REGION 10

Iligan River:

DREAM Ground Surveys Report

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

2015

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

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

UP TCAGP (2015), DREAM Ground Survey for Iligan River, Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program, DOST Grants-In-Aid Program, 54 pp.

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National Library of the Philippines
ISBN: 978-971-9695-37-0

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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.

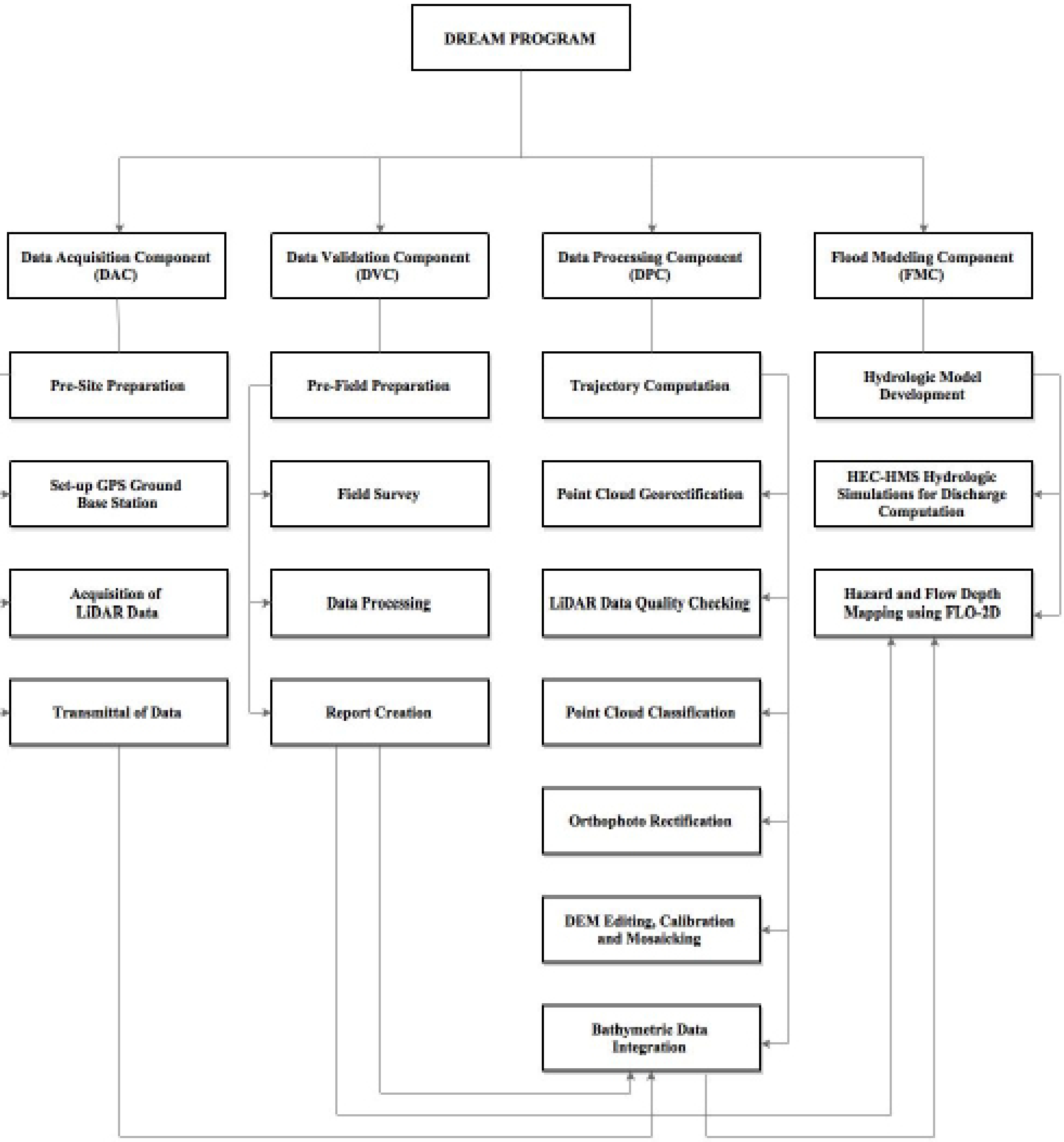

Figure 1. The General Methodological Framework of the Program

The Iligan River Basin

The Iligan River Basin

The area for the flood development in this study is the Tagoloan River Basin located in Misamis Oriental, north of Mindanao. The basin is as shown in Figure 2. The Tagoloan River Basin is considered as the 13th largest river system in the Philippines in terms of watershed size, as classified by the National Water Resources Board. It covers an area of 1,704 square kilometers and travels an approximate length of 106 kilometers. It traverses from as far as Malaybalay City, Bukidnon and flows outward through the province of Misamis Oriental. It opens westward and drains into Macajalar Bay. Large Scale Mining in the area has been threatening Tagoloan River. In 2013, a report, prepared by San Isidro College professor Fred Martinez, said that mud from chromite separator equipment used in large scale mining operations were flowing to the Dila Falls and then into Tagoloan River.

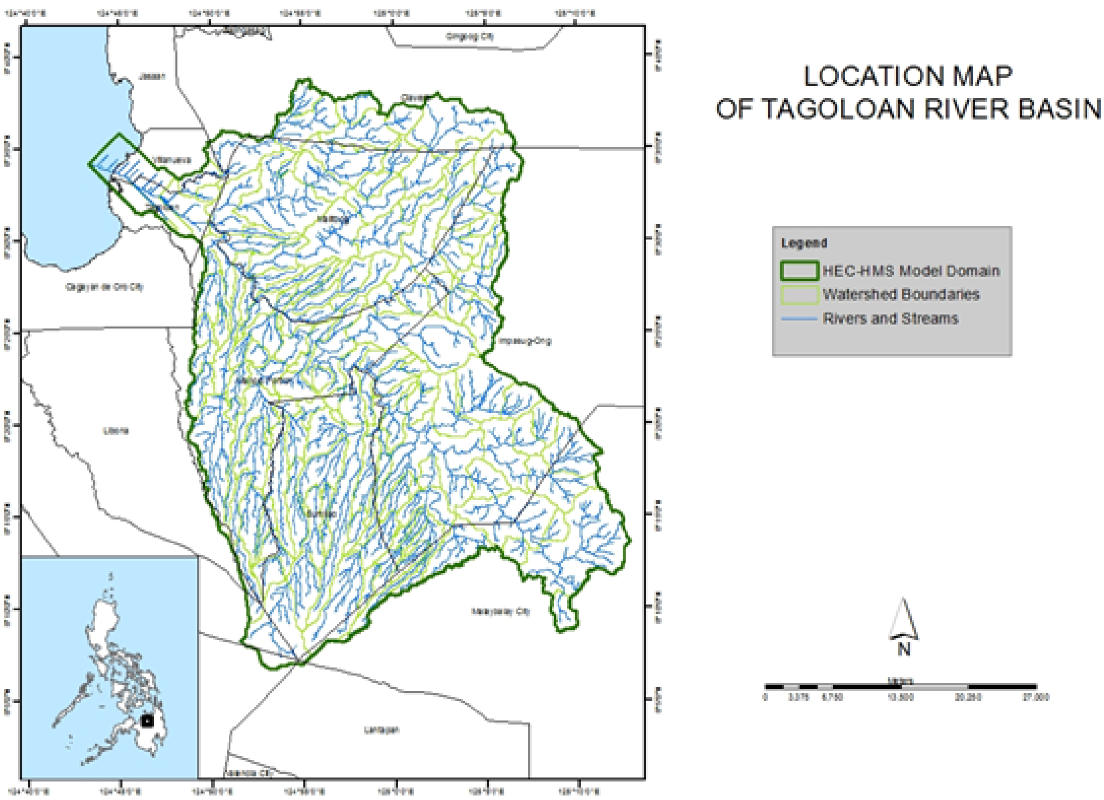

Figure 2. Iligan River Basin Location Map

Some of the important parameters to be used in the characterization of the river basin (e.g. Manning's coefficient – a representation of the variable flow of water in different land covers) are the land cover and soil use. 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 land and soil cover of Tagoloan River Basin are as shown in Figure 2 and Figure 3.

