Impacts of Climate Change upon Asian Coastal Areas:

The case of Metro Manila

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Summary

Climate models supporting the IPCC Fourth Assessment Report predict that climate change will increase local temperatures and precipitation in monsoon regions in Asia, where the number of large cities is increasing and existing urban areas are expanding, particularly along the coasts. In this study, Metro Manila, typical of Asian coastal megacities, is used as a case study to comprehensively simulate impacts of future climate change and identify necessary adaptation measures.

In spite of the various uncertainties inherent in predictions, this study translates future global climate scenarios to regional climate scenarios, a process called “downscaling”. The B1 and A1FI scenarios of the IPCC SRES framework provide a basis for discussing local temperature and precipitation changes in Metro Manila. Based on these scenarios, hydrological conditions such as river overflow and storm surge were projected. Flood simulation maps were then constructed showing the range of potential spatial spreads, inundation depths and flooding durations anticipated in the metropolis.

Based on the flood simulation maps, socio-economic impact analyses were applied to understand the characteristics and magnitude of flood damage anticipated in the year 2050. The benefit side of the analysis calculated avoided damage at the aggregate level. Tangible direct losses were assessed as in conventional flood control project analyses. Incremental costs to transportation (VOC and time costs), and lost wages and income (sales) due to flooding were combined for tangible indirect costs. Note that the simulated flood maps and impacts are some cases among a wide range of future possibilities resulting from a “cascade of uncertainties” inherent in the various steps of the methodology.

If flood control infrastructure improvements were stopped now, and the A1FI climate scenario is assumed, a 100-year return period flood could cause aggregate damages of up to 24% of the GRDP, while damages from a 30-year return period flood would be about 15% of the GRDP. If, however, infrastructure improvement based on the 1990 Master Plan is continued and climate scenario B1 is assumed, the projected damages would be only 9% of the GRDP for a 100-year return period flood, and 3% for a 30-year return period flood.

Finally, options for adapting to the scenarios were selected, with the objective of eliminating as much as possible of the flooding projected in the flood simulations. Economic evaluations using economic internal rate of return (EIRR) and net present value (NPV) were conducted by combining the costs of the adaptation options with the damages avoided by implementing those options. The

EIRR and NPV evaluations yielded different results, but they both suggest that filling the infrastructure gap identified under the current Master Plan (for status quo climate) is the first and foremost priority.

Chapter 1 Introduction and Brief Description of Metro Manila

1.1 Introduction

Assessment reports on climate change impacts prepared by the Intergovernmental Panel on Climate Change (IPCC) show that global warming will likely progress further in the 21st century. Greenhouse gases (GHGs) discharged in the course of industrialization and modernization of socio-economic activities over the world have the changed the carbon concentration in the atmosphere. This gradual change has caused the global temperature to increase, and consequently sea levels have risen, so that ecological systems and human societies may suffer from complex large-scale effects. The international community recognizes that climate change is the most critical issue in the centuries to come and that tackling this issue through reduction of GHG emissions and adoption of appropriate adaptation measures on a global basis is imperative.

Climate models supporting the IPCC Fourth Assessment Report of 2007 predict that climate change will increase local temperatures and precipitation in monsoon regions in Asia, where the number of large cities is increasing and existing urban areas are expanding as their economies grow, especially in coastal areas. Expected to be the most prone to frequent flooding brought on by global warming, these areas will experience the most complex effects, both directly and indirectly.

In the policy arena, Asian megacities' increased vulnerability to climate change has been perceived as a new challenge to be addressed. In general, vulnerability is defined as the degree to which a system or unit is likely to experience harm due to perturbations or stresses and responses of, and impacts on, social groups, ecosystems, and places.[1] Significantly, a society's vulnerability is in part dependent on the society's technical, institutional, economic, and cultural ability to prevent or cope with these impacts.

In this regard, adaptation relates to the degree to which a particular group can cope with adverse effects of climate change, including climate variability and extremes.[2] Developing countries have identified various adaptation policies, most of which focus on direct and tangible impacts. However, climate change impacts are not limited to tangible damages: the drastic changes they bring also have enormous influence on people's daily lives in affected communities and economic activities in affected areas. In the case of floods, examples of such effects are the halt of industrial and commercial activities, infrastructure malfunctions, increased risk of infectious diseases, environmental pollution, and the necessity of relocating people. Thus, physical changes brought

[1] The vulnerability of natural systems should be differentiated from that of socio-economic ones. This report refers to the latter (Nicholls, 1998 cited in Porio 2008, p.4).

[2] Carter and Kankaanpaa 2003, IPCC 2001, Porio 2008, p. 4.

about by climate change will indeed have great local impact socially, economically, environmentally, and psychologically.

In this context, Metro Manila, typical of Asian megacities, was chosen as a case study to comprehensively simulate the impacts of future climate change and identify necessary actions. It is the center of political, economic and socio-cultural activities of the nation. Its strategic location by Manila Bay has supported the capital city's growth and expansion into large suburbs over the last several decades. Metro Manila, whose per capita gross regional domestic product (GRDP) is by far the highest in the country, maintains its position as the premier economic center of the nation as home to the headquarters of domestic and international business establishments. The regional economic growth of Metro Manila is expected to continue to lead the national economy until at least the year 2050, our target timeframe. At the same time, since Metro Manila is in a low-lying area facing the sea, a large lake (Laguna de Bay) and embracing two river systems, it is prone to flooding disasters.

An introduction and description of Metro Manila comprise Chapter 1 of this report. Chapters 2 through 4 discuss methodologies used in the study. Chapter 2 describes the climate models used to set up the year 2050 study framework and explains how climate models are linked to hydraulic models that estimate floods anticipated in 2050 under different climate scenarios. Chapter 3 elaborates on the methodology used to analyze tangible socio-economic impacts and quantify costs avoided by preventing flooding at the aggregate level. Chapter 4 attempts to simulate intangible damages focusing on health. Chapter 5 continues with micro-level analyses to identify intangible vulnerabilities of selected segments of the economy and society. Chapter 6 presents the results of the economic evaluation under different adaptation options. Chapter 7 provides a summary and conclusions. Figure 1-1 shows the flow of the study's analyses. Note that the simulated flood maps and impacts are some cases among a wide range of future possibilities resulting from a "cascade of uncertainties" inherent in the various steps of the methodology.

