Technical Report on

Discharge Measurement

Conducted at Arayat Station in

Pampanga River Basin

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19 November 2013

Introduction

Streamflow, or discharge, is defined as the volumetric rate of flow of water in an open channel, including any sediment or other solids that may be dissolved or mixed with it. Streamflow is usually expressed in dimensions of cubic metres per second (m3/s) and cannot be measured directly, but must be computed from variables that can be measured directly, such as stream width, stream depth and flow velocity. Even though streamflow is computed from measurements of other variables, the term streamflow measurement is generally applied to the final result of the calculations.

As part of Stream Gauging, the Discharge Measurement in Hydrological Training Course (HTC) conducted by Training Unit under Research Development and Training Division (RDTD) of the Philippines Atmospheric, Geophysical and Astronomical Services and Administration (PAGASA), a field work was done in October 15 -25, 2013.

The field work study done in Pampanga River Basin and Flood Forecasting and Warning Center (PRFFWC) headed by Mr. Hilton T. Hernando, the area was located at bridge of Barrio San Agustin, Arayat, Pampanga. Throughout the field work training Mr. Hernando with his staff Mr. Niemes, Mr. Jun Paat and Mr. Roy Badilla were present during conducting discharge measurement in different method on the said bridge, also the training staff lead by Ms. Encarnacion Borjal, Ms. Jocelyn Balaquit and Mr. Luisito Atos.

Additional insight as a hydrologist trainee, we also visited the following La Mesa Dam, Pantabangan Dam, Angat Dam and Cong Dadong Dam in Arayat, Pampanga to know its operations as they managed water in their reservoirs to use in many ways, we also visited a Municipal Disaster Risk Reduction Management Council in Calumpit, Bulacan for us to understand their local Early Flood Forecast and Warning System.

Objectives

The study conducted is guided with the general aim to fully understand and conduct an actual discharge measurement/stream gauging to implement the four methods of discharge measurement indirect and direct methods in Arayat station of the Pampanga River Basin.

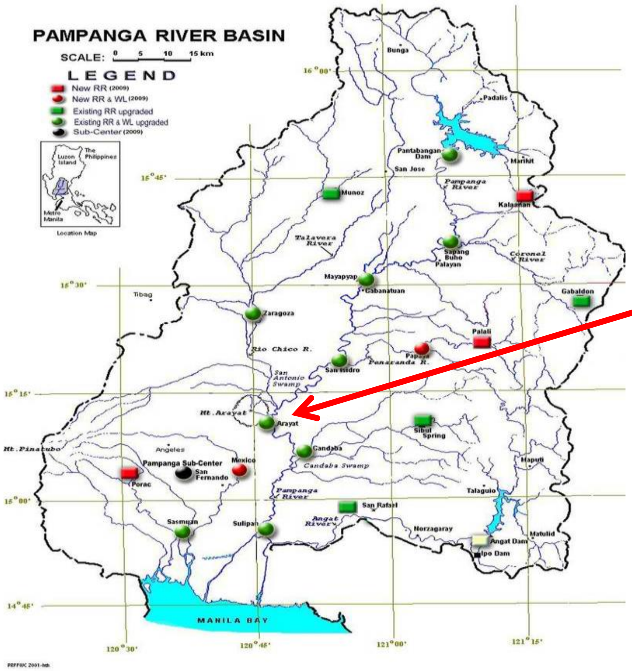
Specifically, the activity aims:

a.) compare and contrast the four discharge measurement methods such as the Float, Slope-Area, ADCP and Current Meter Methods in terms of practical applications and advantages and disadvantages;

b.) investigate the flooding event in the Arayat Station of Pampanga River; and

c.) Construct a Rating Curve in Arayat Station.

Site Description



Arayat Station

Coordinates: 15°10’5.88”N

120°46’55.99” S

Map of Pampanga River Basin and Picture of Arayat Station

The Pampanga River Basin, the 4th largest basin in the Philippines and covers an approximate aggregate area of 10,540 sq. km. (includes the allied basin of Guagua River). The basin extends over the southern slopes of the Caraballo Mountains, the western slopes of the Sierra Madre range and the major portions of the Central Plain of Luzon. It encompasses the provinces of Nueva Ecija; part of Bulacan, Tarlac and Quezon; and almost whole of Pampanga. The total length of the main river, the Pampanga River, is about 260 kilometers.

The basin is drained through the Pampanga River and via the Labangan Channel into the Manila Bay. The main river is supported by several tributaries, the principal ones of which are the Peñaranda, the Coronel-Santor and the Rio Chico River. The Angat River joins the Pampanga River at Calumpit in Bulacan via the Bagbag River. Somewhere between the middle and lower portion of the basin stands Mount Arayat, about 1,026 meters in elevation. Adjacent to Mount Arayat, across Pampanga River.

This area is submerged during the rainy season but is relatively dry during summer. The dry season generally occurs from December to May, and wet the rest of the year. The wettest months are from July to September.

The Arayat Station, one of the Water Level and Rain Gauges station in the Pampanga River basin, it is in the bridge of San Agustin located in Barangay San Agustin Norte municipality of Arayat in Pampanga which is a one hour drive from the PRFFWC situated in the Regional Center in City of San Fernando. Due to its accessibility the training of actual river cross-sectioning and discharge measurement was conducted.

The weather condition for the entire training is mostly sunny. The situation in the banks are muddy due to the fact that the arayat station has been flooded a week before the study, the highest flood recorded was 8.3 meters high due to Typhoon Santi, the riverbank was submerged in the said flood events. The riverbanks composed of muds and grasses because they are no levee or permanent structure within the both banks except on the foot of the bridge and its culvert.

The stream flow during the first day of training was considerably at moderate level at above 5.4 meters height measured in the gauge and receded at the last day of training to low level at 4.2 meters in height considering the Cong Dadong Dam hundred meter upstream of the station were close that affect and lessen the flow of the water.

Note: Photo taken on the top of the bridge.

Upstream Right Bank

Upstream Left Bank

Downstream Left Bank

Downstream Right Bank

Methodology

During the ten-day fieldwork, four methods of discharge measurement were done in the downstream portion of the San Agustin Bridge in Arayat, Pampanga. Of the four methods, some were direct measurements such as the float, ADCP and current meter methods while slope area method is an indirect measurement. Details of each method were summarized in the following sections below. An additional task by one of the groups was to take a cross section of the river reckoning from the bridge top which will be used for the derivation of a rating curve and a rating table for Arayat.

Float Method

The float method is generally applied for floods which discharge observation by current meter and all other techniques is impractical to use. As the name of the method implies, floats are thrown down into the river and their travelling time in a certain cross section of the river is measured thus, the average velocity in the section can be estimated. This method is the easiest, most practical and cost-effective method for discharge measurements during high flow.

Floats are thrown from bridges but there are emergency cases when they are thrown from the river bank. Float materials used for this study are improvised using bamboo sections of about 1-meter length, filled with 3/4 –full sand with a flag marker for visibility. Travelling time of the float was determined using a stopwatch.

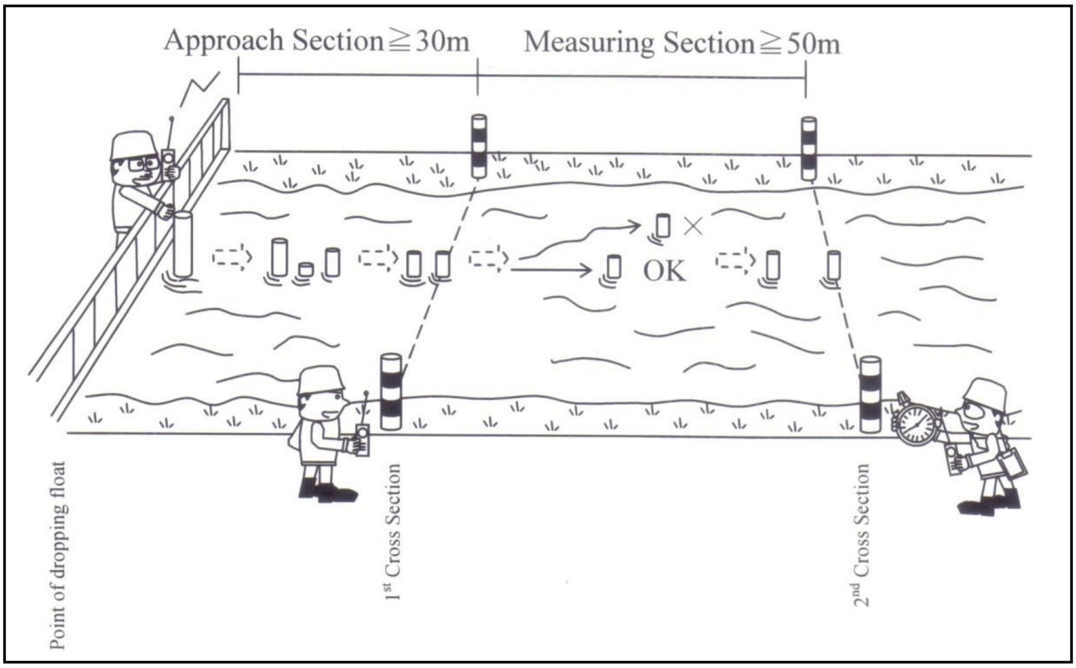


Figure 1. Discharge measurement by float method.

A requirement for this method is a straight section of the river with enough length consisting of approach section and measurement section. The approach section is from dropping point to the first cross section which requires at least 30-meter distance in order to enable a float to maintain its draft. The measurement section is from the first cross section to the second cross section in order to measure the travelling time of a float which requires at least 50 meters. However, in practice, the distance is determined by the maximum velocity multiplied by 10-15 seconds. In Japan, distances ranging from 50 to 100 meters are popular. Too long section causes error in measurement due to variation of stage for long travelling time.