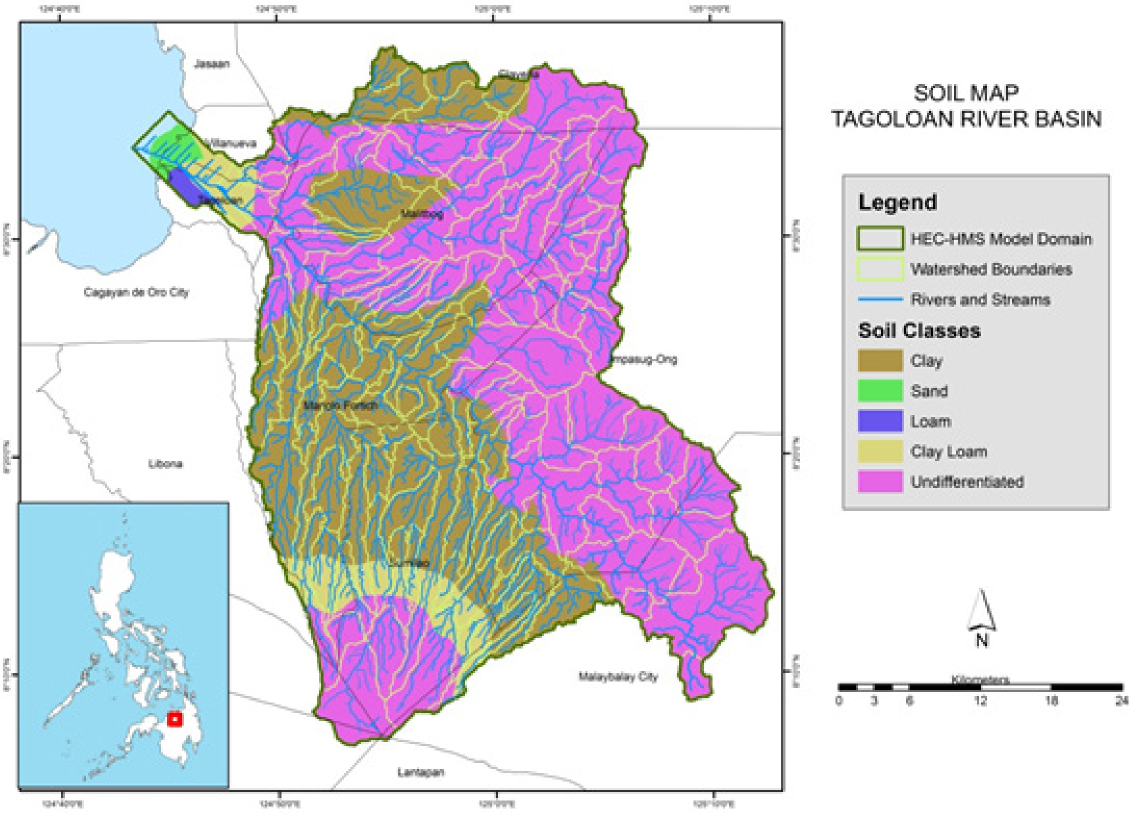

Figure 3. Iligan River Basin Soil Map

DVC Methodology

DVC Methodology

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

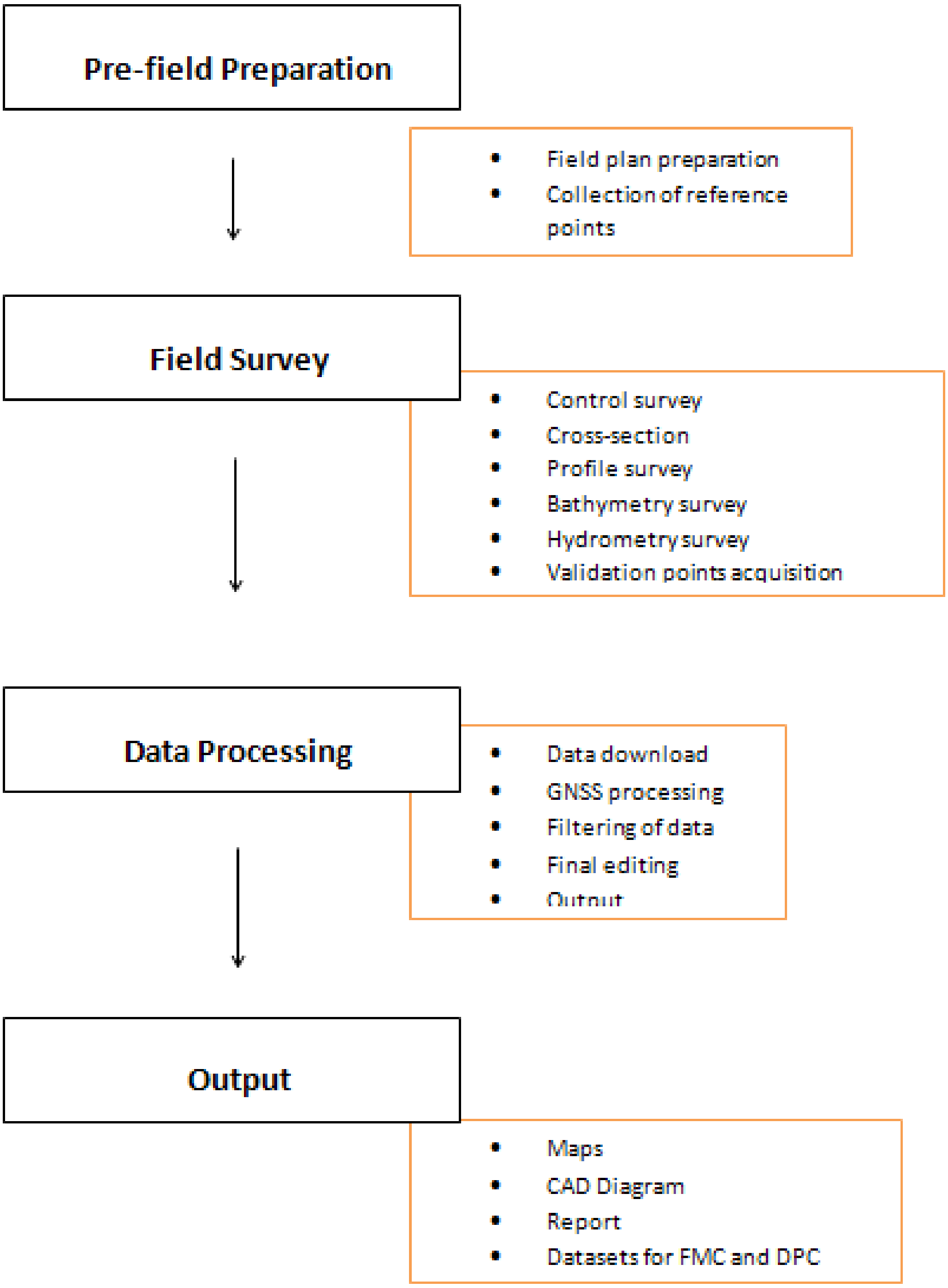

Figure 4. DVC Main Activities

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

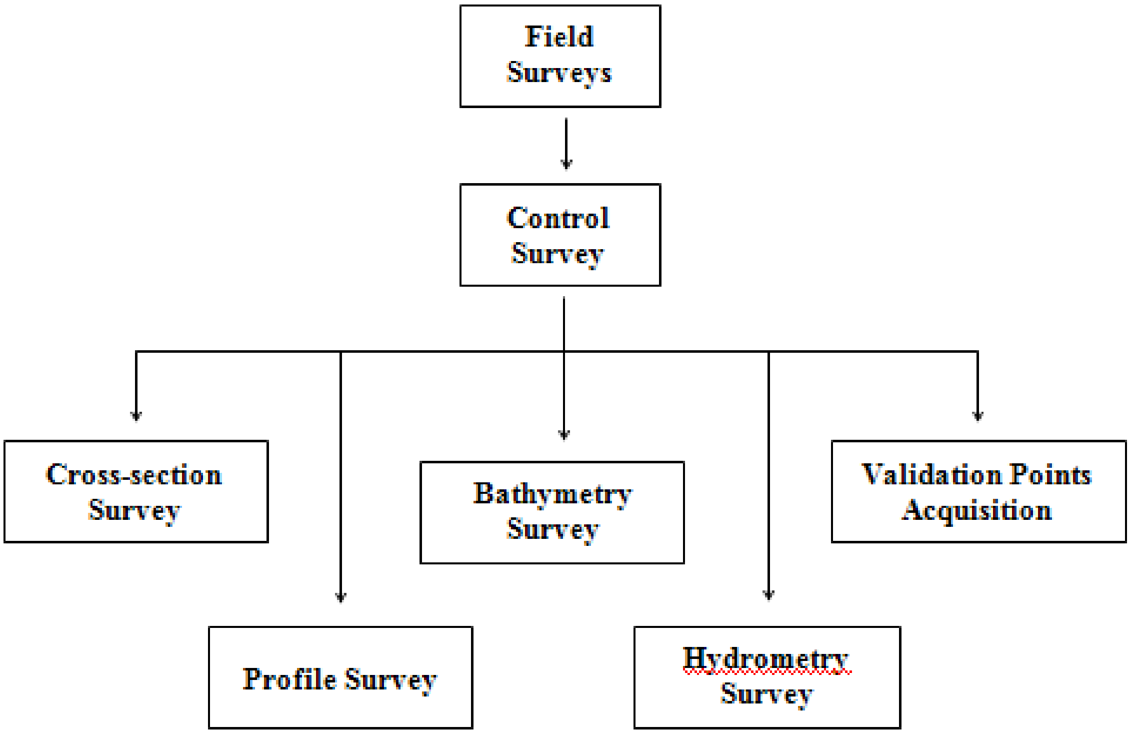

Figure 5. DVC Field Activities

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

Bathymetry is the measurement of the depths of water bodies from the water surface. It is the marine equivalent to topography. Bathymetric surveys are conducted with a transducer attached to a boat which transmits a sound pulse from the water surface and records that same signal when it bounces from the bottom of the water body. An echo sounder attached to the transducer filters and records the travel time of the pulse. At the same time that the pulse occurs, a GPS unit can record the location of the reading. After many of these readings are taken, corrections are made based on fluctuations in the water surface elevation that may have occurred during the 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 6.

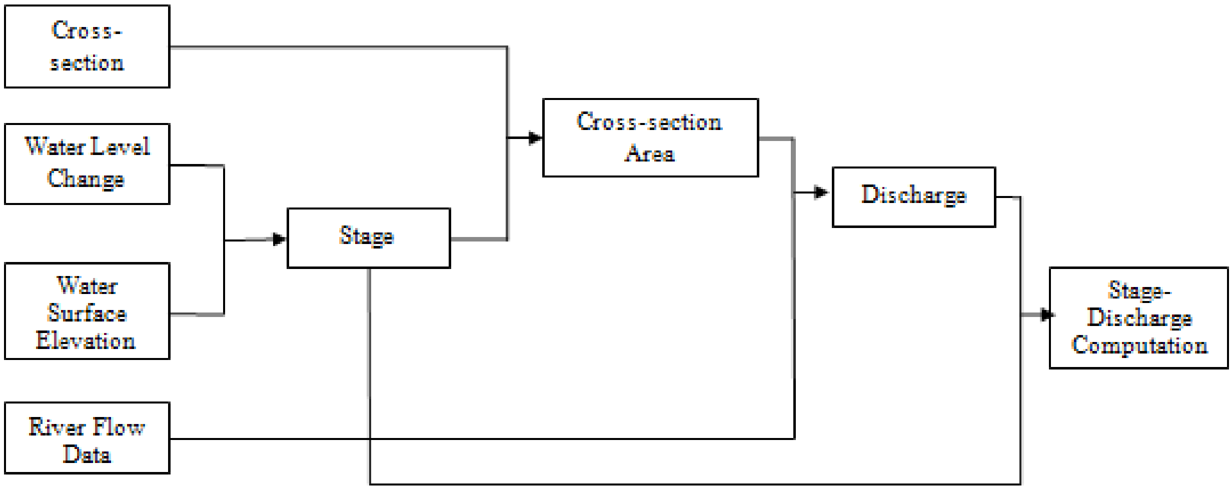

Figure 6. Flow Chart for Stage-Discharge Correlation Computation

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 7.

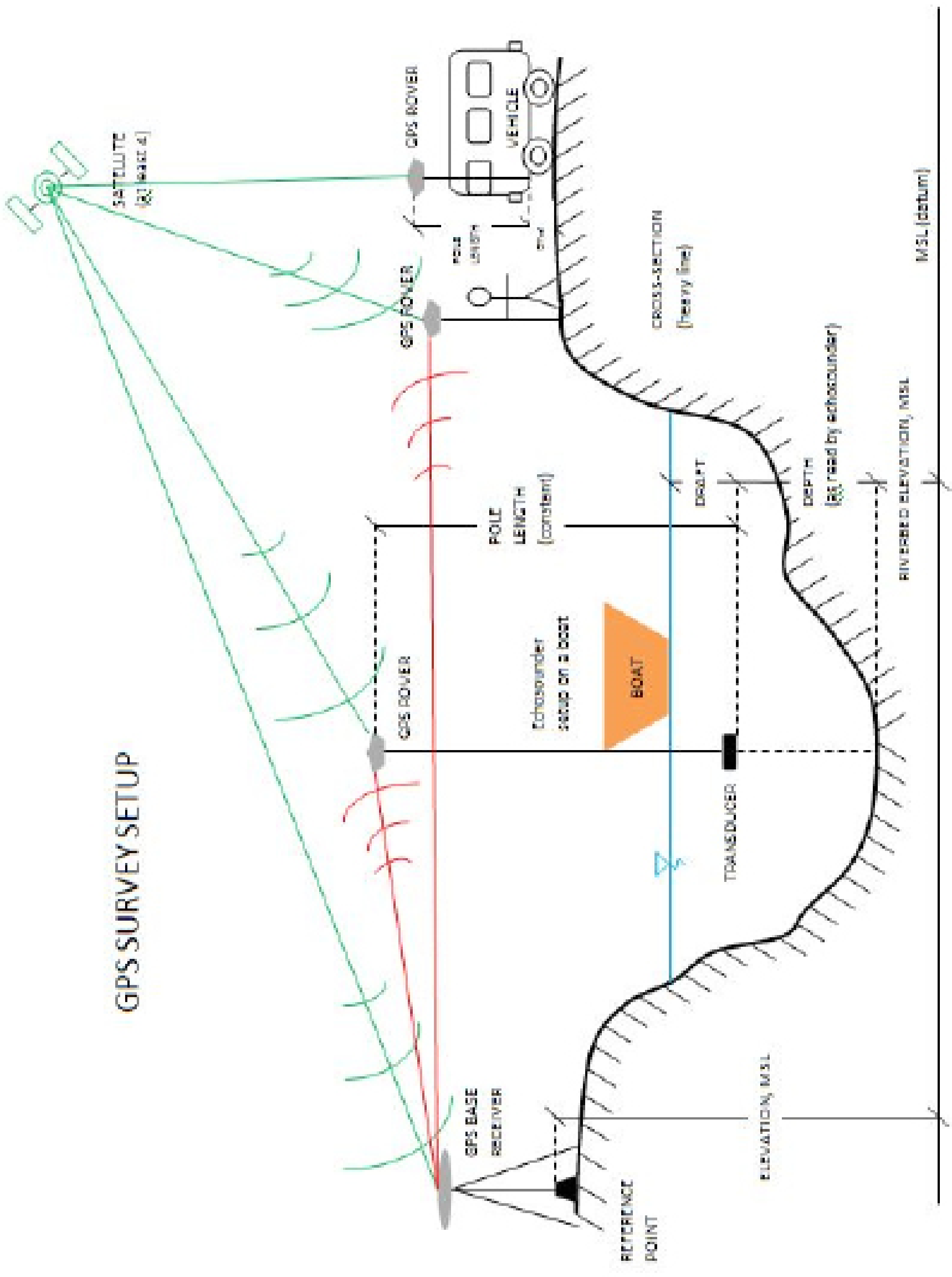

Figure 7. Set-up for GNSS Survey

3.3 Data Processing

Data processing procedures used by DVC are summarized in Figure 8.

