Estimation of Pollution Load in the Rivers of Labac-Alemang Watershed, Cavite, Philippines

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ABSTRACT

A Pollution Load Model and an L-Q Relationship Model were used to estimate the pollution load in the rivers of the Labac-Alemang Watershed. The rivers of the watershed were found to be positive for organic pollution, nutrient pollution, suspended matter and sediment pollution, and microbiological pollution. Point and non-point sources contributed to the high pollution loads in the rivers. Agriculture (livestock and poultry) contributed the most BOD, NH_4 and total phosphorus. The highest total suspended solid load came from non-point sources, such as plantations, while highest total coliform load was contributed by domestic sources. The highest loads were observed on the station nearest to the outlet before discharging to Manila Bay.

Keywords: point and non-point sources, water pollution, water quality, Labac River, Manila Bay

INTRODUCTION

The Manila Bay is known for its importance as a marine resource and for its cultural and historical value but it continues to be degraded due to various sources of pollution from the cities and provinces surrounding it. In 1999, concerned residents of the area filed a complaint against polluters leading to a Supreme Court-issued *mandamus* to rehabilitate and restore the bay to SB level (recreational water class I, suitable for bathing, swimming, skin diving; fishery water class I, suitable as spawning areas of *Chanos chanos* and similar species) as per DENR Administrative Order 34 series of 1990 (Patajo-Kapunan, 2019). A study by the Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), the Department of Environment and Natural Resources (DENR) and the Laguna Lake Development Authority (LLDA) in 2013 showed that high levels of biochemical oxygen demand, total phosphorus, and total nitrogen are emitted by the industry, domestic, agriculture, and forest sectors of the 58 sub-basins of Laguna de Bay-Pasig River-Manila Bay Watershed, which enter and drain into Manila Bay.

Cavite is one of the provinces that surround Manila Bay and most of its river systems drain into it. These rivers are components of the six major watersheds of the province, among which is the Labac-Alemang Watershed (LAW). LAW covers two cities (Tagaytay and Trece Martires) and four municipalities (Mendez, Indang, Tanza, and Naic) of the province and has a total drainage area of 9,086 ha (90.86 km^2). The watershed provides numerous ecosystem services such as water resources, agricultural crops, medicinal plants, and fishes and crustaceans on its rivers. It also provides habitat for the critically endangered Southern Luzon Slender-tailed Giant Cloud Rat (*Phloemys cumingi*) (Department of Environment and Natural Resources-Provincial Environment and Natural Resources Office Cavite & Cavite State University, 2015).

As the province progressed through the years, the rate of urbanization and industrialization in the area also increased resulting to more anthropogenic activities that contribute to pollution to the rivers. According to the study of Cero (2015), high levels of microbiological contamination were observed in the downstream section of the watershed, as well as indicators of organic pollution. Other water quality studies also revealed poor and degraded quality of the rivers of the watershed, which were below the acceptable standards set by the Department of Environment and Natural Resources (DENR). The pollutants, whether filtered or treated by either natural or artificial processes, eventually go to Manila Bay. Hence, the ecological integrity or the overall quality of both the watershed and the bay is affected, resulting in altered uses and ecosystem services that can be obtained from them (Figure 1).

To address this problem, this study estimated the amount of pollution loaded into the rivers of the watershed and discharged to Manila Bay by identifying and computing the estimated pollution load from both point and non-point sources within the watershed. Estimating the pollution load is necessary for assessing the current state of the watershed and in creating appropriate mitigating measures and policies for its protection and rehabilitation.

METHODS

By definition, pollution load is the amount of substance that passes a particular point of the river (such as sampling sites on a watershed outlet) in a specified amount of time (Meals, Richards, & Dressing, 2013). The pollution load of Labac-Alemang Watershed (Figure 2) that can be attributed to the activities occurring in the two cities and four municipalities within its boundaries

