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

LiDAR Surveys and Flood Mapping of Iwahig Brookes River

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

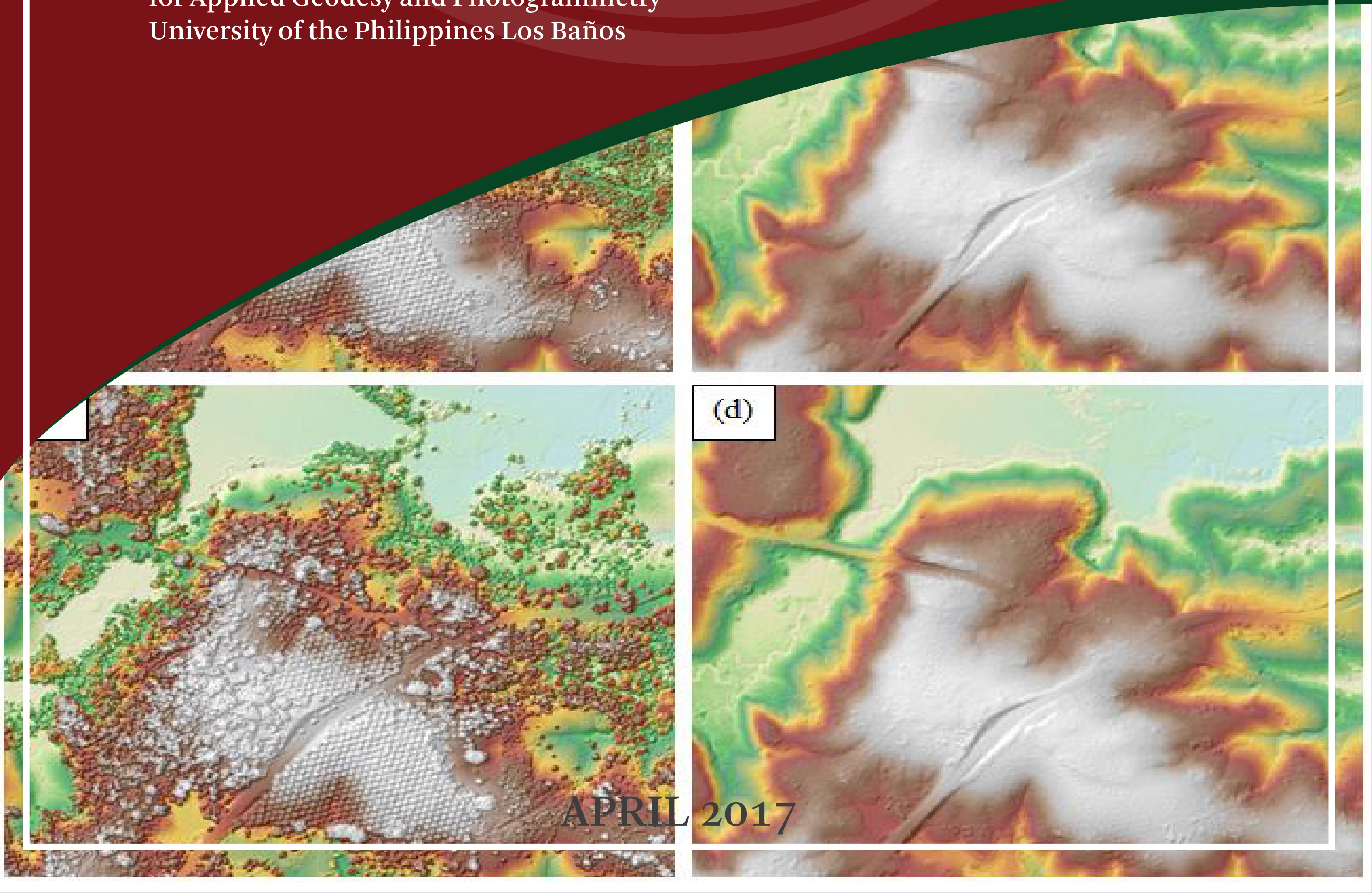

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TABLE OF CONTENTS

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
BSWM	Bureau of Soil and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RBCO	River Basin Control Office
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 IWAHIG BROOKES RIVER

Enrico C. Paringit, Dr. Eng. and Dr. Edwin R. Abucay

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines 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 Southern Luzon region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Iwahig River Basin

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.

Iwahig Brooke’s River basin is a 18,430-ha watershed located in Palawan. It covers barangay Bulalacao, Culandanum, Igang-igang, Iwahig, Ocayan, Sandoval, and Tarusan in Bataraza; Panalingaan, and Taburi in Rizal. The basin area is predominantly from Oligocene-Miocene (Sedimentary & Metamorphic Rocks) followed by Recent and Pliocene-Pleistocene. Majority of the area in the river basin has gently sloping to moderately steep slopes and elevation range of 10-50. Taburos clay is the dominant soil type in the area followed by Sibul clay. However large area in basin are still unclassified (rough mountainous land). Natural grassland and cultivated land (annual crops) also occupies large area in the basin. Other land cover types include natural marshland, open forest (broadleaved), mangrove forest and cultivated land (perennial).

Iwahig river basin passes through Taburi in Rizal, Culandanum, Sandoval and Iwahig in Bataraza. The 2010 NSO Census of Population and Housing, showed that Culandanum is the most populated barangay in the area.

The study conducted by the Mines and Geosciences Bureau showed that Culandanum, Iwahig, Tarusan and Taburi (areas near the river) has high susceptibility to flooding. The field surveys conducted by the PHIL-LiDAR 1 validation team showed that only three weather disturbances caused flooding in 2016 (Nina), and 2017 (Auring). In terms of landslide, barangay Panaligaan has moderate to high, Taburi with low to moderate and the rest of the barangays with low susceptibilities, respectively.

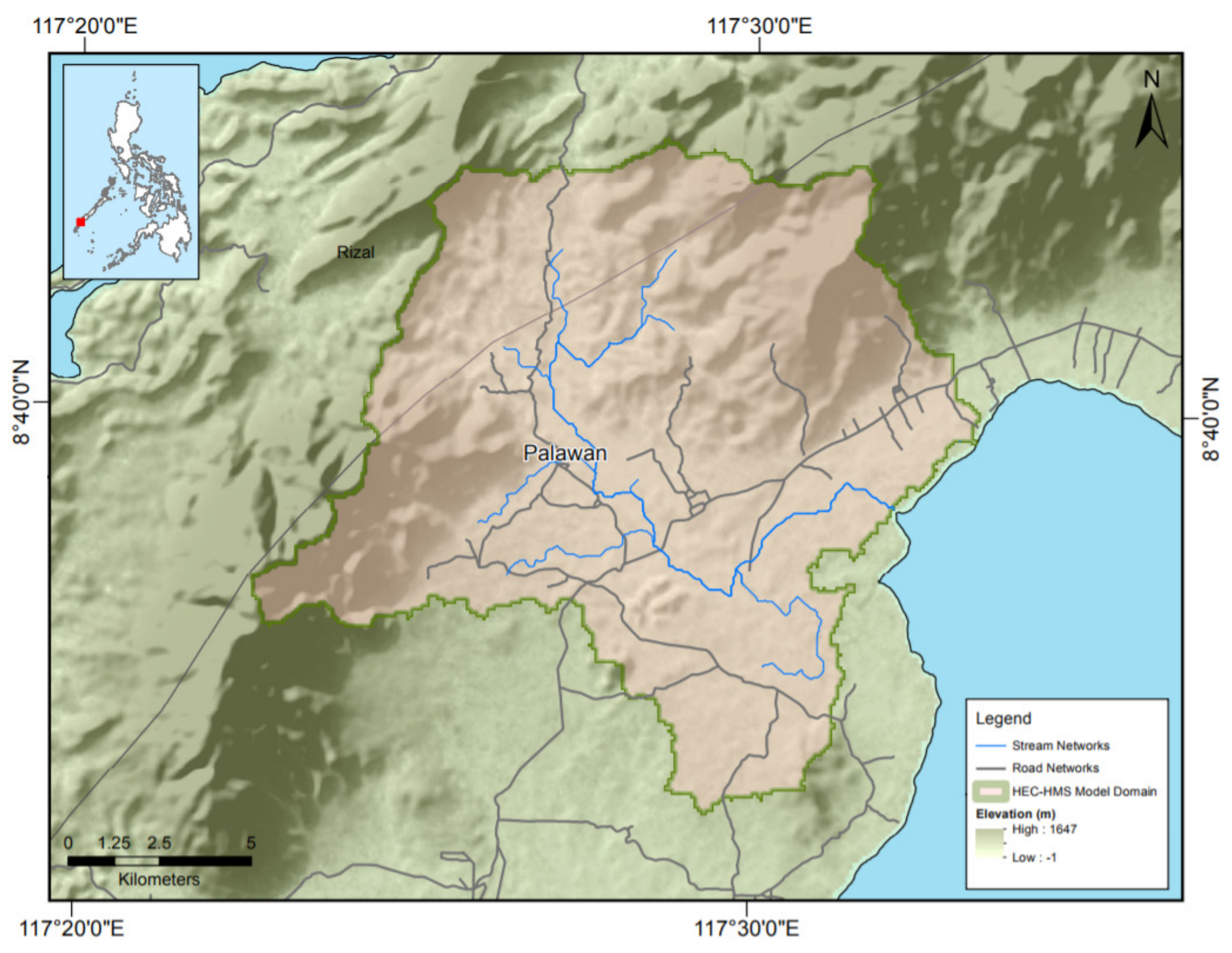

Figure 1. Map of Iwahig Brookes River Basin

The Iwahig Brookes River Basin covers one (1) municipality in Palawan; namely, the municipality of Bataraza. The DENR River Basin Control Office (RBCO) states that the Iwahig Brookes River Basin has a drainage are of 150 km² and an estimated 240 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Iwahig Brookes River, is part of the forty-five (45) river systems under the PHIL-LIDAR 1 Program partner HEI, University of the Philippines Los Baños. According to the 2015 national census of PSA, a total of 4,926 persons are residing in Brgy. Tarusan in the Municipality of Bataraza, which is within the immediate vicinity of the river. The economy of the province of Palawan is primarily agriculture-based; particularly fishing, tourism, trade, commerce, and mineral extraction (Source: pkp.pcsd.gov.ph/images/ppcprofile/Economic%20Profile.pdf). On November 17, 2016, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Iwahig Brookes River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Southern Luzon, Visayas and Mindanao as per NDRRMC report (Source: http://www.ndrrmc.gov.ph/attachments/article/3/General_ Flood_Advisories_as_of_17NOV2016_1700H.pdf).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE IWAHIG BROOKES 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 Iwahig Brookes floodplain in Palawan. These missions were planned for 19 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plan for Iwahig Brookes floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK42Q	1200	30	50	200	30	130	5
BLK42R	1200	30	50	200	30	130	5
BLK42T	1200	30	50	200	30	130	5

Table 2. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK42Q	1200	30	50	200	30	130	5
BLK42R	1200	30	50	200	30	130	5
BLK42T	1200	30	50	200	30	130	5
BLK42eN	1200	30	50	200	30	130	5
BLK42eP	1200	30	50	200	30	130	5
BLK42eQ	1200	30	50	200	30	130	5
BLK42eR	1200	30	50	200	30	130	5
BLK42eS	1200	30	50	200	30	130	5
BLK42eT	1200	30	50	200	30	130	5

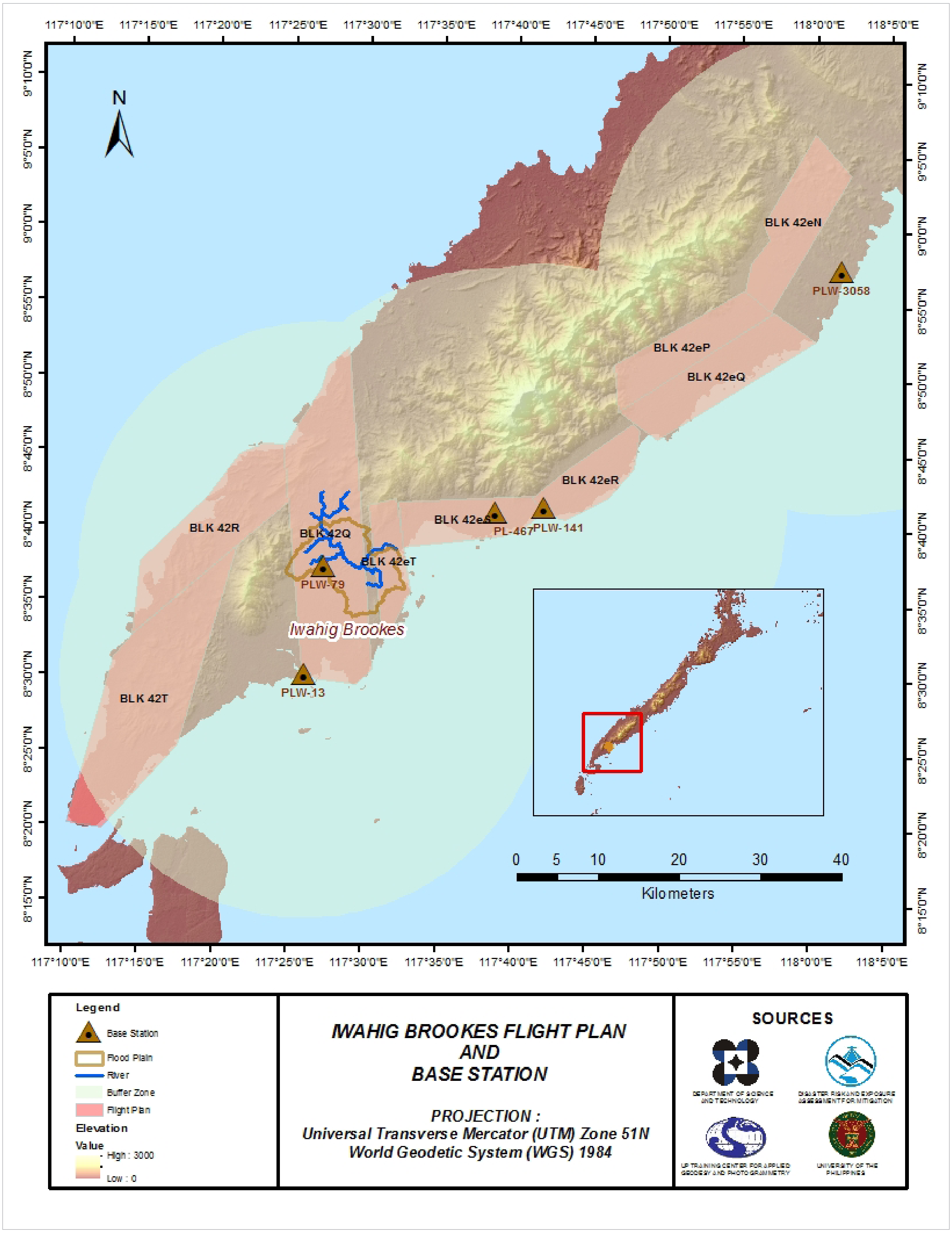


Figure 2. Flight plans used for Iwahig Brookes Floodplain

2.2 Ground Base Station

The project team was able to recover three (3) NAMRIA ground control points: PLW-13, PLW-79, and PLW-136 which are of second (2^{nd}) order accuracy. The project team also re-established ground control point PLW-3058, a NAMRIA reference point of fourth (4th) order accuracy. One (1) NAMRIA benchmark was used: PL-467 which is of first (1^{st}) order accuracy. This benchmark was used as vertical reference point and was also established as ground control point. The certifications for the NAMRIA reference points are found in ANNEX 2, while the processing reports for the re-established point and benchmark are found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (June 28 to July 8, 2015; December 3-10, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Iwahig Brookes floodplain are shown in Figure 2. The list of LiDAR acquisition team members are shown in ANNEX 4.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area, in addition Table 3 to Table 7 show the details about the following NAMRIA control stations and established points, Table 8 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

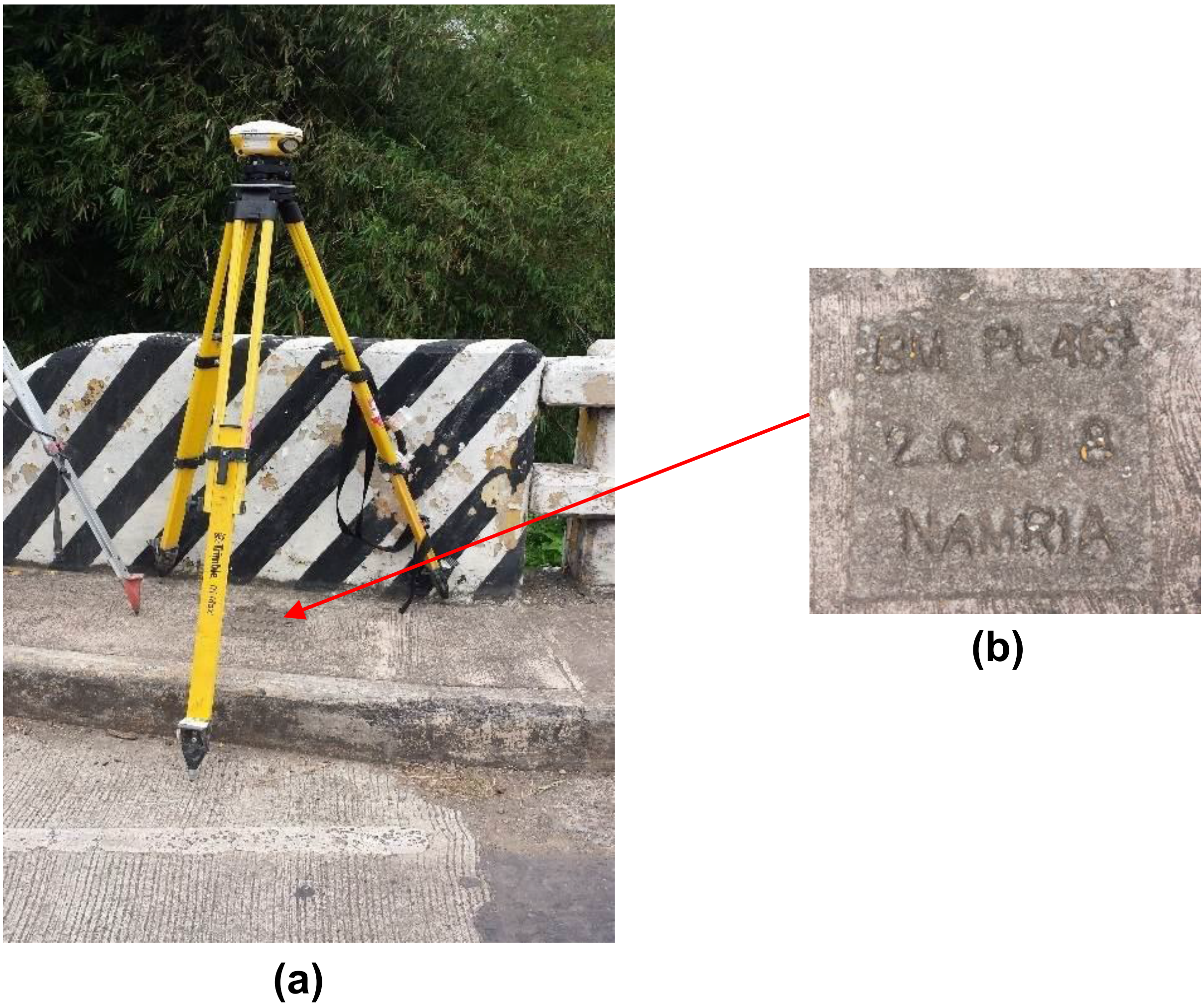
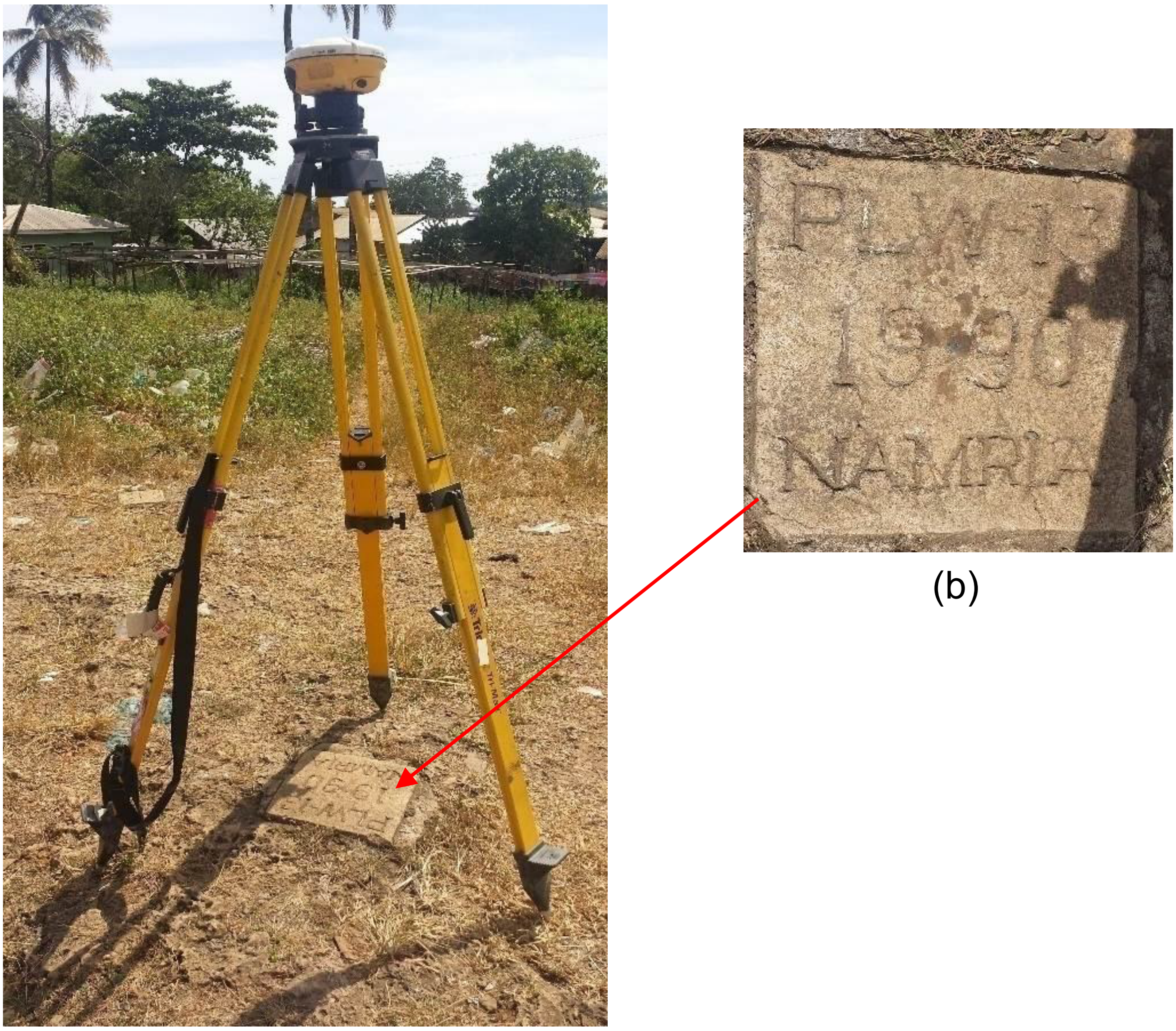


Figure 3. GPS set-up over PL-467 recovered on Inogbong Bridge, Bataraza Palawan (a) and NAMRIA reference point PL-467 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA Benchmark PL-467 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	PL-467	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 41’ 12.30540” North 117° 38’ 32.43781” East 7.171 meters
Grid Coordinates, Philippine Transverse Mercator Zone 50 (UTM Zone 50N WGS84)	Easting Northing	570829.589 meters 960149.784 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 41’ 8.04286” North 117° 38’ 37.85953” East 56.931 meters



(b)

(a)

Figure 4. GPS set-up over PLW-13 as recovered at Brgy. Rio Tuba, Palawan (a) and NAMRIA reference point PLW-13 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point PLW-13 used as base station for the LiDAR acquisition

Station Name	PLW-13	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 30' 17.42901" North 117° 25' 55.42672" East -0.25567 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	382414.126 meters 940540.844 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°30 '13.19373" North 117°26'0.86501" East 49.35 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting Northing	547553.57 meters 940076.76 meters

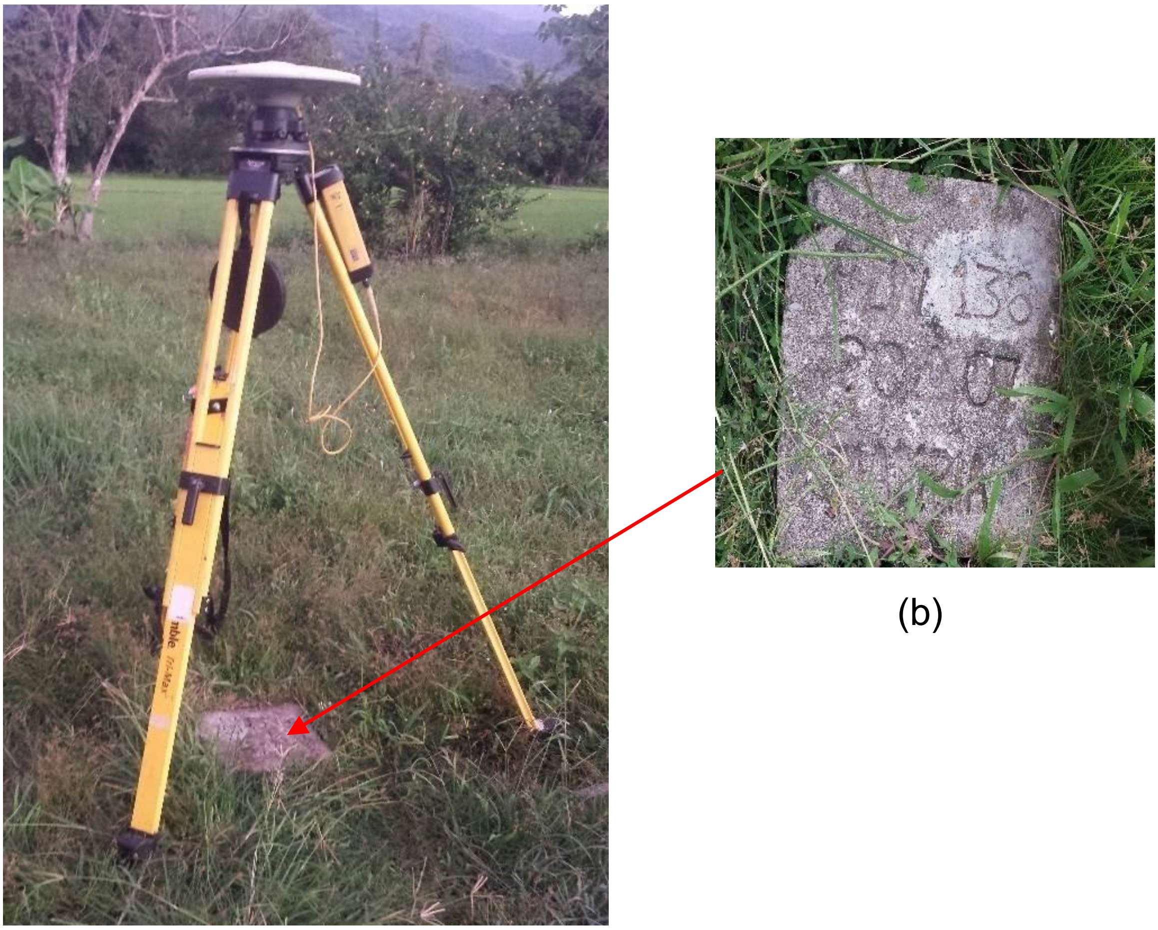
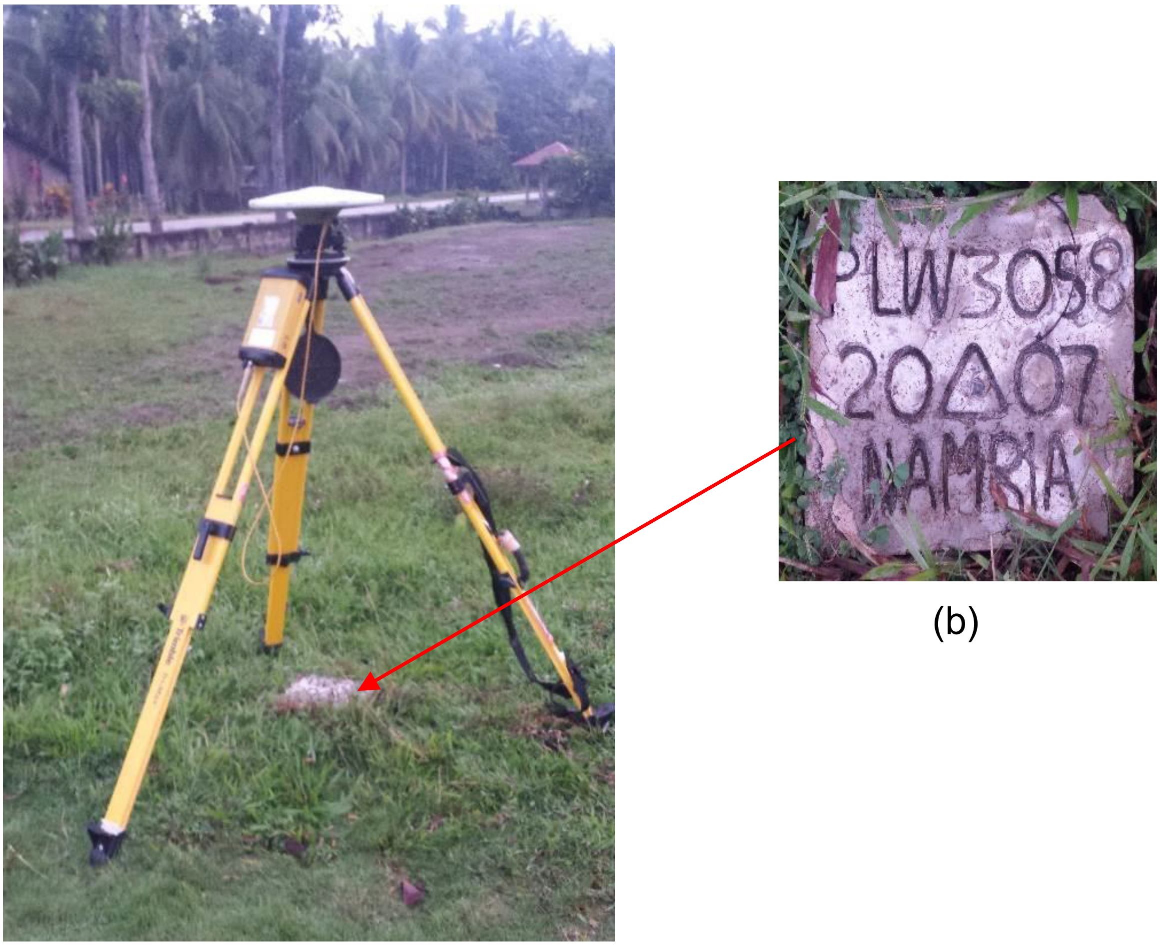


Figure 5. GPS set-up over PLW-136 as recovered in Malis Elementary School, Brooke's Point, Palawan (a) and NAMRIA reference point PLW-136 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point PLW-136 used as base station for the LiDAR acquisition

Station Name	PLW-136	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 41' 32.51585"North 117°41' 48.08062"East -2.493 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	411596.8 meters 961210.738 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 41' 28.25671" North 117° 41' 53.50178" East 47.391 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting Northing	576642.18 meters 960851.09meters



(a) (b)

Figure 6. GPS set-up over PLW-3058 as recovered on the ground inside Caranasan Elementary School, Espanola, Palawan (a) and NAMRIA reference point PLW-3058 (b) as recovered by the field team.

Table 6. DDetails of the recovered NAMRIA horizontal control point PLW-3058 used as base station for the LiDAR acquisition with re-processed coordinates.

Station Name	PLW-3058	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 57'34.41144"North 118° 1' 39.35193"East -2.979 meters
Grid Coordinates, Philippine Transverse Mercator Zone 50 (UTM Zone 50 WGS84)	Easting Northing	613130.87 meters 990407.36 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 57' 30.11418" North 118° 1' 44.74872" East 47.176 meters

Table 7. Details of the recovered NAMRIA horizontal control point PLW-79 used as base station for the LiDAR acquisition.

Station Name	PLW-79	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 32' 30.44877"North 117° 27' 5.39850"East 25.88011 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	384591.01 meters 953839.48 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 37' 26.18482" North 117° 27' 10.82604" East 75.29000 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 51N PRS 92)	Easting Northing	549677.23 meters 953376.65 meters

Table 8. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
28-Jun-15	3105P	1BLK42QR179A	PLW-13, PLW-79
29-Jun-15	3109P	1BLK42QR180A	PLW-13, PLW-79
8-Jul-15	3141P	1BLK42QRT188A	PLW-13, PLW-79
8-Jul-15	3145P	1BLK42QRT189A	PLW-13, PLW-79
3-Dec-15	3565G	2BLK42QR337A	PL-467, PLW-136
4-Dec-15	3571G	2BLK42Tv338A	PLW-13
8-Dec-15	3585G	2BLK42N342A	PLW-13, PLW-3058
10-Dec-15	3593G	2BLK42TwEwF344A	PLW-13, PLW-136
10-Dec-15	3595G	2BLK42US344B	PLW-13, PLW-136

2.3 Flight Missions

Nine (9) missions were conducted to complete the LiDAR Data Acquisition in Iwahig Brookes Floodplain, for a total of twenty-eight hours and forty-three minutes (28+43) of flying time for RP-C9022. All missions were acquired using the Pegasus and Gemini LiDAR system. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight Missions for LiDAR Data Acquisition in Iwahig Brookes 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
28-Jun-15	3105P	766.78	290.43	24.63	265.8	566	3	21
29-Jun-15	3109P	314.79	158.16	45.61	112.55	NA	2	15
8-Jul-15	3141P	766.78	337.17	11.71	325.46	34	4	5
8-Jul-15	3145P	170.51	104.30	NA	104.3	3	2	5
3-Dec-15	3565G	382.21	154.05	NA	154.05	NA	3	19
4-Dec-15	3571G	368.73	92.59	32.26	60.33	NA	3	5
8-Dec-15	3585G	246.31	120.42	2.09	118.33	NA	3	53
10-Dec-15	3593G	505.92	127.29	6.16	121.13	NA	3	59
10-Dec-15	3595G	83.37	140.93	NA	140.93	NA	2	41
TOTAL		**3605.40**	**1525.30**	**122.46**	**1402.90**	**603**	**28**	**43**

Table 10. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3105P	1100	30	50	200	30	130	5
3109P	100	30	50	200	30	130	5
3141P	1200	30	50	200	30	130	5
3145P	800	30	50	200	30	130	5
3565G	100, 850	30	26	100	50	130	5
3571G	850, 1000	30	26	100	50	130	5
3585G	1000, 700	30	26	100	50	130	5
3593G	1000	30	26	100	50	130	5
3595G	850, 600	30	26	100	50	130	5

2.4 Survey Coverage

Iwahig Brookes floodplain is located in the province of Palawan, with majority of the floodplain situated within the municipality of Bataraza. Municipality of Bataraza is mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Iwahig Brookes floodplain is presented in Figure 7.

Table 11. List of municipalities and cities surveyed during Iwahig Brookes Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Palawan	Bataraza	818.11	593.89	73%
	Brooke's Point	893.39	148.67	17%
	Rizal	980.59	266.84	27%
	Sofronio Espanola	477.50	88.39	19%
TOTAL		**3169.59**	**1097.79**	**35%**

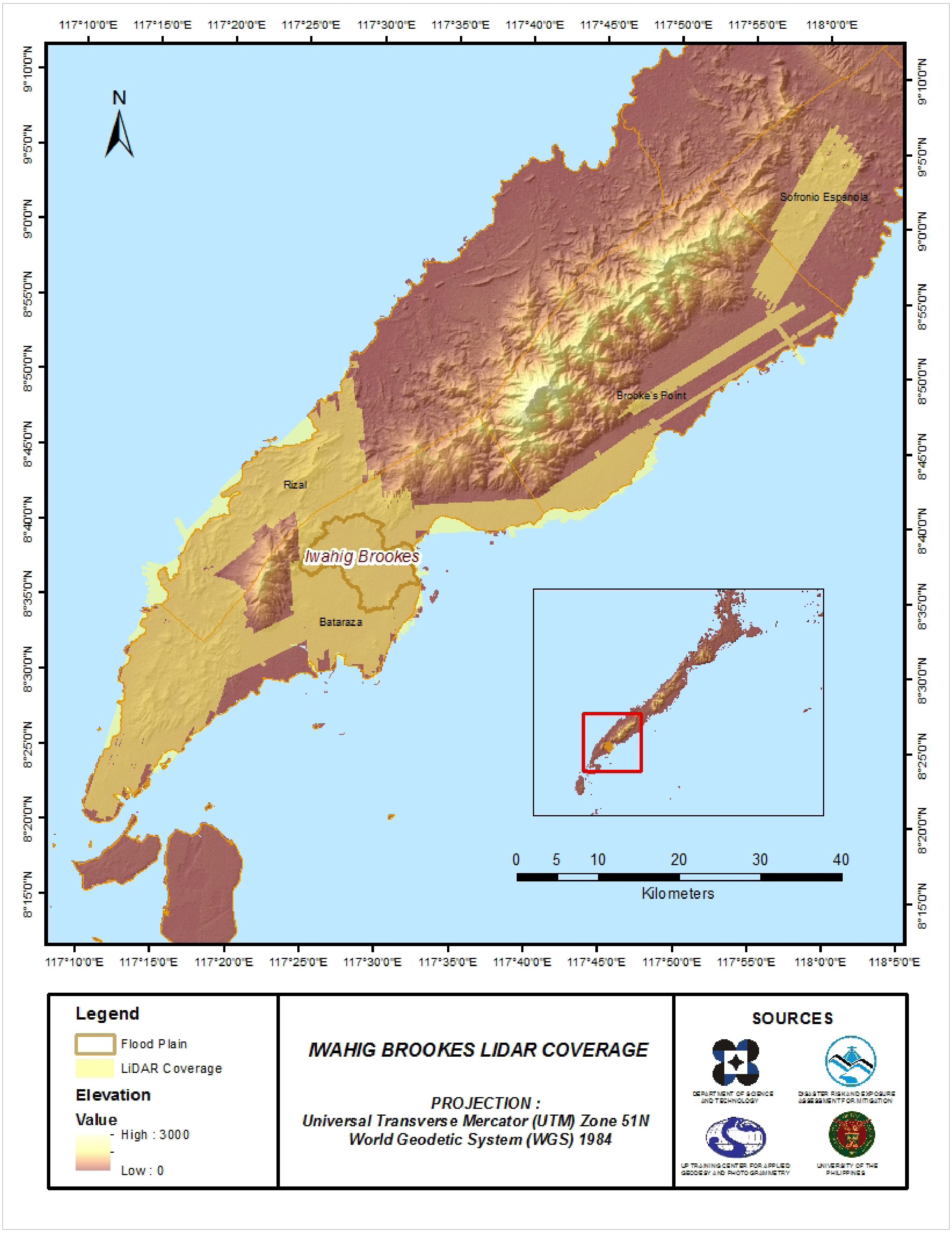


Figure 7. Actual LiDAR survey coverage for Iwahig Brookes floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE IWAHIG BROOKES 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 are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 8.

