REGION 11

Compostela Valley 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.

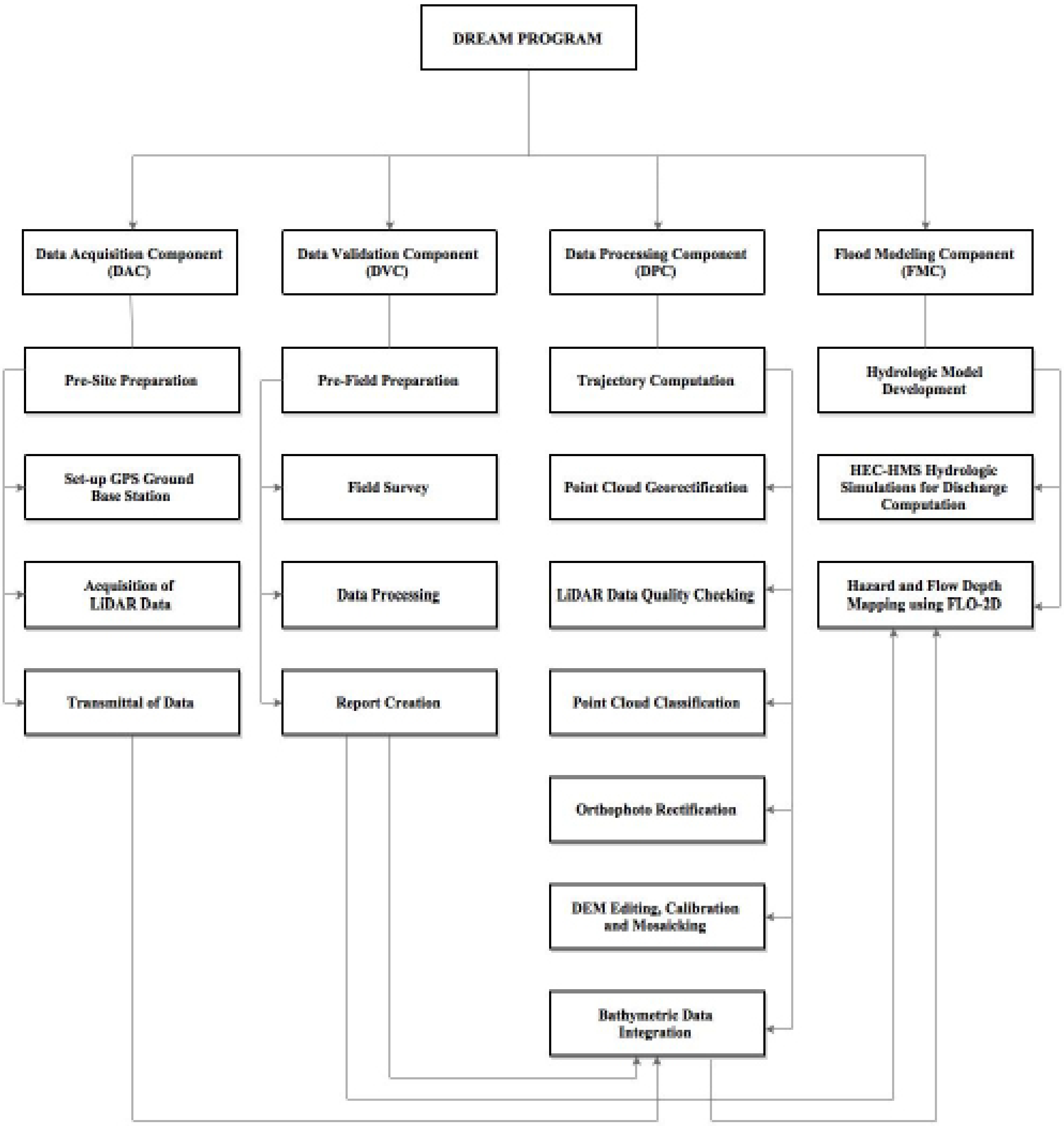


Figure 1. The General Methodological Framework of the Program

The Agusan River Basin

The Agusan River Basin

Located in the eastern part of Mindanao, the Agusan River Basin covers the provinces of Davao Oriental, Compostela Valley, Agusan del Sur, Agusan del Norte and Surigao del Norte. Draining an area of 10,921 square kilometers, it is the third largest river basin and also the third longest river in the Philippines. The location of Agusan River Basin is as shown in Figure 1.

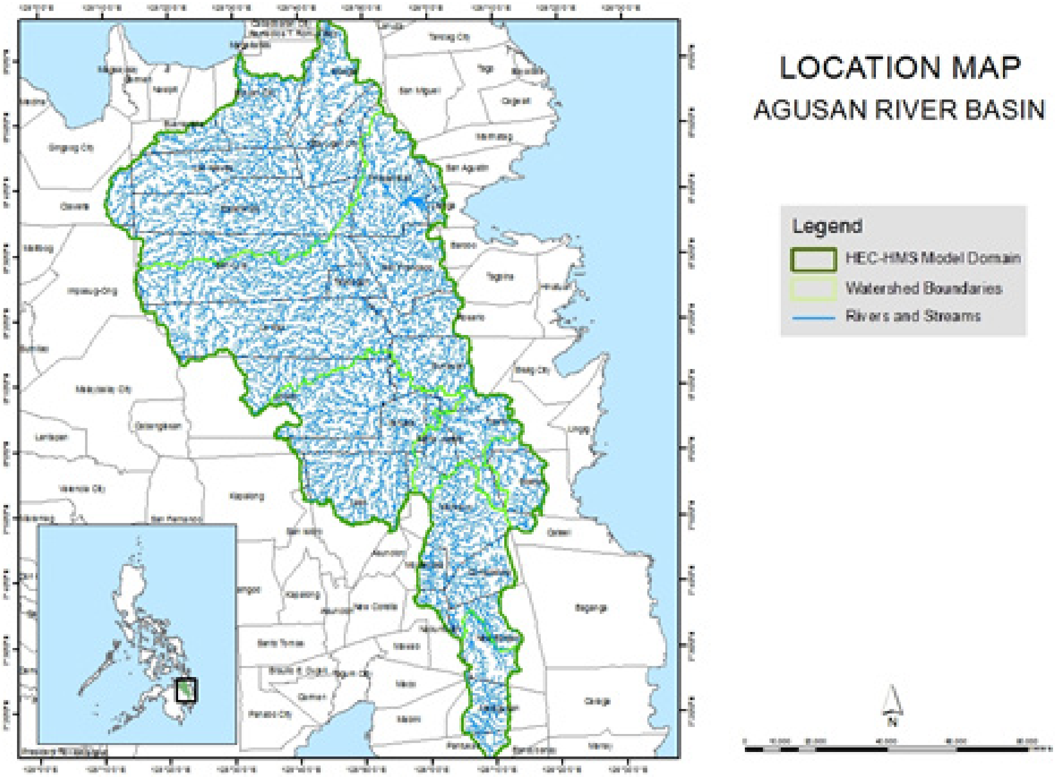


Figure 2. The Agusan River Basin Location Map

Upstream from the Compostela Valley, the river drains to the north and traverses Butuan City and Magallanes in Agusan del Norte. Three sub-basins comprise the Agusan River basin: The upper, middle, and lower Agusan River subbasins which traverses the river from the headwaters in Compostela Valley down to the mouth at Agusan del Norte.

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

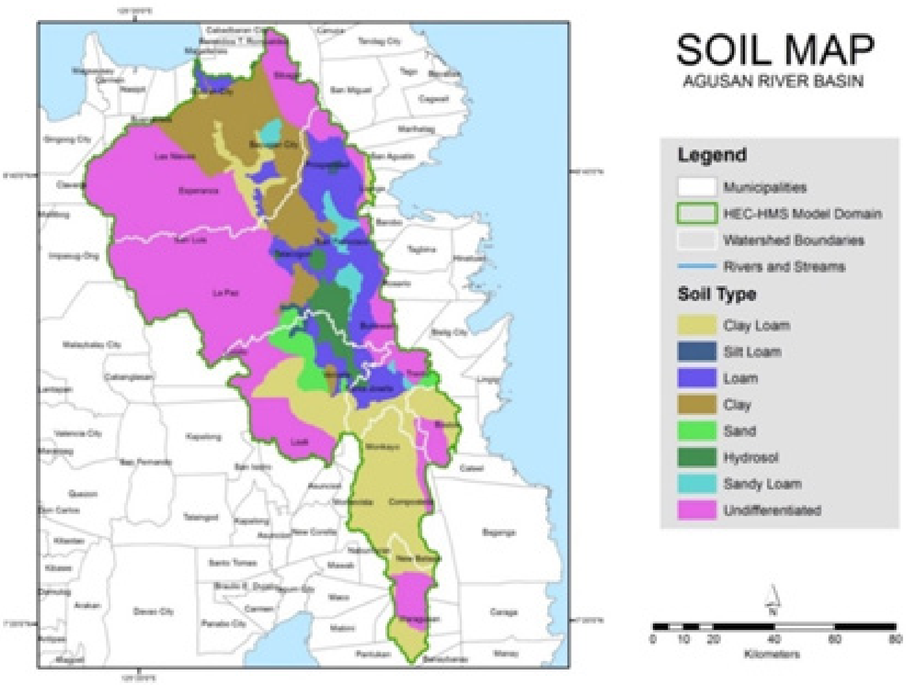


Figure 3. Agusan River Basin Soil Map

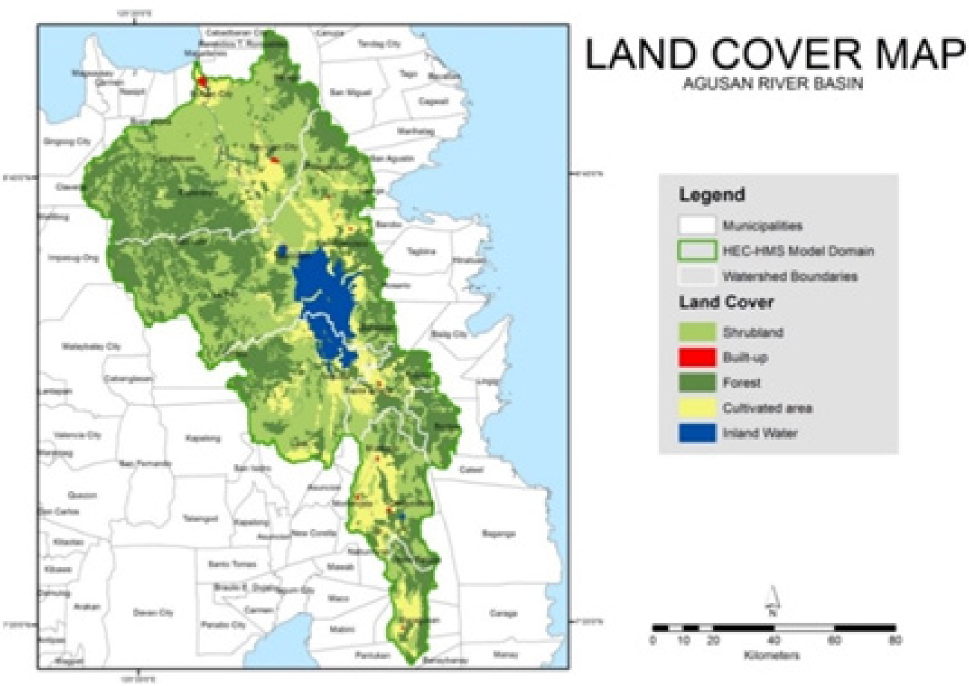


Figure 4. Agusan River Basin Land Cover Map

DVC Methodology

DVC Methodology

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

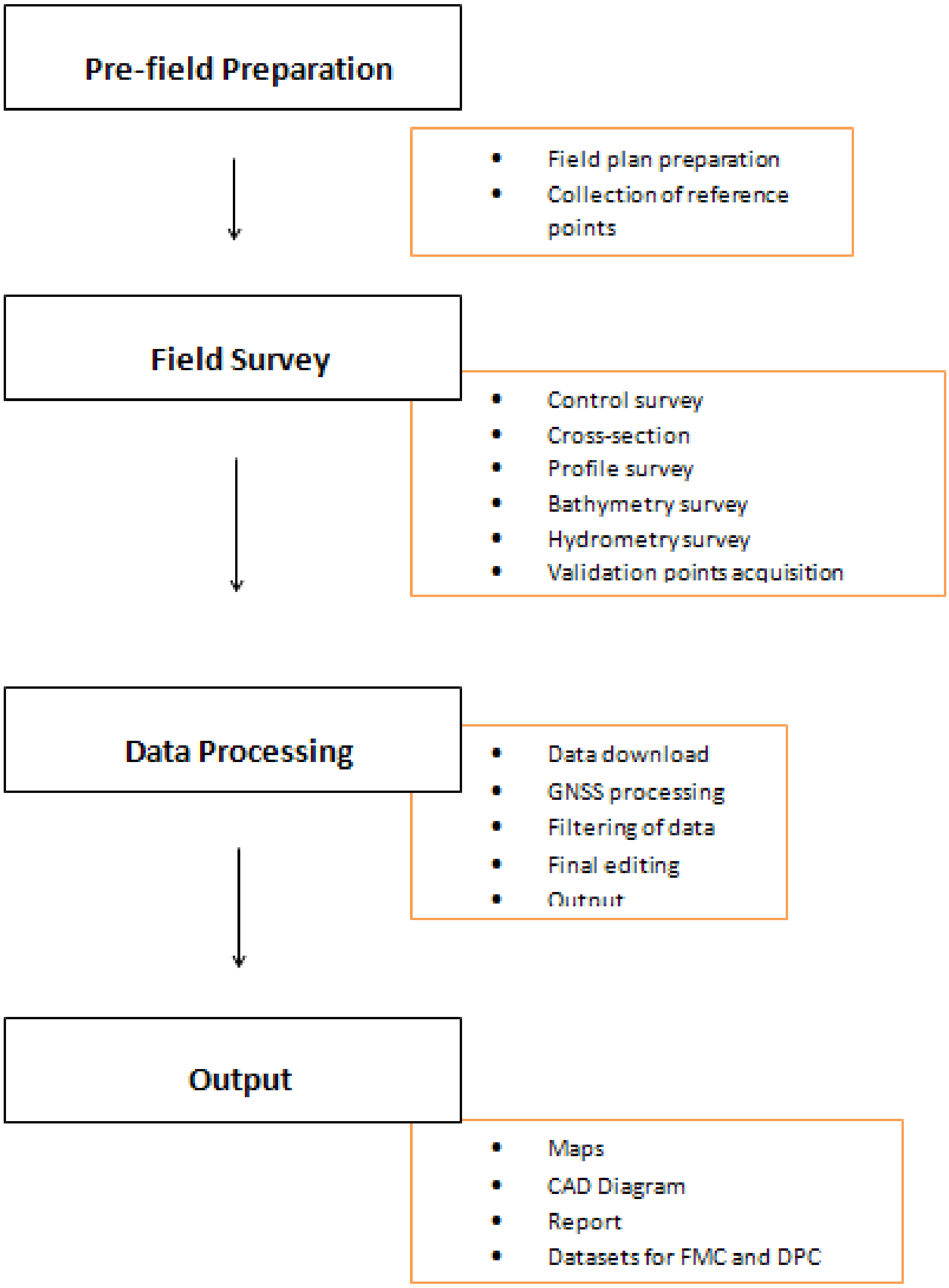


Figure 5. DVC Main Activities

3.1 Pre-field Preparation

3.1.1 Preparation of Field Plan

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

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

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

3.1.2 Collection of Reference Points

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

3.2 Field Surveys

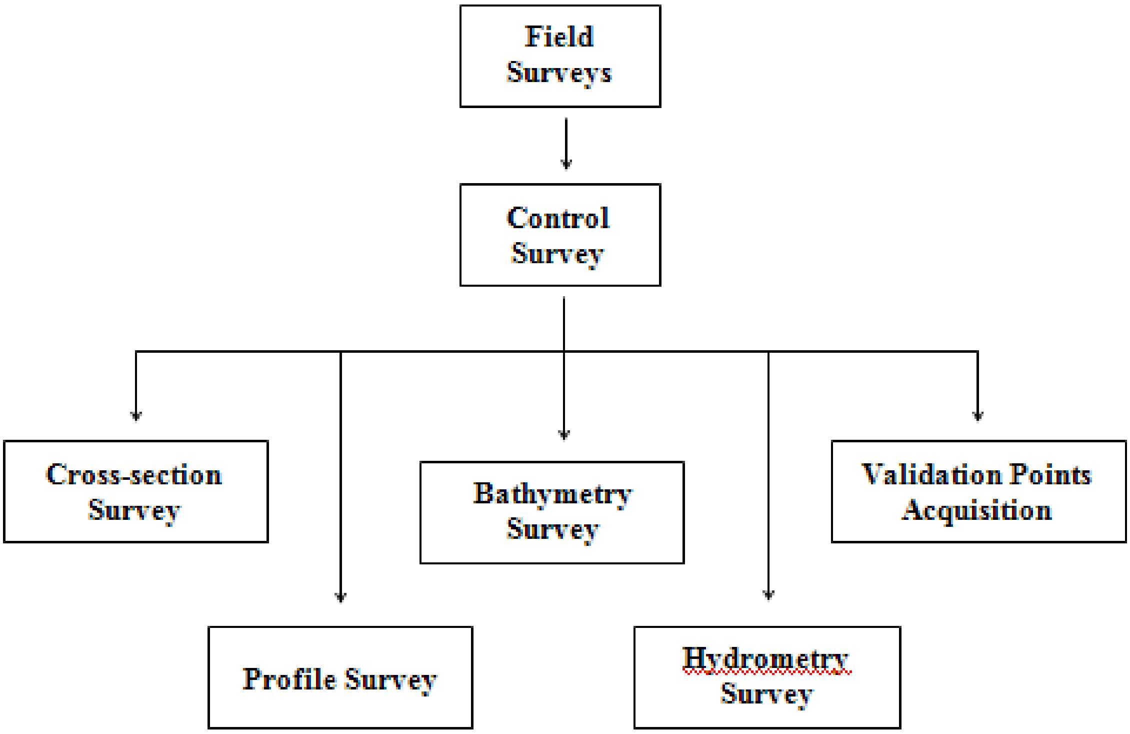


Figure 6. DVC Field Activities

3.2.1 Control Survey

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

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

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

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

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

3.2.2 Cross-section Survey

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

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

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

3.2.3 Profile Surveys

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

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

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

3.2.4 Bathymetric Survey

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

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

3.2.5 Hydrometric Survey

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

The elements of discharge computation are the ff.:

