REGION 3

Angat 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.

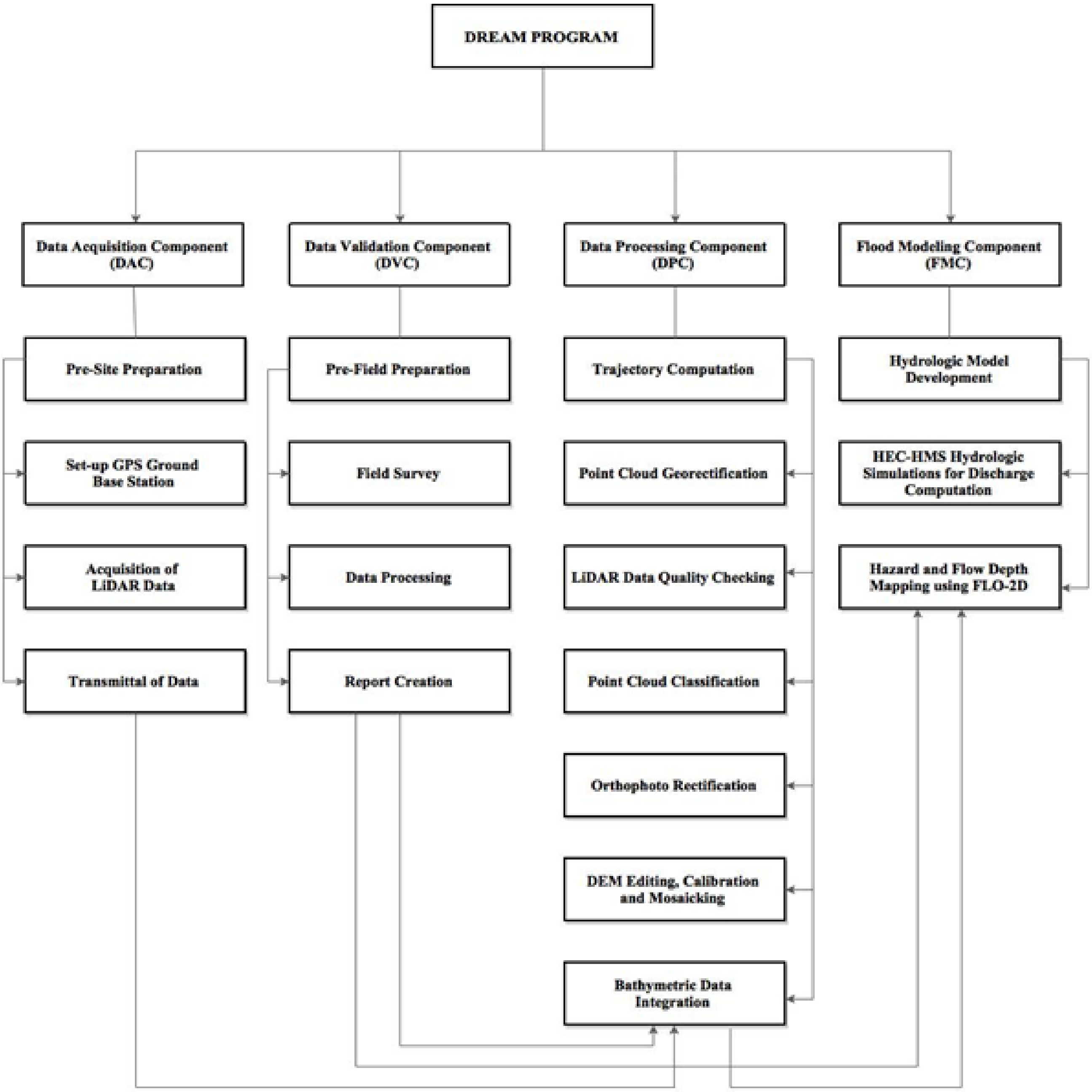


Figure 1. The General Methodological Framework of the Program

The Angat River Basin

The Angat River Basin

Angat River Basin is located in the province of Bulacan. According to DENR-RCBO, it has a drainage area of 781 square kilometres and an estimated 723 million cubic meter annual run-off. To the northeast is the Umiray River Basin, Kanan River Basin to the southeast and the Marikina River Basin to the south (National Power Corporation). The location of Angat River Basin is as shown in Figure 2.

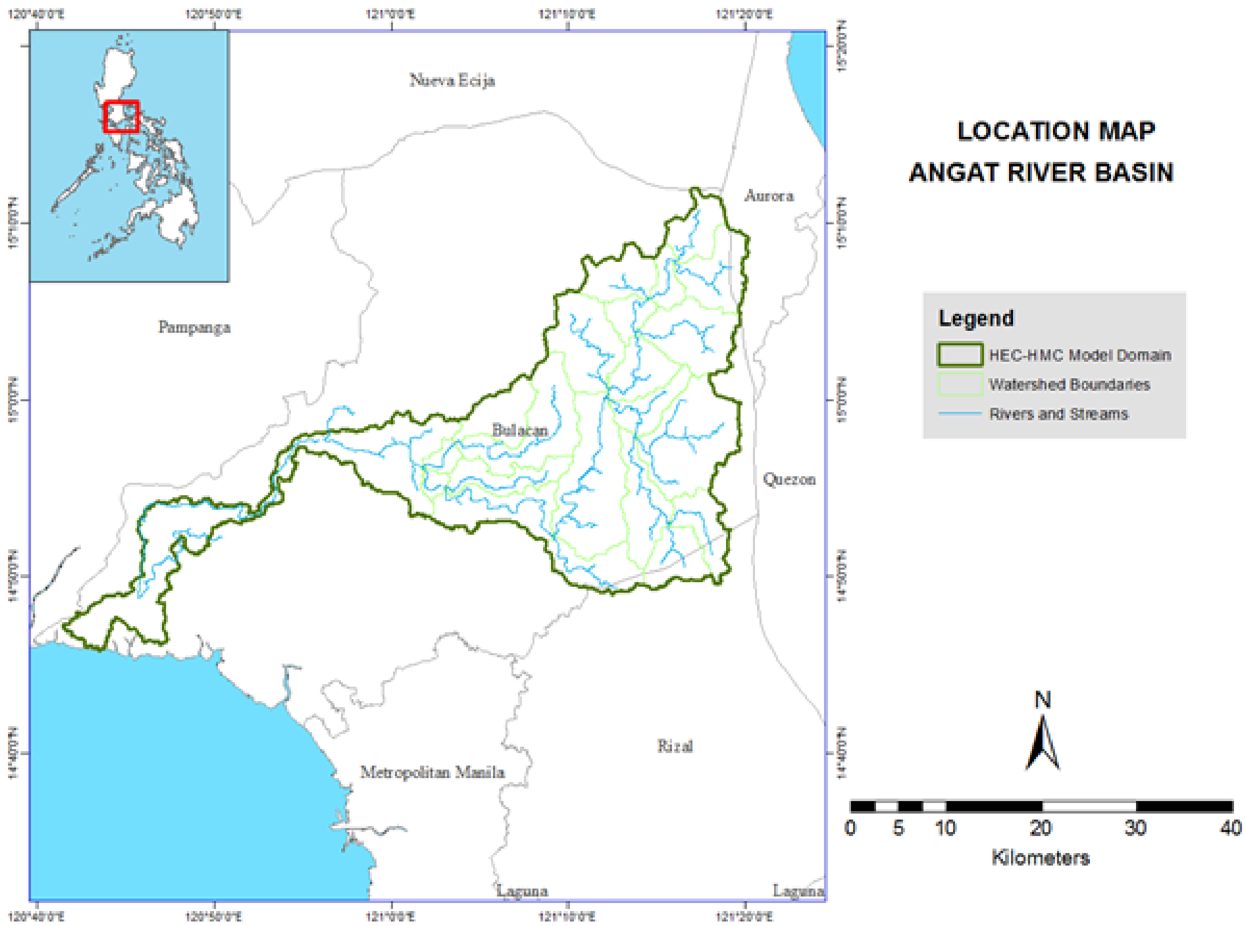


Figure 2. The Angat River Basin Location Map

Its main stem, the Angat River, is the largest river in Bulacan and it drains the west flank of the Sierra Madre Mountain Range and empties into Manila Bay. Along the river are the municipalities of Angat, Baliwag, Bustos, Doña Remedios Trinidad, Norzagaray, Pulilan, Calumpit, San Rafael, Plaridel, Paombong, and Hagonoy (House of Representatives). There are three dams along Angat River namely Angat, Ipo, and Bustos. Angat Dam supplies 500 million gallons per day and it supplies 97% of water in Metro Manila. It also irrigates about 28,000 hectares of farmland in the provinces of Bulacan and Pampanga.

Due to rains brought by Typhoon "Pedring" on September 2011, much of the provinces of Bulacan, Nueva Ecija, Pampanga, and Pangasinan were flooded. However, because several dams continued to release water in preparation for Tropical Storm Quiel, flooding lasted longer than it should have been. In Bulacan, most of the barangays in the towns along Angat River were under water (Burgonio, 2011)

DVC Methodology

DVC Methodology

A set of activities were designed and implemented by DVC with four (4) main activities as shown in Figure 3.

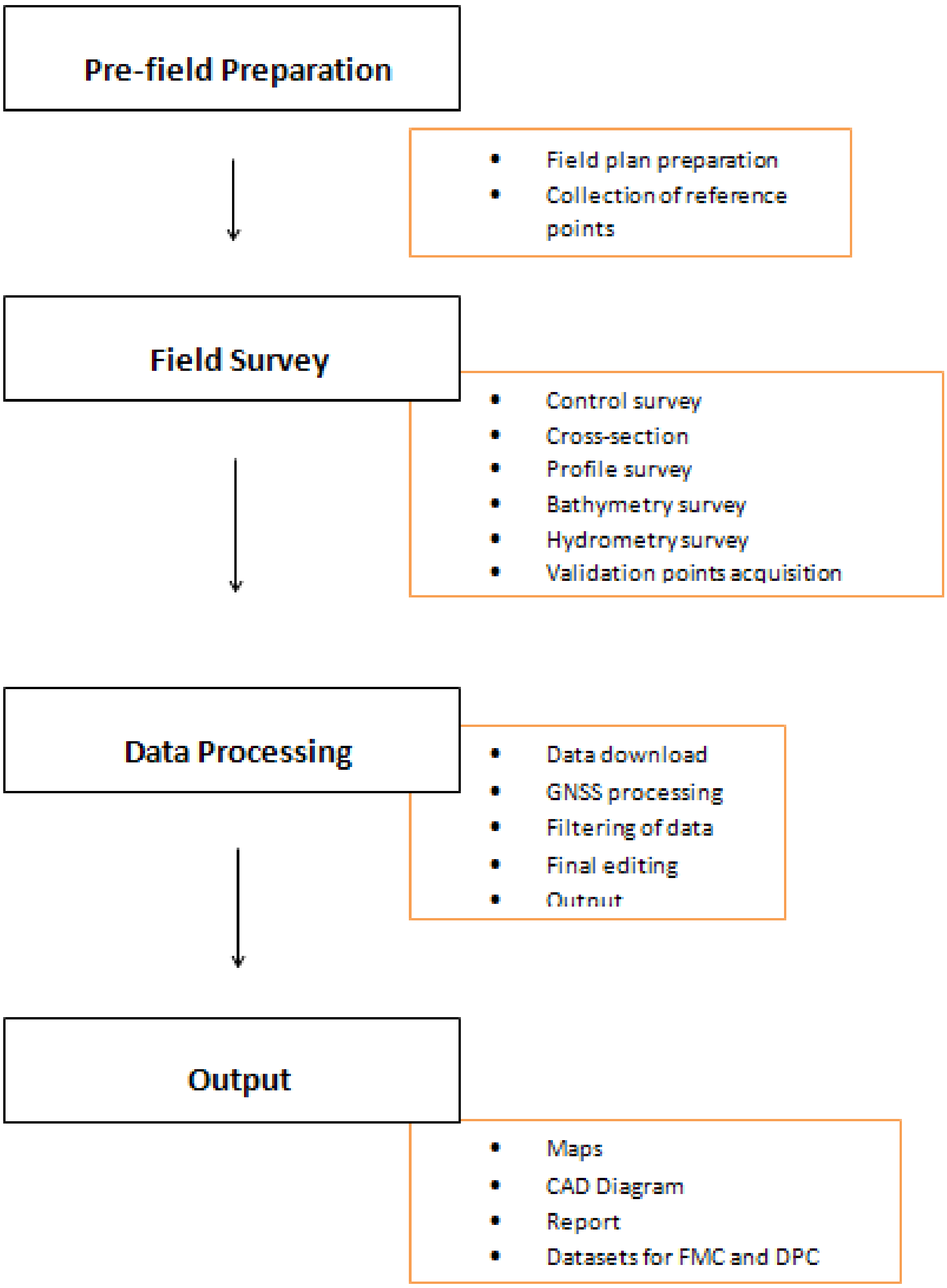


Figure 3. DVC Main Activities

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

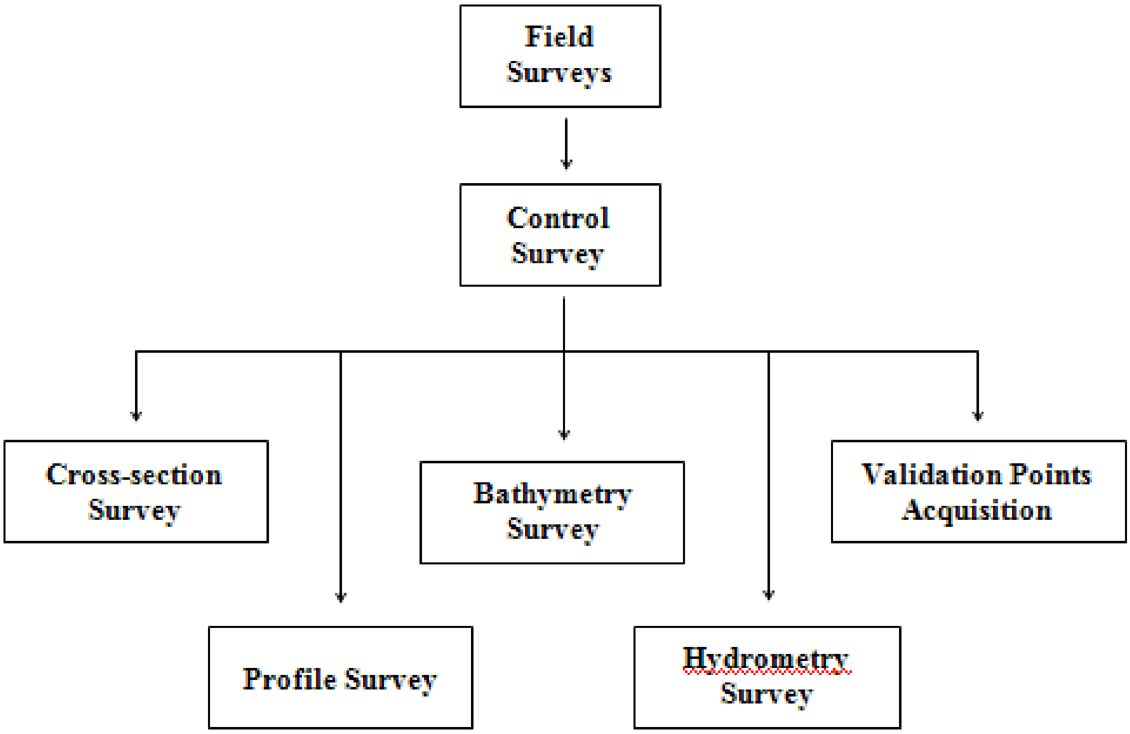


Figure 4. DVC Field Activities

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 5.

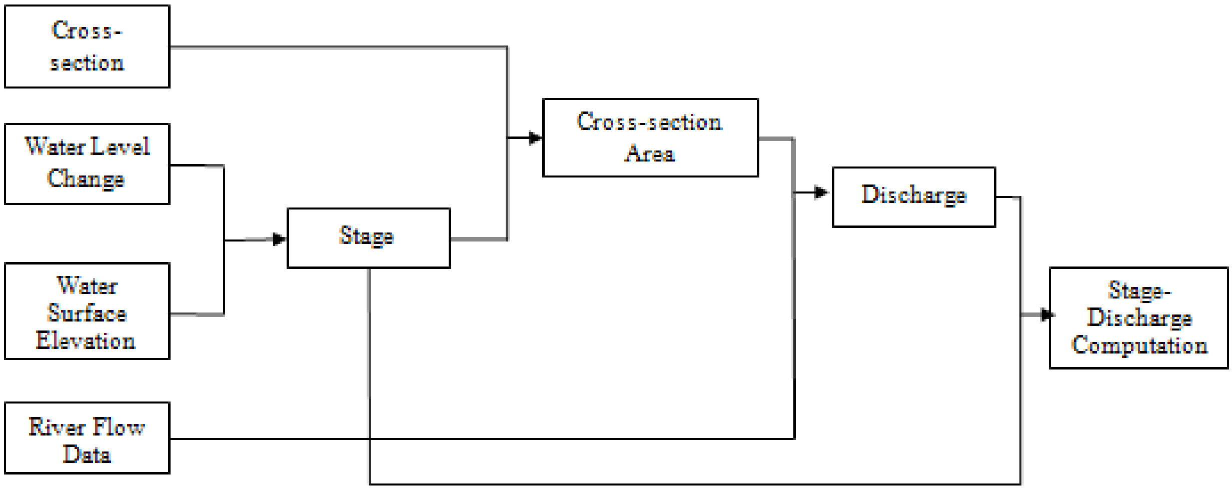


Figure 5. Flow Chart for Stage-Discharge Correlation Computation

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 6.