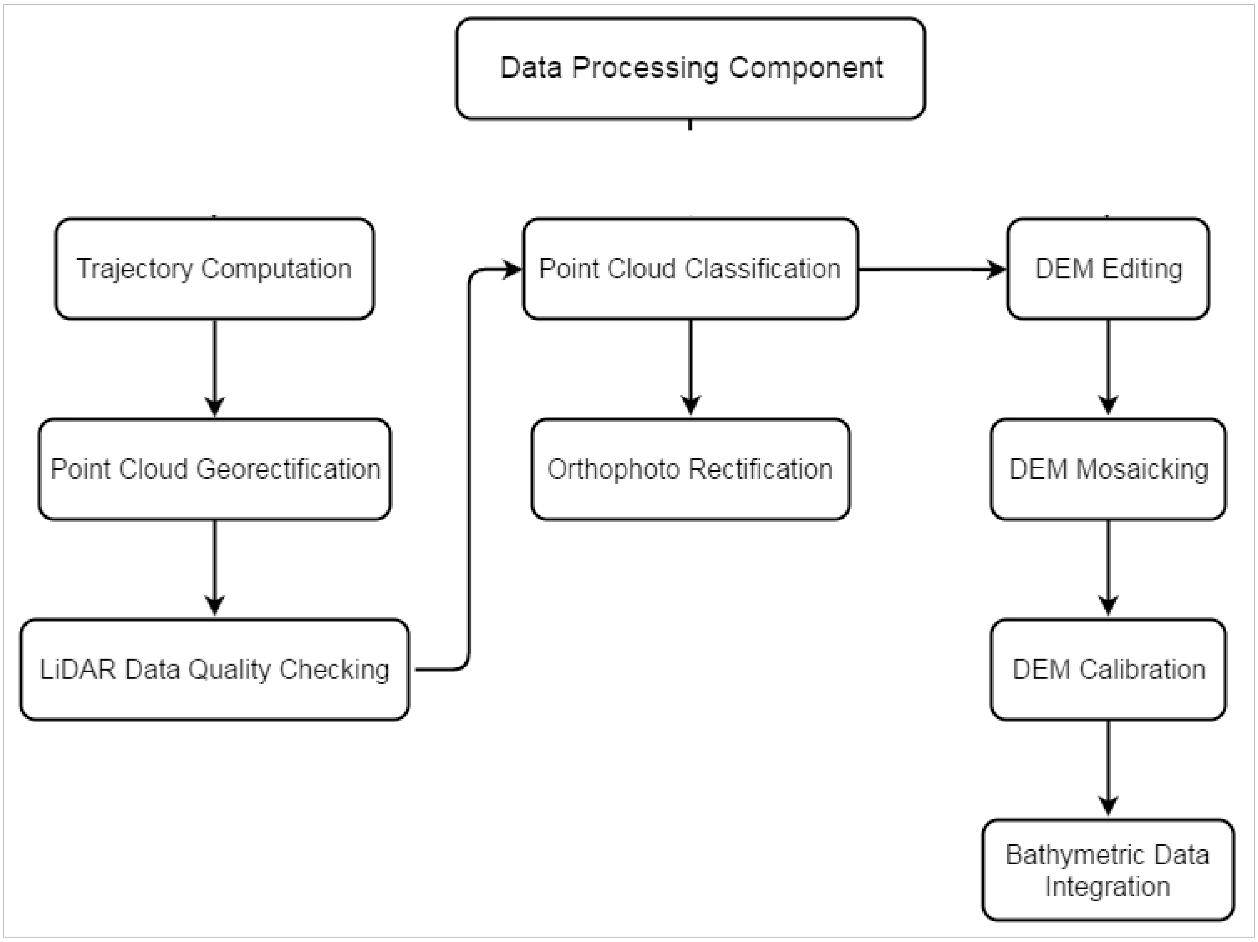

Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Iwahig Brookes floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on June 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on November 2015 were flown using the Gemini system over Bataraza, Palawan.

The Data Acquisition Component (DAC) transferred a total of 170.9 Gigabytes of Range data, 1.73 Gigabytes of POS data, 71.98 Megabytes of GPS base station data, and 223.01 Gigabytes of raw image data to the data server on July 8, 2015 for the first survey and December 3, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Iwahig Brookes was fully transferred on January 5, 2016, as indicated on the Data Transfer Sheets for Iwahig Brookes floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3109P, one of the Iwahig Brookes flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 29, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

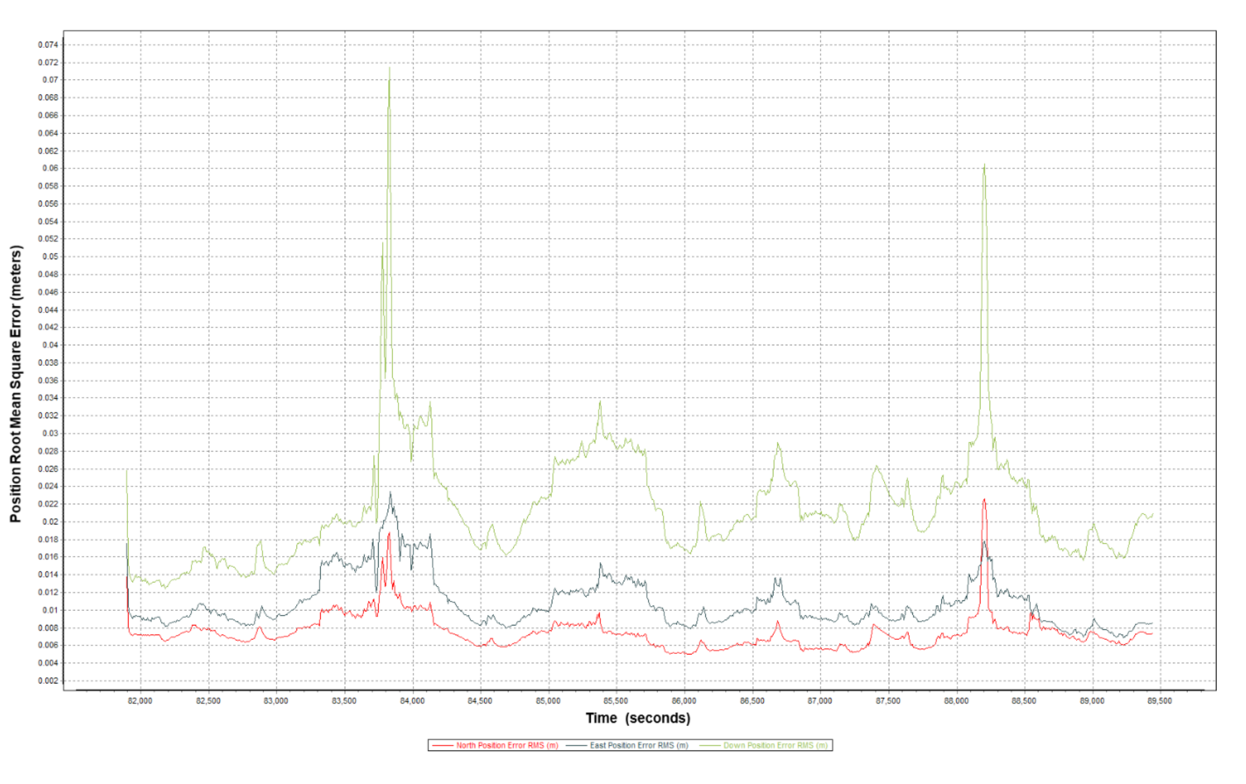

Figure 9. Smoothed Performance Metric Parameters of Iwahig Brookes Flight 3109P.

The time of flight was from 81900 seconds to 89500 seconds, which corresponds to morning of June 29, 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 starts 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 9 shows that the North position RMSE peaks at 2.20 centimeters, the East position RMSE peaks at 2.40 centimeters, and the Down position RMSE peaks at 7.20 centimeters, which are within the prescribed accuracies described in the methodology.

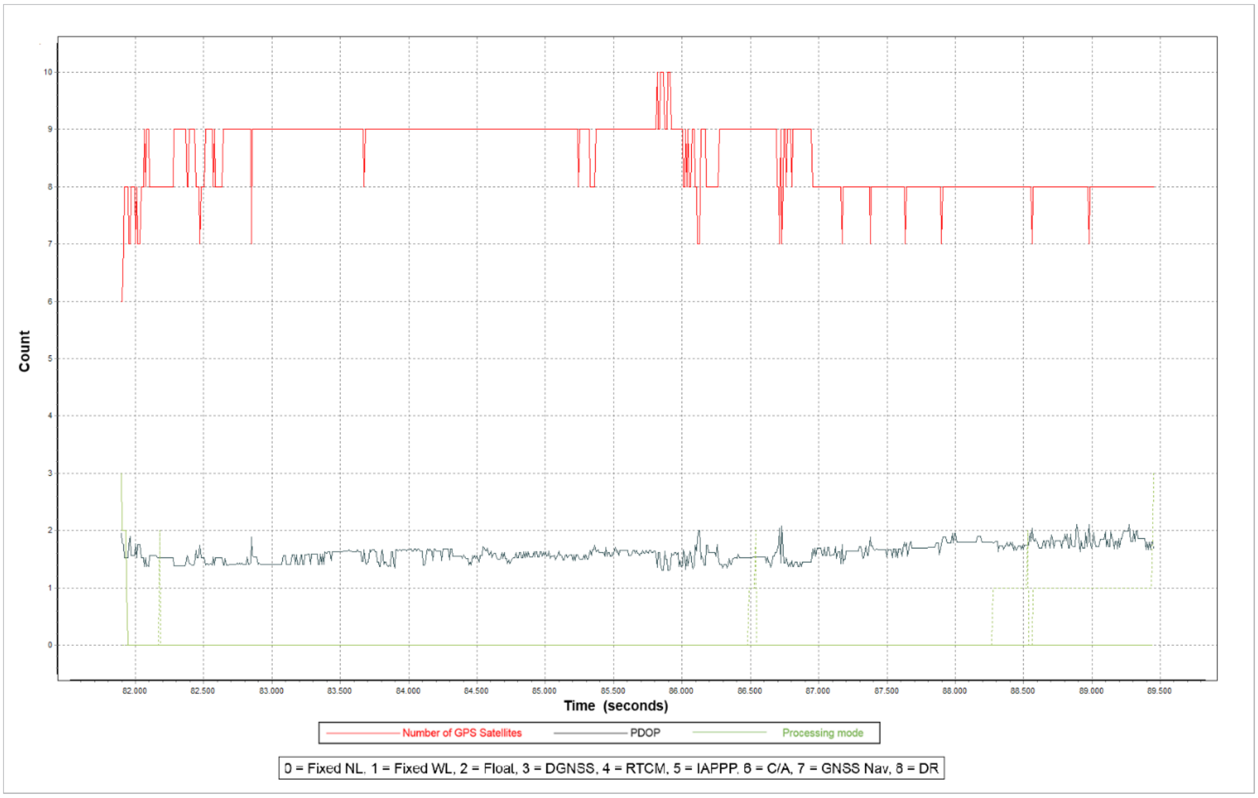

Figure 10. Solution Status Parameters of Iwahig Brookes Flight 3109P.

The Solution Status parameters of flight 3109P, one of the Iwahig Brookes flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 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 Iwahig Brookes flights is shown in Figure 11.

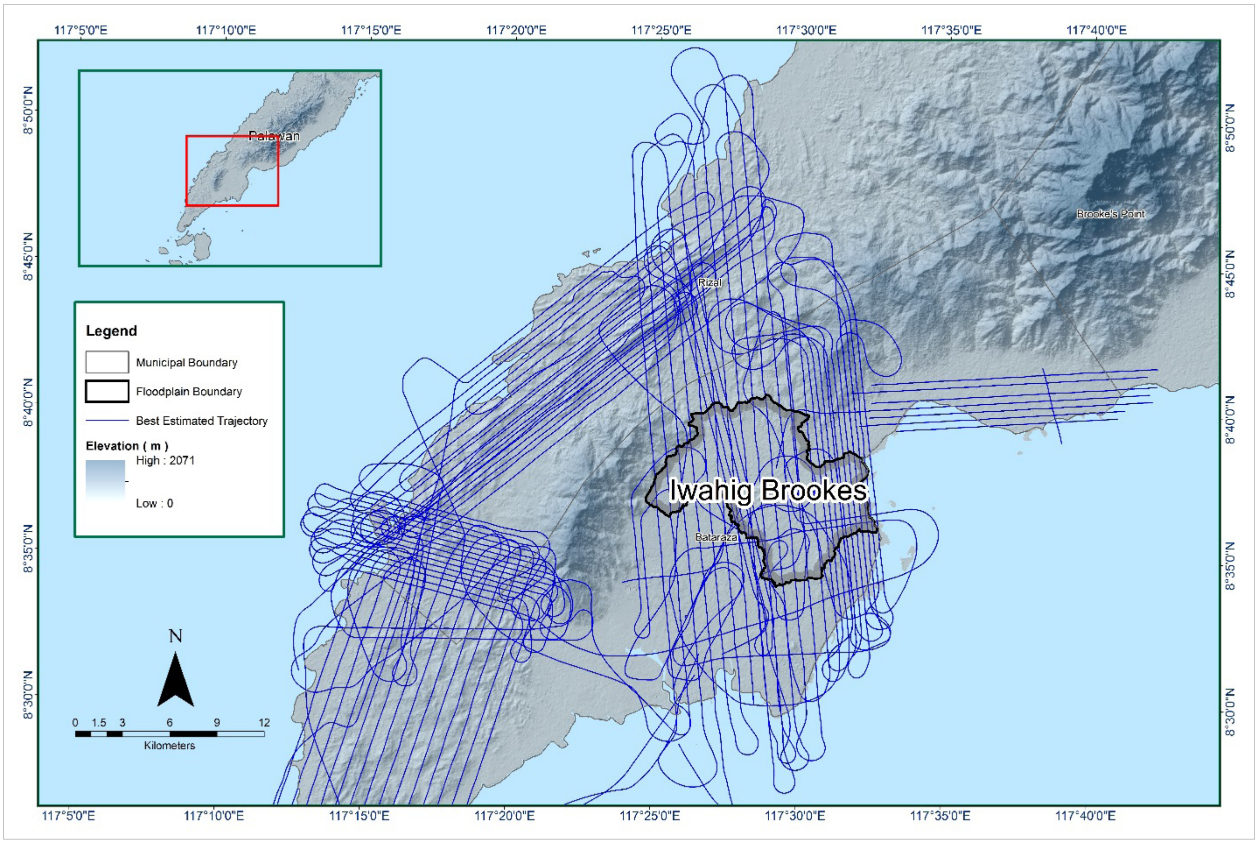

Figure 11. Best Estimated Trajectory for Iwahig Brookes Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 78 flight lines, with each flight line containing one channel for the Gemini system and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Iwahig Brookes floodplain are given in Table 12.

Table 12. Self-Calibration Results values for Iwahig Brookes flights.

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000201
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000705
GPS Position Z-correction stdev	(<0.01meters)	0.0016

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Iwahig Brookes Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

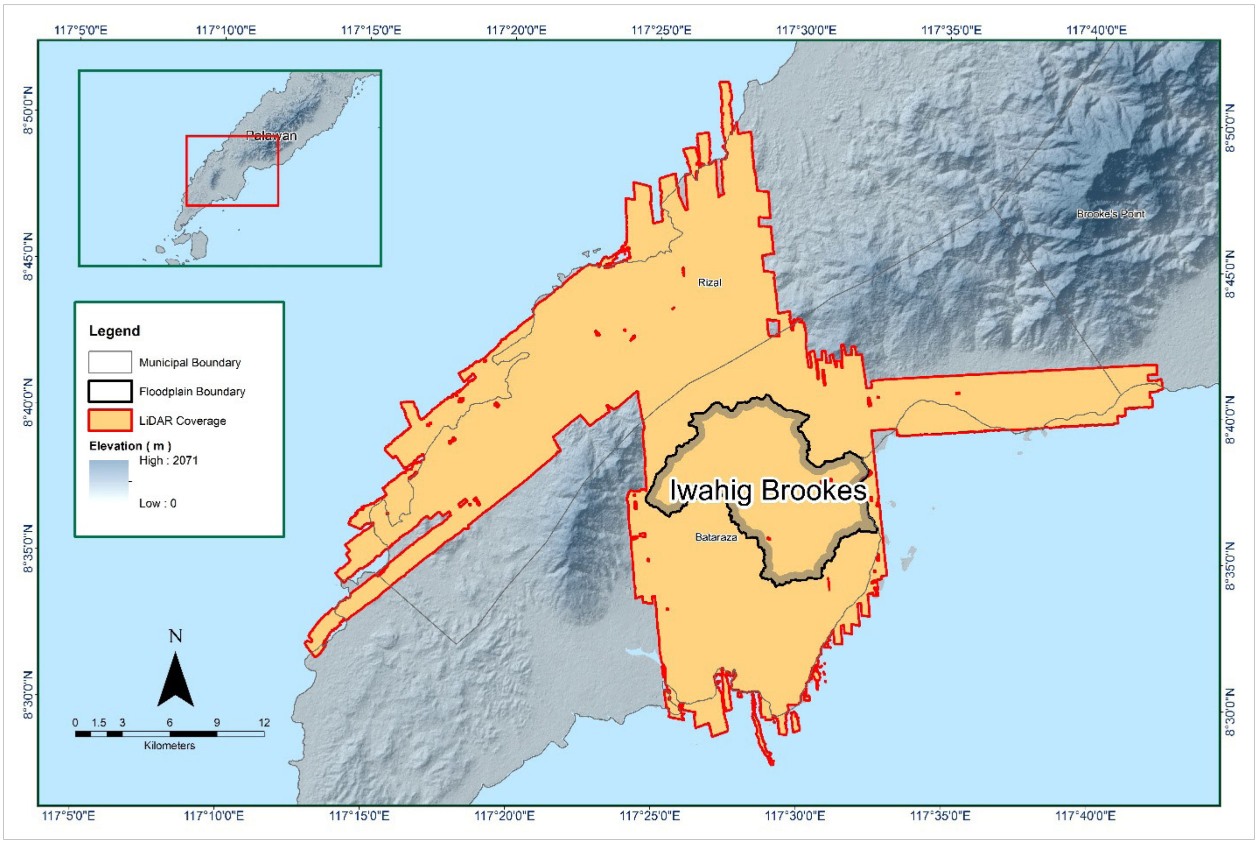

Figure 12. Boundary of the processed LiDAR data over Iwahig Floodplain

The total area covered by the Iwahig Brookes missions is 736.05 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Iwahig Brookes Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_Blk42Q	3109P	231.80
	3105P	
Palawan_Blk42Q_additional	3141P	126.29
Palawan_Blk42R	3105P	174.43
	3141P	
	3145P	
Palawan_reflights_Blk42Q	3571G	37.71
Palawan_reflight_Blk42Q_additional	3571G	9.98
	3585G	
Palawan_reflights_Blk42R	3593G	33.71
Palawan_reflights_Blk42eS	3595G	62.56
	3565G	
Palawan_reflights_Blk42eT	3593G	59.57
	3571G	
TOTAL		**736.05 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 13. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

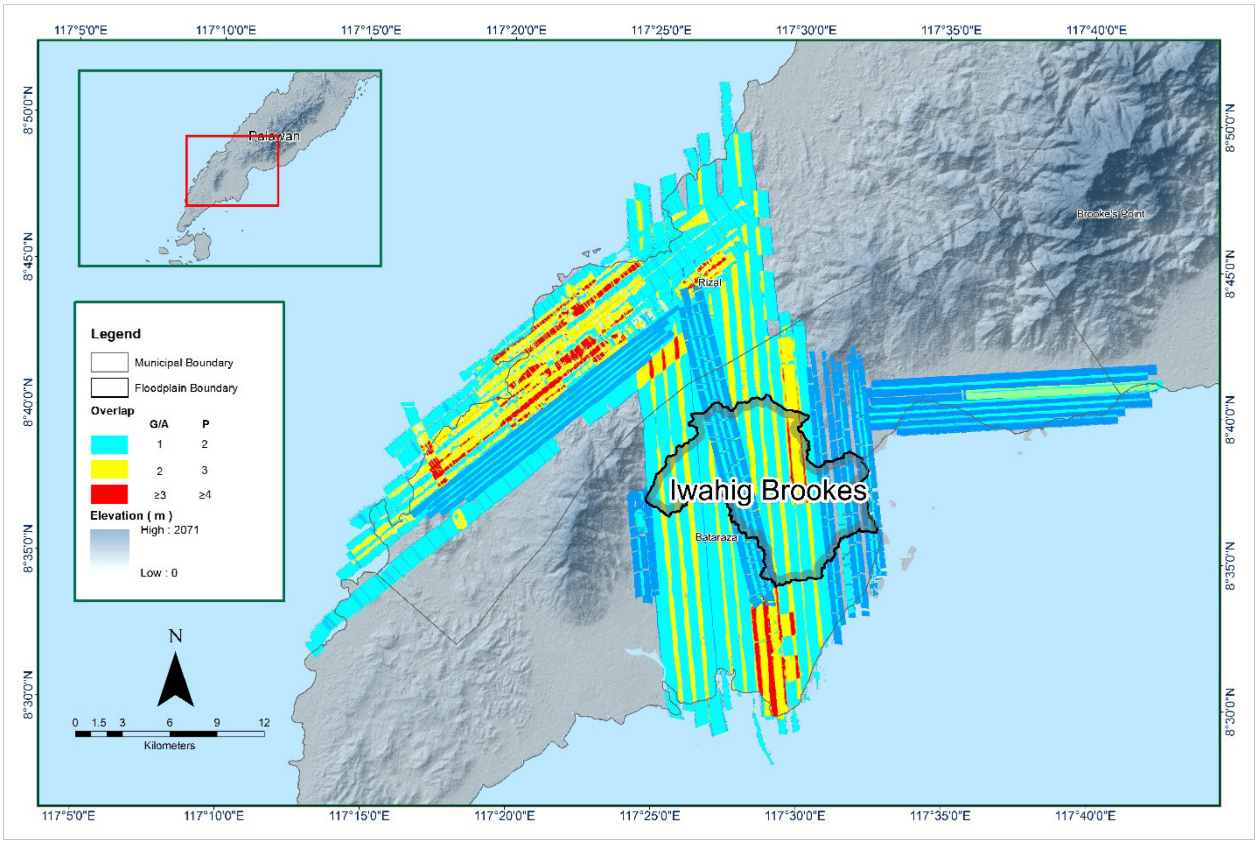

Figure 13. Image of data overlap for Iwahig Brookes Floodplain.

The overlap statistics per block for the Iwahig Brookes floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.85% and 43.57% 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 14. It was determined that all LiDAR data for Iwahig Brookes floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.44 points per square meter.

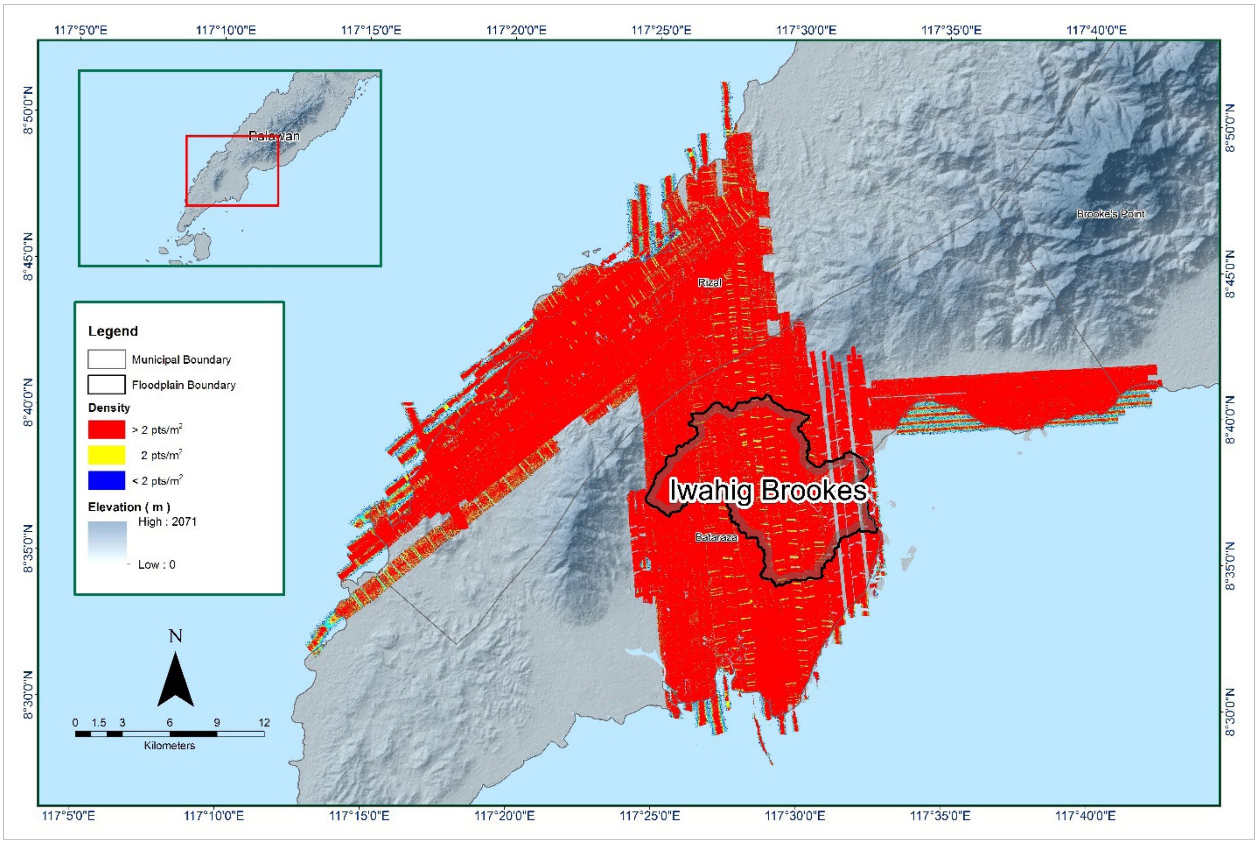

Figure 14. Pulse density map of merged LiDAR data for Iwahig Brookes Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

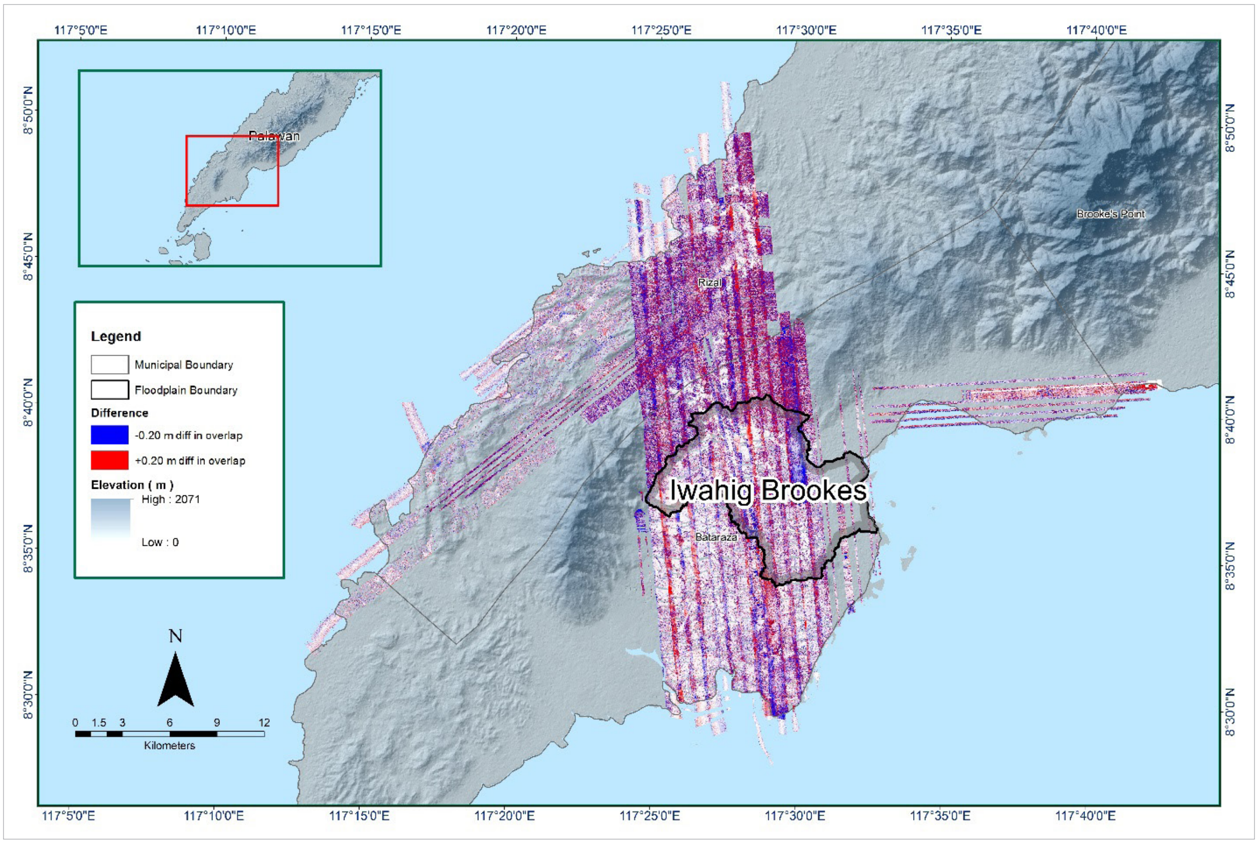

Figure 15. Elevation difference map between flight lines for Iwahig Brookes Floodplain.

A screen capture of the processed LAS data from an Iwahig Brookes flight 3109P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

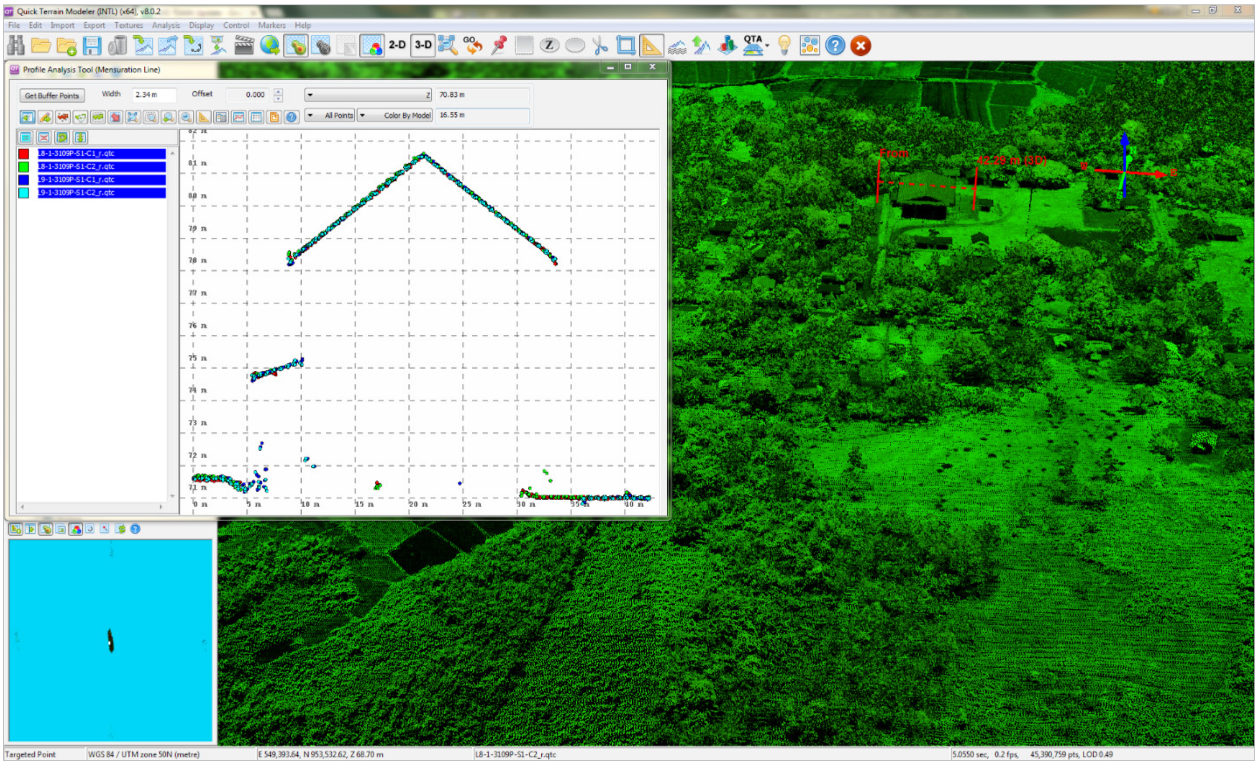

Figure 16. Quality checking for Iwahig Brookes flight 3109P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Iwahig Brookes classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	531,576,680
Low Vegetation	408,678,353
Medium Vegetation	1,290,906,261
High Vegetation	2,220,240,310
Building	38,681,537

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Iwahig Brookes floodplain is shown in Figure 17. A total of 1,093 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 755.44 meters and 31.86 meters respectively.

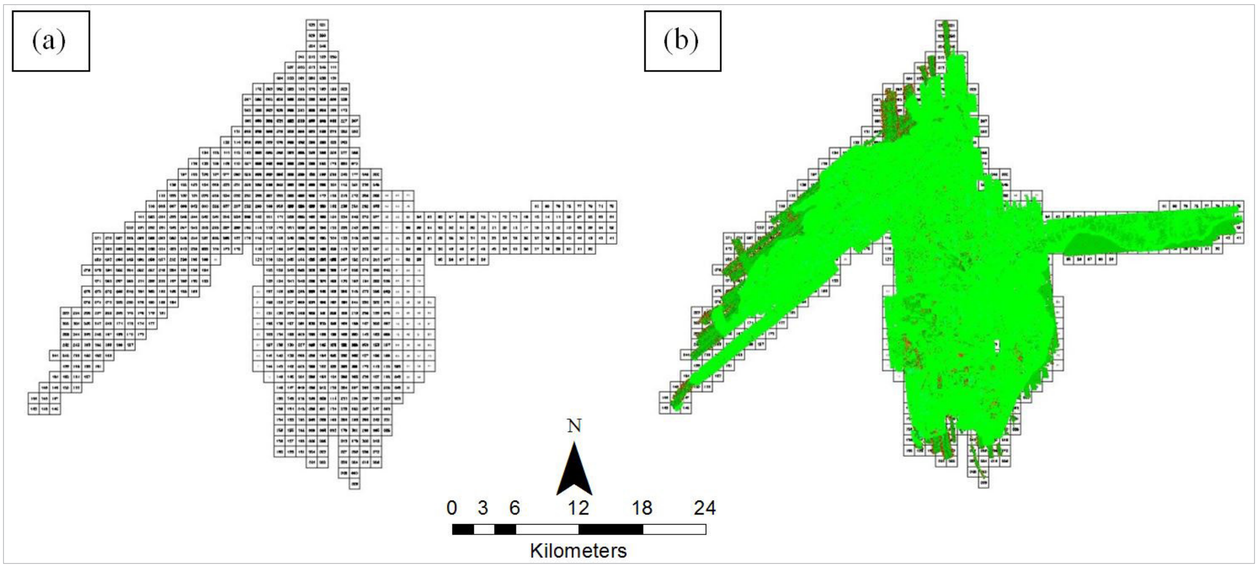

Figure 17. Tiles for Iwahig Brookes Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. 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.

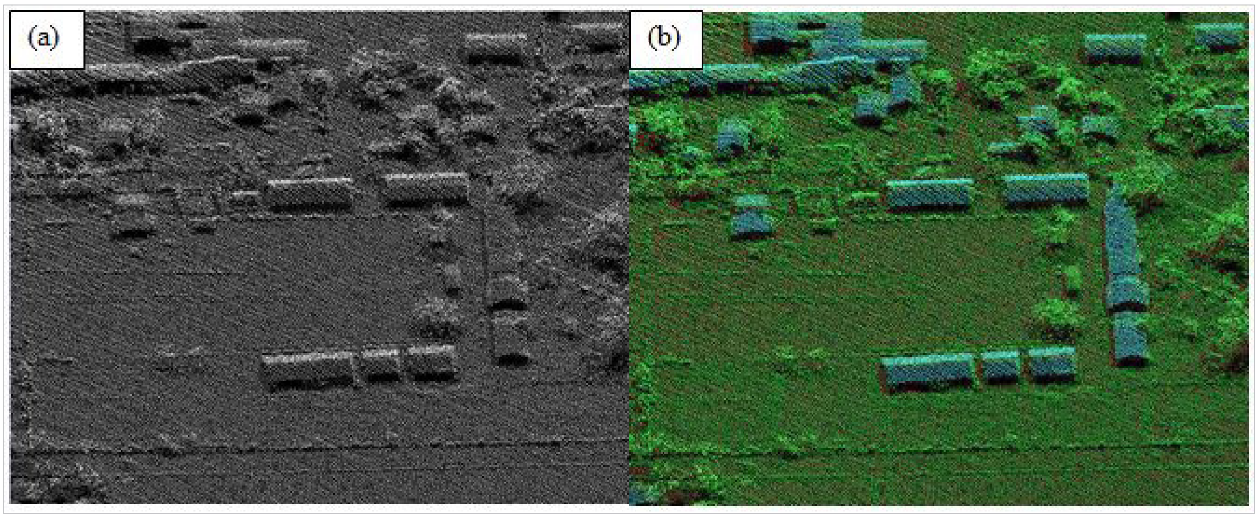

Figure 18. Point cloud before (a) and after (b) classification.