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

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

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

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

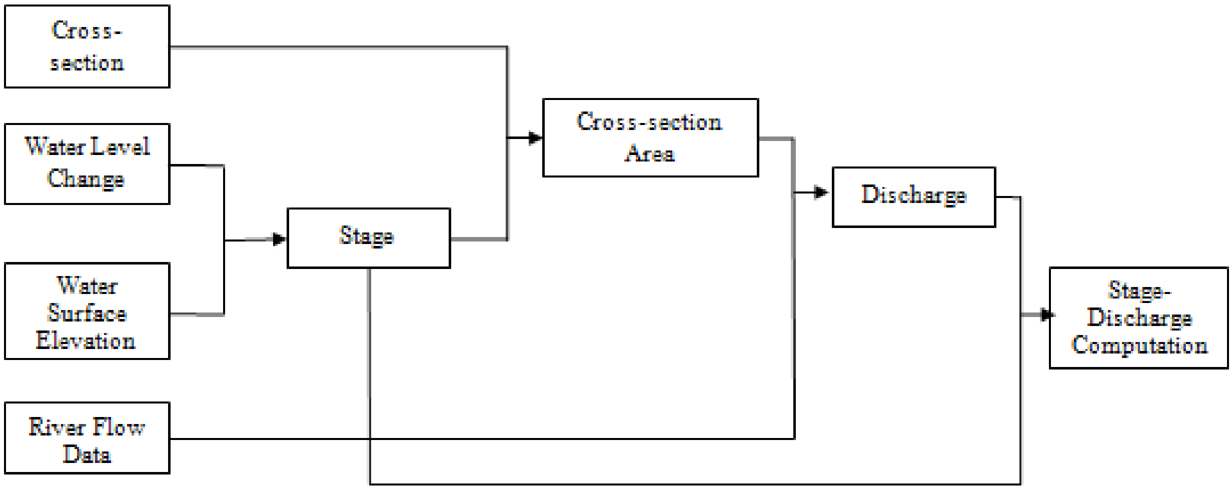


Figure 7. Flow Chart for Stage-Discharge Correlation Computation

3.2.6 Validation Points Acquisition Survey

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

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

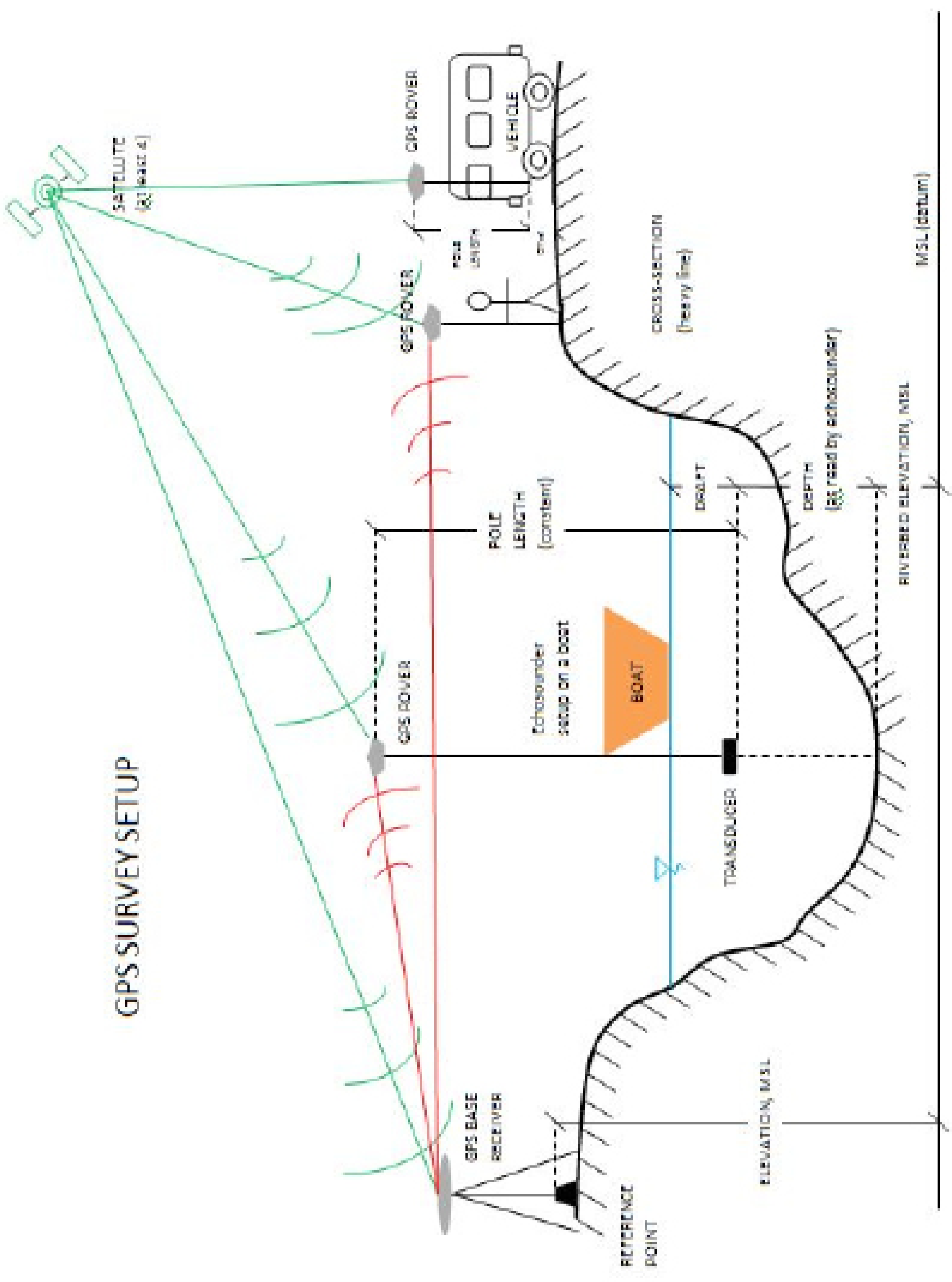


Figure 8. Set-up for GNSS Survey

3.3 Data Processing

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

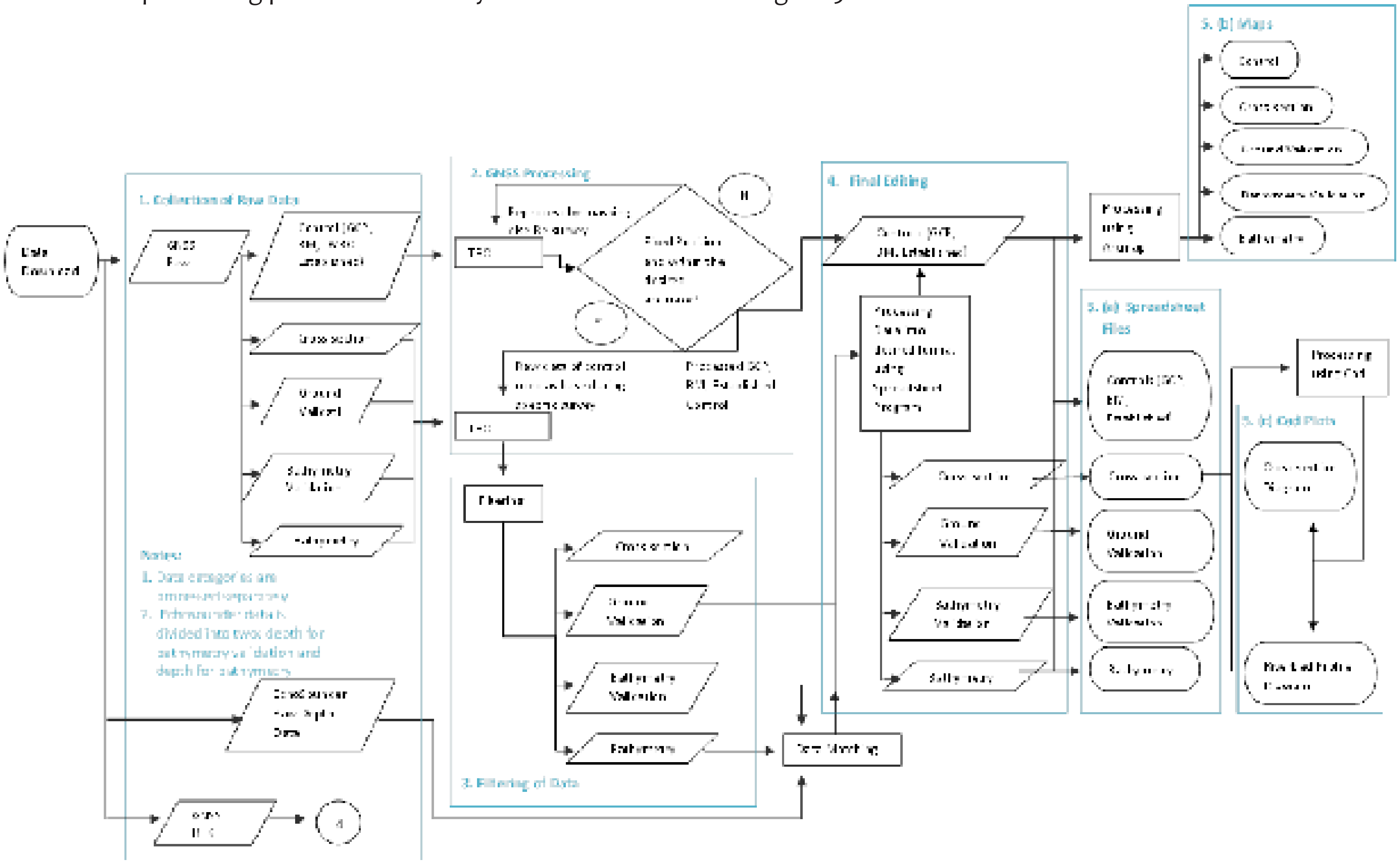


Figure 9. DVC Data Processing Methodology

3.3.1 Collection of Raw Data

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

3.3.2 Data Processing

Processing for GNSS Data

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

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

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

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

Computation for offset:

Equation 1:

$$OFFSET = BM - EGM$$

Computation for BM_ortho:

Equation 2:

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

where:

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

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

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

Depth Data Processing

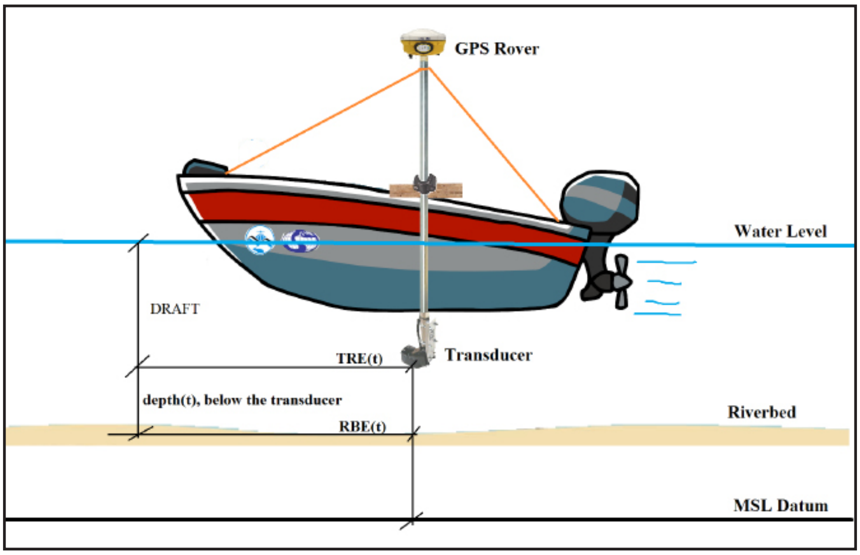


Figure 10. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

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.

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.

Compostela Valley River Basin Survey

Compostela Valley Basin Survey

The Compostela Valley River Basin survey was conducted on January 15-February 2, 2013 with the following activities: control, hydrometric, cross sections, and profile using GNSS and terrestrial LiDAR surveys.

Batoto River, Mayo River and two new rivers created by typhoon Pablo consists of 30 delineated cross-section lines with a total length of 30.842 km for both left and right banks starting from the upstream in Brgy. Andap, New Bataan down to Brgy. Magsaysay, New Bataan, Compostela Valley near the mouth of the river. The total length of profile lines is about 7.6 km for its both left and right banks.

Another set of fieldwork was conducted on Jan 21-23, 2014 to acquire the cross-section and sensor elevation of the installed AWLS and to perform flow data gathering in Panag Bridge, Brgy. Panag, New Bataan; San Roque Bridge in Brgy. San Roque, New Bataan and Poblacion Bridge in Brgy. Poblacion, Compostela.

4.1 Control Survey

Two (2) NAMRIA established reference points and two (2) established UP- TCAGP control points were considered for the static GNSS observations of Compostela Valley River. These include a first order benchmark DVS-1 at Sta. Ana Wharf, Town Proper, Davao City, Davao del Sur; a second order reference point DVA-12 at Mawab Bridge in Brgy. Sibunga, Nabunturan, Davao del Norte and; established control point UP-NB 1, at the top of the New Bataan Town Hall in Brgy. Fatima, New Bataan, Compostela Valley; and a point on the grounds of Compostela Town Hall, Town Proper, Compostela, Compostela Valley. The GNSS set-up for the four (4) base stations are shown in Figure 12, Figure 13, Figure 14 and Figure 15 while the location of these controls are shown in Figure 11.

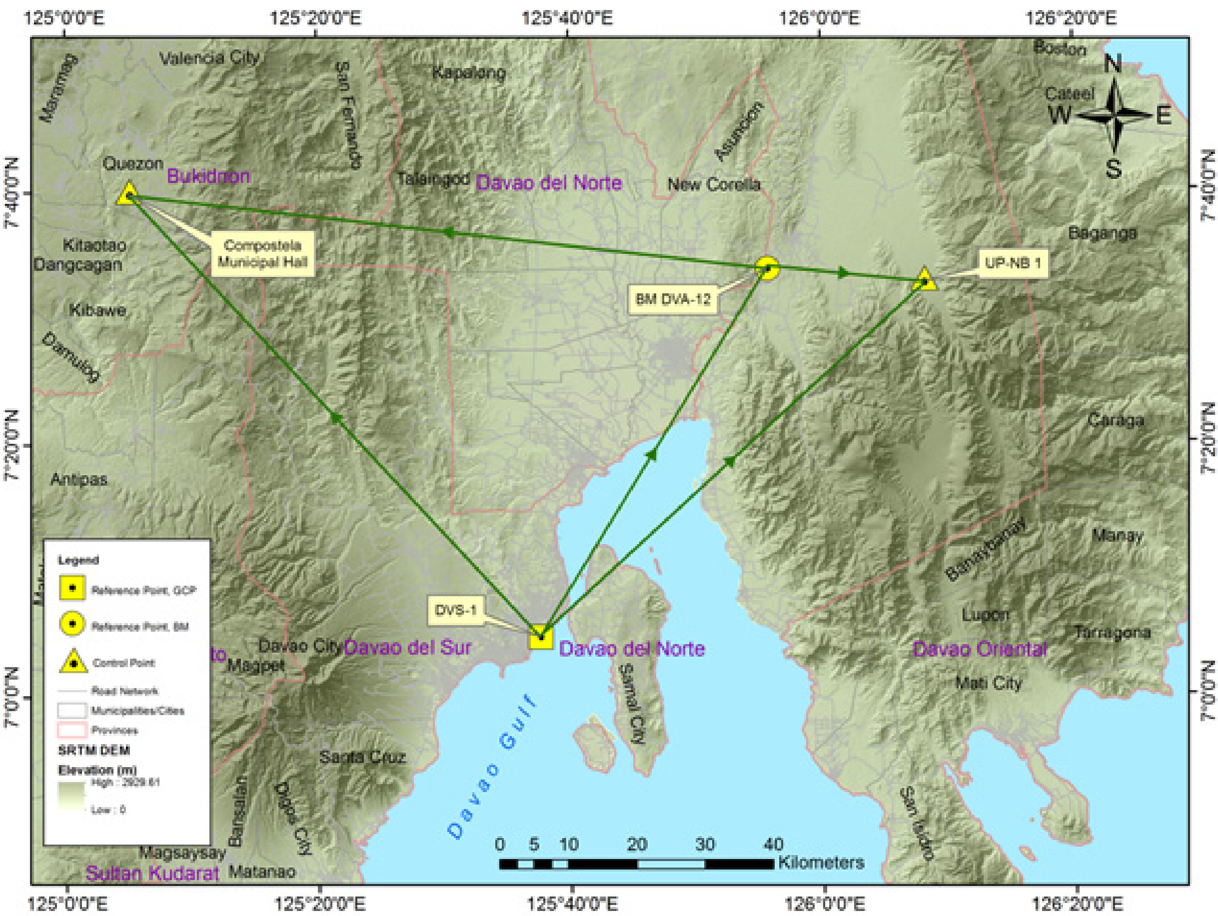


Figure 11. Location of control points

Continuous differential static observations were done simultaneously at these four stations for two hours to provide reference control points for the ground and bathymetric surveys. The horizontal coordinates and elevations of the four (4) 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 Compostela Valley Survey (Source: NAMRIA; UP-TCAGP)

Point Name	Order of Accuracy	WGS84 UTM Zone 51N					Elevation in MSL (m)
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	
BM DVA-12	3rd	7°33'41.70682" N	125°55'44.59728" E	142.931	836918.925	823251.765	76.243
DVS – 1	1st	7°04'38.36201" N	125°37'36.77094" E	68.275	783162.170	790026.110	0.727
Compostela Municipal Hall	3rd	7°40'03.17522" N	126°05'08.08229" E	135.198	848769.187	840457.817	67.970
UP-NB1	3rd	7°32'51.98377" N	126°08'12.29123" E	278.338	835549.861	846205.484	211.421

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

Figure 12. Static GNSS observation at DVA-12 at Mawab Bridge, Brgy. New Sibunga, Nabunturan, Davao del Norte

Figure 13. Static GNSS observation at DVS-1 at Sta. Ana Wharf, Town Proper, Davao City

Figure 14. Static GNSS observation at the ground area of Compostela Town Hall, Town Proper, Compostela, Compostela Valley

Figure 15. Static GNSS observation at UP-NB 1 at the roof top of New Bataan Town Hall in Brgy. Fatima, New Bataan, Compostela Valley

Figure 16. RTK base set up at UP-NB 1 at the roof top of New Bataan Town Hall in Brgy. Fatima, New Bataan, Compostela Valley.

4.2 Cross-section Survey

Cross-section survey was conducted last January 15-February 2, 2013 in Batoto River, Mayo River and two new rivers created by typhoon Pablo. 30 cross-sections were done from the left and right banks of the river. Cross-section and profile extent are shown in Figure 17.

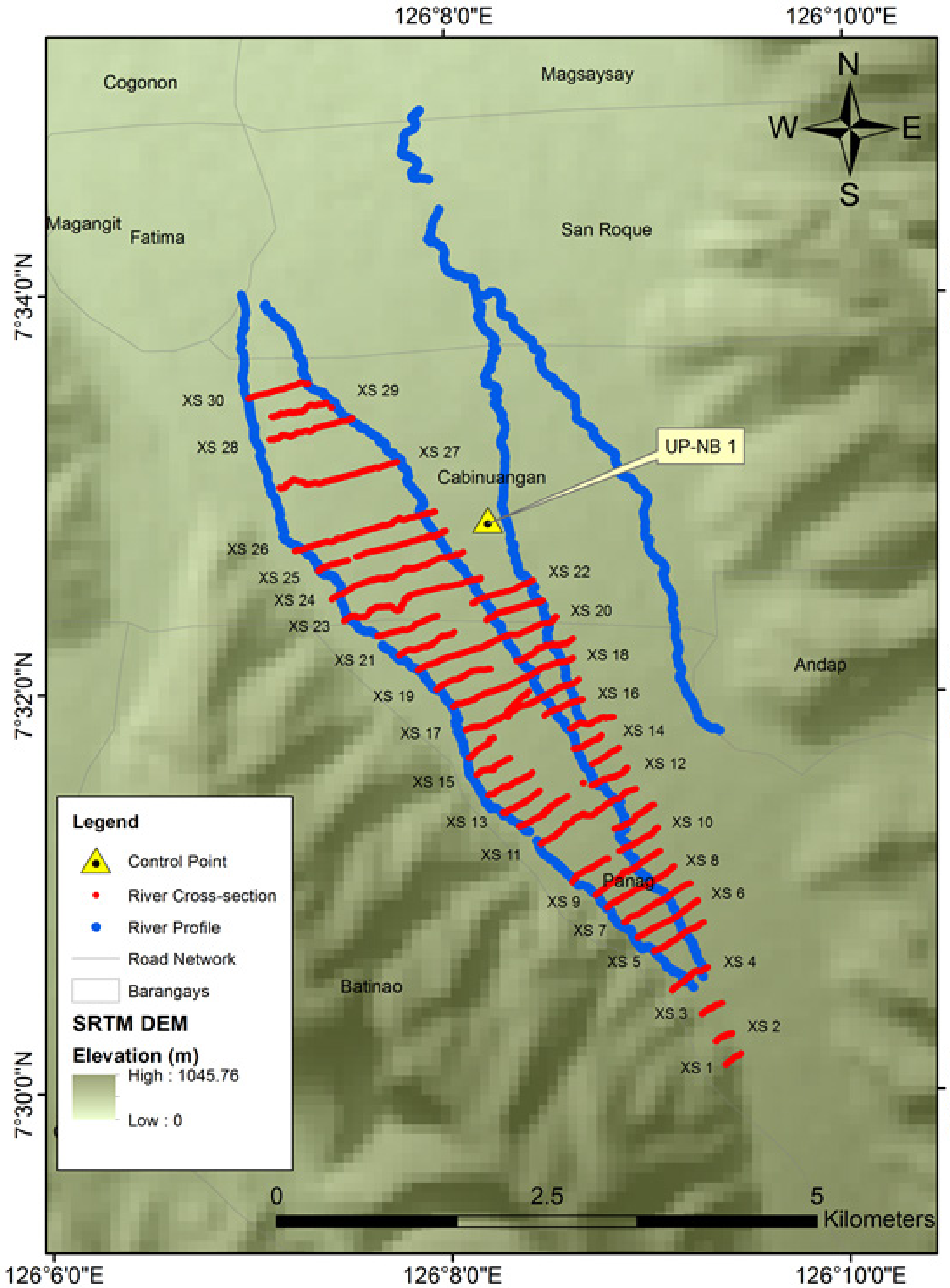


Figure 17. Profile and Cross-section map

The cross-section team (CST) is composed of two (2) to three (3) DVC field personnel and one (1) survey aide and/or guide. At the start of every cross-section lines, each member of CST was dropped-off at an accessible point nearest to the planned cross-section lines. The actual gathering of cross-section lines is shown in Figure 18.

Figure 18. Cross-section using RTK surveying technique

The variations in the elevation of the cross-sections in New Bataan Flood plain are illustrated in Figures 19-48 in CAD format. The cross-sections are plotted from the left to right facing downstream.