Since discharge observation by float is conducted during high floods, it is difficult to measure water depth simultaneously thus, only water level is measured during discharge observation by float and cross section survey is conducted to estimate discharge area soon after the flood.

In the duration of the fieldwork activity, the two cross sections were measured by boat method and utilizing an echo sounder to record water depth and a range-finder to determine the horizontal distance of every vertical reckoned from the water edge. Water levels upon the start of observation and at the end were noted to be used to estimate the discharge area of each cross-section using the equation $Q_i = V_i \times A_i$.

Slope Area Method

The slope-area method consists of using the slope of the water surface in a uniform reach of channel and the average cross-sectional area of that reach to give a rate of discharge. The discharge may be computed from the Manning formula:

$$Q = (1.486/n)\ A\ R_h^{2/3}\ S^{1/2}$$

where:
Q = discharge (m^3/s)
A = mean area of the channel cross section (m^2)
R_h = mean hydraulic radius of the channel (m)
σ = energy slope of the flow
n = a roughness factor depending on the character of the channel lining

A fairly straight reach of the channel should be chosen with length of equal or greater than 75 times the mean water depth and is a contracting area. If the reach is free of rapids, abrupt falls, or sudden contractions or expansions, then the water surface slope is the same as the energy slope.

The slope, σ, or the fall may be determined by dividing the difference in the water surface elevations at the two ends of the reach represented by the high water marks in cross sections 1 and 3 by the total length of the reach. A value of greater than or equal to 0.15 or greater than or equal to the velocity head should be attained.

The hydraulic radius, R_h, is defined as the area of the cross section divided by its wetted perimeter. Where the channel or canal is of regular cross section, and the depths at the ends of the course are equal, the area and the wetted perimeter will be constant through-out the course. In irregular channels, the area and the wetted perimeter at several cross sections will be required, and a mean value will be used in computing the hydraulic radius.

The factor, *n*, depends on the character of the channel. It may vary from 0.010, where conditions approaching the ideal are maintained, to 0.060, where the channel is strewn with stones and debris or is about one-third full of vegetation.

Because the proper selection of the roughness factor, *n*, for many streams is difficult and is, at best, an estimate, the discharge determined by the slope-area method is only approximate. Care must be taken to determine the slope and areas simultaneously if the water levels are changing.

Using the total station, the benchmark (BM) in the old station at the left bank upstream of the Pampanga River was used. The known elevation of 9.114 meters was used to start with the measurements. In this study, a total of 36 Tie Points and 5 BM Backsights were measured taking off from the known elevation in the benchmark to the three cross sections for this method. The following equations were used to compute for the elevations of each TP and the Height of the Instrument. Several readings taken from the total station used were the Vertical Distance (VD), Horizontal Distance (HD) and Horizontal Angle (HA).

$$\text{HI} = \text{BM} + \text{Height of Prism Rod} - \text{BS}$$

$$\text{Unknown Elevation} = \text{HI} + \text{FS} - \text{Height of Prism Rod}$$

where: HI = height of Instrument
BM = Benchmark Elevation
BS = Back Sight (VD reading from total station)
FS = Fore Sight (VD reading from total station)

For easy computations, an excel suite provided by the PRFFWC for automatic discharge computation by slope-area method was provided.

Acoustic Doppler Current Profiler Method

In recent years, advances in technology have allowed the USGS to make discharge measurements by use of an Acoustic Doppler Current Profiler (ADCP). An ADCP uses the principles of the Doppler Effect to measure the velocity of water. The Doppler Effect is the phenomenon we experience when passed by a car or train that is sounding its horn. As the car or train passes, the sound of the horn seems to drop in frequency.

The ADCP uses the Doppler Effect to determine water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. The sound is transmitted into the water from a transducer to the bottom of the river and receives return signals throughout the entire depth. The ADCP also uses acoustics to measure water depth by measuring the travel time of a pulse of sound to reach the river bottom at back to the ADCP.

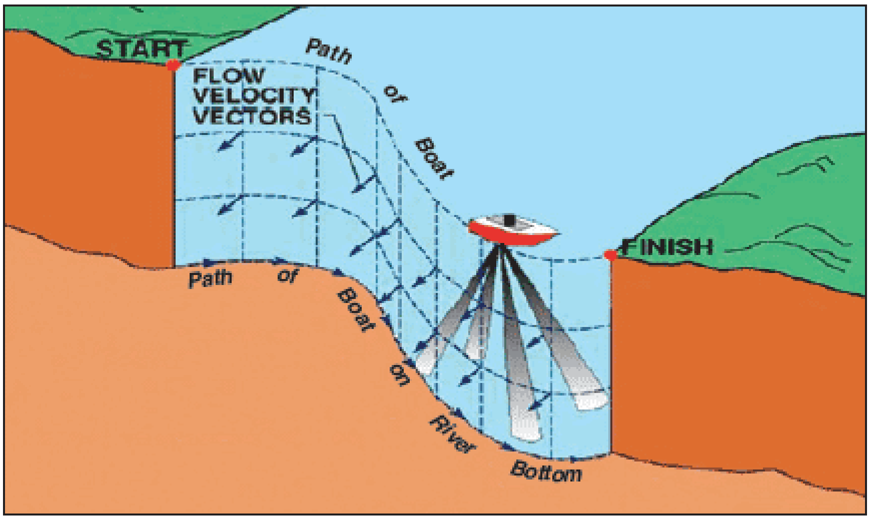


Figure 2. The ADCP Principle of discharge measurement.

To make a discharge measurement, the ADCP is mounted onto a boat or into a small watercraft with its acoustic beams directed into the water from the water surface. The ADCP is then guided across the surface of the river to obtain measurements of velocity and depth across the channel. The river-bottom tracking capability of the ADCP acoustic beams or a Global Positioning System (GPS) is used to track the progress of the ADCP across the channel and provide channel-width measurements. Using the depth and width measurements for calculating the area and the velocity measurements, the discharge is computed by the ADCP using discharge = area x velocity, similar to the conventional current-meter method. Acoustic velocity meters have also been developed for making wading measurements.

The World Meteorological Organization (WMO) guide to stream gauging using ADCP suggests four transects to be measured at certain distances. For this study, a total of eight transects were measured at varying distances estimated from each transect.

Conventional Current Meter Method

The most common method used by the USGS for measuring discharge is the mechanical current-meter method. In this method, the stream channel cross section is divided into numerous vertical subsections. In each subsection, the area is obtained by measuring the width and depth of the subsection, and the water velocity is determined using a current meter. The discharge in each subsection is computed by multiplying the subsection area by the measured velocity. The total discharge is then computed by summing the discharge of each subsection.

Numerous types of equipment and methods are used by USGS personnel to make current-meter measurements because of the wide range of stream conditions throughout the United States. Subsection width is generally measured using a cable, steel tape, or similar piece of equipment. Subsection depth is measured using a wading rod, if conditions permit, or by suspending a sounding weight from a calibrated cable and reel system off a bridge, cableway, or boat or through a hole drilled in ice.

For this study, current meter measurements were taken using the boat method. The Price AA current meter was used with a sounding reel loaded in the boat. Since the water level is significantly low compared from the high flow during the first day of fieldwork, a one point method was used – which is 0.6 from the water surface. Several verticals were measured guided with a tagline to ensure a relatively straight cross section. The calibration equation to be used will be:

$$V = 0.702N + 0.013$$

Rating Curve

If a measurement of the flow is made by the current-meter method on different occasions when the river is flowing at different depths, these measurements can be used to draw a graph of amount of flow against depth of flow. The depth of flow of a stream or river is called stage, and when a curve has been obtained for discharge against stage, the gauging station is described as being rated. Subsequent estimates of flow can be obtained by measuring the stage at a permanent gauging post, and reading off the flow from the rating curve.

If the cross-section of the stream changes through erosion or deposition, a new rating curve has to be drawn up. To plot the rating curve, it is necessary to take measurements at many different stages of flow, including infrequently occurring flood flows. Clearly this can take a long time, particularly if access to the site is difficult, so it is preferable to use some type of weir or flume which does not need to be individually calibrated, and these are discussed in later sections.

For this particular method, a cross section of the river measured from the bridge top using a sounding rope with weights was obtained. With the aid of the excel suite for rating curve from the PRFFWC, the rating curve and table were derived.

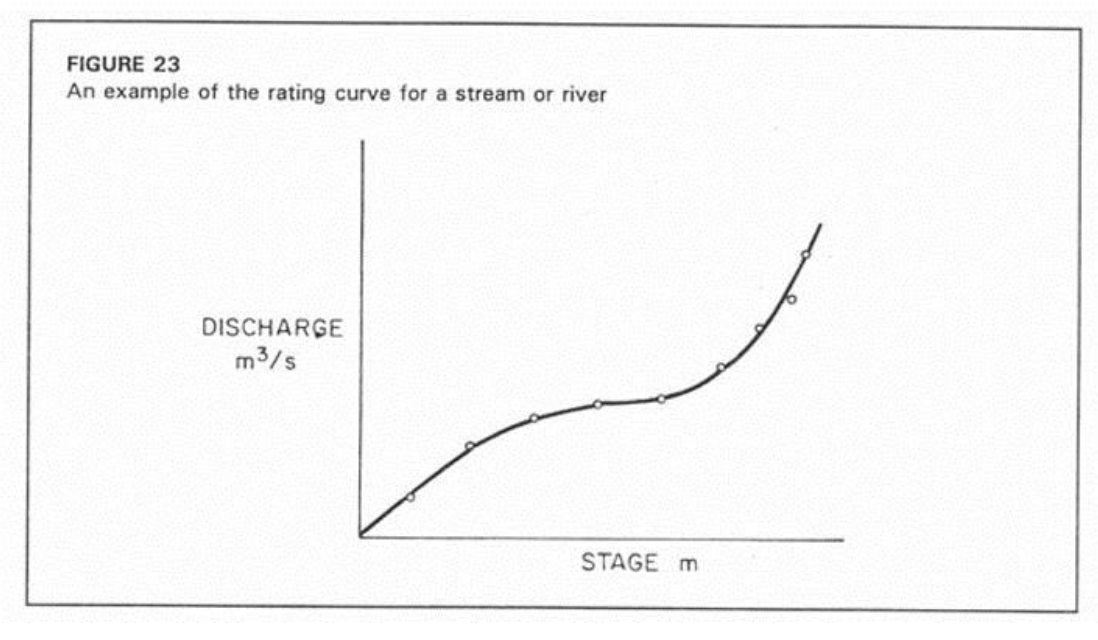


Figure 3. Rating curve sample.

