iraan River generated through Arcmap HEC GeoRAS tool

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.

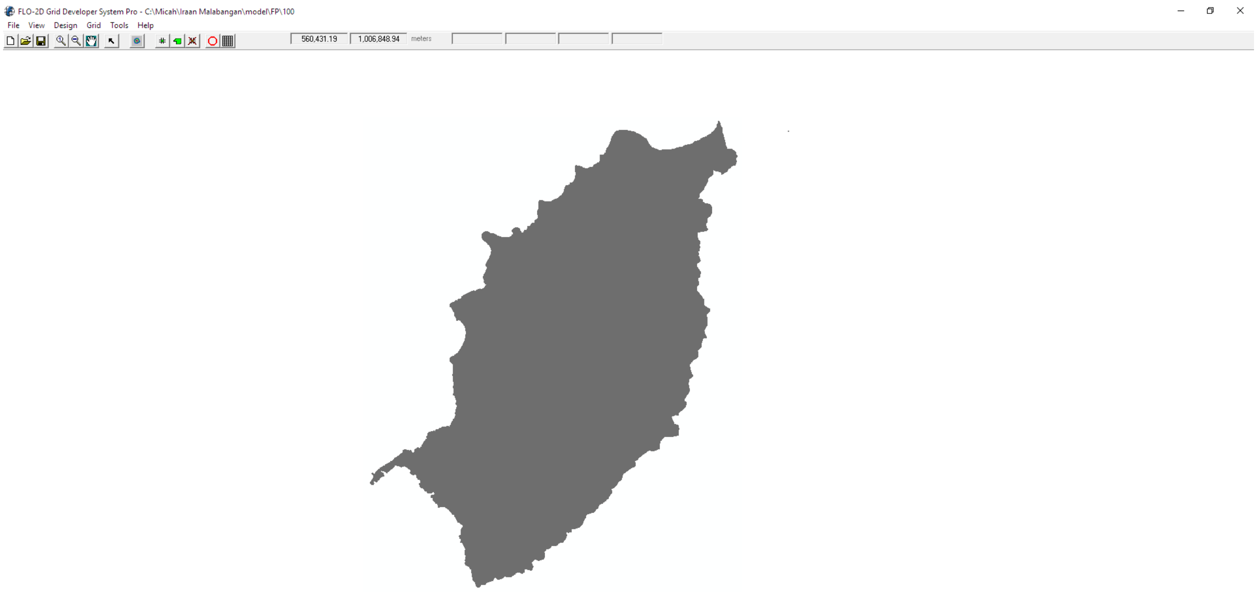


Figure 61. Screensho[No text for this section and figure ?]t of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 31.95605 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 80 183 700.00 m2.

There is a total of 36 447 348.62 m3 of water entering the model. Of this amount, 22 918 238.06 m3 is due to rainfall while 13 529 110.56 m3 is inflow from other areas outside the model. 7 005 949.50 m3 of this water is lost to infiltration and interception, while 4 475 535.98 m3 is stored by the flood plain. The rest, amounting up to 24 965 868.70 m3, is outflow.

5.6 Results of HMS Calibration

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

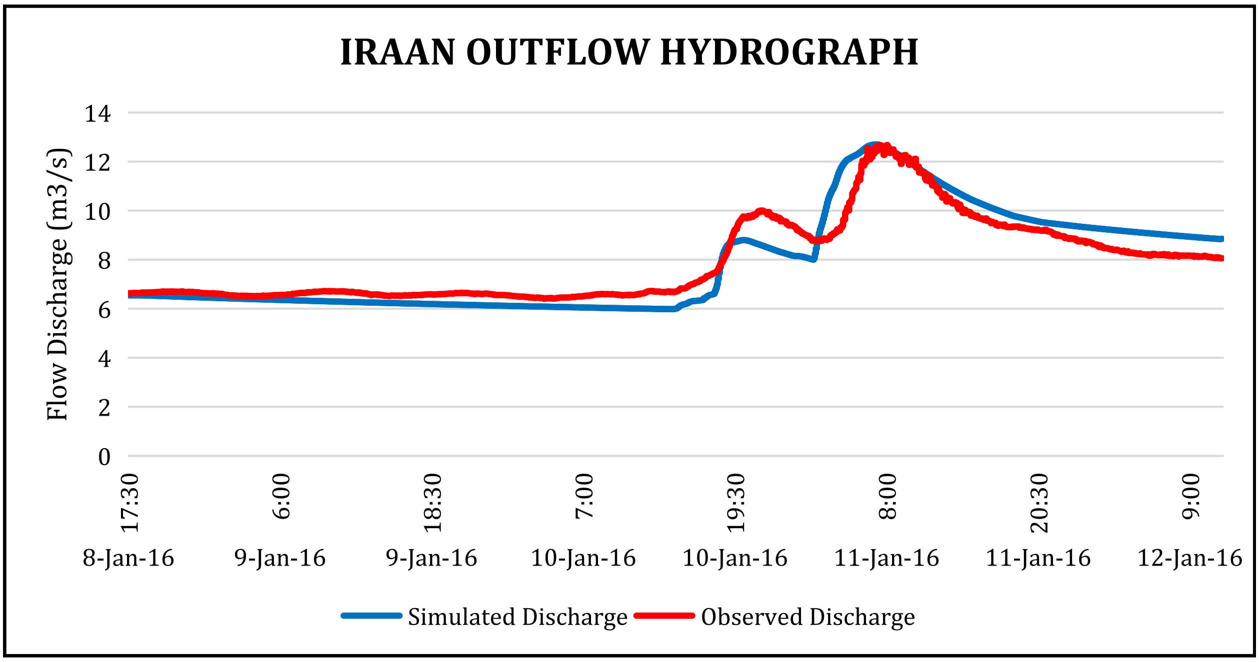


Figure 62. Outflow Hydrograph of Iraan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 25 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 25. Range of Calibrated Values for Iraan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	2 - 159
			Curve Number	35 - 83
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.03 - 2
			Storage Coefficient (hr)	3 - 180
	Baseflow	Recession	Recession Constant	0.3 - 1
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.002

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 2 to 159 mm means that there is high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 39 to 99 for curve number means that there is a diverse characteristic for this watershed depending on its subbasin.

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 0.03 hours to 180 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. Same as the curve number, the characteristics of this watershed differs per reach.

Manning's roughness coefficient of 0.002 is relatively low compared to the common roughness of watersheds (Brunner, 2010).

Table 26. Summary of the Efficiency Test of the Iraan HMS Model

Accuracy measure	Value
RMSE	0.650
r2	0.954
NSE	0.851
PBIAS	0.689
RSR	0.386

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.650.

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 0.954.

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 0.851.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 0.689.

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 0.386.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 63) shows the Iraan outflow using the Puerto Princesa Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

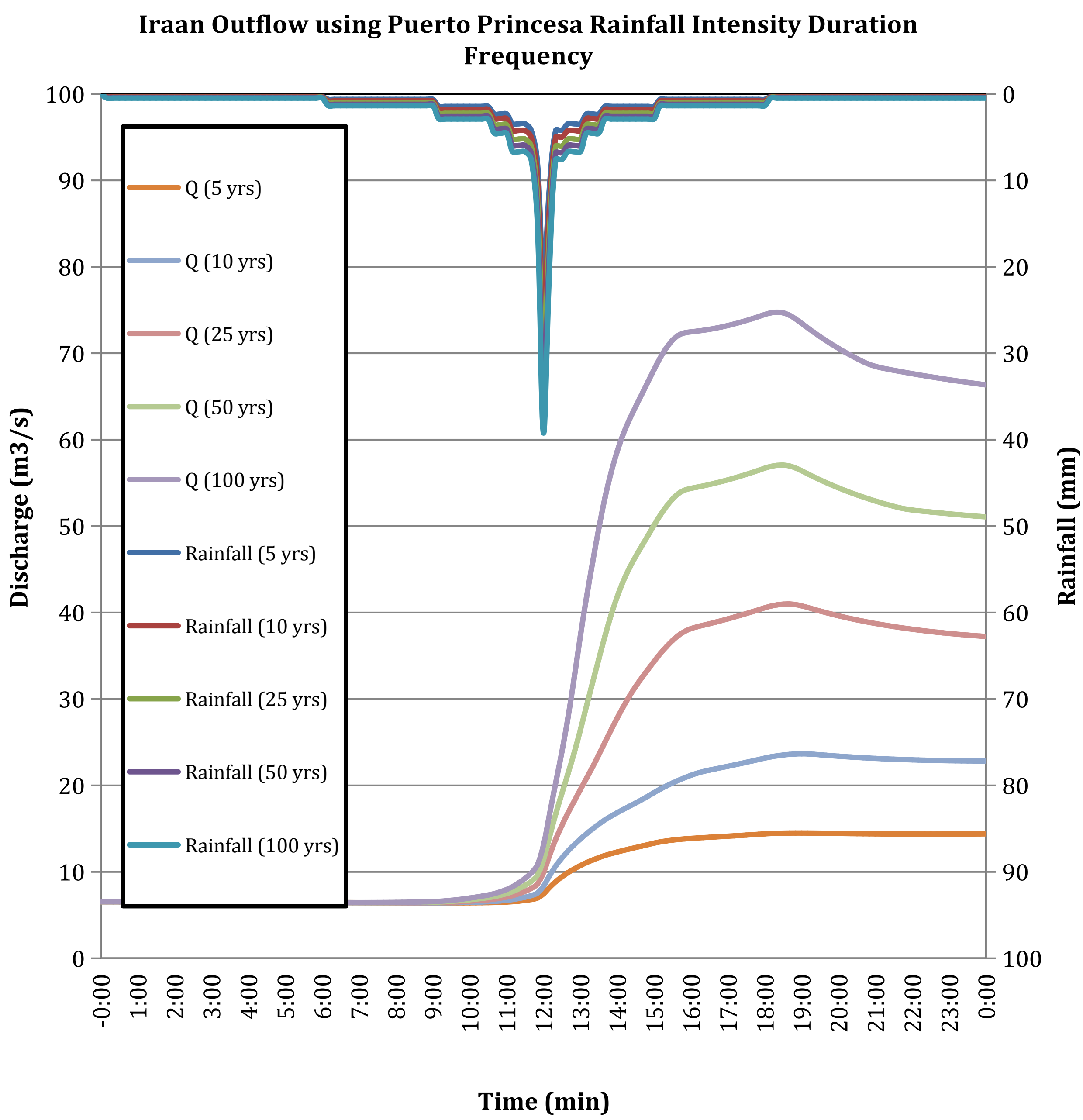


Figure 63. Outflow hydrograph at Iraan Station generated using Puerto Princesa RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Iraan discharge using the Puerto Princesa Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 27.

Table 27. Peak values of the Iraan HECHMS Model outflow using the Puerto Princesa RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	156.40	21.30	14.495	6 hours 50 minutes
10-Year	191.10	25.60	23.657	7 hours
25-Year	234.90	31.1	40992	6 hours 40 minutes
50-Year	267.30	35.20	57.059	6 hours 30 minutes
100-Year	299.60	39.20	74.748	6 hours 20 minutes

5.8 River Analysis (RAS) Model Simulation

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

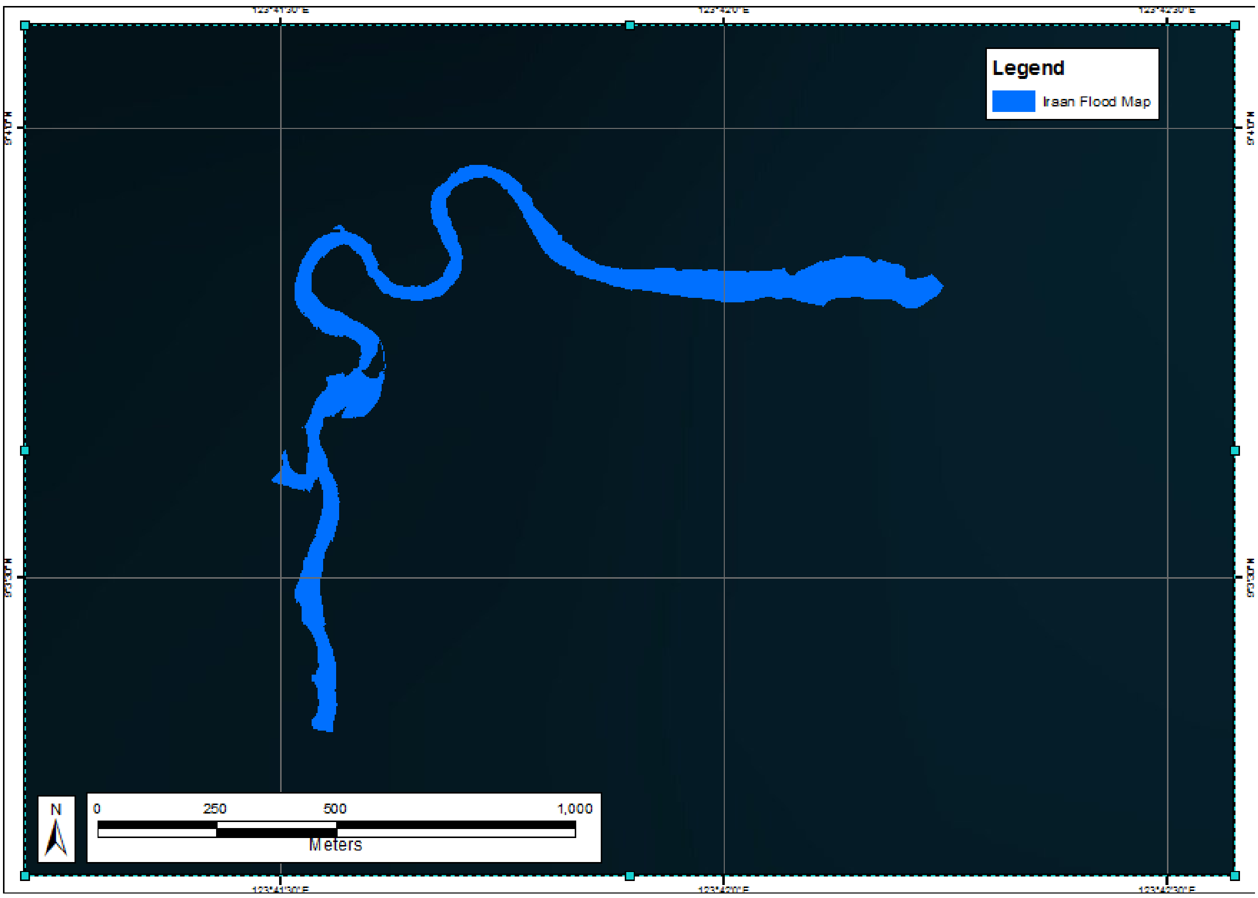


Figure 64. Sample output map of Iraan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Iraan Floodplain are shown in Figure 65 to 70. The floodplain, with an area of 79.82 sq. km., covers one municipality namely Rizal. Table 28 shows the percentage of area affected by flooding per municipality.

Table 28. Municipalities affected in Iraan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Rizal	980.59	79.76	8.13

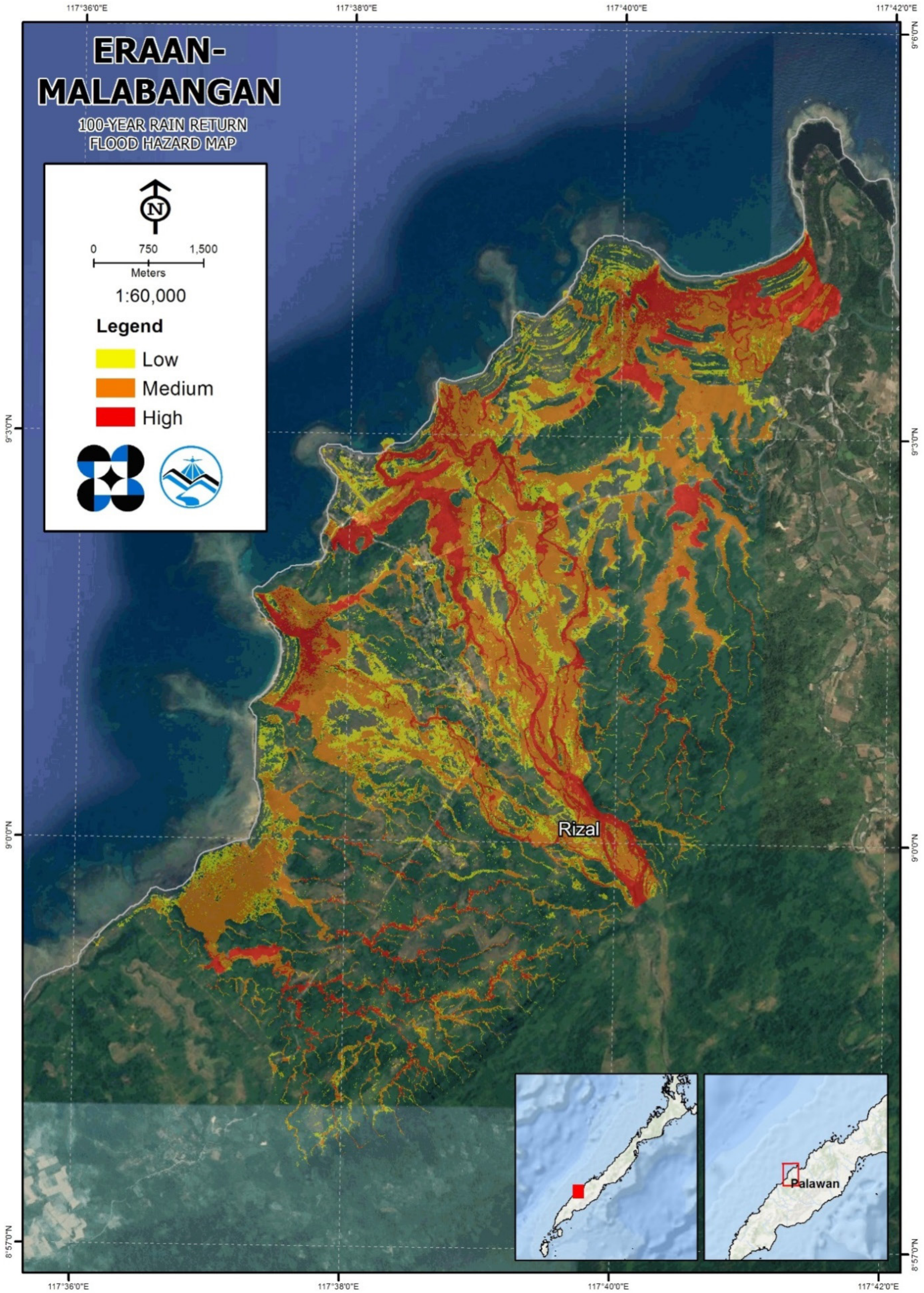


Figure 65. A 100-year flood hazard map for Iraan (also known as Eraan) Floodplain