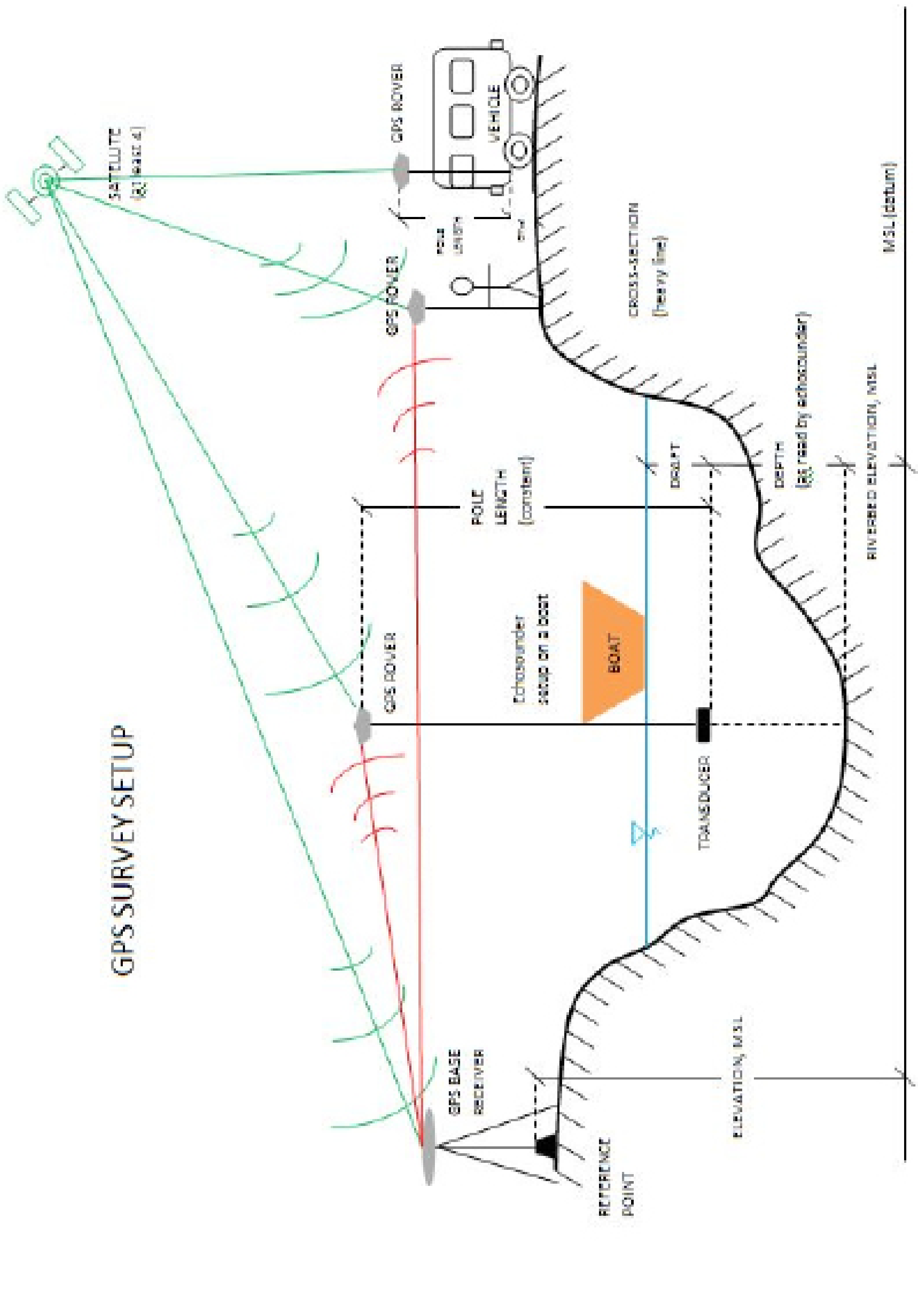


Figure 6. Set-up for GNSS Survey

3.3 Data Processing

Data processing procedures used by DVC are summarized in Figure 7.

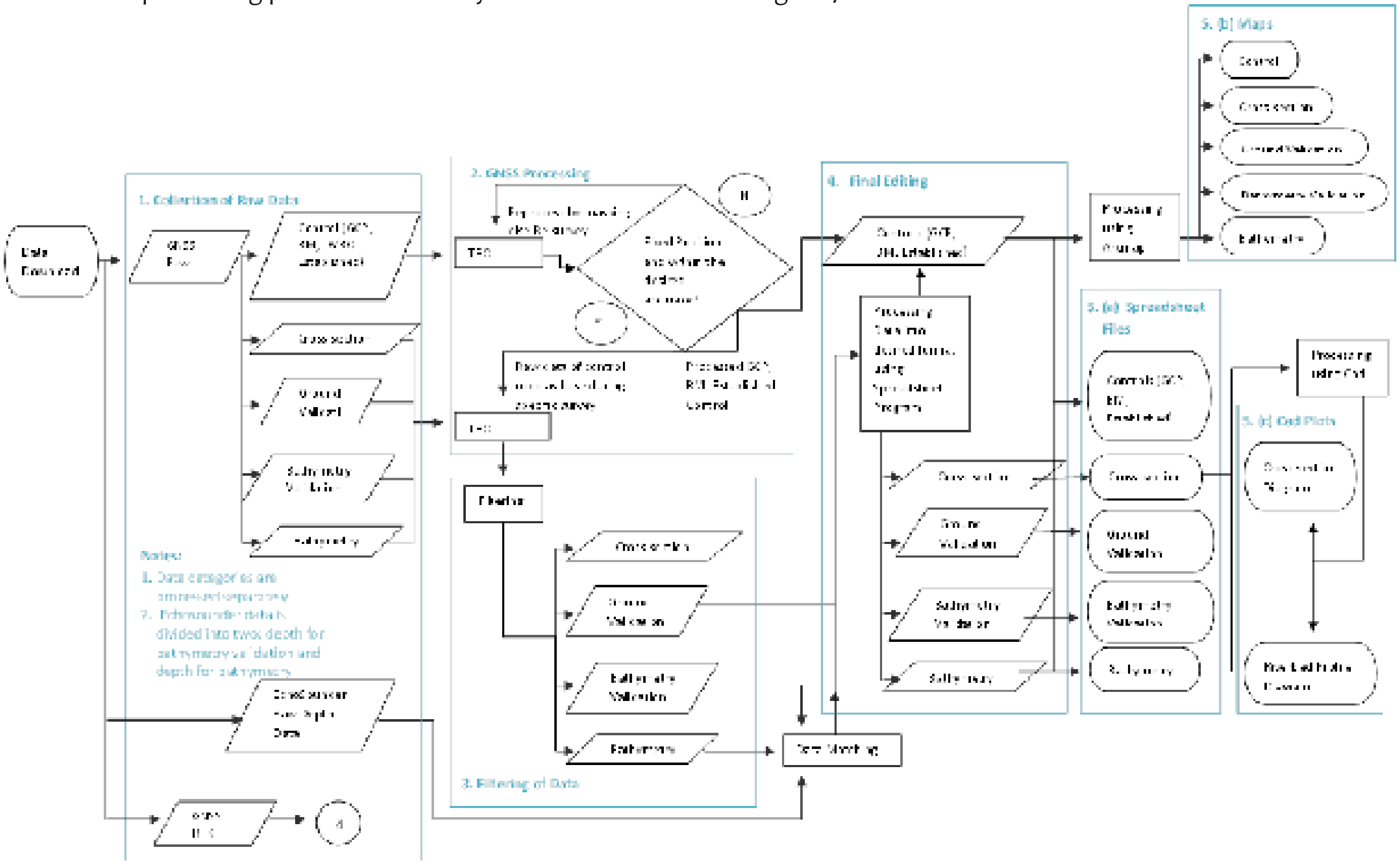


Figure 7. DVC Data Processing Methodology

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

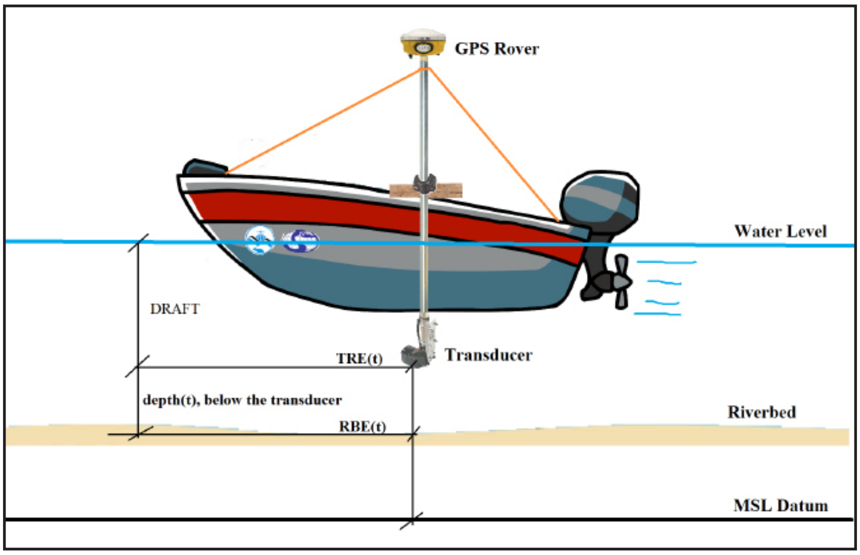


Figure 8. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

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.

Angat River Basin Survey

Angat River Basin Survey

The survey for Angat River Basin was conducted simultaneously to the field survey in Pampanga River for twenty-five (25) days, from June 21 to 29 and July 9 to 24, 2012 with the following activities: profile, cross-section, bathymetric and flow measurement surveys.

Angat River consists of 19 delineated cross section lines with a total length of 35.85 km for both left and right banks starting from Brgy. Lumang Bayan, Plaridel in the upstream down to Brgy. Pugad, Hagonoy near the mouth of the river. The total length of profile lines is about 27 km for its both left and right banks.

4.1 Control Survey

Two (2) NAMRIA points were considered for the static GNSS observations for Angat River System survey on June 21-29, 2012. These include a benchmark, PA-177, located in Brgy. San Agustin, Arayat; a first-order ground control point, BLN-3062, situated in Brgy. Sapang-bayan, Calumpit; and established control points located in San Miguel, Bulacan; Sulipan, Apalit; Sta. Maria, San Luis; and Candaba in Pampanga. The locations of these controls are shown in Figure 9 while the sample GNSS set-ups are shown in Figure 10 and Figure 11.

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. Control points occupied during Angat River Survey (Source: NAMRIA, UP-TCAGP)

Point Name	Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Elevation in MSL
PA-177	15.095962	120.470200	59.994	1677953.608	261885.383	15.5589
BLN-3062	14.545025	120.463795	46.259	1650003.740	260885.565	1.8909
San Miguel	14.511865	120.440146	51.666	1643545.303	256141.177	8.6240
Sulipan	14.561419	120.453031	59.302	1652604.406	258889.384	16.1670
Candaba	15.053922	120.485327	51.944	1669914.796	265128.133	8.6180
San Luis	15.021844	120.472364	57.379	1663768.972	262388.892	14.0410

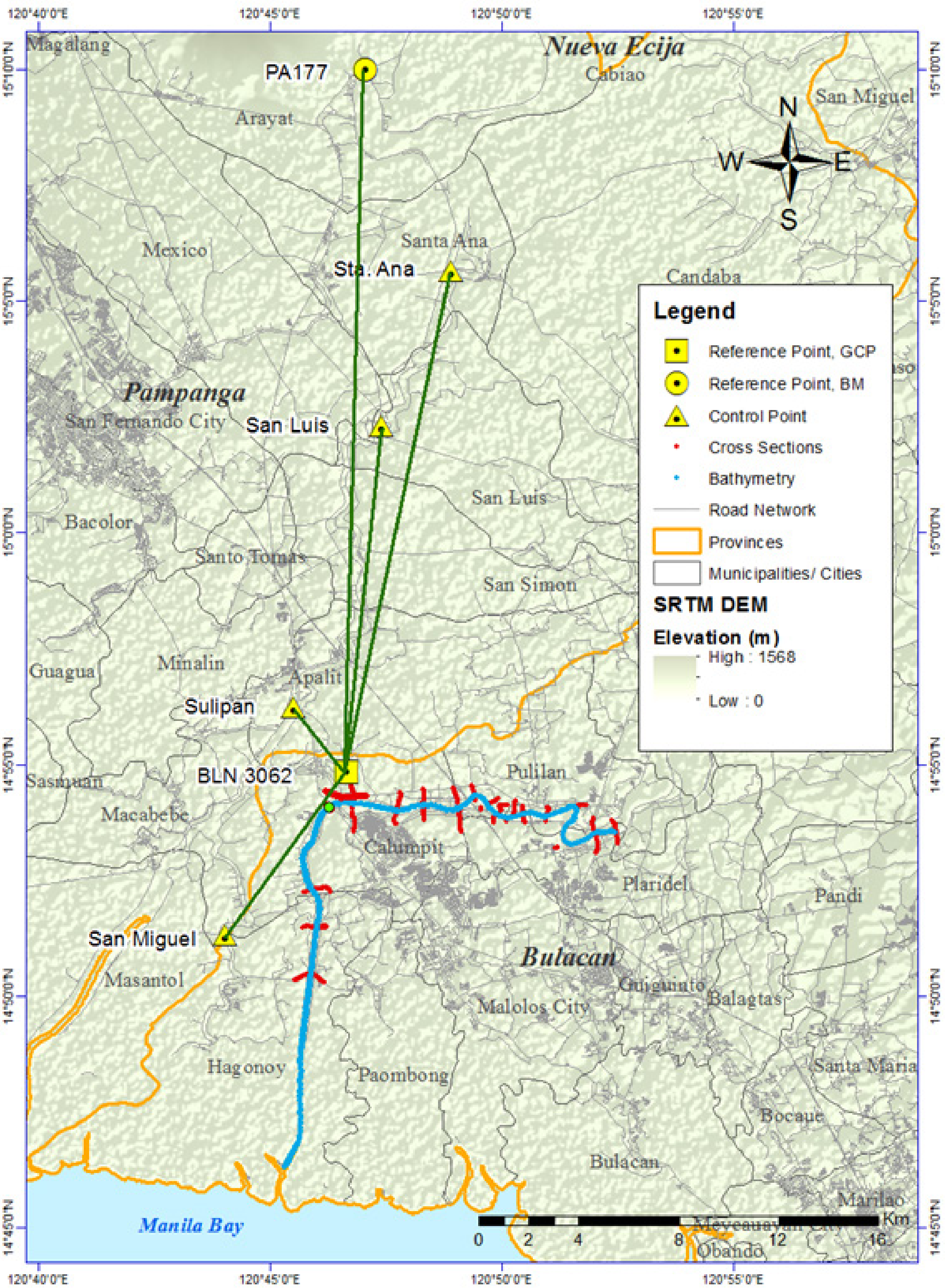


Figure 9. Location of control points for Angat River Survey

The GNSS setup for the control points are illustrated in Figure 10 and Figure 11.

