International Journal of Disaster Recovery and Business Continuity
Vol.7 (2016), pp.1-12
http://dx.doi.org/10.14257/ijdrbc.2016.7.01

The Human Impact of Floods towards Mega Dike Effectiveness

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Abstract

Flooding caused by typhoon inflicted serious damage in the Philippines River and the incremental high lake stage, respectively. The study is based on the perception of people in Taguig City about floods and flood control, the existing Pampanga mega dike and specifically on the construction of Taguig City mega dike along the Laguna Lake. The aim of the study is to present the human impact of floods and its resources of constructing a mega dike and to compare the effectiveness of the mega dikes in Pampanga and Taguig City.

Keywords: *Dike, flood control, flooding, floodway, mega dike*

1. Introduction

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 cased the said areas will always be subjected to flooding especially during the months of October to December [1,2].

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. 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.

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 [3].

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 meter 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.

In [4], 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 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 indicates flood risk area according to flood height. The following are its characteristics by sub-area (1) Villages in Napindan Ibayo, Wawa, Hagonoy,

ISSN: 2005-4289 IJDRBC

Bambang, Sta Ana and Liquid areas: These areas are experiencing flood heights ranging from 1.5 to 2 meters. [5,6] 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. The area flood plain covered is characterized a middle delta, meaning that once the river overflow, floodwater stagnates in the area for longer period. Average flood height is 1.5 meters with the Poblacions the reference point. This value is however, exceeded in either villages shown in Figure 1.

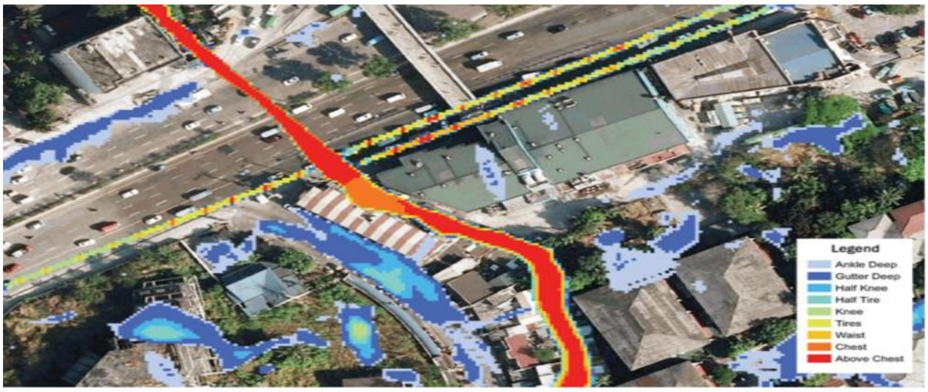

Figure 1. Street Floods in Taguig City

(3) 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 its farther distance from Taguig and Hagonoy Rivers. Occasional flooding in these villages is sometimes caused by overflow of the local stream, which is narrow and shallow.

Figure 2. Flood Areas in Taguig City

This stream stretches from Western Bicutan to Maharlika Village, from which it has discharges to the Taguig River through a tributary creek. Overflowing in the vicinity has duration of 18 minutes or more, the stream serves as the only drainage system of the area and its size is not capable of containing excess surface run-off which causes its swelling and at the same time overflowing to the adjacent villages, including the ton proper. The maximum flood height experienced in these areas is less than 0.5 meter. (4) The Villages Napindan, Calzada, Santa Ana and Wawa along the coast of Laguna de Bay is inundated by the Napindan Channnel, Labasan River, and Santa Ana river and by excess surface run-off coming from the elevated town areas. The flood height experiences in these villages vary from 0.50 to 3 meters. [7, 8] On the average flooding occurrence is as height as 1.5 to 2 meters depth. (5) As shown in figure 2, the high flood occurrence in these areas can also be attributed to their physiographic, which allows that the soil in these areas composed of broad alluvial deposits and retention of bay clay loam, Marikina City clay loam and Village of Guadalupe.

2. Contributory Factors Causing Laguna Lake to Overflow

Domestic wastes dumped in Laguna Lake produce sediments and silt on the lake bottom thereby decreasing or reducing its depth. During rainy seasons in Laguna Lake instantly overflow in nearby lakeshore and communities because of its reduced or abridged depth.