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

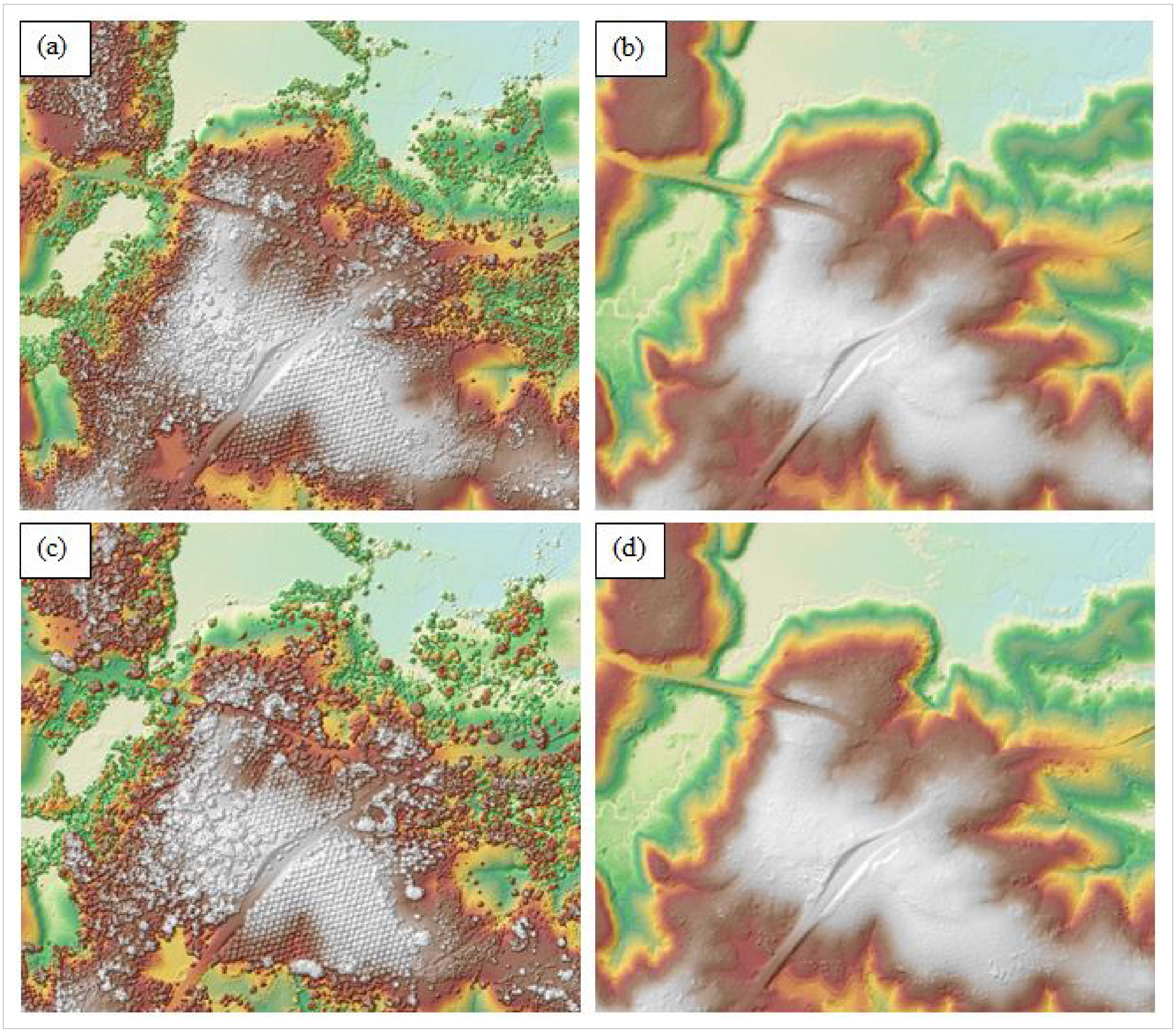

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Iwahig Brookes Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 385 1km by 1km tiles area covered by Iwahig Brookes floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Iwahig Brookes floodplain has a total of 215.10 sq.km orthophotogaph coverage comprised of 800 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

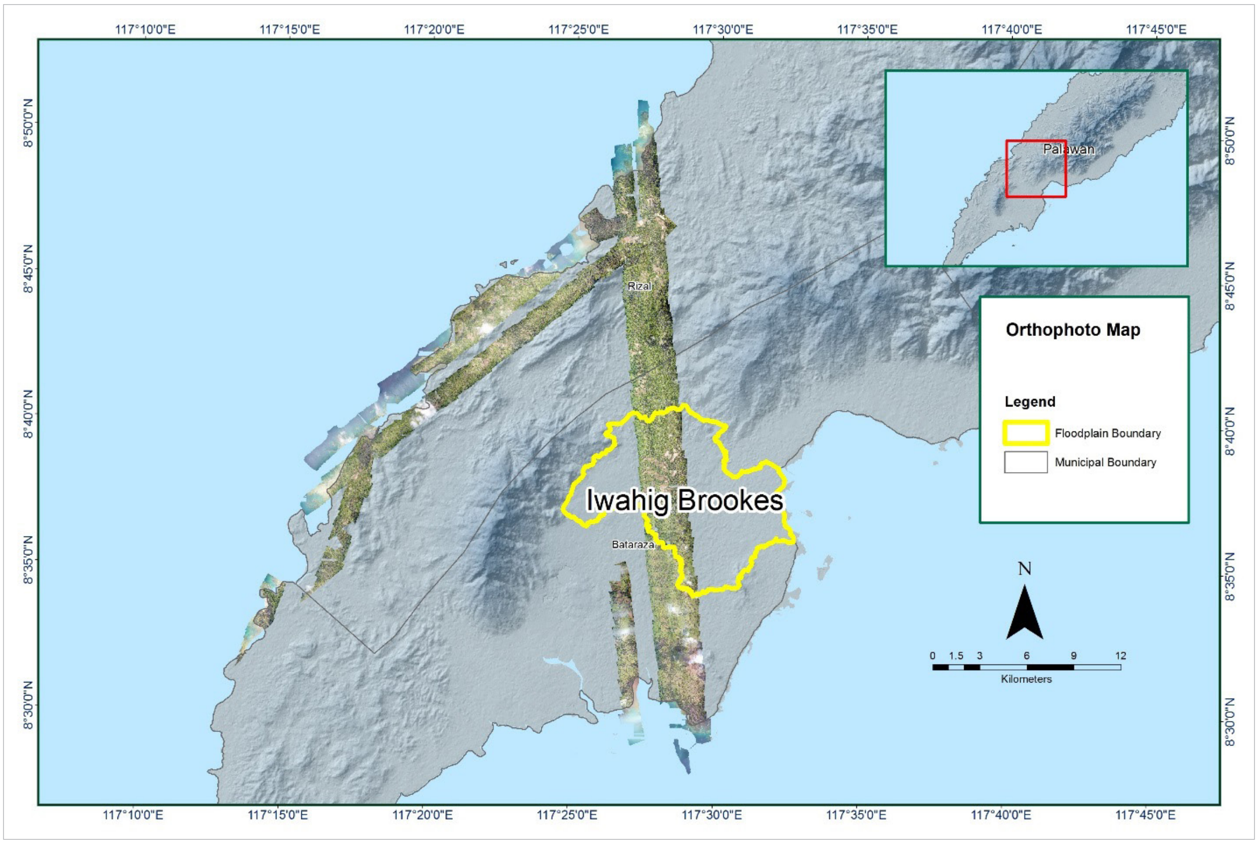

Figure 20. Iwahig Brookes Floodplain with available orthophotographs.

Figure 21. Sample orthophotograph tiles for Iwahig Brookes Floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Iwahig Brookes flood plain. These blocks are composed of Palawan blocks with a total area of 736.05 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Palawan_Blk42Q	231.80
Palawan_Blk42Q_additional	126.29
Palawan_Blk42R	174.43
Palawan_reflights_Blk42Q	37.71
Palawan_reflight_Blk42Q_additional	9.98
Palawan_reflights_Blk42R	33.71
Palawan_reflights_Blk42eS	62.56
Palawan_reflights_Blk42eT	59.57
TOTAL	**736.05 sq.km**

Portions of DTM before and after manual editing are shown in Figure 22. The data gap (Figure 22a) has been filled to complete the surface (Figure 22b) to allow the correct flow of water. The terrain (Figure 22c) was deformed and has the feature has be retrieved (Figure 22d) from the t ascii in order to correct the surface.

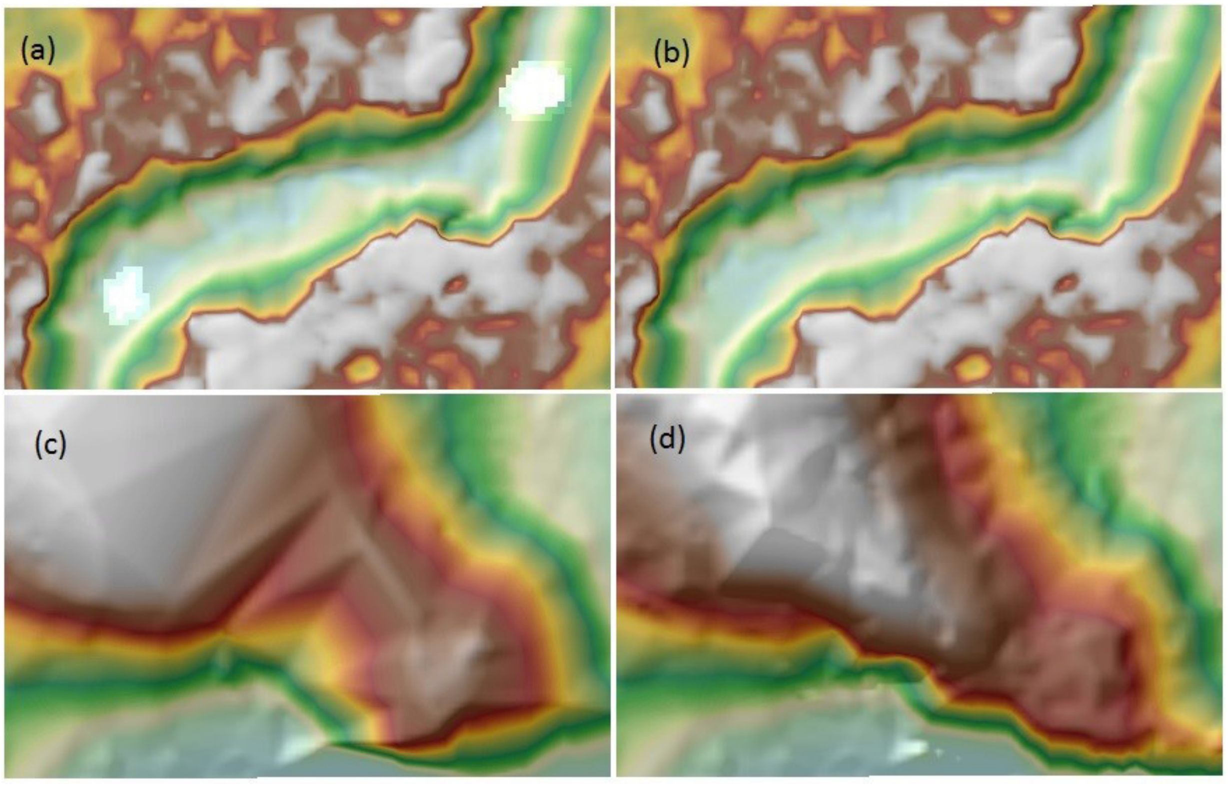

Figure 22. Portions in the DTM of Iwahig Brookes Floodplain – a data gap (a) and after (b) manual editing; and a deformed feature before (c) and after (d) object retrieval.

3.9 Mosaicking of Blocks

Palawan_Blk42Aa 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. Upon inspection of the blocks mosaicked for the Iwahig Brookes floodplain, it was concluded that the elevation of all the blocks are in need to be adjusted before mosaicking the DTM. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Iwahig Brookes floodplain is shown in Figure 23. It can be seen that the entire Iwahig Brookes floodplain is 98.94% covered by LiDAR data.

Table 16. Shift Values of each LiDAR Block of Iwahig Brookes Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42Q	0.00	0.00	6.20
Palawan_Blk42Q_additional	0.00	0.00	6.02
Palawan_Blk42R	0.00	0.00	6.10
Palawan_reflights_Blk42Q	0.00	0.00	7.09
Palawan_reflight_Blk42Q_additional	0.00	0.00	5.65
Palawan_reflights_Blk42R	0.00	0.00	6.60
Palawan_reflights_Blk42eS	0.00	0.00	6.55
Palawan_reflights_Blk42eT	0.00	0.00	6.38

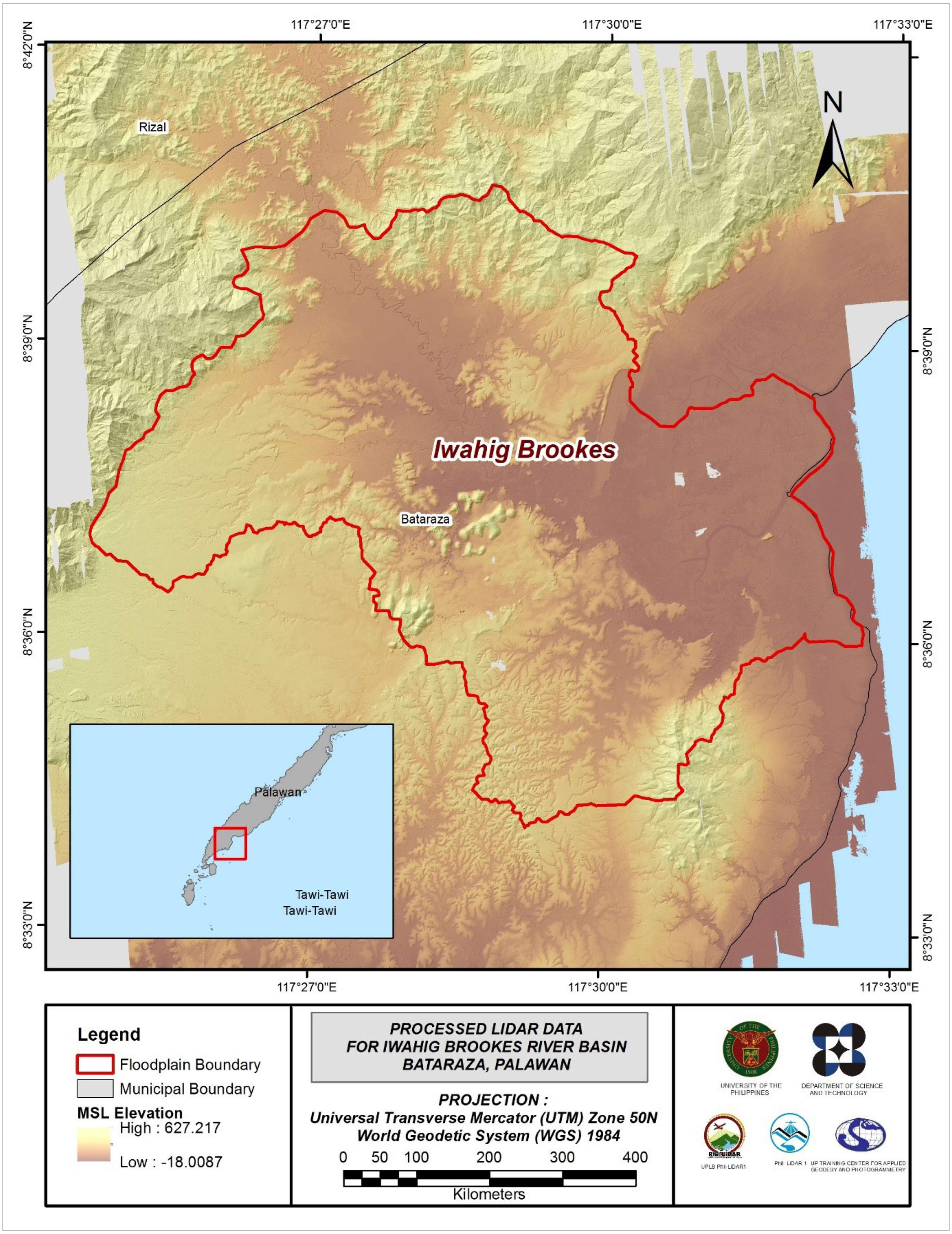

Figure 23. Map of Processed LiDAR Data for Iwahig Brookes Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Iwahig Brookes to collect points with which the LiDAR dataset is validated is shown Figure 24. A total of 211 survey points were used for calibration and validation of Iwahig Brookes LiDAR data. Random selection of 80% of the survey points, resulting to 169 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. 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 17.05 meters with a standard deviation of 0.12 meters. Calibration of Iwahig Brookes LiDAR data was done by adding the height difference value, 17.05 meters, to Iwahig Brookes mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

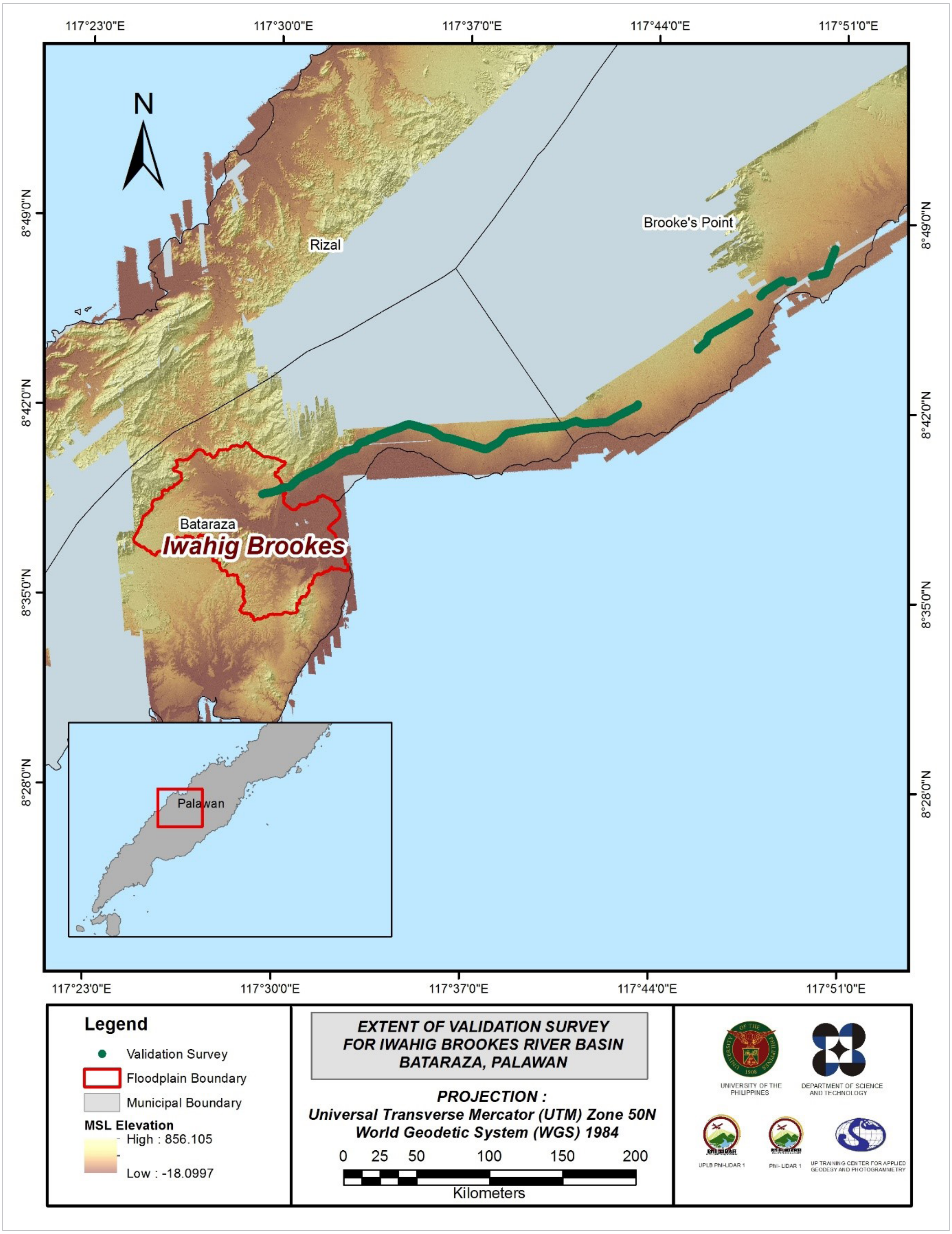

Figure 24. Map of Iwahig Brookes Floodplain with validation survey points in green.

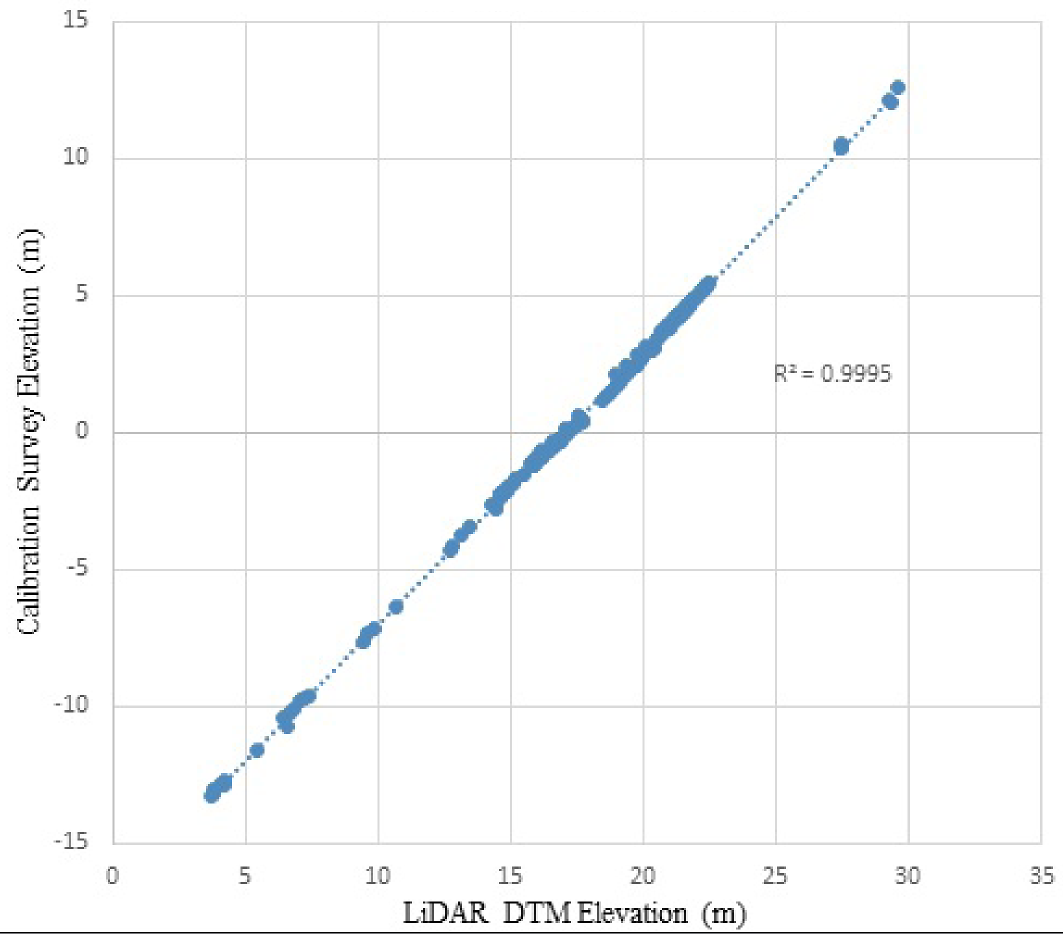

Figure 25. Correlation plot between calibration survey points and LiDAR data

Table 17. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	17.05
Standard Deviation	0.12
Average	17.05
Minimum	16.80
Maximum	17.30

The remaining 20% of the total survey points, resulting to 42, were used for the validation of calibrated Iwahig Brookes 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.14 meters with a standard deviation of 0.14 meters, as shown in Table 18.

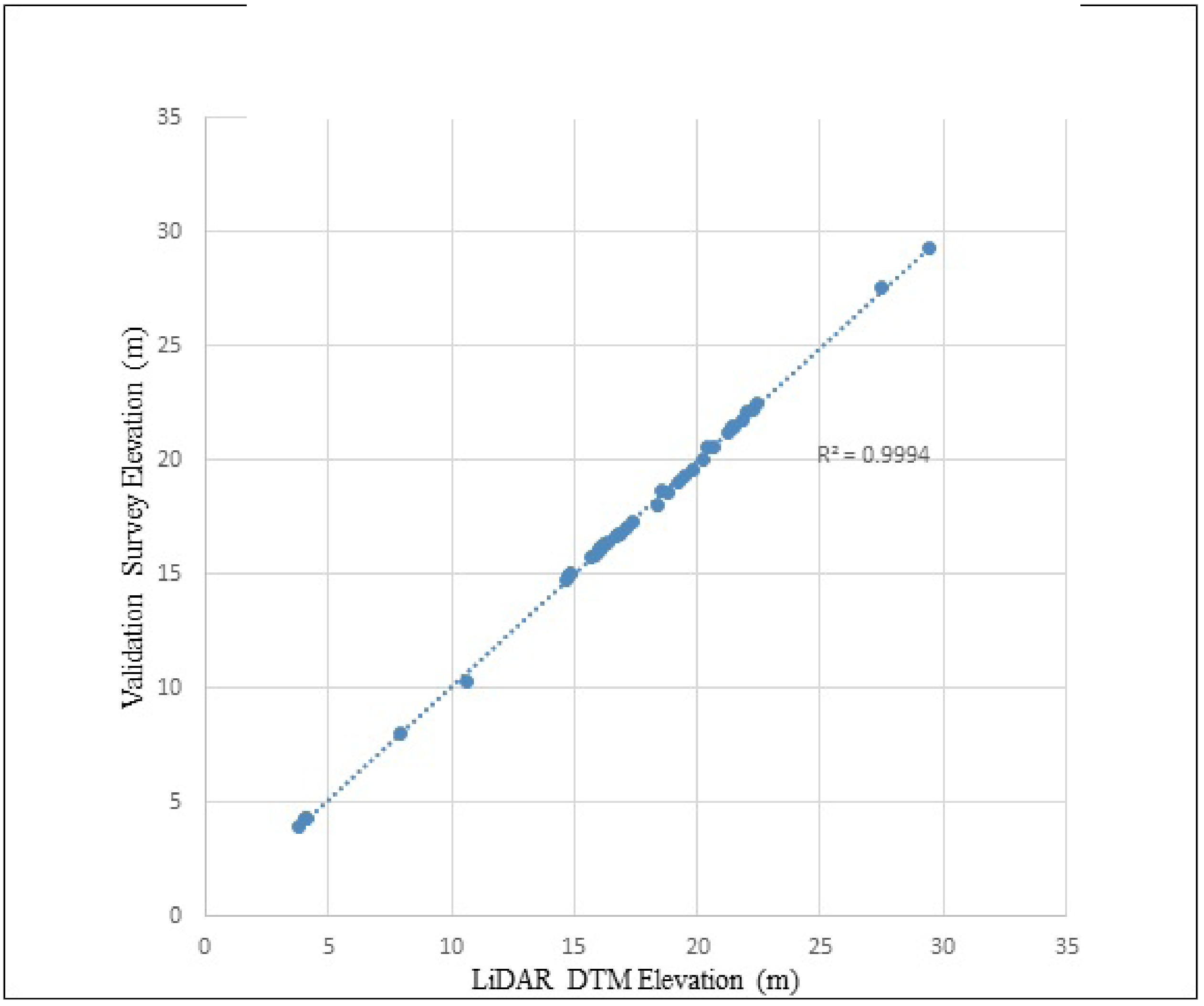

Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.14
Standard Deviation	0.14
Average	0.003
Minimum	-0.28
Maximum	0.28

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag points with 3,314 and 5,157 survey points, respectively were available for Iwahig Brookes with a total of 8,471 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.07 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Iwahig Brookes integrated with the processed LiDAR DEM is shown in Figure 27.

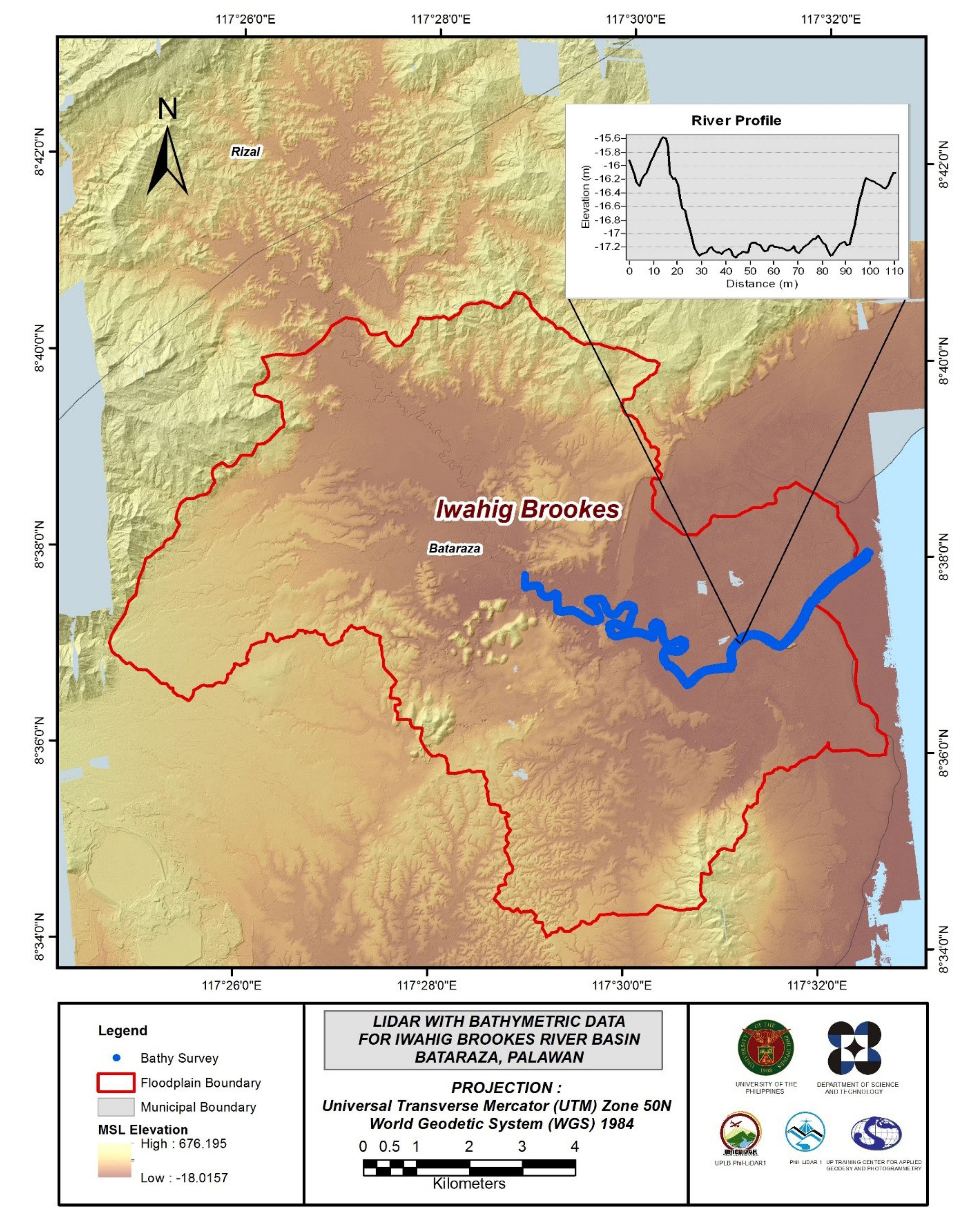

Figure 27. Map of Iwahig Brookes Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF IWAHIG BROOKES 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 Iwahig Brookes River on December 1, 2015, December 15 to 16, 2015 with the following scope: reconnaissance; control survey, cross-section, bridge as-built and water level marking in MSL of Iwahig Brookes Bridge; and bathymetric survey from the mouth of the river in Brgy. Tarusan up to the upstream in Brgy. Iwahig, both in the Municipality of Bataraza, Province of Palawan using GNSS survey technique and Hi-Target™ echo sounder. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVC 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 Iwahig Brookes River Basin area. The entire survey extent is illustrated in Figure 28.

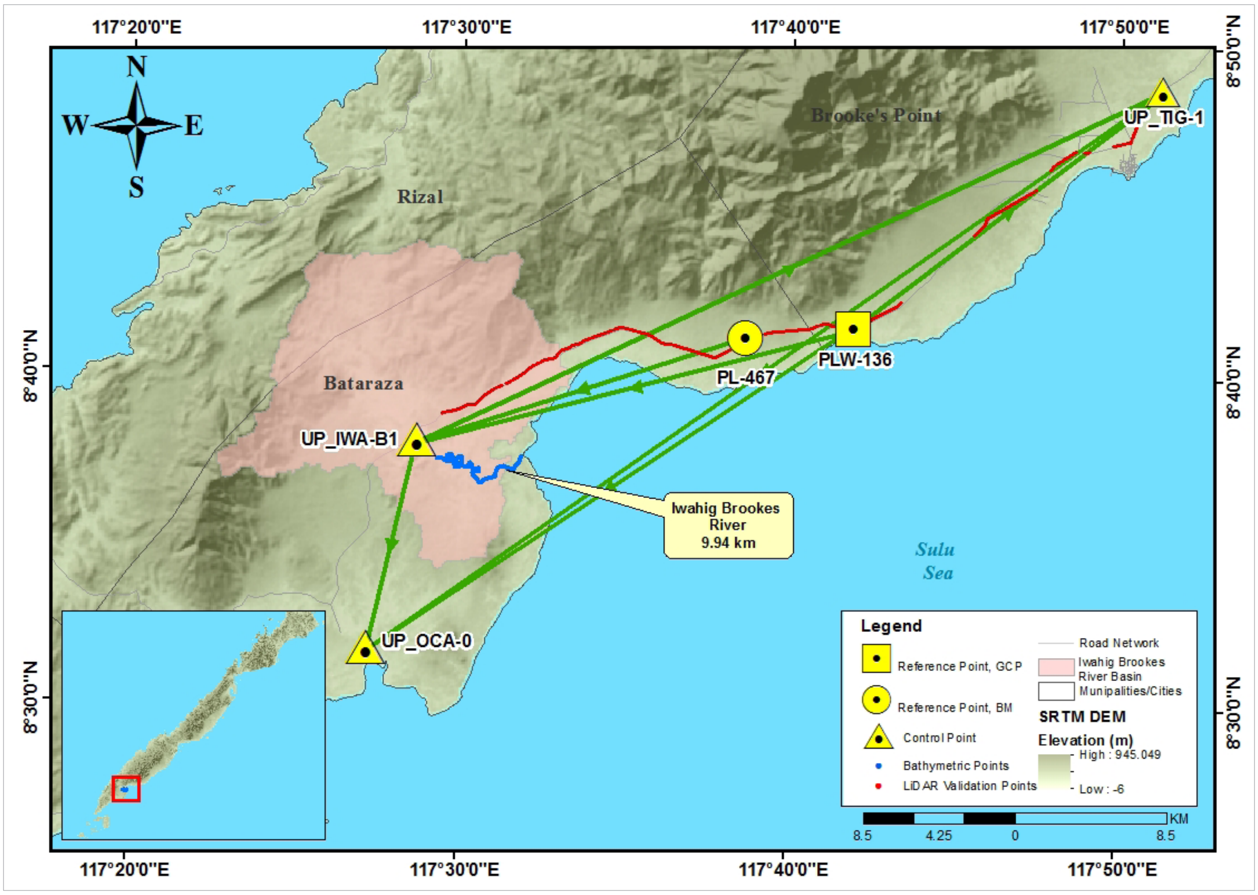


Figure 28. Iwahig Brookes River Survey Extent, with the Iwahig Brookes baseline shown in green

4.2 Control Survey

The GNSS network used for Iwahig Brookes River is composed of three (3) loops established on December 11 and 15, 2015 occupying the following reference point: PLW-136, a second-order GCP, in Brgy. Malis, Brookes Point, Palawan.

Three (3) control points were established in the area by ABSD were also occupied: UP_IWAS_B-1 near Iwahig Brookes River in Brgy. Iwahig, Bataraza, Palawan, UP_OCA-0 near Ocayan River in Brgy. Rio Tuba, Bataraza, Palawan; and UP_TIG-1 near Tigaplan River in Brgy. Barong-Barong, Brooke's Point, Palawan.

The summary of reference and control points and its location is summarized in Table 19while GNSS network established is illustrated in Figure 28.

Table 19. List of reference and control points used during the survey in Iwahig Brookes River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
PLW-136	2nd order, GCP	8°41'28.25671"N	117°41'53.50178"E	47.391	-2.115	2007
UP_ IWA_B-1	Established	8°37'56.73695"N	117°28'38.14147"E	47.522	-0.457	December 2015
UP_OCA-0	Established	8°31'39.42064"N	117°27'09.07545"E	50.661	2.778	December 2015
UP_TIG-1	Established	8°48'46.72614"N	117 51'10.83936"E	54.024	4.178	December 2015

The GNSS set-ups on recovered reference points and established control points in Iwahig Brookes River are shown from Figure 29 to Figure 32.

Figure 29. GNSS receiver set up, Trimble® SPS 882, at PLW-136, located at the Malis Elementary School compound, Brgy. Malis, Brooke's Point, Province of Palawan

Figure 30. GNSS receiver set up, Trimble® SPS 985, at UP_IWA-1, located at the approach of Iwahig Bridge in Brgy. Iwahig, Bataraza, Province of Palawan

Figure 31. GNSS base set up, Trimble® SPS 882, at UP_OCA-0, located about 23 m from Elementary School near Ocayan River in Brgy. Rio Tuba, Bataraza, Province of Palawan

Figure 32. GNSS receiver set up, Trimble® SPS 985, at UP_PAN-1, located on the approach of Tigaplan Bridge in Brgy. Barong-Barong, Brooke's Point, 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 Iwahig Brookes River Basin is summarized in Table 20 generated by TBC software.

Table 20. Baseline Processing Report for Iwahig Brookes River Static Survey (Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
UP_IWA_B-1 --- UP_OCA-0	8-21-2016	Fixed	0.016	0.053	193°13'25"	11907.513	3.115
PLW-136 --- UP_OCA-0	8-21-2016	Fixed	0.010	0.035	236°14'14"	32535.077	3.274
PLW-136 --- UP_IWA_B-1	8-21-2016	Fixed	0.006	0.030	255°03'15"	25168.863	0.136
UP_TIG-1 --- UP_OCA-0	8-21-2016	Fixed	0.030	0.070	234°25'32"	54210.634	-3.402
PLW-136 --- UP_TIG-1	8-21-2016	Fixed	0.009	0.033	51°39'07"	21717.287	6.663
UP_IWA_B-1--- UP_TIG-1	8-21-2016	Fixed	0.008	0.052	64°11'35"	45917.125	6.496

As shown Table 20, a total of six (6) baselines were processed with coordinate and ellipsoidal height values of PLW-136 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for complete details.

The four (4) control points, PLW-136, UP_IWA_B-1, UP_OCA-0, and UP_TIG-1 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of PLW-136 were held fixed during the processing of the control points as presented in Table 21. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 21. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
PLW-136	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 22.

Table 22. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PLW-136	576807.192	?	960781.167	?	-2.115	?	LLh
UP_IWA_B-1	552510.181	0.007	954247.549	0.008	-0.457	0.053	
UP_OCA-0	549801.726	0.014	942656.632	0.010	2.778	0.062	
UP_TIG-1	593808.816	0.009	974282.807	0.007	4.178	0.057	

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

a. PLW-136
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. UP_IWA_B-1
horizontal accuracy = √((0.7)² + (0.8)²
= √ (0.49 + 0.64)
= 1.06< 20 cm
vertical accuracy = 5.3 < 10 cm

c. UP_OCA-0
horizontal accuracy = √((1.4)² + (1.0)²
= √ (1.96 + 1.0)
= 1.4 < 20 cm
vertical accuracy = 6.2 < 10 cm

d. UP_TIG-1
horizontal accuracy = √((0.9)² + (0.7)²
= √ (0.81 + 0.49)
= 1.14 < 20 cm
vertical accuracy = 6.2 < 10 cm

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

Table 23. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
PLW-136	N8°41'28.25671"	E117°41'53.50178"	47.391	?	LLh
UP_IWA_B-1	N8°37'56.73695"	E117°28'38.14147"	47.522	0.053	
UP_OCA-0	N8°31'39.42064"	E117°27'09.07545"	50.661	0.062	
UP_TIG-1	N8°48'46.72614"	E117°51'10.83936"	54.024	0.057	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. 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 24.