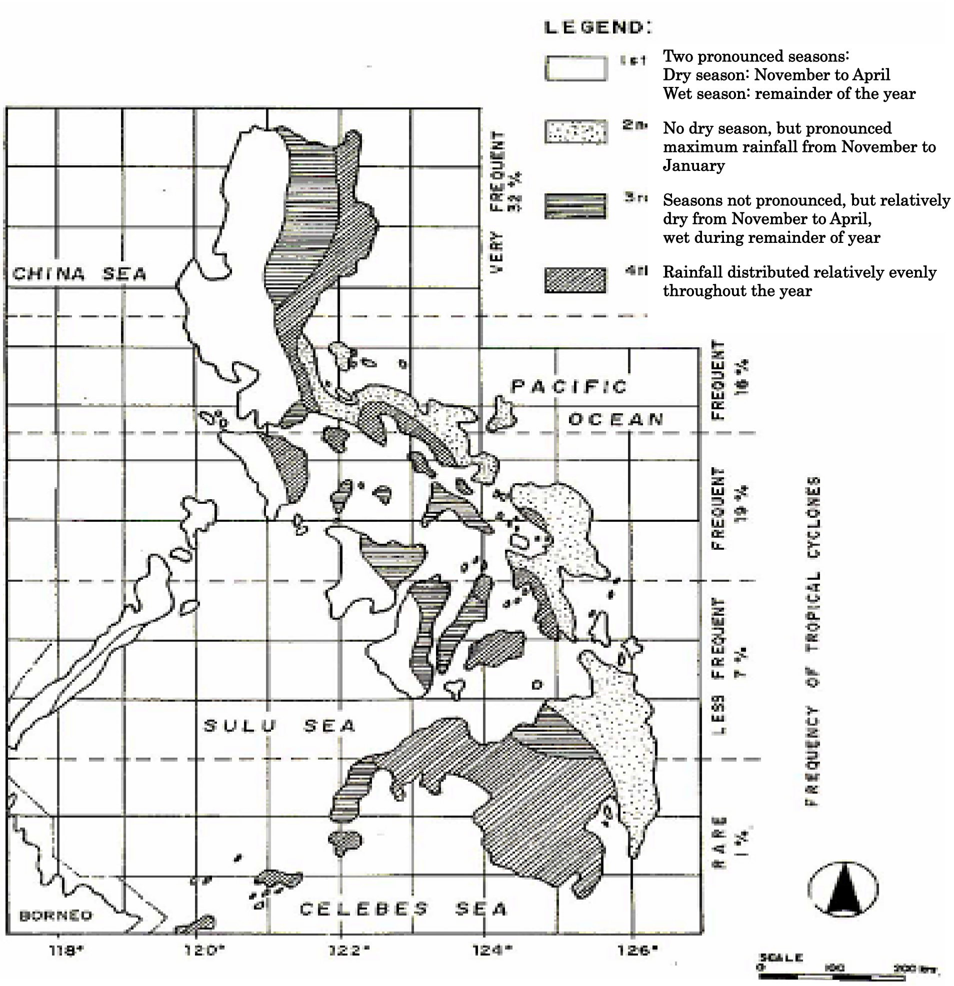
1. Downscale IPCC Climate Models for temperature expected in 2050 under B1 and A1FI scenarios
2. Assess local effects on precipitation and combine with sea level rise / storm intensification
3. Simulate different types of hydraulic effects: 1) through river systems,2) through accumulation of water in Laguna de Bay, and 3) through sea level rise and storm surge at the coast (combination depends on city)
4. Based on the flood maps produced for 18 cases (3 climate scenarios x 2 infrastructure scenarios x 3 return periods), estimate socioeconomic impact (both direct and indirect) with available data to estimate benefits derived from adaptation options.
5. Consider investment mix and cost of adaptation options.
6. Calculate Economic Net Present Value and Estimated Internal Rate of Return

Figure 1-1 Study Analysis Flow

1.2 Study Locations

Metro Manila was chosen as the site of this study because of the diverse hydrological characteristics existing in the same urban area. The Pasig-Mariquina area has several river systems; the KAMANAVA (Kalookan, Malabon, Navotas, Valenzuela) area along the low lying coast is prone to typhoons. West of Mangahan facing Laguna de Bay Lake is prone to interior flooding.

Metro Manila resides in the first of four Philippine climatological regions. The first region has two pronounced seasons: the dry season from November to April, and the wet season that spans the rest of the year, when typhoons and tropical cyclones usually hit the islands.



Note: Frequency of tropical cyclones is the probability of a cyclone passing through the indicated area (land).

Figure 1-2 Climatologic Regions in the Philippines

Metro Manila lies on a semi-alluvial plain formed by sediment flows from the Meycawayan and Malabon-Tullahan river basins in the north, the Pasig-Marikina river basin in the east. The city is open to Manila Bay on the West and to a large lake, Laguna de Bay, on the southeast. Thus, "the metropolitan area is a vast drainage basin that experiences frequent inundations from overflowing rivers and storm waters that render the existing system of *esteros* (modified natural channels) and canals constructed during the Spanish and American colonial periods inadequate."[3]

There are several types of flooding: storage flooding, overbanking, and interior flooding. In Metro Manila, the following three areas experience these different flood types: The KAMANAVA area is

3 Liongson, 2000 (cited in Porio 2008).

vulnerable to storage-type flooding, the Pasig-Marikina river basin (hereinafter "Pasig-Marikina") is prone to overbanking, and the West Mangahan area (hereinafter "West Mangahan") experiences interior flooding (Figure 1-3).