On January 7, 2009, one civic oriented organization in Taguig City wrote the Department of Public Works and Highways (DPWH) inquiring and protesting on the incorrect implementation and operation of the hydraulic control structures in Manggahan and Napindan Villages and cited the following observations: “Pollution comes not only from Pasig river but also, and probably more, from sources and causes in the tributaries, and along the shores of Laguna Lake. The disadvantages and advantages of backflow of saline water into Laguna Lake still is the subject of controversy. The modernists claim saline backflow is undesirable, our forefathers who have had ample sources of livelihood from the lake of ages back and present day fishermen, had been very vocal about their experience that saline backflow rejuvenates the lake water, helps in controlling the fast growth of water hyacinth, grass and other undesirable weeds in the lake” [9,10]. Residents around the Laguna lake will not mind bearing their proportionate shatters of the effects of the acts of nature such as floods, but to let the several hundreds of thousands of coastal residents suffer for long periods for the sake of a thousand better off Manila area residents who may suffer for much shorter periods, simply does not seem to have neither rhyme nor reason.

Figure 3. Laguna Lakeshore Expressway Dike

The water level at the Laguna lake was at least one (10 meter below normal shore level, however the floodgates of NHCS were kept open, the overflow from Marikina River went upstream through Napindan river to Laguna Lake, whereas water level at Pasig River from junction of Marikina City up to pasty Lambingan Bridge has an average of at least two (2) meters below the river bank. The level of coffee with milk colored water Laguna Lake which apparently came from Marikina River rise by almost two (2) meters.

The Laguna de bay Control project shown in Figure 3 under DPWH to produce urban lands which can be potential source of substantial funds for the implementation of dikes and other infrastructure projects in the area such as Paranaque Spillway, dredging of Laguna de bay, Circumferential Road (C-6) and water supply. This project is expected to increase the capacity of the Laguna de bay to retain water of result of dredging the lake bed, which is initially considered as a major source of filing materials for the flood control work.

Moreover, in line with national and regional development goals and objectives, the proposed flood control project is intended to prime lands for urban development such as residential, commercial, industrial, open spaces and recreational uses.

The said projects will focus on residential and recreational uses considering the unique amenities and advantages of the Laguna de Bay being closest flesh Water Lake adjacent to Metro Manila. Moreover, the purpose of the project is to prepare the Master Plan for the Flood Control and drainage improvement in Metro Manila with the target of 2020 as well as the Frame work plan which presents the future comprehensive flood plain, and to carry out feasibility study on the priority project area selected on the basis of the results of the Master Plan Study.

Metro Manila that encouraged four (4) cities and thirteen (13) municipalities with the population of over 6 million in the economic and the political core of the Philippines. One of the most serious problems in the area is the habitual flooding.

A flood plan of the Pasig-Marikina River including the Metro manila was formulated in 1954 with Marikina River Multipurpose Project, followed by several studies on flood control of the Pasig-Marikina-Laguna Lake Basin. The Manggahan Floodway, Napindan Hydraulic Control Structure and the improvements works of the Pasig River, consisting mainly of river wall and dredging of the channel, have been constructed in line with the flood control plan of the Pasig-Marikina River.

As of the storm drainage in Metro Manila, the drainage program by the construction of pumping station in central manila was started in 1974 initiated by the Drainage Master Plan Study in 1952; ten (10) pumping stations were constructed. In parts of the other areas of Metro Manila, embankment and drainage gates have been constructed as urgent countermeasures for flood inundation,

Notwithstanding the continuous efforts and big investments on Flood Control drainage works, several development projects and the rapid urbanization achieved in the past years have worsened the flooding conditions. Metro manila is still facing the menace of flood damage caused by the poor flow capacity of Pasig-Marikina River and other rivers, and also the insufficient capacity of drainage channels and facilities in the low-lying areas.

Considering the above situation, it is expected the immediate action to mitigate flood and inundation damage in the object area be taken at the earliest possible opportunity. Metro Manila suffered from serious flood damage in 1948, 1966, 1967, 1972, 1977, 1986, 1988 and 2009, overtopping of the main rivers, as well as inland water causing floods.

Flooding in 2009 caused by the typhoon Ondoy, inflicted the most serious damage in recent years in Metro manila. The flood area in Metro manila reached 91.6 square kilometers, 16.2% of Metro manila. When the flooded areas of Provinces of Cainta and Tagaytay located in Marikina Valley are included, the total flooded area was 109.2 square meters.

