REGION 1

Agno River:

DREAM Ground Surveys Report

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

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List of Abbreviations

ADCP	Acoustic Doppler Current Profiler
AWLS	Automated Water Level Sensor
BM	Benchmark
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DG	Depth Gauge
DOST	Department of Science and Technology
DPC	Data Processing Component
DREAM	Disaster Risk Exposure and Assessment for Mitigation
DVC	Data Validation Component
EGM 2008	Earth Gravitation Model 2008
FMC	Flood Modeling Component
GCP	Ground Control Point
GE	Geodetic Engineer
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LGUs	Local Government Units
NAMRIA	National Mapping and Resource Information Authority
PCG	Philippine Coast Guard
PDRRMC	Provincial Disaster Risk Reduction Management Council
PPA	Philippine Ports Authority
PPK	Post Processed Kinematic
RG	Rain Gauge
TCAGP	Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

Introduction

Introduction

1.1 DREAM Program Overview

The UP training Center for Applied Geodesy and Photogrammetry (UP TCAGP) conducts a research program entitled "Nationwide Disaster Risk and Exposure Assessment for Mitigation" supported by the Department of Science and Technology (DOST) Grant-in-Aide Program. The DREAM Program aims to produce detailed, up-to-date, national elevation dataset for 3D flood and hazard mapping to address disaster risk reduction and mitigation in the country.

The DREAM Program consists of four components that operationalize the various stages of implementation. The Data Acquisition Component (DAC) conducts aerial surveys to collect LiDAR data and aerial images in major river basins and priority areas. The Data Validation Component (DVC) implements ground surveys to validate acquired LiDAR data, along with bathymetric measurements to gather river discharge data. The Data Processing Component (DPC) processes and compiles all data generated by the DAC and DVC. Finally, the Flood Modeling Component (FMC) utilizes compiled data for flood modeling and simulation.

Overall, the target output is a national elevation dataset suitable for 1:5000 scale mapping, with 50 centimeter horizontal and vertical accuracies, respectively. These accuracies are achieved through the use of state-of-the-art airborne Light Detection and Ranging (LiDAR) Systems collects point cloud data at a rate of 100,000 to 500,000 points per second, and is capable of collecting elevation data at a rate of 300 to 400 square kilometer per day, per sensor.

1.2 Objectives and target outputs

The program aims to achieve the following objectives:

a. To acquire a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management,
b. 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,
c. To develop the capacity to process, produce and analyze various proven and potential thematic map layers from the 3D data useful for government agencies,
d. To transfer product development technologies to government agencies with geospatial information requirements, and,
e. To generate the following outputs
    1. flood hazard map
    2. digital surface model
    3. digital terrain model and
    4. orthophotograph

1.3 General methodological framework

The methodology employed to accomplish the project's expected outputs are subdivided into four (4) major components, as shown in Figure 1. Each component is described in detail in the following sections.

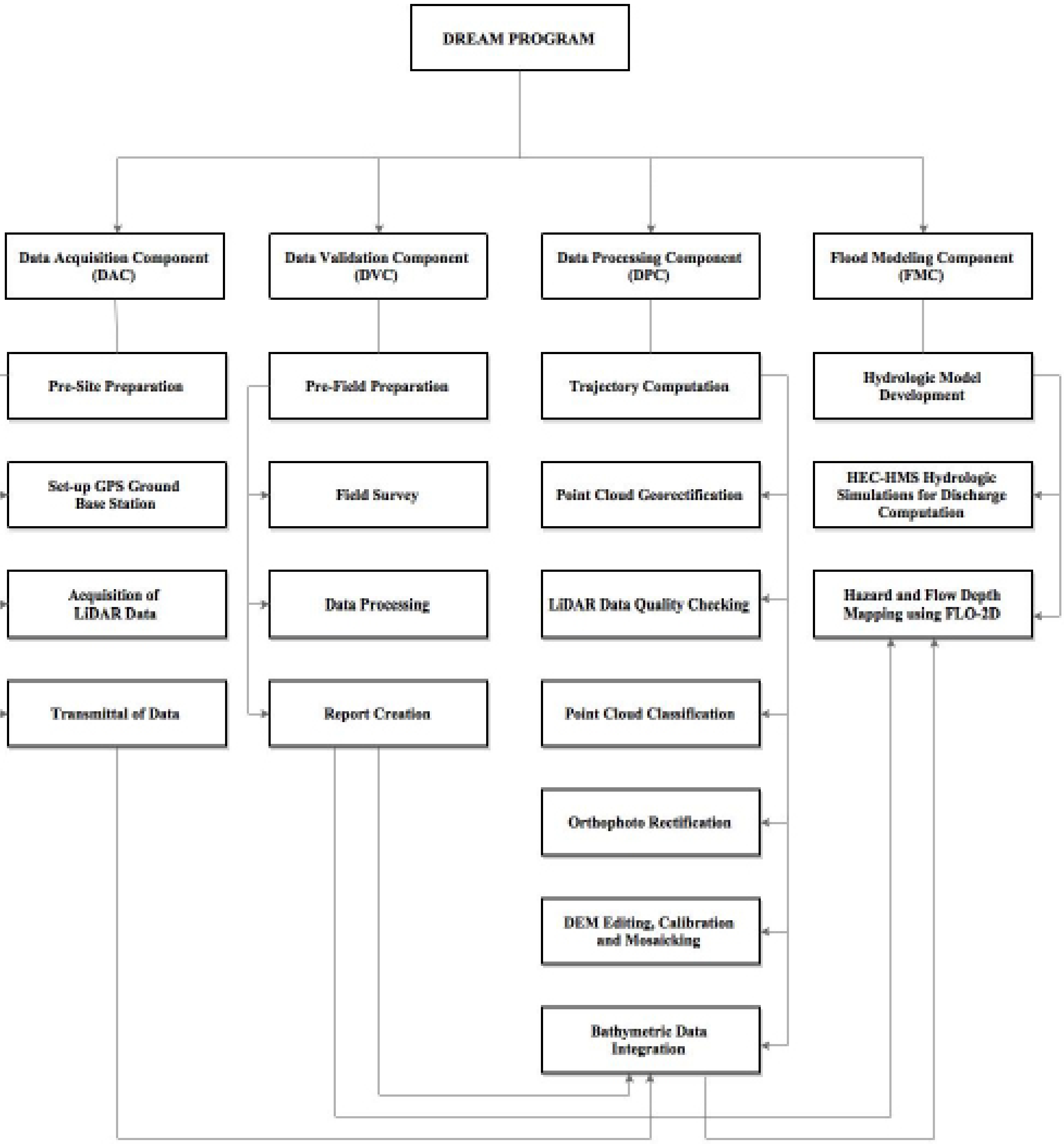


Figure 1. The General Methodological Framework of the Program

The Agno River Basin

The Agno River Basin

The Agno River Basin is situated in Luzon and is the fifth largest river basin in the Philippines, with an estimated basin area of 5,852 square kilometers. The Agno River is also considered as the third largest in Luzon, with its river system having a length of 270 kilometers, 90 kilometers of which runs through mountainous terrain and canyons. The location of the Agno River Basin is as shown in Figure 2.

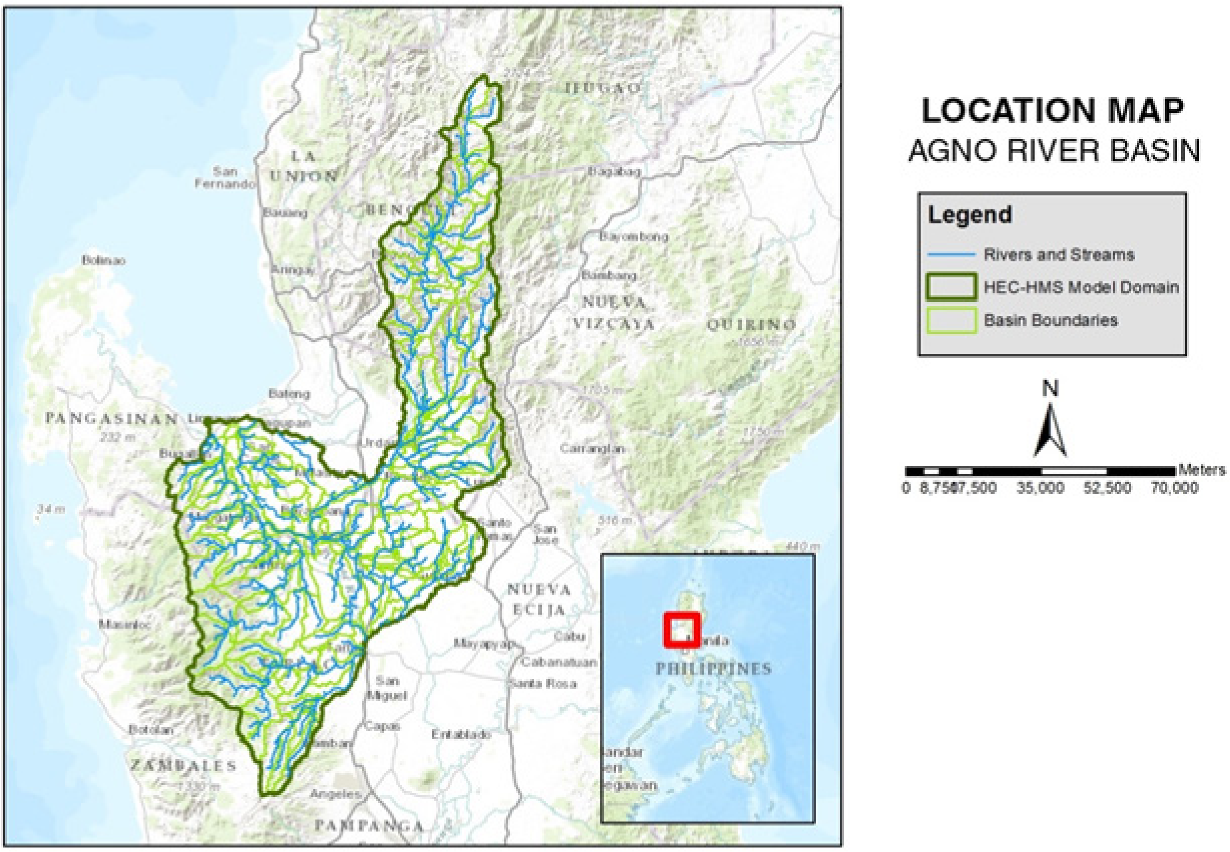


Figure 2. The Agno River Basin Location Map

The headwaters of the Agno River are at the Cordillera Mountains and drains about 6.6 cubic kilometres of fresh water into the Lingayen Gulf in Pangasinan, becoming the largest Philippine river in terms of water discharge. It has 4 principal tributaries-- Tarlac River, which is the main branch, the Pila River, the Camiling River, and the Ambayoan River. It drains the western portion of the island and a large part of its catchment is located in Pangasinan. According to the Agno River Basin Development Commission (ARBDC), the river basin covers 68 municipalities and 5 cities in the provinces of Benguet, Tarlac and Pangasinan.

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e. rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

The Agno River Basin

The shape files of the soil and land cover were taken from the Bureau of Soils, which is under the Department of Environment and Natural Resources Management, and National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of Agno River Basin are shown in Figure 3 and Figure 4, respectively.

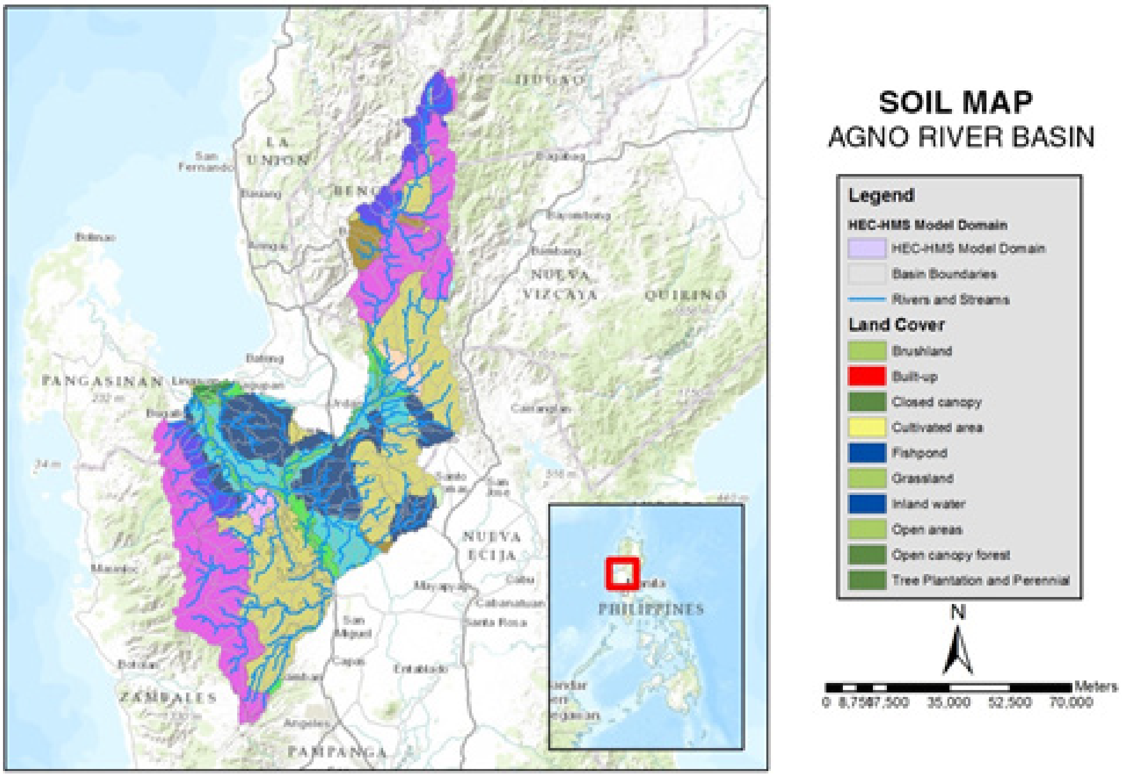


Figure 3. Agno River Basin Soil Map

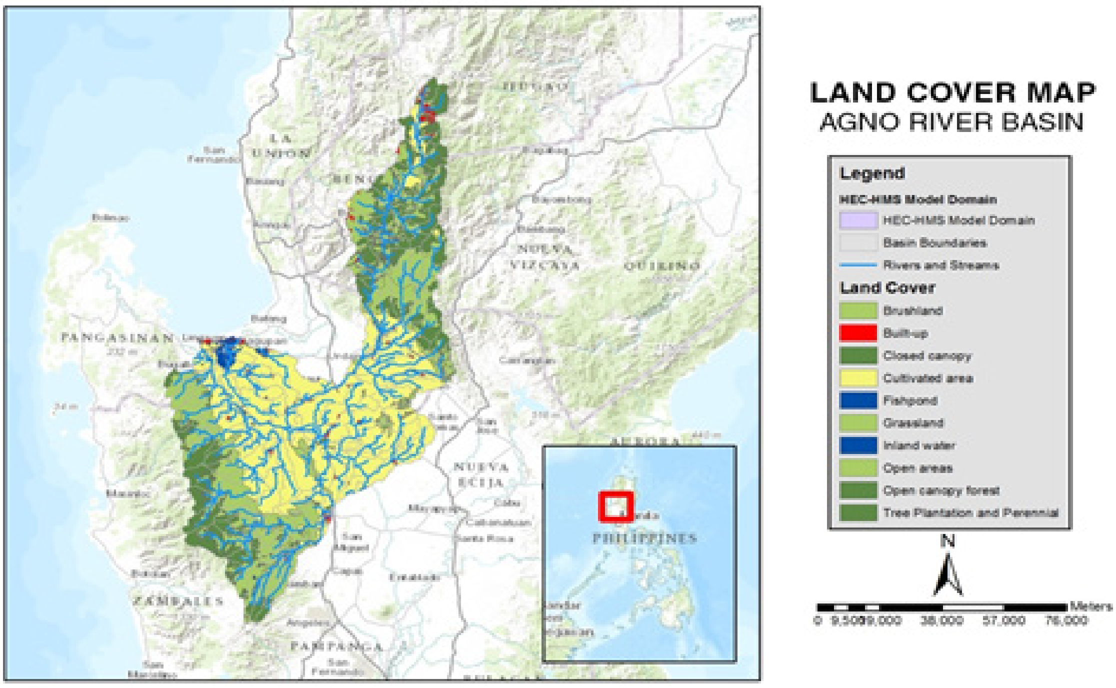


Figure 4. Agno River Basin Land Cover Map

DVC Methodology

DVC Methodology

A set of activities were designed and implemented by DVC with four (4) main activities as shown in Figure 5.

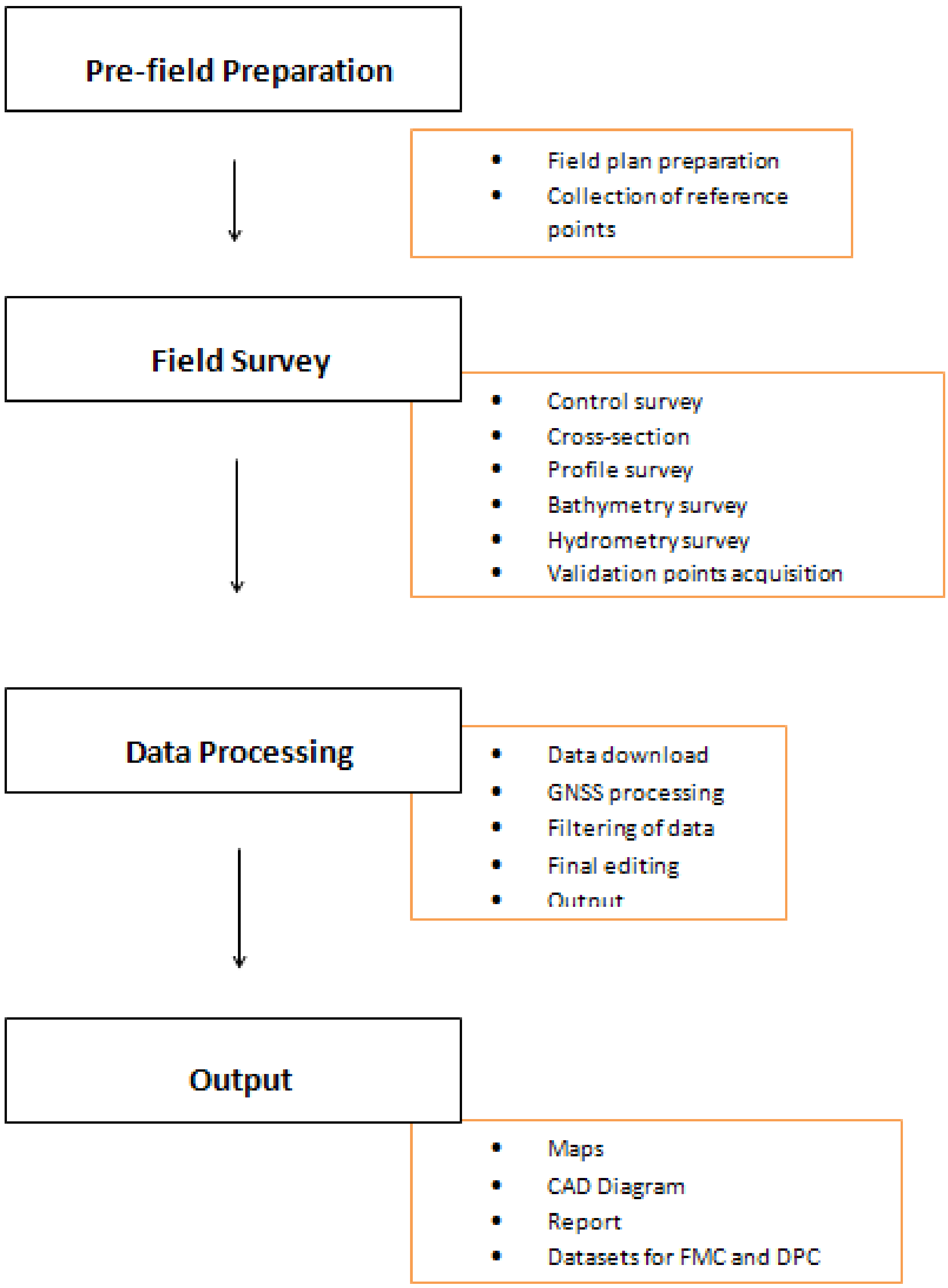


Figure 5. DVC Main Activities

3.1 Pre-field Preparation

3.1.1 Preparation of Field Plan

The planning for research fieldwork considers all the necessary technical and logistical concerns conceptualized in a field plan.

This serves as a basis and guide of the survey team in the implementation of the fieldwork activities and included the following activities:

- Delineation of bathymetry lines and determination of the river basin extent using Google Earth® images and available topographic maps;
- Listing and preparation of the survey equipment and other materials needed;
- Designation of tasks to DVC members for the field survey;
- Approximation of field duration and cost based on the delineated survey extent; and
- Assessment of the initial field plan by the program management for approval and implementation.

3.1.2 Collection of Reference Points

Technical data and other relevant information are collected from the National Mapping and Resource Information Authority (NAMRIA) such as locations and descriptions of established horizontal and vertical control points with a minimum of 2nd order accuracy. These ground control points and benchmarks are selected and occupied as primary reference points for the establishment of a GNSS network for the survey.

3.2 Field Surveys

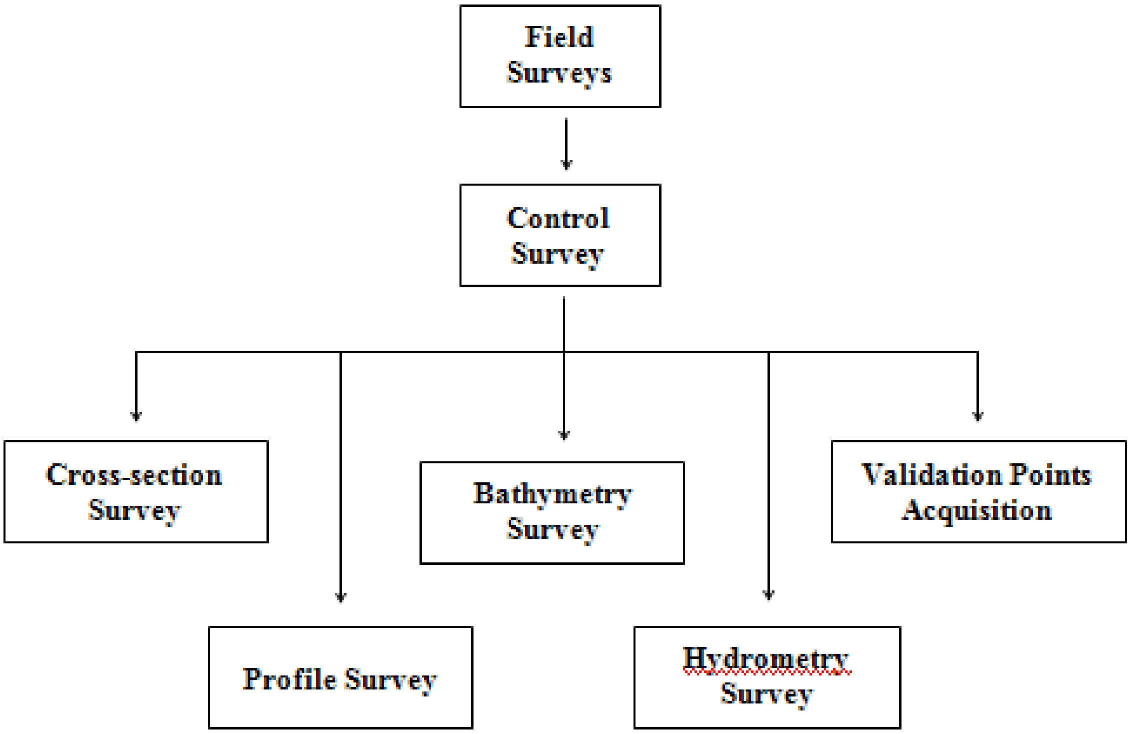


Figure 6. DVC Field Activities

3.2.1 Control Survey

A GNSS network is established through occupation of reference points with dual frequency GNSS receivers for four (4) hours. Reference points from NAMRIA only bear vertical coordinates (z or elevation value) and horizontal coordinates (x and y values) for benchmarks and ground control points, respectively.

Control survey aims to provide both the horizontal and vertical position for every control point established through network adjustment. Horizontal position is acquired through static survey while establishment of vertical position can be done either using a Total Station (TS) or digital level or through static survey.

For the vertical position control survey using a TS or Level, a double run is carried out connecting the nearest existing NAMRIA benchmarks (BMs) to the control point. A double run consists of a forward run (from BM to GCP) and backward run (from GCP to BM). The accuracy shall be assessed and accepted if it is within the third order differential leveling standard.

A benchmark may be used to refer elevation data to Mean Sea Level (MSL) within 20-km radius. Additional benchmarks are located for survey areas exceeding this 20-km radius.

Establishment of a GNSS network through control survey is pre-requisite for the conduct of other ground survey activities. Reference and control points occupied for the control survey may serve as base stations throughout the survey area.

3.2.2 Cross-section Survey

The objective of this activity is to derive a sectional view of the main river and the flood plain (right and left banks). Cross-sections are surveyed perpendicular to the riverbanks with an average length of 100 meters for each bank. The cross-section line shall follow the path of the nearby road or goat trails with a 10-meter interval for each point measurement. Additional points are obtained to describe apparent change in elevation along the cross-section line. Each cross-section is identified sequentially from upstream to downstream direction.

Cross-section surveys are done using dual frequency GNSS receivers and differential kinematic GNSS survey technique. The accuracy of the horizontal position and elevation of each individual cross-section surveys is within ±20 cm for horizontal and ±10 cm for vertical position residuals.

Areas where kinematic GNSS survey is not applicable due to the presence of obstructions such as tall structures and canopy of trees, conventional surveying techniques such as total stations and level are used to collect cross-sectional data.

3.2.3 Profile Surveys

Profile surveys are conducted to obtain the upper and lower banks of the river. This data is overlaid with LIDAR data to delineate the longitudinal extent of the river.

A profile survey consists of the Left Upper Bank (LUB) and Left Lower Bank (LLB), Right Upper Bank (RUB) and Right Lower Bank (RLB). An interval between successive profile points is approximately 10 meters. Additional points are gathered to describe apparent change in elevation along the profile line

Profile surveys are conducted using dual frequency GNSS receivers and kinematic survey technique with a prescribed vertical accuracies of ±20 cm for horizontal and ±10 cm for vertical position, respectively. Conventional surveying techniques such as total stations and level are used to collect profile data for areas where kinematic GNSS survey is not applicable due to obstructions such as tall structures and canopy of trees.

3.2.4 Bathymetric Survey

Bathymetric survey is performed using a survey-grade single beam echo sounder capable of logging time-stamped depth value in centimeter and dual frequency GNSS using kinematic survey technique, with prescribed vertical accuracies of ±20 cm for horizontal and ±10 cm for vertical position for rivers navigable by boat. Data acquisition is logged at one second intervals both for GPS positions and elevation and echo sounder depth reading

For portions of the river that is not navigable by boat due to shallow waterless than a meter, riverbed may be acquired using manual bathymetric survey. Manual bathymetric survey means manually acquiring riverbed points without the use of an echo sounder. It can be done using a GPS receiver, Total Station or Level.

3.2.5 Hydrometric Survey

Hydrometric survey consists of deployment of flow gathering sensors in order to produce a Stage-Discharge (HQ) computation for specific locations in the river such as in its upstream, tributaries, and downstream. This is done to determine the behavior of the river given specific precipitation levels.

The elements of discharge computation are the ff.:

- **River flow data –** river flow data can be acquired using an Acoustic Doppler Current Profiler (ADCP) or by mechanical or digital flow meters. River flow data sensors measure velocity of the river for a specific time period and interval.
- **Cross-section data –** cross section data is acquired using dual frequency GPS receivers to obtain the cross-section area of the river. Cross-section area of a river changes in time as influenced by water level change.
- **Water level change –** water level change is measured using either a depth gauge or an Automated Water Level Sensor (AWLS) installed by DOST. Depth gauges relates pressure to water level change while AWLS uses laser pulsed at specific time intervals for measurement.
- **Water surface elevation –** water surface elevation in MSL is measured near the banks of the river with dual frequency GPS receivers. This will refer the measured water level change to a corresponding elevation value in MSL in order to derive Stage or water level height a particular time.

Precipitation is the biggest factor influencing stage and river velocity. These two (2) sets of data must be synchronized by time in order to compute for its cross-section area, and subsequently, for discharge.

The element of time is crucial in determining the delay between the onset of precipitation and the time of significant water level change along key points of the river for early flood warning system of communities. The correlation of stage-discharge computation is used for calibrating flood-simulation programs utilized by the Flood Modeling Component (FMC).

The summary of elements for discharge computation is illustrated in Figure 7.

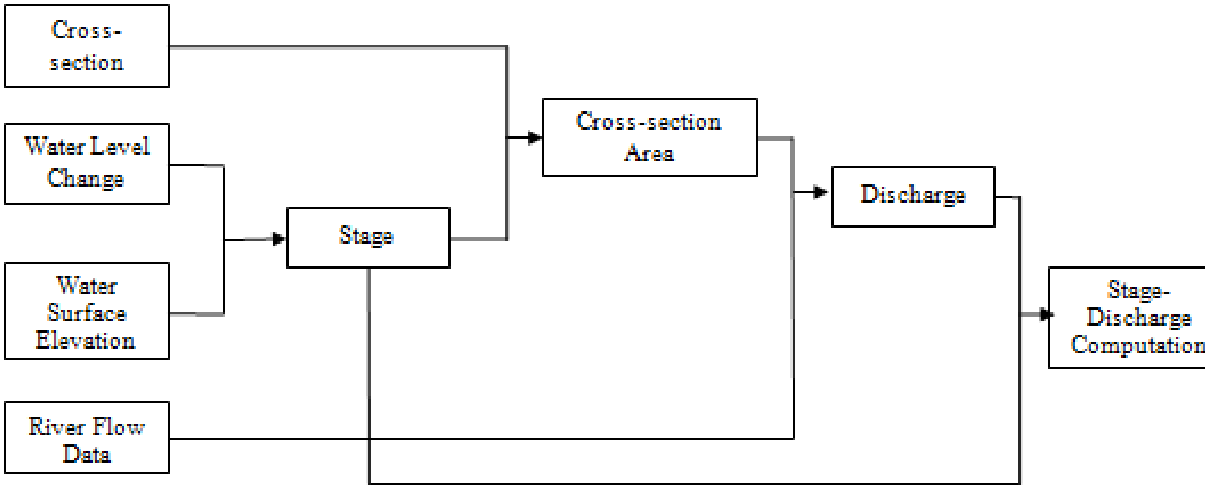


Figure 7. Flow Chart for Stage-Discharge Correlation Computation

3.2.6 Validation Points Acquisition Survey

Ground validation survey is conducted for quality checking purpose of the Aerial LiDAR data acquired by the Data Acquisition Component (DAC). A roving GNSS receiver is mounted on a range pole attached to a vehicle to gather points thru continuous topo method in a PPK Survey Technique. Points are measured along major roads and highway across the flight strips provided by DAC.

GNSS surveys setup used to accomplish DVC's field survey activities are illustrated in Figure 8.

