REGION 6

Panay River:

DREAM Ground Surveys Report

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

2015

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines Diliman
Quezon City
1101 PHILIPPINES

This research work is supported by the Department of Science and Technology (DOST) Grants-in-Aid Program and is to be cited as:

UP TCAGP (2015), DREAM Ground Survey for Davao River, Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program, DOST Grants-In-Aid Program, 134 pp.

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National Library of the Philippines
ISBN: 978-971-9695-50-9

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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.

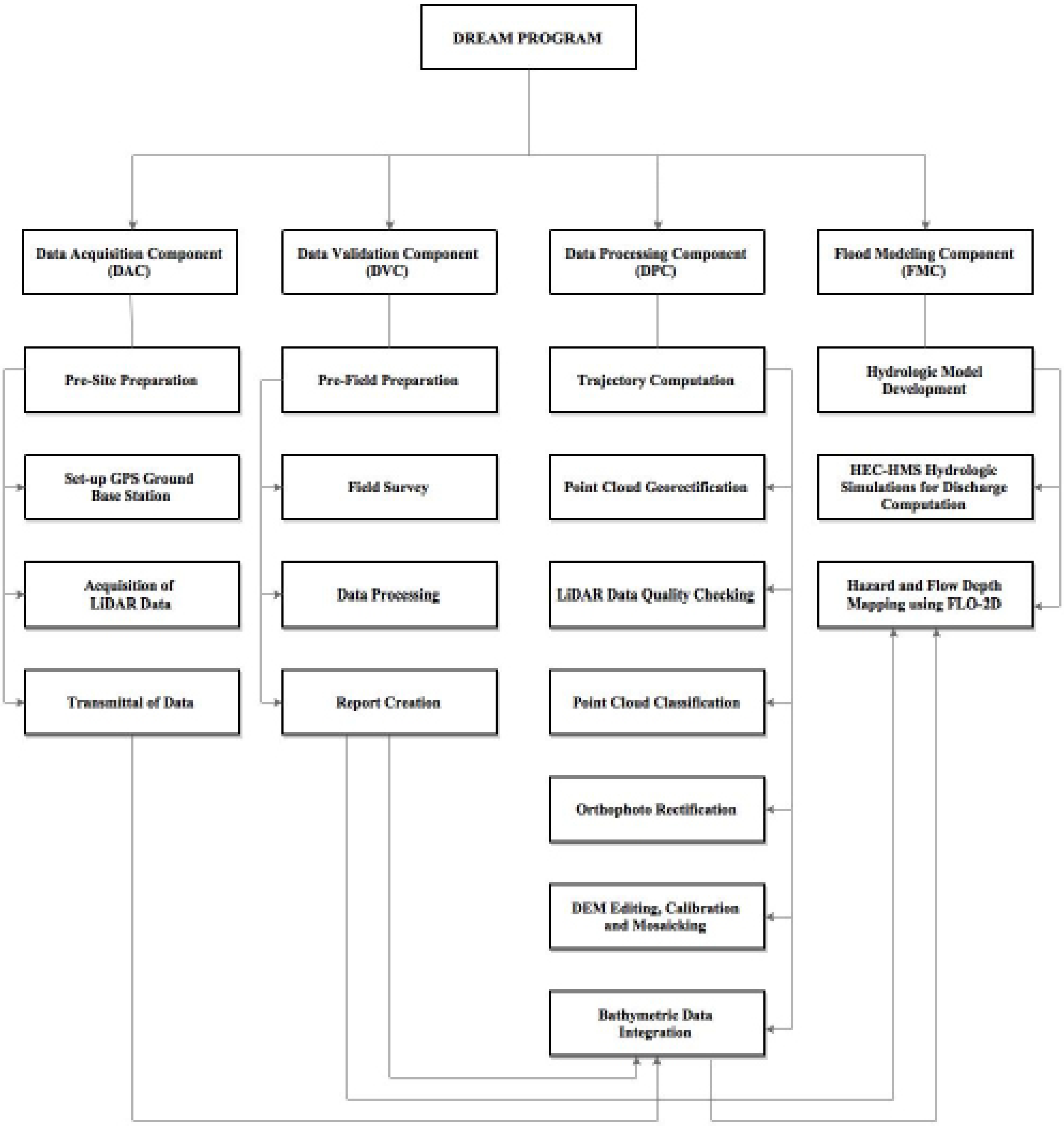

Figure 1. The General Methodological Framework of the Program

The Panay River Basin

The Panay River Basin

The Panay River Basin located in the north eastern part island of Panay in Western Visayas. The Panay River Basin is considered as the 12th largest river basin in the Philippines. It covers an estimated basin area of 1,843 square kilometers. The location of Panay River Basin is as shown in Figure 2.

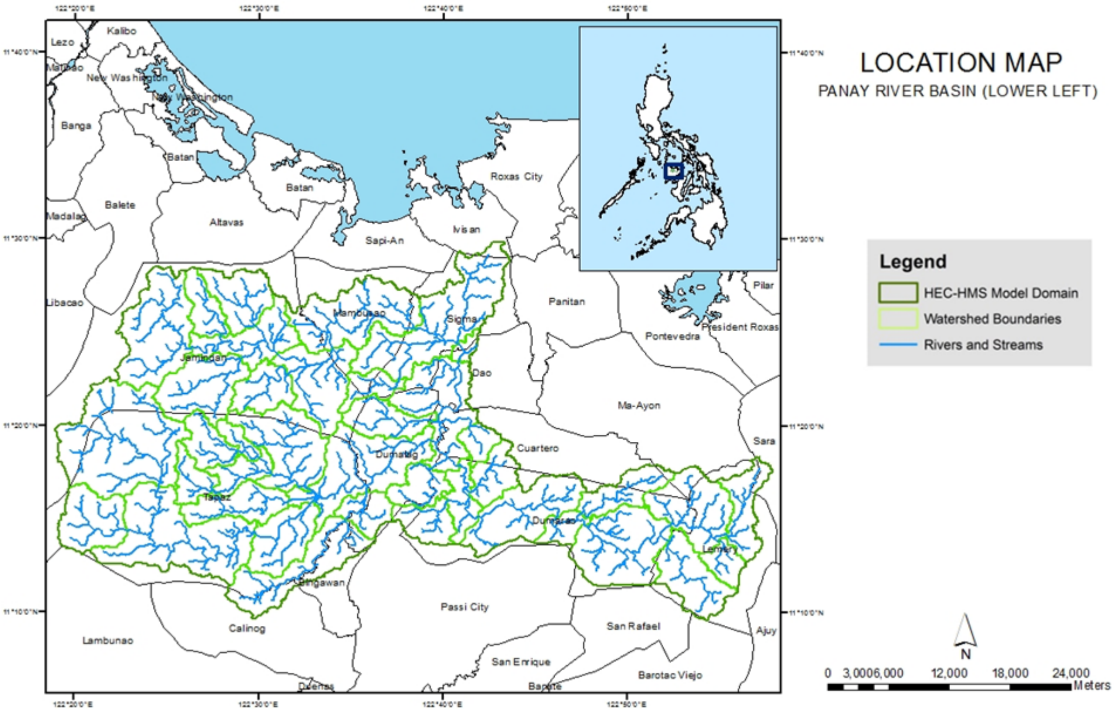

Figure 2. Panay River Basin Location Map

This area includes the whole province of Capiz and a part of Iloilo and Aklan.. The upper part of the Panay River Basin consists of the Upper Panay River mainstream basin and three major tributary basins, the Badbaran, Mambusao, and Maayon river basins. It traverses through the Roxas City and the towns of Capiz and Pontevedra and drains the northern portion of the island.

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 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 the Panay River Basin are shown in Figure 3 and 4, respectively.