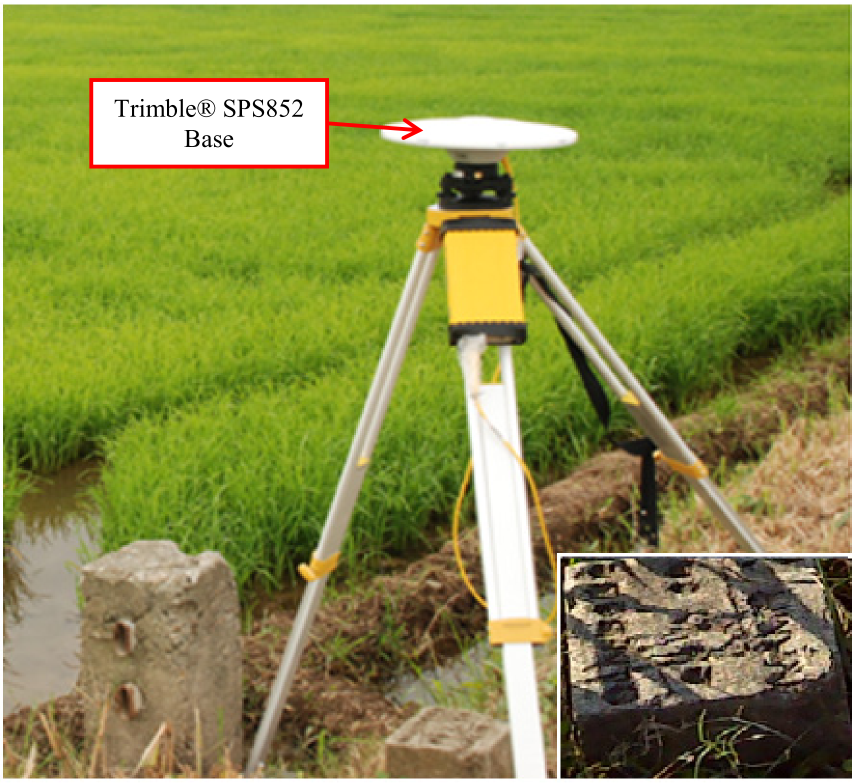


Figure 10. Static GNSS observation at BLN-3062 in Brgy. Sapangbayan in Calumpit, Bulacan

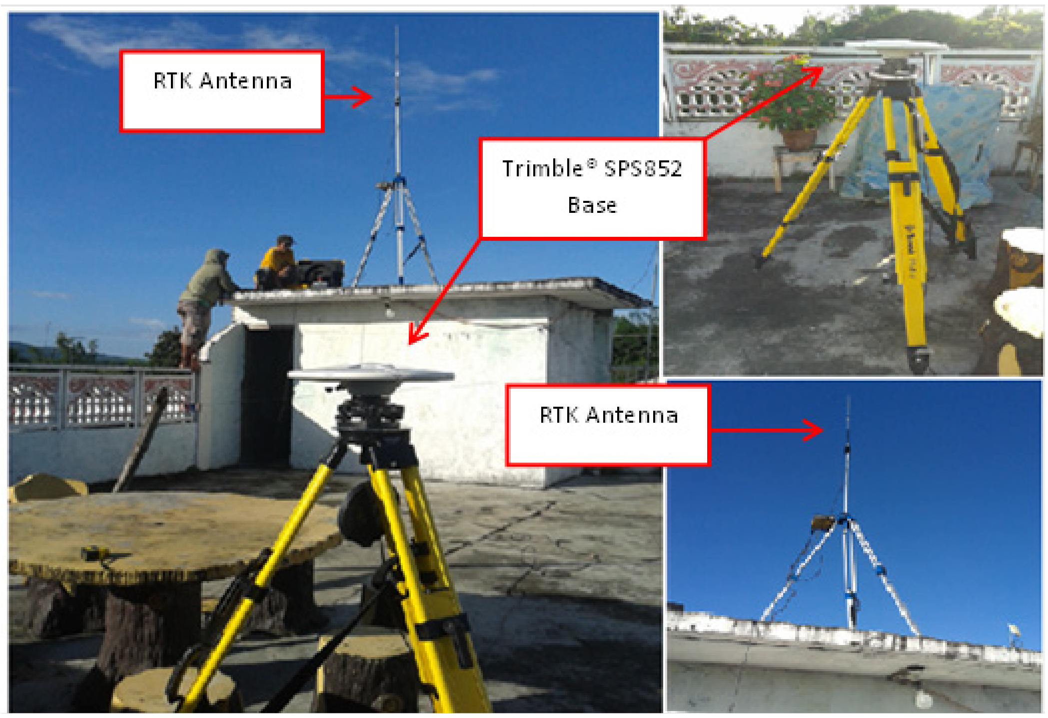


Figure 11. RTK Base station in Brgy. Cupang, Arayat, Pampanga

4.2 Cross-section Survey

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

Horizontal position (easting and northing) and vertical (elevation) measurements were done at a specific interval as one traverses starting from riverbank across the floodplain. Cross-section survey was done through differential kinematic GNSS surveying of either post-processed kinematic or in real-time kinematic. The survey started between the municipalities of Pulilan and Plaridel and ended near the municipality of Hagonoy in Bulacan.

Each cross-section lines were located using handheld GPS (Garmin Montana™ 650). Reconnaissance for profile lines were conducted simultaneously with the bathymetric surveys.

Gathering of cross-section points is shown in Figure 12 and the overall cross-section data acquired is illustrated in Figure 13.

Figure 12. Cross-section teams conducting PPK GNSS survey

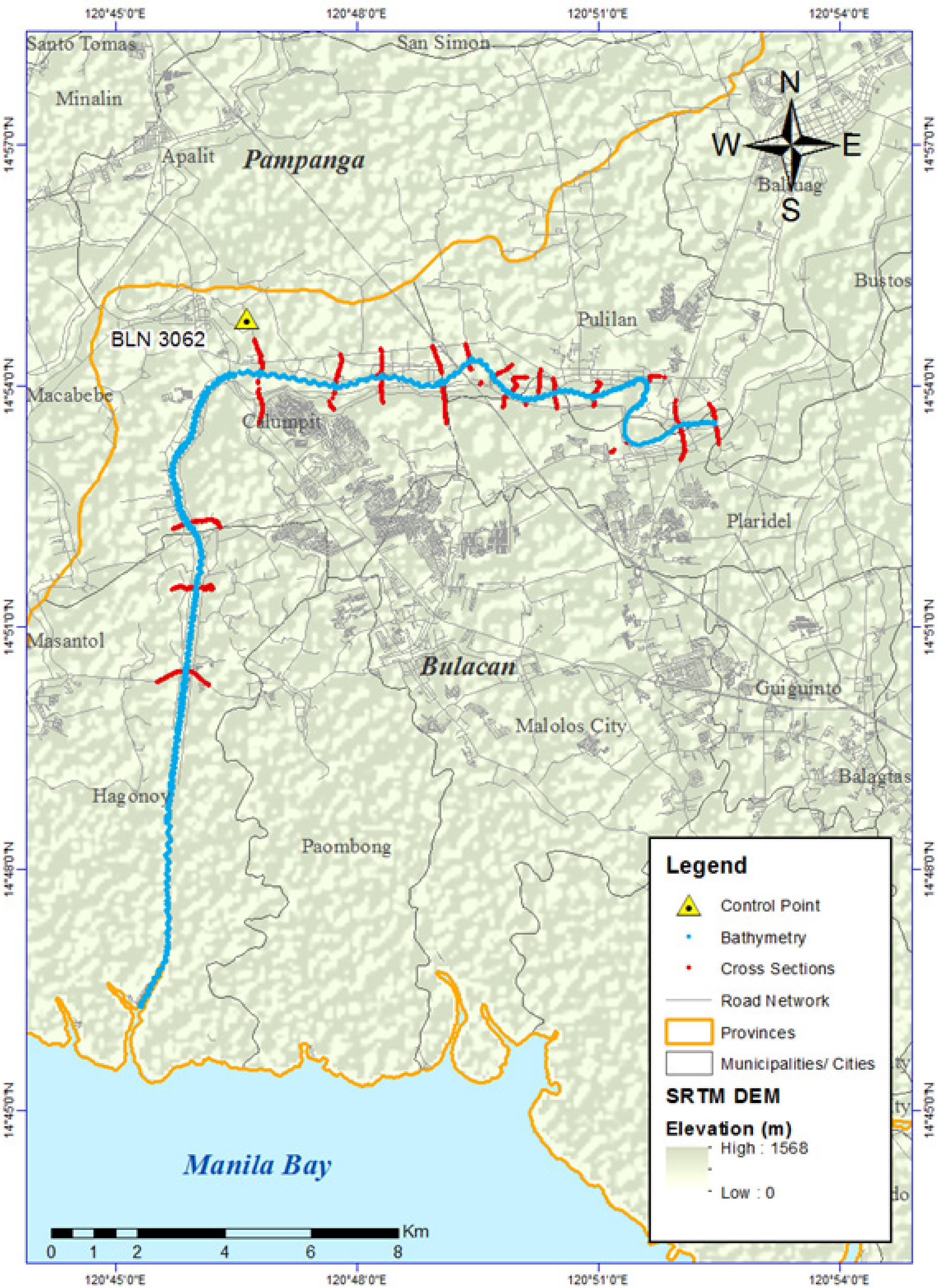


Figure 13. Cross-section data of Angat River

Diagrams in Figure 14 to Figure 30 show the cross-sections gathered across certain locations along Angat River. Since Cross-section 15 and 16 was noted impassable, there were no diagrams processed for both cross-sections.