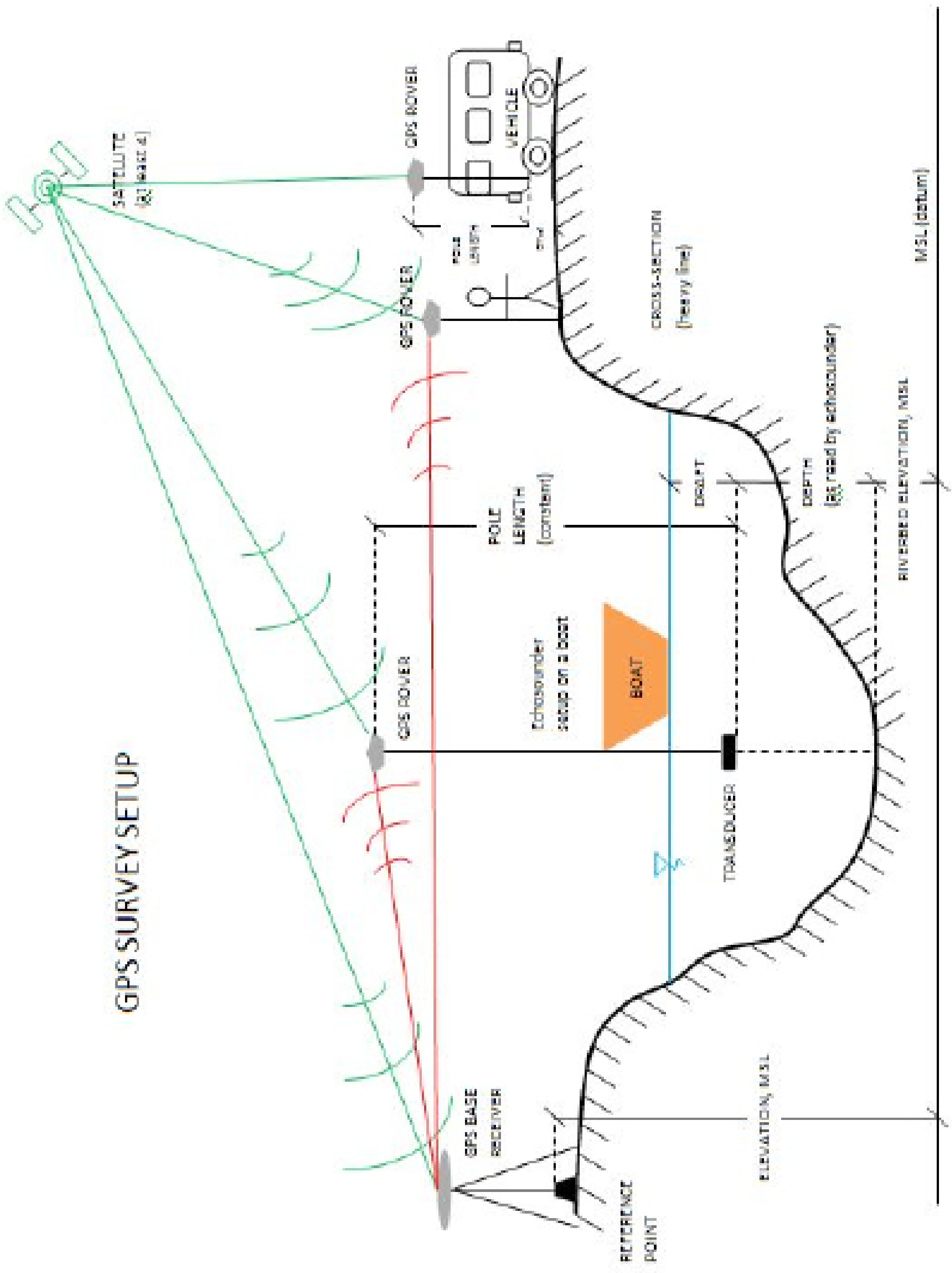


Figure 8. Set-up for GNSS Survey

3.3 Data Processing

Data processing procedures used by DVC are summarized in Figure 9.

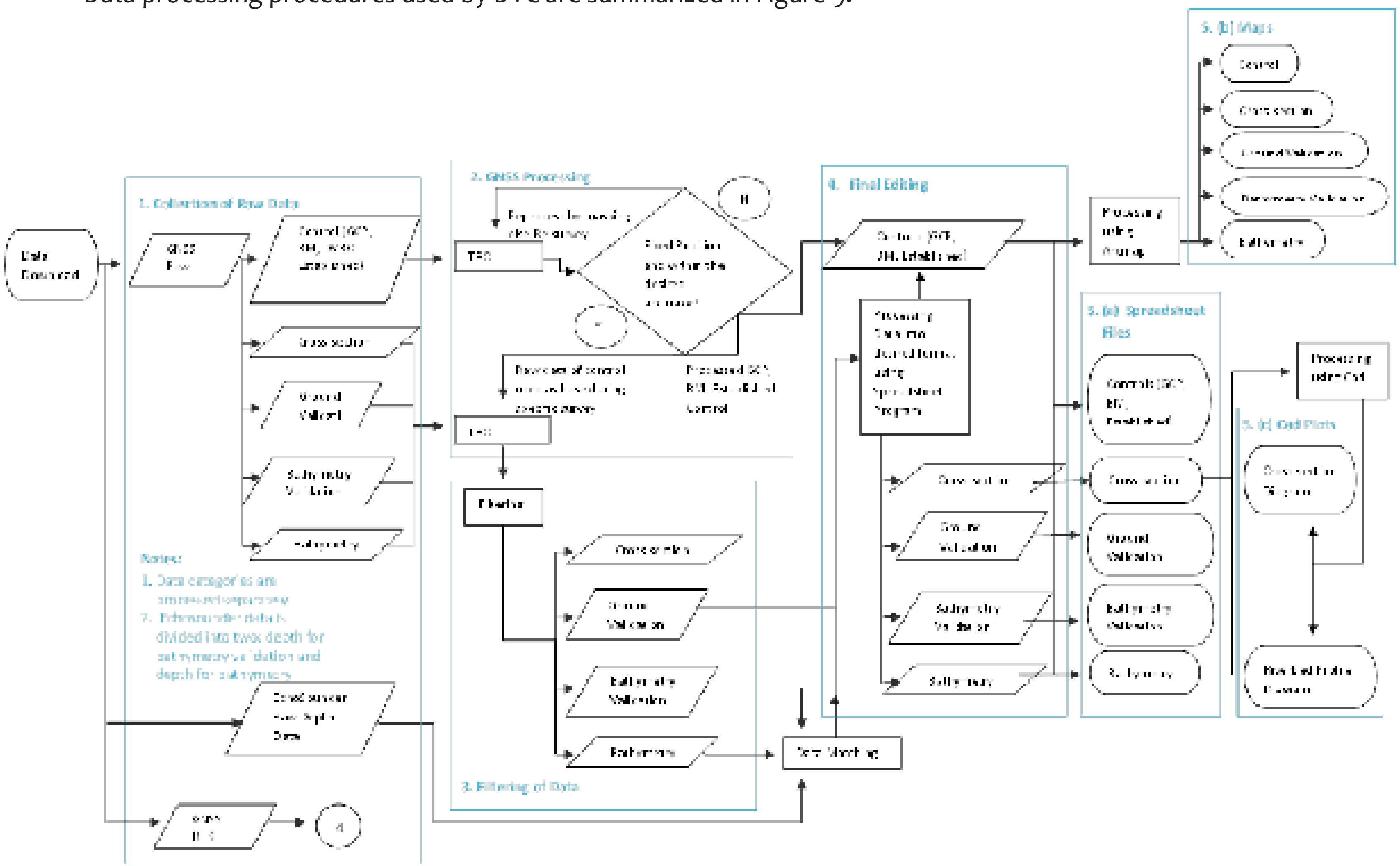


Figure 9. DVC Data Processing Methodology

3.3.1 Collection of Raw Data

GPS Raw data in (*.t02) format are downloaded from Trimble™ GPS receivers used in static, cross-section, LiDAR ground validation, and bathymetric surveys. Depth values in (*.som) files from bathymetric surveys are also downloaded from OHMEX® echo sounder.

3.3.2 Data Processing

Processing for GNSS Data

The horizontal and vertical coordinates of the reference point used as base station are held fixed, based on its NAMRIA certification, for the establishment of a GNSS network for the survey area. Coordinates of this fixed point is used to give horizontal and vertical coordinates for the other reference points occupied and control points established.

Data from GNSS control surveys are processed in Trimble™ Business Center (TBC) software and settings were set to the required accuracy of +/-10cm for vertical and +/-20cm for horizontal controls. The TBC coordinate system parameters were set to Universal Transverse Mercator (UTM) Zone 51 North, World Geodetic System of 1984 (WGS1984), and the geoid model EGM2008 for horizontal and vertical datum, respectively.

An offset is derived by comparing the MSL elevation of the benchmark stated in the NAMRIA certification and its elevation value that resulted from the processed and adjusted control survey. This offset is used to refer all elevation from other surveys into MSL (BM_ Ortho).

The formulas used for offset and BM_Ortho computation are shown in Equations 1-2:

Computation for offset:

Equation 1:

$$OFFSET = BM - EGM$$

Computation for BM_ortho:

Equation 2:

$$BM_{\_ortho} = EGM_{\_ortho} \pm OFFSET$$

where:

OFFSET	= difference/offset between Geoid model, EGM 2008 and MSL datum. Can be a positive or negative value
BM	= MSL elevation of vertical control point certified by NAMRIA
EGM	= EGM2008 elevation of the same NAMRIA vertical control point derived from TBC software processing
EGM _Ortho	= elevation of points referred to geoid model, EGM 2008
BM _Ortho	= elevation of points referred to MSL

GNSS processing is also done for the other surveys with the coordinates from the occupied points for the control survey held fixed, depending on which base station is used for the survey.

Processed and adjusted data are exported to comma delimited (*.csv) file format with the ff. columns: Point Name, Latitude, Longitude, Ellipsoidal Height, Northing, Easting, and Elevation (EGM_Ortho). This file format can be accessed through Microsoft Excel/Spreadsheet program.

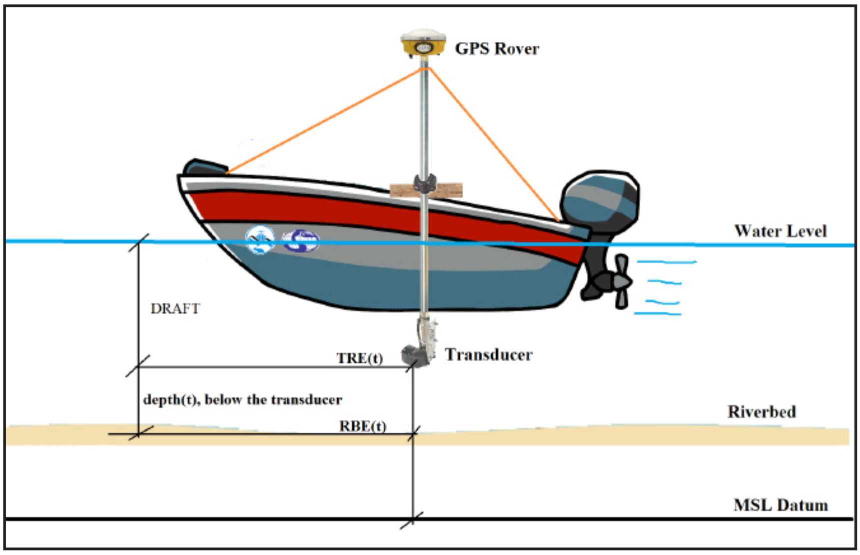


Figure 10. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

There are two types of echo sounders used for bathymetric surveys – Hi-Target™ single beam echo sounder which is capable of recording depth data of one decimal place and the OHMEX™ single beam echo sounder capable of recording two-decimal places of depth data.

Raw depth data from Hi-Target™ single beam echo sounder is exported in (*.txt) file format with the ff. columns: Point No., Time, Depths H, Depths L, Draft, and Sound Velocity. This (*.txt) file is copied to a spreadsheet, retaining only the columns for Time and Depths H.

Raw depth data from OHMEX™ single beam echo sounder are exported in (*.som) file format. It is imported into SonarVista then exported into *.csv format with the ff. columns: Type, Date/Time, Sec, X/E, Y/N, Z/H, Tide, Depth and QA. SonarVista is used as file conversion tool only. The (*.csv) file opened using spreadsheet, making use of only the columns for Date/Time and Depth.

Data Matching for Bathymetric Data

Data matching is done by pairing an individual attribute of a bathymetric point to a depth data acquired using either OHMEX or HI-Target echo sounder. Matching is possible by ensuring that both bathymetric points and depth values acquisition has time stamp capability. These two sets of data are matched using VLOOKUP tool of a spreadsheet program, such that each point will have an accompanying (x,y,z) and depth data.

Below is the formula used for computing the elevation of the riverbed:

Equation 3:

$$RBE(t) = TRE(t) - Depth(t)$$

where:

RBE(t) = elevation of the riverbed during time t,

TRE(t) = transducer elevation (reckoned from EGM 2008)

Depth(t) = depth recorded by the echo sounder at time t, with the assumption that depth is measured from the bottom of the transducer down to the riverbed

The resulting RBE(t) data are referred to MSL (BM_ortho) by applying the offset for the established network.

Final processed data are imported to Google Earth™ and Geographic Information Systems (GIS) software for viewing and checking horizontal position.

Hydrometry Data Processing

The processes done for Hydrometry data for HQ computation are described in the ff. steps:

1. **River Flow Data**

a.) ADCP

Data from the ADCP is logged internally and can be downloaded using either SonUtils™ or View Argonaut™ software. River velocity is recorded for a specified time duration and interval can be exported in a (*.csv) format.

b.) Flow Meter

Acquisition of river velocity using flow meters is done manually. Measurements for a specified time duration and interval is recorded in a field notebook and saved in a spreadsheet program.

2. **Cross Section and Water Surface Elevation Data**

Cross Section data and water surface elevation data is acquired using GNSS receivers described in section 3.3.4 for GNSS data processing with a resulting file in (*.xls) format.

3. **Water Level Change-Stage**

a.) Depth Gauge

Data from depth gauge can be downloaded using HobowarePro™. Water level in meters are logged for a specific time interval and it can be exported in a (*.csv) format.

b.) AWLS

Data from installed AWLS can be accessed via the internet (http://repo.pscigrid.gov.ph/predict/). Water levels are logged in ten-minute time intervals and can be copied into a spreadsheet program.

4. **Discharge Computation**

River flow data and water level change is synchronized by time. Parameters were preset in its respective programs so the deployment of each instrument will begin and end in the same time. All data in (*.csv) and (*.csv) format are combined in a single worksheet wherein the computation for the coefficient of determination or R2 are done.

The illustration in Figure 7 shows how each set of data from each instrument can be synchronized.

3.3.3 Filtering of Data

A processed point which resulted to float or did not meet the desired accuracy is filtered out. Resurveys are conducted immediately if data gaps are present for the ground surveys.

3.3.4 Final Editing

Final editing is performed to be able to come up with the desired data format: Point Value, Latitude, Longitude, Ellipsoidal Height, Northing, Easting, EGM_Ortho and BM_Ortho.

Processes discussed are valid for static, cross section, ground validation, and manual bathymetric surveys not employing echo sounders. For bathymetric surveys using a single beam echo sounder, the GPS rover is mounted on top of a 2m pole and a transducer at the bottom (see Figure 10). Figure is valid in both using OHMEX and HI-Target echo sounders. The GPS rover provides horizontal and vertical coordinates whereas the echo sounder transducer measures depth of the river from its bottom down to the riverbed.

3.3.5 Output

Filtered data are furthered processed into desired template using a spreadsheet program. Final data are generated into maps and CAD plots for cross-section, profile, and riverbed profiles. Cross-section, Profile, Validation Points, and Bathymetric data shall be turned-over to DPC while hydrometric data shall be turned-over to FMC.

Agno River Basin Survey

Agno River Basin Survey

There are three (3) phases of ground surveys conducted for Agno River Basin. The first phase survey was conducted on August 1 - 13, 2012 with the following activities: profile, cross-section, bathymetric and flow measurement surveys. The second phase, which included LiDAR data validation and discharge measurement surveys, was conducted on May 15 to 18, 2013. Lastly, the survey on AWLS cross-section and flow measurement of Agno river basin was conducted on September 3 to 6, 2013

Agno River consists of 15 delineated cross-section lines with The total length of profile lines is about 40.99 km for its both left and right banks. A total of 3,693 cross-sectional points each with vertical and horizontal positions were gathered during the field survey.

4.1 Control Survey

The control survey conducted at the Agno River Basin has two (2) phases: Phase 1 was conducted on August 1 to 13, 2012, and Phase 2 was on May 15 to 18, 2013 wherein they used the control survey for LiDAR Validation.

The first phase consists of three (3) NAMRIA reference points and two (2) established control points considered for the static GNSS observations for Agno River System survey. These include two (2) benchmarks: PS-591, which is located in Brgy Laoac East in the municipality of Alcala, Pangasinan; first-order reference point, and PS-674. Also, a ground control point (GCP), PNG-56, which is located in Brgy. Poblacion, Sto. Tomas, Pangasinan and a second-order reference point. The two established control points for the survey were situated at Villasis, Pangasinan and in Brgy. Carmen East, found in Rosales, Pangasinan. The locations of these controls are shown in Figure 11.

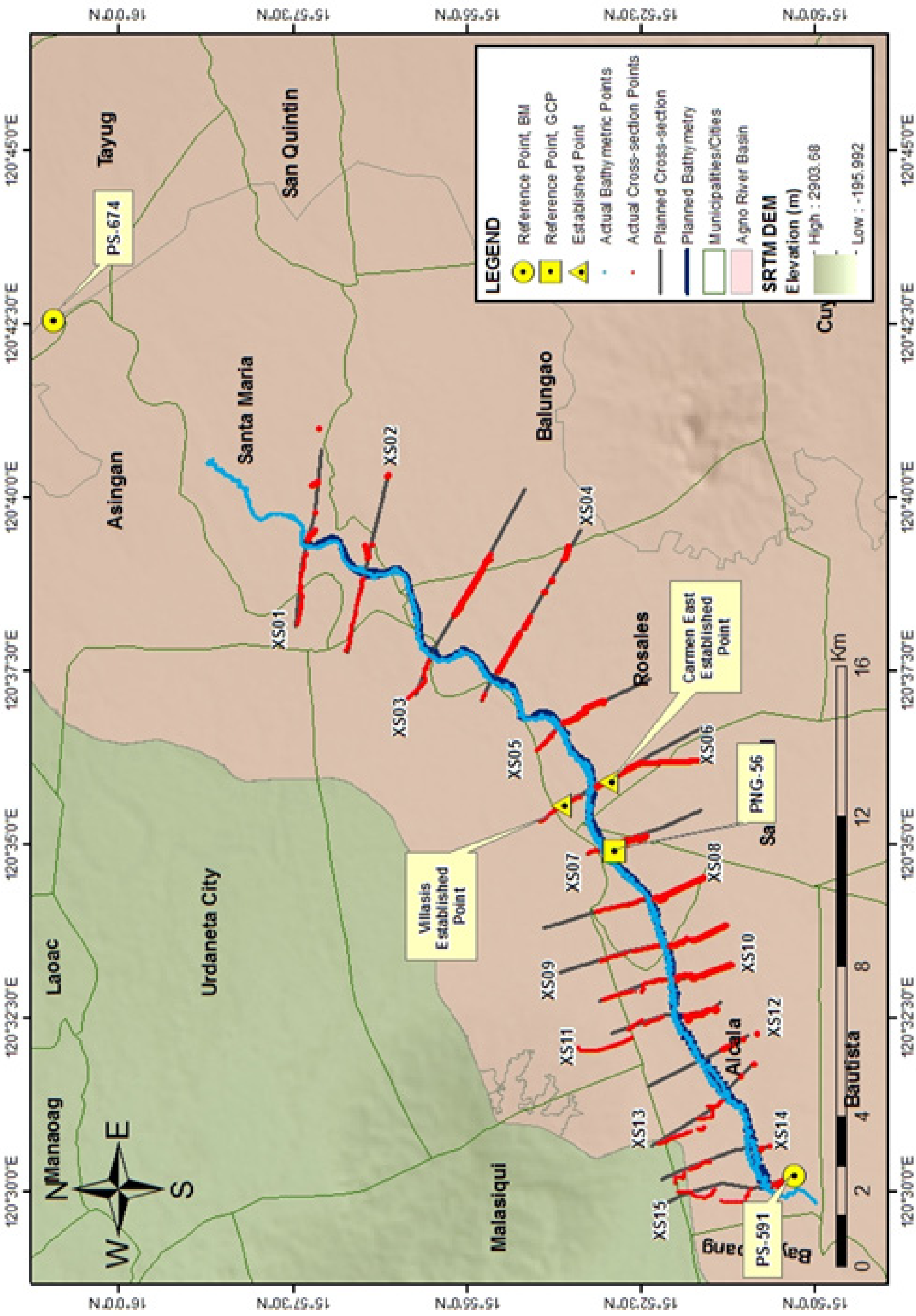


Figure 11. Location of control points in Agno River

Continuous differential static observations were done simultaneously at these five stations for two hours to provide reference control points for the ground and bathymetric surveys. The horizontal coordinates and elevations of the five (5) control points were computed using Trimble® Business Center GNSS processing software. The result of control survey for the control points are indicated in Table 1.

Table 1. Result of control survey used in the Agno River (Source: NAMRIA, UP-TCAGP)

Base Station	Latitude (in decimal degrees)	Longitude (in decimal degrees)	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Elevation (MSL) (m)
PS-674	120.686817	15.993571	92.285	1769601.727	252443.605	47.7939
PNG-56	120.583219	15.878039	68.768	1756938.753	241202.845	24.2269
PS-591	120.504509	15.837861	69.538	1752589.96	232716.912	24.8409
Villasis	120.593946	15.891921	79.765	1758462.201	242369.849	28.2599
Carmen	120.598121	15.885419	75.701	1757737.342	242808.824	34.128

The GNSS setup for the five (5) control points are shown in Figure 12 to Figure 16.

Figure 12. Static GNSS Network Observation Set-up at PNG-56 in Sto.Tomas, Pangasinan

Figure 13. Trimble SPS 882 Rover Set-up at PS-674 at Ramos Bridge in Asingan, Pangasinan

Figure 14. Control Point established at Villasis Bridge in Villasis, Pangasinan

Figure 15. Static GNSS Network Observation in Brgy. Carmen East, on top of the Revita Bldg. in Rosales, Pangasinan

Figure 16. Derived Control point in Brgy. Carmen East in Rosales, Pangasinan served as a base for RTK GNSS Survey

Agno River Basin Survey

The second phase of the control survey conducted on May 15 to 18, 2013 connected the three (3) recovered NAMRIA reference points to establish a GPS network for this survey area. It consists of two 2nd order horizontal control and a 1st order vertical control. The NAMRIA benchmark reference point, PS-608, is located in Brgy. Rajal, Balungao, Pangasinan. Two (2) GCPs were recovered for the survey namely, PNG-47 in San Quintin, Pangasinan, and PNG-56, which was also occupied during the first phase of the control survey, in Brgy. Poblacion, Sto. Tomas, Pangasinan. The result of the control survey conducted is shown in Table 2.

Table 2. Result of Control survey conducted on Agno River (Source: NAMRIA, UP-TCAGP)

Point Name	Order of Accuracy	Latitude	Longitude	Ellipsoidal Height	Northing	Easting	EGM Ortho	BM Ortho
PNG-47	2nd	16d00' 08.70477"	120d47' 00.98451"	117.67	1770467.974	262816.955	74.768	71.3633
PNG-56	2nd	15d52' 40.94078"	120d34' 59.58895"	69.457	1756938.752	241202.85	27.865	24.4603
PS-608	1st	15d54' 10.32647"	120d42' 20.95705"	90.771	1759539.275	254367.834	48.805	45.4003

Base station set-up of control points established in San Quintin and Sto. Tomas, Pangasinan are shown in Figure 17.


Figure 17. Base Station set-up for Phase 2 of Control Survey in Agno River

4.2 Cross-section Survey

The topography of a river can be described using series of cross-sections that cut perpendicularly across the channel of the river. Bathymetric survey data of the river combined with ground survey data of the floodplain can produce a series of cross-sections along the stretch of the river.

Horizontal position and vertical measurements were done at a specific interval as one traverses starting from riverbank across the floodplain. Cross-section survey was done by the team through differential kinematic GNSS surveying either post processed (PPK) or in real-time (RTK). PPK and RTK GPS survey methods were implemented in the cross-section surveys. Three (3) rover receivers were utilized for RTK and one rover for PPK. Initialization time for PPK survey was set at 5 to 10 minutes, depending on the field conditions.

The RTK GNSS surveying uses radio signals to feed corrections to the measurements recorded by the rover, high-gain antenna was attached to these rovers to increase reception of radio signals emitted by the RTK base station. PPK survey was primarily conducted at both ends of the survey area described as cross-sections XS01 and XS15 where RTK radio signals were expected to be weak. RTK survey was conducted first at cross-sections nearest to the RTK base stations named as XS06. Trimble® Business Center Software was used in processing PPK data and plotting RTK data.

Figure 18. Cross-section teams conducting RTK GNSS Survey

As shown in Figure 18, a cross-section team is composed of two to three field personnel consisting of (1) member from DVC, one (1) survey aide and/or one (1) local-hire if needed. At the start of every cross-section survey, each cross-section team was dropped-off at an accessible point nearest to the planned cross-section lines.

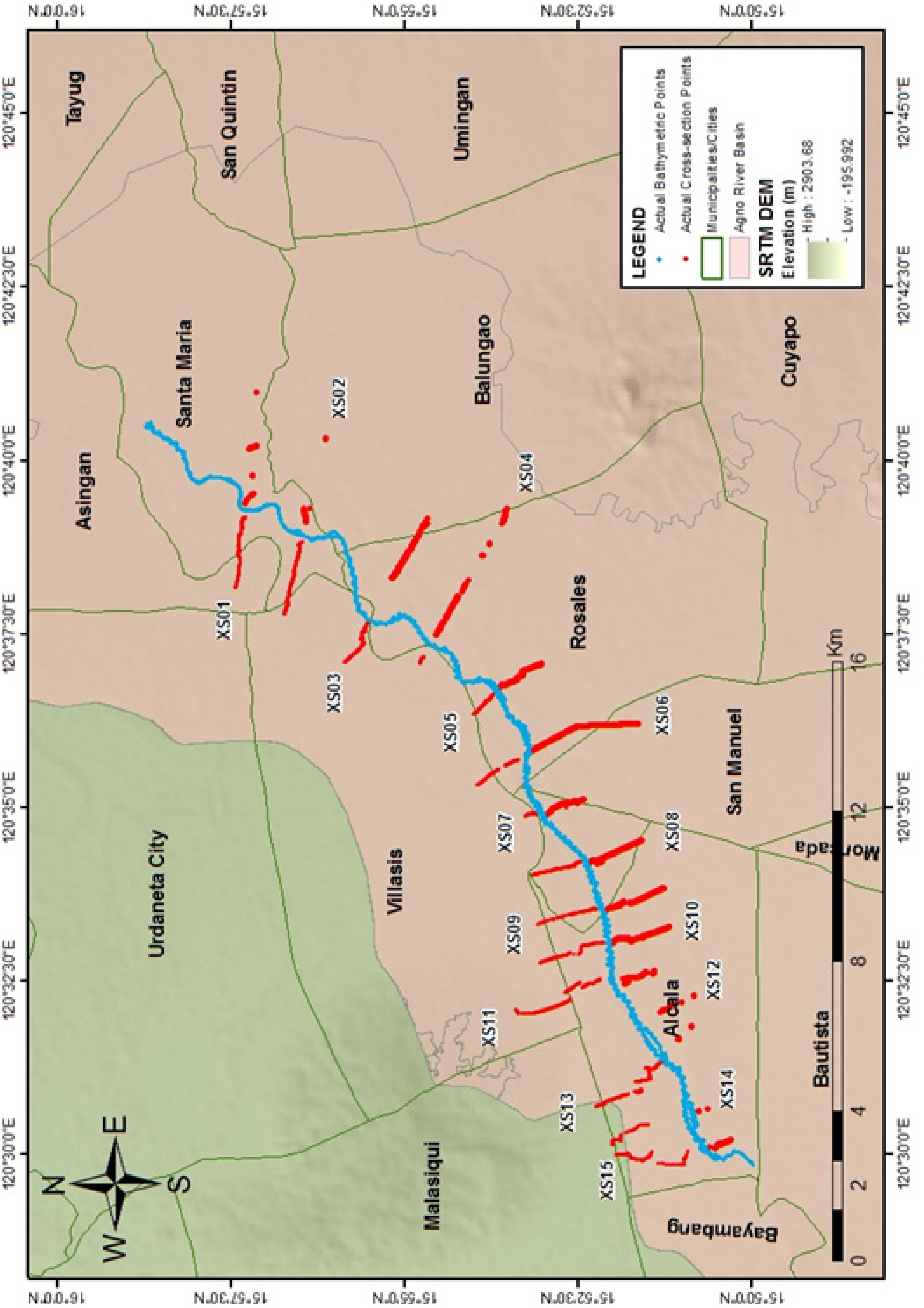


Figure 19. Actual Cross-section and Bathymetry survey conducted in Agno River Basin

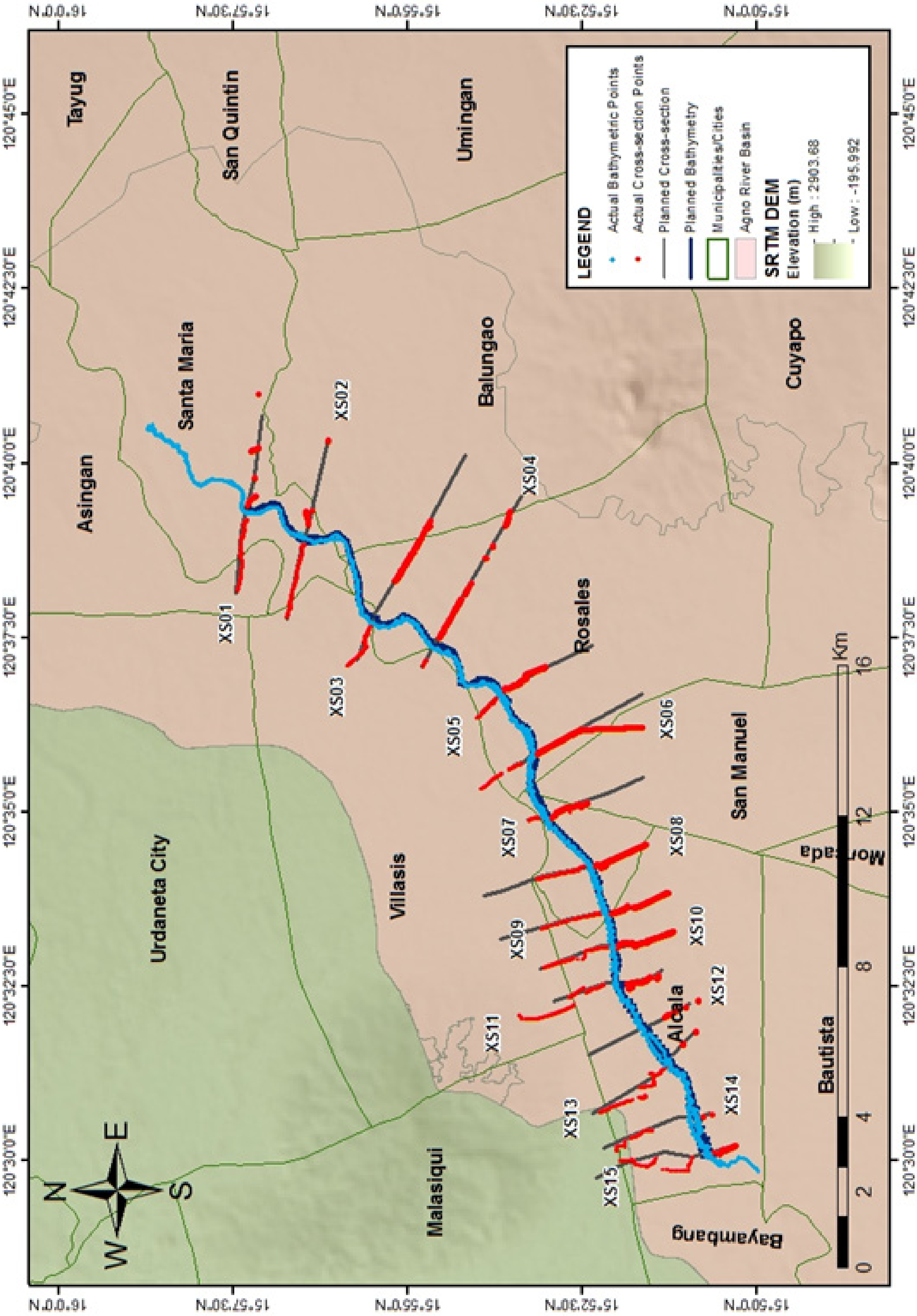


Figure 20. Planned vs. Actual Cross-section and Bathymetry Survey of Agno River

The image in Figure 19 and Figure 20 show the comparison between the actual cross-section data gathered from the field and the proposed cross-sectional lines from the Agno field plan. The entire fieldwork was conducted from August 1 to 13, 2012, nine (9) days of which were spent on cross-section surveys. Deviations of the actual from the proposed cross-sections are evident. Quantitative analysis of the deviations was done using simple parameters. A total of 3,690 survey points were gathered for all fifteen cross sections with an average of 246 points for every cross section with a standard deviation of 96.25.

The cross-section survey data were tested on whether the actual cross-sections fall within the 10-m maximum deviation from the planned cross-sections. This was done by creating a 10-m buffer around every planned cross section. The number of actual surveyed points within these buffers was determined using ArcGIS. The result of the buffer analysis is shown in Table 3, while the following map displays the percentages of points within the buffer for every cross-section. In general, 1,320 out of the 3,690 surveyed points or 35.77 percent fall within the 10-m buffer around the planned cross-section lines.