The Panay River Basin

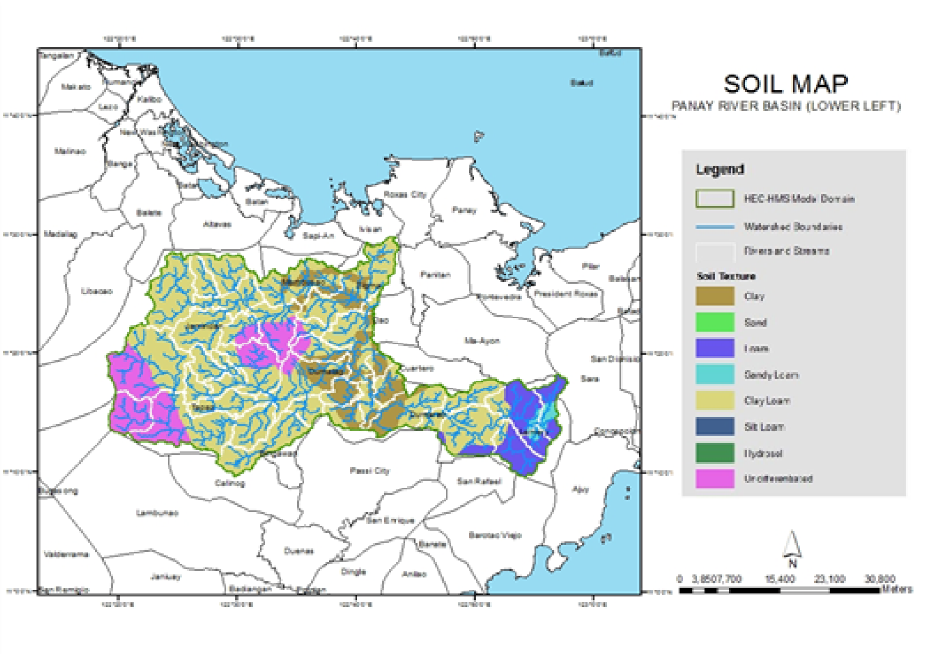

Figure 3. Panay River Basin Soil Map

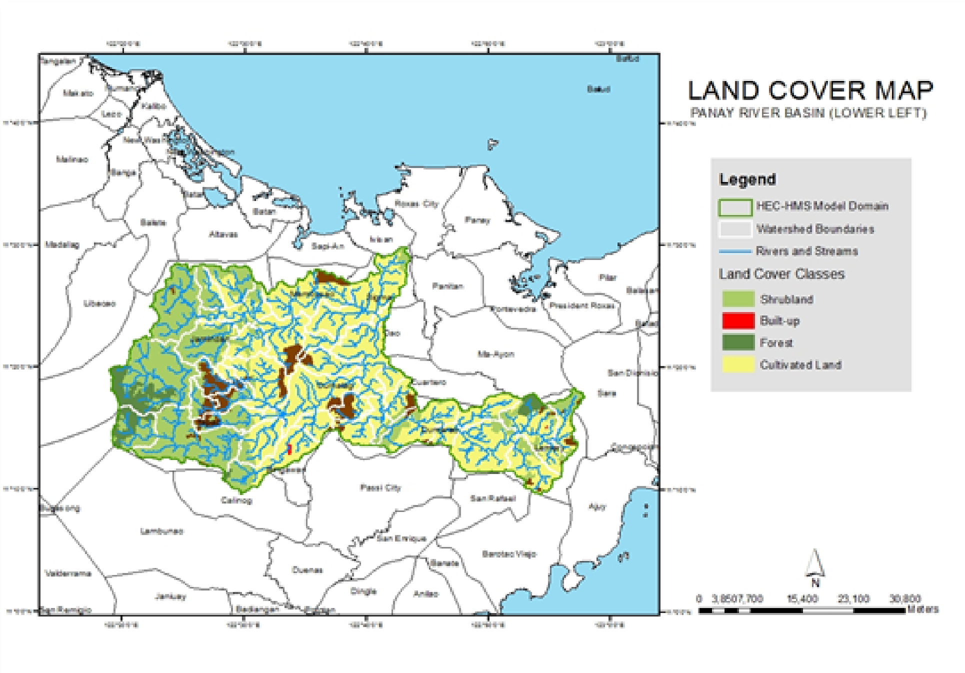

Figure 4. Panay River Basin Land Cover Map

DVC Methodology

DVC Methodology

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

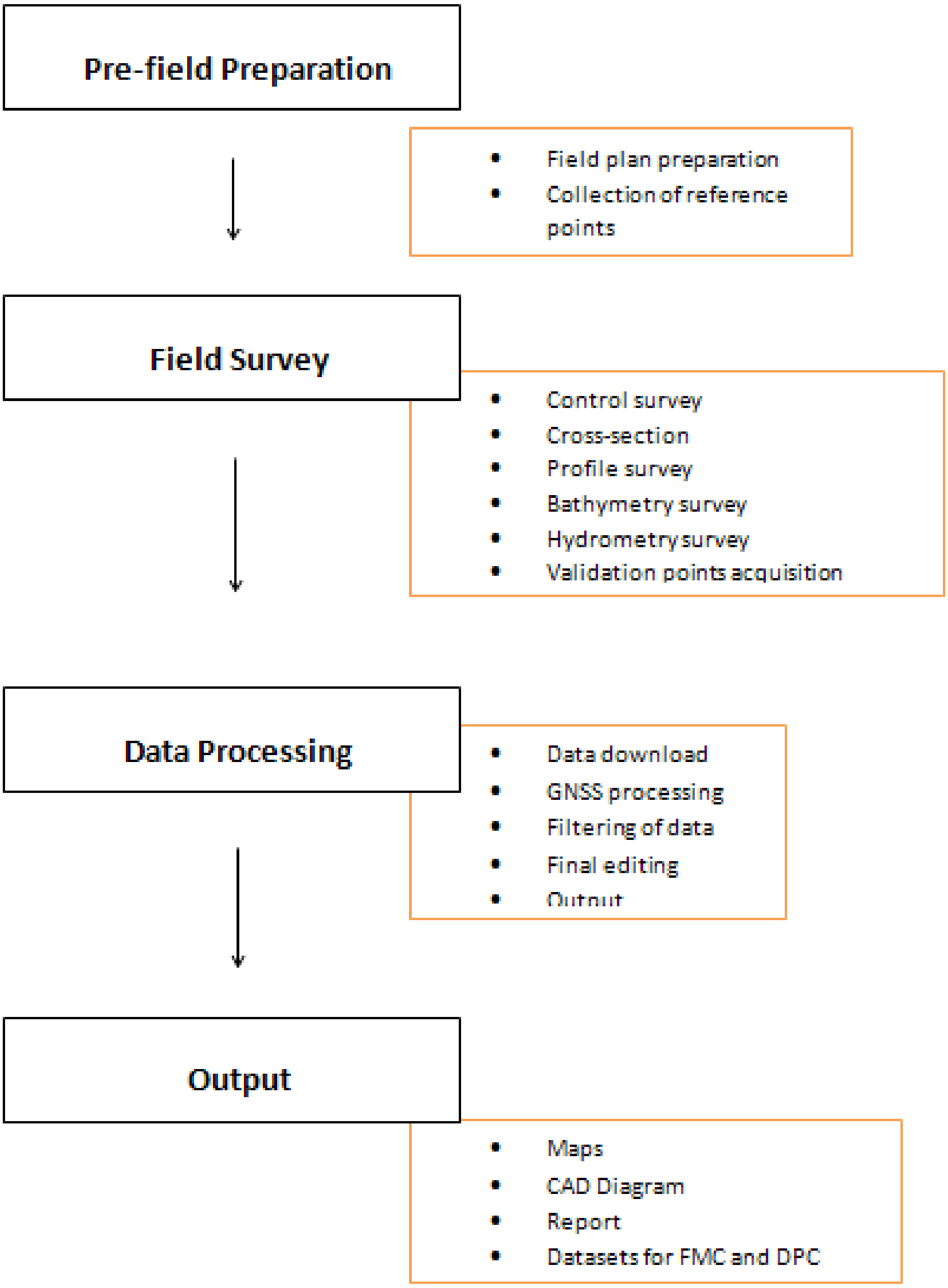

Figure 5. DVC Main Activities

DVC Methodology

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

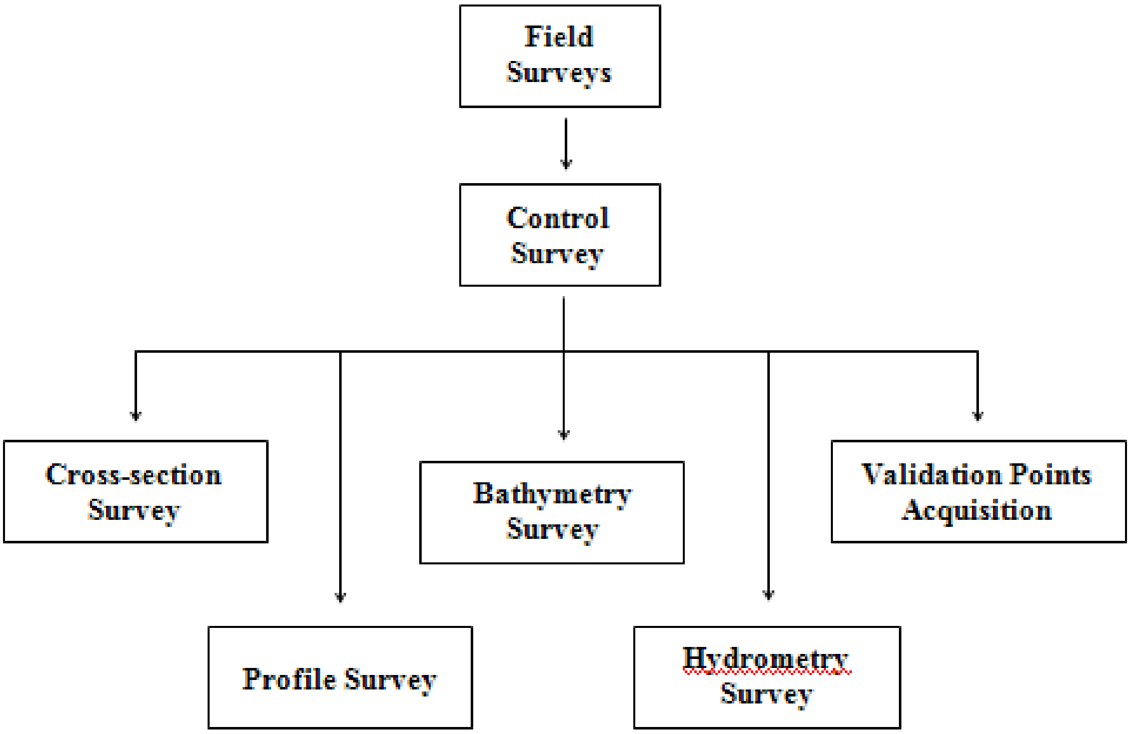

Figure 6. DVC Field Activities

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.

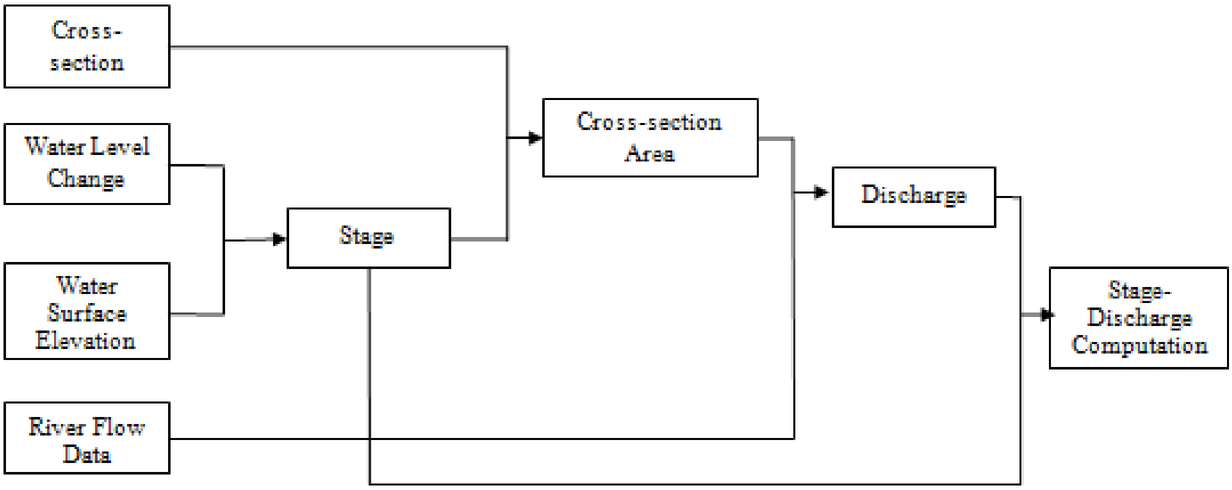

Figure 7. Flow Chart for Stage-Discharge Correlation Computation

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.

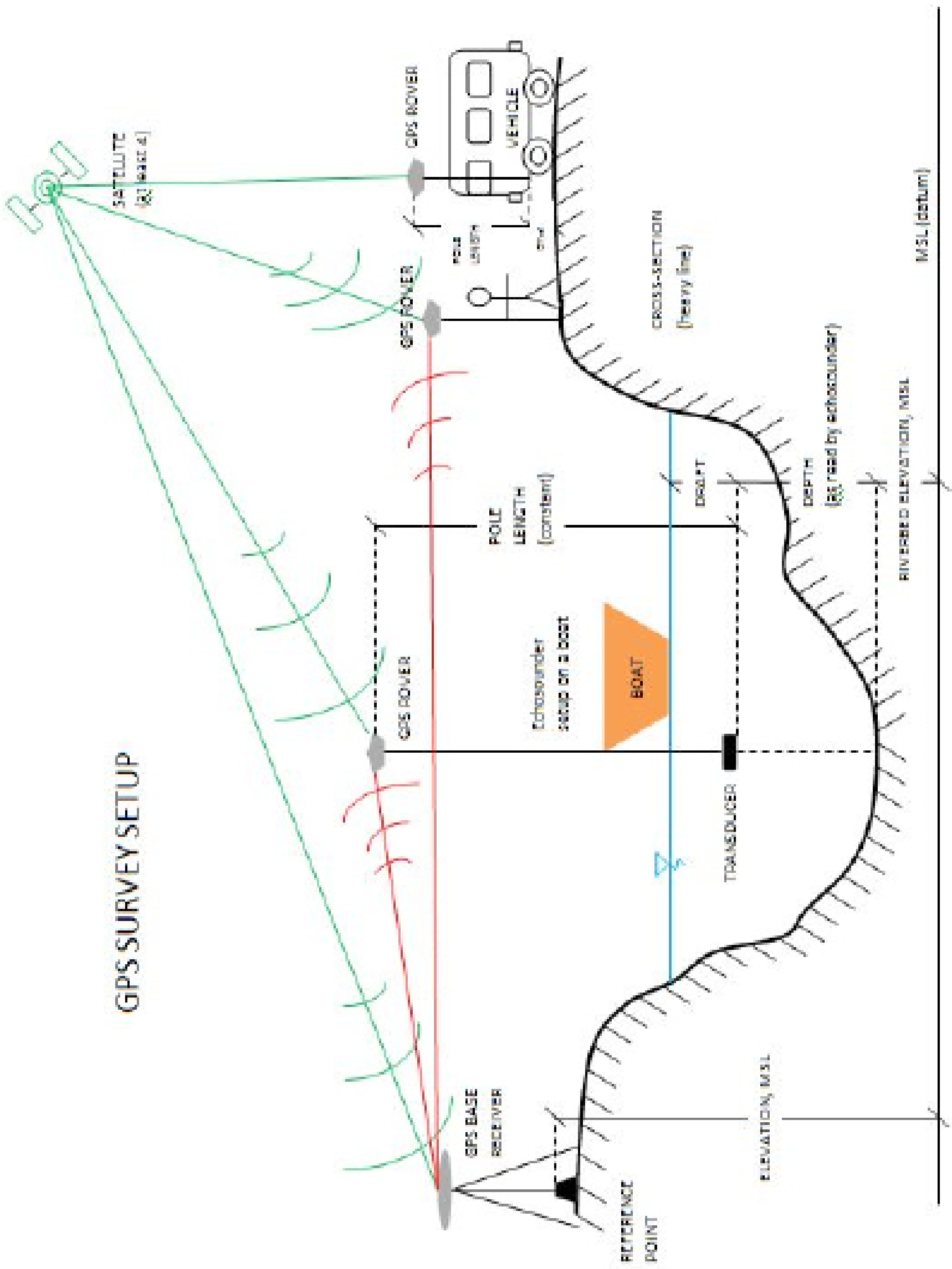

Figure 8. Set-up for GNSS Survey

3.3 Data Processing

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

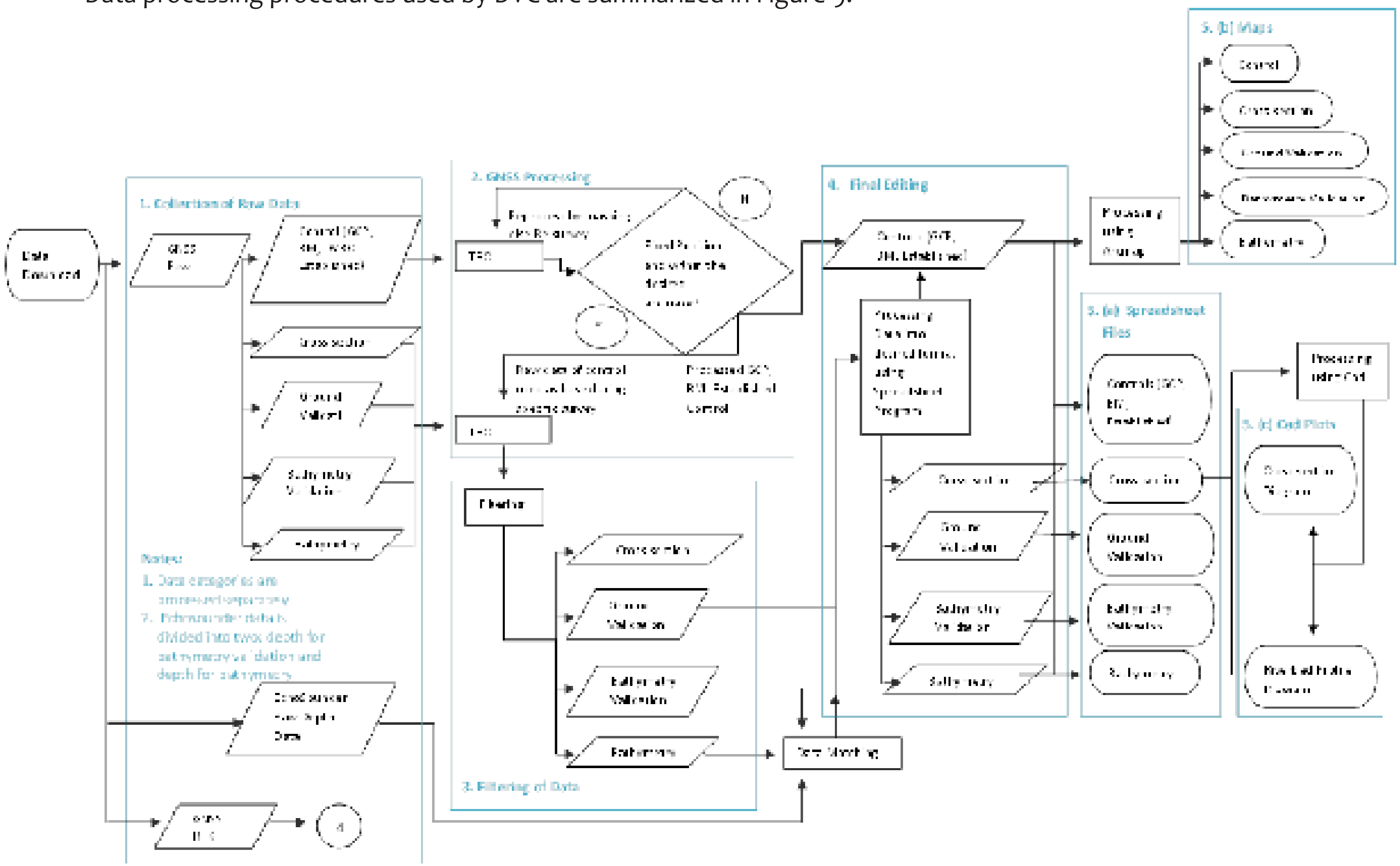

Figure 9. DVC Data Processing Methodology

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.

Depth Data Processing

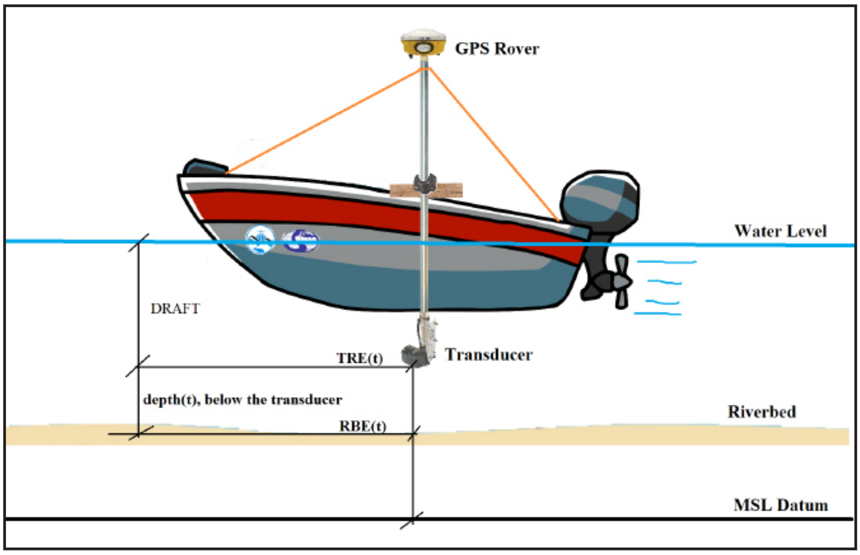

Figure 10. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

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.