Results and Discussion

After all data has been harmonized, integrated and analyzed, results of the study from the four different discharge measurement methods were summarized in the succeeding tables below. Table 1 summarizes the data for the float method. Since during the actual measurement, water level is relatively high, a discharge of 738.24 m^3 was computed by averaging the discharges at the first and second cross sections established.

Table 1. Summary of measurements for the Float Method.

Station	Time (s)	Distance (m)	Velocity (m/s)	Cross Section 1			Cross Section 2		
				HD (m)	Depth (m)	Q (cms)	HD (m)	Depth (m)	Q (cms)
0				0.0			0.0		
1	129	100	0.775	61.0	4.3	136.67	63.0	4.9	159.53
2	106	100	0.943	82.0	6.4	102.64	84.0	6.0	127.36
3	75	100	1.333	95.0	9.2	202.40	108.0	7.0	182.00
4	100	100	1.000	115.0	11.6	208.80	123.0	7.6	117.80
5	125	100	0.800	131.0	7.2	112.32	139.0	6.9	126.96
6				154.0			169.0		
Total						**762.83**			**713.65**
Average*						**738.24**			
*Mid-section method was used to compute for the Q									

Based on the table of measurements above, the two cross sections were plotted as shown in the succeeding figures. The plots of the cross sections show that the water depth increases from right to left bank with the deepest portion recorded at about 11.6 and 7.6 meters, for the first and second cross sections, respectively.

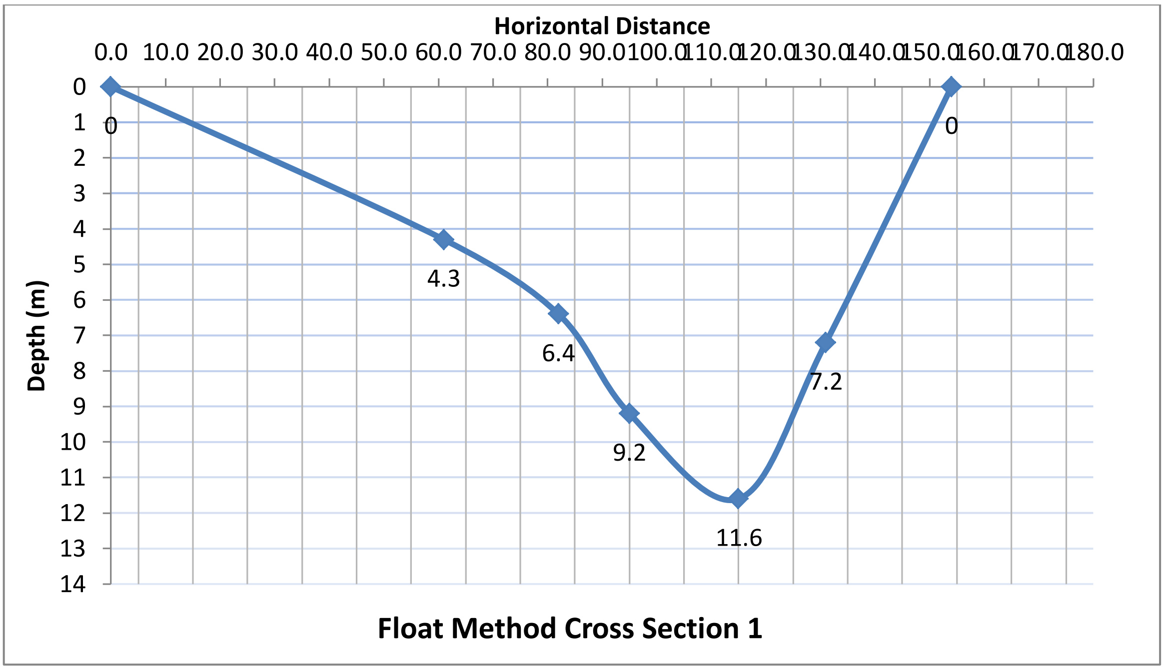


Figure 4. Float Cross Section 1 Profile

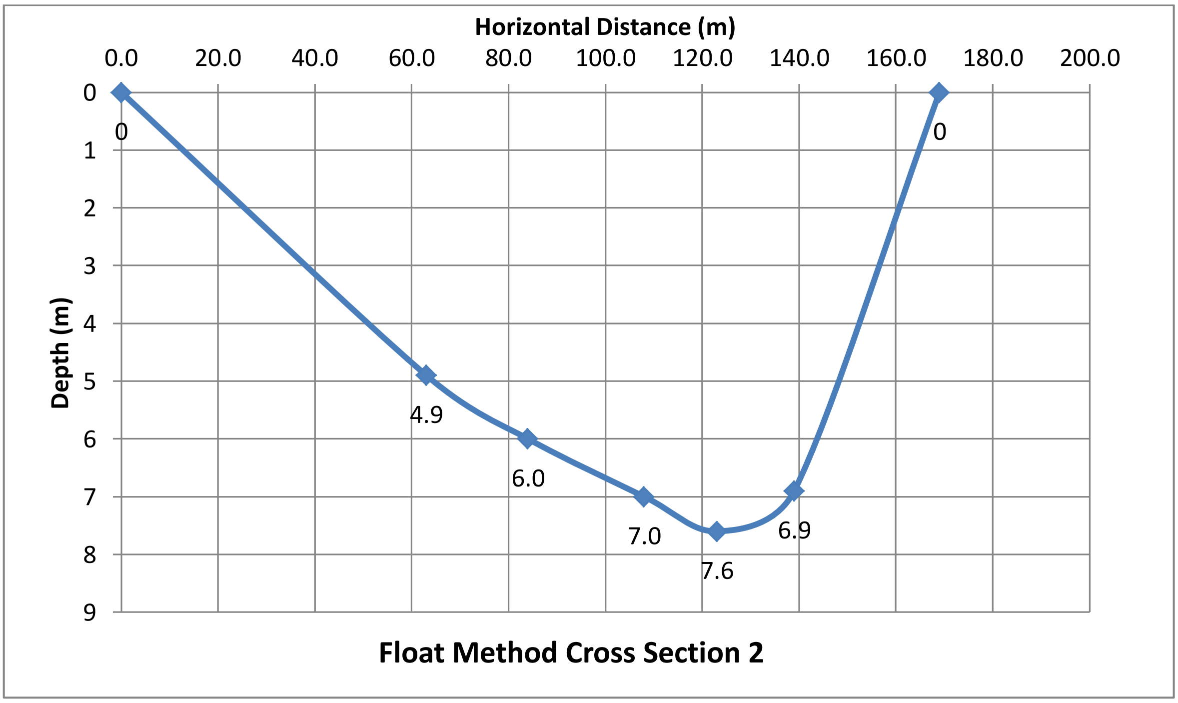


Figure 5. Float Cross Section 2 Profile

On the other hand, the slope area measurements were summarized in Table 2. It appears that the highest water elevation during the flood was at 8.274 meters at the right bank of the first cross section.

Table 2. Summary of measurements for the Slope-Area Method.

Station	VD (m)	HA (deg-min-sec)	HD (m)	Elevation m)	Remarks
BS1	0.776	24° 34' 00"	8.642	9.538	
TP1	-0.792	225° 45' 20"	209.487	7.546	
BS2	-0.586	119° 20' 20"	37.278	9.332	
TP2	0.142	233° 09' 20"	104.74	8.274	HWM1 RB
TP3	-0.526	248° 45' 20"	35.468	7.606	
TP4	0.326	247° 59' 00"	11.93	8.458	
TP5	0.197	107° 14' 00"	19.707	8.329	
TP6	-0.889	84° 18' 40"	50.677	7.243	
BS3	0.68	293° 30' 90"	7.821	8.066	
TP8	-1.735	78° 04' 20"	103.399	5.131	
TP9	-3.018	77° 58' 00"	109.198	3.848	RB WE1
TP10	0.713	79° 50' 40"	284.873	7.579	HWM1 LB
TP7	-1.018	82° 34' 00"	77.728	5.848	
TP11	0.906	79° 51' 20"	212.274	7.772	
TP12	-0.743	80° 06' 40"	201.579	6.123	
TP13	-3.057	80° 22' 40"	199.509	3.809	LB WE1
BS4	0.263	350° 48' 00"	108.521	8.483	
TP14	-1.12	80° 14' 20"	96.287	3.763	RB WE2
TP15	-0.996	69° 56' 00"	93.386	6.287	
TP16	-3.421	72° 10' 20"	243.28	3.862	LB WE2
TP17	1.092	72° 37' 20"	250.296	8.375	
TP18	-0.746	70° 34' 40"	87.386	6.537	
TP19	0.539	73° 21' 00"	302.738	7.822	HWM2 LB
TP20	-0.663	69° 50' 40"	67.002	6.62	
TP21	0.083	61° 13' 00"	26.601	7.366	
TP22	-0.041	20° 11' 40"	8.162	7.242	
TP23	1.039	290° 51' 20"	16.994	8.322	
TP24	0.973	255° 05' 20"	38.451	8.256	HWM2 RB
BS5	0	351° 28' 20"	277.511	8.746	
TP25	-0.867	91° 02' 00"	100.313	4.279	RB WE3
TP26	-3.41	91° 21' 40"	249.356	4.136	LB WE3
TP27	-1.507	90° 42' 00"	97.097	6.039	
TP28	0.788	87° 36' 20"	290.393	7.534	HWM3 LB
TP29	-1.098	91° 01' 20"	257.446	6.448	
TP30	-0.845	92° 00' 00"	93.696	6.701	
TP31	-0.379	100° 18' 20"	53.608	7.167	
TP32	0.1	122° 52' 40"	9.815	7.646	
TP33	-0.018	238° 39' 40"	15.247	7.528	
TP34	0.94	256° 58' 40"	19.332	8.486	
TP35	0.96	267° 08' 40"	45.271	8.506	
TP36	0.683	267° 33' 20"	94.086	8.229	HWM3 RB

Given the data in Table 2, the three cross sections of the river were plotted taking into consideration the highest water mark at both banks as shown in the figures below. All the measurements were then used in the excel suite for the automation of calculations and is summarized in the figures below.

