A Summary Report on

HTC-PAGASA
Field Work and Field Visit

October 15-24, 2013

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I N T R O D U C T I O N

Maybe at one point in a person's life, as one saw or encountered a certain river, he or she might have asked "How much water is flowing in this river?" or "How deep is that river?" The answer to that is very simple – become a hydrologist first. But as an aspiring hydrologist, it is best at the moment to share the knowledge that was learned throughout the course of the field work.

The concept of the amount of water flowing in a body of water is closely related to streamflow. Streamflow, or *discharge*, is the volume of water that moves over a designated point over a fixed period of time. It is often expressed in cubic meters per second (m3/sec) or *cumecs*. Streamflow greatly influences the character of a stream. On the other hand, the concept of the river's depth relates the term "stage". Stream stage (also called *gage height*) is the height of the water above an established altitude where the stage is zero (0). This zero level is arbitrary, but is often close to the streambed.

Being a hydrologist though, takes more than just measuring the streamflow or stage across a certain river. They play a significant role in imparting to other people the impact of these changes, especially since rivers are an essential part of our everyday living, either directly or indirectly. Hydrologists are somewhat modern-day heroes. And as one of those heroes (well, almost), elaboration of these concepts will be expected using the experiences acquired during the 10-day field work and field visit of HTC-PAGASA trainees in Central Luzon.

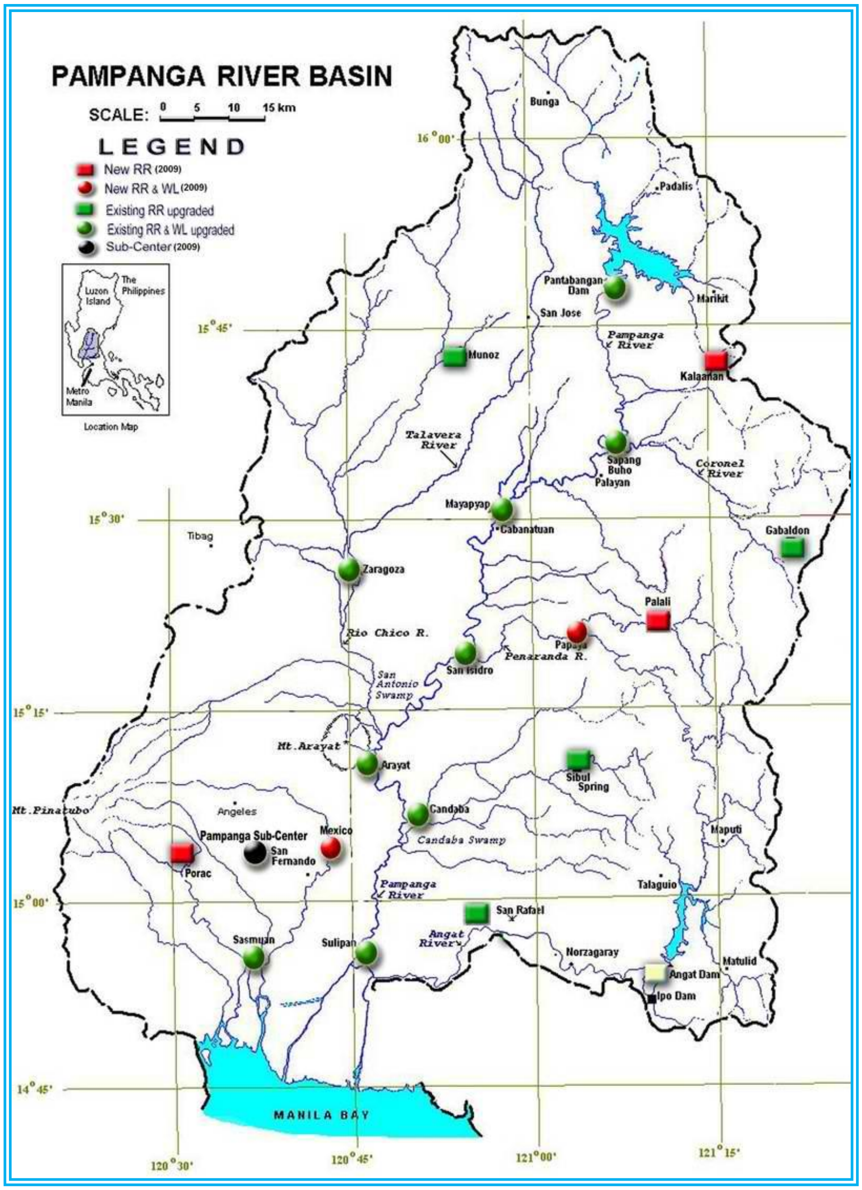
OBJECTIVES

The goals of the field work, basically, is to measure streamflow of Pampanga River in terms of discharge using four known methods and evaluate its rating curve. Specifically, the activity aims:

1. To perform the four common methods of discharge measurement along Pampanga River and identify the pros and cons of each
2. To determine the equivalent stream discharge (Q) of the river using the data obtained in the four methods
3. To show the relation between various stages of the river cross-section with its equivalent discharge

