Technical Report in Stream Gauging II

Presented to:

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in partial fulfilment in Requirements in Stream Gauging II
Hydrological Training Course
Philippine Atmospheric Geophysical Astronomical Services Administration

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1 Introduction

Stream flow, 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). Streamflow 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.

Discharge measurements are made by the several. However, the basic instrument most commonly used in making the measurement is the current meter. The observations of water velocity and depth are usually made by a hydrographer while stationary at each of a number of observation points in the cross section of a stream. This is referred to as the conventional (stationary) method of making a discharge measurement. This method can be done in a bridge, cable car, wading or in a moving boat. Another indirect method in measuring the discharge is the Float Method that uses floats in computing the velocity and Slope- Area method, the most tedious one, that uses uniform-flow equation, preferably the Manning Equation , involving channel characteristics, water-surface profiles and a roughness or retardation coefficient. In contrast to this conventional method is the moving boat method, the Acoustic Doppler Current

1.1 Objectives

- To be able to compute for the discharge of the river in high and low flow.
- To be able to familiarize different kinds of method in computing the discharge, i.e. Float method, Current Meter Method, ADCP, Slope-Area Method
- To be aware in the actual situation in the field.

1.2 Location and Site Description

Figure 1.1: Pampanga River

Pampanga River (formerly known as *Rio Grande de Pampanga* - Great River of Pampanga) is the second largest river in the island of Luzon, next to Cagayan River and the third largest but most important river in the Philippines. It is located in the Central Luzon region and traverses the provinces of Pampanga, Bulacan, and Nueva Ecija. Its headwaters are located at the Sierra Madre and runs a south and southwesterly course for about 260 kilometers until it drains into Manila Bay. The river's basin covers an area of 10,540 km², including the allied basin of Guagua River. The basin is drained through the Pampanga River and via the Labangan Channel into the Manila Bay.

Its main tributaries are Peñaranda and the Coronel-Santor Rivers on the eastern side of the basin and the Rio Chico River from the northwest side. The Angat River joins the Pampanga River at Calumpit, Bulacan via the Bagbag River. Mount Arayat (elevation: 1,026) stands in the middle of the basin. Southeast of Mount Arayat and the Pampanga River is the Candaba Swamp, covering an area of some 250 km². absorbing most of the flood flows from the western slopes of a portion of the Sierra Madre and the overflowing of the Pampanga River via the Cabiao Floodway. This area is submerged during the rainy season but is relatively dry during summer.

Figure 1.2: Site of Fieldwork

The site where we do our fieldwork is located at San Agustin Bridge, Pampanga River, Brgy. Camba, Arayat, Province of Pampanga (Latitude 15°09′57″ N Longitude 120°47′05″E). It is in the southern part and downstream of the Pampanga River. The place just experienced flooding due to typhoon Santi just visited the Province causing its river cross section to change. Traces of flood marks and flood debris are apparent. Its river bed consists mostly of muddy soil and clay. The site is part of the Pampanga River that stretches 200km from the Pantabangan Reservoir to the Laguna Bay. Its riverside consist mostly of tall grasses and shrubs causing us trainee to have a difficult time in doing our activity. There are also a lot of water lilies and debris that are constantly flowing in the river at the first day causing us who do the Current Meter method a lot of problems. There are also a lot of water lilies and debris that are trapped in the pier of the bridges causing the reading of the staff gage hard to see. The river serves also as the main source of livelihood of the citizens along the riverside.

2 METHODS

2.1 Current Meter Method

A current meter measurement, from the name itself, uses some type of current meter to measure stream velocity. It is made by sub-dividing a stream cross section into segments (sometimes referred to as partial areas or panels) and measuring the depth and velocity in a vertical within each segment. The total discharge for a current meter measurement is the summation of the products of the partial areas of the stream cross section and their respective average velocities. There are a lot of methods in finding the velocity in a certain area. These are:

- Vertical-velocity curve
- Two point
- Six-tenths depth
- Two-tenths depth
- Three point
- Surface and subsurface
- Integration

In our case, we use two-point and Three-point Method in finding our average velocity. In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of these two observations is used as the mean velocity in the vertical. This method is based on many studies of actual observation and on mathematical theory. Experience has shown that this method gives more consistent and accurate results than any of the other methods except for the vertical-velocity curve method. The two-point method is the one generally used for depths of 0.75 m or greater. The two-point method is not used at depths less than 0.75 m because the current meter would be too close to the water surface and to the streambed to give dependable results.

The three-point method consists of observing the velocity at 0.2, 0.6 and 0.8 of the depth, thereby combining the two-point and 0.6-depth methods. The preferred method of computing the mean velocity is to average the 0.2 and 0.8-depth observations and then average this result with the 0.6-depth observation. Our instructor assigned us to use the three-point method because he believed that the more points we made in finding the velocity, the more accurate is data that we will gather. But before you can use the current meter, it should be calibrated first. In calibrating the current meter, the spin of the bucket wheel should last for about 2 minutes. If not, then it should threaten with special oil. In our case, we use the common Price AA current meter.

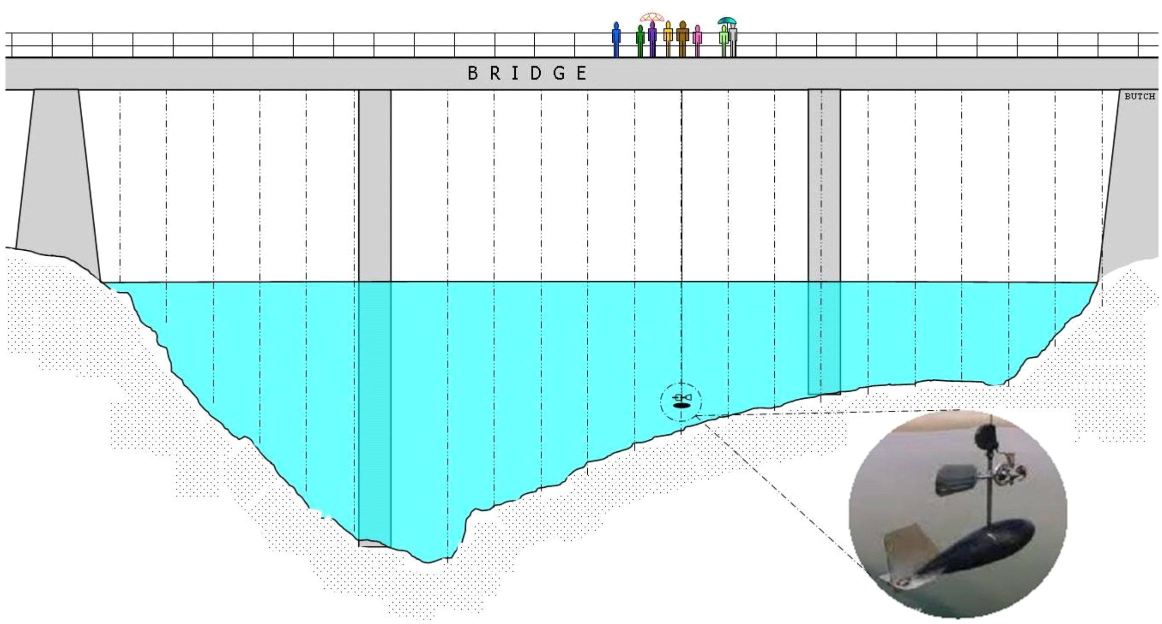

Figure 2.1: Current Meter Method

In measuring its velocity, you will have to listen to its beep made by the sounding reel. Within one minute, one should take note the number of beeps made by the sounding reel. You can choose whether 1 revolution per beep or 5 revolutions per beep, but you should take note of it in computing the velocity, depending on the characteristics of the flow. If the flow is too fast, then choose the 5 revolutions per beep, and if the flow is too slow, then choose the 1 revolution per beep. Since it's the first day of the field and the flow is high, we use the 5 revolutions per beep. The calibration equation used is **V = 0.702N + 0.013**, where N is the number of revolutions per time. You should also take note of the angle of the rope because it might affect your gathered data. A coefficient of correction is being added to minimize errors.

Figure 2.3: Discharge Measurement using Current Meter

One advantage of this method is that it's reliable and it is easy to do if all the equipment's are available but it is a tedious part in the hydrologist if the method that will use is the 3-point method because it is a long process. You should also be very cautious to the current meter and its weights because it is quite expensive. Also, you should always be aware of the flowing lilies and debris that might get stuck to the current meter and might destroy it. There is also a limitation in this method. In dividing the stream cross section, the more cross section you have, the more accurate the data you will gather. But on the other hand, it is always a burden to the hydrologist. Thus, the accurateness of data that you will gather is always depends on how motivated and dedicated the hydrologist is to his/her job.