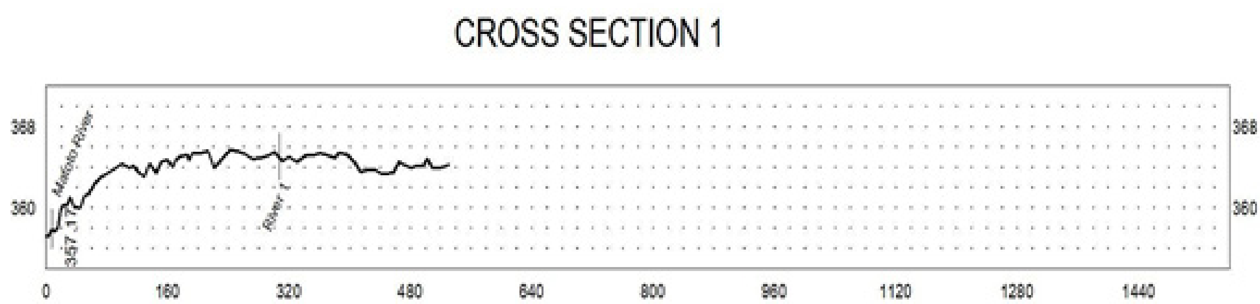


Figure 19. Cross-Section 1 at New Bataan Survey Area

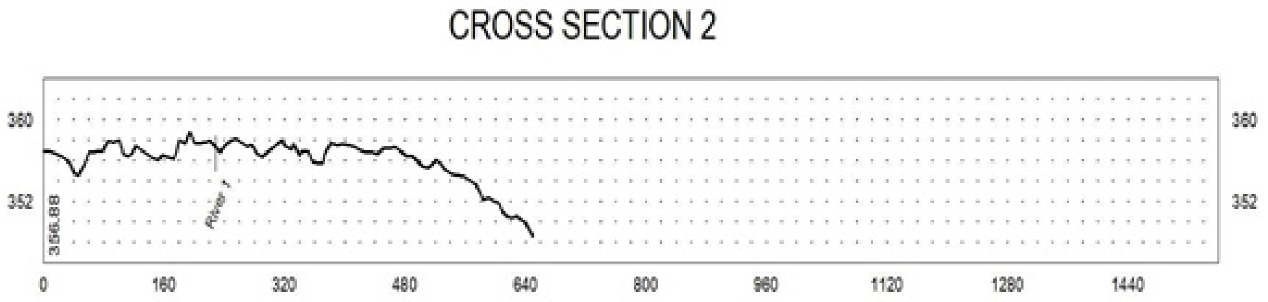


Figure 20. Cross-Section 2 at New Bataan Survey Area

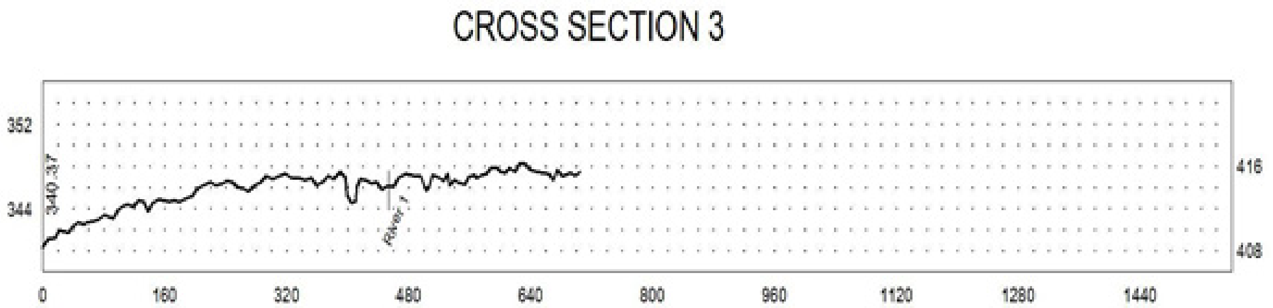


Figure 21. Cross-Section 3 at New Bataan Survey Area

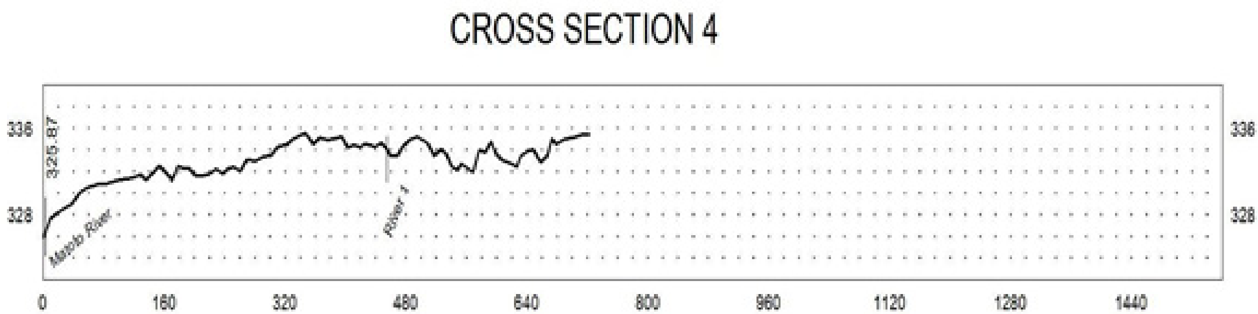


Figure 22. Cross-Section 4 at New Bataan Survey Area

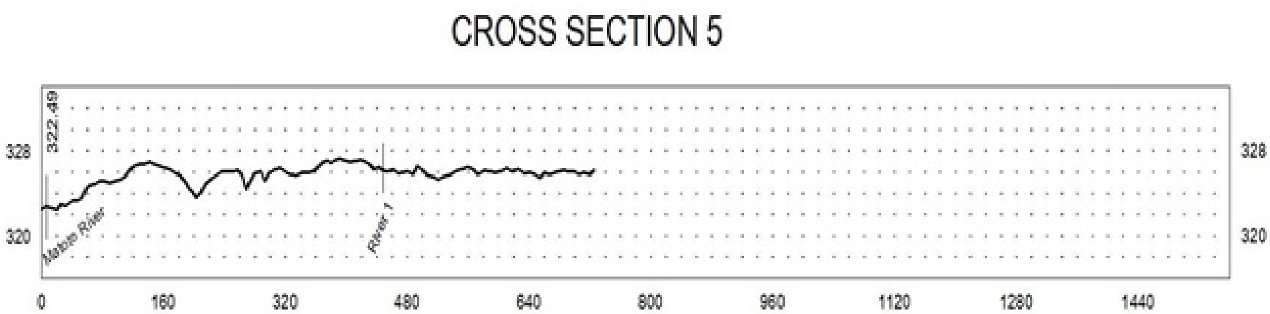


Figure 23. Cross-Section 5 at New Bataan Survey Area

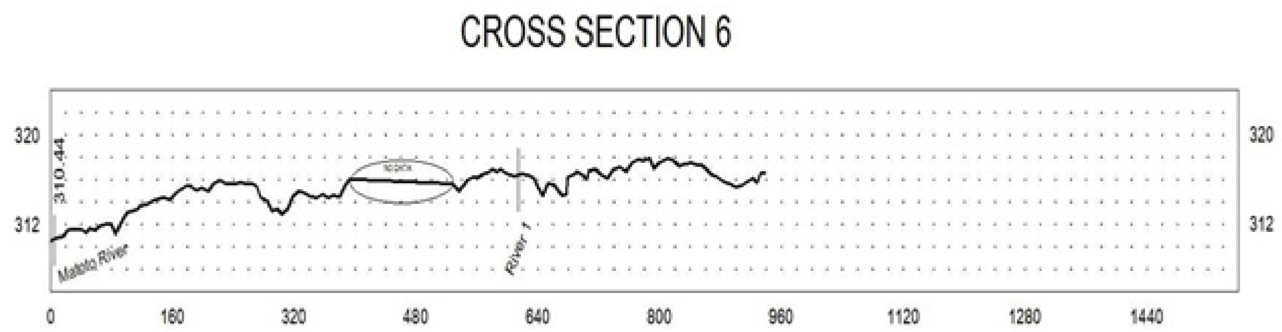


Figure 24. Cross-Section 6 at New Bataan Survey Area

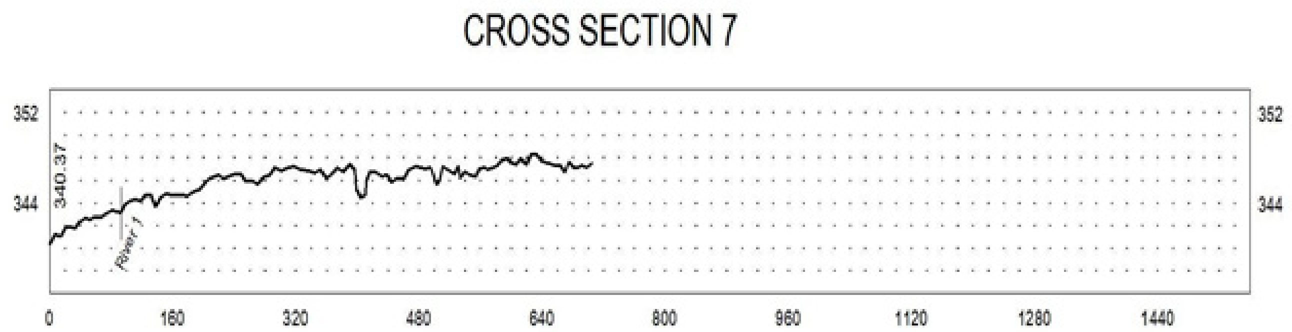


Figure 25. Cross-Section 7 at New Bataan Survey Area

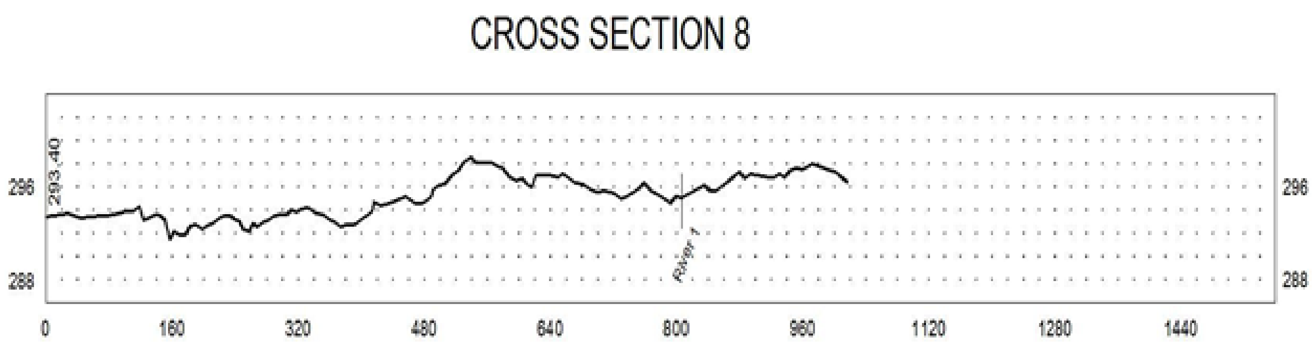


Figure 26. Cross-Section 8 at New Bataan Survey Area

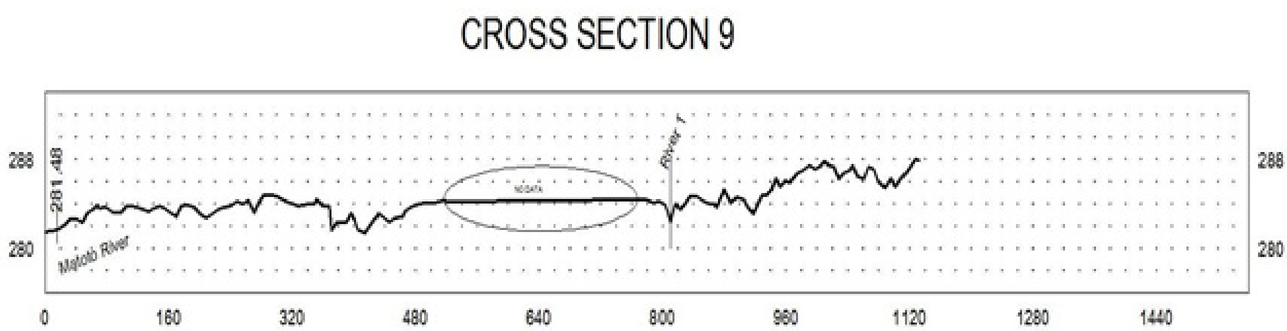


Figure 27. Cross-Section 9 at New Bataan Survey Area

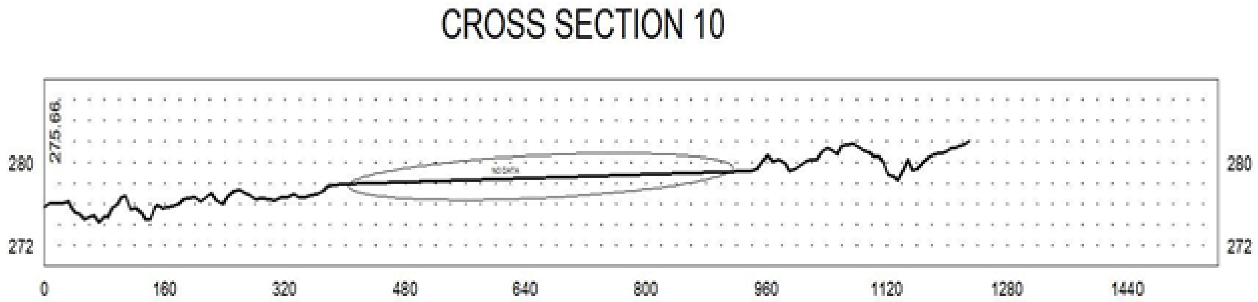


Figure 28. Cross-Section 10 at New Bataan Survey Area

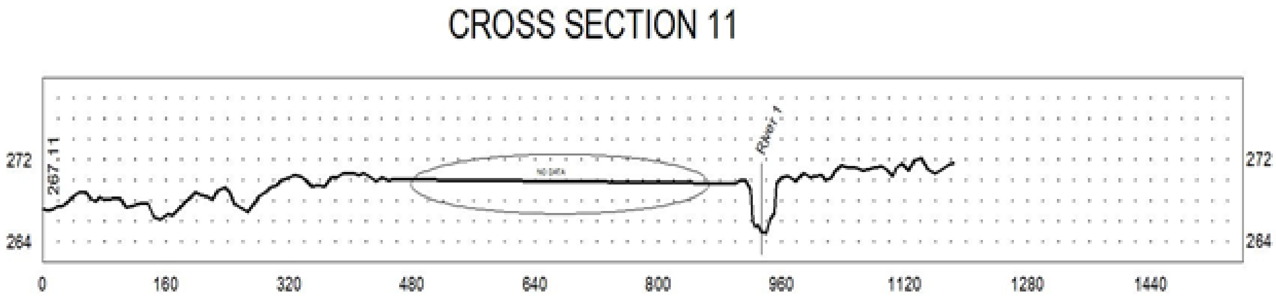


Figure 29. Cross-Section 11 at New Bataan Survey Area

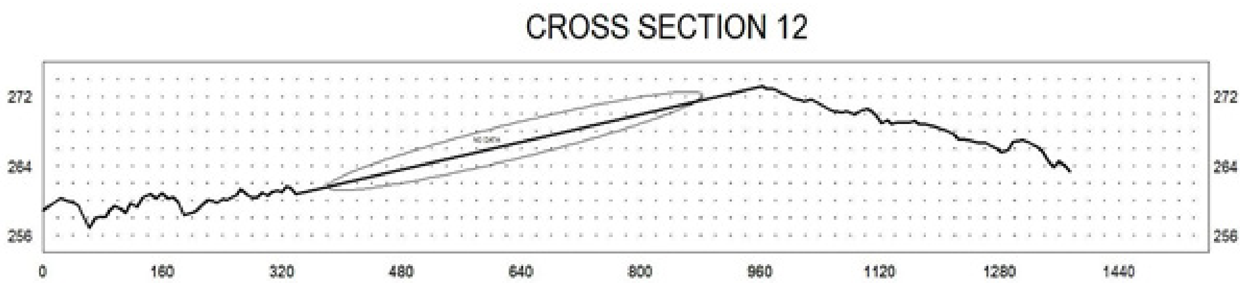


Figure 30. Cross-Section 12 at New Bataan Survey Area

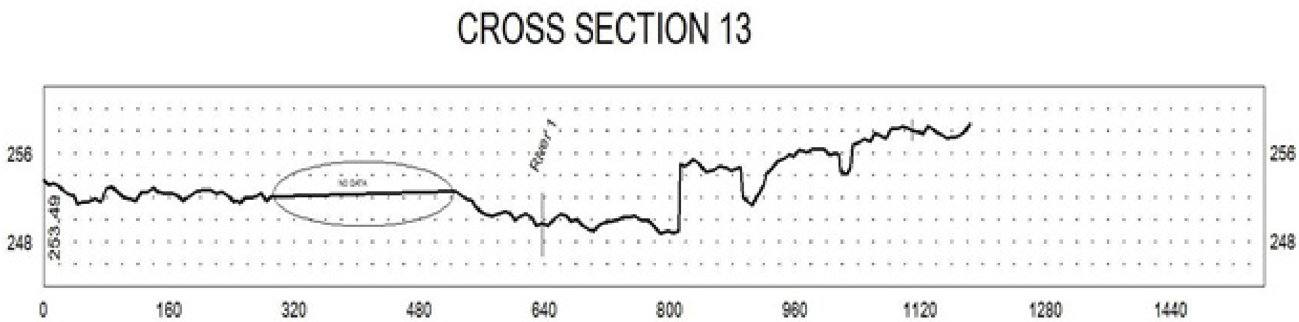


Figure 31. Cross-Section 13 at New Bataan Survey Area

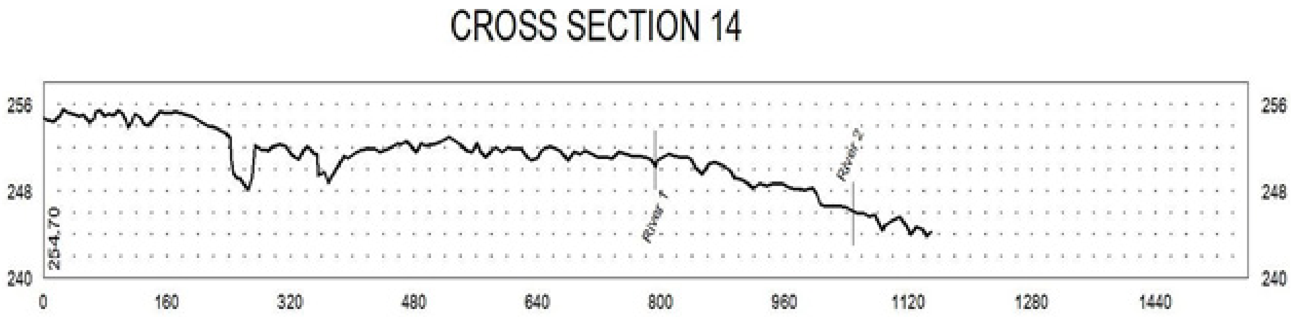


Figure 32. Cross-Section 14 at New Bataan Survey Area

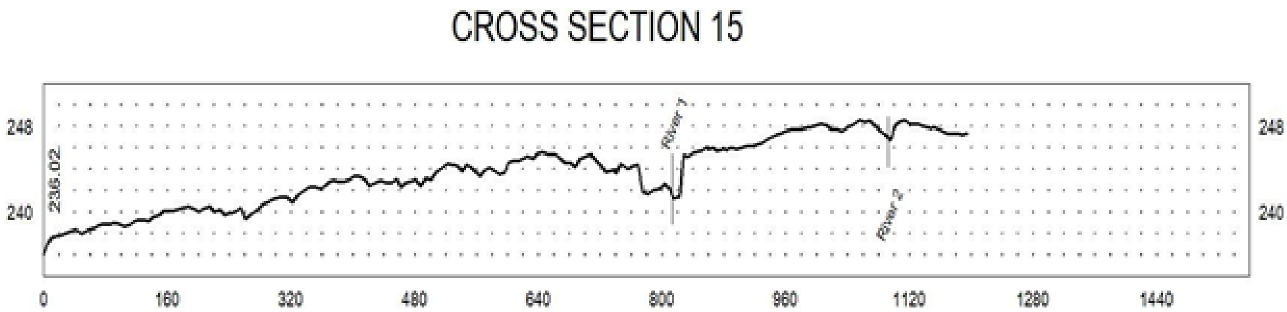


Figure 33. Cross-Section 15 at New Bataan Survey Area

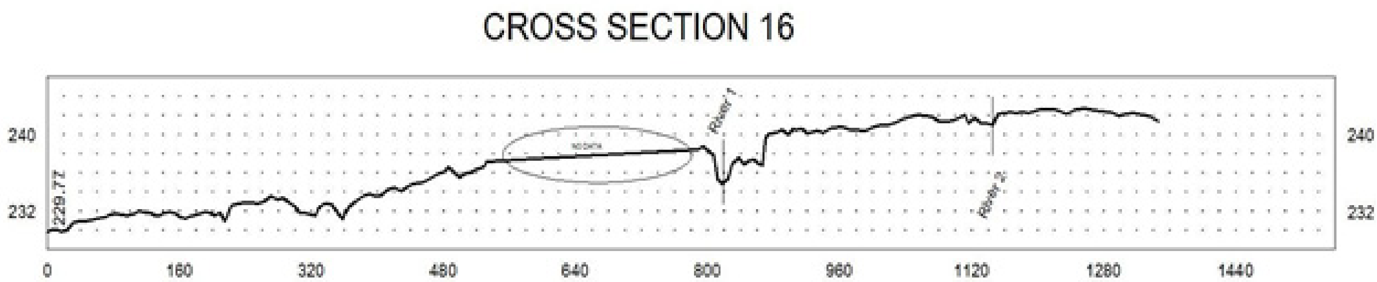


Figure 34. Cross-Section 16 at New Bataan Survey Area

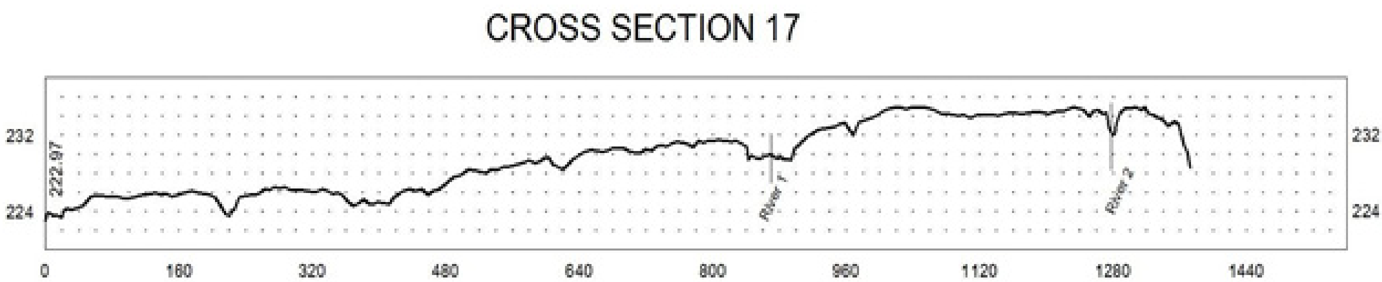


Figure 35. Cross-Section 17 at New Bataan Survey Area

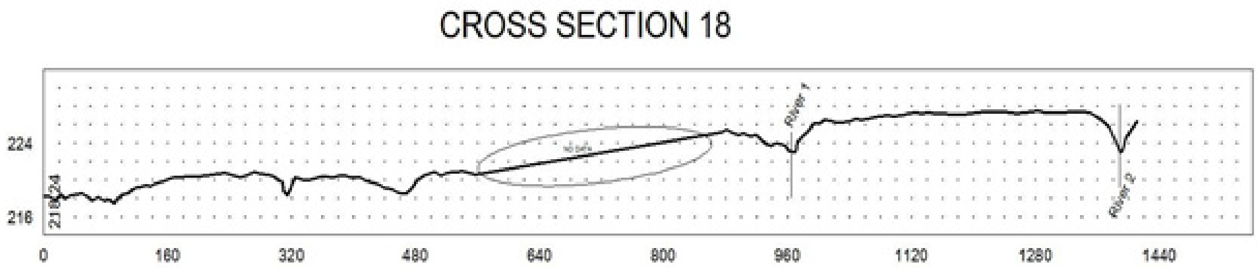


Figure 36. Cross-Section 18 at New Bataan Survey Area

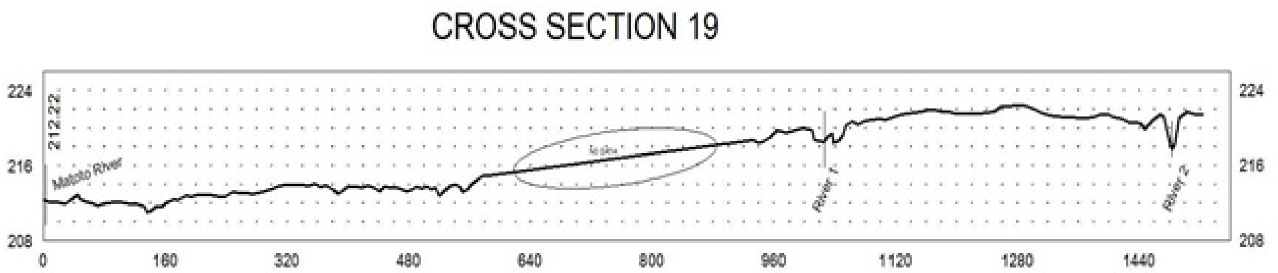


Figure 37. Cross-Section 19 at New Bataan Survey Area

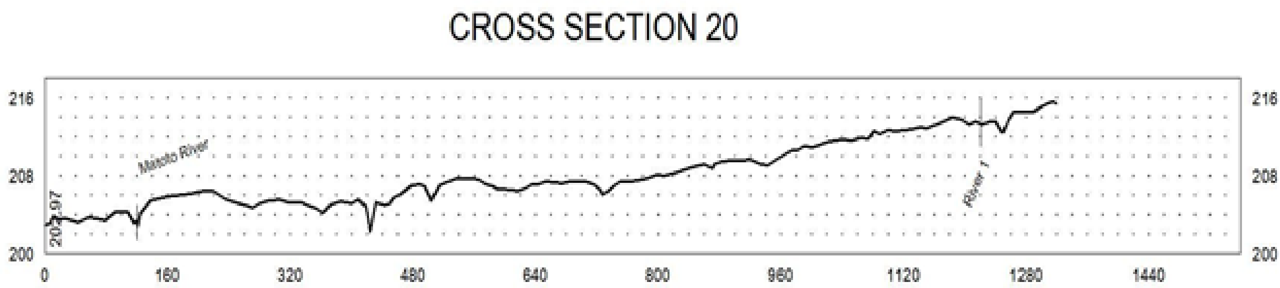


Figure 38. Cross-Section 20 at New Bataan Survey Area

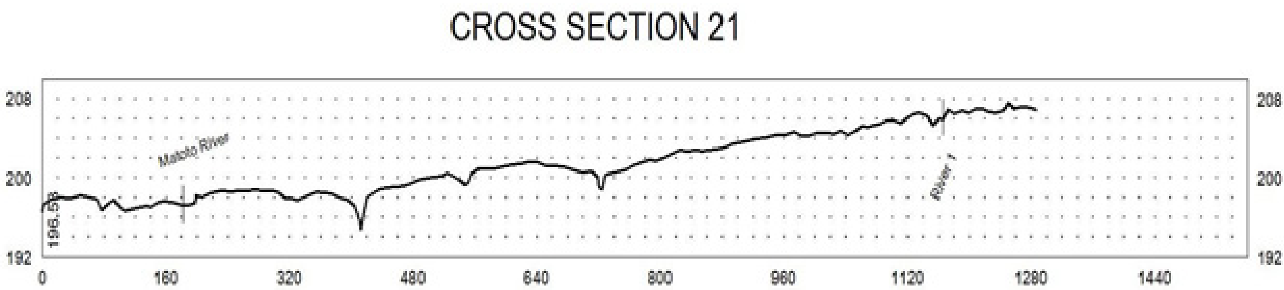


Figure 39. Cross-Section 21 at New Bataan Survey Area

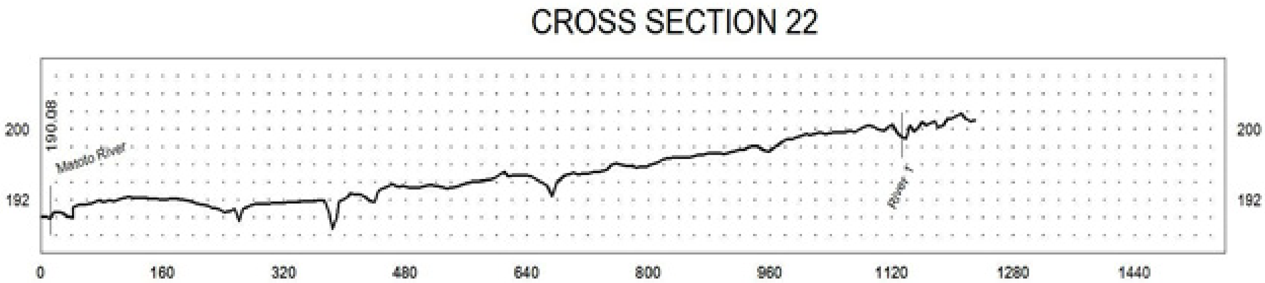


Figure 40. Cross-Section 22 at New Bataan Survey Area