Table 24. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
PLW-136	2nd order, GCP	8°41'28.25671"N	117°41'53.50178"E	47.391	960781.167	576807.192	-2.115
UP_IWA_B-1	Established	8°37'56.73695"N	117°28'38.14147"E	47.522	954247.549	552510.181	-0.457
UP_OCA-0	Established	8°31'39.42064"N	117°27'09.07545"E	50.661	942656.632	549801.726	2.778
UP_TIG-1	Established	8°48'46.72614"N	117°51'10.83936"E	52.045	974282.807	593808.816	4.178

4.5 Cross-section and Bridge As-Built Survey, and Water Level Marking

Cross-section and as-built surveys were conducted on December 1, 2015 at the upstream side of Iwahig Brookes Bridge in Brgy. Iwahig, Municipality of Bataraza as shown in Figure 33. A Horizon® Total Stationwas utilized for this survey as shown in Figure 34.

Figure 33. Iwahig Brookes Bridge from the downstream side

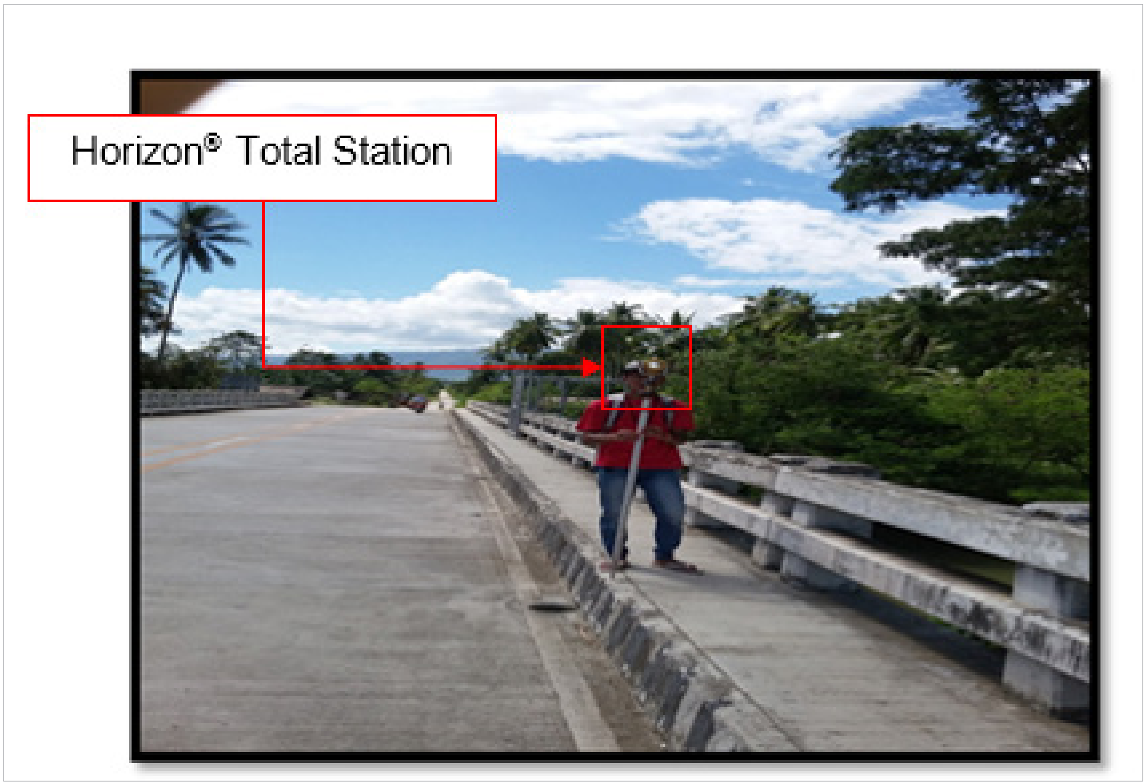


Figure 34. As-built survey of Iwahig Brookes Bridge

The cross-sectional line of Iwahig Brookes Bridge is about 107.33 m with fifty-seven (57) cross-sectional points using the control points UP_IWA-B1 and UP_IWA-B2 as the GNSS base stations. The location map, cross-section diagram, and bridge data form are shown in Figure 35, Figure 36, and Figure 37.

Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 22, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole.

Linear square correlation (R^2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is 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 R^2 value must be within 0.85 to 1. An R^2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R^2 value of 0.9895 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is 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 bridge cross-section data, a computed value of 0.3639 was acquired. The computed R^2 and RMSE values are within the accuracy requirement of the program

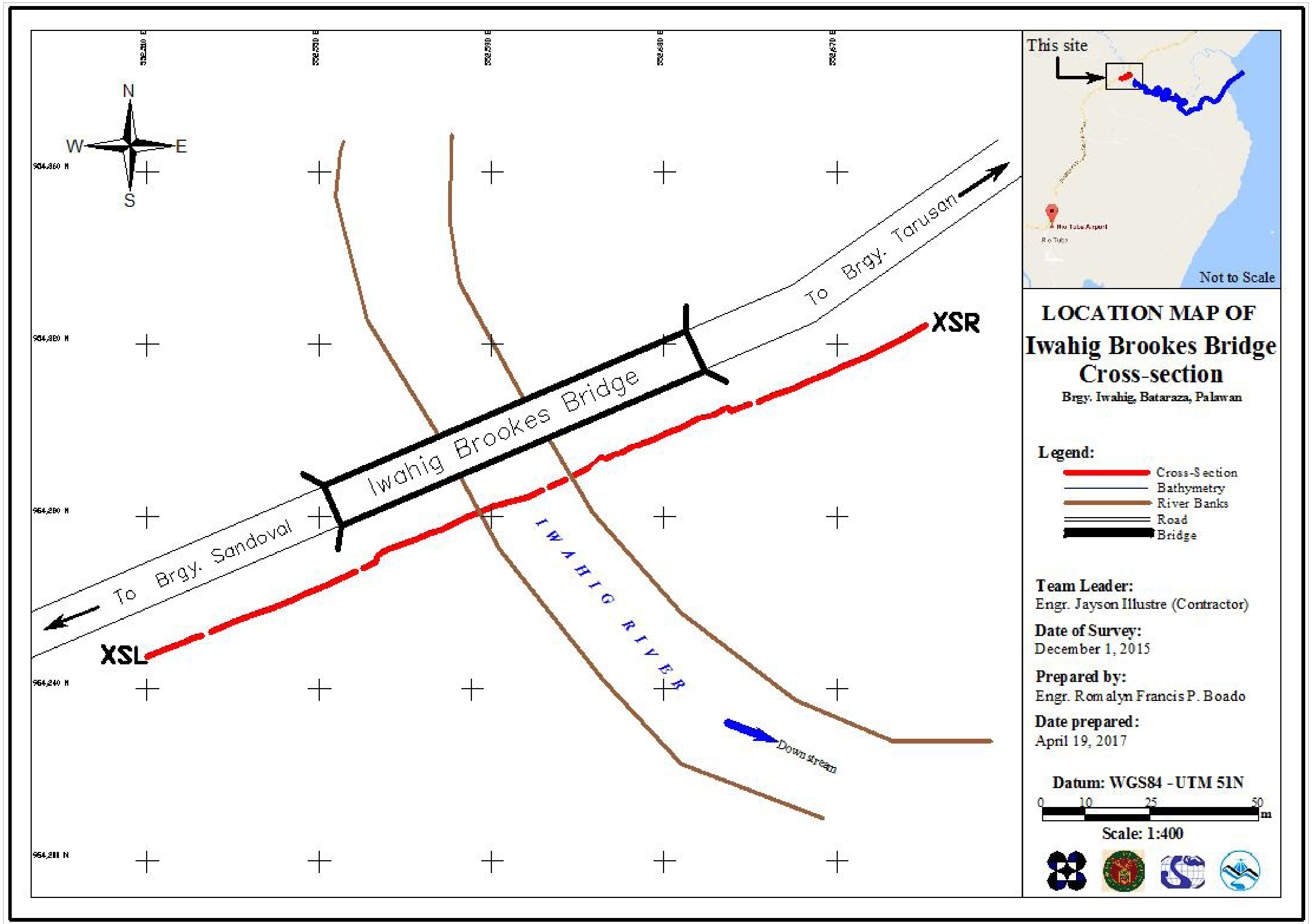


Figure 35. Iwahig Brookes Bridge from the downstream side

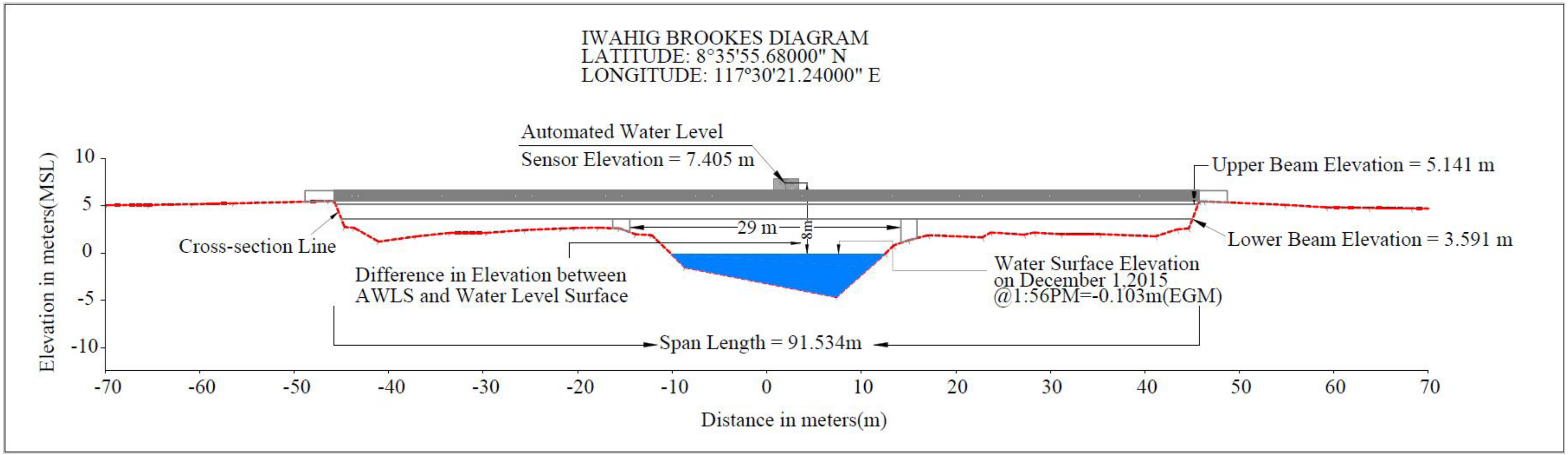


Figure 36. Iwahig Brookes Bridge cross-section diagram

Bridge Data Form

Bridge Name: IWAHIG BROOKES BRIDGE

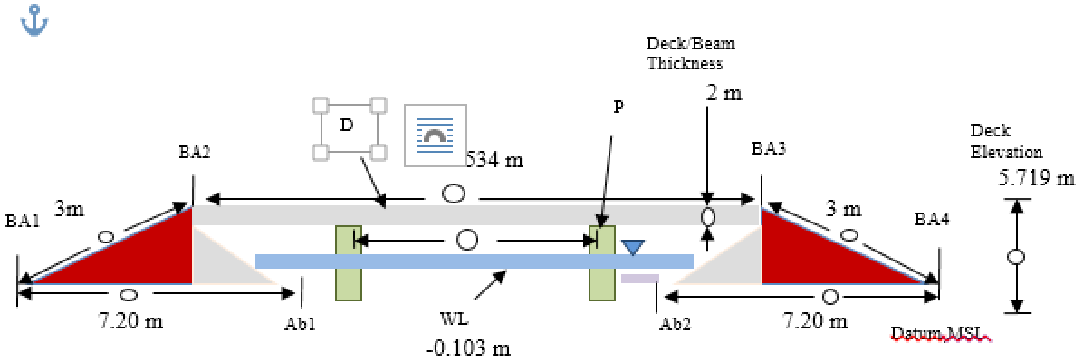
River Name: IWAHIG BROOKES RIVER
Location (Brgy,City,Region): Brgy. Iwahig, Bataraza, Palawan

Survey Team: Jayson Illustre, Local Aide
Date and Time: December 1, 2015, 1:56 P.M.

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 m	
2. BA2-BA3	91.534 m	
3. BA3-BA4	3 m	
4. BA1-Ab1	7.20 m	
5. Ab2-BA1	7.20 m	
6. Deck/beam thickness	2 m	
7. Deck elevation	5.719 m	

Note: Observer should be facing downstream

Figure 37. Bridge as-built form of Iwahig Brookes Bridge

Water surface elevation of Iwahig Brookes River was determined by a Horizon® Total Station on December 1, 2015 at 1:56 PM at Iwahig Brookes Bridge area with a value of -0.103 m in MSL as shown in Figure 36. This was translated into marking on the bridge's pier as shown in Figure 38. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Iwahig Brookes River, the University of the Philippines Los Baños.

Figure 38. Water-level markings on Iwahig Brookes Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 16-28, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 39. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.361 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 PLW-136 occupied as the GNSS base station in the conduct of the survey.

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

The survey started from Brgy. Salogon, Municipality of Brooke's Point, Palawan going southwest along the national high way covering two (2) barangays in the Municipality of Brooke's Point and six (6) barangays in the Municipality of Bataraza, and ended in Brgy. Tarusan, Municipality of Bataraza, Palawan. The survey gathered a total of 6,340 points with approximate length of 28.27 km using PLW-136 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 40.

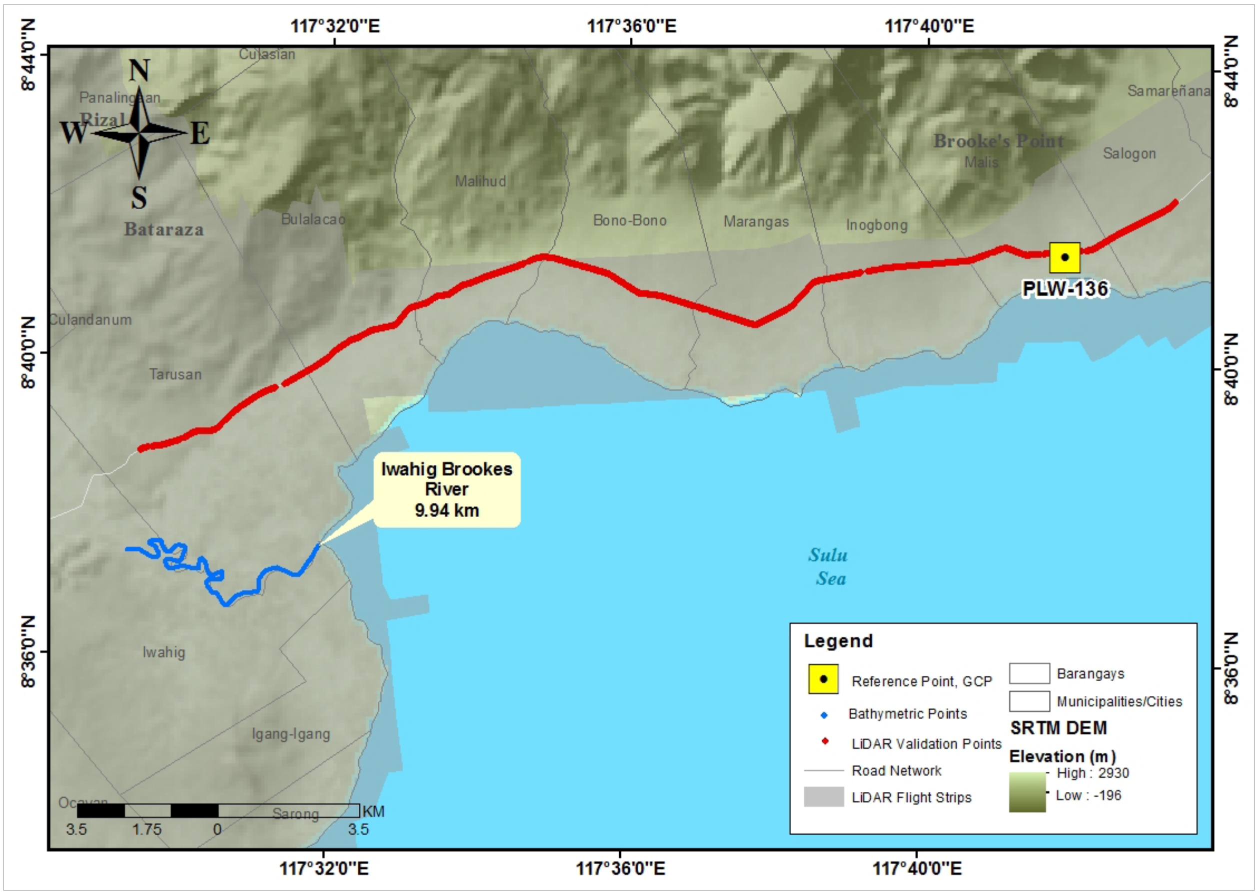


Figure 40. Validation point acquisition survey of Iwahig Brookes River Basin area

4.7 Bathymetric Survey

Bathymetric survey was executed on December 15-16, 2015 using a Hi-Target™ Echo Sounder as illustrated in Figure 41. The survey started in Brgy. Iwahig, Municipality of Bataraza, Palawan with coordinates 8° 37' 23.44115"N, 117° 29' 48.242420"E and ended at the mouth of the river in Brgy. Tarusan, Municipality of Bataraza as well, with coordinates 8° 37' 45.23648"N, 117°28'57.35928"E. The control points UP_IWA-B-3 and UP_IWA-B-4 were used as GNSS base stations all throughout the entire survey.

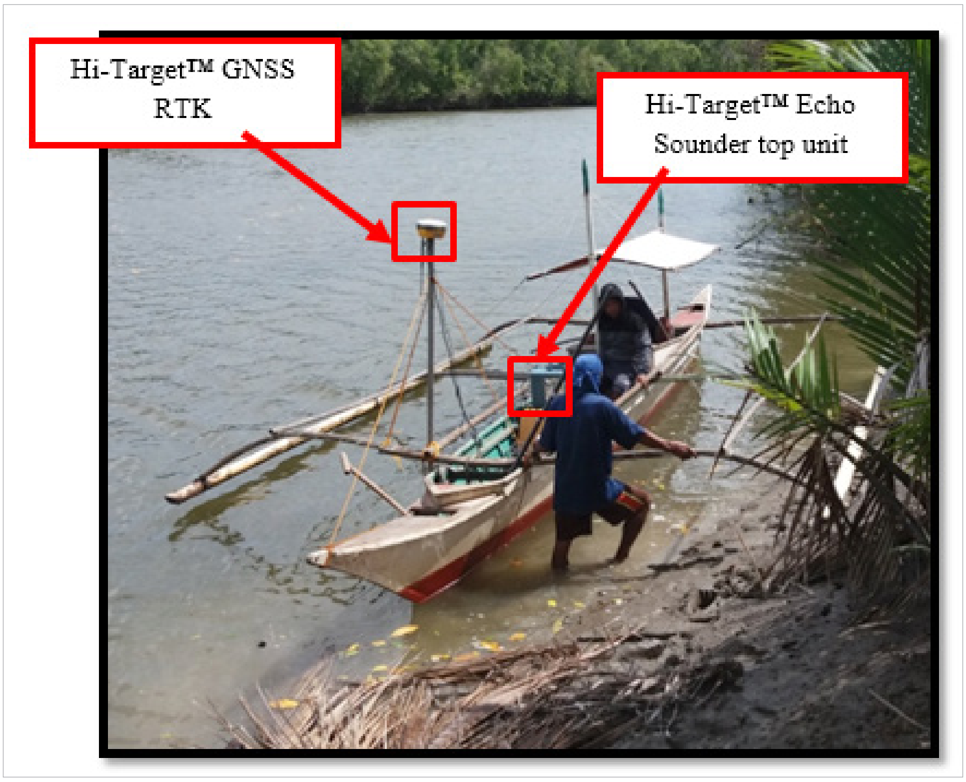


Figure 41. Bathymetric survey of ABSD at Iwahig Brookes River using Hi-Target™ Echo Sounder (upstream)

No bathymetric checking points were gathered for Iwahig Brookes River due to heavy rains caused by the southwest monsoon on August 23, 2016, which rendered the river unnavigable, both on foot and by boat by the time of quality checking.

The bathymetric survey for Iwahig Brookes River gathered a total of 8,737 points covering 11.3 km of the river traversing barangays of Iwahig and Tarusan, both in the Municipality of Bataraza, as shown in Figure 42. A CAD drawing was also produced to illustrate the riverbed profile of Iwahig Brookes River as shown in Figure 43, wherein the highest and lowest elevation has a 10-m difference. The highest elevation observed was -1.303 m below MSL while the lowest was -11.97 m below MSL located in Brgy. Tarusan, Municipality of Bataraza.

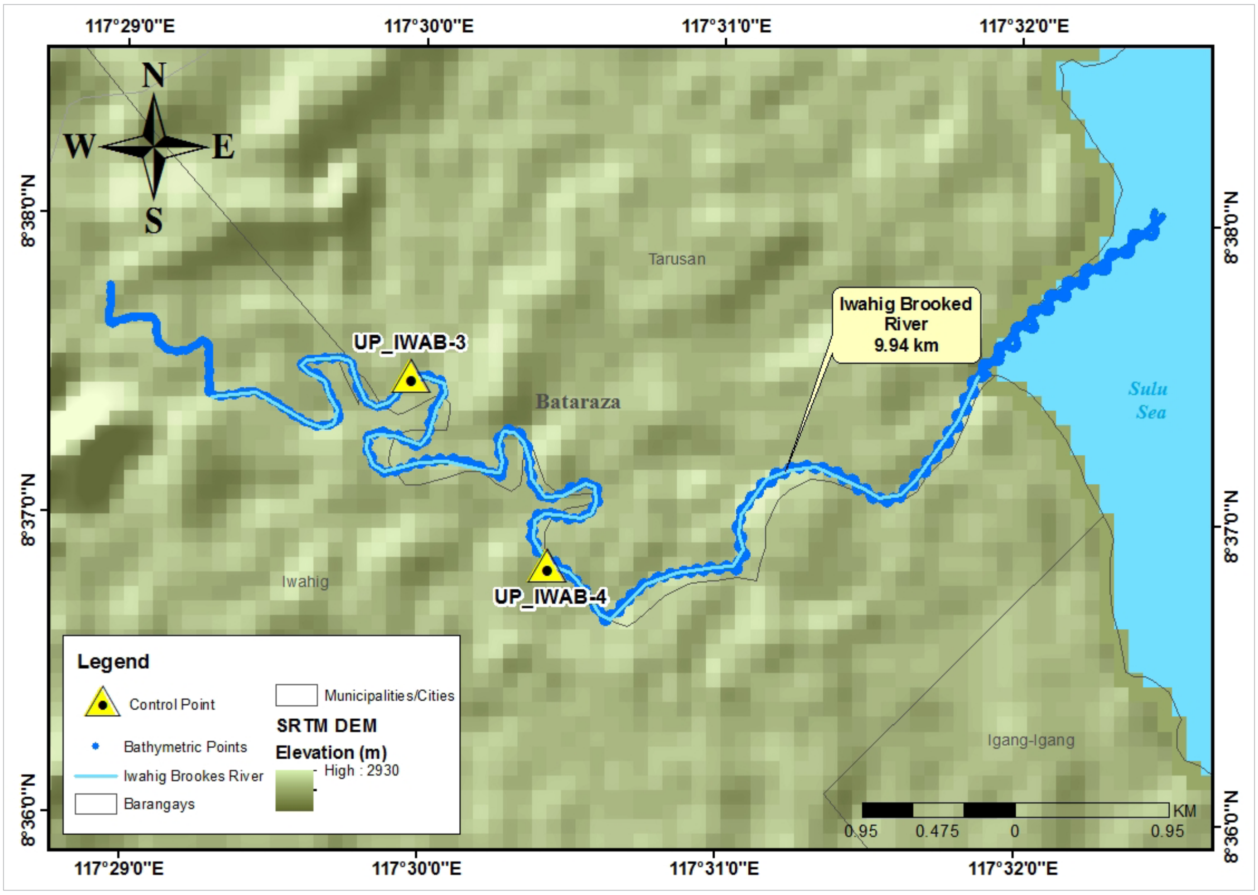


Figure 42. Bathymetric survey of Iwahig Brookes River

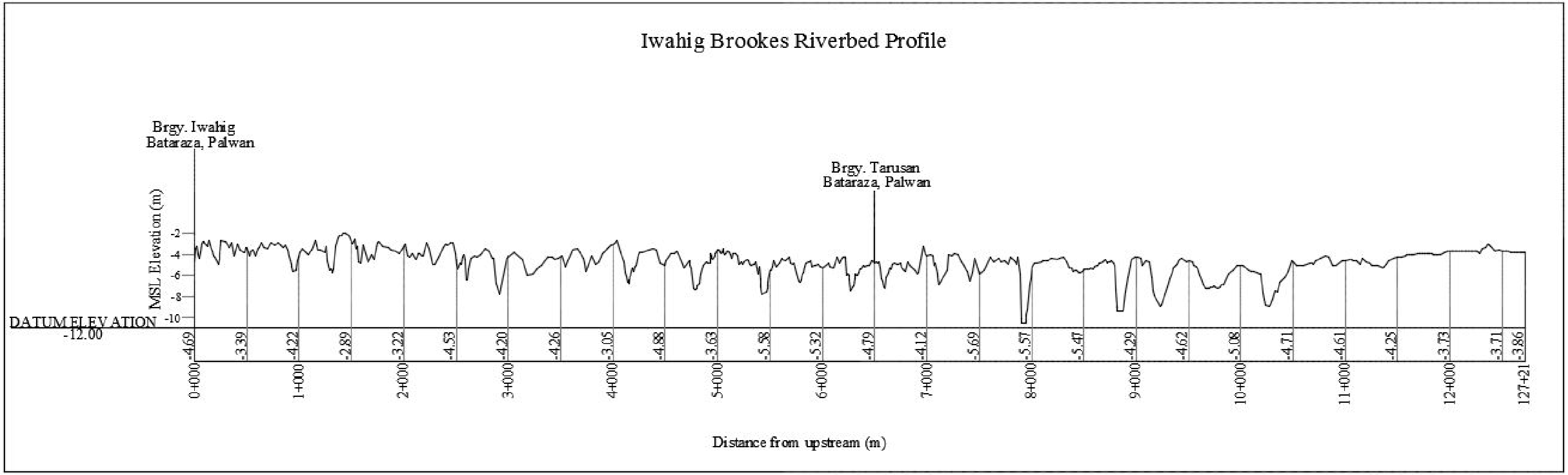


Figure 43. Iwahig Brookes Riverbed Profile

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, Field validation, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, 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 in Hydrologic Modeling

No gathered rainfall data for Iwahig Brookes river basin. The HMS model is not calibrated. The values generated HMS model are by default.

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 will be attained at a certain time. This station chosen based on its proximity to the Iwahig watershed. The extreme values for this watershed were computed based on a 58-year record, with the computed extreme values shown in Table 25.

Table 25. 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

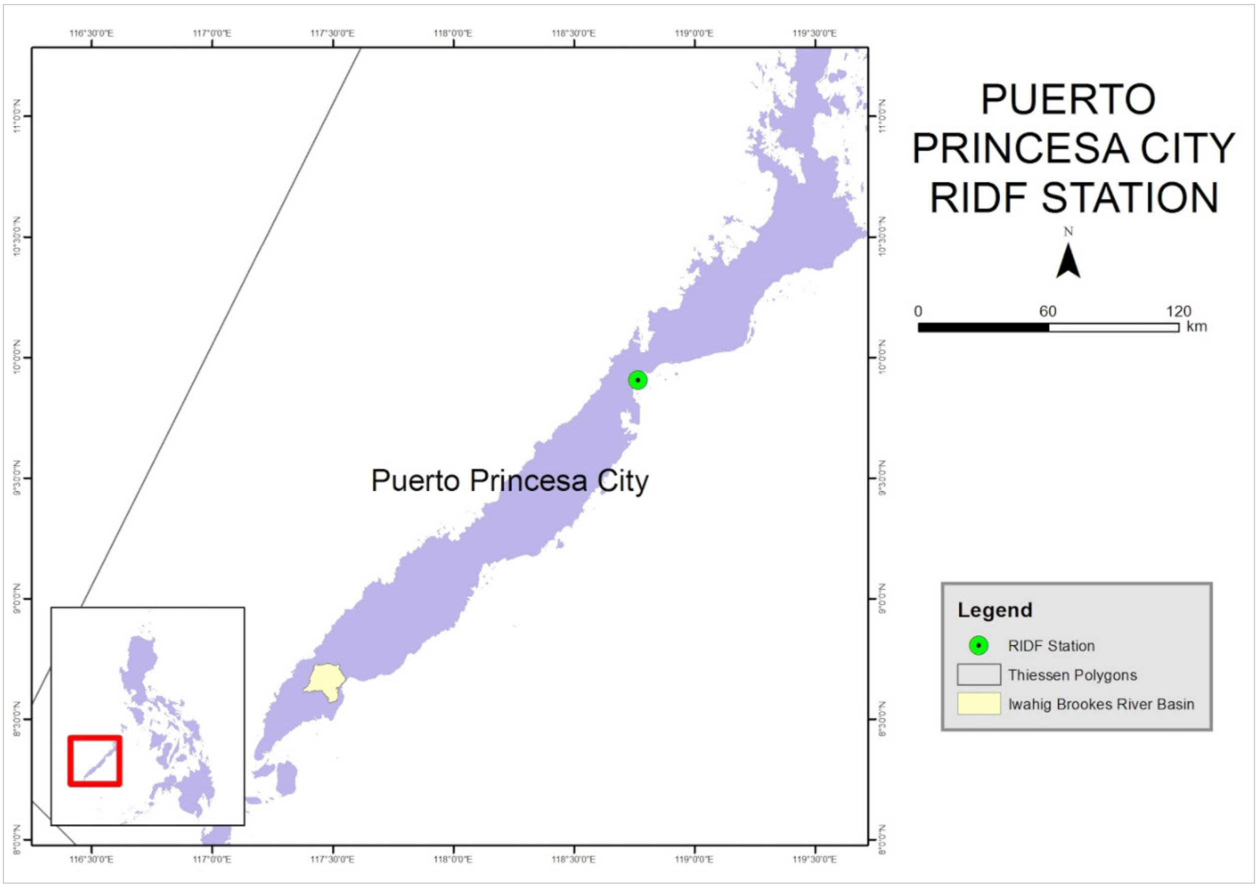


Figure 44. Location of Puerto Princesa RIDF relative to Iwahig Brookes River Basin

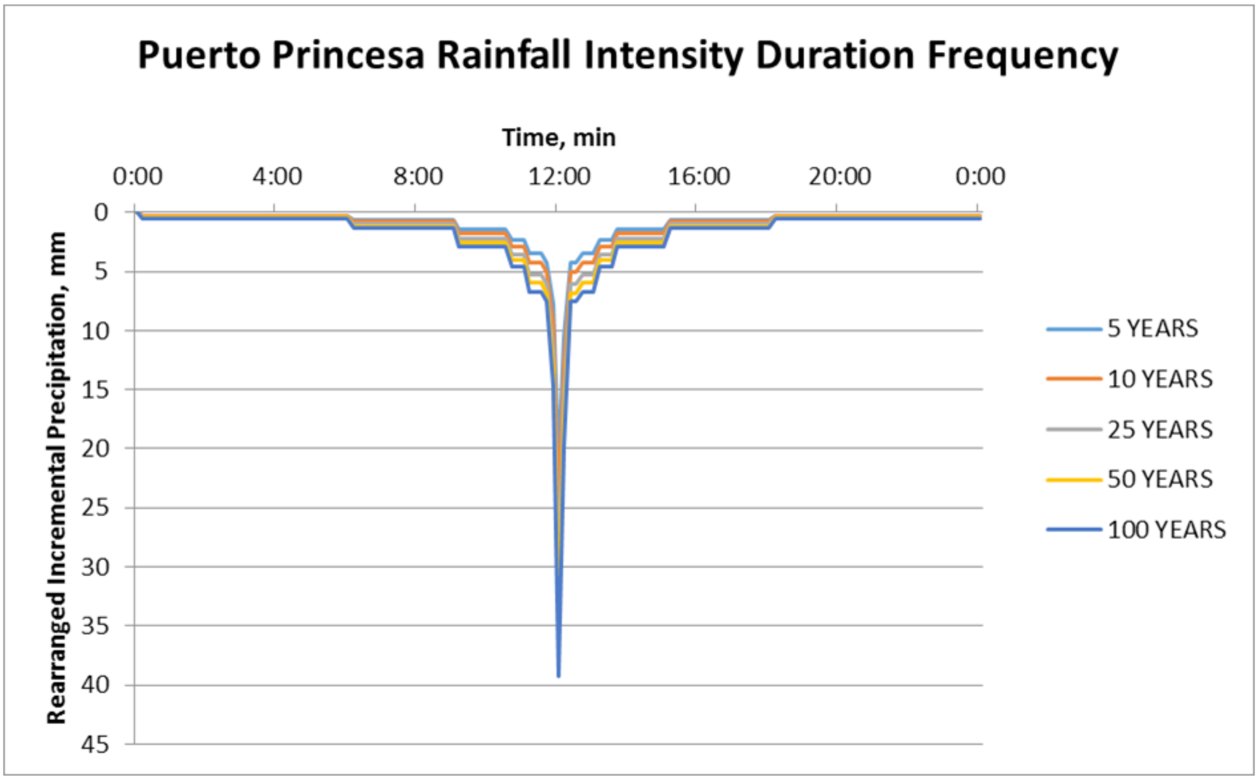


Figure 45. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Iwahig Brookes River Basin are shown in Figure 46 and Figure 47, respectively.

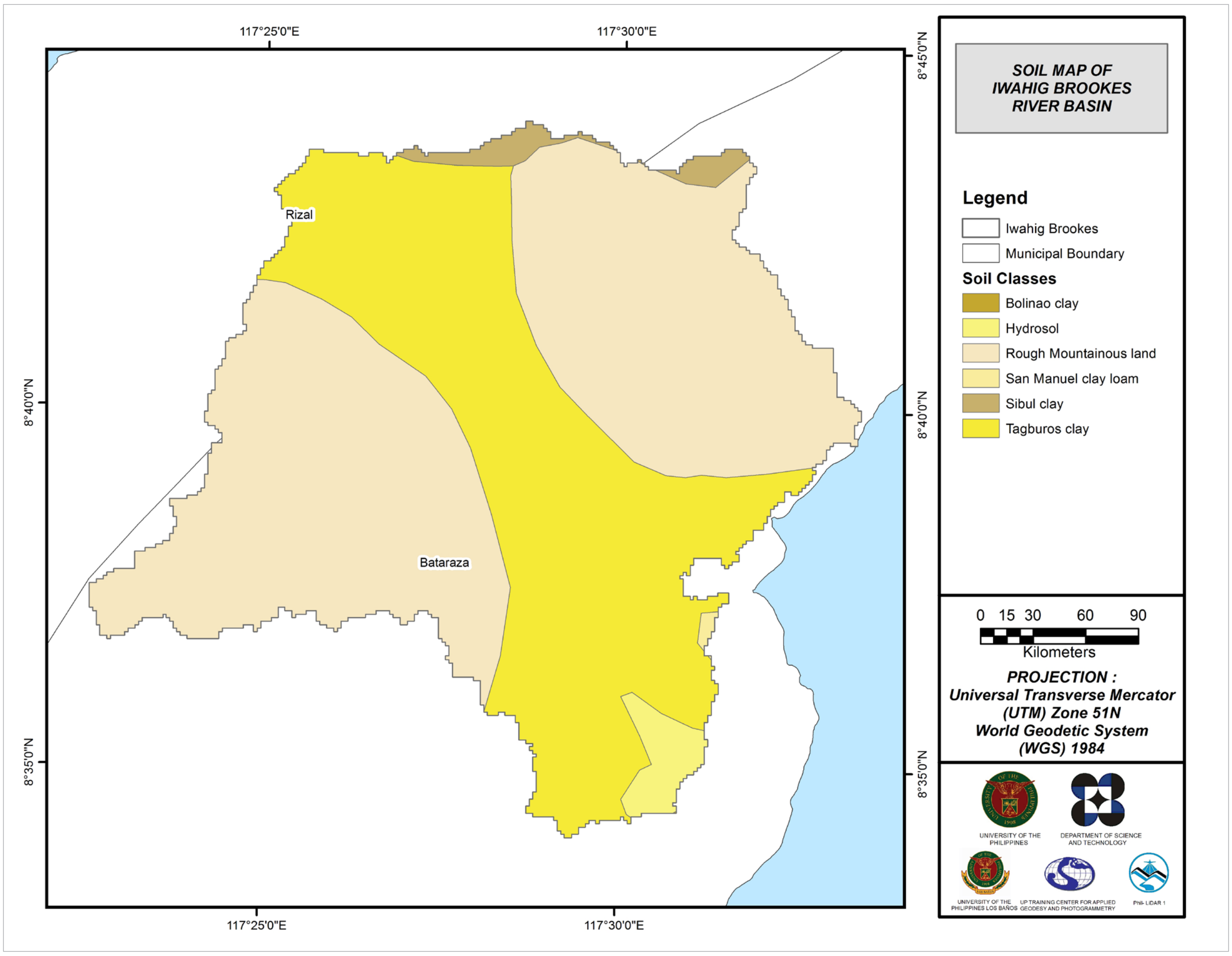


Figure 46. Soil map of Iwahig Brookes River Basin used for the estimation of the CN parameter. (Source: DA)

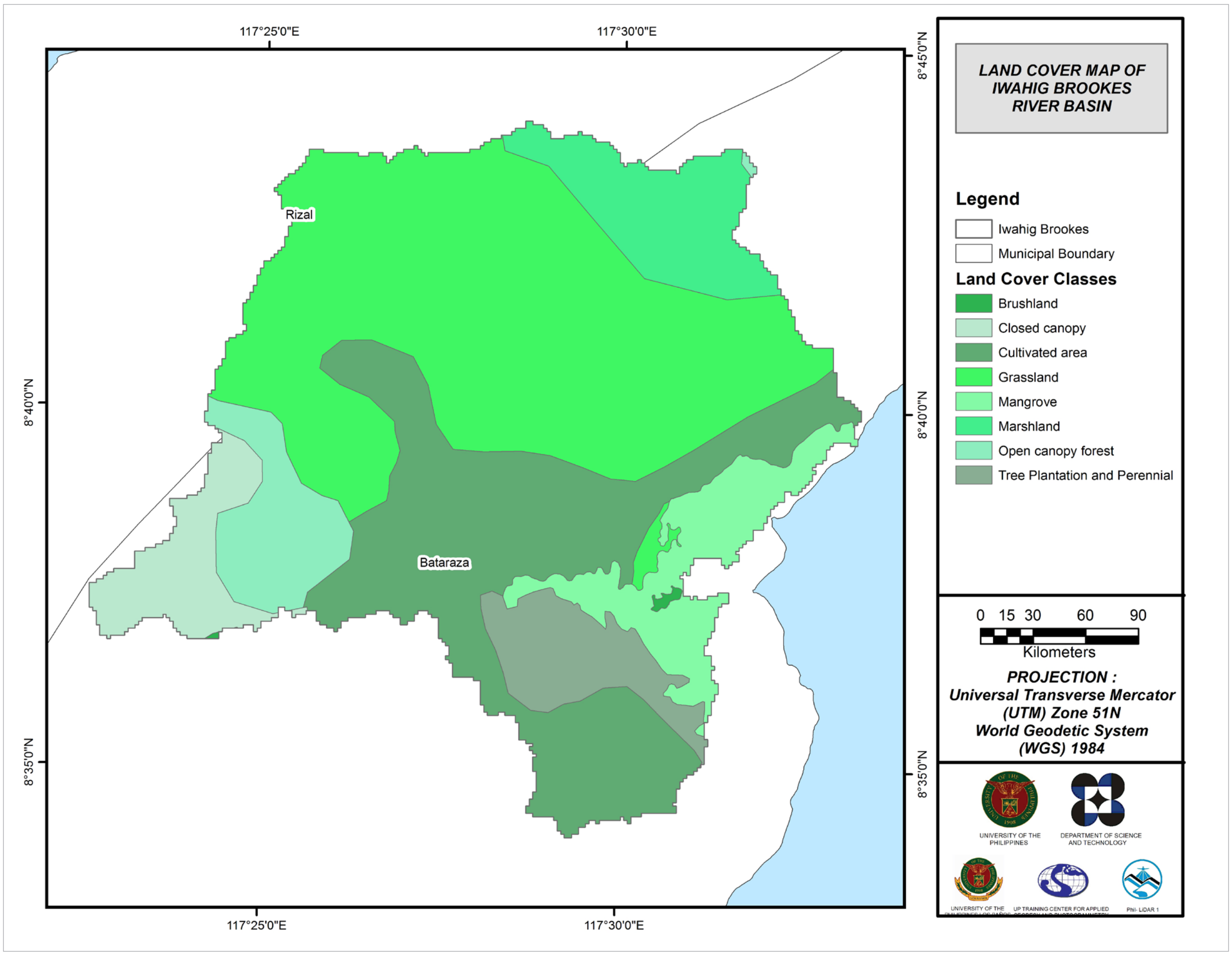


Figure 47. Land cover map of Iwahig Brookes River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Iwahig Brookes River Basin, four (4) soil classes were identified. The river basin is mostly rough mountainous land and Tagburos clay, with portions of hydrosol and Bolinao clay. The eight (8) land cover types identified were grassland, cultivated areas, open canopy forest, closed canopy forest, tree plantation and perennial, marshland, brushland, and mangrove.