DVC Methodology

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.

Panay River Basin Survey

Panay River Basin Survey

The Panay River Basin Survey in the Capiz Province was conducted on February 5-23, 2013. The survey includes cross-section and profile reconnaissance, bathymetric survey and flow measurements in Panay River. Cross-section and profile reconnaissance was done simultaneously with bathymetric and hydrometric measurements during the survey period.

Additional fieldworks were conducted on July 21-22, 2013 and on October 23-29, 2013 to acquire the LiDAR data validation and to gather cross section data and flow measurement at the installed Automated Water Level Sensors (AWLS) in the Panay River System respectively.

4.1 Control Survey

Three (3) NAMRIA established control points were occupied simultaneously: CP-175, CPZ-14, and an established point near Jumbo Bridge. CPZ-175 is a 1st order NAMRIA benchmark located at Brgy. Lanot, Roxas City, Capiz. CPZ-14 is a 2nd order NAMRIA control point located at Pan-ay Church, Panay, Capiz. And, a temporary point was occupied as base station established near Jumbo Bridge at Brgy. Punta Tabuc, Roxas City, Capiz. The GNSS loop is shown in Figure 11.

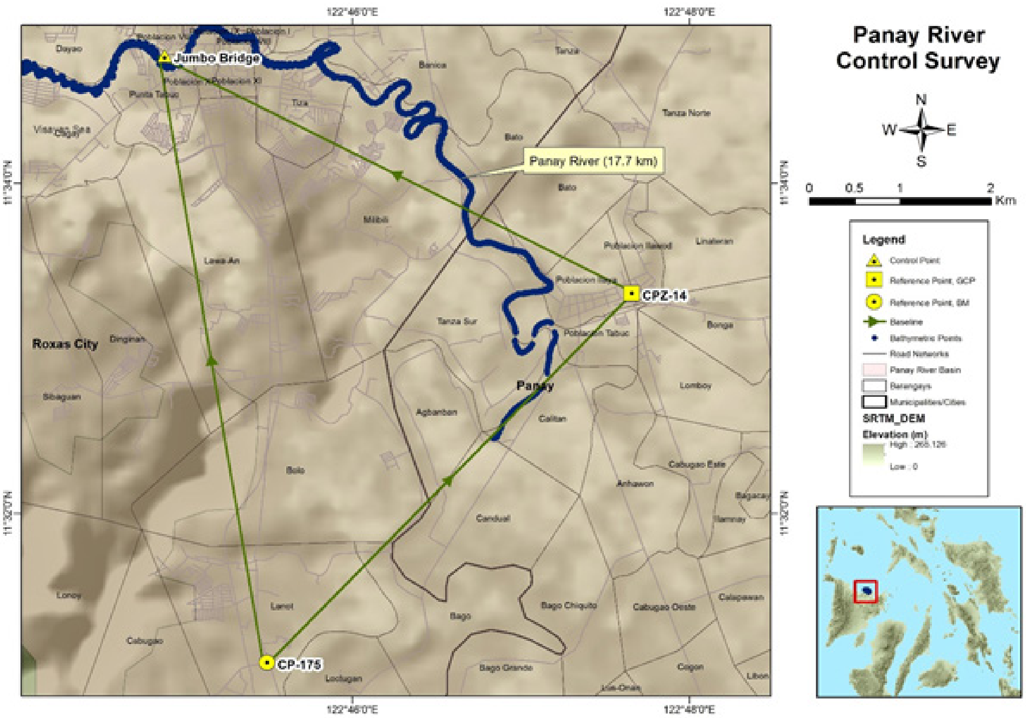

Figure 11. Location of control points

Three hours of continuous differential static observations were conducted at these three points to provide reference control points for the ground and bathymetric surveys. The horizontal coordinates and elevations of the three (3) control points were computed using Trimble® Business Center GNSS processing software. The NAMRIA certified horizontal values and vertical value of CPZ-14 and CP-175 respectively were fixed during the processing. The result of static survey for the control points are indicated in Table 1.

Table 1. Control points occupied during Panay River Survey (Source: NAMRIA; UP-TCAGP)

Point Name	WGS84 UTM Zone 51N					Elevation in MSL (m)
	Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	
CP-175	11°31'05.92471" N	122°45'29.71479" E	65.487	1273301.575	473637.89	6.880
CPZ-14	11°33'19.98412" N	122°47'39.56494" E	60.96	1277416.185	477574.199	2.391
Jumbo Bridge	11°34'46.19407" N	122°44'53.19336" E	60.645	1280068.194	472537.555	2.320

The GNSS setup for the four (4) control points are illustrated in Figures 12-16:

Figure 12. Static GNSS observation at CP-175,
a benchmark at Barangay Lanot, Roxas City, Capiz

Figure 13. GNSS observation at a reference point, CPZ 14 at Pan-ay church, Panay, Capiz

Figure 14. Established control point at Brgy. Punta Tabuc, Roxas City, Capiz

4.2 Reconnaissance of Cross-section and Profile Lines

The objective of the Reconnaissance Team (RT) is to inspect the pre-defined cross section and profile lines along Panay River. The RT noted the characteristics of the location of the cross section and took pictures of the area. Garmin Montana™ 650 was used to locate the planned cross section and profile lines.

The majority of the cross sections were deemed passable. Most obstructions are caused canopy of trees which makes GNSS surveying not ideal. Using a total station is advised in such cases.

Cross sections 1 – 23 are generally rice fields with lines passing through private properties. Cross sections 24 – 35 are within the city proper where the population is dense. Most of these cross section lines fall along the roads. Cross Sections 36 – 42 are located on fishponds which fall along the footpath rice paddies or pilapil. More details and summary of the reconnaissance for cross-section and profile can be found in Annex E.

The bank of the river is rich in vegetation which covers about eighty (80) percent of the survey extent. There are lots of nipa trees in the upstream portion of the river and mangroves near the mouth of the river. The upper and lower banks are covered by thick vegetation and trees.

4.3 Bathymetric Survey

The objective of the bathymetric survey is to obtain the topography and elevation of the river bed since river channel is the main carrier of water from the watershed down to a floodplain area. These datasets will be incorporated in the flood modelling.

Ohmex Sonarmite Echosounder was used for hydrographic survey which measures the depth along certain points on the surface of the river. The elevation and coordinates of these points were measured through differential GPS PPK mode in which a PPK base station was set-up on a known control point. The transducer was mounted to a pole placed vertically beside the boat where a cable was connected to the echosounder for a depth measurement. A GPS receiver Trimble® SPS882 was connected above the pole to determine the position of the points which the echo sounder collected. A wireless Trimble® TSC3 GPS controller employed for logging and viewing the gathered GPS points. The elevation of the riverbed is then derived from the GPS-derived elevation minus the antenna-to-echo-sounder length minus the depth recorded by the echo sounder. This survey equipment was installed in a motor boat.

The survey was conducted from Brgy. Barra, Roxas City down to the floodplain of Panay River.

As an observation during the survey, upstream of the river are narrow areas with trees and nipas from left and right banks. Some pieces of wood and nipa are floating in the river that the motorboat could not pass through. Cross-section seven (7) going downstream of the river were passable. Thee hindrances are shown in Figure 15. Overall bathymetry coverage is illustrated in Figure 16

Figure 15. Hindrances along Panay River during the bathymetry survey

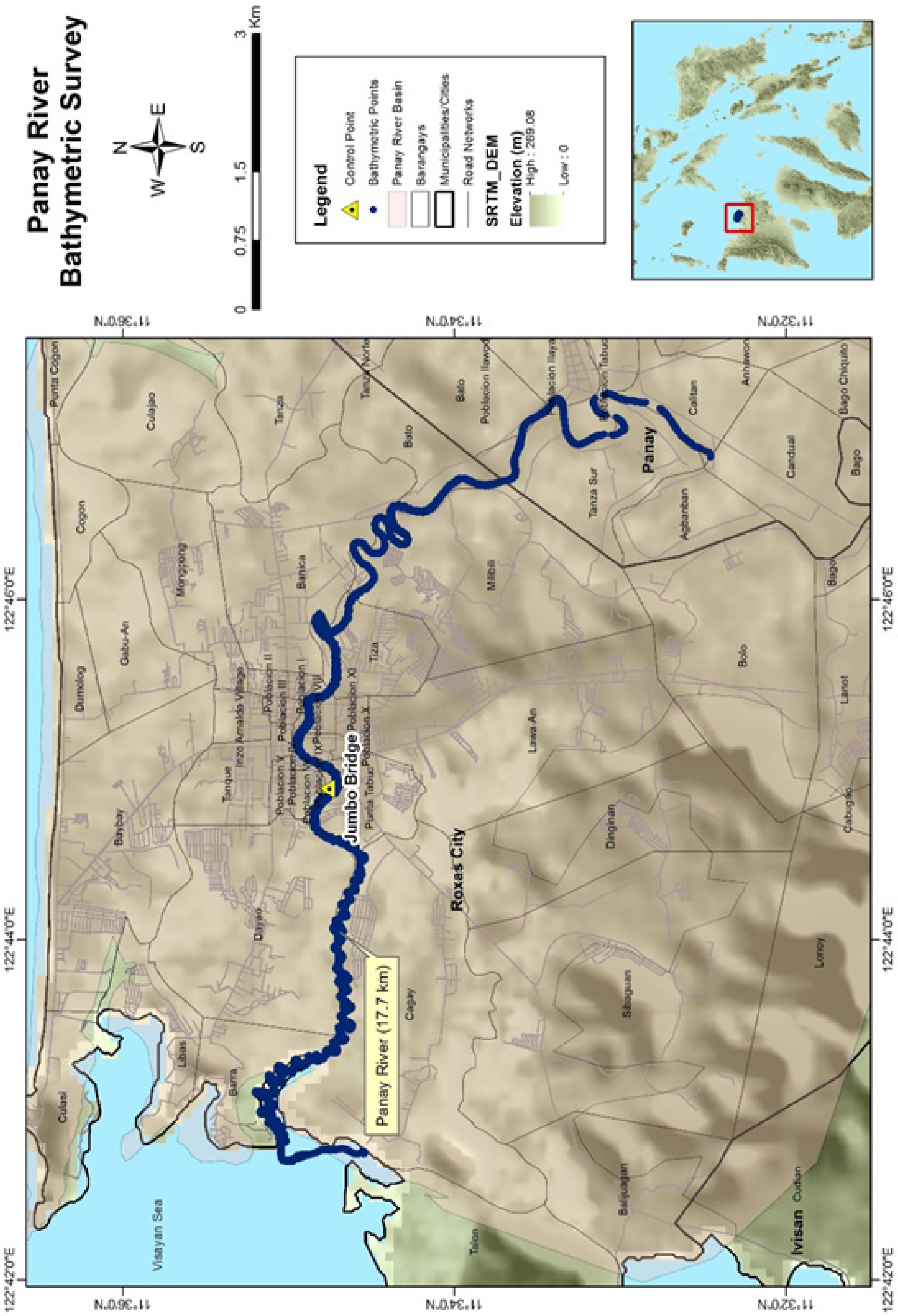

Figure 16. Bathymetric survey coverage of Panay River.

4.4 Hydrometric Survey

Different sensors were deployed on the banks of Panay 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.

Data collection in Panay using ADCP, Depth Gauge and Rain Gauge deployment started on February 9, 2013 at Panitan Bridge Brgy. Tabuc Sur, Panitan, Capiz and retrieved on February 11, 2013. Then, it was re-deployed at Brgy. Agbanban, Panay on the same day until February 20, 2013. The setups of the deployed sensors are illustrated in Figure 17, 18 and 19 while the summary of the deployment schedule was tabulated in Table 2.

The ADCP was monitored and its data was downloaded every two (2) days while the depth gauge which was installed on the metal frame together with the ADCP and the Rain Gauge installed in Dao, Maayon, Panitan and Sigma Bridge was continued gathering data until its retrieval.

The data gathered from the rain gauge shows the distribution of rainfall within the observation period on February 9-11, 2013. Measurements were recorded every five (5) minutes.

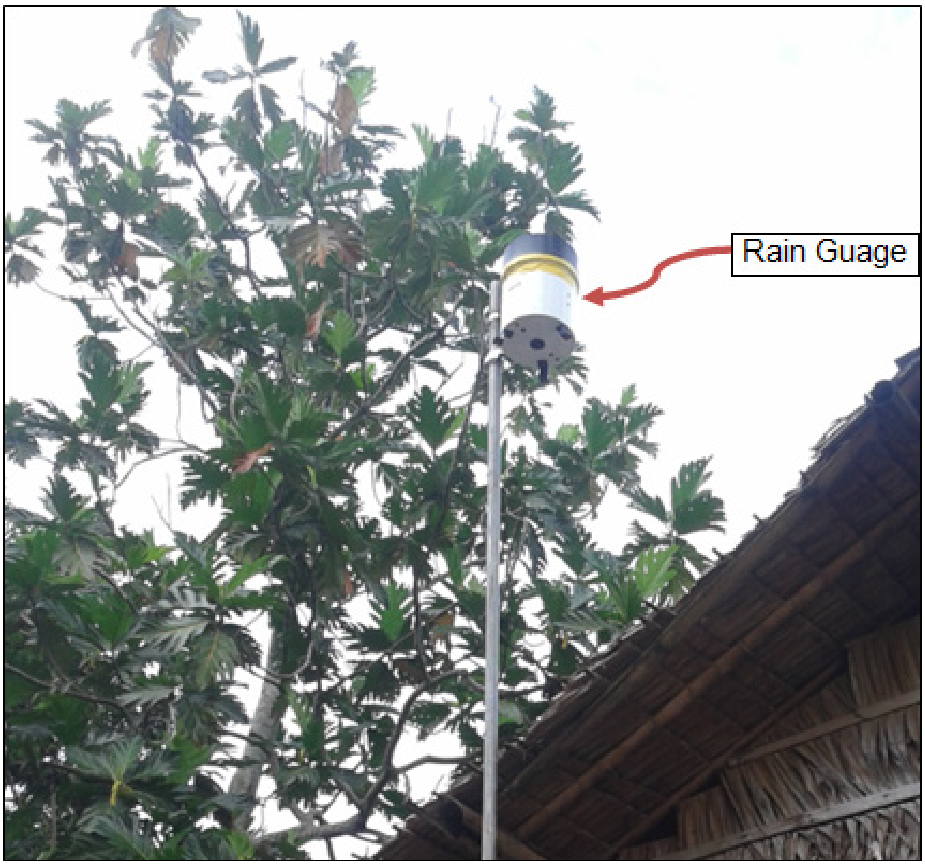

Figure 17. Rain gauge deployed at Brgy. Agbanban, Panay

Figure 18. Rain gauge deployed at Brgy. Tabuc Sur, Capiz

Figure 19. Deployment of Velocity Meter and Depth Gauge (a) Panit-an Bridge, (b) Preparation of the deployment site, (c) buoy tied to the crate, (d) & (e) actual set-up of the depth gauge and velocity meter

Plotting the relationship of hydrometric data gathered by the sensors for rainfall vs water level is shown in Figure 20. This shows that the highest peak of rainfall was observed on February 11, 2013 with an approximately 5.6 mm.