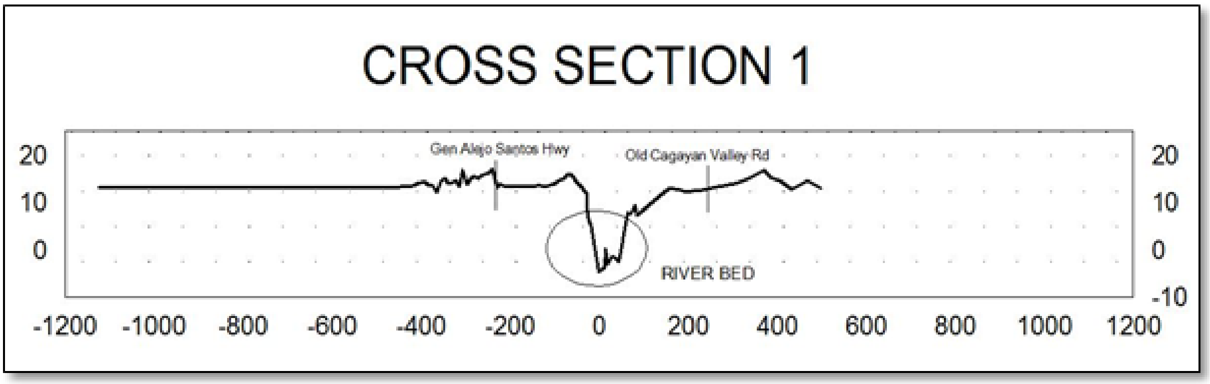


Figure 14. Cross-section 1 at Angat River

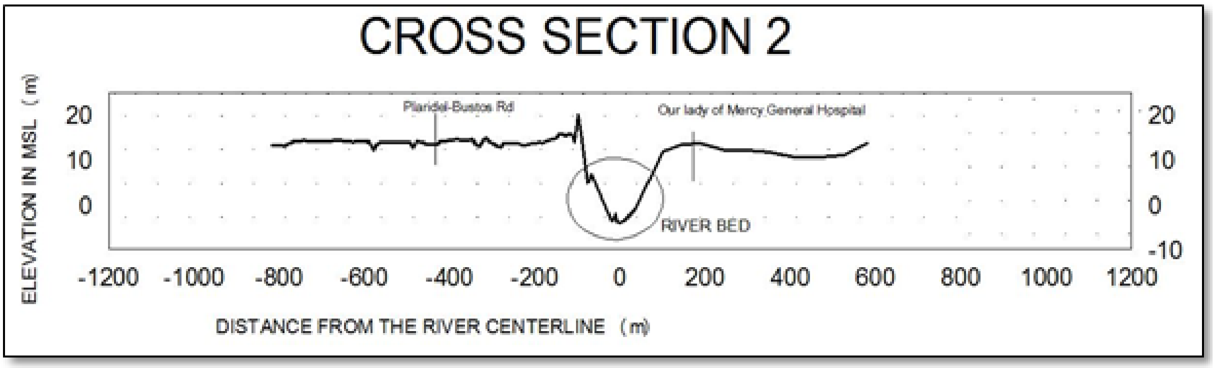


Figure 15. Cross-section 2 at Angat River

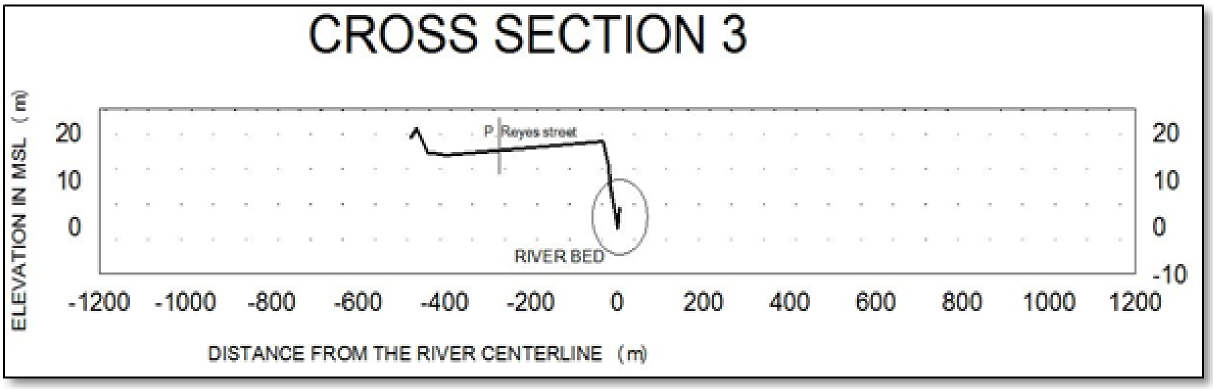


Figure 16. Cross-section 3 at Angat River

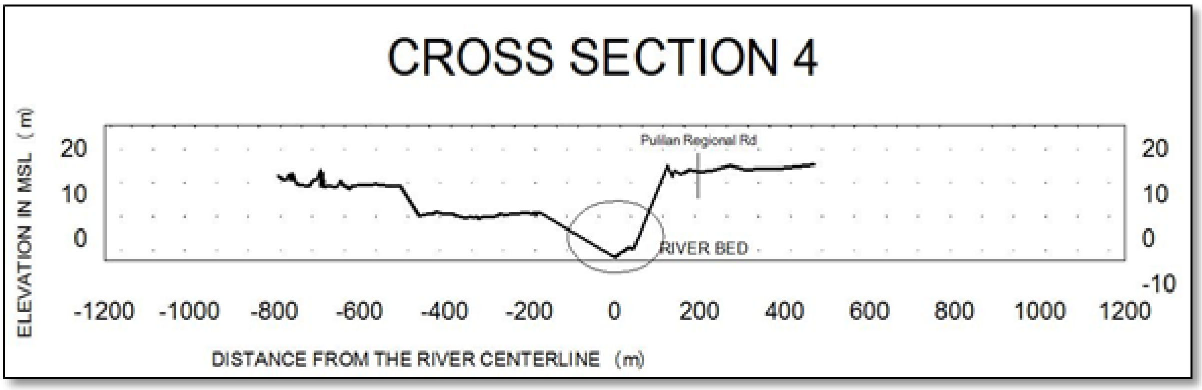


Figure 17. Cross-section 4 at Angat River

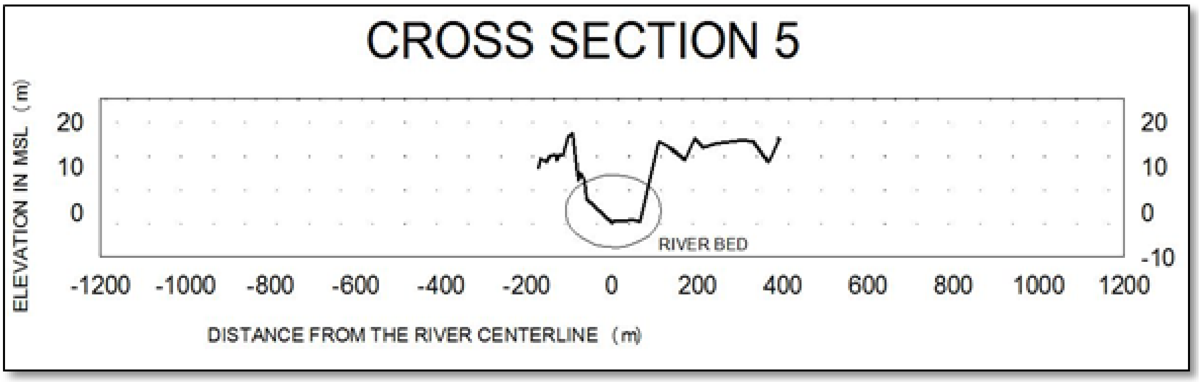


Figure 18. Cross-section 5 at Angat River

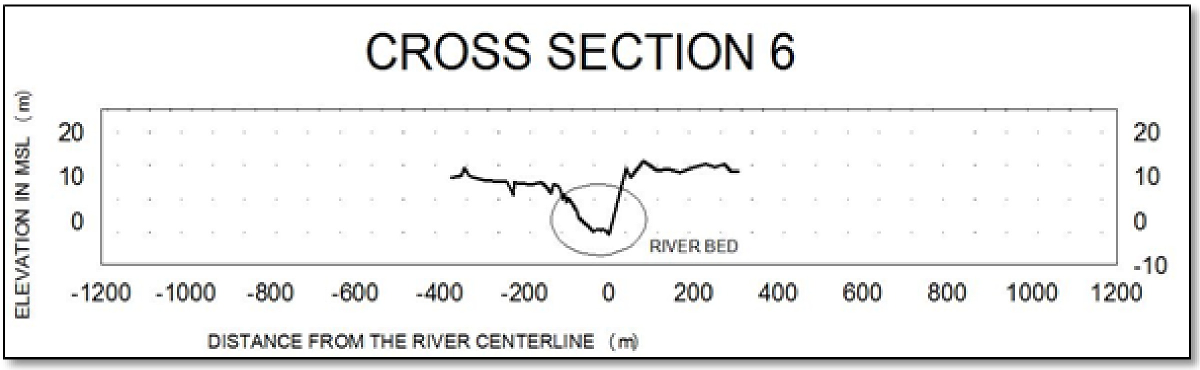


Figure 19. Cross-section 6 at Angat River

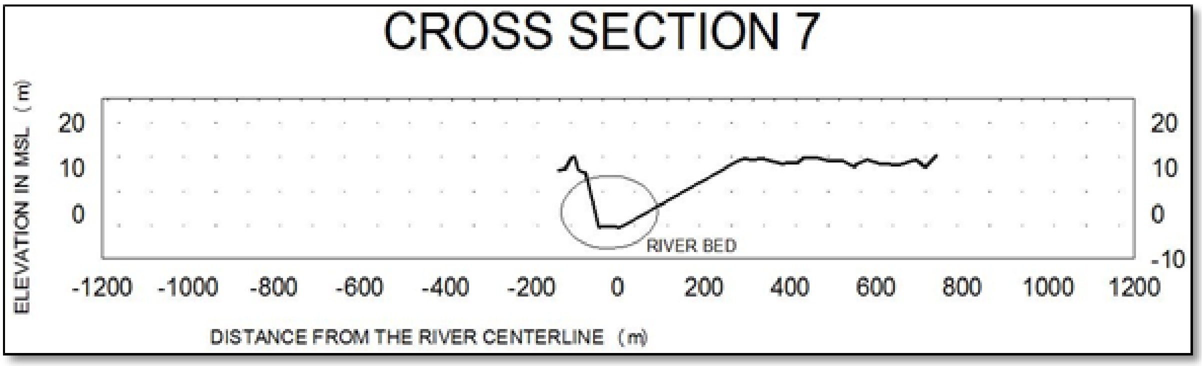


Figure 20. Cross-section 7 at Angat River

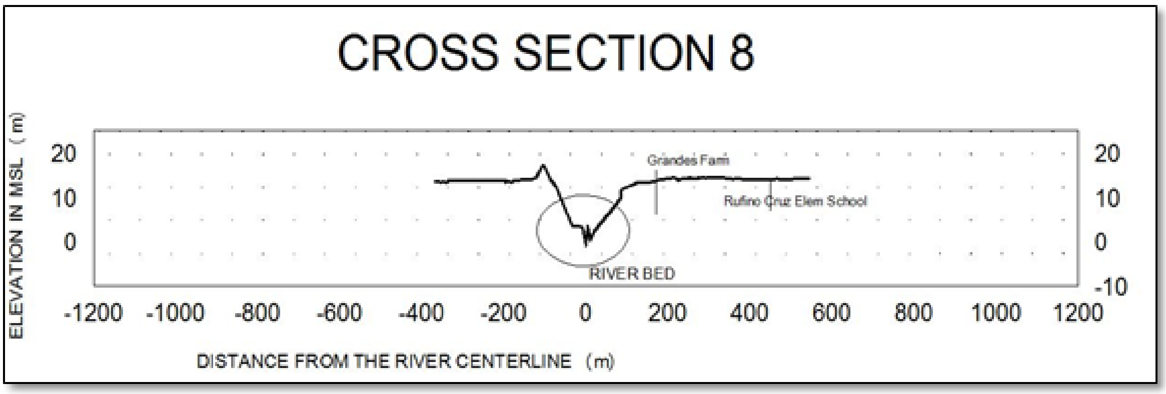


Figure 21. Cross-section 8 at Angat River

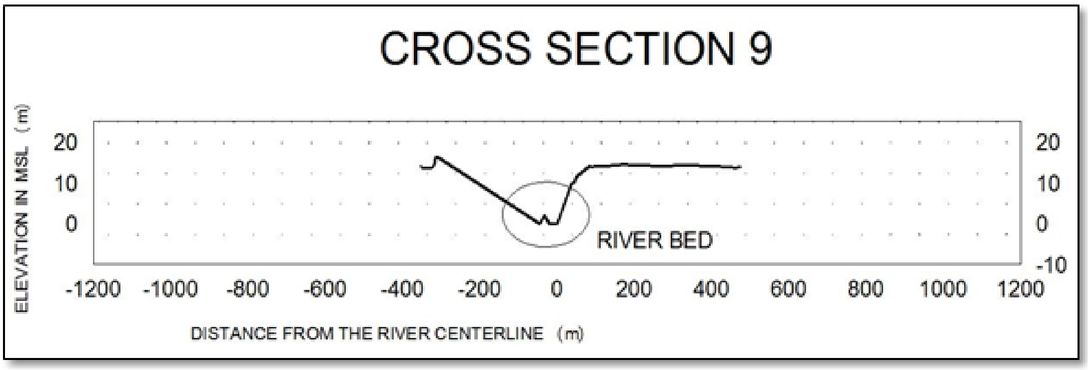


Figure 22. Cross-section 9 at Angat River

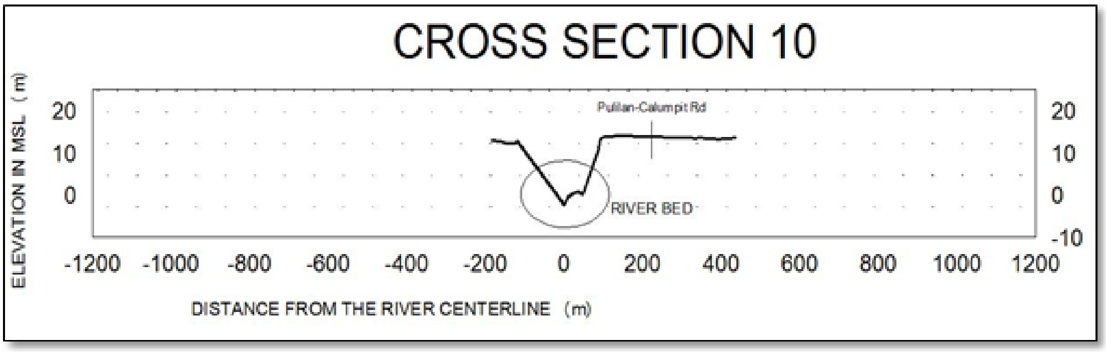


Figure 23. Cross-section 10 at Angat River

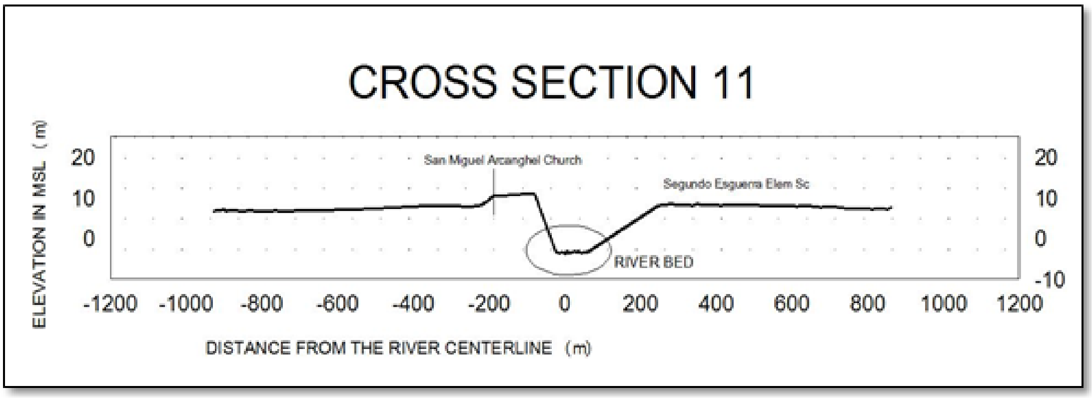


Figure 24. Cross-section 11 at Angat River

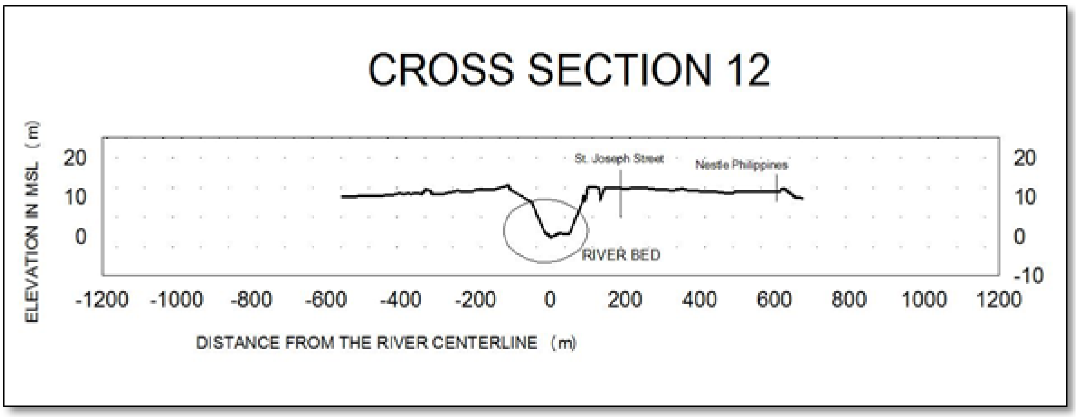


Figure 25. Cross-section 12 at Angat River

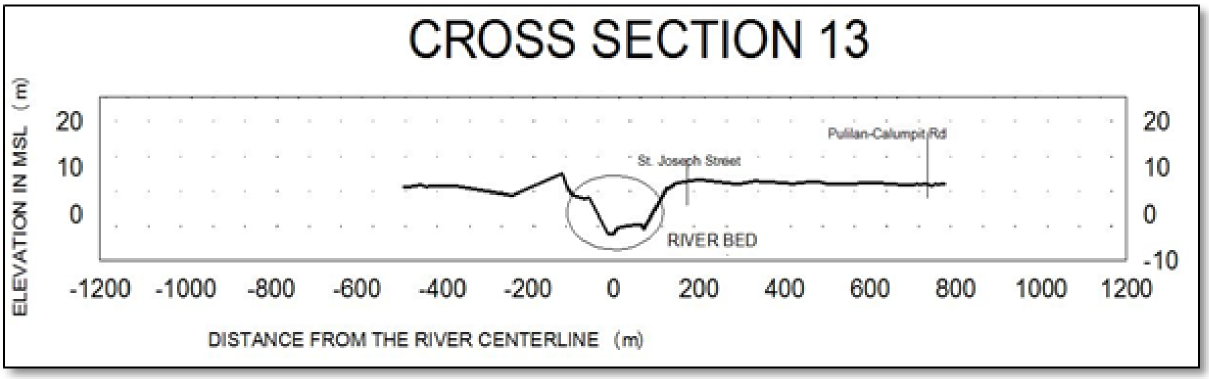


Figure 26. Cross-section 13 at Angat River

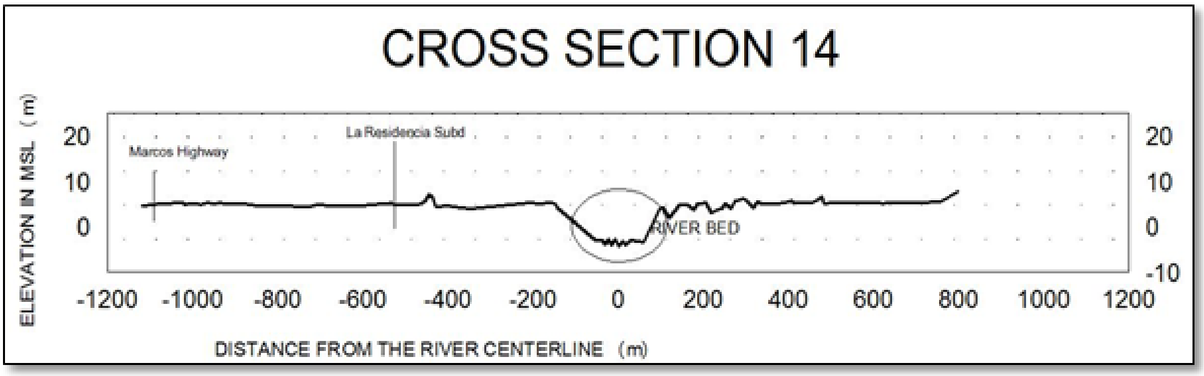


Figure 27. Cross-section 14 at Angat River

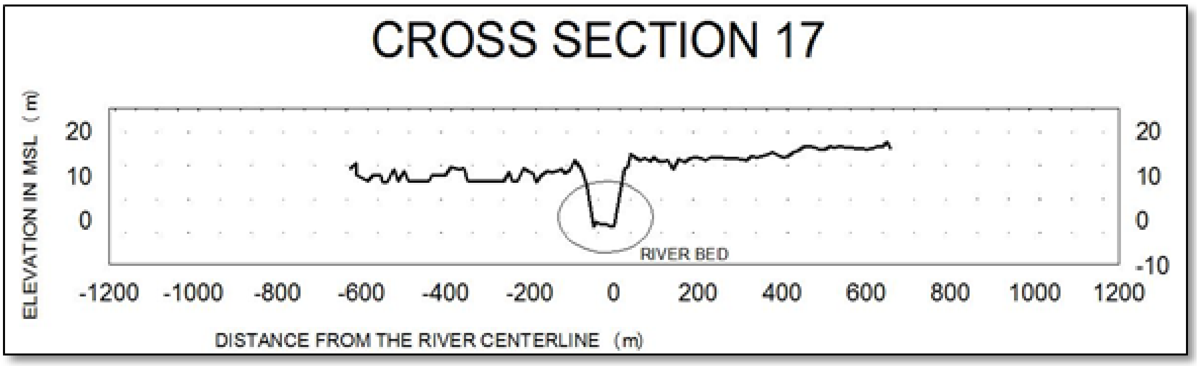


Figure 28. Cross-section 17 at Angat River

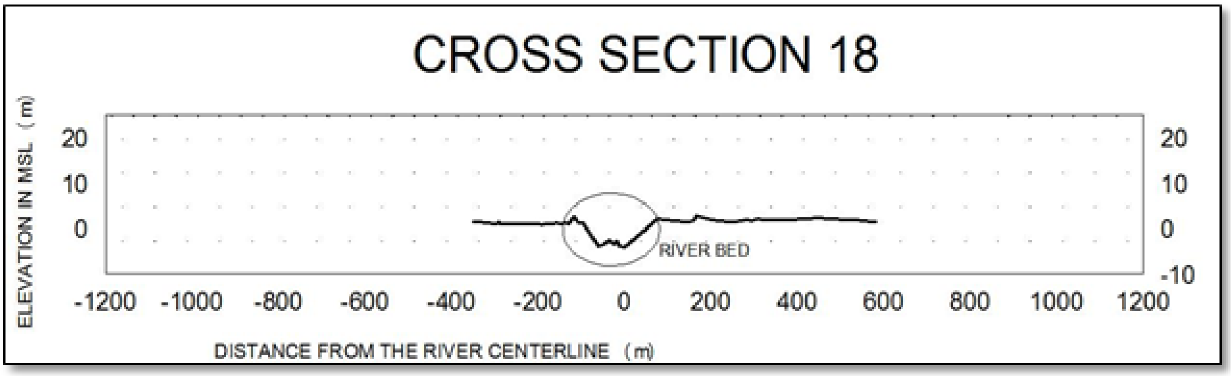


Figure 29. Cross-section 18 at Angat River

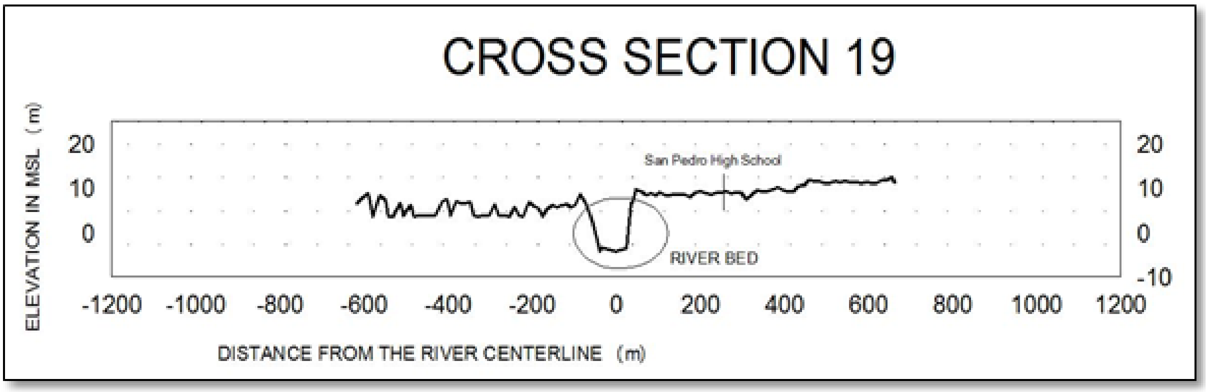


Figure 30. Cross-section 19 at Angat River

Total number of cross-section points acquired during the survey is listed in Table 2.