2.2 Float Method

Measuring discharge by float is done by throwing down floats into the river and measures their travelling time in a certain section of a river. In our case, we have 5 vertical cross sections. We did two trials in every cross section. As a result, average velocity in the section can be estimated. The velocity of the float is equal to the distance between the cross sections divided by the time of travel. This method generally applied for high floods where discharge measurement by current meter is difficult. Floats are thrown from bridges. This method requires a straight cross section and measurement cross section for about 200 meters. The approach section is 53 meters from the dropping point, in our case it's in the edge of the bridge, to the first section. In choosing a dropping point, one should choose where the turbulence is minimum throughout the reach.

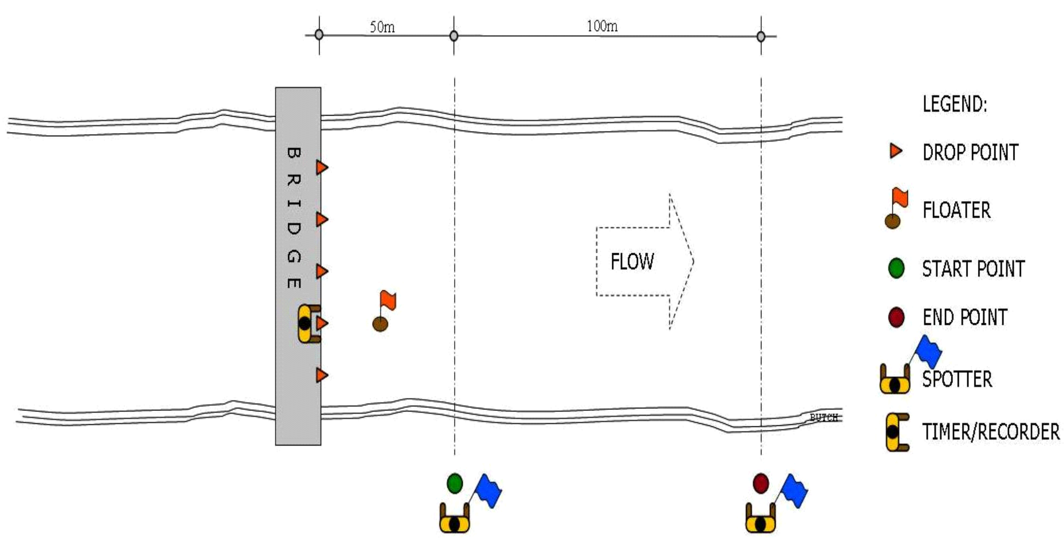

Figure 2: Discharge Measurement by Float

The measurement section is from 1st cross section to the 2nd cross section, where the travel time of the float is being measured. This requires at least 50, in our case, we use 100m. After dropping the bamboo downstream from the bridge, the one assigned in the 1st section should give a signal to the one assigned to do the timer as soon as the bamboo reaches the 1st cross section. That's the time the timer will start the stopwatch. Then the one assigned at the 2nd cross section should also give a signal to the timer as soon as the bamboo reaches the 2nd cross section. That's the time the timer will stop the time. This step was being done twice at each dropping point. There are circumstances that the bamboo failed to float. And the float also can hardly be seen because most of its body was in the water. That's why we have to consolidate the data thoroughly.

Figure 2.3: Bamboo Floats

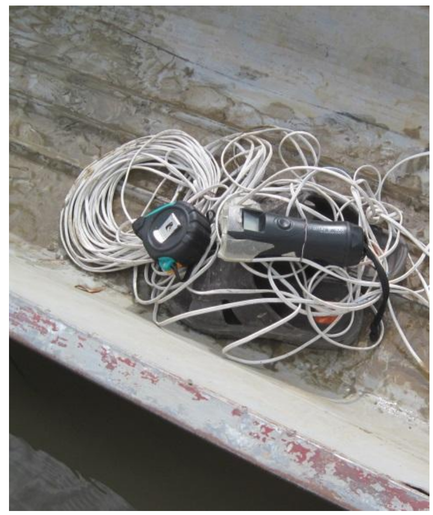

Figure 2.4: Echo Sounder

In finding the cross sectional area, we used the echo sounder. This measures the depth of the river by means of sound waves. These were done by riding in a boat while crossing the river. The depth of the river was recorded in every point where sir Hilton asked to stop, along the right to left bank of the river. Rangefinder is used in determining the horizontal distance. We did this step in each cross section, and in every cross section, we did two trials, from left to right bank and from right to left bank.

One advantage in this method is that it is economical and less expensive. The most appropriate method to use during high floods where use of current meter is difficult. But it has disadvantages also. One disadvantage is that it is not applicable in low water level for the float can be stocked to the river bed causing it to sink. Another disadvantage is that if the reach experiences turbulent flow between the points of measurement, the float won't have a straight path, giving us an unreliable data.

2.3 Slope-Area Method

The slope-area method is one of the most commonly used techniques of indirect discharge determination. This method is a type of indirect method of computing discharge which is particularly useful in estimating discharge at flood events. It 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 compute for discharge. In the slope-area method, there are considerations you must consider. First, the reach must be fairly straight and contracting. Second, there must be at least 3 cross sections within that reach, while the length of the whole reach must be greater than or equal to 75x the mean depth. Lastly, the fall of the reach must be greater than 0.15 meters.

In doing the survey, a benchmark located at the left bank at about 100 meters northwest from San Agustin Bridge was used as the basis of our survey. The benchmark has an elevation of 9.114 AMSL, within the vicinity of the old gaging station. Using the total station, the reach surveyed was divided into three cross-sections 150 meters apart. From the edge of the bridge, a distance of 53m is measured for the first cross section. In every cross section, we determine the highest, medium and lowest flood markings. These markings are hard to find. There are some markings that are not accessible due to some perimeter issue. There are also some issues in using the total station.

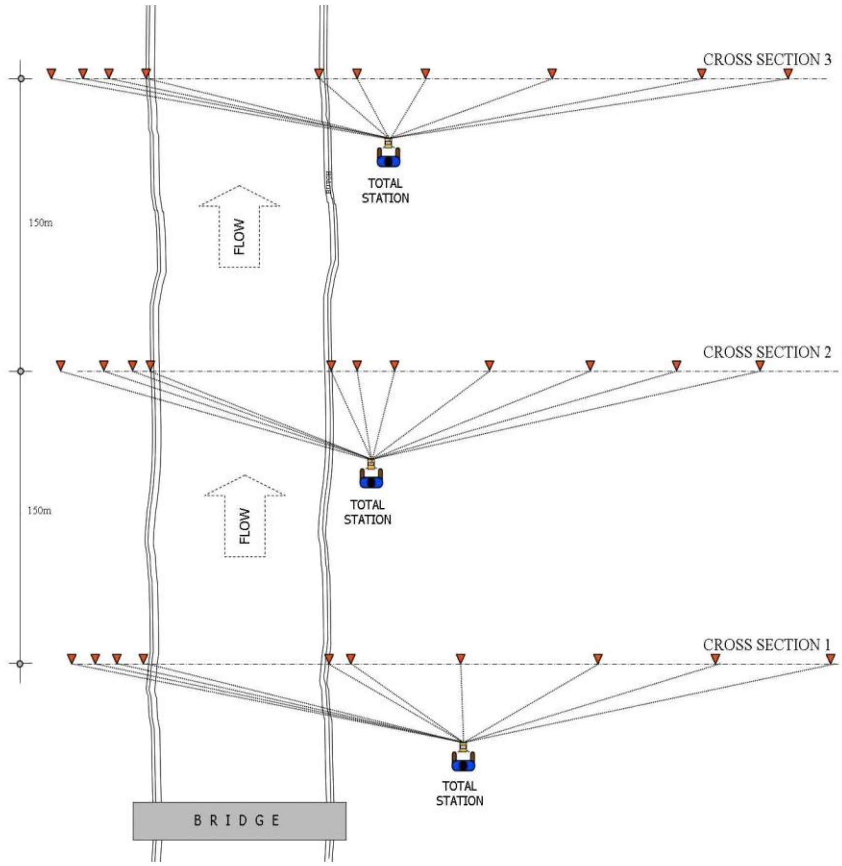

Figure 2.5: Slope-Area Method

Some other groups complain of rapid rate of running out of batteries. That's why, before going to the field, you must bring some extra batteries. And also, before using the total station, you must always direct its point of view to the north as reference by using a compass, because total station also reads its horizontal angle.

The only thing I can say about this method is that this method is very tedious to do. The whole activity was time consuming. We have three cross sections and each section, we have to determine its highest, medium and lowest flood marks. This is not an easy job. Patience is really a virtue here.

2.4 Acoustic Doppler Current Profiler (ADCP)

The ADCP method measures velocity magnitude and direction using the Doppler shift of acoustic energy reflected by material suspended in the water column providing essentially a complete vertical velocity profile. It also tracks the bottom providing stream depth and boat positioning. The ADCP method uses a moving boat to traverse the stream. During the traverse of the boat across the stream, a sonic sounder or ADCP records the profile of the cross-section, and a continuously operating current meter or ADCP senses the combined stream and boat velocities. In some groups, they traverse the stream by rowing, but in our group, we use a tag line, because the water level is low enough and the flow of the water is slow. By using a tag line, we traverse the stream in a straight path, thus minimizing the errors and increase the accurateness of the data. So if possible, use a tag line in traversing the stream.