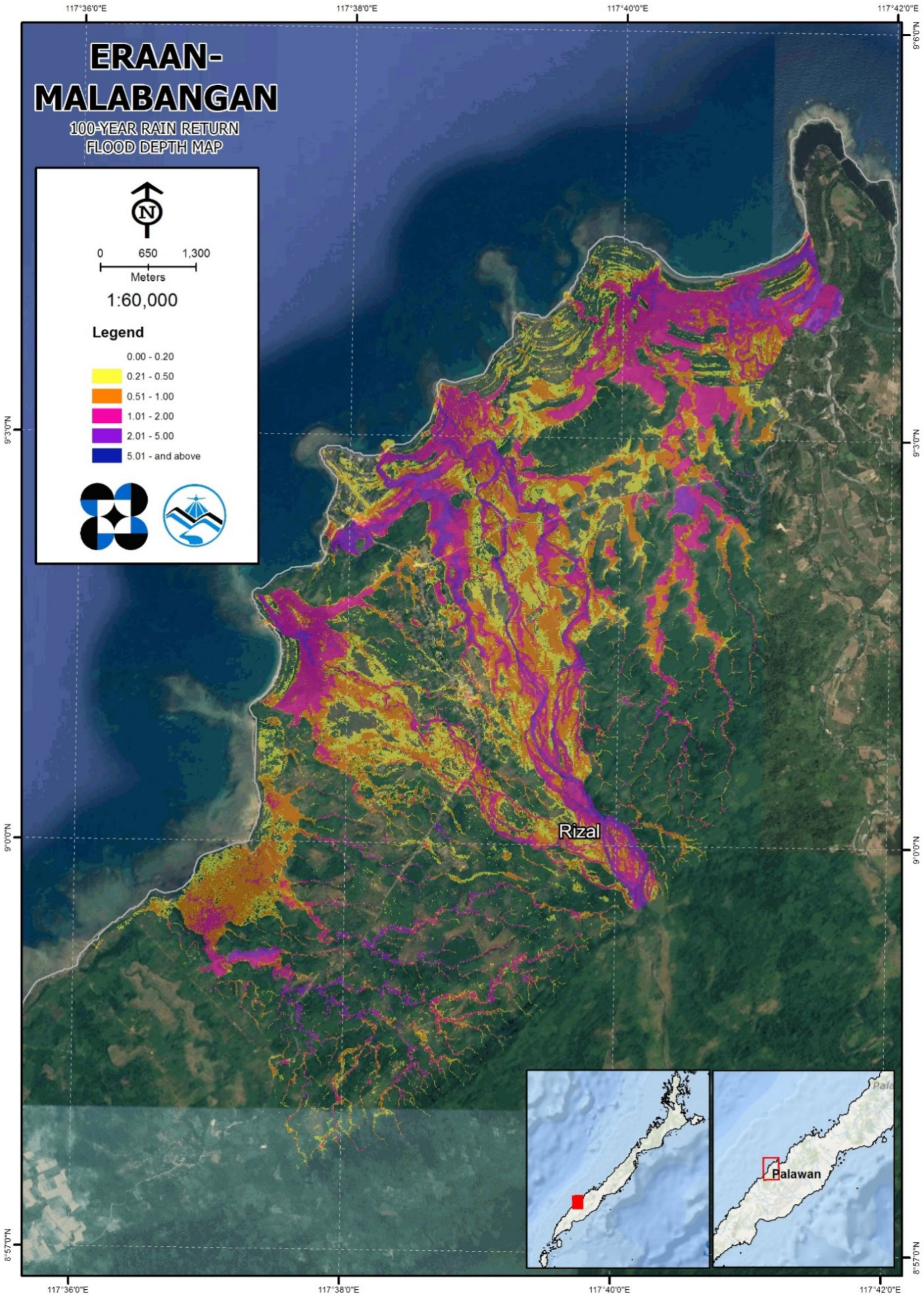


Figure 66. A 100-year Flow Depth Map for Iraan (also known as Eraan) Floodplain

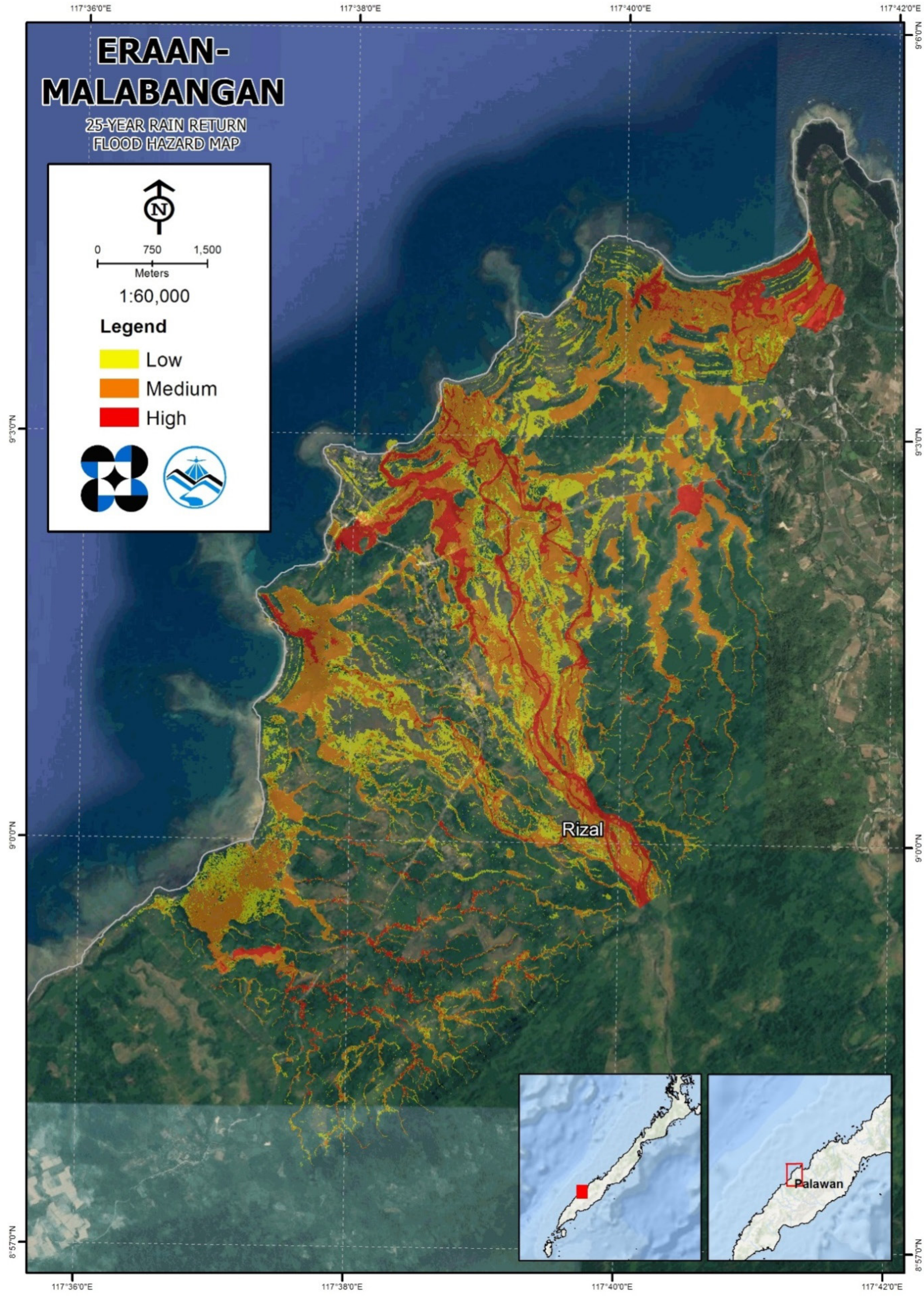


Figure 67. A 25-year Flood Hazard Map for Iraan (also known as Eraan) Floodplain

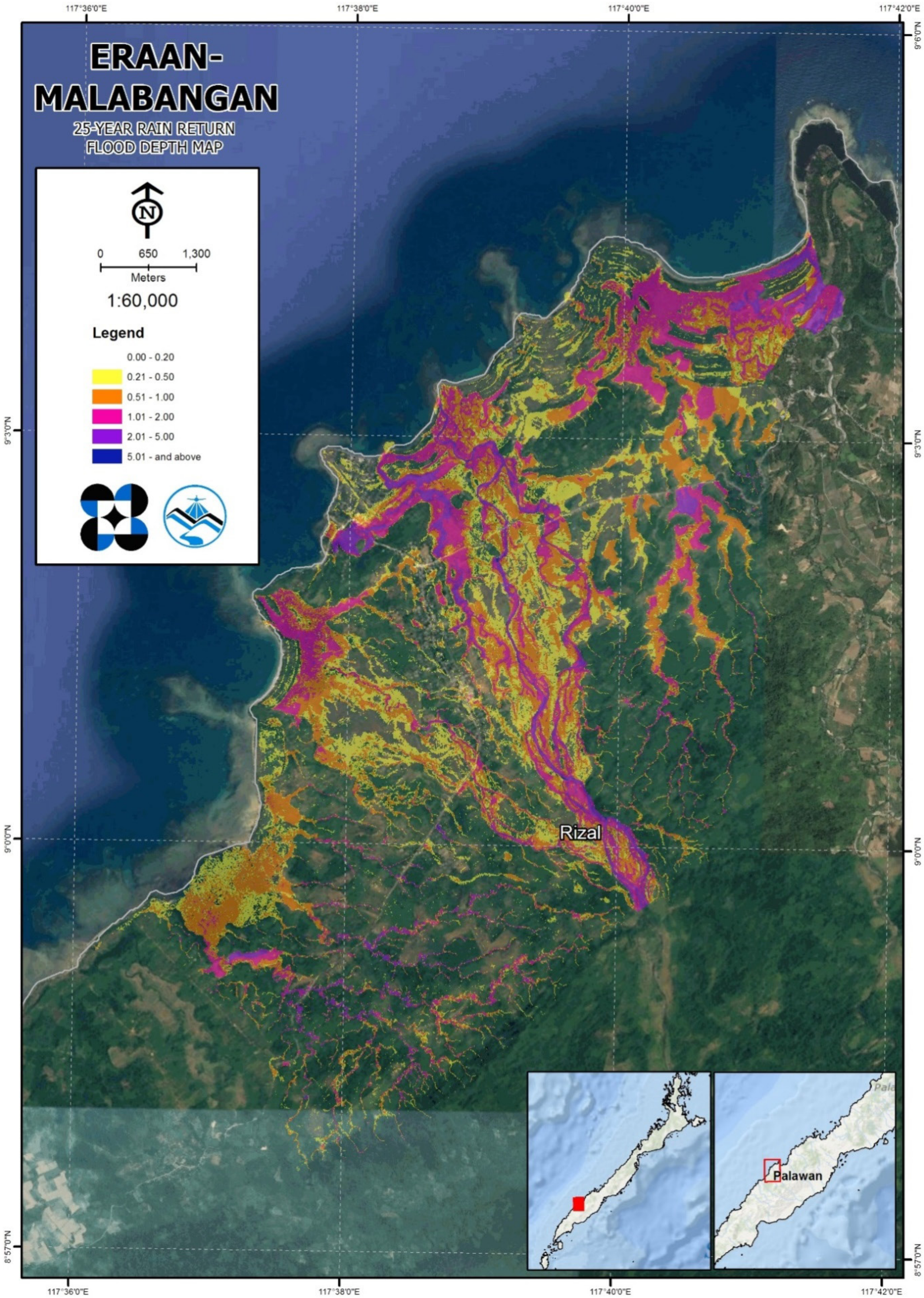


Figure 68. A 25-year Flow Depth Map for Iraan (also known as Eraan) Floodplain

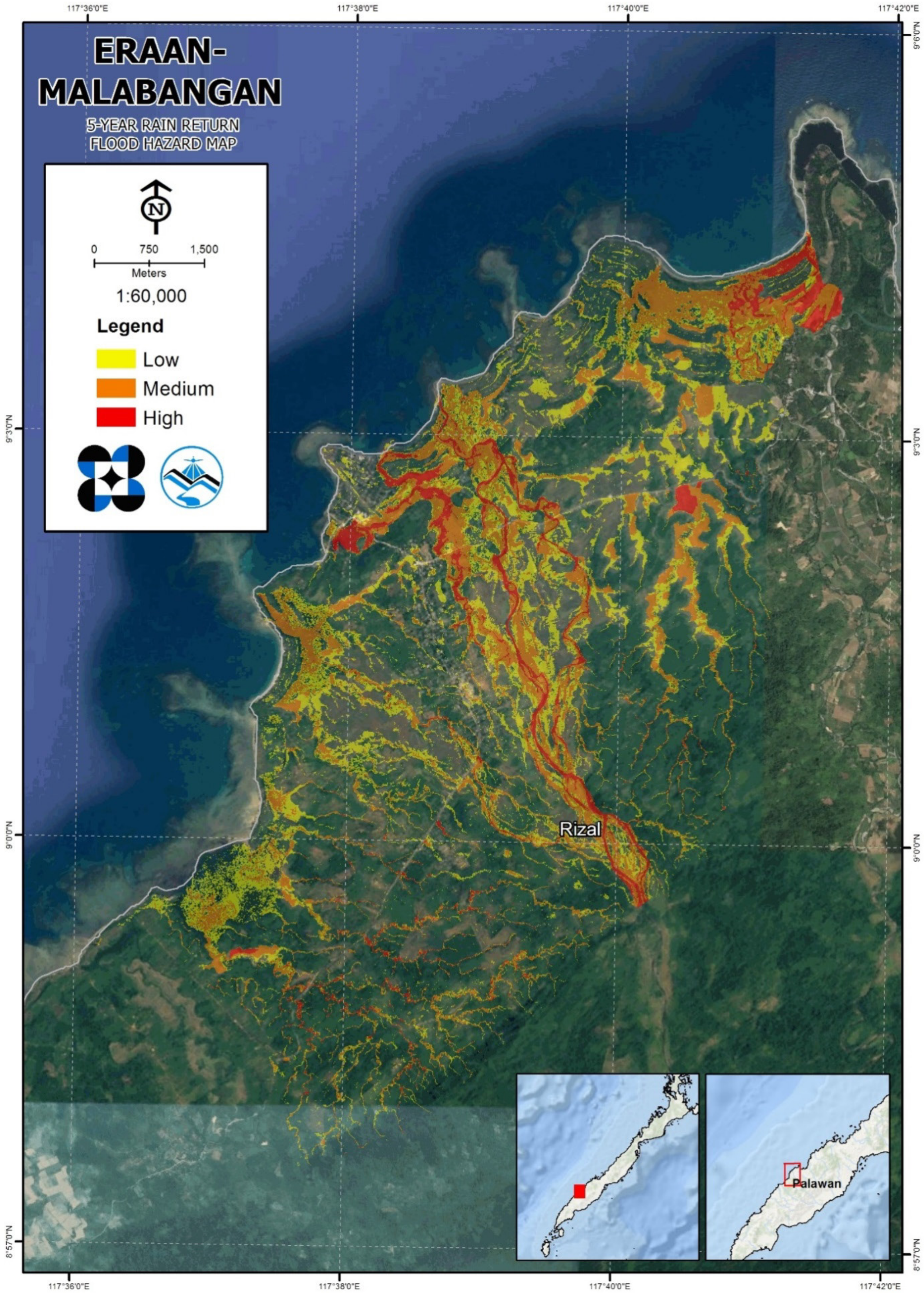


Figure 69. A 5-year Flood Hazard Map for Iraan (also known as Eraan) Floodplain

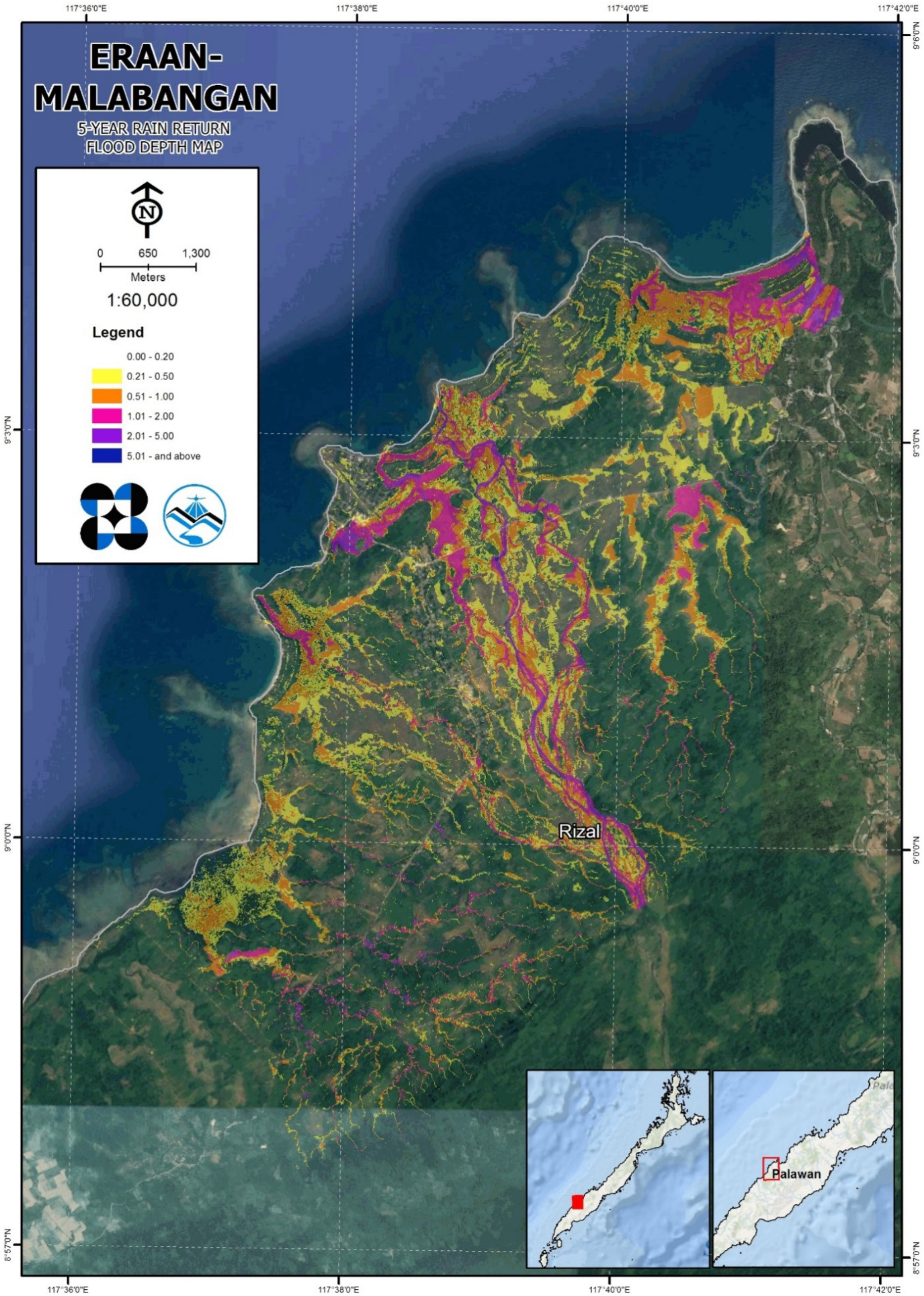


Figure 70. A 5-year Flow depth map for Iraan (also known as Eraan) Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Iraan river basin, grouped by municipality, are listed below. For the said basin, one municipality consisting of 3 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 5.51% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.66%, 1.01%, 0.53%, and 0.00004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 29 are the affected areas in square kilometers by flood depth per barangay.

Table 29. Affected Areas in Rizal, Palawan during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Rizal		
	Bunog	Iraan	Punta Baja
0.03-0.20	20.26	25.91	7.87
0.21-0.50	1.095	2.41	0.36
0.51-1.00	1.21	4.85	0.43
1.01-2.00	1.84	7.19	0.91
2.01-5.00	0.44	3.68	1.13
> 5.00	0.0004	0	0

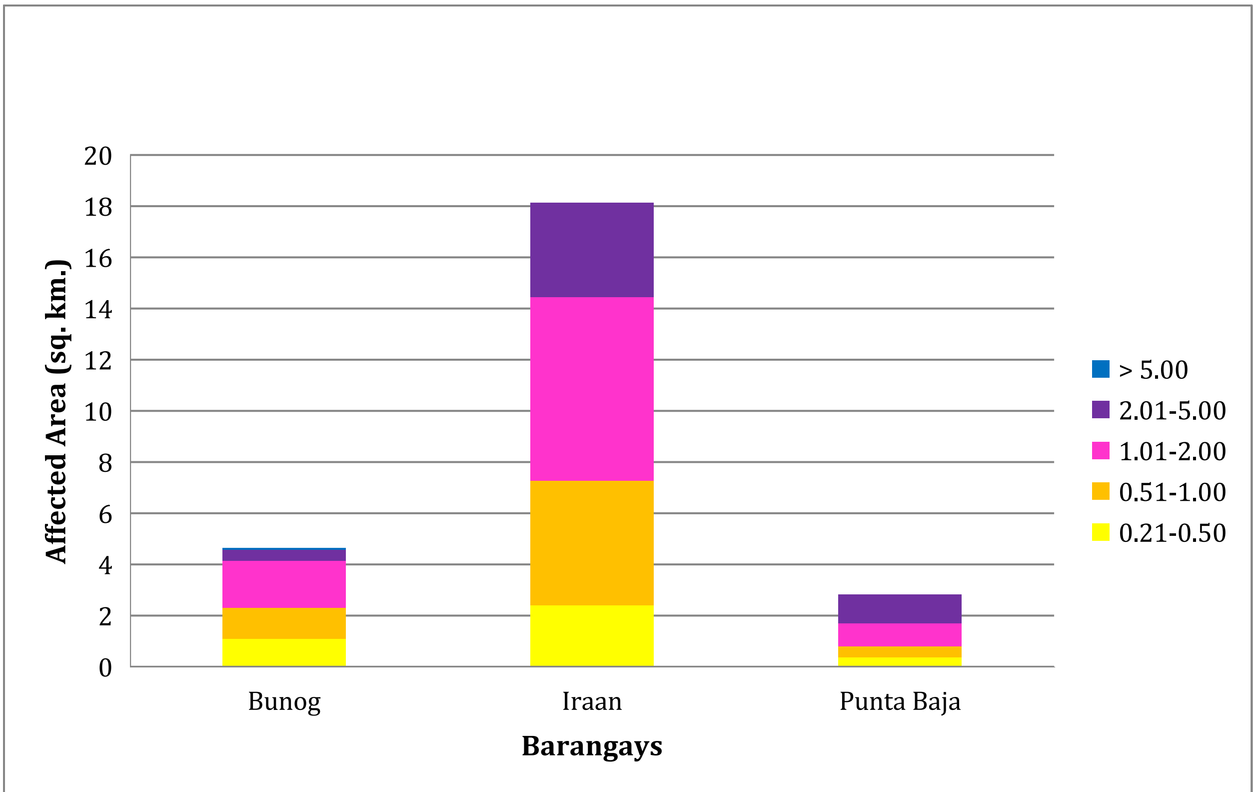


Figure 71. Affected Areas in Rizal, Palawan during 5-Year Rainfall Return Period

For the 25-year return period, 5.67% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters while 0.77%, 0.83%, 0.36%, and 0.008% 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 meter, respectively. Listed in Table 30 are the affected areas in square kilometers by flood depth per barangay.

Table 30. Affected Areas in Rizal, Palawan during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Rizal		
	Bunog	Iraan	Punta Baja
0.03-0.20	20.63	26.92	8.0
0.21-0.50	1.080	3.30	0.38
0.51-1.00	1.31	5.706	0.52
1.01-2.00	1.55	5.70	0.99
2.01-5.00	0.28	2.50	0.82
> 5.00	0.0002	0.079	0.0037

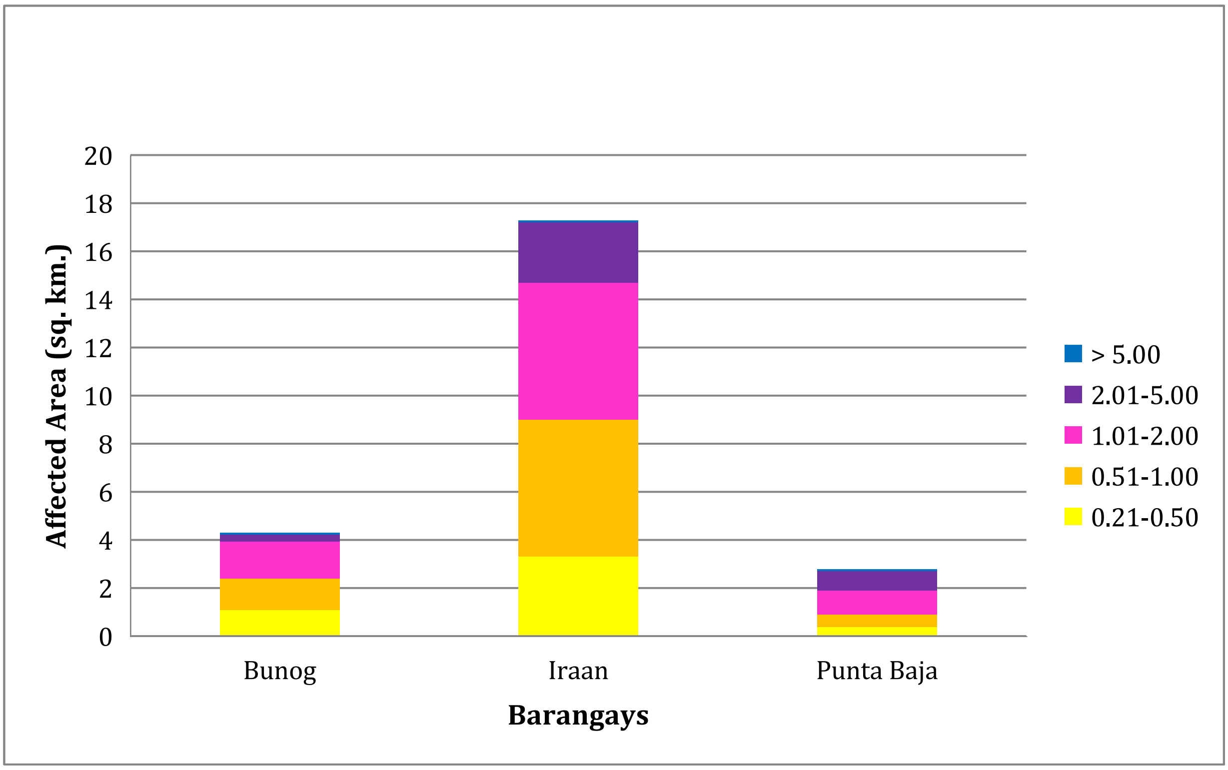


Figure 72. Affected Areas in Rizal, Palawan during 25-Year Rainfall Return Period

For the 100-year return period, 5.51% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.67%, 1.01%, 0.53%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 31 are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Rizal, Palawan during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Rizal		
	Bunog	Iraan	Punta Baja
0.03-0.20	20.26	25.91	7.87
0.21-0.50	1.095	2.41	0.36
0.51-1.00	1.21	4.85	0.43
1.01-2.00	1.84	7.19	0.91
2.01-5.00	0.44	3.68	1.13
> 5.00	0.0004	0.16	0.0086

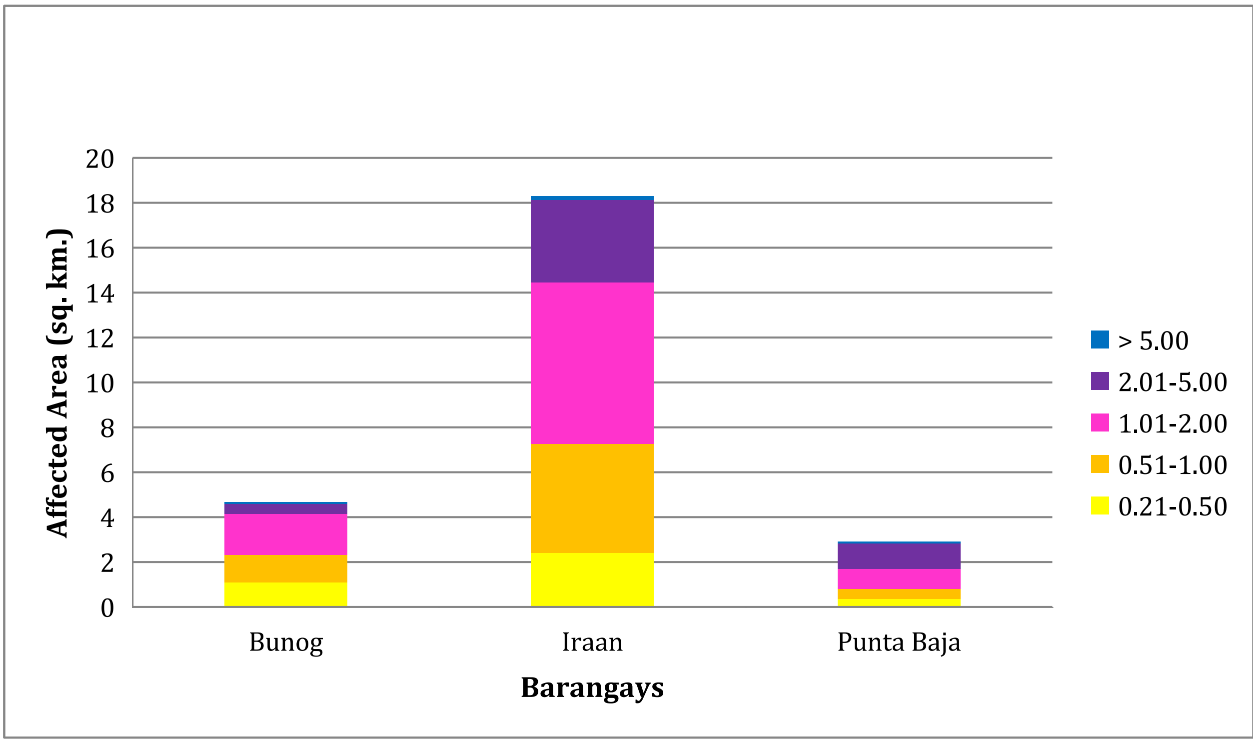


Figure 73. Affected Areas in Rizal, Palawan during 100-Year Rainfall Return Period

Among the barangays in the municipality of Rizal, Iraan is projected to have the highest percentage of area that will experience flood levels at 4.50%. Meanwhile, Bunog posted the second highest percentage of area that may be affected by flood depths at 2.53%.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there was 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 are identified for validation.

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 75.

The flood validation consists of 115 points randomly selected all over the Iraan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.53m. Table 32 shows a contingency matrix of the comparison.