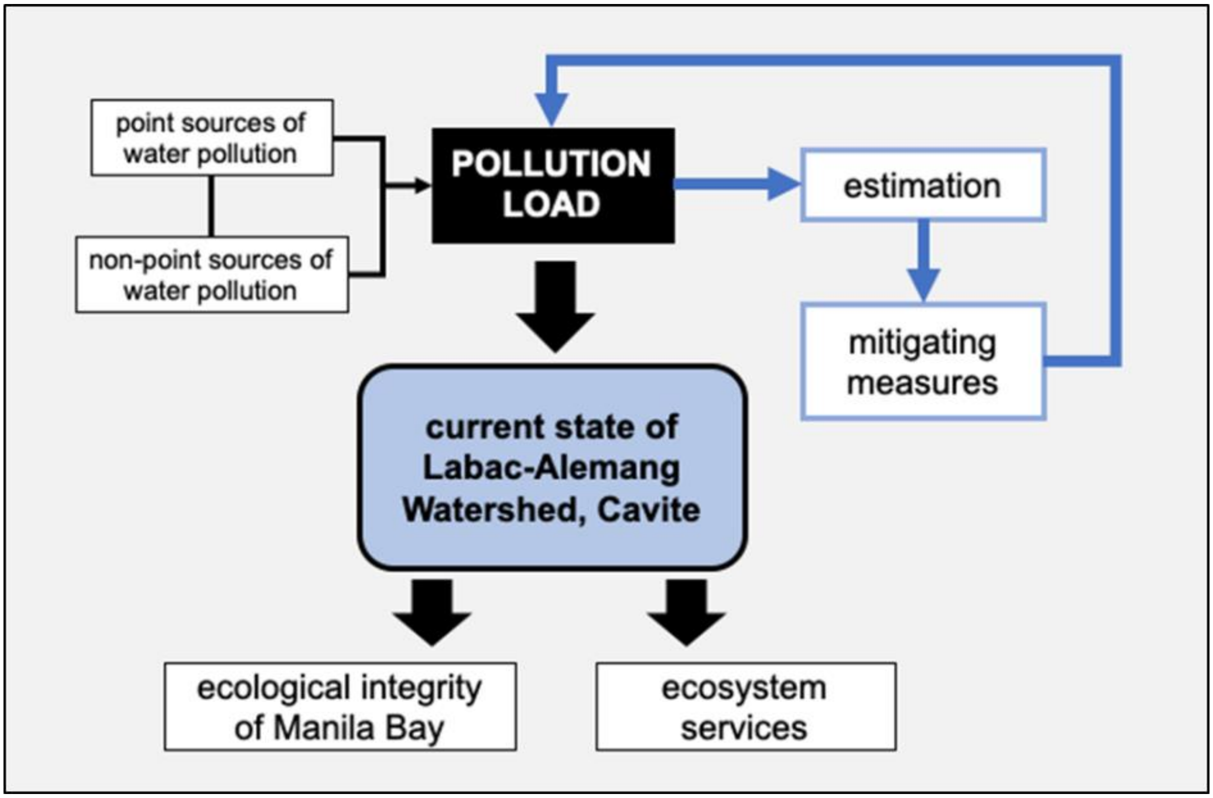


Figure 1. Conceptual framework of the study

were computed and estimated using the Pollution Load Model that was adopted from the Laguna Lake Development Authority and Amaya *et al.* (2012). This model contains two major elements: (1) pollution load generation module, which estimates the pollution load at source (generated load), and (2) pollution load treatment module, which computes for the estimated load discharged to waters after treatment (discharged load). This model utilizes the unit-load approach, hence, cannot estimate the actual load in the rivers. To estimate the actual load in the rivers, the Load-Discharge (LQ) Relationship Model was used, which utilizes actual field data.

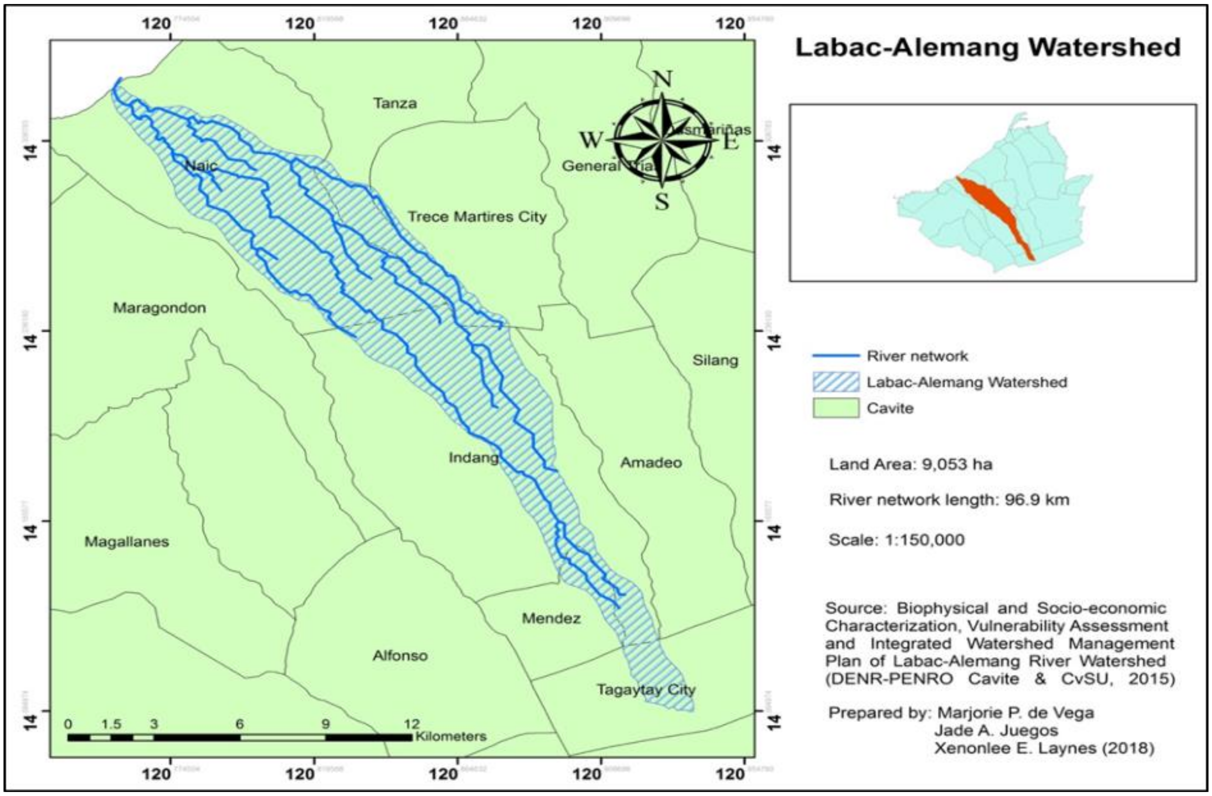
Computation of the pollution load using Pollution Load Model