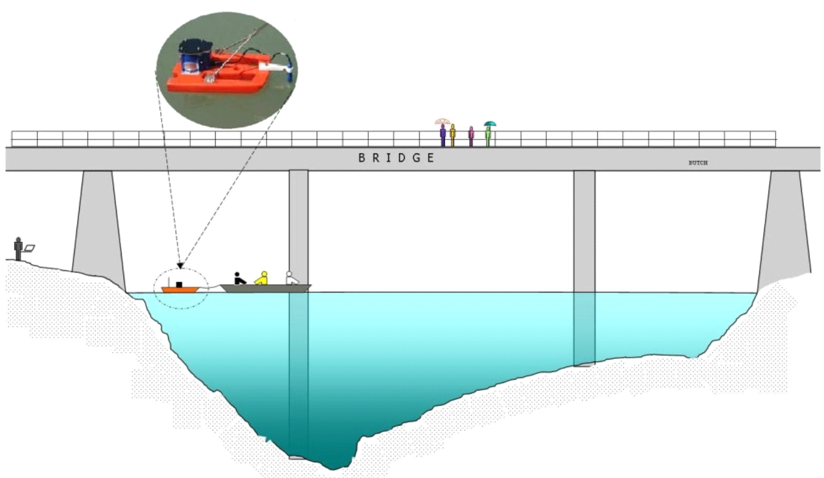

Figure 2.6: Acoustic Doppler Current Profiler (ADCP) Method

We have our starting point in traversing the stream 3 to 4 meters from the right edge of the water to avoid destroying the transducer. We traverse the stream 3 times. There is a person assigned in the data at the bridge. He is the one responsible in inputting the data and giving directions by means of handheld radio. In all 4 methods, this method is the easiest and the most convenient method to use. It gives lesser burden to the hydrologist, less time to consume and less energy to spend. In the past, measuring the current depth profile required the use of long strings of current meters. With this equipment, it is no longer needed. With the use of this apparatus, the so-called "human factor", as a source of errors, is eliminated. Even a single scale of currents or a depth of a thousand meters, this equipment still measures it.

But like the 4 other methods, it has also some disadvantages. One disadvantage of this method is that its equipment used is so expensive. It is so expensive that there are only 2 of them in the country. Another disadvantage of this method is the process in calibrating it. It needs to be calibrated before it can be used. By the use of the lap-top computer the ADCP was calibrated on its pitch, roll and yaw axis. The equipment is quite heavy, giving the calibrator a hard time in calibrating. Also, ADCPs set to "pulse of sound" rapidly also run out of batteries rapidly. If the water is very clear, as in the tropics, the pulse of sound may not hit enough particles to produce reliable data.

Figure 2.7: Calibrating and Mounting the ADCP

3 RESULTS and DISCUSSIONS

3.1 Float Method

This table shows the data of the first cross section, with its elevation above main sea level is 4.732.

Station	distance	elevation	water sfc.	depth	mean depth	area	wetted perimeter
0.00		4.73	4.73	0.00			
24.00	24.00	2.33	4.73	2.40	1.20	28.80	24.12
39.00	15.00	1.93	4.73	2.80	2.60	39.00	15.01
40.00	1.00	1.73	4.73	3.00	2.90	2.90	1.02
58.00	18.00	-0.07	4.73	4.80	3.90	70.20	18.09
79.00	21.00	-4.97	4.73	9.70	7.25	152.25	21.56
91.00	12.00	-5.57	4.73	10.30	10.00	120.00	12.01
105.00	14.00	-6.47	4.73	11.20	10.75	150.50	14.03
110.00	5.00	-6.67	4.73	11.40	11.30	56.50	5.00
128.00	18.00	-5.07	4.73	9.80	10.60	190.78	18.07
142.00	14.00	-3.47	4.73	8.20	9.00	125.97	14.09
146.00	4.00	2.43	4.73	2.30	5.25	20.99	7.13
149.00	3.00	4.73	4.73	0	4.73	x	x
Total Width	149						
Total Area	957.896						
W. P (P)	150.1368						
Hydraulic Radius ®	6.380154						
Mean sect. Depth	6.428832						
Remarks:							

Table 3.1: 1st Section Cross Sectional Data

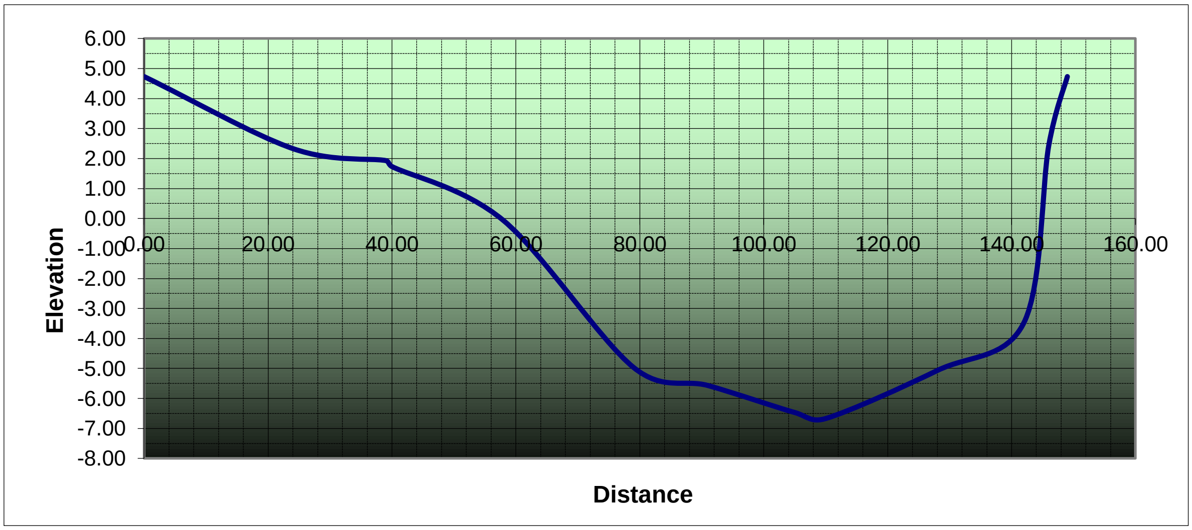

Figure 3.1: 1st Cross Sectional Area

This table shows the cross sectional data of the 2nd cross section.

Station	distance	elevation	water sfc.	depth	mean depth	area	wetted perimeter
0.00		4.73	4.73	0.00			
25.00	25.00	2.73	4.73	2.00	1.00	25.00	25.08
43.00	18.00	1.83	4.73	2.90	2.45	44.10	18.02
47.00	4.00	1.83	4.73	2.90	2.90	11.60	4.00
55.00	8.00	0.63	4.73	4.10	3.50	28.00	8.09
65.00	10.00	0.23	4.73	4.50	4.30	43.00	10.01
78.00	13.00	-0.57	4.73	5.30	4.90	63.70	13.02
84.00	6.00	-0.77	4.73	5.50	5.40	32.40	6.00
100.00	16.00	-1.37	4.73	6.10	5.80	92.80	16.01
105.00	5.00	-1.57	4.73	6.30	6.20	31.00	5.00
118.00	13.00	-2.07	4.73	6.80	6.55	85.12	13.01
126.00	8.00	-1.87	4.73	6.60	6.70	53.58	8.00
138.00	12.00	-1.57	4.73	6.30	6.45	77.38	12.00
145.00	7.00	-2.07	4.73	6.80	6.55	45.84	7.02
165.00	20.00	1.43	4.73	3.30	5.05	100.96	20.30
172.00	7.00	3.73	4.73	1.00	2.15	15.04	7.37
174.00	2.00	4.73	4.73	0	4.73	x	x
Total Width	**174**						
Total Area	**749.511**						
W. P (P)	**172.9488**						
Hydraulic Radius ®	**4.333715**						
Mean sect. Depth	**4.307534**						
Remarks:							

Table3.2: 2nd Cross Section Data

Figure 3.2: 2nd Cross Sectional Area

This table shows the manually computed data of the two cross section, its average area and the computed total discharge.

Station	Traveling time		Ave Time (sec)	Velocity (m/s)	Correction Coeff	Corrected Vel (m/s)	1st Section (m^2)	2nd Section (m^2)	ave Area (m^2)	Divided Q (m^3/s)
	1st trial	2nd trial								
1	FAIL	1:36:59	96.00	1.04	0.92	0.959	54.71	62.35	58.53	56.11
2	01:37:37	1:51:30	104.00	0.96	0.92	0.885	107.50	143.50	125.50	111.01
3	1:34:11	FAIL	93.00	1.08	0.92	0.989	197.50	125.40	161.45	159.72
4	1:37:35	1:38:36	97.50	1.03	0.92	0.944	262.50	165.10	213.80	201.74
5	2:17:50	2:12:27	134.55	0.74	0.92	0.684	91.43	158.40	124.91	85.44
								Total Discharge= 614.02m^3/s		

Table 3.3: Computed Data of Two Cross Sections

3.2 Acoustic Doppler Current Profiler

This ff. figure shows the detailed cross section and as well as the discharge of the 1st cross section in 1st, 2nd and third trial courtesy of the *RiverSurveyor®* software that was program by SonTek. This application is Windows-based system and operates in real time.