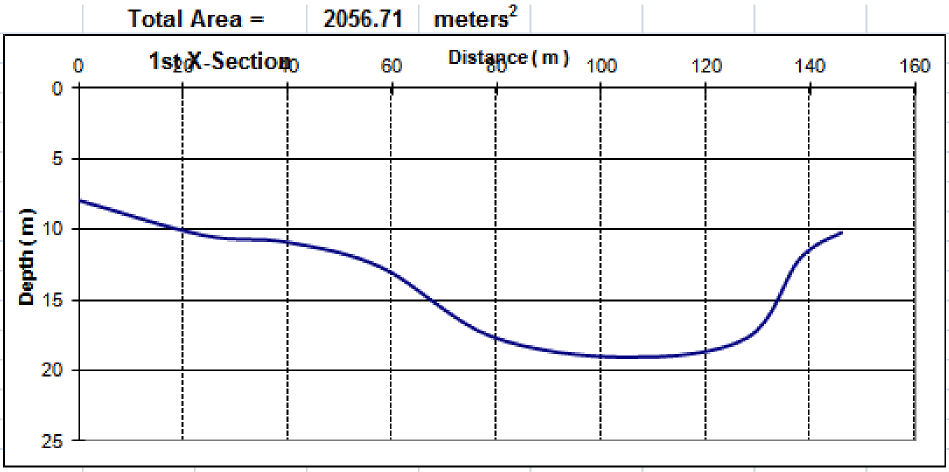


Figure 6. Slope Area first Cross Section

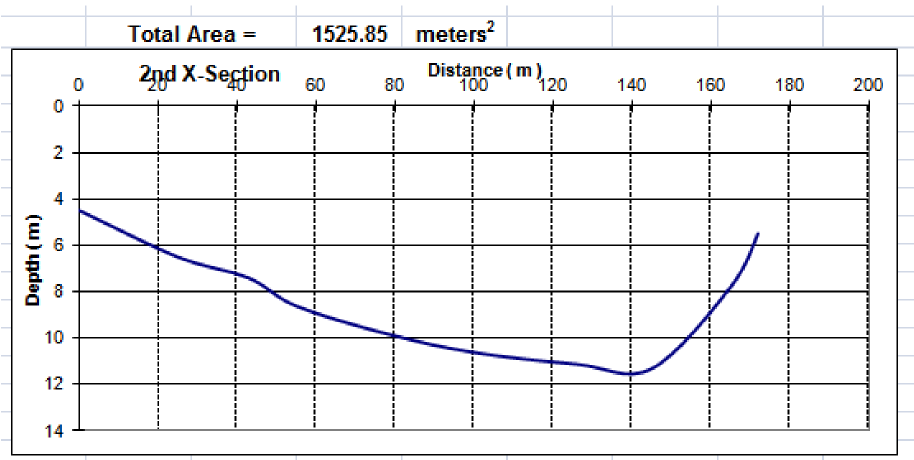


Figure 12. Slope Area Cross Second Section

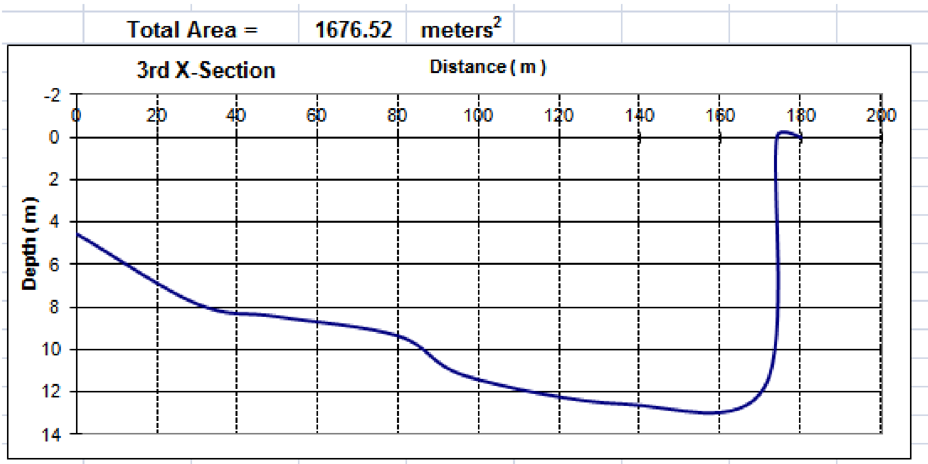


Figure 7. Slope Area Thrird Cross Section

Republic of the Philippines
Department of Science and Technology
PHILIPPINE ATMOSPHERIC, GEOPHYSICAL AND ASTRONOMICAL SERVICES ADMINISTRATION (PAGASA)
Pampanga River Flood Forecasting and Warning Center (PRFFC)
Agham Road, Diliman, Quezon City

FFB, PAGASA

Slope-Area Summary Sheet (3-Section)

Station:	*Arayat*	River:	*Pampanga River*
Flood Date:	*13-Oct-13*	Drainage Area:	
Gauge Height:		Meas. #:	

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X - Section Properties:

			Highwater Marks										
X-Sect.	Width	Area	Left Bank	Right Bank	Average Water Sfc.	d_m (mean depth)	n	r	K	K^3/A^2	α	F	State of Flow
1	146.00	2056.71	7.579	8.274	7.9265	14.087	0.03	13.84	398751.9	1.5E+10	1	0.099	tranquil
2	172.00	1525.85	7.822	8.256	8.039	8.871	0.03	8.83	218797.6	4.5E+09	1	0.168	tranquil
3	180.00	1676.52	7.534	8.229	7.8815	9.314	0.03	9.24	247827.2	5.4E+09	1	0.149	tranquil

note: Assume no sub-divided sections, hence α is always 1!!

Reach Properties:

Reach	Length	Δh Fall	k	reach condition	K_U/K_D	K_U/K_D Condition	Ave. A	**Q** by formula	Ave V
1-2	100	-0.1125	0	contracting	1.822469	poor	1791.280	x	x
2-3	200	0.1575	0.5	expanding	0.882863	good	1601.182	9334.831	5.830
1-2-3	300	0.045	0	contracting	1.608991	poor	1753.026	**2389.701**	1.363

n - roughness coefficient
K - conveyance
K_w - wtd. conveyance (Geometric mean of K of 2 sections).
F - Froude no.(indicates the state of flow).
α - velocity head coefficient
r - hydraulic radius
k - coefficient for differences in velocity heads between 2 sections.
h_v - velocity head
h_f - energy loss due to boundary friction in the reach.
S - friction slope

Discharge Computation:(comparison)

		h_v							
Reach	Assumed Q	U/S	D/S	Δh_v	h_f	$S=h_f/L$	$S^{1/2}$	K_w	**Computed Q**
1-2	x	0.068878	0.125144	-0.05627	-0.16877	-0.00169	x	295374.2	x
2-3	9334.831	0.125144	0.103661	0.021483	0.168241	0.000841	0.029004	232860.5	6753.786

Rem:

$Q_{1\text{-}2\text{-}3}$ = **2389.70** cumecs

Discharge

Figure 8. Slope-Area Summary using the PRFFWC Excel Suite

The slope of the river which was obtained by taking the difference of the highest water elevations from the first and the last cross sections divided by the total reach. A slope value of 0.00015 was then computed. The roughness coefficient used was

0.030. Substituting these values together with other parameters computed in the Manning's formula, a discharge of 2,389.70 was obtained for this method.

For the ADCP method, the discharges computed by the instrument in the eight transects were summarized in Table 3. An average discharge of 288.881 m^3 was recorded. Supporting graphs and time series plots were included in the succeeding figures.

Table 3. Summary of measurements for the ADCP.

Transect	Discharge (Q in cms)
1	292.871
2	292.668
3	304.15
4	334.503
5	250.691
6	238.568
7	296.384
8	301.213
Average	**288.881**

The first transect was measured starting off at the downstream of the bridge reckoning from the left bank. A discharge of 292.871 m^3 was recorded.

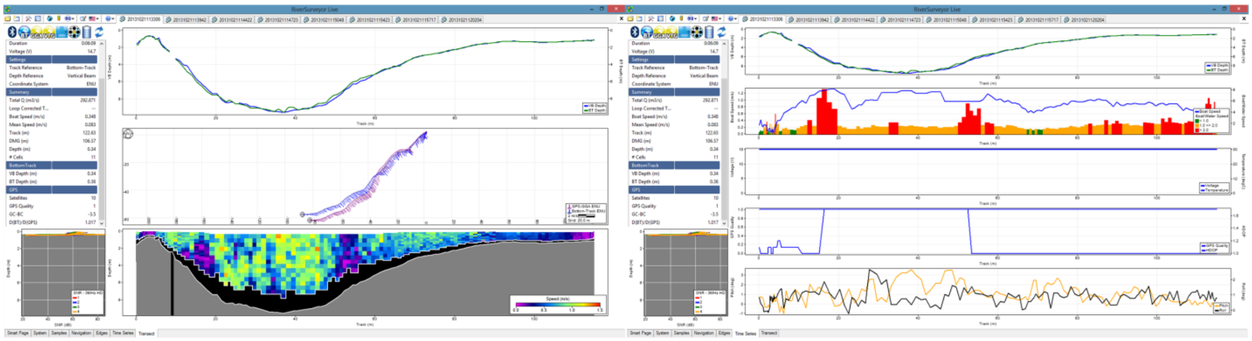

Figure 15. Transect and Time Series Plot 1

The second transect was measured from the right bank after the first transect. A discharge of 292.668 m^3 was recorded. A little difference was noted.