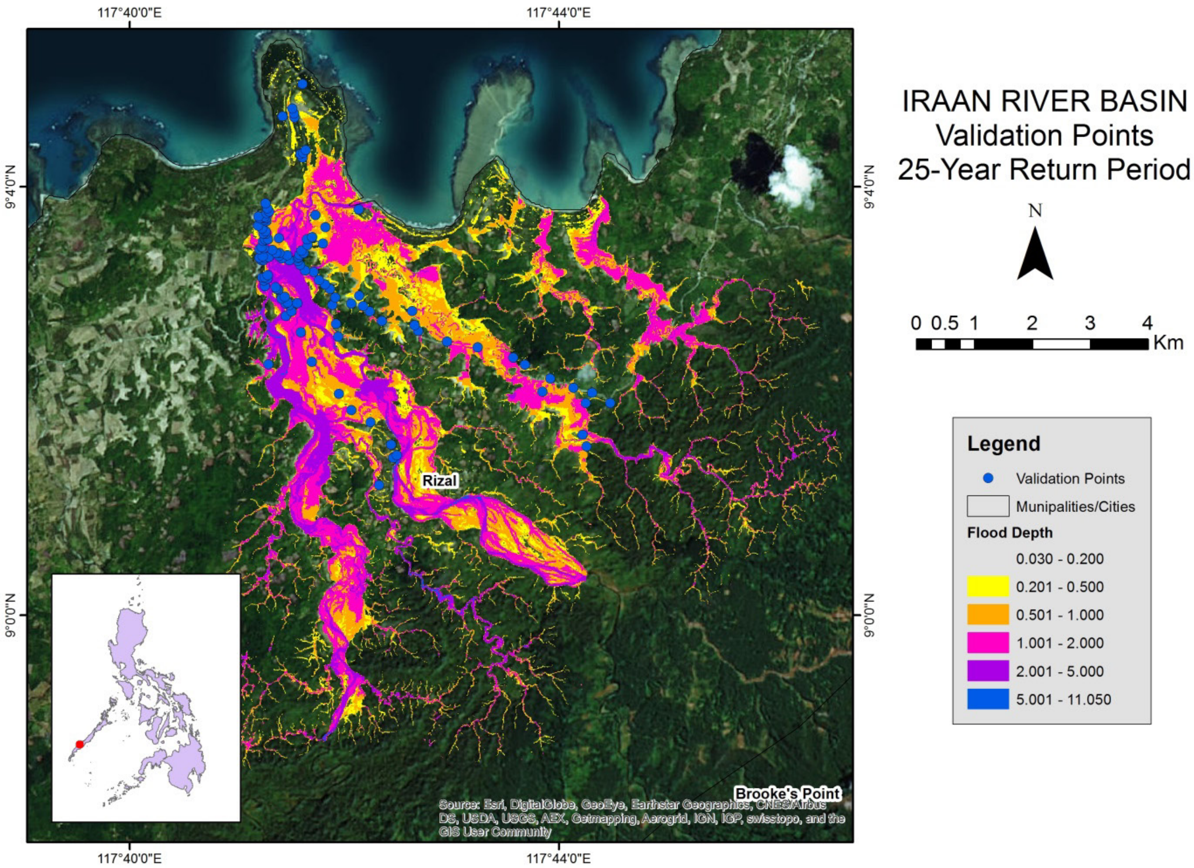


Figure 74. Validation points for 25-year Flood Depth Map of Iraan Floodplain

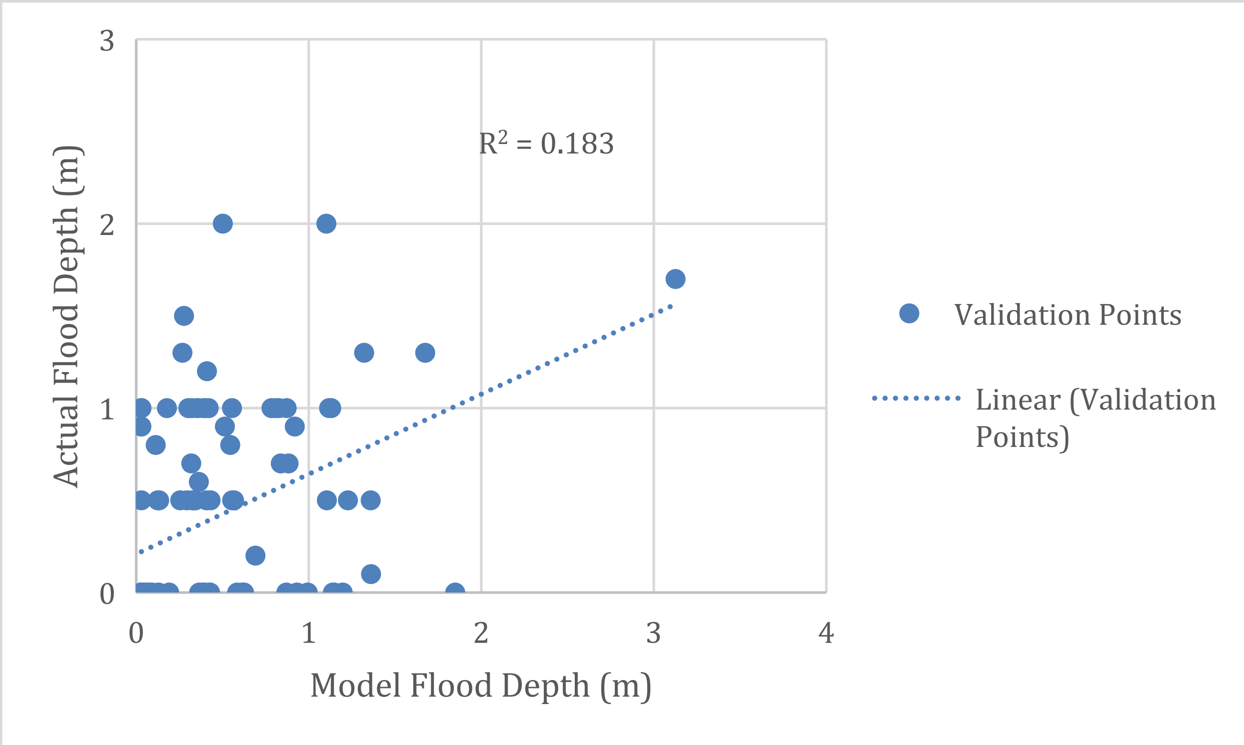


Figure 75. Flood map depth vs. actual flood depth

Table 32. Actual flood vs simulated flood depth at different levels in the Iraan River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	48	5	8	5	0	0	66
0.21-0.50	3	7	2	3	0	0	15
0.51-1.00	5	9	10	2	0	0	26
1.01-2.00	0	3	1	3	1	0	8
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	56	24	21	13	1	0	115

The overall accuracy generated by the flood model is estimated at 59.13% with 68 points correctly matching the actual flood depths. In addition, there were 14 points estimated one level above and below the correct flood depths while there were 19 points and 5 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 21 points were underestimated in the modelled flood depths of Iraan. Table 33 depicts the summary of the Accuracy Assessment in the Iraan River Basin Survey.

Table 33. The summary of the Accuracy Assessment in the Iraan River Basin Survey

	No. of Points	%
Correct	68	59.13
Overestimated	26	22.61
Underestimated	21	18.26
Total	115	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specification of the Pegasus Sensor

Table A-1.1 Parameters and Specifications 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 Certificates of Reference Points Used

1. PLW-121

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

July 21, 2015

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: **PALAWAN**
Station Name: **PLW-121**
Order: **2nd**

Island: **LUZON**
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**
Barangay: **CAMPONG ULAY**
MSL Elevation:

PRS92 Coordinates

Latitude: **8° 56' 1.71426"**	Longitude: **117° 34' 23.99157"**	Ellipsoidal Hgt: **8.98036 m.**

WGS84 Coordinates

Latitude: **8° 55' 57.38325"**	Longitude: **117° 34' 29.39124"**	Ellipsoidal Hgt: **58.05800 m.**

PTM / PRS92 Coordinates

Northing: **987945.887 m.**	Easting: **398086.54 m.**	Zone: **1A**

UTM / PRS92 Coordinates

Northing: **987,521.12**	Easting: **563,030.26**	Zone: **50**

Location Description

PLW-121
From poblacion Rizal travel S towards Brgy. Campong Ulay approximately 16 kms. up to Cabkungan Elem. School. Station is located in an open lot inside the school SW edge of the basketball court. Mark is the head of 4" copper nail flushed in a cement putty 30cm x 30cm x 120cm embedded 1m on the ground with inscriptions "PLW-121 2007 NAMRIA."

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8086767 I**
T.N.: **2015-1696**

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

9907212015170528

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 PLW-121

2. PLW-137

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

December 02, 2015

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: **PALAWAN**
Station Name: **PLW-137**
Order: **2nd**

Island: **LUZON**	Barangay: **IPILAN**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 11' 2.95364"**	Longitude: **118° 4' 48.04729"**	Ellipsoidal Hgt: **35.83359 m.**
	WGS84 Coordinates	
Latitude: **9° 10' 58.60442"**	Longitude: **118° 4' 53.42391"**	Ellipsoidal Hgt: **85.64700 m.**
	PTM / PRS92 Coordinates	
Northing: **1015530.347 m.**	Easting: **453844.056 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **1,015,326.41**	Easting: **618,656.03**	Zone: **50**

Location Description

PLW-137
From Narra poblacion, travel SW towards Brgy. Abo-Abo for 36 kms. Upon reaching the junction turn NW and travel for 4 kms. until reaching Brgy. Ipil. Station is located at the top of the ridge along the highway approximately 170 m SE of KM 133. Mark is the head of 4" copper nail flushed in a cement putty 30cm x 30cm x 120cm embedded 1 m on the ground with inscriptions "PLW-137 2007 NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088735 I**
T.N.: **2015-3959**

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

9912022015105606

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 PLW-137

Annex 3. Baseline Processing Reports of Reference Points Used

Project information		Coordinate System	
Name:	C:\Users\Windows User\Documents \Business Center - HCE\PLW121-BLLM1.vce	Name:	UTM
		Datum:	PRS 92
Size:	189 KB	Zone:	50 North (117E)
Modified:	8/5/2015 5:59:19 PM (UTC:8)	Geoid:	EGMPH
Time zone:	Taipei Standard Time	Vertical datum:	
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
PLW 121 --- BLLM1A (B2)	PLW 121	BLLM1A	Fixed	0.004	0.010	33°32'53"	13490.902	-11.050
PLW 121 --- BLLM1B (B1)	PLW 121	BLLM1B	Fixed	0.004	0.011	33°32'53"	13490.909	-11.052

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

PLW 121 - BLLM1A (7:49:14 AM-1:25:04 PM) (S2)

Baseline observation:	PLW 121 --- BLLM1A (B2)
Processed:	8/5/2015 6:01:20 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.010 m
RMS:	0.009 m
Maximum PDOP:	1.767
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	7/11/2015 7:49:34 AM (Local: UTC+8hr)
Processing stop time:	7/11/2015 1:25:04 PM (Local: UTC+8hr)
Processing duration:	05:35:30
Processing interval:	5 seconds

1

Figure A-3.1 Baseline Processing Report - A

Vector Components (Mark to Mark)

From:	PLW 121				
Grid		Local		Global	
Easting	563030.260 m	Latitude	N8°56'01.71425"	Latitude	N8°55'57.38325"
Northing	987521.114 m	Longitude	E117°34'23.99161"	Longitude	E117°34'29.39124"
Elevation	10.335 m	Height	8.980 m	Height	58.058 m

To:	BLLM1A				
Grid		Local		Global	
Easting	570465.682 m	Latitude	N9°02'07.68639"	Latitude	N9°02'03.33580"
Northing	998772.489 m	Longitude	E117°38'28.10618"	Longitude	E117°38'33.49665"
Elevation	-0.716 m	Height	-2.070 m	Height	46.965 m

Vector					
ΔEasting	7435.421 m	NS Fwd Azimuth	33°32'53"	ΔX	-5788.617 m
ΔNorthing	11251.375 m	Ellipsoid Dist.	13490.902 m	ΔY	-5020.895 m
ΔElevation	-11.052 m	ΔHeight	-11.050 m	ΔZ	11103.460 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000061683		
Y	-0.0000089563	0.0000212884	
Z	-0.0000018603	0.0000039102	0.0000013613

2

Figure A-3.2 Baseline Processing Report - B

Project information		Coordinate System	
Name:	C:\Users\Windows User\Documents \Business Center - HCE\PLW 137 QZT 1 QZT 2.vce	Name:	UTM
		Datum:	PRS 92
Size:	271 KB	Zone:	50 North (117E)
Modified:	7/24/2015 6:13:47 PM (UTC:8)	Geoid:	EGMPH
Time zone:	Taipei Standard Time	Vertical datum:	
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
plw 137 --- qzt 1 (B1)	plw 137	qzt 1	Fixed	0.005	0.011	269°40'42"	21218.741	-26.495
plw 137 --- qzt 2 (B2)	plw 137	qzt 2	Fixed	0.018	0.037	269°35'56"	21211.522	-28.970

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

plw 137 - qzt 1 (7:23:34 AM-1:08:19 PM) (S1)

Baseline observation:	plw 137 --- qzt 1 (B1)
Processed:	7/24/2015 6:14:51 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.011 m
RMS:	0.005 m
Maximum PDOP:	2.209
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	7/13/2015 7:23:34 AM (Local: UTC+8hr)
Processing stop time:	7/13/2015 1:08:19 PM (Local: UTC+8hr)
Processing duration:	05:44:45
Processing interval:	5 seconds

1

Figure A-3.3 Baseline Processing Report - C

Vector Components (Mark to Mark)

From:	plw 137				
Grid		Local		Global	
Easting	618656.024 m	Latitude	N9°11'02.95363"	Latitude	N9°10'58.60442"
Northing	1015326.411 m	Longitude	E118°04'48.04733"	Longitude	E118°04'53.42391"
Elevation	35.993 m	Height	35.834 m	Height	85.647 m

To:	qzt 1				
Grid		Local		Global	
Easting	597443.484 m	Latitude	N9°10'58.89071"	Latitude	N9°10'54.52473"
Northing	1015143.507 m	Longitude	E117°53'13.01663"	Longitude	E117°53'18.39361"
Elevation	10.136 m	Height	9.338 m	Height	58.674 m

Vector					
ΔEasting	-21212.540 m	NS Fwd Azimuth	269°40'42"	ΔX	18740.467 m
ΔNorthing	-182.904 m	Ellipsoid Dist.	21218.741 m	ΔY	9950.677 m
ΔElevation	-25.857 m	ΔHeight	-26.495 m	ΔZ	-128.040 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000094504		
Y	-0.0000117410	0.0000274170	
Z	-0.0000021534	0.0000044403	0.0000015882

2

Figure A-3.4 Baseline Processing Report - D

Processing style

Elevation mask: 10.0 deg

Auto start processing: Yes

Start automatic ID numbering: AUTO0001

Continuous vectors: No

Generate residuals: Yes

Antenna model: Automatic

Ephemeris type: Automatic

Frequency: Multiple Frequencies

Processing Interval: Use all data

Force float: No

Acceptance Criteria

Vector Component	Flag	Fail
Horizontal Precision >	0.050 m + 1.000 ppm	0.100 m + 1.000 ppm
Vertical Precision >	0.100 m + 1.000 ppm	0.200 m + 1.000 ppm

plw 137 - qzt 2 (1:21:54 PM-5:50:14 PM) (S2)

Baseline observation: plw 137 --- qzt 2 (B2)

Processed: 7/24/2015 6:15:02 PM

Solution type: Fixed

Frequency used: Dual Frequency (L1, L2)

Horizontal precision: 0.018 m

Vertical precision: 0.037 m

RMS: 0.004 m

Maximum PDOP: 1.717

Ephemeris used: Broadcast

Antenna model: NGS Absolute

Processing start time: 7/13/2015 1:21:54 PM (Local: UTC+8hr)

Processing stop time: 7/13/2015 5:50:14 PM (Local: UTC+8hr)

Processing duration: 04:28:20

Processing interval: 5 seconds

22

Figure A-3.5 Baseline Processing Report - E

Vector Components (Mark to Mark)

From:	plw 137				
Grid		Local		Global	
Easting	618656.024 m	Latitude	N9°11'02.95363"	Latitude	N9°10'58.60442"
Northing	1015326.411 m	Longitude	E118°04'48.04733"	Longitude	E118°04'53.42391"
Elevation	35.993 m	Height	35.834 m	Height	85.647 m

To:	qzt 2				
Grid		Local		Global	
Easting	597450.975 m	Latitude	N9°10'57.93286"	Latitude	N9°10'53.56696"
Northing	1015114.108 m	Longitude	E117°53'13.25970"	Longitude	E117°53'18.63670"
Elevation	7.660 m	Height	6.864 m	Height	56.200 m

Vector					
ΔEasting	-21205.049 m	NS Fwd Azimuth	269°35'56"	ΔX	18732.854 m
ΔNorthing	-212.303 m	Ellipsoid Dist.	21211.522 m	ΔY	9949.197 m
ΔElevation	-28.333 m	ΔHeight	-28.970 m	ΔZ	-157.483 m

Standard Errors

Vector errors:					
σ ΔEasting	0.007 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.011 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.007 m	σ ΔY	0.016 m
σ ΔElevation	0.019 m	σ ΔHeight	0.019 m	σ ΔZ	0.005 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0001228363		
Y	-0.0001285827	0.0002649111	
Z	-0.0000183105	0.0000652757	0.0000238832

23

Figure A-3.6 Baseline Processing Report - F

Annex 4. The LiDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Research Associate (RA)	JASMINE ALVIAR	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ARIES TORNO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JUSTINE JOYA	AAC

Annex 5. Data Transfer Sheet for Iraan Floodplain Flights

DATA TRANSFER SHEET
8/3/2015(palawan)

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	
14-Jun-15	3049P	1BLK42S165A	Pegasus	969	na	7	162	31	252	18.3	29.3	16.3	1KB	1KB	70/67	na	Z:\DAC\RAW DATA
20-Jun-15	3073P	1BLK42S171A	Pegasus	361	na	3.65	107	12.3	88	7.1	NA	4.15	1KB	1KB	92	na	Z:\DAC\RAW DATA
7-Jul	3141P	1BLK42QRT188A	Pegasus	1.84	na	11.6	256	2.11	15/20/9/1	35.5	108	8.43	1KB	1KB	95	na	Z:\DAC\RAW DATA
8-Jul	3145P	1BLK42QRT189A	Pegasus	752	na	5.41	124	184	101	14.8	NA	11.9	1KB	1KB	176/95	na	Z:\DAC\RAW DATA
11-Jul	3157P	1BLK42PO192A	Pegasus	2.29	na	13	279	35.2	369	43.3	113	20.6	1KB	1KB	206	na	Z:\DAC\RAW DATA
11-Jul	3159P	1BLK42PO192B	Pegasus	1.11	na	8.95	199	55.5	1	21.6	25.9	20.6	1KB	1KB	NA	na	Z:\DAC\RAW DATA
12-Jul	3161P	1BLK42LM193A	Pegasus	1.51	427/407	9.62	214	41.7	359	28.8	67.6	4.29	1KB	1KB	215	na	Z:\DAC\RAW DATA
13-Jul	3165P	1BLK42LM194A	Pegasus	1.5	na	10.5	255	36.4	295	28.9	na	11.5	1KB	1KB	na	na	Z:\DAC\RAW DATA
13-Jul	3167P	1BLK42JS194B	Pegasus	329	na	3.65	106	4.93	2	7.36	11	11.5	1KB	1KB	106/123	NA	Z:\DAC\RAW DATA
15-Jul	3173P	1BLK42KS196A	Pegasus	160	96/28	2.73	63.2	na	na	3.33	7.6	1.19	1KB	1KB	11	NA	Z:\DAC\RAW DATA

Received from

Name
Position KA
Signature

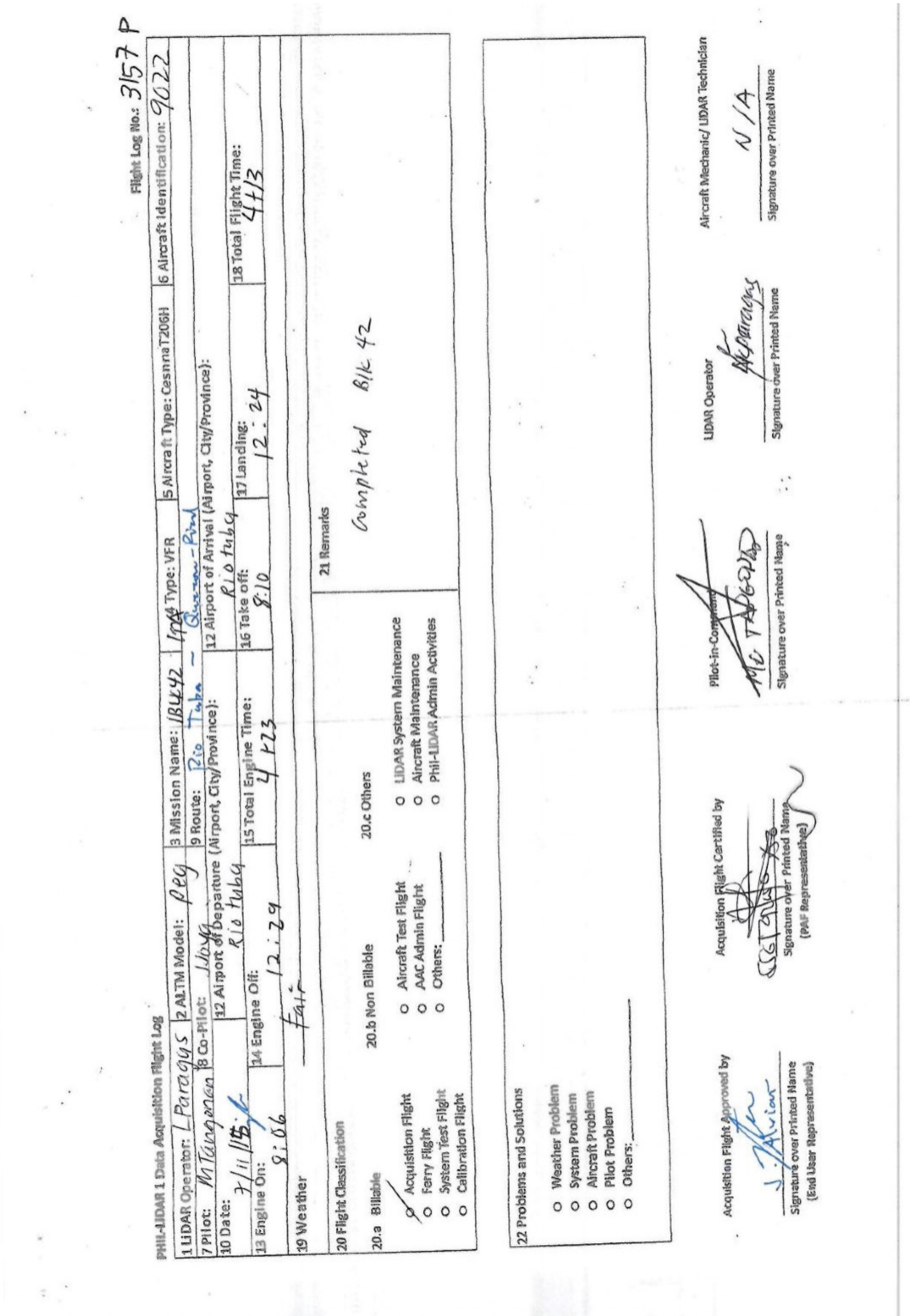
Received by

Name AC Bongat
Position SSRS
Signature 8/5/2015

Figure A-5.1 Data Transfer Sheet for Iraan Floodplain

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1BLK42PO192A Mission


Flight Log No.: 3157P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: L Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK42	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot:	9 Route: Rio Tuba –			
10 Date: 7/11/15	12 Airport of Departure (Airport, City/Province): Rio tuba	12 Airport of Arrival (Airport, City/Province): Rio tuba			
13 Engine On: 8:06	14 Engine Off: 12:29	15 Total Engine Time: 4+23	16 Take off: 8:10	17 Landing: 12:24	18 Total Flight Time: 4+13
19 Weather: Fair					

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

Completed Blk 42

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

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

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

Pilot-in-Command — Signature over Printed Name

LIDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — N/A — Signature over Printed Name

Figure A-6.1 Flight Log for Mission 1BLK42PO192A

2. Flight Log for 1BLK42PO192B Mission

Flight Log No.: 3159P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK42 192B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 7822
7 Pilot: M Tangonan	8 Co-Pilot: J Uy	9 Route: Rio Tuba - Rizal			
10 Date: 7/11/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 15:07	14 Engine Off: 18:19	15 Total Engine Time: 3+12	16 Take off: 15:12	17 Landing: 18:14	18 Total Flight Time: 3+02
19 Weather: Fair					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
✓ Acquisition Flight	o Aircraft Test Flight	o LiDAR System Maintenance
o Ferry Flight	o AAC Admin Flight	o Aircraft Maintenance
o System Test Flight	o Others: ____	o Phil-LiDAR Admin Activities
o Calibration Flight		

21 Remarks

Completed Blk 42

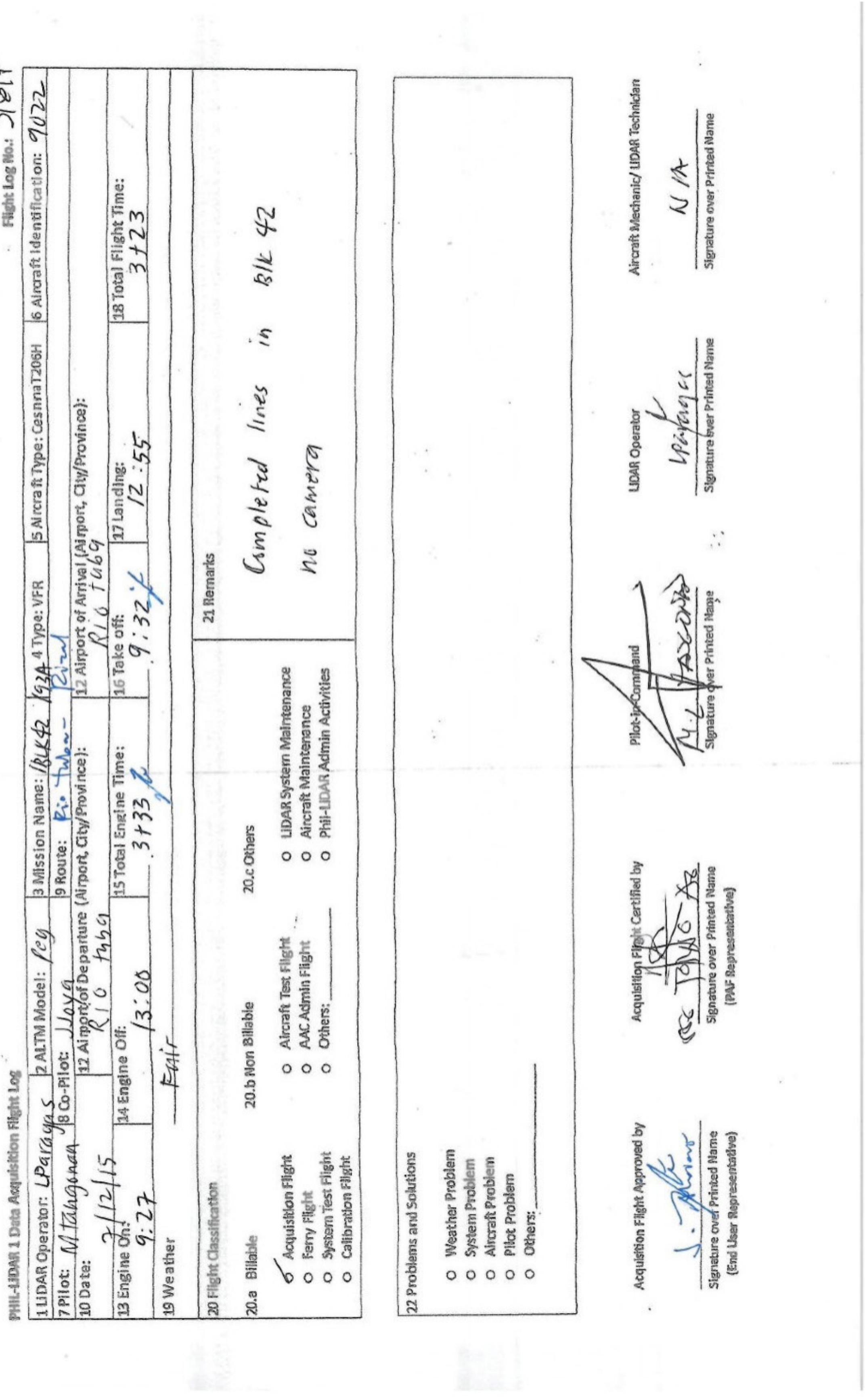
22 Problems and Solutions

- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ____

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Alviar	SSG Bautista PAF	M. Tangonan	G. Sinadjan	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for Mission 1BLK42PO192B