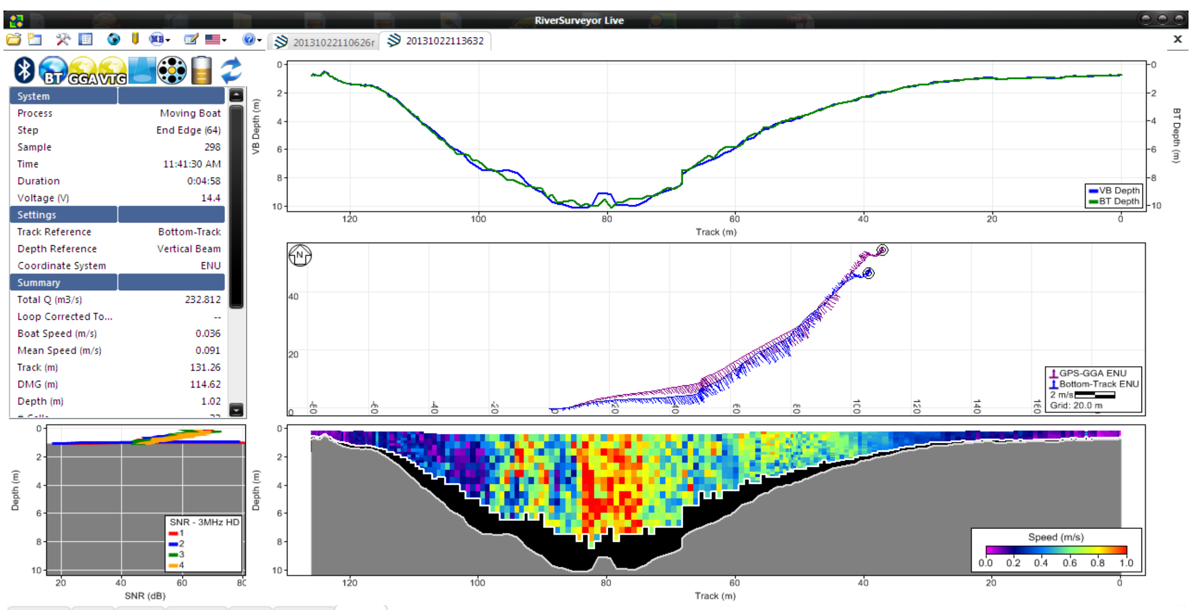

Figure 3.2a: Cross-section and Discharge using ADCP Method (1st trial)

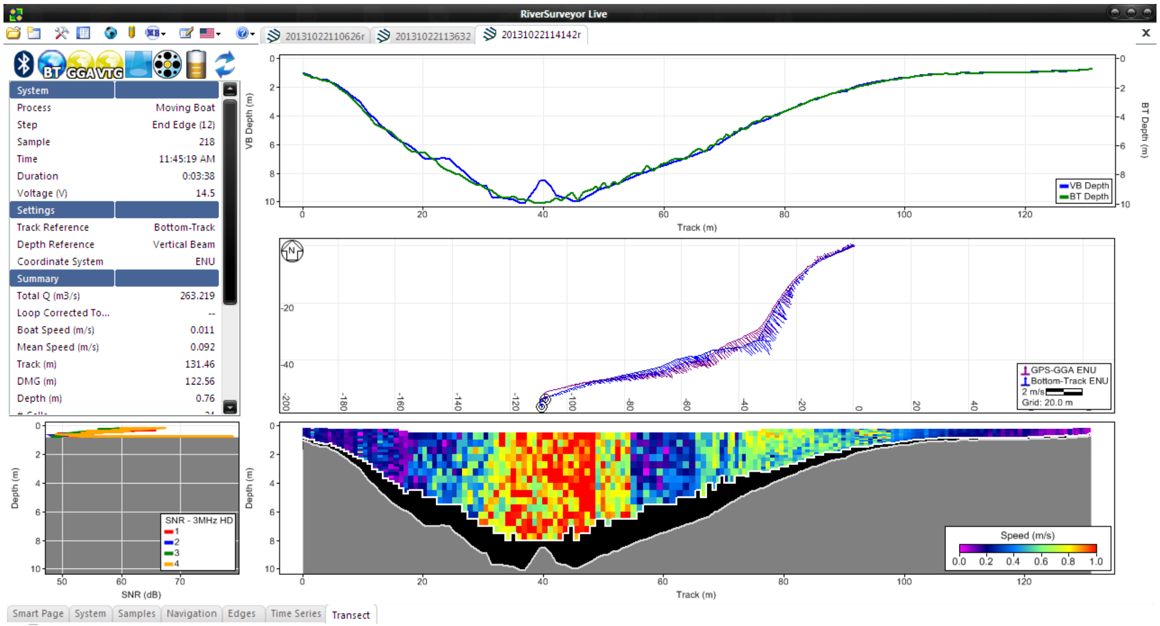

Figure 3.2b: Cross-section and Discharge using ADCP Method (2nd trial)

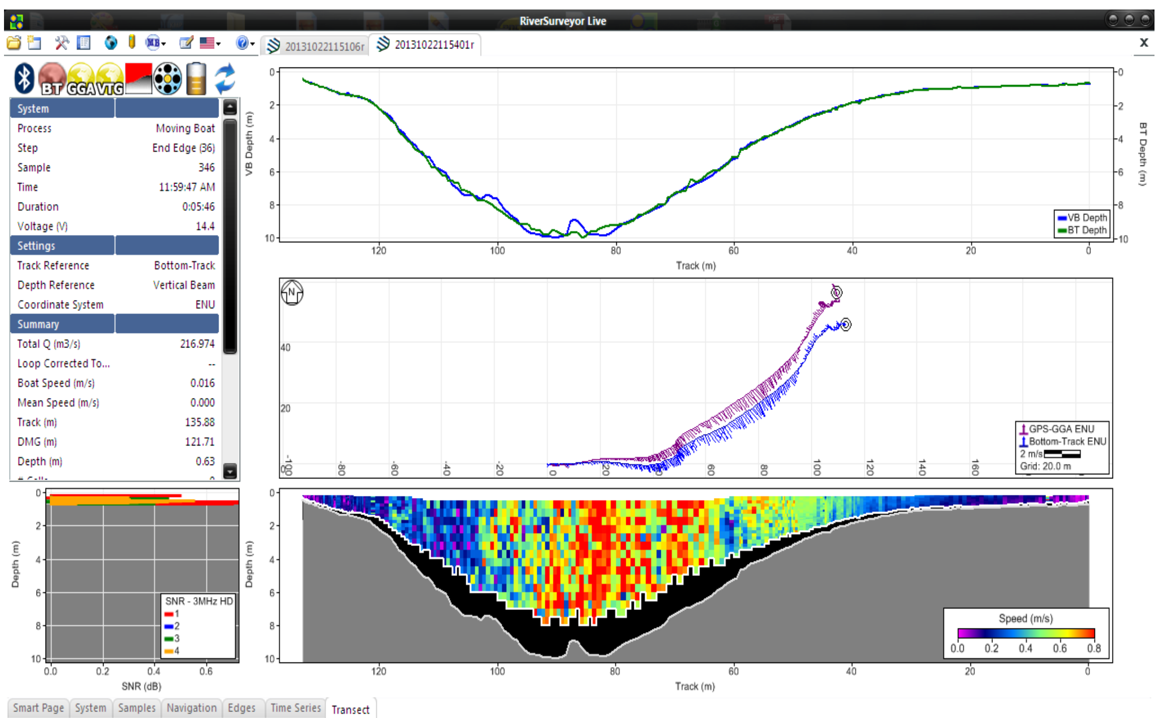

Figure 3.2c: Cross-section and Discharge using ADCP Method (3rd trial)

The *RiverSurveyor®* screen shows the System, Settings, and Summary on the left part and the vessel track and river cross-section on the right. Based on the similarity of the obtained cross-sections (lowest graph on the right), it can be said that the profile of the stream bed is accurate. The colored sections represent water and its velocity, where the red pixels represent flows of up to 0.8 meters per second. The black areas touching the stream bed is also noticeable. These are waters of the river with velocities that could not be determined by the ADCP. Nonetheless, an equivalent discharge for each trial was obtained.

Based on the three trials, with discharges equal to 232.812, 263.219, and 216.974 cumecs respectively, the average discharge is equal to **237.668** cumecs. This is a low discharge compared to the previous methods done due to a sudden drop in the water level of the river during that day.

3.3 Current Meter

Table below are made use of Microsoft Excel Suite that obtains an equivalent total discharge simply by completing all the following beige colored cells.