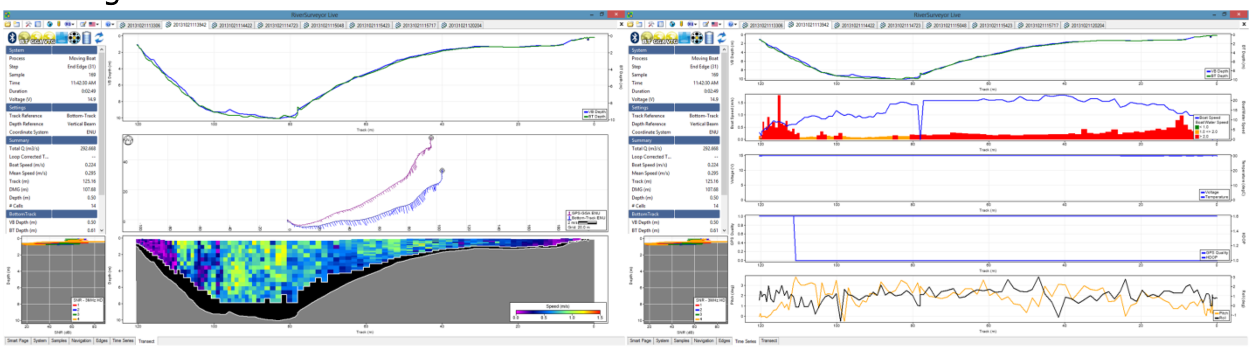

Figure 9. Transect and Time Series Plot 2

The third transect was measured from the left bank which is a few meters away from the first transect. A discharge of 304.15 m^3 was recorded. An increase of about 12 m^3 was noted.

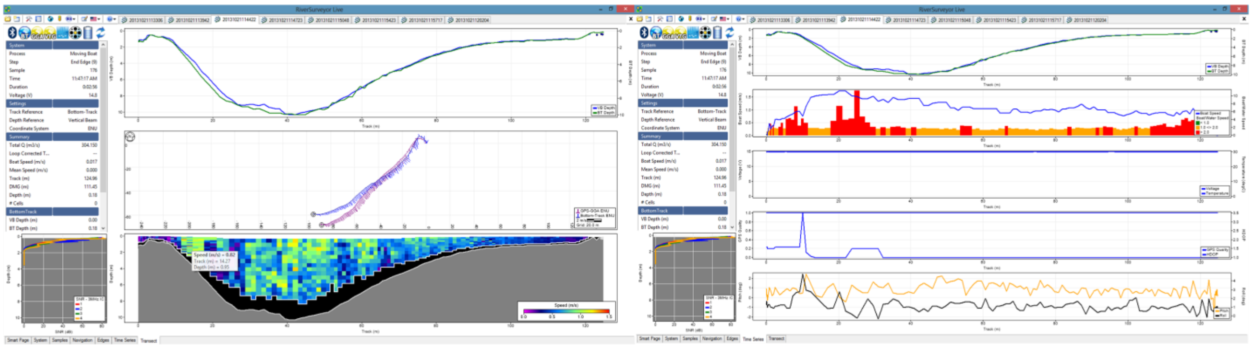

Figure 10. Transect and Time Series Plot 3

The fourth transect was measured from the right bank which is a few meters away from the second transect. A discharge of 334.503 m^3 was recorded. Another increase of about 30 m^3 was noted. This transect gave the highest discharge out of the eight.

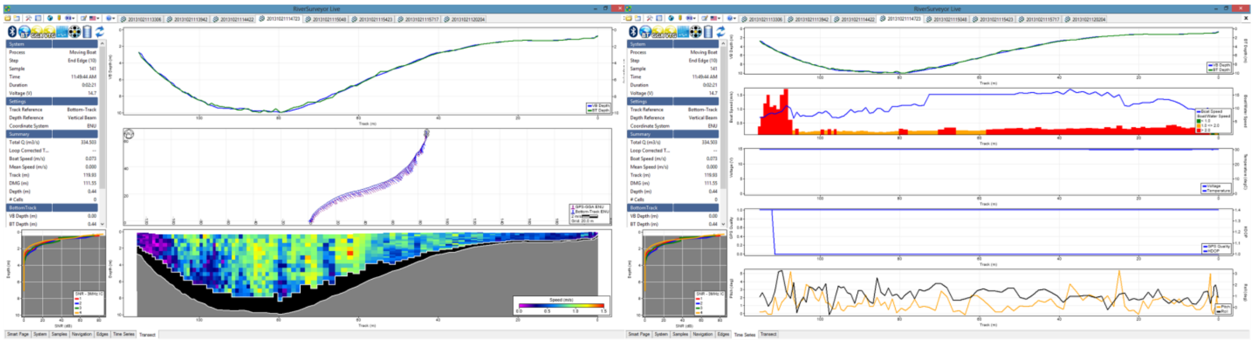

Figure 11. Transect and Time Series Plot 4

The fifth transect was measured from the left bank which is a few meters away from the third transect. A discharge of 250.691 m^3 was recorded. An abrupt decrease was noted which may be due to elevation gradient.

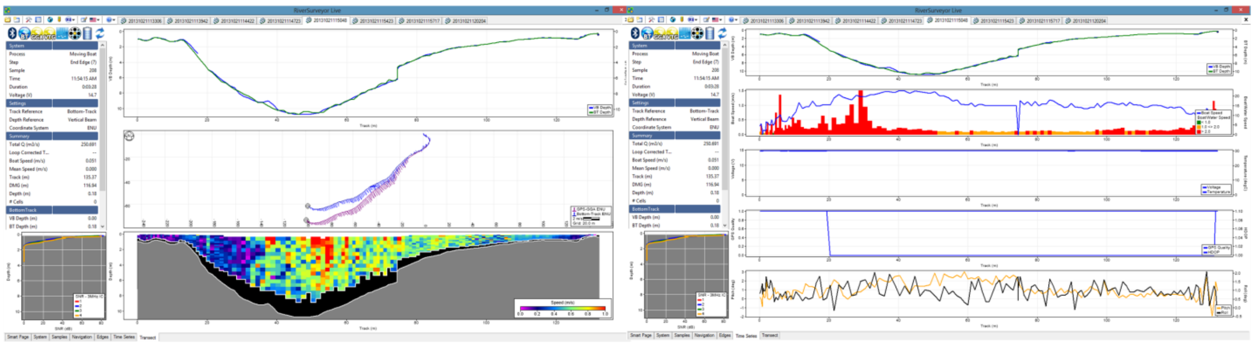

Figure 12. Transect and Time Series Plot 5

The sixth transect was measured from the right bank which is a few meters away from the fourth transect. A discharge of 238.568 m^3 was recorded. Now the water elevation might be decreasing.

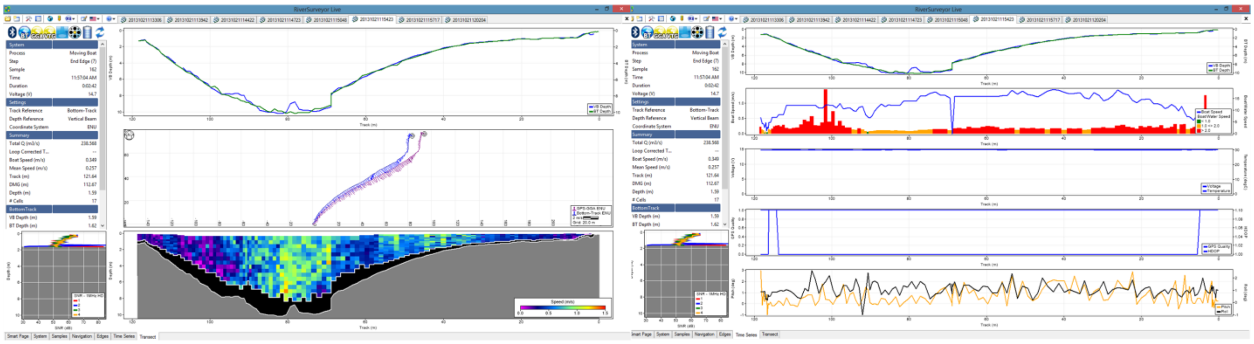

Figure 13. Transect and Time Series Plot 6

The seventh transect was measured from the right bank which is a few meters away from the fifth transect. A discharge of 296.384 m^3 was recorded.

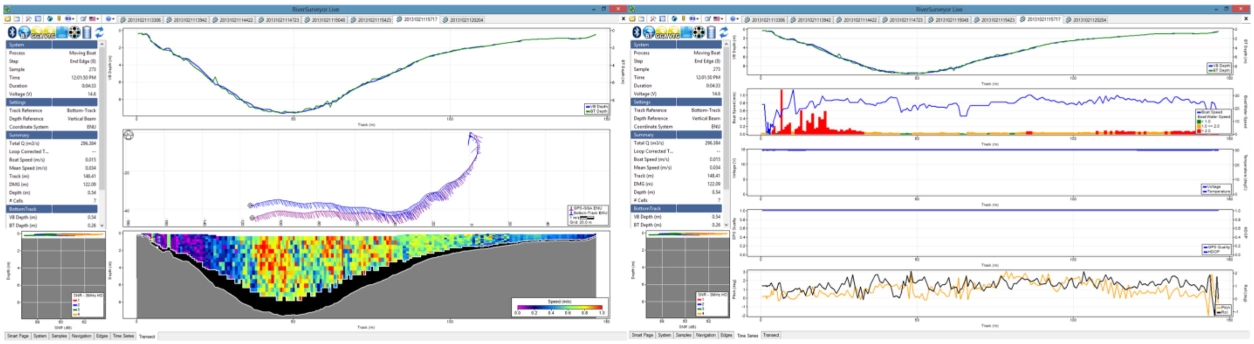

Figure 14. Transect and Time Series Plot 7

Finally, the eighth transect was measured from the right bank which is a few meters away from the sixth transect. A discharge of 301.213 m^3 was recorded.

