Effectiveness of CAMANAVA Flood Control Project: A Case Study of Selected Flood Control Structures during Typhoon Gener and Monsoon Rains in August 2012

James TYREE
Graduate Student
LBJ School of Public Affairs/Cockrell School of Engineering at the University of Texas at Austin
2315 Red River St, Sid Richardson Hall, Unit 3, Austin, Texas USA 78712-1536
james.tyree@utexas.edu

Savin VEN JOHNSON
Graduate Student
LBJ School of Public Affairs at the University of Texas at Austin
2315 Red River St, Sid Richardson Hall, Unit 3, Austin, Texas USA 78712-1536
savin.venjohnson@gmail.com

Marie Claire L. PASCUA
Instructor
Institute of Civil Engineering, University of the Philippines – Diliman
Room 100-102, Melchor Hall, Diliman, Quezon City, Philippines 1101
marieclaire.pascua@gmail.com

Md. Masumur RAHAMAN
Graduate Student
Graduate School for International Development and Cooperation, Hiroshima University
1-5-1 Kagamiyama, Higashi-Hiroshima 739-8529, Japan
masumur21@gmail.com

Arnel L. TENORIO
Supervising Agriculturalist
Batangas Provincial Agriculture's Office
Provincial Capitol Building, Batangas City, Philippines 4200
arneltenorio@yahoo.com

Mohammad LUTFI
Lecturer
STT – Migas Balikpapan
Jl. Brigjen Ery Soeparjan No. 09, Balikpapan – Kalimantan Timur 76112, Indonesia
lutfi_plhld@yahoo.co.id

Abstract

Malabon City, a municipality in north-western Metro Manila near Manila Bay, suffers frequent flooding which has led to its reputation as the "Local Venice" of the Philippines. Eighteen natural and artificial waterways segment Malabon and crest during high tide and heavy precipitation. In 2003, the national government, with funding and partnership from JICA, initiated the CAMANAVA Flood Control Project, aimed at reducing flood prone areas by 75 percent within Malabon and its three neighboring

municipalities. Ten years and over 5 billion Philippine pesos (PhP) later, the project remains incomplete, and Malabon continues to experience debilitating floods. This research note presents a report of the effectiveness of selected flood control structures in Malabon through field observations of structures in the city's three most flood prone districts, locally called *barangays* - Catmon, Tonsuya, and Tañong– during Typhoon Gener and heavy monsoon rains which followed in early August 2012. To evaluate the effectiveness, the research team consulted the initial project design and hydrological and geotechnical studies to ascertain expected flood mitigation results, and evaluated them against site visit observations conducted in early August 2012 before and after torrential rainfall. The findings reveal failures in flood control structures, such as collapsed river walls, resulting in extensive flooding during and immediately after the rainfall. Interviews with local experts and policymakers reveal that these failures stem from several factors. First, the baseline hydrologic parameters used in the original designs are outdated and no longer accurate. Second, the designs failed to consider other factors such as land subsidence in its conceptual planning. Third, some construction remains incomplete and as built do not meet design specifications. To improve flood control management in Malabon, this research team recommends a complete recalculation of hydrometeorological forecasts and structure design based on recently procured data, maps, and modelling techniques. The new models should recognize increased severity and frequency of hydrometeorological activity resulting from climate change, such as greater maximum high tides, rising sea levels, and increased magnitude and frequency of precipitation. Design recalculation should incorporate land subsidence caused by pressures from population growth, water usage, and urban planning. The second recommendation is to rebuild CAMANAVA flood control structures capable of sustaining longer term extreme hydrometeorological conditions based on the outputs derived from the modelling.
Keywords: Malabon City, Flooding, CAMANAVA, Typhoon Gener, Monsoon, Disaster Risk Management

1. Introduction

1.1 Typhoon Gener and Monsoon Event Background

In August 2012 Metro Manila experienced heavy rainfall from Typhoon Gener and prolonged monsoon rains, the combination of which resulted in extensive flooding throughout the metropolitan Manila area (Metro Manila). The flooding forced residents to evacuate their homes and caused significant property and economic damage. One municipality, Malabon City, experiences flooding more heavily and frequently than other municipalities in Metro Manila during the monsoon season because of its location at the mouth of the Tullahan River Basin. The Department of Public Works and Highways (DPWH) is addressing flooding in Malabon and surrounding municipalities through a capital infrastructure improvement project, known as the CAMANAVA Flood Control Project; however, the project remains incomplete and under designed, so residents are still vulnerable to flooding.

This research note will examine selected CAMANAVA flood control structures in Malabon for their effectiveness in protecting Malabon residents from flooding. This will confirm or deny the assertion that the incompleteness of the project and under design is causing flooding in Malabon.

1.2 Malabon City Background

Malabon is a municipality in north-western Metro Manila located near Manila Bay, which is subdivided into 21 *barangays*, or administrative districts (Figure 1). It has a population of roughly 364,000 people spread across approximately 1,571 hectares, making the city one of the more densely populated areas with over 231 persons per hectare. Malabon is home to a large number of informal settlements, defined as "residential areas where a group of housing units has been constructed on land to which the occupants have no legal claim, or which they occupy illegally and are not in compliance with current planning and building regulations" (United Nations Human Settlement Programme, 2006, p. 4). As of December 2011, Malabon had 17,104 informal settler families, representing approximately 22 percent of the families in the city (Malabon City Planning and Development Department, 2011). Many informal settlers live along riverbanks, under bridges, and in other high-risk flooding zones. Their makeshift dwellings made usually of non-durable materials, combined with limited financial resources and inadequate or absent flood protection make them highly vulnerable during flooding. The relatively high proportion of informal settlers in Malabon is a significant policy issue because of challenges in providing adequate hazard protection (Zoleta-Nantes, 2002).