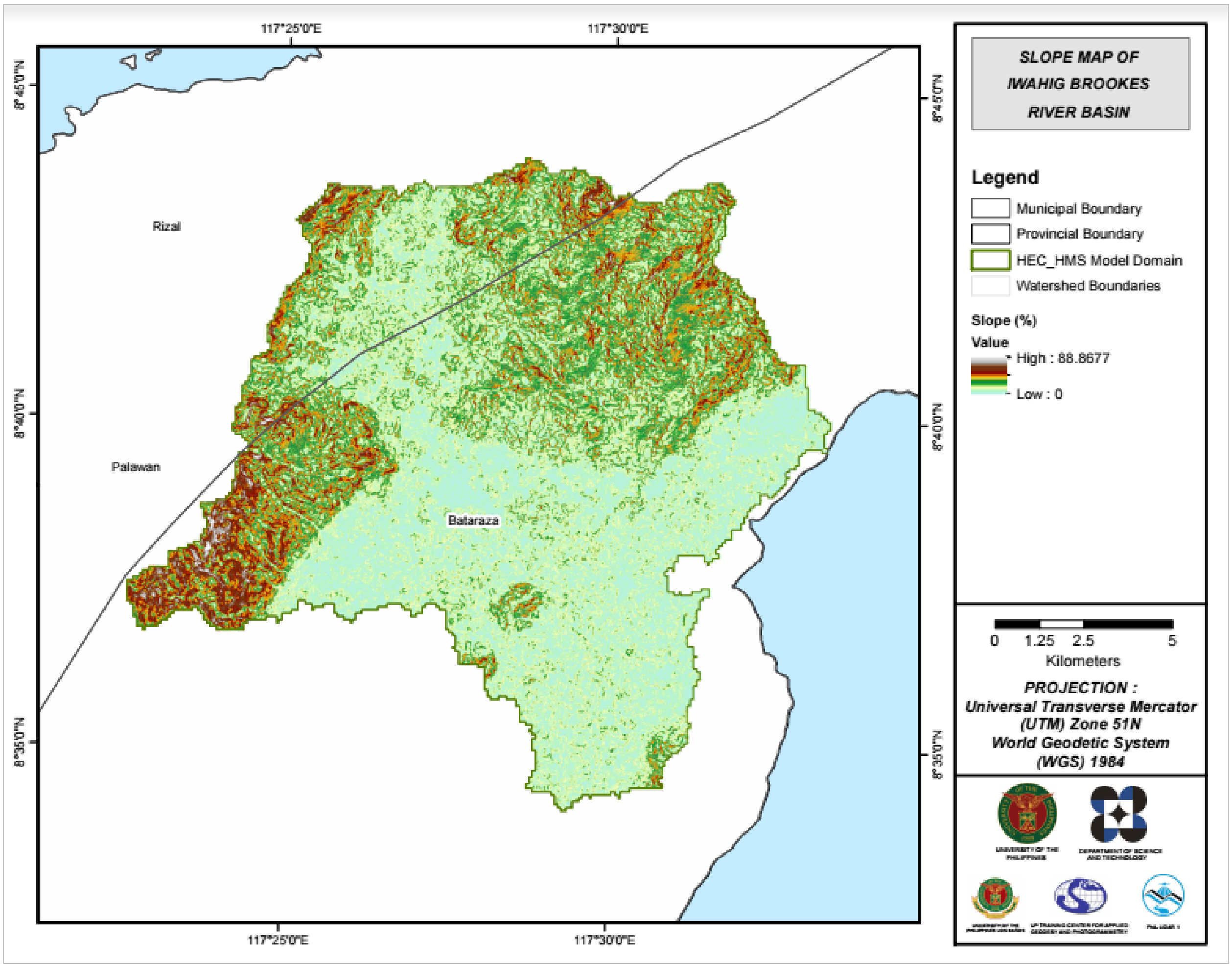


Figure 48. Slope map of Iwahig Brookes River Basin

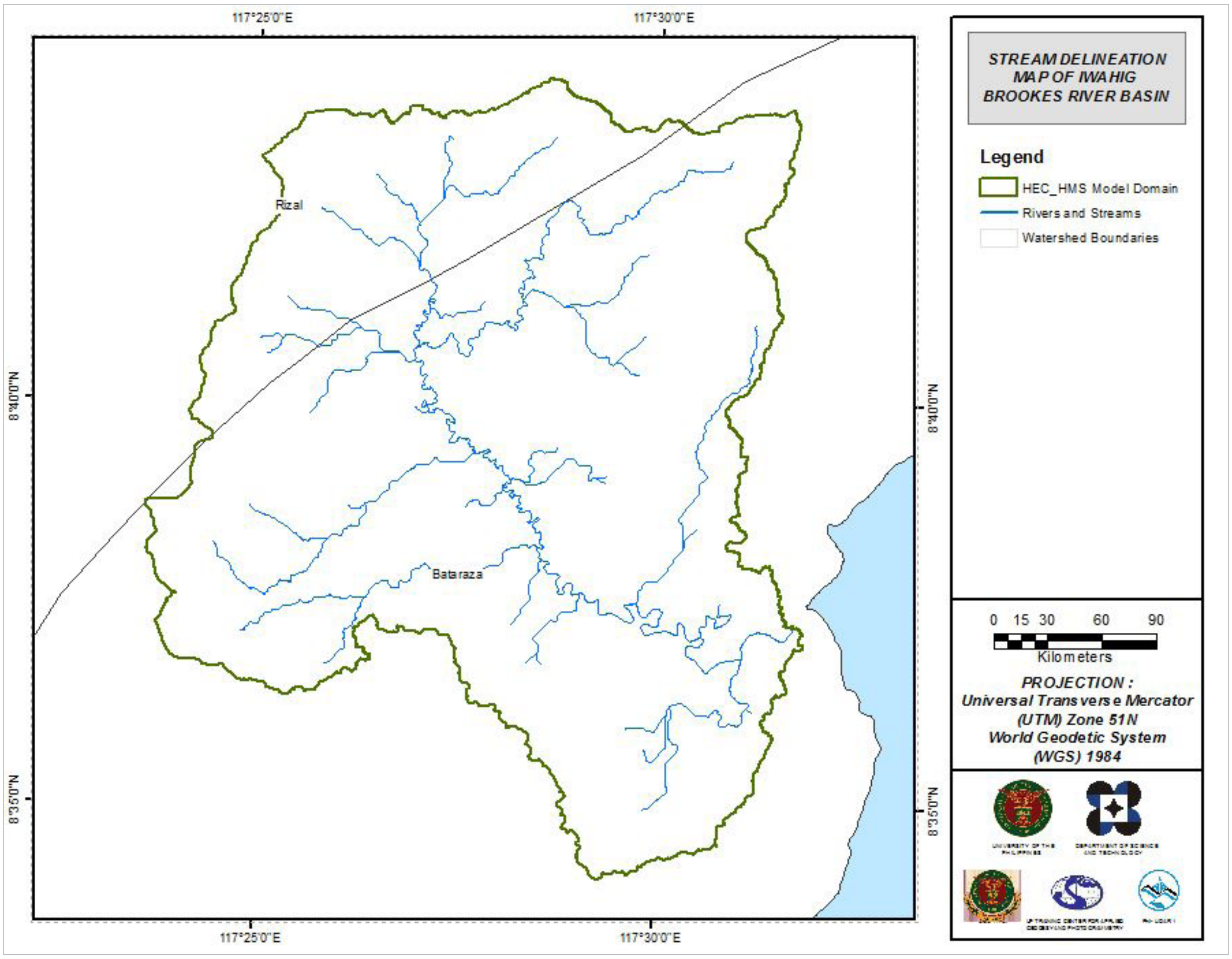


Figure 49. Stream delineation map of Iwahig Brookes River Basin

Using SAR-based DEM, the Iwahig Brookes basin was delineated and further subdivided into subbasins. The model consists of 68 sub basins, 33 reaches, and 32 junctions. The main outlet is labelled as Iwb_ Outlet. This basin model is illustrated in Figure 50. The basins were identified based on soil and land cover characteristics of the area.

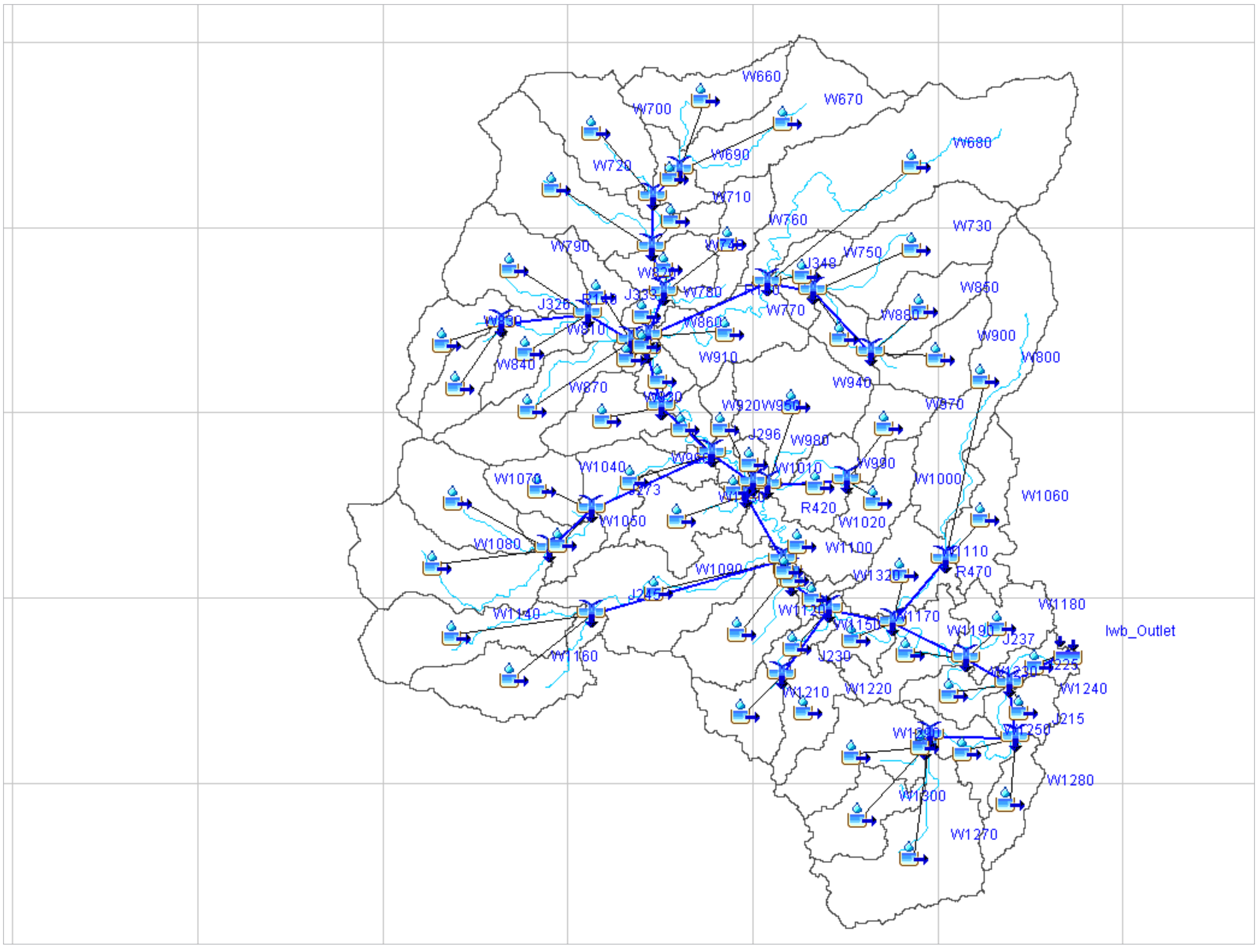


Figure 50. HEC-HMS generated Iwahig Brookes River Basin Model.

5.4 Cross-section Data

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

Figure 51. River cross-section of Iwahig Brookes River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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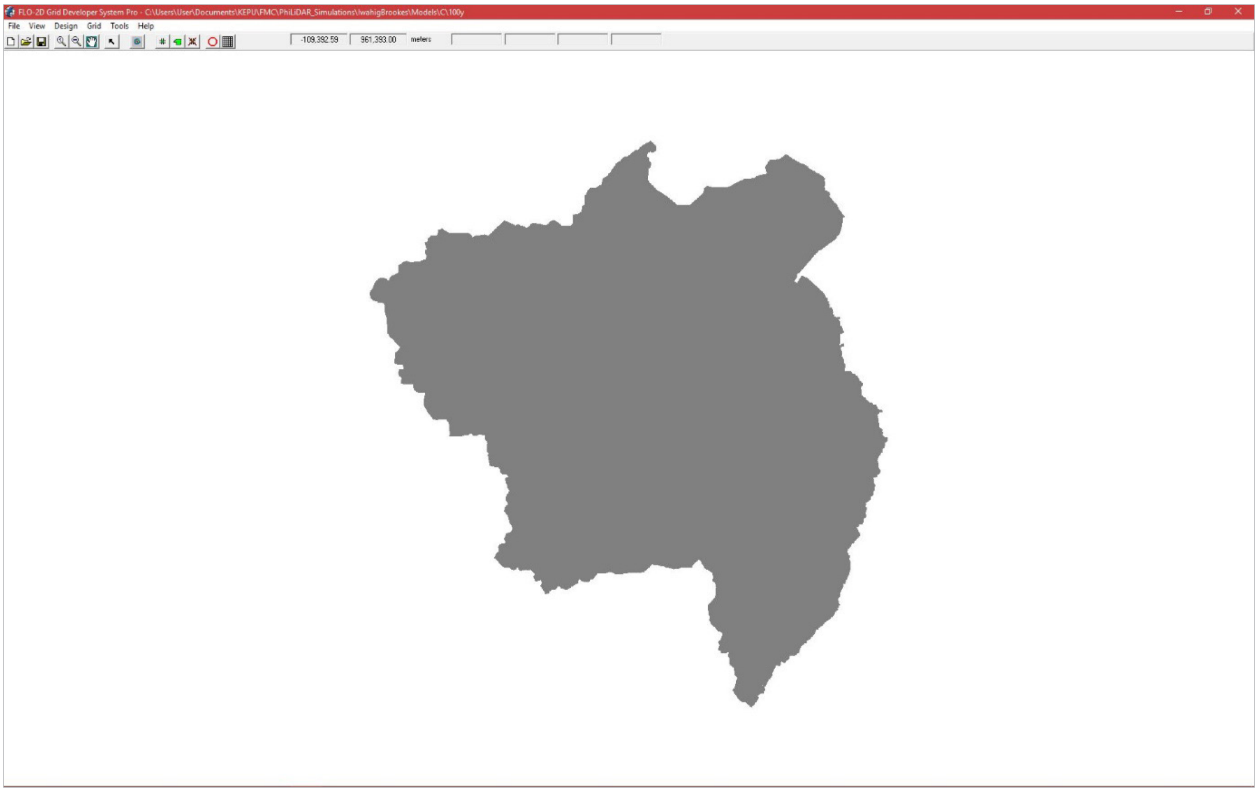

Figure 52. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

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5.6 HEC-HMC Model Values (Uncalibrated)

Enumerated in Table 26 are the range of values of the parameters in the model.

Table 26. Range of calibrated values for Iwahig Brookes River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.3 - 10
			Curve Number	57 - 98
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 5
			Storage Coefficient (hr)	0.5 - 9

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.3 to 10mm means that there is no to minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 57 to 98 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

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 0.3 hours to 9 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.

5.7 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM/ Phil-LiDAR 1 website. The sample generated map of Iwahig Brookes River using the calibrated HMS base flow is shown in Figure 53.

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 0.3 hours to 9 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.

Figure 53. Sample output of Iwahig Brookes RAS Model

5.8 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Iwahig Brookes floodplain are shown in Figure 54 to Figure 59. The floodplain, with an area of 196.64 sq. km., covers two municipalities namely Bataraza, and Rizal. Table 27 shows the percentage of area affected by flooding per municipality.

Table 27. Municipalities affected in Iwahig Brookes Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Bataraza	818.11	191.67	23.43
Rizal	980.59	4.94	0.5

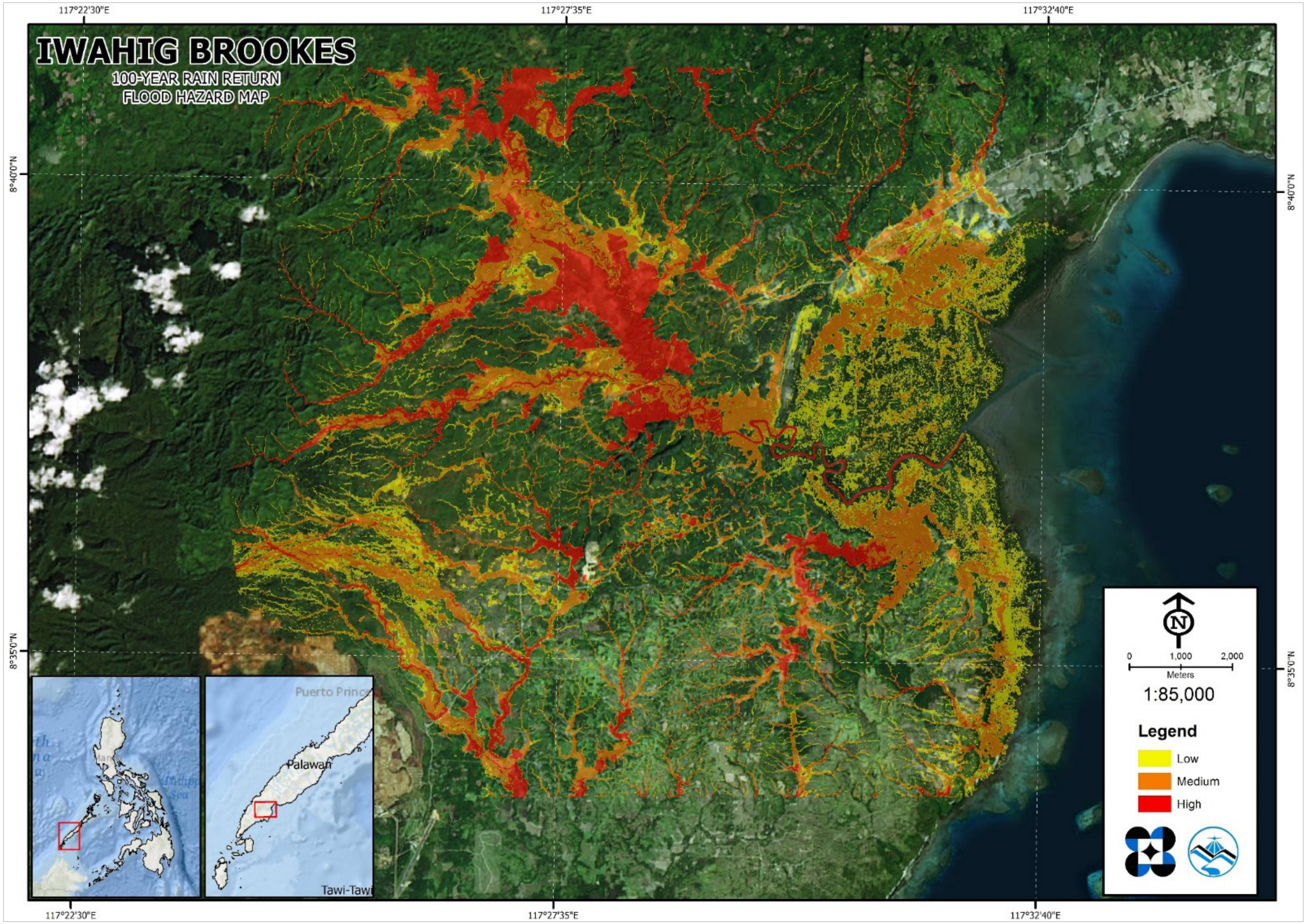

Figure 54. 100-year Flood Hazard Map for Iwahig Brookes Floodplain overlaid on Google Earth imagery

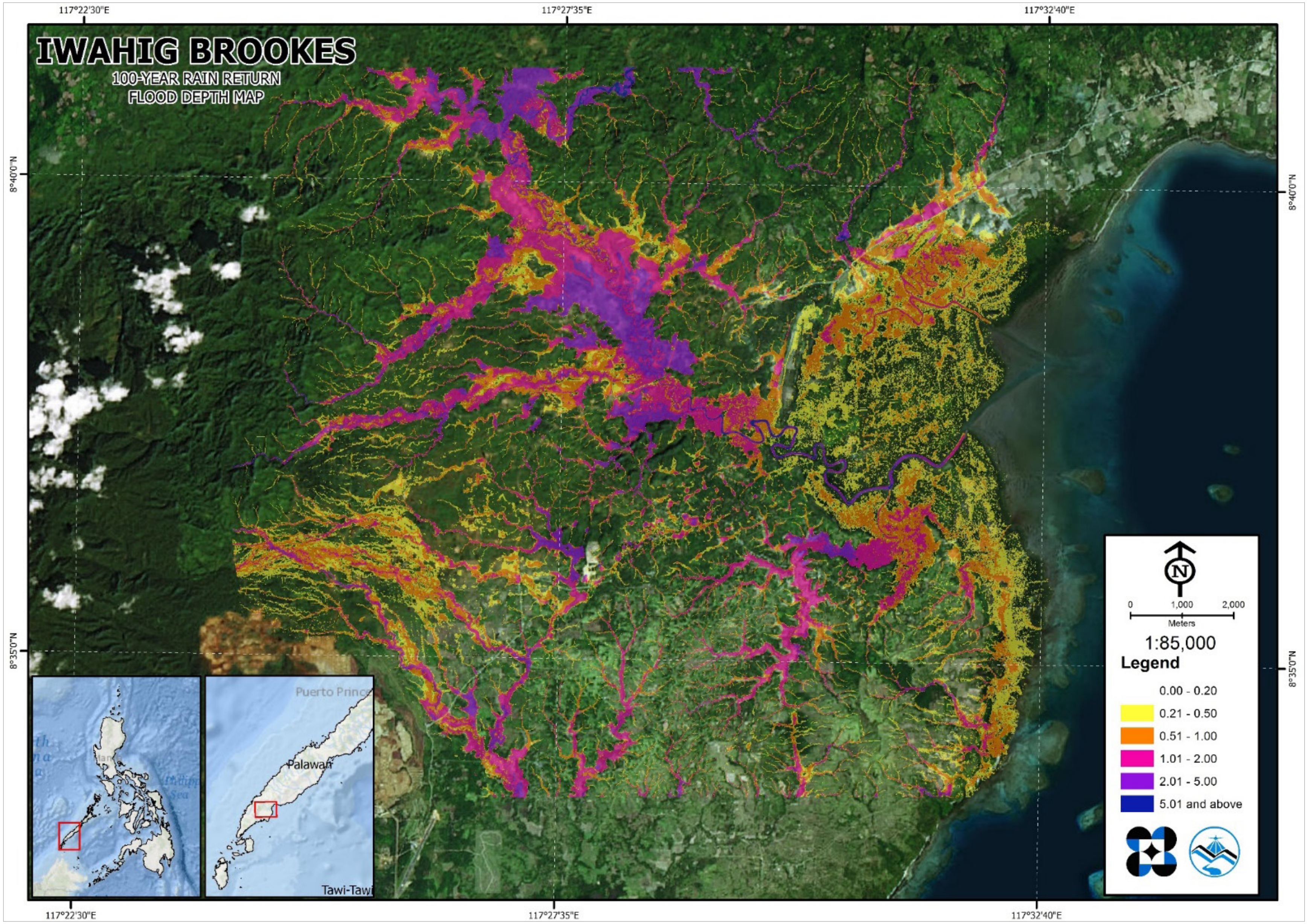

Figure 55. 100-year Flow Depth Map for Iwahig Brookes Floodplain overlaid on Google Earth imagery

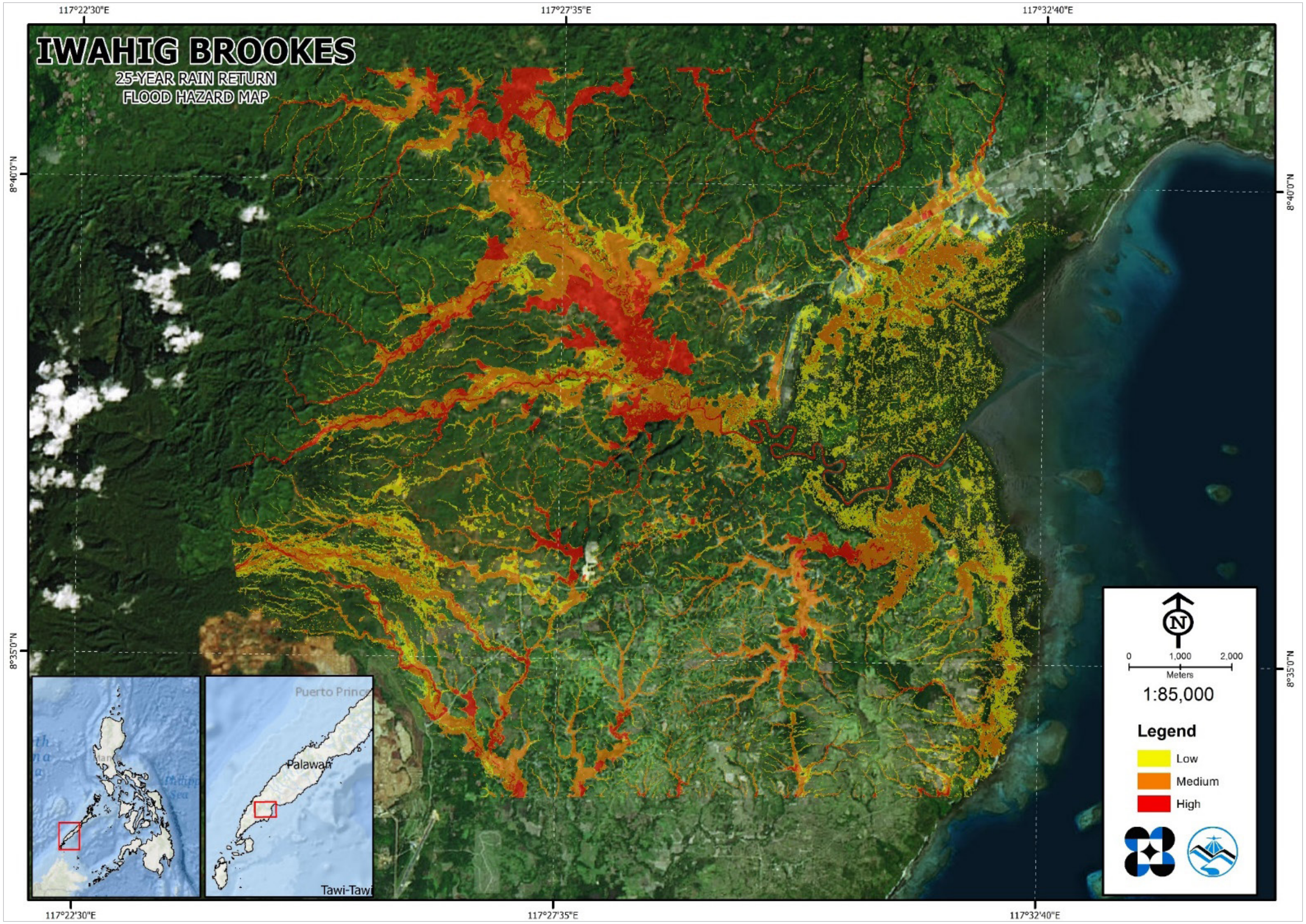

Figure 56. 25-year Flood Hazard Map for Iwahig Brookes Floodplain overlaid on Google Earth imagery

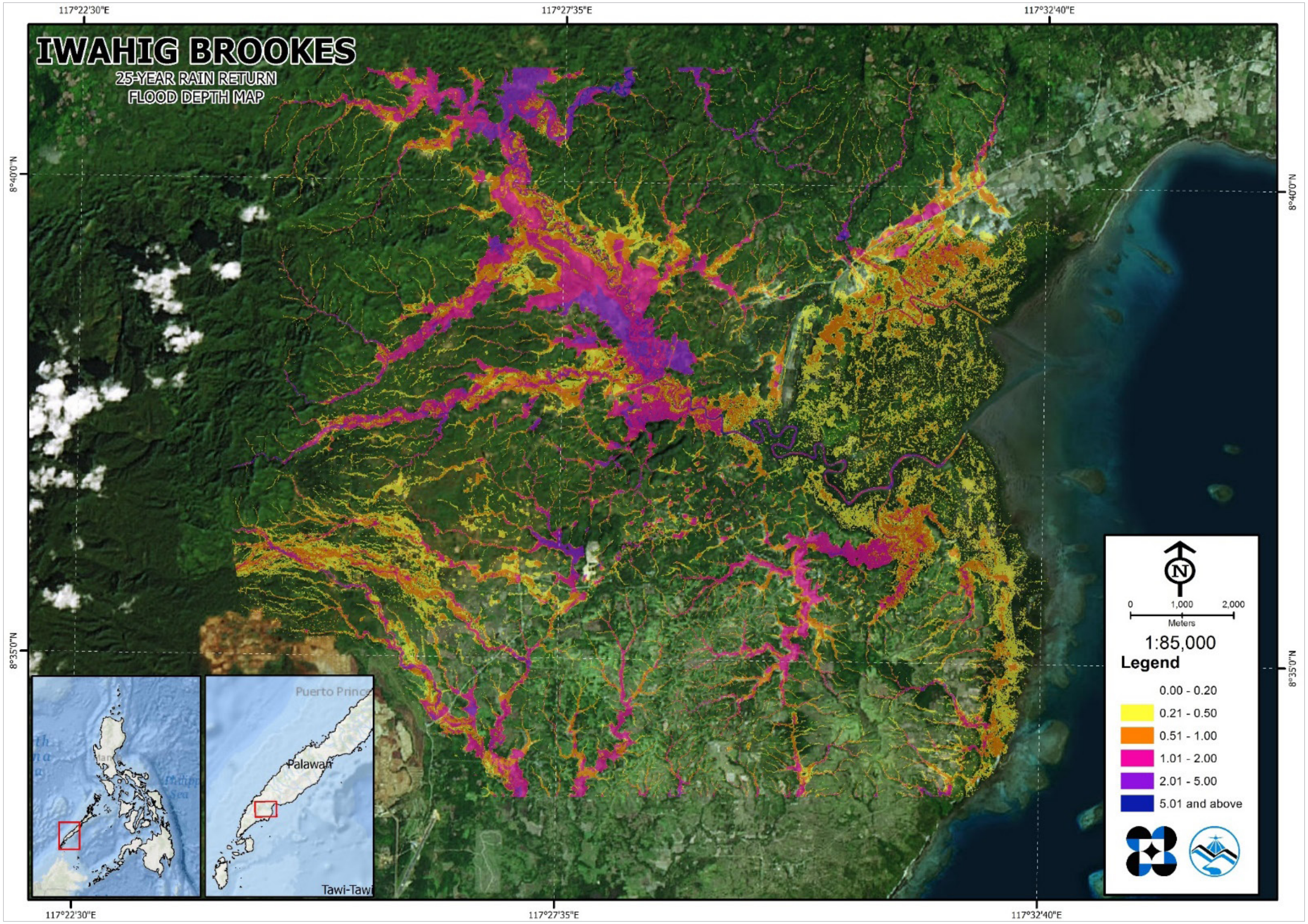

Figure 57. 25-year Flow Depth Map for Iwahig Brookes Floodplain overlaid on Google Earth imagery

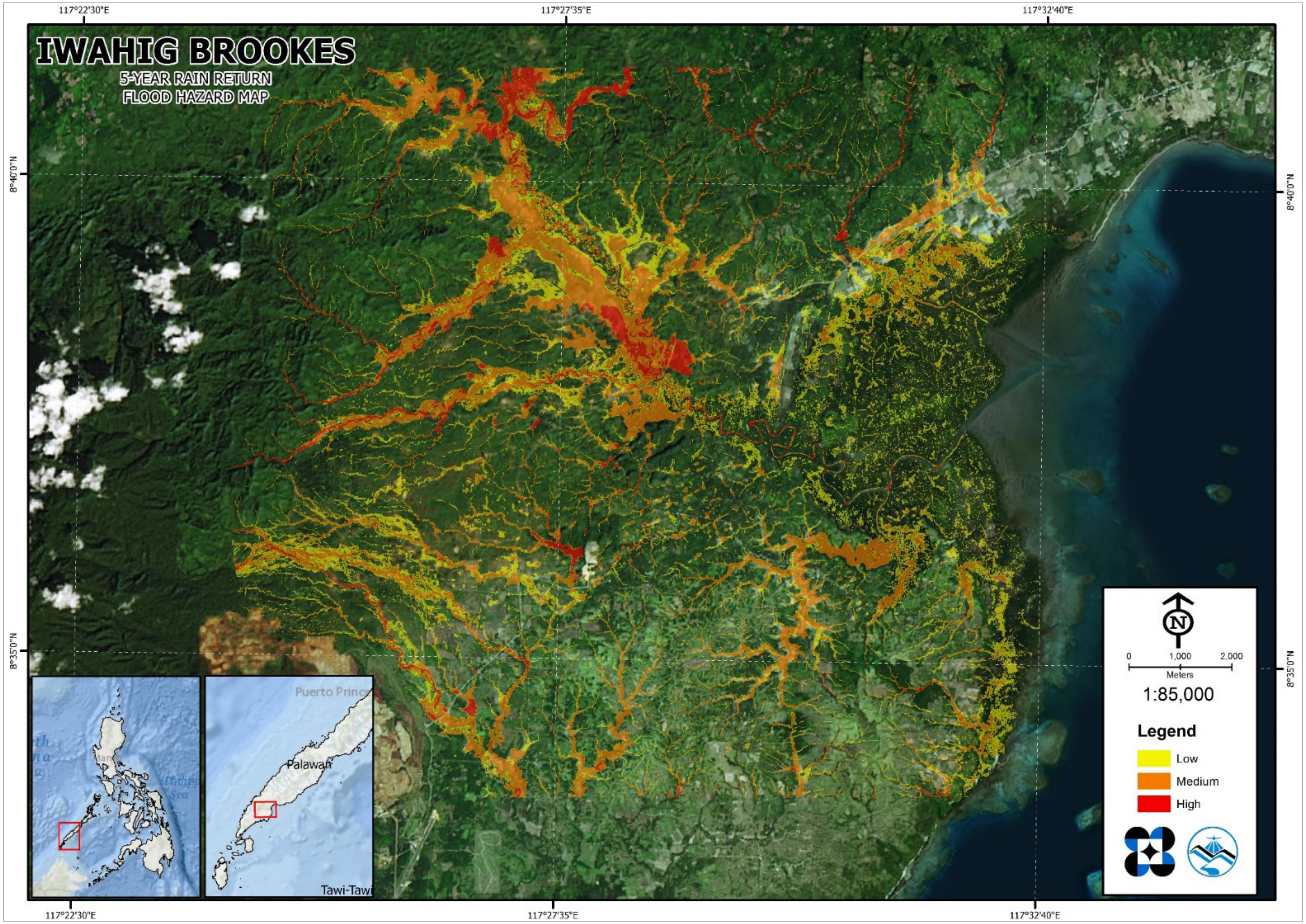

Figure 58. 5-year Flood Hazard Map for Iwahig Brookes Floodplain overlaid on Google Earth imagery

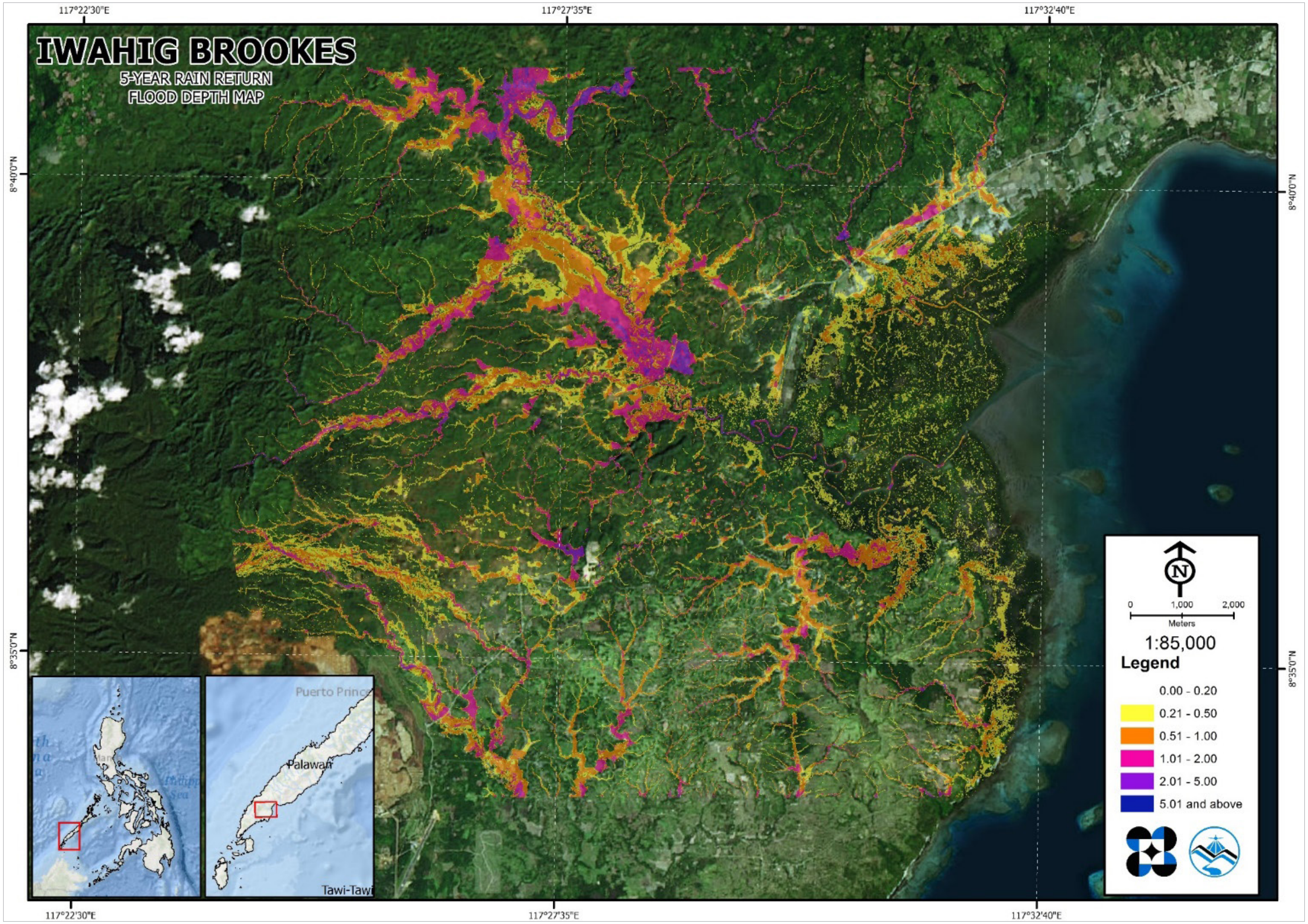

Figure 59. 5-year Flood Depth Map for Iwahig Brookes Floodplain overlaid on Google Earth imagery

5.9 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Iwahig Brookes River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 10 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 18.16% of the municipality of Bataraza with an area of 818.11 sq. km. will experience flood levels of less 0.20 meters, while 2.32% of the area will experience flood levels of 0.21 to 0.50 meters; 1.84%, 0.93%, 0.2%, and 0.004% 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. Table 28 and Figure 60 depict the areas affected in Bataraza in square kilometers by flood depth per barangay.