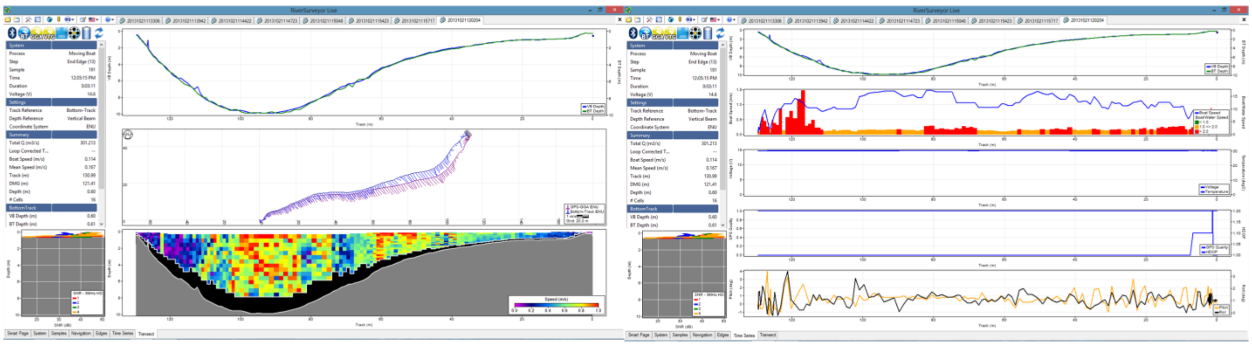

Figure 15. Transect and Time Series Plot 8

The ADCP has several salient points which make discharge measurement fast and easy. In the past, measuring the current depth profile required the use of long strings of current meters but this is no longer needed as ADCP measures small scale currents. Unlike previous technology, ADCPs measure the absolute speed of the water, not just how fast one water mass is moving in relation to another. It measures a water column up to 1000m long.

However, it also presents disadvantages such as a.) High frequency pings yield more precise data, but low frequency pings travel farther in the water. So scientists must make a compromise between the distance that the profiler can measure and the precision of the measurements; b.) ADCPs set to "ping" rapidly also run out of batteries rapidly; c.) If the water is very clear, as in the tropics, the pings may not hit enough particles to produce reliable data; d.) Bubbles in turbulent water or schools of swimming marine life can cause the instrument to miscalculate the current; and e.) Users must take precautions to keep barnacles and algae from growing on the transducers.

As for the current meter method, velocity was measured at 0.6 of the water depth and beeps were recorded within a minute. Out of the 20 verticals, a few were not able to measure velocity due to decreasing water depth from the left bank to the right bank. Another factor which has made measurement impossible is that the flow of the water is controlled by the closing of the Cong Dadong Dam upstream. Water level also decreased since Day 1 of the fieldwork measurements. Several notes in the table below can be found such that entries for the No. of beeps = "unable" which accounts for the negligible flow of water although the current meter can still measure and No. of beeps = "NA" wherein water depth is too shallow or the river bed is already exposed which make it impossible to make measurements.

Table 4. Summary of measurements for the current meter method.

Station	**Distance from Left Water Edge (m)**	**Water Surface Depth (m)**	**0.6 Depth (m)**	**Velocity**	
				No. of Revolutions	**Time (sec)**
1	1	NA	NA	Unable	60
2	6	1	0.4	Unable	60
3	9	2.1	0.84	Unable	60
4	12	3.17	1.268	Unable	60
5	16	4.7	1.88	1	60
6	21	6	2.4	6	61
7	26	6.8	2.72	10	61
8	31	8.1	3.24	10	61
9	36	8.6	3.44	13	62
10	41	8.11	3.244	8	63
11	46	8.05	3.22	5	65
12	51	7.4	2.96	9	75
13	56	6.5	2.6	5	30
14	61	5.42	2.168	1	45
15	66	3.62	1.448	7	66
16	71	2.75	1.1	Unable	60
17	76	1.8	0.72	Unable	75

18	81	0.9	0.36	NA	NA
19	86	0.35	0.14	NA	NA
20	98.3	NA	NA	NA	NA

Discharge measurement taken from the current meter method is a little unreliable due to some limitations during the fieldwork. The flow of the river is affected by the presence of a dam upstream which was closed in order to divert waters coming from the headwaters for irrigation purposes. Water level decreased significantly from day one up to day four thereby making it difficult to measure velocity at a given depth. One more thing is, the instrument used is quite old and is no longer at par with its calibration status.

The discharge measurements from all the groups during the fieldwork was collated and summarized in Table 5 for comparison.

Table 5. Summary of discharge measurements (m^3) for the four methods.

Method	Float	Slope-Area	ADCP	Current Meter
Day 1	**738.24**	3, 983.73	466.911	311.48
Day 2	614.02	**2, 389.70**	441.287	325.7
Day 3	493.163	3, 440.34	**288.881**	293.42
Day 4	240.62	3, 579.19	237.668	**13.86**

Results from the different methods for the four-day actual fieldwork reveal a decreasing pattern from Day 1 to Day 4. Discharge is practically high on the first day for all of the methods while a few deviations were also seen. All the measurements taken were implemented and analyzed presenting some problems in the final computations. Although the values computed vary, it is important to note that the correct process was understood and measurements can be improve in the future if similar task will be done.

Aside from the four methods of discharge measurement, an additional cross section taken from the bridge was also taken and used in the determination of the rating curve and rating table for Arayat. At different gauge heights, discharges were computed and plotted to come up with the rating curve. Similarly, a graph of the gauge height and area was also derived.

Table 6. Discharge at several gauge heights in Arayat.

Pampanga River @ Arayat							
(based on cross-section undertaken on October, 2013)							
Elevation of "0" of S.G.=		0.082	m.(AMSL)				
n=	0.030	I=	0.00015				
Elevation	Equivalent	Area	Width	W.P.	hyd radius	Discharge	Remarks
MSL (m)	G.H.(m)	a (m^2)	w (m)	s	r	Q (cumecs)	
15.40	15.320	3363.89	292.34	302.21	11.13	6846.29	
15.00	14.918	3247.38	291.50	300.97	10.79	6473.36	
14.00	13.918	2956.91	288.60	297.38	9.94	5581.85	
13.00	12.918	2670.61	286.30	294.09	9.08	4745.56	
12.00	11.918	2385.26	283.15	290.25	8.22	3965.54	
11.00	10.918	2104.14	281.00	287.13	7.33	3240.86	
10.00	9.918	1824.65	278.00	283.48	6.44	2577.59	
9.00	8.918	1548.21	275.30	279.97	5.53	1976.52	
8.00	7.918	1291.18	236.10	240.54	5.37	1616.03	
7.00	6.918	1053.37	162.40	166.46	6.33	1471.25	
6.00	5.918	902.84	137.90	141.81	6.37	1266.12	
5.00	4.918	769.53	128.20	131.89	5.83	1018.18	
4.00	3.918	643.90	122.10	125.45	5.13	782.18	
3.00	2.918	525.10	116.30	119.21	4.40	576.02	
2.00	1.918	412.62	108.00	110.58	3.73	405.26	
1.00	0.918	310.25	98.00	100.34	3.09	268.82	
0.50	0.418	262.09	93.50	95.73	2.74	209.40	
-1.00	-1.082	163.04	56.40	57.80	2.82	132.88	
-2.00	-2.082	110.61	40.90	42.35	2.61	85.63	
-3.00	-3.082	72.23	36.90	37.84	1.91	45.37	
-4.00	-4.082	39.10	30.70	31.30	1.25	18.51	
-5.00	-5.082	11.85	25.00	25.27	0.47	2.92	

Given the information on the table above, the rating equation was derived as shown below. The values in this equation were then used to compute for the rating table values.