Figure 1. Malabon City and its 21 Barangays

1.3 Flooding in Malabon

Malabon is prone to natural hazards, particularly flooding, because of its location at the basin of the Tullahan River and low-lying riverine topography. Fifty years ago, about 40 percent of present-day Malabon existed as an estuary. However, population pressures and economic growth pushed policymakers to reclaim submerged areas for residential, business and industrial use. In 1960, a development project filled the majority of the submerged portion of Malabon to its present area (Bautista, 2012a). At present, land elevation in most of Malabon remains at mean sea level (msl) to 3 meters above msl. Eighteen rivers, creeks and canals - remnants of natural waterways and artificial waterways created by the reclamation project – now crisscross the city and are directly impacted by tidal fluctuations in Manila Bay and water level changes within the Tullahan River Basin (Figure 2) (Bautista, 2012a).

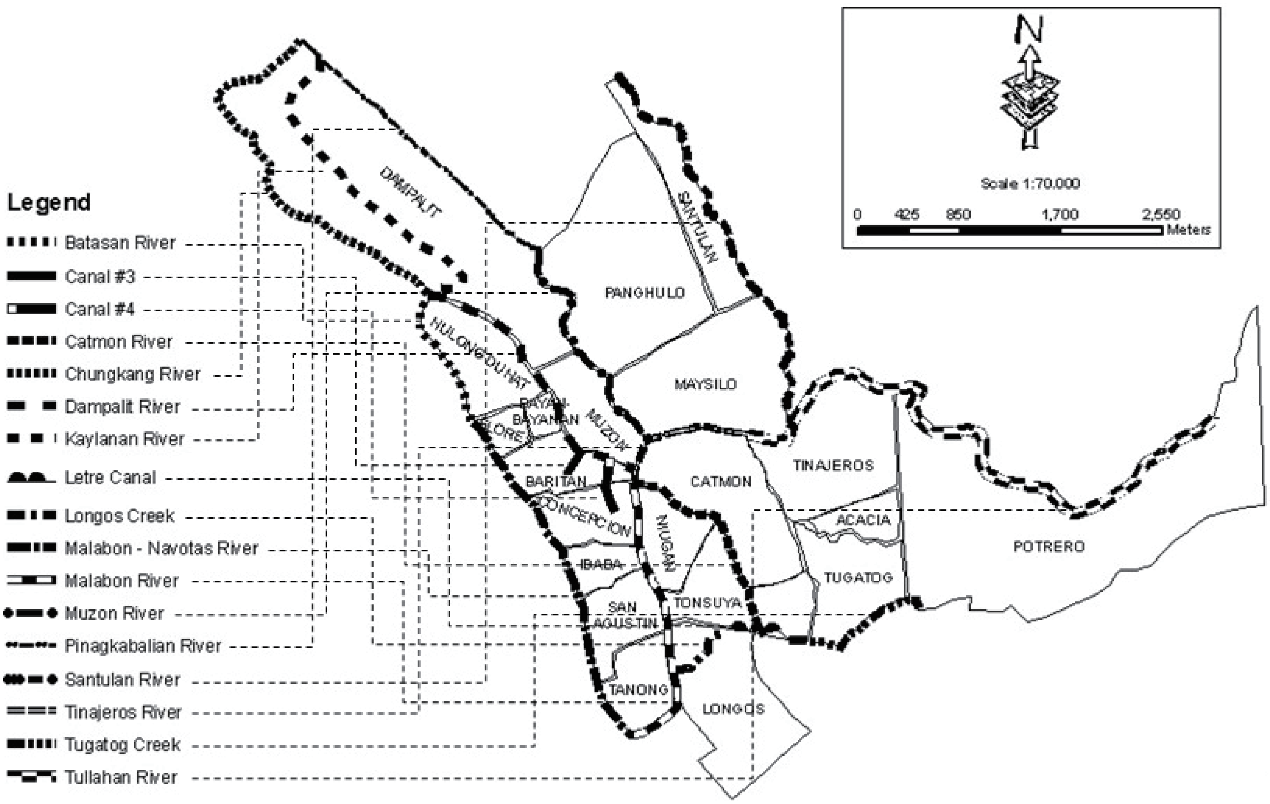

Figure 2. Rivers and Waterways in Malabon City (Source: Bautista, 2012a)

The combination of low elevation, proximity to Manila Bay and other waterways, and deprivation of natural catchment areas because of development and population density has led to greater risks of flooding. Generally, flooding in Malabon originates from three sources: high tide, land subsidence, and heavy precipitation, all which cause waterway cresting. In fact, flooding is so extensive and frequent in Malabon that the city received the title of the local Venice of the Philippines ("Malabon Travel Guide," 2012).

Since 2008, at least 7 major flood disasters have occurred in Malabon (Table 1). This chronic and pervasive flooding has resulted in hundreds of billions of lost pesos in the Filippino economy and constant interputions to residents' lives.

Table 1. Major Natural Disasters Affecting Malabon (Source: Compiled "Disaster Alerts" from Citizens' Response Center Disaster and Manila Bulletin Online)

Date	Typhoon	Impact
6 Aug 2012	Monsoon Rains from Haikui	• 500+ mm in less than 48 hours. • Malabon City 90% flooded
2 Aug 2012	Gener	• 10 to 35 mm per hour • High tide (1.7m) aided by the storm surge and rain led to overtopping of the dike and flooding.
23 June 2012	Ferdie	• 40 mm per hour • 'Waist deep' flooding occurred at Brgy Dampalit; • Brgy Tinajeros, Tanong recieved 406 mm of flooding; • Brgy Panghulo received 508 mm of flooding, • Brgy. Bisig received 254 mm of flooding
18 June 2011	Egay	• Heavy flooding, reported 'chest deep' • 19 families living in river bank at Brgy Tinajeros relocated. • 8 families at Brgy Potrero evacuated due to 672 mm deep flood; Brgy. Tanong, Santolan, Baritan & Concepcion had 762 mm deep flood water level • 3.65-meter deep flooding in Brgy. Dampalit
24-28 Sep 2011	Pedring	• 121 mm in 10 hours • Heavy flooding and "State of Calamity" declared in Malabon City • 11 barangays submerged in flood water • TS Quiel followed
29 Sep 2009 –10 Oct 2009	Pepeng	• Cumulative rainfall in some areas of +1,000 mm • Est. damage and loss from Pepeng and Ondoy $4.35 B.
24-27 Sep 2009	Ondoy	• 455 mm in 24 hours • 600 families affected at Brgy Panghulo, Tonsuyan & Catmon • 250 families affected in Tullahan River area

