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Environmental Flood Protection Dikes

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ABSTRACT

Flooding is a natural event that replenishes the groundwater and revitalizes the soil through the deposit of sediments. However, when communities settle within floodplains, flooding can cause adverse social, economic and environmental impacts. Flood protection works, such as dikes, can further reduce flood risk. These structures particularly relevant in protecting historic communities that were settled before floodplain management policies were implemented. However, it is technically and economically impossible to completely eliminate flood risk with dikes. During severe floods, dike failures may occur due to erosion, overtopping or seepage. This study predicts that dike construction may lead to water level lowering for in-bank flows and to water level increases for out-of-bank (flood) flows. This confirms that, in principle, the existing Pampanga dike and specifically on the construction of Taguig City dike along the Laguna Lake may have contributed to the observed flood water level trends in the Metro Manila.

***Keywords*:** Backwater, dike, dike crest, expressway dike, flood, flood level, freeboard, lakeshore, landslide, seepage

1. INTRODUCTION

Today, hydrologists study past flood patterns to help predict where and when floods will happen in the future. The predictions are only estimates but weather, land, and climate can all change. An area's soil and groundwater provide clues about flooding. Pedologists, or soil scientists, work with hydrologists to determine how much water a region's earth can absorb. Agricultural soil, for instance, can absorb much more water than sand or bare rock. Groundwater is water already in the earth —in a soil, underground reservoirs called aquifers, and even porous rocks. The type of soil and the amount of groundwater tells hydrologists how much more water the earth can absorb (Jonkman et al., 2008).

In the Philippines, Filipinos experience major floods that inundate about one-third of the country. Flood control projects which comprise earthen dikes is therefore built along the major rivers to protect people living in low-lying areas, stabilize the river banks, and improve agricultural productivity by allowing the year-round cultivation of high-yielding varieties of rice using modern methods of cultivation (Ganiron, 2014). These projects, however, also restrict the seasonal deposit of silt upon the flood plains, block the flushing action of receding flood water, lead to the destruction of small fisheries, and cause farmers' lands to be appropriated for use in the development of embankment infrastructure.

In the Netherlands, the Dutch began building dikes to control flooding 800 years ago, because twenty-five percent (25%) of The Netherlands is below sea level and is subject to flooding (Cho, 2011). The Dutch would once have responded to flooding by building their dikes higher, in the late 1990s. They realized that flood risks were only going to intensify with climate change. In 2007 the Dutch government approved a new strategy for dealing with flood threats called room for the river. The strategies are: relocating dikes further inland to widen floodplains, modifying dikes in certain areas to allow for flooding, lowering floodplains because accumulated sediments have made them shallower, reducing the height of groynes (rigid structures placed in rivers to slow the water flow) to allow water to flow more quickly, creating side channels as alternate routes for high water, deepening the river bed, removing obstacles from the river that obstruct flow, and creating temporary water storage areas (Cho, 2011). In places where it’s not possible to create room for the river, dikes may be heightened and strengthened, though incidences of dike slumping and land subsidence will likely increase if dikes are made taller and thus heavier (Apel et al., 2009).

The China Government emphasize that there are economic and long-term benefits of building dikes. This is to reduce flood damage far outweigh their initial cost on a global scale, and it is even possible to reduce the economic damage from river floods in the future to below today's levels. Yan (2017) assessed how much it would cost to build and maintain these dikes and whether the benefits would outweigh the costs using a range of hydrological and economic models. They found that in many parts of the world, it is even possible to reduce the economic damage from river floods in the future to below today's levels, even when climate change, growing populations, and urbanization are taken into account (Dawson et al., 2005).

2. GENERAL

In the Philippines, the Municipality of Taguig City is one of the low-lying areas along the Shore of Laguna Lake with an average elevation of 11.30 meters. The water surface elevation of Laguna Lake from April to December rises up from elevation 10.72 meters to elevation 12.90 meters, in which case the said areas will always be subjected to flooding especially during the months of October to December. Rising of water surface elevation of Laguna Lake is due to thirteen (13) major tributary rivers and more than 100 (minor creeks) at the watershed areas of the lake along the area of Rizal, Laguna, Batangas and Quezon Province (Ganiron, 2016). The Marikina River thru (Manggahan Village) Floodway Project) is only one of the rivers which contribute approximately 7.69% on the rising of water elevation of the said lake (Ganiron, 2016). In 2006, the lake water elevation reaches 16.27 meters and it takes 133 days to subside the lake water elevation up to 12.50 meters, since the only outlet then of the lake floodwater is the Napindan River Channel without Manggahan Floodway.

However, on the year 2008, the same 16.27 meters elevation was attained by the lake but it took only 64 days or 1.80 meters to settle the elevation up to 12.50 meters since Manggahan Floodway and Napindan Hydraulic Control Structure were already operational. Hence, the floodwater is back flowing towards the Manila Bay through two (2) channels, Manggahan Floodway and Napindan.

The following aspects that tend to aggravate flooding problems are (1) Infrastructure development that leads to the creation of more impervious areas that results to higher peak run-offs that cause standing flood. (2) Inadequate or non-existent drainage system. (3) Improper waste disposal that leads to the clogging of the sewerage system, further lowering their water retaining capacity. (4) Heavy siltation of rivers due to previous floods, indiscriminate dumping of garbage, encroachment of squatters and slum dwellers and limited maintenance work. (5) Institutional problems and financial constrain delay implementation of proper flood control and counter measure.

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) and Department of Science and Technology (DOST) flood hazard mapping of Taguig City report indicate flood risk area according to flood height. The following are its characteristics by sub-area (1) Villages in Napindan Ibayo, Wawa, Hagonoy, Bambang, Sta Ana and Liquid areas: These areas are experiencing flood heights ranging from 1.5 to 2 meters. Flood prone areas in these villages are generally low lying areas composed of residential, grassland and rice fields. It is likewise noted that these areas are adjacent Napindan Channel and bounded by bodies of water such as Taguig River and minor tributaries. (2) Villages in Ususan, Bambang, Tuktukan, and Wawa are situated in downstream of the Taguig River which is located a few kilometers away from Laguna de Bay, which affects its flow (Ganiron, 2017). The area flood plain covered is characterized a middle delta, meaning that once the river overflow, floodwater stagnates in the area for the longer period. Average flood height is 1.5 meters with the Poblacion the reference point. This value is, however, exceeded in either village (Ganiron, 2017).