Rating Curve Equation: $$Q = 0.026\ [H - (-10.10)]^{3.851}$$

Table 7. Rating Table for Arayat Station in October, 2013

Rating Table for: *Arayat* Date: *October, 2013*
River: *Pampanga* Location: *San Agustin, Arayat, Pampanga*
Elevation of S.G. "0" reading: *0*
Rating Curve Equation Coefficients: **a =** ***0.026*** **Ho=** ***-10.100*** **b^=** ***3.851***
Range of G.H.: Min. G.H. = ***0.082*** Max. possible G.H.= ***11.08***
Remarks: *readings based on staff gage and not in MSL*

G.H.(m)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.1	197.76	198.51	199.26	200.01	200.77	201.53	202.29	203.05	203.81	204.58
0.2	205.35	206.12	206.89	207.66	208.44	209.22	210.00	210.78	211.57	212.35
0.3	213.14	213.93	214.73	215.52	216.32	217.12	217.93	218.73	219.54	220.35
0.4	221.16	221.97	222.79	223.61	224.43	225.25	226.07	226.90	227.73	228.56
0.5	229.39	230.23	231.07	231.91	232.75	233.60	234.44	235.29	236.15	237.00
0.6	237.86	238.71	239.58	240.44	241.30	242.17	243.04	243.91	244.79	245.67
0.7	246.55	247.43	248.31	249.20	250.09	250.98	251.87	252.77	253.67	254.57
0.8	255.47	256.37	257.28	258.19	259.10	260.02	260.94	261.86	262.78	263.70
0.9	264.63	265.56	266.49	267.42	268.36	269.30	270.24	271.18	272.13	273.08
1.0	274.03	274.98	275.94	276.90	277.86	278.82	279.79	280.76	281.73	282.70

1.1	283.68	284.65	285.63	286.62	287.60	288.59	289.58	290.58	291.57	292.57
1.2	293.57	294.57	295.58	296.59	297.60	298.61	299.63	300.65	301.67	302.69
1.3	303.72	304.75	305.78	306.81	307.85	308.89	309.93	310.97	312.02	313.07
1.4	314.12	315.18	316.24	317.30	318.36	319.42	320.49	321.56	322.64	323.71
1.5	324.79	325.87	326.96	328.04	329.13	330.22	331.32	332.42	333.52	334.62
1.6	335.72	336.83	337.94	339.06	340.17	341.29	342.41	343.54	344.66	345.79
1.7	346.93	348.06	349.20	350.34	351.48	352.63	353.78	354.93	356.09	357.24
1.8	358.40	359.57	360.73	361.90	363.07	364.25	365.42	366.60	367.79	368.97
1.9	370.16	371.35	372.55	373.74	374.94	376.14	377.35	378.56	379.77	380.98
2.0	382.20	383.42	384.64	385.87	387.10	388.33	389.56	390.80	392.04	393.28
2.1	394.53	395.77	397.03	398.28	399.54	400.80	402.06	403.33	404.60	405.87
2.2	407.14	408.42	409.70	410.99	412.27	413.56	414.86	416.15	417.45	418.75
2.3	420.06	421.37	422.68	423.99	425.31	426.63	427.95	429.28	430.61	431.94
2.4	433.28	434.61	435.95	437.30	438.65	440.00	441.35	442.71	444.07	445.43
2.5	446.80	448.17	449.54	450.91	452.29	453.67	455.06	456.44	457.84	459.23
2.6	460.63	462.03	463.43	464.84	466.25	467.66	469.08	470.50	471.92	473.34
2.7	474.77	476.20	477.64	479.08	480.52	481.96	483.41	484.86	486.32	487.78
2.8	489.24	490.70	492.17	493.64	495.11	496.59	498.07	499.55	501.04	502.53
2.9	504.02	505.52	507.02	508.52	510.03	511.54	513.05	514.57	516.09	517.61
3.0	519.14	520.67	522.20	523.74	525.28	526.82	528.37	529.92	531.47	533.03
3.1	534.59	536.15	537.72	539.29	540.86	542.44	544.02	545.61	547.19	548.78
3.2	550.38	551.98	553.58	555.18	556.79	558.40	560.01	561.63	563.25	564.88
3.3	566.51	568.14	569.78	571.41	573.06	574.70	576.35	578.00	579.66	581.32
3.4	582.98	584.65	586.32	588.00	589.67	591.36	593.04	594.73	596.42	598.12
3.5	599.81	601.52	603.22	604.93	606.65	608.36	610.08	611.81	613.53	615.27
3.6	617.00	618.74	620.48	622.23	623.98	625.73	627.49	629.25	631.01	632.78
3.7	634.55	636.32	638.10	639.88	641.67	643.46	645.25	647.05	648.85	650.66
3.8	652.46	654.28	656.09	657.91	659.73	661.56	663.39	665.22	667.06	668.90
3.9	670.75	672.60	674.45	676.31	678.17	680.03	681.90	683.77	685.65	687.53
4.0	689.41	691.30	693.19	695.09	696.99	698.89	700.79	702.70	704.62	706.54
4.1	708.46	710.38	712.31	714.25	716.18	718.13	720.07	722.02	723.97	725.93
4.2	727.89	729.85	731.82	733.80	735.77	737.75	739.74	741.73	743.72	745.71
4.3	747.71	749.72	751.73	753.74	755.75	757.77	759.80	761.83	763.86	765.89
4.4	767.93	769.98	772.03	774.08	776.13	778.19	780.26	782.33	784.40	786.48
4.5	788.56	790.64	792.73	794.82	796.92	799.02	801.13	803.23	805.35	807.47
4.6	809.59	811.71	813.84	815.98	818.11	820.26	822.40	824.55	826.71	828.87
4.7	831.03	833.20	835.37	837.54	839.72	841.91	844.09	846.29	848.48	850.68
4.8	852.89	855.10	857.31	859.53	861.75	863.98	866.21	868.44	870.68	872.92
4.9	875.17	877.42	879.68	881.94	884.20	886.47	888.74	891.02	893.30	895.59
5.0	897.88	900.18	902.47	904.78	907.09	909.40	911.71	914.04	916.36	918.69
5.1	921.02	923.36	925.71	928.05	930.40	932.76	935.12	937.49	939.86	942.23
5.2	944.61	946.99	949.38	951.77	954.16	956.56	958.97	961.38	963.79	966.21
5.3	968.63	971.06	973.49	975.93	978.37	980.82	983.27	985.72	988.18	990.64
5.4	993.11	995.58	998.06	1000.54	1003.03	1005.52	1008.01	1010.51	1013.02	1015.53
5.5	1018.04	1020.56	1023.08	1025.61	1028.14	1030.68	1033.22	1035.77	1038.32	1040.87
5.6	1043.43	1046.00	1048.57	1051.14	1053.72	1056.30	1058.89	1061.48	1064.08	1066.68
5.7	1069.29	1071.90	1074.52	1077.14	1079.76	1082.39	1085.03	1087.67	1090.31	1092.96
5.8	1095.62	1098.28	1100.94	1103.61	1106.28	1108.96	1111.64	1114.33	1117.02	1119.72
5.9	1122.42	1125.13	1127.84	1130.56	1133.28	1136.01	1138.74	1141.47	1144.22	1146.96
6.0	1149.71	1152.47	1155.23	1157.99	1160.76	1163.54	1166.32	1169.10	1171.89	1174.69
6.1	1177.49	1180.29	1183.10	1185.92	1188.74	1191.56	1194.39	1197.22	1200.06	1202.91
6.2	1205.76	1208.61	1211.47	1214.34	1217.20	1220.08	1222.96	1225.84	1228.73	1231.63
6.3	1234.53	1237.43	1240.34	1243.26	1246.18	1249.10	1252.03	1254.96	1257.90	1260.85
6.4	1263.80	1266.76	1269.72	1272.68	1275.65	1278.63	1281.61	1284.60	1287.59	1290.58
6.5	1293.59	1296.59	1299.60	1302.62	1305.64	1308.67	1311.70	1314.74	1317.78	1320.83
6.6	1323.89	1326.95	1330.01	1333.08	1336.15	1339.23	1342.32	1345.41	1348.50	1351.60
6.7	1354.71	1357.82	1360.94	1364.06	1367.19	1370.32	1373.46	1376.60	1379.75	1382.90
6.8	1386.06	1389.23	1392.40	1395.57	1398.75	1401.94	1405.13	1408.33	1411.53	1414.74
6.9	1417.95	1421.17	1424.39	1427.62	1430.85	1434.09	1437.34	1440.59	1443.85	1447.11
7.0	1450.37	1453.65	1456.92	1460.21	1463.50	1466.79	1470.09	1473.40	1476.71	1480.02

7.1	1483.35	1486.67	1490.01	1493.34	1496.69	1500.04	1503.39	1506.75	1510.12	1513.49
7.2	1516.87	1520.25	1523.64	1527.03	1530.43	1533.84	1537.25	1540.67	1544.09	1547.52
7.3	1550.95	1554.39	1557.83	1561.28	1564.74	1568.20	1571.67	1575.14	1578.62	1582.10
7.4	1585.59	1589.09	1592.59	1596.10	1599.61	1603.13	1606.65	1610.18	1613.72	1617.26
7.5	1620.81	1624.36	1627.92	1631.48	1635.05	1638.63	1642.21	1645.80	1649.39	1652.99
7.6	1656.60	1660.21	1663.82	1667.45	1671.07	1674.71	1678.35	1681.99	1685.65	1689.30
7.7	1692.97	1696.64	1700.31	1703.99	1707.68	1711.37	1715.07	1718.78	1722.49	1726.20
7.8	1729.93	1733.66	1737.39	1741.13	1744.88	1748.63	1752.39	1756.15	1759.92	1763.70
7.9	1767.48	1771.27	1775.06	1778.86	1782.67	1786.48	1790.30	1794.12	1797.95	1801.79
8.0	1805.63	1809.48	1813.34	1817.20	1821.06	1824.94	1828.82	1832.70	1836.59	1840.49
8.1	1844.39	1848.30	1852.22	1856.14	1860.07	1864.00	1867.94	1871.89	1875.84	1879.80
8.2	1883.76	1887.74	1891.71	1895.70	1899.69	1903.68	1907.68	1911.69	1915.71	1919.73
8.3	1923.76	1927.79	1931.83	1935.87	1939.93	1943.98	1948.05	1952.12	1956.20	1960.28
8.4	1964.37	1968.47	1972.57	1976.68	1980.79	1984.92	1989.04	1993.18	1997.32	2001.47
8.5	2005.62	2009.78	2013.94	2018.12	2022.30	2026.48	2030.67	2034.87	2039.08	2043.29
8.6	2047.50	2051.73	2055.96	2060.19	2064.44	2068.69	2072.94	2077.21	2081.48	2085.75
8.7	2090.03	2094.32	2098.62	2102.92	2107.23	2111.54	2115.86	2120.19	2124.52	2128.87
8.8	2133.21	2137.57	2141.93	2146.29	2150.67	2155.05	2159.44	2163.83	2168.23	2172.64
8.9	2177.05	2181.47	2185.90	2190.33	2194.77	2199.22	2203.67	2208.13	2212.60	2217.07
9.0	2221.55	2226.04	2230.53	2235.03	2239.54	2244.05	2248.57	2253.10	2257.63	2262.17
9.1	2266.72	2271.27	2275.83	2280.40	2284.98	2289.56	2294.15	2298.74	2303.34	2307.95
9.2	2312.57	2317.19	2321.82	2326.45	2331.09	2335.74	2340.40	2345.06	2349.73	2354.41
9.3	2359.09	2363.79	2368.48	2373.19	2377.90	2382.62	2387.34	2392.07	2396.81	2401.56
9.4	2406.31	2411.07	2415.84	2420.61	2425.39	2430.18	2434.98	2439.78	2444.59	2449.40
9.5	2454.23	2459.06	2463.89	2468.74	2473.59	2478.45	2483.31	2488.19	2493.06	2497.95
9.6	2502.84	2507.75	2512.65	2517.57	2522.49	2527.42	2532.36	2537.30	2542.25	2547.21
9.7	2552.17	2557.14	2562.12	2567.11	2572.10	2577.10	2582.11	2587.13	2592.15	2597.18
9.8	2602.21	2607.26	2612.31	2617.37	2622.43	2627.51	2632.59	2637.67	2642.77	2647.87
9.9	2652.98	2658.10	2663.22	2668.35	2673.49	2678.64	2683.79	2688.95	2694.12	2699.29
10.0	2704.47	2709.66	2714.86	2720.07	2725.28	2730.50	2735.72	2740.96	2746.20	2751.45
10.1	2756.71	2761.97	2767.24	2772.52	2777.81	2783.10	2788.40	2793.71	2799.03	2804.35