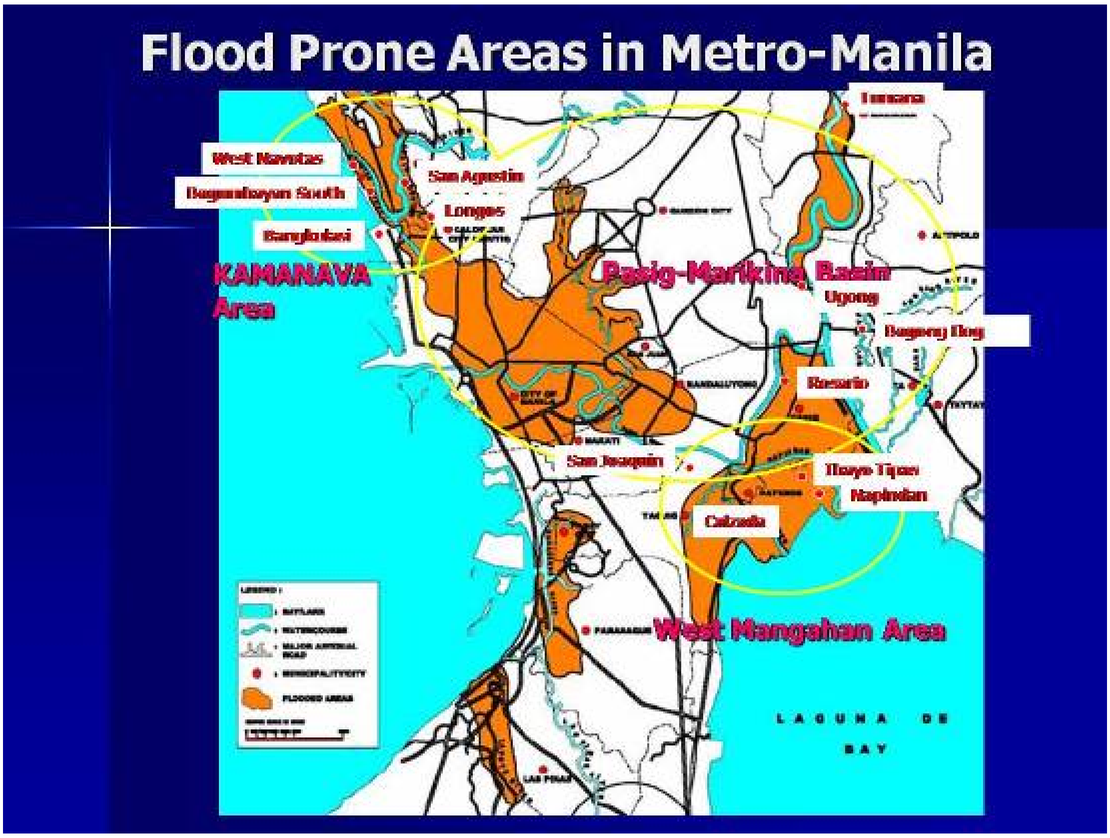


Figure 1-3 Map of Study Areas in Metro Manila

1.2.1 KAMANAVA Area[4]

The KAMANAVA area is low and flat with elevations ranging from around sea level to two to three meters above. Its current population is in excess of one million in an area of approximately 18.5 km^2. Before the 1960's, the KAMANAVA area was made up of widely spread lagoons used as fishponds, but it was partially filled to its current configuration, which consists mainly of commercial districts and residential areas along with fishponds.

Floods covering large areas occur throughout the year, but are particularly frequent during the rainy season from May to October when high tides coincide with heavy rains. These floods are caused by a combination of overflow of the Malabon-Tullahan River and inadequate local drainage systems

[4] "KAMANAVA Area Flood Control and Drainage System Improvement Project," 2001 (cited by CTI, p. 11).

aggravated by high tides in Manila Bay.

The "KAMANAVA Area Flood Control and Drainage System Improvement Project" is a multi-faceted project designed to relieve flooding based on a 10-year return period flood. The project works include construction of a polder dike, heightening of river walls on the Malabon and Marala Rivers, construction of a submersible radial navigation gate facility, construction of flood gates, construction of control gates, construction of pumping stations, and improvement and new construction of drainage channels.

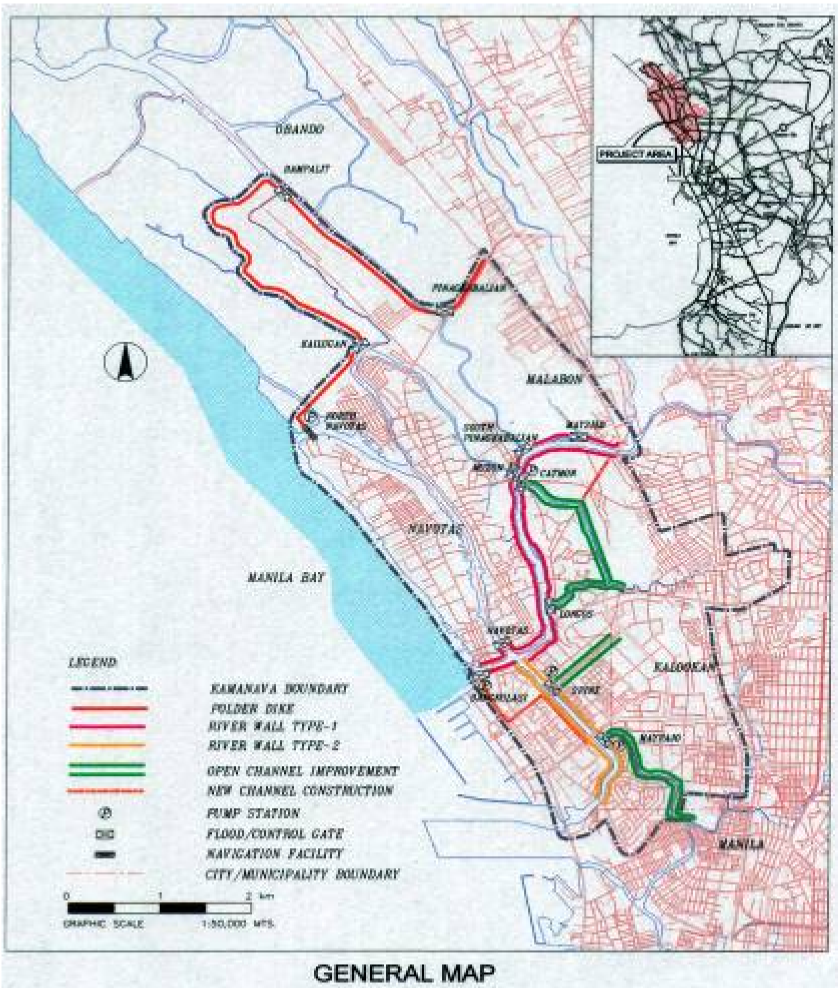


Fig. 1-4 KAMANAVA Area Flood Control and Drainage System Improvement Project

1.2.2 Pasig-Marikina River Area[5]

The Pasig-Marikina River System has a catchment area of 651 km^2 including the catchment area of the San Juan River. It is composed of the 10 cities and municipalities of Mandaluyong, Manila, Marikina, Quezon, San Juan, Antipolo, Cainta, Rodriguez, San Mateo, and Pasay. The downstream part of the river system belongs to Metro Manila, but the upper part is under the jurisdiction of Rizal Province. The section of the river system between the river mouth (Manila Bay) and the Napindan Channel confluence point is called the Pasig River, while upstream from there is called the Marikina River. The Marikina River is also connected with Laguna de Bay Lake at the Rosario Weir through the Mangahan Floodway.