Table 28. Affected areas in Bataraza, Palawan during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bataraza (in sq. km.)								
	Bulalacao	Culandanum	Igang-Igang	Iwahig	Ocayan	Rio Tuba	Sandoval	Sarong	Tarusan
0.03-0.20	5.38	9.4	13.41	37.26	16.05	2.22	26.12	2.77	35.96
0.21-0.50	0.59	1.08	1.55	5.36	1.72	0.37	2.69	0.65	5
0.51-1.00	0.29	1.99	0.58	5.82	2.01	0.2	1.76	0.27	2.1
1.01-2.00	0.066	1.6	0.15	3.18	0.84	0.054	0.9	0.067	0.73
2.01-5.00	0.011	0.55	0.014	0.53	0.051	0.0061	0.17	0.015	0.25
> 5.00	0	0.012	0	0.0079	0	0	0.0047	0.0001	0.011

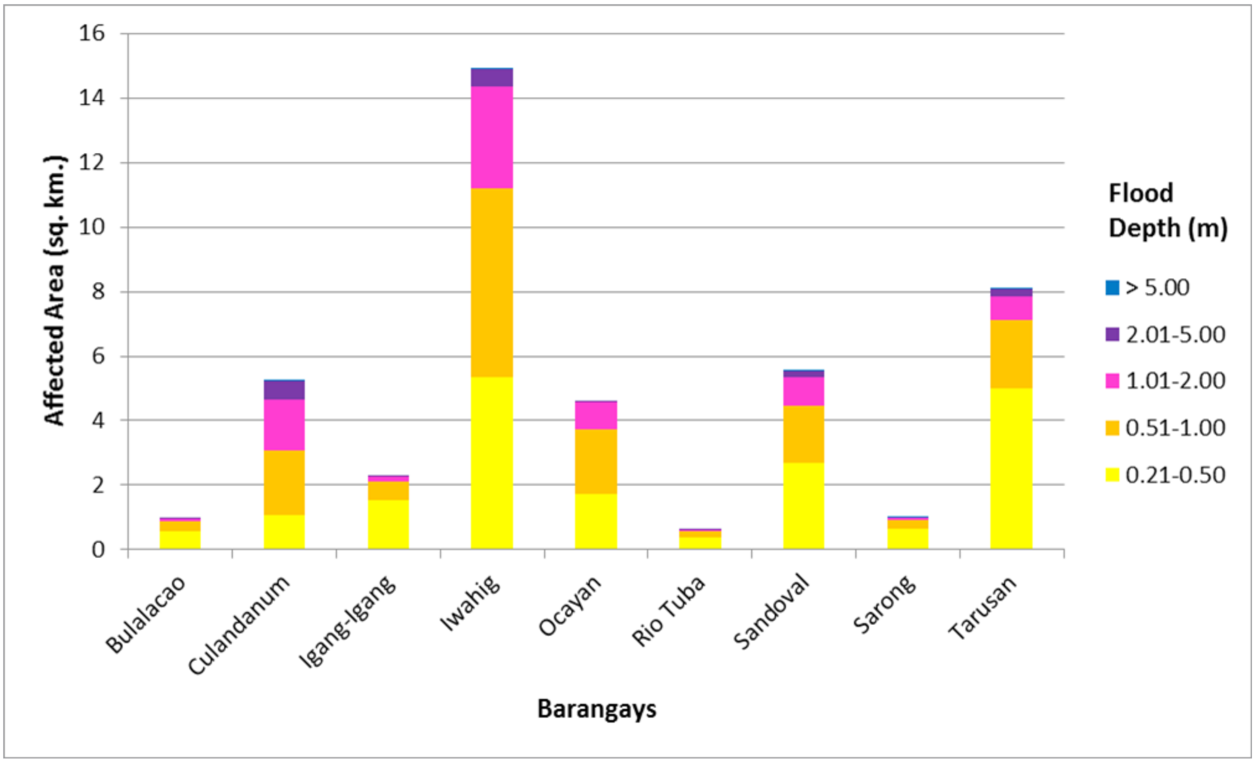

Figure 60. Affected areas in Bataraza, Palawan during a 5-Year Rainfall Return Period.

For the municipality of Rizal, with an area of 980.59 sq. km., 0.43% will experience flood levels of less 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.03%, and 0.0007% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 29 and Figure 61 depict the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)
	Taburi
0.03-0.20	4.18
0.21-0.50	0.2
0.51-1.00	0.31
1.01-2.00	0.24
2.01-5.00	0.0068
> 5.00	0

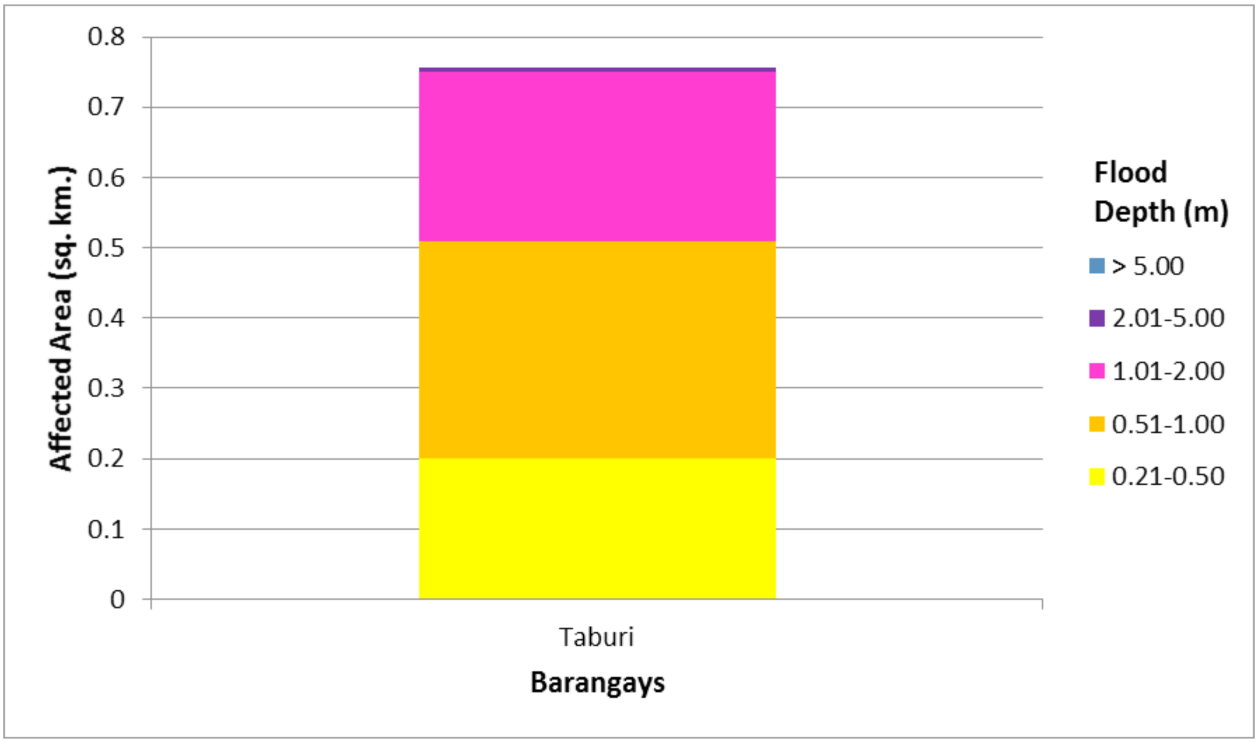

Figure 61. Affected areas in Rizal, Palawan during a 5-Year Rainfall Return Period.

For the 25-year return period, 16.6% of the municipality of Bataraza with an area of 818.11 sq. km. will experience flood levels of less 0.20 meters, while 2.53% of the area will experience flood levels of 0.21 to 0.50 meters; 2.08%, 1.72%, 0.5%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 30 and Figure 62 depict the areas affected in Bataraza in square kilometers by flood depth per barangay.

Table 30. Affected areas in Bataraza, Palawan during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bataraza (in sq. km.)								
	Bulalacao	Culandanum	Igang-Igang	Iwahig	Ocayan	Rio Tuba	Sandoval	Sarong	Tarusan
0.03-0.20	5.07	8.99	12.16	33.09	15.1	2.06	24.75	2.39	32.22
0.21-0.50	0.72	0.69	2.25	4.75	1.6	0.44	3.07	0.76	6.45
0.51-1.00	0.42	1.55	0.95	5.71	2.01	0.26	2.12	0.46	3.56
1.01-2.00	0.11	2.16	0.31	6.76	1.78	0.081	1.4	0.14	1.31
2.01-5.00	0.023	1.19	0.031	1.83	0.18	0.011	0.32	0.023	0.48
> 5.00	0	0.037	0.0001	0.029	0	0	0.0097	0.0003	0.042

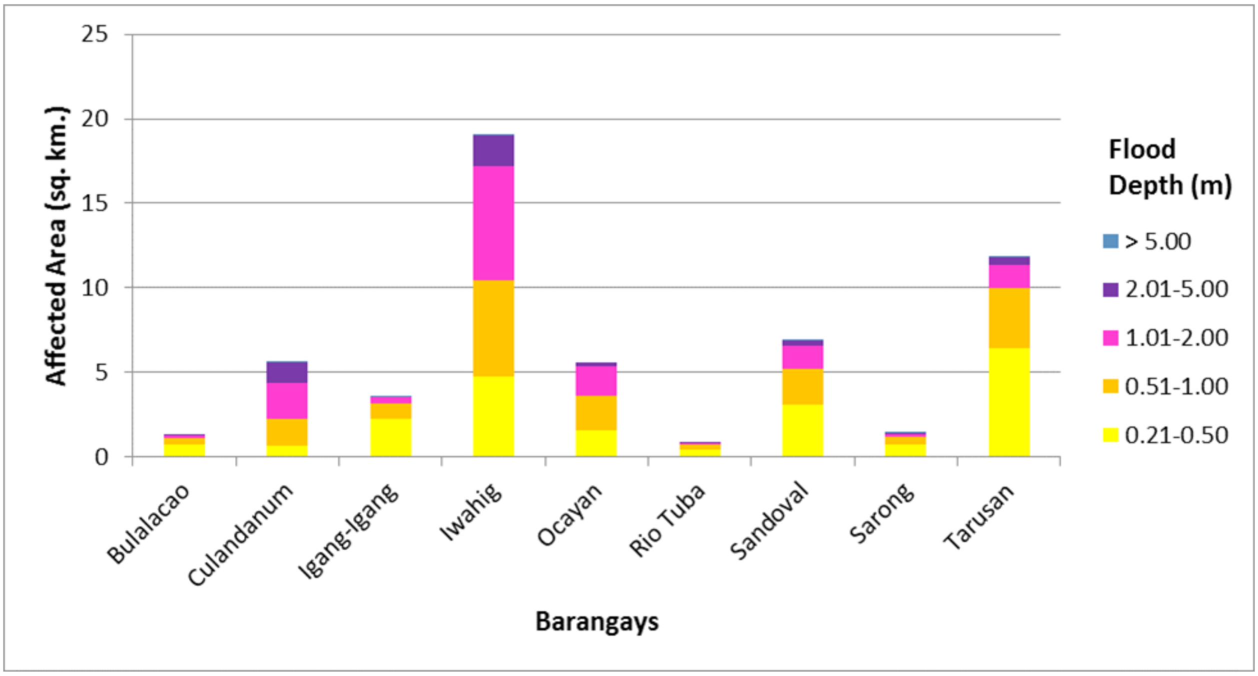

Figure 62. Affected areas in Bataraza, Palawan during a 25-Year Rainfall Return Period.

For the municipality of Rizal, with an area of 980.59 sq. km., 0.42% will experience flood levels of less 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.04%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Table 31 and Figure 63 depict the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Rizal, Palawan during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)
	Taburi
0.03-0.20	4.11
0.21-0.50	0.17
0.51-1.00	0.26
1.01-2.00	0.38
2.01-5.00	0.018
> 5.00	0

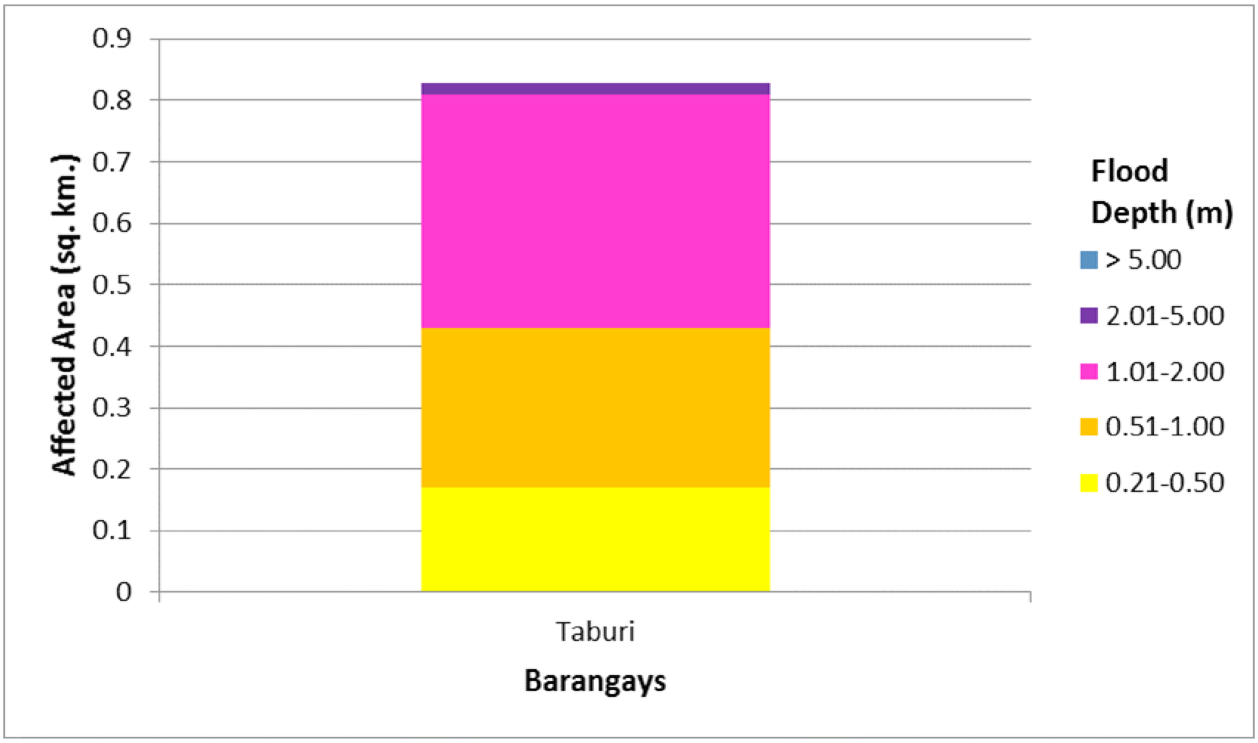

Figure 63. Affected areas in Rizal, Palawan during a 25-Year Rainfall Return Period.

For the 100-year return period, 15.7% of the municipality of Bataraza with an area of 818.11 sq. km. will experience flood levels of less 0.20 meters, while 2.57% of the area will experience flood levels of 0.21 to 0.50 meters; 2.21%, 2.05%, 0.9%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 32 and Figure 64 depict the areas affected in Bataraza in square kilometers by flood depth per barangay.

Table 32. Affected areas in Bataraza, Palawan during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bataraza (in sq. km.)								
	Bulalacao	Culandanum	Igang-Igang	Iwahig	Ocayan	Rio Tuba	Sandoval	Sarong	Tarusan
0.03-0.20	4.86	8.8	11.28	31.21	14.52	1.94	23.78	2.18	29.86
0.21-0.50	0.82	0.58	2.63	4.04	1.51	0.49	3.31	0.77	6.84
0.51-1.00	0.5	1.15	1.32	5.27	1.9	0.3	2.37	0.59	4.65
1.01-2.00	0.13	2.4	0.42	7.6	2.31	0.11	1.7	0.2	1.92
2.01-5.00	0.038	1.63	0.051	4	0.44	0.016	0.49	0.03	0.7
> 5.00	0.0002	0.059	0.0004	0.07	0	0	0.016	0.0004	0.1

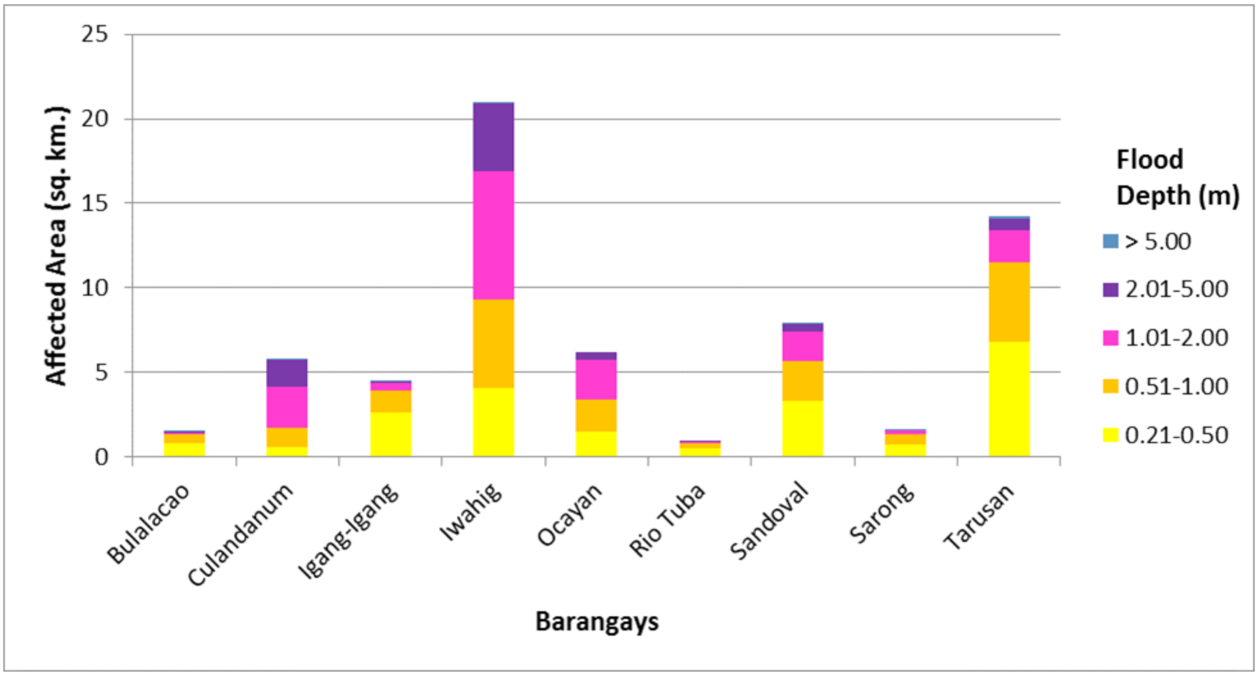

Figure 64. Affected areas in Bataraza, Palawan during a 100-Year Rainfall Return Period.

For the municipality of Rizal, with an area of 980.59 sq. km., 0.42% will experience flood levels of less 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.04%, 0.01%, and 0.00001% 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. Table 33 and Figure 65 depict the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected areas in Rizal, Palawan during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)
	Taburi
0.03-0.20	4.07
0.21-0.50	0.17
0.51-1.00	0.23
1.01-2.00	0.42
2.01-5.00	0.065
> 5.00	0.0001

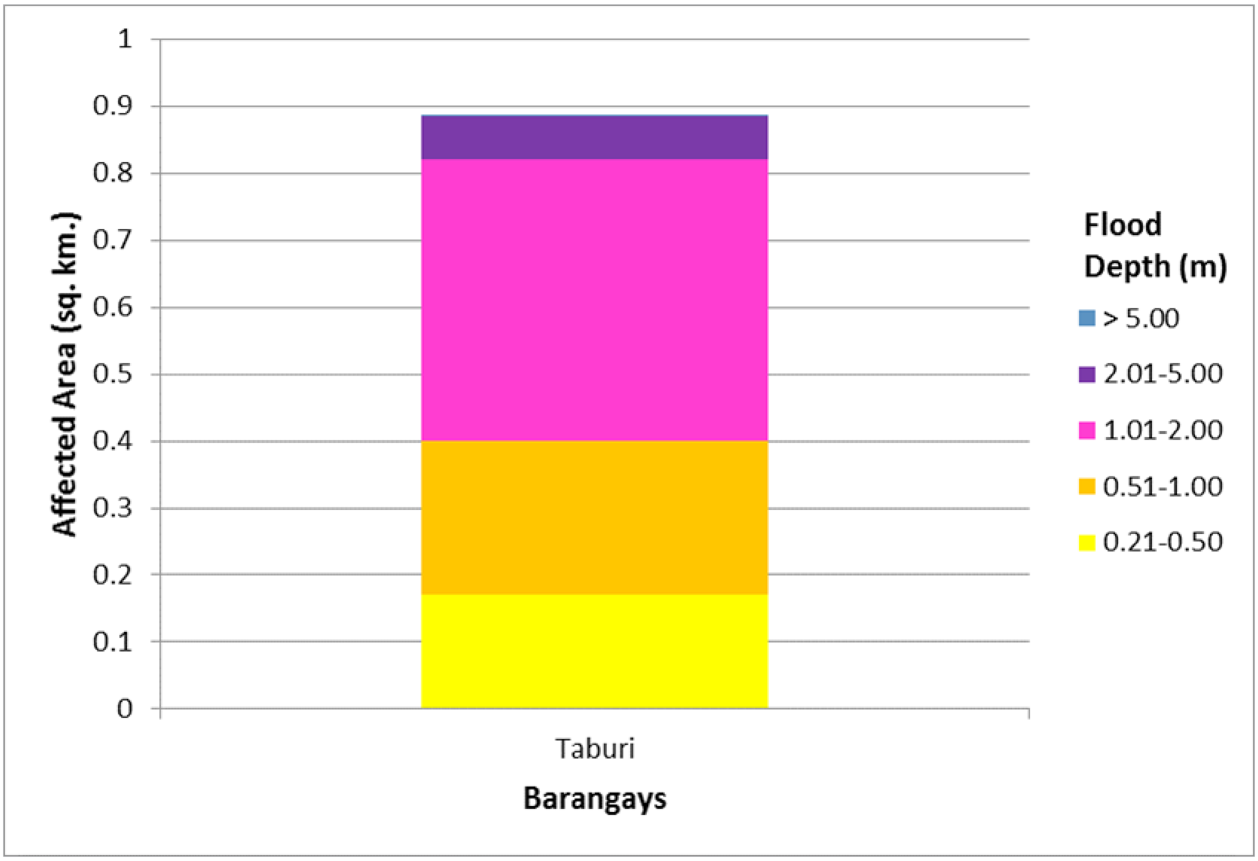

Figure 65. Affected areas in Rizal, Palawan during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Bataraza, Iwahig is projected to have the highest percentage of area that will experience flood levels of at 6.38%. On the other hand, Tarusan posted the percentage of area that may be affected by flood depths of at 5.38%.

Among the barangays in the municipality of Rizal, Taburi is projected to have the highest percentage of area that will experience flood levels of at 0.50%.

5.10 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 were identified for validation.

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 67.

The flood validation consists of 99 points randomly selected all over the Iwahig Brookes floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.47m. Table 34 shows a contingency matrix of the comparison.

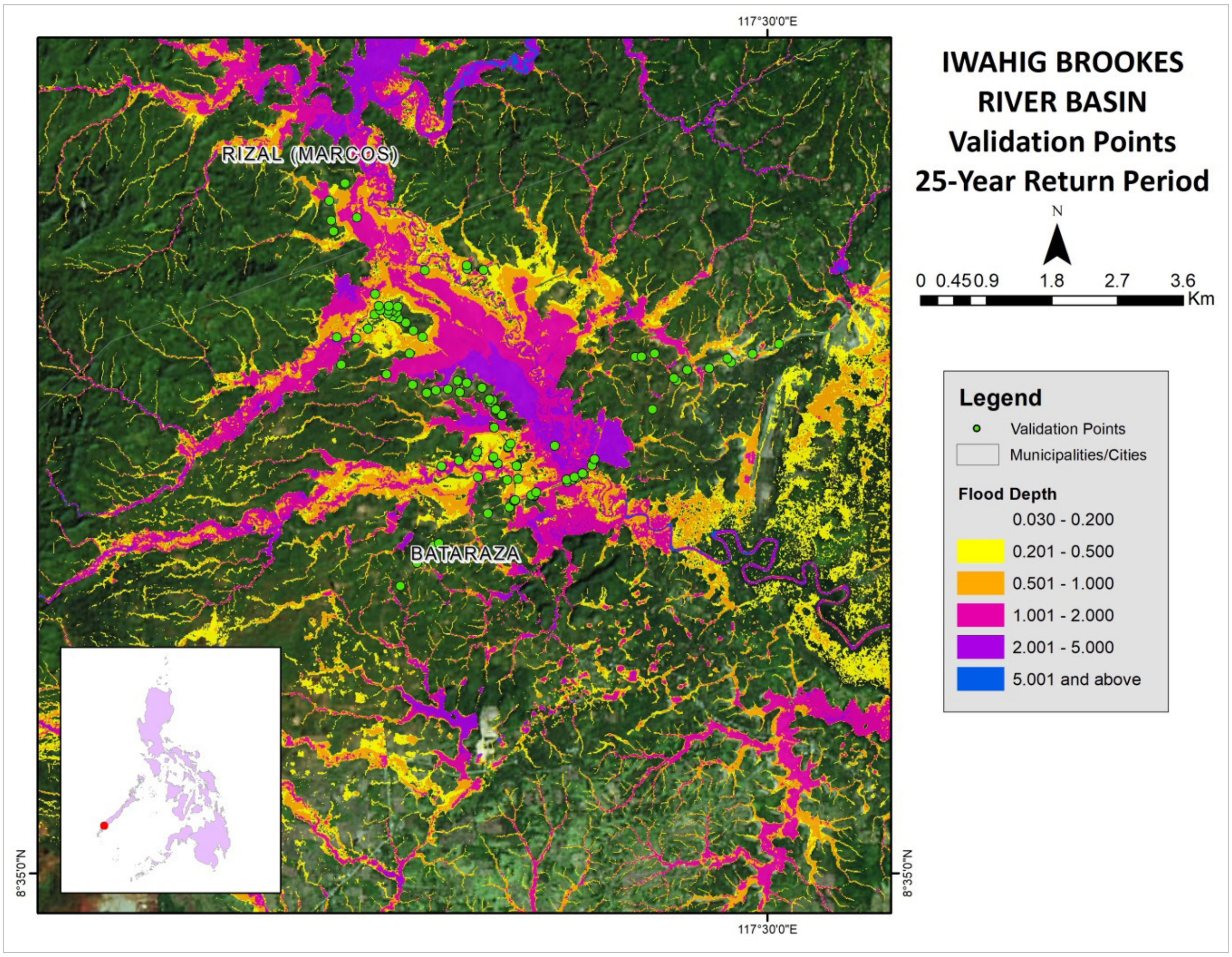

Figure 66. Validation points for 25-year Flood Depth Map of Iwahig Brookes Floodplain

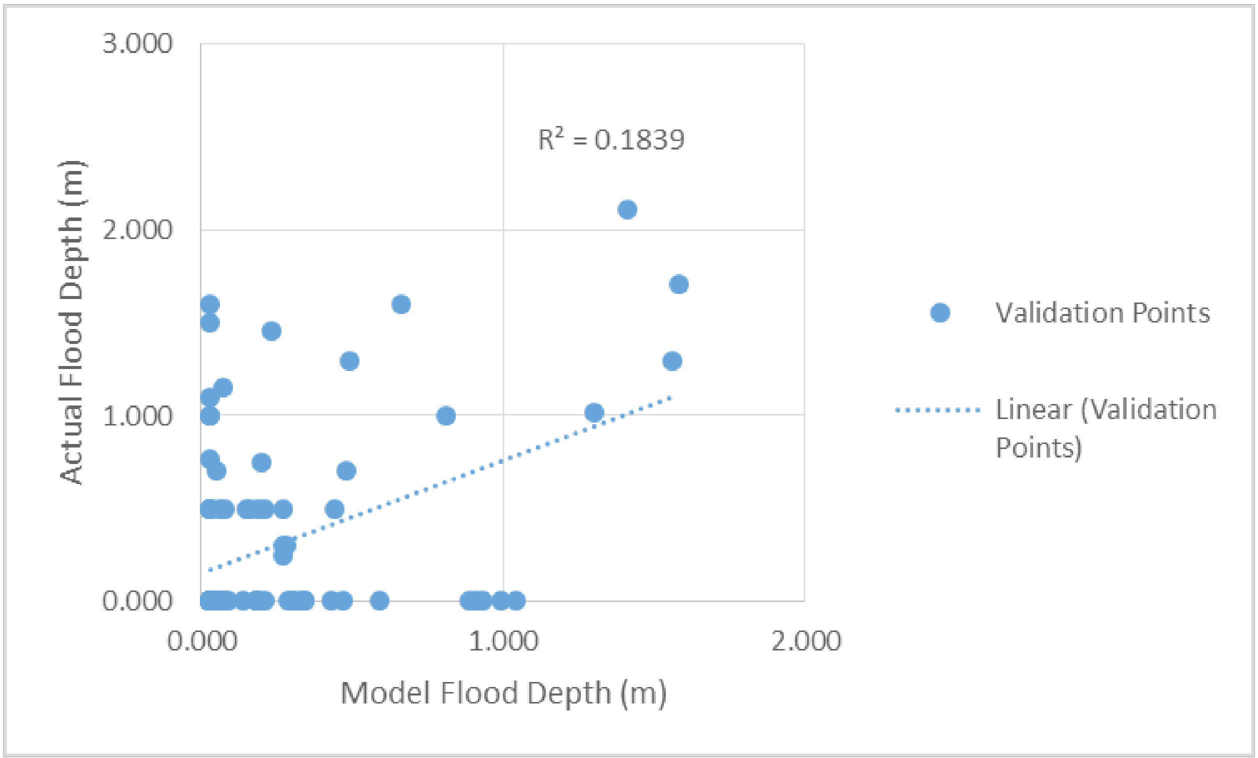

Figure 67. Flood map depth vs. actual flood depth

Table 34. Actual flood vs simulated flood depth at different levels in the Iwahig Brookes River Basin.

IWAHIG BROOKES BASIN		MODELED FLOOD DEPTH (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	51	9	5	1	0	0	**66**
	0.21-0.50	9	6	0	0	0	0	**15**
	0.51-1.00	5	1	1	0	0	0	**7**
	1.01-2.00	4	2	1	3	0	0	**10**
	2.01-5.00	0	0	0	1	0	0	**1**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**69**	**18**	**7**	**5**	**0**	**0**	**99**

The overall accuracy generated by the flood model is estimated at 61.62% with 61 points correctly matching the actual flood depths. In addition, there were 20 points estimated one level above and below the correct flood depths while there were 12 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 23 points were underestimated in the modelled flood depths of Iwahig Brookes. Table 35 depicts the summary of the Accuracy Assessment in the Iwahig Brookes River Basin Survey.

Table 35. Summary of the Accuracy Assessment in the Iwahig Brookes River Basin Survey

	No. of Points	%
Correct	61	61.62
Overestimated	15	15.15
Underestimated	23	23.23
Total	**99**	**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.

ANNEX

ANNEX 1. Optech Technical Specification of the Pegasus and Gemini Sensors

1. Pegasus Sensor

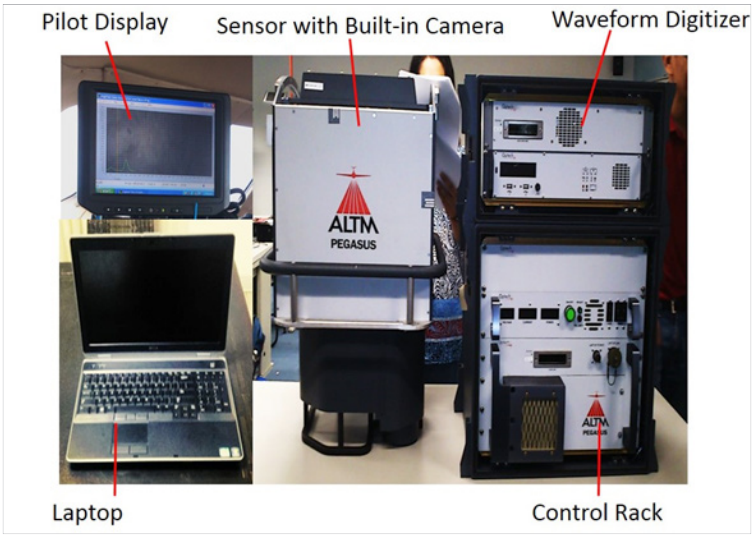

Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

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

1 Target reflectivity ≥20%
2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤20˚
4 Target size ≥ laser footprint5 Dependent on system configuration

2. Gemini Sensor

Figure A-1.2 Gemini Sensor

Table A-1.2 Parameters and Specifications of the Pegasus Sensor

Operational envelope (1,2,3,4)	**150-5000 m AGL, nominal**
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. PL-467

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

December 11, 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: **PL-467**

Island: **Luzon**	Municipality: **BATARAZA**	Barangay: **INOGBONG**
Elevation: **13.3745 +/- 0.04 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

Station Mark: Mark is the head of a four (4) inch copper nail, set in a drilled hole and flushed with cement putty with an inscription of BM PL 467, 2008, NAMRIA. The Station is located in Brgy. Inogbong, Bataraza.

Access: From Brookes Point travel south along National Road toward Bataraza, Station is located on Inogbong Bridge at the right side of the road, about 40 meters before km post 216.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088861 I**
T.N.: **2015-4112**

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

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

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

CIP/4701/12/09/814

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 PL-467

2. PLW-13

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-13**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **RIO TUBA**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 30' 17.42901"**	Longitude: **117° 25' 55.42672"**	Ellipsoidal Hgt: **-0.25567 m.**
	WGS84 Coordinates	
Latitude: **8° 30' 13.19373"**	Longitude: **117° 26' 0.86501"**	Ellipsoidal Hgt: **49.35000 m.**
	PTM / PRS92 Coordinates	
Northing: **940540.844 m.**	Easting: **382414.126 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **940,076.76**	Easting: **547,553.57**	Zone: **50**

Location Description

PLW-13
From Puerto Princesa travel along the National Highway for 249.2 ikilometers, about 4 hours and 15 minutes drive to Rio Tuba Nickel iMining Corporation. Thence travel south direction for 4.7 ikilometers or 5 minutes drive, then turn right going West idirection for 300 meters up to barangay Rio Tuba. The station is ilocated on a big boulder in the pier site; 70 meters North of ibarangay captain's house. Station mark is a cross cut of 0.15 m x i0.01 m in diameter brass rod, set in a drill hole centered in a i30 cm x 30 cm cement patty on big boulder. Inscribed on top with ithe station name. All reference mark numbers 1,2,3 and 4 are icross cut on top of brass rods, set in a drill hole on big iboulder, centered in a 25 cm x 25 cm cement patty, and inscribed iwith the station name and arrows pointing to the station.

Requesting Party:	**ENGR. CHRISTOPHER CRUZ**
Purpose:	**Reference**
OR Number:	**8086767 I**
T.N.:	**2015-1694**

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 ACCREDITED
CIP/4701/12/07/814

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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-13

3. PLW-79

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-79 (PAL-22)**
Order: **2nd**

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

PRS92 Coordinates

Latitude: **8° 37' 30.44877"**	Longitude: **117° 27' 5.39859"**	Ellipsoidal Hgt: **25.88011 m.**

WGS84 Coordinates

Latitude: **8° 37' 26.18482"**	Longitude: **117° 27' 10.82604"**	Ellipsoidal Hgt: **75.29000 m.**

PTM / PRS92 Coordinates

Northing: **953839.48 m.**	Easting: **384591.01 m.**	Zone: **1A**

UTM / PRS92 Coordinates

Northing: **953,376.65**	Easting: **549,677.23**	Zone: **50**

Location Description

PLW-79 (PAL-22)
From Puerto Princesa City travel south bound of the road by a shuttle van going to Brgy Rio Tuba, Bataraza passing through brooks points for almost 2 to 3 hours. The station is located along the brgy. road at Brgy. Sandoval near the house of Tribal Chieftain Acat. Mark is a 4" copper nail centered on top of a 30 x 30 x 100 cm concrete monument 20 cm projection above the ground and 80 cm set on the ground. Station is along the brgy. road at Brgy. Sandoval with inscription PAL-22 2006 NCIP.