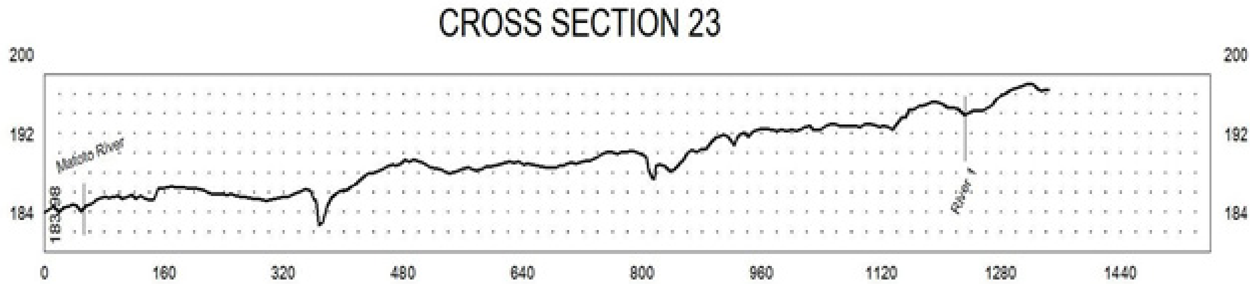


Figure 41. Cross-Section 23 at New Bataan Survey Area

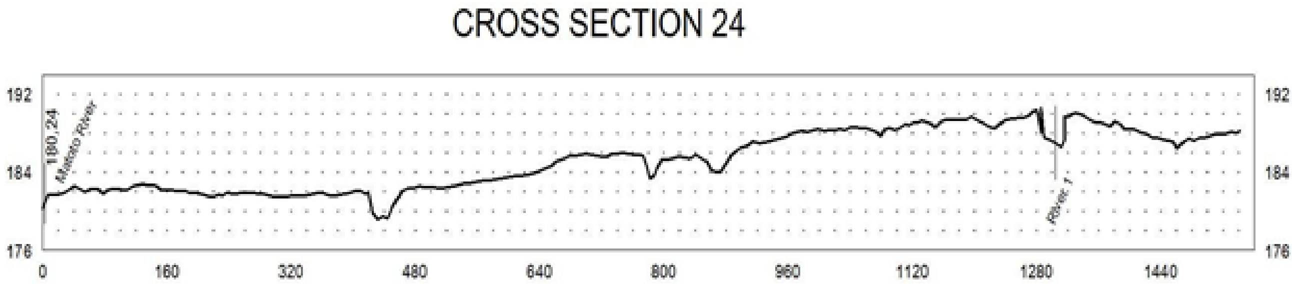


Figure 42. Cross-Section 24 at New Bataan Survey Area

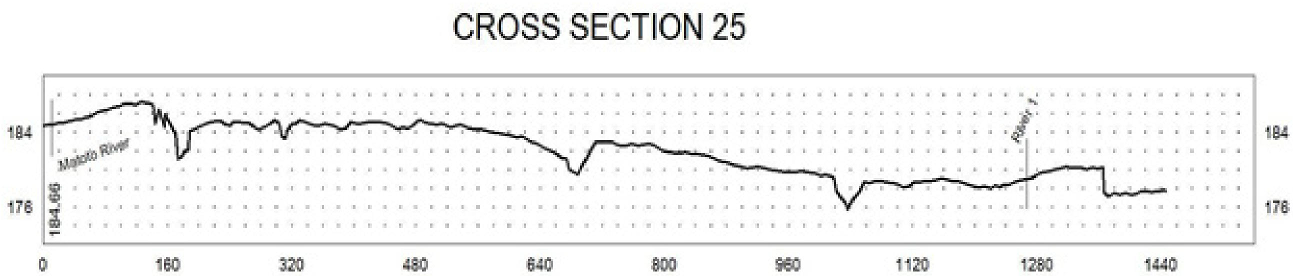


Figure 43. Cross-Section 25 at New Bataan Survey Area

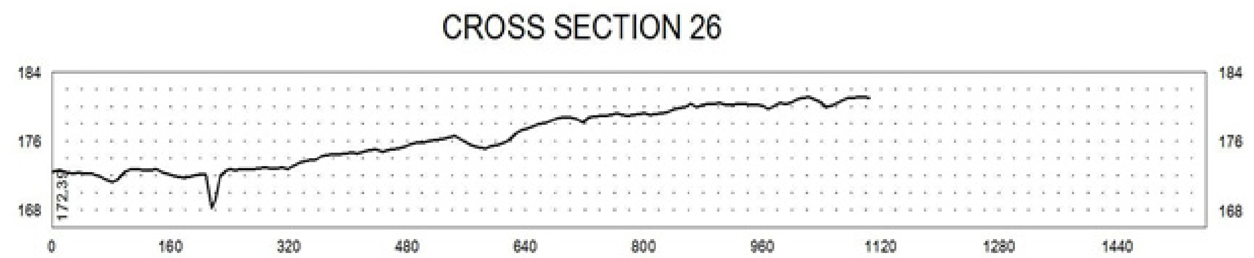


Figure 44. Cross-Section 26 at New Bataan Survey Area

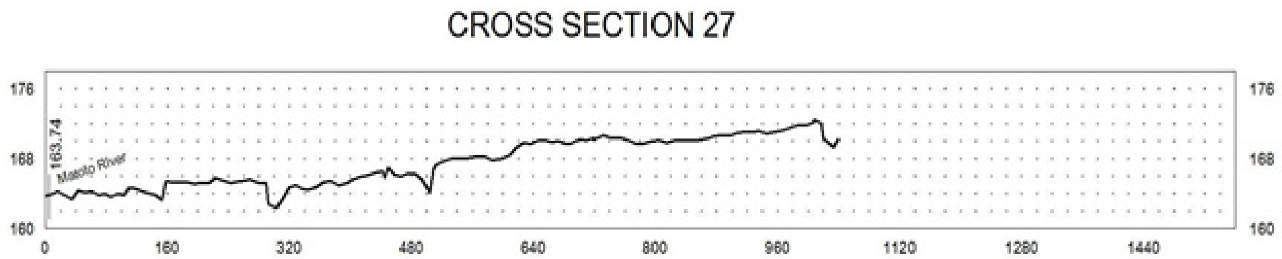


Figure 45. Cross-Section 27 at New Bataan Survey Area

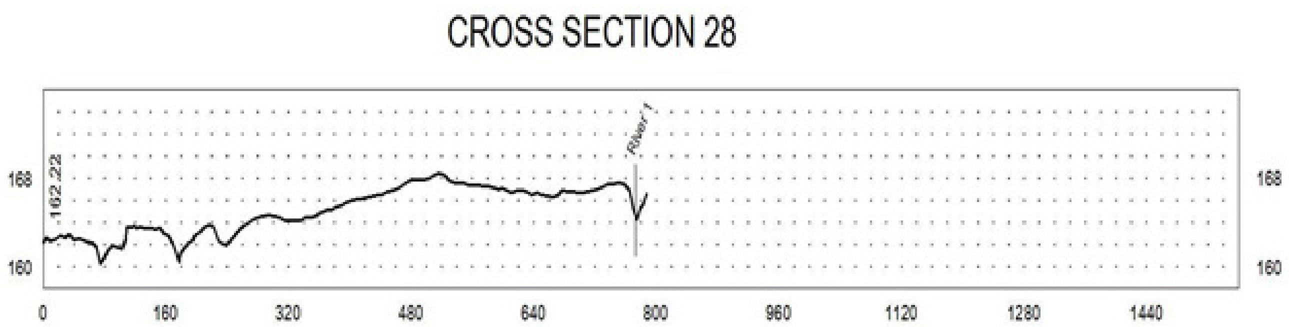


Figure 46. Cross-Section 28 at New Bataan Survey Area

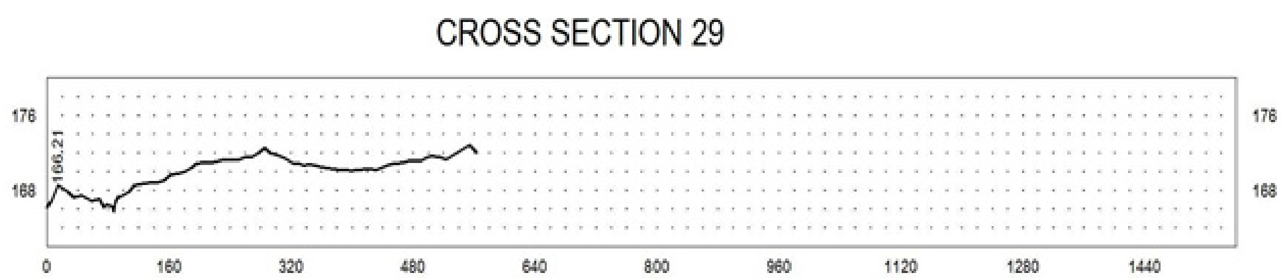


Figure 47. Cross-Section 29 at New Bataan Survey Area

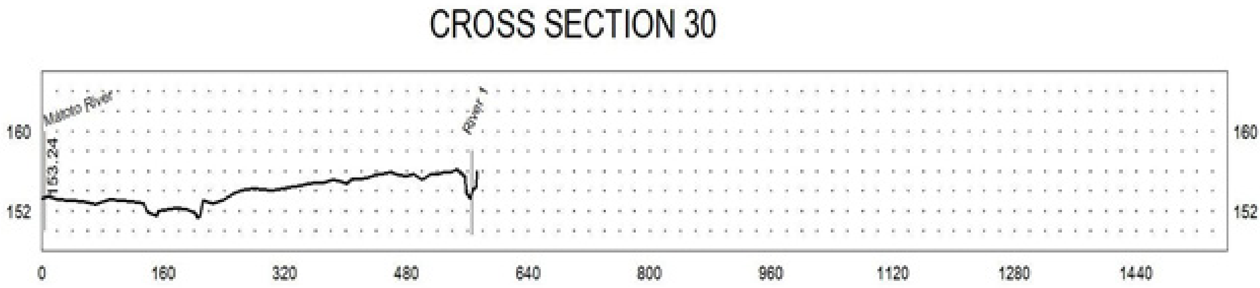


Figure 48. Cross-Section 30 at New Bataan Survey Area

The cross-section data were compared with its respective planned cross-section line to determine whether the acquired data is within the 10-m maximum deviation. This was done by creating a 10-m buffer around every planned cross-section. The result of the buffer analysis is shown in Table 2, while the percentage of points within the buffer for every cross-section is shown in Figure 49.

Table 2. Buffer analysis summary for cross-section survey

Cross section	Total no. of points surveyed	Number of points surveyed within 10-m buffer	Number of points surveyed outside 10-m buffer
1	72	65	7
2	99	72	27
3	108	100	8
4	91	57	34
5	111	51	60
6	120	47	73
7	69	48	21
8	127	69	58
9	150	74	76
10	100	66	34
11	107	76	31
12	107	98	9
13	103	59	44
14	174	53	121
15	186	127	59
16	156	39	117
17	236	94	142
18	150	60	90
19	150	83	67
20	145	53	92
21	145	66	79
22	186	144	42
23	231	204	27
24	244	23	221
25	235	15	220
26	145	13	132
27	114	51	63
28	138	114	24
29	68	15	53
30	57	38	19

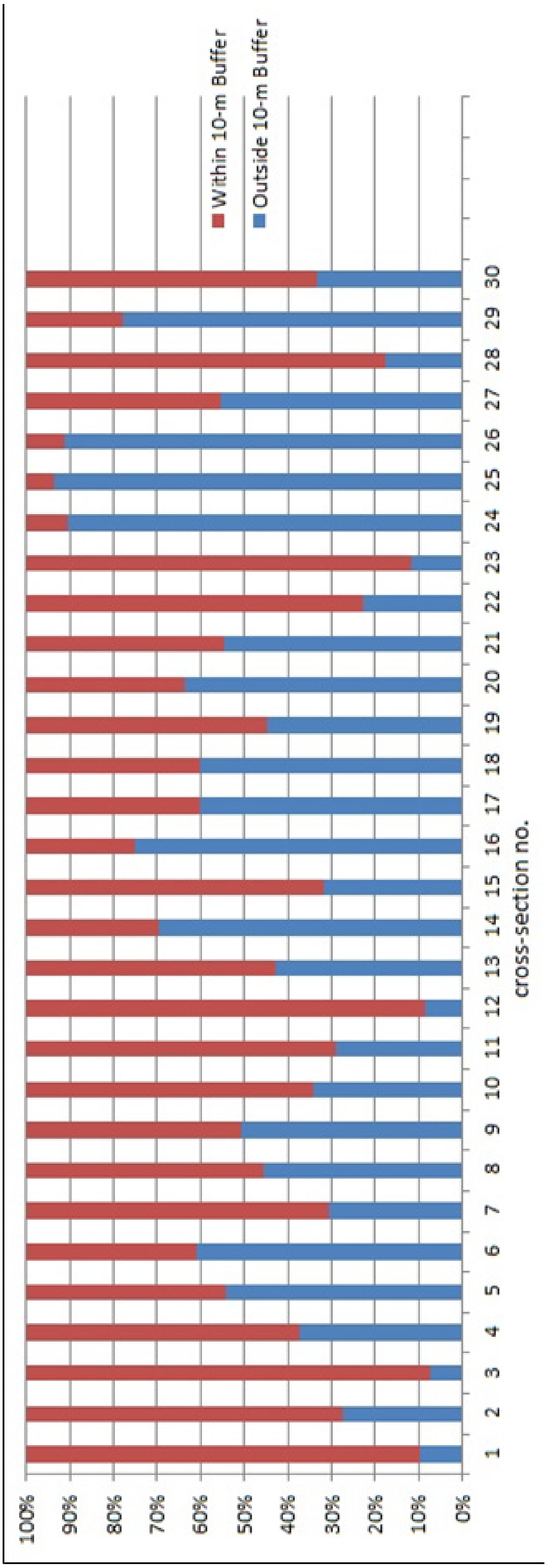


Figure 49. A graph showing the result of buffer analysis

A total number of 4,124 survey points were gathered from the thirty (30) cross section lines. Figure 50 shows the actual number of surveyed points for every cross-section. Cross-section 24 has the most gathered points having a total of 244 points, while cross-section 30 has the least with a total of 57 points.