											Total Area =		873.66		
Rem:											Total Discharge =			311.48	
Discharge Measurement (Current Meter) for :							Arayat Station				River: Ave. Velocity =	Pampanga		0.357	PREFC
DM #:			Date:	October 17,2013			Team:				Group 1				FFB
Gage Height:		Start:	5.40	End:	5.28	Inst. # :					Wx:	fair			PAGASA
Observation Time:		Start:	1:35	End:	4:25	Calibration Eqtn.: V =			0.732	N+	0.013	note: just input negative value			hth/ 97
		Vertical dist. to water surface (m) =				10.50						for latter if eqtn. is minus.			
Total Area (m^2) =				**873.66**			**Ave. Gage Height =**			**5.34**		**Sectional Width (m) =**			**115.0**
Total Q (m^3/s) =				**311.48**			**Ave. Vel. (m/s) =**			**0.357**					
Dist. from		Depth	Vert.	Angle	Observation Depth						Velocity				Remarks
Initial	Width	(ep for pier)	Angle	Corrected	0.2		0.6		0.8		at point	Mean (0.2,0.6 & 0.8) or	Area	Q	Excellent, Good
point	(mts.)	(mts.)	4^0-36^0	Depth	Rev.	Time	Rev.	Time	Rev.	Time	for 0.6 only	(0.2 & 0.8)	(m^2)	(cumecs)	Fair, Poor
0				0											
5	5	3.05	0	range out			80	61.2			0.970	x	x	x	
10	5	5.35		5.350	95	63	85	60	85	61	1.050	1.062	26.75	28.42	
15	5	5.08		5.080	95	61	95	60	100	61	1.172	1.178	25.40	29.91	
20	5	8.31		8.310	110	61	35	65	35	69	0.407	0.633	41.55	26.30	
25	7.5	21.63		21.630							x	x	162.23	x	
35	7.5	21.57		11.170							x	x	83.78	x	
40	5	21.94		14.550							x	x	72.75	x	
45	5	22.48		22.480							x	x	112.40	x	
50	5	9.15	17	8.526	75	60	70	61	65	60	0.853	0.860	42.63	36.66	
55	5	8.02	8	7.891	90	62	85	62	75	63	1.017	0.998	39.46	39.39	
60	5	5.8		5.800	90	61	80	60	75	62	0.989	0.992	29.00	28.78	
65	5	5.77	5	5.724	95	62	85	65	70	62	0.970	0.979	28.62	28.01	
70	5	5.7		5.700	95	63	85	63	70	62	1.001	0.989	28.50	28.20	
75	5	5.28		5.280	85	61	80	61	70	62	0.973	0.955	26.40	25.20	
80	5	4.95		4.950							x	x	24.75	x	
85	5	5.1		5.100							x	x	25.50	x	
90	5	4.9		4.900							x	x	24.50	x	
95	5	4.65		4.650							x	x	23.25	x	
100	5	4.57		4.570	80	60	70	62	70	62	0.839	0.877	22.85	20.04	
105	5	3.39		3.390	60	60	60	60	60	63	0.745	0.736	16.95	12.48	
110	5	3.28		3.280	40	68			45	62	x	0.494	16.40	8.10	

Table 3.4: Discharge (Q) Table using Current Meter Method

As you can see from the data, the accumulated discharge is 311.48. The recorded discharge from the Acoustic Doppler Current Profiler (ADCP) that day was around 460-470 cumecs. Arriving at at this kind of discharge, which is smaller compared to the expected value, may be due to insufficient data along the piers and other obstructions below a subsection. This is due to piers, water lilies, and turbulent flows that hindered in getting an accurate number of revolutions at a certain time. There are some vertical sections where we failed to determine its depth because of shortage of sounding reel.

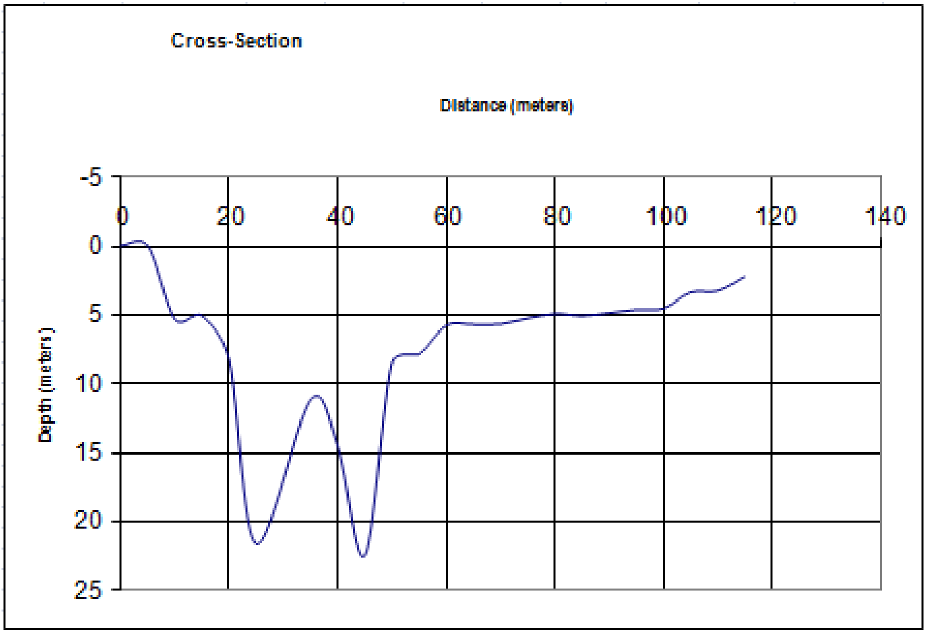

***Figure 1*. Pampanga River Cross-section Derived from Distance-Depth Relation**

Figure above reveals the cross-section of Pampanga River below San Agustin Bridge using the distance and depth acquired from the Q table. As you can see, the curve has an irregular shape compared to the actual shape of a regular stream. This are the sections where its depth cant be measured because of shortage in sounding reel.

3.4 Slope-Area Method

Data for the slope-area method includes three tables for the physical parameters of the three cross-sections, graphic representation of such parameters, and a summary table for determining the equivalent discharge of Pampanga River.

Cross-Section number ONE (1)							hth/ 97
Station	Distance	Elevation	Water Sfc. elev.	Depth	Mean Depth	Area	Wetted Perimeter
0		8.451	5.546	-2.905			
134.1687	134.1687	6.55	5.546	-1.004	-1.9545	-262.233	134.1822
143.8222	9.6535	3.997	5.546	1.549	0.2725	2.630579	9.985383
154.2193	10.3971	0.05	5.546	5.496	3.5225	36.62378	11.12108
167.8637	13.6444	0.006	5.546	5.54	5.518	75.2898	13.64447
185.8268	17.9631	-0.029	5.546	5.575	5.5575	99.82993	17.96313
206.3107	20.4839	-0.069	5.546	5.615	5.595	114.6074	20.48394
227.8004	21.4897	-0.099	5.546	5.645	5.63	120.987	21.48972
244.9382	17.1378	-0.149	5.546	5.695	5.67	97.17133	17.13787
271.3575	26.4193	-0.054	5.546	5.6	5.6475	149.203	26.41947
279.6424	8.2849	5.299	5.546	0.247	2.9235	24.22091	9.863781
284.2909	4.6485	5.546	5.546	0	0.1235	0.57409	4.655058
Total Width =		284.29	meters	Hydraulic Radius(r) =		1.60	meters
Total Area =		458.91	meters^2	Mean Section Depth =		1.61421	meters
Wetted Perimeter(P) =		286.946	meters				