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8086767 I**
T.N.: **2015-1695**

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

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3 PLW-79

4. PLW-136

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **PALAWAN**
Station Name: **PLW-141/136**
Order: **2nd**

Island: **Luzon**	Barangay: **MALIS**	
Municipality: **BROOKE'S POINT**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 41' 32.51585"**	Longitude: **117° 41' 48.08062"**	Ellipsoidal Hgt: **-2.49300 m.**
	WGS84 Coordinates	
Latitude: **8° 41' 28.25671"**	Longitude: **117° 41' 53.50178"**	Ellipsoidal Hgt: **47.39100 m.**
	PTM / PRS92 Coordinates	
Northing: **961210.738 m.**	Easting: **411596.8 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **960,851.09**	Easting: **576,642.18**	Zone: **50**

Location Description

From Brooke's Point Poblacion, travel South bound along Nat'l highway towards the town of Batarazan for approx. 20kms up to Brgy. Malis, then turn SE direction on Malis junction going to Aplaya, and travel for approx. 120m. The station is situated inside Malis Elem. School compd.

Mark is the head of a 4" copper nail flushed in a cement block (30cmx30cmx120cm) embedded 1m in the ground with inscriptions "PLW 136 2007, NAMRIA". The monument is made 20 cm above ground surface with ref. mark 1,2&3.

RM1=120m SE of road centerline
RM2=25m E of school gate
RM3=60m N of school buildings

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number:
T.N.:

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

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

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Figure A-2.4 PLW-136

5. 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

99120220151O5606

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-2.5 PLW-137

ANNEX 3. Baseline Processing Reports of Control Points used in the LIDAR Survey

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
PLW-3058 --- PLW-13 (B1)	PLW-13	PLW-3058	Fixed	0.007	0.024	52°27'10"	82603.650	-2.724
PLW-3058 --- PLW-13 (B2)	PLW-13	PLW-3058	Fixed	0.007	0.019	52°27'10"	82603.646	-2.673

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

PLW-3058 - PLW-13 (7:29:44 AM-1:02:54 PM) (S1)

Baseline observation:	PLW-3058 --- PLW-13 (B1)
Processed:	1/4/2016 1:53:45 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.007 m
Vertical precision:	0.024 m
RMS:	0.005 m
Maximum PDOP:	2.036
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/7/2015 7:30:04 AM (Local: UTC+8hr)
Processing stop time:	12/7/2015 1:02:54 PM (Local: UTC+8hr)
Processing duration:	05:32:50
Processing interval:	5 seconds

1

Figure A-3.1 Baseline Processing Report - A

Vector Components (Mark to Mark)

From:	PLW-13				
Grid		Local		Global	
Easting	-113741.490 m	Latitude	N8°30'17.42900"	Latitude	N8°30'13.19373"
Northing	944471.057 m	Longitude	E117°25'55.42676"	Longitude	E117°26'00.86501"
Elevation	1.573 m	Height	-0.256 m	Height	49.350 m

To:	PLW-3058				
Grid		Local		Global	
Easting	-47262.005 m	Latitude	N8°57'34.41144"	Latitude	N8°57'30.11418"
Northing	994023.989 m	Longitude	E118°01'39.35193"	Longitude	E118°01'44.74872"
Elevation	-3.162 m	Height	-2.979 m	Height	47.176 m

Vector					
ΔEasting	66479.484 m	NS Fwd Azimuth	52°27'10"	ΔX	-54449.894 m
ΔNorthing	49552.932 m	Ellipsoid Dist.	82603.650 m	ΔY	-37251.571 m
ΔElevation	-4.735 m	ΔHeight	-2.724 m	ΔZ	49706.928 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.011 m
σ ΔElevation	0.012 m	σ ΔHeight	0.012 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000356543		
Y	-0.0000566784	0.0001191653	
Z	-0.0000106477	0.0000187894	0.0000078497

2

Figure A-3.2 Baseline Processing Report - B

ANNEX 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		GEROME HIPOLITO	
	Research Associate (RA)	LARAH KRISELLE PARAGAS	
		MARY CATHERINE ELIZABETH BALIGUAS	
Ground Survey	RA	JERIEL PAUL ALAMBAN	
		GRACE SINADJAN	
		JONATHAN ALMALVEZ	
		IRO NIEL ROXAS	
LiDAR Operation	Airborne Security	SSG. PRADYUMNA DAS RAMIREZ	Philippine Air Force (PAF)
		ATC2 JUNMAR PARANGUE	
	Pilot	CAPT. MARK TANGONAN	Asian Aerospace Corporation (AAC)
		CAPT. ALBERT PAUL LIM	
		CAPT. RANDY LAGCO	

ANNEX 5. Data Transfer Sheets

DATA TRANSFER SHEET
7/9/2015(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	
18-Jun	3065P	1BLK42Ac169A	pegasus	1.09	na	7.83	187	37.7	266	20.6	60.1	3.9	1kb	na	96/15	na	Z:\DAC\RAW DATA
28-Jun	3105P	1BLK42QR179A	pegasus	1.45	na	9.25	213	36.9	40	29.4	59.3	9.17	1KB	na	108	na	Z:\DAC\RAW DATA
29-Jun	3109P	1BLK42QR180A	pegasus	988	na	6	147	na	na	18.3	16.3	6.79	1KB	na	108/117	6	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature [signature]

Received by

Name AC Bongat
Position SSRS
Signature [signature] 7/10/15

15-19

Figure A-5.1 Data Transfer Sheet for Iwahig Brookes Floodplain - A

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 C. Joaquin
Position FA
Signature [signature]

Received by
Name AC Bongat
Position SSRS
Signature [signature] 8/5/2015

15-22

Figure A-5.2 Data Transfer Sheet for Iwahig Brookes Floodplain - B

DATA TRANSFER SHEET
PALAWAN 12/17/15

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	
20-Nov-15 (transferred twice)	3565	2BLK42PQR337A	GEMINI	NA	92	535	202	na	na	25.4	na	6.96	1KB	1KB	22/24/22/48/51	NA	Z:\DAC\RAW DATA
21-Nov-15	3571	2BLK42Tv338A	GEMINI	NA	171	370	160	na	na	14.6	na	640	1KB	1KB	22/24/22/48/51	NA	Z:\DAC\RAW DATA
26-Nov-15	3573	2BLK42Ov339A	GEMINI	NA	484	1	227	na	na	19.7	na	12.1	1KB	1KB	24/22/48/53/51/30	NA	Z:\DAC\RAW DATA
27-Nov-15	3575	2BLK42OQ339B	GEMINI	NA	734	530	218	na	na	22.3	na	12.1	1KB	1KB	24/22/30/53/50/48/51	NA	Z:\DAC\RAW DATA
28-Nov-15	3581	2BLK42NPQ341A	GEMINI	NA	872	484	232	na	na	21.2	na	8.55	1KB	NA	24/22/21/27/30/53/50/48/51	NA	Z:\DAC\RAW DATA
30-Nov-15	3585	2BLK42Nv342A	GEMINI	NA	1080	558	234	na	na	23	na	5.29	1KB	1KB	24/22/21/28/27/30/53/50/48/51	NA	Z:\DAC\RAW DATA
30-Nov-15	3593	2BLK42TwEwF344A	GEMINI	NA	1343	523	227	na	na	20.9	na	11.4	1KB	1KB	53/50/48/17	NA	Z:\DAC\RAW DATA
1-Dec-15	3595	2BLK42US344B	GEMINI	NA	253	387	156	na	na	17.4	na	11.4	1KB	1KB	17/16	NA	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

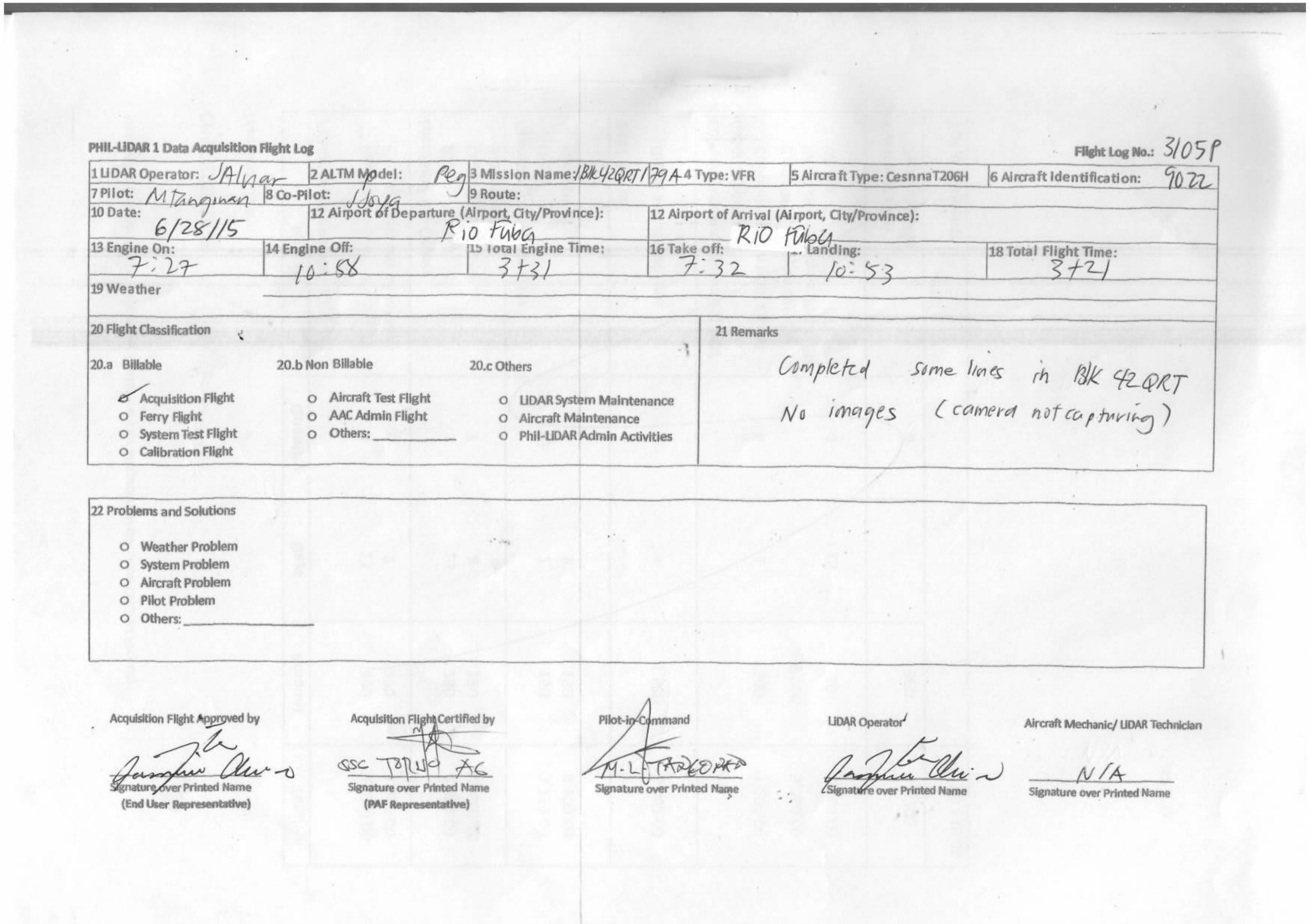
Received by

Name AC Bongat
Position SSRS
Signature 1/5/2016

Figure A-5.3 Data Transfer Sheet for Iwahig Brookes Floodplain - C

ANNEX 6. FLIGHT LOGS

1. Flight Log for 1BLK42QR179A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3105P

1 LIDAR Operator: JAlviar	2 ALTM Model: Peg	3 Mission Name: 1BLK42QRT179A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route:			
10 Date: 6/28/15	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 7:27	14 Engine Off: 10:58	15 Total Engine Time: 3+31	16 Take off: 7:32	17 Landing: 10:53	18 Total Flight Time: 3+21
19 Weather					

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 BLK 42QRT
No images (camera not capturing)

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
[signature]	SSC TORNO AG	M. L. TANGONAN	[signature]	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-6.1 Flight Log for 1BLK42QR179A Mission

2. Flight Log for 1BLK42QR180A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3109P

1 LIDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Soyo	9 Route:			
10 Date: 6/29/15	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 2+25	16 Take off:	17 Landing:	18 Total Flight Time: 2+15
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

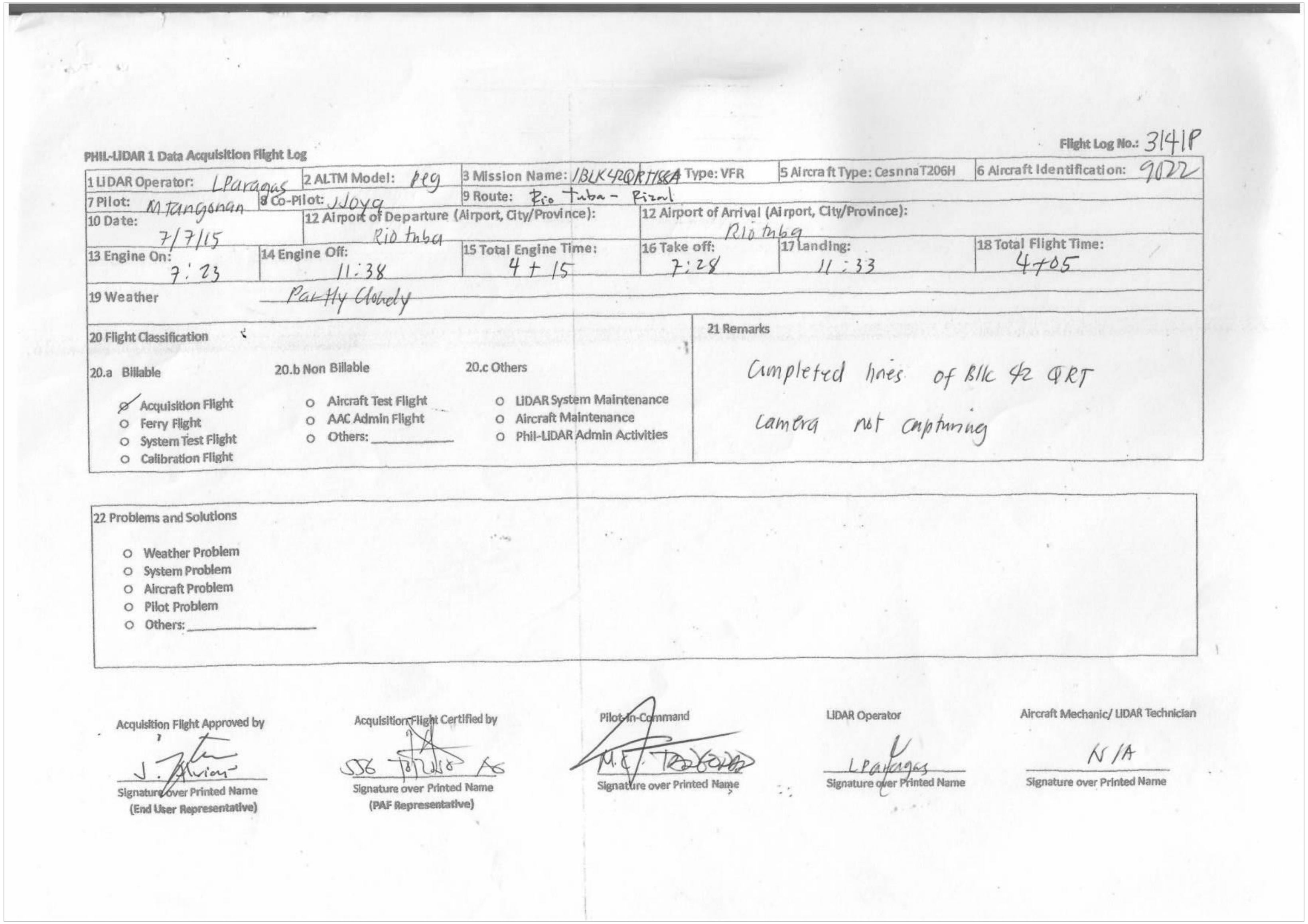
Completed some lines of Blk 42 QRT, No camera images (not capturing)

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Jasmyn [signature]	SSC Afuseto Tayud [signature]	M.L. Tangonan [signature]	G. Sinadjan [signature]	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 1BLK42QR180A Mission

3. Flight Log for 1BLK42QRT188A Mission



Flight Log No.: 3141P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: LParagas	2 ALTM Model: Peg	3 Mission Name: 1BLK42QRT188A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route: Rio Tuba - Rizal			
10 Date: 7/7/15	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: 11:38	15 Total Engine Time: 4+15	16 Take off: 7:28	17 Landing: 11:33	18 Total Flight Time: 4+05
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 lines of Blk 42 QRT

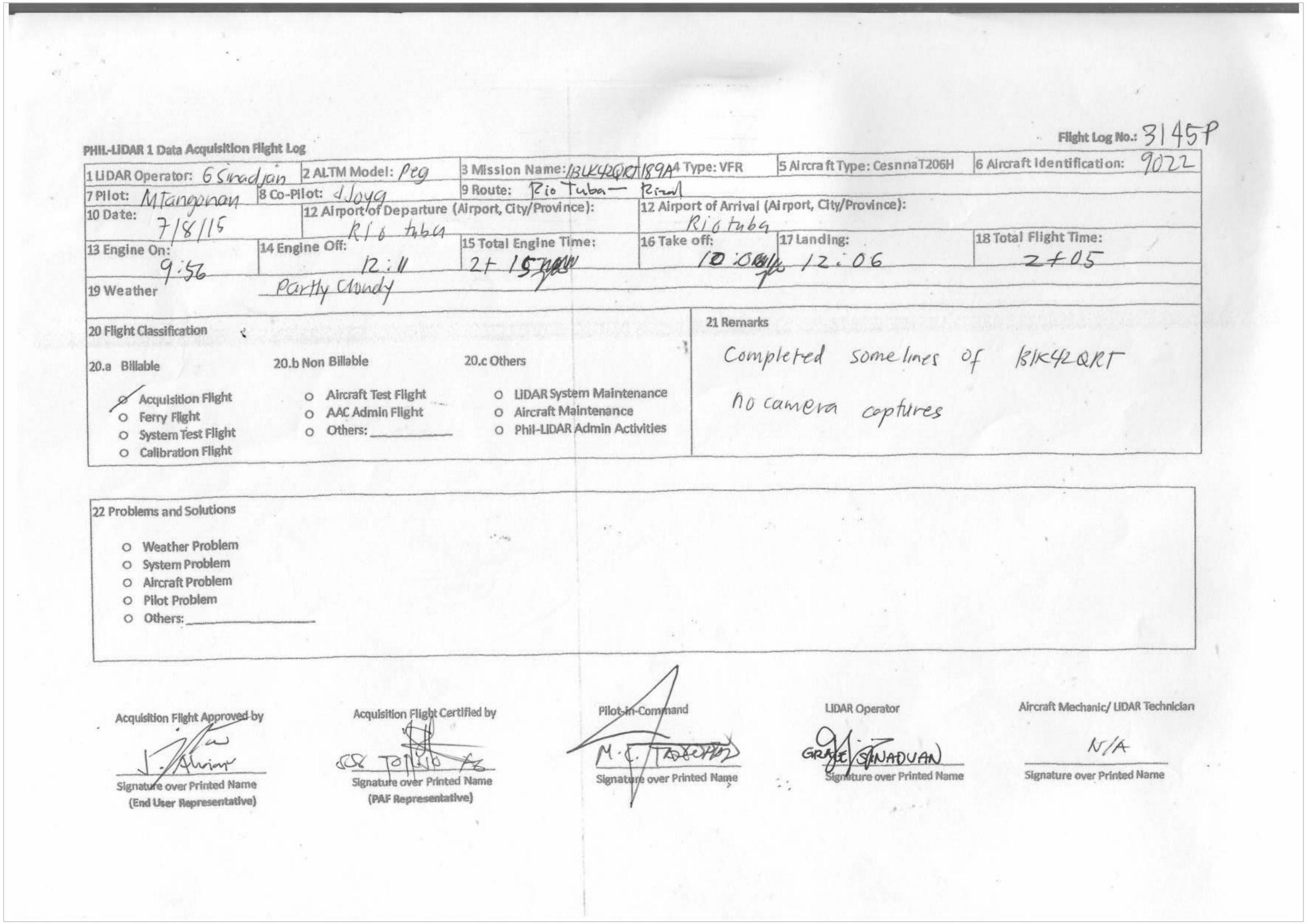
Camera not capturing

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 [illegible] PAF	M.C. Tangonan	LParagas	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-6.3 Flight Log for 1BLK42QRT188A Mission

4. Flight Log for 1BLK42QRT189A Mission



Flight Log No.: 3145P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK42QRT189A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route: Rio Tuba — Rizal			
10 Date: 7/8/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 9:56	14 Engine Off: 12:11	15 Total Engine Time: 2+15	16 Take off: 10:01	17 Landing: 12:06	18 Total Flight Time: 2+05
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 of BlK42QRT
no camera captures

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	[illegible]	M. C. Tangonan	Grace 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-6.4 Flight Log for 1BLK42QRT189A Mission

5. Flight Log for 2BLK42QR337A Mission

Data Acquisition Flight Log

Flight Log No.: 35656

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: GEM	3 Mission Name: 2BLK42QR337A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A. LIM	8 Co-Pilot: R. LACSO	9 Route: Rio Tuba — Rio Tuba			
10 Date: Dec. 3, 2015	12 Airport of Departure (Airport, City/Province): RTN		12 Airport of Arrival (Airport, City/Province): RTN		
13 Engine On: 0835	14 Engine Off: 1204	15 Total Engine Time: 3+29	16 Take off: 0840H	17 Landing: 1159H	18 Total Flight Time: 3+19
19 Weather: Cloudy					

20 Flight Classification

20.a Billable
- Acquisition Flight (checked)
- 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 BLK42R & surveyed 5 lines of BLK42Q and 1 line of BLK42S. Second line was cut & no tieline due to heavy cloud build up.

22 Problems and Solutions

- Weather Problem
- System Problem
- Aircraft Problem
- Pilot Problem
- Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
S. Hipolito	A2C Marlou Paranague PAF	A. Lim	MCE Balicuas	G. Antonio
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-6.5 Flight Log for 2BLK42QR337A Mission

6. Flight Log for 2BLK42Tv338A Mission

Data Acquisition Flight Log | **Flight Log No.** 3571 G

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: LEM	3 Mission Name: 2BLK42Tv338A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A. LIM	8 Co-Pilot: A. LAGCO	9 Route: RTH – RTH			
10 Date: Dec. 4, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 1341	14 Engine Off: 1646	15 Total Engine Time: 03+05	16 Take off: 1346H	17 Landing: 1641H	18 Total Flight Time: 2+55
19 Weather: heavy buildup					

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

Error code 10 was experienced during transit. Surveyed BLK42T and voids from previous flights.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
G. Hipolito	A2C [illegible] PAF	A. Lim	J. Almalvez	G. Antonio
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-6.6 Flight Log for 2BLK42Tv338A Mission

7. Flight Log for 2BLK42N342A Mission

Flight Log No.: 35856

Data Acquisition Flight Log

1 LiDAR Operator: J ALMALVEZ	2 ALTM Model: GEM	3 Mission Name: 2BLK42N342A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A. LIM	8 Co-Pilot: R. LAGCO	9 Route: Rio Tuba – Rio Tuba			
10 Date: Dec. 8, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 0700	14 Engine Off: 1053	15 Total Engine Time: 3+53	16 Take off: 0707H	17 Landing: 1048H	18 Total Flight Time: 3+41
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Completed BLK42N with voids due to clouds

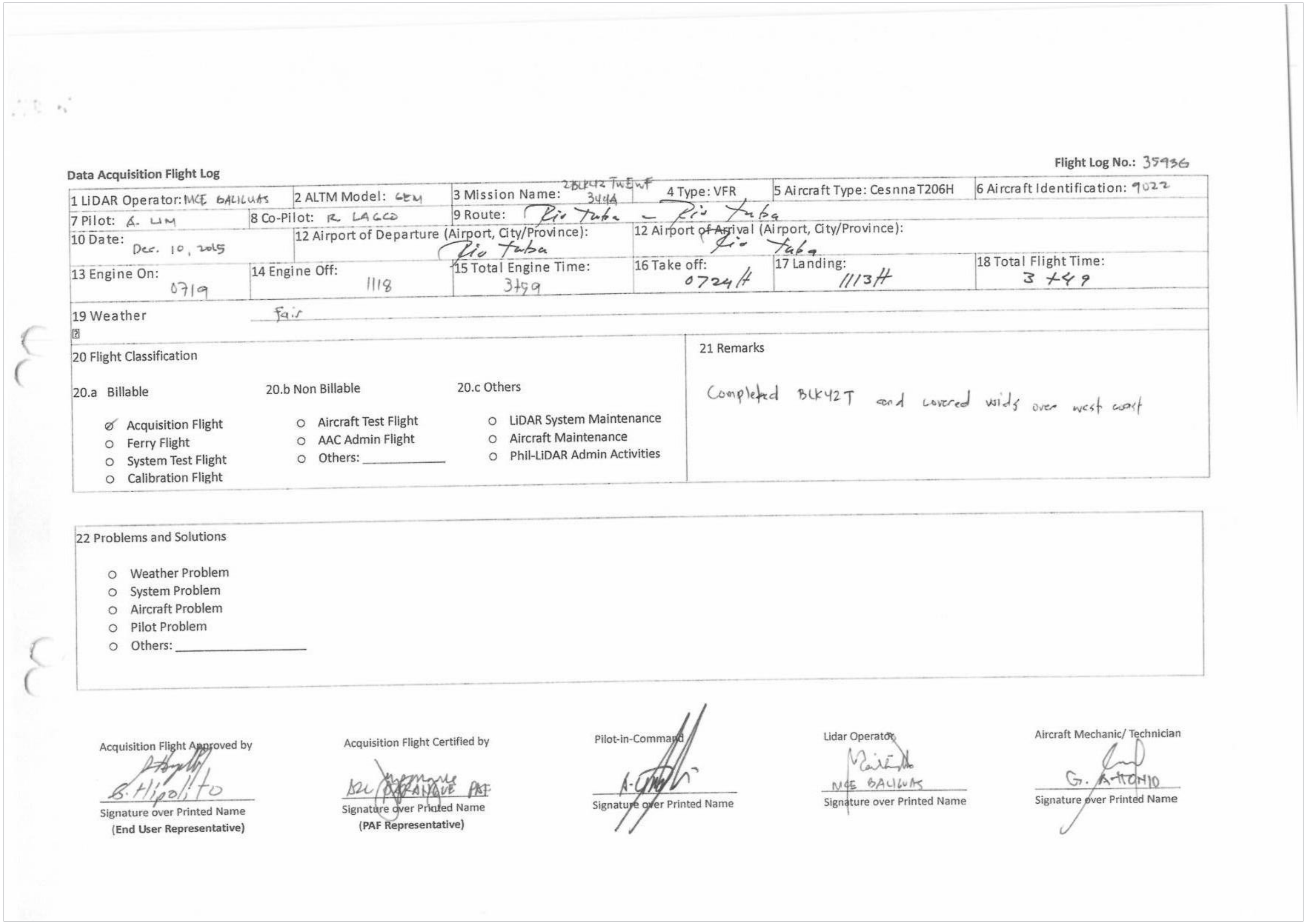
22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
S. LIPALITO	A2C [illegible] PAF	A. LIM	J. ALMALVEZ	G. ANTONIO
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-6.7 Flight Log for 2BLK42N342A Mission

8. Flight Log for 2BLK42TwEwF344A Mission



Flight Log No.: 35936

Data Acquisition Flight Log

1 LiDAR Operator: MCE BALILUAS	2 ALTM Model: GEM	3 Mission Name: 2BLK42TwEwF344A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: G. LIM	8 Co-Pilot: R. LAGCO	9 Route: Rio Tuba – Rio Tuba			
10 Date: Dec. 10, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 0719	14 Engine Off: 1118	15 Total Engine Time: 3+59	16 Take off: 0724H	17 Landing: 1113H	18 Total Flight Time: 3+49
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 BLK42T and covered voids over west coast

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

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

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

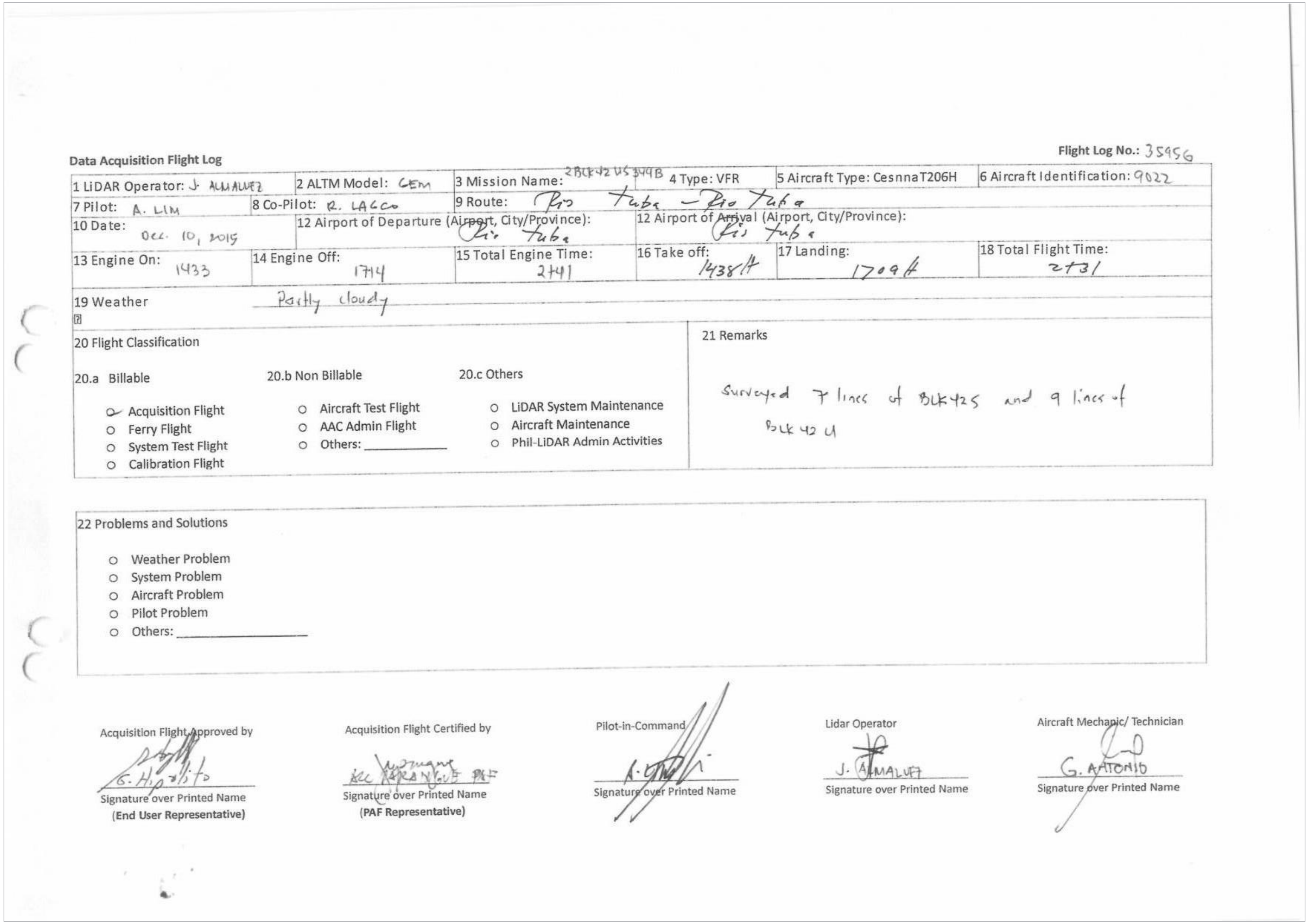
Pilot-in-Command: G. LIM — Signature over Printed Name

Lidar Operator: MCE BALILUAS — Signature over Printed Name

Aircraft Mechanic/ Technician: G. ANTONIO — Signature over Printed Name

Figure A-6.8 Flight Log for 2BLK42TwEwF344A Mission

9. Flight Log for 2BLK42US344B Mission



Data Acquisition Flight Log

Flight Log No.: 35956

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEM	3 Mission Name: 2BLK42US344B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: A. LIM	8 Co-Pilot: R. LAGCO	9 Route: Rio Tuba – Rio Tuba			
10 Date: Dec. 10, 2015	12 Airport of Departure (Airport, City/Province): Rio Tuba		12 Airport of Arrival (Airport, City/Province): Rio Tuba		
13 Engine On: 1433	14 Engine Off: 1714	15 Total Engine Time: 2+41	16 Take off: 1438H	17 Landing: 1709H	18 Total Flight Time: 2+31
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed 7 lines of BLK42S and 9 lines of BLK42U

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

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

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

Pilot-in-Command: A. LIM — Signature over Printed Name

Lidar Operator: J. ALMALVEZ — Signature over Printed Name

Aircraft Mechanic/ Technician: G. ANTONIO — Signature over Printed Name

Figure A-6.9 Flight Log for 2BLK42US344B Mission

ANNEX 7. Flight Status Reports

IWAHIG BROOKES FLOODPLAIN
(June 28-July 8; December 3-10, 2015)

Flight No	Area	Mission	Operator	Date Flown	Remarks
3105P	BLK 42QRT	1BLK42QR179A	J. Alviar	June 28	Surveyed some line in BLK 42Q, BLK 42R, BLK 42T.
3109P	BLK 42Q	1BLK42QR180A	G. Sinadjan	June 29	Cloudy. Cam error.
3141P	BLK 42QRT	1BLK42QRT188A	L. Paragas	July 7	Surveyed BLK 42Q, BLK 42T and BLK 42R at 1200M
3145P	BLK 42R	1BLK42QRT189A	G. Sinadjan	July 8	Surveyed BLK 42R but with gaps due to clouds
3565G	BLK42eP, 42eQ, 42eR, & 42eS	2BLK42PQR337A	MCE Baliguas	03-Dec-15	Completed BLK42eR and surveyed BLK42eP, 42eQ and BLK42eS.
3571G	BLK42eT & 42Q voids	2BLK42Tv338A	JM Almalvez	04-Dec-15	Surveyed BLK42eT and voids/gaps over Rio Tuba RBs
3585G	BLK42eN & 42Q voids	2BLK42Nv342A	JM Almalvez	08-Dec-15	Completed BLK42En.
3593G	BLK42eT, 42R & 42T voids	2BLK42TwEwF344A	MCE Baliguas	10-Dec-15	Completed BLK42eT and covered voids/ gaps over west coast (42R,T)
3595G	BLK42eS	2BLK42US344B	JM Almalvez	10-Dec-15	Surveyed BLK42eS

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT LOG NO. 3105P
AREA: BLOCK 42Q, 42R &42T
MISSION NAME: 1BLK42QR179A
SURVEY COVERAGE:

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

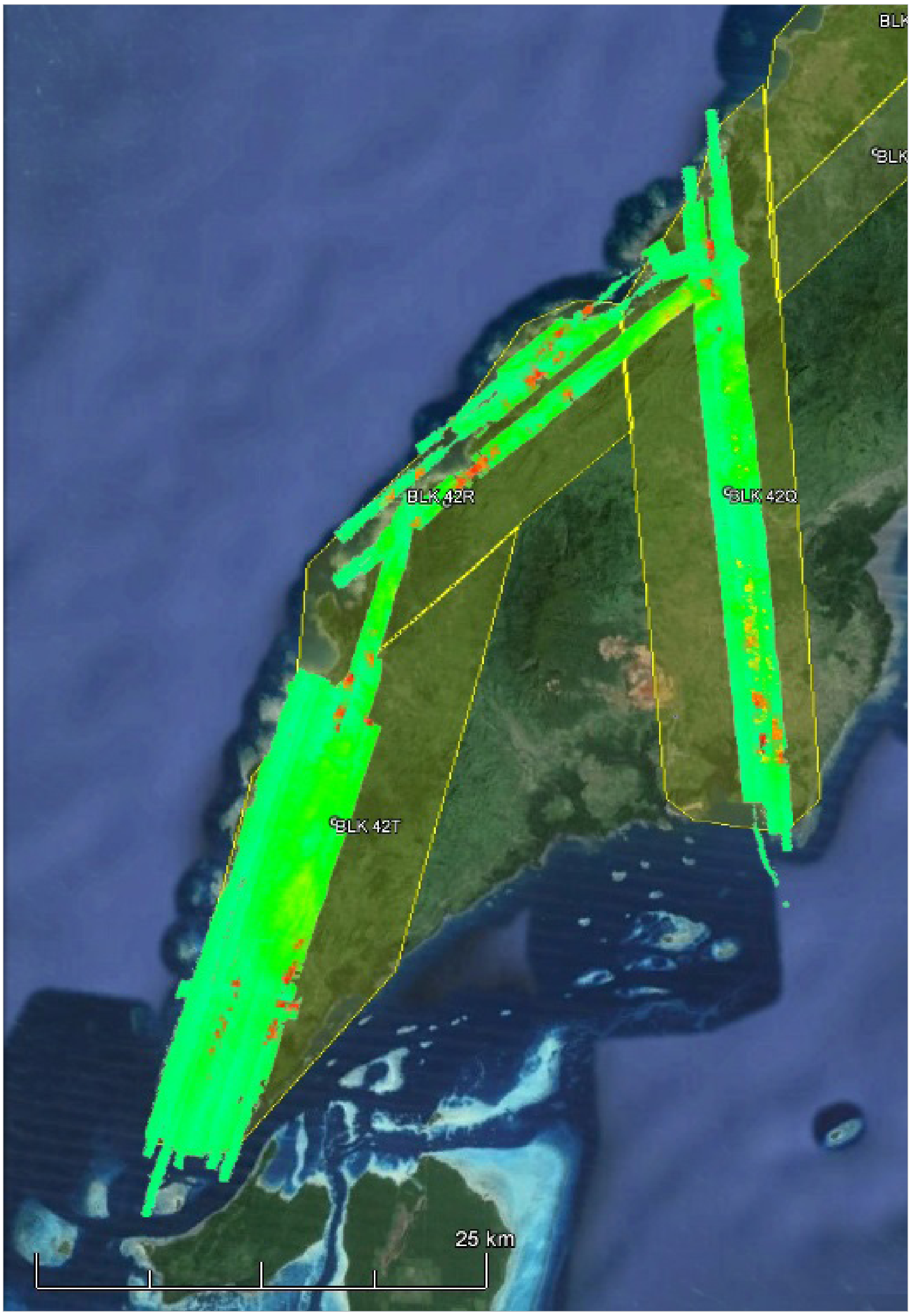


Figure A-7.1 Swath for Flight No. 3105P

FLIGHT LOG NO. 3109P
AREA: BLOCK 42Q
MISSION NAME: 1BLK42QR180A

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

SURVEY COVERAGE:

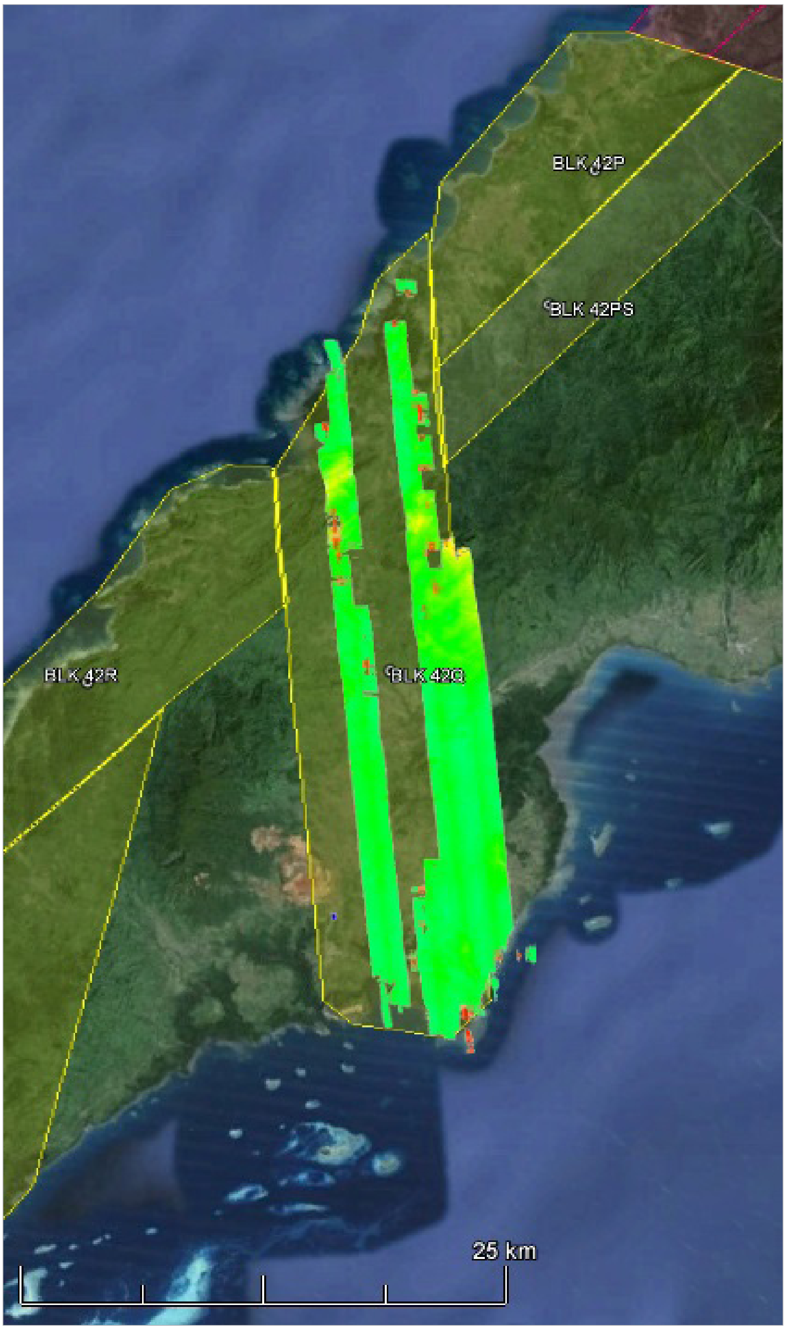


Figure A-7.2 Swath for Flight No. 3109P

FLIGHT LOG NO. 3141P
AREA: BLOCK 42Q, 42R & 42T
MISSION NAME: 1BLK42QRT188A

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

SURVEY COVERAGE:

Figure A-7.3 Swath for Flight No. 3141P

FLIGHT LOG NO. 3145P
AREA: BLOCK 42R
MISSION NAME: 1BLK42QRT189A

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

SURVEY COVERAGE:

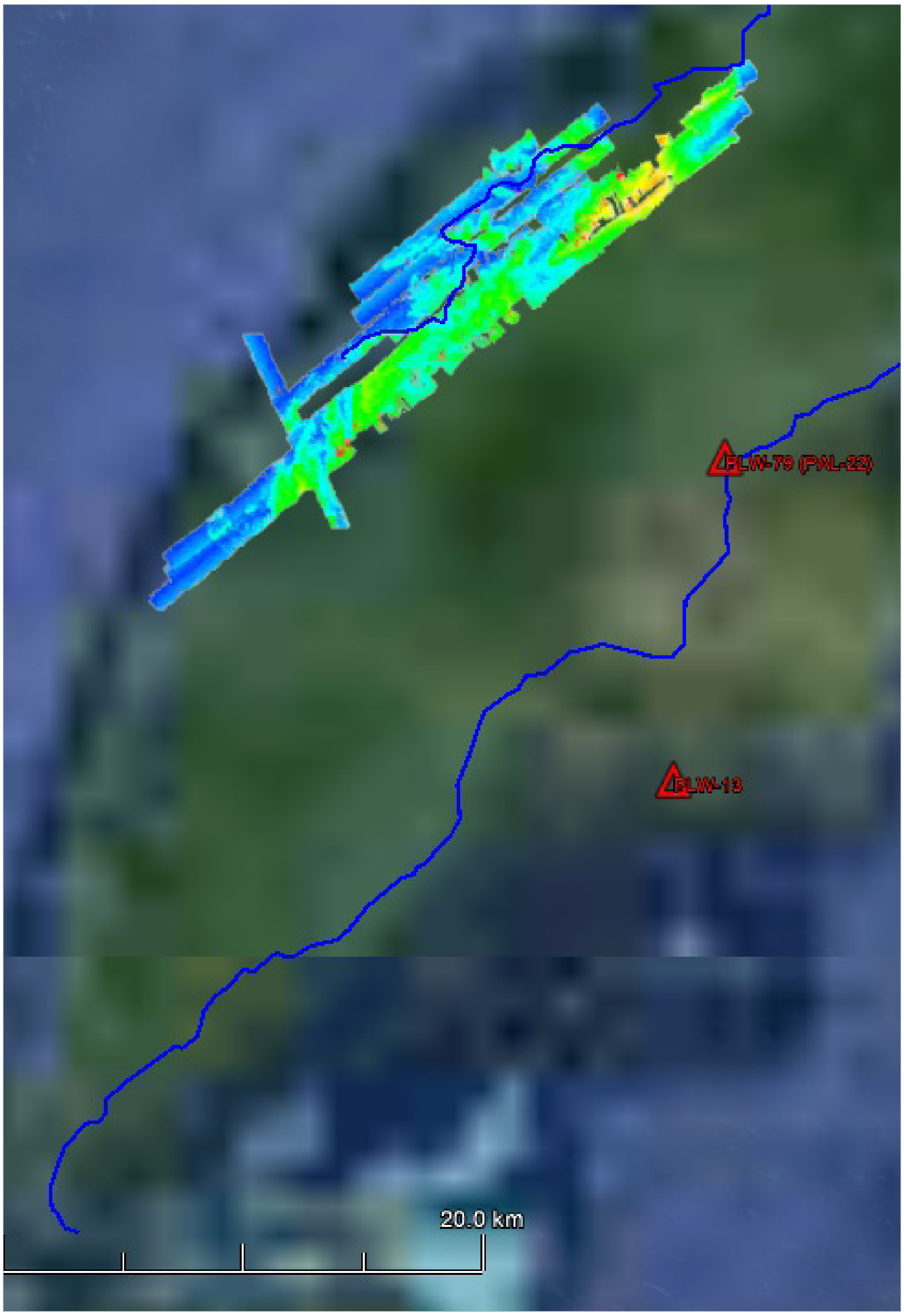


Figure A-7.4 Swath for Flight No. 3145P

FLIGHT LOG NO. 3565G
AREA: BLOCK 42eP, 42eQ, 2eR & 42eS
MISSION NAME: 2BLK42PQR337A

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

SURVEY COVERAGE:

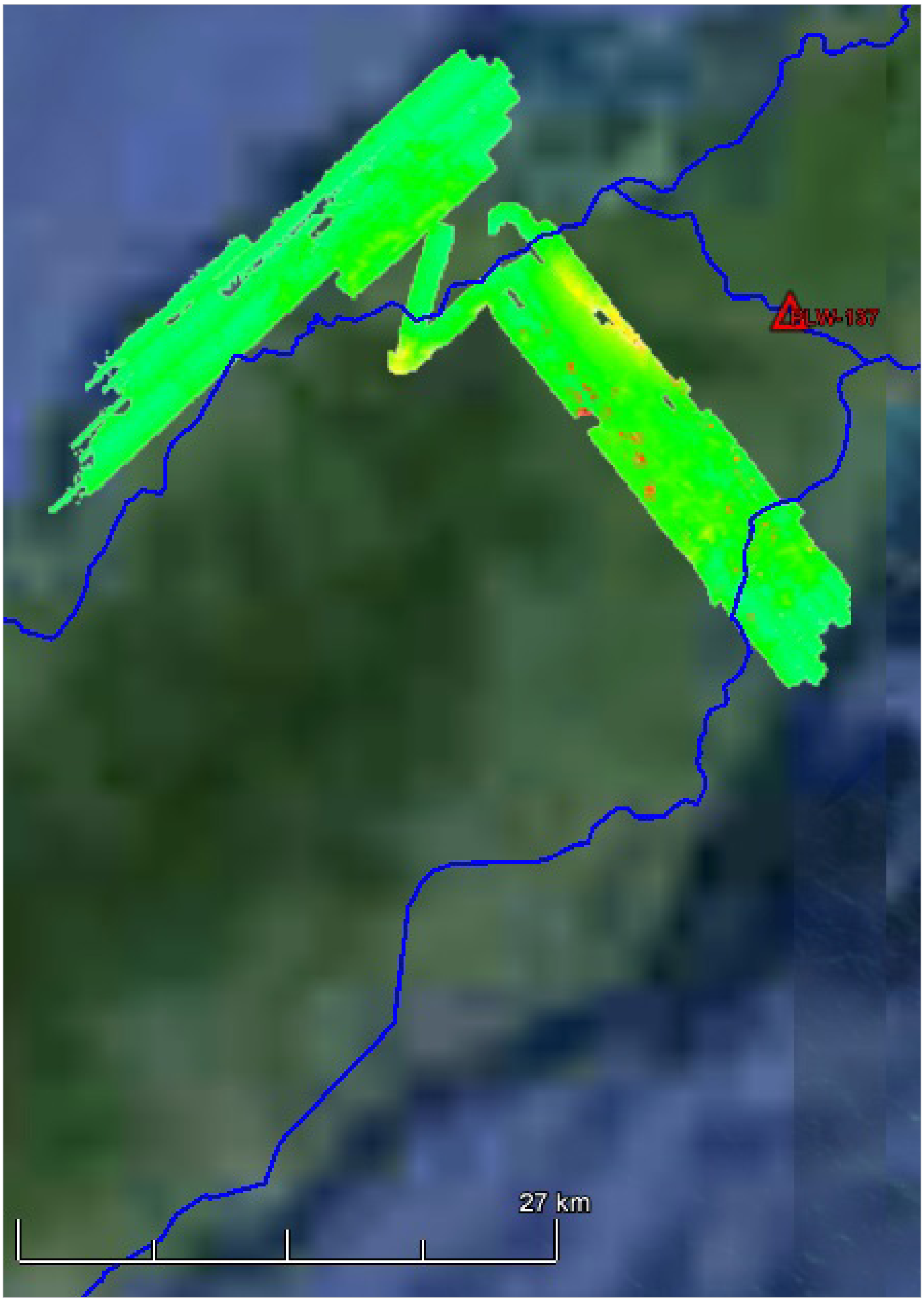


Figure A-7.5 Swath for Flight No. 3565G

FLIGHT LOG NO. 3571G
AREA: BLOCK 42eT & 42Q
MISSION NAME: 2BLK42Tv338A

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

SURVEY COVERAGE:

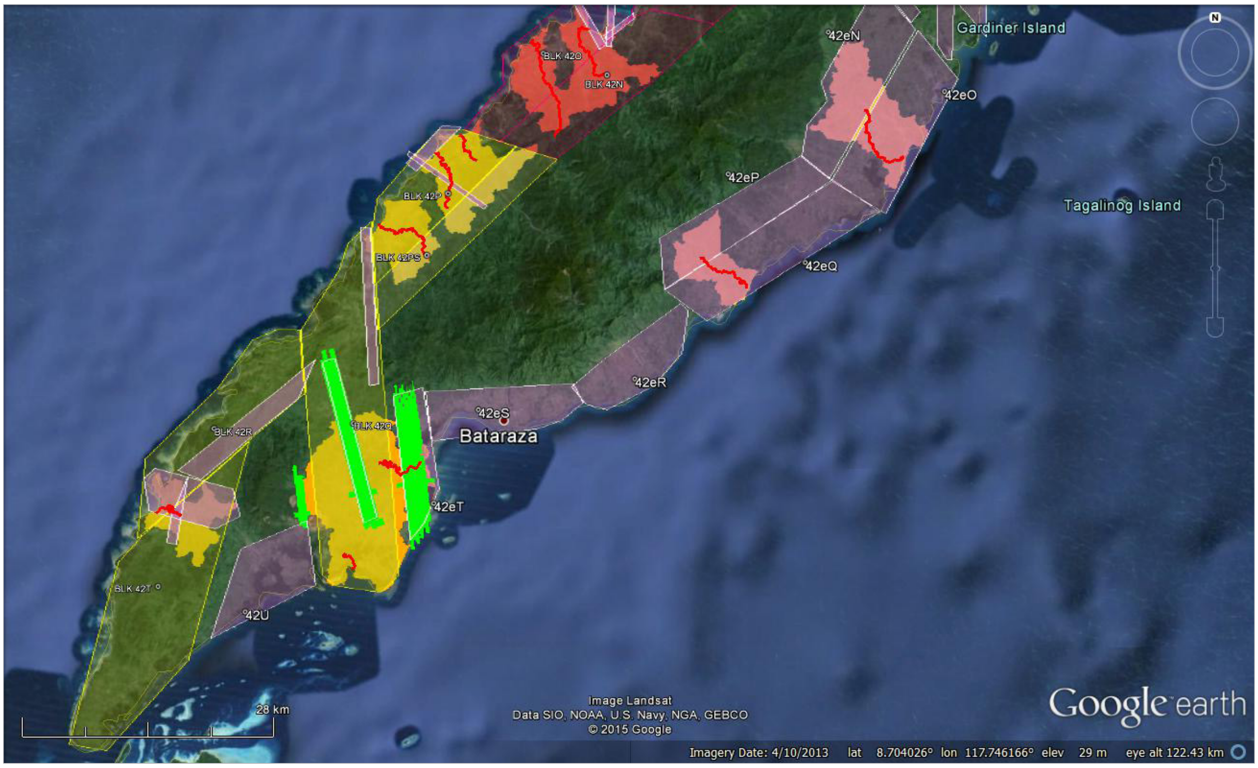


Figure A-7.6 Swath for Flight No. 3571G

FLIGHT LOG NO. 3585G
AREA: BLOCK 42eN & 42Q
MISSION NAME: 2BLK42Nv342A

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

SURVEY COVERAGE:

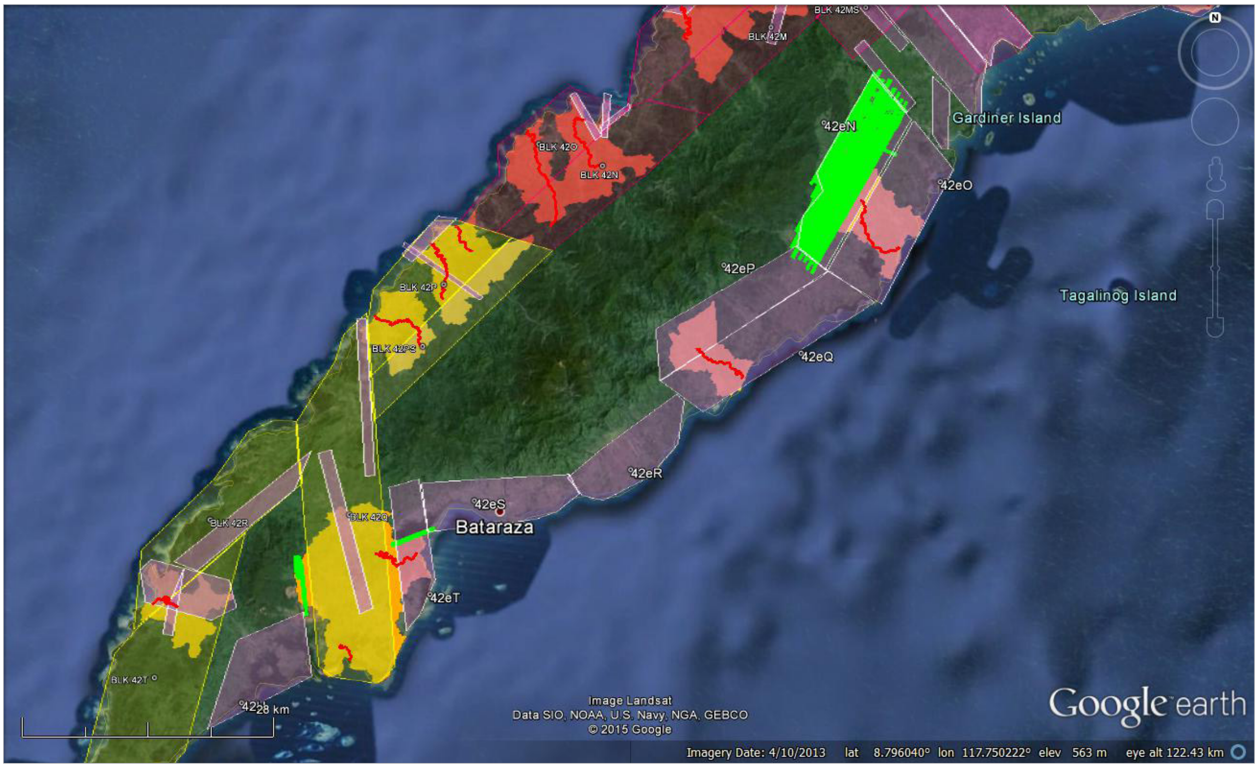


Figure A-7.7 Swath for Flight No. 3585G

FLIGHT LOG NO. 3593G
AREA: BLOCK 42eT, 42R & 42T
MISSION NAME: 2BLK42TwEwF344A

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

SURVEY COVERAGE:

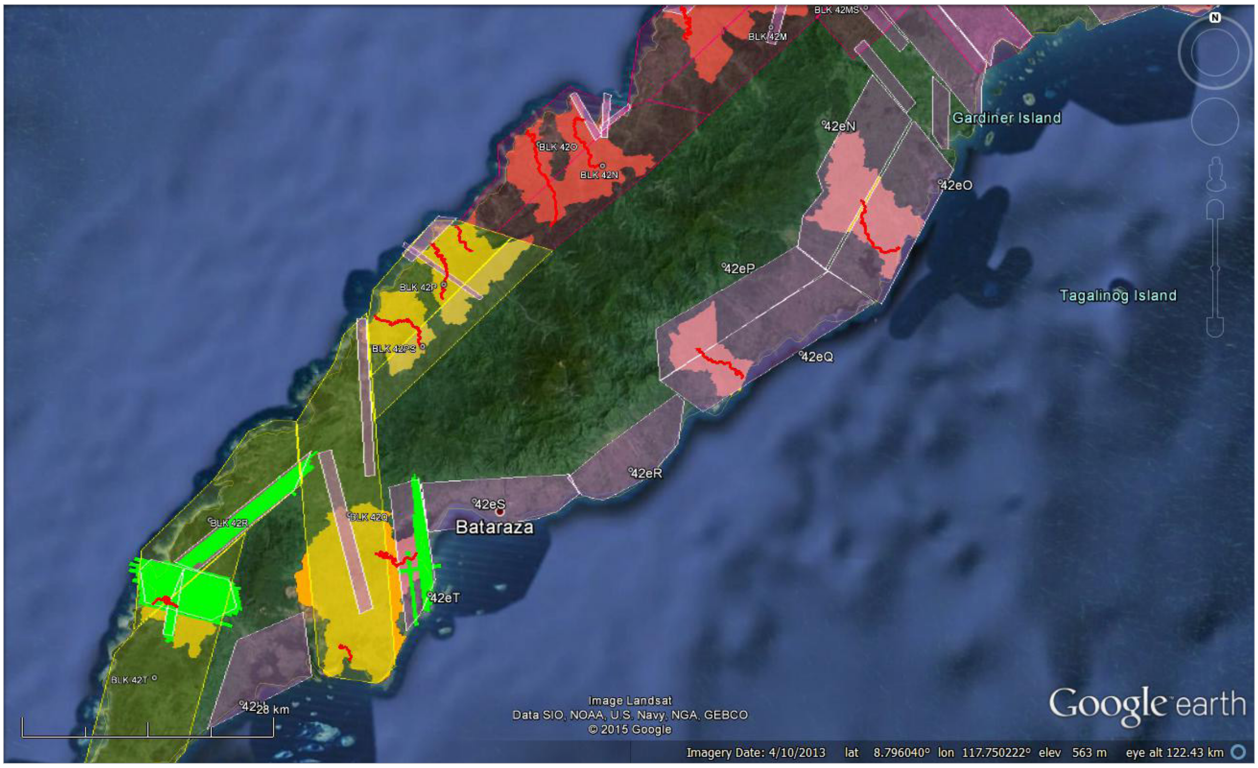


Figure A-7.8 Swath for Flight No. 3593G

FLIGHT LOG NO. 3595G
AREA: BLOCK 42eS
MISSION NAME: 2BLK42US344B

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

SURVEY COVERAGE:

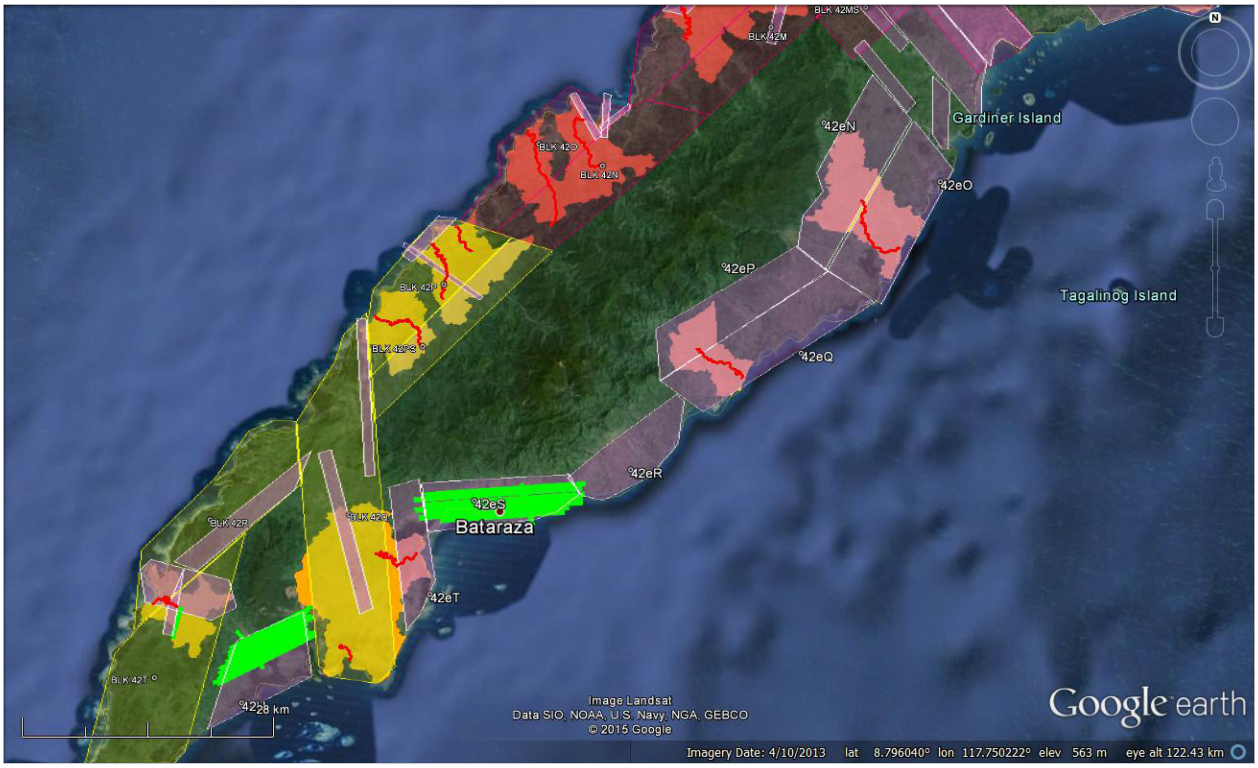


Figure A-7.9 Swath for Flight No. 3595G

ANNEX 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for

Flight Area	
Mission Name	
Inclusive Flights	
Range data size	
POS	
Image	
Transfer date	
Solution Status	
Number of Satellites (>6)	
PDOP (<3)	
Baseline Length (<30km)	
Processing Mode (<=1)	
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	
RMSE for East Position (<4.0 cm)	
RMSE for Down Position (<8.0 cm)	
Boresight correction stdev (<0.001deg)	
IMU attitude correction stdev (<0.001deg)	
GPS position stdev (<0.01m)	
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	
Maximum Height	
Minimum Height	
Classification (# of points)	
Ground	
Low vegetation	
Medium vegetation	
High vegetation	
Building	
Orthophoto	
Processed by	

ANNEX 9. Iwahig Brookes Model Basin Parameters

Table A-9.1. Iwahig Brookes Model Basin Parameters

Sub Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W1000	2.1562	85.486	0	1.606	2.2626
W1010	2.8455	81.696	0	0.53506	2.7512
W1020	1.7357	87.976	0	3.4575	5.4149
W1030	3.8638	76.673	0	3.0531	2.0761
W1040	8.948	58.666	0	1.2896	1.8204
W1050	8.5579	59.743	0	1.4737	1.7174
W1060	3.0096	80.842	0	1.4812	2.2701
W1070	9.7155	56.657	0	1.7223	3.2452
W1080	9.39	57.492	0	2.5061	2.3152
W1090	3.971	76.18	0	4.5512	1.8565
W1100	1.55	89	0	0.77792	3.0718
W1110	1.6034	88.79	0	2.262	3.5859
W1120	3.2909	79.42	0	2.667	1.7968
W1140	8.8757	58.862	0	2.7673	3.4545
W1150	1.5528	89.106	0	1.352	5.0646
W1160	8.0147	61.309	0	2.9649	2.7072
W1170	1.2617	90.963	0	1.9221	3.1587
W1180	0.81321	93.982	0	4.9433	2.7994
W1190	1.2073	91.319	0	5.3516	2.2842
W1200	0.25	98	0	1.8195	2.3839
W1210	3.1627	80.062	0	0.9263	0.44993
W1220	2.4595	83.776	0	1.6149	3.5866
W1230	1.2429	91.086	0	2.1411	3.0709
W1240	0.25	98	0	2.2613	0.99433
W1250	2.4197	83.997	0	2.7677	3.5573
W1260	2.6	83	0	0.40692	4.1724
W1270	2.2754	84.806	0	4.2625	2.8655
W1280	2.7477	82.213	0	1.5115	2.4915
W1290	2.3309	84.492	0	2.8296	2.6437
W1300	1.623	88.668	0	3.3777	3.0291
W1320	1.5252	89.278	0	1.4374	3.9317
W1330	1.55	89	0	0.29111	3.2597
W660	3.5344	78.229	0	1.3864	1.7712

Sub Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W670	4.0355	75.887	0	1.6858	2.8536
W680	4.478	73.932	0	3.318	2.621
W690	3.55	78	0	1.2721	0.87322
W700	3.55	78	0	1.1155	5.6426
W710	3.55	78	0	1.0523	4.9827
W720	3.55	78	0	1.391	2.1046
W730	6.7937	65.149	0	1.9885	2.4051
W740	3.55	78	0	1.4186	2.4173
W750	6.6966	65.475	0	1.1376	2.8108
W760	3.55	78	0	1.8822	4.0899
W770	3.5253	78.273	0	2.1973	7.4276
W780	3.6838	77.516	0	1.101	1.2696
W790	7.1794	63.885	0	2.1167	3.6916
W800	6.7929	65.152	0	3.1033	4.3526
W810	8.5536	59.755	0	1.6588	2.3459
W820	4.2522	74.917	0	1.9355	4.5162
W830	9.1162	58.213	0	1.7153	2.2065
W840	9.0048	58.512	0	1.3996	4.8386
W850	9.15	58	0	1.4607	3.1369
W860	3.0885	80.438	0	0.27569	8.0675
W870	7.7577	62.079	0	2.1977	8.7338
W880	8.7622	59.174	0	1.8817	2.9695
W890	3.55	78	0	0.60927	1.5117
W900	9.15	58	0	2.1797	2.6355
W910	3.5438	78.184	0	2.5566	3.4942
W920	4.5319	73.7	0	1.7558	3.6904
W930	7.1007	64.139	0	1.5267	4.5169
W940	3.6206	77.816	0	1.6199	0.6641
W950	4.3568	74.457	0	1.856	6.9564
W960	7.2254	63.738	0	2.4091	2.4668
W970	5.8747	68.373	0	1.9974	4.618
W980	2.7129	82.398	0	1.0853	5.5124
W990	2.0528	86.085	0	1.7485	0.4751

ANNEX 10. Iwahig Brookes Model Reach Parameters

Table A-10.1 Iwahig Brookes Model Reach Parameters

Reach Number					
	Length (m)	Slope	Shape	Width	Side Slope
R100	1586.8	0.003758	Trapezoid	1	1
R1340	397.99	0.018416	Trapezoid	1	1
R140	2221	0.008413	Trapezoid	1	1
R150	1669.2	0.000691	Trapezoid	1	1
R170	1314.3	0.004459	Trapezoid	1	1
R180	5395.4	0.001124	Trapezoid	1	1
R190	350.42	0.011724	Trapezoid	1	1
R200	476.98	0.006101	Trapezoid	1	1
R220	2238.2	0.011665	Trapezoid	1	1
R240	2702.5	0.001528	Trapezoid	1	1
R270	3089.8	0.000398	Trapezoid	1	
R290	1897.5	0.000212	Trapezoid	1	
R300	369.71	0.006873	Trapezoid	1	
R330	2393.5	0.006513	Trapezoid	1	
R340	584.56	0.006586	Trapezoid	1	
R350	3228.1	0.005258	Trapezoid	1	
R380	1528.5	0.003985	Trapezoid	1	
R40	777.82	0.003911	Trapezoid	1	
R420	3441.9	0.000819	Trapezoid	1	
R430	350.42	0.017843	Trapezoid	1	
R450	1896.8	0.000292	Trapezoid	1	
R460	5366.6	0.005227	Trapezoid	1	
R470	1923.8	0.003313	Trapezoid	1	
R480	2657.2	0.002098	Trapezoid	1	
R520	3926.1	0.001035	Trapezoid	1	
R530	2137.9	0.006601	Trapezoid	1	
R540	1942.2	0.001555	Trapezoid	1	
R580	2378.7	0.000496	Trapezoid	1	
R590	1533.7	0.000508	Trapezoid	1	

Reach Number					
	Length (m)	Slope	Shape	Width	Side Slope
R60	1232.3	0.003125	Trapezoid	1	
R610	251.42	0.003826	Trapezoid	1	
R620	2784.9	0.002869	Trapezoid	1	
R80	1216.8	0.01153	Trapezoid	1	

ANNEX 11. Iwahig Brookes Flood Validation Data

Table A-11.1 Iwahig Brookes Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
1	8.57029700000	117.52875330000	0.060	0.000	-0.060			25-Year
2	8.57091940000	117.52893100000	0.180	0.000	-0.180			25-Year
3	8.57122510000	117.52982190000	0.180	0.000	-0.180			25-Year
4	8.61869800000	117.45474000000	0.030	0.000	-0.030			25-Year
5	8.62151100000	117.45682000000	0.030	0.000	-0.030			25-Year
6	8.62365800000	117.45885000000	0.030	0.000	-0.030			25-Year
7	8.62394300000	117.45949000000	0.030	0.000	-0.030			25-Year
8	8.62758800000	117.46552000000	0.030	0.000	-0.030			25-Year
9	8.62838200000	117.46819000000	0.060	0.000	-0.060			25-Year
10	8.62914900000	117.46873000000	0.030	0.500	0.470	Habagat	August 2016	25-Year
11	8.62922200000	117.46887000000	0.040	0.000	-0.040			25-Year
12	8.62924700000	117.46889800000	0.040	0.000	-0.040			25-Year
13	8.62976500000	117.47126800000	0.030	0.000	-0.030			25-Year
14	8.62980300000	117.47117000000	0.030	0.000	-0.030			25-Year
15	8.62985530000	117.47088000000	0.040	0.000	-0.040			25-Year
16	8.63023960000	117.47148000000	1.300	1.020	-0.280	Auring	January 2017	25-Year
17	8.63149600000	117.47536000000	0.230	1.460	1.230		2015	25-Year
18	8.63176100000	117.47601000000	0.070	1.150	1.080	Nina	Dec. 2016	25-Year
19	8.63175430000	117.47524000000	1.580	1.710	0.130		August 2016	25-Year
20	8.63173400000	117.46792200000	0.080	0.000	-0.080			25-Year
21	8.63185300000	117.46926900000	0.990	0.000	-0.990			25-Year
22	8.63201600000	117.47645000000	0.030	1.500	1.470		2016	25-Year
23	8.63207990000	117.47621000000	0.200	0.750	0.550		2016	25-Year
24	8.63209900000	117.46431800000	0.300	0.000	-0.300			25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
25	8.63241200000	117.47736000000	0.030	1.100	1.070	Nina	Dec. 2016	25-Year
26	8.63256860000	117.47724000000	1.410	2.110	0.700		2014	25-Year
27	8.63351600000	117.47837000000	0.030	0.000	-0.030			25-Year
28	8.63347780000	117.46909930000	0.270	0.250	-0.020		Jan. 2015	25-Year
29	8.63348900000	117.46906800000	0.210	0.000	-0.210			25-Year
30	8.63344200000	117.45980300000	0.890	0.000	-0.890			25-Year
31	8.63375900000	117.46674100000	0.340	0.000	-0.340			25-Year
32	8.63430930000	117.47867000000	0.030	0.770	0.740		January 2013	25-Year
33	8.63410900000	117.46197100000	0.910	0.000	-0.910			25-Year
34	8.63449800000	117.46620600000	0.310	0.000	-0.310			25-Year
35	8.63458530000	117.46624630000	0.190	0.500	0.310		Jan. 2013	25-Year
36	8.63455530000	117.46396680000	0.270	0.500	0.230		Jan. 2013	25-Year
37	8.63457000000	117.46400400000	0.590	0.000	-0.590			25-Year
38	8.63522200000	117.46420100000	0.340	0.000	-0.340			25-Year
39	8.63569800000	117.46803000000	0.470	0.000	-0.470			25-Year
40	8.63581870000	117.46805010000	0.440	0.500	0.060		Jan. 2013	25-Year
41	8.63594430000	117.47378820000	1.560	1.300	-0.260		2016	25-Year
42	8.63619410000	117.46834210000	0.210	0.500	0.290		Jan. 2013	25-Year
43	8.63818270000	117.46634190000	0.030	0.000	-0.030			25-Year
44	8.63974100000	117.46727590000	0.030	0.000	-0.030			25-Year
45	8.64040840000	117.48581000000	0.030	0.000	-0.030			25-Year
46	8.64042880000	117.46648880000	0.030	0.000	-0.030			25-Year
47	8.64130350000	117.46591050000	0.040	0.000	-0.040			25-Year
48	8.64156630000	117.46615830000	0.030	0.000	-0.030			25-Year
49	8.64165390000	117.46570650000	0.030	0.000	-0.030			25-Year
50	8.64242480000	117.45800700000	0.080	0.000	-0.080			25-Year
51	8.64255340000	117.46206220000	0.030	0.000	-0.030			25-Year
52	8.64277070000	117.45912600000	0.030	0.000	-0.030			25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
53	8.64290610000	117.46061950000	0.030	0.000	-0.030			25-Year
54	8.64309490000	117.46478990000	0.030	0.000	-0.030			25-Year
55	8.64345760000	117.45625040000	0.030	0.000	-0.030			25-Year
56	8.64397520000	117.48884000000	0.030	0.000	-0.030			25-Year
57	8.64367620000	117.46295010000	0.030	0.000	-0.030			25-Year
58	8.64426820000	117.48847000000	0.030	0.000	-0.030			25-Year
59	8.64397010000	117.46180420000	0.050	0.000	-0.050			25-Year
60	8.64472810000	117.45305970000	0.030	0.000	-0.030			25-Year
61	8.64527360000	117.49013000000	0.040	0.000	-0.040			25-Year
62	8.64550300000	117.49282000000	0.030	0.000	-0.030			25-Year
63	8.64619800000	117.49553000000	0.190	0.000	-0.190			25-Year
64	8.64590390000	117.44747640000	0.030	0.000	-0.030			25-Year
65	8.64669910000	117.49507000000	0.030	0.000	-0.030			25-Year
66	8.64688000000	117.48371300000	0.030	0.000	-0.030			25-Year
67	8.64691800000	117.48448800000	0.030	0.000	-0.030			25-Year
68	8.64723000000	117.49821000000	0.290	0.000	-0.290			25-Year
69	8.64729700000	117.48607900000	0.030	0.000	-0.030			25-Year
70	8.64730810000	117.45590180000	0.030	0.000	-0.030			25-Year
71	8.64847500000	117.50142000000	0.030	0.000	-0.030			25-Year
72	8.64915760000	117.44930190000	0.930	0.000	-0.930			25-Year
73	8.64936720000	117.45746370000	0.030	1.000	0.970		Sept. 2016	25-Year
74	8.64929870000	117.44692460000	1.040	0.000	-1.040			25-Year
75	8.65012610000	117.45633980000	0.060	0.500	0.440		Sept. 2016	25-Year
76	8.65036970000	117.45075200000	0.180	0.000	-0.180			25-Year
77	8.65109610000	117.45540380000	0.030	0.500	0.470		Sept. 2016	25-Year
78	8.65109610000	117.45540380000	0.030	0.500	0.470		Sept. 2016	25-Year
79	8.65165610000	117.45452910000	0.160	0.500	0.340		Sept. 2016	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
80	8.65187290000	117.45383700000	0.030	0.500	0.470		Sept. 2016	25-Year
81	8.65208770000	117.45159470000	0.330	0.000	-0.330			25-Year
82	8.65217210000	117.45323650000	0.090	0.000	-0.090			25-Year
83	8.6523632	117.4542627	0.080	0.500	0.420		Sept. 2016	25-Year
84	8.6526125	117.4537823	0.050	0.700	0.650		Sept. 2016	25-Year
85	8.6526227	117.4532919	0.270	0.300	0.030		Sept. 2016	25-Year
86	8.6526544	117.4522876	0.480	0.700	0.220		Sept. 2016	25-Year
87	8.6530469	117.4543997	0.15	0.5	0.35		Sept. 2016	25-Year
88	8.6531505	117.4520664	0.03	0	-0.03			25-Year
89	8.6531712	117.4533087	0.28	0.3	0.02		Sept. 2016	25-Year
90	8.6546131	117.4516282	0.81	1	0.19		Sept. 2016	25-Year
91	8.6575802	117.4649711	0.03	1.6	1.57		Sept. 2016	25-Year
92	8.6575423	117.4577717	0.49	1.3	0.81		Sept. 2016	25-Year
93	8.6577301	117.4630005	0.43	0	-0.43			25-Year
94	8.6581457	117.4629166	0.03	0	-0.03			25-Year
95	8.6623778	117.4464974	0.03	0	-0.03			25-Year
96	8.6636844	117.4462395	0.14	0	-0.14			25-Year
97	8.6640666	117.4493751	0.66	1.6	0.94		Sept. 2016	25-Year
98	8.6661051	117.446001	0.03	0	-0.03			25-Year
99	8.6682796	117.4479065	0.03	1	0.97		Sept. 2016	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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