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STRUCTURAL FLOOD MITIGATION IN METRO MANILA: CONSEQUENCES AND IMPLICATIONS ON URBAN FLOOD AND THE ENVIRONMENT

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Abstract
This paper reviews the consequences and implications of implementing structural flood mitigating measures in Metro Manila with respect to flood and environmental protection. It focuses particularly on the effects and consequences of constructing and operating structural flood mitigation measures to Metro Manila's vulnerability as caused by flood hazards. It is surmised that the structural flood mitigation measures are important components in the reduction of flood in Metro Manila, however, examination of its implementation has revealed, aside from the expected benefits, several disadvantages, which in some cases resulted in more damages and greater losses. On one hand, affected communities are protected, to a certain degree from the ravages of flood; on the other hand, it provides a false sense of security to settlers and investors, which paves the way for higher urbanization, which consequently increase Metro Manila's vulnerability, aside from the fact that several environmental components were already sacrificed during the construction phase. Thus, it is imperative to weigh the benefits against the disbenefits of having structural flood mitigation measures prior engaging to such costly endeavor.

Introduction
The use of structural flood mitigation measures is recognized as a valuable option in flood management (Liongson, 2000). Flood prone megacities would usually resort to the installation of infrastructures designed to handle a certain degree of runoffs. Such infrastructures have limited capacities with respect to handling of flood waters and resistance to damage. Thus, the effectiveness of structural flood mitigation measures to reduce vulnerability is then compromised due to these limitations. Nature also has a stake on the implementation of the structural measures, since disturbance of the natural environment normally occurs during construction. Flooding in megacities is usually due to the city's impermeability brought by high urbanization that is exacerbated by poor drainage facilities. Such scenery is observed in Metro Manila, a megacity in the Philippine archipelago, where flood incidents are prevalent, particularly during the rainy season. Since flood occurrences in Metro Manila are frequently due to a long and intense rainfall, most of the structural flood mitigation measures are normally designed to protect the city from two kinds of rain-induced flooding: *local flooding*, where water is temporarily accumulated in small open spaces like roads, urban lots, farmlands, etc.; and *river flood flooding*, where flooding is due to the overflow of major channels to adjacent lots and flood plains (Liongson, 2000). However, due to the resource and financial limitations of the Philippine government, the coverage and protection level of structural flood mitigation facilities are also limited to a certain degree, which poses higher risks if overwhelmed by bigger flood events, like in the case of flooding during the onslaught of Typhoon Ondoy in September 2009. The existing and proposed flood mitigating structures should also be assessed according to resiliency and capacity to address the effects of climate change. Thus it is important to carefully weigh the benefits and disbenefits of choosing such measures, and to balance the possible consequences to the urban and natural environments. This paper presents a summary of ideas on the advantages and disadvantages of building structural flood mitigation measures in Metro Manila.

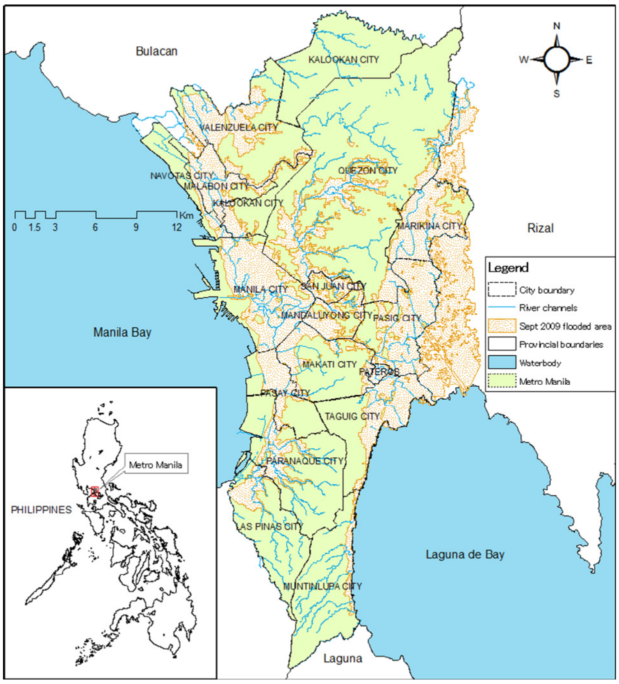

Figure 1. Extent of flood in Metro Manila during Typhoon Ondoy

Brief history of flooding and flood control in Metro Manila
Present-day Metro Manila consists of 16 highly urbanized cities and 1 municipality, with a population density at around 18,000 persons/ km^2. During the early 19^{th} century, Manila, one of the future cities of Metro Manila, was the center of economy, trade, development and political affairs, thus making it the most urbanized Spanish colony in the country. Flood has been known to occur in this area even in its early days. Records indicate that flood waters recede 'unassisted' through the city's natural waterways called *esteros* and canals. However, flooding incidents were going from bad to worst in parallel with the city's growing society. Sanitary conditions were also becoming serious issues associated with floods. The capacity of the esteros and canals were being reduced partly due to reclamation by early settlers and siltation brought by early urban developments. In the late 19^{th} century, the Spanish government ordered the construction of road drainage in every highway within Manila City. In 1905, during the early days of the American colonial period, studies were made to improve the storm-water drainage of Manila City, which includes observation of tidal effects and gauging of esteros and canals, ground water levels, absorption rate, rainfall observations and determination of run-off coefficients. These provided the groundwork for later improvements on road construction and other infrastructure during the American colonial period (Bankoff, 2003, Liongson, 2000). A comprehensive study on the drainage system of Manila, including its suburbs, was made only during 1942 to 1952, following a big flood, which inundated most part of Manila City and lasted for several days in November of 1942. About 5,000 ha (or 8% of the present-day Metro Manila) was

covered by this study.