SITE DESCRIPTION

A. The Pampanga River Basin



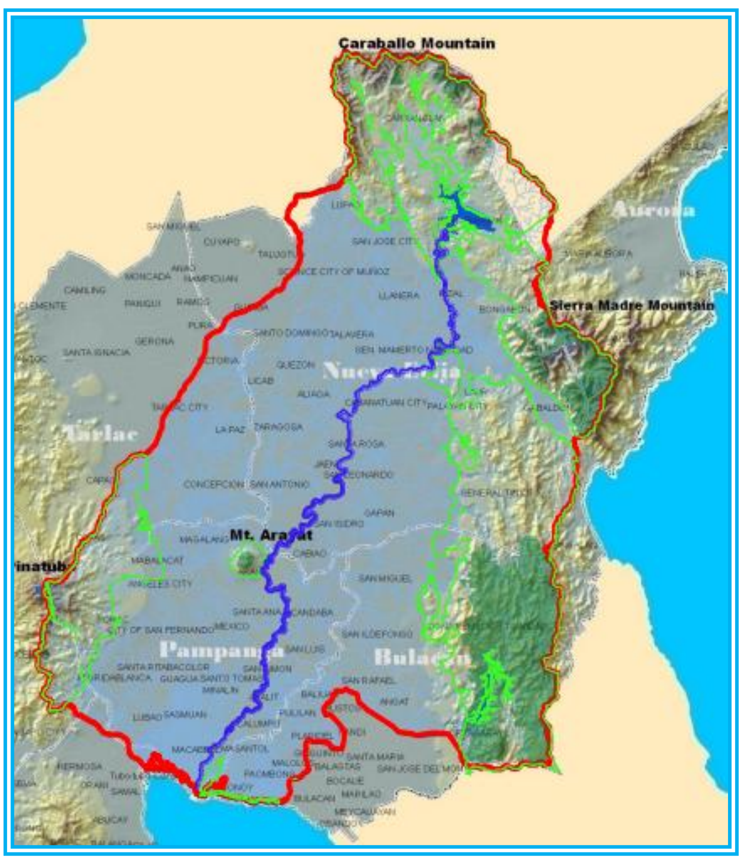
Basin Area:	10,540 km² (4th largest)
No. of Stream Gauging Stations:	14
Large Reservoirs:	Pantabangan Dam (2,996 million m^3)
	Angat Dam (850 million m^3)
	Ipo Dam (7.5 million m^3)

The Pampanga river basin is the fourth largest river basin in the Philippines, covering an area of 10,540 km². The basin is drained through the Pampanga River and via the Labangan Channel into the Manila Bay.

The basin experiences, on an average, at least one flooding in a year. Dry season generally occurs from December to May, and wet the rest of the year. The wettest months are from July to September. The Pampanga River Basin could handle between 100-130mm of 24 Hour Rainfall.

Extensive flooding occurred at the Pampanga River Basin in July 1962, May 1966, May 1976, October 1993, August 2003, August 2004, Late September-October 2009, and August 2012. The flooding that occurred in September 2011 associated with Pedring (Nesat) nearly swallowed the Province of Pampanga and Southern parts of Bulacan.

B. The Pampanga River



The blue distorted line traversing the Pampanga River Basin is the Pampanga River

Pampanga River (formerly *Rio Grande de 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.

The calm waters of Pampanga River downstream

The areas, unfortunately, suffers considerable flood damage almost every year. Its headwaters are located at the Sierra Madre and runs a south/southwesterly course for about 260 kilometers until it drains into Manila Bay. Some of the major uses of Pampanga River are as follows:

- Source of hydro-electric power of Luzon Grid
- Source of irrigation to about 363,246 hectares of farmland
- Source of industrial, commercial and domestic Water
- Supply for Region 3 and Metro Manila

C. San Agustin Bridge (Arayat, Pampanga)

Taking a picture with Mount Arayat on San Agustin Bridge

San Agustin bridge in Barangay San Agustin Norte, Arayat, Pampanga is a one-hour drive from the Pampanga River Flood Forecasting and Warning Center (PRFFWC) in Barangay Maimpis, City of San Fernando. Its accessibility (in which the bridge is a national highway itself) and a picturesque view of Mount Arayat upstream make it an ideal location for measuring the discharge across Pampanga River.

(*top*) GMap view of San Agustin Bridge;
(*lower left*) Arayat rainfall and gauge station; (*lower right*) old Arayat station

Beneath the right side of the bridge (when looking downstream) is the Arayat rainfall and river gauge station (yellow), while looking upstream on the other side is the old Arayat station (red) also where the benchmark (BM) is located. The water level is being monitored using a staff gage, with the "0" measured at __ meters.

D. Site Characteristics

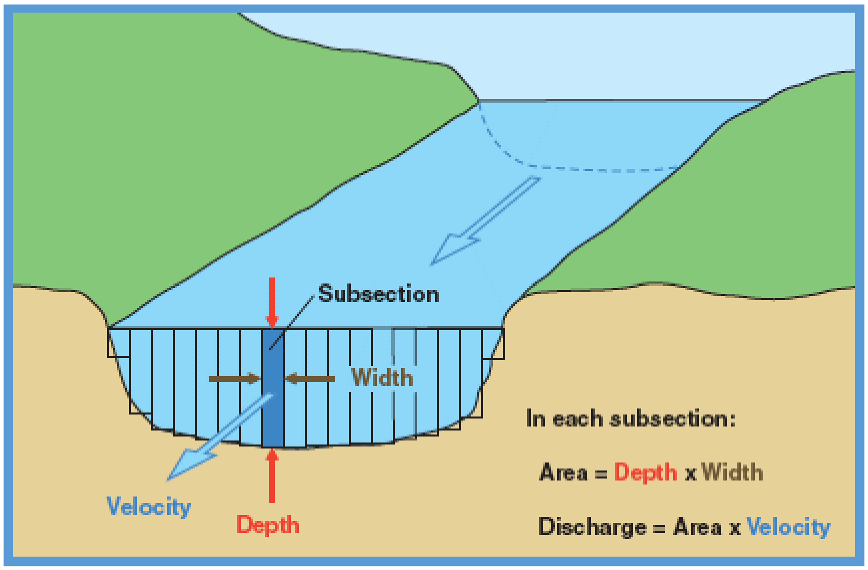
(*top*) looking downstream from San Agustin bridge;
(*lower left*) wide plain beside Pampanga river; (*lower right*) stepping on the Arayat soil

Downstream of San Agustin Bridge is the plain view of Pampanga River and grassy to bushy on either sides. Soil from the dry plains right to the streambed is mixture of silt loam and fine said. A calm sunny weather is also observed during the four-day period.

METHODOLOGY

The following methods for discharge measurement were arranged according to the order they were performed. These steps only comprise the field work activity itself of Group 1 and do not include data manipulation.