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 mega dikes. 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 significant of this study is for the residents of Taguig City. This will make them see the outcome of the dike construction and appreciate change especially on Science and technology.

Still another significant of the study is on education. This will enhance enthusiasm of students to aid in the nation's aim of controlling flood, and to indulge them in the process.

3. Planning and Designing Mega Dike

Dikes or dykes are structures with a trapezoidal cross-section, erected from earthen material along a watercourse to prevent overflow of high waters and flooding of the watercourse valley.

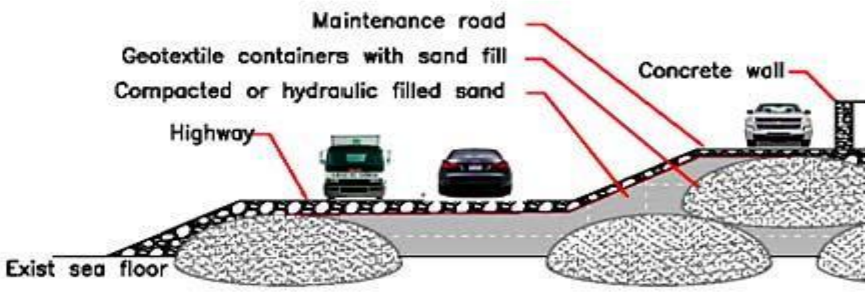

Figure 4. Construction of Dike

Where a riverbed, whether or not modified, lacks sufficient capacity for carrying all water, at peak flow rates of high waters the flooding occurs. As a means of flood defense, the design and erect protective dikes should protect the flat and extensive inundation areas along watercourses where a riverbed itself cannot be sufficiently modified to accommodate flow of peak waters; where the receiving watercourse elevates the water level during flood events too high above the line of its natural banks; and finally, where we wish to protect residential quarters, large structures and traffic routes from flooding.

The inevitable need for construction of dike is well evidenced by the recent series of flood events due to which our economy and population, and the country as such, sustained immense losses. Probably the most devastating were the floods of 2009.

These affected Taguig City by numerous human casualties, and especially huge damages to material values and the landscape. Though, also in the past, the construction of dikes was employed as an important technical measure to control high flood flow rates.

The first priority is regulation of rivers, avoidance of flooding and inundation, dewatering of large land areas. This is linked with both construction of small dikes in side valleys in order to control the flow of waters as well as provide water supply for villages, and regulation of wild mountain creeks and torrents and establishment of ponds.

Particularly important are various works to improve the economic activity: dewatering and irrigation systems and other technical works aiming at rehabilitation of swampy land and other land areas devastated due to negligence.

A particular portion of these works involves establishment and improvement of water supply, drainage and sewerage systems in various towns and villages, as well as use of sewage water for fertilization purposes. Other objectives include reunification and re-division of farmer estates.

Floods against which the researcher wants to be protected by dikes may be regular, caused by higher flows, or irregular, due to exceptional events in a watercourse, such as water level rise due to ice jam, a blocked-up bridge, etc. Irregular floods cannot be predicted, and therefore are more dangerous than those regular.

A flood event may be of temporary or permanent nature. In case of temporary flooding, when the water level declines, water returns back into the riverbed, either alone via the same way through which it overflowed, or flows in parallel along the flooded area and returns back into its normal bed in some section downstream. In case of permanent flooding, water is unable of returning back into its former bed (disabling terrain configuration) and also cannot be detained by soil.