The succeeding figures describe the relationship between the stage and discharge for Arayat station. Similarly, a graph of the stage-area relationship was also made.

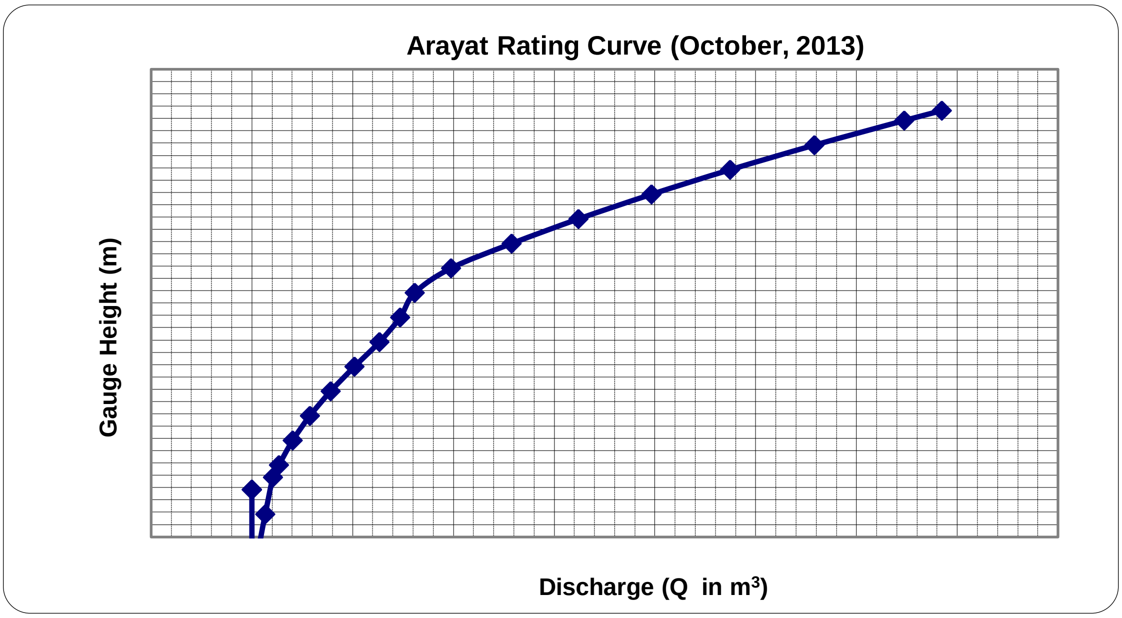

Figure 17. Rating Curve of Arayat Station on October, 2013

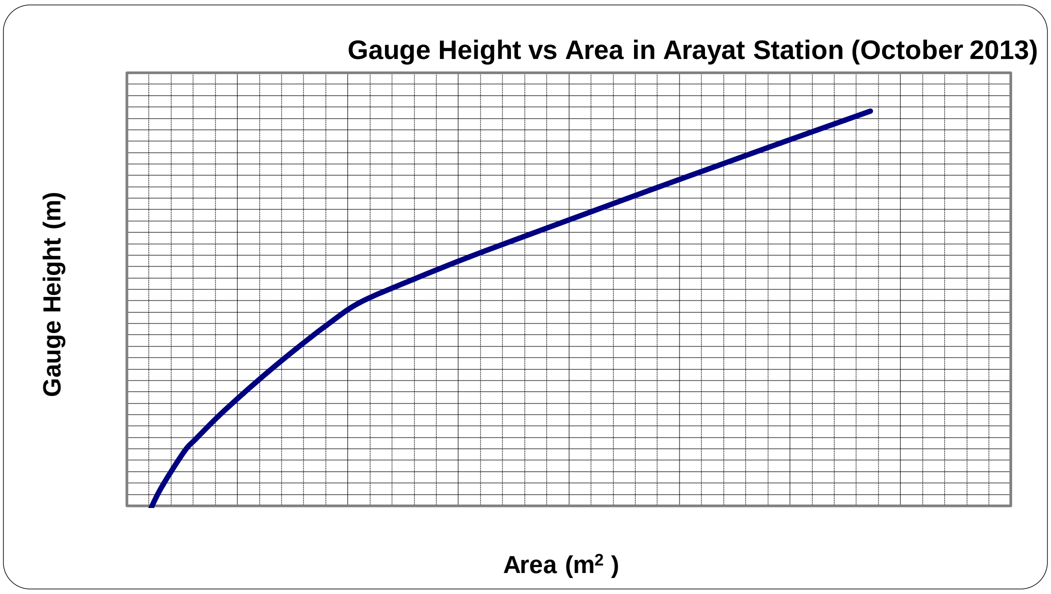

Figure 18. Gauge Height and Area Relationship in Arayat Station.

Summary and Conclusions

Based on the four methods of measurements, it was found out that the different results of discharged measured varies its value. This is because each method conducted by group was in different time and day, differ in stream stage. The nature of the streambeds and differ in wading along the river cross sectioning area.

On the other hand, the group was able to perform the cited objectives using four methods of discharge measurement;

For the float method, it is the most practical and most effective method during high flow for peak discharge determination when all other methods are impossible to be performed.

In the slope area method, it is tedious and exhausted method due to way of calculating discharge, conducting three cross sectional area looking for the highest flood mark on each bank.

In case of current meter method, this is the reliable way of measuring the velocity, in a sense that the instrument was submerged in the water, and divided the streams into subsection were the measurement conducted.

While, the ADCP method, are the most easiest, accurate and sophisticated instrument we have in PAGASA in determining the discharged amount. This high technology instruments were able to provides a detailed profile of water velocity and direction as well as the stream beds by wading it in the river.

Finally, the derivation of a rating curve using mannings equation. Measuring the streams cross sectional area. Rating is a way to see the relationship between water level (stage) and the corresponding discharge of the river. It is also the best input as boundary conditions for flood modelling.

This fieldwork activity is a practical application of the four method of discharge measurement. Problems were encounter and lots of issue was raise over the period, but all of them were solved and this field work activity was a successful, enjoyed and fruitful that served its purpose of training.

Travel Insight

Aside of discharge measurement in Arayat station, this field work activity visited several places in regards to Hydrologist Training Course, additional knowledge gained as this another type of learning outside the room. We visited three dams, La Mesa Dam, Pantabangan Dam, Cong Dadong Dam, Angat Dam and the Calumpit Municipal Disaster Risk Reduction Council, in our visit on the said three dams, we learned how there managed, control and monitor water in the huge reservoir. Flood forecast were discuss by the dam operator as well as the chairman of Calumpit MDRRMC.

The Three Major Dam

The La Mesa Dam and the Pantabangan dam was an earth fill embankment, the first has no gate and spill water as its reach its full capacity while the second have a gate on top of embankment. Different from the Angat Dam compose of concrete water reservoir.

Pantabangan and Angat dam were hydroelectric dam operated by National Power Corporations (NPC) and National Irrigation Administration (NIA) for agricultural purposes, while the La Mesa dam purpose is for domestic water supply and manage by two private concessionaires namely Maynilad Water Services and Manila Water.

In Pantabangan were been able to see the reservoir, the flood forecasting room and its connectivity to the PAGASA Flood Forecast and Warning Center also they conducted lecture about the dam and take some photo on its facilities.

On the Angat dam were been lecture about the dams and able to reach the hydroelectric power plant, see its facilities, lectured about its operation and take photos on the site.

While in La Mesa dam were been looking around the facilities, seen the spill gate, lectured on its operation, water treatment facilities and other matter concerning about water supply in the Metropolitan Manila and nearby provinces.

Cong Dadong dam is different with the three mention dam, because the Cong Dadong dam build for the purpose of irrigation in the province of Pampanga. The dam operation, it stored water for the purpose of irrigation, the gate was lower to be able to divert the water in irrigation canal at stage of 8 meters high.

Calumpit Municipal Disaster Risk Reduction Management Council, the people of Calumpit claims itself to be flood-loving people for the reason they are suffering from flood regularly. In this situation they established the Local Early Warning on Flood Forecasting System the head of the council were discuss about the process they are doing.

Acknowledgement

This fieldwork activity would not be possible without the effort of the training staff and the help and guidance of the PRFFWC and HMD personnel who assisted in the proper conduct of the four discharge measurements and to my group Team Relax for the successful completion of this activity.

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