Excess flood runoff overflows from the Pasig and Marikina riverbanks. Similarly, storm water flowing in drainage and creek networks creates inundation. Excess runoff water from the Marikina River is diverted to the Lake through the Mangahan Floodway during floods to protect Metro Manila's city core. The flood runoff stored in the Laguna de Bay is slowly released to the Pasig River through the Napindan Hydraulic Control Structure (NHCS) in Napindan channel when the water level recedes in the Pasig River and ultimately drains into Manila Bay.

Another broad flood control project, known as the "Pasig-Marikina River Channel Improvement Project" was formulated based on a 30-year return period scale. Aiming at increasing the flow capacity of the Pasig-Marikina River, the channel will be improved for a stretch of about 31 km from the river mouth to Santo Niño. The construction of the Marikina Control Gate Structure (MCGS), an urgent 30-year return period flood control project, is indispensable for securing smooth flood diversion to Laguna de Bay. Improvement of the upper Marina River is also required in line with the construction of the MCGS. Tasks making up the project include heightening of existing parapet walls and rehabilitation of revetments, dredging and excavation, providing new parapet wall embankments and construction of the MCGS, river widening, etc.

1.2.3 West Mangahan Area[6]

The total area west of the Mangahan Floodway is 39 km^2, covering the five cities of Makati, Pasig, Pateros, Taguig, and Taytay. In the area there are a number of drainage channels discharging into Laguna de Bay Lake or the Napindan River, such as the Tapayan, Abasing, Taguig-Pateros and Hagonoy drainage channels.

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5 "Detailed Engineering Design of Pasig-Marikina River Channel Improvement Project," 2002 (cited by CTI, p. 11).
6 "Detailed Design of the North Laguna Lakeshore Urgent Flood Control and Drainage Project," 1992 (cited by CTI, p. 12).

The West Mangahan drainage area topography is flat, and is a typical interior-flood-prone area along Laguna de Bay Lake. Storm rainfall and high water levels in the lake cause flooding in the area. There are several drainage channels and rivers. Storm water runoff is stranded due to the high lake water level. Since urbanization of the paddy fields has progressed in these places, the inundation affects not just paddy fields but also towns, communities, and subdivisions thriving in the area.

This area usually starts being inundated when the water stage of Laguna de Bay rises to approximately 11.5 m, and most of the area is submerged at a water stage of approximately 13.5 m, though the lake is not affected by storm surges. The Mangahan Floodway was constructed in 1985 to divert floodwaters from the Marikina River into Laguna de Bay at a design discharge of 2,400 m^3/s with the flood flow regulated at the proposed MCGS. The northwestern portion of the lake is flanked by Metro Manila while the provinces of Rizal and Quezon bound its northeastern and southeastern borders. Laguna, Batangas, and Cavite provinces border the lake on the south and southwest. The construction of the flood control project in the area west of the Mangahan Floodway was completed in 2007. The project work included a lakeshore dike, bridges at two sites, in Mangahan and Napindan, a parapet wall with a top elevation of 14.1 m, floodgates at eight sites, four pumping stations, and regulation ponds at four sites.

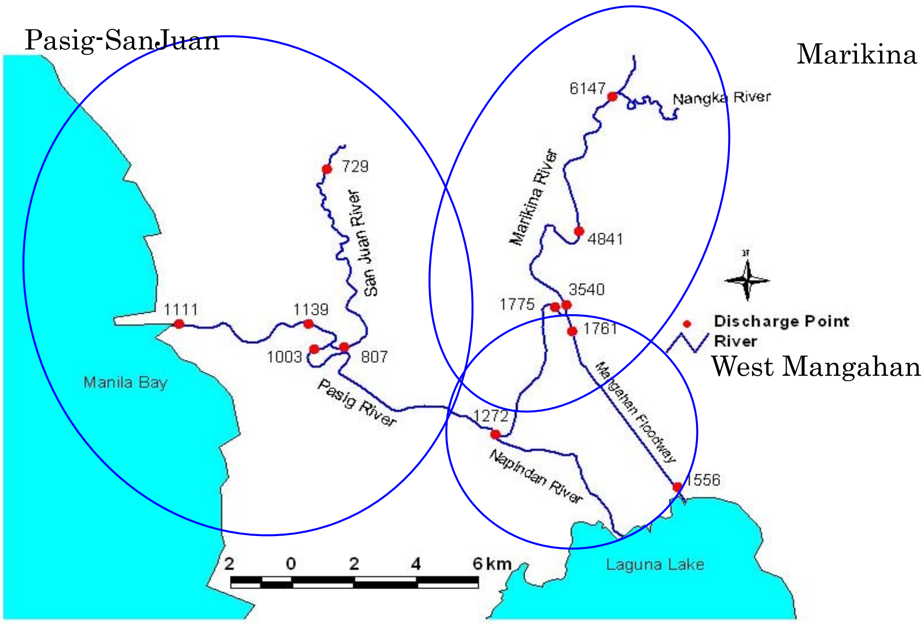

Figure 1-5 Pasig-Marikina Area and West Mangahan Area

Chapter 2 Methodology Part One: Modeling Climate Change scenarios and the Hydrology of Coastal Cities

2.1 Climate Change Scenarios

2.1.1 Climate Change Scenarios.[1]

Any climate impact assessment starts with specifying a global climate scenario that provides the boundary conditions for subsequent analysis. This study is based on global climate projections provided by the Fourth Assessment Report (AR4) of the IPCC, adopting the B1 and A1FI scenarios from the IPCC's Special Reports on Emissions Scenarios (SRES), and comparing them with the Status Quo (SQ) scenario. B1 is the scenario projected by the IPCC to represent the least anticipated change, which makes it the most sustainable case. A1FI, on the other hand represents a large change scenario due to high economic growth. The target year is set as 2050, the halfway mark of the IPCC SRES timeframe. The spatial spreads of flooding for the year 2050 under the SQ, B1, and A1FI scenarios are taken as the basis for impact analyses.