A. Current Meter Method



Determining the Discharge in Each Subsection using Current Meter Method

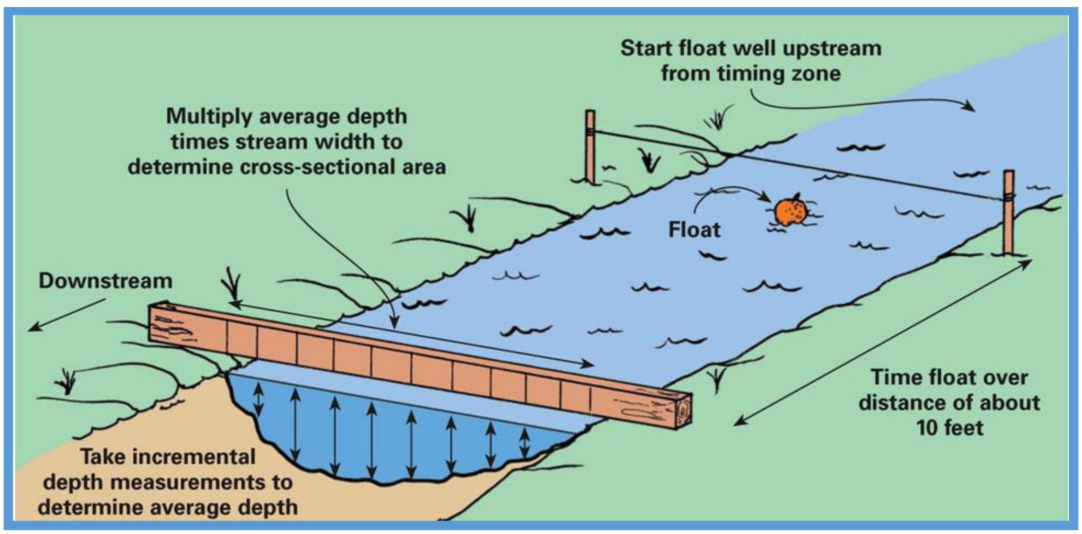
For the current meter method, discharge was measured using the river cross-section right below San Agustin Bridge.

1. Mark 15 to 20 points across the bridge. Points were arbitrarily chosen, but must start and end on the left and right water edges.
2. Assemble the calibrated cable and reel system off a bridge.
3. Attach the Price AA current meter and the sounding weights to the cable.
4. Starting from the left water edge, slowly drop the current meter down the bridge right to where the weight touches the water. Determine the vertical distance.
5. Proceed to the next bridge point without reeling up the meter. Determine the depth of the river at that point.

6. Use the *three-point method* or 0.2-0.6-0.8-depth for deep portions of the river. In this case where the river is shallow, the *one-point method* or 0.6-depth must be used. To do so, multiply the depth by these points, then reel the meter down to those depth points.
7. Keeping the meter steady, count the number of clicks or revolutions within a 1-minute time interval. In cases where flow is rapid, use the one-click-for-every-five-revolutions mode.
8. Do the same for all depth points beneath all the bridge points.

Note: Take into account the turbulent flows, flowing lilies, and pier posts, as these affect water velocity and thus, the overall discharge. Under these hindrances, the depth may only be taken into account.

B. Float Method



Estimating Discharge Using Float Method

Float method has two phases: one is the dropping of ten (10) floats while the other is the depth-range of the two cross-sections measurement using a boat.

1. Mark 5 points of uniform distance across the bridge.

2. Choose two cross sections downstream from the bridge, with the first cross-section at least 30 meters from the bridge and the second cross-section at least 100 meters from the first.
3. Starting from the leftmost marked point, drop one bamboo float down to the river.
4. Carefully observe the time it takes for the float to travel from one cross-section down to the next.
5. Do the same for four other floats. Since there are ten floats all-in-all, repeat the process for the same five points.
6. The second phase requires traversing the two transects by boat. On one cross-section, choose at least seven (7) points randomly and steadily measure the depth and range in each, with the use of echo sounder and range finder respectively. Do the same for the second cross-section.

Note: There may be instances when a float submerges from the drop or fails to reach both cross sections. This is where the averaging of two drops per point comes in place, so discharge measurement will be intact.

C. Slope-Area Method

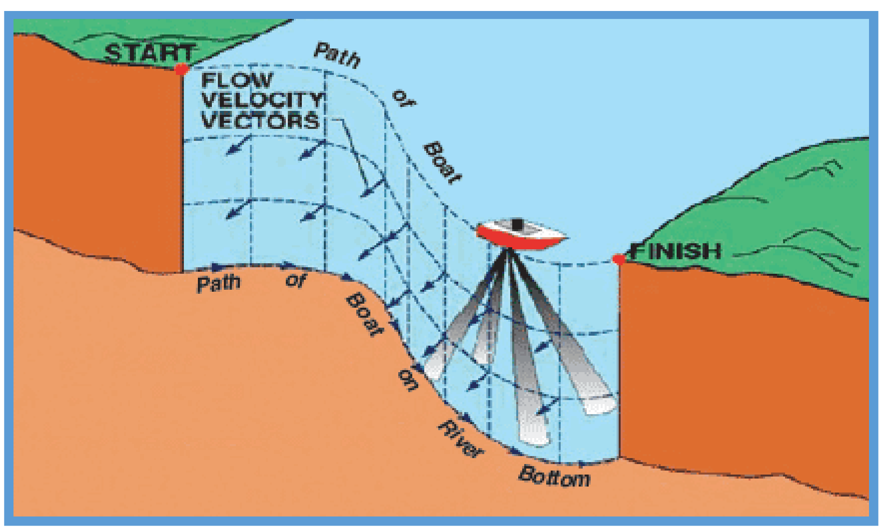
Determining the Discharge using Slope-Area Method

The slope-area method requires a total station and a prism as a means of defining or measuring surface slope. Three cross-sections from the ideal reach, which is downstream the bridge, shall be chosen.

1. Select three cross-sections from the reach downstream that is uniformly straight and has minimum vegetation across. Distance between cross-sections shall range from 50 to 100 meters.
2. Identify the benchmark somewhere near the bridge. This is where the measurement of cross-sections shall start.
3. Using a total station, measure the full-flood waterway at the first cross-section. Identify flood marks and peg these points for future use. Choose as many points of observation as possible.
4. Proceed to the second cross-section using the same procedure as the first. Finish it right up to the third cross-section.

Note: Estimated time for this method is around 4 to 6 hours. Trees and shrubs are the likely hindrances in taking measurements from the total station up to the flood marks so adjustments may be made.