Using the Pollution Load Model, pollution loads produced were calculated using a conventional unit load approach. The model defined 'unit load' as the amount of pollution load produced by one typical unit, such as one inhabitant or one hectare of grassland. The sources which were evaluated include domestic sources (greywater and black/toilet water), non-point sources (forests, arable land, plantations, urban areas, and water bodies), and livestock (cattle, carabao, goat, swine, duck, and chicken). To get the amount of pollution load, the unit load is multiplied by the number of units in a specific area.

For the computation of pollution load using this module, the generated load, and discharged load were determined.

Computation of generated load

The generated load per pollution source was



Land Area: 9,053 ha

River network length: 96.9 km

Scale: 1:150,000

Source: Biophysical and Socio-economic Characterization, Vulnerability Assessment and Integrated Watershed Management Plan of Labac-Alemang River Watershed (DENR-PENRO Cavite & CvSU, 2015)

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Figure 2. River network of Labac-Alemang Watershed in Cavite, Philippines

computed by multiplying the unit load with the number of units that contribute to pollution:

Generated load = unit load x number of unit

Table 1 presents the variables and data that were used to estimate the generated load from different sources.

where:

a. Generated load is the amount of pollution produced by different sources

b. Unit load is the concentration of the pollutants (BOD_5, TSS, NH_4, TP, and total coliform) per individual or per unit area

c. Number of units is the number of individual (person and animal) and sizes of land (arable, plantations and urban) that contributes to the pollution load of the river

Tables 2, 3, and 4 present the estimated concentrations of each parameter from different pollution sources as provided by the Laguna Lake Development Authority (LLDA). The pollutants considered in this study are biochemical oxygen demand (BOD_5), ammonium (NH_4), total phosphorus (TP), total suspended solids (TSS), and total coliform.

The resulting generated loads of the different sources of water pollution from the 57 barangays within the watershed were added to obtain the generated load per parameter.

Computation of discharged load

The discharged load is the total amount of pollution that goes into the river. The formula that was used to compute for this is:

Discharged load = Generated Load - (Generated load x Treatment Efficacy

Table 1. Variables and data used to estimate generated load using unit load approach (LLDA & Amaya *et al*., 2012)

GENERATED LOAD	UNIT LOAD	NUMBER OF UNITS
Domestic waste load	Emission per inhabitant	Number of inhabitants
Industrial waste load	Concentration in wastewater	Discharge of waste water
Agricultural waste load	Concentration per unit area	Surface area
Poultry and livestock	Emission per individual	Number of animal (per type)

Table 2. Waste load from domestic and industrial sources (g/c/d)

GRAMS PER CAPITA PER DAY	BOD_5	NH_4	TP	TSS	TOTAL COLIFORM
Grey	15	1	1.5	48	0
Toilets	35	7	0.8	20	1.00×10^{11}
TOTAL	50	8	2.3	68	1.00×10^{11}

Table 3. Waste load from livestock wastewater (g/c/d)

SPECIES	BOD_5	NH_4	TP	TSS	TOTAL COLIFORM
Cattle	556	40	56.6	20	10
Goat	50	40	30	20	10
Swine	109	40	24	20	10
Duck	5.0	1.0	0.4	20	10
Chicken	5.0	1.0	0.4	20	10

Table 4. Typical waste load from non-point sources (kg/ha/yr)

LAND-USE TYPE	BOD_5	NH_4	TP	TSS	TOTAL COLIFORM
Arable land	75	25	9	1500	0
Plantation	25	1	2	10000	0
Urban Area	50	10	1.2	10	0

Sewage treatment processes (STP) lessen the amount of pollutant from sources before it reaches the water bodies. Tables 5, 6, and 7 present the efficiencies of different STP (natural or artificial) on the different parameters for domestic and livestock wastewater and non-point sources, as provided as well by the Laguna Lake Development Authority (LLDA).

In estimating the number of households with and without septic tanks, the estimated percentage data from each barangay were obtained and multiplied by the number of households located inside the watershed.

Computation of pollution load using Load-Discharge (L-Q) Relationship Model

In getting the actual pollution load of the rivers, the L-Q Relationship Model was used. In this model, actual measurements of selected pollutants and flow rate were done on the field.