Villages in Fort Bonifacio, Bagong Tanyag portion of Upper Bicutan, Western Bicutan and a large portion of Signal Village are not affected by the flooding because of farther distance from Taguig and Hagonoy Rivers (Nangan II et al., 2017). Occasional flooding in these villages is sometimes caused by an overflow of the local stream, which is narrow and shallow.

In Taguig City, the floodwater have long receded but not in one gated middle-class community with a classy name as it remains at the mercy of the swollen Laguna de Bay (Gamil, 2012). Bay Breeze Executive Village in Barangay Hagonoy was built in the late 1980s by Sta. Lucia Realty, the village lies along the shores of the country's largest freshwater lake and is still submerged in waist-deep water long after life in the other barangays. Before the turn of the millennium, this part of Taguig was known to go underwater every five years shown in Figure 1. Back then, it was still a bearable inconvenience for Baybreeze homeowners who chose to stay partly because of the picturesque lakeside view. Over the past three years, however, the floods have become an annual ordeal, not only getting deeper but also lasting much longer. As a result, out of the 350 families living here, 230 have evacuated since August.

The residents initially thought that the C-6 road dike project, which was started in 2007, would be their buffer against the seasonal overflow of Laguna de Bay. But the dike took a different path and ended up "trapping" water in the village instead like what happened during the 2009 onslaught of tropical storm "Ondoy" and again during the heavy monsoon rains last month. Since last month, tricycle drivers in the 89-hectare subdivision have been eking out a living as boatmen instead of cars, boats and rafts are playing the streets.

It's not unusual to spot ducks straying from somebody's yard and swimming on the street. Fish from the lake along with patches of water hyacinth have also moved in. The ground floors of the houses have been deserted and the power supply is limited to the upper floors.

Figure 1. Floods in Bay Breeze Executive Village in Barangay Hagonoy, Taguig City

Since the front door entrance is underwater, residents now climb ladders leading to a second-floor window to get in.

The unoccupied houses have become easy pickings for burglars. The village has guards posted at the gate but is defenseless against robbers entering Baybreeze by boat from the side facing the lake.

3. LAGUNA LAKESHORE EXPRESSWAY DIKE

Based in the Public-Private Partnership Road Projects (2014), Laguna Lakeshore Expressway Dike is a proposed expressway in the Philippines that will start from the coastal area of Laguna de Bay from Taguig in Metro Manila to Calamba and Los Baños in Laguna. The project will involve the construction of a 47-kilometre-long (29 mi), six-lane dike including bridges, pumping stations, and ancillary flood gates. The project also involves reclamation of 700 hectares west of and abutting the expressway-dike, separated from the shoreline by a 100-150 meter channel in Taguig and Muntinlupa. The project aims to provide a high-standard highway that will speed up traffic between the southern part of Metro Manila and Laguna, as well as a dike that would mitigate flooding in the western coastal communities along Laguna Lake. The expressway will cost an estimated PHP36.74 billion or US$854.42 million (Singson, 2010). When constructed, it is expected to ease traffic congestion along Muntinlupa and Calamba area, and to serve as flood control measure for communities on the western shore of Laguna de Bay.

Figure 2. Project map of Laguna Lakeshore Expressway Dike

As shown in Figure 2, the route alignment starts from Bicutan, Taguig connecting to the proposed C-6 Expressway Road Project. It traverses southwards passing the city boundaries of Taguig, Parañaque, and Muntinlupa in the southern part of Metro Manila and then continues further south passing the cities of San Pedro, Biñan, Santa Rosa, Cabuyao, Calamba and ends up at Los Baños in Laguna, near its boundary with Bay. The construction of the expressway dike is proposed to involve two sections. These are from Bicutan to Calamba, and from Calamba to Los Baños.

The project details for the Expressway Dike as of October 2013 indicated plans for a 41.54-kilometre-long (25.81 mi), four-lane dike, but the official announcement of the approved project in June 2014 indicated that it would be 47-kilometre-long (29 mi), and have six-lanes.

While the expressway dike hopes to alleviate flooding on the southwestern shore of Laguna de Bay, officials and planners have acknowledged that there is still a need to cope with the excess water volume in the lake itself, with the urban planner (Kim, 2006).

According to Rodolfo (2016) that a project to build a Laguna Lakeshore Expressway Dike (LLED) east of the shoreline from Bicutan to Los Baños, also meant to protect Metro Manila from lake floods, is very dangerous. Its first phase, from Bicutan to Calamba is proceeding with alarming rapidity. The project would also reclaim 700 hectares of the lake bed west of the dike. If the project is constructed and protects Metro Manila from lake-water floods, people living elsewhere along the lake will suffer, simply because the flood water will have to go somewhere (Yumul et al., 1998). Reclamation would reduce the size of the lake, so storms would make higher floods than before. Real estate interests will profit greatly from the reclaimed land, and people wealthy enough to own cars will enjoy reduced travel time from Bicutan to Los Baños. Bus and jeepney travel times would also be shortened – the only benefit for the poor, who would also bear the greatest costs. Besides worsened flooding along the unprotected Lakeshore, reclamation would displace poor people from their lands, homes, and livelihood.

If the dike fails, it would be catastrophic. The greatest hazard posed to it is an earthquake (Paguican et al.,2009). In 2004, Phivolcs, JICA, and MMDA reported that Metro Manila is overdue for a magnitude 7.2 earthquake, which would most likely be generated at the West Marikina Valley (WMV) Fault. The entire 2 to 3-kilometer wide strip of land adjacent to the lakeshore, the WMV fault zone, would experience Intensity 9 on the Phivolcs Earthquake Intensity Scale. Most buildings are totally damaged. Bridges and elevated concrete structures are toppled or destroyed. Water sewer pipes are bent, twisted or broken. Landslides and liquefaction are widespread. The ground is distorted into undulations. Boulders are commonly thrown out. River water splashes violently or slopes over dikes and banks.

Note that from Bicutan to Muntinlupa, the expressway-dike runs parallel to, and less than two kilometers east of fault segments. Nature does not casually make parallel features; people can reasonably assume that the western lakeshore is related to the fault. If a large earthquake on the WMV Fault ruptures the dike, Metro Manila would be flooded catastrophically, especially if it occurred with the lake at its highest level.