In the 1990s, the CAMANAVA Flood Control Project (hereto referred to as CAMANAVA) was proposed and accepted by both national and local officials to be a lasting solution to address the flooding issue.

2. Research Scope and Methodology

2.1 Research Scope

This research note presents an evaluation of the completion and effectiveness of selected flood control structures in Malabon constructed through the CAMANAVA Flood Control Project during Typhoon Gener and heavy monsoon rains in August 2012. The selected structures offer a representation of total completeness and effectiveness of the project. The methodology for evaluation involves assessing and reviewing accessible structures through site visits in three *barangays*: Catmon, Tonsuya, and Tañong (Figure 3) before and after significant rain events to arrive at a qualitative assessment of the control structures' effectiveness to mitigate flooding; in addition to evaluation of effectiveness through field observations, a comparison was conducted between CAMANAVA design capacity based on historical hydrometeorological data and actual hydrometeorological data.

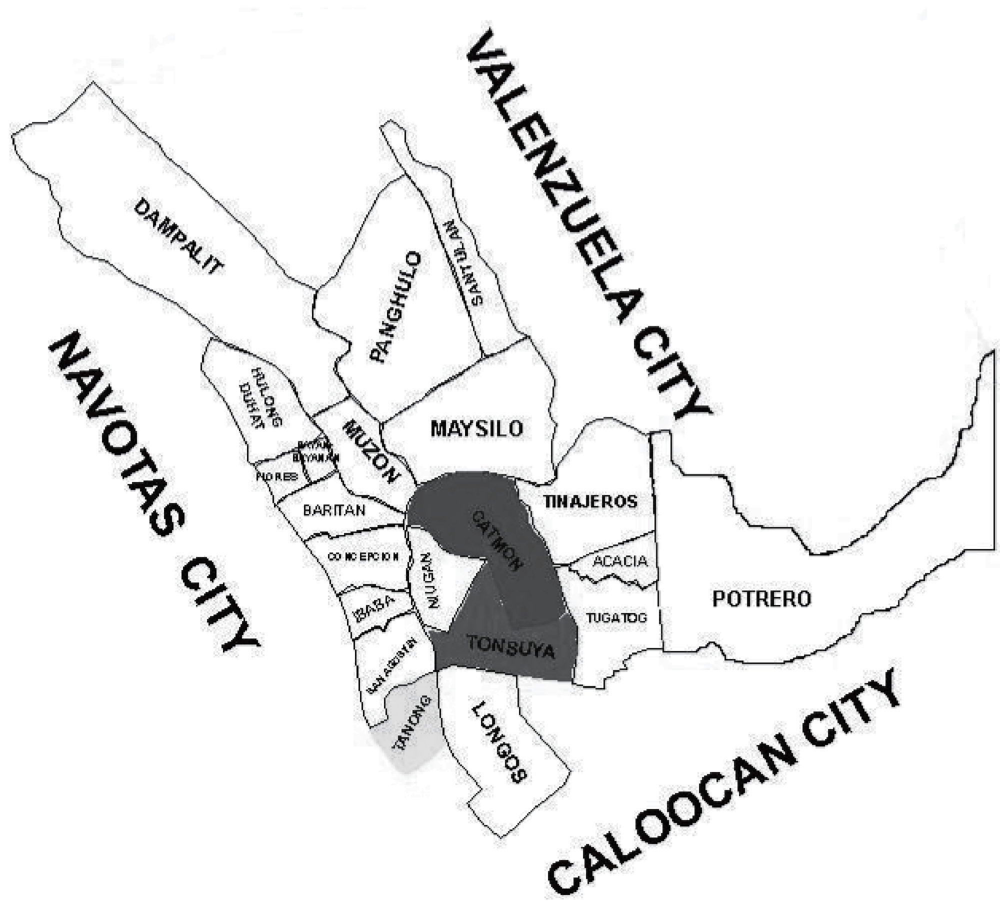

Table 3. Focus Barangays

2.2 Methodology

This assessment focuses on flood control structures in three barangays: Catmon, Tonsuya, and Tañong. Terente, et al (2010) had identified these three barangays as most at-risk for flooding in Malabon. Though the three barangays are situated in the southern portion of Malabon, each barangay represents different land use and population characteristics. Catmon's land use is mixed use and includes residential, commercial, informal settlements and central business district (CBD) areas. It has a relatively average population density but has a significant number of informal settlers. Table 2 summarizes the demographic statistics for the three barangays. Catmon is bordered by the Tinajeros River to the north and by Catmon Creek to the west. CAMANAVA flood control structures in Catmon include a flood gate and water pumping station near the Catmon Creek-Malabon River confluence and river walls along the Tinajeros River and Catmon Creek.