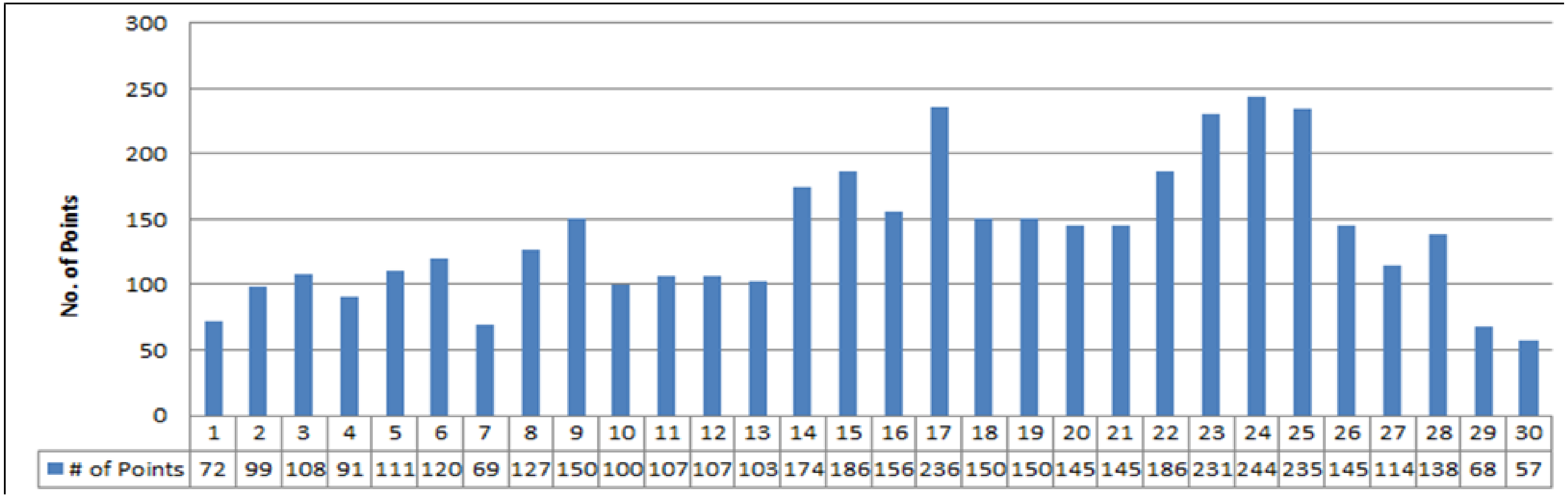
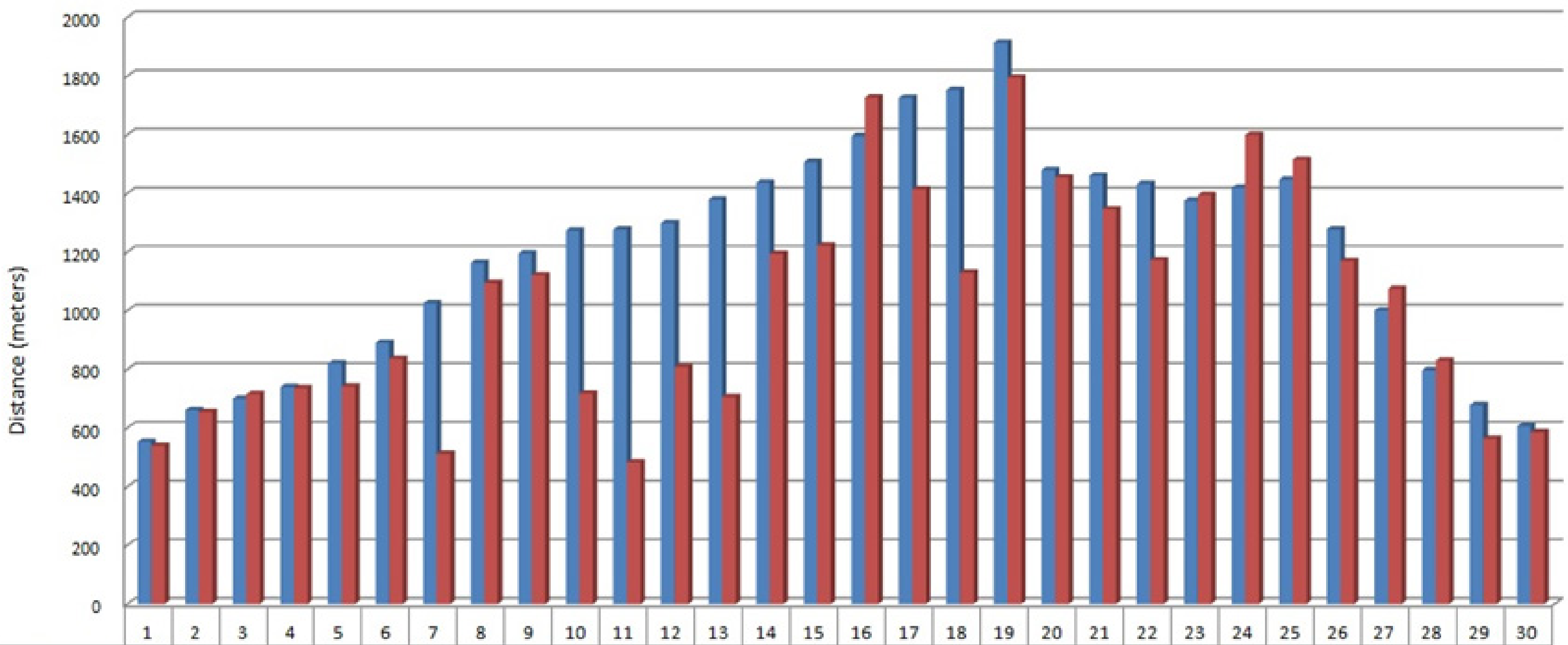


Figure 50. Graph showing the number of survey points gathered in every cross-section line

The lengths of the planned and actual surveyed lines were also computed. The lengths of the actual cross-sectional lines are not measured from the first to last surveyed points but only on segments where there are continuous survey points. Thus, segments where there are data gaps are not included in the computation. The comparison of proposed and actual cross-section length of data is shown in Figure 51. In general, 2749 out of the 4124 surveyed points or 50.29 % fall within the 10-m buffer around the planned cross-section lines. The graph in Figure 51 displays the proposed cross-sectional lines in contrast with the actual data. The total length of proposed cross section is 35.870 kilometers while the actual data gathered is 30.842 kilometers in length. The longest is cross section 19 with 1.794 kilometers in length.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Proposed Distance (meters)	553	660	700	740	820	890	1025	1162	1195	1273	1276	1299	1378	1436	1506	1595	1725	1753	1914	1479	1460	1432	1375	1419	1447	1277	1000	797	678	606
Actual Distance (meters)	539	654	715	736	741	835	513	1094	1121	717	482	808	705	1194	1221	1726	1414	1130	1794	1454	1346	1172	1394	1600	1515	1169	1075	829	564	585

Figure 51. Comparison of proposed and actual length of cross section data

The average interval distances between consecutive points along the entire cross-section are then estimated. The average interval length for every cross-section is illustrated in Table 3. Twenty-eight (28) out of thirty (30) cross sections have point interval that are less than 10 meters.

Table 3. Average interval distance of cross-sections

Cross Section	Average Interval
1	7.59
2	6.68
3	6.69
4	8.18
5	6.73
6	7.02
7	7.54
8	8.68
9	7.63
10	7.31
11	4.59
12	7.70
13	6.98
14	6.90
15	6.60
16	7.57
17	6.02
18	7.58
19	6.52
20	10.10
21	9.35
22	6.34
23	6.06
24	6.58
25	6.47
26	8.12
27	9.51
28	6.05
29	8.41
30	10.44

4.3 Profile Survey

Profile survey was conducted last January 15-February 2, 2013 using GNSS and terrestrial LiDAR surveys. The survey was conducted along the banks of Mayo and Batoto Rivers which started from Brgy. Andap down to Brgy. Magsaysay, New Bataan. The extent of the flood damage happened in the town of New Bataan. Only the lower bank was taken since the river condition is very harsh to conduct a bathymetry survey and a profile was performed through the center of the new river created by Typhoon Pablo that passes through the center of town. The total length of profile lines is about 7.6 km for its both left and right banks. Profile survey extent is shown in Figure 17.


(a) (b)

Figure 52. **Profile Survey Team Conducting RTK GNSS survey (a) river profile traversing at the center of the newly created river by Typhoon Pablo (b) Lower Bank River profiling at Mayo River**

The number of points gathered from the field and the comparison of planned and actual lines are illustrated in Figure 53 and Table 4. The overall number of points gathered for river profile is 3337 with a total length of 29.93 km.

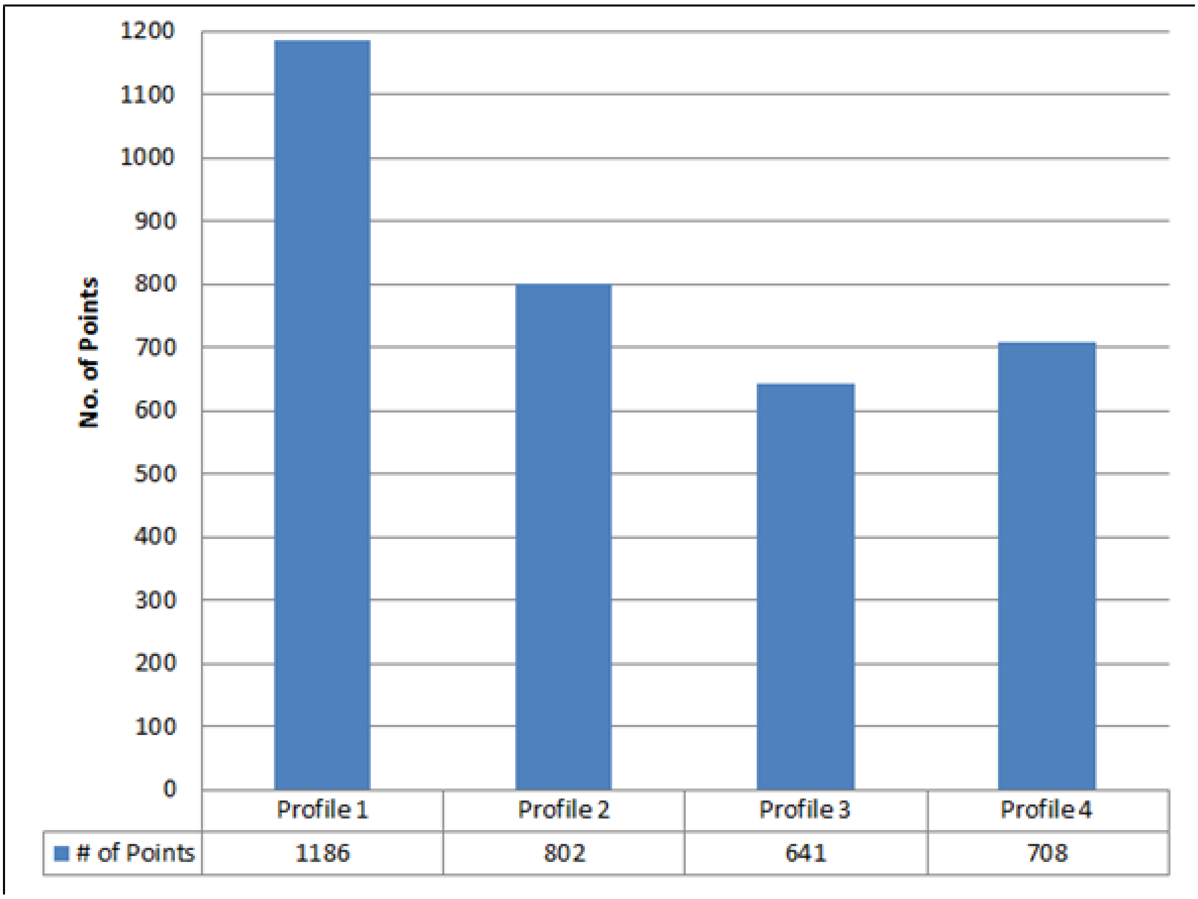


Figure 53. The graph show the no. of points on every river profile line

Table 4. Length of the planned profile lines

	POINTS	Proposed Distance (meters)	Actual Distance (meters)
Profile 1	1186	7642	9316.963
Profile 2	802	6965	8162.157
Profile 3	641	4016	4955.743
Profile 4	708	4388	7490.866
Total	3337	23011	29925.729

The subsequent graphs show the River profile in Batoto, Mayo and the two (2) New Rivers created by Typhoon Pablo.

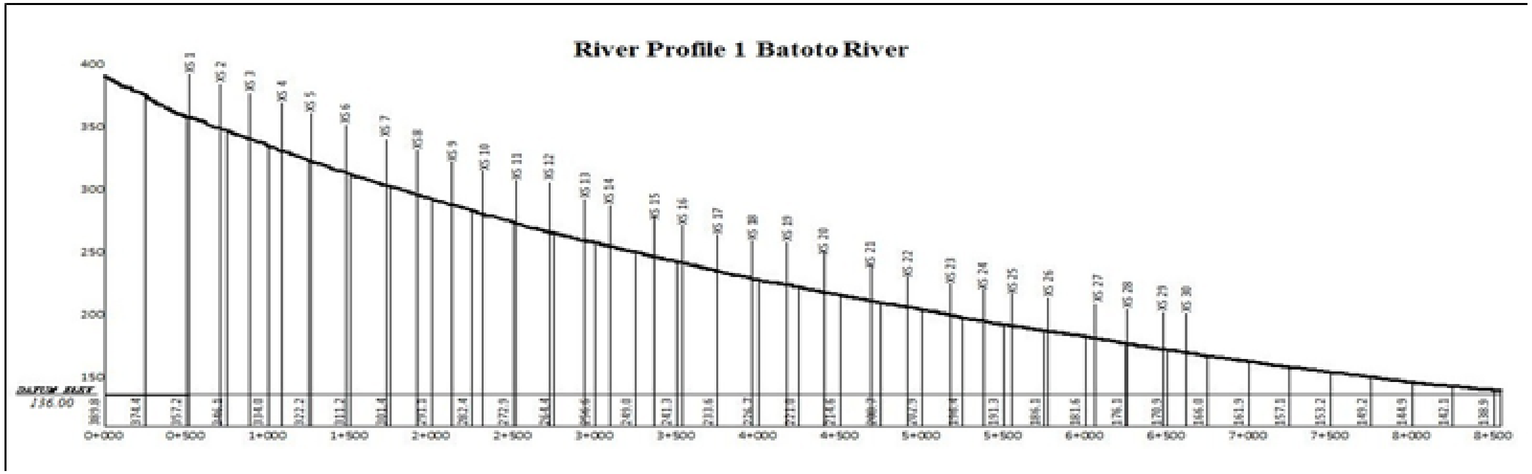


Figure 54. River Profile 1 at Batoto River

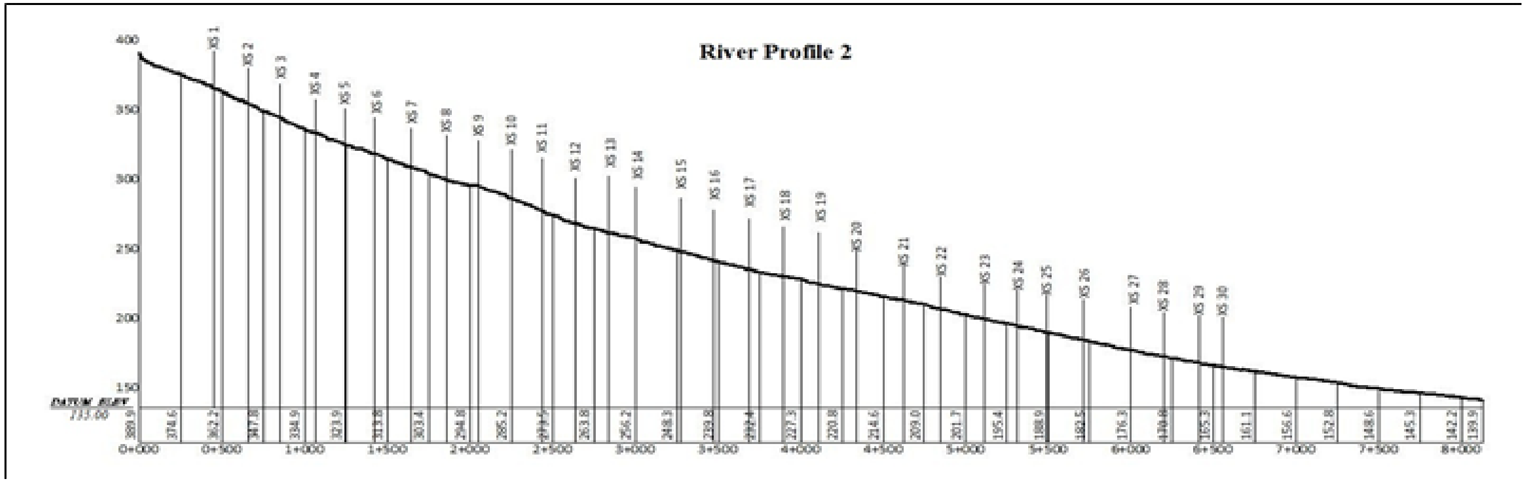


Figure 55. River Profile 2

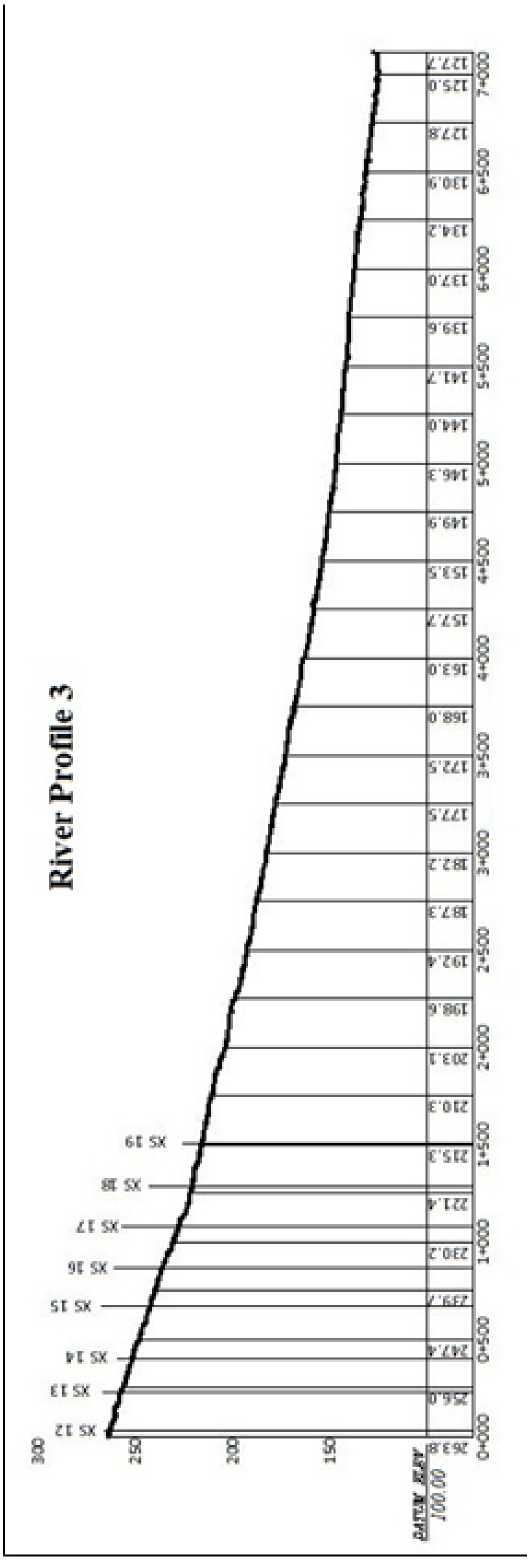


Figure 56. River Profile 3, the new river because of Typhoon Pablo

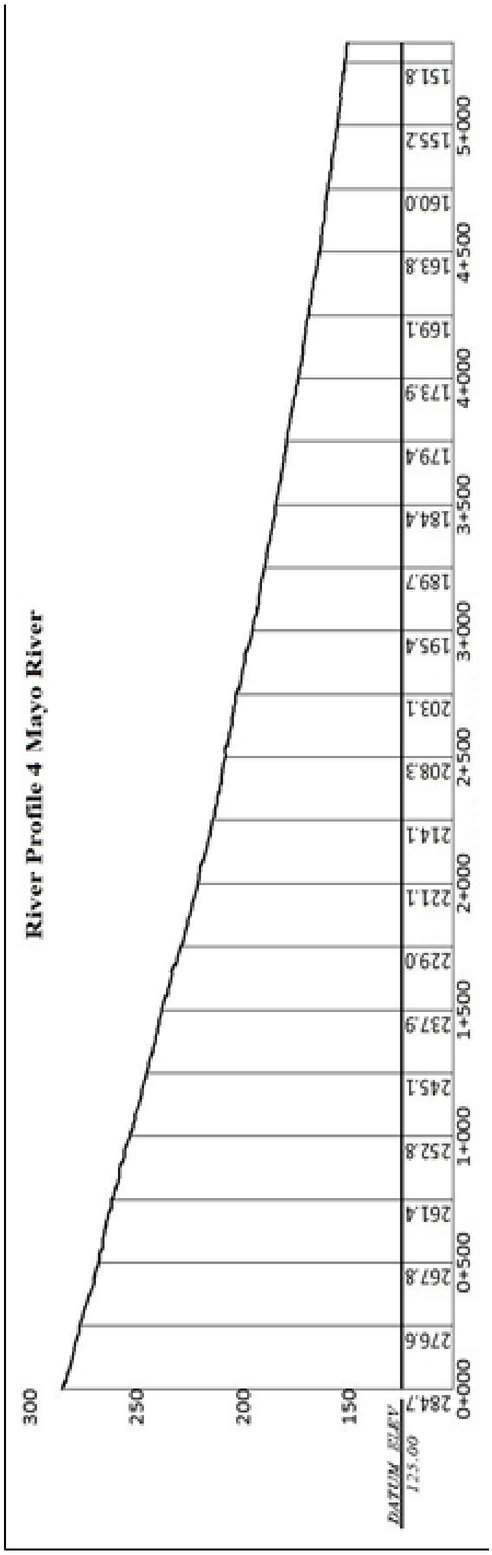


Figure 57. River Profile 4 at Mayo River

4.4 Terrestrial LiDAR Acquisition Survey

To evaluate the change of the area brought about by Typhoon Pablo in New Bataan, a mobile mapping system (MDL Dynascan), was used to survey the town proper. The system makes use of LiDAR technology to acquire point cloud data on the ground and GNSS RTK technology to give horizontal and vertical position to each point acquired. The system was installed on a vehicle to collect LiDAR data in the town proper.