Table 3. Summary of the Buffer Analysis for Cross-section Survey

Cross section		Total no. of points surveyed	Number of points surveyed within 10-m buffer	Number of points surveyed outside 10-m buffer
1	R	218	34	184
	L	36	6	30
2	R	200	71	129
	L	22	7	15
3	R	160	25	135
	L	200	161	39
4	R	22	11	11
	L	135	74	61
5	R	70	41	29
	L	140	44	96
6	R	130	15	115
	L	299	125	174
7	R	45	15	30
	L	105	3	102
8	R	134	75	59
	L	170	105	65
9	R	137	112	25
	L	163	107	56
10	R	174	58	116
	L	172	71	101
11	R	233	26	207
	L	87	22	65
12	R	163	42	121
	L	33	8	25
13	R	246	27	219
	L	8	6	2
14	R	51	8	43
	L	5	2	3
15	R	95	1	94
	L	37	18	19
Total		**3,690**	**1,320**	**2,370**

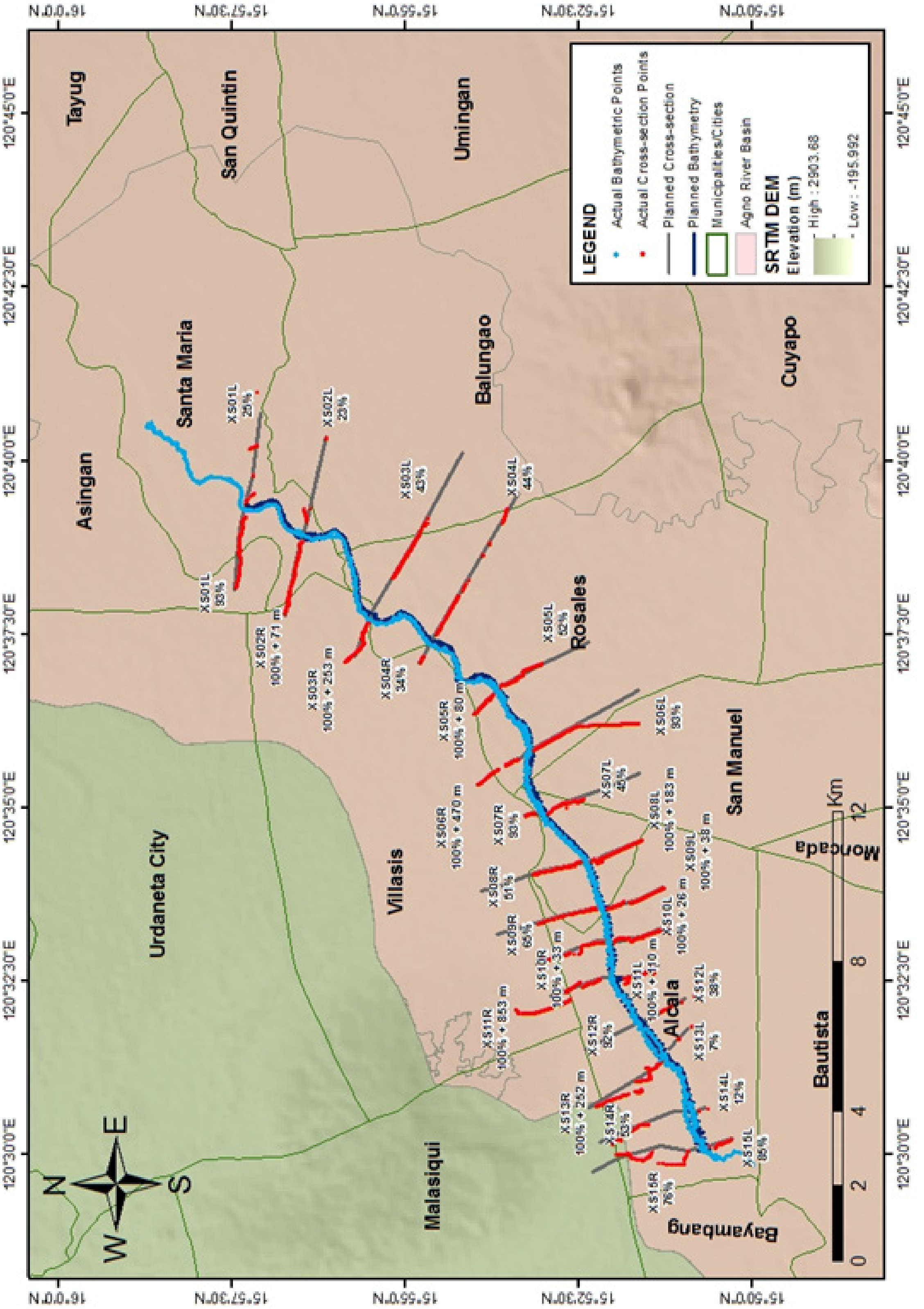


Figure 21. Percentages of the actual survey length covered during the actual cross section survey

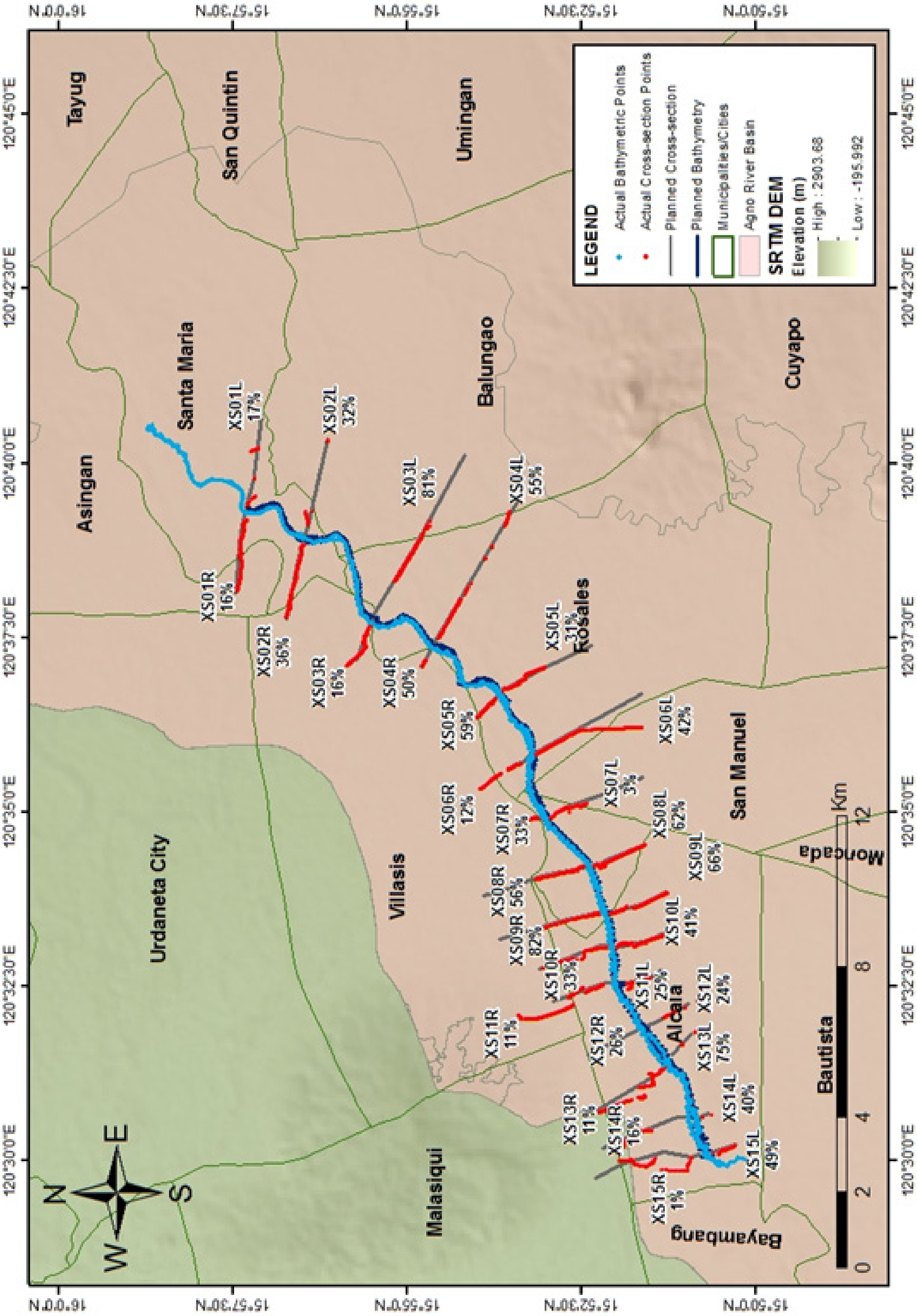


Figure 22. Percentage result of the buffer analysis. The red points are surveyed points that fall within the 10-m buffers.

The XSR09 has the greatest number of points falling within the 10-m buffer, with 82 percent (112 out of 137) of the surveyed points within the 10-m buffer around the planned cross section. This is followed by XSL03, with 81 percent (161 out of 200) of the surveyed points within the 10-m buffer. On the other hand, the least number of points within the 10-m buffer is at XSR15 with 94 percent or only one (1) of the 95 surveyed points is beyond 10 meters from the planned cross section. This is followed by XSL07 with three (3) out of the 105 surveyed points beyond 10-m from the planned cross section.

The lengths of the planned and actual surveyed lines were also computed. The lengths of the actual cross-sectional lines are not measured from the first to last surveyed points but only on segments where there are continuous survey points. Thus, segments where there are data gaps are not included in the computation of the cross-sectional lines. The entire planned cross-sectional lines have a total length of 56.57 km with an average length of 1.89 km for every cross section. The longest of which is XSL03 with a length of 4.74 km, while the shortest is XSL14 with a length of 0.28 km. On the other hand, the actual cross sections have a total length of 40.61 km with an average of 1.35 km. The longest of which is XSL06 with a length of 2.97 km, while XSL14 is the shortest with a length of 0.03 km.

The average interval distance between consecutive points along the entire cross-section was estimated. By and large, all the cross sections have an average interval length of 11.01 meters. The average interval distance of the cross-section is shown in Table 4. Only 14 of the 30 cross sections have interval lengths that are less than 10 meters.

Table 4. Average interval distance of cross-sections.

Cross section		Interval, m
1	R	9.33
	L	16.58
2	R	10.49
	L	26.43
3	R	8.75
	L	10.21
4	R	9.13
	L	14.34
5	R	10.73
	L	9.89
6	R	8.18
	L	9.92
7	R	8.53
	L	9.76
8	R	10.95
	L	9.14
9	R	13.33
	L	9.51

Cross section		Interval, m
10	R	11.27
	L	9.30
11	R	10.77
		12.69
12	R	8.65
	L	14.22
13	R	10.37
	L	6.69
14	R	25.26
	L	6.82
15	R	23.28
	L	15.09
Total		**11.01**

A total of 3,693 cross-sectional points each with vertical and horizontal positions were gathered during the field survey. Table 5 shows the number of points collected for every cross-section.

Table 5. Summary of number of Points and Length of Cross-sections gathered from the Agno River Survey

Cross-section	Number of points	Length (km)
XS01	254	3.583
XS02	222	4.241
XS03	360	3.229
S04	157	3.945
XS05	210	2.086
XS06	432	4.322
XS07	150	1.622
XS08	304	2.991
XS09	300	3.376
XS10	346	3.687
XS11	320	4.248
XS12	196	2.505
XS13	254	2.877
XS14	56	1.709
XS15	132	2.877

4.3 Profile Survey

Another set of ground surveys were conducted along the banks of the river. The upper and lower banks were measured separately, each with different survey techniques. The lower banks were measured using MDL Dynascan M150 (See Figure 23). This is a mobile mapping scanner (MMS) that combined GNSS and laser technology to acquire point clouds to better obtain three - dimensional survey measurements. The MDL Dynascan was attached to the rubber boat so that it can continuously scan the lower bank as the boat traversed along the length of the River. The dual GNSS antenna design of the MDL Dynascan provided positioning and heading of the instrument (See Figure 24 and Figure 25). A high-gain antenna attached to the MDL Dynascan improved the reception of the instrument to RTK corrections from the base station located at Carmen.

Figure 23. The MDL Dynascan installed on one end of the rubber boat was used to profile the lower banks of Agno River

Figure 24. Components of the MDL Dynascan

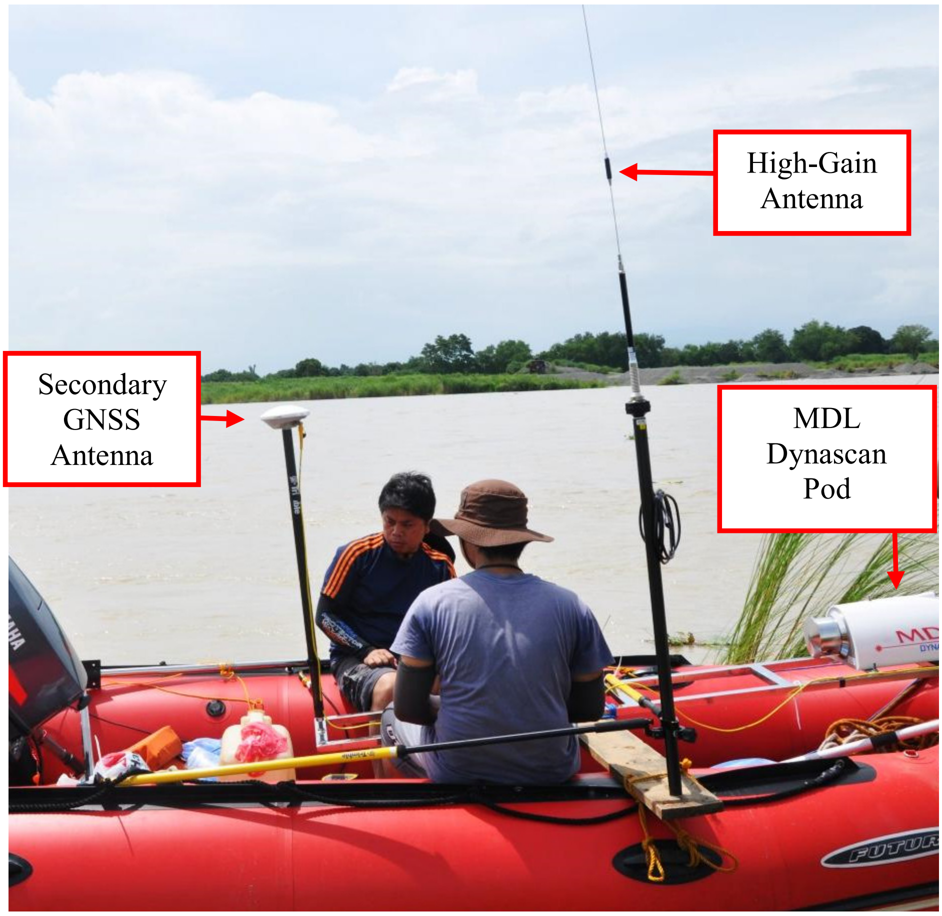


Figure 25. Components of MDL Dynascan

The output of the mobile mapping scanner is point cloud stored in *.pts and *.db format. Trimble® Realworks software was used to view and manage the point cloud data gathered by the mobile mapping scanner.

On the other hand, the upper banks of the river were surveyed using differential kinematic GNSS surveying techniques similar to that in the cross-section surveys. Four profile survey teams from which three used RTK GNSS survey while one employed PPK GNSS survey, were deployed simultaneously at both ends of the upper right and left upper banks of the river. These teams were then expected to meet halfway along the profile length.

All profile survey teams used Trimble®SPS882 as GNSS rover and Trimble®TSC3 as GNSS controller. The data gathered using RTK surveying were instantaneously transferred directly from the GNSS controller in a *.csv (comma delimited) file format, while the PPK data gathered from the field were processed through Trimble® Business Center (TBC) Software.

The following map compares the profile survey data gathered from the field and the profile lines as proposed on the Agno field plan. Note, however, that the ground profile survey was conducted only along the left and right upper banks of Agno River. The entire fieldwork was conducted from the 1st to the 13th of August 2012, from which two (2) days were spent on profile surveys. Marked deviations of the actual from the proposed profile lines are evident.

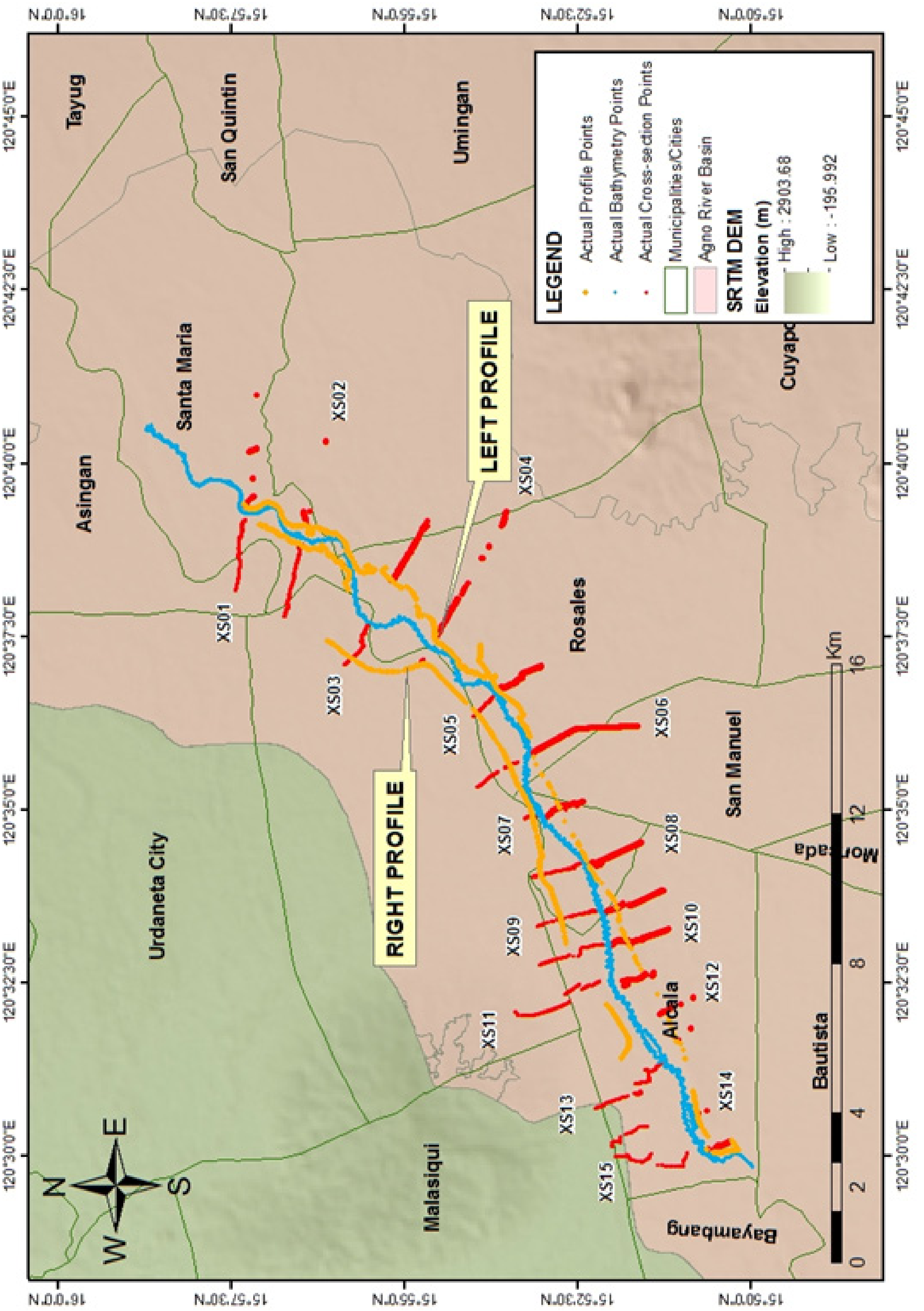


Figure 26. Result of actual profile points gathered in the Profile Survey conducted in Agno River

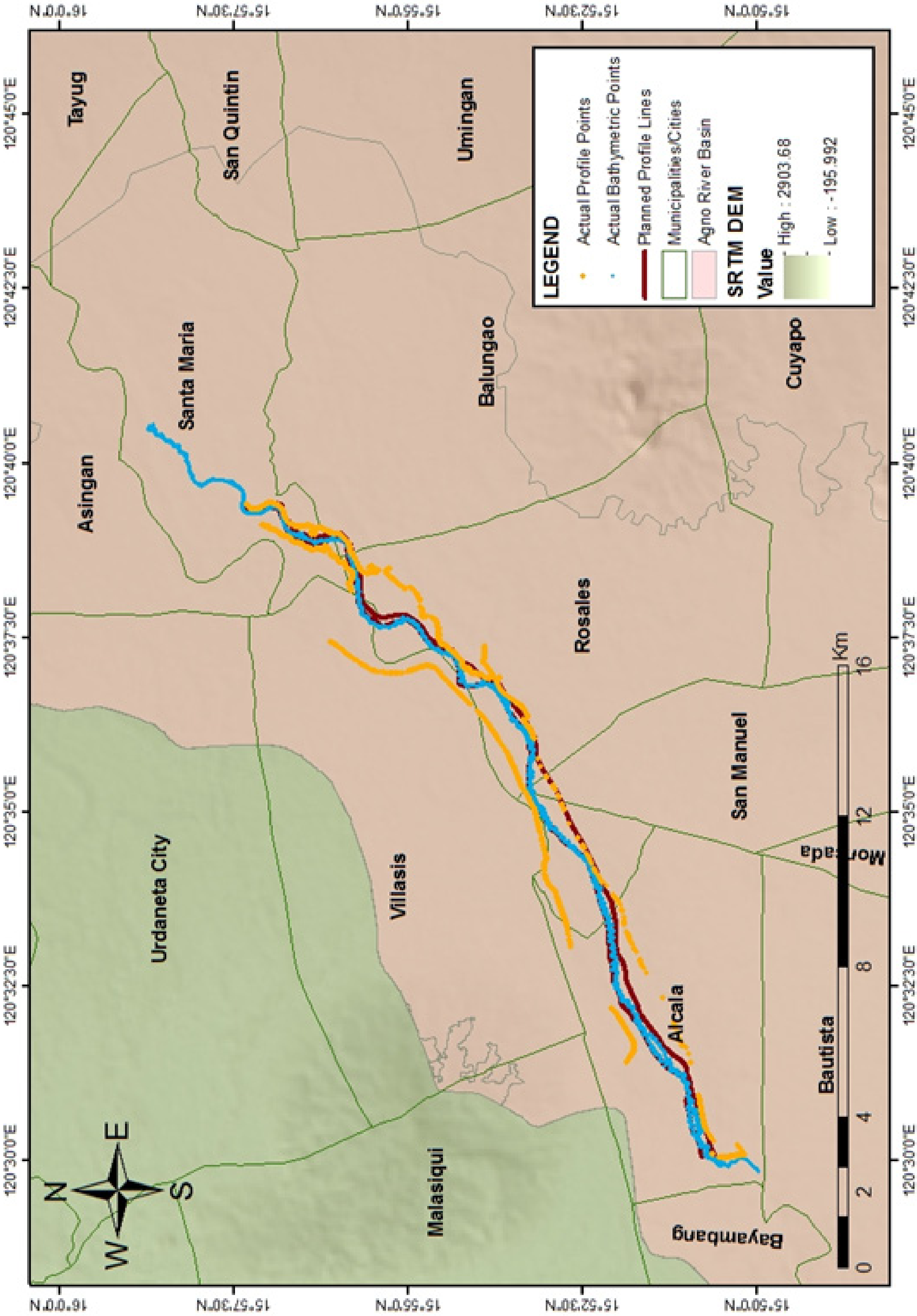


Figure 27. Comparison between planned profile survey and actual profile survey of Agno River

The proposed profile lines have a total length of 46.79 km, with lengths of 23.74 km and 23.05 km for the proposed left and right profile lines, respectively. On the other hand, the actual surveyed profile lines have a total length of 40.99 km, with lengths of 20.34 km and 20.65 km for the left and right profiles, respectively (data gaps are not included in the measurement of profile lengths). Measurement for Profile lines for Agno river survey presented in Table 6.

Table 6. Measurement for profile lines for Agno River survey

Profile	Length of planned profile, km	Length of surveyed profile, km	Percentage completed
LEFT	23.74	20.34	85.70%
RIGHT	23.05	20.65	89.57%
Total	46.79	40.99	87.61%

A total of 3,808 points were surveyed for the profile survey. 1,311 points were gathered on the left profile survey, while another 2,497 points were on the right profile survey. The distribution of points for every profile is shown in Table 7.

Table 7. Distribution of points for left and right profile of Agno River

Profile	Total Points Gathered	Percentage
LEFT	1311	34%
RIGHT	2497	66%
Total	3808	100%

The average interval distance between two consecutive points along the surveyed profile was computed. The average interval distance for the profile survey can be viewed in Table 8.

Table 8. Average distance of surveyed profile points

Profile	Interval distance, m
LEFT	15.52
RIGHT	8.27
Total	10.76

A buffer analysis was conducted by creating a 10-m profile around the planned profile lines. Points that fall within this 10-m buffer are then selected and separated from the pool of surveyed profile points. The result of the buffer analysis of Profile survey data can be found in Table 9, while the map showing the result is presented in Figure 28.

Table 9. Result of the buffer analysis of Profile survey data

Profile	Total number of surveyed points	Number of points within 10-m Buffer	Number of points outside 10-m buffer	Percentage of points within 10-m buffer
LEFT	1311	77	1234	5.87
RIGHT	2497	7	2490	0.28
Total	3808	84	3724.00	2.21

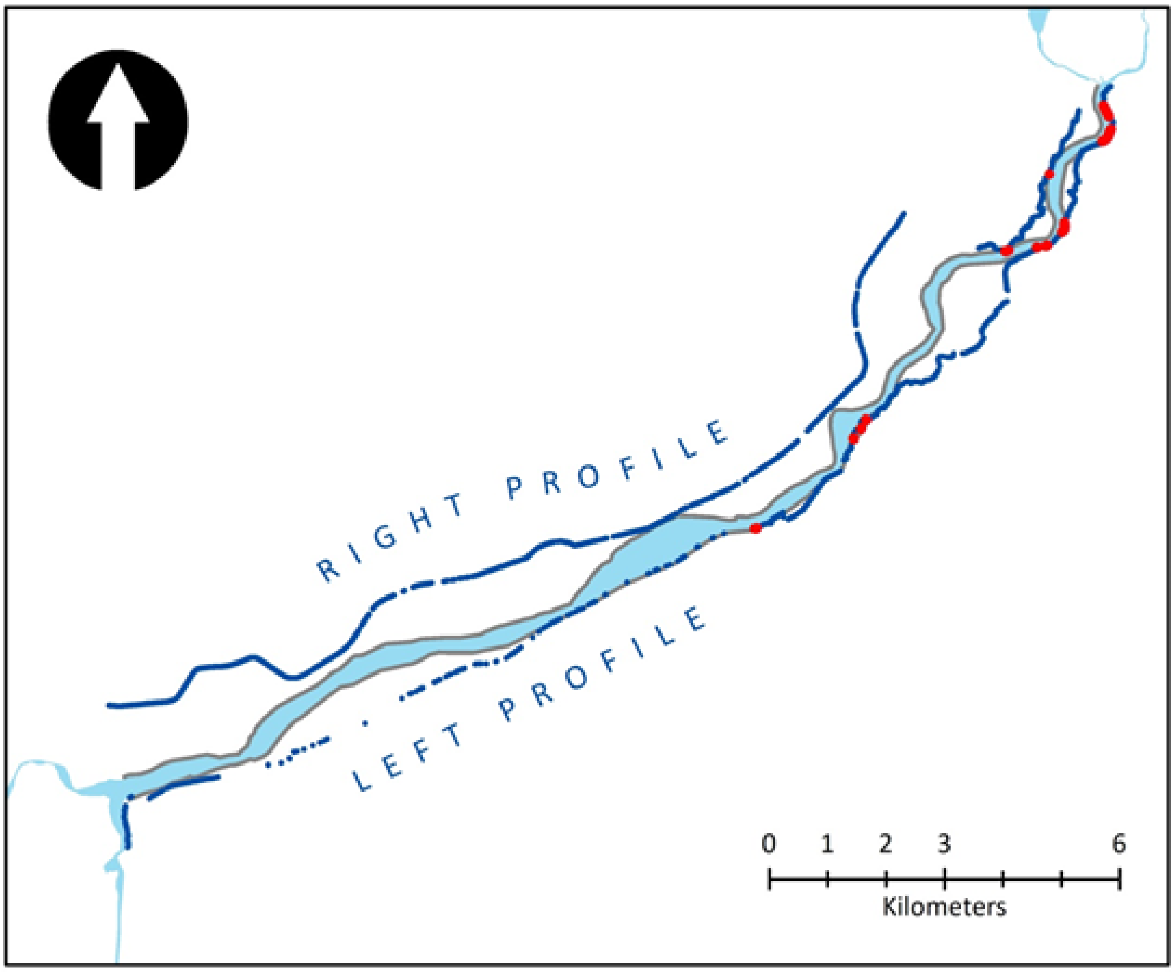


Figure 28. Result of the buffer analysis; red points mark the surveyed points that fall within the 10-m buffer around the planned profile lines.

The downstream profile of the upper left and right banks along Agno River plotted in diagrams found in Figure 29 and Figure 30.

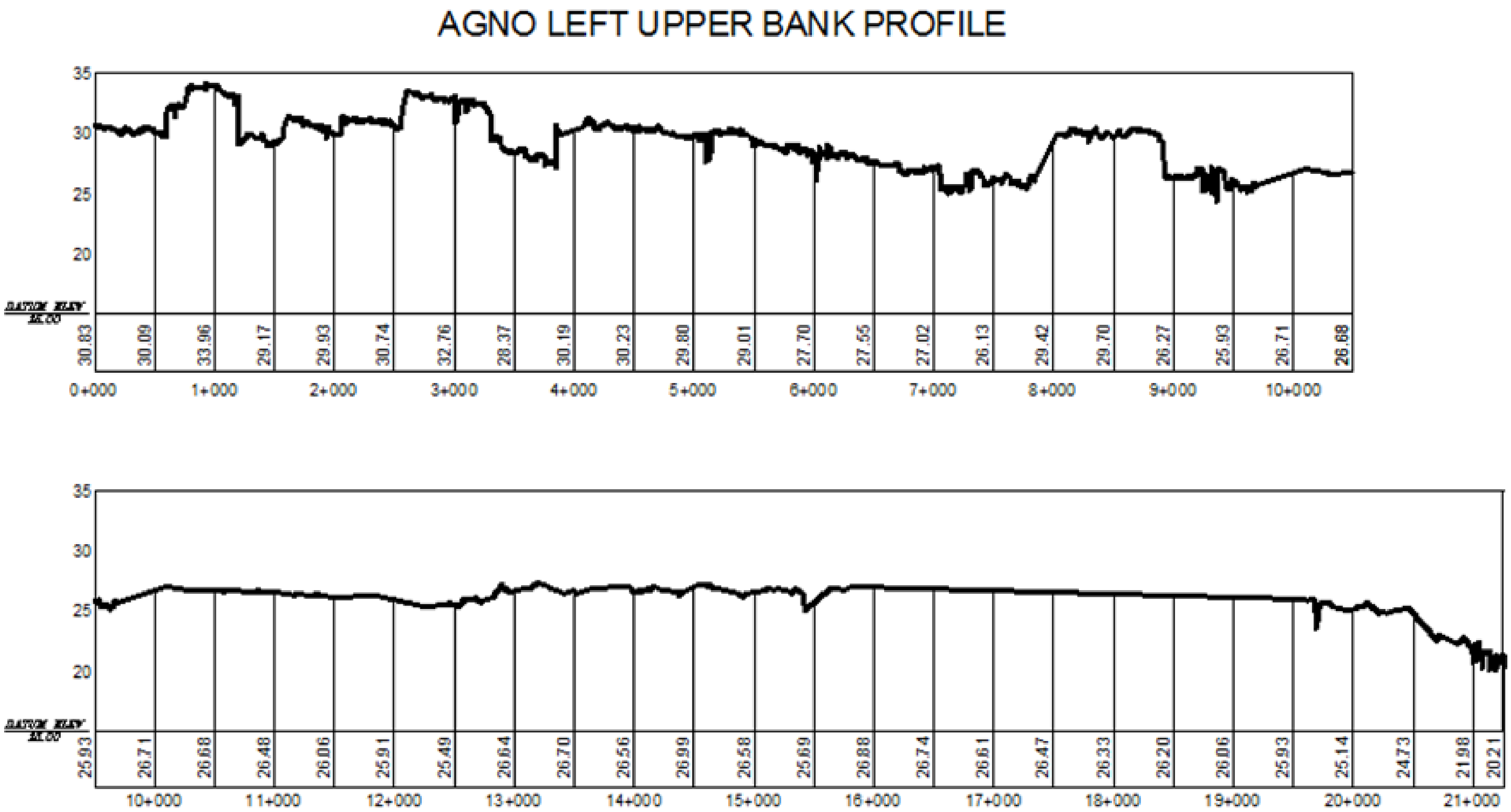


Figure 29. Downstream Profile of the Upper left bank of Agno River

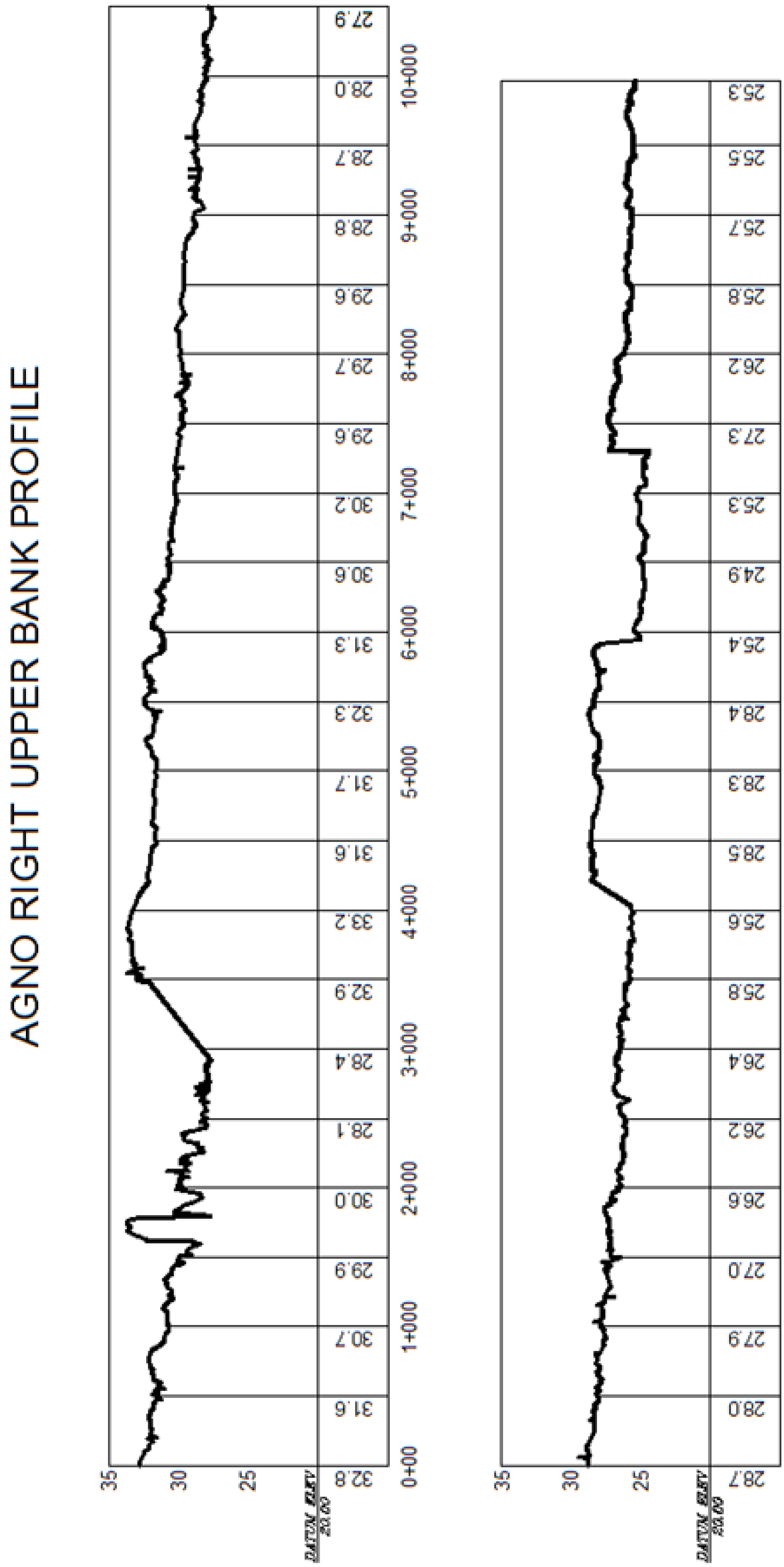


Figure 30. Downstream Profile of the Upper right bank of Agno River

4.4 LIDAR Validation Survey

The LIDAR data validation survey for Agno River Basin was conducted on May 15-18, 2013 Points were gathered along national road in the municipalities of Cuyapo to Sta. Maria and Alcala to Malasiqui. Mobile LiDAR Validation set up is shown in Figure 31 and Manual Ground LiDAR Validation is shown in Figure 32. Map showing the total acquired ground validation points is shown in Figure 33.