2.1.2 Uncertainties.

It should be borne in mind that the present IPCC climate models cannot be directly applied to impact studies on local climate change because of various uncertainties: emission scenarios due to economic growth rates and energy efficiency improvements, carbon cycle response to changes in climate, global climate sensitivity, discrepancies in regional climate change scenarios, and changes in ecosystems, etc. Simulations of local climate change are fundamentally more uncertain than global mean values. Local climate is heavily influenced by atmospheric and oceanic circulation, such as prevailing weather situations and wind directions. For example, global mean precipitation changes do not necessarily determine the changes in local precipitation, so it is impossible to conclusively determine future precipitation rate extremes.

Although climate projections are based on global climate models or general circulation models (GCMs), their results contain various biases. If the raw GCM outputs were used for impact studies, the biases would surely contaminate the assessment outcome. Precipitation remains a stringent test for climate models. Many biases in precipitation statistics remain in both precipitation means and variability, especially in the tropics.[2] Comparison between observations and simulations of 20th

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[1] This Chapter is based on Masahiro Sugiyama, University of Tokyo, "Methodological notes on regional climate scenarios for Study on Climate Change Impact and Adaptation in Asian Coastal Cities," (2008)
[2] Randall et al, "Climate Models and Their Evaluation," Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Forth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.

century conditions reveals that most models do not accurately simulate precipitation extremes.[3]

2.1.3 Downscaling

Despite these various uncertainties, global climate scenarios can be translated to regional climate scenarios, a process called "downscaling."[4], which is employed for this study. While there has been an increasing recognition of the explicit treatment of uncertainty in environmental assessments recently, this report deals with uncertainties qualitatively, rather than quantitatively.[5] Downscaling requires local-level, bias-corrected climate information. The analyses below discuss development of regional climatic changes in the period up to 2050.[6] IPCC SRES scenarios B1 and A1FI provide a basis for discussing changes in local temperature and precipitation in Metro Manila, based on which hydrological conditions such as sea-level rise, storm surge, and land subsidence are projected.

2.1.4 Temperature

IPCC provides projections for global mean temperature changes for various IPCC SRES scenarios up to the year 2100. Projected global temperature rise can be set using projected values as illustrated in fig 2-1.

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[3] A simple example is to calculate the difference in a model between its 20th and 21st century estimates and add that difference to the observed 20th century climate. This renders the estimated variable (at least partially) independent of the model used to simulate the 20th century. Otherwise, the resulting 21st-century modeled precipitation level could be in error. This could lead to a biased impact assessment if used directly without correction. In the case of a 20th century model simulation where precipitation is underestimated at 7 mm/day, the model could project an increase of precipitation to 9mm/day in the future. Since the 21st century figure carries along the underestimation of the 20th century estimate, using it directly would produce precipitation increases that are too small. The simple procedure of adding the difference between the two model simulations to the observed 20th century value can ameliorate this trouble.

.[4] Since downscaling is a common technique, there are a number of useful references for experts and non-experts alike. From a technical viewpoint, Chapter 11 of IPCC AR4 is a good start. Its last section is dedicated to regional climate projection methodologies. The Technical Summary of Working Group I is also helpful. IPCC's Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA) produces guidelines on the use of regional scenarios. "Guidelines for Use of Climate Scenarios Developed from Regional Climate Model Experiments" (Mearns et al. 2003) and "Guidelines for Use of Climate Scenarios Developed from Statistical Downscaling Methods" (Wilby et al., 2004) are of particular relevance. For more broad information, various downscaling techniques for non-experts are compiled by UNFCCC in its "Compendium on Methods and Tools to Evaluate Impacts of, and Vulnerability and Adaptation to, Climate Change" (2008).

[5] There are a number of ways to formally generate probability information at the local scale, including multi-model ensemble and perturbed physics runs. For examples, Chapter of IPCC AR4 provides a concise review of various papers.

[6] Projected climate change up to the year 2050 is highly likely to occur, and has already started to be observed.

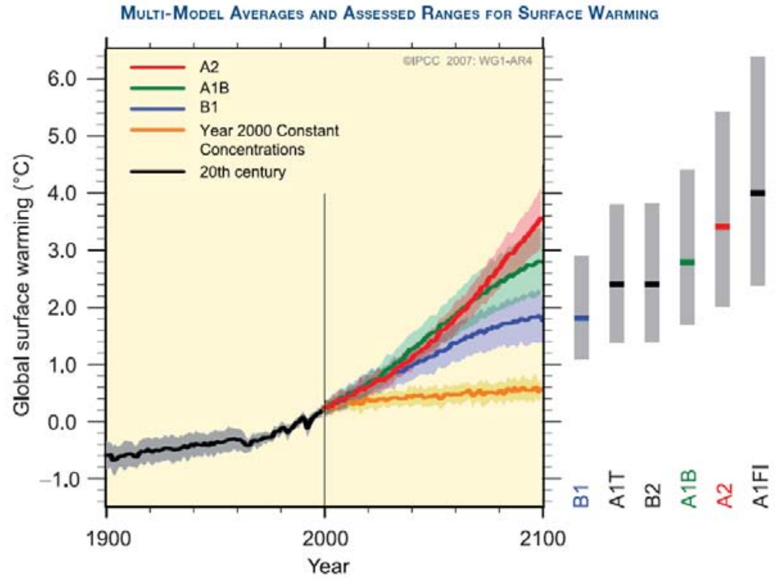


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

Figure 2-1 Global Temperature Rise Projections (IPCC, 2007)

Plotting local temperature changes in the Philippines versus average global temperature changes[7]

[7] Sugiyama, 2008.

The dataset used is the model output archive housed at the Program for Climate Model Diagnosis and Intercomparison (PCMDI; http://www-pcmdi.llnl.gov). In support of IPCC AR4, the Working Group on Coupled Modeling (WGCM) of the World Climate Research Program (WCRP) requested that climate modeling groups submit various outputs of simulations of coupled climate models to PCMDI (Meehl et al. 2007).