3. Flight Log for 1BLK42LM193A Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3161P

1 LiDAR Operator: L Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK42 193A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route: Rio Tuba - Rio Tuba			
10 Date: 7/12/15	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 9:27	14 Engine Off: 13:00	15 Total Engine Time: 3+33	16 Take off: 9:32	17 Landing: 12:55	18 Total Flight Time: 3+23
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed lines in BLK 42

no camera

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

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

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

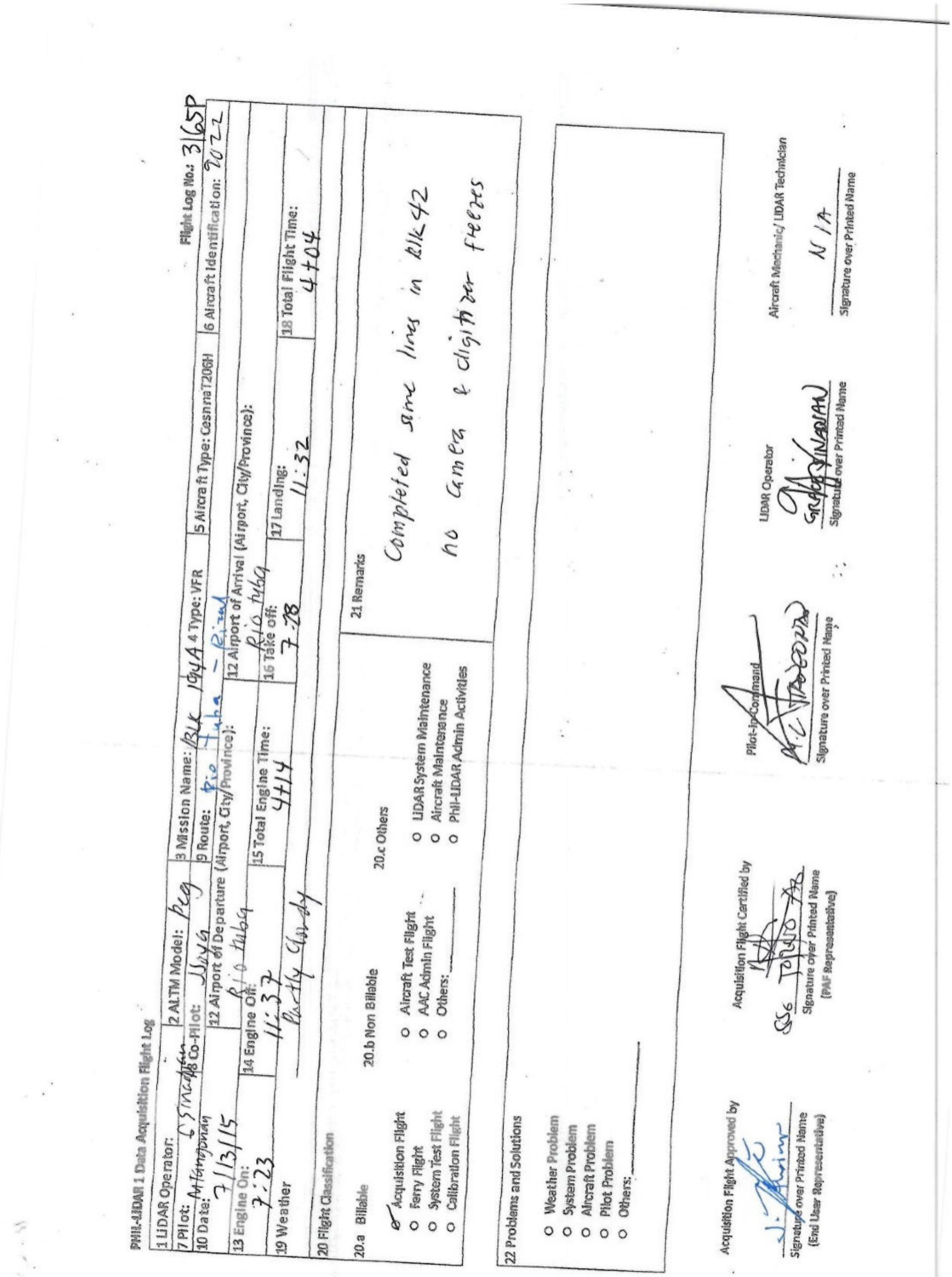
Pilot-in-Command: Signature over Printed Name

LIDAR Operator: Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: N/A Signature over Printed Name

Figure A-6.3 Flight Log for Mission 1BLK42LM193A

4. Flight Log for 1BLK42LM194A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3165P

1 LIDAR Operator: C Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK 194A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot:	8 Co-Pilot:	9 Route: Rio Tuba - Rizal			
10 Date: 7/13/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 7:23	14 Engine Off: 11:37	15 Total Engine Time: 4+14	16 Take off: 7:28	17 Landing: 11:32	18 Total Flight Time: 4+04
19 Weather: Partly Cloudy					

20 Flight Classification

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

20.b Non Billable
- o Aircraft Test Flight
- o AAC Admin Flight
- o Others: ____

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

21 Remarks

Completed some lines in BLK42
no camera & digitizer freezes

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ____

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

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

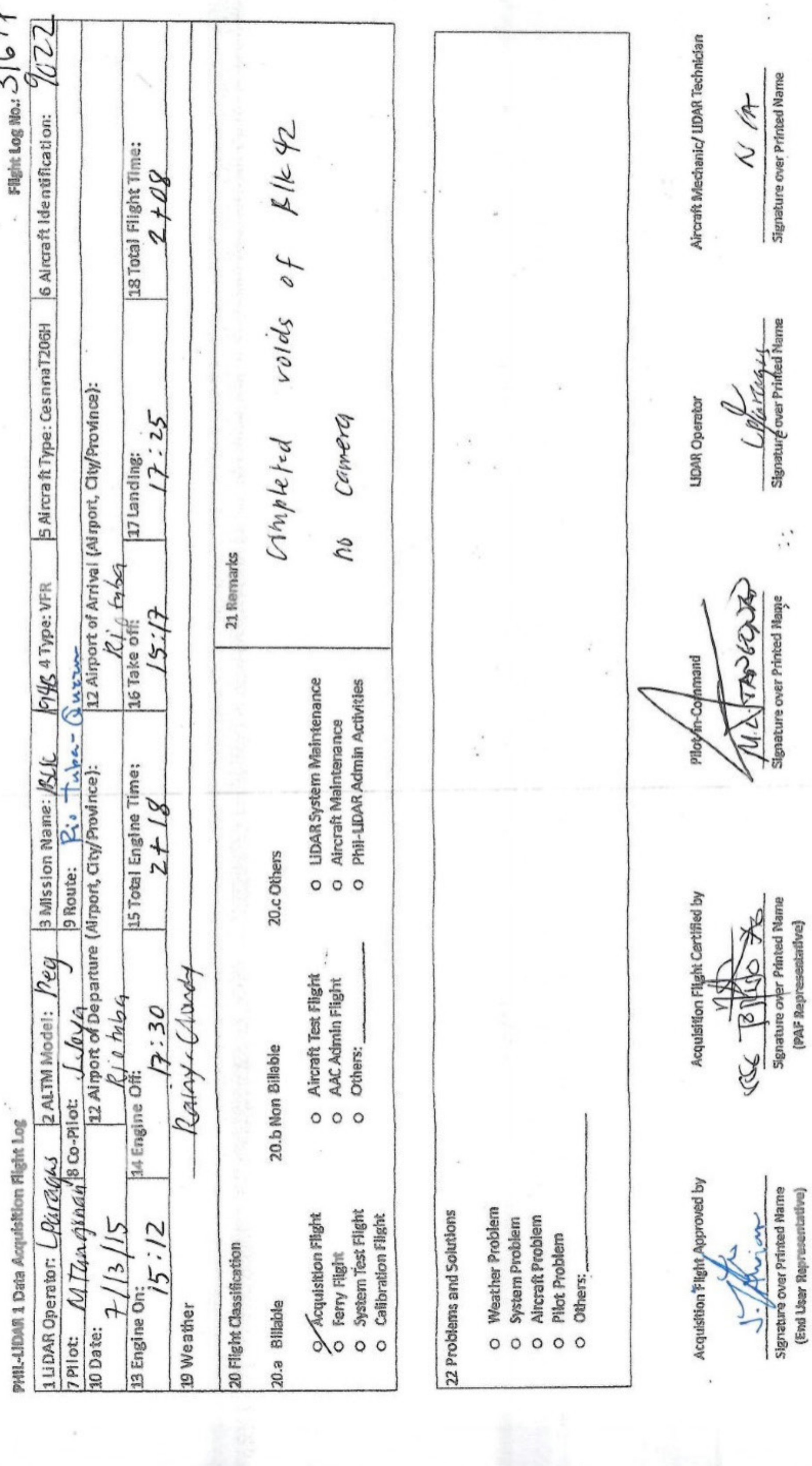
Pilot-in-Command — Signature over Printed Name

LIDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — N/A — Signature over Printed Name

Figure A-6.4 Flight Log for Mission 1BLK42LM194A

5. Flight Log for 1BLK42JS194B Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3167P

1 LiDAR Operator: LParagas	2 ALTM Model: Peg	3 Mission Name: 1BLK 194B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route: Rio Tuba-Quezon			
10 Date: 7/13/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 15:12	14 Engine Off: 17:30	15 Total Engine Time: 2+18	16 Take off: 15:17	17 Landing: 17:25	18 Total Flight Time: 2+08
19 Weather: Rainy, Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Completed voids of Blk 42

no camera

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

Acquisition Flight Approved by: J. Alarion — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: [signature] — Signature over Printed Name (PAF Representative)

Pilot-in-Command: M.L. Tangonan — Signature over Printed Name

LIDAR Operator: L Paragas — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: N/A — Signature over Printed Name

Figure A-6.5 Flight Log for Mission 1BLK42JS194B

Annex 7. Flight Status Reports

Table A-7.1

IRAAN FLOODPLAIN

(July 11-13, 2015)

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3157P	BLK 42P, PS, N, M	1BLK42PO192A	L. Paragas	July 11, 2015	Surveyed BLK 42P, PS, N, and parts of M
3159P	BLK 42O, N, P	1BLK42PO192B	G. Sinadjan	July 11, 2015	Surveyed BLK 42O, N, and gaps in BLK 42P
3161P	BLK 42LM	1BLK42LM193A	L. Paragas	July 12, 2015	Surveyed BLK 42L and BLK 42M
3165P	BLK 42LM	1BLK42LM194A	G. Sinadjan	July 13, 2015	Surveyed remaining areas In BLK 42L and BLK 42M
3167P	BLK 42JS	1BLK42JS194B	L. Paragas	July 13, 2015	Surveyed remaining gap in BLK 42J

FLIGHT LOG NO. 3157P

AREA: BLOCK 42P, 42PS, 42N & 42M

MISSION NAME: 1BLK42PO192A

SURVEY COVERAGE:

Scan Freq: 30 Hz

Scan Angle: 25 deg

PRF: 200

LAS

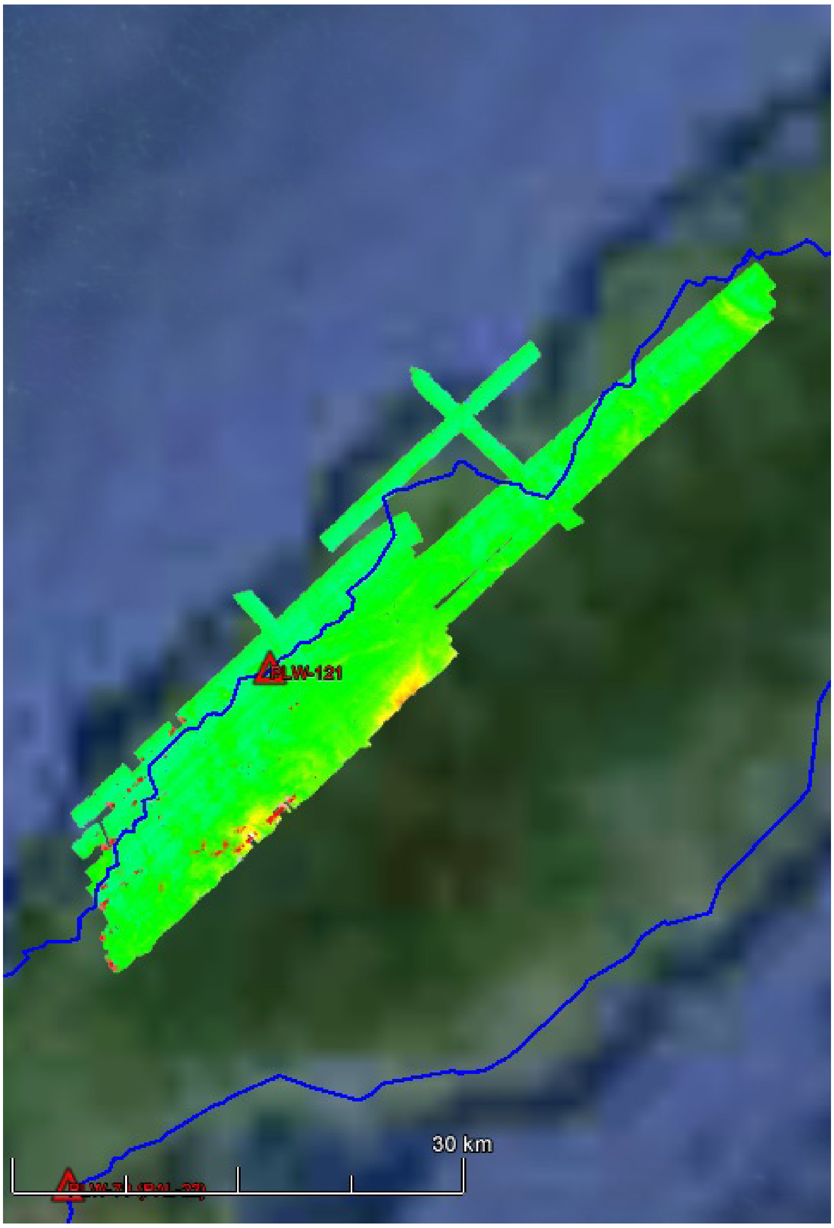


Figure A-7.1 Swath for Flight No. 3157P

FLIGHT LOG NO. 3159P

AREA: BLOCK 42ONP

MISSION NAME: 1BLK42PO192B

SURVEY COVERAGE:

Scan Freq: 30 Hz

Scan Angle: 25 deg

PRF: 200

LAS

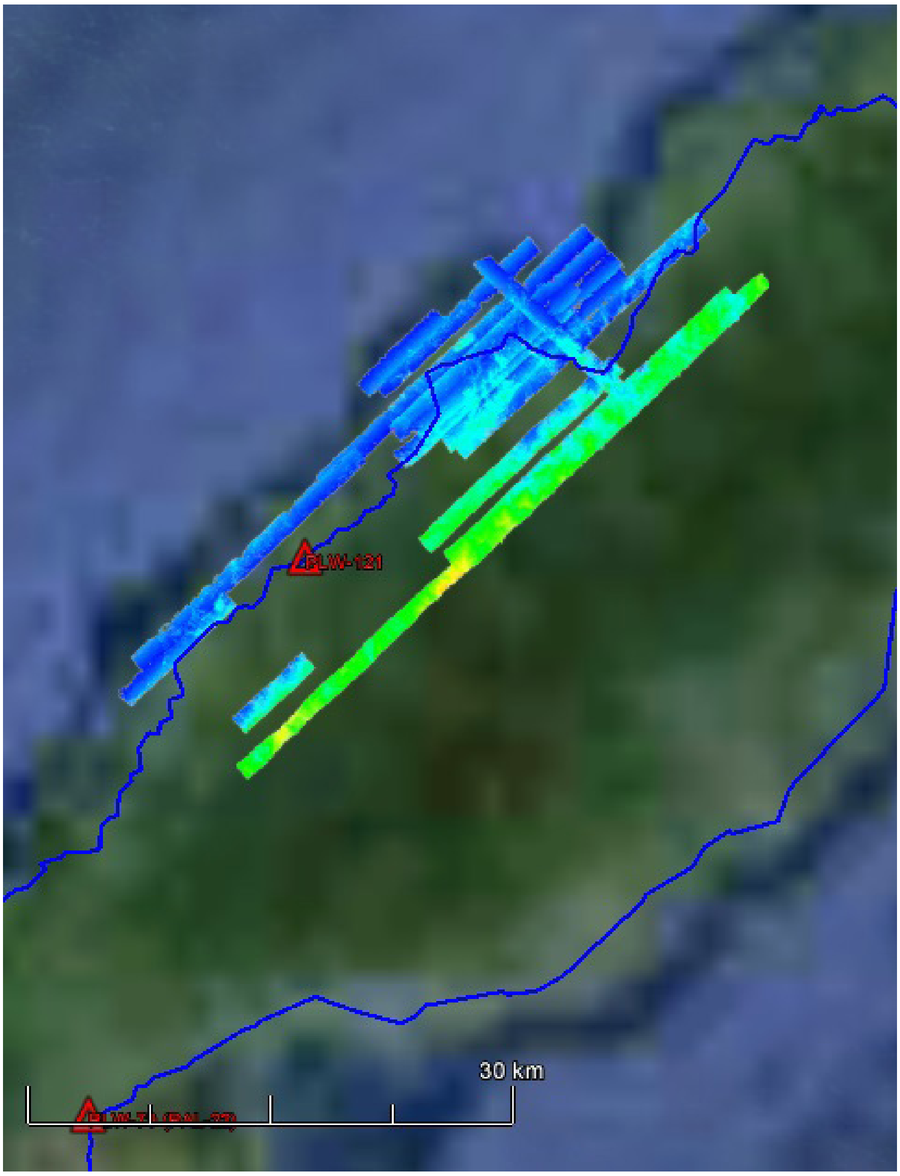


Figure A-7.2 Swath for Flight No. 3159P

FLIGHT LOG NO. 3161P
AREA: BLOCK 42LM
MISSION NAME: 1BLK42LM193A
SURVEY COVERAGE:

Scan Freq: 30 Hz
Scan Angle: 25 deg
PRF: 200

LAS

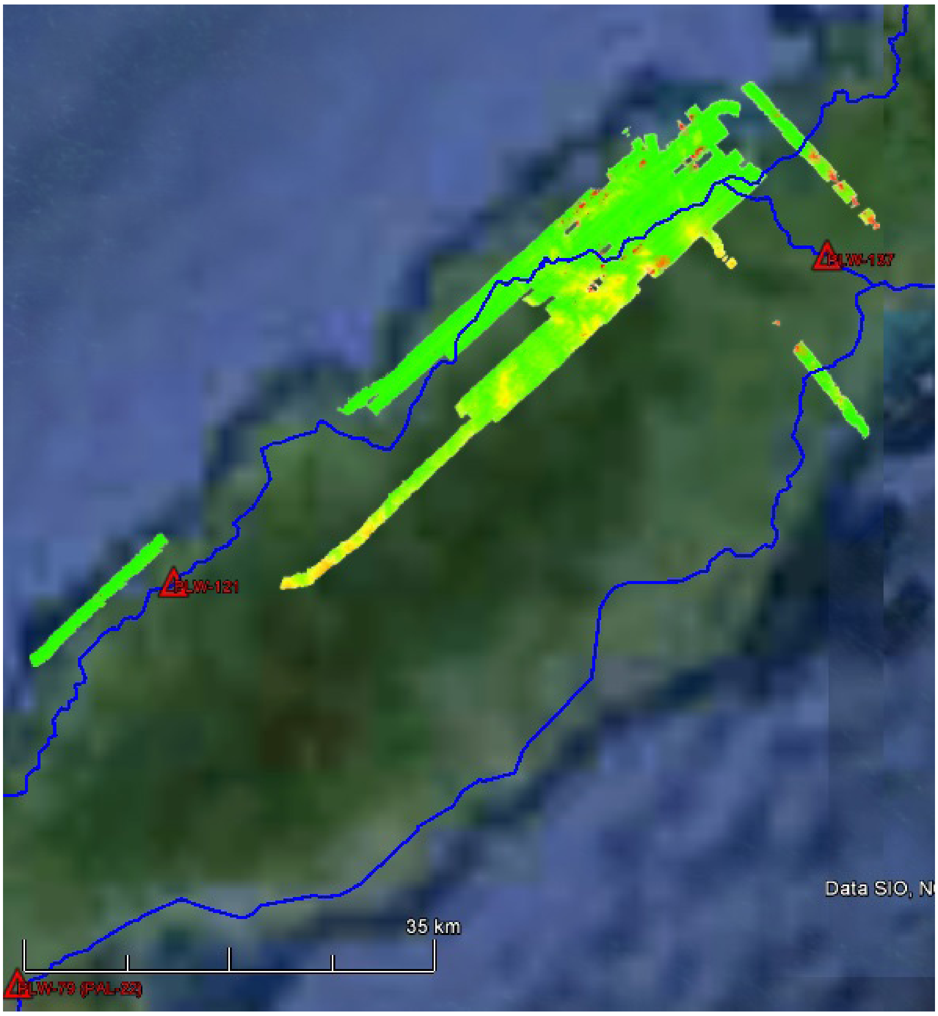


Figure A-7.3 Swath for Flight No. 3161P

FLIGHT LOG NO. 3165P
AREA: BLOCK 42LM
MISSION NAME: 1BLK42LM194A
SURVEY COVERAGE:

Scan Freq: 30 Hz
Scan Angle: 25 deg
PRF: 200

LAS

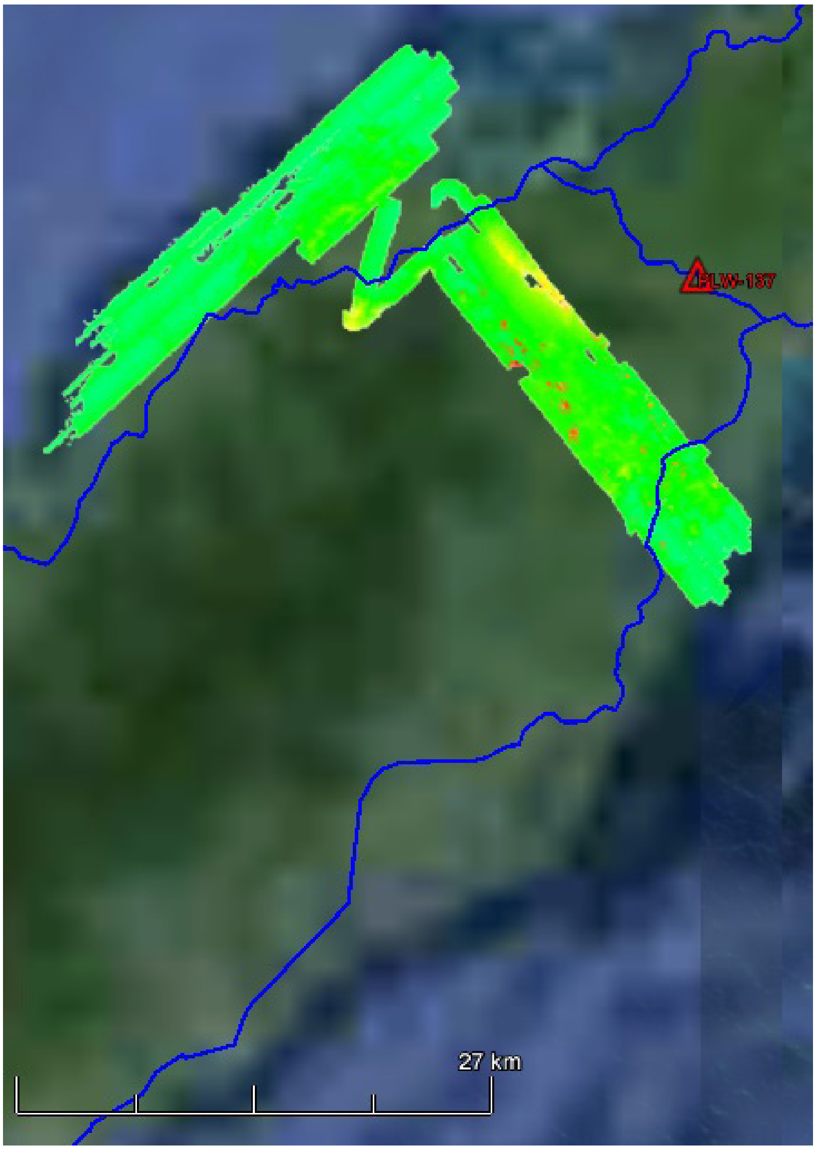


Figure A-7.4 Swath for Flight No. 3165P

FLIGHT LOG NO. 3167P

AREA: BLOCK 42JS

MISSION NAME: 1BLK42JS194B

SURVEY COVERAGE:

Scan Freq: 30 Hz

Scan Angle: 25 deg

PRF: 200

LAS

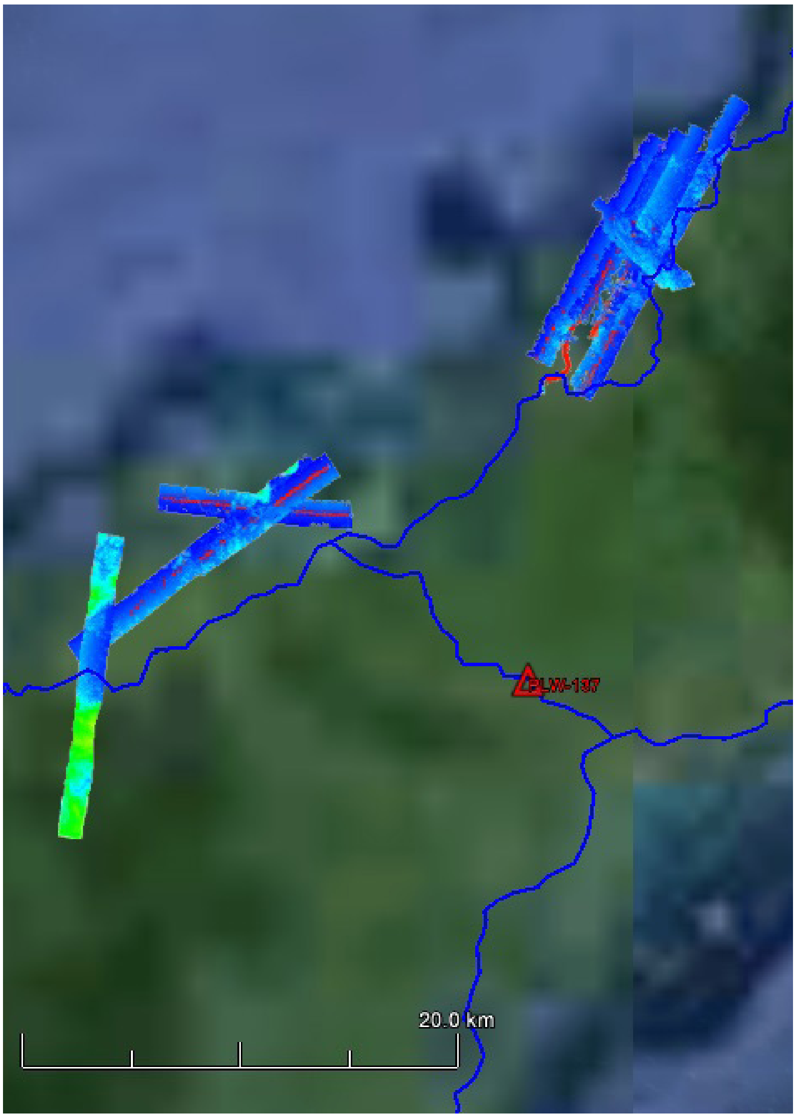


Figure A-7.5 Swath for Flight No. 3167P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Block 42L

Flight Area	West Palawan
Mission Name	Block 42L
Inclusive Flights	3161P & 3165P
Range data size	57.70 GB
POS	469 MB
Image	78.10 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.80
RMSE for East Position (<4.0 cm)	2.60
RMSE for Down Position (<8.0 cm)	1.35
Boresight correction stdev (<0.001deg)	0.000188
IMU attitude correction stdev (<0.001deg)	0.000512
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	41.20
Ave point cloud density per sq.m. (>2.0)	2.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	286
Maximum Height	330.22
Minimum Height	35.92
Classification (# of points)	
Ground	156485701
Low vegetation	131781027
Medium vegetation	193453766
High vegetation	471929280
Building	7313285
Orthophoto	No

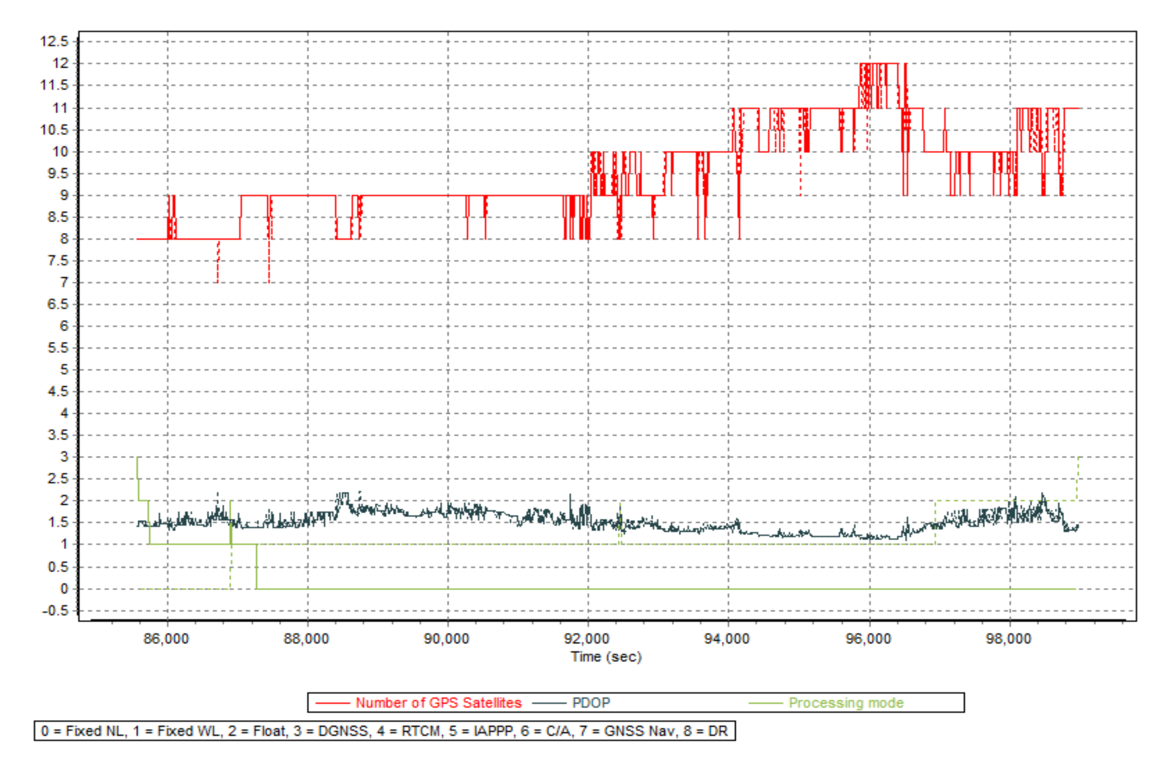


Figure A-8.1 Solution Status

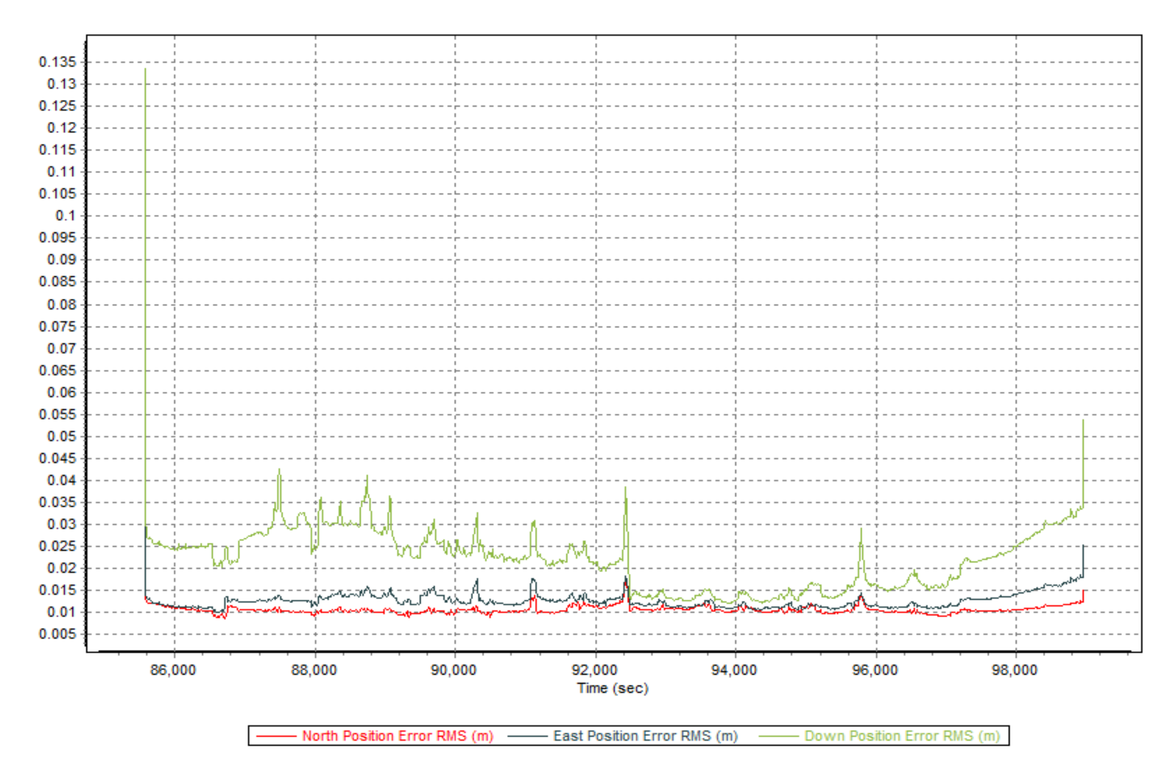


Figure A-8.2 Smoothed Performance Metric Parameters

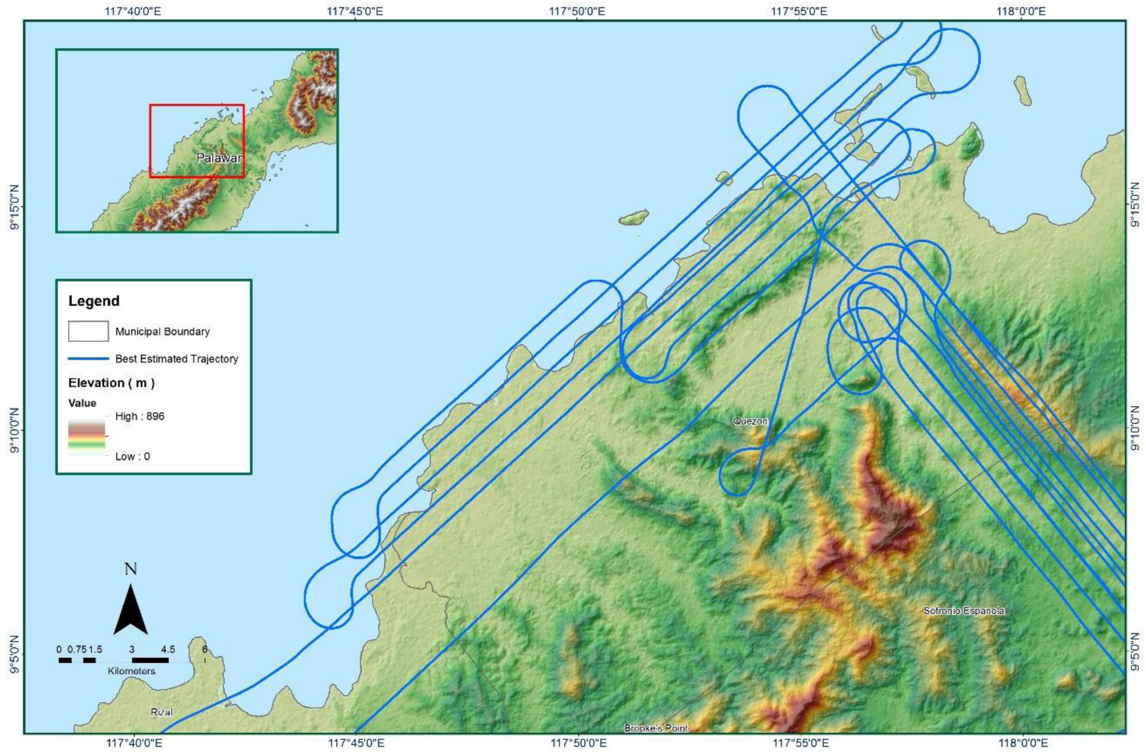


Figure A-8.3 Best Estimated Trajectory

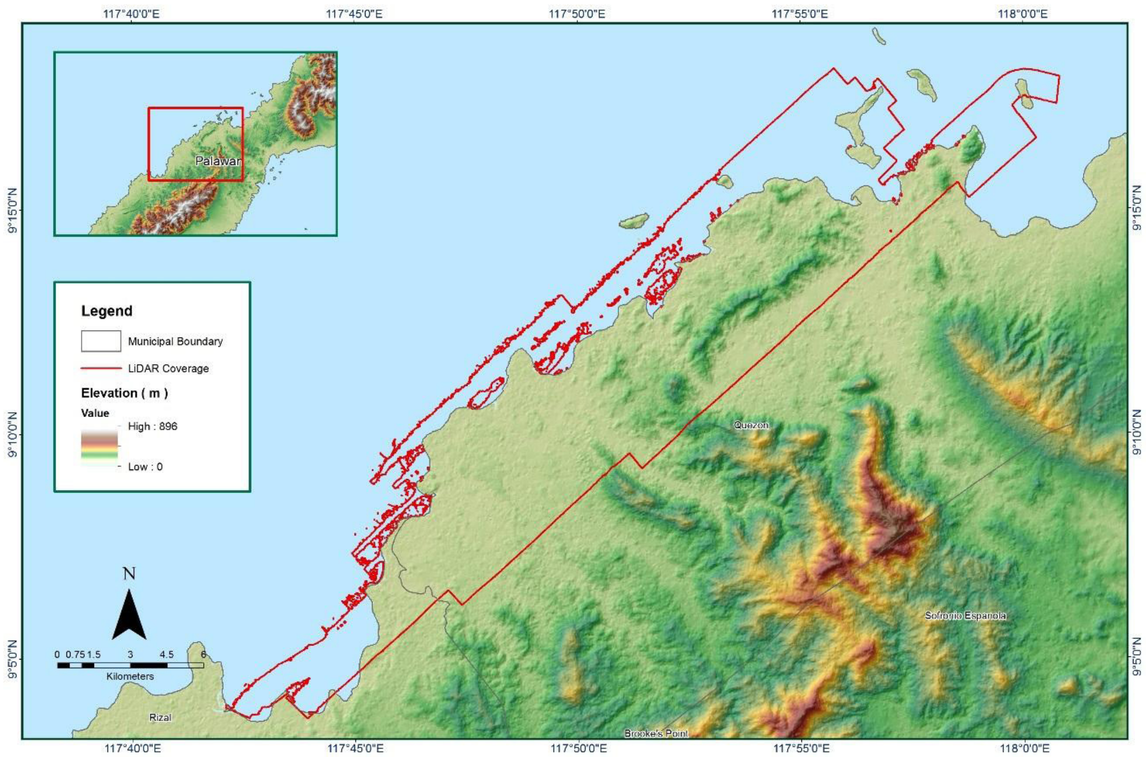


Figure A-8.4 Coverage of LiDAR data

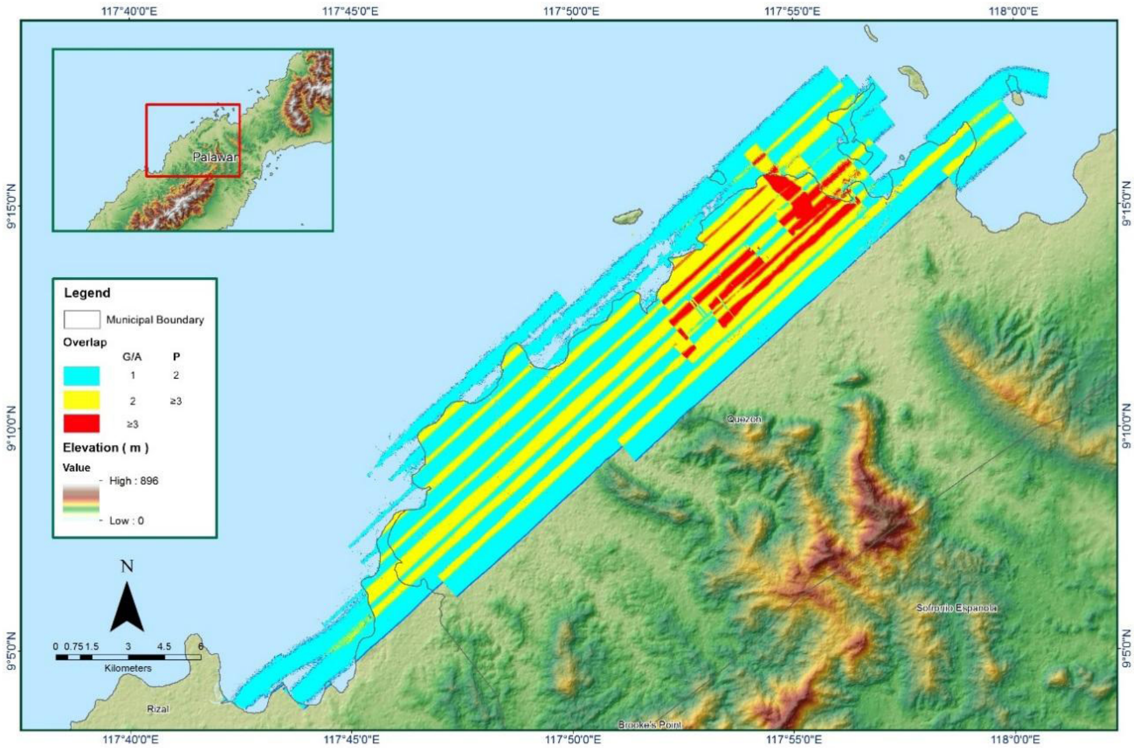


Figure A-8.5 *5* Image of data overlap

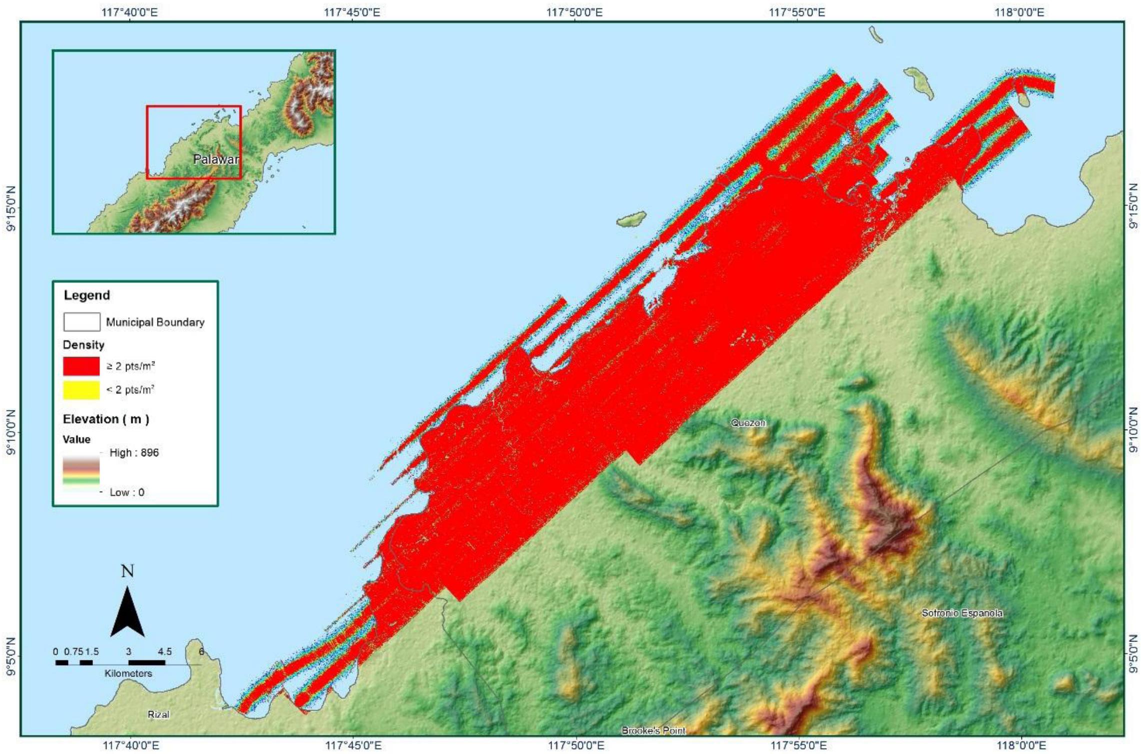


Figure A-8.6 Density map of merged LiDAR data

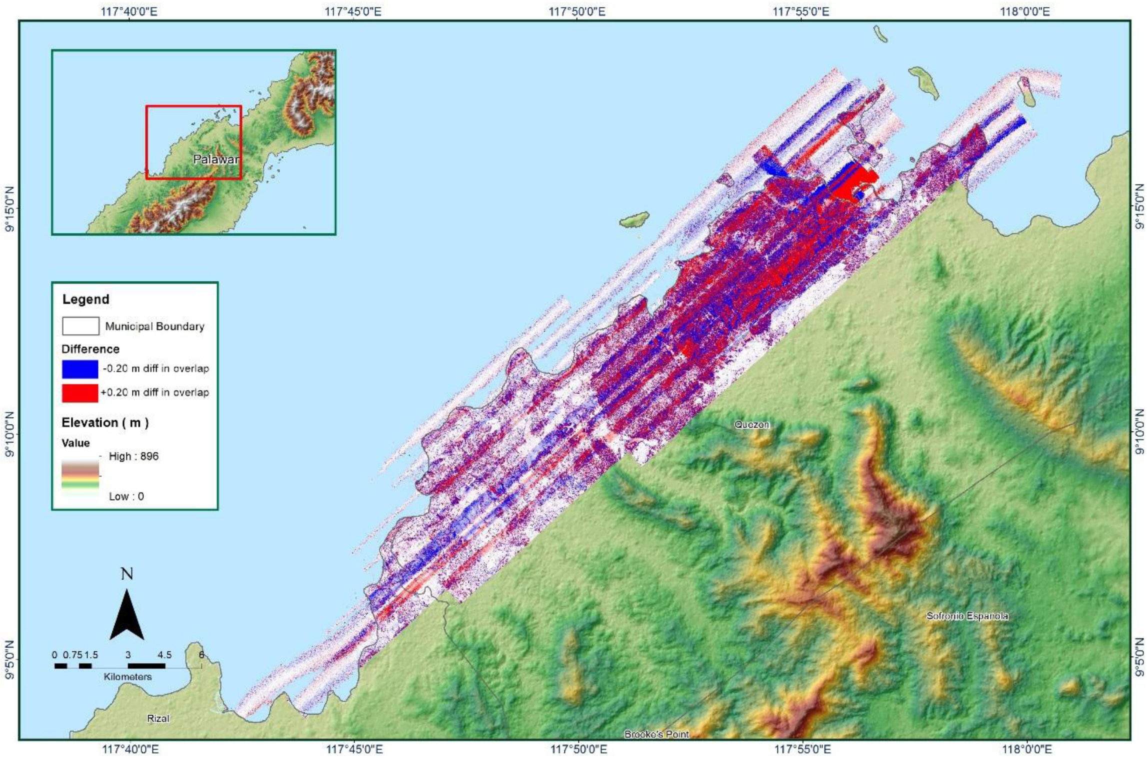


Figure A-8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Block 42M

Flight Area	**West Palawan**
Mission Name	**Block 42M**
Inclusive Flights	3161P, 3165P & 3167P
Range data size	65.06 GB
POS	575 MB
Image	83.03 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.00
RMSE for East Position (<4.0 cm)	4.60
RMSE for Down Position (<8.0 cm)	6.40
Boresight correction stdev (<0.001deg)	0.000283
IMU attitude correction stdev (<0.001deg)	0.000320
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	33.01
Ave point cloud density per sq.m. (>2.0)	2.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	287
Maximum Height	577.26
Minimum Height	41
Classification (# of points)	
Ground	125649379
Low vegetation	76720115
Medium vegetation	157777193
High vegetation	708301440
Building	9606648
Orthophoto	No