Today, the Philippine government is planning to remove the flood control component of the Laguna Lakeshore Expressway Dike Project as it remains interested in pursuing the project. A new road to ring the Laguna Lake is being prepared to replace the ambitious P123 billion Laguna Lakeshore Expressway Dike (LLED) PPP project. The new road not including the dike will be built to bring more development in the Laguna coastline. According to Villar (2017) that without the flood control component (the dike or elevation of the expressway) the project will be more attractive for investors.

The significance of this research is to present the major problems of Taguig City specifically flood, and the resource on flood control and construction of the Laguna Lakeshore Expressway Dike. This study will be significant in the formulation of policies on flood control. Encouraging both national and local authorities to further improve flood control system. Another significance of this study is for the residents of Taguig City that will make them see the outcome of the dike construction and appreciate change, especially on Science and Technology. Lastly, this will enhance enthusiasm of students to aid in the nation's aim of controlling flood and to indulge them in the process.

4. TECHNICAL STANDARDS FOR THE CONSTRUCTION OF DIKES

According to JICA (2010), flood level should be considered in choosing flood control measures. If the calculated design flood level is higher than the surrounding areas, the dike has to be planned. As the dike prevents drainage water from the inland to flow naturally into the river; inland drainage improvement (non-dike system) is provided to address inland flooding. The height of the dike is designed based on the calculated design flood level, which is not fixed by the level of the surrounding areas. But the ground height should be considered in setting the flood level. Flood level should be considered in choosing flood control measures (Vorogushyn, 2010). If the calculated design flood level is higher than the surrounding areas, the dike has to be planned flood level is higher than the surrounding areas, the dike has to be planned (Pilarczyk, 1998).

As the dike prevents drainage water from the inland to flow naturally into the river; inland drainage improvements (a non-dike system is provided to address inland flooding (Lebel, 2009). The height of the dike is designed based on the calculated design flood level, which is not fixed by the level of the surrounding areas but the ground height should be considered in setting the flood level (Kothyari, 2001).

In most cases, a non-diked river is preferable because of ease in maintenance and safety because breaching is unlikely compared to the diked river. Dike is sometimes difficult to implement due to land acquisition problem (Visser, 1998). Moreover, the existence of important facilities, ports, and harbors, etc. hampers the construction/implementation of said project. In such cases, concrete retaining wall type dike may be adopted. In some cases, the dike is used as a roadway (cause way).

Table 1. Causes of dike damages and proposed countermeasures.

Causes of Damage	Countermeasures
Erosion (Scouring)	The surface of the dike on both sides shall be covered with vegetation for protection against erosion. The Riverside should be protected with revetment, if necessary.
Overflow	Sand bagging for an emergency measure. For long term measure, provide concrete and asphalt covering for the crest and the landside slope.
Seepage	To prevent the collapse of dike caused by seepage, embankment materials for the dike should consist of impervious materials (e.g. clay) in the Riverside, and previous materials on the inland side. Drainage structures and related facilities works should be provided at the inland side to drain accumulated water.
Earthquake	Immediately repair/restoration after the earthquake.

Dikes generally consist of soil and sand. The advantages of using earth materials are economical because of the availability of materials, last for a long period of time, easy mixed with the ground materials, follow the ground deformation/settlement of foundation, easy to improve if the scale of flood control plan would be increased, easy to restore if the dike is damaged by flood, and for environmental consideration (JICA, 2010). Table 1 shows the causes of dike damages and proposed countermeasures and Figure 3 shows an example of countermeasure against seepage.

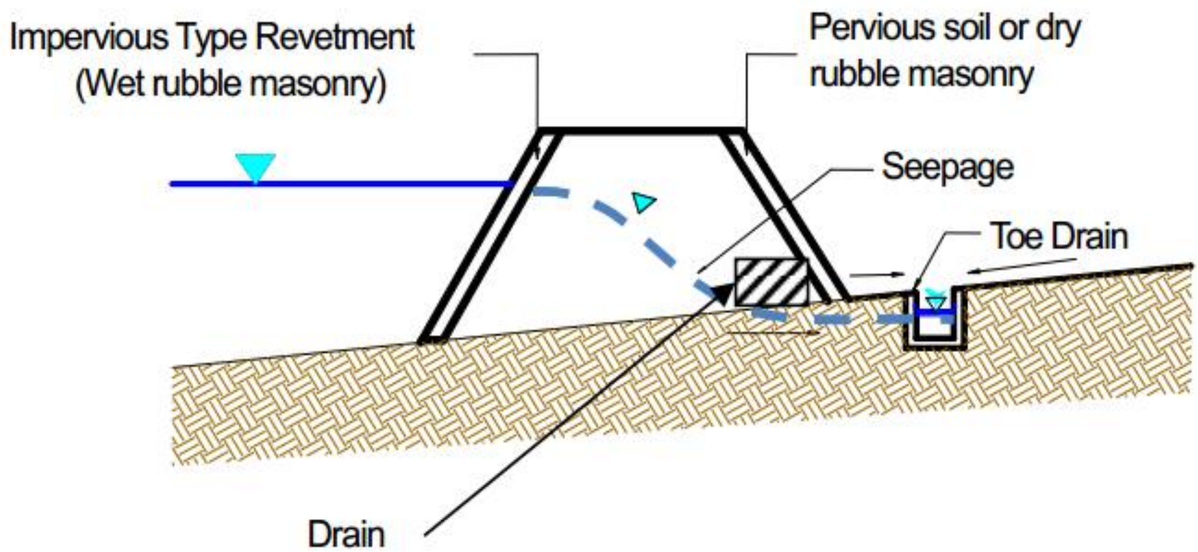

Figure 3. Example of countermeasure against seepage

Dike construction may include new dike and widening or raising existing dike. The new dike shall be designed to protect the affected flood prone areas. In consideration of the stability of the structure, the dike alignment shall avoid unstable peat and muck, weak subsoil, and loose sand foundation to prevent settlement (JICA, 2010). Whenever there is a necessity to heighten/widen the dike on the landside or Riverside, the position depends on the alignment; however, ideally the landside is preferred. When there is a right of way problem or when there is adequate water way, widening may be applied on the riverside. However, when the toe of the dike is close to the low water channel in case of a compound cross section, it is suggested to avoid widening on the riverside even if there is sufficient river width (Renne et. al., 1996). Indeed, as of last November, DPWH is still advocating wholesale reclamation of near shore Manila Bay, as this map from the agency shows. Figure 4 shows the widening and heightening of existing dike while Figure 5 shows the parts of a dike.