For observations, we use the Global Precipitation Climatology Project (GPCP) One-Degree Daily (1DD) dataset based on multiple satellites (Huffman et al. 2001). As its name suggests, the spatial resolution is 1 degree longitude by 1 degree latitude, and the temporal resolution is one day.

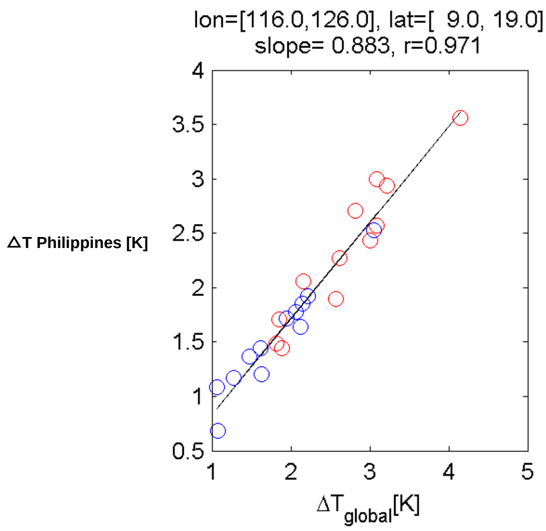
Tables A and B lists the models used. These are a subset of the models used for IPCC AR4. The models in Table A are used to calculate precipitation extremes. As the main analysis here requires daily datasets, those models that do not provide such data are excluded from the present calculation.

Table B shows the models used to calculate seasonal mean precipitation.

Table A. Models used for this study.

Acronym	Modeling center
bccr_bcm2_0	Bjerkness Center for Climate Research,
cccma_cgcm3_1_t63	Canadian Centre for Climate Modelling and Analysis, Canda
cnrm_cm3	Centre National de Recherches Meteologiques, Meteo-France
csiro_mk3_0	CSIRO Atmospheric Research, Australia
gfdl_cm2_0	Geophysical Fluid Dynamics Laboratory, USA
giss_aom	NASA/Goddard Institute for Space Studies, USA
ipsl_cm4	Institut Pierre Simon Laplace, France
miroc3_2_hires	CCSR/NIES/FRCGC, Japan
miroc3_2_medres	CCSR/NIES/FRCGC, Japan
mpi_echam5	Max Planck Institute, Germany
mri_cgcm2_3_2a	Meteorological Research Institute, Japan
ncar_pcm1	National Center for Atmospheric Research, USA

predicted by The B1 and A1FI scenarios and fitting a regression line to them as presented in Fig. 2-2 shows a high correlation between the global mean temperature rise and the local temperature rise in the Philippines. In fact, the local temperature increase in the Philippines is about 90 % of the global average temperature increase.



Circles represent different models, with red ones denoting the SRES A1B scenario and blue ones corresponding to SRES B1.

Figure 2-2 Relationship between Local and Global Temperature Changes

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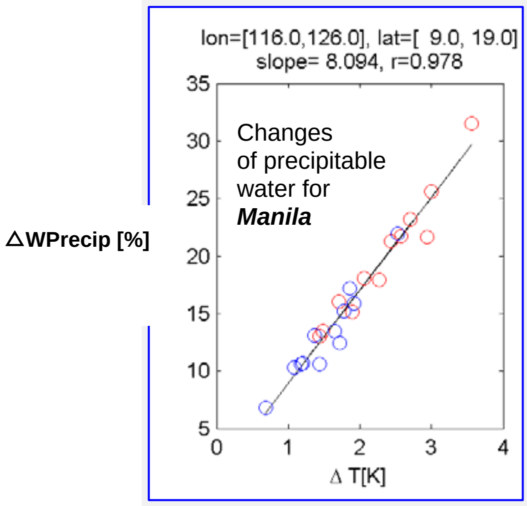
Table B. Models used for calculations of mean precipitation change.

Modeling Center	Model
Bjerknes Centre for Climate Research, Norway	BCM2.0
Canadian Centre for Climate Modelling and Analysis, Canada	CGCM3.1
Canadian Centre for Climate Modelling and Analysis, Canada	CGCM3.1(hires)
Centre National de Recherches Meteorologiques, France	CNRM-CM3
CSIRO Atmospheric Research, Australia	CSIRO Mk3.0
Geophysical Fluid Dynamics Laboratory, USA	GFDL_CM2.0
Geophysical Fluid Dynamics Laboratory, USA	GFDL_CM2.1
NASA/Goddard Institute for Space Studies, USA	GISS AOM
NASA/Goddard Institute for Space Studies, USA	GISS ModelE
Institute of Atmospheric Physics, China	FGOALS1.0_g
National Institute of Geophysics and Volcanology, Italy	INGV-SXG
Iistitute for Numerical Mathematics, Russia	INMCM3.0
Institut Pierre Simon Laplace, France	IPSL-CM4_v1
CCSR/NIES/FRCGC, Japan	MIROC3.2(hires)
CCSR/NIES/FRCGC, Japan	MIROC3.2(medres)
University of Bonn, Germany	ECHO-G
Max Planck Institute for Meteorology, Germany	ECHAM5/MPI-OM
Meteorological Research Institute, Japan	MRI-CGCM2.3.2a
National Center for Atmospheric Research, USA	CCSM3.0
National Center for Atmospheric Research, USA	PCM
Hadley Center, Met Office, UK	HadCM3
Hadley Center, Met Office, UK	HadGEM1

2.1.5 Precipitation

Local precipitable water, the source of the intense rainfall that is a main cause of storm events, increases in the Philippines in the modeled scenarios. The increase could be as much as 8 % of the local temperature rise in degrees Kelvin. This ratio was determined by plotting changes in local precipitable water increases versus local temperature increases in the Philippines. The results of a regression analysis relating them are presented in Fig. 2-3.[8]



Circles represent different models, with red ones denoting the SRES A1B scenario and blue ones corresponding to SRES B1.

Figure 2-3 Relationship between Changes in Precipitable Water and Temperature Increase in the Philippines

Increases in (peak) precipitable water are then translated into increased (peak) water discharge rates for river flood simulation. This means that in the simulations, water discharge at given recurrence periods increases. In this report, 10-year, 30-year, and 100-year recurrence periods are set as target flood levels. To explain the shift caused by climate change, one way is to decrease the number of years in the recurrence periods and the other way is to increase the peak precipitation, but for this report we increase the level of peak precipitation.