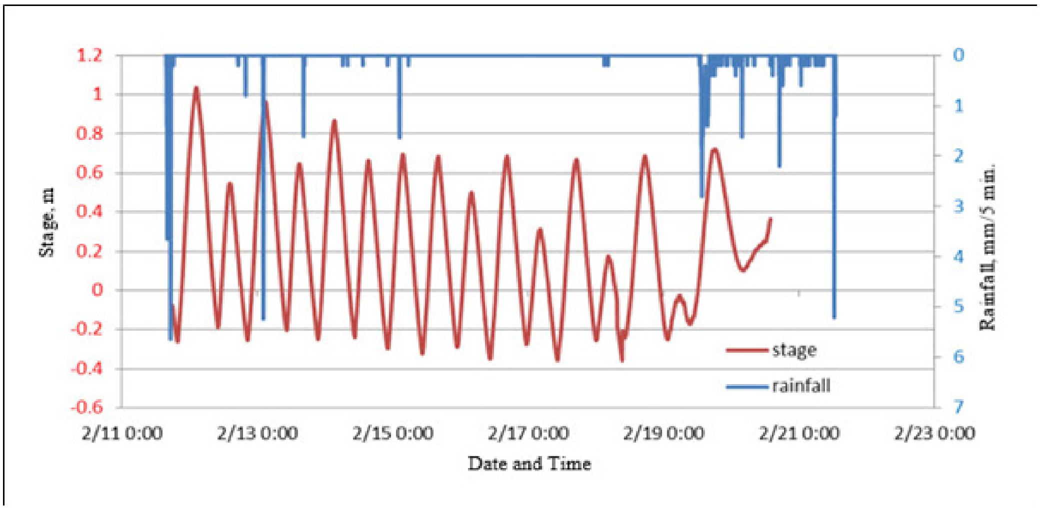

Figure 20. Relationship between rainfall and water level (stage) at Brgy. Agbanban, Panay

The relationship of hydrometric data gathered by the sensors for rainfall vs water velocity and water velocity vs water level is shown in Figure 21 and Figure 22. In Figure 21, peak rainfall was observed on February 11, 2013 with 5.8 mm which followed by the highest velocity on February 12, 2013 with 0.25 meter per second. While in Figure 22, it was observed that the water level increased simultaneously with water velocity.

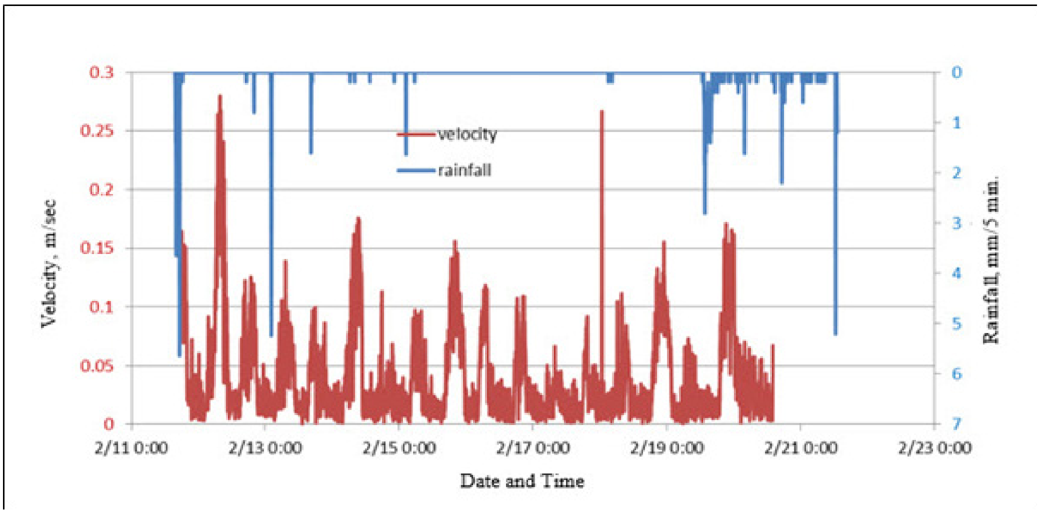

Figure 21. Relationship between rainfall and water velocity at Brgy. Agbanban, Panay

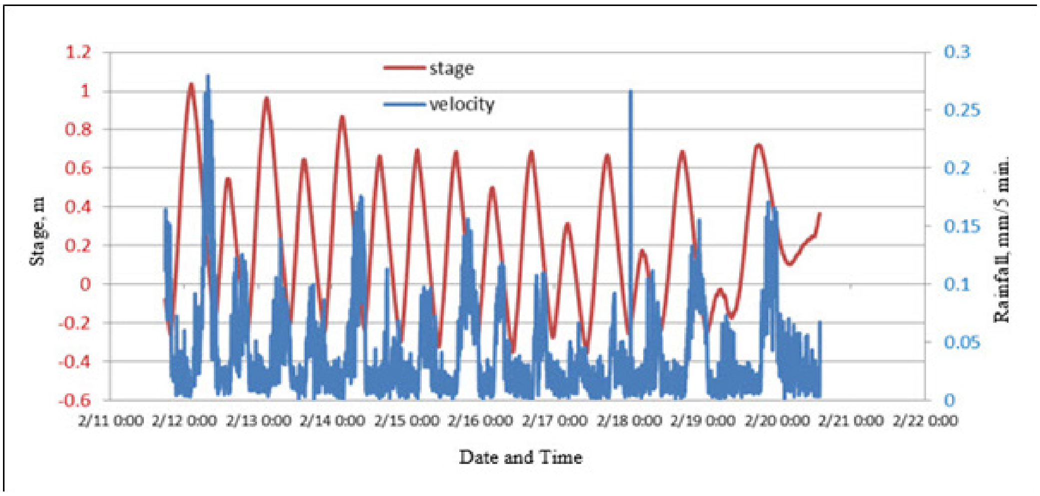

Figure 22. Relationship between water velocity and water level (stage) at Brgy. Agbanban, Panay

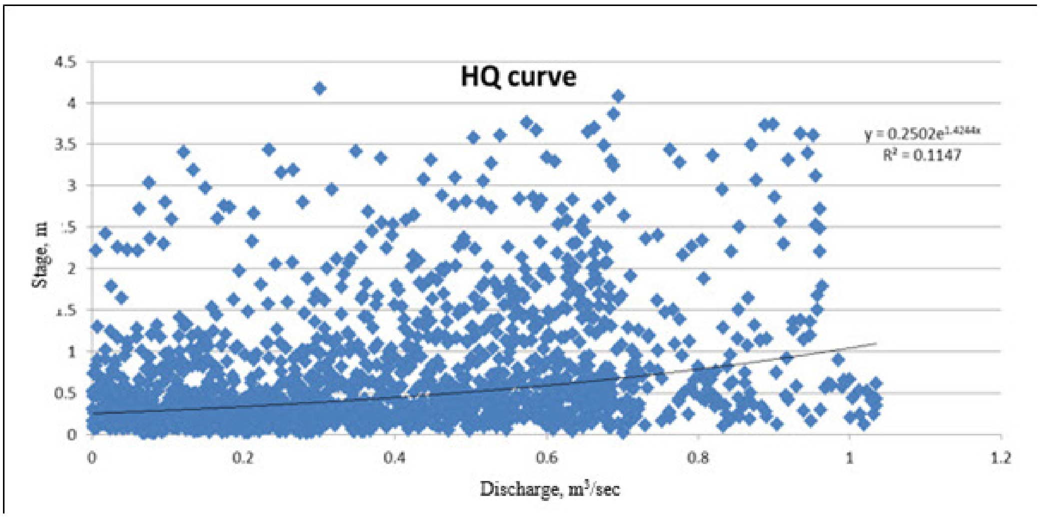

Figure 23. Scatter plot of the stage vs. discharge at Brgy. Agbanban, Panay

The relationship between the stage or water surface elevation referred to MSL and river discharge on a specific area of the river in at Brgy. Agbanban, Panay is illustrated in Figure 23. A value approaching R2 = 1 indicates a good correlation.

Table 2. Summary of the location, the deployment and retrieval date of the sensors used for collecting the hydrometric properties of Panay River.

Sensor	Location	Municipality	Deployment – Start	Deployment – End
Velocity Meter	Brgy. Tabuc Sur	Panitan	9-Feb	11-Feb
Rain Gauge		Panitan	6-Feb	10-Feb
Depth Gauge		Panitan	9-Feb	11-Feb
Velocity Meter	Brgy. Agbanban,	Panay	11-Feb	20-Feb
Rain Gauge		Panay	11-Feb	21-Feb
Depth Gauge		Panay	11-Feb	20-Feb

In addition to the acquired hydrometry data in Brgy. Agbanban, water level data were extracted from repo.pscigrid.gov.ph to acquire the discharge vs stage property of different automated water level sensors (AWLS) installed in bridges within the Panay River System. Rainfall data were extracted from Panitan Automated Rain Gauge (ARG) in Panitan Bridge, Tapulang ARG in Maayon Bridge and Dao ARG in Dao Bridge. Sensors data per bridge are shown from Figure 24 to Figure 36.

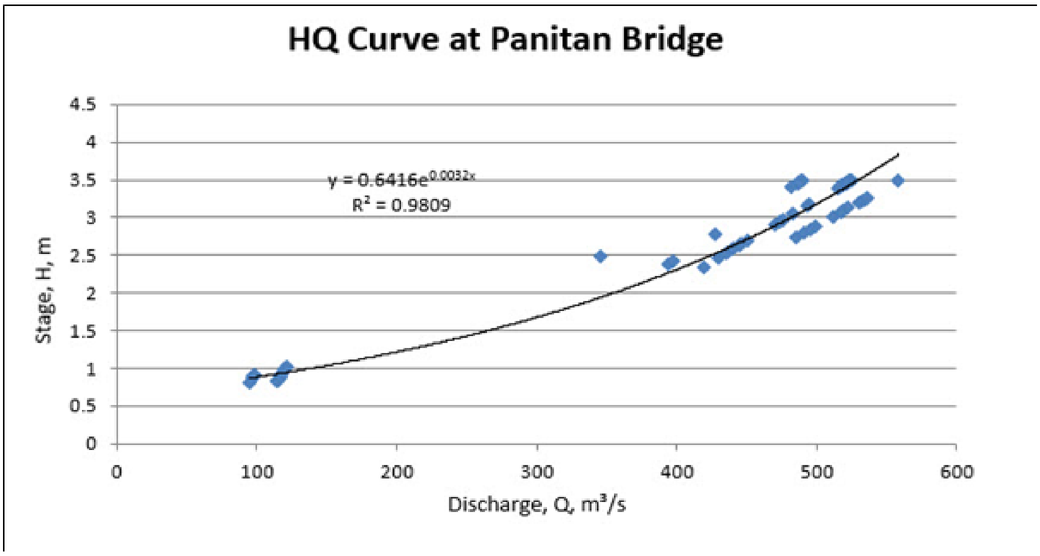

Figure 24. HQ Curve at Panitan Bridge, Brgy. Tabuc Sur, Pinantan, Capiz.