D. ADCP Method



Crossing the ADCP on a River Cross-Section to Measure Discharge

The Acoustic Doppler Current Profiler or ADCP method is the simplest but most delicate among the four methods. Care should be observed in handling this costly equipment.

1. Assemble the ADCP vessel and transmitter-receiver setup as instructed (assembly by parts shall not be discussed)
2. Calibrate the ADCP vessel using the yaw-pitch-roll principle.
3. Open the RiverSurveyor® program and make a new track.
4. Pin the ADCP vessel to a boat. Start with the left bank and measure the distance from the left water edge to the point where the bottom of the ADCP doesn't touch the stream bed. Input this distance to the software when asked.
5. Start tracking the cross-section using the Record button in the computer receiver. Traverse the ADCP straight on the cross-section until it reaches the other bank. Again, measure the distance from the right water edge to the point where the bottom of ACDP doesn't touch the stream bed. Input this distance to the software.
6. Perform the tracking two more times, except the second trial must start from the right bank, proceeding to the left.

RESULTS AND DISCUSSION

A. Current Meter Method

The acquired data for current meter method includes the discharge (Q) table and a graph of depth versus distance that represents the river cross-section below San Agustin Bridge.

Discharge Measurement (Current Meter) for :		*Arayat Station*		River:	*Pampanga*		PRFFC
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 Initial point	Width (mts.)	Depth (ep for pier) (mts.)	Vert. Angle 4^0-36^0	Angle Corrected Depth	Observation Depth 0.2 Rev.	0.2 Time	0.6 Rev.	0.6 Time	0.8 Rev.	0.8 Time	Velocity at point for 0.6 only	Mean (0.2,0.6 & 0.8) or (0.2 & 0.8)	Area (m^2)	Q (cumecs)	Remarks Excellent, Good 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	

Rem:	Total Area =	873.66	
	Total Discharge =		311.48
	Ave. Velocity =		0.357

Table 1. **Discharge (Q) Table using Current Meter Method**

Table 1 above made use of Microsoft Excel Suite that obtains an equivalent total discharge simply by completing all the following beige cells:

- Name of station and name of river
- Gage height at the beginning and end of the activity
- Calibration equation (general formula)
- Vertical distance to water surface in meters
- Distances from the initial point in meters
- Depths of each distance in meters
- Vertical angles ranging only from 4 to 36 degrees (otherwise, leave it blank)
- The number of revolutions within not less than 60 seconds, depending on the depth points used. For shallow points, only the 0.6 depth was filled. For deeper points, all the observation depths 0.2, 0.6, and 0.8 were filled up.
- Remarks or rating of the observation (optional)

Observe from Table 1 that not all sections have a recorded observation depth. This may be due to piers, water lilies, and turbulent flows that hindered in getting an accurate number of revolutions at a certain time. Next, filling up the beige cells will reveal the following data in white cells:

- ✓ Width of each subsection in meters
- ✓ A corrected vertical angle
- ✓ Computed velocity at one-point depths and mean velocity for three-point depths
- ✓ Area of each subsection in square meters
- ✓ Discharge of each subsection in cubic meters per second or cumecs
- ✓ Total area of the cross-section or simply the sum of all the subsections
- ✓ Total discharge of the cross-section or the sum of all the discharges
- ✓ Average of the computed and mean velocities

The recorded discharge from the Acoustic Doppler Current Profiler (ADCP) that day was around 250 to 280 cumecs. Arriving at **311.48 cumecs** discharge, which is way larger compared to the expected value, may be due to insufficient data along the piers and other obstructions below a subsection.

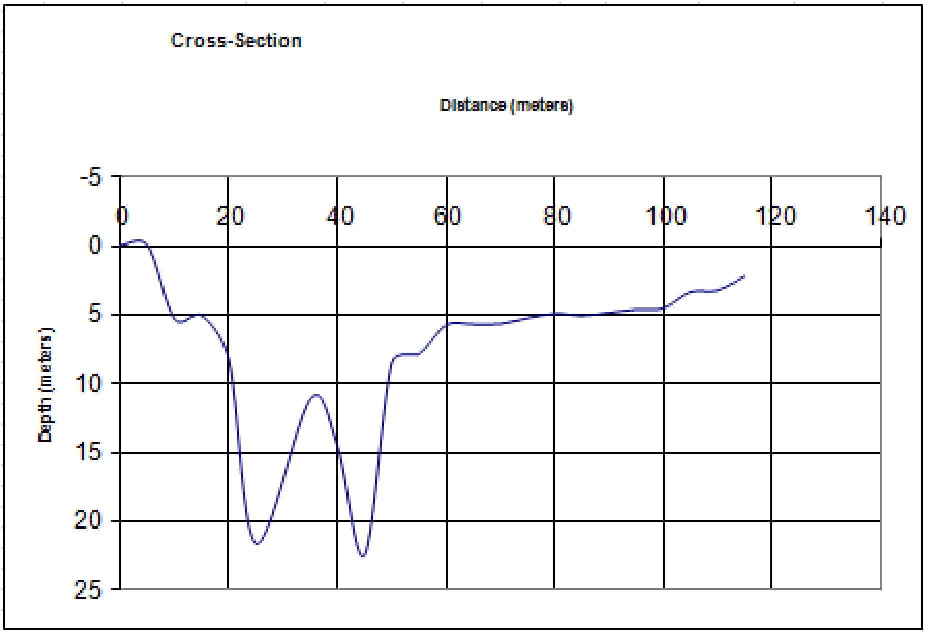


***Figure 1*. Pampanga River Cross-section Derived from Distance-Depth Relation**

Figure 1 reveals the cross-section of Pampanga River below San Agustin Bridge using the distance and depth acquired from the Q table. The curve shows how the cross-section has its deepest points near the left water edge and shallower on the right half of the river.

B. Float Method

The acquired data for float method includes two manually computed tables for the physical parameters of each cross-section, their cross-sections based on distance versus elevation, and the equivalent discharge table for the two transects.