Figure 31. LiDAR Validation Set-up on a van

Figure 32. Manual ground LiDAR Validation using Trimble SPS882 Rover

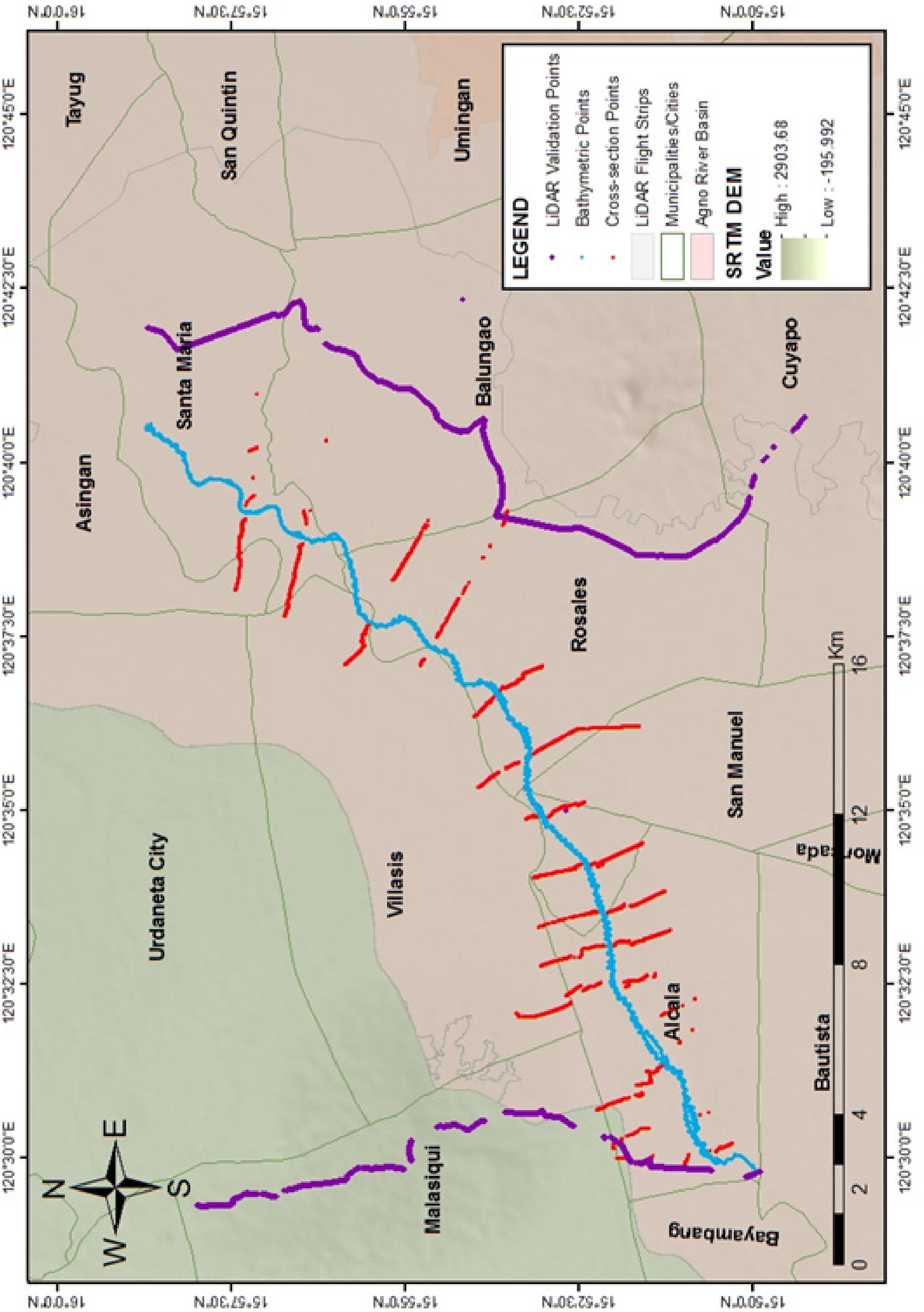


Figure 33. Acquired LiDAR Validation points in Agno River

4.5 Bathymetric Survey

The bathymetry of the river channel itself was surveyed using a different surveying technique. Hi-Target™ HD-370 Digital VF Single Beam Echo Sounder and Ohmex™ echo sounder were used for the bathymetric/hydrographic survey that measured the depth of the river along certain points on the surface of the river. The Hi-TargetTM Echo sounder has a Variable Frequency technology which has the capability to adjust the frequency to a particular application in water sounding.

The elevation and coordinates of these points were measured using differential GNSS PPK mode in which a PPK base station set-up on a known location at PNG-56 in Sto. Tomas and a roving GNSS antenna, Trimble®SPS882, mounted above the transducer determined the position of the echo-sounder. The GNSS rover was wirelessly connected to the Trimble® TSC3 GNSS controller which was used for logging and viewing the GNSS points taken. The set-up of the bathymetric survey can be viewed on Figure 34 to Figure 37.

The entire bathymetry survey took three (3) days to accomplish from August 2 to 4, 2012. In order to fully capture the topography of the riverbed, the bathymetry survey was done in two directions, one is along the center line which approximates the length of the river while the other courses through the river in a zigzag fashion, from one bank to the other. The centerline profile diagram of the river is shown in Figure 38.

Figure 34. Securing the Hi-Target™ HD-370 Digital VF Single Beam Echo Sounder on top of the rubber boat with a metal frame and wooden plank

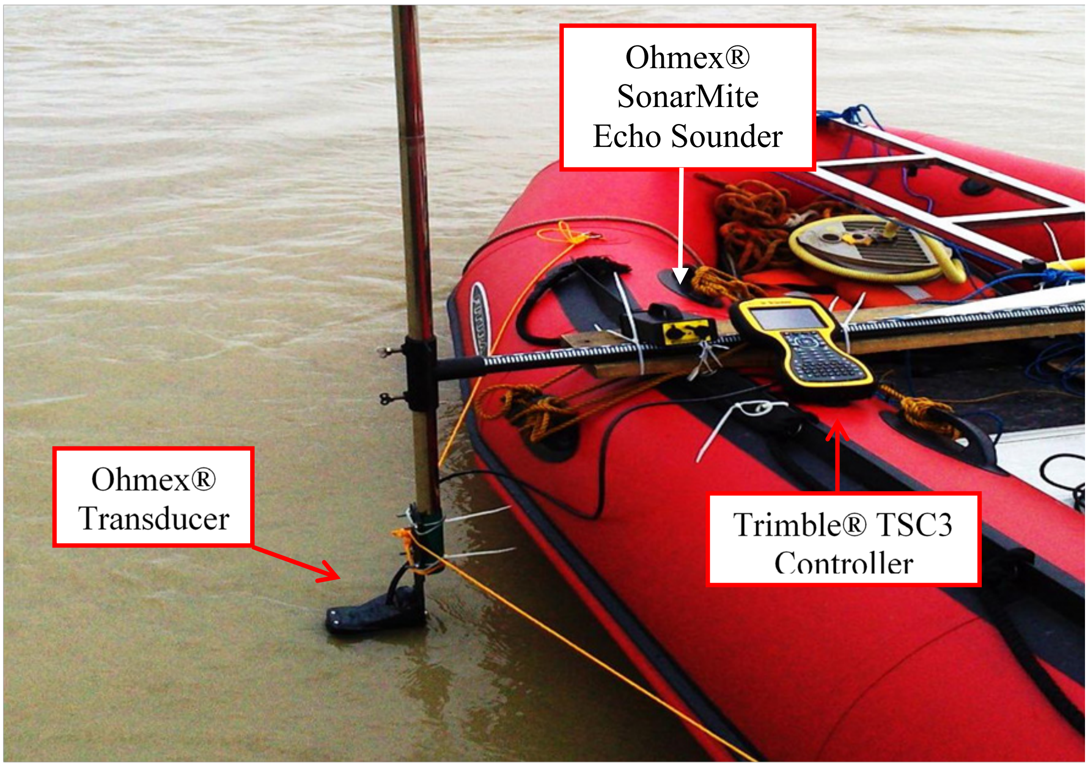


Figure 35. The Ohmex®SonarMite echo sounder and Transducer, and Trimble®TSC3 controller as used in bathymetric survey

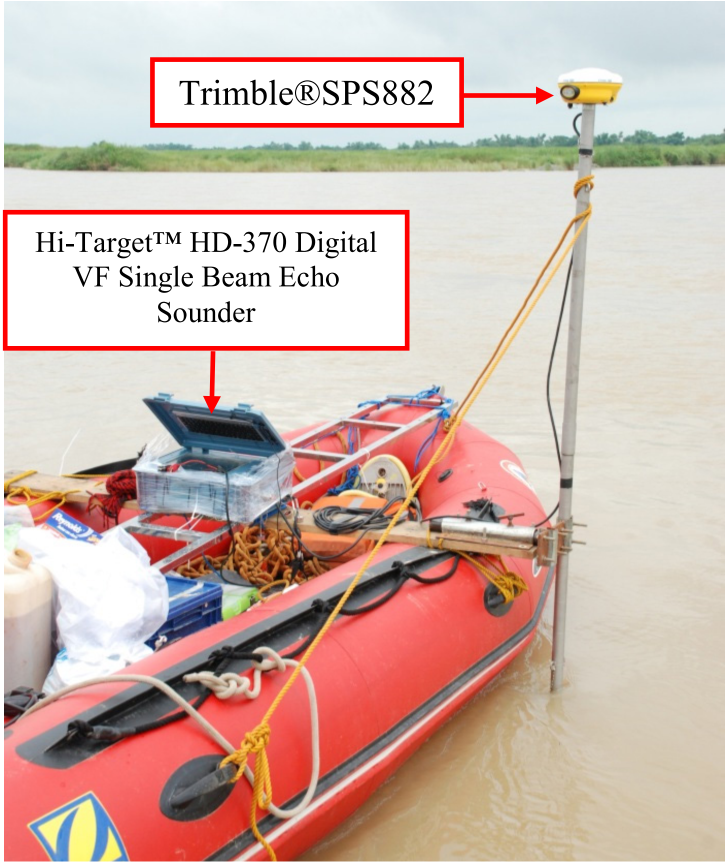


Figure 36. The set-up of instruments for the bathymetric survey with the Trimble®SPS882 mounted on top of the Hi-Target™ Transducer

Figure 37. Deployment of the bathymetry team together with members of the Philippine Coast Guard

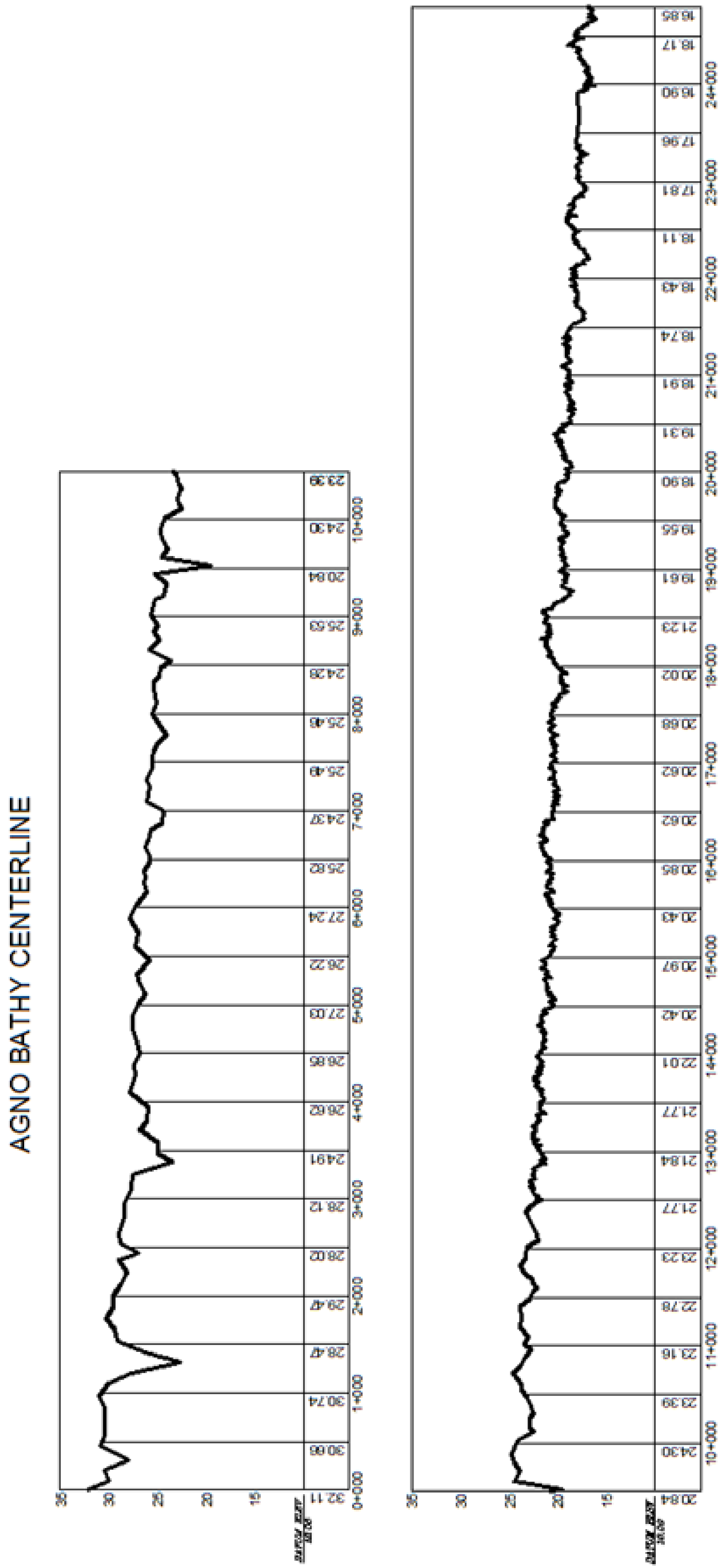


Figure 38. Bathymetric Center Line Profile of Agno River

4.6 Hydrometric Survey

4.6.1 Agno River Hydrometric Survey

In addition to topographic and bathymetric surveys, river flow measurement was also taken at key locations along Agno River. Different sensors were deployed on the banks of Agno River to obtain its physical characteristics such as cross-section elevation in MSL, velocity and elevation of water level in MSL at a particular time. Several parameters to determine stream flow of Agno River were measured accordingly with the following instruments:

a. Acoustic Doppler Current Profiler (ADCP), a sonar (sound navigation and ranging) that uses sound propagation underwater to obtain and record the water current velocities for a range of depths at a particular time. During the survey period, the ADCP acquires data with a logging rate of five (5) minutes.
b. Depth gauge (pressure gauge) that displays the equivalent depth in water as well as detects the changes in water level at particular time. It measures the water pressure and relates it to water depth. Velocity of the current of the river and its depth with its cross- sectional area are the main factors in calculating the discharge.
c. Rain gauge or odometer, a device that measures rainfall events and the amount of liquid precipitation at a particular place over a set period of time. Like ADCP, the rain gauge has a logging rate of five (5) minutes.

The ADCP was deployed on August 2, 2012 along the riverbank of Agno River in Brgy Paitan, Sta. Maria and began logging data at 4:00 PM. After deployment, the ADCP was left at the site to continuously collect data while being monitored by a local hire. The ADCP was also monitored every so often by the team, inspecting the progress of the data collection especially during heavy rainfalls brought by monsoon winds. Deployment and follow up processes are shown from Figure 39 to Figure 40. The ADCP was then retrieved on August 11, 2012 after 10 days of continuous data gathering.

Figure 39. Series of pictures displaying the components and the deployment of ADCP on the bank of Agno River in Barangay Paitan, Sta. Maria

Figure 40. The team, together with Dr. Enrico Paringit, Nationwide DREAM Program Leader, inspected the ADCP deployment site in Brgy. Paitan, Sta. Maria, Pangasinan.

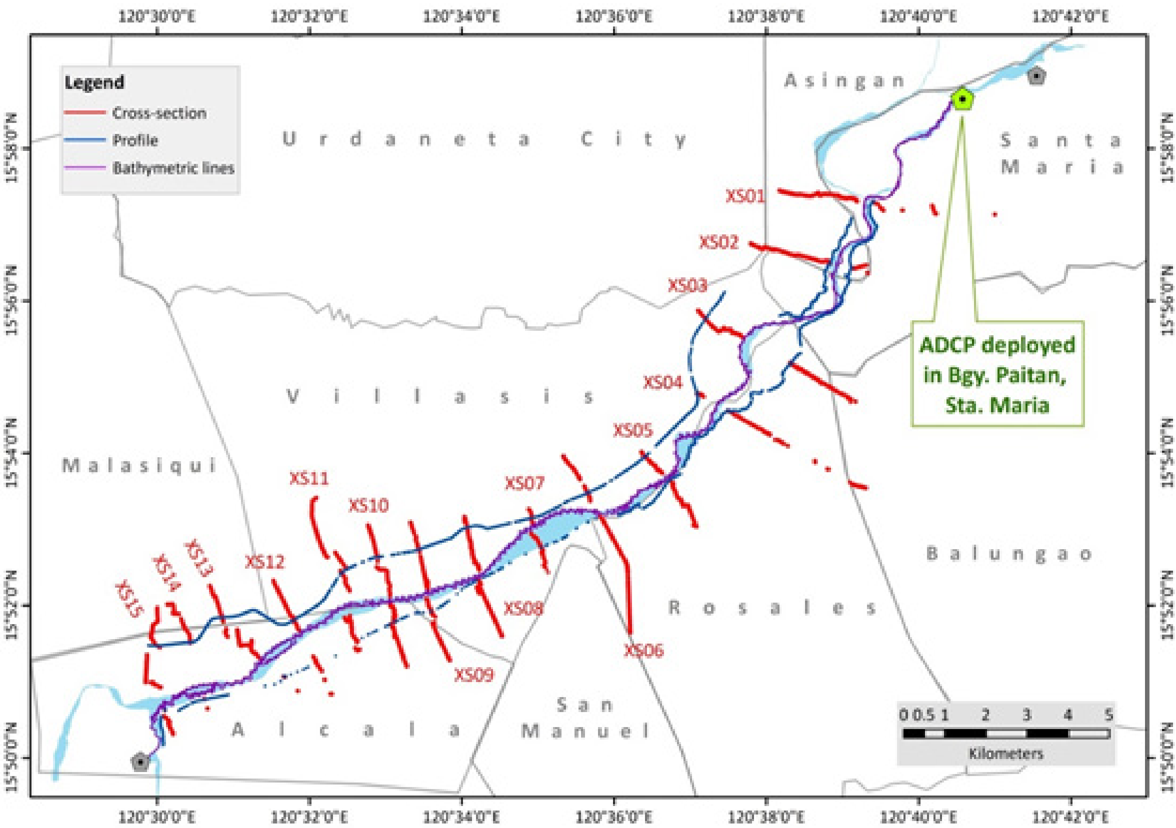


Figure 41. The Acoustic Doppler Current Profiler (ADCP) was deployed at Brgy. Paitan, Sta. Maria

A rain gauge was installed on the approach of Narciso Ramos Bridge in Brgy. Patricio, Sta. Maria, about 1.8 km upstream from the ADCP deployment site as shown in Figure 42.

Figure 42. The rain gauge installation on Narciso Ramos Bridge, Bgy. San Patricio, Sta. Maria, Pangasinan

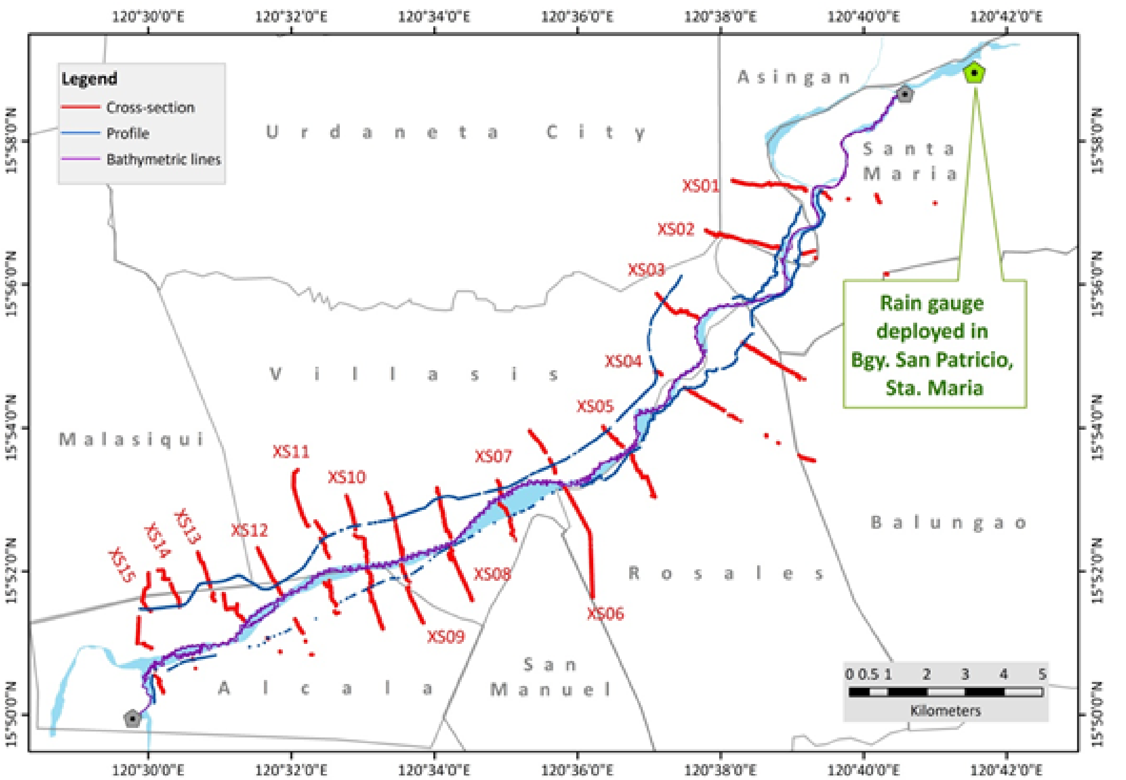
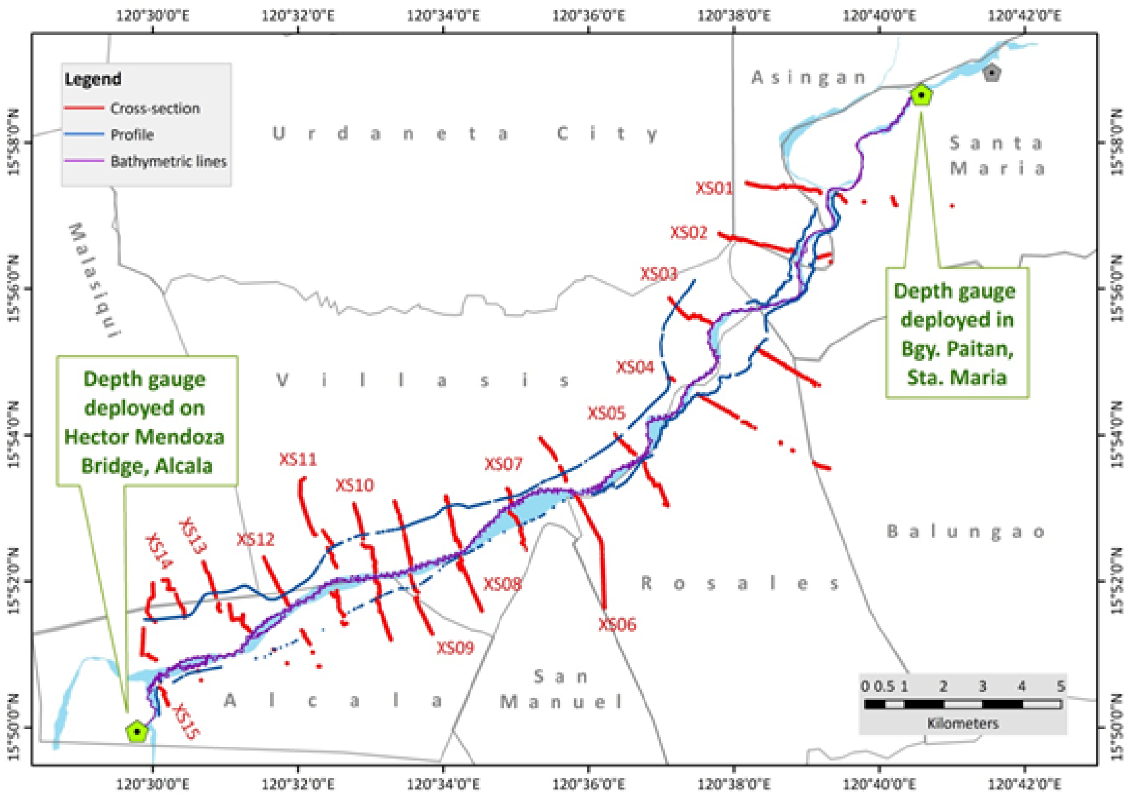


Figure 43. The rain gauge was deployed on Narciso Ramos bridge, Brgy. San Patricio, Sta. Maria, Pangasinan

Depth gauges were also deployed in two locations. The first location was in Brgy. Paitan in Sta. Maria (a), while the other location was installed downstream on Hector Mendoza Bridge, Alcala (b).

Figure 44. (above) The deployment sites of the depth gauges in Sta. Maria (a) and Alcala (b) (below) A map of the location of depth gauge installation in Alcala and in Sta. Maria



Data collection in Alcala started from depth gauge installation last August 4, 2012 to retrieval last August 11, 2012 with a total of eight (8) days. On the other hand, the measurements from the depth gauge in Brgy. Paitan that was installed on the metal frame, together with the ADCP, started from August 2, 2012 to August 11, 2012 with a total of ten (10) days. The summary of location of sensor deployment are shown in Table 10.

Table 10. A summary of the location, start and end of deployment of all the sensors used for stream flow measurements of Agno River

Sensor	Location	Municipality	Deployment - Start	Deployment - End	LATITUDE (WGS84)	LONGITUDE
ADCP	Bgy. Paitan	Sta. Maria	02-Aug 2012	11-Aug 2012	15.978	120.676
Rain Gauge	Narciso Ramos Bridge	Sta. Maria	02-Aug 2012	12-Aug 2012	15.983	120.692
Depth Gauge 1	Bgy. Paitan	Sta. Maria	02-Aug 2012	11-Aug 2012	15.978	120.676
Depth Gauge 2	Hector Mendo-za Bridge	Alcala	04-Aug 2012	11-Aug 2012	15.833	120.496

The results of the hydrometric measurements conducted in the first field survey in Agno River are as follows: the data gathered from the rain gauge show the distribution of rainfall within the observation period which was from August 2, 2012 to August 10, 2012. Measurements were recorded every five (5) minutes. The first surge of rainfall, reached 5 mm was observed on August 3, 2012 at 12:10PM. Rainfall peaked on August 4, 2012 at 6.6 mm. The highest amount of rainfall, , was observed on August 5, 2012 at 6.8 mm at 3:05 PM While aother peak was observed five hours later at 5.8 mm . Rain continually poured but at lesser peaks. The last observed peak reached 4.6 mm on August 10, 2012 at 12:00 PM.