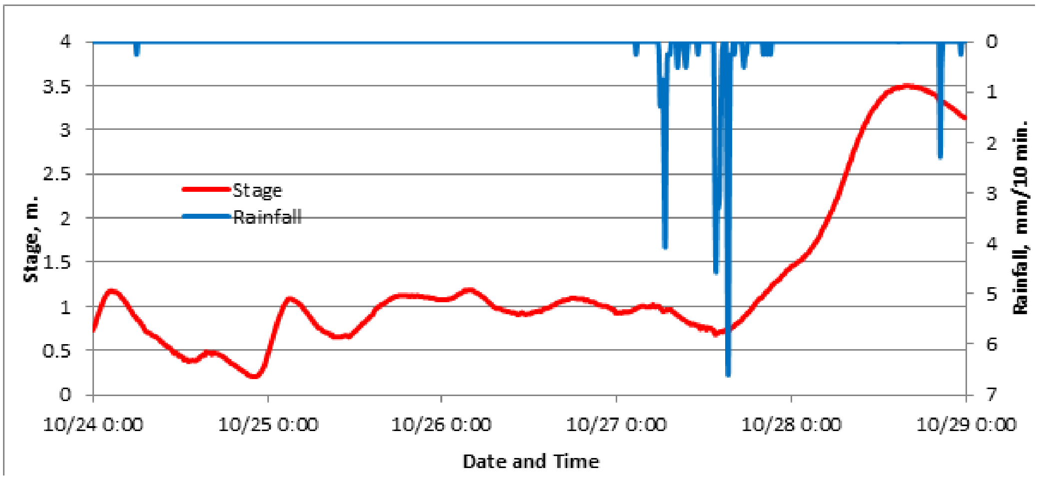

Figure 25. Relationship between Rainfall and Stage at Panitan Bridge

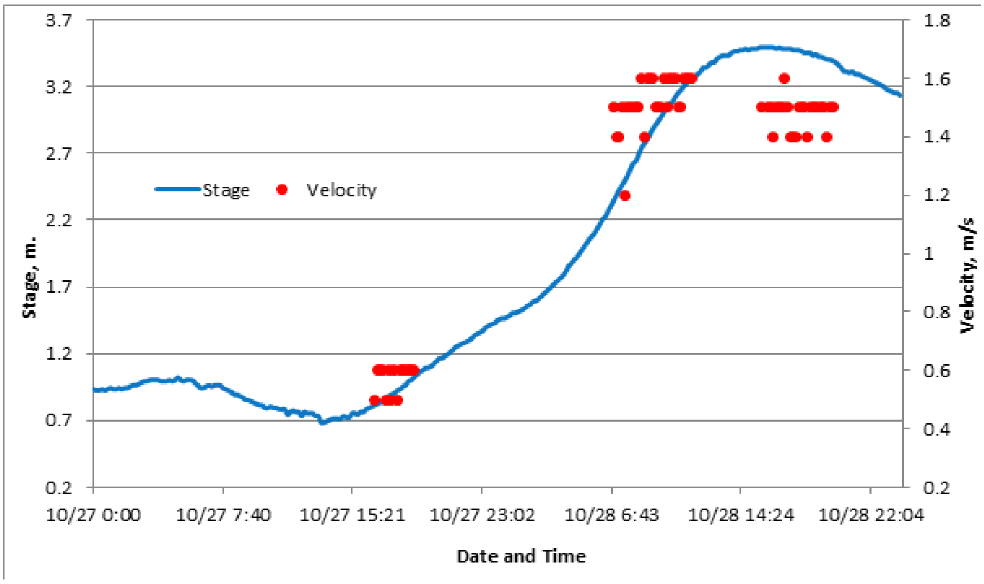

Figure 26. Relationship between Velocity and Stage at Panitan Bridge

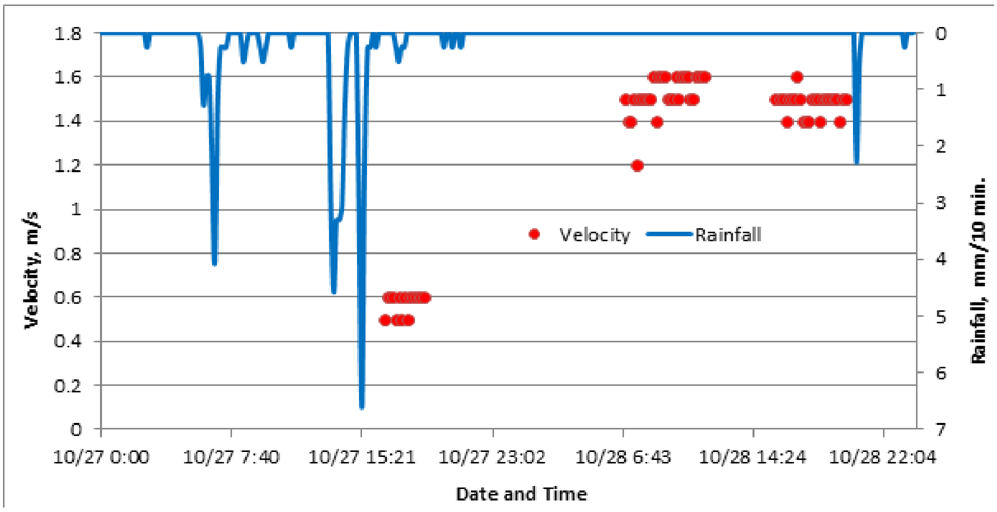

Figure 27. Relationship between Velocity and Rainfall at Panitan Bridge

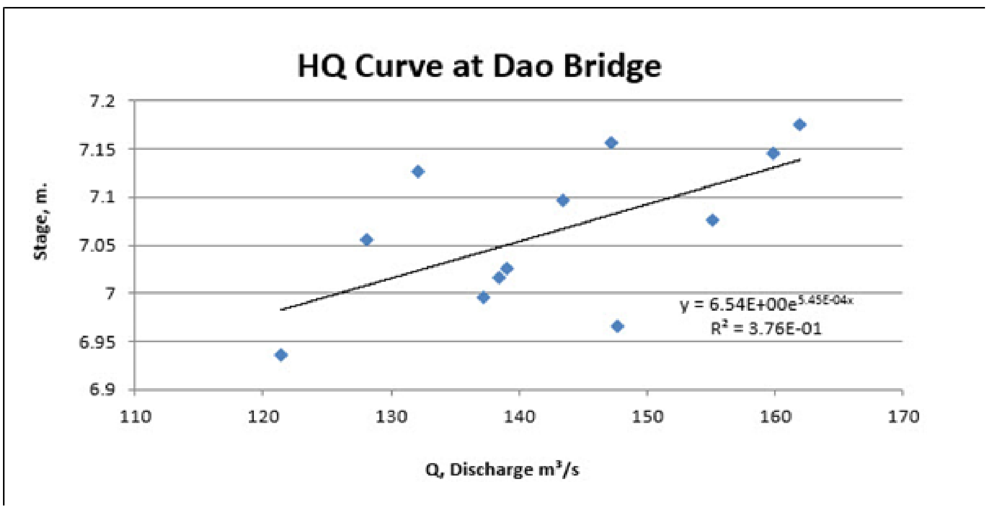

Figure 28. HQ Curve at Dao Bridge Barangay Manhoy, Dao, Capiz

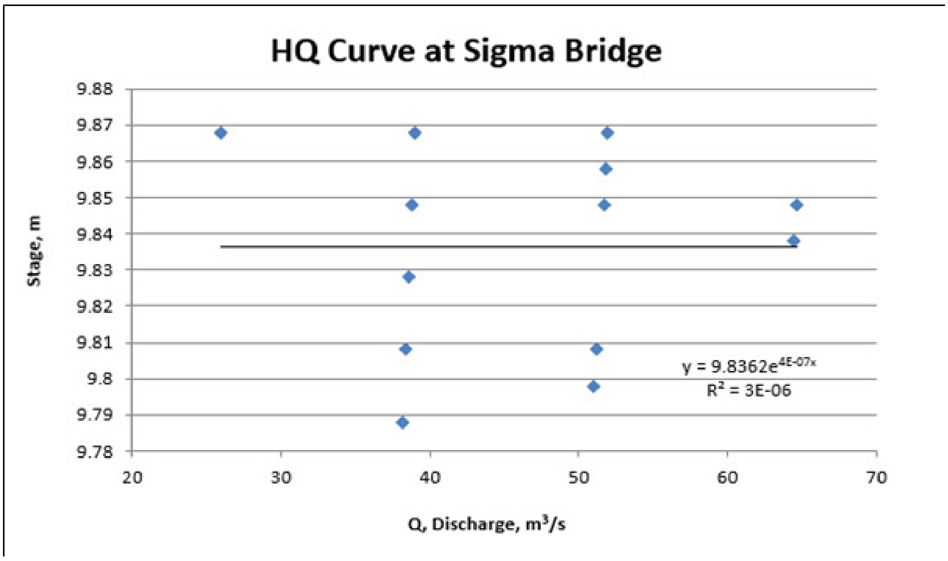

Figure 29. HQ Curve at Sigma Bridge, Brgy. Poblacion Norte, Capiz

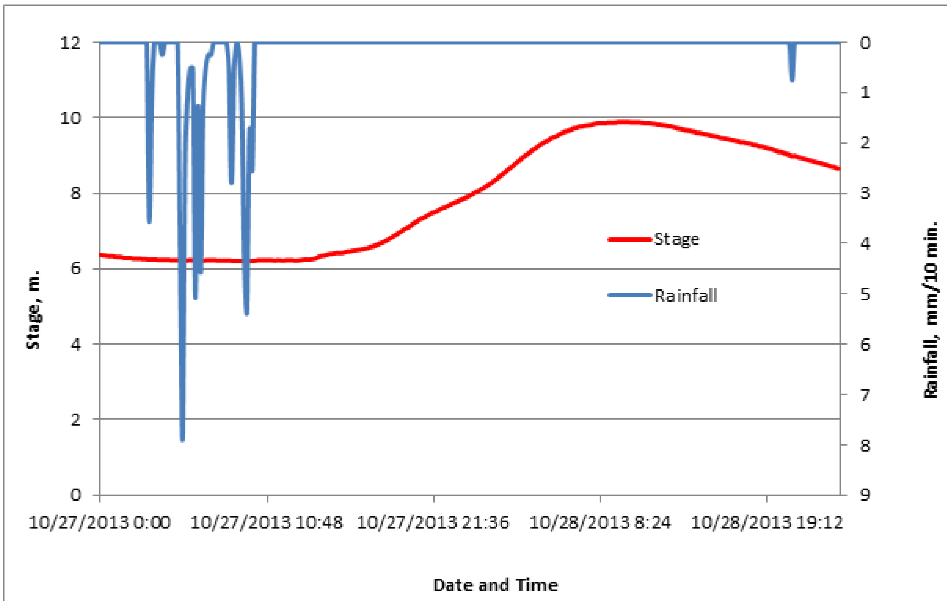

Figure 30. Relationship between Rainfall and Stage at Sigma Bridge

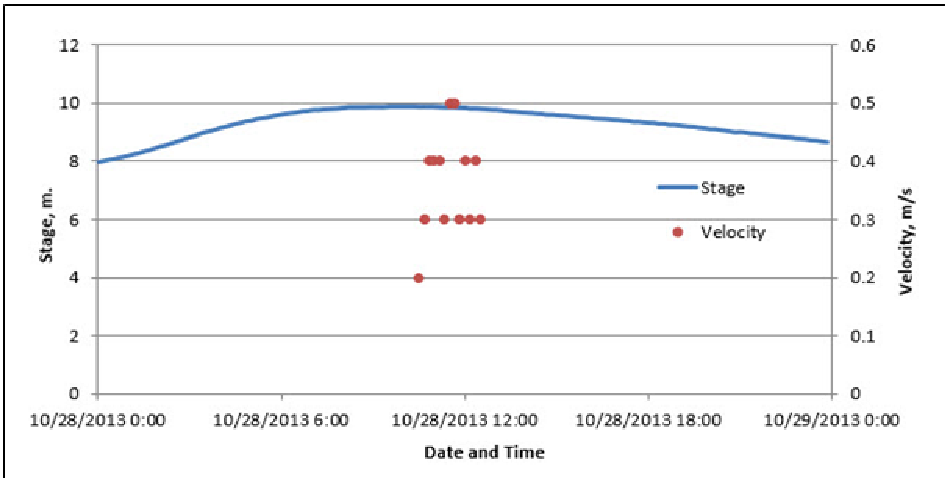

Figure 31. Relationship between Water Velcity and Stage at Sigma Bridge

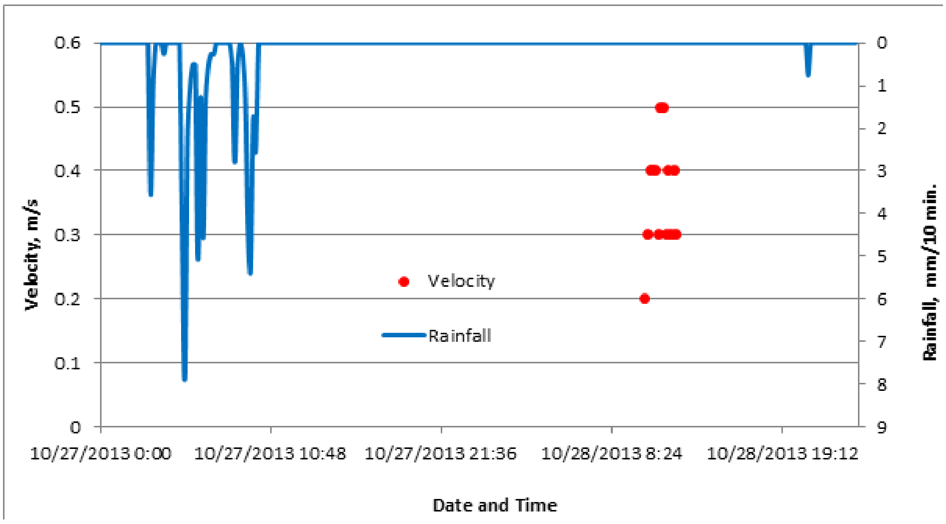

Figure 32. Relationship between Water Velocity and Rainfall at Sigma Bridge

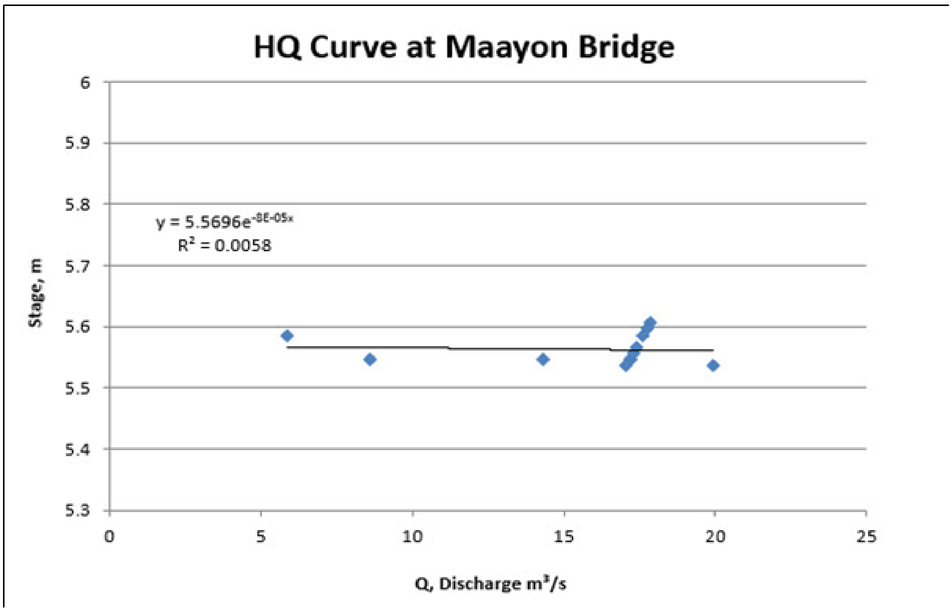

Figure 33. HQ Curve at Maayon Bridge, Brgy. Ma-Ayon, Poblacion Capiz

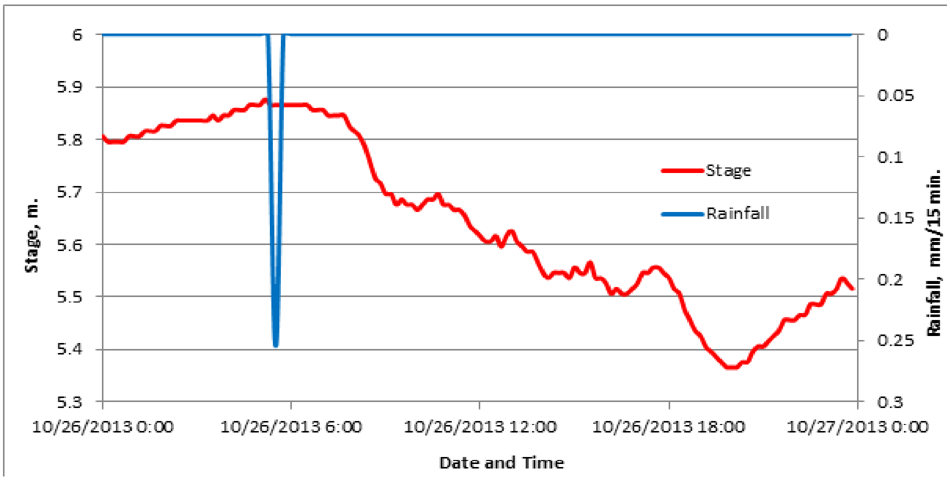

Figure 34. Relationship between Rainfall and Stage at Maayon Bridge

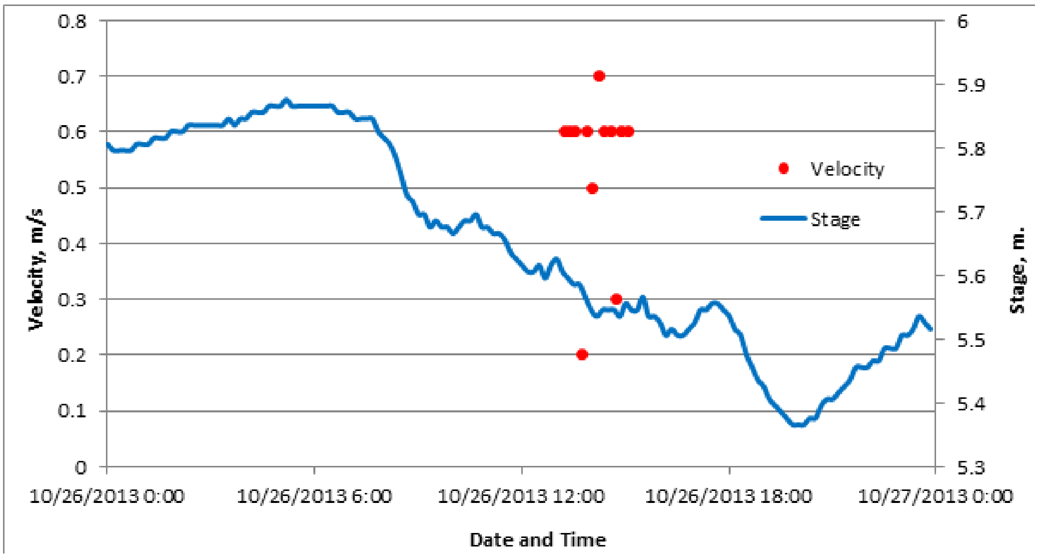

Figure 35. Relationship between Water Velocity and Stage at Maayon Bridge

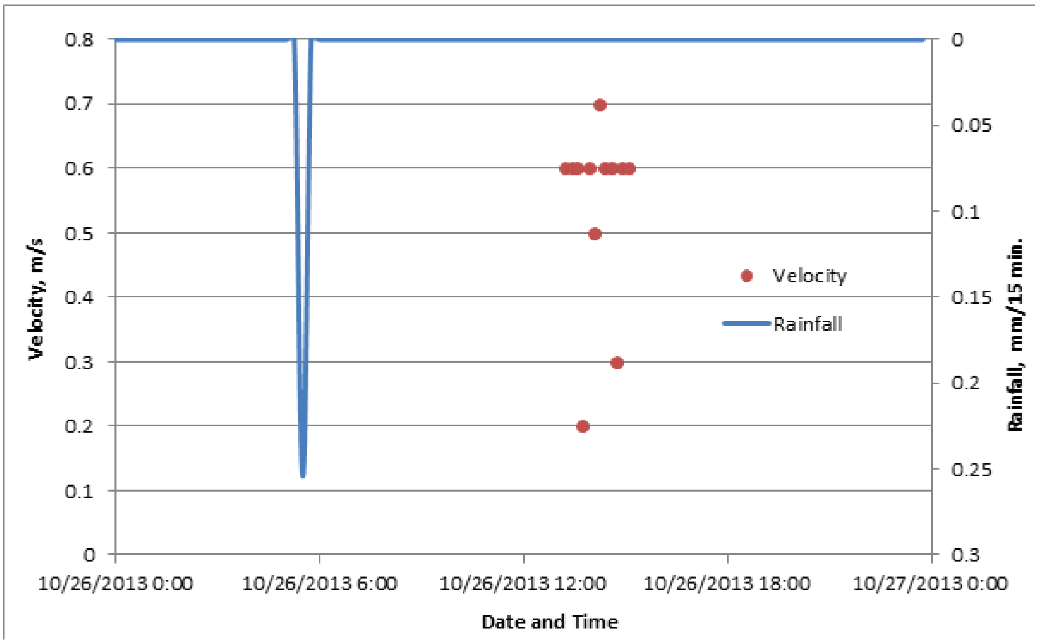

Figure 36. Relationship between Water Velocity and Rainfall at Maayon Bridge

4.4.1 Possible Sites for Automated Water Level Sensor (AWLS) Installation

Reconnaissance for the possible sites for AWLS on existing bridges along the main stream and its tributaries was also conducted. The Advance Science and Technology Institute (ASTI) under the Department of Science and Technology (DOST) aims to install water level sensors to monitor the changes in water elevation on river systems. The location of automated water level sensors in Panay, Roxas City are shown in Figure 37 while Table 3 and 4 summarize the AWLS installation site with its corresponding coordinates.

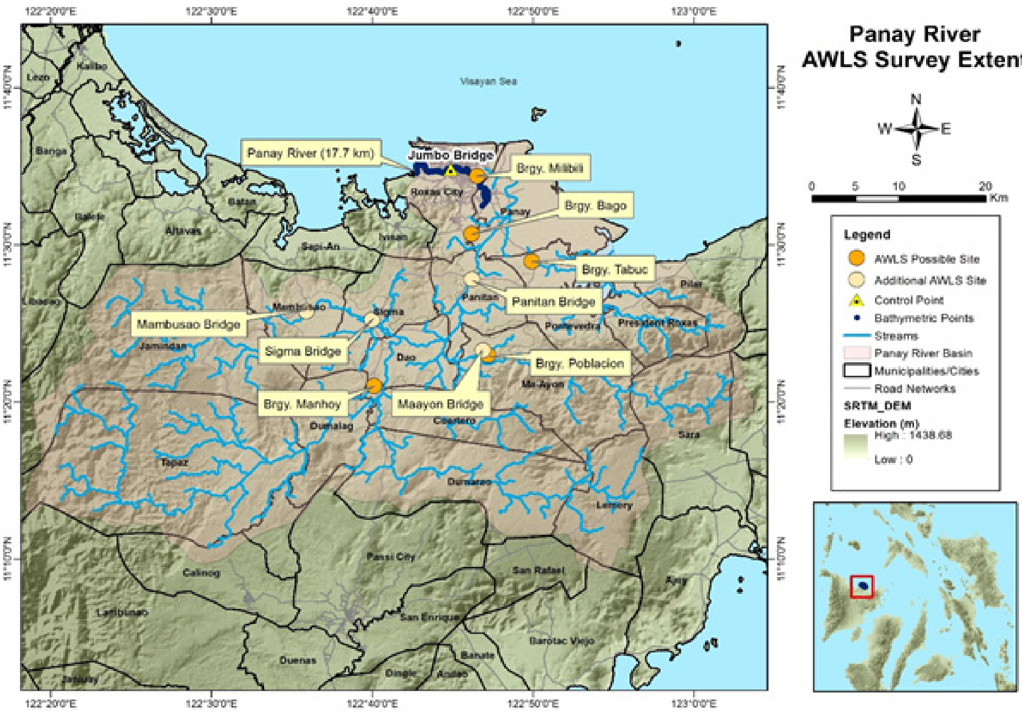

Figure 37. Possible sites for Automated Water Level Sensor (AWLS) installation along Panay River System

Table 3. Possible areas for AWLS installation, the candidates were chosen on Google™ Earth images

Bridge	Latitude	Longitude
Barangay Manhoy, Dao, Capiz	11°21'00.90" N	122°40'06.74" E
Barangay Poblacion Ilaya, Dao, Capiz	11°22'58.49" N	122°47'12.02" E
Barangay Bago Grande, Roxas City	11°30'41.65" N	122°46'10.75" E
Barangay Milibili, Roxas City	11°34'22.71" N	122°46'30.98" E
Barangay Tabuc, Ilaya, Ilawod, Pontavedra	11°28'56.65" N	122°49'55.31" E

On actual ground search, the survey team realized that there are existing bridges not seen on Google™ Earth which can also be suitable for sensor installation. Here are the lists of additional bridges for AWLS.

Table 4. List of additional bridges for AWLS.

Bridge	Latitude	Longitude
Panitan Bridge, Panay	11°27'48.8" N	122°46'11.7" E
Mambusao Bridge, Mambusao	11°25'44.62" N	122°35'54.04" E
Sigma Bridge, Capiz	11°25'13.0" N	122°39'58.9" E
Maayon Bridge, Maayon, Capiz	11°23'17.2" N	122°46'53.0" E

A good sensor deployment site should meet the following criteria.

1. **Cell phone reception availability in the area –** the sensors will be sending real time data to respective units through sms messages. Area shall be checked for available mobile signal reception.
2. **Security of the area –** is the area/bridge isolated or is there a community nearby. A better condition would be a bridge within a community so that there will always be someone to look over the sensors.
3. **Drainage Area**

The installed automated water level sensors (AWLS) in the Panay River System are shown in Figure 38 to 42:

Figure 38. AWLS in Panitan Bridge, Brgy. Agkilo, Panitan, Capiz

Figure 39. AWLS in Dao Bridge, Barangay Manhoy, Dao, Capiz

Figure 40. AWLS in Jamindan Bridge, Jamindan, Capiz

Figure 41. AWLS in Sigma Bridge, Brgy. Poblacion Norte, Capiz