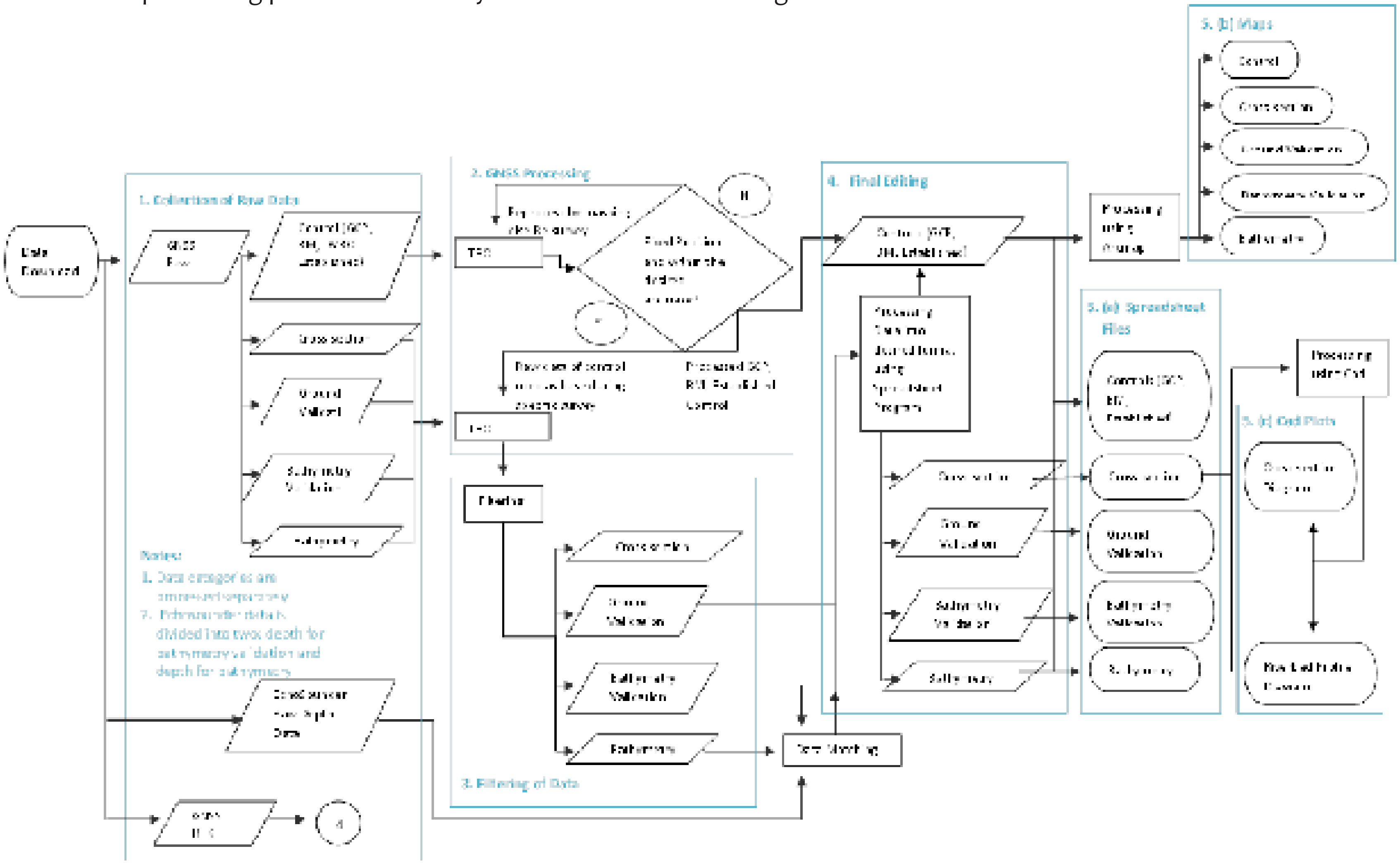

Figure 8. DVC Data Processing Methodology

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

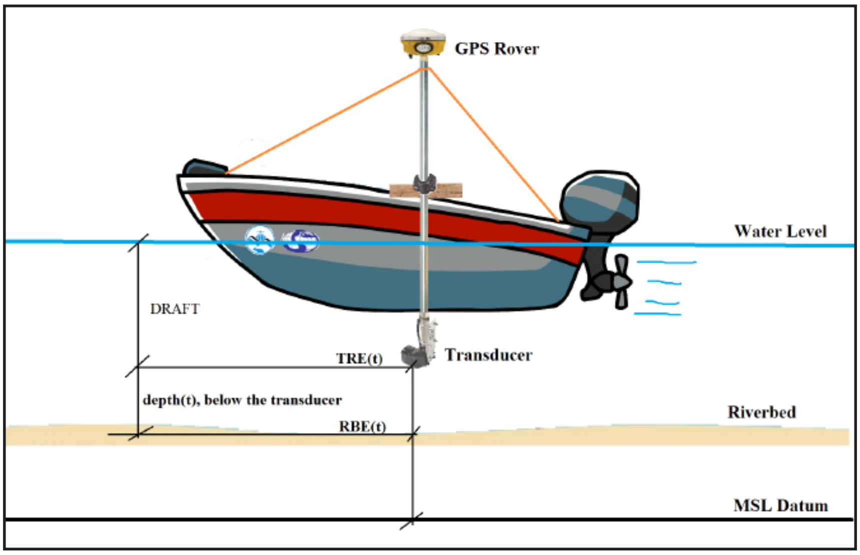

Figure 9. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

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.

Iligan River Basin Survey

Iligan River Basin Survey

The survey for Iligan River Basin was conducted on December 6 to 15, 2012 with the following activities: control, cross-section and profile line, bathymetric and hydrometric surveys.

Iligan River consists of 11 delineated cross section lines with a total length of 45.6 km for both left and right banks starting from Brgy. Rosario in the upstream down to Brgy. Tambobong near the mouth of the river. The total length of profile lines is about 59 km for its both left and right.

4.1 Control Survey

One (1) NAMRIA established control point was considered for the static GNSS observations of Iligan River System. It is a 2nd order ground control point, LDN-01, which is located on top of Philippine Ports Authority building in Brgy. Poblacion, Iligan City. Additionally, two (2) control points were established in Iligan City Hall (UP-ILI) and Brgy. Tipanoy, Iligan City (UP-TIP) to complete the network. Location of these control points is illustrated in Figure 10.

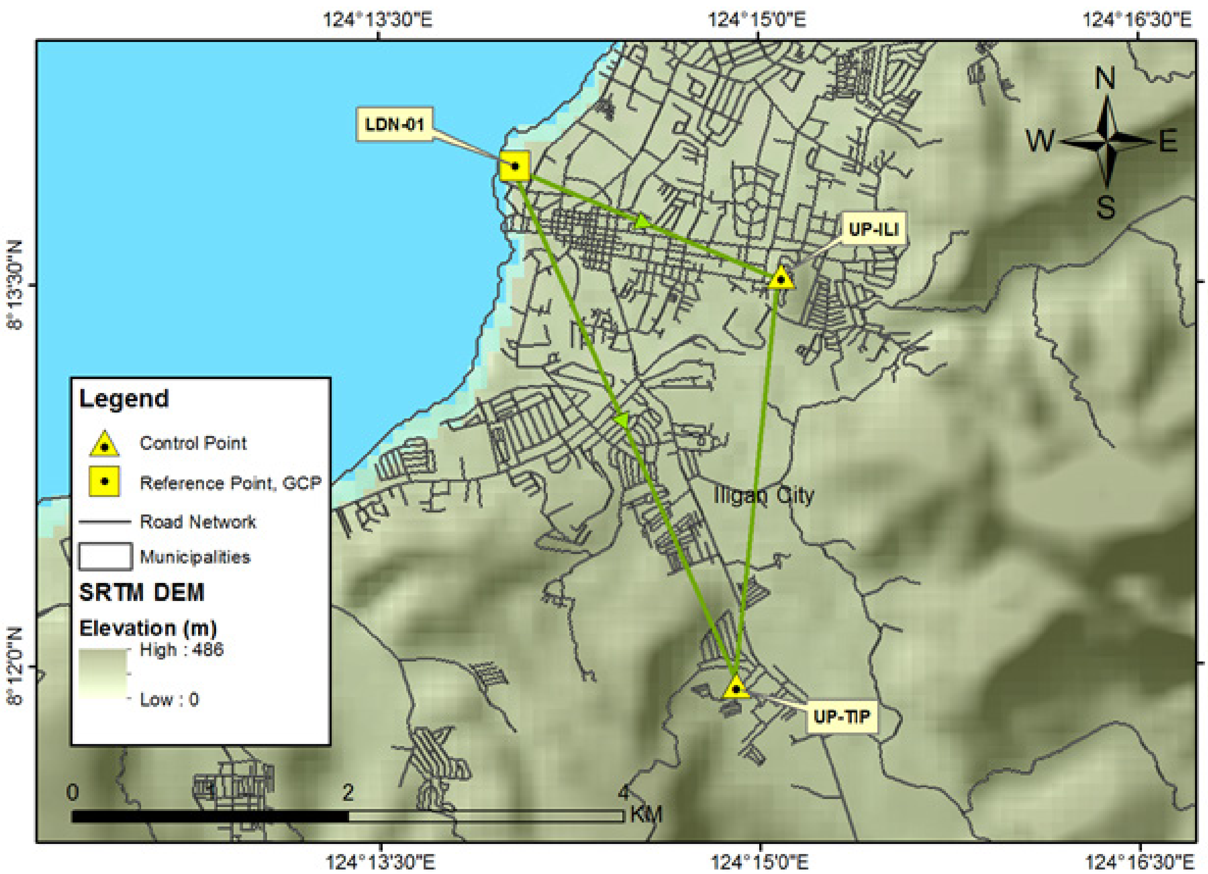

Figure 10. Location of control points

Iligan River Basin Survey

Continuous differential static observations were done simultaneously at these three stations for two hours to provide reference control points for the ground and bathymetric surveys. The horizontal coordinates and elevations of the 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 Iligan River 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)	
LDN-01	2nd	8d13'57.88944"	124d14'02.37264"	78.941	910238.2	635916.9	9.375
UP-ILI		8d13'31.94105"	124d15'05.24685"	118.545	909447.1	637843.3	48.786
UP TIP		8d11'55.15666"	124d14'54.46879"	94.203	906473.2	637522.8	24.238

The GNSS setup for the control points are shown in Figures 11 and 12:

Figure 11. Static GNSS observation on LDN-01 in Brgy. Poblacion, Iligan City

Figure 12. Static GNSS observation on UP-ILI in Brgy. Del Carmen, Iligan City

4.2 Cross-section Survey

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

Horizontal position (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 by the team through differential kinematic GNSS surveying either post-processed (PPK) or real-time (RTK). There are five (5) rover receivers that were utilized for PPK survey while three (3) rovers were used for RTK. Initialization time for the PPK survey was set at 7 to 10 minutes, depending on the field conditions.

A cross-section team is composed of two to three field personnel consisting of one (1) member from DVC, one (1) survey aide and/or one (1) local hire if needed. At the start of every cross-section survey, each cross-section team was dropped-off at an accessible point nearest to the planned cross-section lines. The set-up of instruments in acquiring cross-section data is shown in Figure 13.

Figure 13. Cross Section Survey using PPK and RTK Surveying technique.

The cross-section measurements started from a pre-determined point at the edge of the river bank. . A designed path of the each cross-section line was followed using a Garmin™ Oregon 550 handheld GPS for navigation until reaching the pre-determined end point. Each cross-section team used a GNSS rover, Trimble® SPS882, which received GNSS signal and RTK signal corrections for acquisition of points.

The cross-sections are plotted from the left bank facing downstream. The variation in the elevation from the riverbed to the floodplain in Iligan River is shown in Figures 14-24.