Table 5. Treatment efficiency value for domestic wastewater

SOURCE	POLLUTANT				
	BOD_5	NH_4	TP	TSS	TOTAL COLIFORM
Grey (to septic tank)	0.5	0.2	0	0.2	0.75
Toilet (to septic tank)	0.5	0.2	0	0.2	0.75
Grey (to drain)	0.2	0.2	0	0	0.75
Toilet (to drain)	0.2	0.2	0	0	0.75

Table 6. Treatment efficiency for different livestock

SOURCE		POLLUTANT				
		BOD_5	NH_4	TP	TSS	TOTAL COLIFORM
Cattle	with STP	0.7	0.6	0.6	0.6	0.8
	to ground	0.2	0.2	0	0.2	0.75
Carabao	with STP	0.4	0.6	0.6	0.6	0.8
	to ground	0.2	0.2	0	0.2	0.75
Goat	with STP	0.4	0.6	0.6	0.6	0.8
	to ground	0.2	0.2	0	0.2	0.75
Swine	with STP	0.4	0.6	0.6	0.6	0.8
	to ground	0.2	0.2	0	0.2	0.75
Duck	with STP	0.4	0.6	0.6	0.6	0.8
	to ground	0.2	0.2	0	0.2	0.75
Chicken	with STP	0.4	0.6	0.6	0.6	0.8
	to ground	0.2	0.2	0	0.2	0.75

Table 7. Efficiency of best management practices for non-point sources

SOURCE	POLLUTANT				
	BOD_5	NH_4	TP	TSS	TOTAL COLIFORM
Arable land	0.5	0.5	0.5	0.5	0.5
Plantation	0.5	0.5	0.5	0.5	0.5
Urban Area	0.5	0.5	0.5	0.5	0.5

Obtaining the load

Load refers to the concentration of pollutants in the water. Nine water sampling sites (Table 8 and Figure 3) were designated on selected rivers within the watershed and water samples were taken using grab sampling. The samples were submitted to DENR-recognized environmental laboratories in the province, where analyses were done to obtain the concentrations of biochemical oxygen demand (BOD_5), ammonia (NH_4), total phosphorus (TP), total suspended solids (TSS) and total coliform from the water samples. The sampling and laboratory analyses were done twice: once during the dry season (March 2018) and once during the wet season (September 2017).

Table 8. Water sampling sites in Labac-Alemang Watershed (LAW)

SAMPLING SITE	LOCATION (Barangay, Municipality/City)	GEOGRAPHICAL COORDINATES
1	Kaytapos, Indang	14°11'56.64"N, 120°53'12.73"E
2	Mahabang Kahoy Cerca, Indang	14°10'26.71"N, 120°53'30.73"E
3	Calumpang Lejos, Indang	14°14'12.46"N, 120°50'28.70"E
4	Bancod, Indang	14°14'22.30"N, 120°52'40.20"E
5	Cabuco, Trece Martires City	14°16'45.28"N, 120°50'34.53"E
6	Sabang, Trece Martires City	14°18'14.88"N, 120°47'59.67"E
7	San Roque, Naic	14°18'13.06"N, 120°46'30.12"E
8	Bucana Sasahan, Naic	14°19'14.42"N, 120°45'56.04"E
9	Ibayo Estacion, Naic	14°19'15.59"N, 120°45'33.28"E