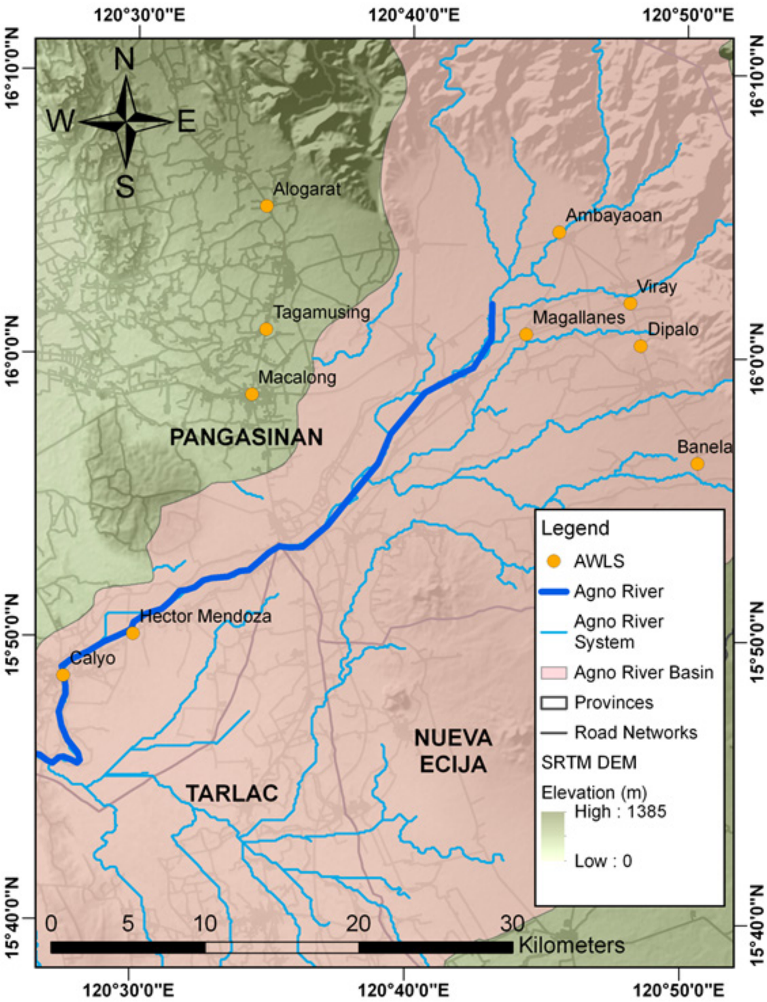


Figure 45. Location of AWLS in Agno River survey

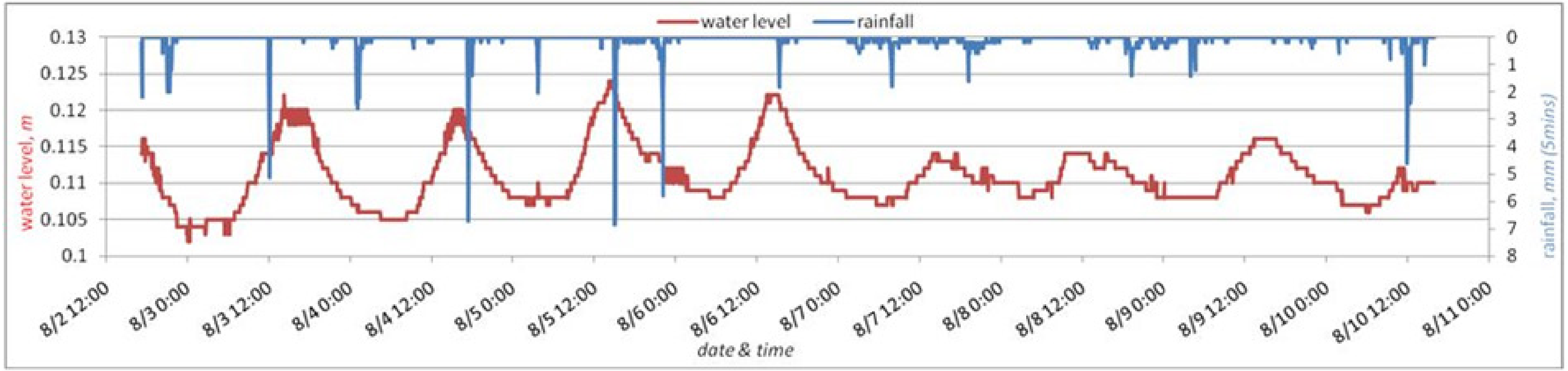


Figure 46. Relationship between rainfall and water level of Agno River within the observation period.

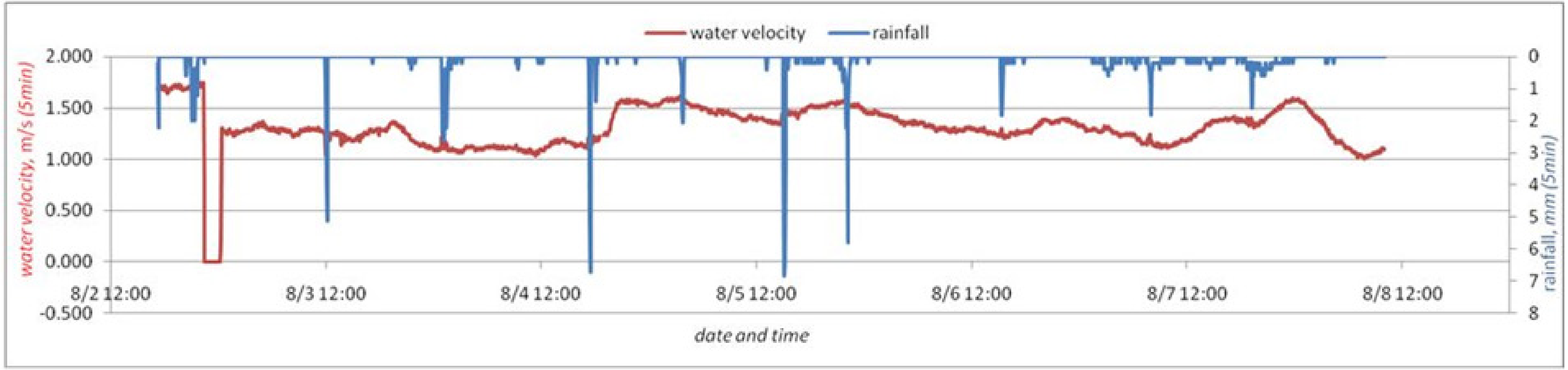


Figure 47. Relationship between rainfall and water velocity of Agno River within the observation period.

The graph on Figure 47 shows peaks in the amount of rainfall corresponded with peaks in water velocity. Water level measurements show pronounced variations in the first five days which have slightly lessened in the last five days. Abrupt changes in rainfall also seem to correspond with a more unstable water level. Plotting of hydrometric data gathered for water velocity & rainfall and water level & velocity are shown in Figure 46, Figure 47, and Figure 48 respectively. Discharge is also measured by multiplying the velocity of the river (measured by the ADCP) and the cross-sectional area within the polygon bounded by the stage and cross-section as presented in Figure 49.

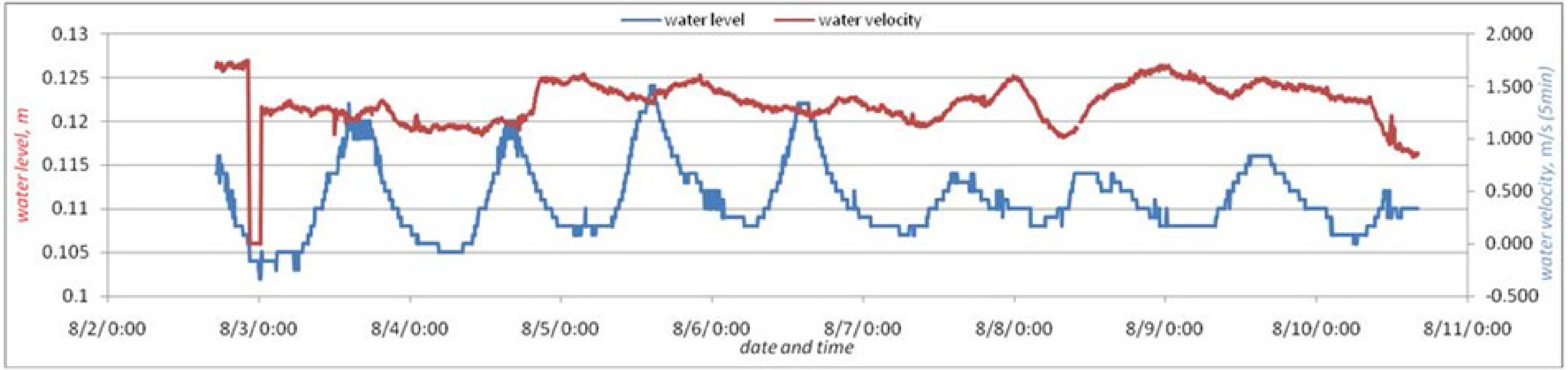


Figure 48. Relationship between water velocity and water level of Agno River within the observation period.

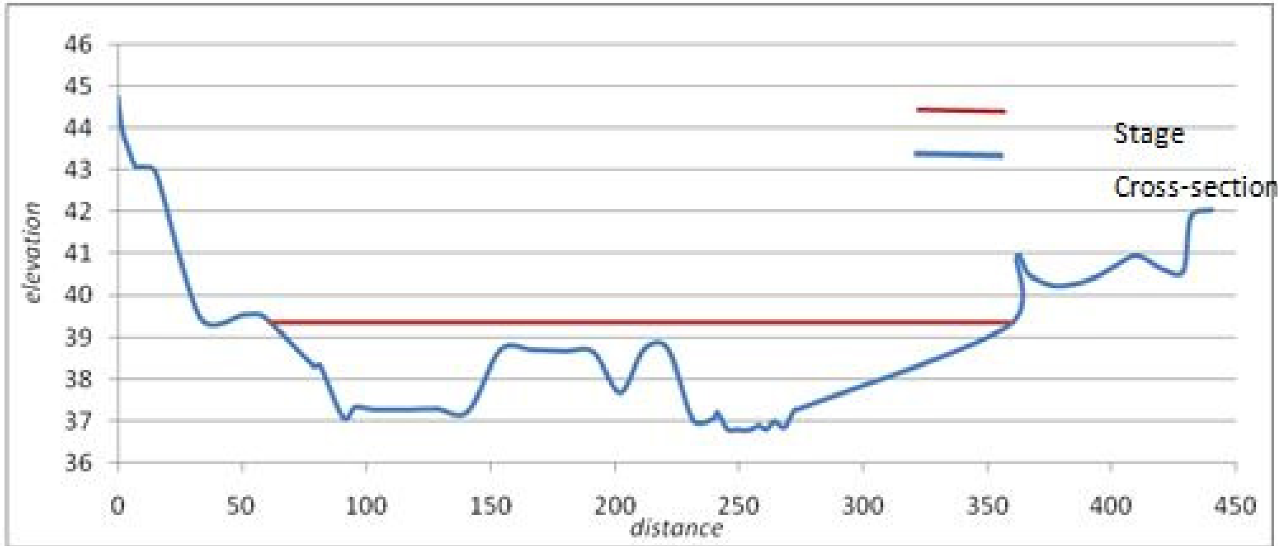


Figure 49. Stage and the cross-section along the ADCP deployment site in Barangay Paitan, Sta. Maria, Pangasinan

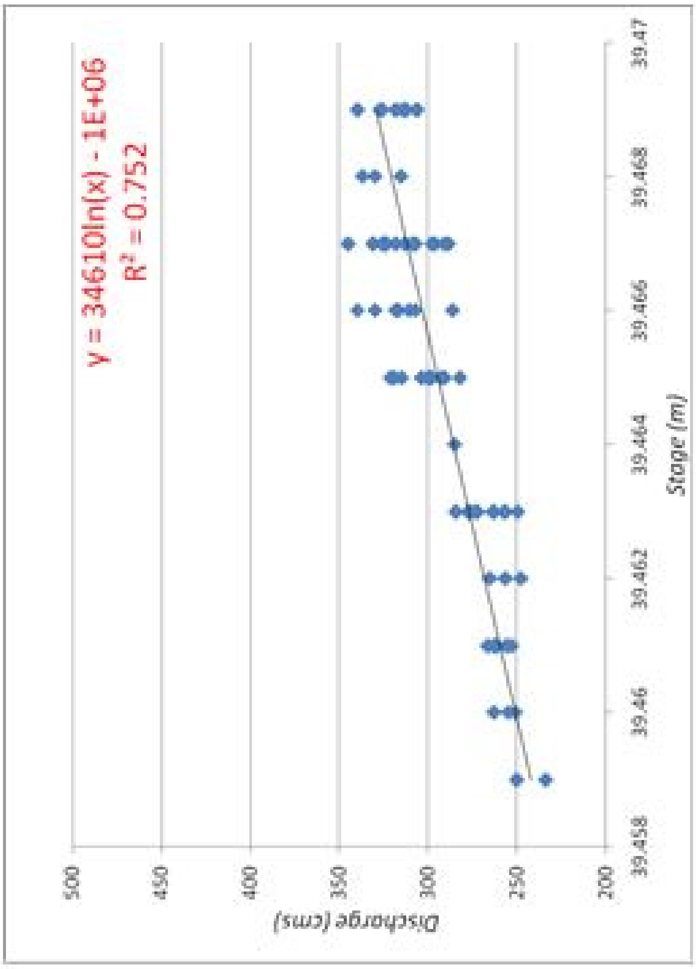


Figure 50. Derived rating curve along the Agno River using velocity magnitude averaged along the measurement profile.

During the field survey of gathering points for LiDAR data validation on May 15 to 18, 2013, four (4) tributaries of Agno River were inspected and flow measurements was conducted by deploying a flow meter and. Cross section data was also acquired to obtain to compute for the discharge of each tributary. A map taken from Google Earth on Figure 51 shows the location where the flow meter was deployed. Cross-section diagrams of the deployment sites were presented in Figure 52 and Figure 53.

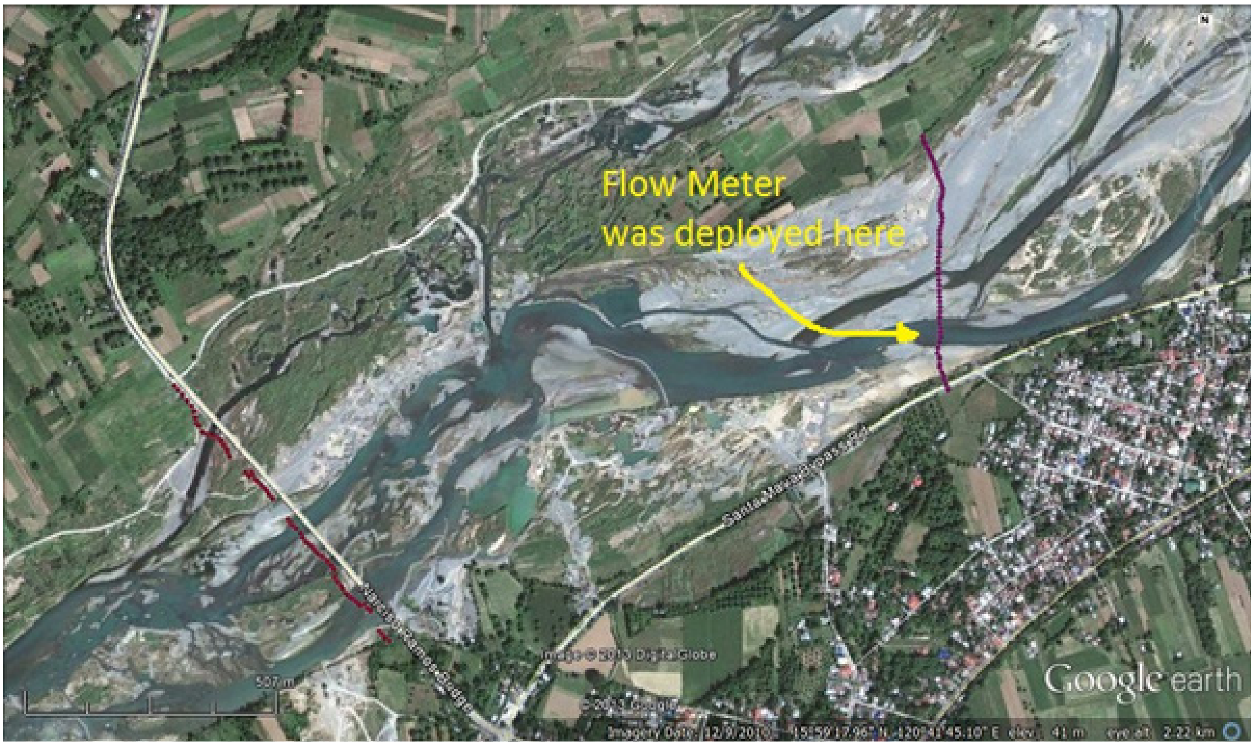


Figure 51. Map showing the location of deployment of Flow Meter in Agno River Survey

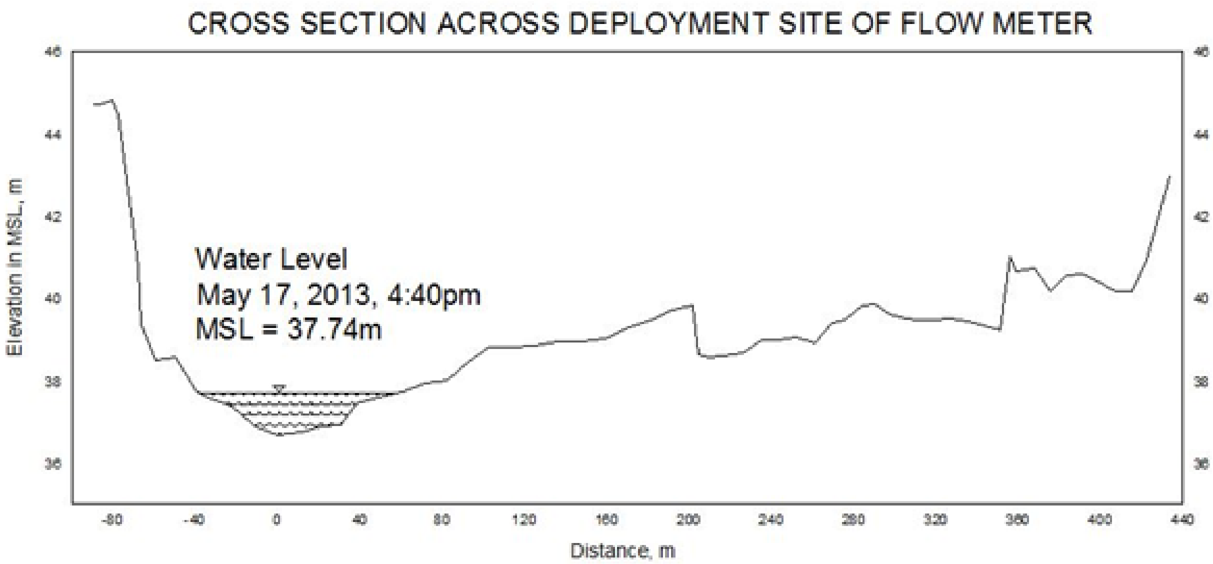


Figure 52. Diagram showing cross-section across the deployment site of Flow meter

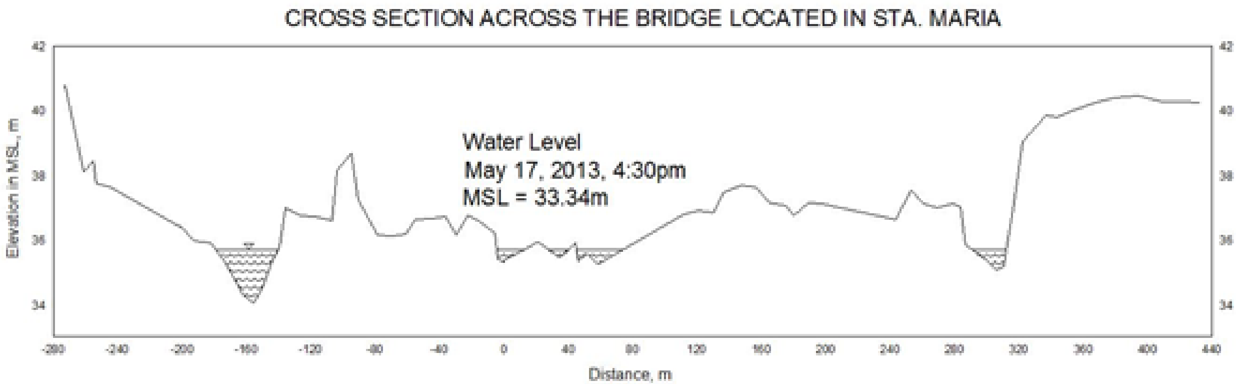


Figure 53. Diagram showing the cross-section of Agno River near the bridge in Sta. Maria

4.6.2 Agno River AWLS Survey

Cross-section survey of 11 bridges with installed AWLS was conducted on September 3-6, 2-13, 2013. The survey was conducted for the installed AWLS on Agno River in order to get its cross-sectional area and water surface elevation in MSL. River velocity was also acquired using vertical and side-looking ADCP and digital flow meter. The ADCP and flow meter were entrusted to a local living near the bridge to gather river velocity measurements during the course of the survey (see Table 11 for Velocity Capturing Duration).

Cross-section survey of 10 bridges with installed AWLS was conduected on September 3-6, 2013. Depth gauges were also deployed at Hector Mendoza Bridge from August 4, 2012 until its retrieval on August 11, 2012; and in Brgy. Paitan, Sta. Maria, Pangasinan from August 2, 2012 until its retrieval on August 11, 2012.

4.6.2.1 Cross-Section Survey

The summary of ten (10) bridges with AWLS in Agno River with corresponding coordinates, date and time of elevation determination and duration of flow data gathering, and images are shown in Table 11.

Table 11. Summary of Cross-section of the ten (10) bridges with AWLS in Agno River Basin

STATION NAME	COORDI-NATES	WATER LEVEL (MSL)	VELOCITY	ELEVATION (MSL)	IMAGES
Ambayaoan Bridge	16-04-24.889 N, 120-45-23.396 E	77.558 m (Sept.3, 2013 at 4:37 PM)	Sept.5, 2013 04:05PM-5:05PM	85.4363 m	
Viray Bridge	16-01-56.326 N, 120-48-00.358 E	86.133 m (Sept.3, 2013 at 3:56 PM)	Sept.5, 2013 10:33AM-12:53PM	91.85553 m	
Banela Bridge	15-56-17.724 N, 120-50-30.700 E	101.411 m (Sept.3, 2013 at 5:03 PM)	Sept.5, 2013 2:25PM-4:25PM	110.5183 m	
Magallanes Bridge	16-00-47.755 N, 120-44-13.449 E	50.677 m (Sept.3, 2013 at 6:07 PM)	Sept.5, 2013 10:15AM-12:05PM	58.603 m	
Aloragat Bridge	16-05-14.289 N, 120-34-43.194 E	41.629 m (Sept.4, 2013 at 3:54 PM)	N/A	52.531 m	
Macalong Bridge	15-58-35.275 N, 120-34-15.320 E	21.875 m (Sept. 4, 2013 at 2:28 PM)	N/A	25.630 m	

Table 11. Summary of Cross-section of the ten (10) bridges with AWLS in Agno River Basin

STATION NAME	COORDI-NATES	WATER LEVEL (MSL)	VELOCITY	ELEVATION (MSL)	IMAGES
Tagamusing Bridge	16-00-52.864 N, 120-34-44.828 E	23.842 m (Sept.4, 2013 at 2:59 PM)	N/A	32.951 m	
Hector Mendoza Bridge	15-50-06.012 N, 120-30-01.275 E	16.873 m (Sept.5, 2013 at 1:06 PM)	Sept.5, 2013 10:40AM-12:40PM	26.985 m	
Calvo Bridge	15-48-35.197 N, 120-27-30.049 E	12.858 m (Sept.4, 2013 at 11:18 AM)	Sept.5, 2013 2:40PM-04:20PM	20.094 m	
Dipalo Bridge	16-0025.647 N, 120-48-23.979 E	89.065 m (Sept.3, 2013 at 4:26PM)	Sept.5, 2013 10:25AM-01:25PM	94.8703 m	

The cross-sectional view and elevation in MSL of AWLS and water surface with specific date and time can be found in Figure 54 to Figure 63.