Table 2. Comparison of Demographics and Land Use in Focus Barangays (Source: Malabon City Planning and Development Department, 2011)

Barangay	Population	Area (Ha)	(% of Malabon)	Population Density (persons/Ha)	# of I.S.[a] Families	Est.# I.S.[ab]	I.S. as % Barangay residents	Land Use Classification
Catmon	36,804	97.77	6.22%	376.43	2,071	9,402.34	25.5%	Mixed
Tanong	36,804	33.83	2.15%	480.55	182	826.28	5.0%	Commercial/ Residential
Tonsuya	40,221	59.40	3.78%	677.12	1,070	4,857.8	12.0%	Residential

a. I.S. = Informal Settlers
b. Calculation of informal settlers: number of families multiplied by the average household size = 4.54

Tañong is a commercial and residential area with the smallest percentage of households as informal settlers. Tañong is on a peninsula with the Malabon-Navotas River to the west and the Malabon River to the east. Like Catmon, Tañong has a floodgate and pumping stations along with segments of new and renovated river wall. The C4 Floodgate in Tañong is a critical flood control structure along with the navigation gate in northern Navotas which control the effects of Manila Bay tidal fluxes and storm surges on the Malabon waterway system.

Tonsuya is primarily a residential area with a high population density. However, the number of informal settlers is low relative the other three barangays. It is bisected then bordered by Catmon Creek to the east, bordered by the Letre Canal and Longos Creek to the south and the Malabon River to the west. The only CAMANAVA structure associated with Tonsuya are river walls.

3. Flood Control Efforts

3.1 History of Flood Control Efforts

CAMANAVA was not the first flood control initiative in Malabon. Because of city's risks exposure and long history of flooding, the government has implemented several flood control programs since the 1980s (Jago-on, 2009). At municipal level, Malabon officials implemented flood control projects to manage disaster risk, including construction and repair of floodwater pumping stations, installation of floodgates, dredging of canals and drainage systems, raising and rehabilitation of river walls, and waterways clean-up. In 2005, Malabon formed Flood Brigade 1 and tasked them with special flood control projects such as clean-up and debris clearing of canals and drainage systems. These local efforts still continue today. Additionally, residents have individually added sandbags along river walls to further strengthen existing flood control structures in their areas.

In 2008, the local government created the Malabon City Advisory Council on Flood Control to monitor flood control initiatives. The council is divided into three committees: public information, waste management, and technical, and members come from different sectors, organizations and communities concerned with alleviating flooding in the city. The council is responsible for assisting the mayor in reviewing and appraising policies and programs on flood control, such as CAMANAVA, as well as for formulating, developing, and serving as an advocate for flood control plans and programs.

3.2 The CAMANAVA Project

The CAMANAVA Flood Control Project was developed to mitigate extensive flooding in the north-western Metro Manila region of Caloocan City, Malabon City, Navotas City, and Valenzuela City, collectively known as the CAMANAVA area. The project's scope involved large scale waterway structural controls. Prior to project construction, the flooded areas within the four cities spanned 1,850 ha of the 8,347 ha CAMANAVA area. Of that area, 49 percent lies within Malabon city limits. The Philippine government, through the DPWH in partnership with the Japanese International Cooperation Agency (JICA), proposed the flood control project with the aim of alleviating flooding in flood-prone area by 75 percent (DPWH, 2001). CAMANAVA selection was based on a 1990 flood mitigation feasibility study commissioned by JICA as a response to the 1985 flooding in Metro Manila. The feasibility study cited the CAMANAVA area in north-western Metro Manila as one of three major areas of concern in Metro Manila. The DPWH used the 1990 feasibility study to prepare the flood control project scope, which was completed in 1997.

(1) Scope, Budget, and Schedule

The initial flood control project was planned in two phases distinguished by project location. Phase 1 was initiated first and comprises flood control structures in the CAMANAVA. Once complete, the new infrastucture will convey flood waters to the majority of Valenzuela City and the municipalities of Obando and Meycauayan, located in the Bulacan province. In Phase 2, referred to as the Valenzuela-Obando-Meycauayan (VOM) Area Drainage System Improvement Project, control structures will be constructed in the VOM area to close the gap and alleviate all flooding in north-western Manila. This research note will evaluate selected structural controls from Phase 1 area.

The CAMANAVA Flood Control Project implementation is divided into Southern and Northern areas. The Northern area is dominated by a polder (earthen) dike and a navigation gate while mechanical control structures and river walls protecting populated areas dominate the Southern area. To date, control structures in both the Southern and Northern areas are incomplete.

The overall scope of Phase 1 includes: Construction of 4 flood control gates, 21 pumping stations, 2.7 km of drainage channel, 1 submersible type navigation gate, 6.0-hectacres retention pond, 8.6 km of polder (earthen) dikes; Raising of 13.1 km of river walls; And improvement of 6 km of existing drainage channels (JICA, 2009). The feasibility study upon which flood control structures were designed was based determined protection from a 30-year flood return (JICA, 2009). According to Bautista (2012b), the project design met the flood mitigation for a 30-year flood return, as they were reported in a 2001 hydrological study of the area; however, the increased frequency and magnitude of flooding in the region has relegated the design to be inadequate for current flood mitigation needs.

The project budget was initially set at PhP 3.479 billion. DPWH secured funding through a JICA loan to cover capital costs. The Philippine government initiated the project in June 2003 with an estimated project completion date set for June 2007. When June 2007 arrived, construction was yet to be completed, but project funding had been depleted. The project was delayed until additional funding was secured, which did not occur until September 2008, whereby DPWH added PhP 1.705 billion more from the Philippine treasury to advance the project. To date, total project costs have exceeded PhP 5.1 billion according to the Metro Manila Development Authority (MMDA) (MMDA, 2010). According to the DPWH, the CAMANAVA flood control structures were expected to curtail annual CAMANAVA flood damage costs by PhP 173 million, resulting in a 30-year return on investment. However, costs for project completion are predicted to inflate an additional PhP 10 billion (Bautista, 2012a).

(2) CAMANAVA Status

As of August 2012, the CAMANAVA Flood Control project remains incomplete. Joint DPWH and the Malabon government reports show the majority of project incompleteness resides in Malabon. In August 2012, DPWH reported 88 percent project-wide completion of CAMANVA project scope. Further, the local Malabon government reported in 2011 CAMANAVA project completion for those structures incomplete in Malabon City to be 79.2 percent. Table 3 presents completion data for control structures as reported by the local government (Bautista, 2012a).