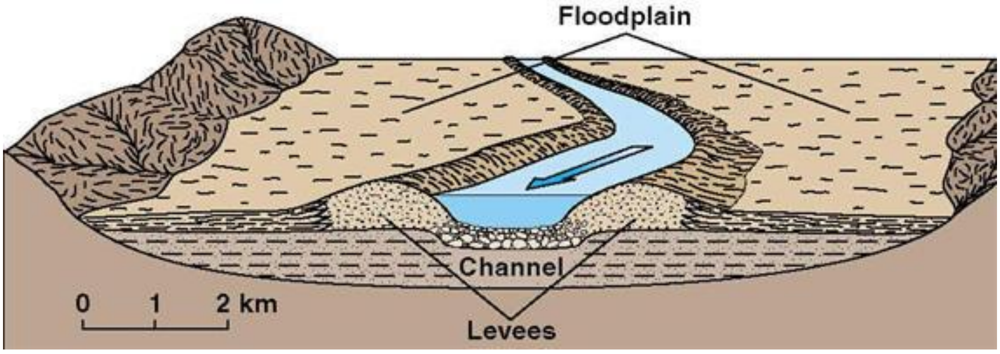

Figure 5. Design of Dike

In some cases, for the sake of protection of an economically significant area, it may be necessary to design dikes along unregulated streams. However, such a dike may be exposed to hazard of sudden damage, such as by a meandering stream which approaches the dike and undermines and breaks it; or uneven deposition of sediments may change the flow pattern and/or height of high water, which may overflow and break the dike; or the bed approaching the dike's route may alter the regime of seepage through the bottom layer and the dike, with weakened dike's stability as a result. Therefore, dikes are normally built concurrently, or after, general bed modification works.

Construction of flood-defense dikes is particularly suitable in lowlands with low gradients. Where higher longitudinal gradients and irregular outflow are involved, construction of dykes is not recommended. A more suitable measure is channeling, *i.e.*, construction of relieving, perimeter, or detention channels, rotation reservoirs, or regulation of the stream. To drain internal waters from the protected area, an independent drainage system should be implemented.

When a watercourse is impounded, the surface level of high water will be remarkably higher than it would be if it could flood the inundation area; and at the same time, the longitudinal gradient is altered as well. As a result of both changes, the water's drifting capacity is increased, with possible deeper incision of the bottom. Vegetation will develop in the upstream section, promoting deposition of sediments and fluvial materials, with clogging as a result. Thus, the high-water flow area will be reduced and a need for increasing the dike's height will arise. However, the higher a dike is the higher hazard of damage in case of failure it poses. At the same time, alluvia may raise the bed itself, and over a time it may grow above the terrain protected by the dike. In such case, a dike failure would have disastrous effects.

Before the construction of dikes, a protected area was directly drained by the non-impounded stream. After the construction of dikes, the area has to be drained by gravitation or pumping, depending on prevailing precipitation conditions and ground water levels. Therefore, when erecting dikes, a consideration is needed as to how the area on the land side of the dike will be drained, and what will be the cost of such works.

As a result of exposure to pressurized ground waters and seepage through dikes, the area behind dikes is wetted. At high water levels the water is unable of draining by gravitation; a pumping station is needed to pump water from the impounded area into the watercourse. Dikes built along an unregulated watercourse pose constant hazard. Therefore, a dike route should be designed only when the watercourse route has been established, and the dike should be placed in a terrain which has not been affected by high water flows, with due regard to prevailing local conditions.

Dike routes should be continuous, with even bends. The main direction of dikes is determined by the valley's axis, which is followed by the outflow of high waters. Thus, dikes are directed in line with the highest gradient of the valley, provided that the angle between a dike and the axis of the riverbed should not exceed 450. Sharp bends are excluded, because they expose dikes to great impact from water, give rise to ice jams and promote dike failures.

Where dikes are placed along both sides, they should be parallel, with a constant distance between the two dikes. Narrowed spans evoke reverse tides varying spans give rise to side flows which hamper the outflow and maintenance of the riverbed. The span between dikes is determined according to the aggregate flow impact force, sizes of projected flow quantities, the natural gradient of the valley, admissible velocity of water in the stream. In small rivers, the span between dike axes should be at least 20 – 30m, and the fore bay width at least 10 – 15m, unless the dikes are incorporated into the regulated stream's cross section. When designing a dike route, presence of rigid foundation soils must be assured. Wetted areas and abandoned riverbeds and oxbows should be omitted, as well as sharp bends with eroded banks (the erosion may further develop).

Where a dike is a part of the normal cross-section, and the watercourse is of a rather small or medium size, the largest possible length of dike should be positioned close to the concave bank. Where dikes are designed to protect farming land, only a gap for a field way should be provided for. Where sufficient area is not available, the dike may merge with the bank behind the concave section.

The dike crest height (after the dike body and the bottom layer have settled) is determined by the elevation point of the surface of the projected flow between the dikes, and the rise above that point. This point is determined by the hydrologic design and the hydraulic calculation. Full protection dikes are elevated 0.4 to 1.0m above that point, depending on the nature of a stream and the significance of protection. Where appropriate (in bends, near built structures *etc.*,) the designed elevation may be further increased.

The elevation gain of high water surface due to impounding can be approximated by comparing the flow rates prior and after the construction of dikes.