Table 2. List of surveyed cross-sections

Cross-section	Number of Data Points
1	70
2	115
3	12
4	101
5	29
6	48
7	25
8	125
9	47
10	36
11	180
12	89
13	93
14	152
15	Not passable
16	Not passable
17	136
18	87
19	105
Total	1450

4.3 Profile Survey

The upper and lower banks of Angat River were measured using a mobile mapping system (MMS), the MDL Dynascan™ as shown in Figure 33. The instrument utilizes LiDAR and GNSS technology to gather point cloud data. The instrument is mounted on a motorized boat and it scans the banks as it traverses the length of the river. A high-gain antenna was also attached to the MDL Dynascan™ to improve the reception of the RTK correction from the Brgy. Sapang-Bayan base station. The MMS set-up is shown in Figure 31while sample output is illustrated in Figure 32.

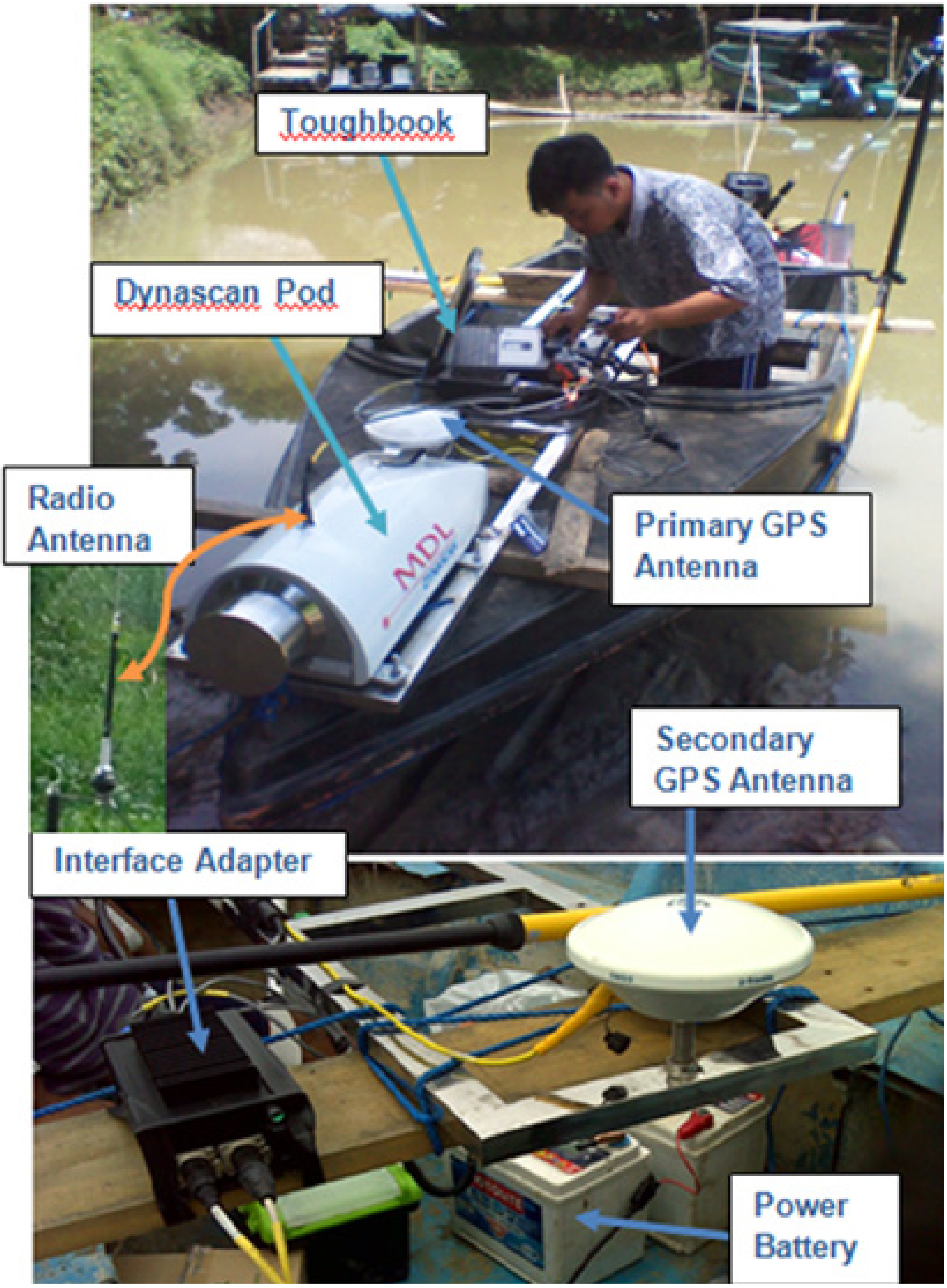


Figure 31. The MDL Dynascan™ installed on one end of the boat for the river bank profile surveys of Angat River

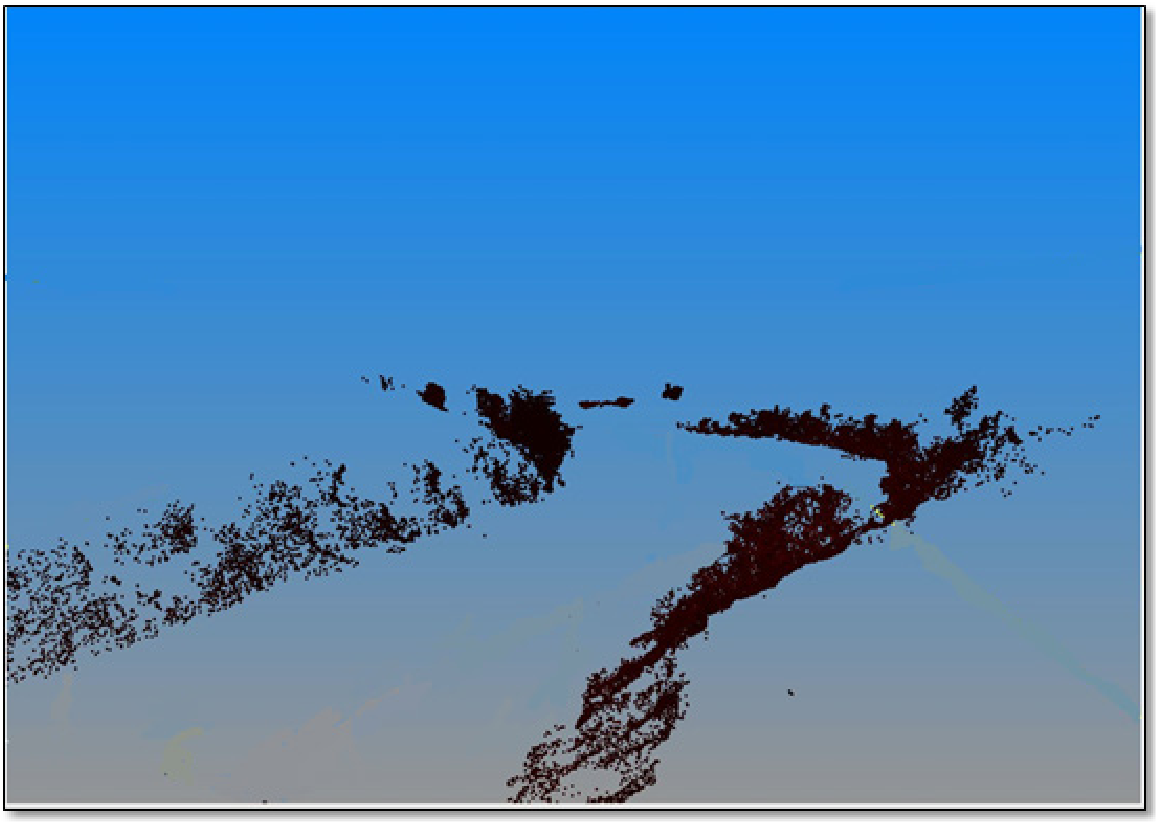


Figure 32. Left and Right bank using MMS along Angat River

4.4 Bathymetric Survey

The bathymetry of the river channel was surveyed using an echo sounding surveying technique. Differential GNSS surveying technique and a Hi-Target Single beam echo sounder were utilized in measuring the depth, eventually obtaining elevation with corresponding horizontal position.

The entire bathymetric survey was done in two (2) days from July 12, 2012 for both centerline and zigzag bathymetry. A boat was borrowed from the Armed Forces of the Philippines-Special Forces accompanied by the Special Forces personnel as shown in Figure 33.

An approximate length of 26.2 km of centerline and 65.5 km length of zigzag sweep were covered starting in the intersection between the municipalities of Plaridel and Pulilan area down to Brgy. Castillo, Cabusao as illustrated in Figure 34.

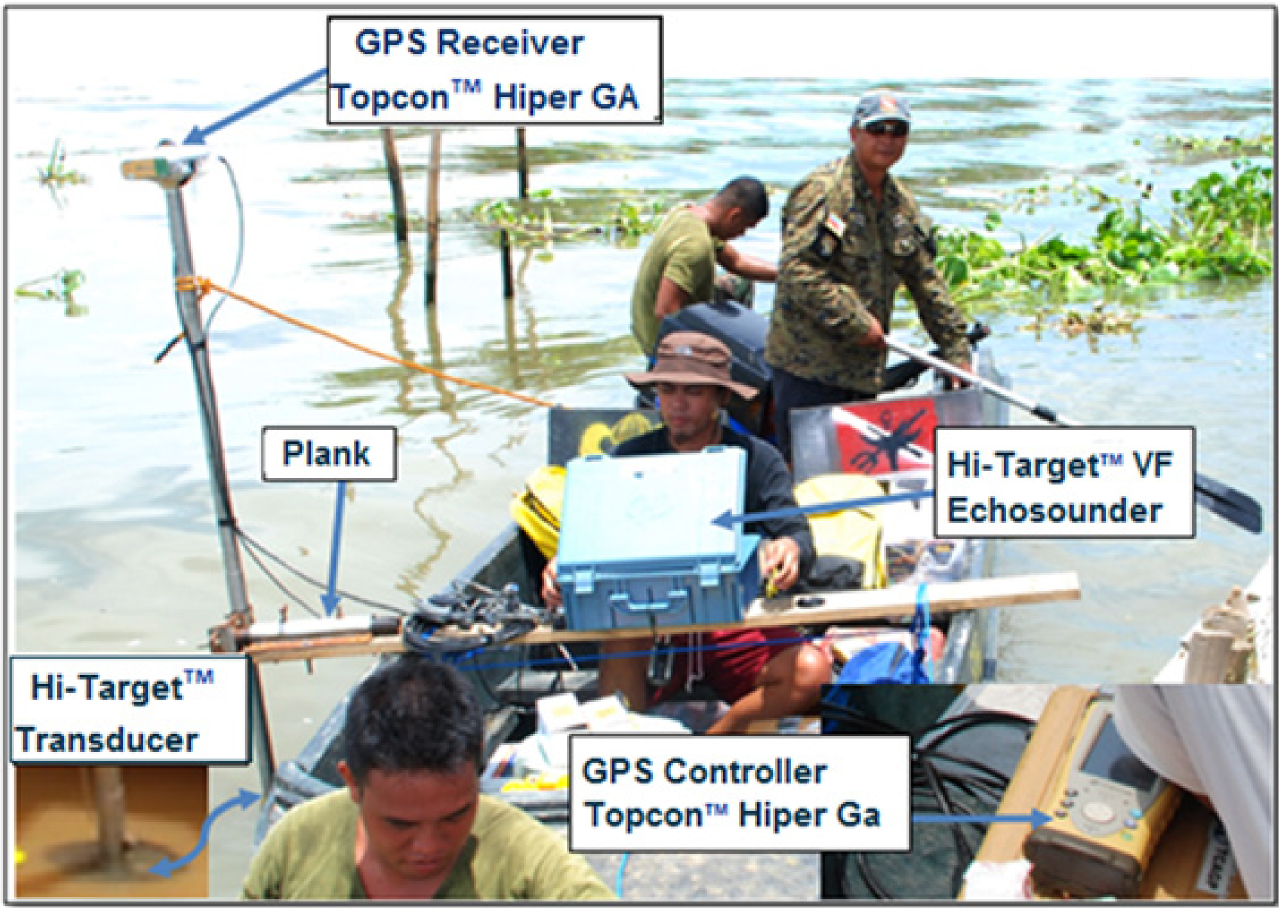


Figure 33. Bathymetric survey setup

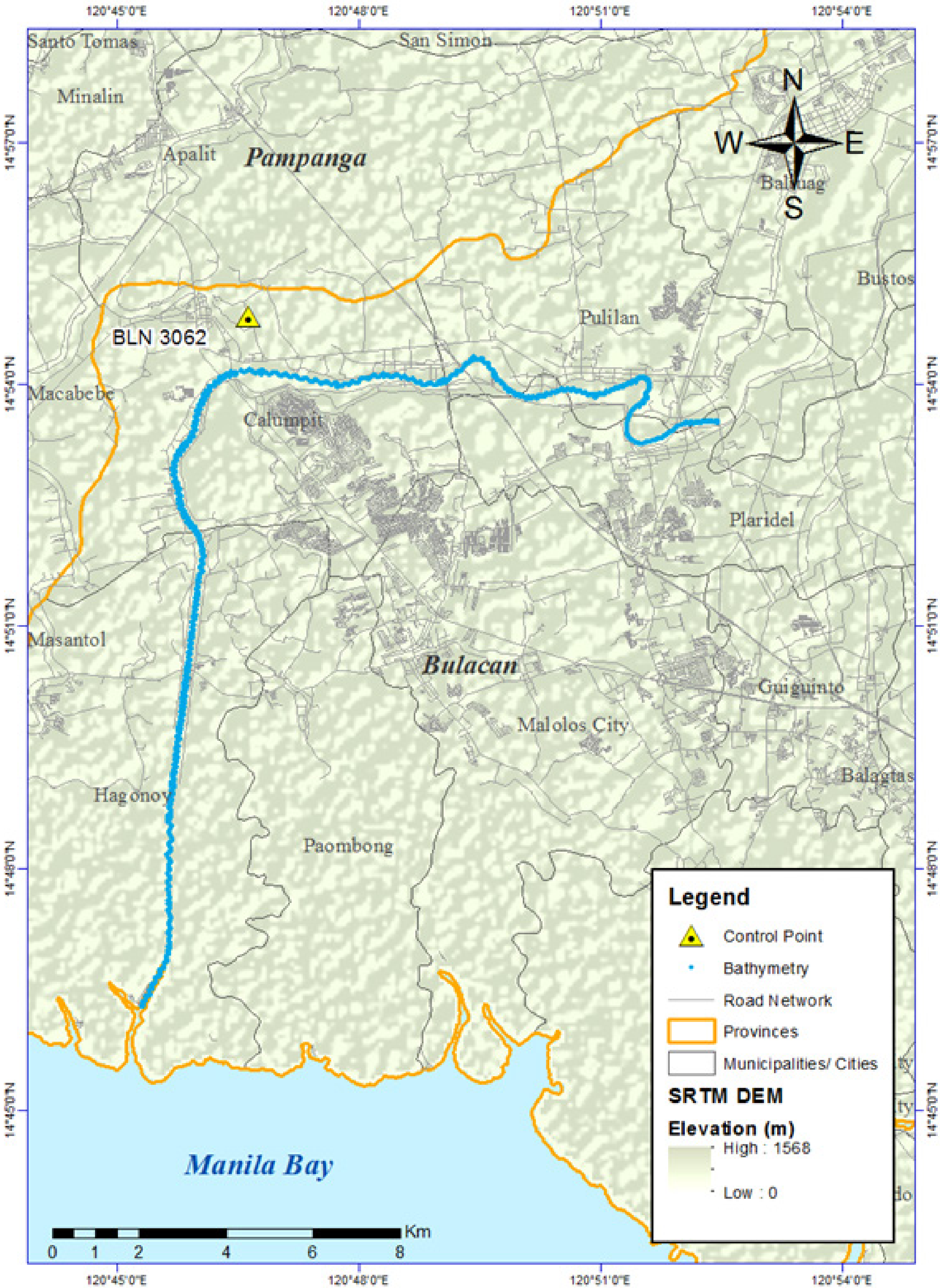


Figure 34. Bathymetric data in Angat River

4.5 Hydrometric Survey

Different sensors were deployed on the banks of Angat 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.