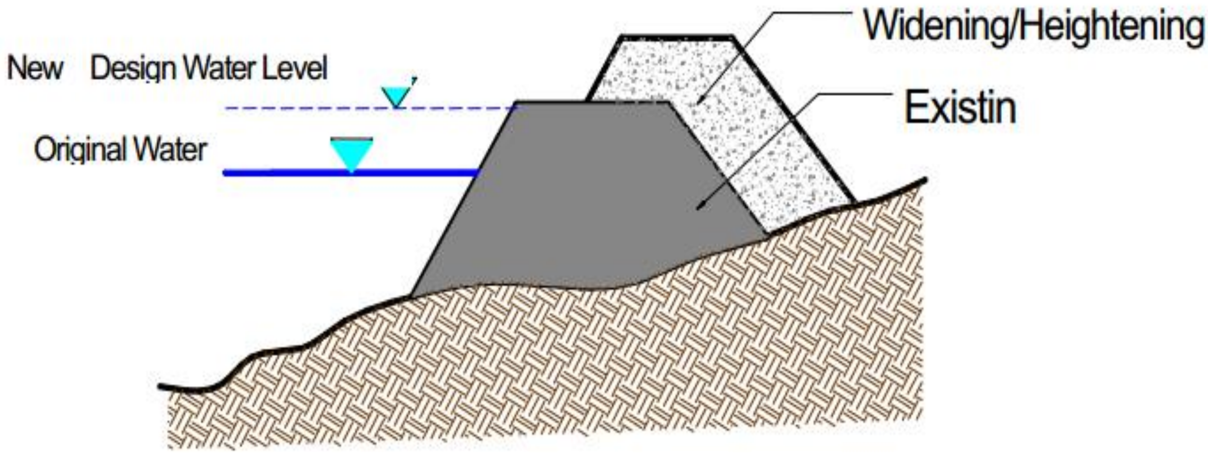

Figure 4. Widening and heightening of existing dike

The following shall be considered for the proposed alignment of a dike: (a) Reduction of the existing stream area shall be avoided as much as possible. (b) The alignment shall be as straight as possible. Sharp curves should be avoided since these portions are subject to direct attack of flow. (c) Where there is sufficient space, the dike should not be too close to the river channel or riverbanks to prevent undermining or scouring. (d) Valuable land, historical or religious structures, and weak/permeable foundation should be avoided.

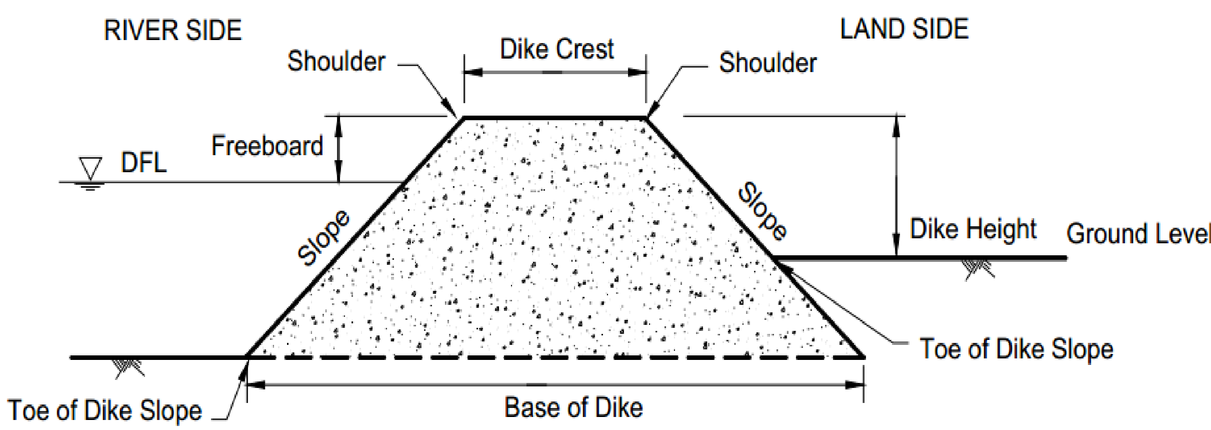

Figure 5. Parts of a dike

The height of a dike shall be based on the design flood level plus the required freeboard (JICA, 2010). The calculated flow capacity shall be used as the Design Flood Discharge for establishing the freeboard shown in Figure 6.

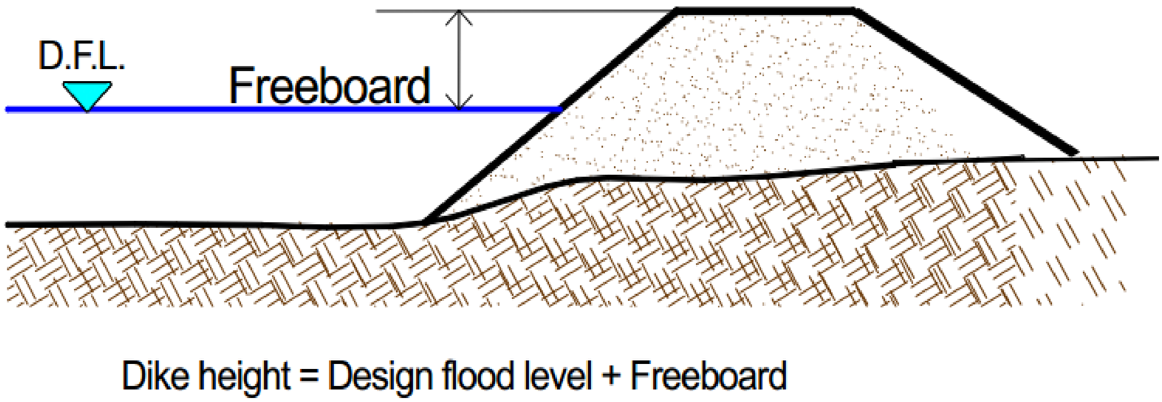

Figure 6. Dike height

Freeboard is the margin from design flood level up to the elevation of the dike crest. It is the margin of the height which does not allow overflow (JICA, 2010). The freeboard shall be based on the design flood discharge which shall not be less than the value given in table 2

Table 2. Minimum Required Freeboard

Design flood discharge Q (m^3/s)	Freeboard (m)
Less than 200	0.6
200 and up to 500	0.8
500 and up to 2,000	1.0
2,000 and up to 5,000	1.2
5,000 and up to 10,000	1.5
10,000 and over	2.0

For the backwater effect in a tributary, the height of the dike in the transition stretch shall not be lower than that of the main river or even higher at the confluence in order to prevent inundation in the subject areas. In general, the dike's height of the main river at the confluence point is projected following its design flood level. Figure 7 shows the free board due to backwater effect and Figure 8 shows the freeboard when landside is higher than design flood level.