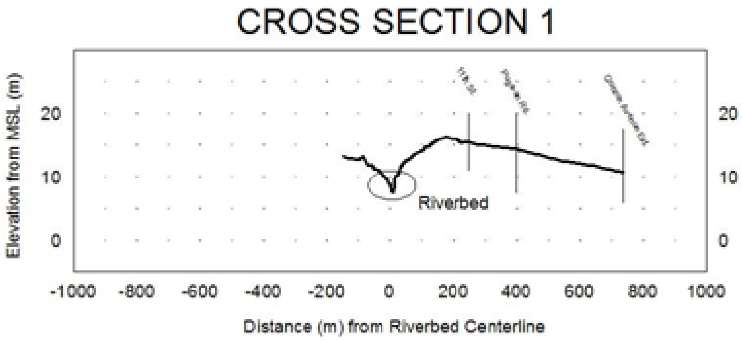

Figure 14. Cross Section 1 along Iligan River

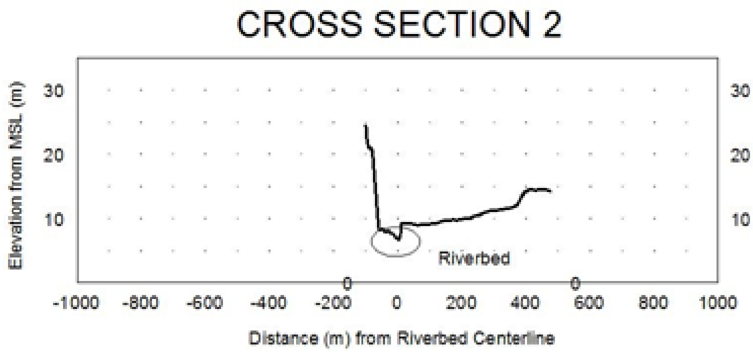

Figure 15. Cross Section 2 along Iligan River

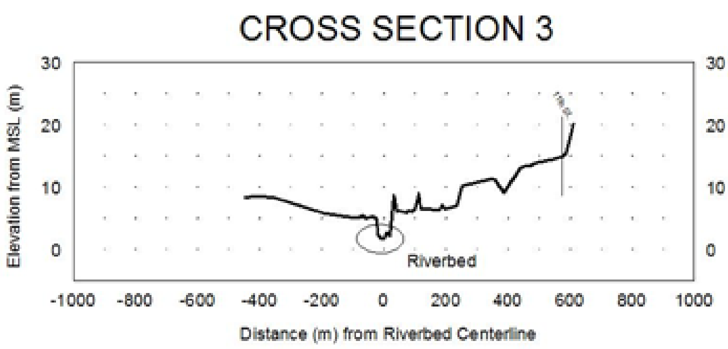

Figure 16. Cross Section 3 along Iligan River

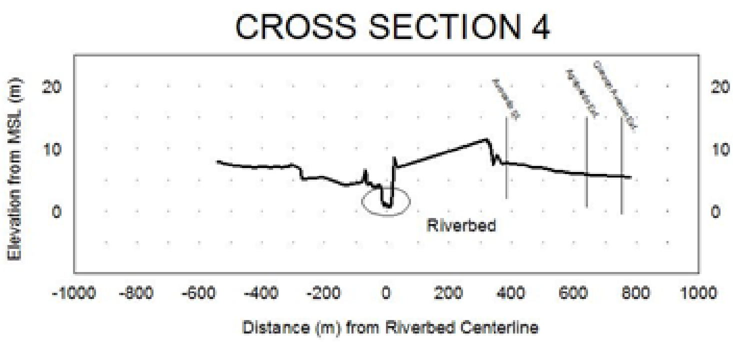

Figure 17. Cross Section 4 along Iligan River

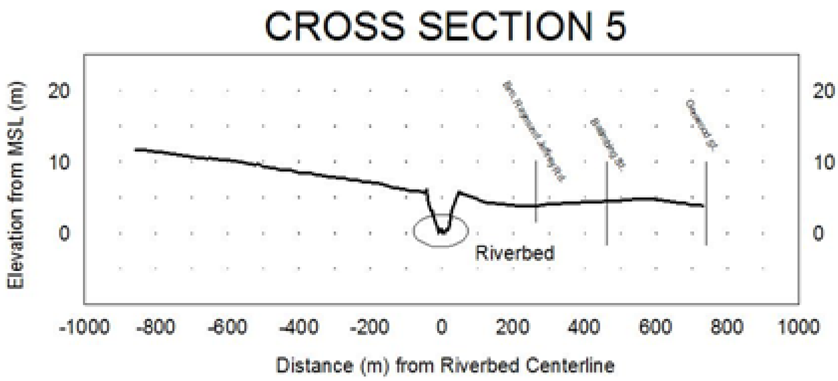

Figure 18. Cross Section 5 along Iligan River

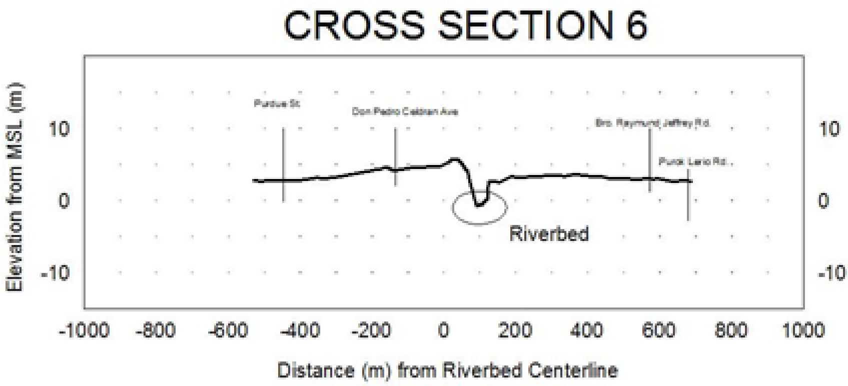

Figure 19. Cross Section 6 along Iligan River

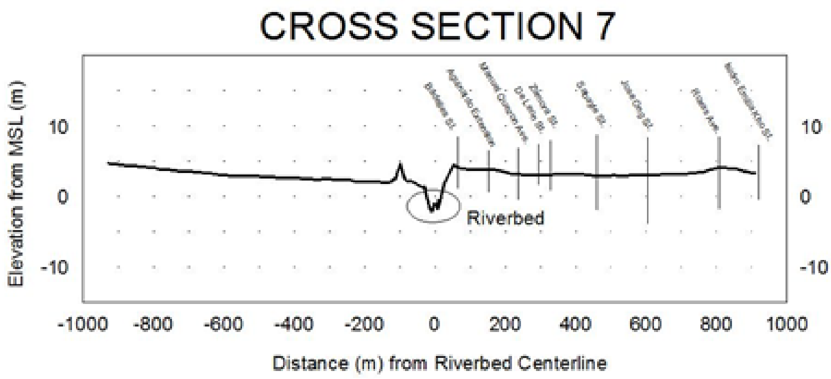

Figure 20. Cross Section 7 along Iligan River

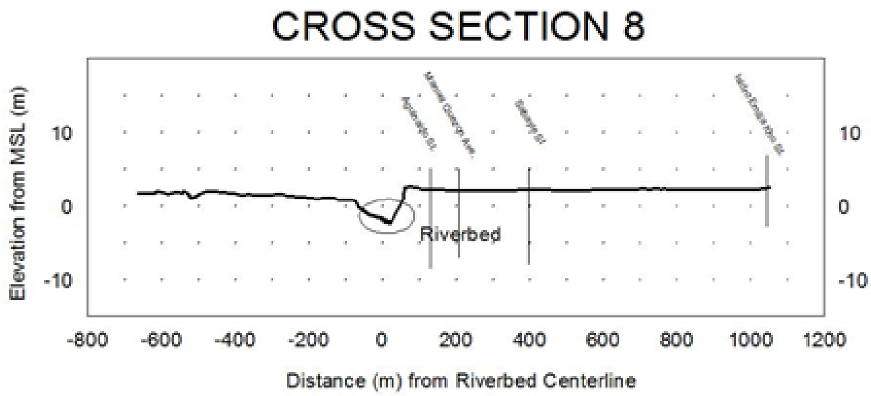

Figure 21. Cross Section 8 along Iligan River

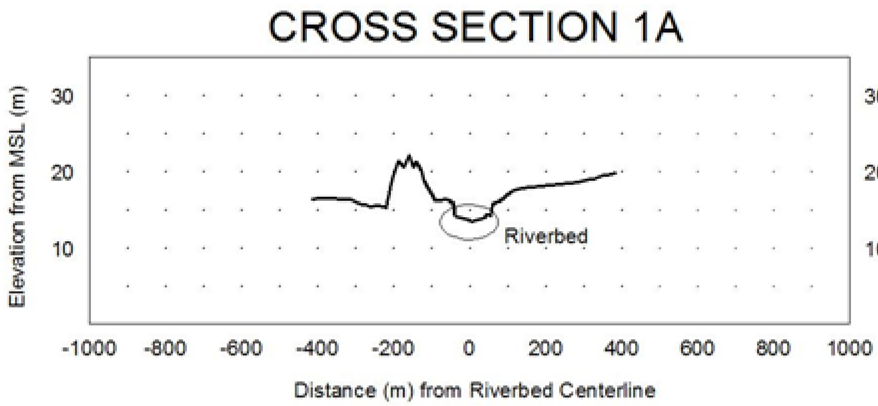

Figure 22. Cross Section 1A along Iligan River

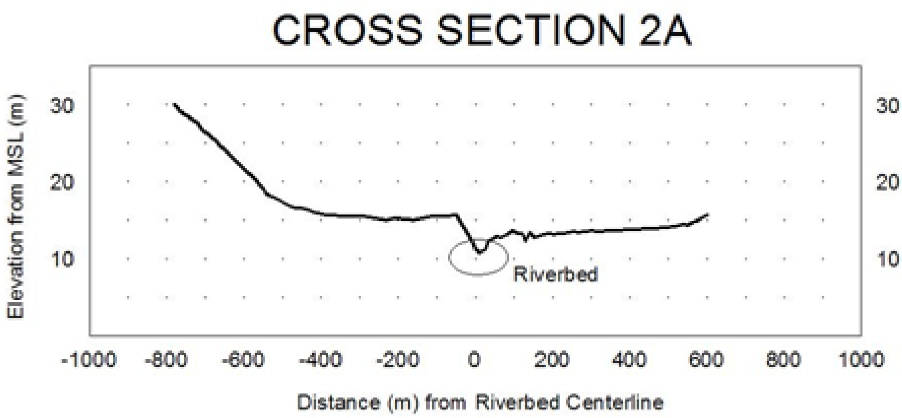

Figure 23. Cross Section 2A along Iligan River

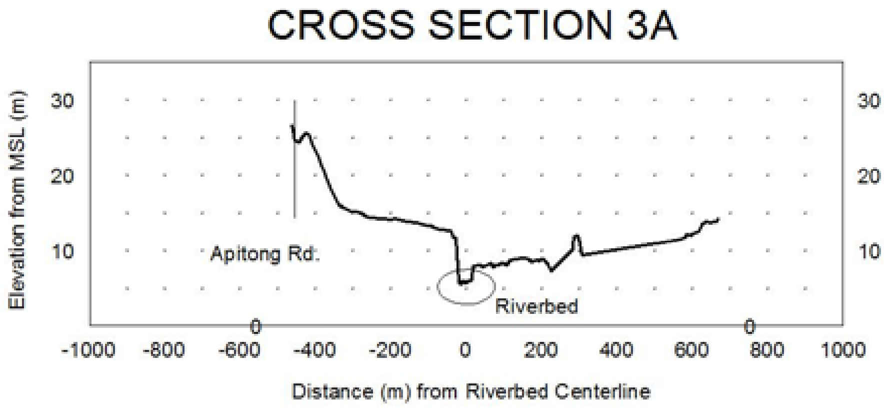

Figure 24. Cross Section 3A along Iligan River

4.3 Profile Survey

Profile survey started from Brgy. Tipanoy and ended along the mouth of the river in which it drains into Iligan Bay. The upper and lower banks were measured using differential kinematic GNSS surveying using either PPK or RTK technique. The survey technique that was used for the (a) lower bank is PPK GNSS surveying because generally, lower bank has less obstruction than the (b) upper bank shown in Figure 25.

Figure 25. Profile Survey Team Conducting PPK and RTK GNSS Survey

The proposed profile lines have a total length of 17.78 km as displayed in Table 2. For the upper bank 92.86% of the entire planned profile line was covered. The total length covered is 16.512 km. 87.56% of the entire proposed planned profile line was covered for lower bank having a total length of 15.568 km.

Table 2. Length of the planned profile lines

Profile	Length of planned profile, km	Length of surveyed profile, km	Percentage completed
Upper Bank	17.78 km	16.512	92.86 %
Lower Bank		15.568	87.56 %

The profile of the lower bank of Iligan River is illustrated in Figures 26 - 29. Left A and Right A is the tributary from the south originating from Brgy. Tipanoy in Iligan City.