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**						

***Table 2a*. Physical Parameters for the First Cross-section using Float Method**

***Figure 2a.* Equivalent First Cross-section using Distance and Elevation**

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**						

***Table 2b*. Physical Parameters for the Second Cross-section using Float Method**

***Figure 2b.* Equivalent Second Cross-section using Distance and Elevation**

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 2c. **Discharge (Q) Table for the Two River Cross-sections using Float Method**

Float method shows a similar, but simpler approach compared to the slope-area method. Microsoft Excel Suite may be used (Tables 2a and 2b) in determining the total width, area, wetted perimeter, hydraulic radius, mean depth, and a graphic representation of the cross-sections (Figures 2a and 2b).

However, the discharge (Q) table is the most important among the given data since it shows in detail the time it took for one float to travel from one cross-section to another. From this, the mean velocity of the two trials can be obtained. A FAIL on one trial shall be disregarded so the average time will be the other trial itself. Table 2c was manually computed, revealing a total average discharge of **614.02 cumecs**. This is roughly 7 to 8 times higher compared to the discharge measurement using current meter method.

C. 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**

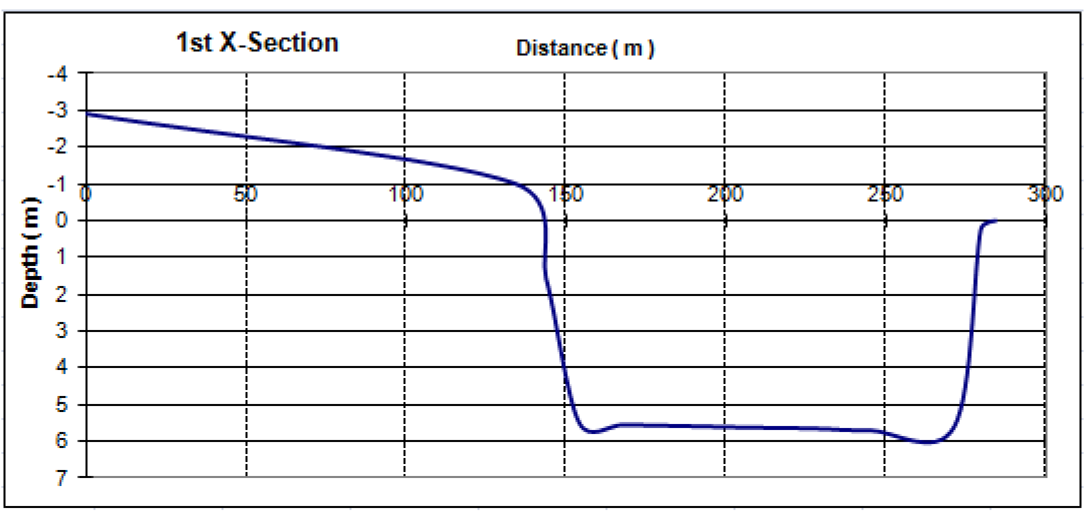


***Figure 3a*. Graphic Representation of the 1st Cross-section Using Distance-Depth Relation**

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**

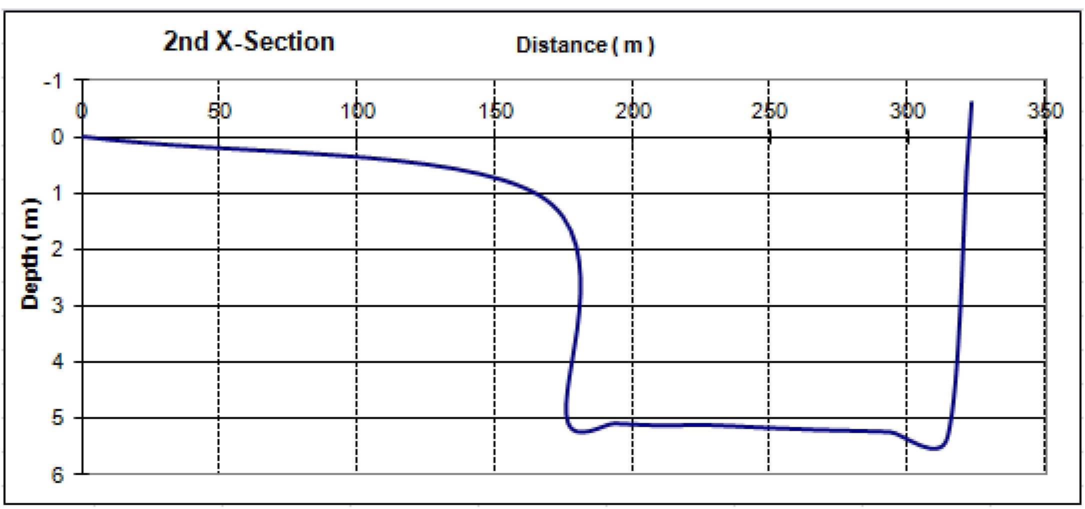


***Figure 3b*. Graphic Representation of the 2nd Cross-section Using Distance-Depth Relation**

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**

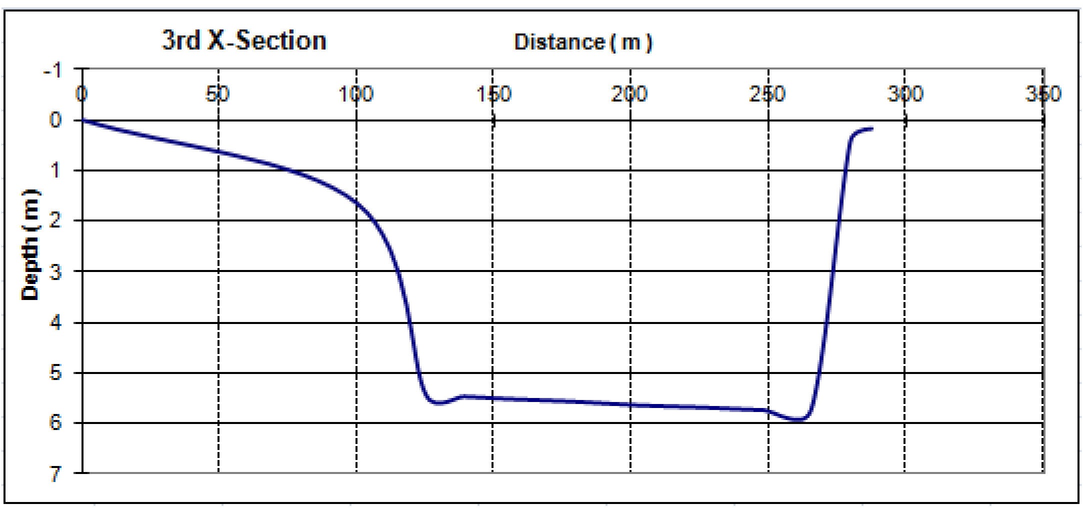


***Figure 3c*. Graphic Representation of the 3rd Cross-section Using Distance-Depth Relation**

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. Inputting these to the Microsoft Excel Suite will automatically reveal the 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, the raw data also 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:

$Q_{1\text{-}2\text{-}3}$ = 3440.34 **cumecs**

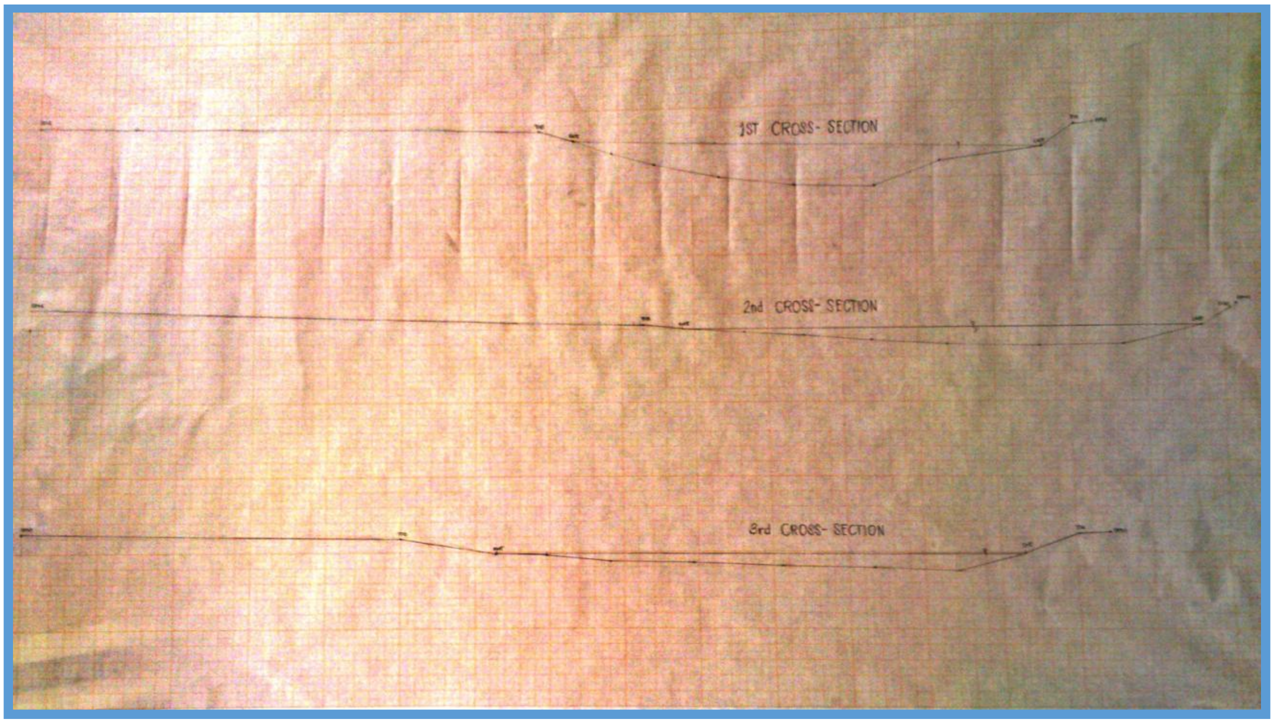
Discharge

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

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

The final table 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.

The following is the actual sketch of the three cross-sections using graphing paper, as derived from CAD software:



Draft of the Three Cross-sections in Slope-Area method

D. ADCP Method

The *RiverSurveyor®* software illustrates in detail the river cross-section as well as its discharge in the shortest amount of time. This software program made by SonTek is Windows-based and operates in real time.

As mentioned, three trials were made across the same river cross-section, some 50 meters downstream from the bridge. A cross from one edge to the other edge is equivalent to one trial thus, one set of data. Captions were taken from the computer as follows:

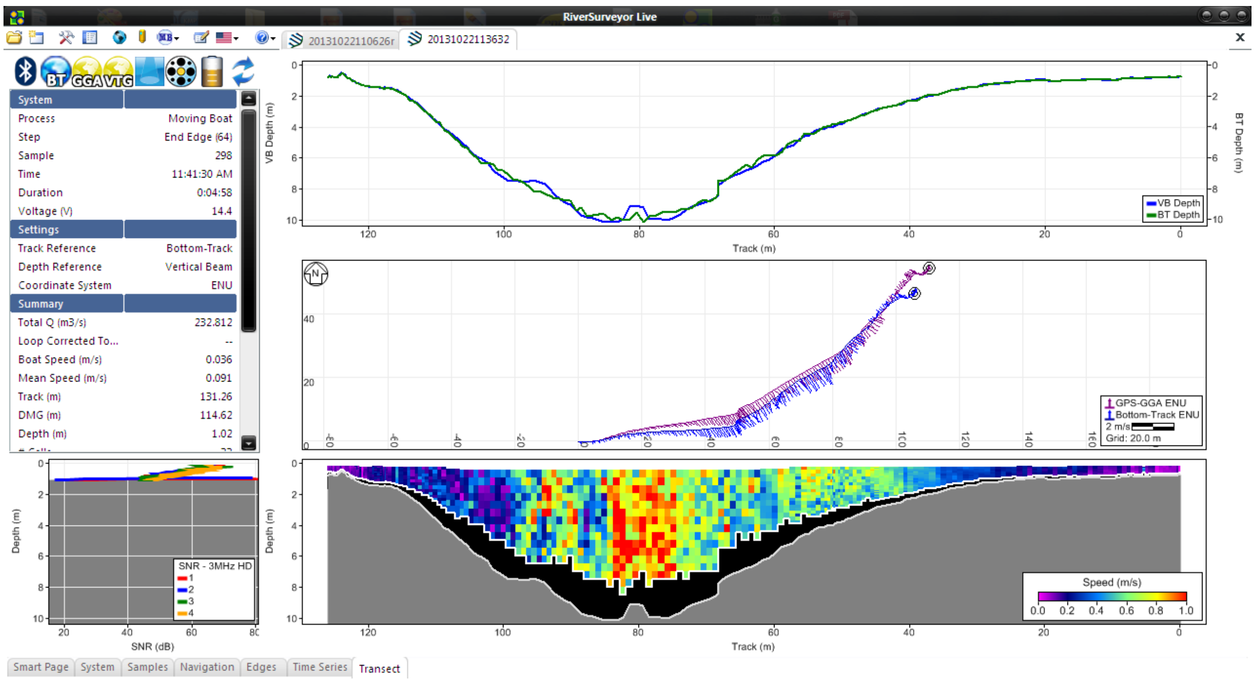


***Figure 4a*. Cross-section and Discharge from *RiverSurveyor* using ADCP Method (1st trial)**

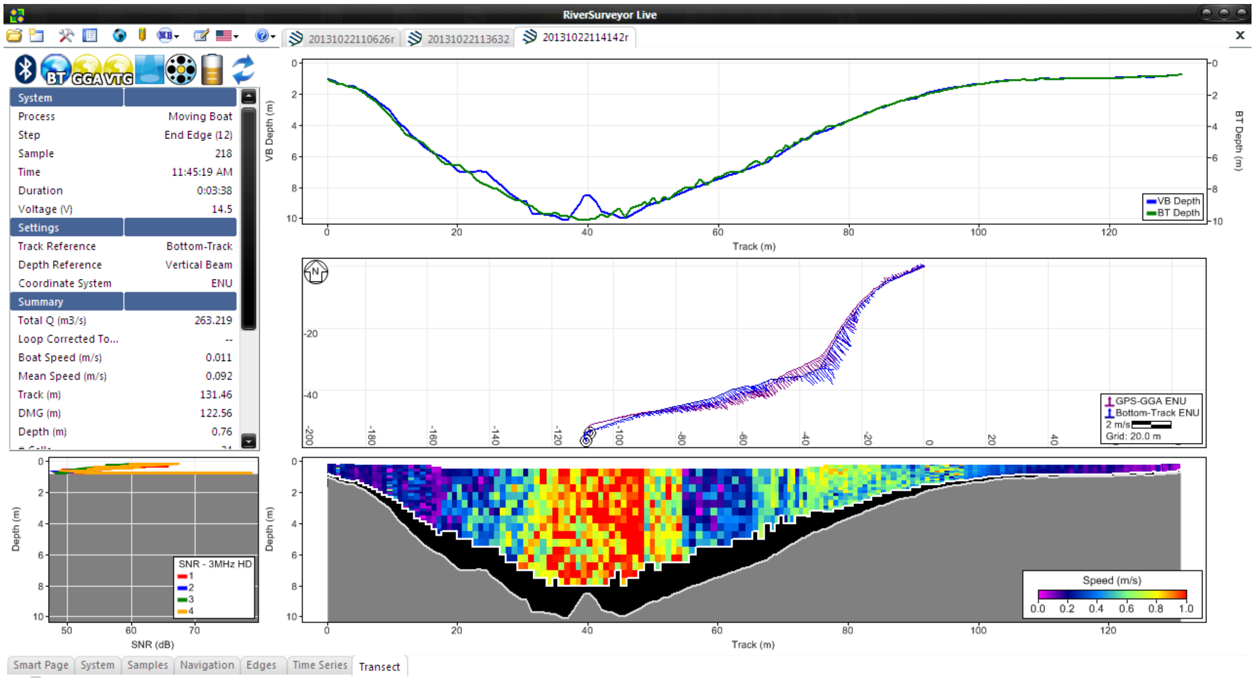


***Figure 4b*. Cross-section and Discharge from *RiverSurveyor* using ADCP Method (2nd trial)**

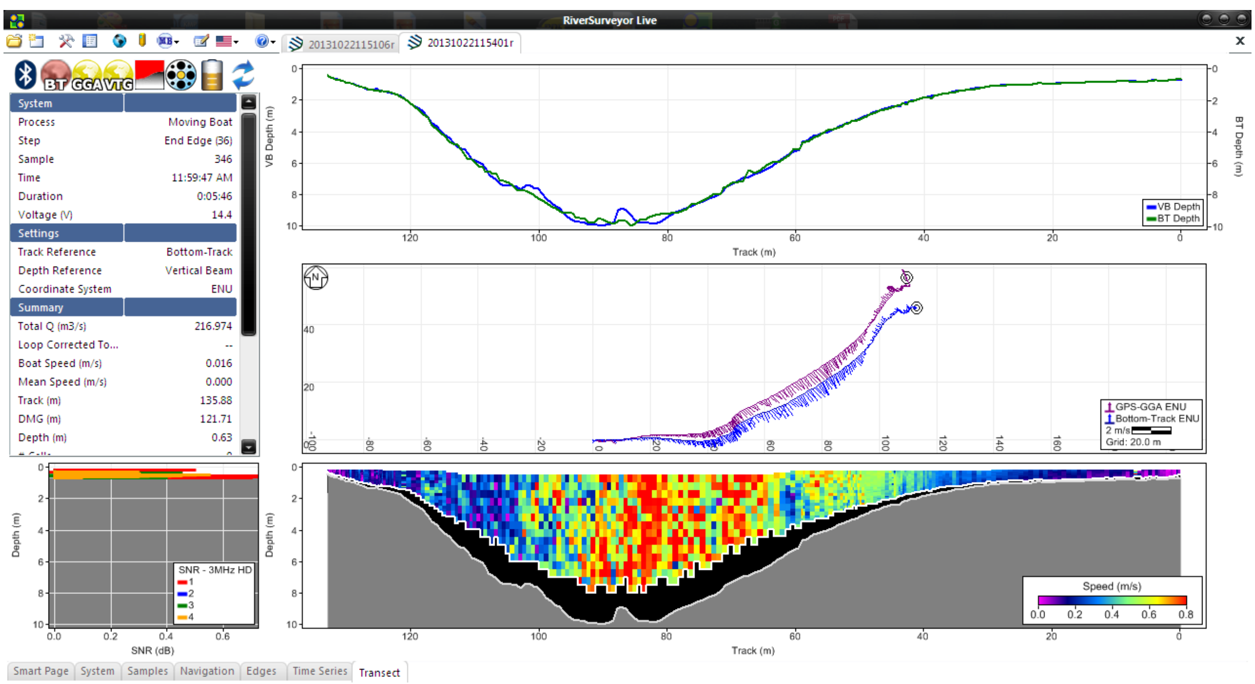


***Figure 4c*. Cross-section and Discharge from *RiverSurveyor* using ADCP Method (3rd trial)**

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.

THE RATING CURVE AND EQUATION

A rating curve is established by making a number of concurrent observations of stage and discharge over a period of time covering the expected range of stages at the river gauging section. The profile sketch was conducted by Group 1.

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	

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

Table 5. Discharge from different stages and the Equivalent Rating Curve Equation

The rating curve equation was derived from the cross section of the river just below the bridge, from one endpoint to the other. The general equation was actually

$$\boxed{Q = c(h + a)^b}$$

where: Q = discharge (m^3/sec)

h = measured water level (m)

a = water level (m) corresponding to Q = 0

c,b = rating curve constants derived from the relationship corresponding to the station characteristics

FIELD WORK SUGGESTIONS

The four-day field work, in general, is a tiring yet fun experience that any aspiring hydrologist should not miss. Each of the four methods offered a different approach in measuring stream discharge, without hang-ups from the lack of equipment or time restraint. Working in groups 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, most of the personal suggestions would be regarding the materials and equipment used during the field work, though the solutions would mostly require funding. For the four discharge measurement methods, except ADCP method, it could be suggested to:

1. have a larger (and functioning) sounding reel for the deeper portions of the river cross-section during current meter method;
2. obtain more cross-sections (thus, more bamboo floats) during the float method so that discrepancies will be compensated especially with missing floats; and

3. have a cableway or a fixed rope with markings that will serve as a tagline in slope-area method.

OBSERVATIONS DURING THE FIELD VISIT

Other than the field work, the trainees were also given a chance to visit several accessible dams and landmarks that may be of use for future endeavours as hydrologists:

Day 1 - La Mesa Dam

The La Mesa Watershed is the first destination, and the first of the four dams visited during the field work. It is an overflow dam without a gate. The visit to the dam includes a brief discussion of how significant is the La Mesa watershed from the waters processed by Manila Water and Maynilad, to the waters consumed by residents of Metro Manila.

Day 5 - Pantabangan Dam

In general, the visit to Pantabangan Dam was literally warm but welcoming. The nearly four-hour trip to the dam was compensated with a sophisticated ambience of the hall and a heavy snack. In addition, the flood forecasting and warning center for dam operations of Pantabangan has a mix of modern and old school facilities. Above all, the dam's watershed and spillway turned out to be a breathtaking landscape. It was very nice taking pictures within the area.

Day 6 - Subic

A free day at Subic in Zambales did not turn out as fruitful as everyone had expected. The bus had a few stops in Camayan Beach Resort for picture-taking and in Duty Free Freeport Exchange for shopping.