This survey was conducted for eight (8) days from January 17-18, 2013 and January 21-27, 2013 with RTK base station occupying UP-NB 1 at the roof top of New Bataan Town Hall in Brgy. Fatima, New Bataan, Compostela Valley.

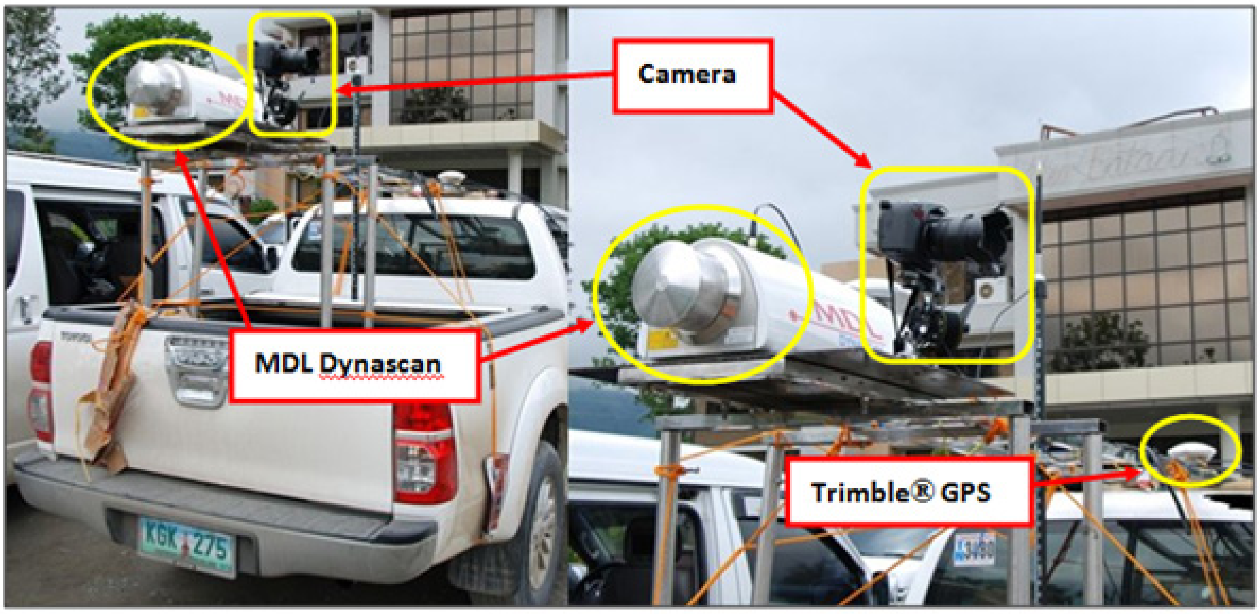


Figure 58. The MDL Dynascan installed on a 4x4 pickup truck

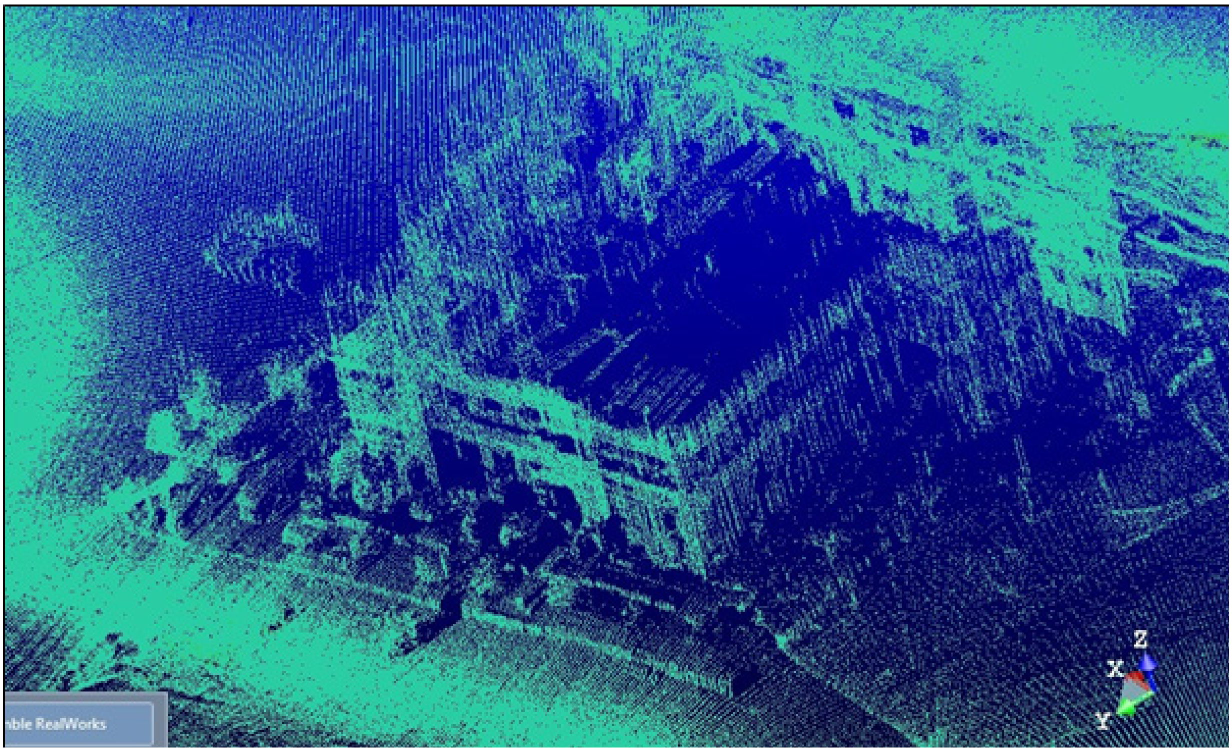


Figure 59. New Bataan Town Hall Image, Terrestrial LiDAR (MMS) point cloud data using Trimble® **Realworks**

4.5 Hydrometric Survey

4.5.1 Hydrometric Sensors Deployment with Stage Discharge Computation

Different sensors were deployed along Agusan River Streams in Compostela Valley and New Bataan to obtain its physical characteristics such as cross-section elevation in MSL, velocity and elevation of water level in MSL at a particular time.

A Sontek™ Acoustic Doppler Current Profiler was deployed with a depth gauge and rain gauge in Brgy. Poblacion, Compostela from January 31, 2013 at 12:00 PM and was then retrieved on February 1, 2013.

The summary of the location and deployment dates of the sensors used in Compostela Valley and New Bataan are shown in Table 5.

Table 5. Sensor location and deployment dates in Compostela Valley and New Bataan

Sensor	Location	Municipality	Deployment – Start	Deployment – End	Latitude	Longitude
ADCP Side Looking	Brgy. Poblacion	Compostela	Jan. 31, 2013	Feb. 1, 2013	7°40'33.84"	126° 5'22.13"E
Depth Gauge	Brgy. Poblacion	Compostela	Jan. 31, 2013	Feb. 1, 2013	7°40'33.84"	126° 5'22.13"E
Rain Gauge	Brgy. San Roque	New Bataan	Jan. 31, 2013	Feb. 1, 2013	7°32'52.31"	126° 8'11.96"

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.

Figure 60. Rain Gauge deployment at the Roof top of New Bataan Town Hall

Figure 61. ADCP deployment with depth gauge in Brgy. Poblacion, Compostela

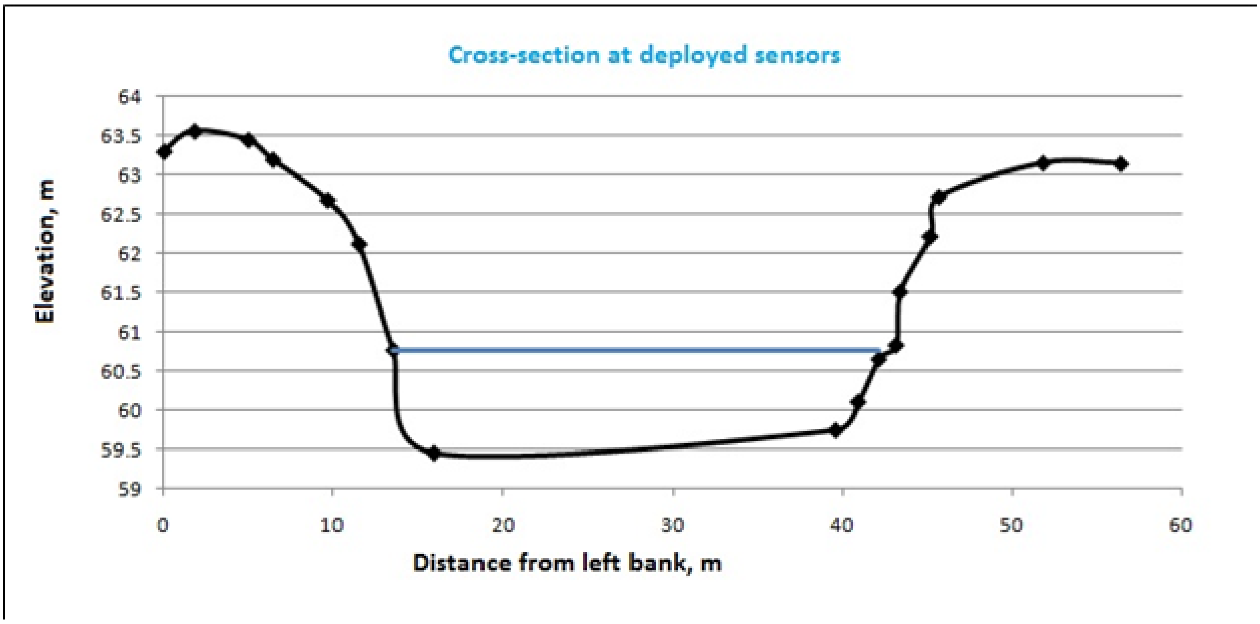


Figure 62. Cross-section graph at the deployment site in Brgy. Poblacion, Compostela

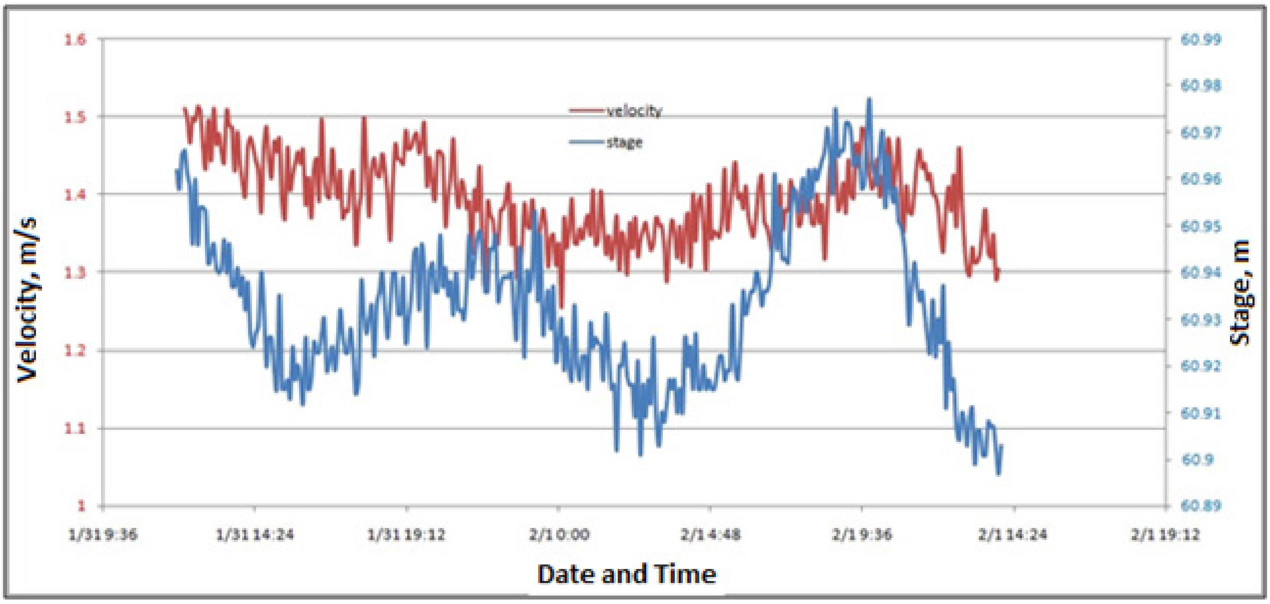


Figure 63. Velocity vs Stage graph for Brgy. Poblacion, Compostela

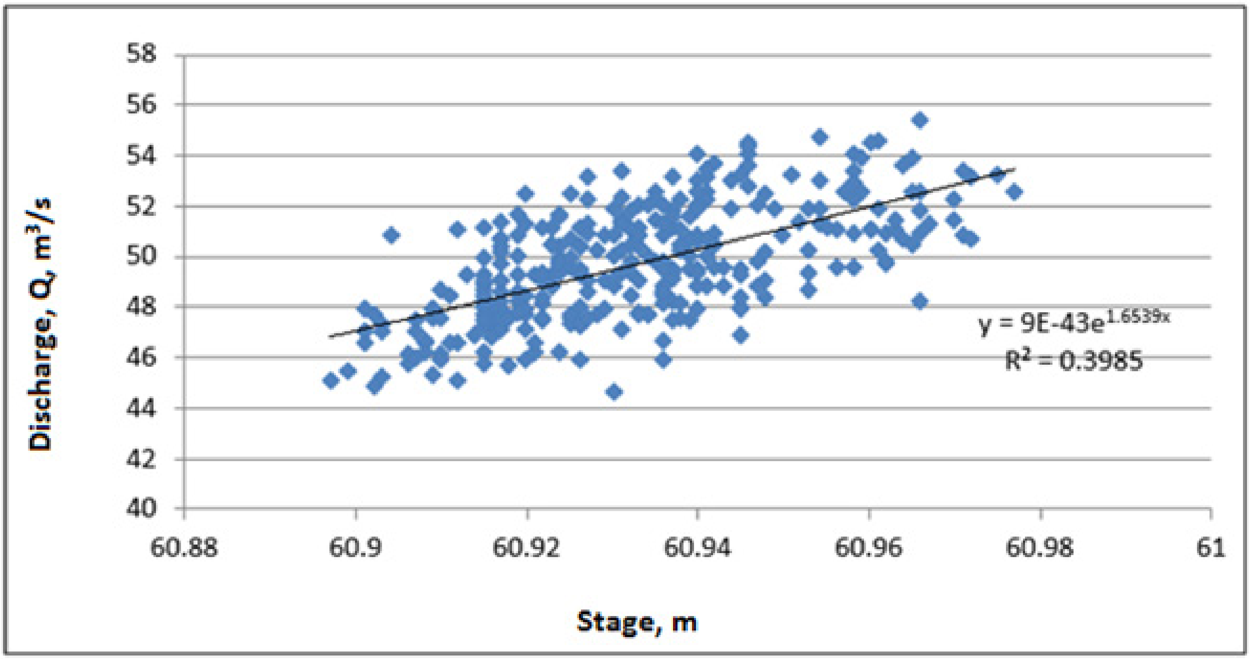


Figure 64. Brgy. Poblacion, Compostela HQ Curve

4.5.2 Compostela Valley AWLS Survey

Another survey was conducted for the installed AWLS in Compostela Valley in order to get its cross-sectional area and water surface elevation in MSL on January 21-23, 2014. The sensors were left in the care of local hires for continuous data gathering and were retrieved on March 20-23, 2014. A mechanical flow meter was used to acquire river velocity for all AWLS locations which as shown in the map in Figure 65.

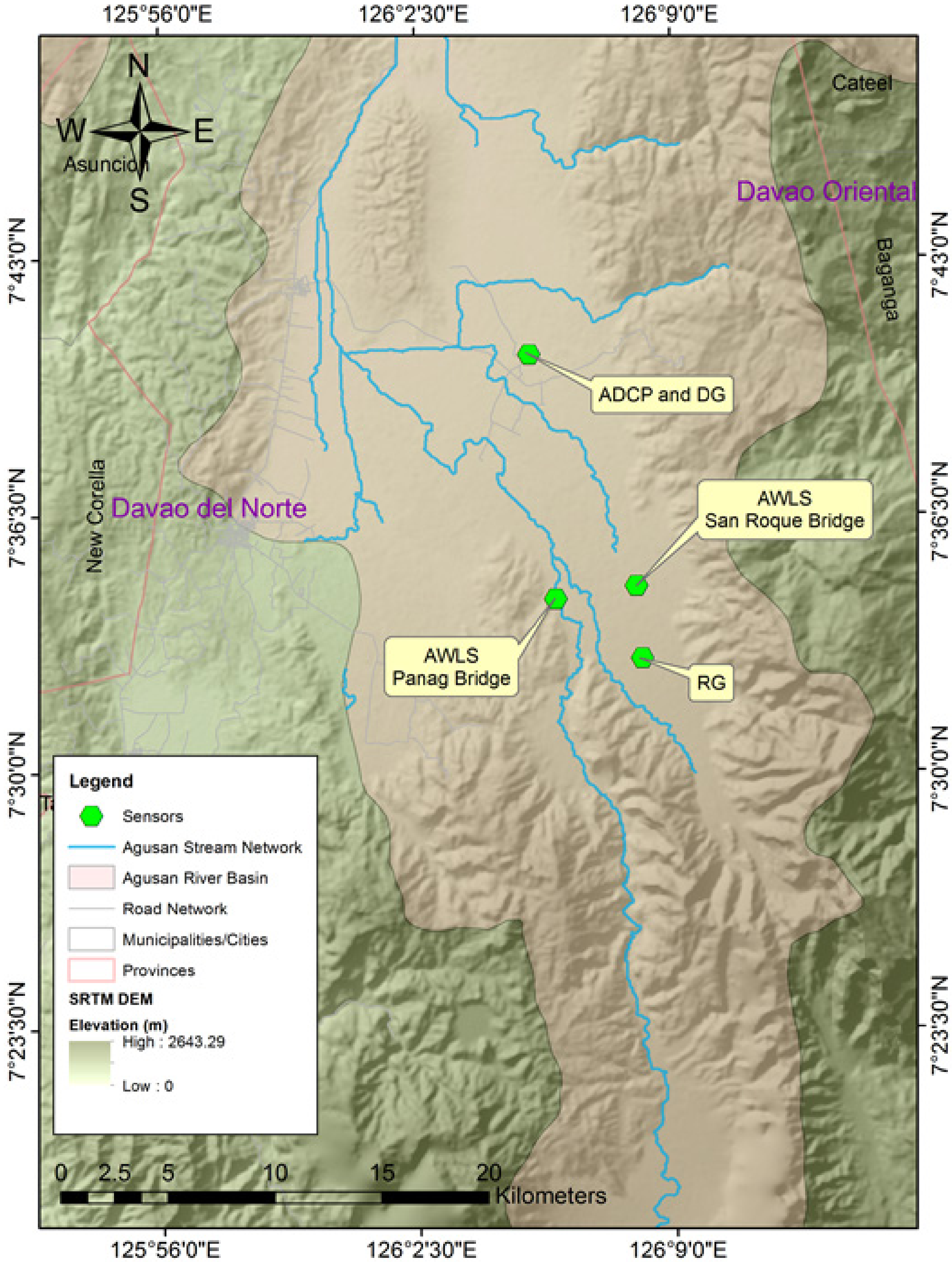
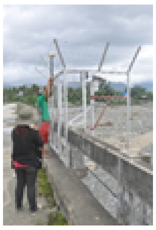


Figure 65. Compostela and New Bataan Hydrometry and AWLS Survey Extent

4.5.2.1 AWLS Cross-section Survey

Cross-section surveys were conducted for the bridges with installed AWLS along Agusan River System in Compostela and New Bataan using GNSS PPK survey technique. The elevation of the installed AWLS and the water surface elevation along the banks near the sensor were acquired as well. The summary of data gathered is shown in Table 6.