Dikes are structures made of bulk earth material, with trapezoidal cross-section and flat crest. Proposed widths of dikes are min. 2m for dykes with heights up to 2m and 3m for dike heights over 2m. Today, the prevailing designed crest width is 4m in order to provide for passage of heavy-duty off-road motor vehicles. A dike crest should be drained and protected against weather exposure and damage due to the passage of vehicles by appropriate reinforcement measures. Where additional reinforcement is not required, the crest is at least grassed. When designing the dike's cross section, the following factors should be considered: (a) physical and mechanical properties of materials from which the dike is to be made; (b) hydro-geologic conditions prevailing in the bottom layer, and its physical and mechanical properties; (c) control of seepage through the dyke and particularly its bottom layer, and its effects on stability of the dyke and the bottom layer; and the method of draining the dyke's land-side toe; (d) duration of the dike and bottom-layer loading by the projected flow rate, and the associated effects (seepage, hydrostatic upward pressure, drainage of the protected area, *etc.*); and, (e) flood protection measures.

Stability of a dike also needs to be assessed as to the potential for shifting along the base of foundation. A dike is secured against such shift if its friction resistance (T) along the base of foundation is higher than the horizontal component of hydrostatic pressure force (H).

Dikes with heights above 4m are extended on the land-side by 2-4m wide berms. A berm should be placed 1.5 – 3meters below the dike crest, depending on the cross-section and the seepage depression curve shape. It is used during flood situations as a two-way passageway. A slope is designed with a single or broken inclination, in which case the more moderate inclination section is that at the dyke toe. The inclination breaking level is typically the berm level.

Approx. 15m wide (measured from the toe) protective strips are provided for on both land-side and water-side of a dyke. No digging, ploughing or excavations are allowed within the land-side strip. On the water side, the terrain within the protective strip must be kept intact, or a seal coat could be provided here. In addition to stability, another consideration involved in the dyke dimensioning is seepage through the dike at high water outflows, when the space between the dikes is filled up to the maximum admissible limit. A dike cross-section is properly designed if the seepage curve crosses the base of foundation inside the dyke's cross-section, and is protected by at least 1m layer of the material. The seepage curve may be lowered by implementation of drainage at the land-side toe of the dike. Protrusion of the seepage curve from the dyke's body on the land-side must be avoided in order to prevent removal of soil and a dyke failure. At the same time, capillary seepage water must not reach the space which is subject to freezing, or otherwise dangerous cracks in the dike's body might develop. The capillary height in sand soil is only 5 – 15cm, while in clays and clay-sand soils it is 05 – 1.50m.

The seepage curve shape depends on permeability of the dike's soil material, the size of hydrostatic pressure force, and permeability of the bottom layer material. Generally, the average inclination ratio of the seepage curve is 1:6, varying according to permeability of the soil; the curve inclination ratio of more permeable soils is 1:8. For seepage curve calculations, please refer to specialized literature. Normally, slopes of a dike are covered by a 10cm layer of arable land, which is sowed with grass in the vegetation period. Where appropriate, it is protected by grass sods. When assessing permeability of the designed section, it should not be taken in account as sealing layer.

In order to assure water-proof design, wherever possible the dike should be built from impermeable soils; the best choice are clay-earth soils with 50 to 60 volume per-cent of sand, free of organic substances. Fine-grain, earth and clay soils are impermeable, however they are susceptible to strong wetting in water, and after drying they crack, and therefore are unable of providing sufficient stability of a dyke. As regards permeability, the soil to be used is assessed in view of the projected duration of high water loads. Where possible, soil material for the dyke building should be obtained from local sites, *i.e.*, the riverbed or the fore bay, as close to the dikes route as possible. However, one important consideration here is the potential of material extraction pits for causing dike failures. They should be excavated in a manner providing for their further refilling by fluvial deposits either by the natural activity of the stream, or by means of transversal structures. No pits may be excavated within the protective strip mentioned above.

The dike building material and the bottom-layer material are always permeable to some extent. A dike made from permeable material requires sealing. The water-side or central sealing is typically made from clay or earth (permeability coefficient $k \leq .02$cm per day), and today also from concrete, bitumen-concrete, or synthetic materials.