***Table 3a*. Physical Parameters of the 1st Cross-section Using Slope-Area Method**

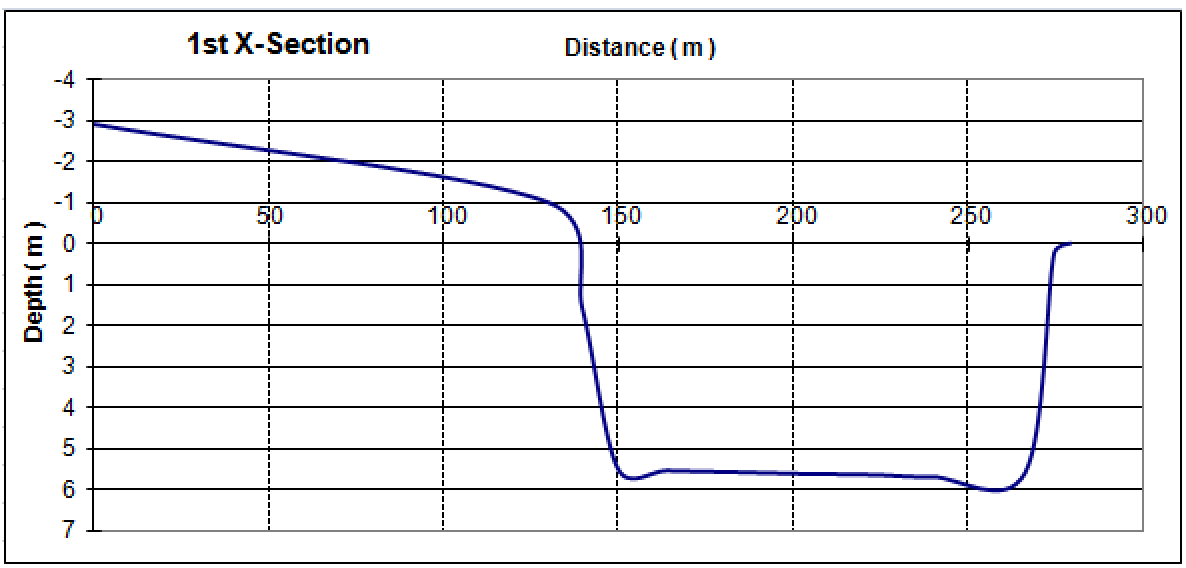

***Figure 3a*. Graphic Representation of the 1st Cross-section Using Distance-Depth Relation**

Cross-Section number TWO (2)							hth/ 97
Station	Distance	Elevation	Water Sfc. elev.	Depth	Mean Depth	Area	Wetted Perimeter
0		5.061	5.061	0			
166.1196	166.1196	4.018	5.061	1.043	0.5215	86.63137	166.1229
176.4954	10.3758	-0.003	5.061	5.064	3.0535	31.68251	11.1277
193.3365	16.8411	-0.029	5.061	5.09	5.077	85.50226	16.84112
209.3011	15.9646	-0.064	5.061	5.125	5.1075	81.53919	15.96464
227.7976	18.4965	-0.057	5.061	5.118	5.1215	94.72982	18.4965
247.5566	19.759	-0.103	5.061	5.164	5.141	101.581	19.75905
271.4966	23.94	-0.149	5.061	5.21	5.187	124.1768	23.94004
293.6271	22.1305	-0.179	5.061	5.24	5.225	115.6319	22.13052
314.3919	20.7648	-0.28	5.061	5.341	5.2905	109.8562	20.76505
321.6627	7.2708	4.653	5.061	0.408	2.8745	20.89991	8.786297
323.2061	1.5434	5.659	5.061	-0.598	-0.095	-0.14662	1.842314
Total Width =		323.21	meters	Hydraulic Radius(r) =		2.62	meters
Total Area =		852.08	meters^2	Mean Section Depth =		2.63635	meters
Wetted Perimeter(P) =		325.776	meters				

***Table 3b*. Physical Parameters of the 2nd Cross-section Using Slope-Area Method**

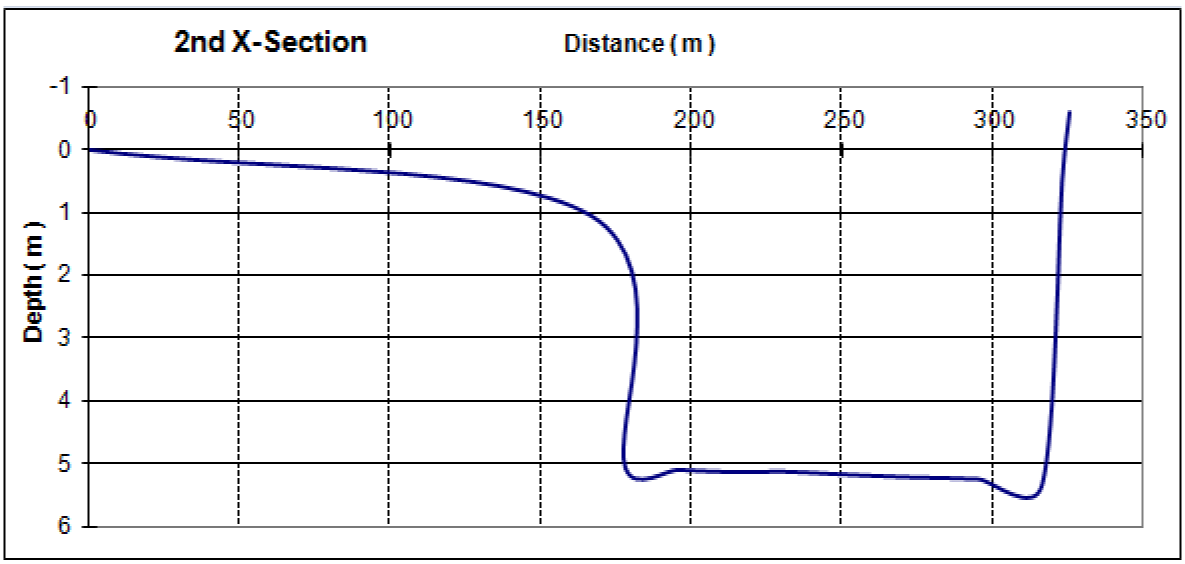

***Figure 3b*. Graphic Representation of the 2nd Cross-section Using Distance-Depth Relation**

Cross-Section number THREE (3)							hth/ 97
Station	Distance	Elevation	Water Sfc. elev.	Depth	Mean Depth	Area	Wetted Perimeter
0		4.967	4.967	0			
100.0491	100.0491	3.318	4.967	1.649	0.8245	82.49048	100.0627
125.3529	25.3038	-0.483	4.967	5.45	3.5495	89.81584	25.58769
138.9185	13.5656	-0.5	4.967	5.467	5.4585	74.04783	13.56561
155.9567	17.0382	-0.549	4.967	5.516	5.4915	93.56528	17.03827
178.0093	22.0526	-0.596	4.967	5.563	5.5395	122.1604	22.05265
201.759	23.7497	-0.671	4.967	5.638	5.6005	133.0102	23.74982
226.1464	24.3874	-0.715	4.967	5.682	5.66	138.0327	24.38744
248.0367	21.8903	-0.766	4.967	5.733	5.7075	124.9389	21.89036
265.2483	17.2116	-0.76	4.967	5.727	5.73	98.62247	17.2116
279.5832	14.3349	4.55	4.967	0.417	3.072	44.03681	15.28677
287.2792	7.696	4.793	4.967	0.174	0.2955	2.274168	7.699835
Total Width =		287.28	meters	Hydraulic Radius(r) =		3.48	meters
Total Area =		1003.00	meters^2	Mean Section Depth =		3.49136	meters
Wetted Perimeter(P) =		288.533	meters				

***Table 3c*. Physical Parameters of the 3rd Cross-section Using Slope-Area Method**

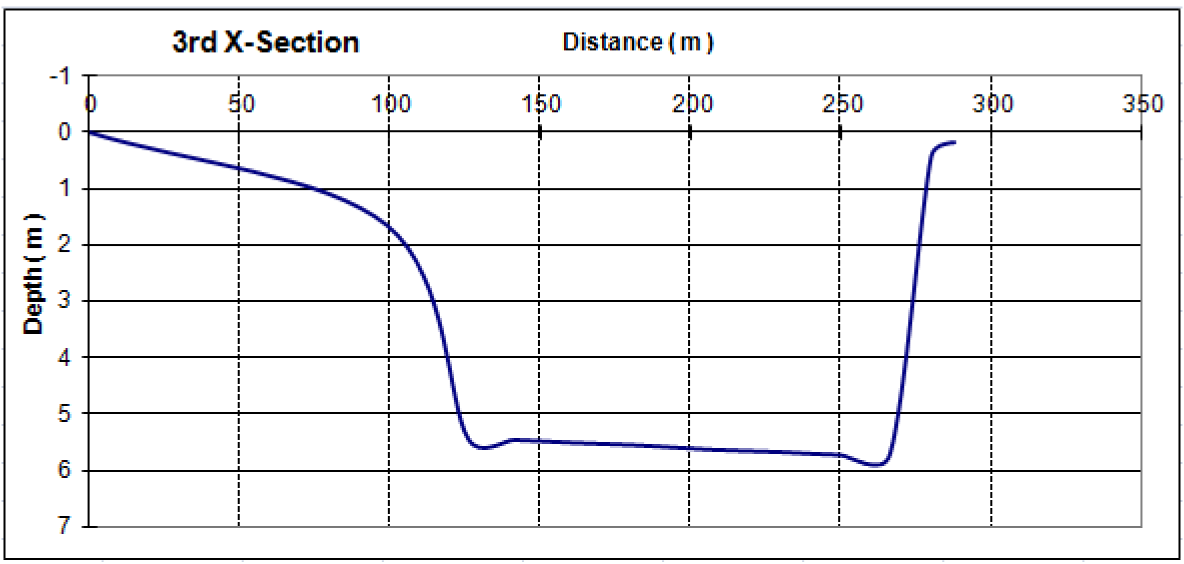

***Figure 3c*. Graphic Representation of the 3rd Cross-section Using Distance-Depth Relation**

The the tables and figures shown above, you can differentiate the three cross sections. the raw data for the slope-area method include horizontal distance from the total station, elevation or vertical distance, and water level for the three cross-sections. All you have to do is to input the data to the excel that sir Hilton gave us, and automitically, it will determine its width, mean depth, area, and wetted perimeter (WP) of each subsection, as seen in Tables 3a, 3b, and 3c. The total width, area, WP, hydraulic radius, and mean section depth shall also appear at the bottom of these tables.

