Validating the Manila Bay, Cavite Province, and Pampanga Province Pollution Reduction Opportunity Analyses

1. Introduction

The Manila Bay Pollution Reduction Opportunity Analysis (PROA) for nitrogen and phosphorus and the related PROAs for Cavite and Pampanga Provinces were prepared in January 2017. At that point in time, the development of a comprehensive strategy for restoring Manila Bay is in its infancy, as is the implementation of monitoring programs and the collection of data on nutrient sources and loadings, water quality impacts, available technologies for reducing both point source and nonpoint source nutrient loads, and the costs of applying these technologies.

The lack of information and data specific to Manila Bay meant that a number of assumptions had to be made in the development of the PROAs and that these PROAs rely heavily on the use of international reference data as proxy data.

As a result, these PROA should not yet be used to make definitive decisions about strategies to adopt or actions to implement. The PROAs can however, be continuously improved as more data becomes available and efforts to develop and implement restoration strategies become more advanced. The PROA model is no different than the other models being developed and applied to Manila Bay. The same process of continuous improvement will occur for other Manila Bay models, such as the Pollution Load Model (PLM), and the hydrodynamic and the water quality models.

Initial steps to validate the Manila Bay PROAs should focus on the three areas:
- Evaluation of the assumptions made in the PROA analyses;
- Replacement of proxy data with local data; and
- Conforming PROA assumptions and data to the assumptions and data of the Nutrient Load Model.

This should be followed by continuous improvement as new data and information become available.

2. Evaluation of PROA Assumptions

Following is a list of the assumptions used in the first iteration of the Manila Bay PROA models. Suggestions for validating the each of the assumptions are presented where feasible.

2.1. Sewage Flow Volumes

The volume of sewage was estimated from per capita water use. For sewered urban areas, a base value of 58 l/d (Inocencio et al, 1999) was used. The PROA model assumed that consumptive use was twenty percent, resulting in a per capital net sewage flow volume of 46.4 liters per day. The consumptive use assumption was based on best professional judgement, (BPJ).

Per capita water use is generally lower in unsewered urban areas than in sewered ones. No literature value estimates were available for per capita water use in these areas so an assumption was made that it is 48 l/d. The assumption of twenty percent consumptive use was also used for unsewered areas, resulting in a per capita sewage flow volume of 38.4 liters per day.

The Philippine Institute for Development Studies report on per capita water use used as the basis for the PROA assumptions was published in 1999 and is likely outdated. The assumptions used in the PROA should be reviewed by those in government and the private sector who are responsible for urban planning and the provision of water and wastewater services. The water companies are responsible for designing the new wastewater treatment plants and collection system components that will be required to meet the goal of expanding wastewater treatment in Metropolitan Manila, hence they may have the most information and insight into current estimates for per capita water use and the consumptive percentages. The Metropolitan Waterworks and Sewerage System (MWSS) should also be asked to review the PROA assumptions and the Manila City Planning and Development Office if it has any planning responsibilities related to water and sewer infrastructure.

2.2. Wastewater Treatment

Seven assumptions were made about wastewater treatment. Of these, only assumptions 1 and 2 are subject to empirical verification; the remaining five deal with future scenarios for wastewater treatment that were developed as alternatives for evaluation in the PROA model.

<u>Assumption 1</u>—The PROA analysis assumed that the nitrogen concentration of untreated domestic sewage entering the wastewater treatment plants (WWTPs) is 15 mg/L. This assumption is based on international experience.

<u>Assumption 2</u>—The phosphorus concentration of untreated domestic sewage entering WWTPs is 11 mg/L. This assumption is based on international experience as well.

The water companies may have data on influent nitrogen and phosphorus concentrations, though none was included in the data they provided for the PROA development. If there is no data, the companies should be asked to start collecting it.

Assumptions 4, 5, and 6 were necessary in order to include wastewater treatment alternatives in the PROA analysis although no requirements for nitrogen or phosphorus removal by WWTPs have been established, or possibly not yet even contemplated. All three deal with design requirements for WWTP nitrogen and phosphorus removal levels.

Assumption 4—For existing WWTPs that are upgraded to add nitrogen and phosphorus removal capabilities, target effluent concentrations are 3 mg/L nitrogen and 0.1 mg/L phosphorus. These are generally nominally the limits of technology LOT) for nutrient removal. LOT could very well be infeasible or unnecessary in Manila. It was used in the PROA analysis simply because there is no cost data available in Manila or internationally for any other level of upgrade.

This assumption should be discussed with MWSS and the water companies, keeping in mind that this is just a scenario to be included in the model and not a recommendation. Engineering consulting firms with WWTP design expertise could also be consulted.