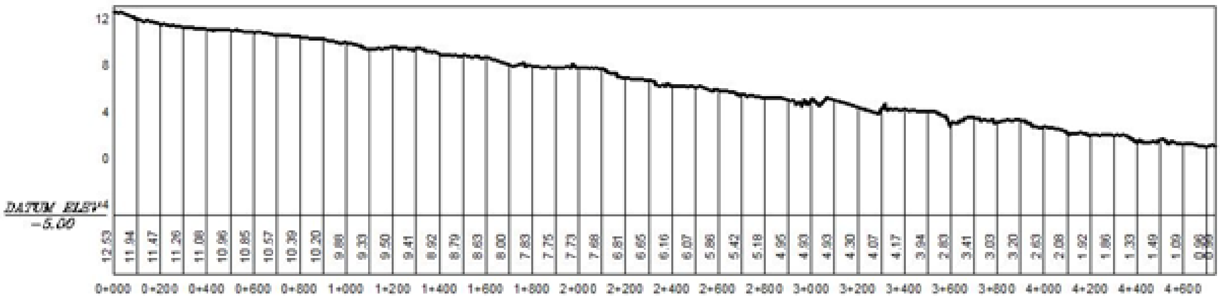

Figure 26. Lower Left A profile of Iligan River

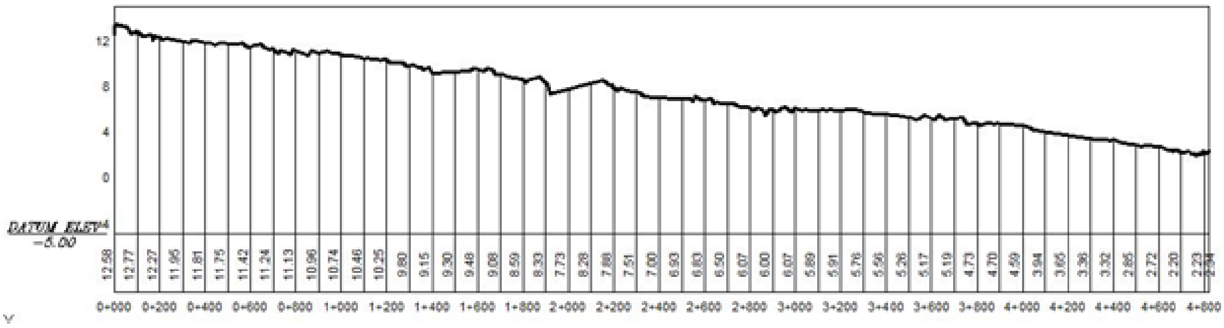

Figure 27. Lower Right A profile of Iligan River

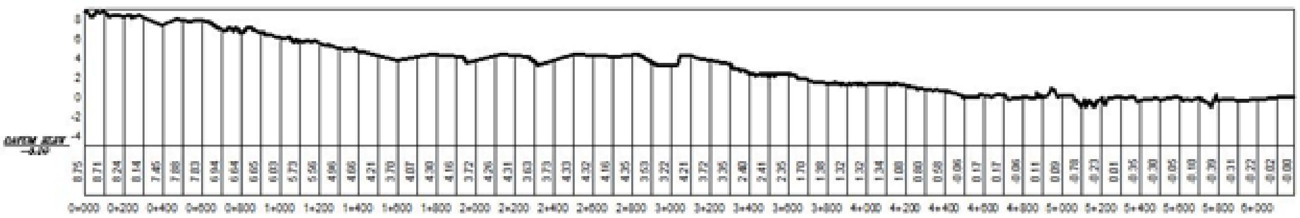

Figure 28. Lower Left profile of Iligan River

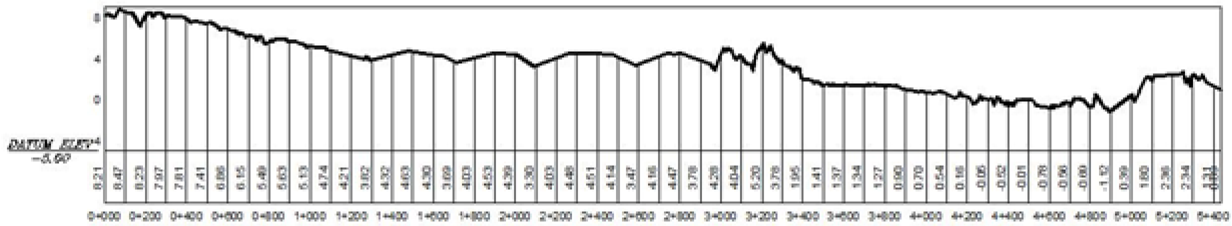

Figure 29. Lower Right profile of Iligan River

The profile of the upper bank of Iligan River is illustrated in Figures 30 - 33. Left A and Right A is the tributary from the south originating from Brgy. Tipanoy in Iligan City.

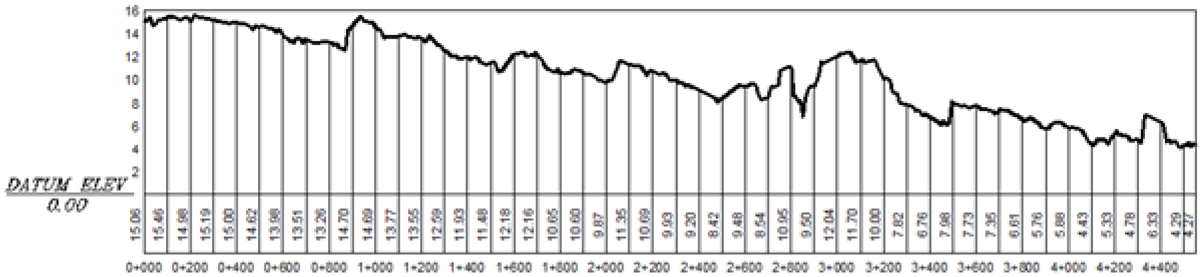

Figure 30. Profile of the upper bank left A of Iligan River.

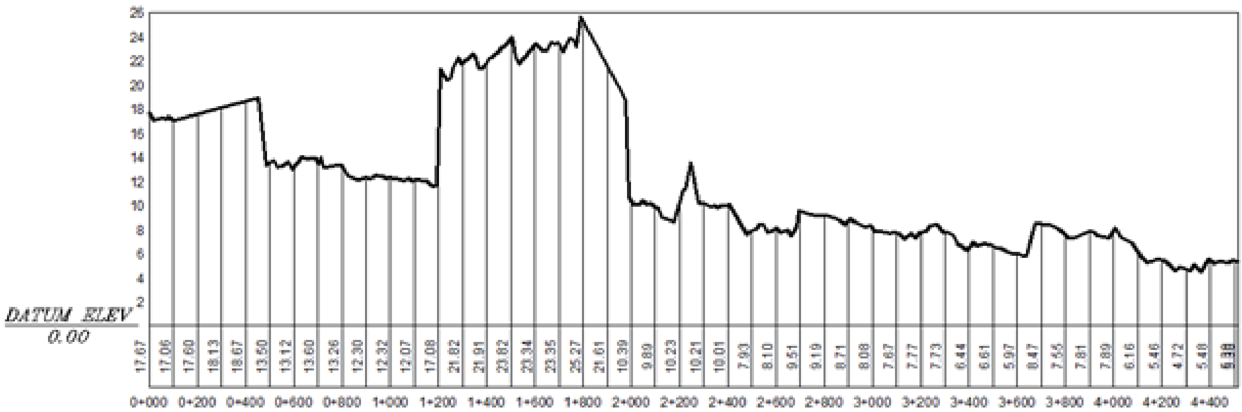

Figure 31. Profile of the upper bank right A of Iligan River.

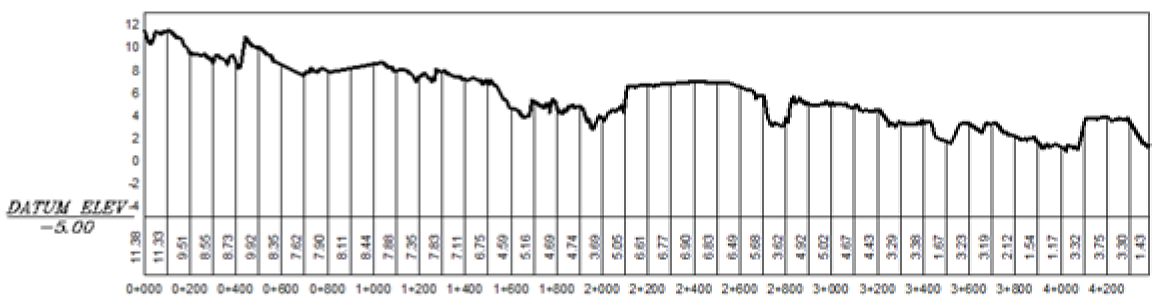

Figure 32. Profile of the upper bank left of Iligan River.

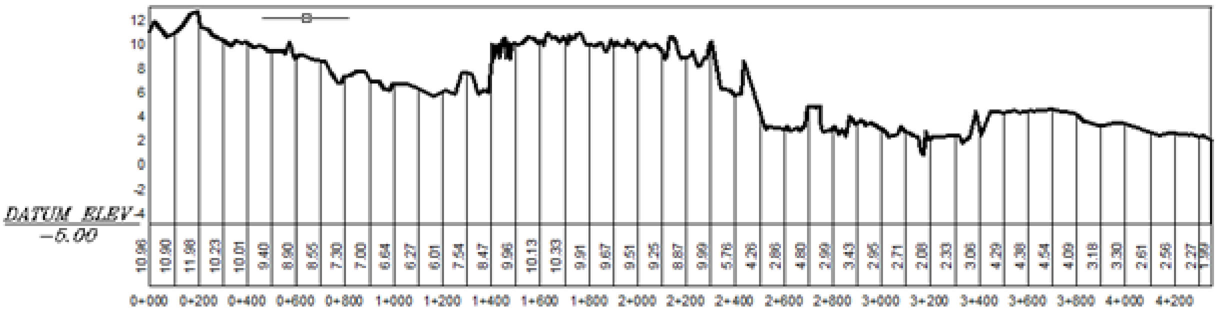

Figure 33. Profile of the upper bank right of Iligan River

4.4 Bathymetric Survey

The entire bathymetry survey took three (3) days to accomplish from December 10 to 12, 2012. Iligan River is shallow compared to the other major river basin. The team utilized differential GNSS PPK surveying technique for areas that are not passable by boat whereas an OHMEX™ echo sounder was used in the deeper parts of the river. The elevation and coordinates of these points were measured using differential GNSS PPK mode in which a PPK base station set-up on a known location, UP-ILI (Iligan City Hall), and a roving GNSS antenna, Trimble® SPS882, was mounted above the transducer to determine the position of the echo sounder. The GNSS rover was wirelessly connected to the Trimble® TSC3 GPS controller which was used for logging and viewing of obtained GNSS points. Bathymetry setup during the Iligan bathymetry survey is illustrated in Figure 34 and 35.

Figure 34. Bathymetric survey setup using Trimble®SPS 882 mounted on top of the OHMEX™ Transducer

Figure 35. Manual bathymetric survey using PPK GNSS technique

Centerline and zigzag sweep of the survey were performed in order to fully capture the topography of the river. An approximate centerline length of 9.2 km and a zigzag sweep length of 15 km were covered starting from upstream in Brgy. Tipanoy on the south and Brgy. Palao on the east ending at the mouth of Iligan River in Iligan Bay. Gathered bathymetry data is illustrated in a map in Figure 36.