The collection of data at Brgy. Parulan, Plaridel was conducted using ADCP with depth gauge and rain gauge for the deployment on July 18, 2012. In Brgy. Caniogan, Calumpit and Brgy. Bustos, Bulacan using a side-looking ADCP for the deployment was on August 25, 2013. A depth gauge was deployed in Brgy. Balungao, Calumpit on August 22 to 26, 2013. The ADCP and depth gauge were monitored and its data downloaded on the day of retrieval.

The data gathered from the deployed ADCP, depth gauge and rain gauge in Brgy. Parulan are shown from Figure 35 to Figure 41.

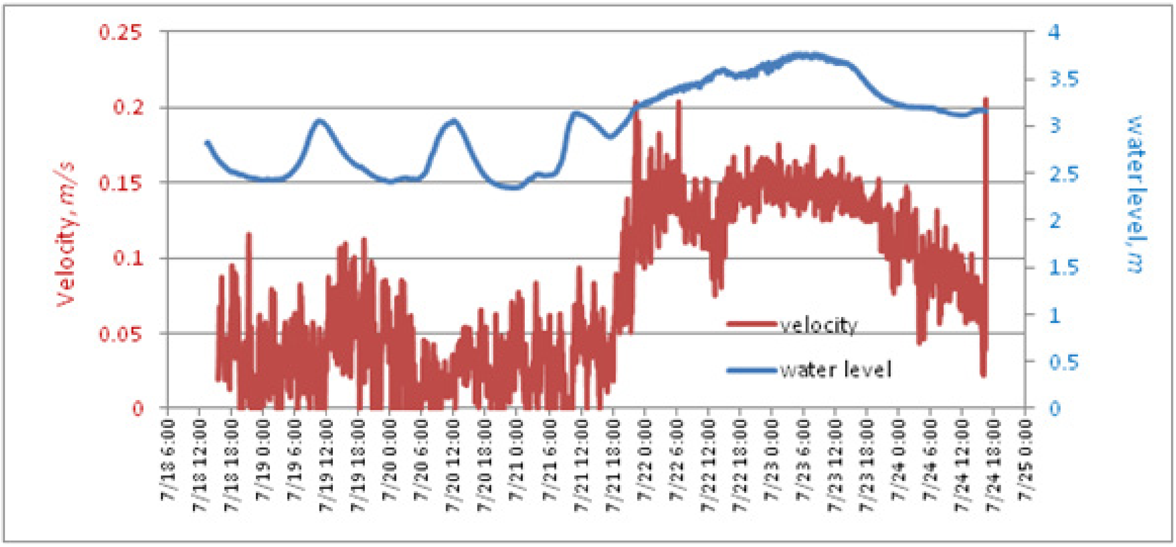


Figure 35. Relationship between velocity and stage in Brgy. Parulan, Plaridel

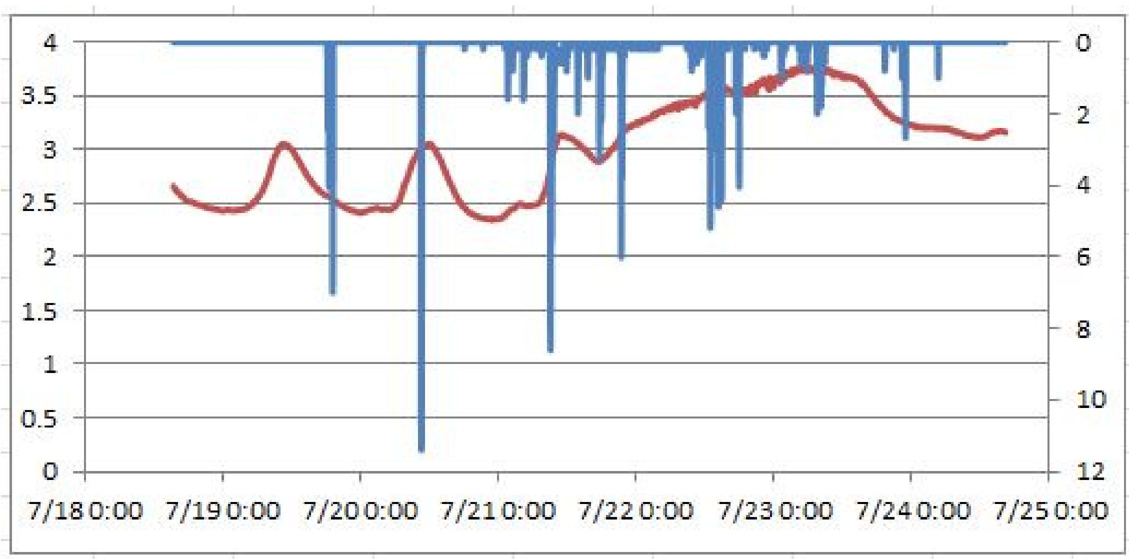


Figure 36. Relationship between stage and rainfall in Brgy. Parulan, Plaridel

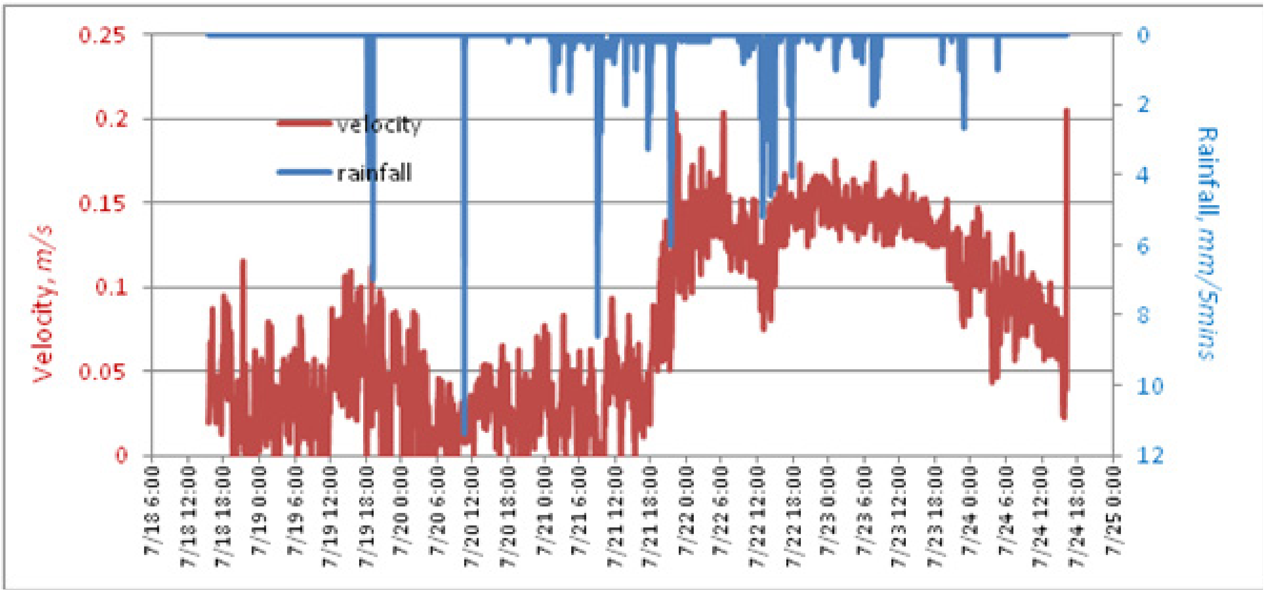


Figure 37. Relationship between velocity and rainfall in Brgy. Parulan, Plaridel

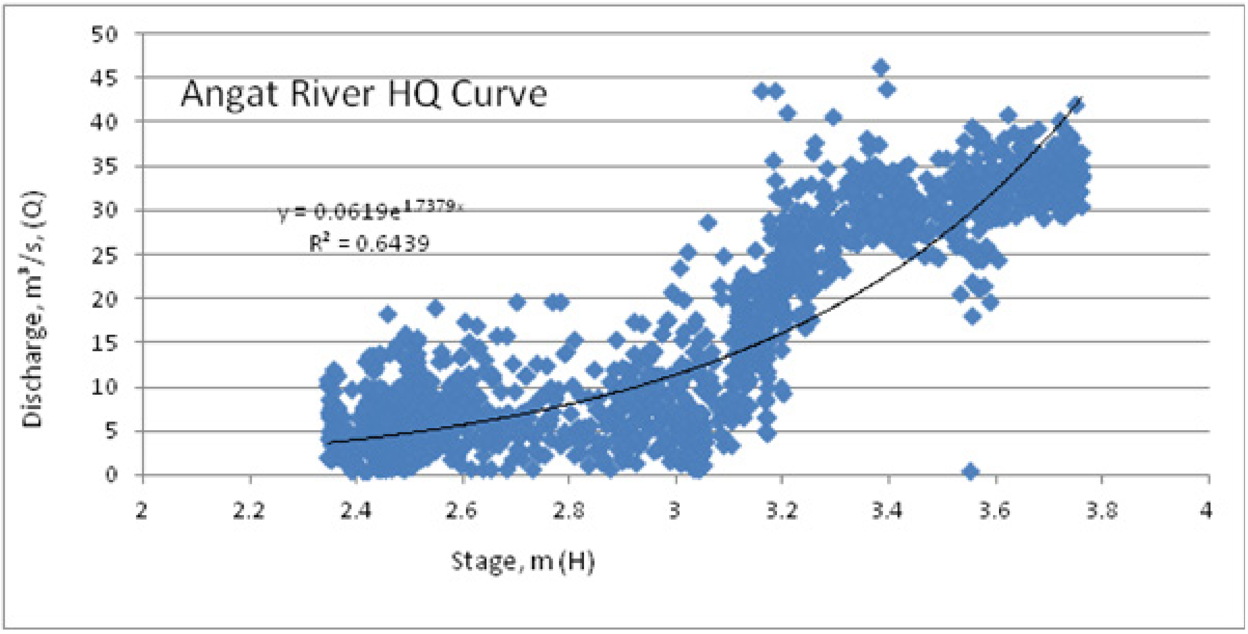


Figure 38. Stage-discharge computation in Brgy. Parulan, Plaridel

The stage gathered in the deployment of depth gauge in Brgy. Balungao, Calumpit is shown in Figure 39.

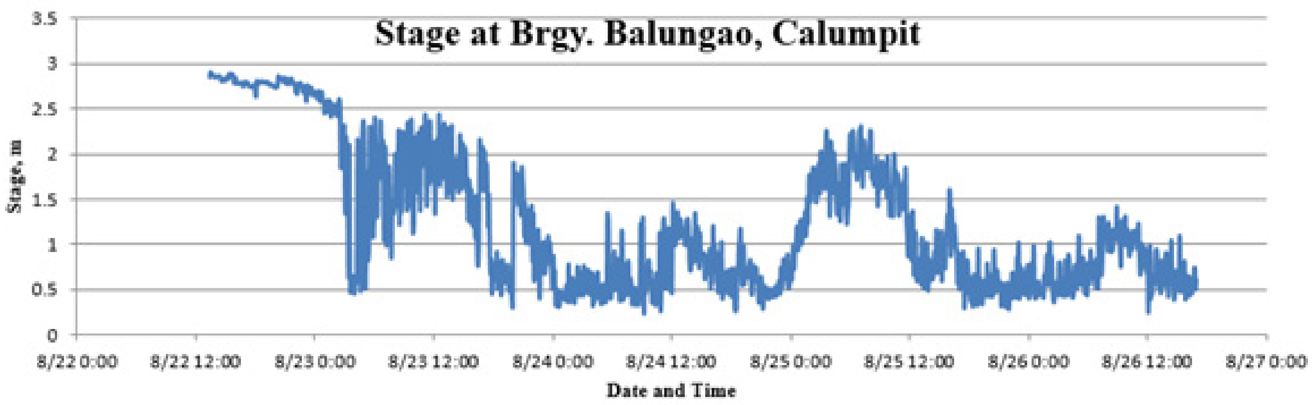


Figure 39. Stage of Angat River in Brgy. Balungao, Calumpit

The setup for sensors deployment are illustrated in Figure 40and Figure 41.

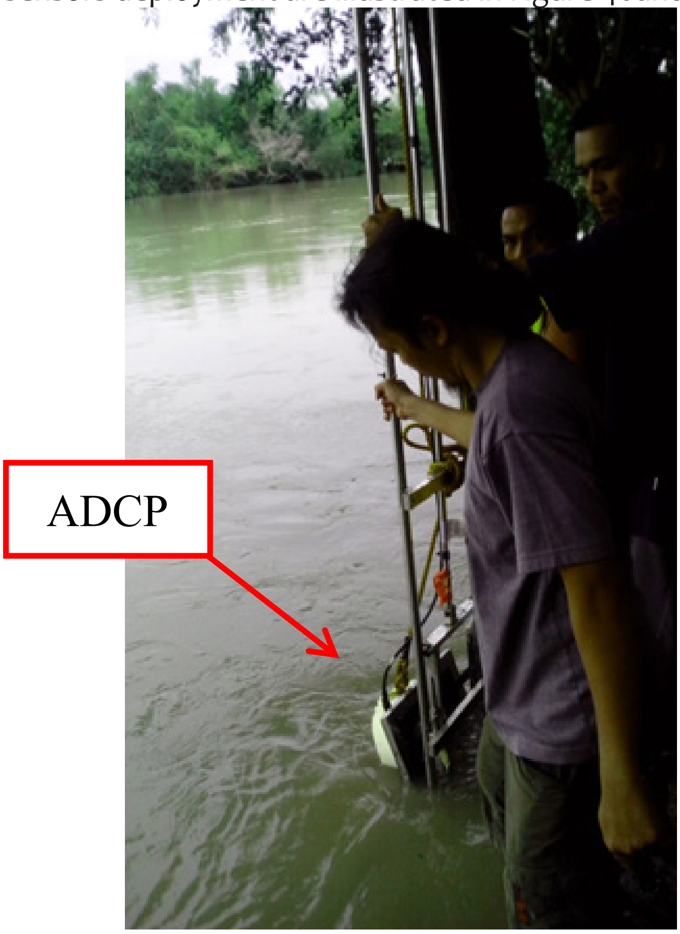


Figure 40. Deployment of ADCP and depth gauge in Brgy. Parulan in Plaridel, Bulacan

Figure 41. Rain gauge deployment in Brgy. Parulan, Plaridel

The summary of location of sensor deployment are shown in Table 3 and Figure 42.