Table 3. Status of Completion of Selected Flood Control Structures (Source: Bautista, 2012a)

Project Component In Malabon	Percent Accomplished
Polder Dike at Brgy. Dampalit	70.00%
L, Malabon-Tullahan Riverwalls Rehabilitation	93.00%
Catmon Creek Drainage Channel Improvement	78.00%
Longos Creek Drainage Channel Improvement	78.00%
Northern Catmon Drainage (Box Culvert)	77.00%
Overall Accomplishment (Malabon)	79.20%

DPWH continues to lead the CAMANAVA project until its full completion at which time the national agency will turn project maintenance and operations to the local authority, MMDA. MMDA is unwilling to accept control of the project until DPWH completes needed maintenance on damages to flood control infrastructure and provides for effective operation and as well as financial sustainability. Current operations and maintenance costs, including fuel for pumping stations, total PhP 44 million per year. City officials estimate that PhP 88 million per year is needed to adequately sustain operations but DPWH has not provided resources or plans to address this gap (Bautista, 2012b).

4. Field Observations

In August 2012, the CAMANAVA flood control structures were challenged when Typhoon Gener followed by four days of heavy monsoon rains inundated nearly 90 percent of Malabon (Oreta, 2012). Typhoon Gener delivered 10 to 35 mm of rain per hour during landfall, and the monsoon rains contributed greater than 500 mm of rain in less than 48 hours. Extensive flooding limited access to barangays for study and observations of flood control structures. Nevertheless, the research team conducted observations from nearby bridges and major roadways that crossed or ran parallel to Malabon waterways to assess the effectiveness of flood mitigation structures. The findings below concern the following structures and areas assessed after the August monsoon rains: river wall effectiveness in Catmon and Tonsuya barangays and flood gate effectiveness in Tañong barangay. Additionally, the Malabon City Engineering Office provided primary data and photos taken before and after Typhoon Gener (August 2 and July 31) of the Malabon portion of the CAMANAVA flood control structures evaluated.

4.1 Tonsuya Observations

Observations of river wall section in Tonsuya were conducted August 2, 2012, following Typhoon Gener, August 5, prior to the monsoon rain, and August 12, after the monsoon rain. The photos were taken from the Tonsuya Bridge on Rizal Avenue downstream (south) of the observed Tonsuya river wall section. Tonsuya's river wall was raised as part of the CAMANAVA Flood Control Project in order to protect the residents of Tonsuya from Malabon River flooding. Following Typhoon Gener, the observed river wall revealed the river wall height to be inadequate and flooding did occur (Figure 4). Figure 4 shows a section of the river wall approximately 50 meters upstream of the bridge.

Figure 4. Tonsuya river wall immediately after Typhoon Gener (Photo credit: Malabon City, 2012)

The river remained swollen after Gener rains, but the renovated river wall maintained its structural integrity as displayed in Figure 5. Figure 5 shows a section of the river wall approximately 250 meters upstream of the bridge on August 5, 2012.

Figure 5. Functional river wall upstream in Tonsuya (Photo credit: James Tyree)

However, when monsoon rains followed the typhoon, extreme flooding occurred as the Malabon River swelled past its crest and overtopped the renovated river wall. For a second time in a span of 7 days, Tonsuya barangay flooded, and residents had to evacuate. Post-monsoon observations were collected on August 12, 2012. The same section of river wall, observed seven days earlier (Figure 6) had collapsed after the monsoon rain event, exacerbating flooding in Tonsuya. As seen in the photo, Tonsuya residents used sandbags to temporarily raise the river wall until permanent repairs can be made.

Figure 6. River wall collapse, sandbags provide temporary protection (Photo credit: Claire Pascua)

In an effort to limit cost and expedite the schedule, DPWH added formed concrete to the top of the existing river wall but did not modify the river wall foundation to handle the added load from the increased river flow, thus causing the river wall to tilt, as seen on the left side of Figure 6 (Bautista 2012b). Figure 6 also shows the sheering of the river wall along the surface of the previous top of river wall. The raising of river walls with formed concrete added to the top is a design flaw in river wall renovations (Siringan, 2012 and Bautista, 2012b).

4.2 Tañong Observations

The C4 Floodgate is the primary flood control structure in Tañong barangay. A critical flood control structure for the CAMANAVA area, the gate controls the effect of Manila Bay tidal fluxes and storm surges on the Tullahan River Delta. Prior to floodgate installation, the Tullahan River Delta flooded during periods of high tide and inclement weather. Observations of the C4 Floodgate were conducted 50 meters downstream (south) from the Circumferential Bridge.

Figure 7 shows the floodgate before Typhoon Gener's rain on July 31, 2012. It was unclear whether the Malabon River overtopped the floodgate during Typhoon Gener landfall or the monsoon rains that followed one week later. However the floodgate did prohibit flow when it was observed.