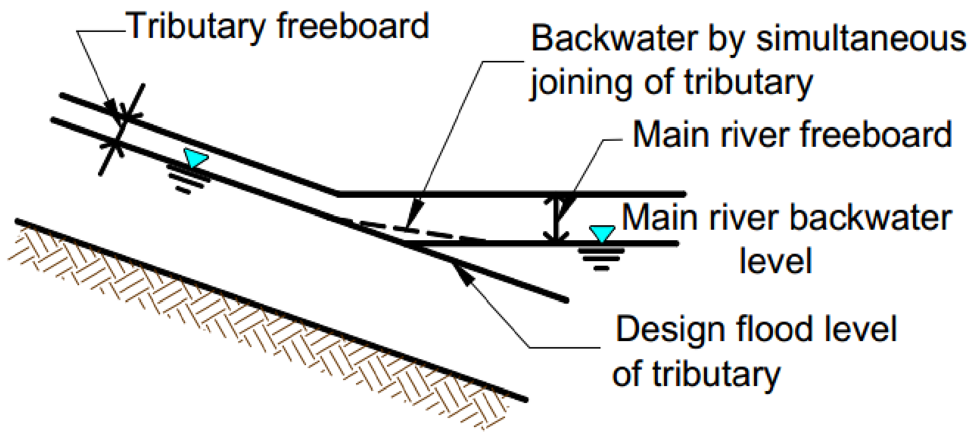

Figure 7. Free board due to backwater effect

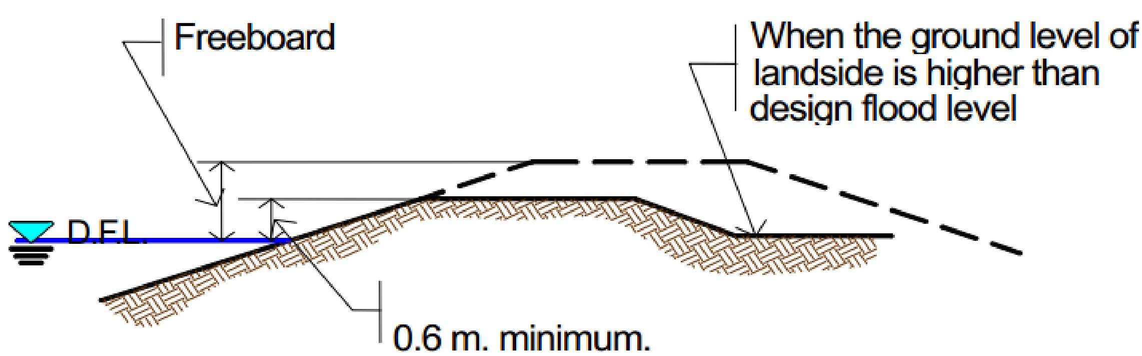

Figure 8. Freeboard when landside is higher than design flood level

Table 3. Crest width of dike

Design flood discharge, Q (m^3/sec)	Crest Width (m)
Less than 500	3
500 and up to 2,000	4
2,000 and up to 5,000	5
5,000 and up to 10,000	6
10,000 and over	7

The crest width of the dike, especially for Wide River, shall be based on the design flood discharge, and shall not be less than the values given in Table 3. When the landside ground level is higher than the design flood level, the crest width shall be 3 meters or more regardless of the design flood discharge (JICA, 2010). Crest width shall be designed for multi-purpose use, such as for patrolling during floods and in the execution of emergency flood prevention works. The base of the dike is fixed by the width of its crest and slope. Likewise, the dike shall be designed to prevent from possible collapse due to seepage which is also dependent on the width of the dike's crest. For backwater effect on the affected tributary, the crest width of the dike shall be designed such that it is not narrower than the dike crest width of the main river (JICA, 2010).

The dike shall be provided with a maintenance road for patrolling the river during emergency flood prevention activity. When a permanent road is to be built and the difference in height between the dike crest and the landside is below 0.6 meters; maintenance road is no longer necessary. However, the dike's crest itself can be used as a maintenance road. The maintenance road shall be 3.0 meters or more (JICA, 2010).

In principle, the slope of the dike shall be as gentle as possible at least lesser than 2:1. When the crest height from riverbed is more than 6.00 meters, the slope of the dike shall be gentler than 3:1.

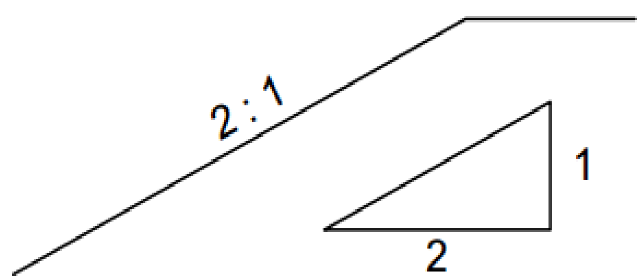

Figure 9. Minimum slope of dike

A slope of 4:1 is usually used for a dike consisting of sand and shall be protected by providing a cover of good soil sodded at least 300 mm thick. When the surface of a dike is covered by a revetment, the slope of dike could be steeper than 2:1 shown in Figure 9.

If the height of the dike is more than 5 meters, a berm shall be provided along the slopes for stability, repair and maintenance purposes (JICA, 2010). The berm width shall be 3.00 meter or more.

5. RESEARCH METHODOLOGY

The researcher employed a descriptive method of research in the study. The aim of this research is to investigate the impact and current situation of floods in Taguig City and identify the potential hazards affecting local communities. After these surveys, the researcher identified the Bay Breeze Executive Village as one of the most vulnerable communities in

Hagonoy, Taguig City, lies along the shores of the Philippines largest freshwater lake and is still submerged in waist-deep water long after life in the other communities.