Assumption 5—Target effluent concentrations for new WWTPs are 6 mg/L nitrogen and 1.0 mg/L phosphorus (again based on availability of international data).

This assumption should be also be discussed with MWSS, the water companies, and engineering consulting firms.

Assumption 6—Twenty percent of the capital cost for new WWTPs is attributable to nutrient removal, split evenly between nitrogen and phosphorus.

This was a difficult assumption to decide on; there is no real data or information to base a judgement on. Possibly the only way to add more certainty would be to ask WWTP design engineers to produce conceptual designs of a new WWTP with and without nitrogen and phosphorus removal, and then to prepare planning level cost estimates for the designs. This level of effort may not really be warranted even if it doubled or halved the twenty percent assumption. However, the water companies and engineering consulting firms should asked their opinion on this assumption.

Assumption 7—No costs for expanding the sewage collection system were included.

This assumption was made because the design of new sewage collections system components would not be affected by the addition of nutrient removal capability at wastewater treatment plants. While MWSS, the water companies, and engineering consulting firms should be asked to review the assumption, valid arguments against it would be required before it is amended.

2.3. Phosphate Detergent Ban

Three assumptions were made about the costs and benefits of a phosphate detergent ban.

The first assumption was that of the total phosphorus concentration in domestic wastewater (generally around 8 mg/l) 2.75 mg/l comes from phosphate detergents. This was based on research in the United States (Lee and Jones, 1984 and 2007).

The second assumption dealt with the delivery of phosphate detergent to surface waters. Making an assumption on this was only necessary for wastewater generated in the urban unsewered areas where wastewater is released to the environment untreated. The first assumption of phosphorus concentration in wastewater of 2.75 mg/l was used to estimate the mass load of detergent-related phosphorus being released in unsewered areas.

Not all of the released phosphorus reaches Manila Bay however, so an assumption had to be made about the delivery ratio. Phosphorus is thought to have relatively low mobility in the environment (Maki, 1948), though the only readily available research on this is nearly seventy years old. No literature values were found, so a fifty percent delivery ratio was selected. Lacking further research on phosphorus mobility, it would be difficult to refine this assumption.

No information on the cost to manufacturers and consumers of switching to non-phosphate detergents is available. It would also be very difficult to acquire because manufactures are not generally willing divulge that kind of information (and some may exaggerate the potential costs, as happened in the U.S. during the heated political debate over banning phosphate detergents). No research on costs to consumers as a result of bans was found in literature searches.

The PROA assumption is that the cost of a ban in the Manila Bay watershed would be 1 USD per household per year.

2.4 Agriculture

Assumptions were made about nitrogen and phosphorus fertilizer loss rates from agricultural operations and the selection of agriculture Best Management Practices to model.

The fertilizer loss is defined in the PROA as the fraction of the total nitrogen and total phosphorus in chemical fertilizers that is applied to a crop acreage that ends up in surface waters instead of being taken up by the crops. Loss rates are greatly affected by crop types, fertilizer application practices, soil type, typography, and weather patterns. Hence they are highly variable and very localized, making it difficult to derive generalized loss rates.

The PROA assumed that the fertilizer loss rates are twenty percent for nitrogen and Ten percent for phosphorus.

Selection of the agricultural BMPs to include in the model (constructed wetlands, grass and forest buffers, and improved nutrient management) was based on international experiences with agricultural BMPs, specifically their reliability and frequency of use.

2.5. Geographical Issues

Two assumptions related to geographical considerations were made.

The first involved estimating the percentages of the populations of Tarlae Province and Bataan Province that are in the Manila Bay watershed. The percentages of the populations of these two provinces that reside in the MB watershed were estimated by visually examining a map showing both provincial and watershed boundaries and estimating the percentage of each province's land area that lies in the MB watershed. These percentages were then applied to the provincial population numbers. The resulting percentages were thirty percent for Tarlae and fifty percent for Bataan.

These assumptions can be greatly improved by examination of population density maps if they are available. Detailed land use maps could also be used if adequate population density maps aren't available.

The second assumption involved the locations of nitrogen and discharges, both point and nonpoint in nature. Unless a discharge is directly into Manila Bay, not all of the discharged nutrient loads would reach the bay because of physical and biological processes on the land and in streams and rivers. The percentage of the discharged load from a specific location that actually reaches the water body of concern is known as the delivery ratio or factor for that location.

Location of discharges and delivery ratios were not considered in the PROA analysis because it was not feasible to collect location and geographic data for all of the point and nonpoint sources in the Manila Bay watershed within the timeframe and budget of the PROA analysis. Addressing this assumption is discussed below in Section 4 - C Coordinating the PROA Analysis with the Watershed Loading Model.