The thickness of the sealing layer should be 30-50 centimeters (or more) and the layer should be bound down to the impermeable stratum of the bottom layer, so that not only the dike itself, but also permeable strata of the bottom-layer are secured against seepage (for excess hydrostatic pressures at depths of up to 1m, a 30cm thick layer is sufficient; up to 2m, 40cm layer, and up to 3m, 60cm layer should be provided). With bigger depths of the impermeable stratum underneath the base of foundation, the bottom layer should be sealed by means of a steel or concrete sheet-pile wall shown in Figure 6.

Figure 6. Concrete Sheet Pile Wall

Where smaller dike heights are involved, the sheet-pile protrudes together with the dike body above the high water level. Where the impermeable bottom-layer stratum is laid too deep, such approach is impossible. In such case, the seepage water velocity should be reduced to a non-harmful level by applying a horizontal impermeable coat in the fore bay or a vertical curtain, or a combination of both.

4. Respondents Feedback

The researcher employed a descriptive method of research in the study. The focus of concern of the research is to analyze the major problems of the Municipality of Taguig specially flood and its resource of constructing a mega dike and to compare the effectiveness of the mega dikes in the province of Pampanga and Taguig City. Every year, its' residents and public is affected by floods and the problem is causing a big concern among them. Accidental sampling under the category of non-probability sampling was adapted. The researcher went through the area within the subject and conducted a survey to those who gave them a chance. One hundred sixty two (162) respondents who are making a living nearby the location of the subject and also the everyday passers-by were selected and employed in the study. The population consists of twenty eighty one 1) males and eighty one (81) females. They belonged to almost all walks of life including DPWH staffs, some residents that were affected and from the people involve and knowledgeable in the topics being discussed. A structured interview was conducted among the one hundred sixty two (162) respondents guided by a specifically prepare questionnaires.

Rating will be given by the respondents based on the levels. The questionnaire determines the rate of the effectiveness of Pampanga mega dike to Taguig mega dike. The statistical equation was used, and the development of slope gives the effectiveness of both mega dikes.

Many feasibility studies was conducted by the Government of the Philippines and the researcher believes that Taguig mega dike will solve the problem in flood and will give Metro Manila a home place to live for.

4.1. Levels of Flooding in Taguig City

Figure 7 and 8, and table 1 show that the respondents are experiencing flood for more than thirty (30) years of residency of Taguig City. In the interview, most of the people in the area are hoping that the construction of the Taguig mega dike can solve the problem in flood.

4.2. Rating of Effectiveness of Mega Dikes

Figure 9 and 10 shows that there is a significant relationship between the rating of Pampanga mega dike and the rating of Taguig mega dike as effective flood control. The effectiveness of their purposed is the same and most of the respondents believed that the Taguig mega dike could be more effective than Pampanga mega dike. Since the regression coefficient is $0.5 \leq r \leq 1.0$, then it can be said that there is a significant positive relationship between the effectiveness of the Pampanga mega dike and Taguig mega dike.