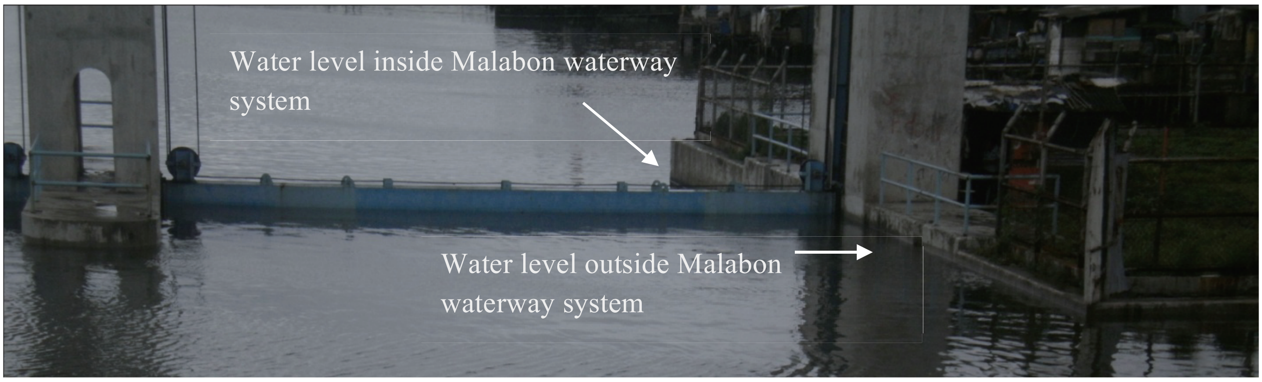

Figure 7. Floodgate regulating water level (Photo credit: Malabon City, 2012)

On August 12, 2012, the C4 Floodgate was observed raised and the water level on both sides of the floodgate was approximately 2 m below the top of the side walls of the floodgate (Figure 8). The water level outside the Malabon waterway system had subsided after the respective storm events which allowed for the raising of the floodgate for navigation purposes and hydrological exchange.

Figure 8. Raised C4 Floodgate (Photo credit: Arnel Tenorio)

4.3 Catmon Observations

As of August 1, 2012, the river wall along Catmon Creek is 80 percent complete, except for an 800 meter section. Figure 9 shows the incomplete section before Typhoon Gener. The earthen foundation and drainage culverts have been laid but the concrete river wall has yet to be constructed, so residential and informal settler areas along this reach of the creek without protection and exposed to flooding (Bautista 2012a).

Figure 9. Incomplete Section of Catmon Creek Wall (Photo credit: Malabon City, 2012)

Figure 10 shows a part of the completed section of the Catmon Creek wall approximately 400 meters downstream of the incomplete section, observed on August 2, 2012, one day after Typhoon Gener made landfall in Manila. Comparable swelling of the river occurred along the incomplete section of the river wall. However, after additional precipitation from the monsoon rains a week later, Catmon residents were forced to evacuate because of extensive flooding.

Figure 10. Section of Catmon Creek wall at Letre Canal Confluence on 2 Aug. 2012 (Photo credit: Malabon City, 2012)

5. Discussion

Local government officials interviewed perceived the causes and deficiencies of failed CAMNAVA structures to be a lack of project prioritization within DPWH as well as insufficient consultation with local stakeholders, i.e. Malabon officials and community members. Additionally, city officials added that the project design was inadequate from the start. For example, the design did not consider several important factors enhanced by climate change, including maximum high tide, storm surges, and heavier rates of precipitation causing water levels to rise greater than 2.6 meters above msl (Bautista, 2012b).

Recent events offer supporting evidence of the under designed nature of flood control structures. In June 2012, while there were no rains, high tide alone overtopped the dikes (Mangunay, 2012). The following month, the same dikes were overtopped by a combination of high tide and minimal amounts of rainfall (Salazar, 2012). In early August 2012, heavy rains from Typhoon Gener combined with high tide led to overtopped river walls and waist-deep floods in several barangays (Flores, 2012).

In 2001, DPWH contracted an engineering firm to conduct a hydrological study of the CAMANAVA area to define design requirements for the flood control structures. The hydrological study examined historical hydrometeorological data including rainfall, flood runoff and tides as well as land use (DPWH, 2001). It did not include forecasted hydrometeorological scenarios due to climate change. DPWH then used the data to develop flood discharge values specific to CAMANAVA flood control structures design. DPWH decided that the flood control structures should be designed to be effective for no greater than a 30-year return period based on data prior to 2001, which covers all potential flood discharges to the 96.67 percentile. From hyetograph modeling of the Malabon-Tullahan River drainage area, the study concluded that a 30-year return period is defined as a rainfall event with 489 mm of rainfall in a 48-hour period. A copy of this hyetograph table is in Appendix A. The study concluded that because of the size of the CAMANAVA study area and the boundaries of the Tullahan River Basin there is no difference between point rainfall and area rainfall. So, rainfall values reported across Metro Manila are representative of rainfall values in CAMANAVA.

However, the last decade has shown an increasing frequency and magnitude of rainfall events in the Philippines, thereby exacerbating flooding in flood prone areas. The study reported that the highest average monthly rainfall values in July, August and September between 1994 and 1998 were around 400 mm. However, in 2009, Typhoon Ondoy delivered over 400 mm in a 24-hour period in several parts of Metro Manila. Two years later, Typhoon Pedring, though not as intense as Ondoy, brought 121 mm in a 10-hour period over Metro Manila. In August 2012, the monsoon rains, referred to in this research note, poured over 500 mm of rain across Metro Manila in a two day period. The three rain event totals were compared with the summation of the 30-year return period precipitation rates for the rain events respective durations to determine design exceedance. All three events exceeded the 30-year return period as defined in the hydrological study's hyetograph table. This along with empirical field observations suggests CAMANAVA flood control structures are under designed thereby resulting in unnecessary flooding.

In an interview with Dr. Fernando Siringan (2012), University of the Philippines (UP) Marine Science Institute researcher, he noted a 1997 geotechnical report that land subsidence was not factored into the CAMANAVA's project design, which caused initial land elevation projections to be incorrect. Groundwater use has increased significantly due to population increase and lack municipal water supply expansion, but the average recharge rate is insufficient to replenish the groundwater supply (Rodolfo & Siringan, 2006). This claim was confirmed by the research team after a thorough review of the report. When land subsidence is not factored into design, set elevation survey points are compromised which has a cascading effect on the accuracy of the construction. Land subsidence in Malabon can be attributed to excessive groundwater extraction. According to Siringan, DPWH required firmer evidence on land subsidence before they incorporated it into their designs. DPWH is hesitant to believe that groundwater extraction is the cause of land subsidence. Rather, the attribute the sinking to Malabon's loction on reclaimed wetlands and marsh, and the subsidence is only a result of campaction from heavy loads, and that the compation will reach a terminus (Macairan and Botial, 2008).