Agno River Basin Survey

A. AWLS on the right upstream of Agno River

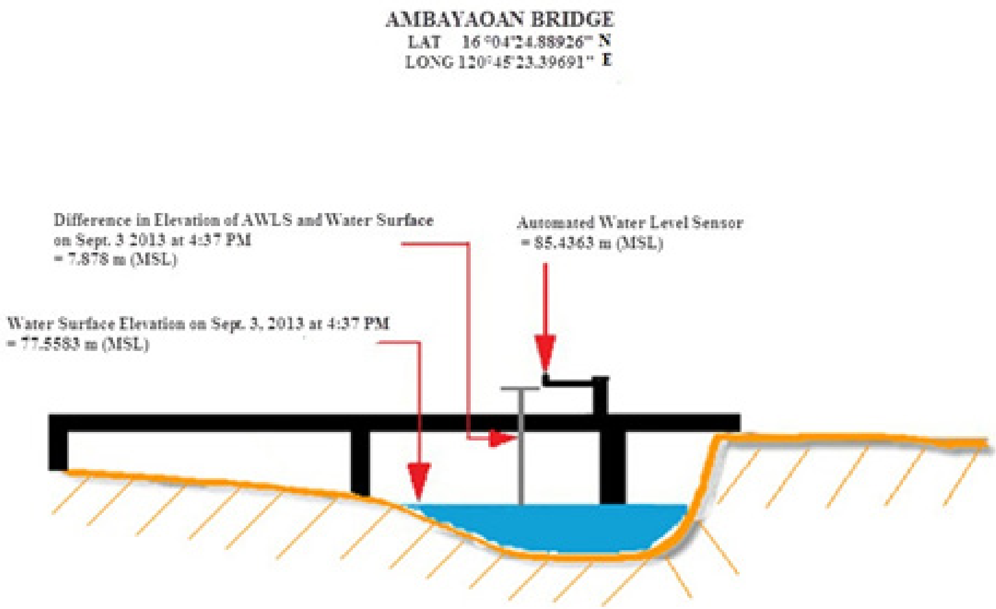


Figure 54. AWLS in Ambayaoan bridge

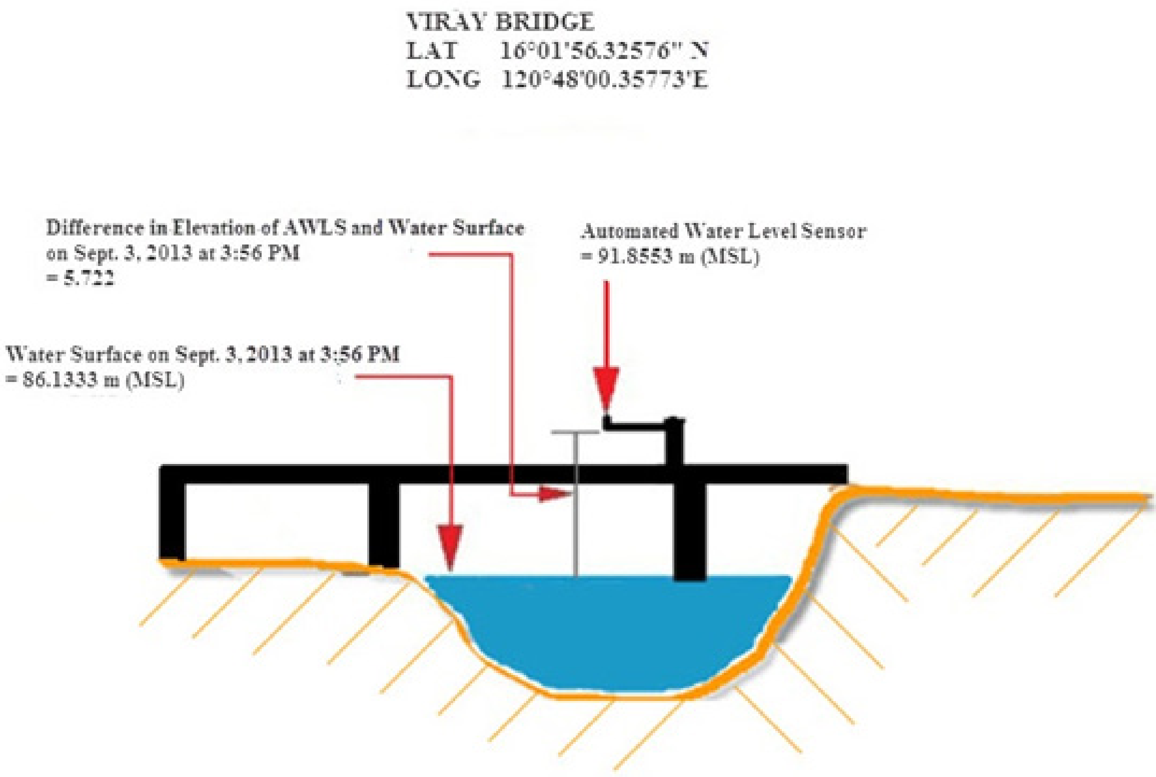


Figure 55. AWLS in Viray bridge

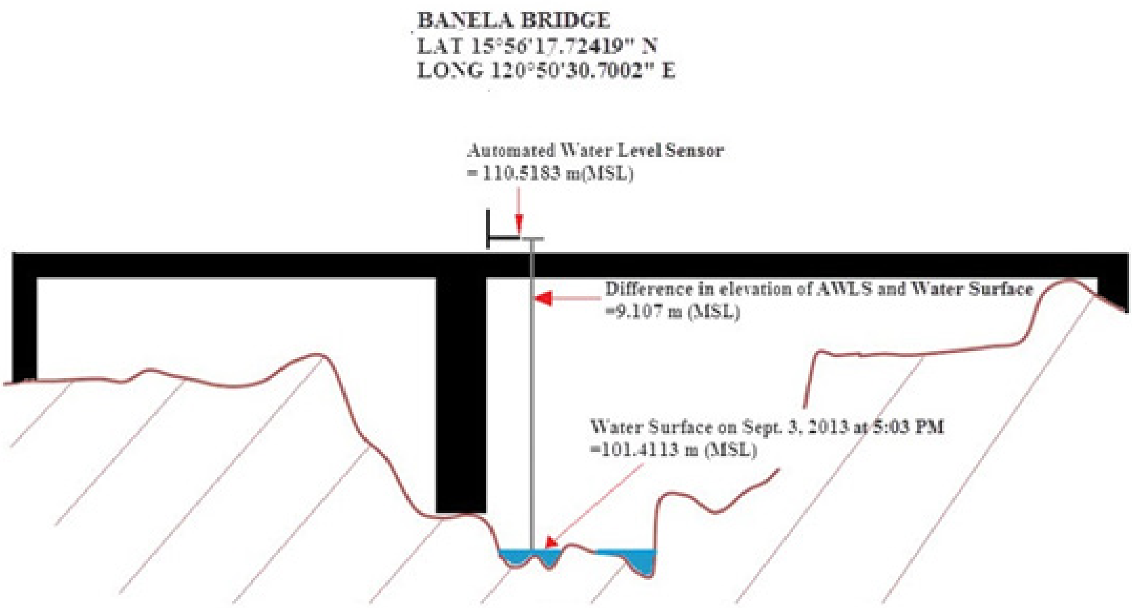


Figure 56. AWLS in Banela bridge

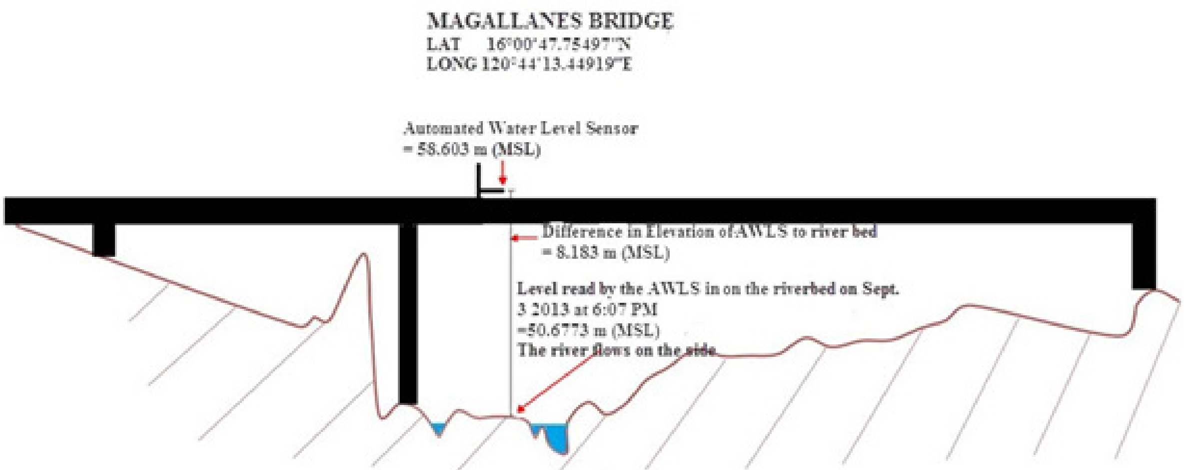


Figure 57. AWLS in Magallanes bridge

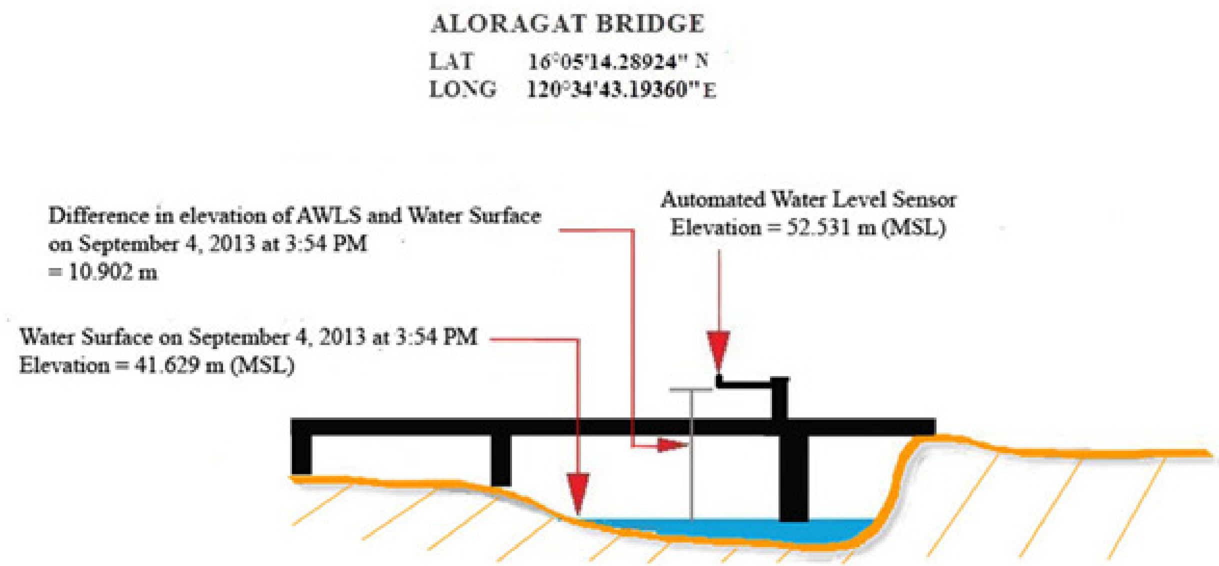


Figure 58. AWLS in Alogarat bridge

B. AWLS on the left upstream of Agno river

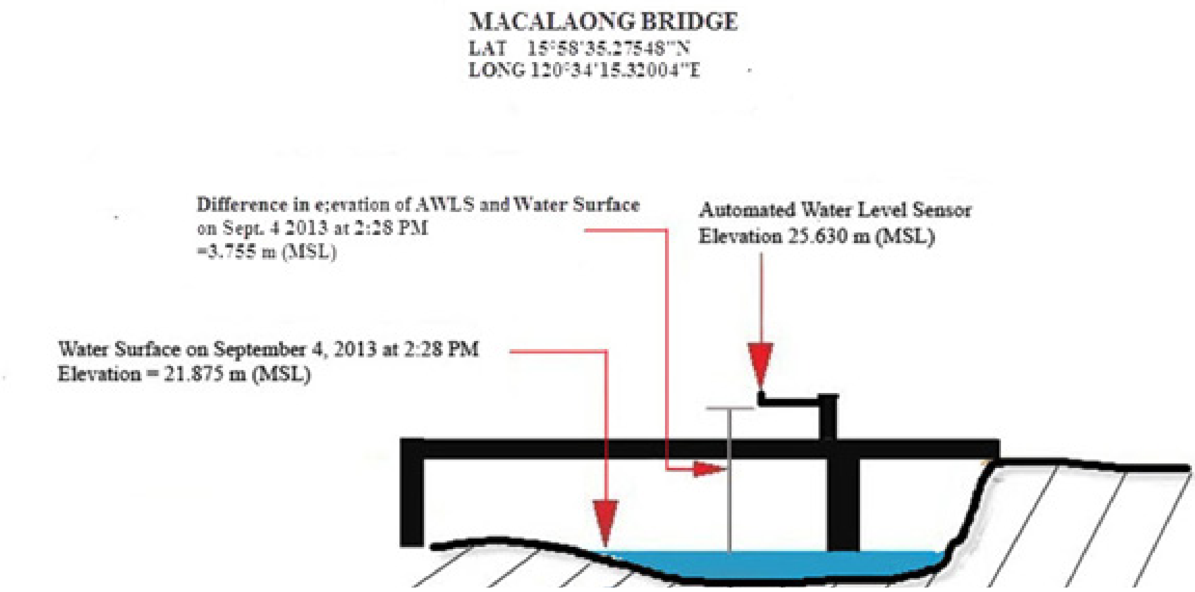


Figure 59. AWLS in Macalong bridge

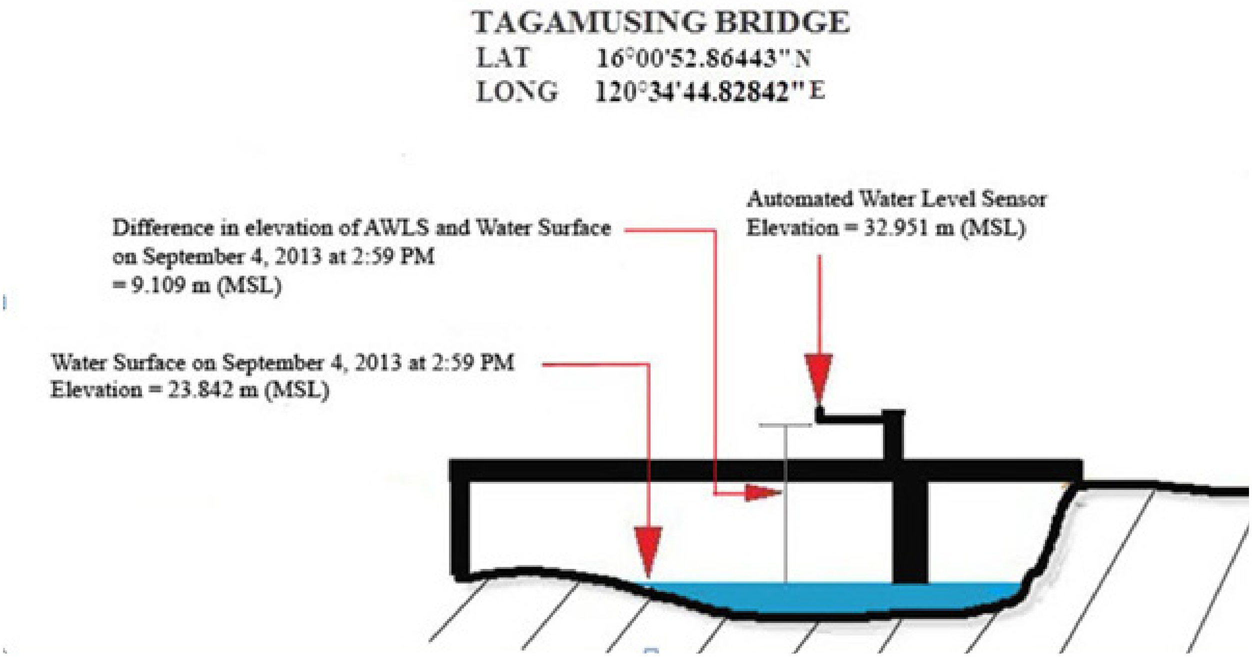


Figure 60. AWLS in Tagamusing bridge

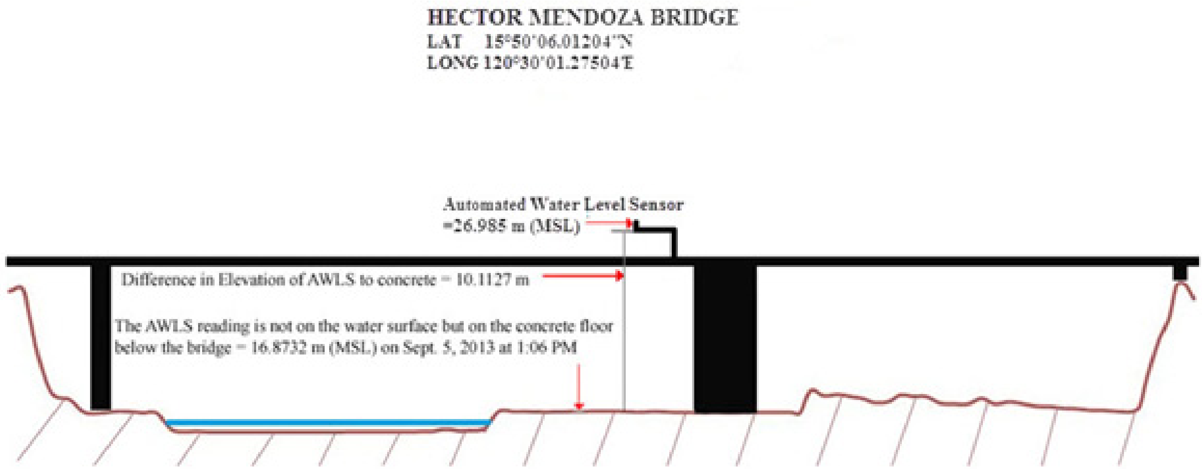


Figure 61. AWLS in Hector Mendoza bridge

C. AWLS on the mainstream of Agno River

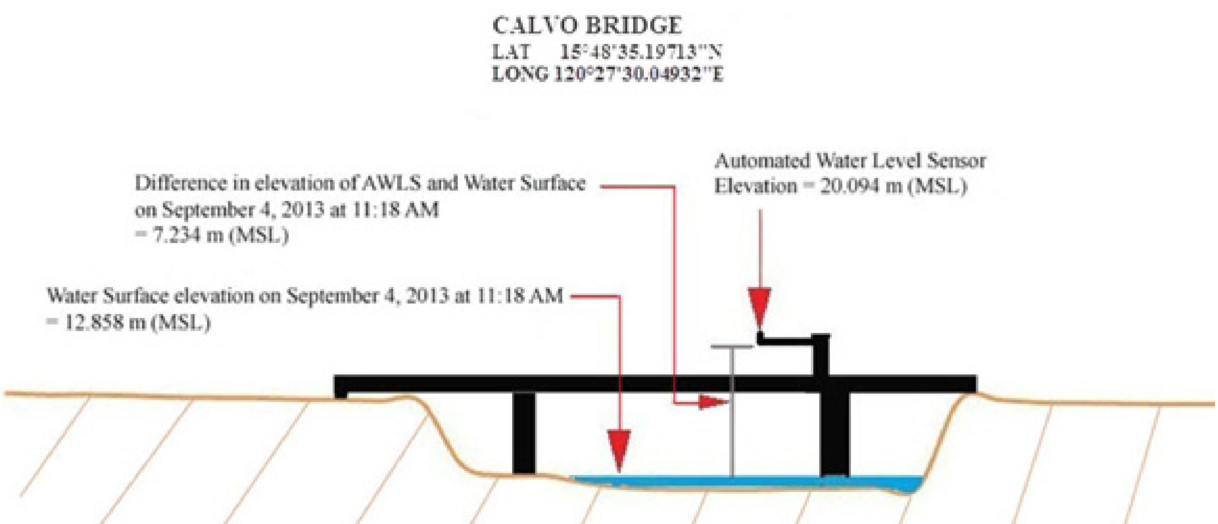


Figure 62. AWLS in Calyo bridge

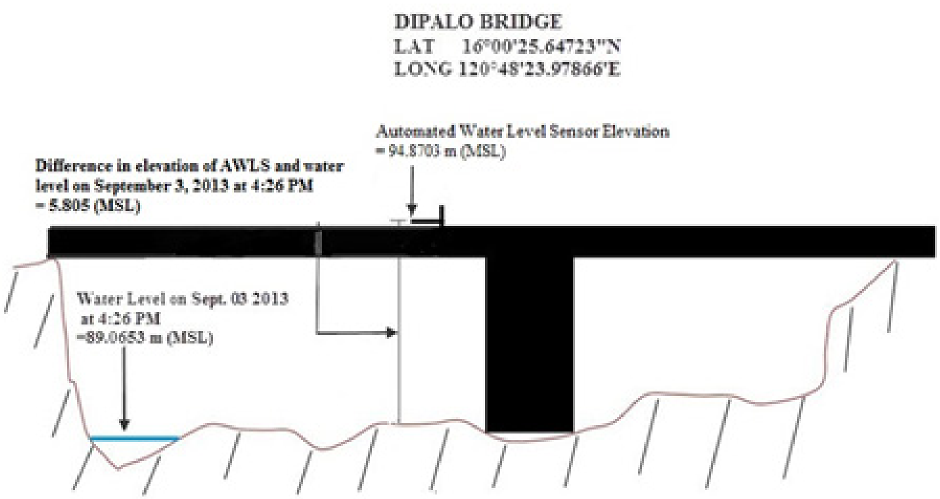


Figure 63. AWLS in Dipalo bridge

4.6.2.2 Flow Measurement

The sensor data of the deployed flow meter and depth gauge during the Agno AWLS cross-section field survey can be seen in the graph presented from Figure 64 to Figure 91.

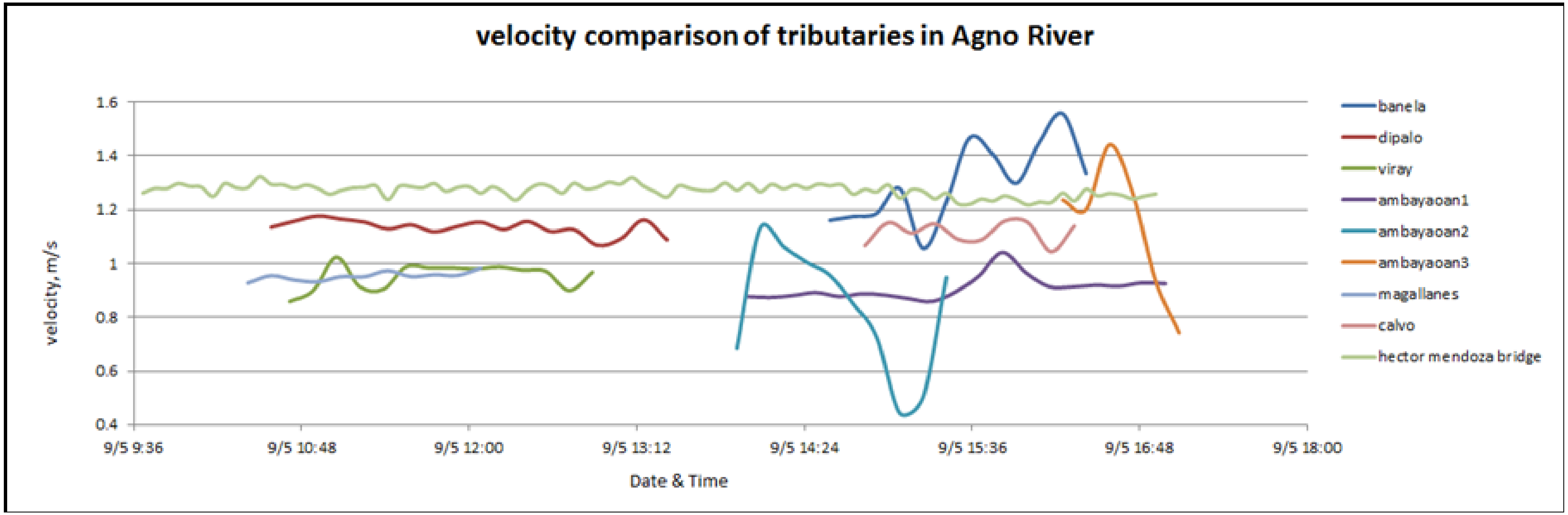


Figure 64. Comparison of Velocities of tributaries in Agno River

A. Sensor graphs and HQ at Ambayaoan Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Ambayaoan bridge on September 2 to 8, 2013 are shown from Figure 65 to Figure 68.

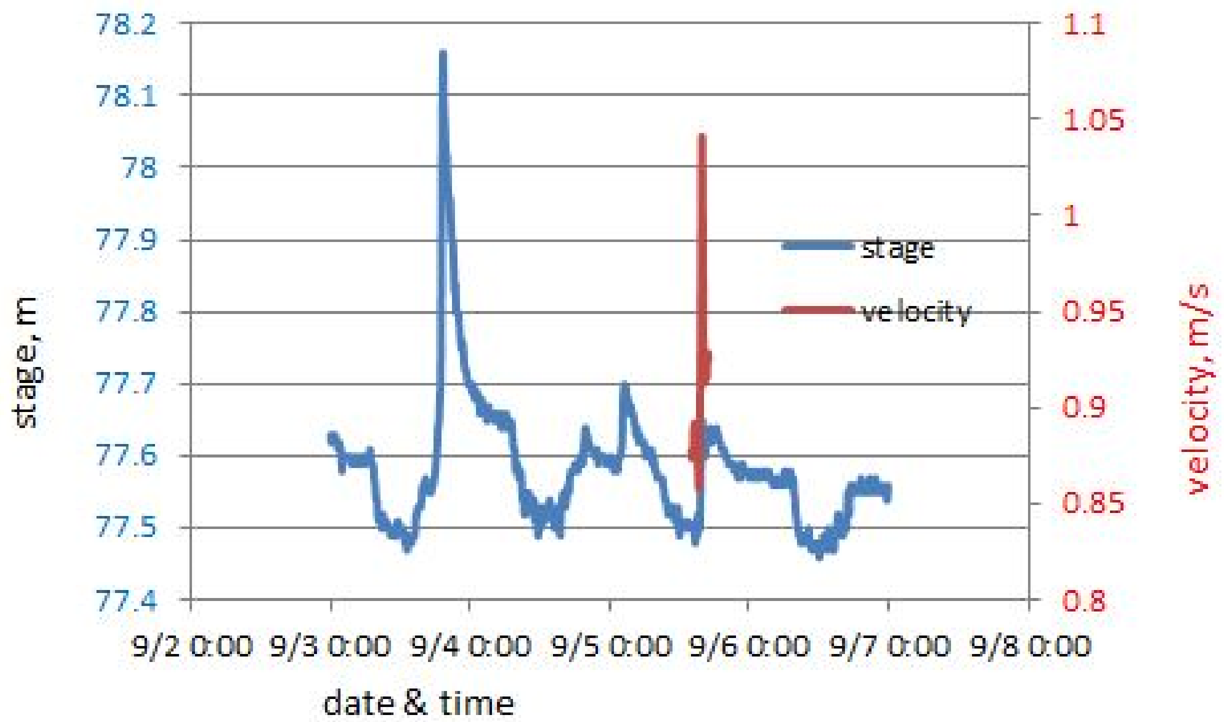


Figure 65. Relationship between stage and velocity in Ambayaoan bridge

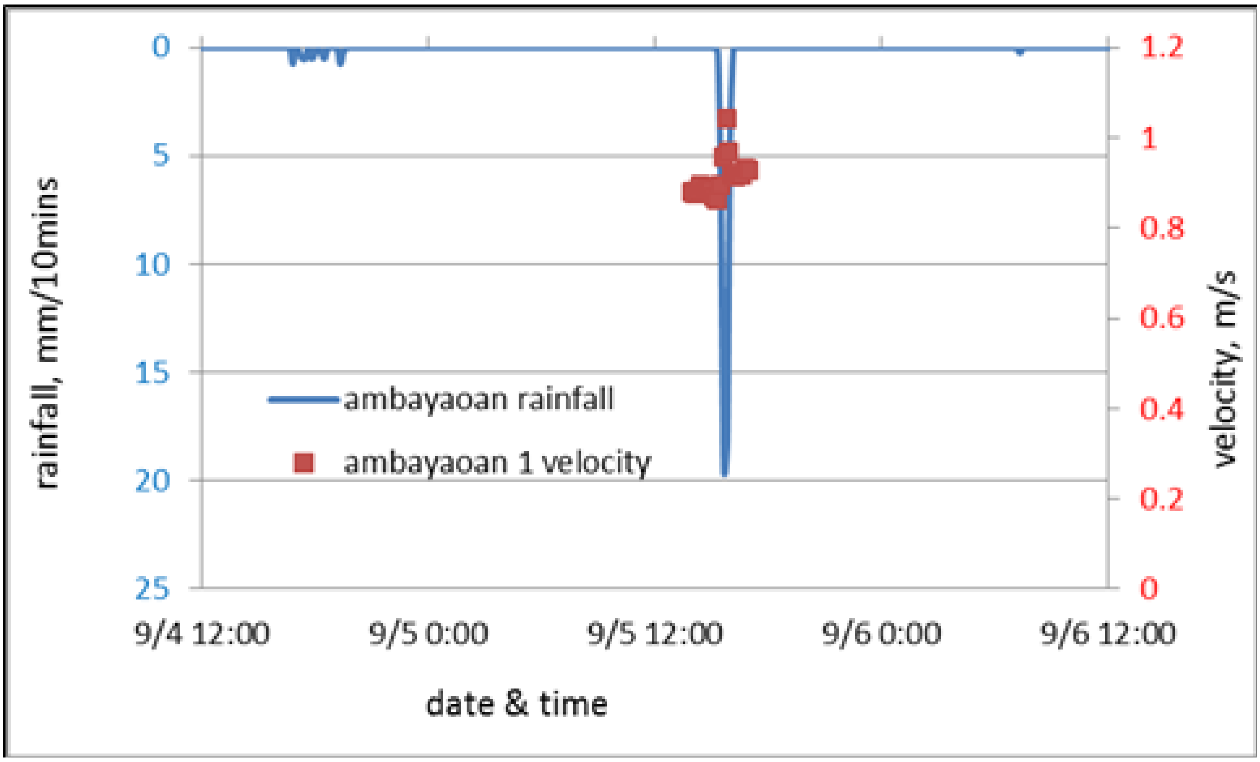


Figure 66. Relationship between rainfall and velocity in Ambayaoan bridge

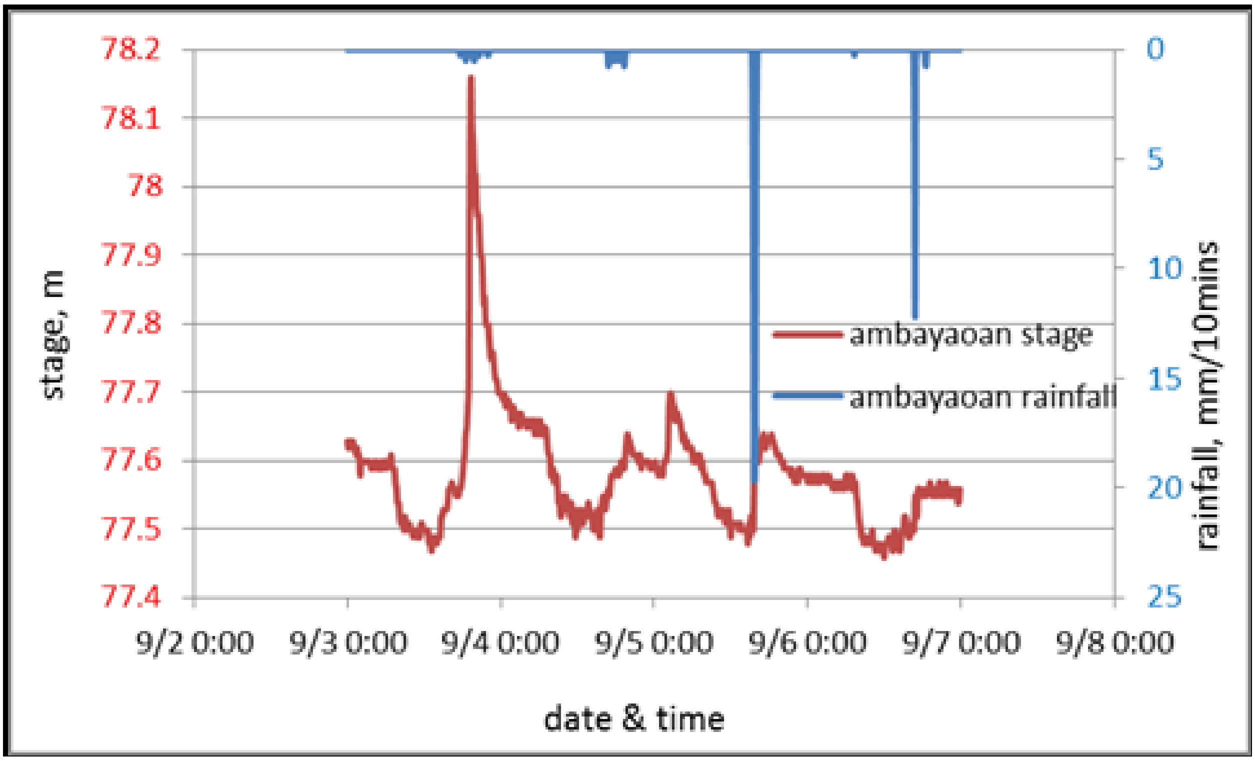


Figure 67. Relationship between stage and rainfall at Ambayaoan bridge

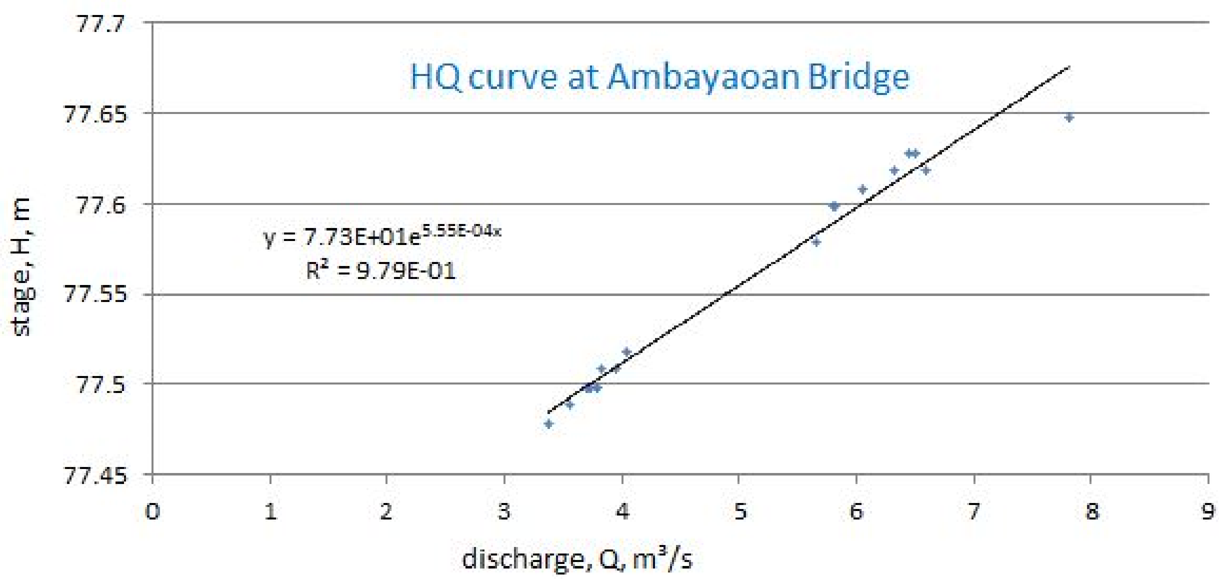


Figure 68. Stage-discharge computation at Ambayaoan bridge

B. Sensor Graphs and HQ at Banela Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Banela Bridge on September 3 to 8, 2013 are shown from Figure 69 to Figure 72.

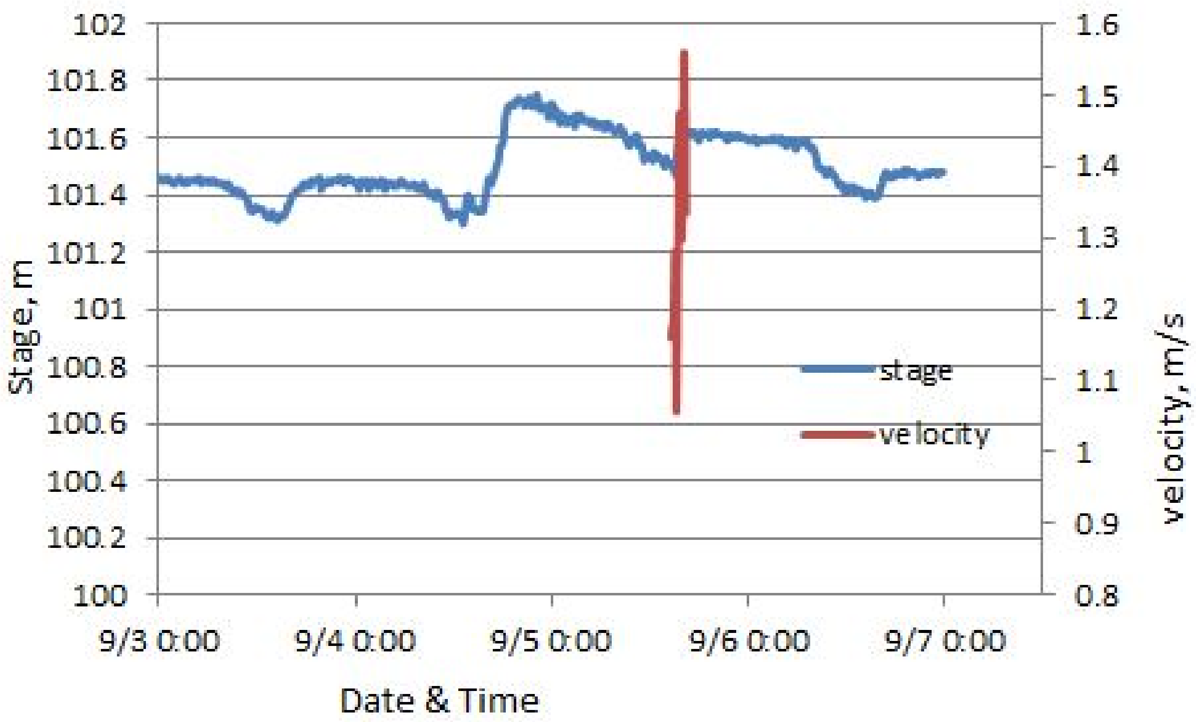


Figure 69. Relationship between stage and velocity in Banela bridge

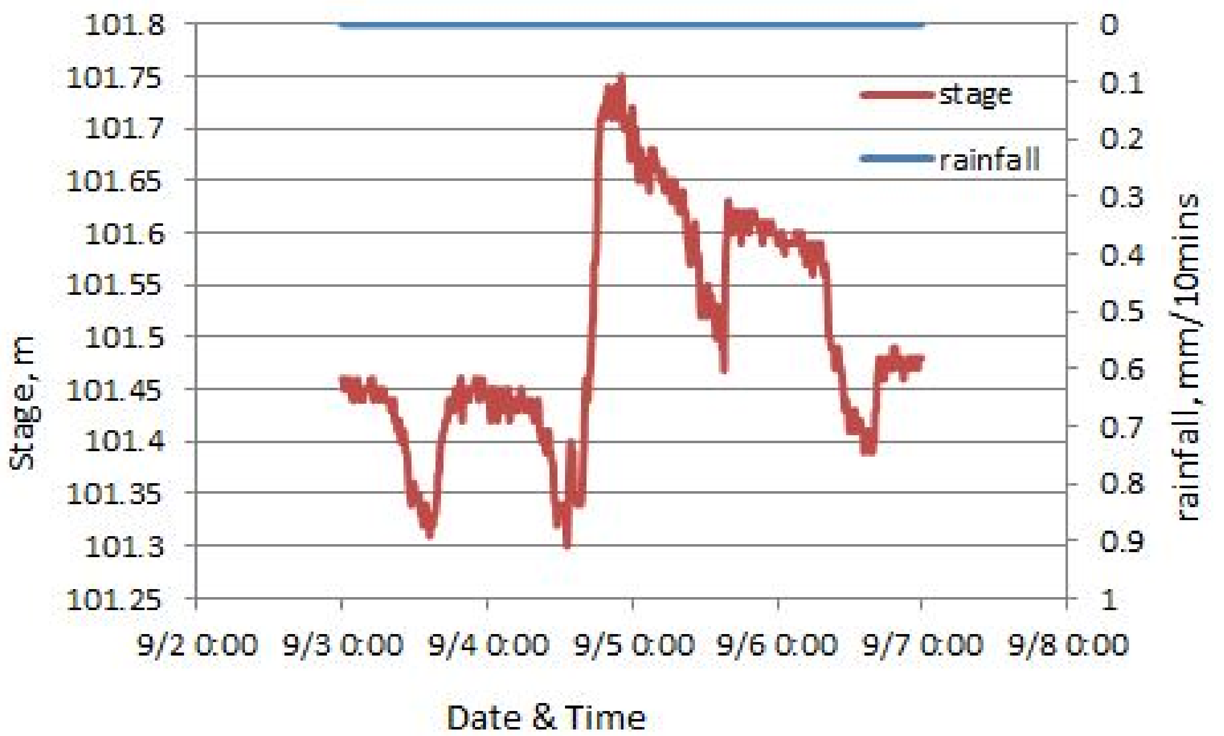


Figure 70. Relationship between stage and rainfall in Banela bridge

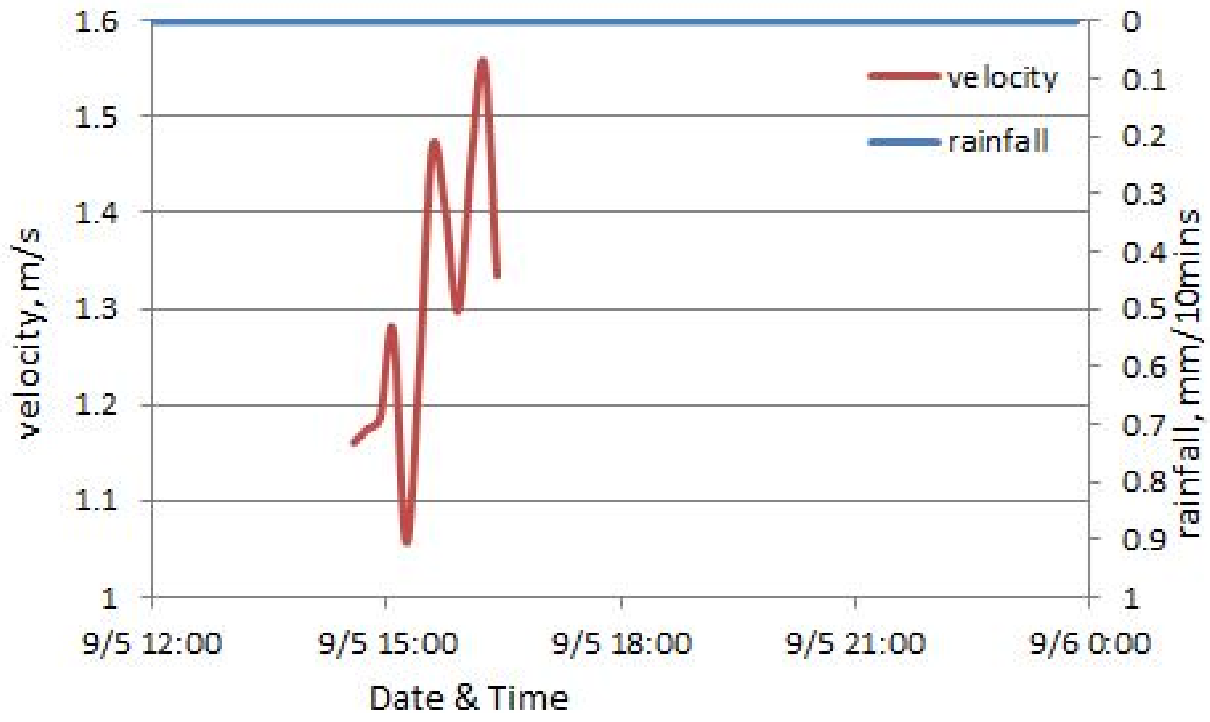


Figure 71. Relationship between velocity and rainfall in Banela bridge

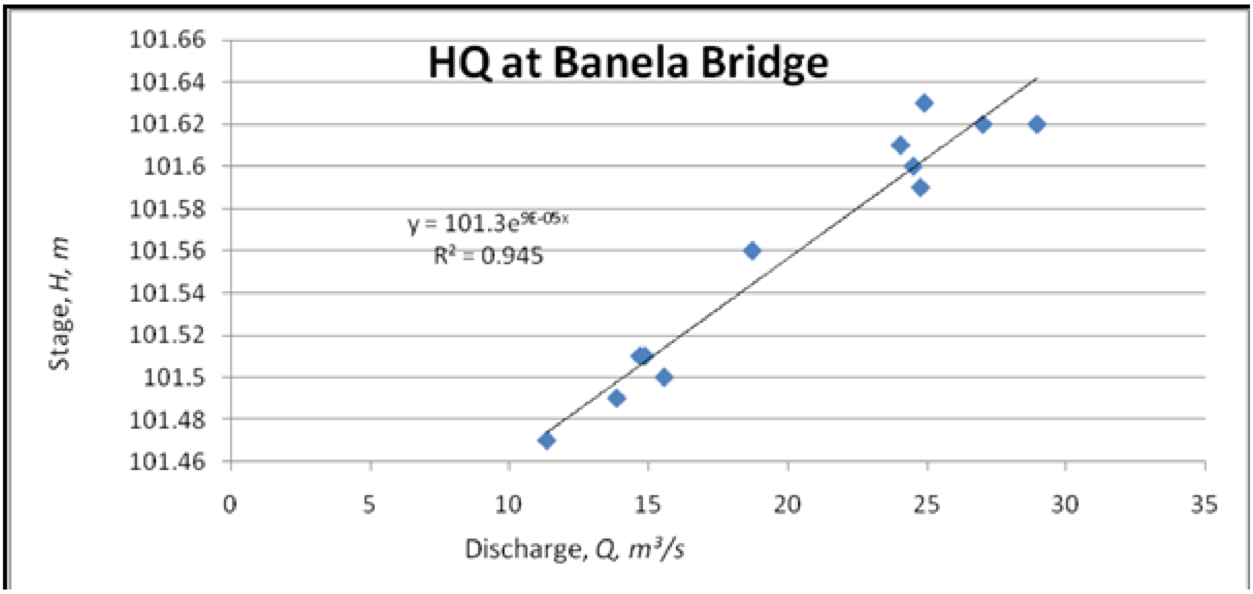


Figure 72. Stage-discharge computation for Banela bridge

C. Sensor Graphs and HQ at Magallanes Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Magallanes Bridge are shown from Figure 73 to Figure 76.