Table 1. Major structural flood mitigation measures in Metro Manila

Major Structural Flood Mitigation Measures	Current status and Locations
River bank improvements (such as dikes and parapet walls)	Built in the core areas of Metro Manila, Proposed for the core areas and northwest part of Metro Manila
River and channel dredging	Built and proposed for the core areas of Metro Manila
River widening	Built in the core areas of Metro Manila
Pumping stations	Installed in the northwest part, west part and core areas of Metro Manila
Sluice gates	Installed in the northwest part and southeast part of Metro Manila
Navigation lock	Built in the northwest part of Metro Manila
Diversion canal	Built in the southeast part of Metro Manila
Detention basins	Proposed for the northwest part of Metro Manila
Open channels and interceptors	Proposed for the northwest part of Metro Manila
Coastal dikes	Built along most part of Manila City bay area and proposed for Navotas bay area

However, none of the proposed improvements was accomplished due to financial constraints (Fano, 2000). The study completed in 1952 has become the foundation for the modern-day studies related to drainage improvement in Metro Manila starting from 1982 to the present day (Fano, 2000). Since then, major drainage improvements have taken place including river improvements, diversion canals, and installation of storm-water management facilities such as underground drainage pipes, pump stations and flood gates to name but a few (Bankoff, 2003). Despite the improvements, flood occurrences are still observed progressing, and affect a greater area of Metro Manila. Figure 1 shows the flood occurrence in September 2009, which affected more than 30% of the 638 km^2 area of Metro Manila. This far greater than the area affected during the 1950s, which is less than 20% (Nantes, 2000). This phenomenon can be attributed to both natural and man-made factors. The increasing population adds to the vulnerability of Metro Manila to flood hazards. The Philippine government finds the necessity to construct additional flood mitigation structures to alleviate the extent of perennial flooding and address some of the effects of anticipated effects of climate change.

Structural flood mitigation measures in Metro Manila

According to Tabios et al (2000), there are three types of flood occurrence in Metro Manila: local street floods, moderate floods and regional floods. The current drainage network in Metro Manila consists of 44 km mains, 1,200 km drainage laterals, 290 km of esteros and canals, and 153 km of river and major streams. To address the storm-water that exceeds the current capacity of the drainage network, the Philippine government has installed several structural flood mitigation measures to further reduce the extent of flooding. A summary of the kinds of major structures, built and proposed for Metro Manila, are shown in Table 1.

Consequences and implications on Urban Flood

Structural measures are basically designed to reduce the incident of flooding. However, most designs have limitations, the structures are only as good as the design criteria used. Most of the modern structural flood mitigation measures in Metro Manila are designed for 10-30 years return periods. However, the flood that occurred in September 2009, was estimated at 50 years or more return period (Gatan 2009). The flood structures in the hardly hit part of Metro Manila were overwhelmed, leaving a devastated population of more than 4 million. The costly nature of the infrastructures often limits the technology options. Thus, more advanced and bigger scale structural flood mitigation measures, such as underground floodways and super levees, that are effective for megacities are forgone (Liongson, 2000). Basic structural flood mitigation technologies tend to address the immediate issues, but not its root cause. Individually, these technologies are relatively small in scale and can address only a small area. Use of basic technologies in one part of a basin may have consequences to the other portions of the basin as brought by the change in the hydraulic properties of storm-water. Effects on the downstream of the structural measures should also be included in the assessment. In a system with multiple flood mitigation structures, failure in the operation of one of the structural measures can lead to the reduction of flood control efficiency; at worst, it may lead to unprecedented damages. The structures may also create a false sense of security on the population and investors, creating a notion that they can build more settlements and businesses with little or no regards on the area's vulnerability to possible bigger floods.

Consequences and implications on the environment

Structural flood mitigation measures affect the physical, biological, social and economic components of the natural environment during the construction phase, which are often irreversible, with minimum negative impacts during the operation phase, Some of the relevant impacts are the following:

1. During the construction phase, there can be removal of vegetation and natural habitats along major rivers and channels; disturbance of river benthic environment during construction and operation; removal of settlements; On the positive side: job generation, clearing of clogged waterways, construction of access roads.
2. During the operation phase, the structural measures may have effect on the groundwater level; the area's seismicity; agricultural productivity; health issues on untended structures; high cost of maintenance; false sense of security; On the positive side: improvement in drainage flow; job generation; better opportunities for economic growth and urban expansion.

Conclusion

Structural flood mitigation measures are valuable components in Metro Manila flood management. These structures however have direct negative impacts to the environment, aside from its benefits, that is worth looking into prior its implementation, aside from the fact that limitations in the structures' capacity to prevent or control flood exist since the affordable technologies often offer only a relatively small degree of protection, which should be higher in highly vulnerable megacities. Careful assessment of the benefits and disbenefits should be made prior engaging to a very costly endeavor, especially now that flood patterns are expected to change due to climate change.

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