Table 3. Deployment of sensors along Angat River in Pampanga River Basin

Sensor	Location	Deployment	Retrieval	Latitude	Longitude
ADCP, Rain Gauge and Depth Gauge 1st Deployment	Brgy. Parulan, Plaridel	July 9, 2012	July 18, 2012		
ADCP and Depth Gauge 3rd Deployment	Brgy. Caniogan, Calumpit, Bulacan	August 25, 2013	August 26, 2013	14°54'17"N	120°46'30"E
ADCP and Depth Gauge 4th Deployment	Brgy. Bustos, Bulacan	August 25, 2013	August 26, 2013	14°57'22"N	120°54'29"E
Depth Gauge 1	Brgy. Balungao, Calumpit	August 22, 2013	August 26,2013	14°54'17"N	120°46'30"E

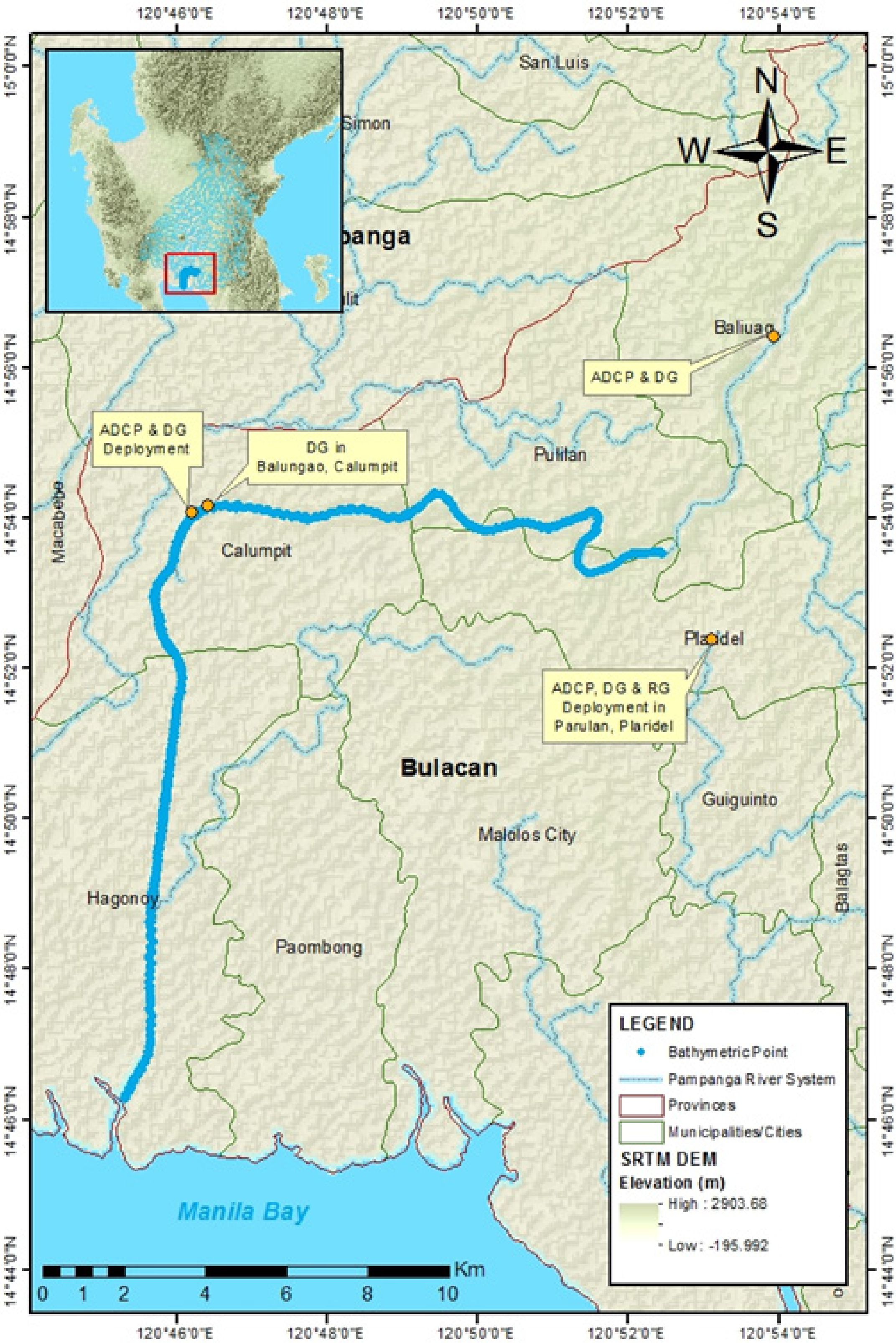


Figure 42. Location of Sensors in Angat River

4.5.1 Angat River AWLS Survey

A survey was conducted for the installed AWLS on Angat River in order to get its cross-sectional area and water surface elevation in MSL. River velocity was acquired using a side-looking ADCP which were entrusted to a local living near the bridge to gather river velocity measurements during the course of the survey (see Table 3 for Velocity Capturing Duration).

Cross-section survey of 2 bridges with installed AWLS was conducted on August 25 – 26, 2013. Depth gauges were also deployed at Sto. Nino Bridge in the Municipality of Calumpit and Alejo Santos Bridge in Bustos from August 25, 2013 until its retrieval on August 26, 2013 However, no precipitation occurred throughout the duration of the survey and during the gathering of the flow for the river. Location of these bridges are shown in Figure 43.

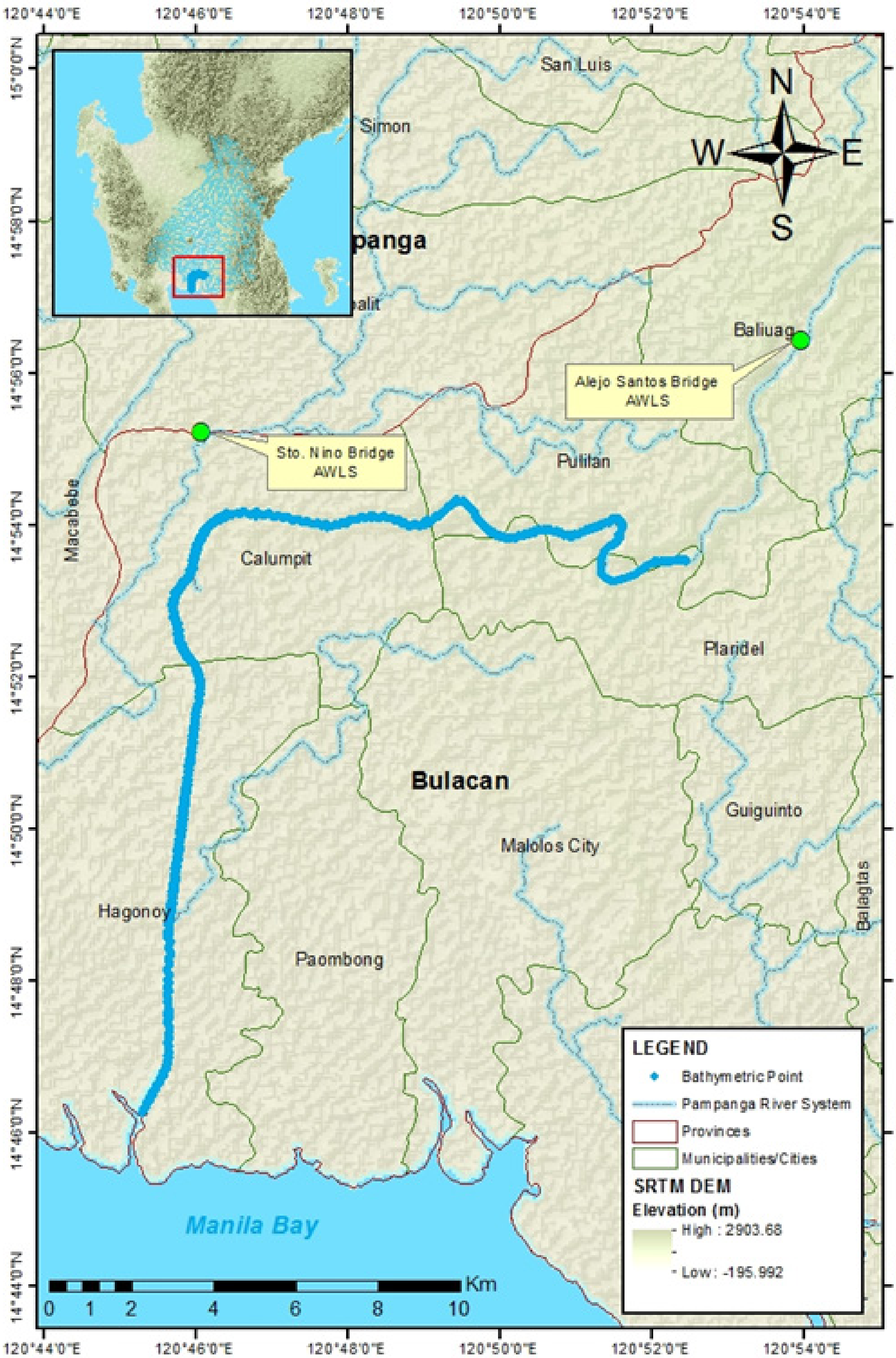
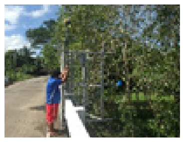


Figure 43. Location of AWLS in Angat River

4.5.1.1 Cross-section Survey

The summary of the two (2) bridges with AWLS in Angat River with corresponding coordinates, date and time of elevation determination and duration of flow data gathering, and images are shown in Table 4.

Table 4. Location and summary of data for Bicol River System AWLS field survey

LOCATION	COORDINATES	WATER SURFACE ELEVATION, (MSL)	VELOCITY CAPTURING DURATION	ELEVATION OF AWLS, (MSL)	IMAGES
Sto. Nino Bridge	Lat 14-54-17 N Long 120-46-30 E	2.85 m (August 22, 2013 at 1:25 PM)	August 25, 2013 At 6:25 PM to August 26, 2013 at 4:20 PM	17.431 m	
Alejo Santos Bridge	Lat 14-57-22 N Long 120-54-29 E	17.866 m (Dec. 1 2013 at 12:06 PM)	August 25, 2013 At 3:00 PM to August 26, 2013 at 1:10 PM	8.953 m	

The diagrams in Figure 44 and Figure 45 show the cross-section of the bridges with installed AWLS. These diagrams show the elevation of the AWLS in referred MSL.

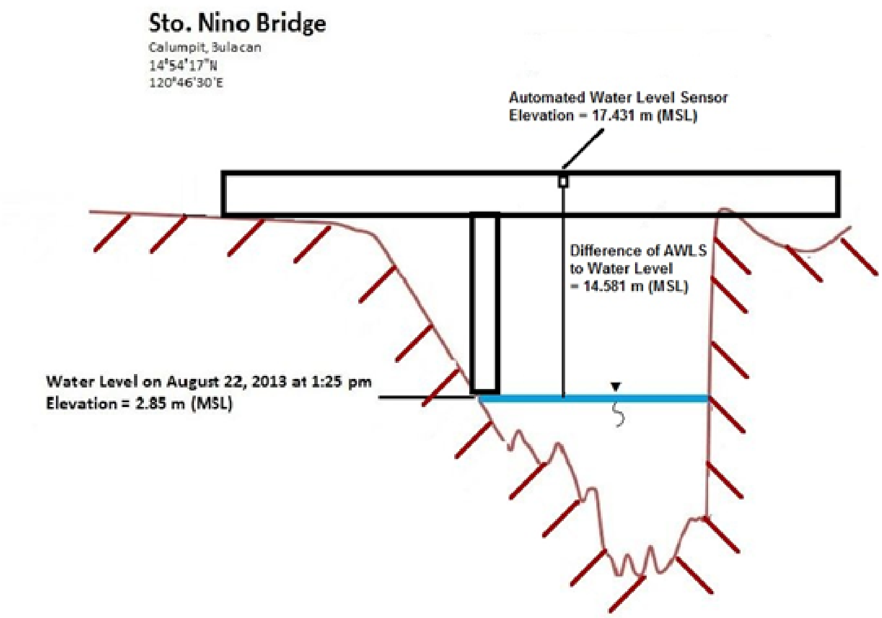


Figure 44. Cross-section diagram of Sto. Nino Bridge

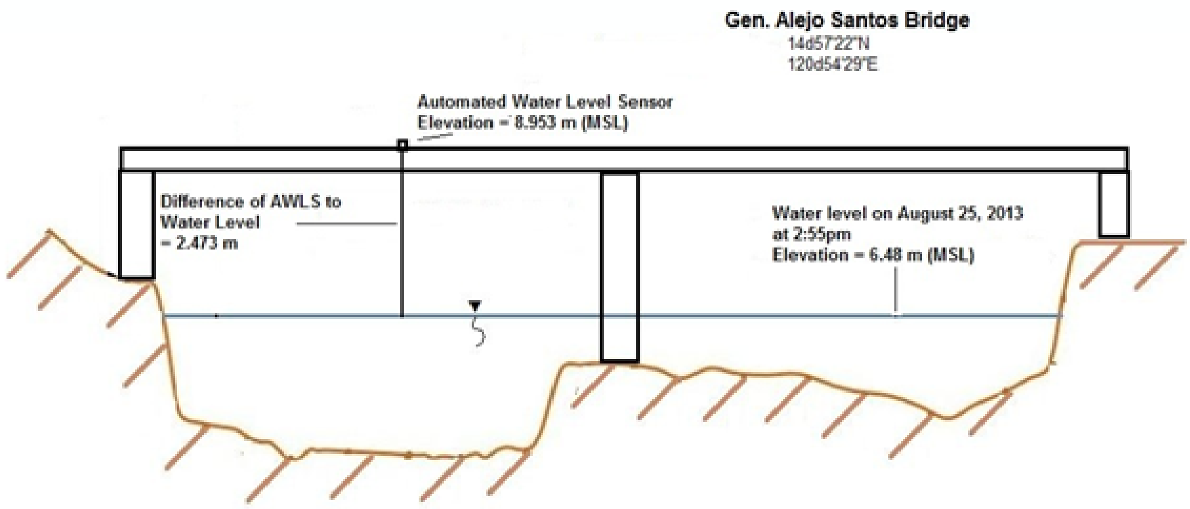


Figure 45. Cross-section diagram of Alejo Santos Bridge

4.5.2.1 Flow Measurements

Two local hires living within the vicinity of the bridge were employed to gather flow measurements. Two types of events are needed by the team – (1) base flow or the normal stream flow, without the influence of a precipitation. In this scenario, local hires were tasked to record the velocity of the river for three hours each in the morning and afternoon for a single day; and (2) the flow of the river during the occurrence of a rain event.

Two (2) rainfall events were needed prior retrieval of the flow meters. In this type of event, the water velocity was recorded for six-hours straight while precipitation was on-going, day and night. Continuous recording of flow measurements were done until two rain events were observed. However, the data gathered was only the flow of the river with no precipitation occurrence throughout the duration of the survey.

Summary of cross-section with flow measurement, stream gauges and rain gauges data are shown in Table 5.

Table 5. Summary of Angat River System AWLS Field Survey

Bridges	Cross Section	Water Level	Flow Measurement	Rainfall	Remarks
Sto. Nino Bridge	✓	✓	✓	No data from repo.pscigrid.gov.ph	No rainfall data from repo.pscigrid.gov.ph within the observation period.
A. Alejo Santos Bridge	✓	✓	✓	No data from repo.pscigrid.gov.ph	No water level and rainfall data from repo.pscigrid.gov.ph; Flow measurement is not applicable within the observation period.

The series of graphs, Figure 46- 51, shows the sensor data of the deployed ADCP and depth gauge during the Angat AWLS Cross-section Field Survey.

A. Sensor graph of Sto. Nino Bridge

The stage gathered from the deployed depth gauge Brgy. Caniogan, Calumpit, Bulacan is shown in Figure 46. The measurement of the stage were recorded from August 25 to 27, 2013 showing the changes in water elevation in MSL of Angat river near Sto. Nino bridge.

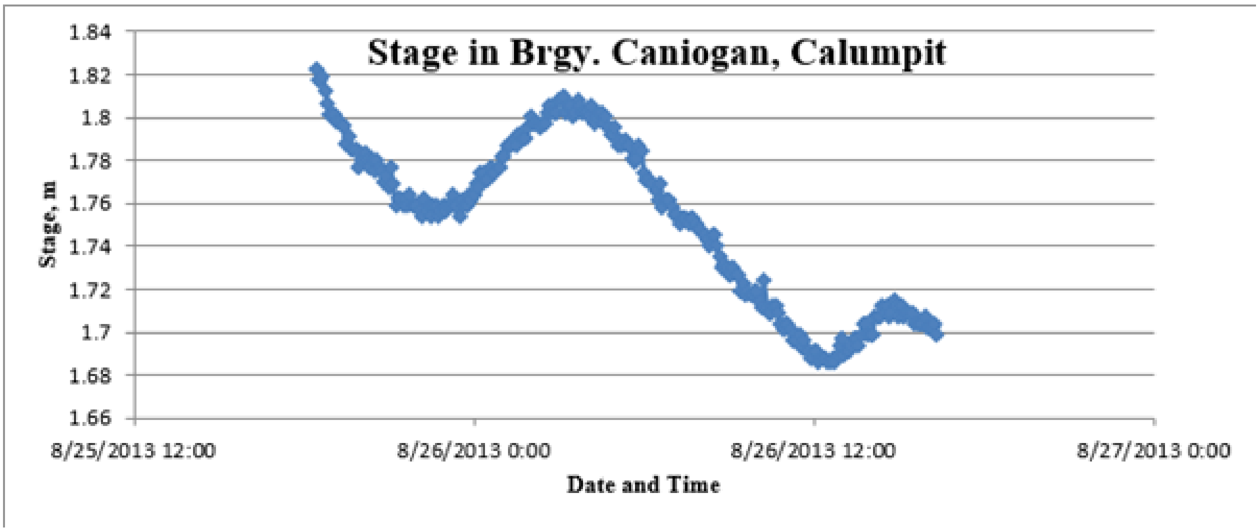


Figure 46. Elevation of Angat River in Brgy. Balungao, Calumpit

The relationship of velocity gathered using a side-looking ADCP and stage from the deployed depth gauge in Brgy. Caniogan, Calumpit is shown in Figure 47.