Other than the table, you can also see the figure above that shows on another sheet the graphic representation of the three cross-sections using the parameters of depth and distance. Comparing Figures 3a, 3b, and 3c, the cross-sections are somehow different from one another, though they reveal that the right bank has an abrupt rise in flood as compared to the left bank which has a wide flat plain proceeding to the highest flood mark.

FFB, PAGASA — **Slope-Area Summary Sheet (3-Section)**

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

❖❖

X - Section Properties: hth/ 97

X-Sect.	Width	Area	Highwater Marks Left Bank	Right Bank	Average Water Sfc.	d_m (mean depth)	n	r	K	K^3/A^2	α	F	State of Flow
1	284.29	458.91	8.451	5.546	6.9985	1.614	0.035	1.60	17959.04	2.8E+07	1	1.885	rapid
2	323.21	852.08	5.061	5.659	5.36	2.636	0.035	2.62	46364.11	1.4E+08	1	0.794	tranquil
3	287.28	1003.00	4.967	4.793	4.88	3.491	0.035	3.48	66034.39	2.9E+08	1	0.586	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	155.157	1.6385	0.5	expanding	0.387348	poor	655.495	4040.949	6.165
2-3	270.726	0.48	0.5	expanding	0.702121	good	927.540	2470.455	2.663
1-2-3	425.883	2.1185	0.5	expanding	0.271965	poor	771.328	**3440.336**	4.460

Discharge Computation:(comparison)

Reach	Assumed Q	h_v U/S	D/S	Δh_v	h_f	$S=h_f/L$	$S^{1/2}$	K_w	**Computed Q**
1-2	4040.949	2.867476	0.831726	2.035749	2.656375	0.017121	0.130846	28855.76	3775.648
2-3	2470.455	0.831726	0.600272	0.231454	0.595727	0.0022	0.046909	55331.96	2595.582

Rem:

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

Q_{1-2-3} = 3440.34 cumecs

Discharge

***Table 3d*. Summary Sheet of the Three Cross-sections Using Slope-Area Method**

The final table (above) shows the slope-area summary sheet, where only the bank elevations, lengths of the reach, and a roughness coefficient *n* shall be inputted. The table is simply about the usage of Manning's formula and computation of discharge Q by multiplying the average area with the average velocity. Estimation of *n* is not easy, so it is assumed to be similar to a normal river which is 0.035. Based on calculations, the total discharge amounted to a whopping **3440.34 cumecs**, almost 11 times higher than that of the current meter discharge.

4 THE RATING CURVE

On the last day of the field work, Group 1 is tasked to take measurements on the bed profile from the top of the bridge assuming the bridge is perfectly horizontal. Below is the CAD illustration of the entire length of the bridge from bank to bank.

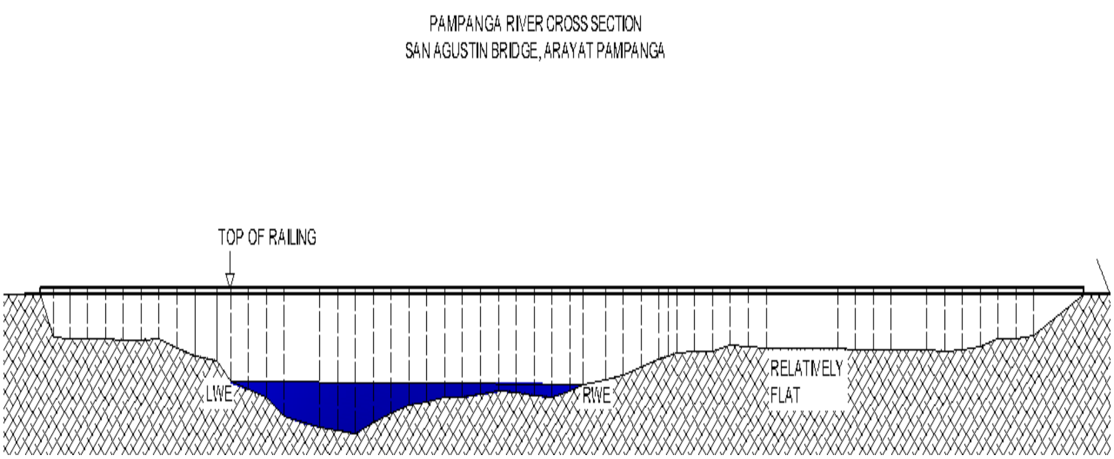

Figure 4a: **Elevation data of the river bed from top of the bridge**

PAMPANGA RIVER BED PROFILING
Arayat, Pampanga

Bridge Measurements:

Start Time: 1342 HH
End Time 1405 HH
Date: Oct. 23, 2013

Heigth of Railing to Curb: 0.75 m
Height of Curb to Ground Level: 0.16 m

Measurements are taken from Top of the Bridge Railing, Left To Right of the Banks.

Station Interval	Depth (m)	Accumulated Horizontal Length (m)	Remarks	Station Interval	Depth (m)	Accumulated Horizontal Length (m)	Remarks
0	0.91	0	top of dike	6.2	14.18	158.34	
3.8	7.6	3.8	Foot of dike	5	13.36	163.34	
4.54	7.8	8.34		5	12.22	168.34	
5	7.8	13.34		5	10.95	173.34	
5	7.97	18.34		2.5	10.41	175.84	
5	7.97	23.34		2.5	9.93	178.34	
5	7.89	28.34		5	9.91	183.34	
5	9.26	33.34		5	9.91	188.34	
5	10.4	38.34		5	8.87	193.34	
5	11.17	43.34		5	9.16	198.34	
6.2	14.55	49.54	Left Water Edge	5	9.33	203.34	
3.8	15.57	53.34		5	9.33	208.34	
5	16.86	58.34		5	9.33	213.34	
5	19.88	63.34		5	9.33	218.34	
5	21.63	68.34		5	9.33	223.34	
10	21.57	78.34	Edge of Pier	5	9.59	228.34	
5	21.94	83.34		5	9.56	233.34	
5	22.48	88.34		5	9.56	238.34	
5	20.7	93.34		10	9.46	248.34	
5	19.39	98.34		5	9.71	253.34	
5	18	103.34		5	9.63	258.34	
5	17.63	108.34		5	9.05	263.34	
5	16.99	113.34		5	7.9	268.34	
5	16.79	118.34		5	7.77	273.34	
5	16.39	123.34		5	7.4	278.34	Foot of dike
5	15.97	128.34		14	0.91	292.34	top of dike
5	16.02	133.34					
5	16.51	138.34					
5	16.84	143.34					
5	15.78	148.34					
3.8	14.83	152.14	Right Water Edge				

Table 4.1: **Data converted to AMSL**

The data above is then converted to the mean sea level elevation based on the benchmark from the old PAGASA gaging station situated in the area. Using the excel suite, the rating equation is deduced.

This rating curve equation governs the change in the discharge (Q) of the river at any change of stage. So with this equation, the discharge of the water is predictable and can be used in simulation software like HECRAS.

The rating curve illustrates the discharge versus stage relationship of a river. By the nature of the bed profiles, rating curves of any river is different from the other.

4.1 The Rating Curve Equation

Rating Curve Development for . . . . ***Pampanga River***

Measuring Station:	***Arayat Station***
Drainage Area:	***6487***
River:	***Pampanga River***
Location:	***San Agustin Bridge, Arayat, Pampanga***
Elev. S.G."0" rdg.=	***0.000*** **meters**

Meas. #	Day	Month	Year	S.G.(m)	Q(m^3/sec)	Remarks
				15.402	6731.219	
				14.000	5488.026	
				13.000	4665.799	
				11.000	3186.386	
				10.000	2534.263	
				9.000	1943.296	
				8.000	1588.867	
				7.000	1446.523	
				6.000	1244.836	
				5.000	1001.068	
				4.000	769.036	
				3.000	566.342	
				2.000	398.449	
				1.000	264.299	
				0.500	205.881	
				-1.000	130.644	
				-2.000	84.195	
				-3.000	44.612	
				-4.000	18.203	
				-5.000	2.871	

$$Q = 0.306\ [H - (-7.39)]^{3.190}$$

The Rating Curve Equation !!!

Table 4.1: **Rating curve Euation**

Summary test for Ho						
Ho	a	b	ΣX^2			
-7.50	0.26	3.239	159.0038	Minimum	$\Sigma X^2 =$	157.77577
-7.39	0.31	3.190	157.7758			
-7.28	0.36	3.140	160.9545			
-7.17	0.42	3.090	169.2081			
-7.06	0.49	3.039	183.3305			
-6.95	0.58	2.986	204.2726			
-6.84	0.68	2.933	233.1833			
-6.73	0.81	2.879	271.4649			
-6.62	0.96	2.824	320.8478			
-6.51	1.14	2.767	383.4949			
-6.40	1.35	2.708	462.1486			
-6.29	1.62	2.648	560.3451			
-6.18	1.94	2.586	682.7326			
-6.07	2.34	2.521	835.5621			

Table 4.2: **Summary test for Ho**

The rating curve illustrates the discharge versus stage relationship of a river. By the nature of the bed profiles, rating curves of any river is different from the other.