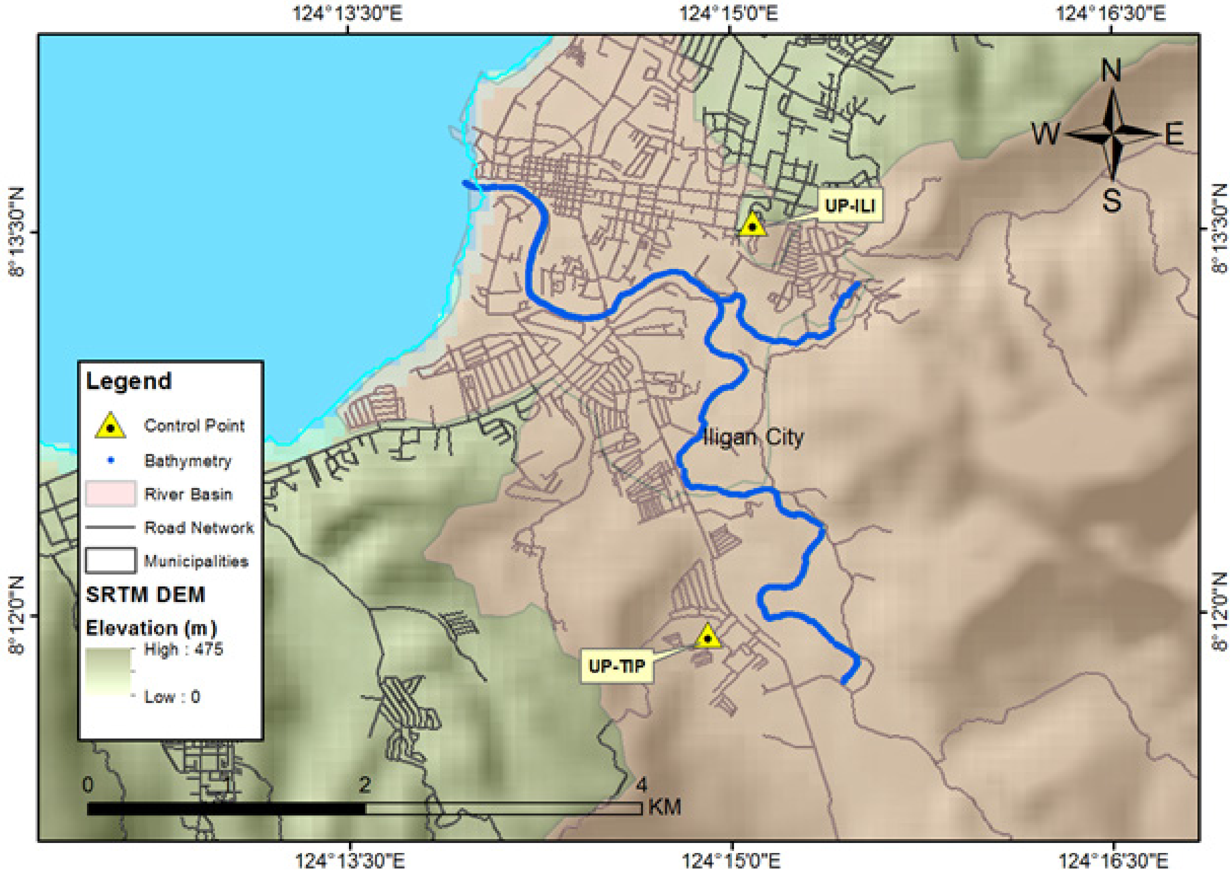

Figure 36. Bathymetry Survey along Iligan River

4.5 Hydrometric Survey

Different sensors were deployed on the banks of Iligan 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. Flow measurements were taken using the following instruments:

a. Sontek™ Acoustic Doppler Current Profiler (ADCP) is a sonar (sound navigation and ranging) that uses sound propagation underwater to obtain and record the water current velocities for a range of depths at a particular time.
b. Hoboware™ Rain gauge or udometer is a device that measures rainfall events and the amount of liquid precipitation at a particular place over a set period of time.
c. Hoboware™ Depth gauge (pressure gauge) displays the equivalent depth in water as well as detects the changes in water level at particular time. It measures the water pressure and relates it to water depth. Velocity of the current of the river and its depth with its cross- sectional area are the main factors in calculating the discharge.

The Sontek™ ADCP side looking was deployed on December 7, 2012 at certain portion of the riverbank in Brgy. Ubaldo Laya. The ADCP reading started at 2:08 PM and was left on site to continuously collect data while being watched over by a team of local hire, inspecting the progress of the data collection especially during heavy rainfalls brought by monsoon winds. The Sontek™ ADCP was then retrieved on December 14, 2012 after 8 days of constantly gathering data. Deployment site is shown in the map in Figure 37 and setup of the instruments are illustrated in Figures 38 to 41.

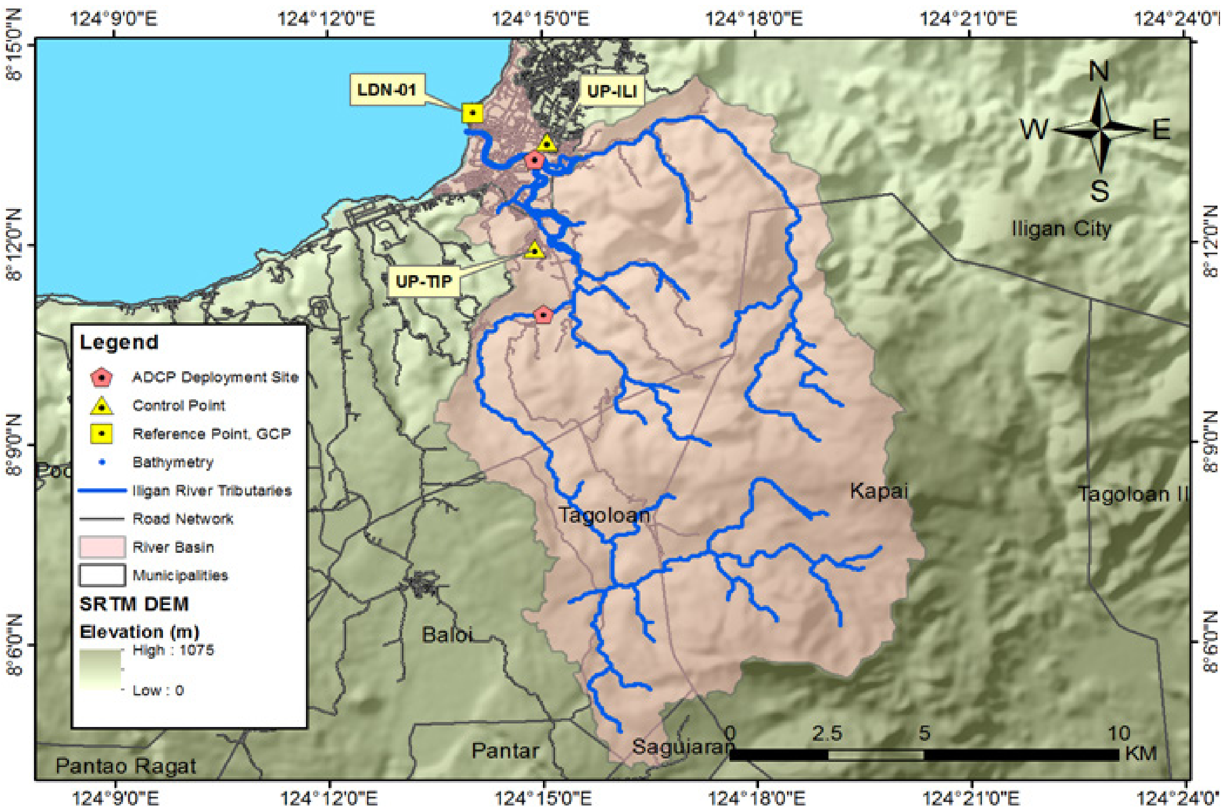

Figure 37. Iligan River ADCP Deployment Site

Figure 38. (a) Deployment of ADCP in Brgy. Ubaldo Laya. (b) ADCP was left for 8 days.

The ADCP was re deployed on December 27, 2012 in Bgy. Abuno, Iligan City. Data collection ended on the December 29, 2012 upon retrieval of the sensor as shown in Figure 39.

Figure 39. Deployment of the ADCP in Brgy. Abuno Iligan City.
(b) ADCP was left for three (3) days.

A rain gauge was installed in Brgy. Puga-An Iligan City from December 9, 2012 to December 14, 2012. The set-up of rain gauge is shown in Figure 40.

Figure 40. Deployment of Rain gauge at a residence in Brgy. Puga-An, Iligan City.

The depth gauges were deployed from December 7-14, 2012 in two locations – one was installed with the ADCP in Brgy. Ubaldo Laya, while the other was installed in Brgy. Poblacion near Tambacan Bridge.

Figure 41. Setting up of Depth Gauge in Brgy. Poblacion near Tambacan Bridge.

Table 3. Location of all the sensors used for Iligan River

Sensor	Location	Municipality	Deployment – Start	Deployment – End	LATITUDE	LONGITUDE
ADCP Side Looking 1st Deployment	Brgy. Ubaldo Laya	Iligan City	7-Dec.-2012	14-Dec.-2012	8º13'16.245"	124º14'54.346"
ADCP Side Looking 2nd Deployment	Brgy. Abuno	Iligan City	27-Dec.-2012	29-Dec.-2012	8º10'56.15941"	124º15'01.68945"
Rain Gauge	Brgy. Puga-An	Iligan City	9-Dec.-2012	14-Dec.-2012	8º13'23.8"	124º15'53.9"
Depth Gauge	Brgy. Poblacion	Iligan City	7-Dec.-2012	14-Dec.-2012	8º13'38.06025"	124º14'14.20386"
Depth Gauge	Brgy. Ubaldo Laya	Iligan City	7-Dec.-2012	14-Dec.-2012	8º13'16.245"	124º14'54.346"

The data gathered from rain gauge shows the distribution of rainfall from December 9 to 14, 2012 and December 27 to 29, 2012. Data gathered from the sensors and their relationships are shown in Figures 42 to 50.

Cross-Sectional data at ADCP Deployment site in Brgy. Ubaldo Laya is shown in Figure 42.

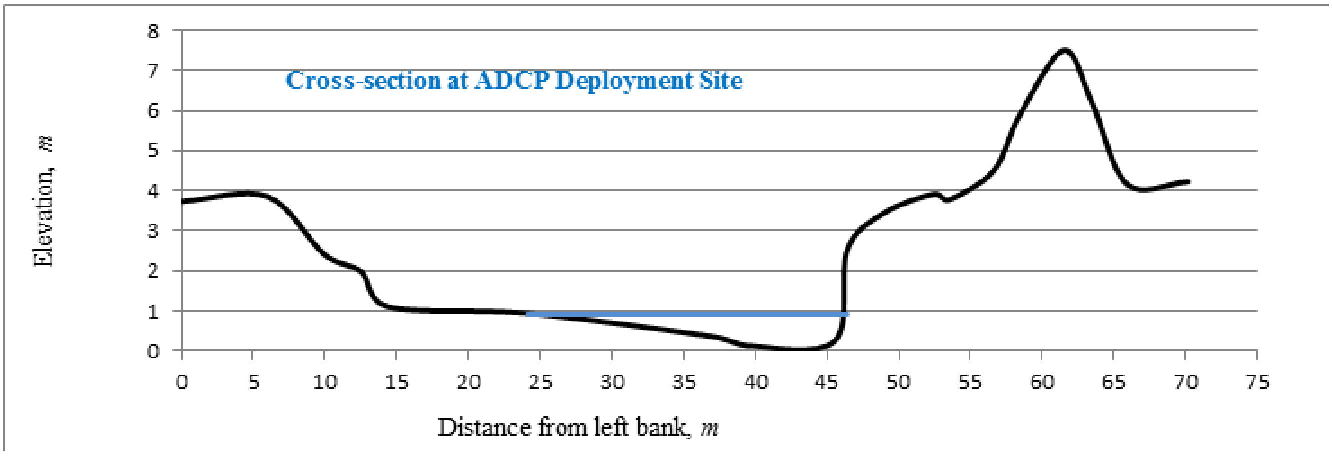

Figure 42. Cross section diagram at ADCP deployment site in Brgy. Ubaldo Laya.

Rainfall data gathered from the deployed Rain Gauge in Brgy. Puga-an, Iligan City is shown in Figure 43. The first surge of rain, which is also the peak of the rainfall data reached 3.8mm on December 9, 2012.

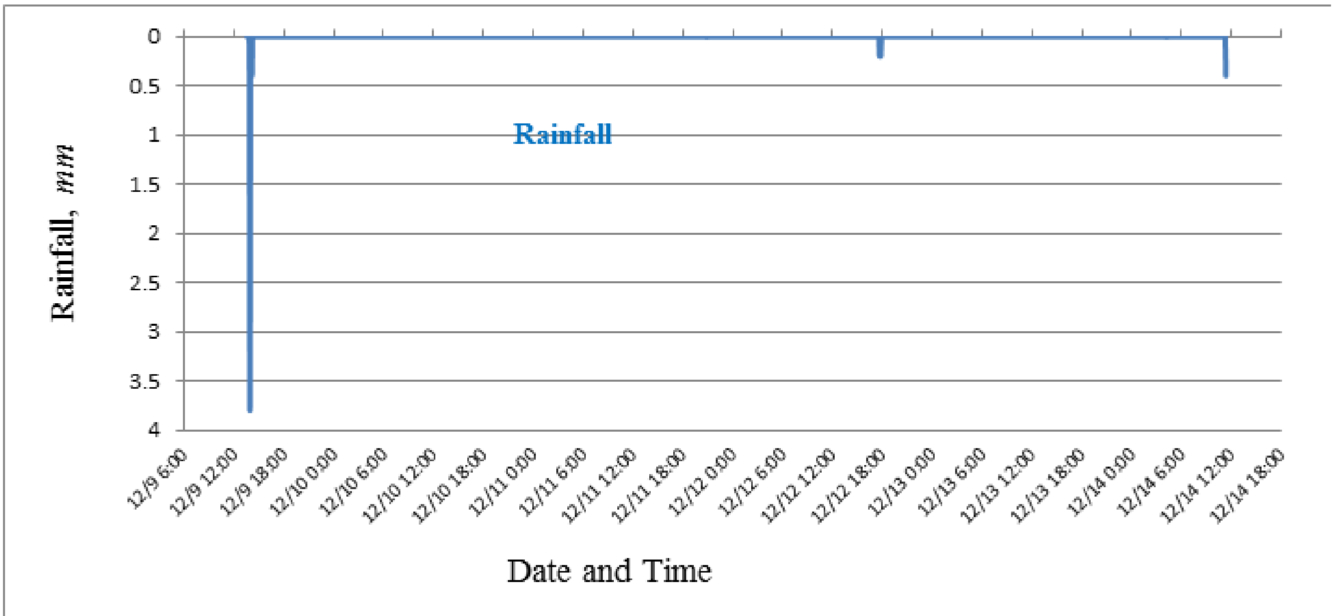

Figure 43. Rainfall data in Brgy. Puga-an, Iligan City

The relationship between stage and discharge for December 7-14, 2012 survey resulted in an R2 of 0.0397 shown in Figure 44. A value approaching R2 = 1 indicates a good correlation.