3. Replacement of Proxy Data with Local Data

A lack of data specific to the watershed will almost always be a major concern in the early stages of a watershed restoration effort. It is likely that some of the desired data, including water quality data; sources, locations, and magnitudes of pollutants being discharged; and the cost of remedial actions, will not be available or even exist. A PROA uses the best data that is available at the time it is created. It is likely that the first iteration of any PROA will rely heavily on literature and proxy values.

Because of the initial lack of specific data, restoration efforts usually begin with establishment of water quality and pollutant loading monitoring programs. It takes time to identify all of the sources and quantify pollutant loads by source, sector, and location. Over time, the monitoring and data collections efforts will allow the replacement of the proxy and literature values with local data.

The lack of data is the case with the Manila Bay PROAs, as evidenced by the heavy reliance on international reference data and the assumptions described above. Over time, the proxy data can and should be replaced with local data. Among the sources of local data will be monitoring programs for nutrient discharges, the government planning processes for expanding wastewater treatment, and increased efforts the agricultural community to better understand fertilizer practices and nutrient loss rates. Concerted effort may be required to bring some of this monitoring and research about.

4. Coordinating the PROA Analysis with the Watershed Loading Model

A fair amount of the data used in the PROA analysis was input data used in the Watershed Loading Model (WLM). This data included population statistics (population by province and percentages of population sewered and unsewered) and total fertilizer usage (as well as the nitrogen and phosphorus fertilizer loss rates discussed above in Section 2). However, there are some significant differences between approaches taken in the NLM and the PROA model.

As an example, one of these differences is discharge locations and delivery ratios. As discussed in Section 2.5 above, the PROA analysis did not address locations of discharge or delivery ratios. The NLM does do this. It uses a grid cell map of the watershed. Nitrogen and phosphorus load generation is estimated in each cell and then a water transport model is used to transfer loads in each cell (including accumulated loads from upstream sources) to a downstream cell. Estimates of load attenuation are applied to this transfer, hence an ultimate delivery ratio to Manila Bay for each cell is inherent in the model.

The PROA methodology should be refined to be consistent with the NLM methodology for incorporating location impacts on loadings to the bay. There are no doubt other significant ways in which the PROA model can be coordinated with the NLM. The PROA and NLM modelers should work closely together in the future to identify these differences and find ways to conform the two models.

5. Using the PROAs Results in an Adaptive Management Process

The Manila Bay PROAs should be considered the first step of what might be a lengthy process for selecting actions to undertake. Its value in these early stages lies in pointing the Manila Bay restoration efforts in the most promising directions. As the efforts grows and mature, the PROAs should evolve and help the restoration effort to come closer to a preferred action plan.

It is important to understand the strengths and weakness of these initial PROAs for Manila Bay and Cavite and Pampanga Provinces. The weaknesses are that they rely on a number of preliminary assumptions as described in Section 2 above and suffer from the lack of watershed specific data described above in Section 3. In addition, the alternatives available for nutrient control measures might change in the future.

However, the initial PROAs provide some valuable insights. They point to what the most cost-effective nutrient control measures might be. This can help guide ongoing data collection, modeling, and research strategies. They can also be factored into pending political and economic decisions affecting water management policy and infrastructure planning.

In deciding whether or not to use the preliminary results in pending decisions on Manila Bay restoration strategies, it is useful to distinguish between quantitative and qualitative uncertainty. To illustrate this, while it is very difficult to quantitatively model the loading reductions and unit costs of a phosphate detergent ban to any degree of certainty, qualitatively there is little doubt that a ban would result in significant reductions in phosphorus loads at relatively low unit cost. Likewise, engineering experience has proven that nutrient removal can be incorporated into designs of new wastewater treatment plants without significantly adding to capital or operating costs, and in some cases can actually lower costs. This fact makes lends qualitatively certainty that adding nutrient removal capability to new wastewater treatment plants planned for metropolitan Manila would be a very cost-effect measure.

The Manila Bay PROAs should incorporate new data and assumptions as they become available. In this way, the PROAs will evolve and contribute to the adaptive management process that is needed for the Manila Bay restoration strategy.

References

Inocencio, A., Padilla, J. and Javier Esmyra (1999). Determination of Basic Household Water Requirements. Philippine Institute for Development Studies

Lee, G. F. and Jones, A.(1986,2007), Originally published as “Detergent phosphate bans and eutrophication,” Environmental Science and Technology 20:330-331 (1986). Updated in January 2007. http://www.members.aol.com/annejlee/DetergentPBan.pdf. Published by the American Chemical Society.

Maki, A. W.; Porcella, D. B.; Wendt, R. H. Water Res. 1984, 18, 893-903.