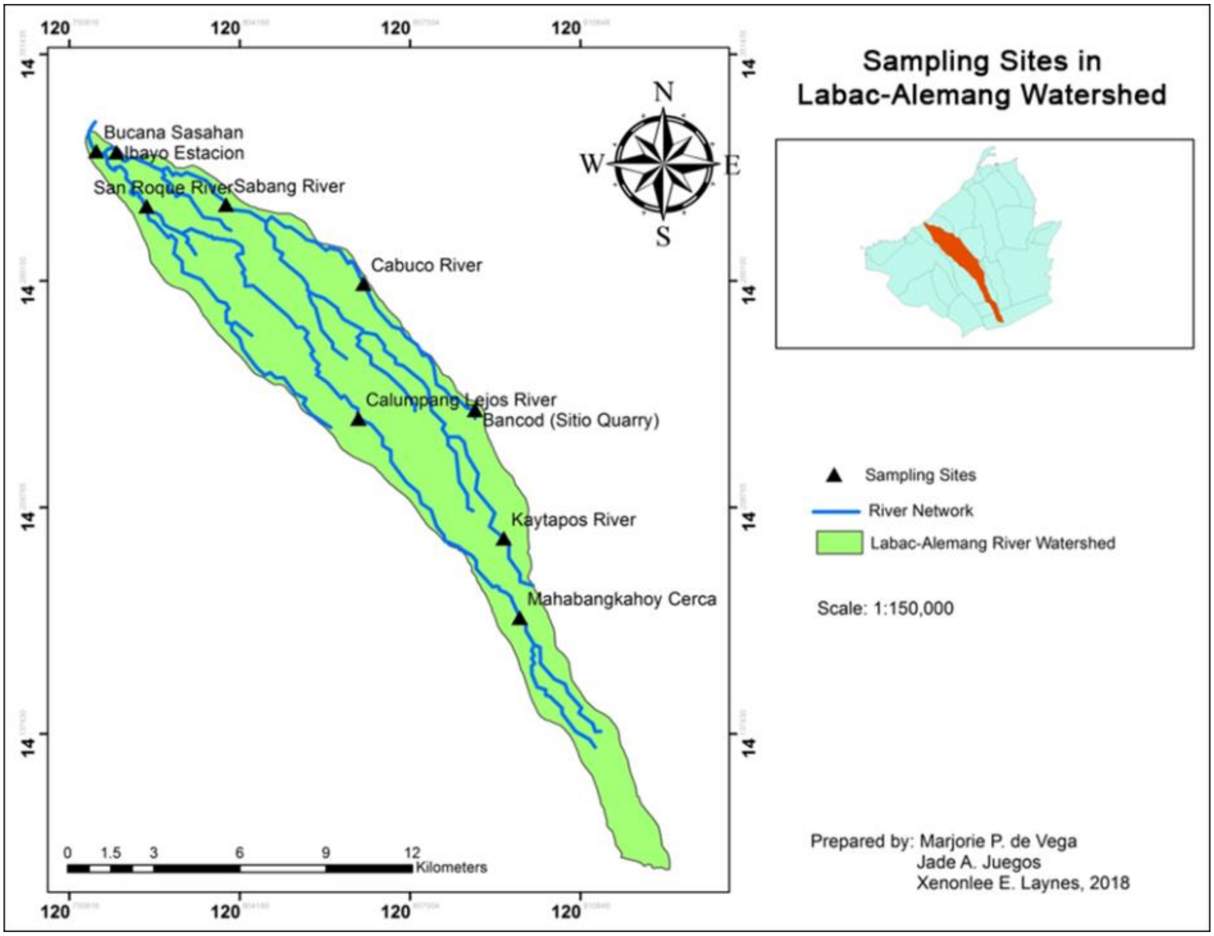

Figure 3. Water sampling sites in Labac-Alemang Watershed (LAW)

Obtaining the discharge rate

Discharge rate refers to the flow rate of the river, which was also measured on the same sites were water samples were taken.

Computing for the pollution load.

The formula that was used is:

$$Load = Q \times C \times cf$$

where:

Q = flow rate of the river (m^3/sec)

C = concentration of pollutant in the sampling point (mg/L)

cf = conversion factor (0.001 m^3/L)

The resulting load is expressed in mg/sec. Further conversions were done to reach the final unit of MT/year.

RESULTS AND DISCUSSION

Estimated Pollution Load using the Pollution Load Model

The pollution load of LAW from point sources (domestic sources and agriculture such as livestock and poultry farms) and non-point sources (plantations, rice fields, and urban areas) were estimated in terms of BOD_5, NH_4, total phosphorus, TSS, and total coliform. The livestock and poultry farm sector was found to be the highest contributor of BOD, ammonia, and total phosphorus loads in the watershed. On the other hand, non-point sources such as plantations, rice fields, and urban areas contributed most of the TSS loads while domestic sources contributed the highest total coliform load into the river watershed (Table 9).

Table 9. Summary of estimated pollution loading from different sources

POLLUTION SOURCES		BOD_5 (MT/YR)	NH_4 (MT/YR)	TOTAL P (MT/YR)	TSS (MT/YR)	TOTAL COLIFORM (MPN/YR)
Domestic	Generated	2001.75	320.28	92.08	2722.38	$4.00X10^{18}$
	Discharged	1193.49	256.22	92.08	2566.99	$1.00 X10^{18}$
Livestock and poultry farms	Generated	4191.79	1160.63	638.48	7778.52	$3.89 X10^{09}$
	Discharged	2983.86	689.56	434.99	5348.89	$9.18 X10^{08}$
Non-Point	Generated	225.25	36.36	17.64	44504.56	0
	Discharged	112.62	18.18	8.82	22252.28	0
TOTAL	**Generated**	**6418.79**	**1517.27**	**748.20**	**55005.50**	$\mathbf{4.0X10^{18}}$
	Discharged	**4289.97**	**963.96**	**535.89**	**30168.20**	$\mathbf{1.0X10^{18}}$

Biochemical oxygen demand (BOD)

BOD indicates the amount of oxygen needed to decompose organic matter in water which comes from various pollution sources. A sufficient amount of oxygen in water is critical for the survival and maintenance of aquatic life, as well as the aesthetic quality of streams and lakes. High BOD values indicate that there is depletion of dissolved oxygen in the water and generally, a greater degree of pollution is present, and lower water quality can be inferred (U.S. Geological Survey, n.d. & Water Education Foundation, 2018).

After the generated BOD loads from various sources have undergone either artificial or natural treatments, only 67 percent or 4289.97 MT/yr BOD load is discharged into the river system (Table 9). Livestock and poultry farms accounted for most of the BOD loads (Figure 4), as their wastewater contributes high organic matter load to the rivers. On the other hand, non-point sources contributed the least BOD in the year 2017.

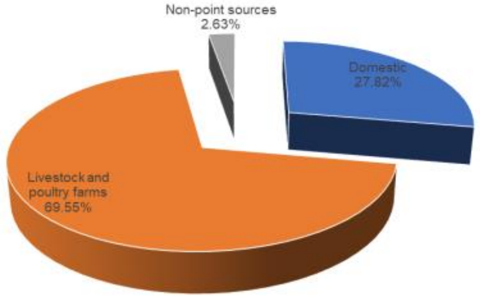

Figure 4. Percent contribution of the different pollution sources to the discharged BOD pollution load of LAW during year 2017

Ammonium

Ammonium concentration indicates organic pollution caused by wastewater treatment plants, industrial effluents, and agricultural run-offs (Trent & Nixon, n.d.). The generated ammonium load of 1517.27 MT/yr was reduced by 36.47 percent after undergoing various treatments. In 2017, only 963.96 MT/yr of ammonium load was released into the river system (Table 9). Due to high ammonium load per individual and high population of livestock animals, the livestock and poultry sector contributed the most ammonium load, while non-point sources contributed the least (Figure 5).