Table 6. AWLS sites in Compostela and New Bataan with its respective MSL value

AWLS	Barangays	Coordinates	AWLS Elevation, m, (MSL)	Water Surface Elevation, m, (MSL)	Date & Time of Water Elevation	Image
Panag Bridge	Brgy. Panag, New Bataan	7°34'22.38742" N 126°06'00.55699" E	129.951	124.157	Jan. 23, 2014 @ 3:11 PM	
San Roque Bridge	Brgy. San Roque, New Bataan	7°34'41.92616" N 126°08'03.63118" E	140.393	133.504 (ground surface read by awls, not hitting the water) 133.850 (actual water surface elevation)	Jan. 23, 2014 @ 4:52 PM	
Poblacion Bridge	Brgy. Poblacion, Compostela	7°40'33.39670" N 126°05'22.56412" E	70.681	62.884	Jan. 24, 2014 @ 12:14PM	

The diagram of cross-section data gathered for bridges with installed AWLS is illustrated in Figures 66-68.

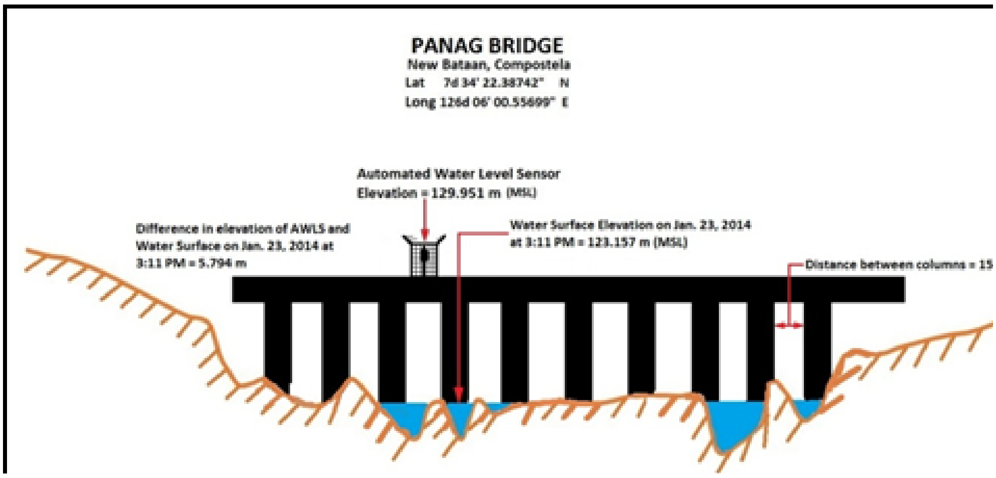


Figure 66. AWLS in Panag Bridge, New Bataan, Compostela

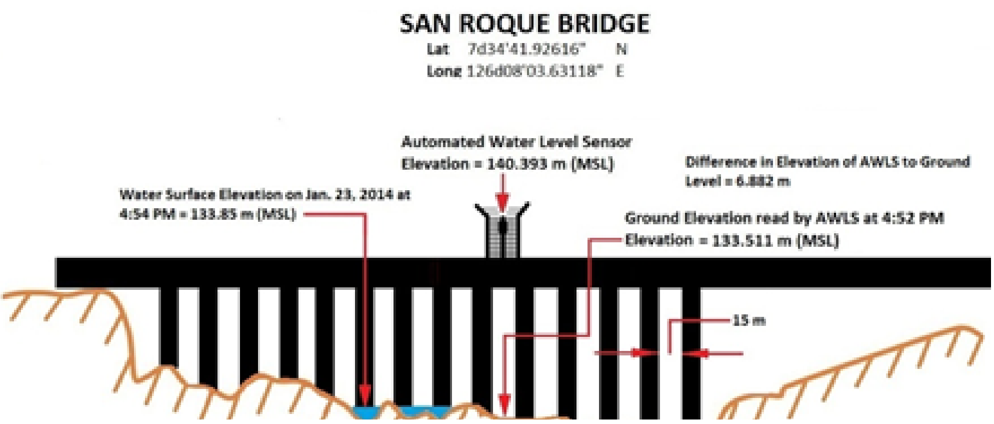


Figure 67. AWLS in San Roque Bridge, San Roque, Compostela

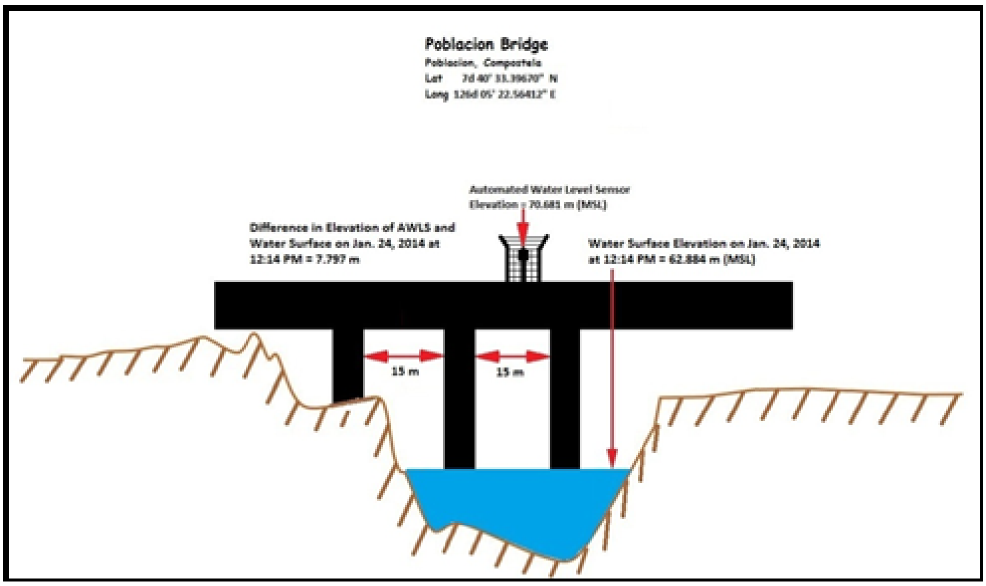


Figure 68. AWLS in Poblacion Bridge, Poblacion, Compostela Valley

4.5.2.2 Flow Measurements and Stage Discharge Computation

Two (2) local hires living within the vicinity of the bridge were employed to gather flow measurements. Two types of events were recorded 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 two 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 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. The summary of hydrometric data, gathered per bridge location is summarized in Table 7.

Figure 69. Flow measurements using a rotor-type flow meter

Table 7. Summary of cross section and flow meter deployment in New Bataan and Compostela, Compostela Province

Bridges	Cross-section	AWLS	Flow measurement	Remarks
Panag, New Bataan	✓	✓	✓	Done all necessary tasks
San Roque, New Bataan	✓	✓	✓	Done all necessary tasks
Poblacion, Compostela	✓	✓	✓	Done all necessary tasks

A. Panag Bridge Stage Discharge Computation

River velocity data for Panag Bridge was plotted against water level data from an Automatic Water Level Sensor. Flow measurements were recorded for thirty (33) days starting on Jan 24, 2014 until February 26, 2014, for nine (9) hours observation per day. The summary of data gathered is illustrated in Figures 70-73. Rain and water level data are extracted from repo.pscigrid.gov.ph.

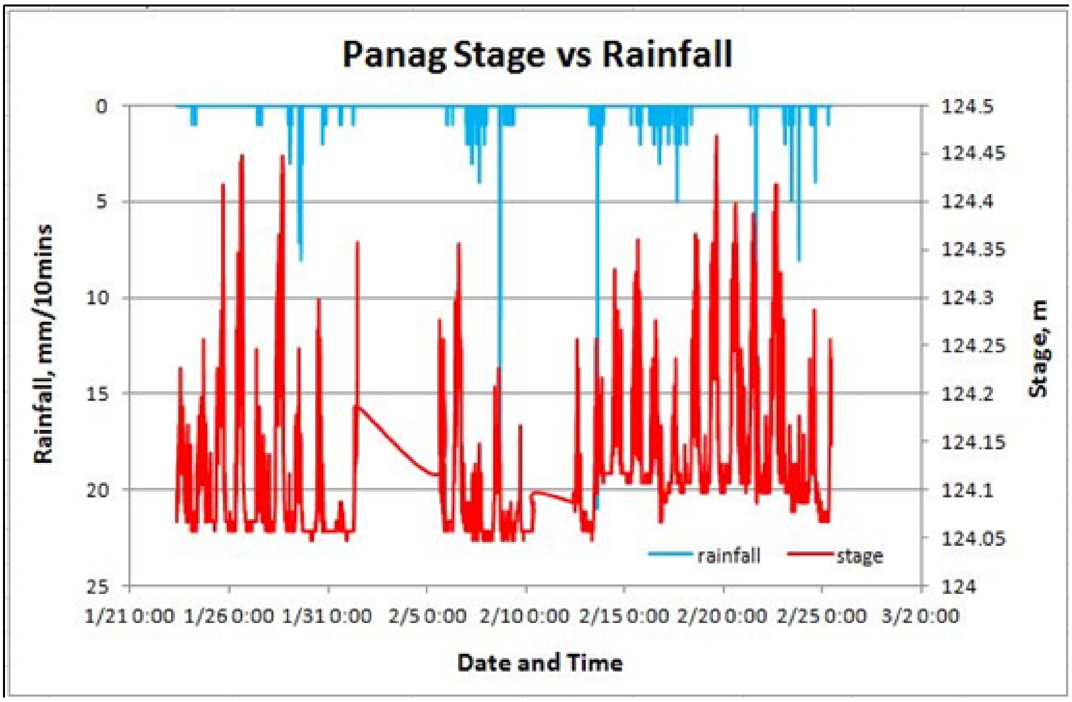


Figure 70. Stage vs Rainfall graph for Panag Bridge

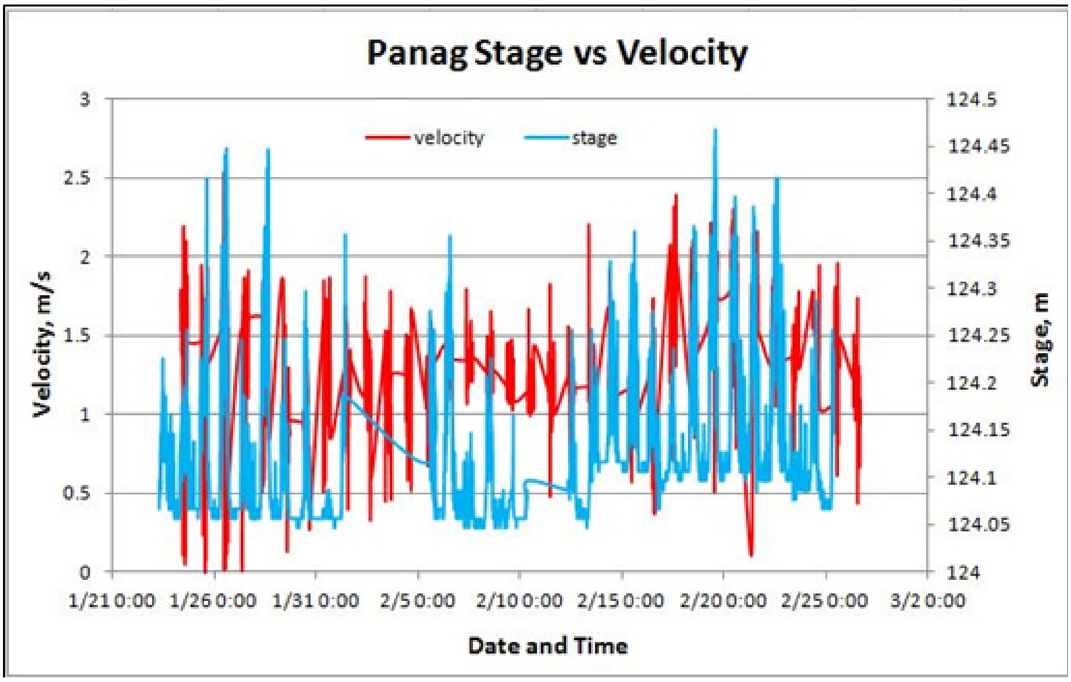


Figure 71. Stage vs Velocity graph for Panag Bridge

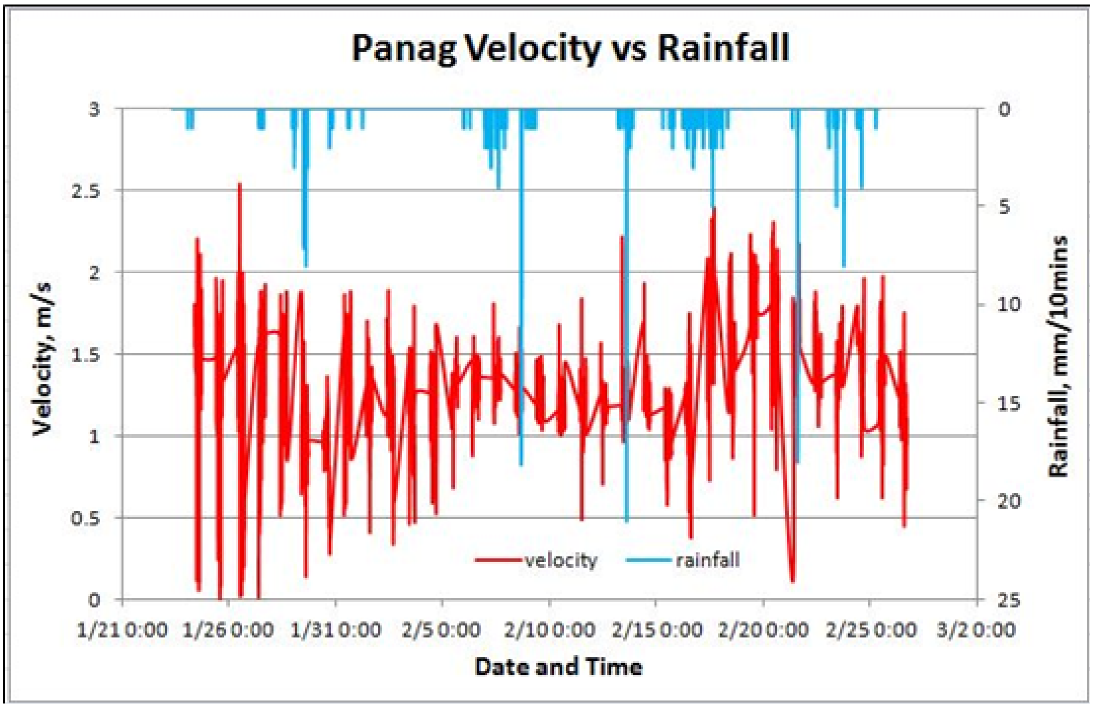


Figure 72. Velocity vs Rainfall graph for Panag Bridge

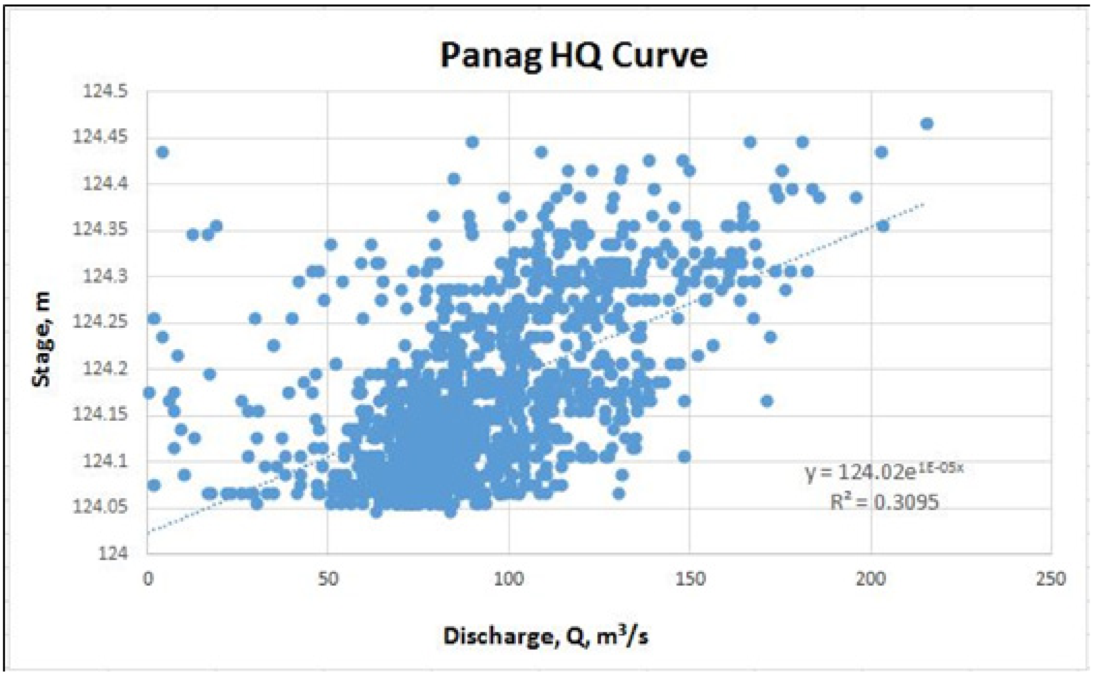


Figure 73. Stage-discharge computation for Panag Bridge

B. San Roque Bridge Stage Discharge Computation

River velocity data for San Roque Bridge was plotted against water level data from an Automatic Water Level Sensor. Flow measurements were recorded for twenty-six (26) days starting on Jan 25, 2014 until February 19, 2014 for four (4) hours observation per day. The summary of data gathered is illustrated in Figures 74-77. Rain and water level data are extracted from repo.pscigrid.gov.ph.