Day 7 - Cong Dadong Dam

Cong Dadong Dam was visited right after the third field work. It was located upstream of Pampanga River from San Agustin Bridge, a few kilometers away. The dam was said to be mainly for irrigation purposes, thus, its construction is fairly simple compared to other dams.

Day 9 - Calumpit/Bacolor/Clark

First of the three trips during Day 9 is the Municipal Disaster Risk Reduction and Management Council (MDRRMC) in Calumpit, Bulacan. The town of Calumpit claims itself to have flood-loving people. This is the reason why they came up with a flood monitoring system using Microsoft Excel Suite. This is an impressive move on the part of the municipality of Calumpit and a good initiative for other nearby towns to follow suit.

Next stop is the San Guillermo Parish Church, also known as the Sunken Church of Bacolor in Pampanga. By the name itself, it was noticed how the church sank by a few meters after the Mount Pinatubo eruption in 1991, giving the impression that it has a low elevation. However, it was admirable to see how the church was saved and still preserves its historical attributes.

Last stop for the day was the tour of Clark Freeport Zone near Angeles City, Pampanga. The place is best known for its airport and leisure hubs, but the group decided to stop again at Duty Free. Clark looked clean and peaceful in general.

Day 10 -Angat Dam

The last destination of the field work and the last of the four dams is the Angat Dam in Norzagaray, Bulacan. The way to the dam, as well as its landscapes and spillway, is closely similar to that of Pantabangan dam. However, the trainees were given a closer look inside the Angat Hydroelectric Power Plant which contains huge electrical rotors, armatures, and transformers.

RELATING HTC WITH THE FIELD VISIT

As a hydrologist trainee, it is important that we were able to visit the dams around Central Luzon as there are chances of career opportunities there one day. There are a few ways that relate hydrology to dam operation. It all starts with the concept of streamflow.

For all we know, rivers tend to change its flow rate at any moment in time. This could likely put the communities and vegetation downstream of the river into danger. Dams, particularly storage dams for this purpose, could control these changes in flow by storing a huge amount of water that may be released for future use. Other dams can also divert the streamflow from the main river, directing part of the water for irrigation and vegetation. Finally, some dams come with hydroelectric power plants that supply electricity to communities surrounding the dam. Thus, hydrologists should carefully monitor and control the inflow and outflow on these important watersheds.

Hydrologists designated on flood forecasting are a big help for dam operations as they monitor water level and discharge of major rivers downstream. Moreover, hydrologists designated on flood warning for dam operations help the community be warned of the possible dangers of immediate streamflow.

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:
   a. 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.
   b. 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.

c. 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.

d. 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:

   a. 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.

   b. 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.

   c. 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.

d. 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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