Figure 42. AWLS in Maayon Bridge, Tabuc, Brgy. Ma-Ayon, Poblacion Capiz

Table 5. Summary of awls reconnaissance result

	BRIDGE	CURRENT STATE	SECURITY	CELL PHONE RECEPTION	AS TOLD BY THE RESIDENTS	REMARKS	RECOMMENDATION
1	Barangay Manhoy, Dao, Capiz (Manhoy Quartero Bridge)	flowing water	houses near the bridge; national road, security can be considered okay	has strong Smart and Globe reception, no Sun signal	during storm quinta, Manhoy Bridge, the area was flooded up to below knee level, Dao Municipal Bldg. Included	DOST region VI once visited the area for inspection of sensor deployment last October 2012 according to MDRRMO	Recommended site for installation
2	Barngay Poblacion Ilaya, Dao, Capiz	flowing water	residents near the bridge; water level is almost at the same level as the bridge: less than 1 meter	has strong Smart and Globe reception, no Sun signal	--	there is a bridge near thisd site approximately 800 m downstream (Maayon Bridge)	Not recommended for AWLS installation due to very low level of the bridge
3	Barangay Bago Grande, Roxas City	no flowing water on the river; river is almost dry	houses exists near the bridge	has strong Smart and Globe reception	water does not rise along the area even in the rainy season	--	Not recommended for AWLS installation due to no flowing water
4	Barangay Milibili, Roxas City	water is almost still during the time of inspection	bridge is isolated to nearby community; road connected; not sure about security	has strong Smart and Globe reception	--	--	Not recommended due to security reasons
5	Barangay Tabuc, Ilaya, Ilawod Pontavedra	flowing water	near houses and establishments; security okay	has strong Smart and Globe reception	--	wide river; near to sea, downstream flow goes to other area rather than Panay River	Not recommended because it is near the mouth of the river
1	Panitan Bridge, Panay	flowing water	near houses and establishments; security okay	has strong Smart and Globe reception	--	--	Recommended site for installation
2	Sigma Bridge, Capiz	flowing water	near houses and establishments; security okay	has strong Smart and Globe reception	known as the area that is always flooded	--	Recommended site for installation
3	Mambusao Bridge, Mambusao	flowing water	near houses and establishments; security okay	has strong Smart and Globe reception	near Sigma Bridge	--	an alternative area for Sigma bridge
4	Maayon Bridge, Maayon Cpiz	flowing water	near houses and establishments; security okay	has strong Smart and Globe reception, no Sun signal	--	--	Recommended site for installation

4.4.2 Flow measurement

Flow measurement is necessary to compute the river discharge. The survey team conducted flow measurements simultaneously on the bridges where there are installed AWLS. The team gathered data for 2 to 3 hours and recorded every ten (10) minutes. Gathering of flow data of the river at Jamindan Bridge, Maayon Bridge and Sigma Bridge are shown in Figure 43, 44 and 45 respectively.

Figure 43. Flow measurement along Jamindan Bridge, Municipality of Jamindan, Capiz

Figure 44. Flow measurement along Maayon Bridge, Brgy. Ma-Ayon, Poblacion Tabuc, Capiz

Figure 45. Flow measurement along Sigma Bridge, Brgy. Poblacion Norte, Capiz

Another survey was performed for the cross-section of the installed AWLS on the bridges located in Panay River. The data gathering weas conducted on October 25 – 27, 2013 for the five (5) installed AWLS on the Panay River namely: Panitan and Dao bridges in the mainstream, Sigma and Jamindan bridges in the left tributaries, and finally Maayon bridge in the right tributary. The control point at Jumbo Bridge was occupied as base for the surveying at Brgy. Punta Tabuc, Roxas City, Capiz. The following series of pictures shows the cross-sectional view and elevation in MSL of AWLS and water surface on specific date and time.

Digrams of bridges located in the Panay mainstream are shown in Figure 46 and 47.