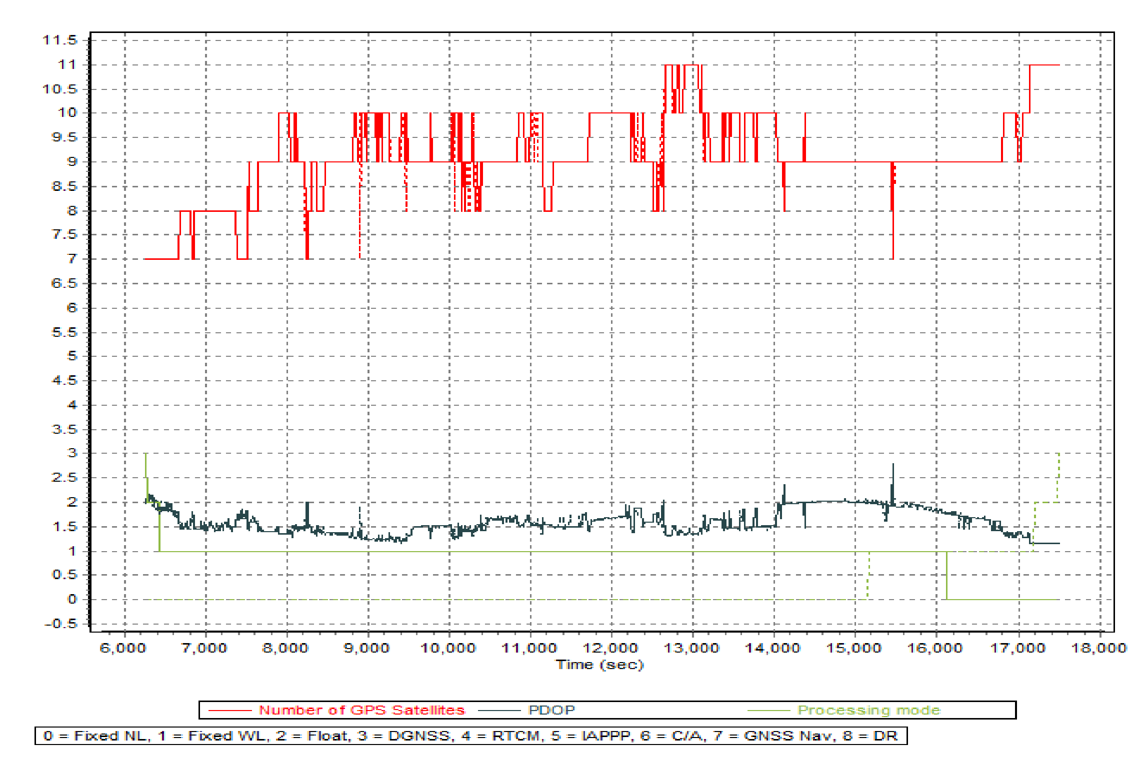


Figure A-8.8 . Solution Status

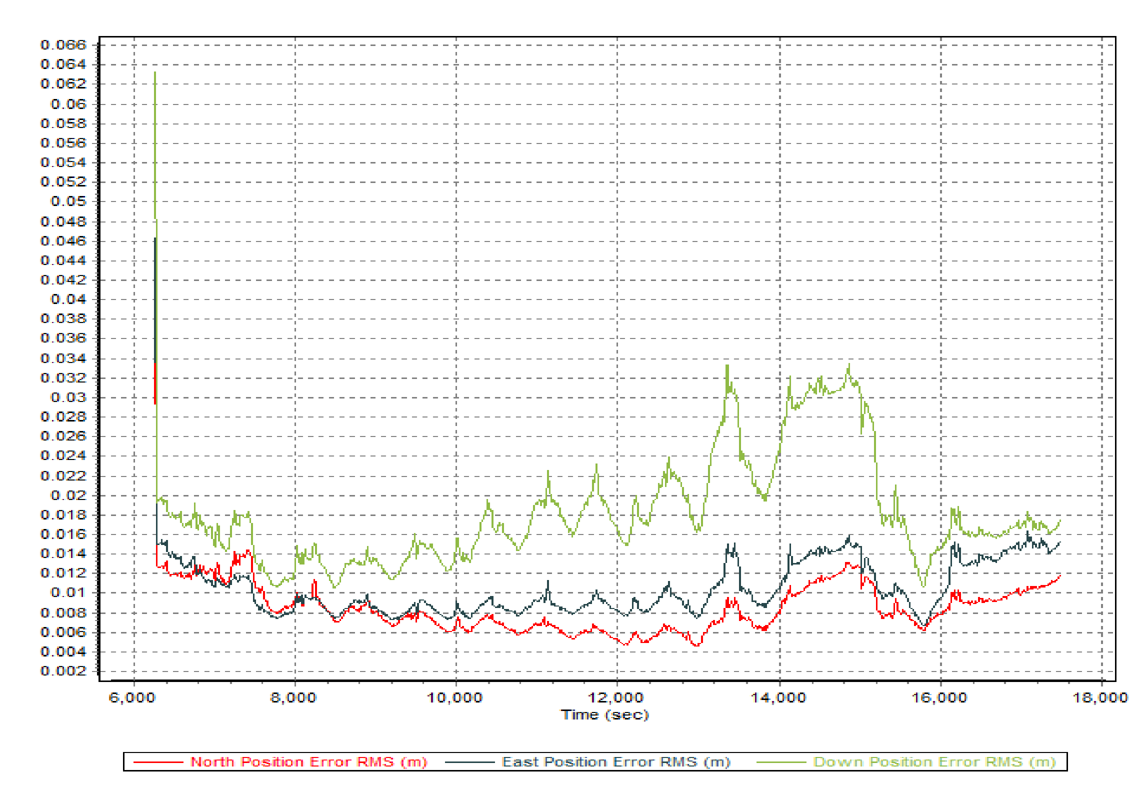


Figure A-8.9 Smoothed Performance Metric Parameters

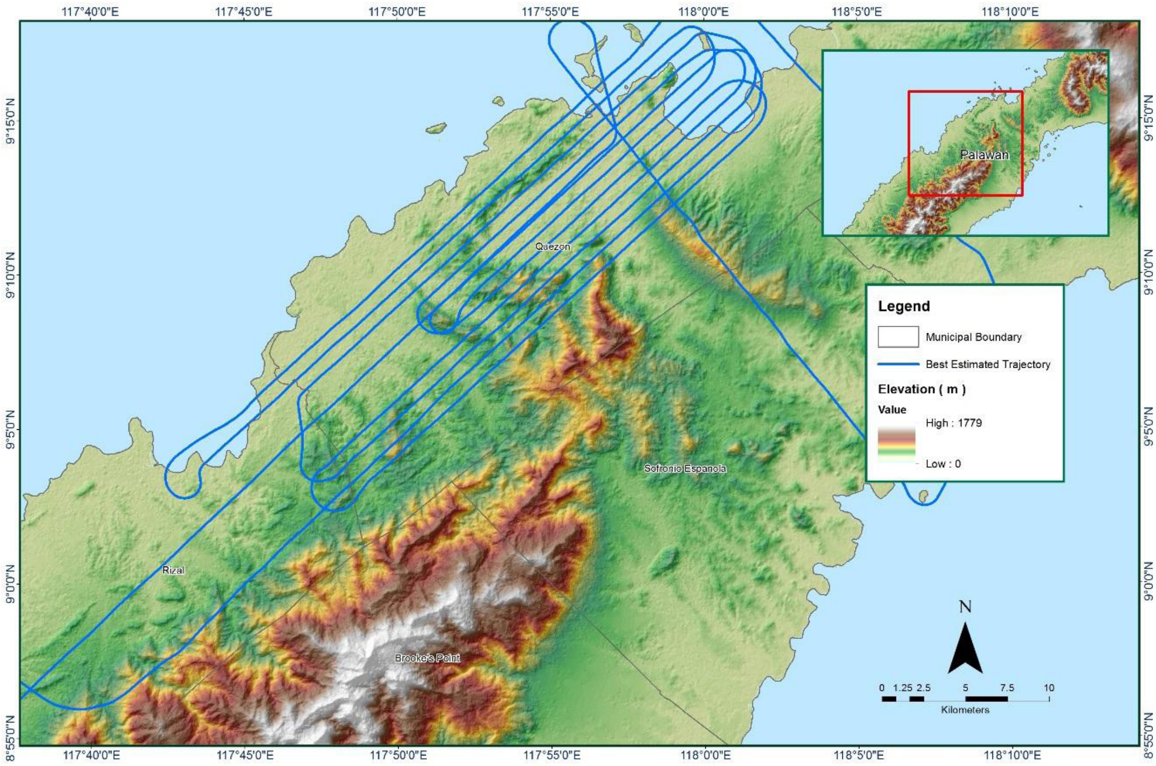


Figure A-8.10 Best Estimated Trajectory

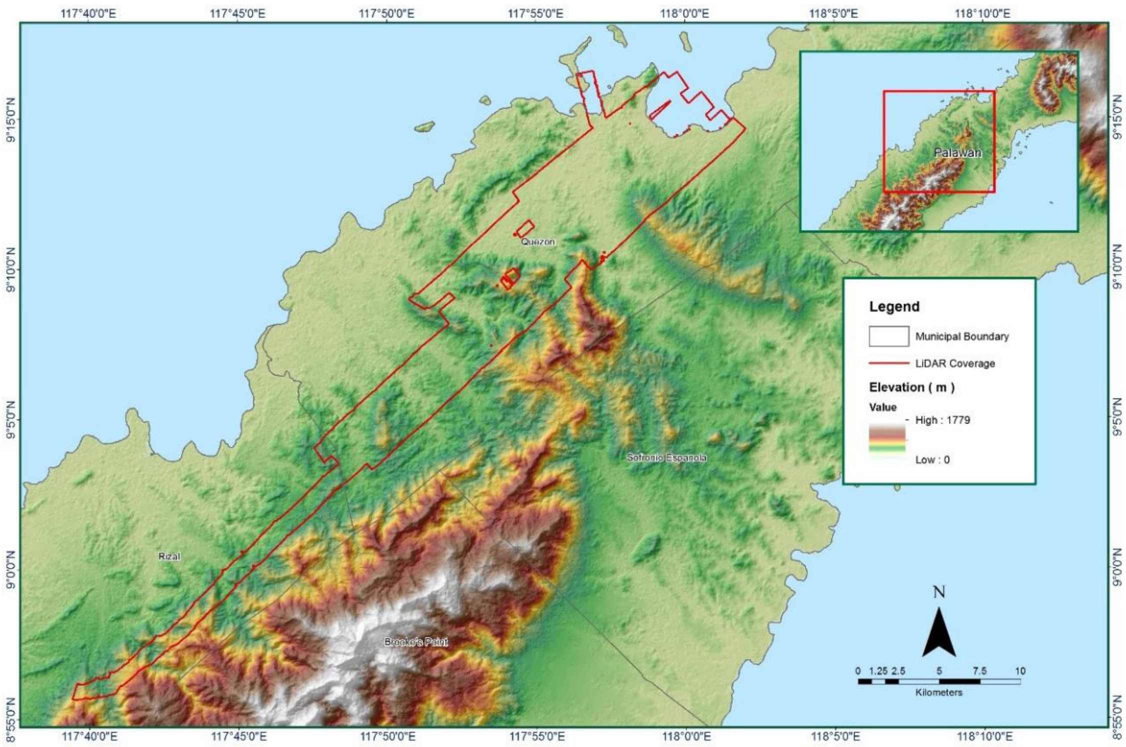


Figure A-8.11 Coverage of LiDAR data

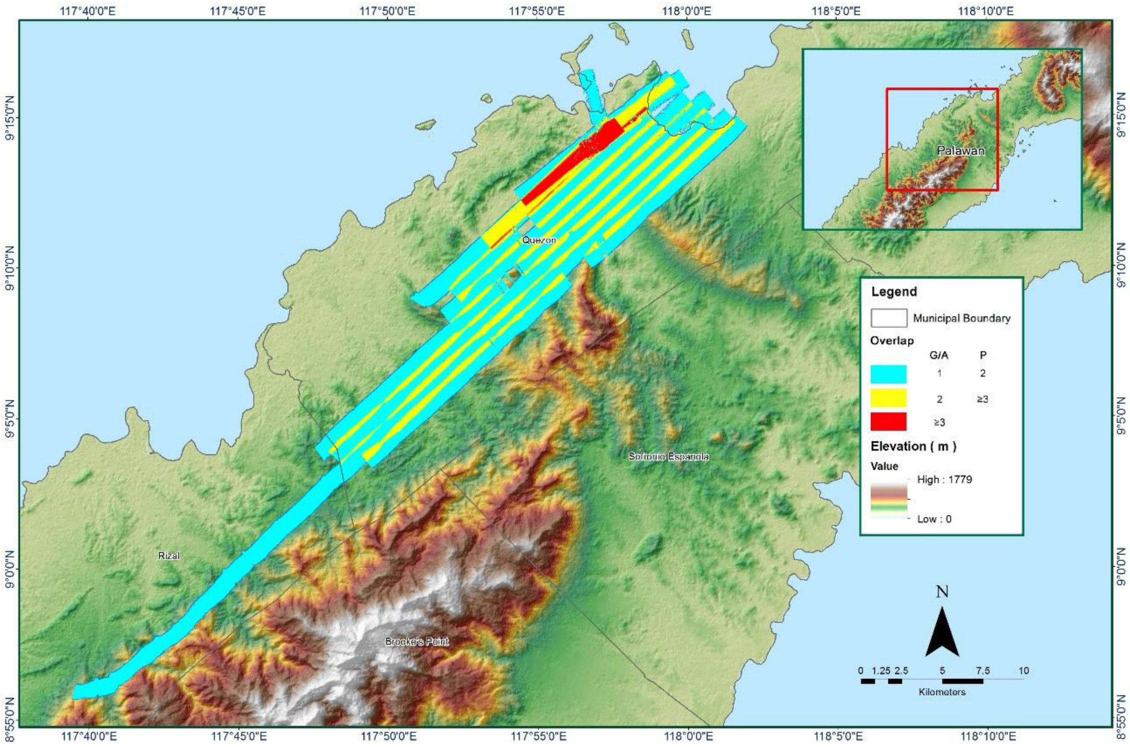


Figure A-8.*12* Image of data overlap

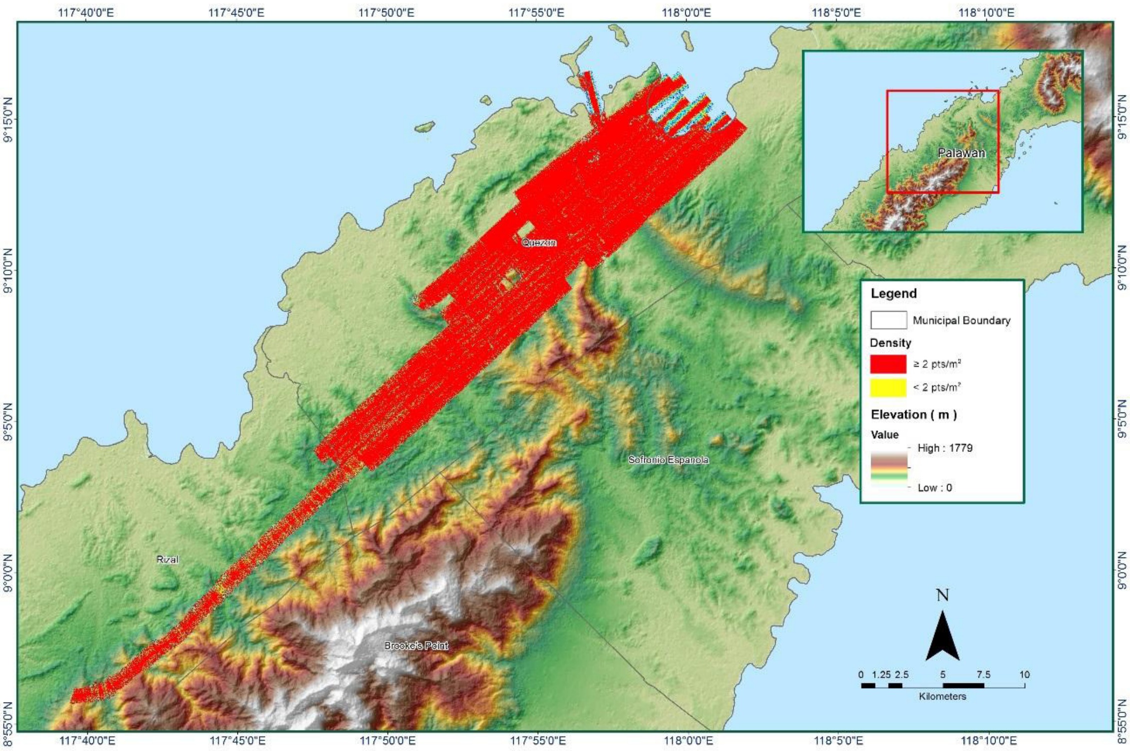


Figure A-8.*13* Density map of merged LiDAR data

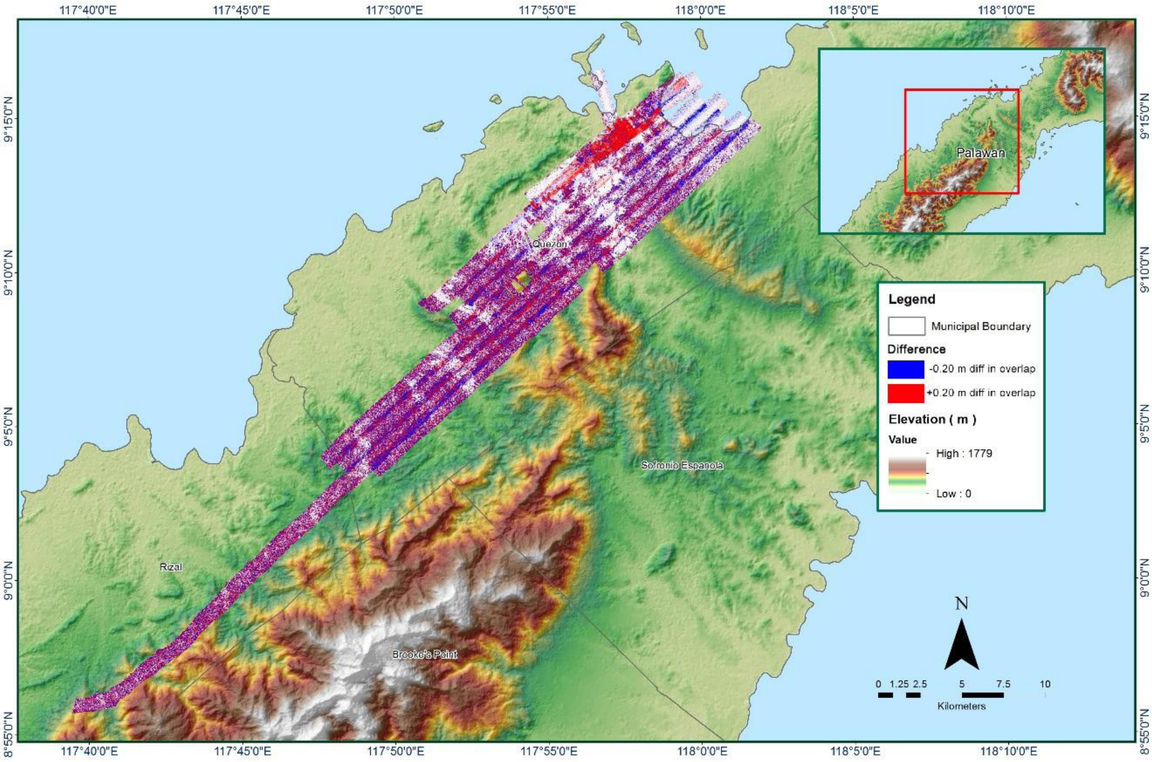


***Figure A**-8.14* Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Block 42N

Flight Area	West Palawan
Mission Name	**Block 42N**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
POS	478 MB
Image	90.70 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	18.19
Ave point cloud density per sq.m. (>2.0)	2.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	251
Maximum Height	658.32
Minimum Height	42.09
Classification (# of points)	
Ground	83015160
Low vegetation	50176090
Medium vegetation	153087772
High vegetation	599974416
Building	9903936
Orthophoto	No