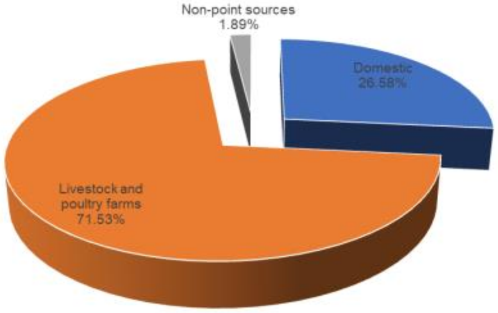

Figure 5. Percent contribution of the different pollution sources to the discharged ammonium pollution load of LAW during year 2017

Total phosphorus

Phosphorus, in natural waters, is found in the form of inorganic and organic phosphates. It is a limiting nutrient that aquatic and algae-like plants need to grow. Phosphorus in the water comes from various sources, which include human and animal wastes, soil erosion, detergents, septic systems and run-off from farmlands. Excess concentrations of phosphorus in water can result to algal blooms (PHILMINAQ, 2010).

The generated total phosphorus load in the watershed in 2017 was 748.20 MT, which was reduced to 535.89 MT/yr after various treatments (Table 9). The livestock and poultry sector had the highest total phosphorus contribution, while non-point sources had the least (Figure 6).

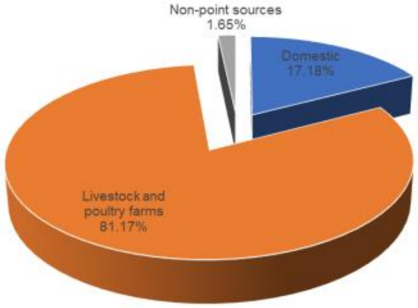

Figure 6. Percent contribution of the different pollution sources to the discharged total phosphorus pollution load of LAW during year 2017

Total suspended solids (TSS)

TSS include organic particles (microbes, algae, plant particles, animal detritus), and inorganic particles (silt, clay, industrial wastes, and sewage) which reach water bodies through surface runoff or sewers. Higher amounts of this important water quality indicator make it more difficult for sunlight to penetrate, thus, affecting the photosynthetic activity under the water, which is a source of oxygen. Furthermore, high amounts of TSS make the water warmer as more particles absorb heat, which results in to decrease in oxygen level. Solids can also clog the gills of fish and reduce their growth rate and disease resistance, as well as prevent egg and larval development (Thorpe, 2009).

The total generated TSS load for the year 2017 in LAW is 55,005.5 MT/yr, which was significantly reduced by 45.15 percent after artificial and natural treatments. The 30,168.2 MT/yr of TSS that went into the river mostly came from non-point sources accounting for 73.76 percent of the total (Table 9). Plantations and rice fields contribute a very high TSS load to the river due to agricultural run-offs, which carry sediments into the waters (Figure 7). On the other hand, domestic sources had the least TSS contribution with 2,566.99 MT/yr or 8.51 percent.

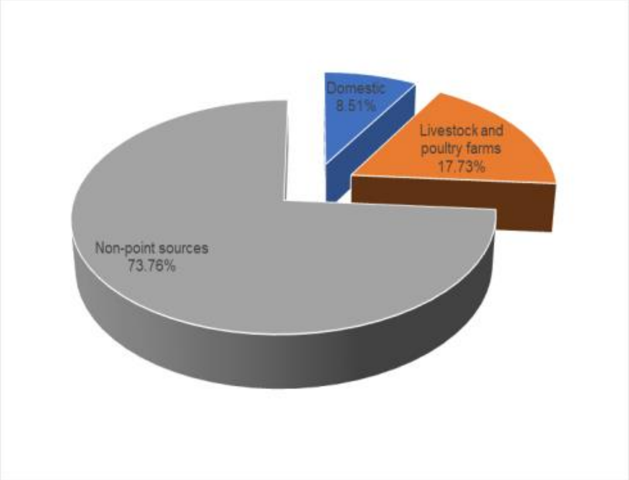

Figure 7. Percent contribution of the different pollution sources to the discharged TSS pollution load of LAW during year 2017

Total coliform

Total coliform refers to a large group of Gram-negative, rod-shaped bacteria that are commonly found in the environment and are generally harmless to humans. A subgroup of this bacteria are the fecal coliforms, which come from the feces of warm-blooded animals but can also be found naturally in soil. Fecal coliforms are considered indicator organisms; their presence in water can indicate contamination by human sewage and animal droppings which can contain other bacteria and disease-causing organisms. Ingestion of water that is contaminated by these organisms causes intestinal illnesses and some even lead to death (The British Columbia Ground Water Association, 2007).

Wastewater from domestic sources, specifically blackwater (i.e. wastewater from toilets), contributed very high total coliform levels, that reached 1.00 x 10^{18} MY/yr in 2017. Most of the total coliform load came from domestic sources (1.00 x 10^{18} MT/yr) while 9.18X10^{8} MY/yr came from livestock and poultry (Table 9 and Figure 8). Following the assigned unit loads based on Table 4, non-point sources have zero contribution to total coliform load.