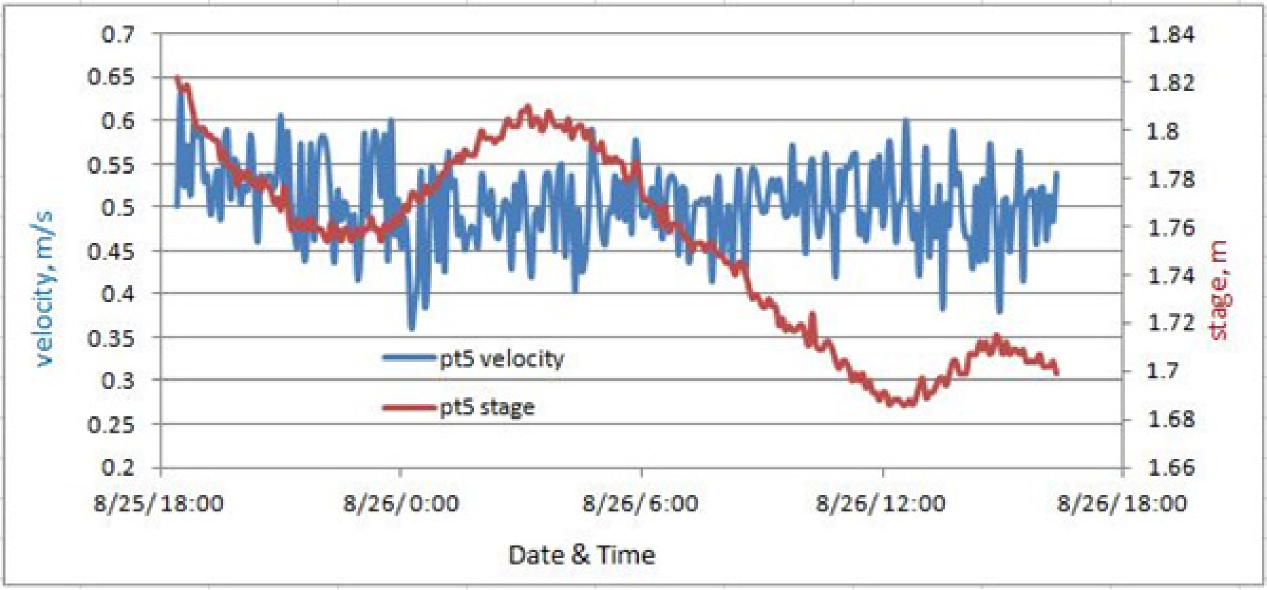


Figure 47. Relationship between velocity and stage in Brgy. Caniogan, Calumpit

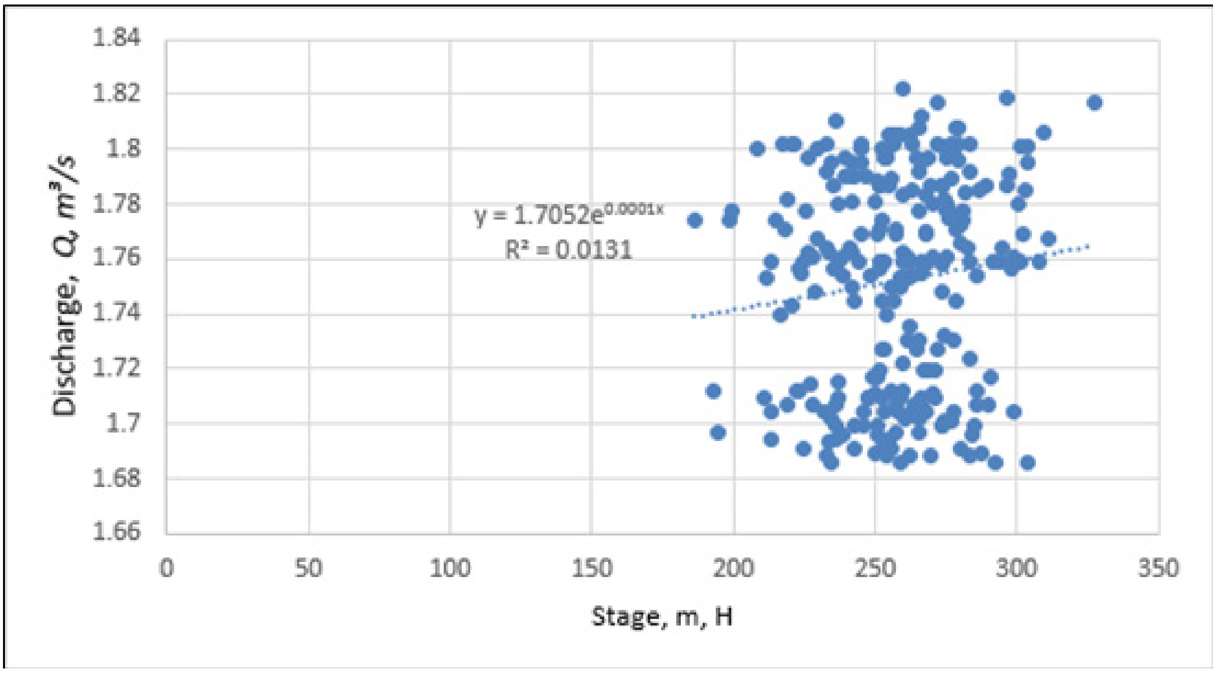


Figure 48. Stage-discharge computation at Sto.Nino Bridge in Brgy. Caniogan, Calumpit, Bulacan

The diagram in Figure 48 shows the discharge of water with corresponding water level elevation and installed AWLS in Sto. Nino Bridge referred to MSL.

B. Sensor graph of Alejo Santos Bridge

The stage gathered from the deployed depth gauge in Brgy. Bustos, Bulacan is shown in Figure 49.

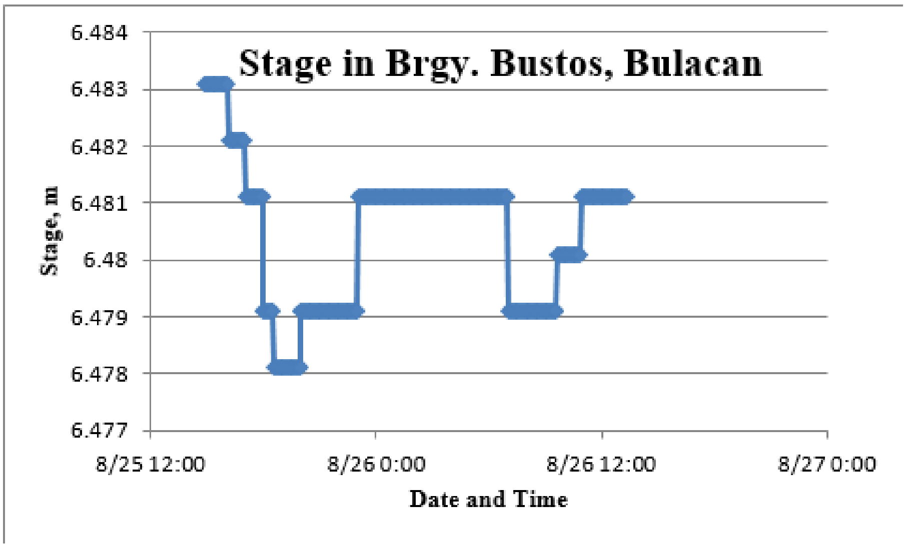


Figure 49. Elevation of Angat River in Brgy. Bustos, Bulacan with respect to date and time.

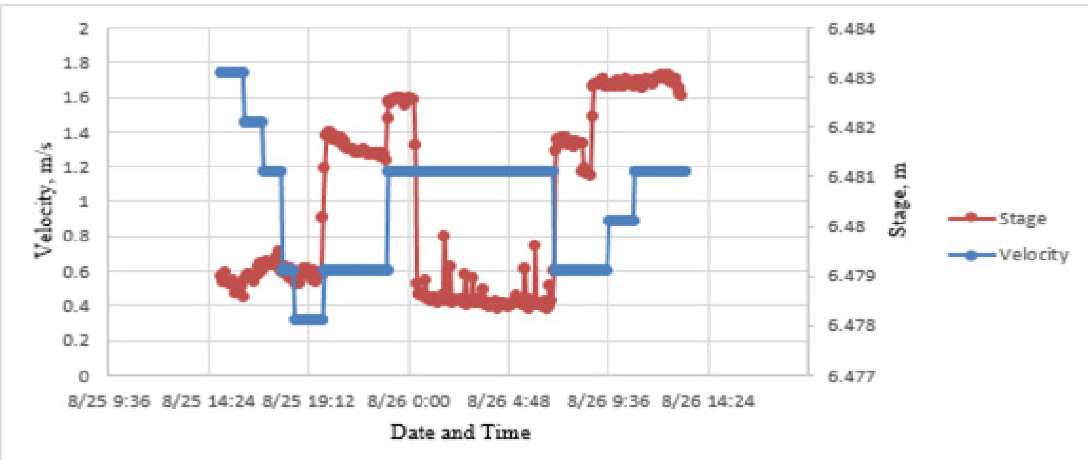


Figure 50. Relationship between stage and velocity in Brgy. Bustos, Bulacan

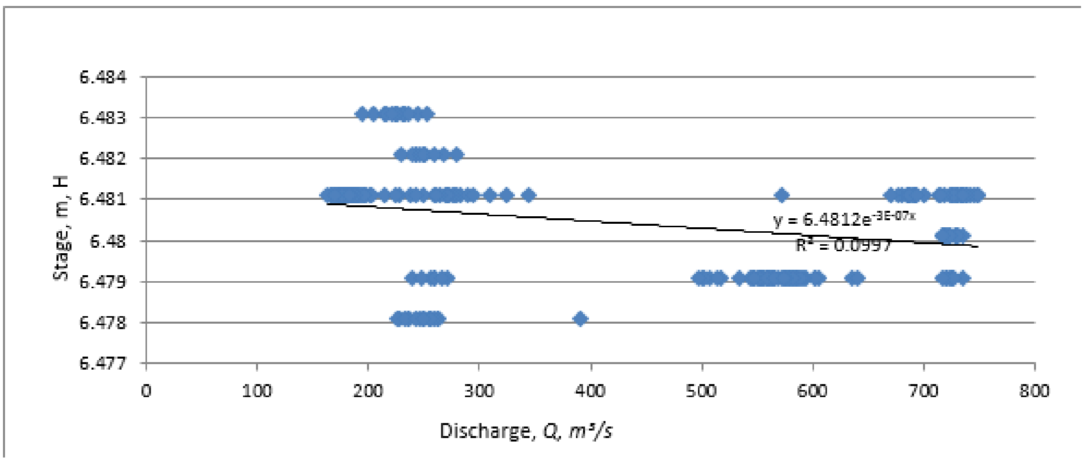


Figure 51. Stage-discharge computation at Alejo Santos Bridge in Brgy. Bustos, Bulacan

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

The table shows the problems and limitations encountered and the actions or solutions taken by the team during Angat Field Survey.

Limitation/Problems	Solutions
No rainfall data gathered during the survey period	Just noted in the report
Stranded at first day of reconnaissance in Hagonoy, Bulacan because of inundation	Standby, reroute and walked up to the Municipal Hall of Hagonoy
June 25, 2012: Hi-Target Echo sounder to be used for bathymetric survey malfunctioned	Checked wirings and connections then program restart. Performed testing of the echo sounder for a day
June 25-27: No communication between base and rover in RTK mode	Looked for a higher area to set-up the base
July 12, 2012: Zigzag sweep bathymetric data got corrupted during the processing	Re-surveyed the portion with corrupted bathymetric data
July 13, 2012: The scanning speed of 10 Hz did not work for the MMS because of low power supply available. (used a 12v car battery)	Instead, the MMS team applied a 1Hz scanning speed
IMU heading problem encountered due to incorrect set-up of heading	Consulted with Sun East Asia Corporation (SEAC) personnel for the issue. SEAC technician contacted the supplier in Hydronav. The issue was resolved and continued MMS survey.
June 21-22, 2012: Could not proceed to survey due to bad weather condition.	Checked the deployed sensors and ensured the safety and stability in anticipation for the upcoming typhoon.

ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

Type	Brand	Serial number	Owner	Quantity
1. GPS Receivers	Topcon HiperGa	457-02818	UP-TCAGP	Two (2) rovers, two (2) controllers
		457-02822	SITECH	One (1) base, one (1) rover
	Trimble	SPS 852-5203K81512		
	Trimble	SPS 852-5208K82363		
	Trimble	SPS 882-5152479277		
	Trimble	SPS 882-5152479972		One (1) rover
	Trimble		UP- TCAGP	Two (2) rovers
2. Singlebeam Echosounder	Hi-Target		UP-TCAGP	One (1) unit with accessories
3. Acoustic Doppler Current Profiler (ADCP)			UP- TCAGP	One (1) unit with accessories
		Coupler-2B	UP- TCAGP	One (1) unit
4. Handheld GPS	Garmin Oregon 550	210757	UP-TCAGP	Four (5) units
		210758		
		210759		
5. Laptops	Lenovo	Latitude E6420	UP-TCAGP	One (1) unit
	Dell			One (1) unit
	Panasonic Tough book (MDL)			One (1) unit
6. Digital Level	Topcon DL502		UP-TCAGP	One (1) unit with two (2) level rods
7. Depth Gauge	Onset Hobo wares	9997437	UP-TCAGP	Four (4) units
8. Rain Gauge			UP- TCAGP	One (1) unit
9. Digital Flow Meter			UP-TCAGP	One (1) unit
10. Range Poles			UP-TCAGP	Two (2) units
11. Prism with range poles			UP-TCAGP	One (1) unit
12. Tripod	Trimble		UP-TCAGP	One (2) units
	Trimble		SITECH	Two (2) units

Type	Brand	Serial number	Owner	Quantity
12. Tripod	Trimble		UP-TCAGP	One (2) units
	Trimble		SITECH	Two (2) units
13. Bipod	Trimble		SITECH	Five (5) units
14. Echo Sounder (Lowrance)			UP-TCAGP	One (1) unit
15. Total Station (Prism Less)			UP-TCAGP	Two (2) units
16.Laser Range Finder			UP-TCAGP	Three (3) units
17. Toolbox			UP-TCAGP	One (1) unit
18. Installers	Sontek		UP-TCAGP	One (1) unit
	Topcon			
19. MMS	MDL Dynascan		UP-TCAGP	One (1) unit
20. Echosounder	Ohmex		SITECH	One (1) unit

ANNEX C. THE SURVEY TEAM

Data Validation Component Sub-Team	Designation	Name	Agency/ Affiliation
	Project Component Leader	ENGR. LOUIE BALICANTA	UP TCAGP
Survey Coordinator	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	ENGR. JMSON J. CALALANG	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	JELINE M. AMANTE	UP TCAGP
	Research Associate	PATRIZCIA MAE P. DELACRUZ	UP TCAGP
	Research Associate	MARY GRACE S. JASON	UP TCAGP
	Research Associate	JOJO E. MORILLO	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

Republic of the Philippines
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY
Department of Environment and Natural Resources
Lawton Avenue, Fort Andres Bonifacio, 1634 Taguig City

June 20, 2012

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: **PAMPANGA**
Station Name: **PA-177**

Island: **LUZON**	Municipality: **ARAYAT**	Barangay: **SAN AGUSTIN**
Elevation: **15.5589 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

PA-177 is located on the N side of the Olongapo - Gapan Road. It is on the E end of the sidewalk of the San Agustin Bridge, and is 0.24m S of the easternmost post of the steel railing. The concrete bridge is marked with Km. 90 and its E approach is the boundary between barangay San Agustin Norte and Camba of Arayat.

Mark is the head of a 4" copper nail set in a drilled hole and cemented flushed on the pavement with an inscription "PA 177; NAMRIA; 2006."

Requesting Party: **Joemarie Caballero**
Pupose: **Reference**
OR Number: **4480776 U**
T.N.: **626-2012**

For JOSE GALO P. ISADA, JR.
Director, MGD

9 9 0 6 2 0 2 0 1 2 1 6 0 2 1 3

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: **BULACAN**	
	Station Name: **BLN-3062**	
Island: **LUZON**	Order: **4th**	Barangay: **SAPANG BAYAN**
Municipality: **CALUMPIT**		
	PRS92 Coordinates	
Latitude: **14° 54' 55.63872"**	Longitude: **120° 46' 33.09915"**	Ellipsoidal Hgt: **4.71100 m.**
	WGS84 Coordinates	
Latitude: **14° 54' 50.12985"**	Longitude: **120° 46' 37.96741"**	Ellipsoidal Hgt: **46.80100 m.**
	PTM Coordinates	
Northing: **1649463.205 m.**	Easting: **475885.112 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,650,069.47**	Easting: **260,739.06**	Zone: **51**

Location Description

BLN-3062

Station is located in the Province of Bulacan, Mun. of Calumpit, Brgy. Sapang Bayan. From Pungo Boundary travel 30 m W past the Smart Tower. Then, travel 450 m N towards Sapang Bayan. Station is situated at the left side of the road about 480 m from Pugong Boundary, about 280 m from BLN-3061 and about 250 m from the concrete road going to BLN-3061. Mark is the head of a 4 in. copper nail centered on a 0.20 m x 0.20 m x 1.00 m concrete monument embedded in the ground with inscriptions, "BLN-3062, 2008, NAMRIA".

Requesting Party: **UP-TCAGP DREAM**
Pupose: **Reference**
OR Number: **3943775B**
T.N.: **2013-0556**

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Director, Mapping and Geodesy Department

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Disaster Risk and Exposure Assessment for Mitigation