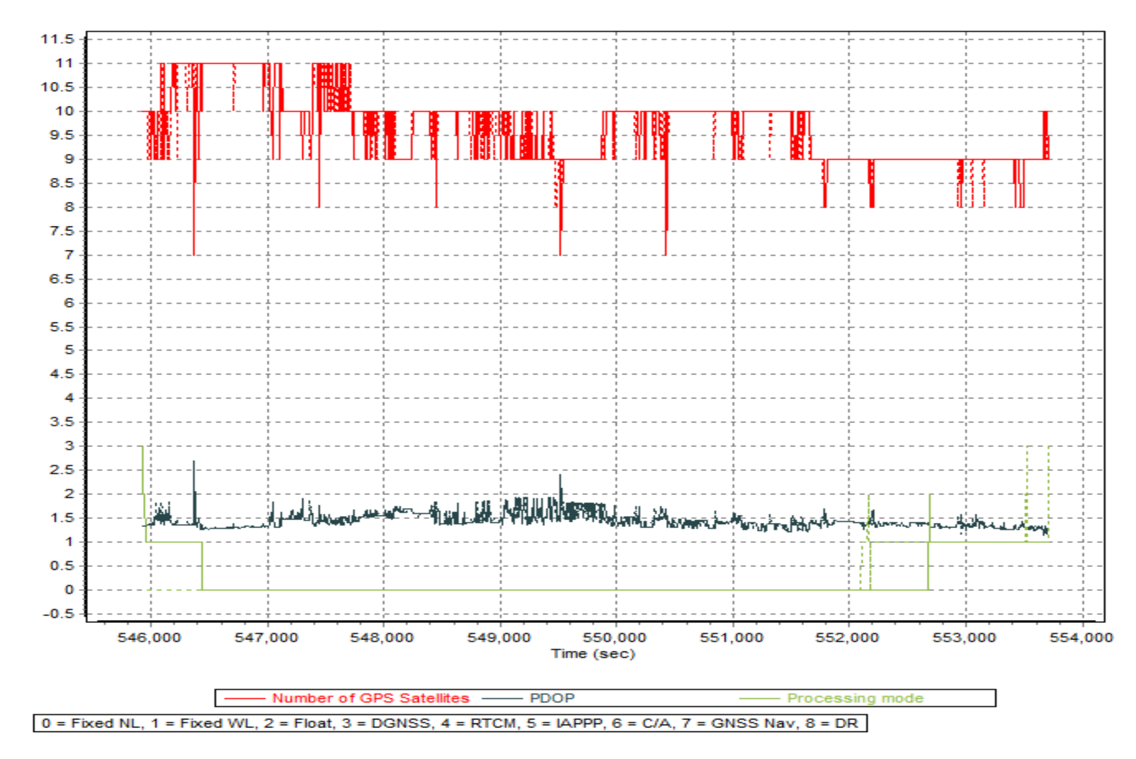


Figure A-8.15 Solution Status

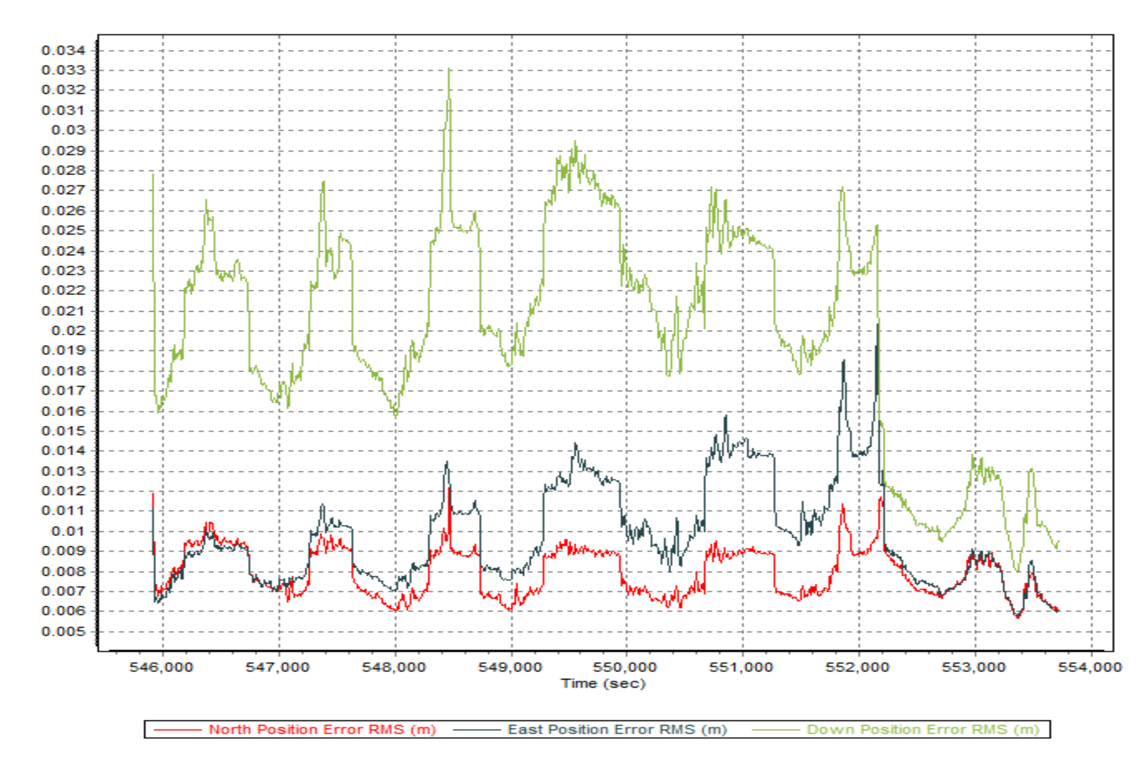


Figure A-8.16 Smoothed Performance Metric Parameters

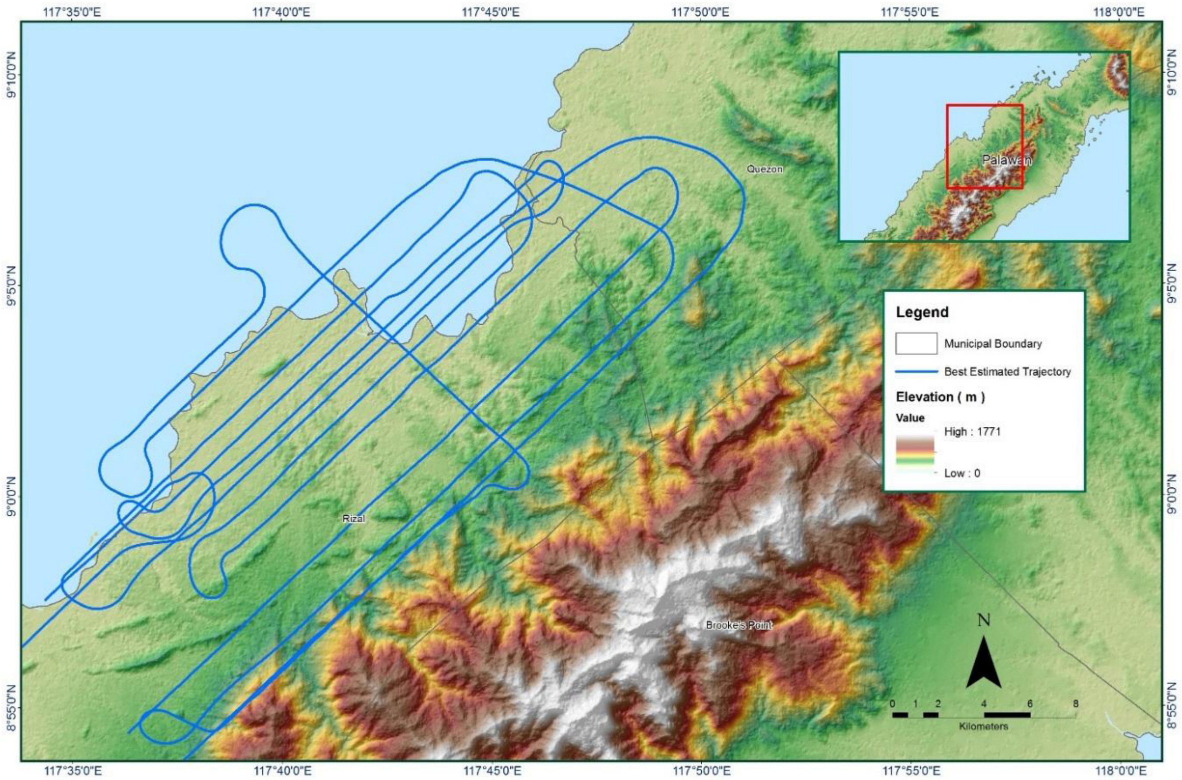


Figure A-8.17 Best Estimated Trajectory

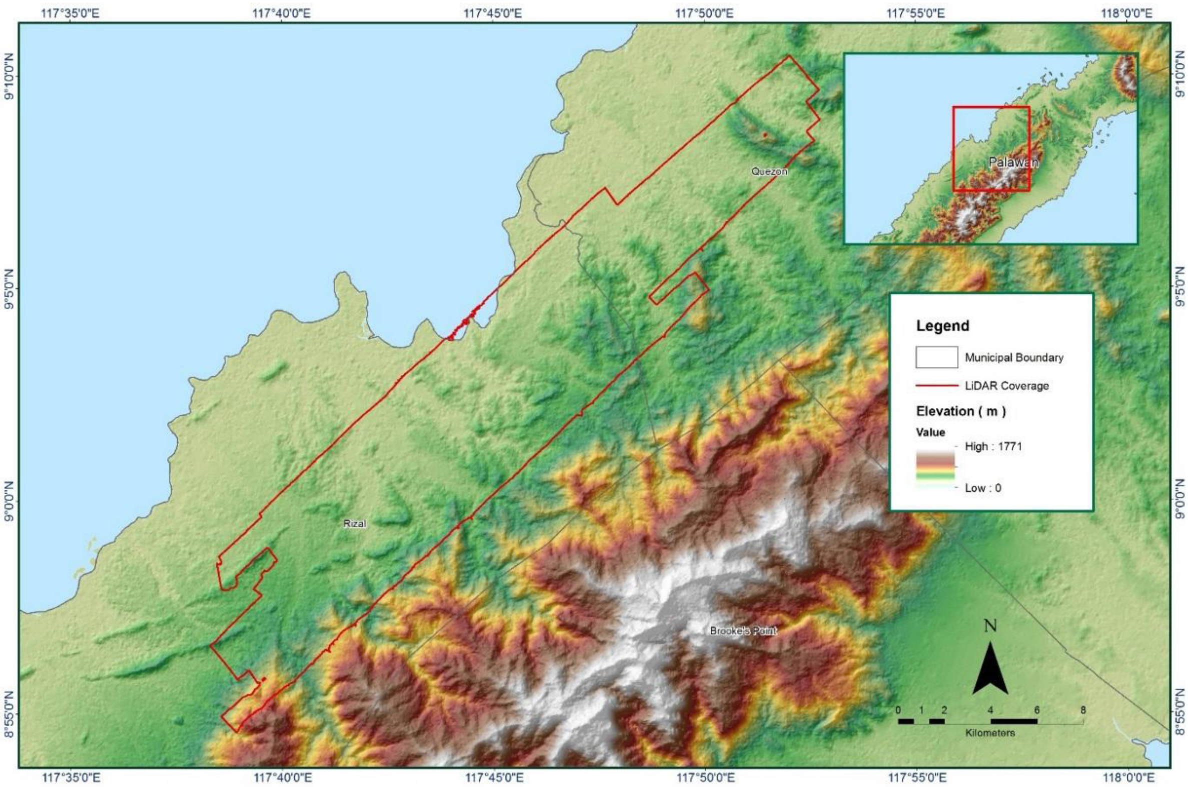


Figure A-8.18 Coverage of LiDAR data

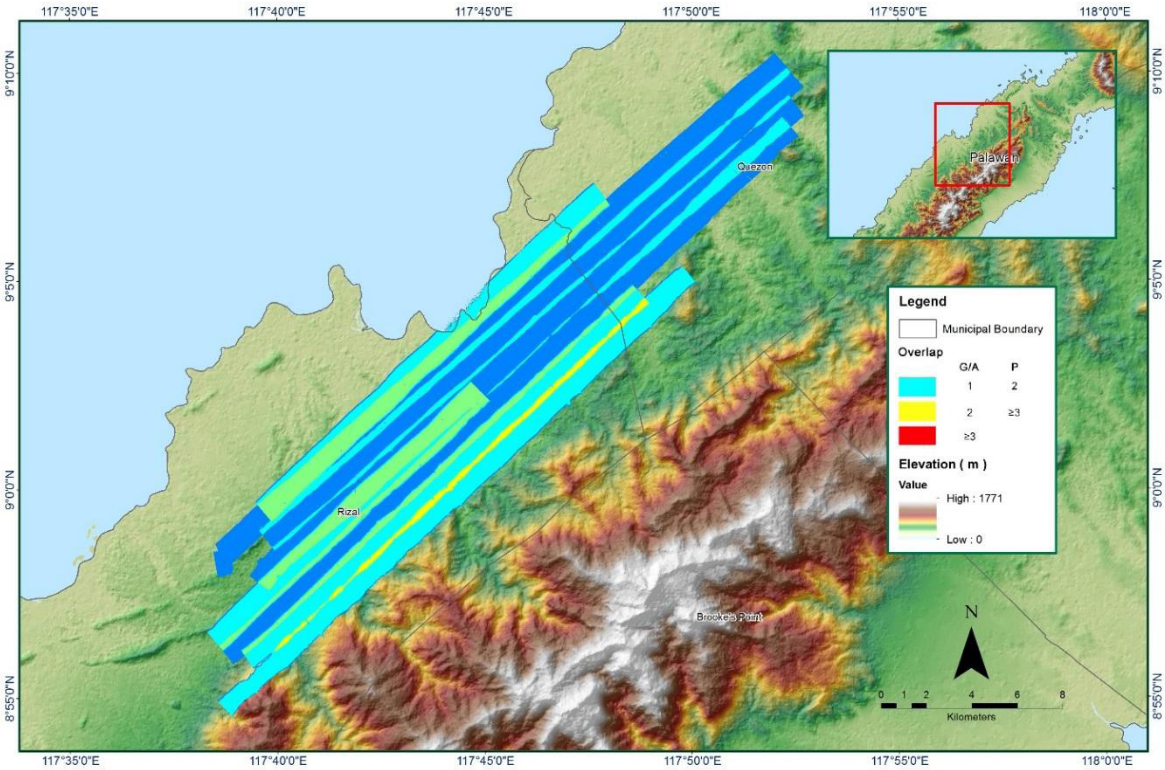


Figure A-8.19 Image of data overlap

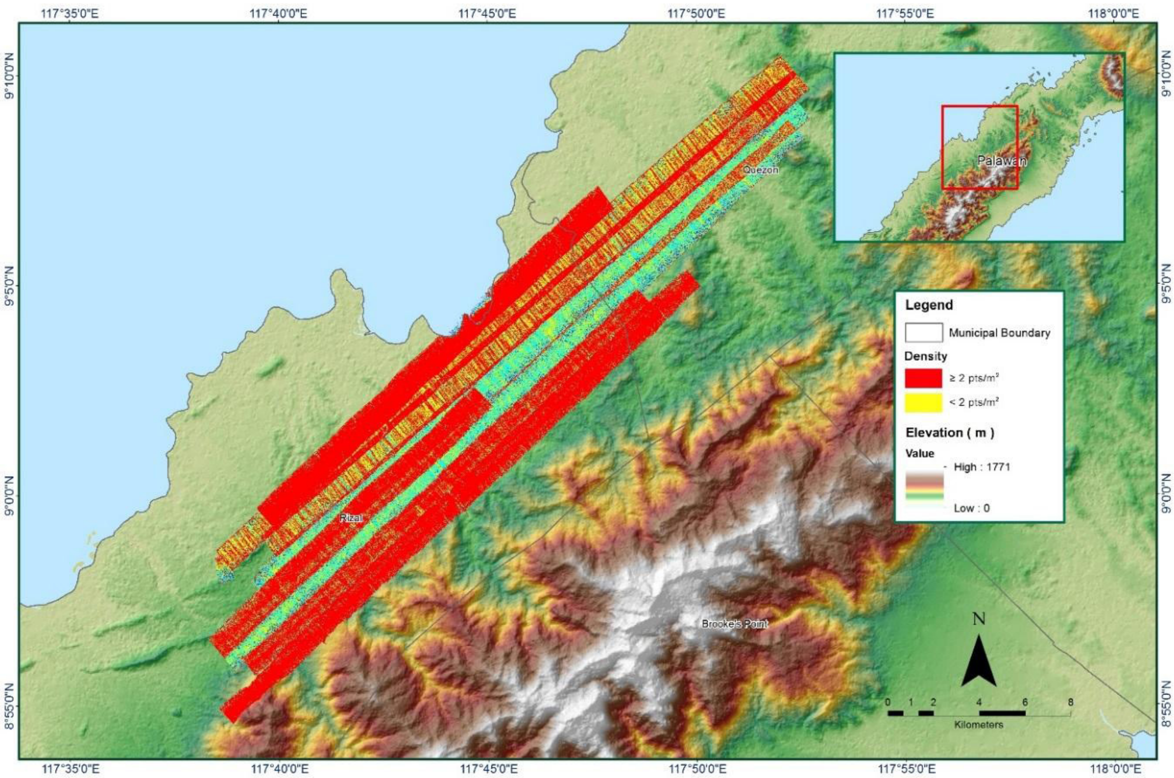


Figure A-8.20 Density map of merged LiDAR data

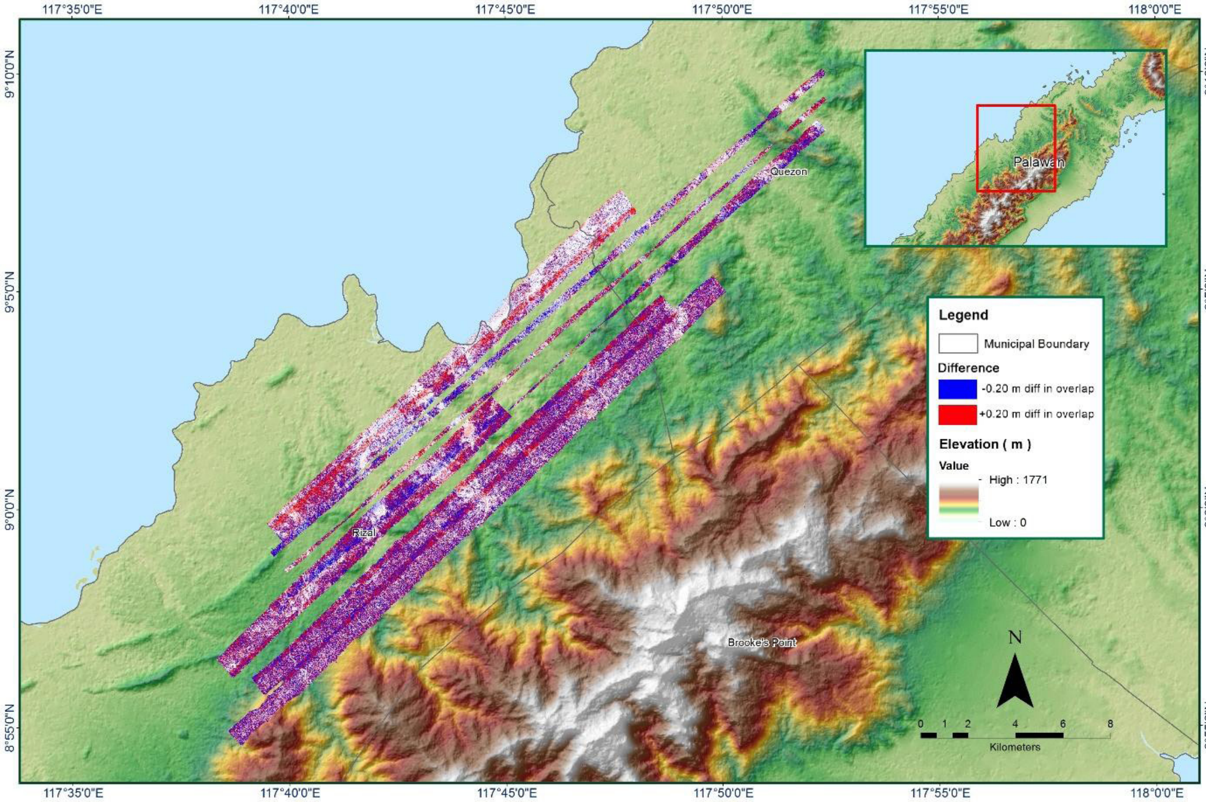


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Block 42O

Flight Area	West Palawan
Mission Name	**Block 42O**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
POS	478 MB
Image	90.70 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	21.33
Ave point cloud density per sq.m. (>2.0)	1.96
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	160
Maximum Height	178.72
Minimum Height	40.13
Classification (# of points)	
Ground	112805844
Low vegetation	95911890
Medium vegetation	80712706
High vegetation	142125592
Building	4713926
Orthophoto	Yes