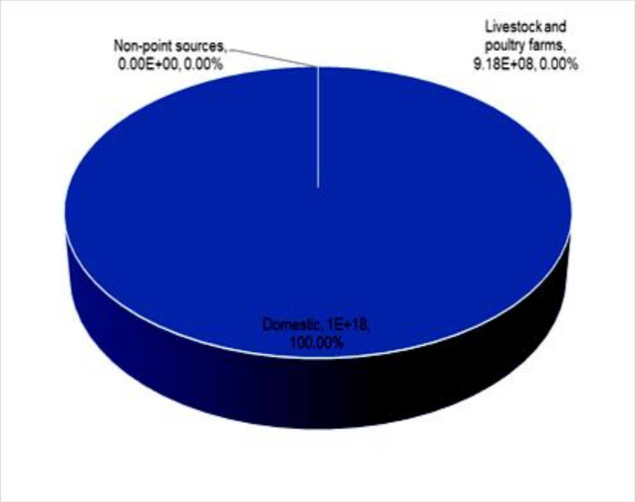

Figure 8. Percent contribution of the different pollution sources to the discharged total coliform pollution load of LAW during year 2017

Using the Pollution Load Model, the generated and discharged load from point and non-point sources in the watershed were estimated. Before entering river systems, wastewater undergoes several treatments or processes that somehow reduce the concentration of pollutants. It can be natural since a river has its own purification capability to naturally treat water pollutants as it travels along the stream, or artificial such as treatment plants, septic tanks, or surface water systems. The Pollution Load Treatment Module provided the treatment efficiencies of the sewage treatment process (for domestic and livestock sources) and treatment efficiencies of best management practices (for non-point sources) in terms of BOD_5, NH_4, TP, TSS, and total coliform.

Generated loads were significantly reduced after undergoing different artificial and natural treatments. This means that interventions such as septic tanks and drains for domestic sources, sewage treatment plants for livestock and poultry farms and best management practices for non-point sources must be enforced to improve the condition of the rivers and reduce the amount of pollutants that goes to Manila Bay.

Estimated Pollution Load using Load-Discharge (L-Q) Relationship Model

Unlike the Pollution Load Model, the Load-Discharge (L-Q) Relationship Model does not specify where the pollution comes from. Rather, it estimates the load of the river as a whole or divided into upstream, midstream, and downstream. In this model, the amount of pollutants and the surface flow had to be obtained. Pollution load was obtained by multiplying the concentration of pollutants with the flow rate of the sampling site. However, the number of sampling and measurement was limited, hence, the values obtained are only rough estimates.

As required by this model, the volumetric flow rate or discharge of LAW were obtained. Measurements were done once during the wet season (September 2017) and once during the dry season (March 2018). The mean discharge of LAW was 0.79 m^3/s during the wet season and 0.53 m^3/s during the dry season.

Table 10. Estimated pollution load during the wet season (September 2017)

SAMPLING SITE	BOD_5 (MT/YR)	NH_4 (MT/YR)	TOTAL P (MT/YR)	TSS (MT/YR)	TOTAL COLIFORM (MPN/YR)
Kaytapos	2.33	2.33	0.63	0.01	2.80×10^{15}
Mahabangkahoy Cerca	0.51	0.51	0.03	1.27	2.34×10^{14}
Calumpang Lejos	7.88	7.88	0.83	47.26	9.45×10^{15}
Bancod	0.11	0.11	0.02	0.38	2.67×10^{13}
Cabuco	11.53	11.53	4.50	80.73	2.02×10^{16}
Sabang	3.78	0.63	0.31	9.46	2.49×10^{14}
San Roque	122.25	27.17	4.48	597.65	1.49×10^{16}
Bucana Sasahan	974.59	389.84	37.03	11695.06	2.14×10^{17}
Ibayo Estacion	27.42	11.52	1.21	416.76	1.81×10^{15}

Other than the discharge rates, the actual concentrations of pollutants (BOD_5, NH_4, total phosphorus, TSS, and total coliform) in the rivers were also determined to compute for the pollution load. Except for the total coliform load during the dry season, Bucana Sasahan had the highest load for all parameters during both seasons. On the other hand, Bancod had the lowest load for all the parameters, except for the total coliform load during the dry season (Tables 10 and 11).

The river network of the watershed flows into two separate parts: the western and eastern parts. The total discharged load of western rivers drains at San Roque, while the eastern part drains at Ibayo Estacion. They then meet and converge at Bucana Sasahan (main outlet) before it finally discharges to Manila Bay. Therefore, the pollution load in Bucana Sasahan represents the actual discharged load of the watershed to Manila Bay. Results showed that the estimated pollution load for all the parameters are highest on this site, which reflects the combined effects of pollution loading activities throughout the watershed and the high values suggest that LAW contributes to the poor quality of Manila Bay.

The amount of BOD_5 load within the rivers of the watershed can be mainly attributed to livestock and poultry farms, especially large commercial farms without sewage treatment plants. High levels of ammonium in LAW, which cause nutrient pollution, come from the discharged load of large animals such as cattle, carabao, and swine. The ammonium load in Cabuco can be attributed to the high amount of discharged load from domestic sources in the highly-populated Aguado, a barangay in the upstream area of Cabuco.