Accidental sampling under the category of non-probability sampling was adapted. The researcher went through the area on the subject and conducted a survey to those who gave them a chance. A total of 162 responses were collected, all of which were valid (n = 162). The population consists of eighty (80) males and eighty-two (82) females who were all residents of Taguig City or adjacent districts in Metro Manila. Most respondents were of working age, with 75.6 % are being between 22 to 47 years old. The majority of the respondents were Department of Public Highway (DPWH) staffs and residents of the Bay Breeze Executive Village

The structured questionnaire was administered by three enumerators, based on an original drafted in English that was then translated into Filipino, the national language of the Philippines. Since the area is surrounded by both the sea and the river, enumerators started by informing respondents that the definition of “coastal flood” is a flood when water levels rise over the top of river banks due to excessive rain from tropical systems making landfall, persistent thunderstorms over the same area for extended periods of time, combined rainfall and snowmelt, or an ice jam which should be different from a “river flood”, which is the inundation of land areas along the coast, is caused by higher than average high tide and worsened by heavy rainfall and onshore winds (i.e., wind blowing landward from the ocean)

6. CURRENT SITUATION OF FLOODS AS REVEALED BY THE RESPONDENTS

This section shows how land subsidence will be the main reason why the impact of flooding is likely to become more severe in the future. The results of the questionnaire survey regarding the current situation of coastal floods in the target coastal community are also described.

Figure 10 indicates that 71% of respondents (n = 162) have experienced some sort of damage caused by floods in the course of their lives, with about 44% of them answering that their properties/houses suffered major damage or were completely destroyed shown in Figure 11. This is not surprising considering that the last major floods took place in 2009, as reported by Gamil (2012). Essentially, this was an important benchmark event that could be used to calibrate the responses of those interviewed, giving the authors confidence in the results of the questionnaire.

As a result of this 2017 event, few respondents appeared to have been spared the consequences of this event, with 29% of the respondents replying that they have not experienced any sort of damage, and 16% replying that there was no damage due to flooding. As these two answers should theoretically coincide, the slight difference points out that there is some confusion regarding flood type among local people, who may not necessarily distinguish the mechanism behind the floods.

From the results, it is clear that events where the Laguna Lake overtops the floods vulnerable communities adjacent to Manila Bay are already taking place

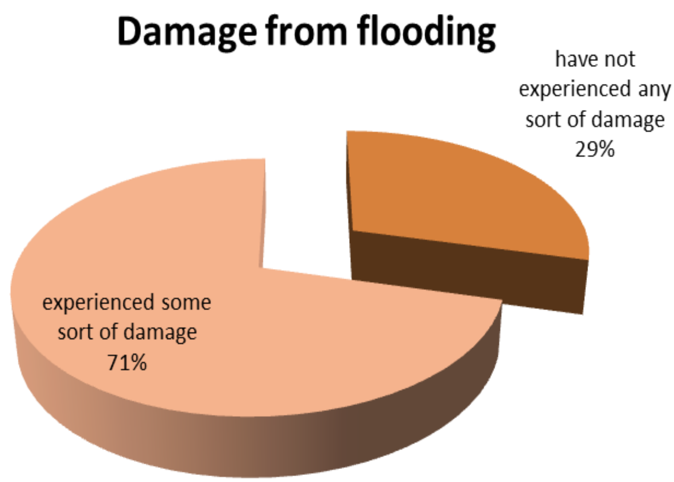

Figure 10. Percentage distribution of sort of damage

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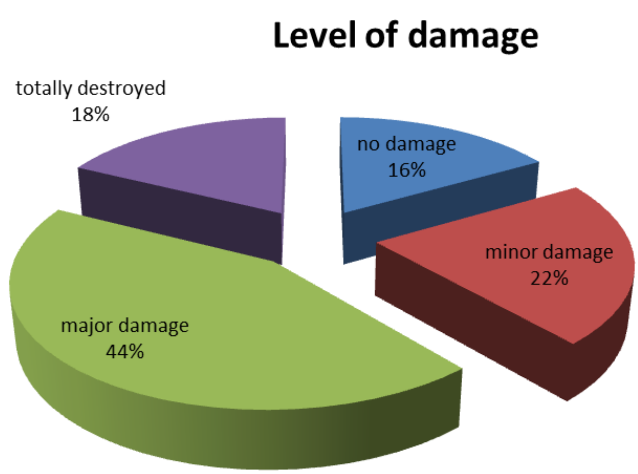

Figure 11. Percentage distribution level of damage

Figure 12 shows that, according to respondents, the frequency of floods is between once a week to once every few years, indicating that the chance of inundation is not uniformly distributed even in this small community.

Regarding the most severe flood they had experienced during their lives, 65% of respondents replied that water was 1.5 m deep or more shown in Figure 13. As the researcher had not originally foreseen that such deep inundation was taking place, the questionnaire could not accurately capture the ranges for higher inundations. Nevertheless, some respondents indicated that the flood waters reached up to the second floor of their houses, which would represent a maximum inundation of nearly 3.5 m.