Furthermore, Siringan pointed to outdated data used in the planning and feasibility studies. DPWH planned for storm waves of at most 1 meter, when it could actually reach three meters. The estimated 1 meter max storm surge is based on an inaccurate reading of depths in Manila Bay and assumes weak storm wind velocities (Siringan, 2012).

Unlike the river walls along the Malabon and Tullahan Rivers, the Catmon Creek river wall improvements include complete reconstruction from foundation to the top of the wall. Though this design is more structurally sound, if DPWH cannot complete the project residents along this reach of the river will continue to be exposed to flood hazards (Bautista 2012b).

Additionally, during project implementation, some of the flood control structures were built below required specifications. These include dike portions built below the planned 12.6 meters (Mangunay, 2012). City officials also noted episodes of negligence with DPWH operations citing that their staff had forgotten to close the flood gate along Malabon-Navotas River during August 2012 floods (Bautista, 2012b).

6. Recommendations

The evaluation of CAMANAVA Flood Project in Malabon revealed that data used to develop the technical designs were incorrect or outdated. Project engineers misjudged projected maximum river levels caused by 30-year flooding and failed to consider the impact of climate change on precipitation and tides in the area. Poor structural designs are further exacerbated by land subsidence.

The first recommendation is to recalculate future hydrology scenarios in north western Metro Manila using the most current data, maps, and computer simulation models. This includes incorporating land subsidence, increased hydrometeorological activity resulting from climate change and pressures from population growth and urbanization. The initial CAMANAVA project was designed for 30-year flood events from 1990s data, but flood intensity and frequencies have and will continue to increase. From the recalculated projections a new 30-year scenario should be defined along with future maximum high tides and continuous land subsidence, previously ignored in CAMANAVA project modeling.

Based on these new parameters, the second recommendation is for construction of flood control structures capable of handling greater river flows and maximum high tides as a result of long term alterations in hydrometeorology caused by climate change. Considering that Malabon will continue to face greater flooding risks as climate change progresses and population is expected to increase, constructing an appropriate flood control structures to reduce these risks will be a costly and long term endeavor. However, functioning projects will result in returns many times over in lives saved and cost averted from damages. The anticipated life of the flood control structures should also be considered in the design phase and aligned with the modeling, since structural designs have a lifespan.

While this report focused on an evaluation of the infrastructure, the team must also note that infrastructure alone insufficient for flood control and mitigation. Non-structural measures must also be a prominent component of the updated project design. These measures include proper land use planning; consideration of urbanization pressures; and policies towards informal settlements.

References

Bautista, Ed, (2012a), *Malabon City*, from a PowerPoint presentation delivered by the Malabon City Assistant Engineer on August 12, 2012.

Bautista, Ed, (2012b), Interview with Malabon City Assistant Engineer Ed Bautista on August 12, 2012.

Department of Public Works and Highways (DPWH), (2001), Consultancy Services for KAMANAVA Area Flood Control and Drainage System Improvement Project (PH-P212): Sectoral Report-C Hyrological Study, Republic of the Philippines, prepared by CTI Engineering Co., Ltd., August 2001.

"Disaster Alerts." Citizens' Disaster Response Center. Accessible at: http://www.cdrc-phil.com/

Flores, Helen, (2012), Monsoon Surge Swamps Manila, *The Philippine Star* posted 2 August 2012, Retrieved from http://www.philstar.com/Article.aspx?publicationSubCategoryId=63&articleId=833737

Jago-on, Karen Ann, (2009), *Communities Survival and Coping Mechanisms in Flood Prone KAMANAVA*, Metro Manila, Utrecht University, Netherlands, presented at the Annual International Sustainable Development Research Conference.

Japan International Cooperation Agency (JICA), (2009), *DPWH Recent and On-Going Major Flood Control Projects*, Retrieved from http://www.pfwrmankamoto.com%2Fpfwrfiles%2Fproj%2520profile%2520November%252012%25202.pdf

Macairan, Evelyn and Botial, Jerry, (2008), DPWH Exec Denies Camanava Is Sinking, posted 29 July 2008, *The Philippine Star*, Retrieved from http://beta.abs-cbnnews.com/node/14984

Malabon City Planning and Development Department, (2011), *Malabon City 2011 Annual Accomplishment Report,* Retrieved from http://www.malabon.gov.ph/more_accomp.html.

Malabon City, (2012) *Malabon City's Current Issues*, from a PowerPoint presentation from the Malabon City Engineer's Office, created August 2012.

"Malabon Travel Guide, Philippines." (2012). Retrieved 9 September 2012, from http://www.travelgrove.com/travel-guides/Philippines/Malabon-Travel-Guide-c1494659.html.

Mangunay, Kristine Felisse, (2012), P5.5B Camanava Dike 'Flawed,' Execs Claim, *Philippine Daily Inquirer*, posted 13 June 2012, Retrieved from
http://newsinfo.inquirer.net/212075/p5-5b-camanava-dike-%E2%80%98flawed%E2%80%99-execs-claim

Manila Bulletin, (2012), *Flood Project Failed – Malabon Officials*, 8 August 2012, Retrieved from
http://www.mb.com.ph/articles/368860/flood-project-failed-malabon-officials
Manila Bulletin Newspaper Online. Manila Bulletin Publishing Corporation. http://www.mb.com.ph.

MMDA (Metro Manila Development Authority), (2010), *CAMANAVA Flood Control Project*, Video retrieved from http://www.youtube.com/watch?v=gEOQOLhTHco.