Commercial farms are the major sources of the total phosphorus load in the rivers. These can be attributed to the plantations and rice fields, which contribute to agricultural run-off. On the other hand, in terms of microbiological pollution, domestic sources were the main contributors. The total coliform load in Bucana Sasahan was extremely high compared to the total coliform load of all the other sampling sites. This is mainly due to the direct discharge from the toilet of the households located very close to the river. Most of the households in this area also do not have a septic tank.

In comparison to the results of the study by

Table 11. Estimated pollution load during the dry season (March 2018)

SAMPLING SITE	**BOD_5 (MT/YR)**	**NH_4 (MT/YR)**	**TOTAL P (MT/YR)**	**TSS (MT/YR)**	**TOTAL COLIFORM (MPN/YR)**
Kaytapos	1.79	0.02	0.02	0.15	1.79×10^{14}
Mahabangkahoy Cerca	0.23	0.02	0.03	0.12	6.97×10^{11}
Calumpang Lejos	142.01	4.14	3.55	23.67	6.39×10^{16}
Bancod	0.13	0.00	0.02	0.04	6.52×10^{13}
Cabuco	34.00	7.79	0.13	9.76	5.39×10^{16}
Sabang	2.20	0.02	0.02	0.30	5.48×10^{14}
San Roque	5.74	6.09	0.31	1.91	6.50×10^{14}
Bucana Sasahan	669.36	53.55	44.62	2231.21	6.02×10^{16}
Ibayo Estacion	293.73	4.81	13.35	106.81	6.41×10^{15}

Amaya *et. al.* in 2012 for the Biñan River Basin, which drains to Laguna de Bay, the estimated total generated pollution load of Labac-Alemang Watershed in terms of BOD_5 using the Pollution Load Model is lower. This is because industrial sources of pollution, which are not present in LAW, were accounted for in the said study. Meanwhile, in terms of total phosphorus, LAW has a higher pollution load, which can be attributed to the presence of numerous livestock and poultry farms in the watershed. However, these comparisons are inconclusive due to the differences in the data sets and assumptions, and the size of the study area, and its corresponding population density. Studies on the estimation of pollution load also vary on the manner of categorizing pollution sources and on the water quality parameters used, hence, limiting the validity of comparisons.

As required by the Supreme Court *mandamus* to restore Manila Bay to Class SB level, the pollution load of Labac-Alemang Watershed rivers must then not exceed the allowable maximum load based on the standards of the same class or higher. Currently, not all parameters tested and sampling sites on the rivers in the watershed comply with Class C water quality, which is a level lower than Class SB. According to the Department of Environment and Natural Resources Administrative Order 2016-08: Water Quality Guidelines and General Effluent Standards of 2016, Class C freshwater must be usable for propagation and growth of fish and other aquatic resources; boating, fishing, or similar activities (recreational water class II); and, agriculture, irrigation, and livestock watering. This means that more effective interventions are necessary to clean and rehabilitate the rivers of LAW such that their discharge to Manila Bay will not worsen its condition and to contribute to its restoration to Class SB level.

CONCLUSIONS

Labac-Alemang Watershed provides various ecosystem services to the two cities and four municipalities within its boundaries. Through the years, anthropogenic sources of pollution, both point and non-point, have increased mainly due to the increasing population of the province. This has led to pollution loading in the rivers of the entire province, which drain to Manila Bay. In LAW, numerous water quality data have consistently proven excessive pollution loads. While programs and policies are in place to address the problem, the scenario still persists. An estimation of the pollution load was then conducted to support water quality findings and refine pollution abatement efforts.

Different sources of pollution contribute different types and amount of pollutants. Livestock and poultry farms contribute the highest amount of BOD_5, NH4, total phosphorus, and total coliform while non-point sources contribute the highest amount of total suspended solids. Further, the estimated pollution load in Labac-Alemang Watershed using Load-Discharge (L-Q) Relationship Model shows the highest levels of NH_4, BOD_5, total suspended solids, and total coliform in the sampling site at Barangay Bucana Sasahan, which is nearest the delta and outlet of the watershed. This reflects the contribution of the whole watershed and indicates that high amount of pollutants are contributed by LAW to Manila Bay.

Improving the water quality condition and overall ecological integrity of Manila Bay, therefore, will require rehabilitation of its tributary rivers, which includes LAW. However, this will only be effective if proper measures are done to reduce the amount of pollution in the rivers, and more importantly, from sources before they even enter the streams.

RECOMMENDATIONS

Based on the results of the study, it is recommended that pollution reduction measures must be done on the livestock and poultry sectors of the municipalities within the watershed, followed by domestic and other sources. More stringent policies and implementation of environmental laws, creation of sewage treatment facilities, adherence to best practices, and concerted efforts among the local government units and concerned agencies are necessary to improve the condition of the rivers in the watershed. Compliance to septage management system and wastewater treatment must be strictly implemented and wastewater reduction at source is highly recommended.

On the other hand, to improve this study, more reliable and up-to-date secondary data for the Pollution Load Model is necessary to yield better estimates of generated load. Further, the frequency of water sampling and measurement of discharge must be increased to yield better estimates of actual pollution load in the rivers. Studies on the allowable maximum load in the rivers of the watershed to meet Class C freshwater and projections on the load reductions are also recommended in order to aid decision making related to the rehabilitation of LAW and Manila Bay.

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