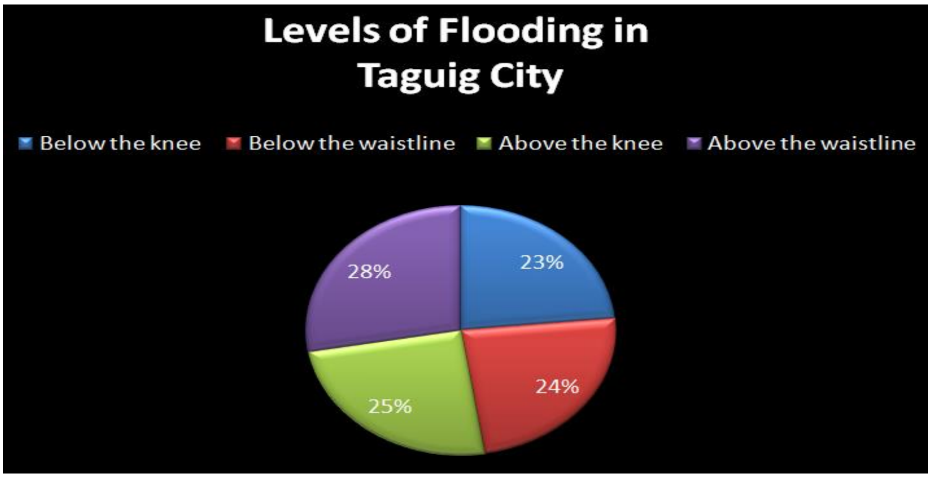

Figure 7. Percentage Distribution of Levels of Flooding in Taguig City

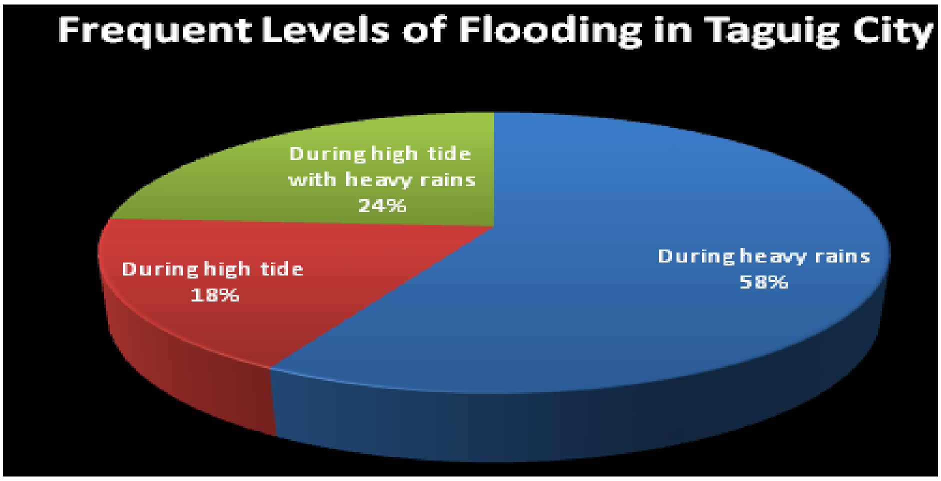

Figure 9. Percentage Distribution of Frequent Levels of Flooding in Taguig City

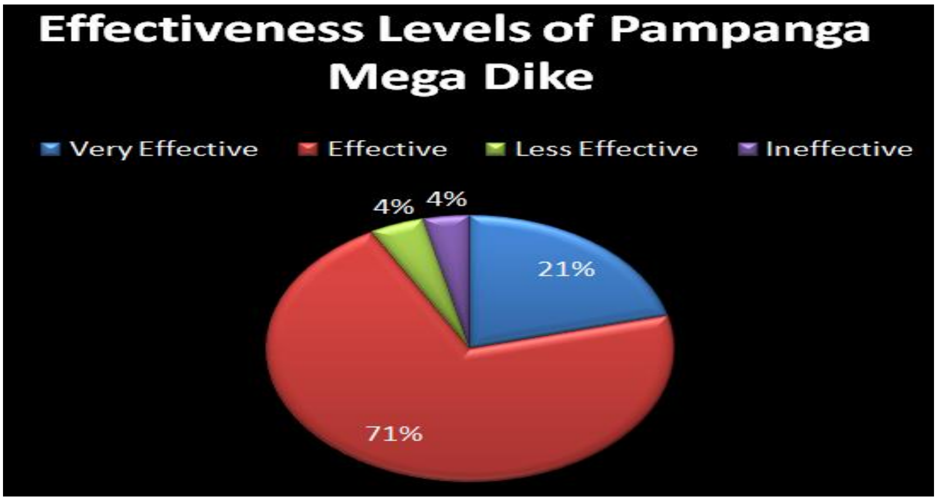

Figure 10. Percentage Distribution of Effectiveness Levels of Taguig Mega Dike

Table 1. Frequency Distribution of Construction of Mega Dikes

Questions	Yes	No	Total
Do you think that the construction of Taguig dike will solve the problem of flooding in the area?	122	40	162
Do you agree that construction of the dike should continue?	150	12	162
Are you familiar with the Pampanga mega dike?	140	22	162
Did you know how it withstands the flood and Lahar flow in the province of Pampanga?	153	9	162
Do you think that Taguig City will become effective as the Pampanga dike?	134	28	162

5. Conclusions

The positive results indicated that residents have a great expectation on, the said on-going construction of Taguig mega dike. Their response could also be attributed to the idea of having a very good living condition with less worry on their health and sanitation. Other thoughts especially the business, this will give better future for commerce and industry that will help to increase the growth in the area. Development will become better services to the people of Taguig City.

Therefore, Taguig mega dike is the future of Taguig City. It is also the future of Metro Manila because it could contribute to the improvement of the flood control system of the eighteen (18) cities and municipalities. Moreover, it could lead to the economic growth of the Philippines

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