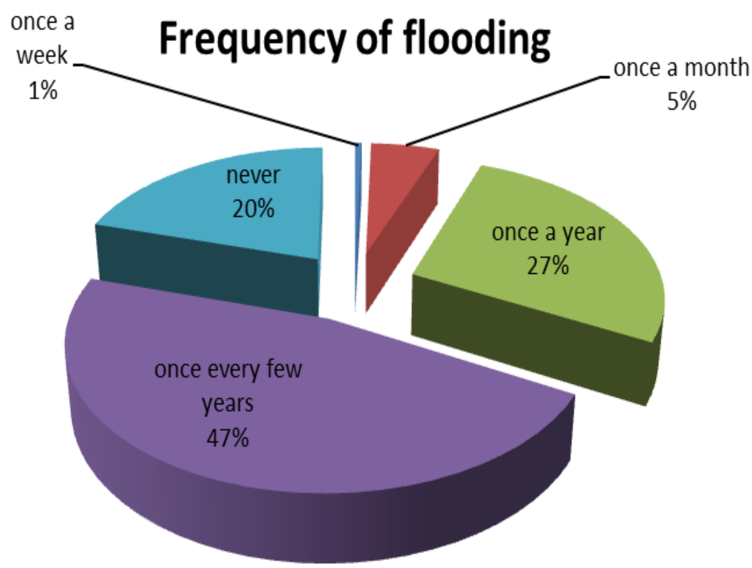

Figure 12. Frequency of flooding

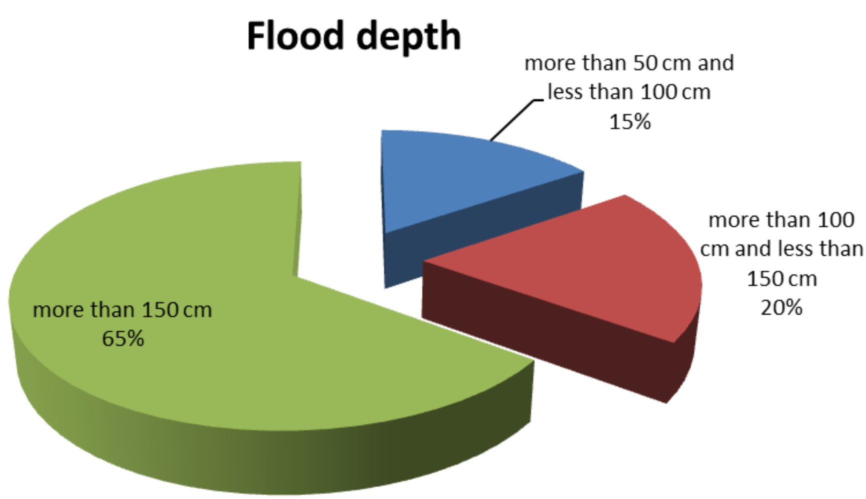

Figure 13. Flood depth during the worst flood in their lives

Finally, respondents were also asked about what measures the government should implement to address the issue of flooding in the Taguig City shown in Figure 14 with most of them indicating to build the Laguna Lakeshore Expressway Dike (78%), and about thirteen percent (13) of the respondents also favoring an even bigger "seawall" in the Laguna de Bay.

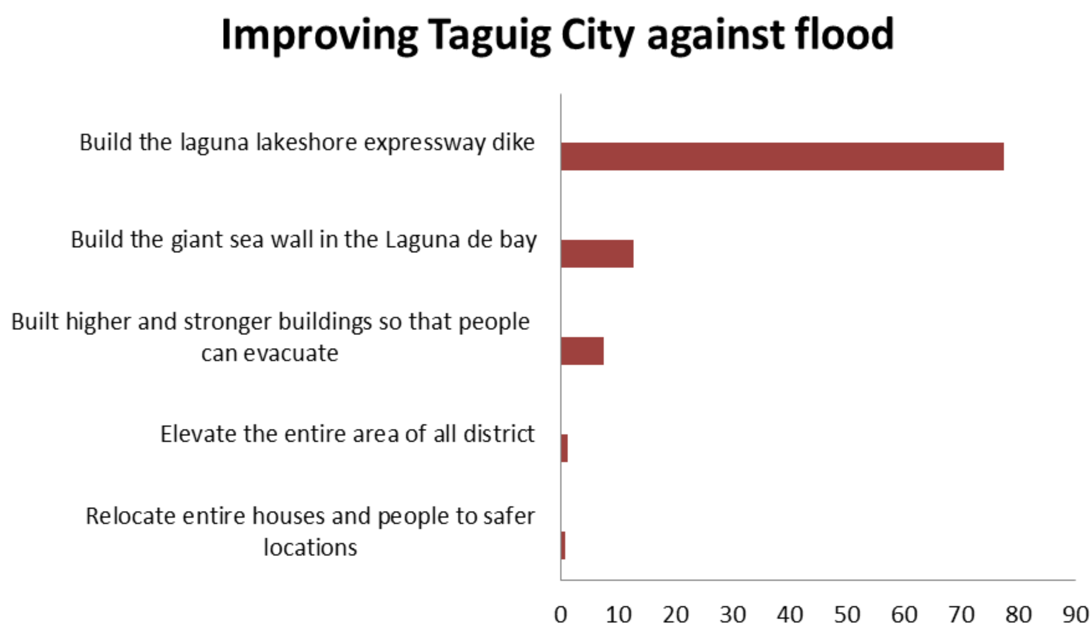

Figure 14. Perceived role of the government in improving Taguig City against flood

7. CONCLUSIONS

The inhabitants of the area adjoining the Laguna Lake have a long history of struggling against floods. Various methods have been implemented in the struggle to protect human lives and property. Actions nowadays focus on flood control measures covering severely flood-prone areas, especially priority like Taguig City and Pampanga, the development of a legal framework for disaster mitigation and prevention, and a combination of structural and non-structural methods to achieve maximum efficiency.

As corroborated by the present study, the Laguna Lakeshore Expressway dike project would be expected to contribute to the reduction of flood damage, at least over the course of the next 10 to 20 years. The researcher questionnaire survey confirmed that local people consider that the construction of the Laguna Lakeshore Expressway dike should be the first countermeasure to be implemented. However, the possibility of extensive floods affecting the Metro Manila would resurface by the middle of the 21st century if land subsidence continues, potentially allowing seawater to reach several kilometers inland, effectively affecting downtown of Metro Manila.

The level of protection of a dike provides can vary greatly based its physical characteristics and the amount, height, and duration of flood waters. Dikes that were not designed or built to provide protection from events such as the 1-percent-annual-chance flood may not be large enough to provide adequate protection during such events. Other dikes designed, built, and maintained to provide protection from the 0.2-percent-annual-chance (or 500-year) flood may provide adequate protection during a flood of that magnitude.

A more precise analysis of a given dike system may indicate a greater flood risk than was previously understood in certain areas. Dikes are designed to provide a specific level of protection. They can be overtopped or fail in larger flood events. Dikes also decay over time and require regular maintenance and periodic upgrades to retain their level of protection. When dikes do fail, they can fail catastrophically. The DPWH currently carry a warning that overtopping or failure of the dike or other structure is possible and that flood insurance and adherence to evacuation procedures are strongly recommended. Accordingly, the DPWH urges people to understand their flood risk. Because of the critical role, the dikes play in mitigating flood risk, and their ultimate effects on flood insurance rates and economic well-being, associated communities must still remain engaged in flood risk management activities.