2.1.6 Sea level rise

Fifty percent of the sea level rise for the year 2100 as projected in IPCC AR4 is assumed for the year 2050. Sea level, as a boundary condition for flood simulation can be estimated by adding tidal factors. High tidal level is a critical determiner of flooding. In consideration of future global climate change, sea level rise must be added to the high tide level. Therefore, the Mean Spring High High Water (MSHHW) level in Manila Bay is set as the baseline level for flood simulation, and sea level

[8] Ibid.

rises predicted from the global warming scenarios are placed above that level.

For a global average temperature rise of 2 degrees, the global sea level is estimated to have risen an average of 29 cm in 2050.[9] In Metro Manila, local sea levels would rise and flooding in some parts may intensify as global warming progresses, while droughts may become more severe in other locations.

2.1.7 Storm surge

The historic typhoon that caused the largest rise above general sea level was used as the model typhoon. Typhoons with the lowest pressures or strongest winds do not always cause the highest storm surge. After choosing the model typhoon, its at-sea winds and barometric pressure field were calculated, which were then used to estimate the storm surge. In addition, an intensified storm surge case (the model typhoon with 10% lower central pressure) was calculated.[10] Table 2-1 shows the maximum calculated surge based on a typhoon that hit the islands in November 1957.

Table 2-1 Maximum Simulated Tidal Deviation Caused by Storm Surge in Manila Bay

Simulated storm	Maximum water level increase
Reproduction of Historical Typhoon	0.91 m
10 % Increase over Historical Typhoon	1.00 m

2.1.8 Land subsidence

Projecting land subsidence in space and time is very difficult, since its occurrence and intensity depend on local geological settings, not on climate change. Future land subsidence in the Metro Manila area is not considered in the simulations due to data constraint.

2.1.9 Climate- Hydrological matrix

The matrix below is a summary of climatic-hydrological conditions for the SQ, B1, and A1FI scenarios. Return periods of 10, 30, and 100 years are considered. These conditions provide a basis for flood impact analysis for this entire study, including analyses for other cities.

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[9] CTI, "Study on Climate Impact Adaptation and Mitigation in Asian Coastal Mega Cities," March 2008.
[10] Ibaraki University, "Prediction of storm surges for Manila, Bangkok and Mekong Delta." 31 July, 2008.

Table 2-2 Global Climate Scenario Settings and Conditions for Inundation Simulations for Metro Manila[11]

Simulation Case		Temperature Rise (°C) (downscaled)	Sea Level Rise (cm) (global)	Increase Rate of Rainfall (%)	Storm Surge Height (m) in Manila Bay
1	Status quo climate	0	0	0	0.91
2	B1 scenario with storm level at status quo	1.17	19	9.4	0.91
3	B1 scenario with strengthened storm level	1.17	19	9.4	1.00
4	A1FI scenario with storm level at status quo	1.80	29	14.4	0.91
5	A1FI scenario with strengthened storm level	1.80	29	14.4	1.00

2.1.10 Flood Control Infrastructure Scenarios

In choosing an infrastructure scenario, this report focuses on flood control. During the past several decades, the Philippine government has been implementing a series of strategic flood control infrastructure projects protecting Metro Manila, covering the Pasig-Marikina River Basin, the KAMANAVA (Kalookan- Malabon- Navotas- Valenzuela) Area, and the area west of Mangahan. Recently implemented flood control projects are included in those identified in the JICA 1990 Master Plan. In addition, the government has several other flood control projects planned that will complete the implementation of the priority projects identified in the 1990 Master Plan. These projects are summarized in Table 2-3 and their locations around the Metro Manila area are shown in Fig. 2-4.

[11] JICA, Ibid.

Table 2-3 Flood Control Studies and Projects in Metro Manila

Flood Control Studies and Projects	Funding Source
Northern Section	
KAMANAVA Area Flood Control and Drainage System Improvement Project	JICA (PH-P212, Special Yen Loan)
Feasibility Study on Valenzuela-Obando-Meycauayan Area Drainage System Improvement and Related Works Project	JICA (F/S: Completed in March 2001)
Central Section	
Metro Manila Flood Control Project – West of Mangahan Floodway	JICA (PH-P179, 21st Yen Loan)
Pasig-Marikina River Channel Improvement Project	JICA (D/D: 23rd Yen Loan, Construction I: 26th Yen STEP Loan)
San Juan River Flood Control Project	JICA (F/S: Completed in 2002)
Study on Drainage Improvement in the Core Area of Metropolitan Manila	JICA (Completed in March 2005)
Feasibility Study on Marikina-Cainta Area (East of Mangahan) Flood Control Project	JICA (Pre-F/S: Completed in March 2007)
Southern Section	
Feasibility Study on the Integrated Drainage Improvement Project in Ninoy Aquino International Airport and its Vicinity	JETRO (Completed in March 2004)