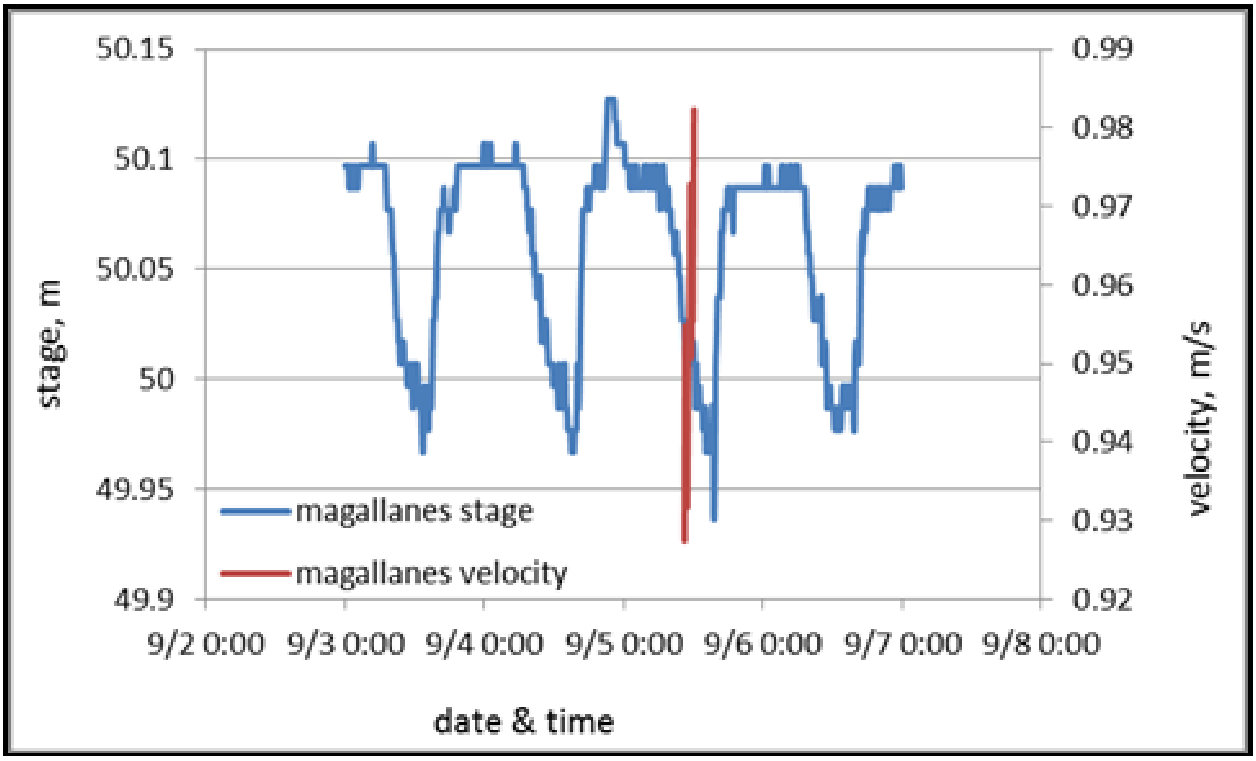


Figure 73. Relationship between stage and velocity in Magallanes bridge

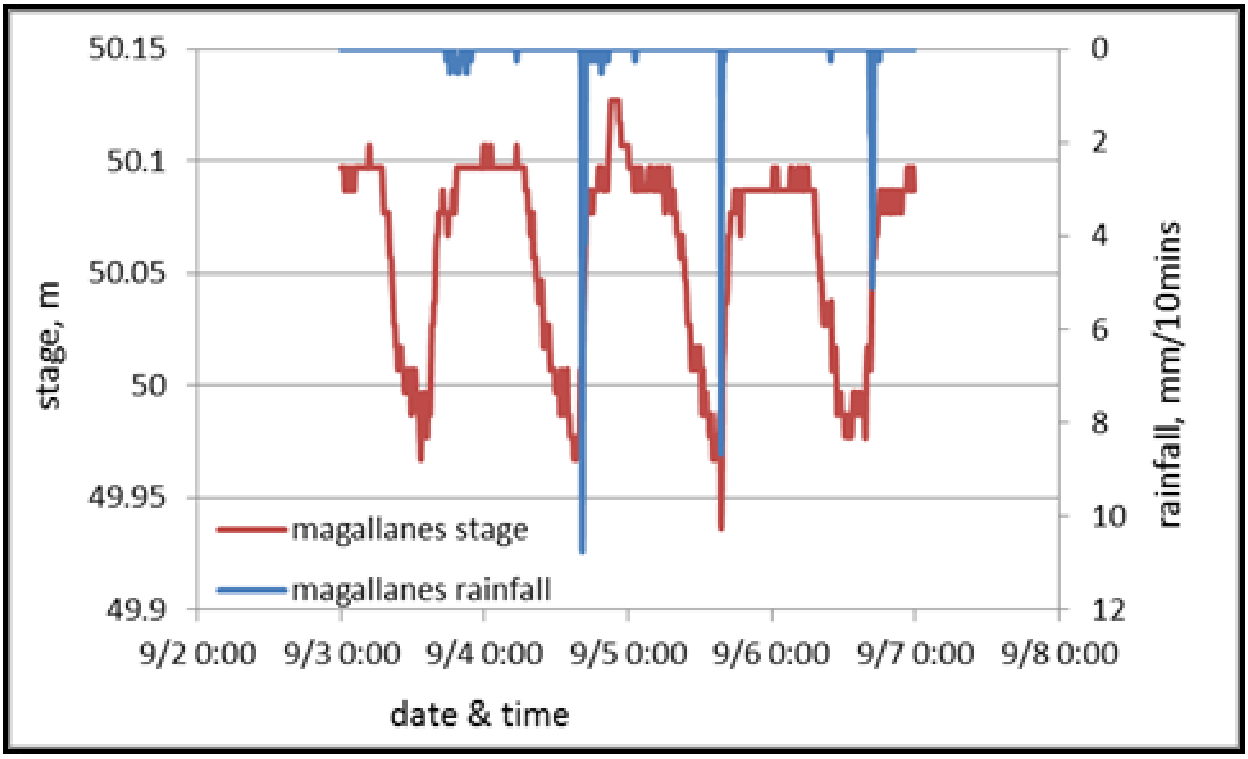


Figure 74. Relationship between stage and rainfall in Magallanes bridge

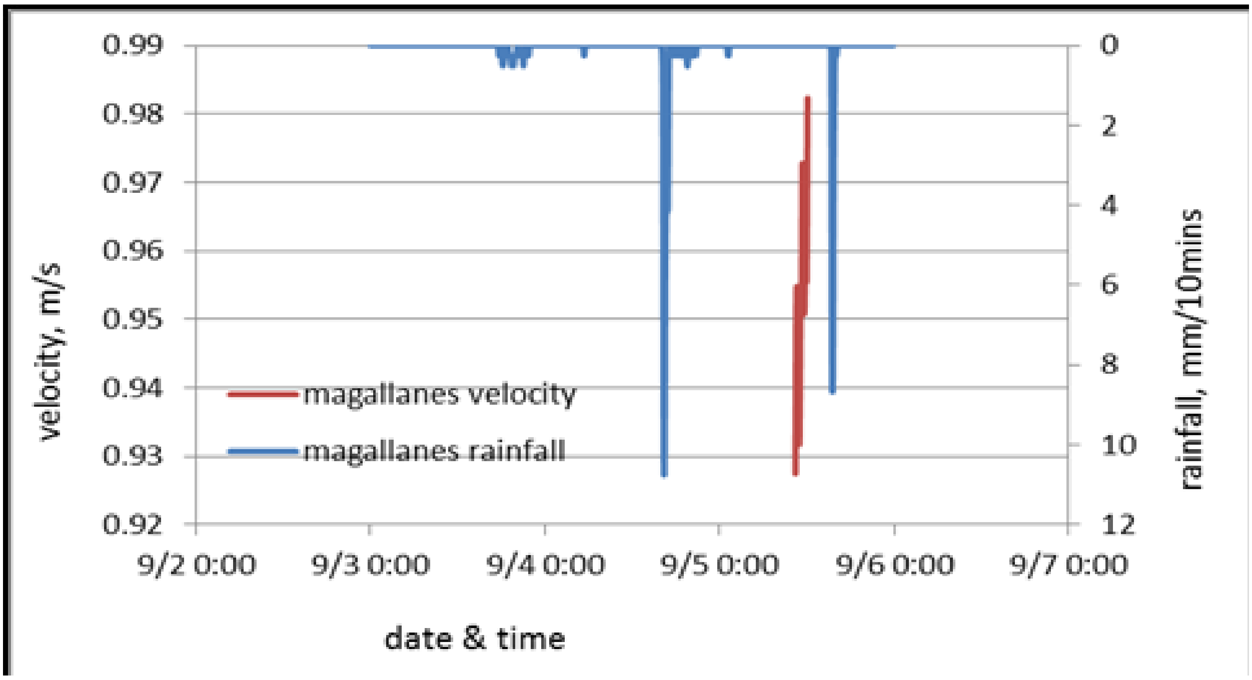


Figure 75. Relationship between rainfall and velocity in Magallanes bridge

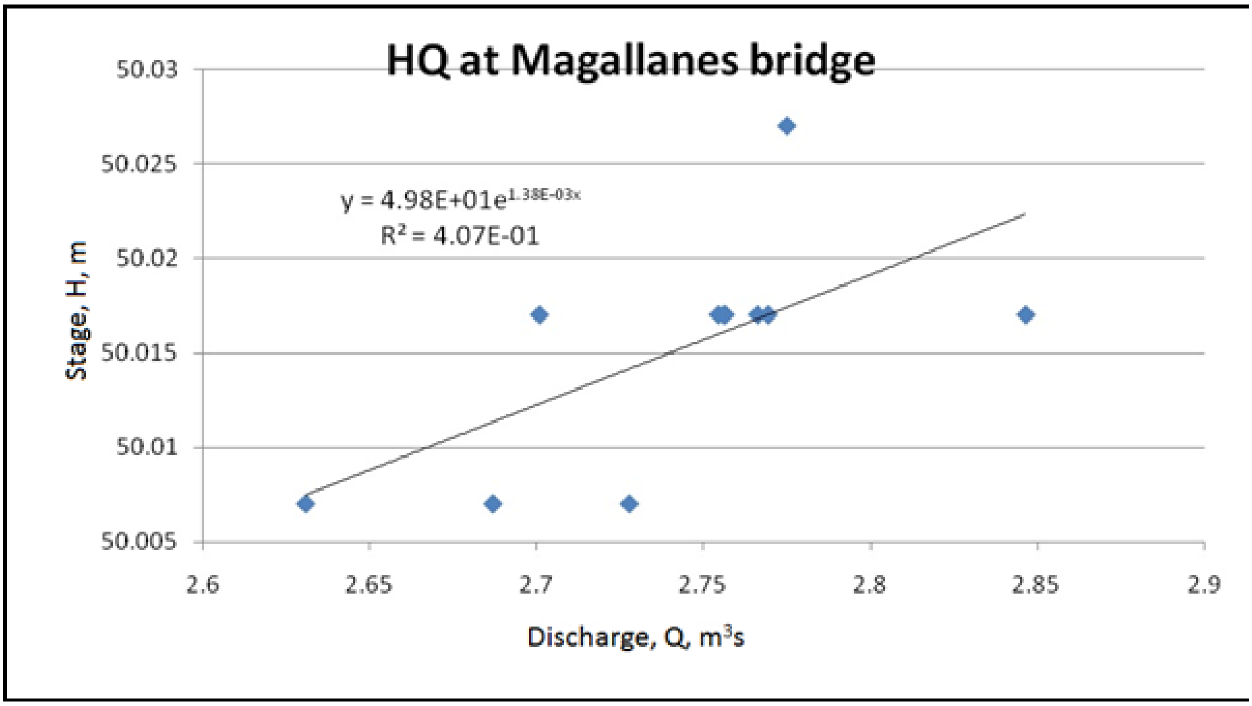


Figure 76. Stage-discharge computation at Magallanes bridge

D. Sensor Graph and HQ at Aloragat Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Aloragat Bridge is shown in Figure 77.

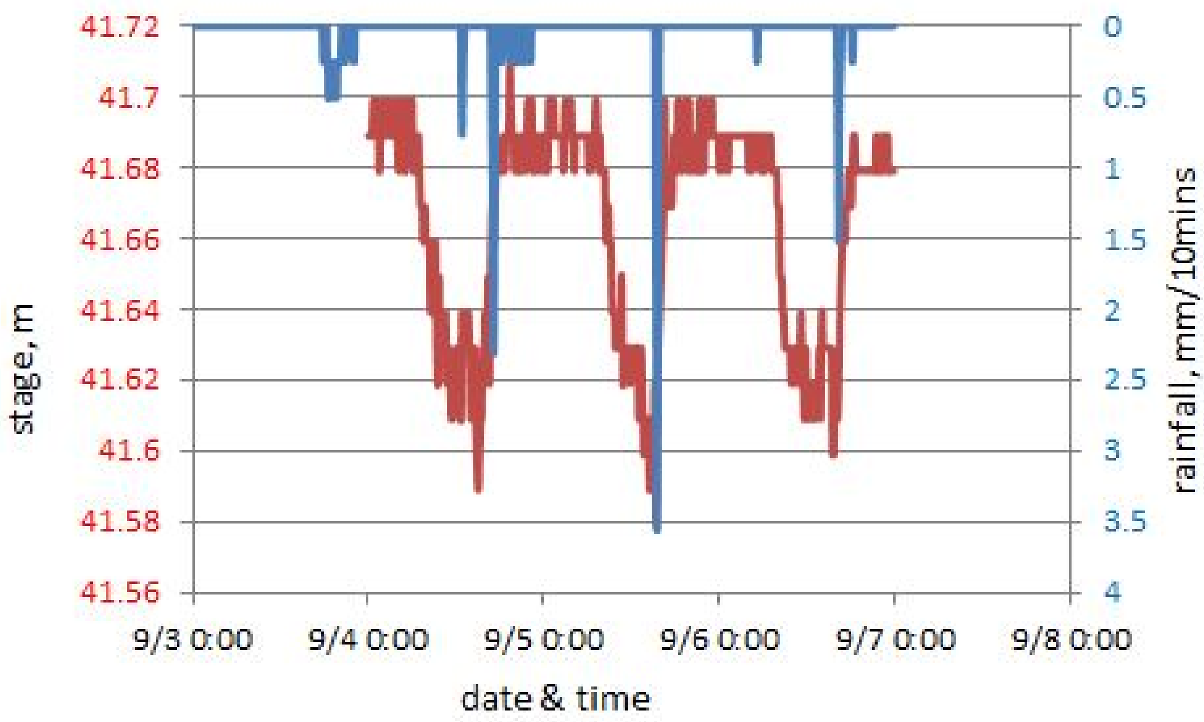


Figure 77. Relationship between stage and rainfall in Aloragat bridge

E. Sensor Graph of Macalong Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Macalong bridge is shown in Figure 78.

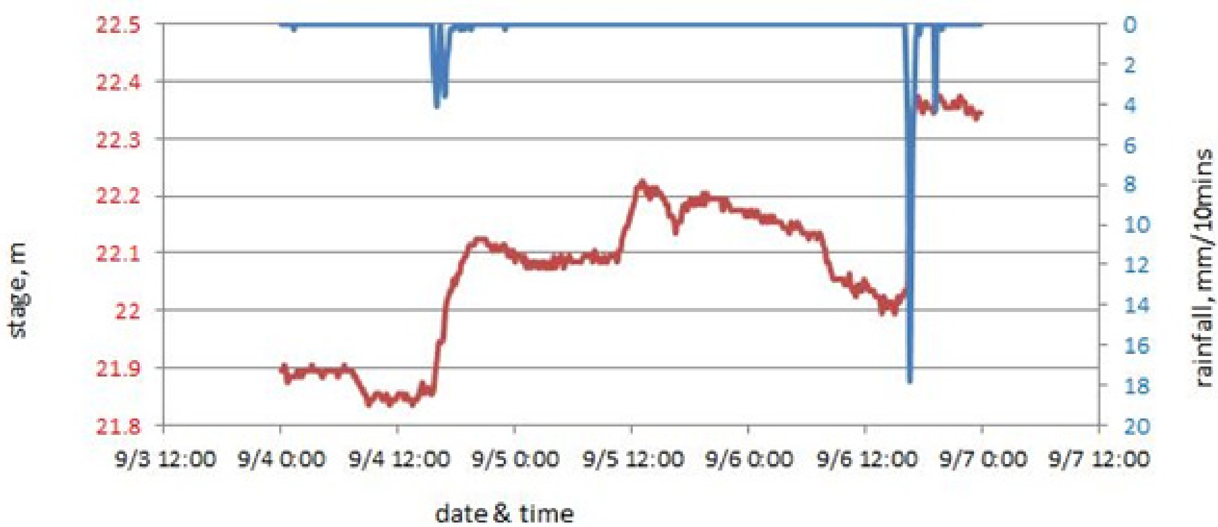


Figure 78. Relationship between stage and rainfall in Macalong bridge

F. Sensor Graph of Tagamusing Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Tagamusing bridge is shown in Figure 79.

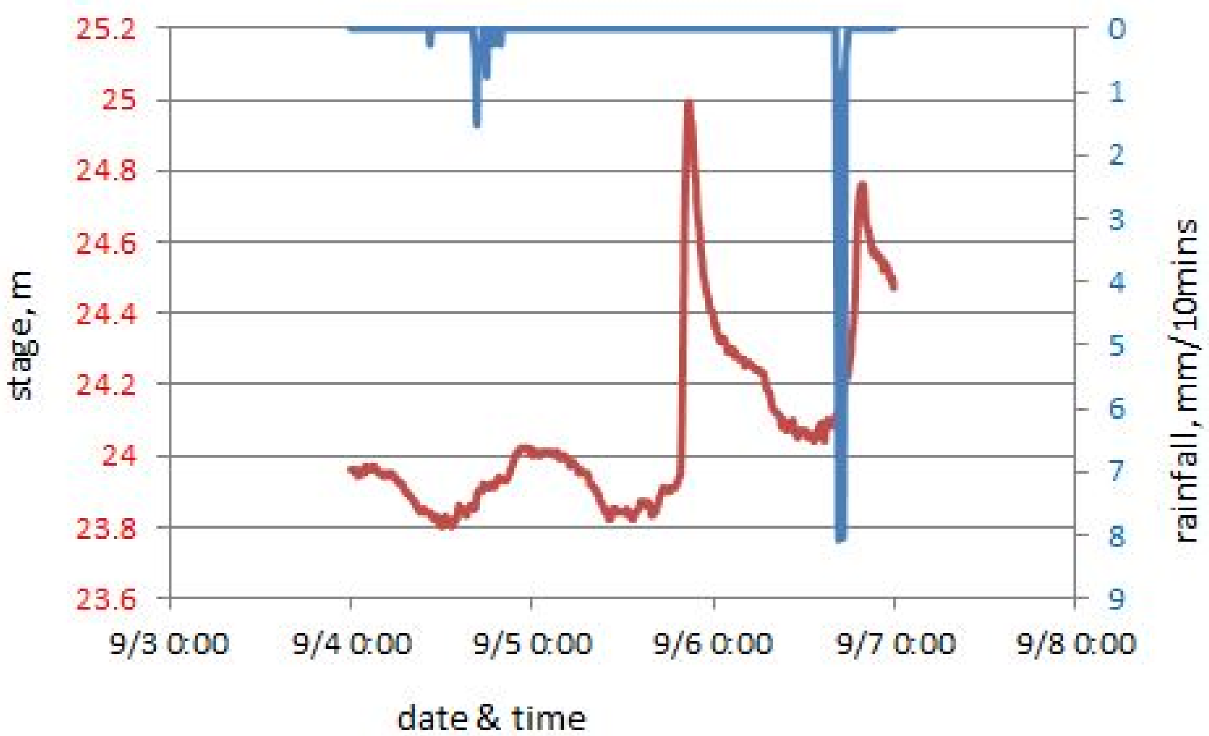


Figure 79. Relationship between stage and rainfall in Tagamusing bridge

G. Sensor Graphs and HQ at Hector Mendoza Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Hector Mendoza bridge are shown from Figure 80 to Figure 83.

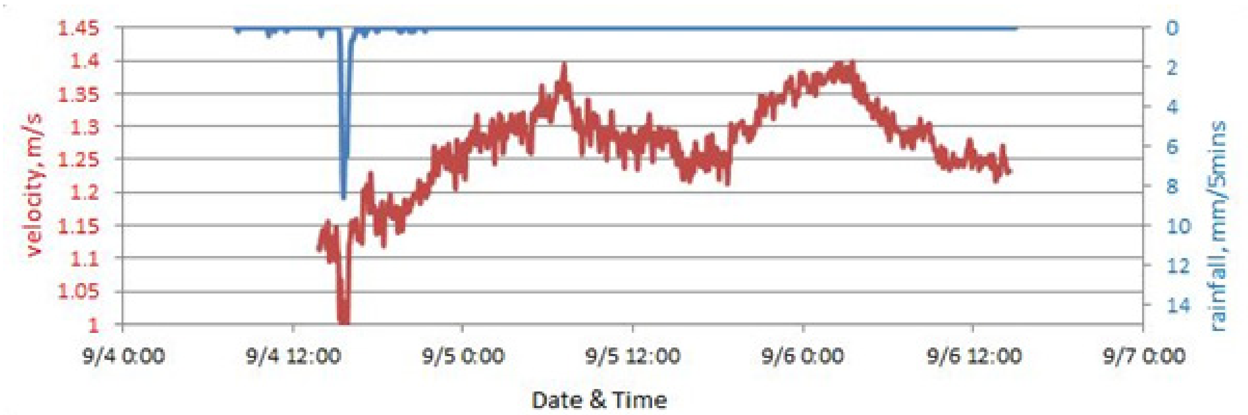


Figure 80. Relationship between velocity and rainfall in Hector Mendoza bridge

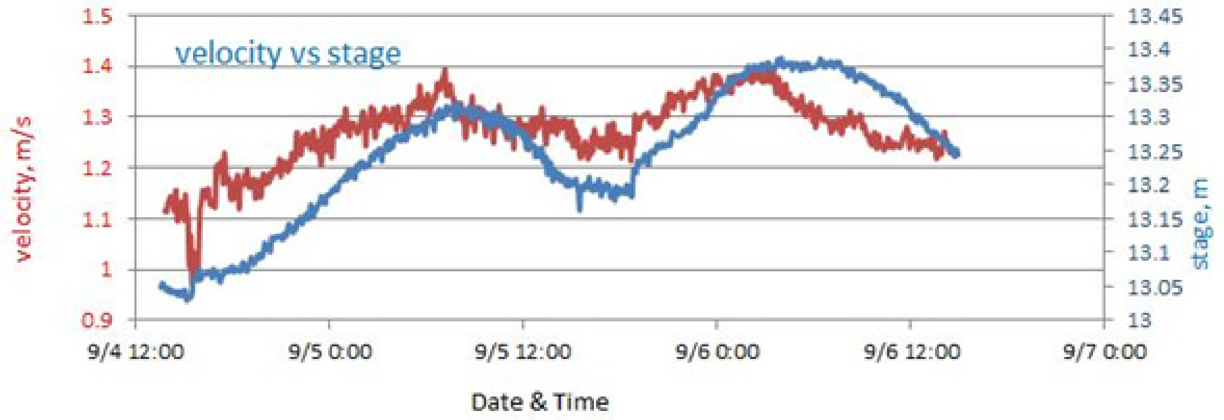


Figure 81. Relationship between velocity and stage in Hector Mendoza bridge

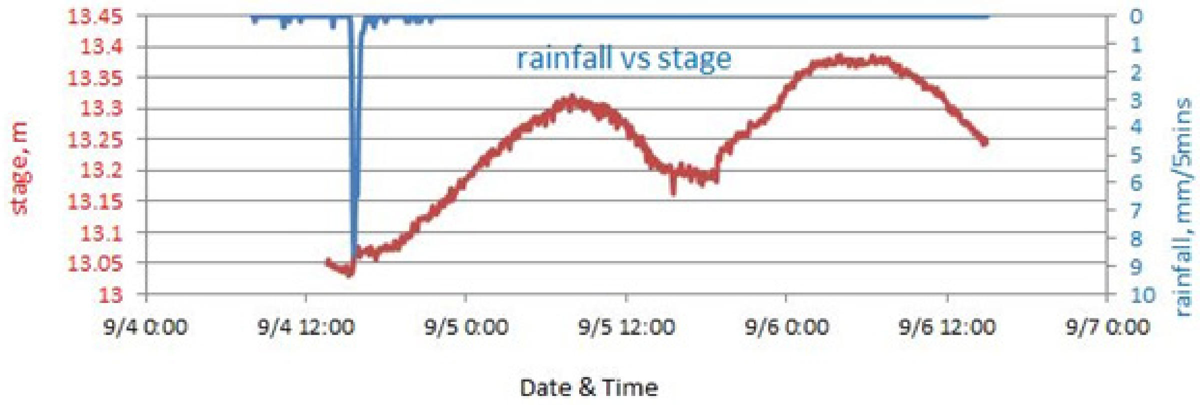


Figure 82. Relationship between rainfall and stage in Hector Mendoza bridge

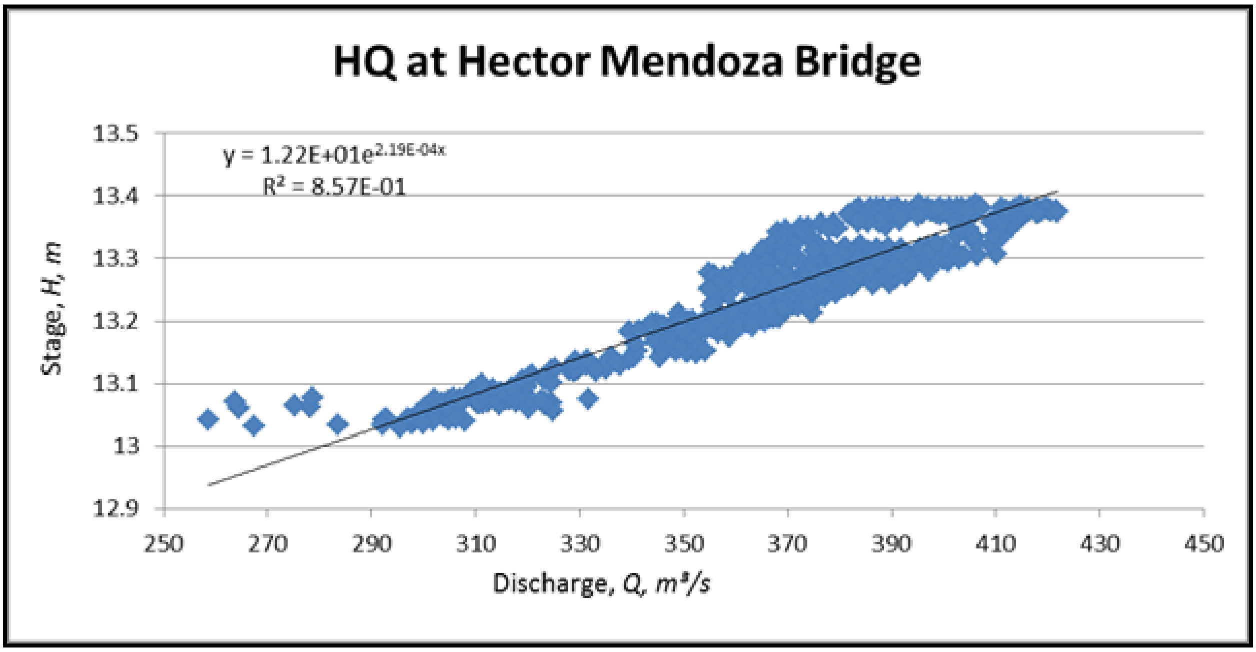


Figure 83. Stage-discharge computation at Hector Mendoza Bridge

H. Sensor Graphs and HQ at Calvo Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Calvo bridge are shown from Figure 84 to Figure 87.