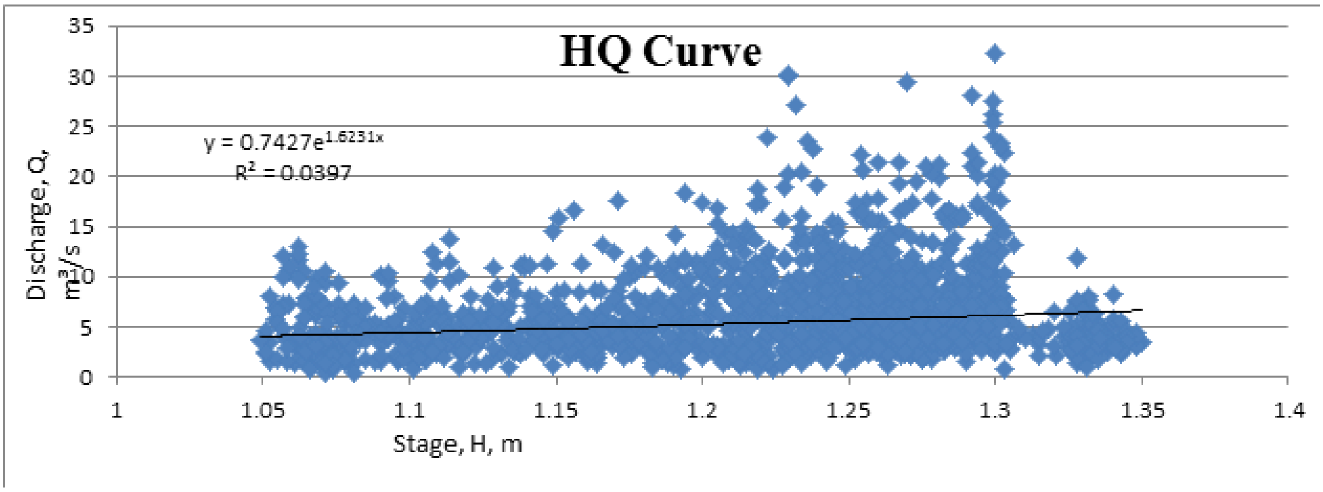

Figure 44. Stage-discharge computation in Brgy. Ubaldo Laya.

The stage data from the deployed depth gauge from December 7-14, 2012 is shown in Figure 45.

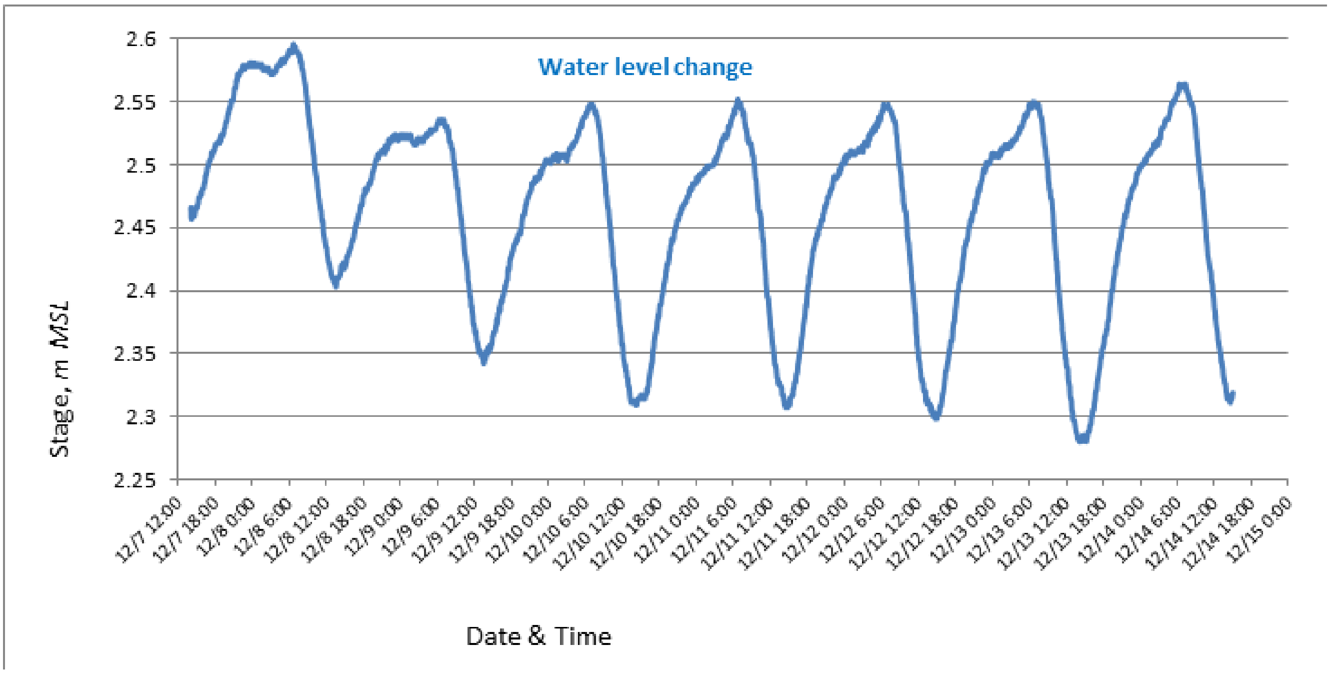

Figure 45. Stage data in Brgy. Ubaldo Laya.

The rain gauge and ADCP are re-deployed in Brgy Abuno on December 27 to 29, 2012 while the cross-sectional data at the ADCP deployment site in Brgy. Abuno is shown in Figure 46.

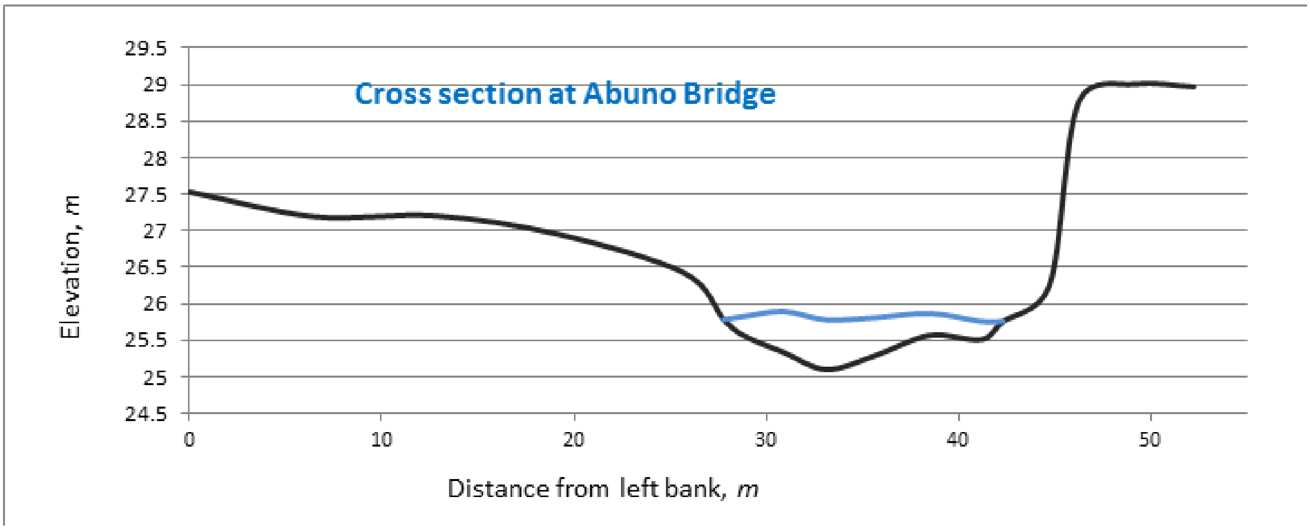

Figure 46. Cross section at the ADCP deployment site in Brgy. Abuno

Rainfall data gathered from the re-deployed Rain Gauge in Brgy. Abuno is shown in Figure 47. The first surge of rain was observed on December 27, 2012 which reached 1.4mm. The highest surge of rain was observed on December 29, 2012 which reached 1.8mm.

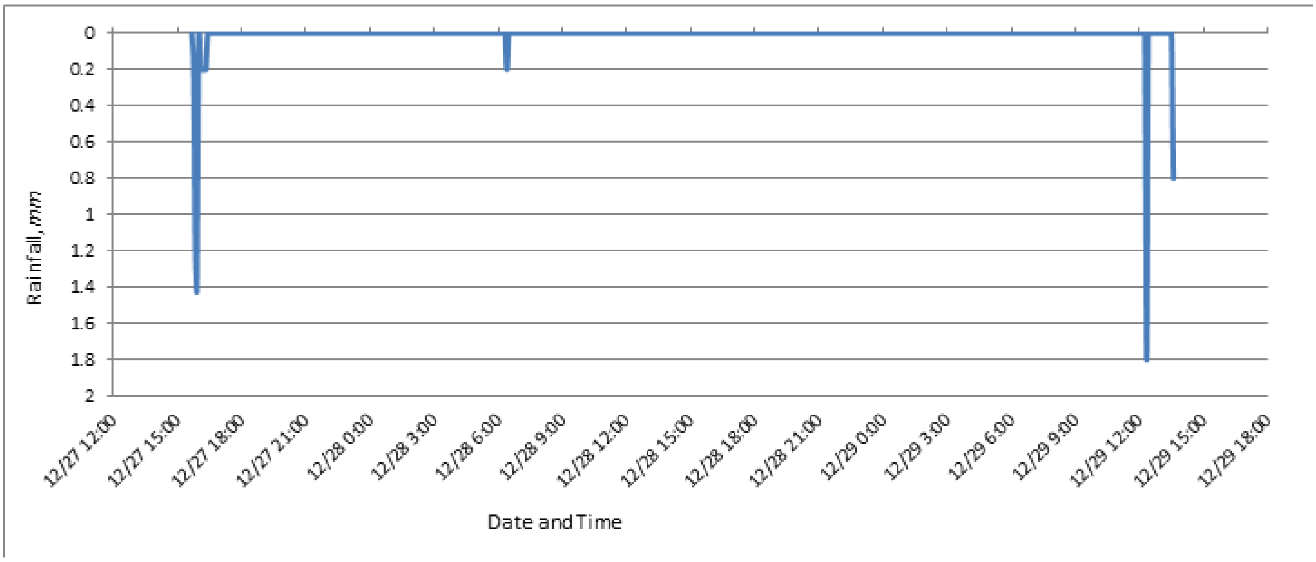

Figure 47. Rainfall data in Brgy. Abuno, Iligan City

The stage data from the deployed depth gauge from December 27-19, 2012 is shown in Figure 48.