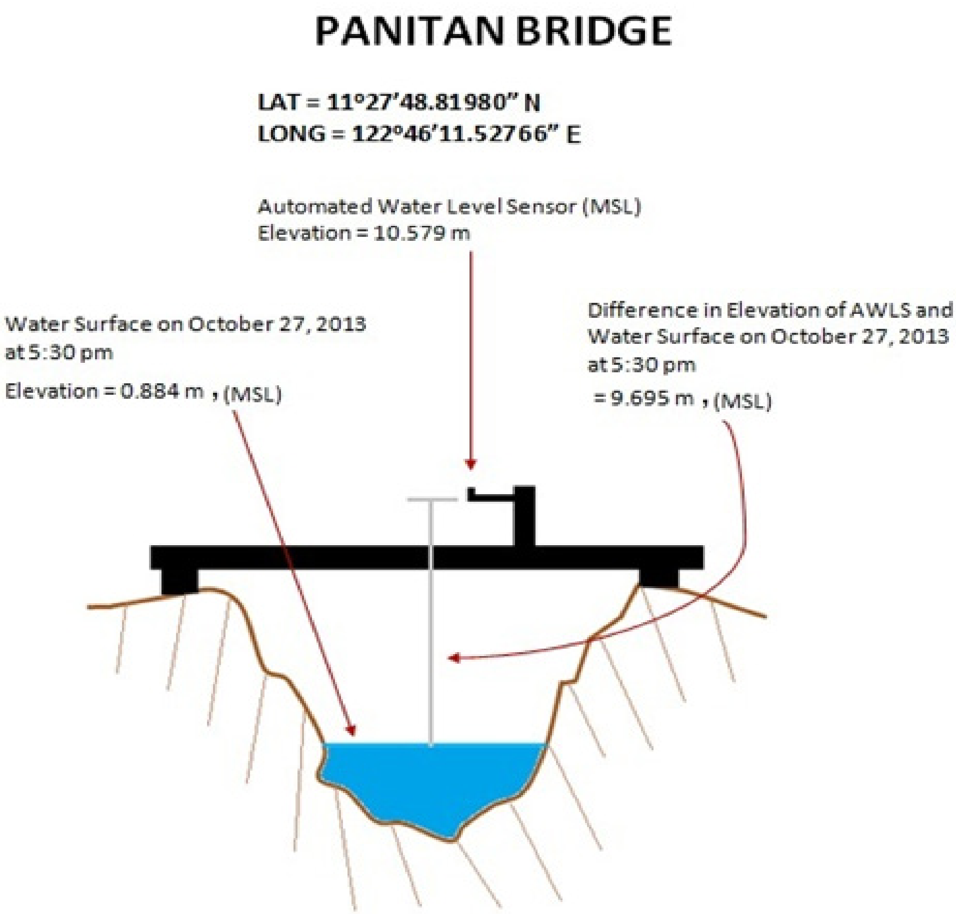

Figure 46. AWLS in Panitan Bridge, Brgy. Agkilo, Panitan, Capiz

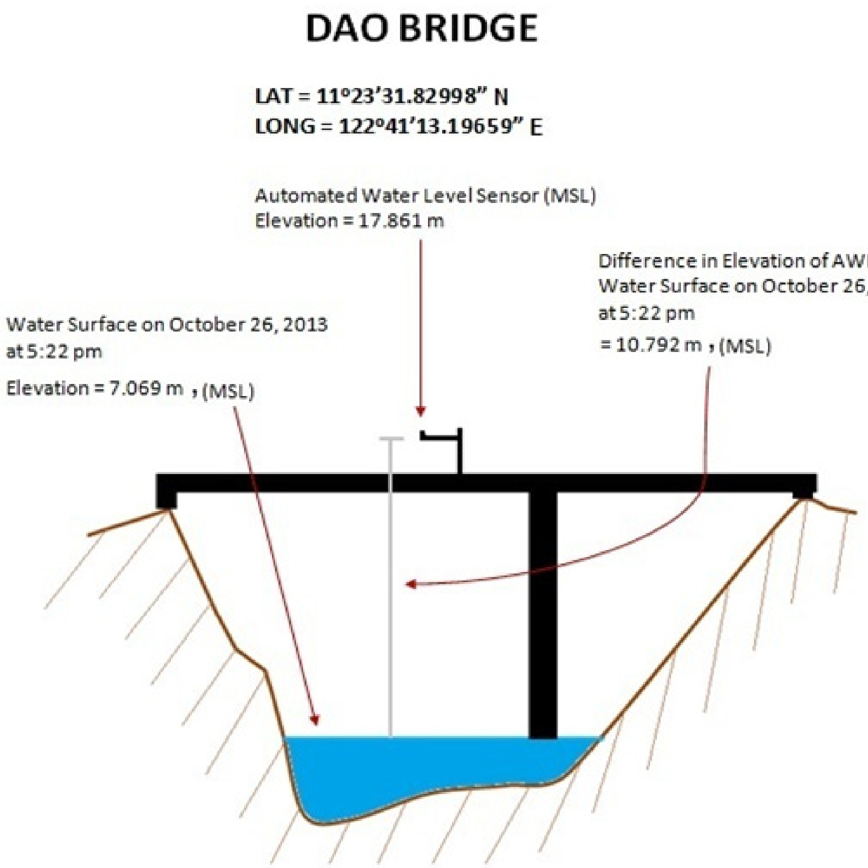

Figure 47. AWLS in Dao Bridge, Barangay Manhoy, Dao, Capiz

Diagrams of bridges located in the left tributary of the Panay river are illustrated in Figure 48 and 49

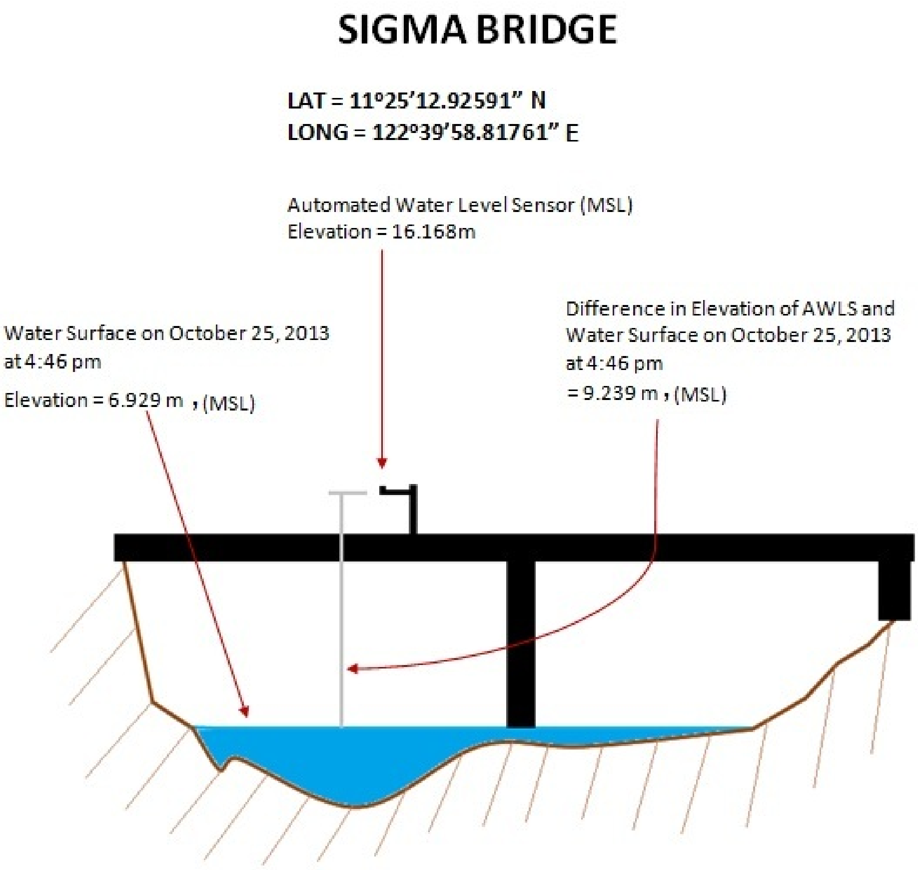

Figure 48. AWLS in Sigma Bridge, Brgy. Poblacion Norte, Capiz

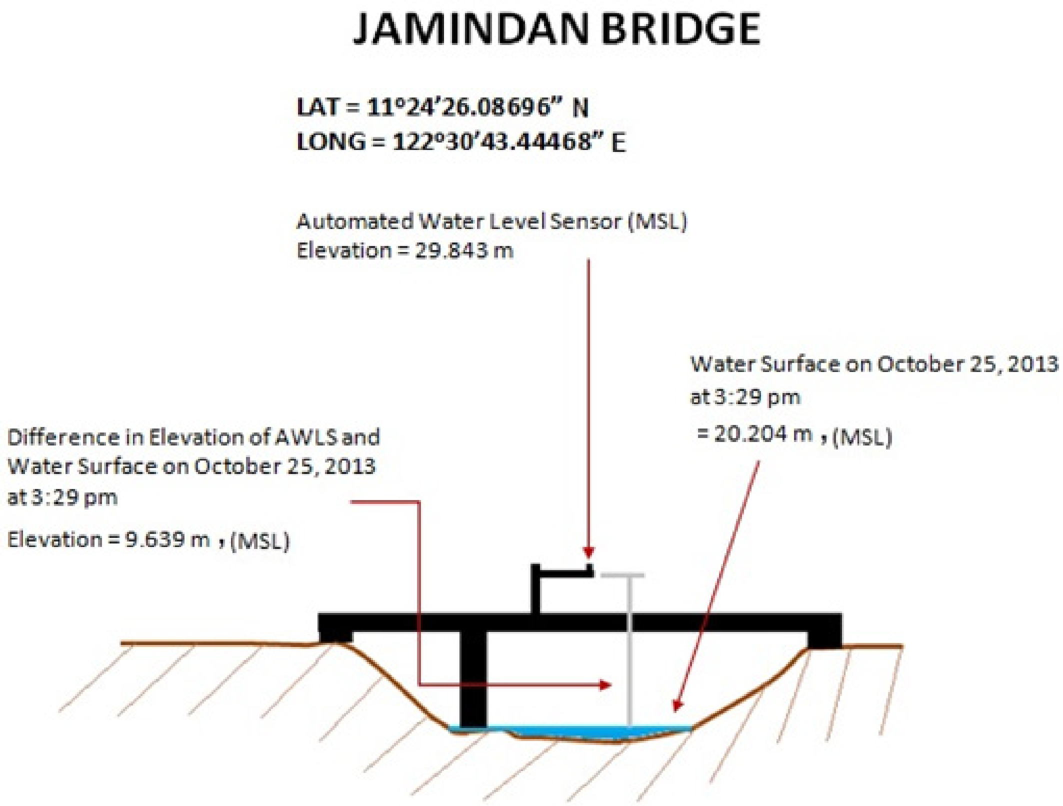

Figure 49. AWLS in Jamindan Bridge, Municipality of Jamindan, Capiz

The diagram of Maayon Bridge located in the right tributary of the Panay river is displayed in Figure 50.

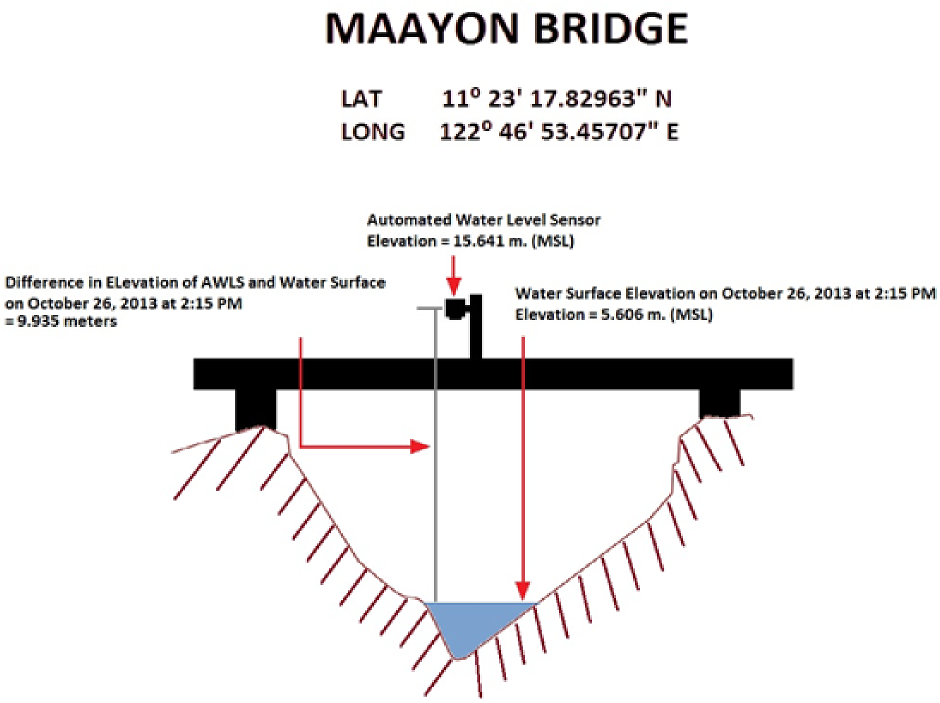

Figure 50. AWLS in Maayon Bridge Brgy. Ma-Ayon, Poblacion Tabuc, Capiz

4.5 Validation Points Acquisition Survey

Validation Points Acquisition Survey was conducted on July 21-22, 2013. Data Validation Component was able to recover a horizontal control point, CPZ-20. This recovered control point was occupied as one of the bases for the road validation survey. Panay River validation survey was conducted to serve as accuracy check as well as validation for data acquired from LIDAR.

LiDAR validation set-up is shown in Figure 51 while Figure 52 shows the coverage of the LiDAR validation survey.