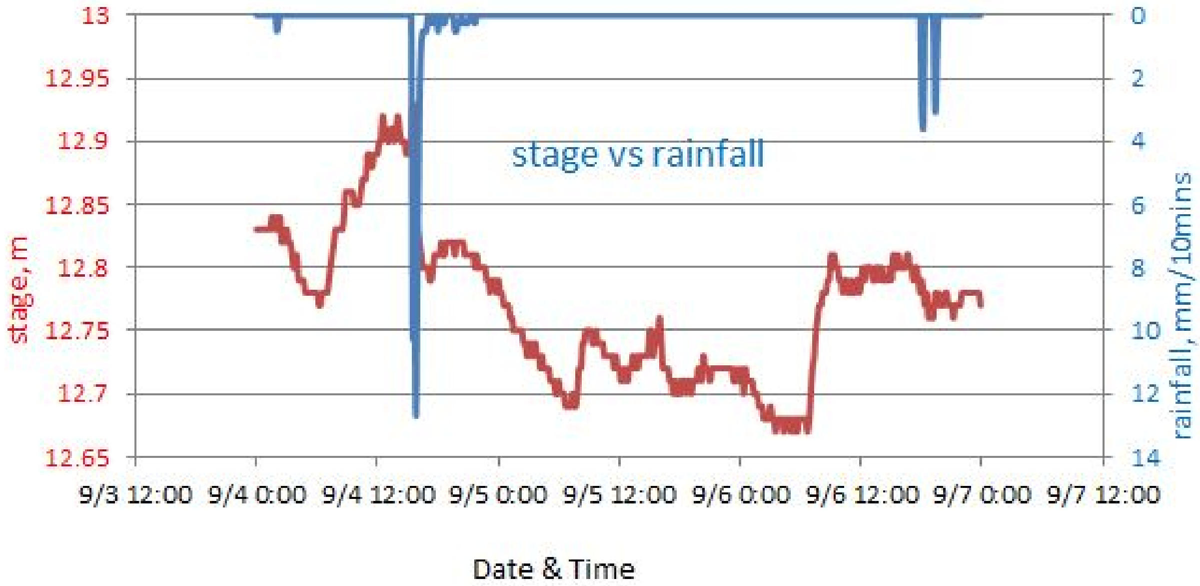


Figure 84. Relationship between stage and rainfall in Calvo bridge

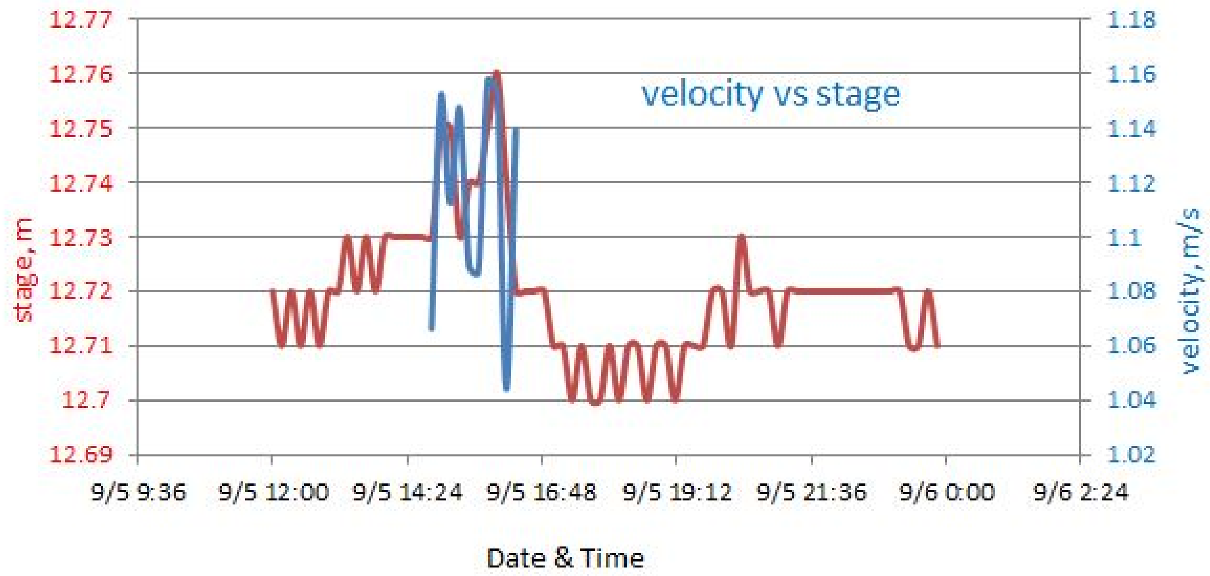


Figure 85. Relationship between velocity and stage in Calvo bridge

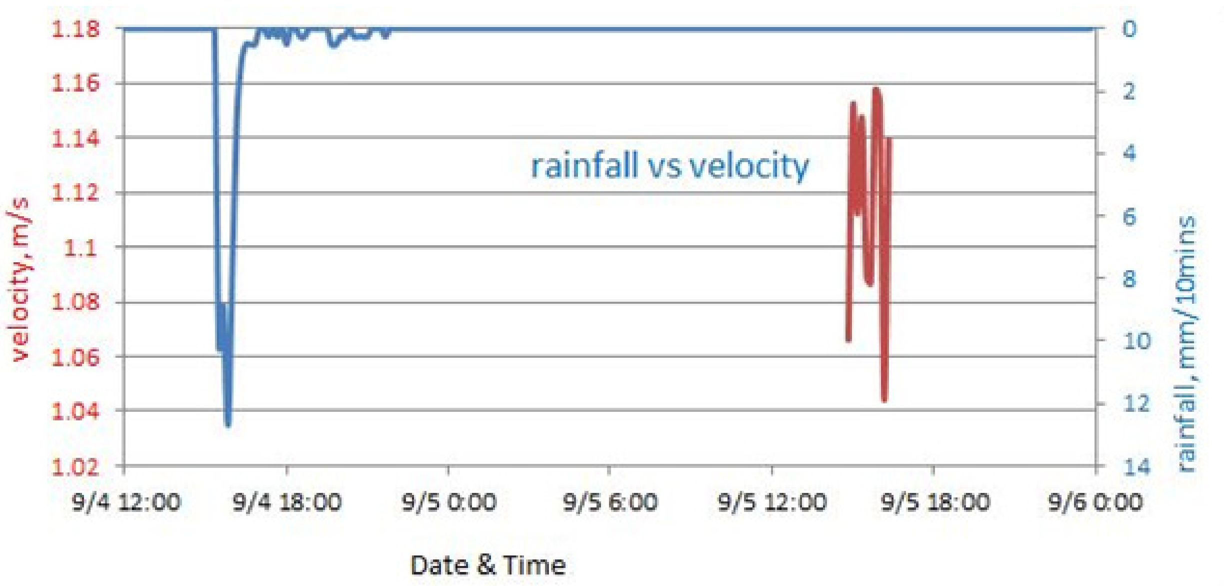


Figure 86. Relationship between rainfall and velocity in Calvo bridge

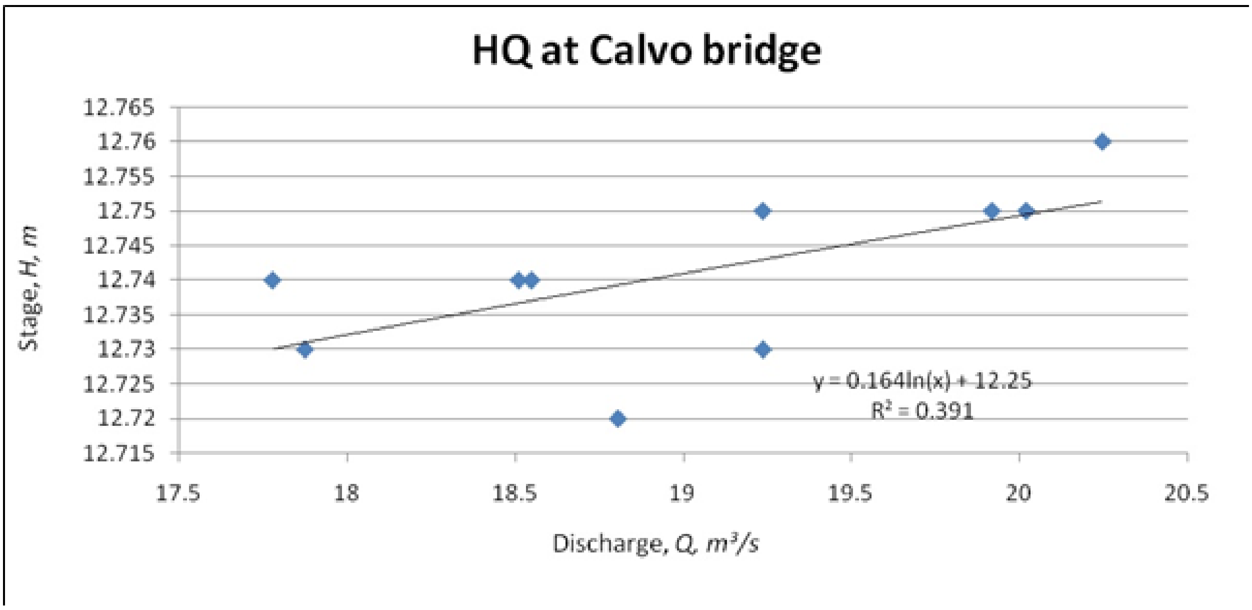


Figure 87. Stage-discharge computation at Calvo bridge

I. Sensor Graphs and HQ at Dipalo Bridge

The data gathered from the deployed ADCP, depth gauge and rain gauge in Dipalo bridge are shown from Figure 88 to Figure 91.

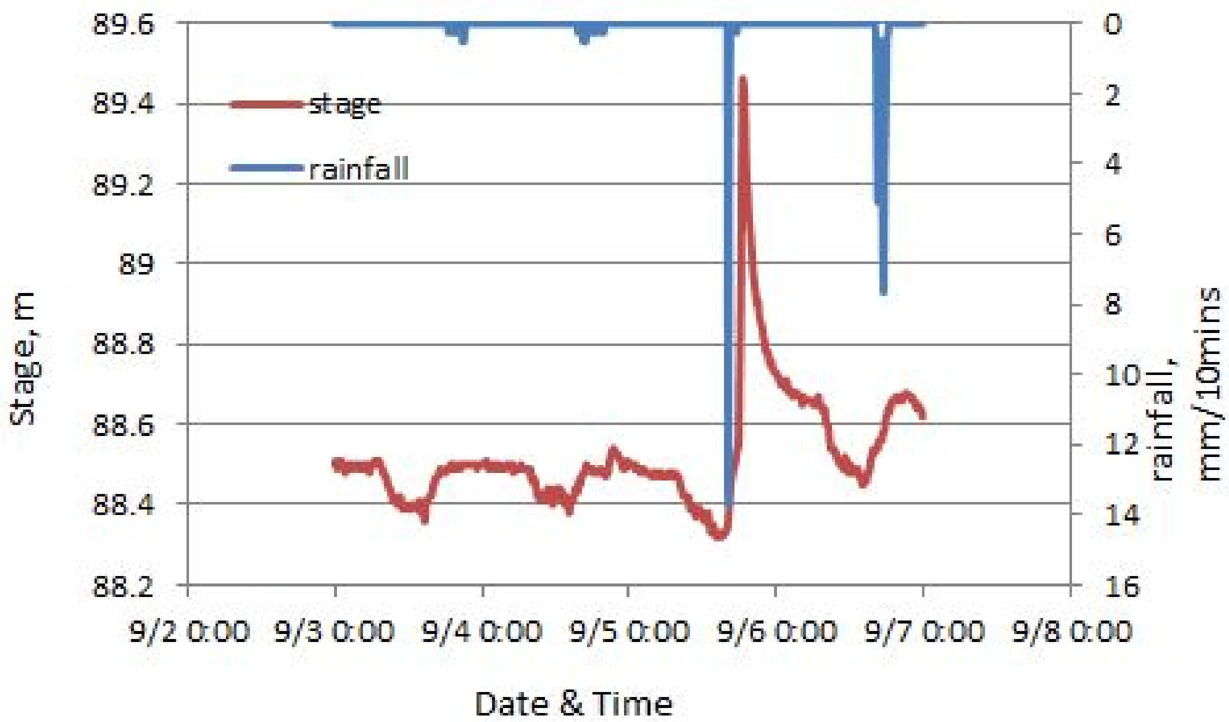


Figure 88. Relationship between stage and rainfall in Dipalo bridge

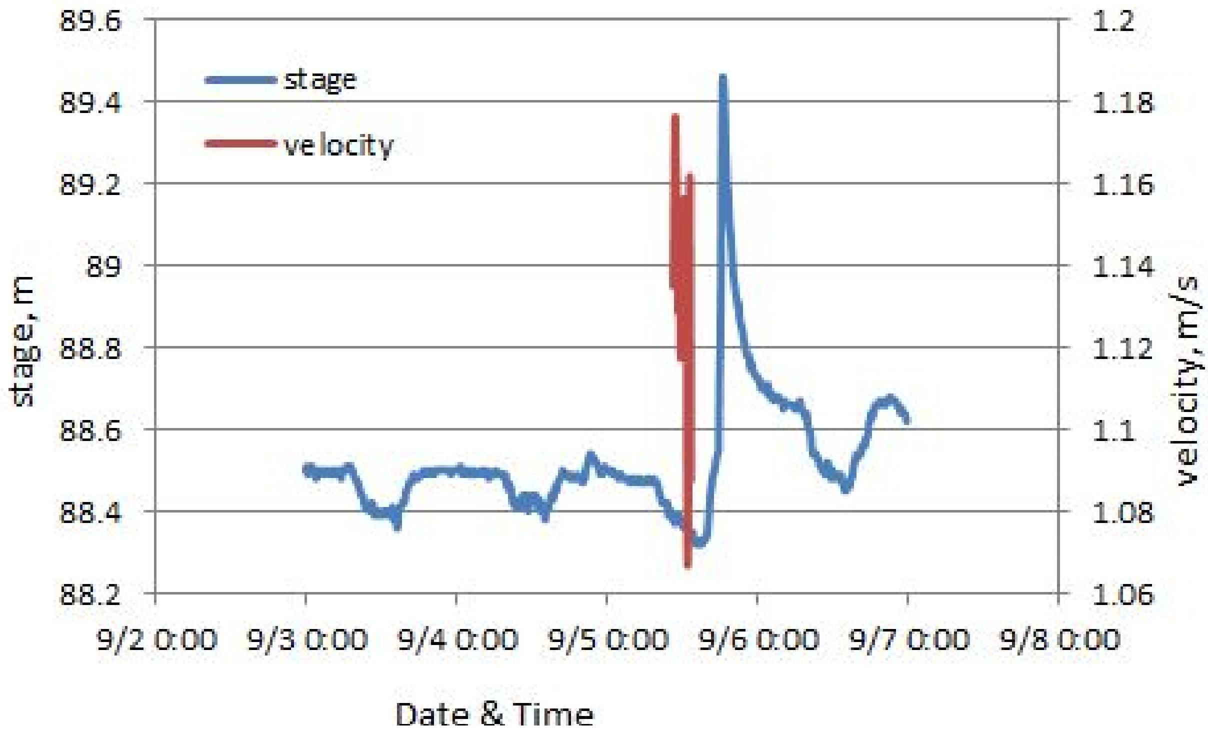


Figure 89. Relationship between stage and velocity in Dipalo bridge

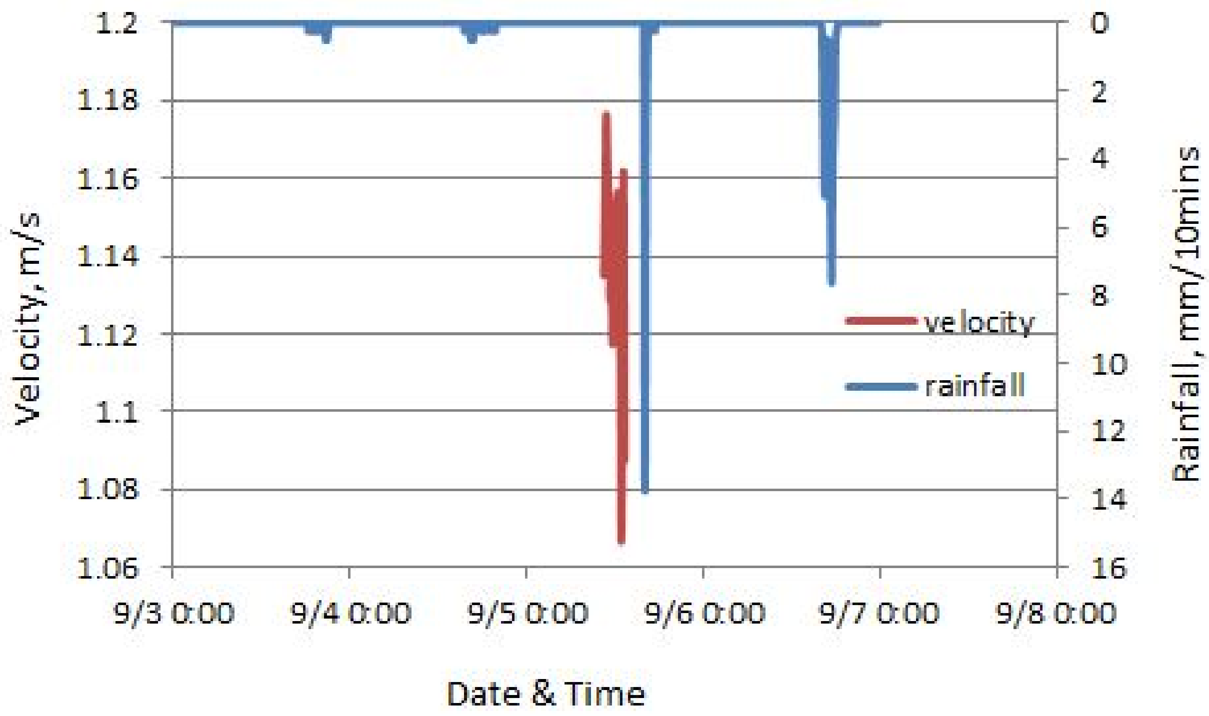


Figure 90. Relationship between velocity and rainfall in Dipalo bridge

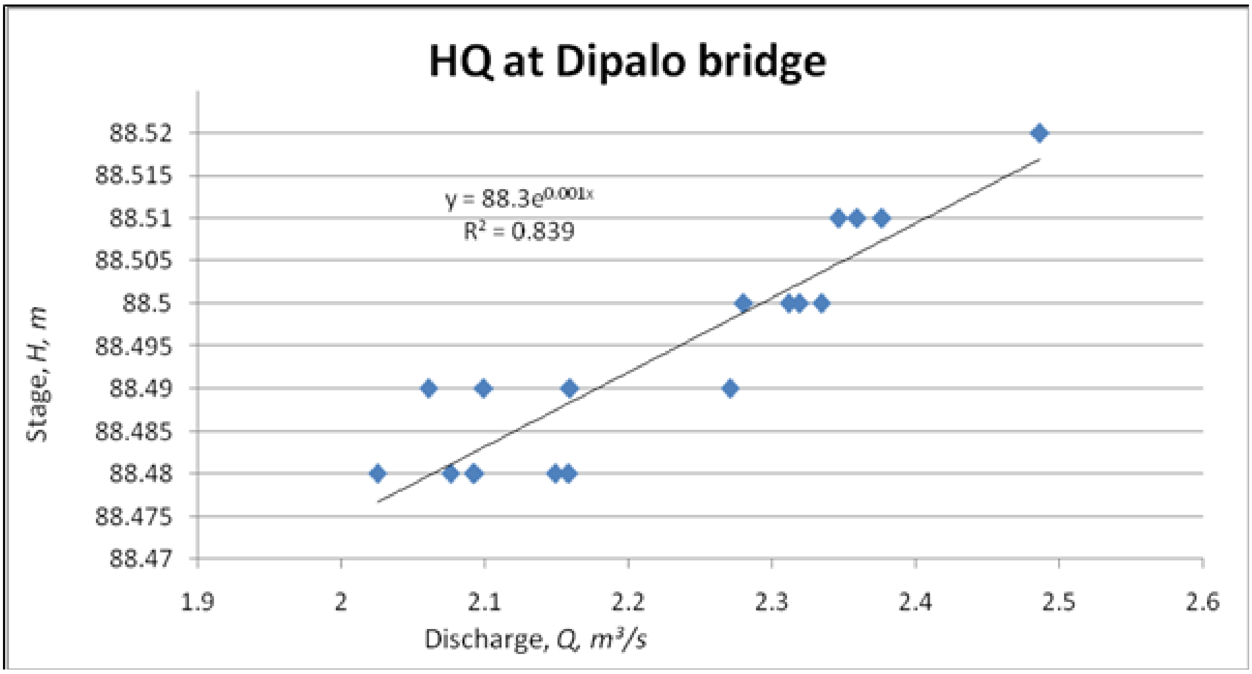


Figure 91. Stage-discharge computation at Dipalo bridge

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

The following shows the problems and limitations encountered during the fieldwork and the actions or solutions taken by the team during Agno River Field Survey.

Limitation/Problems	Solutions
1. August 2: The MMS was not utilized for the Agno River survey because the red OXTS heading issue still persists, despite the compliance with the recommended power supply for the MMS by Engr. Del Rosario.	The DVC team conducted an RTK and PPK survey for the upper bank profile of the river from August 12-13, 2012.
2. The MMS also failed to calibrate due to the strong current of river	
3. August 2: Strong river currents due to heavy monsoon rains and the continual release of water by San Roque dam made it difficult to conduct bathymetry cross section and zigzag lines.	Continue the bathymetry survey despite of the river conditions
4. August 2: Unable to establish the RTK Base on a suitable site (i.e. on a higher elevation to maximize the coverage of the RTK radio signal)	Sought permit from the Mayor of Rosales to establish the RTK Base at an apartment rooftop proximate from the river
5. August 2: Neither structures nor households were present near cross section 1 to anchor and man the sensors. The rising waters and strong current of the Agno River roused concerns for the safety of the sensors.	The team had to scout upstream for suitable sites for sensor deployment.
6. August 2: The Topcon Digital Level used to create the cross-section for the ADCP data was malfunctioning	Conduct PPK survey instead
7. August 3: Points on XS14 and XS15 gathered through PPK were float	Redo PPK survey
8. August 3: Unable to follow the straight path along XSL11 due to thick cogon grasses	Found an alternate path which ran parallel from XSL11
9. August 3: Cannot continue XSL07 to the endpoint due to obstructing fences	Continue to the next cross-section
10. August 4: Rover cannot connect to the RTK base station	Replace the rover unit with a functioning one
11. August 4: The planned starting point of XSL05, XSL12 and XSL13 cannot be reached due to high water level.	The wetted width at that time became the actual starting point of XSL05, XSL12 and XSL13
12. August 4: Difficulty to course through XSL05 due to wet and slippery rice paddies.	Follow an alternate path which ran parallel from XSL05

Limitation/Problems	Solutions
13. August 4: Unable to initially follow a straight path as corn fields obstructed the proposed XSL10 path	Follow an alternate path which deviated a few meters away from XSL10
14. August 7: Unable to continue field survey due to bad weather conditions (heavy rainfall and strong river current)	Continue downloading and processing of data
15. August 8: Unable to connect to base stations at around 3 PM due to depleted batteries	Ensure that batteries will be fully charged for the next surveys; redo portions of XS surveys that were done through PPK
16. August 9: Unable to continue field survey due to bad weather conditions (heavy rainfall and strong river current)	Whole day was spent on data processing
17. August 10: Unable to reach starting point of XSL03 due to an impassable tributary of Agno River	Try to reach the starting point of XSL03 through rubber boats the next day
18. August 11: Still unable to reach and start XSL03 due to thick cogon grasses and high water level	Survey not pursued for the safety of the survey team
19. August 11: Cannot conduct profiling along river islands as these islands were submerged in high water levels	Survey not pursued for the safety of the survey team
20. August 11: Dense residential structures render some areas difficult to gain GNSS satellite reception	Find alternate path clear from obstructions

ANNEX B. LIST OF EQUIPMENTS AND INSTRUMENTS

Type	Brand	Serial number	Owner	Quantity
GNSS Receiver (Base)	Trimble SPS852		UP-TCAGP	Three (3) units
GNSS Receiver (Rover)	Trimble SPS882		UP-TCAGP	Six (6) units
GNSS Controller	Trimble TSC3		UP-TCAGP	Six (6) units
High-Gain Antenna			UP-TCAGP	Three (3) units
RTK radio and antenna			UP-TCAGP	One (1) unit with battery
Singlebeam	Hi-Target		UP-TCAGP	One (1) unit with accessories
Echosounder				
Acoustic Doppler Current Profiler (ADCP)	SonTek		UP-TCAGP	One (1) unit with accessories
Coupler-2B			UP-TCAGP	One (1) unit
Handheld GNSS	Garmin Oregon 550	210757	UP-TCAGP	Five (5) units
		210758		
		210759		
	Magellan			
AA-Battery Charger	Akari		UP-TCAGP	Two (2) units
Multi-tester			UP-TCAGP	One (1) unit
Laptops	Lenovo		UP-TCAGP	One (1) unit
	DellLatitude E6420			One (1) unit
	Panasonic Tough book (MDL)			One (1) unit
Digital Level	Topcon DL502		UP-TCAGP	One (1) unit with two (2) level rods
Depth Gauge	Onset Hobo wares	9997437	UP-TCAGP	Four (4) units
Rain Gauge			UP-TCAGP	One (1) unit
Type	Brand	Serial number	Owner	Quantity
Digital Flow Meter	SonTek	F494	UP-TCAGP	One (1) unit
Echosounder	Ohmex		UP-TCAGP	One (1) unit
Range Pole			UP-TCAGP	One (1) unit

Type	Brand	Serial number	Owner	Quantity
Prism			UP-TCAGP	One (1) unit
12-volt deep cycle batteries			UP-TCAGP	Two (2) units
Tripod	Trimble		UP-TCAGP	One (2) units
Bipod	Trimble		UP-TCAGP	Five (5) units
Tribrach			UP-TCAGP	One (1) unit
Laser Range Finder	Bushnell		UP-TCAGP	Three (3) units
Installers	SonTek		UP-TCAGP	One (1) unit
	Topcon			One (1) unit
	Trimble Business Center			One (1) unit
	Trimble Realworks			One (1) unit
Mobile Mapping Scanner (MMS)	MDL Dynascan		UP-TCAGP	One (1) unit with dual-GNSS antenna, one (1) interface adapter and accessories
Toolbox			UP-TCAGP	One (1) unit
Printer			UP-TCAGP	One (1) unit

Annexes

ANNEX C. THE SURVEY TEAM

Data Validation Component Sub-team	Designation	Name	Agency/ Affiliation
Data Component Leader	Data Component Project Leader -II	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. JOEMARIE S. CABALLERO	UP TCAGP
Bathymetric Survey Team	Senior Science Research Specialist	ENGR. DEXTER T. LOZANO	UP TCAGP
	Research Associate	RAQUEL NAJJA M. HAO	UP TCAGP
Profile Survey Team	Senior Science Research Specialist	ENGR. BERNARD PAUL D. MARAMOT	UP TCAGP
	Senior Science Research Specialist	ENGR. MELCHOR REY M. NERY	UP TCAGP
Cross Section Survey Team and Deployment Team	Research Associate	ENGR. JMSON J. CALALANG	UP TCAGP
	Research Associate	PATRIZCIA MAE P. DELACRUZ	UP TCAGP
	Research Associate	JOJO E. MORILLO	UP TCAGP
	Research Associate	JELINE AMANTE	UP TCAGP
	Research Associate	KRISTINE AILENE P. BORROMEO	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

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

June 11, 2013

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: **PANGASINAN**
Station Name: **PS-608**

Island: **LUZON**	Municipality: **BALUNGAO**	Barangay: **RAJAL**
Elevation: **45.4003 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM PS-608

Station is located in the Province of Pangasinan, Municipality of Balungao, Barangay Rajal. From Camiling Tarlac travel NE towards the Rajal, Balungao until reaching Matoblang Bridge. Station is located at the right side of the Matoblang Bridge (pathway).

Mark is the head of a 4" copper nail and centered in a cement putty with inscriptions "BM PS-608; 2008; NAMRIA."

Requesting Party:	**UP-TCAGP DREAM**
Pupose:	**Reference**
OR Number:	**3943775B**
T.N.:	**2013-0560**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

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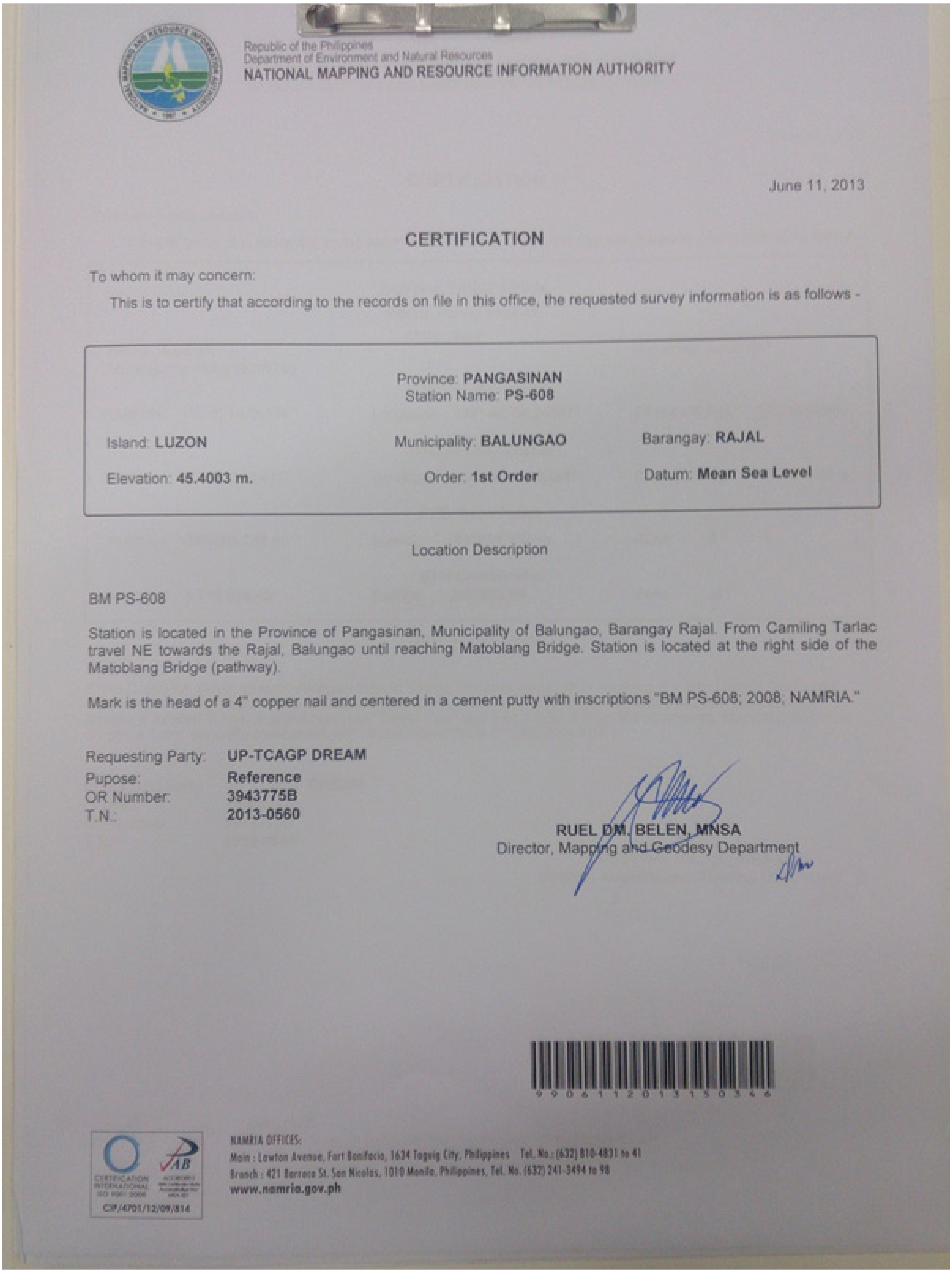
CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/814

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



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

June 11, 2013

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: **PANGASINAN**
Station Name: **PS-608**

Island: **LUZON**	Municipality: **BALUNGAO**	Barangay: **RAJAL**
Elevation: **45.4003 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM PS-608

Station is located in the Province of Pangasinan, Municipality of Balungao, Barangay Rajal. From Camiling Tarlac travel NE towards the Rajal, Balungao until reaching Matoblang Bridge. Station is located at the right side of the Matoblang Bridge (pathway).

Mark is the head of a 4" copper nail and centered in a cement putty with inscriptions "BM PS-608; 2008; NAMRIA."

Requesting Party:	**UP-TCAGP DREAM**
Pupose:	**Reference**
OR Number:	**3943775B**
T.N.:	**2013-0560**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

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

April 18, 2013

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: **PANGASINAN**
Station Name: **PNG-56**
Order: **2nd**

Island: **LUZON**		Barangay: **POBLACION**
Municipality: **STO. TOMAS**		
	PRS92 Coordinates	
Latitude: **15° 52' 46.68500"**	Longitude: **120° 34' 54.80152"**	Ellipsoidal Hgt: **30.68000 m.**
	WGS84 Coordinates	
Latitude: **15° 52' 40.94082"**	Longitude: **120° 34' 59.58898"**	Ellipsoidal Hgt: **69.45900 m.**
	PTM Coordinates	
Northing: **1756173.446 m.**	Easting: **455222.371 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,757,009.80**	Easting: **241,058.87**	Zone: **51**

Location Description

PNG-56

From Urdaneta, travel S until reaching Villasis then pass the Carmen Bridge. Then turn right until reaching Sto. Tomas Mun. Hall, about 2 km. from the intersection of Brgy. Carmen. Station is located in the town plaza fronting the mun. hall. It is situated 8.6 m. from the NE column of the waiting shed and 8.2 m. from the S entrance road. Mark is a 30 cm. x 30 cm. x 1 m. concrete monument, with inscriptions "PNG-56 2007 NAMRIA".

Requesting Party: **UP DREAM/ Melchor Nery**
Pupose: **Reference**
OR Number: **3943540 B**
T.N.: **2013-0309**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

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CERTIFICATION INTERNATIONAL ISO 9001:2008
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DREAM

Disaster Risk and Exposure Assessment for Mitigation