Oreta III, Antolin, (2012), Interview with Malabon City Mayor Antolin Oreta on August 12, 2012.

Rodolfo, Kevin S. and Sirigan, Fernando P. (2006), "Global sea-level rise is recognized, but flooding from anthropogenic land subsidence is ignored around northern Manila Bay, Philippines." *Disasters*, *30*(1), 118-139.

Salazar, Mark, (2012), Di matapos-tapos na earth dike sa Malabon, dahilan ng pagbaha sa Camanava, (Unfinished earth dike in Malabon causes flooding in CAMANAVA) posted 31 July 2012, *GMA News*, Video retrieved from http://www.gmanetwork.com/news/video/128389/balitanghali/di-matapos-tapos-na-earth-dike-sa-malabon-dahilan-ng-pagbaha-sa-camanava

Siringan, Ferndando P. (2012) *The worsening floods of Metro Manila: Role of river constrictions and land subsidence*. Class seminar and interview on August 13, 2012.

Terante, Danilo C., et al., (2010) Risk-based Analysis of a Flood Plain: A Case in the City of Malabon, Philippines, Sydney, N.S.W, Australia, *The 5th Civil Engineering Conference in the Asian Region and Australasian Structural Engineering Conference 2010* (Engineers Australia). 859-867.

United Nations Human Settlements Programme (2006). "Enabling shelter strategies – Review of experience from two decades of implementation." p. 11. Accessible at http://ww2.unhabitat.org/programmes/housingpolicy/documents/HS-785.pdf

Zoleta-Nantes, Doracie B. (2002), Differential Impacts of Flood Hazards Among the Street Children, the Urban Poor and the Residents of Wealthy Neighborhoods in Metro Manila, Philippines, *Mitigation and Adaptation Strategies for Global Change*, 7(3), 239-266.

Appendix A: Hyetograph modeling of the Malabon-Tullahan River drainage area

Time	Rainfall Distribution Return Period						
(Hour)	2-yr (mm/hr)	5-yr (mm/hr)	10-yr (mm/hr)	20-yr (mm/hr)	30-yr (mm/hr)	50-yr (mm/hr)	100-yr (mm/hr)
1	0.93	1.75	2.18	2.95	3.22	3.56	4.01
2	0.97	1.81	2.26	3.05	3.34	3.68	4.16
3	1.01	1.89	2.35	3.17	3.46	3.82	4.31
4	1.06	1.96	2.45	3.30	3.59	3.97	4.48
5	1.11	2.05	2.57	3.42	3.73	4.13	4.67
6	1.17	2.15	2.69	3.57	3.89	4.31	4.87
7	1.24	2.27	2.82	3.74	4.08	4.51	5.09
8	1.32	2.38	2.97	3.91	4.27	4.72	5.34
9	1.39	2.52	3.15	4.10	4.50	4.96	5.61
10	1.48	2.67	3.34	4.34	4.74	5.23	5.92
11	1.60	2.84	3.55	4.59	5.01	5.54	6.26
12	1.72	3.04	3.81	4.88	5.33	5.90	6.67
13	1.86	3.28	4.11	5.22	5.70	6.31	7.13
14	2.04	3.55	4.45	5.61	6.14	6.79	7.68
15	2.26	3.88	4.88	6.09	6.66	7.37	8.32
16	2.53	4.29	5.39	6.65	7.27	8.06	9.10
17	2.86	4.81	6.03	7.36	8.04	8.91	10.08
18	3.31	5.46	6.87	8.26	9.03	9.99	11.30
19	3.91	6.35	7.98	9.43	10.32	11.43	12.93
20	4.79	7.58	9.54	11.06	12.11	13.41	15.17
21	6.14	9.46	11.90	13.49	14.76	16.34	18.48
22	6.66	10.09	12.54	14.27	15.56	17.17	19.35
23	10.61	15.27	18.83	20.72	22.56	24.85	27.94
24	23.55	31.35	37.75	40.30	43.58	47.65	53.11
25	53.40	68.49	78.05	88.44	93.79	100.54	109.56
26	14.78	20.54	25.14	27.17	29.52	32.45	36.38
27	8.21	12.15	15.05	16.86	18.37	20.26	22.82
28	7.14	10.81	13.59	15.21	16.63	18.41	20.81
29	5.38	8.41	10.59	12.15	13.29	14.72	16.65
30	4.30	6.91	8.69	10.18	11.14	12.33	13.94
31	3.59	5.87	7.37	8.80	9.63	10.65	12.05
32	3.06	5.11	6.43	7.78	8.50	9.41	10.65
33	2.68	4.53	5.69	6.98	7.64	8.46	9.56
34	2.39	4.08	5.12	6.36	6.95	7.69	8.70
35	2.15	3.72	4.66	5.84	6.39	7.06	7.99
36	1.95	3.40	4.28	5.42	5.91	6.54	7.40
37	1.79	3.15	3.96	5.05	5.51	6.10	6.89
38	1.66	2.94	3.68	4.73	5.17	5.72	6.46
39	1.53	2.75	3.44	4.46	4.88	5.38	6.09
40	1.44	2.59	3.24	4.21	4.61	5.10	5.76
41	1.35	2.44	3.06	4.01	4.37	4.84	5.47
42	1.28	2.32	2.90	3.82	4.16	4.61	5.21
43	1.20	2.20	2.76	3.65	3.98	4.41	4.98
44	1.14	2.11	2.65	3.51	3.82	4.19	4.75
45	1.09	2.02	2.50	3.36	3.66	4.05	4.57
46	1.03	1.93	2.40	3.22	3.52	3.89	4.40
47	1.00	1.85	2.31	3.11	3.39	3.76	4.24
48	0.94	1.78	2.23	3.00	3.28	3.62	4.09
TOTAL	210.0	314.8	384.2	450.8	489.0	536.8	601.4

Source: Department of Public Works and Highways, 2001