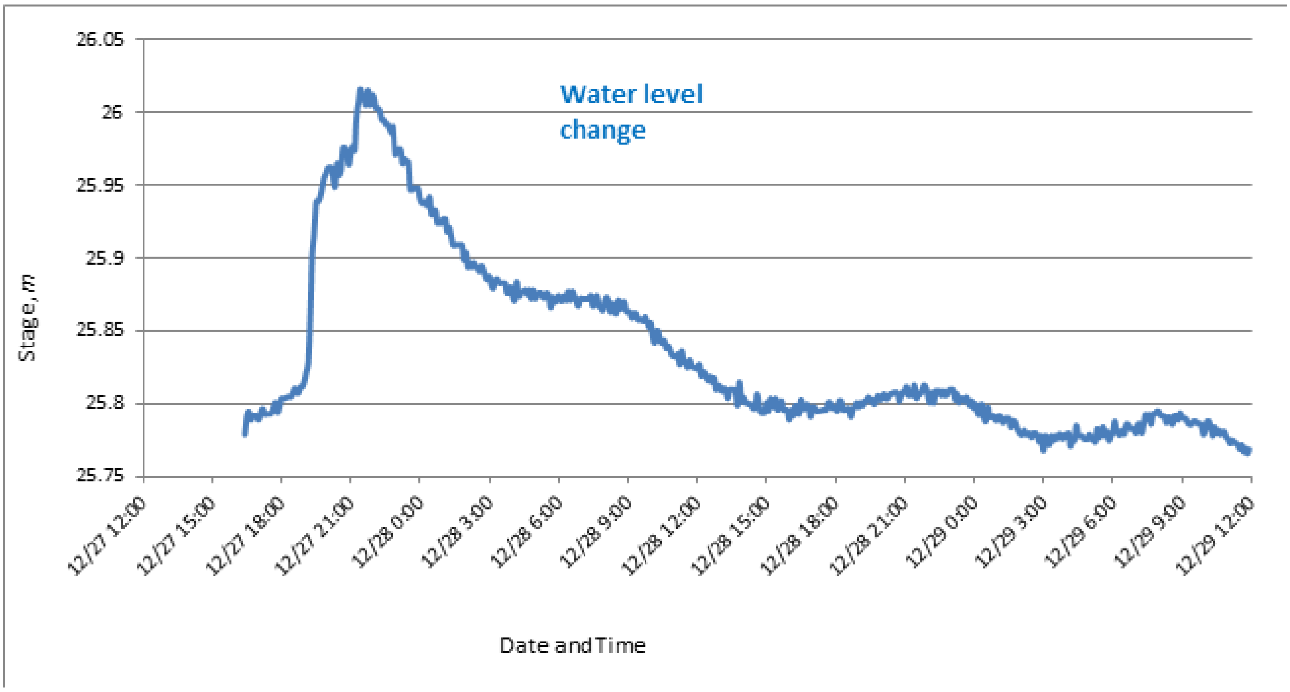

Figure 48. Stage data at deployment site in Brgy. Abuno

The relationship between the stage or water surface elevation referred to MSL and river discharge resulted to an R2 = 0.9528 in normal mode while an R2 = 0.8989 in burst mode and are illustrated in Figure 49 and 50. A value approaching R2 = 1 indicates a good correlation.

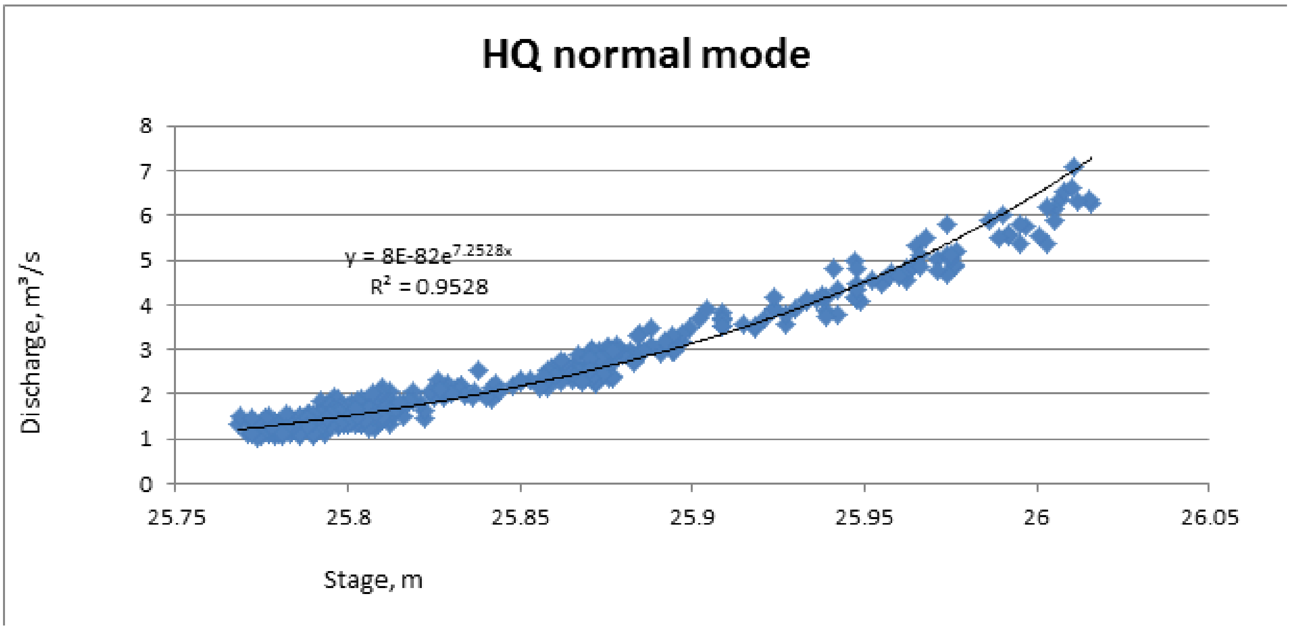

Figure 49. Stage-discharge computation in a normal mode along Iligan River from the ADCP deployed in Brgy. Abuno

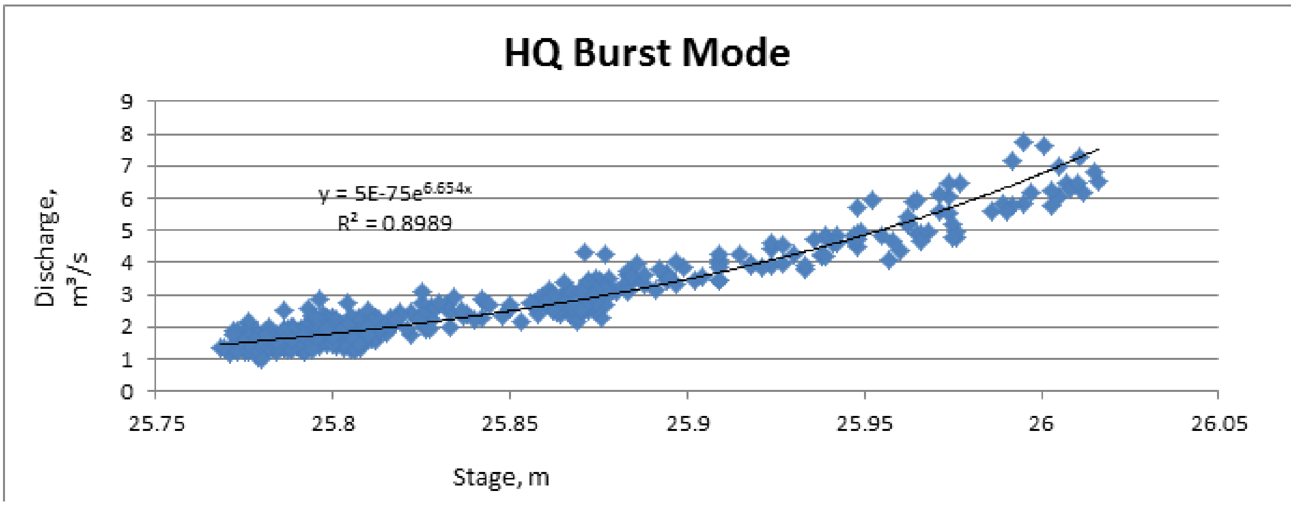

Figure 50. Stage-discharge computation in a burst mode along Iligan River from the ADCP deployed in Brgy. Abuno

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

The following Table 4 shows the problems and limitations encountered during the fieldwork and the actions or solutions taken by the team.

Table 4. Problems Encountered and Resolutions Applied

Limitation/Problems	Solutions
1) Dec. 7: Lack of control point that could cover the survey area	Established control point on top of Iligan City Hall
2) Dec. 8: A part of XS 3 falls on a private property	The team moved on to the next cross section.
3) Dec. 9: River not passable by boat for bathymetric survey	The team decided to walk and use GNSS surveying techniques.
4) Dec. 10: Sudden changes in the elevation of the river	The team proceeded being more cautious.
5) Dec. 10: Steep slopes of the terrain	The team proceeded with the survey.
6) Dec. 11: Canopies block Satellite signals	Re initialize for 10 minutes.
7) Dec. 13: Upper bank is lined with fences and structures	The team asked for permission from one of the property owners.
8) Dec. 13: Nipa trees were abundant proper delineation of lower bank was not possible	The team continued the survey skipping the area with nipa trees.
9) Dec. 14: Some areas are too deep and strong river current.	The team skipped the areas that are too deep for the safety of the tem and equipment.

Shallow waters causes delay for the team. The bathymetric survey team proceeded by foot. The bathymetric team proceeded slowly and with caution because of sudden changes in the river bed elevation and the strong river current.

Figure 51. Some parts of Iligan River has thick vegetation and getting satellite signal is quite impossible

Figure 52. Areas with canopies and buildings caused delay for the team because the GNSS receiver can not get satellite signals.

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
High-Gain Antenna			UP- TCAGP	Four(4) units
Single beam Echo sounder	Hi-Target		UP-TCAGP	One (1) unit with accessories
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	UP-TCAGP	Four (4) units
		1MW086842		
		1MW086920		
		1MW079764		
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	9997437,9951530 9983753,9759371	UP- TCAGP	Three (3) units
Rain Gauge		1293784	UP-TCAGP	One (1) unit
Echo sounder	Ohmex™	2969	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
Laser Range Finder	Bushnell		UP-TCAGP	Two (2) units
Toolbox			UP-TCAGP	One (1) unit
QINSy dongle			UP-TCAGP	One (1) unit
Transducer	Ohmex™		UP-TCAGP	One (1) unit

ANNEX C. LIST OF EQUIPMENT AND INSTRUMENTS

Data Validation Component Sub-team	Designation	Name	Agency/Affiliation
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. JOEMARIE S. CABALLERO	UP TCAGP
Bathymetric Survey Team	Senior Science Research Specialist	ENGR. DEXTER T. LOZANO	UP TCAGP
	Senior Science Research Specialist	ENGR. BERNARD PAUL D. MARAMOT	UP TCAGP
		CARA KATRINA N. PUNAY	
Profile Survey Team	Senior Science Research Specialist	ENGR. MELCHOR REY M. NERY	UP TCAGP
	Research Associate	REGINA ANNE G. FAELGA	UP TCAGP
Cross Section Survey Team and Deployment Team	Research Associate	ENGR. JMSON CALALANG	UP TCAGP
	Research Associate	CARL ARVIN C. CARO	UP TCAGP
	Research Associate	JOJO E. MORILLO	UP TCAGP
	Research Associate	MARK LESTER D. ROJAS	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

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

April 18, 2013

CERTIFICATION

To whom it may concern:

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

Province: **LANAO DEL NORTE**
Station Name: **LDN-01**
Order: **3rd**

Island: **MINDANAO**
Municipality: **ILIGAN CITY**
Barangay: **POBLACION**

	PRS92 Coordinates	
Latitude: **8° 14' 1.44528"**	Longitude: **124° 13' 56.94179"**	Ellipsoidal Hgt: **11.87000 m.**
	WGS84 Coordinates	
Latitude: **8° 13' 57.88944"**	Longitude: **124° 14' 2.37264"**	Ellipsoidal Hgt: **78.95000 m.**
	PTM Coordinates	
Northing: **910480.055 m.**	Easting: **415436.191 m.**	Zone: **5**
	UTM Coordinates	
Northing: **910,289.41**	Easting: **635,751.93**	Zone: **51**

Location Description

LDN-01
From Iligan City, travel northeast going to Iligan City Pier for about 15 minutes drive. The station is located at the roof top of Iligan City PPA Administration building, inside the Iligan City Pier compound. Mark is a 30x30 cm cement putty monument, on top of PPA Administration building, with 4-inches on the center of the cement putty monument inscribed with station name LDN-01 2007 NCIP.

Requesting Party: **UP DREAM/ Melchor Nery**
Pupose: **Reference**
OR Number: **3943540 B**
T.N.: **2013-0307**

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

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

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Disaster Risk and Exposure Assessment for Mitigation