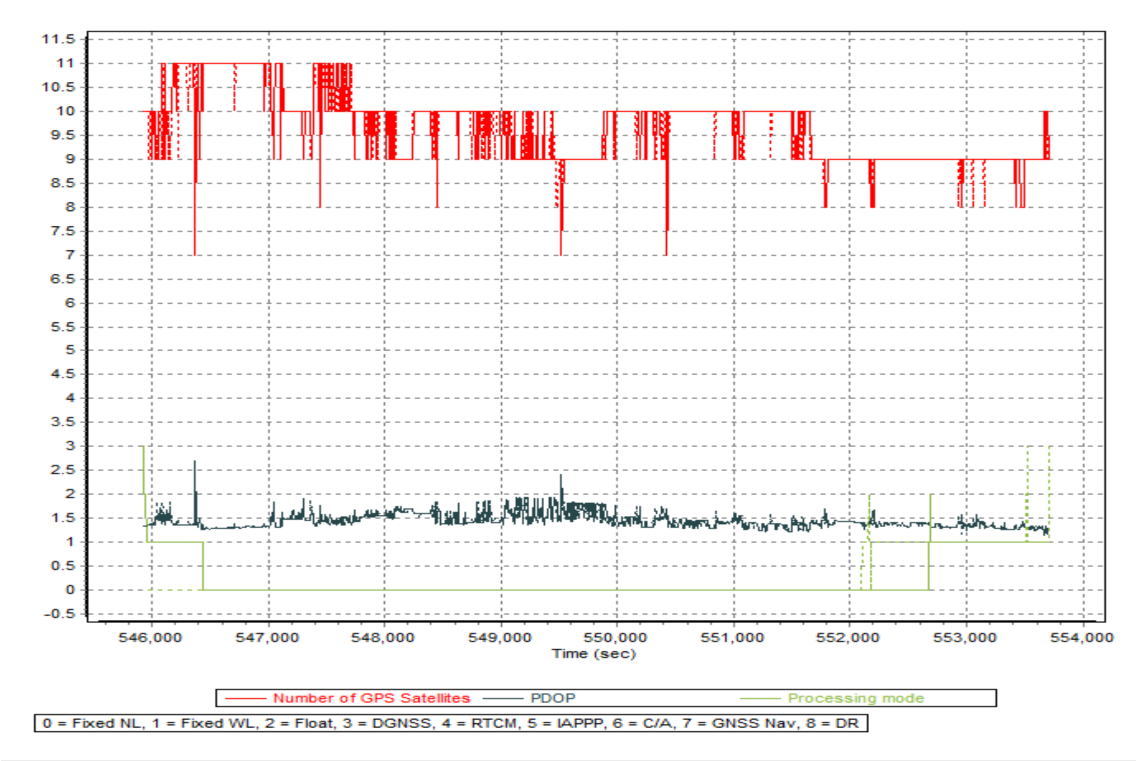


Figure A-8.22 Solution Status

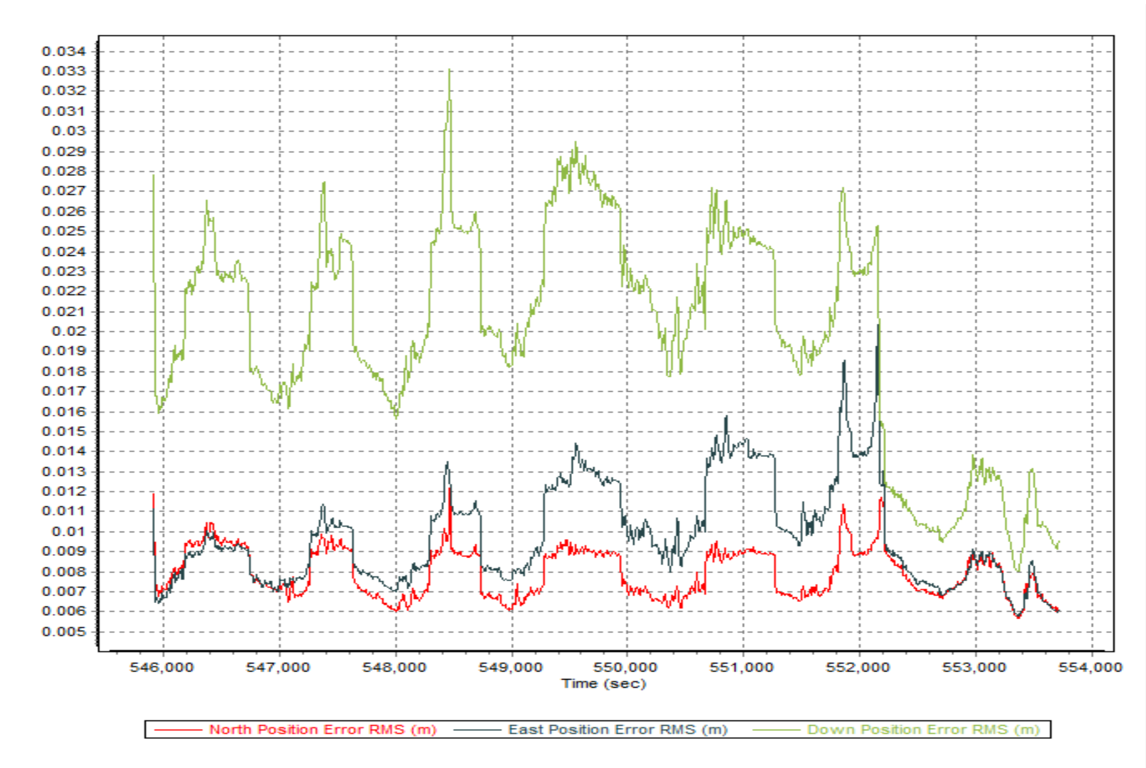


Figure A-8.23 Smoothed Performance Metric Parameters

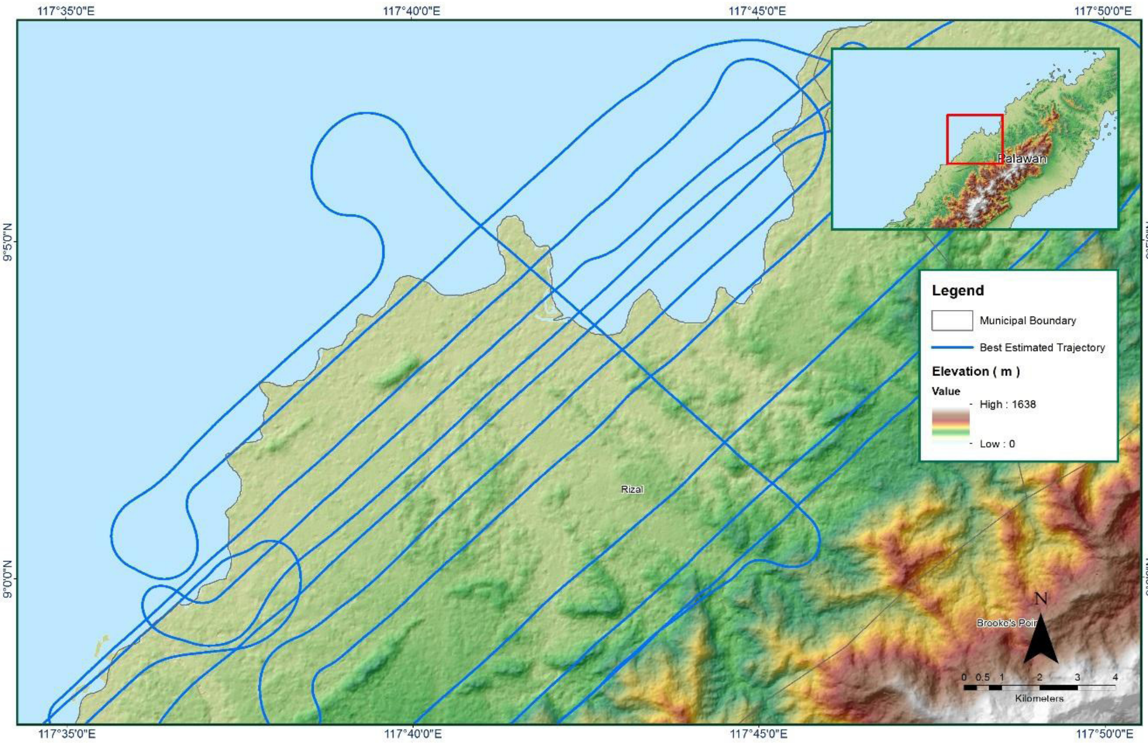


Figure A-8.24 Best Estimated Trajectory

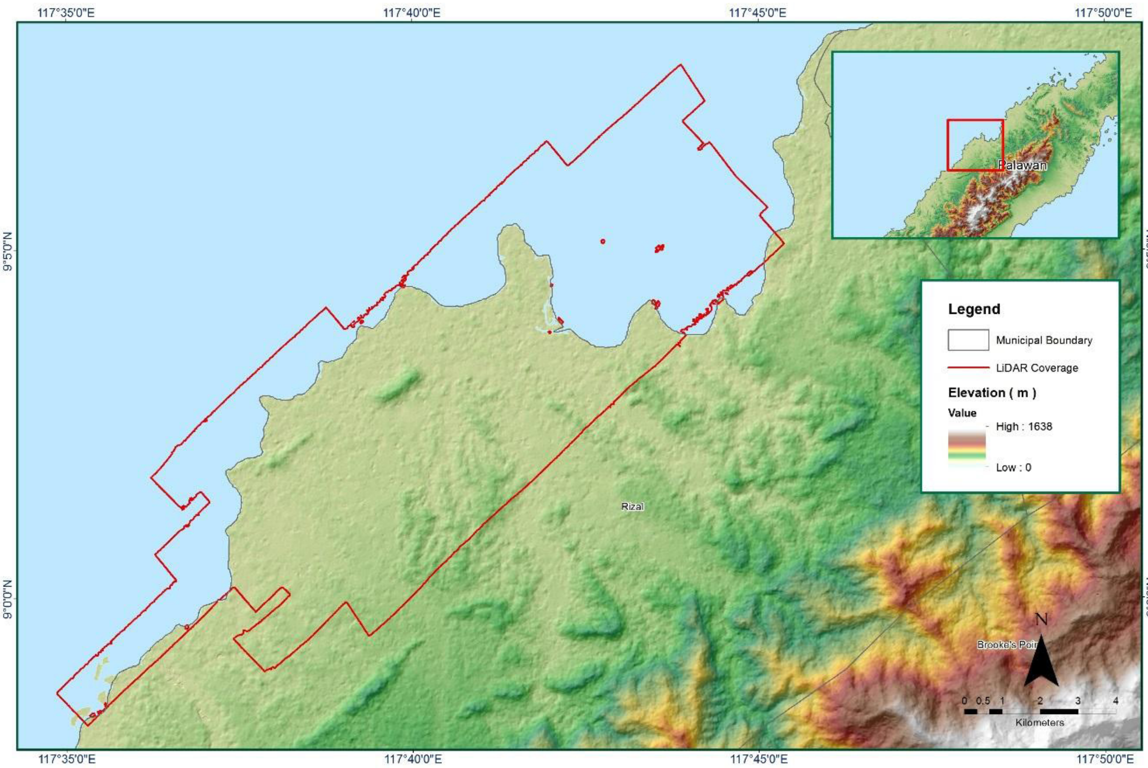


Figure A-8.25 Coverage of LiDAR data

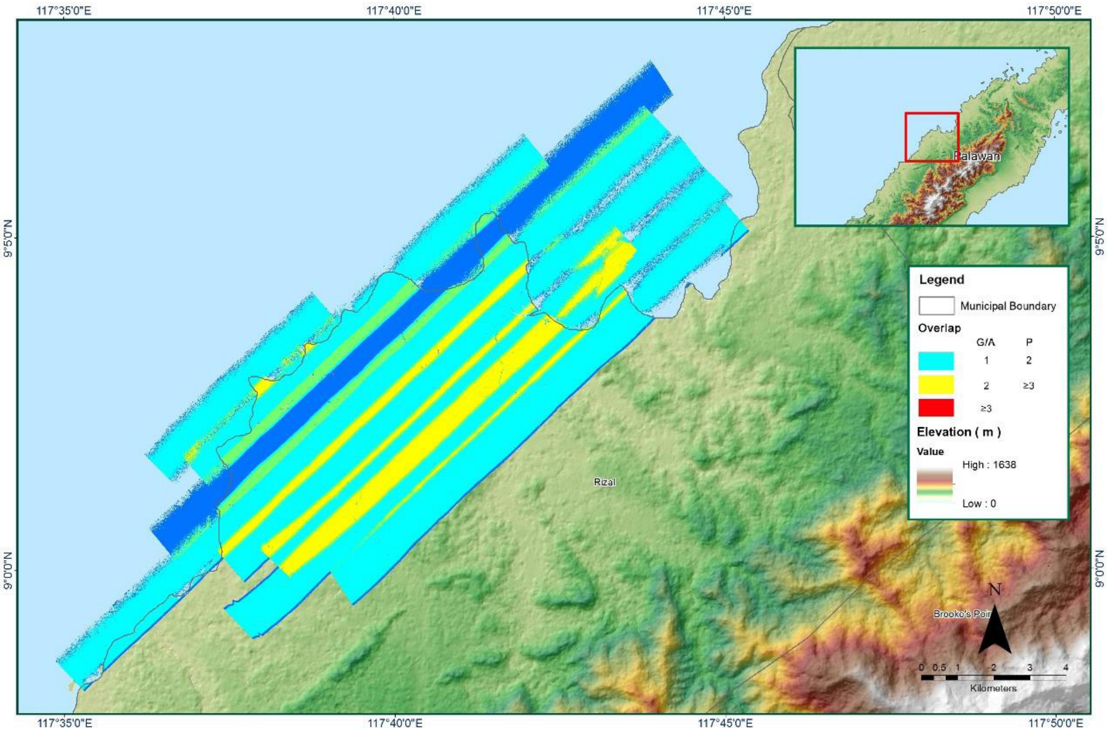


Figure A-8.26 Image of data overlap

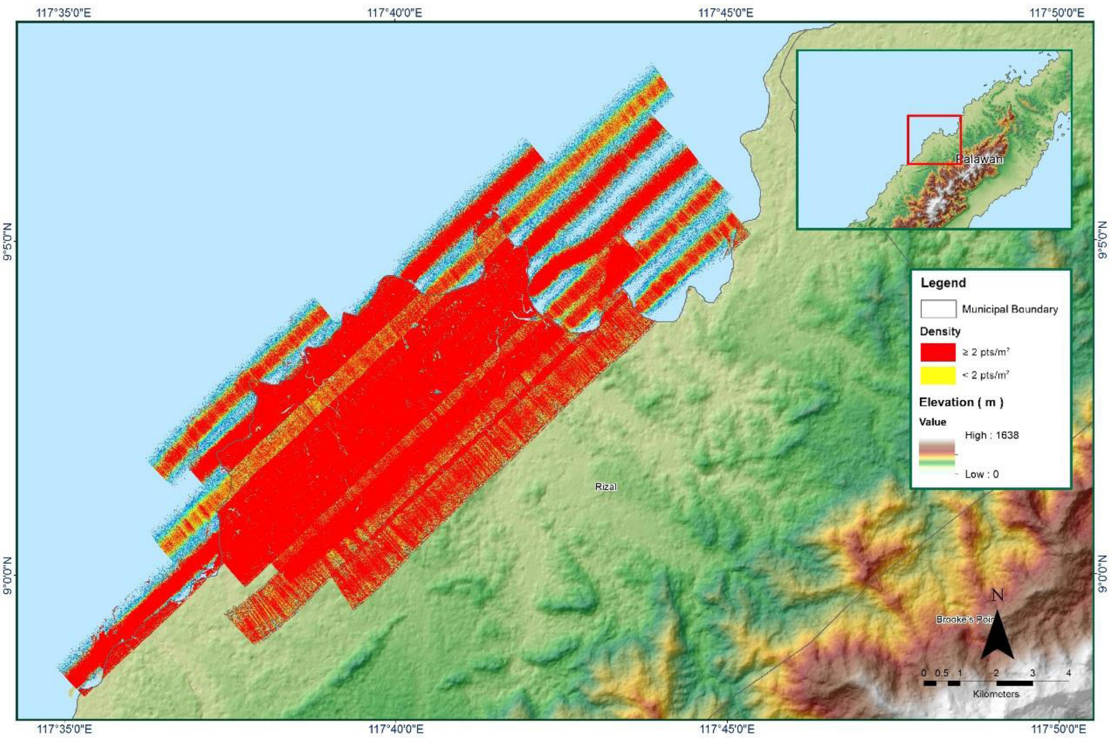


Figure A-8.27 Density map of merged LiDAR data

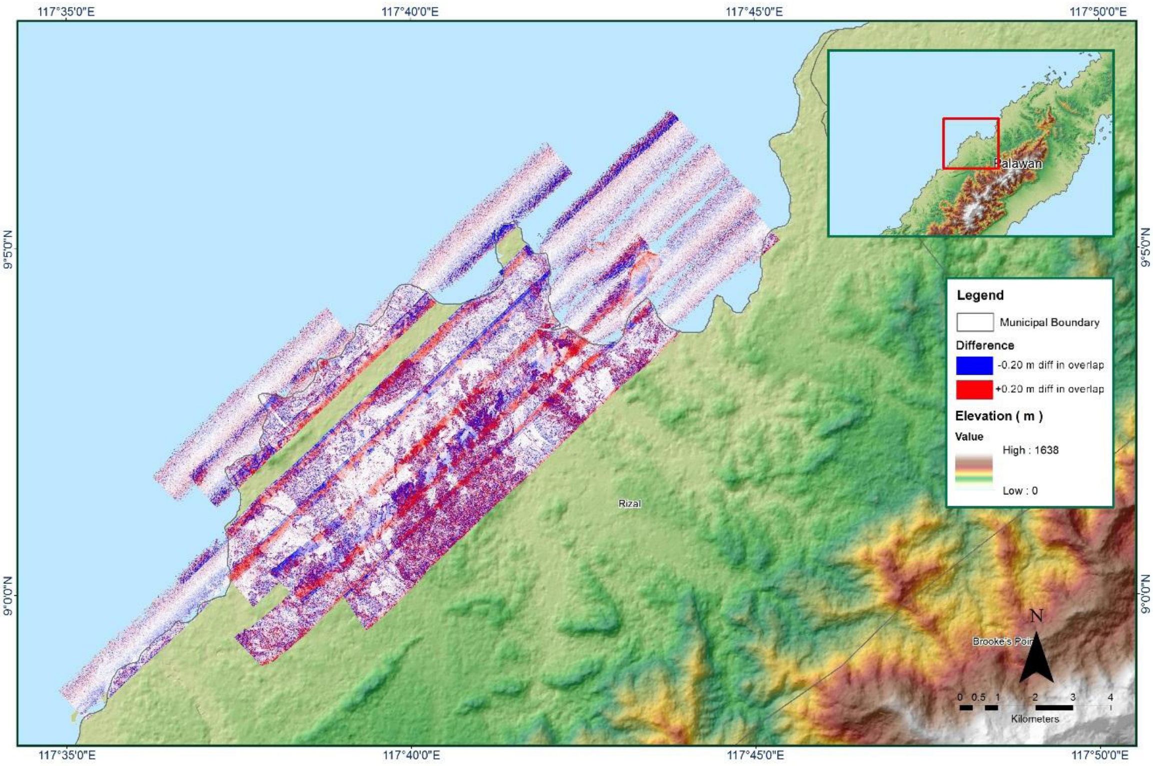


Figure A-8.28 Elevation difference between flight lines

Annex 9. Iraan Model Basin Parameters

Table A-9.1 Iraan Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W1000	137.0300	37.6010	0.0	0.0925	36.6430	0.0770702	0.9693	0.5000
W1010	129.4000	37.5370	0.0	0.0720	8.8487	0.1090755	0.6599	0.4778
W1020	155.2500	41.4510	0.0	0.2819	22.7840	0.17588	0.9846	0.5000
W1030	155.2500	40.4250	0.0	0.0801	49.4770	0.0343421	0.6371	0.5000
W1040	140.4400	37.6460	0.0	0.1928	91.5190	0.11470	0.9698	0.5000
W1050	140.8500	51.6900	0.0	0.0722	2.9122	0.27488	0.9800	0.5000
W1060	152.6400	41.8410	0.0	0.3773	91.3500	0.16259	1.0000	0.5000
W1080	2.6000	83.0000	0.0	1.4541	173.5700	0.0535763	1.0000	0.5000
W1090	88.3840	55.1430	0.0	0.0333	58.9830	.000518372	0.9861	0.5000
W1130	23.7180	40.2250	0.0	0.0333	17.3940	5.0165E-5	0.9865	0.4900
W1140	31.8330	35.0220	0.0	0.0926	12.1870	0.23675	1.0000	0.4706
W1180	15.7790	40.2250	0.0	0.0745	15.7410	0.0114209	0.9925	0.4900
W1190	73.7030	56.8130	0.0	0.0650	28.0450	0.0161573	0.9928	0.5000
W550	20.2420	35.2020	0.0	0.0779	15.5990	0.11183	0.9992	0.4900
W560	7.2892	36.4500	0.0	0.0412	7.3220	0.0087747	1.0000	0.4706
W570	23.5950	41.0450	0.0	0.0828	15.6340	0.0151331	1.0000	0.4900
W580	18.7870	37.8330	0.0	0.0728	15.5920	0.0811796	0.9987	0.4900
W600	61.4430	35.8790	0.0	0.1102	38.8930	0.14147	0.9987	0.5000
W610	101.2000	35.0590	0.0	0.1911	93.4070	0.0858993	1.0000	0.5000
W620	20.8870	35.2230	0.0	0.0965	52.7270	0.12627	1.0000	0.5000
W630	99.7640	35.8710	0.0	0.1416	85.0060	0.0990049	1.0000	0.5000
W650	53.6880	35.2390	0.0	0.1335	39.5290	0.14572	1.0000	0.5000
W660	26.3860	35.0340	0.0	0.0769	8.7756	0.0768486	1.0000	0.4706
W670	54.3150	35.1000	0.0	0.1305	23.4980	0.14921	1.0000	0.4900
W680	90.0890	36.6940	0.0	0.1397	87.2630	0.0661928	1.0000	0.5000

W690	44.2590	36.1080	0.0	0.1395	180.0400	0.22548	1.0000	0.5000
W700	104.7900	35.6910	0.0	0.1323	82.2680	0.11595	1.0000	0.5000
W710	99.3400	35.3780	0.0	0.1567	59.7400	0.20390	1.0000	0.5000
W720	100.4300	38.3240	0.0	0.3800	68.3560	0.62228	1.0000	0.5000
W730	137.9500	39.6770	0.0	0.0702	46.6800	0.10703	1.0000	0.5000
W740	142.4200	40.3050	0.0	0.0984	34.6390	0.13137	1.0000	0.5000
W750	125.1500	35.7710	0.0	0.0721	122.4200	0.10959	1.0000	0.5000
W760	16.0150	35.1160	0.0	0.0333	21.8860	0.0015760	0.6533	0.4706
W770	110.3400	46.1330	0.0	0.2413	65.4960	0.0977633	0.9605	0.5000
W780	147.5600	44.5140	0.0	0.1508	25.0400	0.0683331	1.0000	0.5000
W790	137.7400	37.0290	0.0	0.2210	90.8910	0.34649	0.9382	0.5000
W800	158.2000	52.9500	0.0	0.1301	14.8470	0.0807406	0.9451	0.4900
W810	157.4800	52.9500	0.0	0.1074	50.3020	0.10075	0.9413	0.5000
W820	147.2700	40.9620	0.0	0.7056	95.1950	0.30877	0.9224	0.5000
W830	106.3800	35.3000	0.0	0.0613	5.8683	0.0356255	0.9850	0.4706
W840	155.2500	41.3050	0.0	0.0415	32.9650	0.0180218	0.9734	0.5000
W850	103.9500	38.7040	0.0	0.1483	30.2930	0.13344	0.6621	0.4802
W860	141.4700	83.3620	0.0	0.0587	16.7280	0.0470548	0.9645	0.5000
W870	134.9600	36.7870	0.0	0.3898	51.6150	0.16534	1.0000	0.5000
W880	102.5100	38.0000	0.0	0.1545	52.3670	0.0821661	0.6489	0.5000
W890	136.7100	39.8360	0.0	0.0934	61.6060	0.0704819	0.6495	0.5000
W900	25.3900	40.6760	0.0	0.0333	35.5270	0.0106224	0.9751	0.5000
W910	101.9900	38.0460	0.0	0.2059	40.2890	0.34171	0.9455	0.4900
W920	129.6900	40.6760	0.0	0.2468	70.7250	0.21664	1.0000	0.5000
W930	128.4200	40.6760	0.0	0.0333	66.6730	0.0034363	1.0000	0.5000
W940	37.3430	37.3560	0.0	0.1332	46.6240	0.12121	1.0000	0.5000
W950	156.0100	40.4250	0.0	0.4041	39.7280	0.0733914	0.9702	0.5000
W960	158.8900	37.1820	0.0	0.1573	63.3600	0.0670288	0.9000	0.5000
W970	105.7900	40.6270	0.0	0.1350	9.9198	0.0991512	0.9509	0.4706
W980	156.0000	40.4250	0.0	0.1408	82.3400	0.0675598	0.2978	0.5000
W990	156.0000	41.4560	0.0	0.3685	24.2090	0.15256	0.6534	0.5000

Annex 10. Iraan Model Reach Parameters

Table A-10.1 Iraan Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R10	Automatic Fixed Interval	1988.4	0.0590421	0.04	Trapezoid	30	1
R100	Automatic Fixed Interval	30	0.0590421	0.002	Trapezoid	30	1
R1100	Automatic Fixed Interval	112.43	0.0257604	0.002	Trapezoid	30	1
R1160	Automatic Fixed Interval	6435.8	0.00080065	0.002	Trapezoid	30	1
R120	Automatic Fixed Interval	2154.1	0.0060370	0.002	Trapezoid	30	1
R1200	Automatic Fixed Interval	704.56	0.0103780	0.002	Trapezoid	30	1
R150	Automatic Fixed Interval	3356.3	0.0088544	0.002	Trapezoid	30	1
R160	Automatic Fixed Interval	4153.6	0.0074102	0.002	Trapezoid	30	1
R170	Automatic Fixed Interval	4807.9	0.0031992	0.002	Trapezoid	30	1
R20	Automatic Fixed Interval	489.41	0.0031107	0.002	Trapezoid	30	1
R200	Automatic Fixed Interval	178.99	0.0204617	0.002	Trapezoid	30	1
R230	Automatic Fixed Interval	1557.8	0.0183512	0.002	Trapezoid	30	1
R250	Automatic Fixed Interval	3811.5	0.0155435	0.002	Trapezoid	30	1
R260	Automatic Fixed Interval	882.55	0.0328508	0.002	Trapezoid	30	1
R290	Automatic Fixed Interval	510.42	0.0098523	0.002	Trapezoid	30	1
R30	Automatic Fixed Interval	1897.9	0.0017829	0.002	Trapezoid	30	1
R310	Automatic Fixed Interval	905.69	0.0224553	0.002	Trapezoid	30	1
R320	Automatic Fixed Interval	1139.1	0.0348926	0.002	Trapezoid	30	1
R350	Automatic Fixed Interval	463.14	0.0678961	0.002	Trapezoid	30	1
R360	Automatic Fixed Interval	271.42	0.13600	0.002	Trapezoid	30	1
R390	Automatic Fixed Interval	6934.8	0.0225243	0.002	Trapezoid	30	1
R410	Automatic Fixed Interval	2211.4	0.0827301	0.002	Trapezoid	30	1

R440	Automatic Fixed Interval	1718.1	0.0387095	0.002	Trapezoid	30	1
R450	Automatic Fixed Interval	901.54	0.0647780	0.002	Trapezoid	30	1
R490	Automatic Fixed Interval	1860.7	0.0611930	0.002	Trapezoid	30	1
R50	Automatic Fixed Interval	1223.1	0.00042213	0.002	Trapezoid	30	1
R500	Automatic Fixed Interval	946.40	0.0350357	0.002	Trapezoid	30	1
R70	Automatic Fixed Interval	4612.7	0.0025940	0.002	Trapezoid	30	1
R90	Automatic Fixed Interval	740.12	0.00038635	0.002	Trapezoid	30	1

Annex 11. Iraan Field Validation Points

Table A-11.1 IIraan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Latitude	Longitude						
1	9.02025413000	117.70542960000	0.030	0.000	-0.030			25-Year
2	9.02451419000	117.70764480000	0.031	0.000	-0.031			25-Year
3	9.02492414000	117.70820190000	0.074	0.000	-0.074			25-Year
4	9.02629194000	117.73763310000	0.030	1.000	0.970		13-Jan-17	25-Year
5	9.02658105000	117.70732610000	0.030	0.000	-0.030			25-Year
6	9.02808211000	117.73703730000	0.420	1.000	0.580		13-Jan-17	25-Year
7	9.03002103000	117.70409050000	0.178	1.000	0.822		13-Jan-17	25-Year
8	9.03193987000	117.70113220000	0.351	1.000	0.649		13-Jan-17	25-Year
9	9.03301862000	117.74132120000	0.030	0.000	-0.030			25-Year
10	9.03299717000	117.73752580000	0.030	0.000	-0.030			25-Year
11	9.03464844000	117.73851040000	0.031	0.000	-0.031			25-Year
12	9.03476637000	117.73081650000	0.919	0.900	-0.019		13-Jan-17	25-Year
13	9.03445816000	117.69919230000	0.322	1.000	0.678		13-Jan-17	25-Year
14	9.03540491000	117.73561670000	0.365	0.000	-0.365			25-Year
15	9.03681707000	117.73199460000	0.423	0.000	-0.423			25-Year
16	9.03896090000	117.72809170000	0.031	0.000	-0.031			25-Year
17	9.03907079000	117.68827560000	1.675	1.300	-0.375		13-Jan-17	25-Year
18	9.03942584000	117.69498290000	0.883	0.700	-0.183		13-Jan-17	25-Year
19	9.04008744000	117.72625010000	0.030	0.000	-0.030			25-Year
20	9.04167774000	117.72074790000	0.400	1.000	0.600		13-Jan-17	25-Year
21	9.04255986000	117.71596760000	0.030	0.000	-0.030			25-Year

22	9.04337892000	117.69907710000	0.030	0.900	0.870		13-Jan-17	25-Year
23	9.04426178000	117.71149330000	0.060	0.000	-0.060			25-Year
24	9.04404154000	117.69330590000	1.359	0.500	-0.859		13-Jan-17	25-Year
25	9.04514508000	117.71095070000	0.031	0.000	-0.031			25-Year
26	9.04536063000	117.69875500000	0.031	0.000	-0.031			25-Year
27	9.04577833000	117.70587190000	0.030	0.000	-0.030			25-Year
28	9.04653806000	117.69096380000	0.868	0.000	-0.868			25-Year
29	9.04730534000	117.71057890000	0.030	0.500	0.470		13-Jan-17	25-Year
30	9.04726079000	117.70401570000	0.031	0.000	-0.031			25-Year
31	9.04726243000	117.69186000000	0.030	0.000	-0.030			25-Year
32	9.04809796000	117.70293590000	0.031	0.000	-0.031			25-Year
33	9.04828106000	117.69819330000	0.030	0.000	-0.030			25-Year
34	9.04822600000	117.69146440000	0.030	0.000	-0.030			25-Year
35	9.04850746000	117.70112980000	0.030	0.000	-0.030			25-Year
36	9.04850924000	117.69096000000	0.030	0.000	-0.030			25-Year
37	9.04856457000	117.69274000000	0.030	0.000	-0.030			25-Year
38	9.04866011000	117.69122830000	0.030	0.000	-0.030			25-Year
39	9.04927052000	117.69032140000	0.030	0.000	-0.030			25-Year
40	9.04940566000	117.69861980000	0.031	0.000	-0.031			25-Year
41	9.04953235000	117.69079620000	0.030	0.000	-0.030			25-Year
42	9.04971664000	117.70232290000	0.031	0.000	-0.031			25-Year
43	9.05063074000	117.68982720000	0.030	0.000	-0.030			25-Year
44	9.05076894000	117.69781860000	0.037	0.000	-0.037			25-Year
45	9.05077641000	117.68953680000	0.030	0.000	-0.030			25-Year
46	9.05102218000	117.68933670000	0.625	0.000	-0.625			25-Year
47	9.05120030000	117.68767720000	3.126	1.700	-1.426		13-Jan-17	25-Year
48	9.05145093000	117.69705790000	0.031	0.000	-0.031			25-Year
49	9.05214170000	117.69609880000	0.031	0.000	-0.031			25-Year

50	9.05209974000	117.68751620000	0.585	0.000	-0.585			25-Year
51	9.05235774000	117.68808700000	0.396	0.000	-0.396			25-Year
52	9.05252969000	117.68731160000	1.148	0.000	-1.148			25-Year
53	9.05256734000	117.68769880000	0.428	0.000	-0.428			25-Year
54	9.05292437000	117.68814700000	0.870	0.000	-0.870			25-Year
55	9.05340702000	117.69527770000	0.030	0.000	-0.030			25-Year
56	9.05363336000	117.69396990000	0.031	0.000	-0.031			25-Year
57	9.05449038000	117.69316100000	0.031	0.000	-0.031			25-Year
58	9.05509440000	117.69283810000	0.030	0.000	-0.030			25-Year
59	9.05522634000	117.69150320000	1.197	0.000	-1.197			25-Year
60	9.05523177000	117.68716360000	0.030	0.000	-0.030			25-Year
61	9.05525379000	117.68749060000	0.410	1.200	0.790		Janaury 2013	25-Year
62	9.05553461000	117.69281620000	0.994	0.000	-0.994			25-Year
63	9.05551493000	117.69036900000	0.390	1.000	0.610		13-Jan-17	25-Year
64	9.05561874000	117.68688910000	0.030	0.000	-0.030			25-Year
65	9.05564051000	117.68768470000	1.105	0.500	-0.605		13-Jan-17	25-Year
66	9.05572086000	117.69296330000	1.361	0.100	-1.261		13-Jan-17	25-Year
67	9.05575131000	117.68828790000	1.227	0.500	-0.727		13-Jan-17	25-Year
68	9.05587396000	117.68985480000	0.567	0.500	-0.067		13-Jan-17	25-Year
69	9.05585927000	117.68738200000	1.140	0.000	-1.140			25-Year
70	9.05598990000	117.69120130000	0.277	1.500	1.223		13-Jan-17	25-Year
71	9.05606832000	117.69307540000	0.932	0.000	-0.932			25-Year
72	9.05630693000	117.69371770000	0.325	0.500	0.175		13-Jan-17	25-Year
73	9.05634589000	117.68994310000	0.294	0.500	0.206		13-Jan-17	25-Year
74	9.05636040000	117.68944790000	0.332	0.500	0.168		13-Jan-17	25-Year
75	9.05671930000	117.69339280000	0.133	0.500	0.367		13-Jan-17	25-Year
76	9.05682178000	117.68888520000	0.556	0.500	-0.056		13-Jan-17	25-Year
77	9.05696238000	117.68686540000	1.102	2.000	0.898		13-Jan-17	25-Year

78	9.05710887000	117.68754030000	1.849	0.000	-1.849			25-Year
79	9.05726584000	117.68721360000	0.827	1.000	0.173		13-Jan-17	25-Year
80	9.05760226000	117.69432770000	0.255	0.500	0.245		13-Jan-17	25-Year
81	9.05785311000	117.69670160000	0.408	0.500	0.092		13-Jan-17	25-Year
82	9.05820863000	117.68743990000	1.130	1.000	-0.130		13-Jan-17	25-Year
83	9.05850538	117.6941963	0.343	0.500	0.157		13-Jan-17	25-Year
84	9.05844915	117.6877743	1.321	1.300	-0.021		13-Jan-17	25-Year
85	9.05846767	117.6881829	0.691	0.200	-0.491		13-Jan-17	25-Year
86	9.0586637	117.6898358	0.872	1.000	0.128		13-Jan-17	25-Year
87	9.05883547	117.6950266	0.113	0.8	0.687		13-Jan-17	25-Year
88	9.05930911	117.6877974	0.808	1	0.192		13-Jan-17	25-Year
89	9.05935305	117.6874922	0.615	0	-0.615			25-Year
90	9.05976504	117.6878324	0.502	2	1.498		13-Jan-17	25-Year
91	9.06016157	117.687253	0.358	1	0.642		13-Jan-17	25-Year
92	9.06036862	117.6970852	0.387	0	-0.387			25-Year
93	9.06056866	117.6866452	0.268	1.3	1.032		13-Jan-17	25-Year
94	9.0612858	117.6879029	1.118	1	-0.118		13-Jan-17	25-Year
95	9.06146456	117.6876079	0.784	1	0.216		13-Jan-17	25-Year
96	9.06174346	117.6872775	0.431	0.5	0.069		13-Jan-17	25-Year
97	9.0617666	117.6869383	0.363	0.6	0.237		13-Jan-17	25-Year
98	9.0618258	117.6879021	0.838	0.7	-0.138		13-Jan-17	25-Year
99	9.06197178	117.6876385	0.514	0.9	0.386		13-Jan-17	25-Year
100	9.06201644	117.6867291	0.125	0.5	0.375		13-Jan-17	25-Year
101	9.06226746	117.6955636	0.555	1	0.445		13-Jan-17	25-Year
102	9.0624986	117.6879825	0.545	0.8	0.255		13-Jan-17	25-Year
103	9.06282166	117.68838	0.319	0.7	0.381		13-Jan-17	25-Year
104	9.0631521	117.702263	0.03	0	-0.03			25-Year
105	9.0633125	117.6880642	0.302	1	0.698		13-Jan-17	25-Year

106	9.06409522	117.6878275	0.03	1	0.97		13-Jan-17	25-Year
107	9.07117064	117.6935353	0.129	0	-0.129			25-Year
108	9.07174238	117.6932372	0.191	0	-0.191			25-Year
109	9.07192505	117.6936823	0.09	0	-0.09			25-Year
110	9.0723718	117.6940579	0.038	0	-0.038			25-Year
111	9.07744538	117.6922681	0.03	0	-0.03			25-Year
112	9.07758845	117.6904913	0.071	0	-0.071			25-Year
113	9.07803653	117.6922553	0.032	0	-0.032			25-Year
114	9.07883433	117.6919603	0.03	0	-0.03			25-Year
115	9.0826344	117.6935845	0.041	0	-0.041			25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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