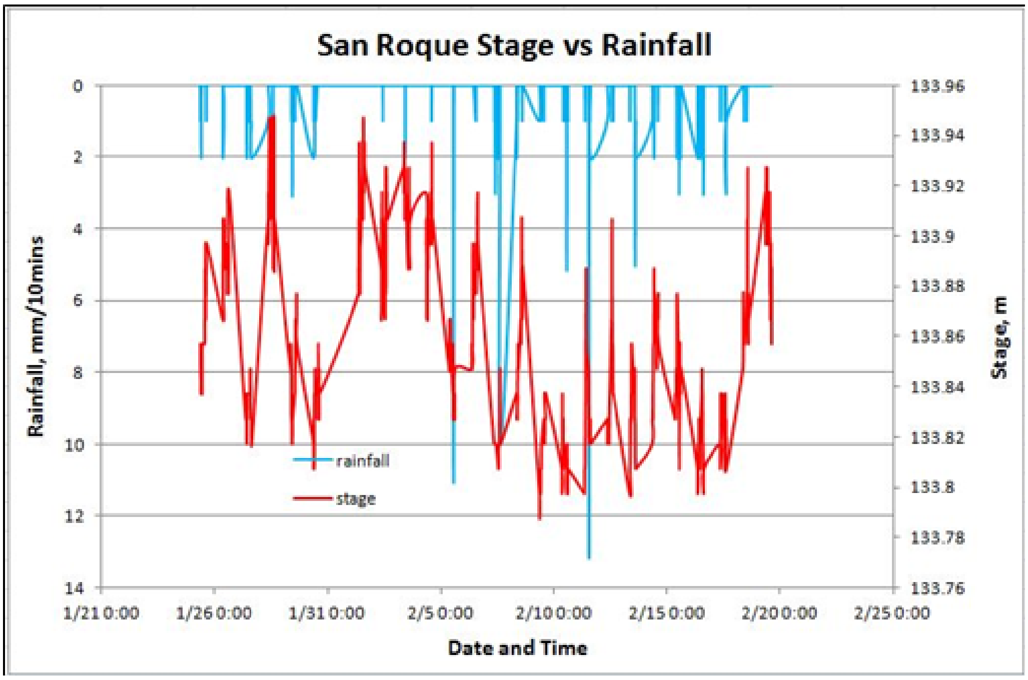


Figure 74. Stage vs Rainfall graph for San Roque Bridge

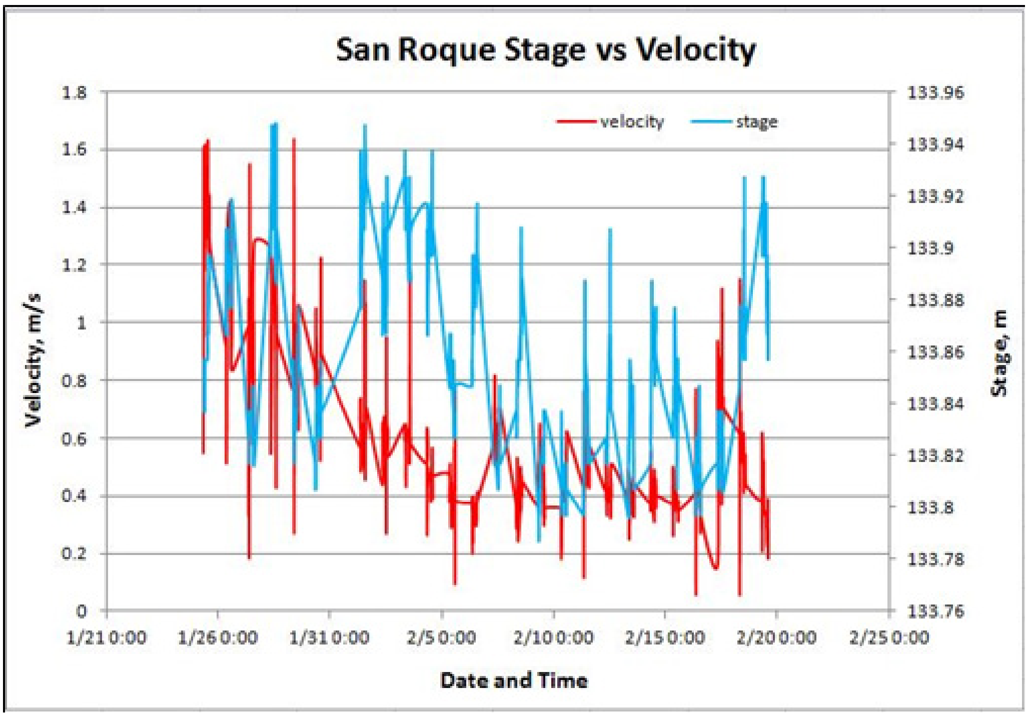


Figure 75. Stage vs Velocity graph for San Roque Bridge

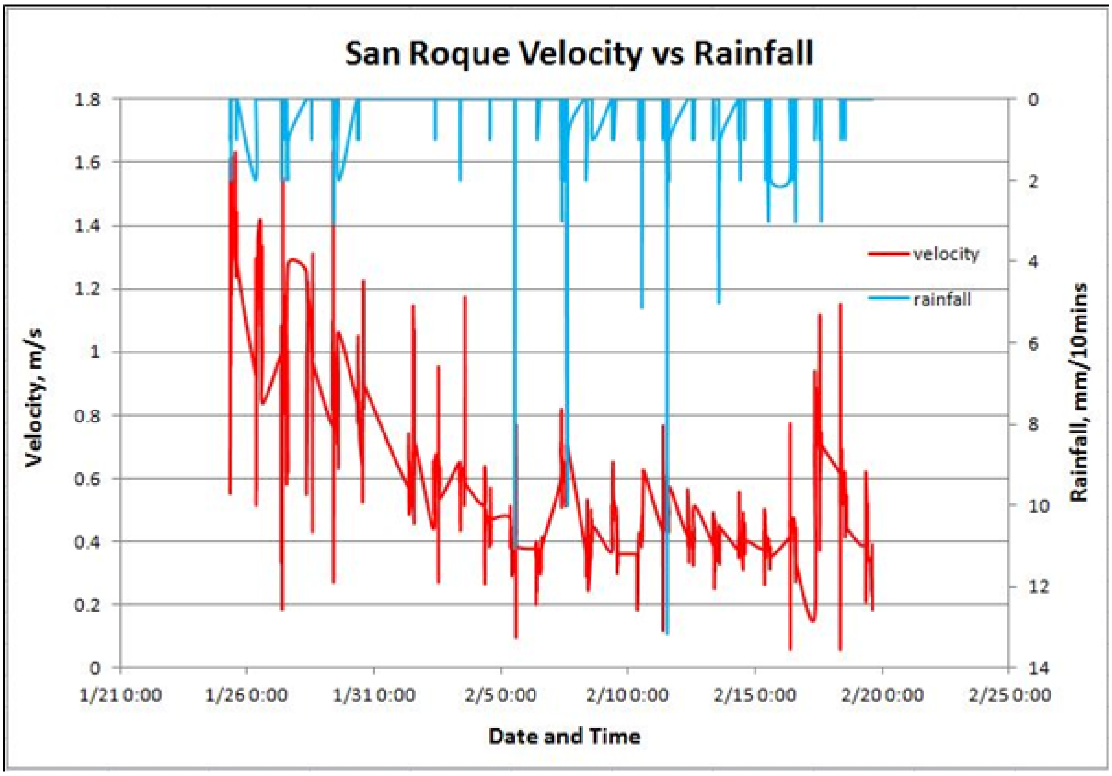


Figure 76. Velocity vs Rainfall graph for San Roque Bridge

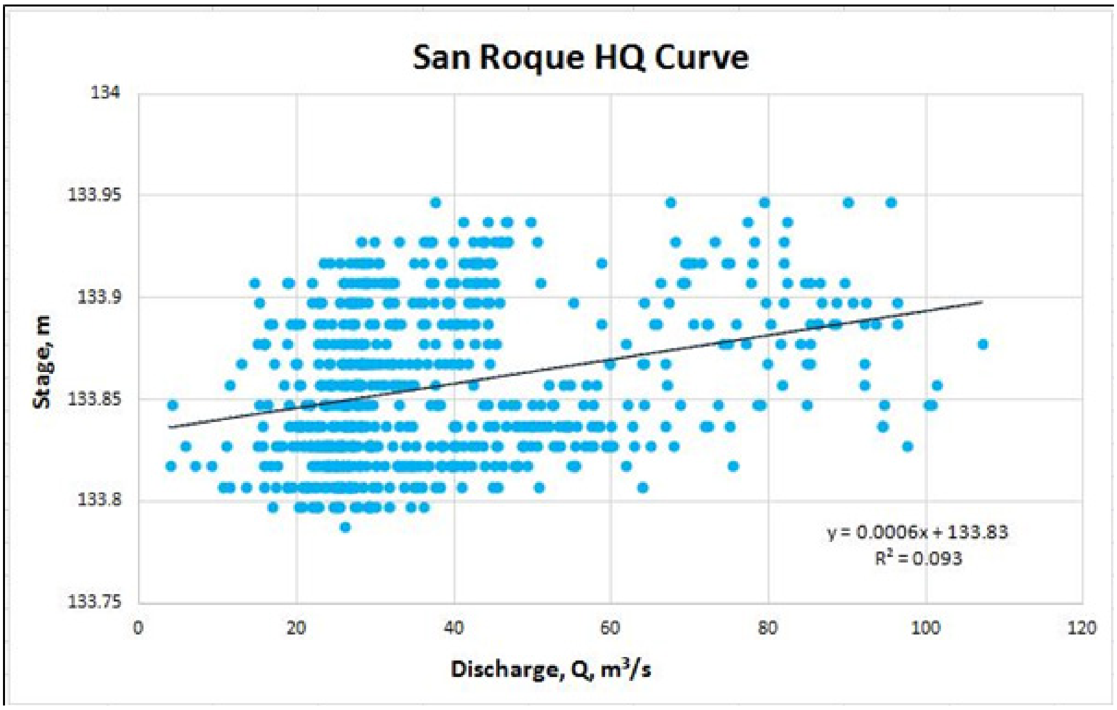


Figure 77. Stage-discharge computation for San Roque Bridge

C. Poblacion Bridge Stage Discharge Computation

River velocity data for Poblacion Bridge was plotted against water level data from an Automatic Water Level Sensor. Flow measurements were recorded for thirty-one (31) days starting on Jan 25, 2014 until February 24, 2014 for seven (7) hours observation per day. The summary of data gathered is illustrated in Figures 78-81. The AWLS data extracted from repo.pscigrid.gov.ph is plotted in inverted values.

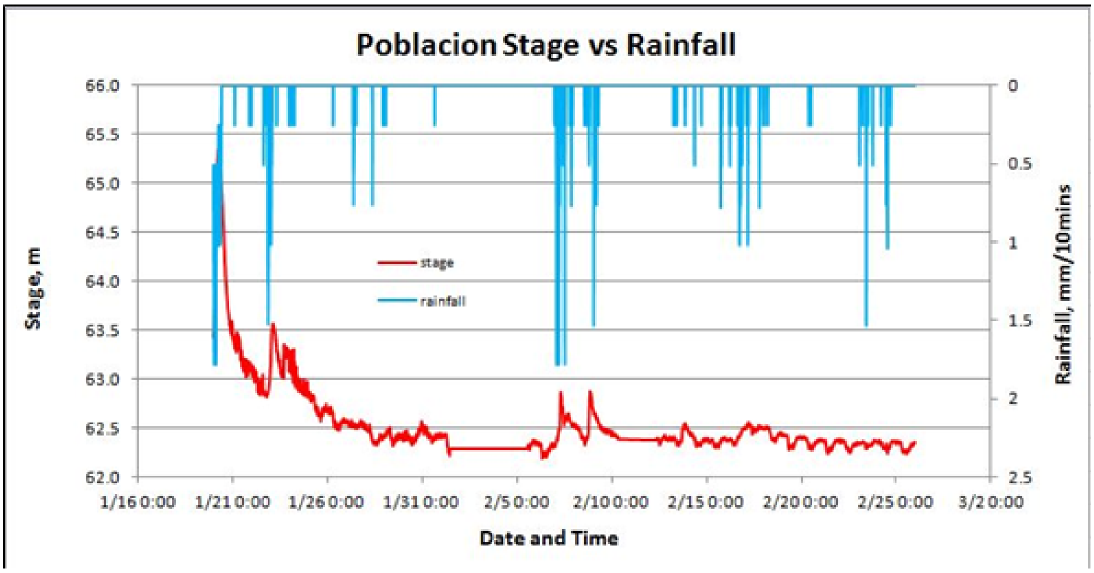


Figure 78**. Stage vs Rainfall graph for Poblacion Bridge**

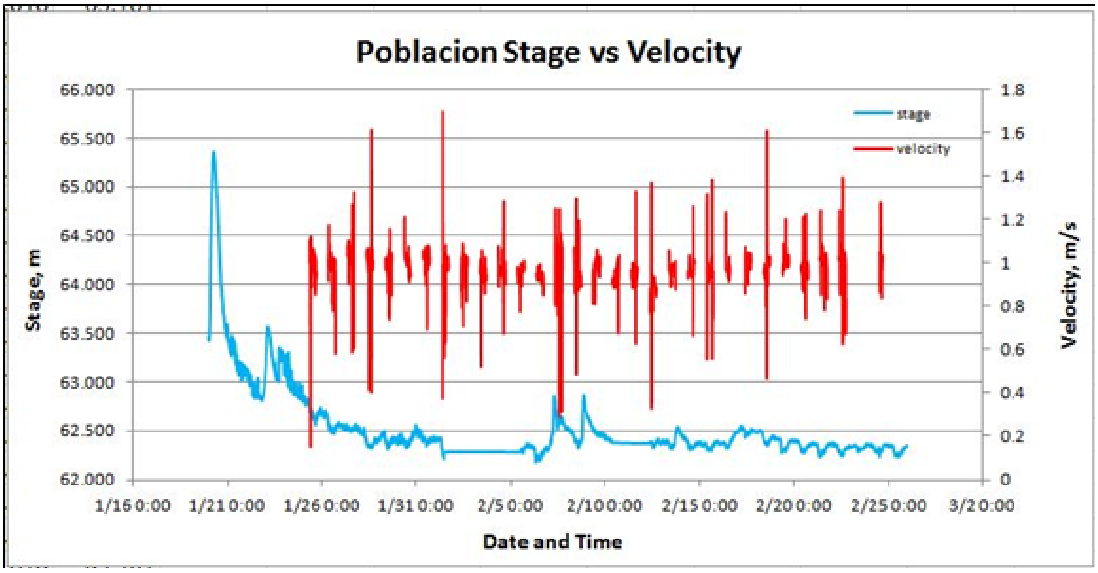


Figure 79. Stage vs Velocity graph for Poblacion Bridge

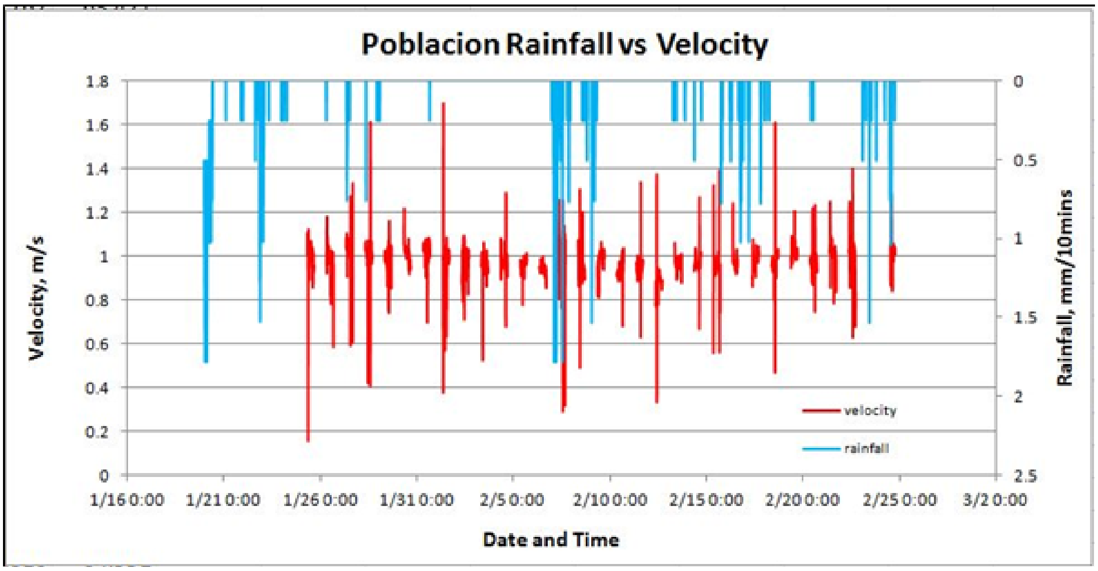


Figure 80. Rainfall vs Velocity graph for Poblacion Bridge

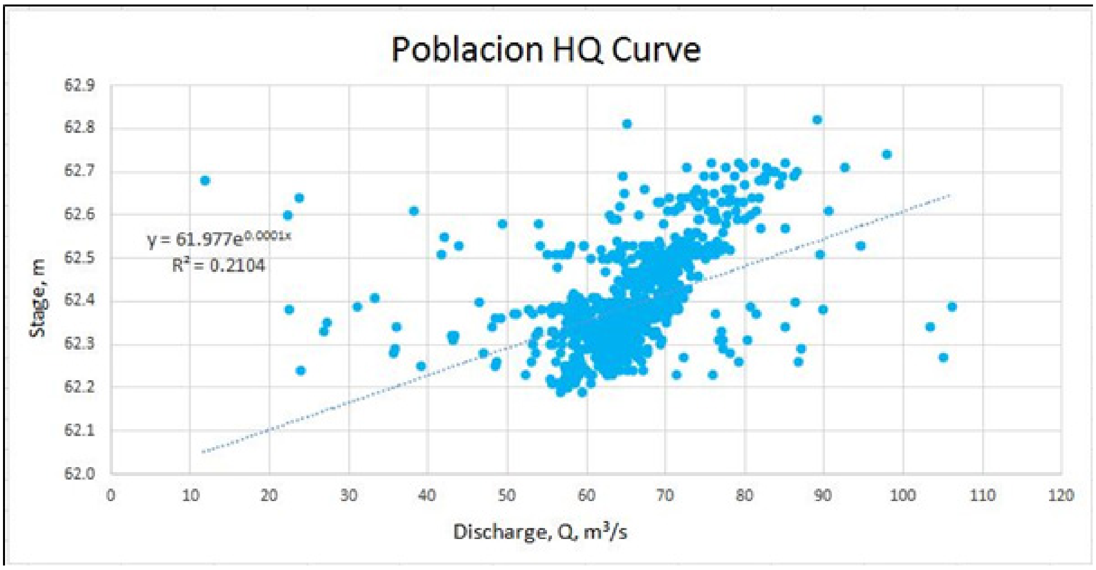


Figure 81. Stage-discharge computation for Poblacion Bridge

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

Limitation/Problems	Solutions
1) Jan. 16: GCP and BM's by NAMRIA were not recovered near the survey area.	Established control points on the grounds of Compostela Munincipal Hall and at the roof top of the New Bataan Mun. Hall tied from DVS-1 and DVA-12
2) Jan. 17: The whole length of the cross sections were blocked by boulders	The team still decided to continue the proposed line going over the boulders with caution.
3) Jan. 19: Heavy rains on the survey area caused flood to the access road to Compostela and New Bataan.	The survey team still proceeded to New Bataan, but later found out that the survey area is flooded. As per the team's safety, Engr. Caballero decided to discontinue the survey for that area. Processing of gathered data was done instead.
4) Jan. 24: Sudden rain occurred while performing the cross-section survey causing the boulders to be slippery.	The survey halted and resumed in a slow pace after the rain ceased.
5) Jan. 25: Thick vegetation at the center of the cross section lines.	The CST skipped the forested part and had the obstructions noted. Survey for the opposite length was done instead.

Figure 82. Boulders are along the line of the cross-section. Team members were reminded to be extra cautious since small miss-steps on the boulders might cause injury.

Figure 83. The access roads to the cross-sections drop off points were blocked. Vehicles cannot pass on the area

Figure 84. Thick vegetation at cross-sections 9-13

ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

Type	Brand	Serial Number	Owner	Quantity
GPS Receiver (Base)	Trimble® SPS852		UP-TCAGP	Two (2) units
GPS Receiver (Rover)	Trimble® SPS882		UP-TCAGP	Eight (8) units
GPS Controller	Trimble® TSC3		UP-TCAGP	Eight (8) units
Mobile Mapping Scanner (MMS)	MDL Dynascan		UP-TCAGP	One (1) unit with dual-GNSS antenna, one (1) interface adapter and stainless steel mounting accessories
High-Gain Antenna			UP- TCAGP	Four(4) units
Acoustic Doppler Current Profiler (ADCP)	Sontek™		UP- TCAGP	One (1) unit with accessories
Coupler-2a and 2b			UP-TCAGP	One (1) unit each
Handheld GPS	Garmin Oregon™ 550	1MW086831 1MW086842 1MW086920 1MW079764	UP-TCAGP	Four (4) units
AA-Battery Charger	Akari		UP-TCAGP	Two (2) units
Multi-tester			UP-TCAGP	One (1) unit
Laptops	Lenovo ThinkPad		UP-TCAGP	One (1) unit
	Dell Laptop			One (1) unit
Digital Level	Topcon DL502		UP-TCAGP	One (1) unit with two (2) level rods
Depth Gauge	Onset Hobo wares	9759371	UP-TCAGP	one (1) unit
Rain Gauge		1293784	UP- TCAGP	One (1) unit
Range Pole	Trimble®		UP-TCAGP	Six (6) units
Tripod	Trimble®		UP-TCAGP	Four (4) units
Bipod	Trimble®		UP-TCAGP	Six (6) units
Tribrack			UP-TCAGP	Three (3) units

LaserRange Finder	Bushnell		UP-TCAGP	Two (2) units
Toolbox			UP-TCAGP	One (1) unit
QINSy dongle			UP-TCAGP	One (1) unit
Flow Meter	General Oceanic	25347, 25344, 24907	UP-TCAGP	Three(3) units

Annexes

ANNEX C. THE SURVEY TEAM

Data Validation Component Sub-team	Designation	Name	Agency/Affiliation
Survey Supervisor	Chief Science Research Specialist (CSRS)	Engr. Joemarie S. Caballero	UP TCAGP
Profile Survey Team	Senior Science Research Specialist	Engr. Melchor Rey M. Nery	UP TCAGP
		Engr. Mark Lester D. Rojas	UP TCAGP
Cross Section and Deployment Team	Senior Science Research Specialist	Engr. Bernard Paul D. Maramot	UP TCAGP
	Research Associate	Engr. JMson J. Calalang	UP TCAGP
	Research Associate	Jojo E. Morillo	UP TCAGP
	Research Associate	Erlan Patrick T. Mendoza	UP TCAGP
	Research Associate	Engr. Edjie M. Abalos	UP TCAGP
MMS Team	Research Associate	Patrizcia Mae dela Cruz	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

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

June 11, 2013

CERTIFICATION

To whom it may concern:

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

Province: **DAVAO DEL NORTE**
Station Name: **DVA-12**

Island: **MINDANAO**	Municipality: **NABUNTURAN**	Barangay: **NEW SIBUNGA**
Elevation: **76.3040 m.**	Order: **3rd Order**	Datum: **Mean Sea Level**

Location Description

BM DVA-12
Is in the province of Davao del Norte, municipality of Nabunturan, brgy. New Sibunga. The station is a 4 m. N 70° W of the centerline of national road leading to Davao City; 45 m. S 70° W of wooden electric Post No. 213, 60 m. N 30° W of wooden electric post No. 212. Mark is a 0.15 m. x 0.01 m. diameter brass rod set in a drill hole with cement putty at the SW corner end of Mawab bridge; inscribed on top is "BM 1989 DVA-12".

Requesting Party: **UP-TCAGP DREAM**
Pupose: **Reference**
OR Number: **3943775B**
T.N.: **2013-0562**

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

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

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

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D R E A M

Disaster Risk and Exposure Assessment for Mitigation