In the process of struggling against floods, cooperation with international partners has a special meaning. A large number of a project has been implemented, mainly focused in the Laguna Lakeshore Expressway Dike, improving people's awareness of and preparedness for disaster mitigation and developing a legal framework for disaster prevention. Through such projects, Filipino people have learned many valuable lessons on disaster reduction that are applicable in the case of Metro Manila.

References

[1] Apel, H., Merz, B., & Thieken, A. H. (2009). Influence of dike breaches on flood frequency estimation. *Computers & Geosciences*, 35(5), 907-923.

[2] Cho, R. (2011, June 7). Making Room for Rivers: A Different Approach to Flood Control. *News from the Earth Institute*. Retrieved from http://blogs.ei.columbia.edu/2011/06/07/making-room-for-rivers-a-different-approach-to-flood-control/

[3] Dawson, R., Hall, J., Sayers, P., Bates, P., & Rosu, C. (2005). Sampling-based flood risk analysis for fluvial dike systems. *Stochastic Environmental Research and Risk Assessment*, 19(6), 388-402.

[4] Gouldby, B., Krzhizhanovskaya, V., & Simm, J. (2010). Multiscale modelling in real-time flood forecasting systems: From sand grain to dike failure and inundation. *Procedia Computer Science*, 1(1), 809.

[5] Gamil, J. (2012, September 29). Still flooded, lakeside Taguig village cries out in the breeze. *The Philippine Daily Inquirer*. Retrieved from http://newsinfo.inquirer.net/279710/still-flooded-lakeside-taguig-village-cries-out-in-the-breeze

[6] Ganiron Jr, T. U. (2017). Performance of Community Water Supply Management towards Designing Water Safety Plan. *World News of Natural Sciences*, 10, 10-25.

[7] Ganiron Jr, T.U. (2017). Natural Flood Management: A restatement of the natural Science Evidence. *World News of Natural Sciences*, 12, 92-106

[8] Ganiron Jr, T. U. (2016). The Human Impact of Floods towards Mega Dike Effectiveness *International Journal of Disaster Recovery and Business Continuity*, 7, 1-12.

[9] Ganiron Jr, T. U. (2016). Analysis and Design of Gravitational Sub-Pumping Station. *International Journal of Smart Home*, 10(5), 207-216.

[10] Ganiron Jr, T. U. (2016). A Case Study of Site Conditions and Ground Stability of Town Homes. *International Journal of Smart Home,* 10(1), 207-216.

[11] Ganiron Jr, T. U. (2017). Use of Forensic Engineering for Abandoned Building. *World Scientific News,* 83, 150-167.

[12] JICA (2010). Technical Standards and Guidelines for Design of Flood Control Structures. DPWH

[13] Jonkman, S. N., Kok, M., & Vrijling, J. K. (2008). Flood risk assessment in the Netherlands: A case study for dike ring South Holland. *Risk Analysis*, 28(5), 1357-1374.

[14] Kim, I. B. (2006). Communication Strategy Analysis of a Community-Initiated Social Mobilisation Against a Road Dike Project in Taguig, Metro Manila, Philippines. *Media Asia*, 33(3-4), 212-218.

[15] Kothyari, U. C., & Ranga Raju, K. G. (2001). Scour around spur dikes and bridge abutments. *Journal of hydraulic research*, 39(4), 367-374.

[16] Laguna Lakeshore Expressway Dike Project (2014, February 2014). Public-Private Partnership Road Projects. Retrieved from http://ppp.gov.ph/?in_the_news=laguna-lakeshore-expressway-dike-calamba-los-banos-toll-expressway

[17] Lebel, L., Sinh, B. T., Garden, P., Seng, S., Tuan, L. A., & Truc, D. V. (2009). The promise of flood protection: Dikes and dams, drains and diversions. *Contested waterscapes in the Mekong region*, 283.

[18] Nangan II, A. P., Ganiron Jr, T. U., & Martinez, D. T. (2017). Concrete Foundation Systems and Footings. *World Scientific News,* 80, 1-17.

[19] New road for Laguna Lake to replace LLED PPP project. (2017, January 9). *Philippine Constructors Association Inc*. Retrieved from http://www.pcainc.org/news/2017/1/12/new-road-for-laguna-lake-to-replace-lled-ppp-project

[20] Paguican, E. M. R., Lagmay, A. M. F., Rodolfo, K. S., Rodolfo, R. S., Tengonciang, A. M. P., Lapus, M. R., ... & Obille, E. C. (2009). Extreme rainfall-induced lahars and dike breaching, 30 November 2006, Mayon Volcano, Philippines. *Bulletin of volcanology*, 71(8), 845-857.

[21] Pilarczyk, K. (Ed.). (1998). *Dikes and revetments: design, maintenance and safety assessment*. CRC Press.

[22] Renne, P. R., Deckart, K., Ernesto, M., Fe, G., & Piccirillo, E. M. (1996). Age of the Ponta Grossa dike swarm (Brazil), and implications to Paraná flood volcanism. *Earth and Planetary Science Letters*, 144(1-2), 199-211.

[23] Rodolfo, K. (2016, January 24). The dangerous Laguna Lakeshore Expressway Dike. *Rappler*. Retrieved from http://www.rappler.com/science-nature/ideas/120068-dangerous-laguna-lakeshore-expressway-dike

[24] Singson, R. (2010, September 18). PPP Road Projects. *Finance Asia.* Retrieved from http://ppp.gov.ph/wp-content/uploads/2010/11/DPWH-PPP-Presentation.pdf

[25] Visser, P. J. (1998). *Breach growth in sand-dikes* (p. 172). Delf University of Technology.

[26] Vorogushyn, S., Merz, B., Lindenschmidt, K. E., & Apel, H. (2010). A new methodology for flood hazard assessment considering dike breaches. *Water Resources Research*, 46(8).

[27] Yan. (2017, August). Benefits of dikes outweigh costs in flood control: study. *Xinhua*. Retrieved from http://news.xinhuanet.com/english/2017-08/01/c_136489040.htm

[28] Yumul, G. P., Dimalanta, C. B., Faustino, D. V., & De Jesus, J. V. (1998). Upper mantle–lower crust dikes of the Zambales Ophiolite Complex (Philippines): distinct short-lived, subduction-related magmatism. *Journal of volcanology and geothermal research*, 84(3), 287-309.

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