5 FIELD WORK SUGGESTIONS

In general, the four-day field work, is a tiring yet fun experience for us future hydrologist. This is our first fieldwork in the training course, and hopefully, it wont be the last. Each of the four methods that we've used offered a different kind approach in measuring stream discharge. With the help of our beloved and anspiring instructors, we've managed to survive the four-day fieldwork. It is such a great honor to work and be part of their history. And also, with the help of my group, that composed of eight, we've managed to survive with a smile in our face. The group of eight is also good enough, since any one member will always have something to do. You generally work while you learn, which is a rare find compared to college-day experiments.

Since the overall management and facilitation of the field work is already satisfactory, thanks to our hardworking training coordinator. From my own point of view, most of the personal suggestions would be regarding the materials and equipment used during the field work, and also to the instructor, though the solutions would mostly require funding and patience. But in overall, the whole activity was successfull. To those instructors that accompanied us, to our trainee coordinator, to the boat men who rowed the boat, to the driver of our bus and the jeepney, to the citizen of the Brgy. Camba, Arayat, Pampanga, thank you for being part of our history.

Suggestions that are needed to make the activity more reliable:

1. have a larger (and functioning) sounding reel for the deeper portions of the river cross-section during current meter method;
2. always be cautious for the flowing lilies and debris in doing the current meter for it might destroy the equipment
3. dont forget to calibrate first the current meter.
4. In using the current meter, for faster flow, use the 5 revolution per beep and 1 revolution per beep for slower flow.

5. obtain more cross-sections (thus, more bamboo floats) during the float method so that discrepancies will be compensated especially with missing floats;
6. in doing the float, choose the section where the flow for the whole reach is not so turbulent
7. always make your float visible, by putting flags for you to be able to easily recognize it.
8. In doing the total staion, patience is really a virtue.
9. In every activity, always record the time you started and ended and that also goes to staff gage reading.
10. always wear protective gear for the heat of the sun.
11. dont forget to bring extra batterries for the total station
12. always refer your total station to the north before using it.
13. Dont ever change the height of the prism rod for it may affect the gathered data from the total sation.
14. have a cableway or a fixed rope with markings that will serve as a tagline in slope-area method.
15. For more accurate data, use a tag line if possible, and lastly,
16. Dont forget to bring a camera for documentary purposes.

6 FIELD VISIT

6.1 La Mesa Dam

(October 15, 2013 Tuesday)

It was Tuesday morning when we arrived at our 1st destination, the La Mesa Dam. The La Mesa Dam is an earth dam whose reservoir can hold up to 50.5 million cubic meters occupying an area of 27 square kilometers. It is part of the Angat-Ipo-La Mesa water system, which supplies most of the water supply of Metro Manila. It was built in the year 1929 and its main purpose is to impound water. It has a maximum water elevation at 80.15m, beyond that, the water will overflow. It has no spill gates, thus they cannot discharge water at their own will.

I felt quite excited because it is first my time to visit a dam. Not just an ordinary dam but one of the well-knowned dam in the country. During that trip, I've learned that the water collected in the reservoir is treated on-site by the Maynilad Water Services, and at the Balara Treatment Plant further south by the Manila Water.

6.2 Pantabangan Dam

(October 19, 2013 Saturday)

It was a hot sunny day when we visited the Pantabangan Dam. This dam is an earth-fill embankment dam on the Pampanga River located in Pantabangan in Nueva Ecija province of the Philippines The 5 hour trip to this area was all worth it because of the warm welcome of the management and the delicious snack that they'ed offer to us. The scenery in this dam is really a one of a kind. Perfect for picture taking and for those who want to have some fresh air.

6. 3 Cong Dadong Dam

(October 21, 2013 Monday**)**

After our fieldwork we headed directly to Cong Dadong Dam. The dam was located at the northern part from the site of our fieldwork. The dam was said to be mainly for irrigation purposes, thus, its construction is fairly simple compared to other dams. The name "Cong Dadong" means "Kuya Dadong", named after President Macapagal-Arroyo's father, the late President Diosdado Macapagal.

6.4 Angat Dam

(October 24, 2013)

It is our last day in our fieldwork, and for the last destination, we save the best for last. For the last day, we visited the Angat Dam that is located at Norzagaray, Bulacan. The dam is a concrete water reservoir embankment hydroelectric dam that supplies the Manila metropolitan area water. It was a part of the Angat-Ipo-La Mesa water system. The reservoir supplies about 90 percent of raw water requirements for Metro Manila through the facilities of the Metropolitan Waterworks and Sewerage System and it irrigates about 28,000 hectares of farmland in the provinces of Bulacan and Pampanga.

Like in pantabangan dam, the dam also has a breathtaking scenery. But compared to Pantabangan dam, we've given a chance to go inside to their control room in Power Generating Section. Well, as an Electrical Enginner, it is a great oppurtunity for me to be able to see their gigantic turbines and motors. Luckily, I was able to see thier large motors and generators that I've never seen during my college years. It was a great experience, that will forever be cherished for a lifetime.

6.5 Municipal Disaster Risk Reduction and Management Council (MDRRMC)

(October 23, 2013)

It was wednesday morning when we went to Bulacan to visit the Municipal Disaster Risk Reduction and Management Council (MDRRMC) of Calumpit, Bulacan. After hearing the discussion of the head of the MDDRMC about their effort in preparation for flood forecasting, I've come to realize that even though you are not a PAGASA employee of did'nt have any traning about flood forecasting, you can still help your community in flood forecasting by means of web resources. In this municipality, they have their own flood forecasting data that were gathered from different kind of sources, i.e PAGASA, DOST, Project NOAH, etc.

7 CONCLUSION

Based from the given objectives, the following conclusions were drawn:

1. The group was able to perform the four methods of discharge measurement along Pampanga River in San Agustin Bridge, Arayat, Pampanga. All methods were done on four separate days on a normal weather condition as follows:
    - Current meter method is the most common among the methods for measuring discharge. In this method, a stream channel cross-section is divided into numerous vertical subsections and the water velocity is determined using a Price AA current meter.
    - Float method is the most preferred over other methods in terms of practicality during high flows. The idea is to measure the time it takes for a buoyant object to float downstream from one cross-section to another. While float method is observed as very simple, it may be prone to glitches especially when the dropped objects do not float.
    - Slope-area method is the most tedious of the discharge measurement methods. Three cross-sections, each from one reach to the other (flood marks) were selected downstream from the bridge. The horizontal distance (HD), elevation (VD), and vertical angle (VA) were then determined using a total station and a reflecting prism.
    - The Acoustic Doppler Current Profiler or ADCP method is likely the most sophisticated, most efficient, and most accurate among the four methods. ADCP made use of the Doppler Effect to measure the velocity of water as well as acoustics in order to measure water depth.

2. Determining the discharge for each method requires computation, either manually or with the use of Microsoft Excel Suite. River profiles were also drawn using cross-section paper and other drafting software:

- In the current meter method, recorded data were simply inputted and the immediate velocity, area, corrected angle, and discharge were automatically computed in a programmed Excel table. Practically, the discharge in each subsection is the product of the subsection area and the velocity. The total discharge is then the sum of the discharge of each subsection.
- Float method requires manual computation of discharge. The subsections and their corresponding depth comprise the area, whereas the velocity is the time travelled from the first cross-section to the next. Since the method was performed twice, the average of the velocities and time should be noted to come up with the discharge.
- The stream discharge from using slope-area method could be readily determined using a programmed Excel table, where the left and right bank elevations as well as roughness coefficient were inputted. However, a detailed sketch of the river cross-sections and top view must be taken into account.
- Discharge measurement using ADCP did not require any data manipulation. After crossing the ADCP, data were automatically transmitted to the receiver end connected to a computer. This is where the detailed river cross-section and the discharge are readily available.

The equivalent discharges of all methods were as follows:

Method	**Discharge (cumecs)**
Current Meter	311.48
Float	614.02
Slope-Area	3440.34
ADCP	237.668

It was noticed that the different discharge measuring methods resulted to different discharge values. This is likely due to the nature of accuracy of each method and differences in water levels for each day. A proof of this is the fact that the discharge of one group doing a certain method is different from another group doing the same method on another day. Another is the fact that the discharge of one group doing a certain method is different from another group doing a different method on the same day.

3. Stage-discharge relations are developed for streamgages by physically measuring the flow of the river. The rating curve of Pampanga River reveals that for each measurement of discharge there is a corresponding measurement of stage. And as the stage increases, the equivalent discharge increases, at a rate that is getting higher as the depth approaches the uppermost portions of the cross-section.

   Special effort is made to measure extremely high and low stages and flows because these measurements occur less frequently. The stage-discharge relation depends upon the shape, size, slope, and roughness of the channel at the streamgage and is different for every streamgage.

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