Figure 51. LiDAR Validation setup

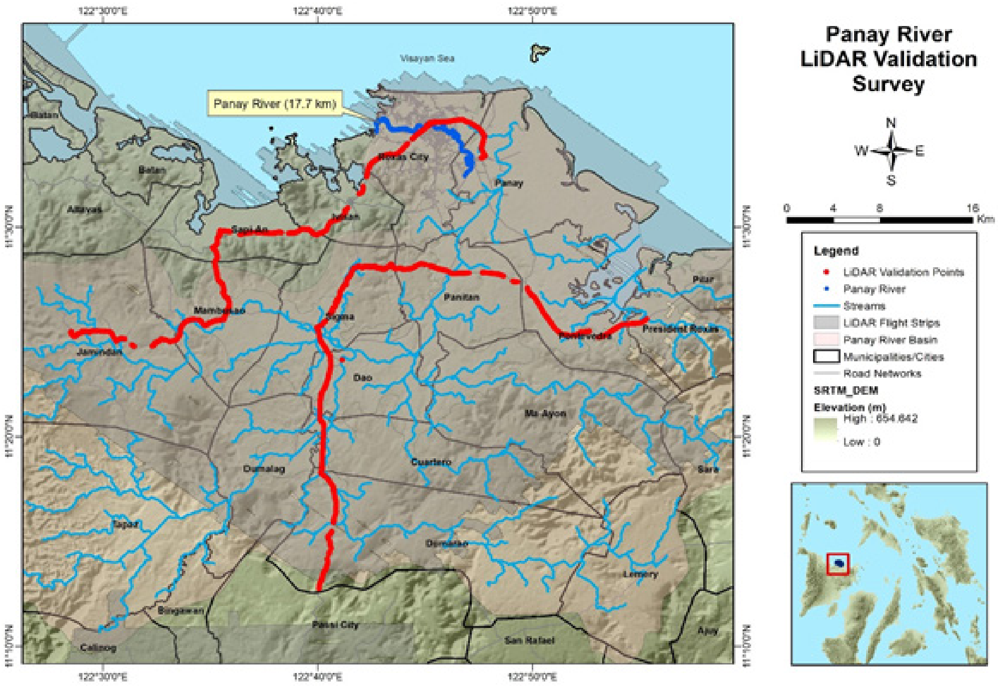

Figure 52. LiDAR validation coverage for Panay River Basin

Panay River Basin Survey

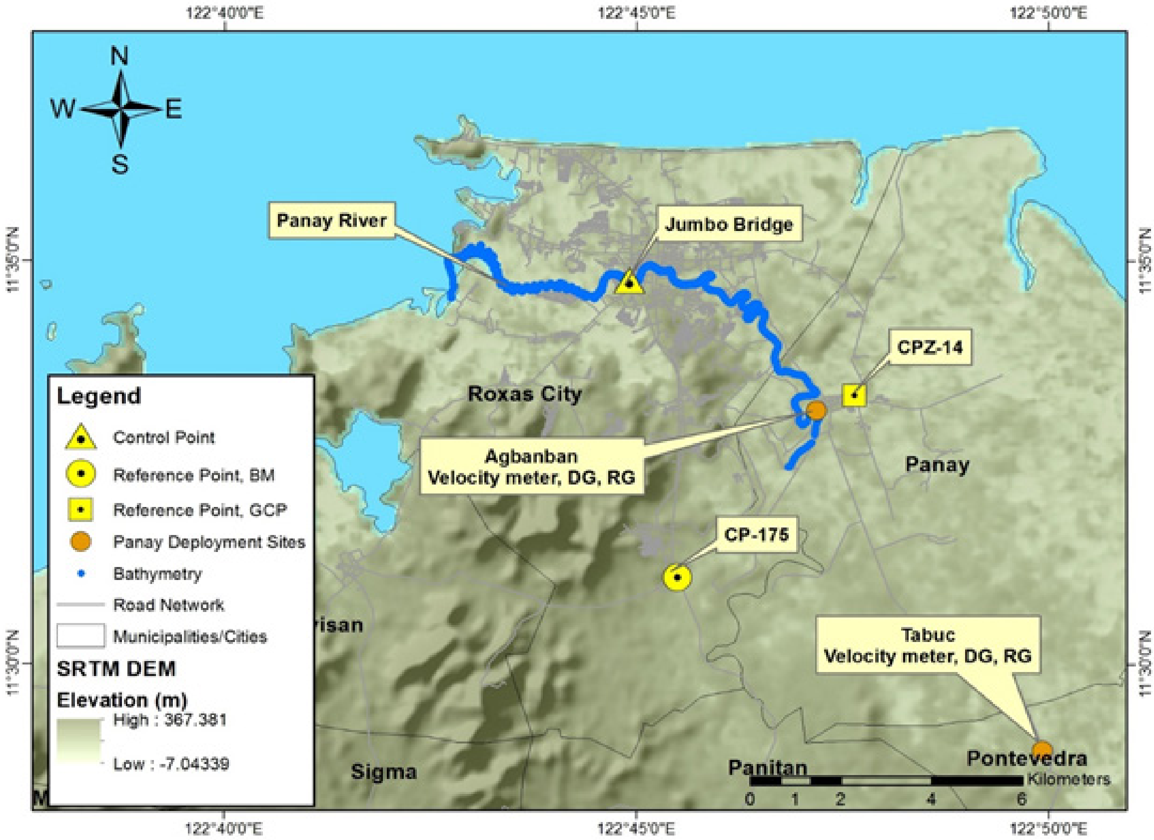

Figure 53. Panay River Sensor Locations

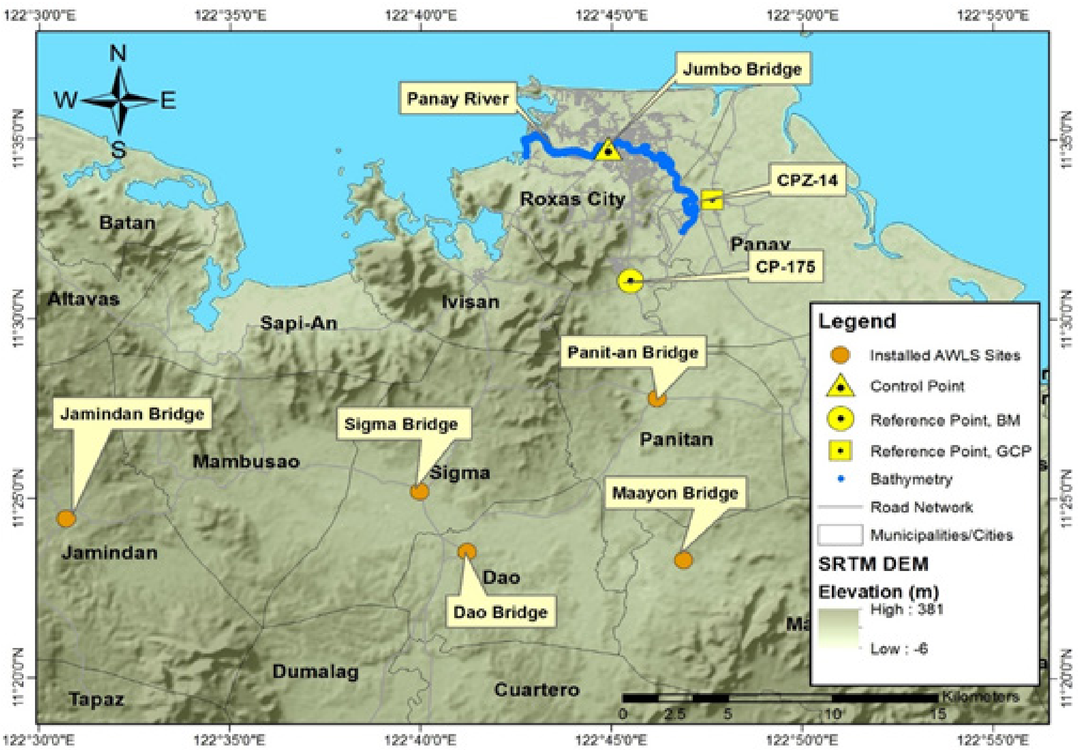

Figure 54. Location of Installed AWLS in Panay River

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

The problems encountered by the team with respective solutions are summarized below:

Limitations/Problems	Solutions
The City Mayor and Provincial Governor is not available for courtesy call	Reschedule the courtesy call
Some starting points of the cross-section are not reachable due to thick vegetation primarily of Nipa.	Used a boat to reach the starting point
Nipa trees block the satellite signals for zigzag sweep	Used portable echo sounder to determine depth and GNSS RTK mode to get the coordinates.
Sensor site at Bato Grande is not possible because there is no flow.	Find another sensor site, the team deployed the sensors in Bgy. Agbanban.

The image in Figure 60 and Figure 61 shows the deployment of rain gauge and preparation of the velocity meter and depth gauge in Brgy. Poblacion, Compostela respectively. The cross section stage-discharge data computations of these sensors are shown in Figures 62-64.

ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

Type	Brand	Serial Number	Owner	Quantity
GPS Receiver (Base)	Trimble™ SPS852		UP-TCAGP	One (1) units
GPS Receiver (Rover)	Trimble™ SPS882		UP-TCAGP	Three (3) units
GPS Controller	Trimble™ TSC3		UP-TCAGP	Three (3) units
High-Gain Antenna			UP- TCAGP	Three (3) units
Single Beam Echosounder with accessories	Ohmex	2969	UP-TCAGP	One (1) unit
Coupler-2a and 2b			UP- TCAGP	One (1) unit each
Handheld GPS	Garmin Oregon™ 550		UP-TCAGP	Two (2) units
AA-Battery Charger	Akari		UP-TCAGP	Two (2) units
Laptops	Dell Laptop		UP-TCAGP	One (1) unit
	Dell Laptop			One (1) unit
Depth Gauge	Onset Hobo wares		UP-TCAGP	One (1) unit
Rain Gauge		1293784	UP- TCAGP	One (1) unit
Echosounder	Ohmex™	2969	UP-TCAGP	One (1) unit
Range Pole	Trimble™		UP-TCAGP	Three (3) units
Tripod	Trimble™		UP-TCAGP	One (1) unit
Bipod	Trimble™		UP-TCAGP	Three (3) units
Tribrach			UP-TCAGP	One (1) unit
Laser Range Finder	Bushnell		UP-TCAGP	One (1) unit
Toolbox			UP-TCAGP	One (1) unit
QINSy dongle			UP-TCAGP	One (1) unit

NNEX C. THE SURVEY TEAM

Data Validation Component Sub-team	Designation	Name	Agency/Affiliation
Survey Supervisor	Senior Science Research Specialist	ENGR. BERNARD PAUL D. MARAMOT	UP TCAGP
Bathymetric Survey Team	Senior Science Research Specialist	ENGR. DEXTER T. LOZANO	UP TCAGP
	Research Associate	MARY GRACE S. JASON	UP TCAGP
Profile Survey Team	Research Associate	MARK LESTER D. ROJAS	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

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

April 26, 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: **CAPIZ**
Station Name: **CP-175**

Island: **Visayas**	Municipality: **ROXAS CITY**	Barangay: **LANOT**
Elevation: **6.8878 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM CP-175
is in island of Panay, Province of Capiz, Roxas City barangay Lanot along national highway, located on a road junction leading to Ivisan and Panitan, at E concrete gutter of welcome monument, 0.10 m N of N edge of concrete base. Mark is 4" copper nail embedded in a drilled hole with inscription on top of cement putty thus; "NAMRIA 1994 CP-175".

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**3943584 B**
T.N.:	**2013-0367**

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

9904262013163534

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

April 26, 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: **CAPIZ**	
	Station Name: **CPZ-14**	
	Order: **2nd**	Barangay: **POBLACION ILAWOD**
Island: **VISAYAS**		
Municipality: **PANAY**		
	PRS92 Coordinates	
Latitude: **11° 33' 24.51899"**	Longitude: **122° 47' 34.41876"**	Ellipsoidal Hgt: **4.91900 m.**
	WGS84 Coordinates	
Latitude: **11° 33' 19.98412"**	Longitude: **122° 47' 39.56494"**	Ellipsoidal Hgt: **60.96000 m.**
	PTM Coordinates	
Northing: **1277923.165 m.**	Easting: **477410.249 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,277,475.87**	Easting: **477,418.16**	Zone: **51**

Location Description

CPZ-14
From Roxas City, travel E to the Mun. of Panay. Then proceed directly to the town plaza, where the station is located. Station is located at Panay Park, about 30 m. from the chuch and about 30 m. from the nat'l. road. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "CPZ-14 2007 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943584 B**
T.N.: **2013-0364**

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

9 9 0 4 2 6 2 0 1 3 1 6 3 4 2 5

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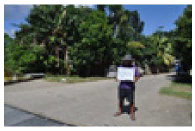
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

Annexes

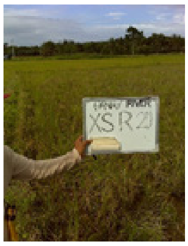
ANNEX E. RECONNAISSANCE SUMMARY

Cross-section Reconnaissance						
Remarks		Left	Cross-section	Right		Remarks
PASS-ABLE		nipa trees at the bank, rice field	1	nipa trees at the bank, private com-pound, open filed		PASS-ABLE
PASS-ABLE		nipa trees at the bank, vegetation, clump trees, open field	2	nipa trees at the bank, private com-pound, open filed		PASS-ABLE
PASS-ABLE		nipa trees at the bank, pri-vate property, open field	3	nipa trees and banana at the bank, open field		PASS-ABLE
PASS-ABLE		rice field	4	nipa trees at the bank, private prop-erty, open field		PASS-ABLE
PASS-ABLE		nipa trees at the bank, rice field	5	trees at the bank, private compound, rice field		PASS-ABLE

Remarks		Left	Cross-section	Right		Remarks
PASSABLE		nipa trees at the bank, rice field	6	nipa trees at the bank, private compound, rice field		PASSABLE
PASSABLE		nipa trees at the bank, rice field	7	vegetation at the bank, rice field		PASSABLE
PASSABLE		nipa trees at the bank, private property, open field	8	nipa trees at the bank, private property, open field		PASSABLE
PASSABLE		nipa trees at the bank, rice field	9	nipa trees at the bank, private residence, barangay road		PASSABLE
PASSABLE		start point at bridge, road, cogon grass	10	start point at bridge, concrete road, rural bank of Panay		PASSABLE
PASSABLE		nipa trees at the bank, grasses	11	nipa trees at the bank, rice field		PASSABLE

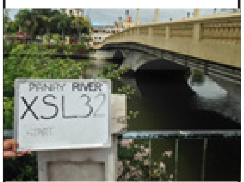
Re-marks		Left	Cross-section	Right		Re-marks
PASS-ABLE		nipa trees at the bank, rice field	12	nipa trees at the bank, rice field		PASS-ABLE
PASS-ABLE		private property, road	13	nipa trees at the bank, rice field		PASS-ABLE
PASS-ABLE		nipa trees and vegetation at the bank, rice field	14	nipa trees at the bank, rice field, private compound, concrete road		PASS-ABLE
PASS-ABLE		nipa trees at the bank, private property, rice field	15	nipa trees at the bank, private coca-cola depot		PASS-ABLE
PASS-ABLE		nipa trees at the bank, private compound, rice field	16	nipa trees at the bank, private property of coca-cola		PASS-ABLE

Annexes

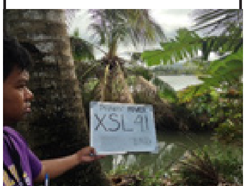
Remarks		Left	Cross-	Right		Remarks
PASSABLE		nipa trees and vegetation at the bank, rice field	17	nipa trees at the bank, private property of coca-cola		PASSABLE
PASSABLE		nipa trees at the bank, trees, rice field	18	nipa trees at the bank, private property, road		PASSABLE
PASSABLE		nipa trees at the bank, private property, fishpond	19	nipa trees at the bank, private property, open field		PASSABLE
PASSABLE		nipa trees and vegetation at the bank, rice field	20	trees at the bank, rice field		PASSABLE
		nipa trees at the bank, private property, rice field	21	nipa trees at the bank, hilly dirt road		

Annexes

Remarks		Left	Cross-section	Right		Remarks
PASSABLE		nipa trees at the bank reachable by boat, tall cogon	26	nipa trees at the bank, concrete road,		PASSABLE
PASSABLE		fishpond, open space, concrete road	27	nipa trees at the bank, fishpond		PASSABLE
PASSABLE		private property, rough road	28	Fishpond and nipa trees at the bank, open field		PASSABLE
PASSABLE		private property, concrete road	29	nipa trees at the bank, rough road		PASSABLE

Remarks		Left	Cross-section	Right		Remarks
PASSABLE		starting point at the bridge, road	30	road		PASSABLE
PASSABLE		starting point at the bridge, concrete road	31	Starting point at the bridge, road, airport runway		Minor revisions are made, original cross section crosses the runway, reroute it to an adjacent road nearby
PASSABLE		Starting point at the bridge, road	32	Starting point at the bridge, road, building		Divert it to the nearby road since it crosses buildings.
PASSABLE		road	33	vegetation at the bank, private property, open space		

Remarks		Left	Cross-section	Right		Remarks
Densely populated area, with cross sections intersecting manmade structures. Reroute to adjacent road.		Starting point at the Jumbo bridge, densely populated area	34	Starting point at the Jumbo bridge, densely populated area		Densely populated, crossing private properties and structures. Reroute to adjacent road.
PASSABLE		fishpond, mangroves	35	private property, small pond, village		Densely populated, crossing private properties and structures. Reroute to adjacent road.
PASSABLE		mangroves, fishpond	36	mangroves, fishpond		PASSABLE
PASSABLE		mangroves, private property, open space	37	mangroves, fishpond		Densely populated, crossing private properties and structures. Reroute to adjacent road.

Remarks		Left	Cross-section	Right		Remarks
PASSABLE		mangroves and nipa trees at the bank, village	38	mangroves, fishpond		PASSABLE
PASSABLE		nipa trees at the bank, fishpond	39	fishpond		Densely populated, crossing private properties and structures. Reroute to adjacent road.
PASSABLE		nipa trees at the bank, fishpond	40	mangroves, fishpond		PASSABLE
PASSABLE		mangroves, fishpond	41	open space		PASSABLE
PASSABLE		nipa trees at the bank, fishpond	42	Houses, alley, private property		PASSABLE

Bibliography

- Panay River Basin Integrated Development Project. (2012, October 11). Retrieved October 29, 2015, from https://niaregion6.wordpress.com/panay-river-basin-integrated-development-project/

D R E A M

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