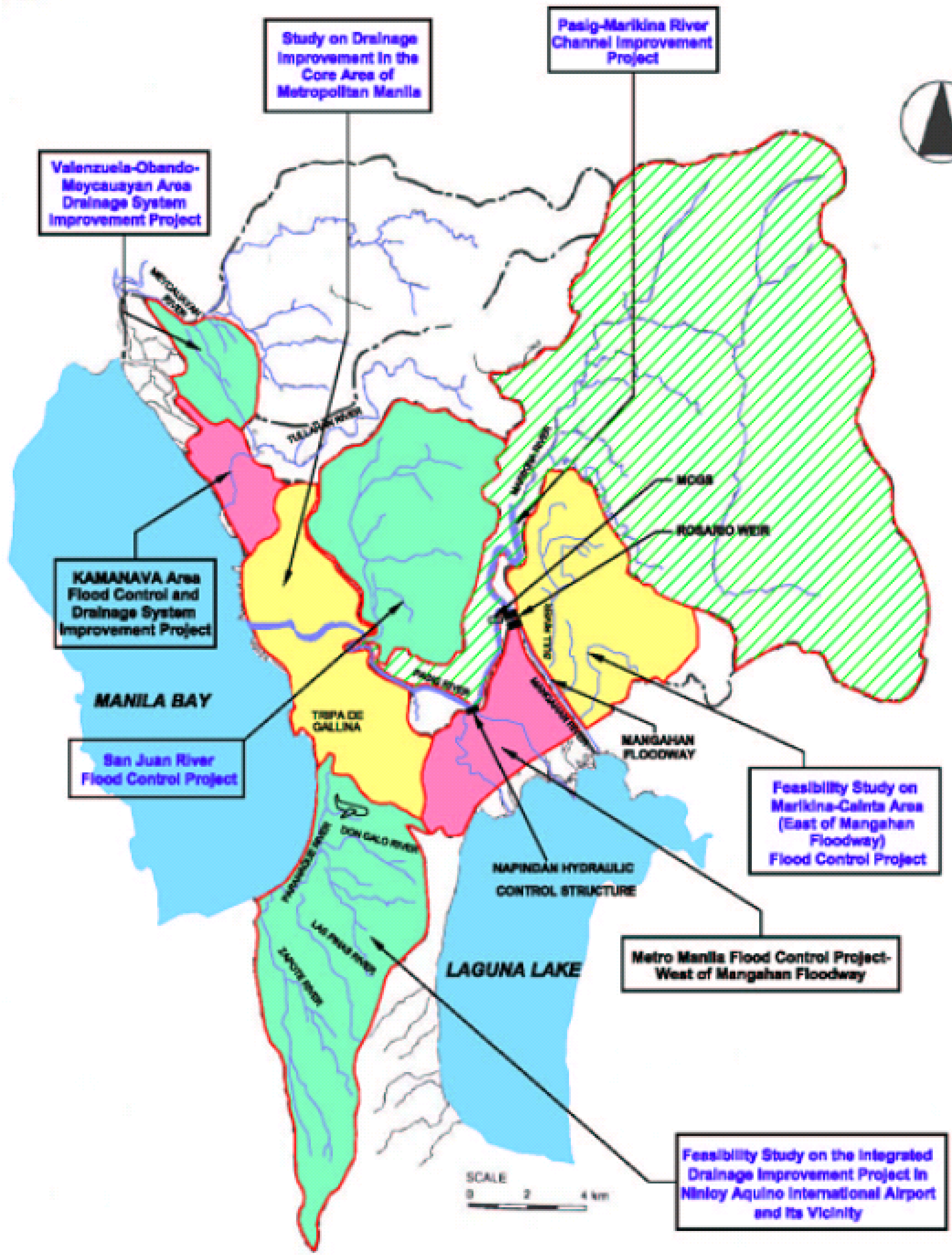

Fig. 2-4 Flood Control Studies/Projects in Metro Manila

In order to identify necessary adaptation measures, two flood control infrastructure scenarios were considered. The first is the existing infrastructure level, including projects completed by base year 2008. The second is the 1990 Master Plan scenario, which assumes continued implementation of projects identified in the 1990 Master Plan until the year 2050. Consequently, the two flood control infrastructure scenarios are added to the Climate-Hydrological Matrix below (Table 2-4).

Table 2-4. Climate-Hydrologic-Infrastructure scenarios: Summary

Cases	Return period	Climate	Hydrological (storm surge)	Infrastructure EX: existing MP:1990 M/P	Adaptation
100-SQ-cu-EX	100 years	SQ	current	EX	-
100-SQ-cu-MP			current	MP	-
100-B1-st-EX-wD		B1	strengthened	EX	with Dam
100-B1-st-MP-wD			strengthened	MP	with Dam
100-A1FI-st-EX-wD		A1FI	strengthened	EX	with Dam
100-A1FI-st-MP-wD			strengthened	MP	with Dam
30-SQ-cu-EX	30 years	SQ	current	EX	-
30-SQ-cu-MP			current	M/P	-
30-B1-st-EX-wD		B1	strengthened	EX	with Dam
30-B1-st-EX-nD			strengthened	EX	no Dam
30-B1-st-MP-wD			strengthened	MP	with Dam
30-B1-st-MP-nD			strengthened	MP	no Dam
30-A1FI-st-EX-wD		A1FI	strengthened	EX	with Dam
30-A1FI-st-EX-nD			strengthened	EX	no Dam
30-A1FI-st-MP-wD			strengthened	MP	with Dam
30-A1FI-st-MP-nD			strengthened	MP	no Dam
10-SQ-cu-EX	10 years	SQ	current	EX	-
10-SQ-cu-MP			current	M/P	-
10-B1-st-EX-nD		B1	strengthened	EX	no Dam
10-B1-st-MP-nD			strengthened	MP	no Dam
10-A1FI-st-EX-nD		A1FI	strengthened	EX	no Dam
10-A1FI-st-MP-nD			strengthened	MP	no Dam

The case code consists of 5 sets of alphanumeric symbols. The first set (100, 30, 10) indicates the assumed return period; the second set (SQ, B1, A1FI) shows the climate scenario; the third (cu, st) tells whether storm surge was set at the current (cu) or strengthened level (st). In the fourth set, EX or MP denotes the infrastructure scenario. Lastly, wD/nD means with or without the Maikina Dam.

2.1.11 Hydrologic Modeling

For each climate-hydrologic-infrastructure scenario described above, a flood simulation was conducted using a suitable hydrologic model for each river basin or drainage area, considering the topography and flooding type. The interface between the climate scenarios and the hydrologic modeling is increased peak precipitation that affects the hydrodynamics of the river. Depending on the target area, sea level rise, storm surge in Manila Bay or the Laguna de Bay lake water level were added as variables to produce the flood map. Flood inundation model setup and information related to each target area are described in the following sub-sections.

2.2 Flood Analysis Areas

2.2.1 Pasig-Marikina River Basin

The Pasig-Marikina River basin was divided into two parts from a flooding viewpoint, the Marikina River basin and the Pasig-San Juan River basin, as illustrated in Fig. 2-5.

2.2.2 Marikina River Basin

The upper reaches of the Pasig River are called the Marikina River. Considering the extent of previous and computed probable flooding, the stretch upstream from the diversion point to the Napindan channel is regarded as the Marikina River in this study. The floodwater flows down, being confined to the valley-bottom plain in this stretch. Therefore, a one-dimensional unsteady flow model can simulate the flooding mechanism there. The MIKE 11 model was used to do these computations. The following basic data are used for the hydraulic simulation:

- River channel survey results from the Pasig-Marikina River Improvement Project were used for river cross-section data.
- Manning’s roughness coefficients of 0.03 and 0.10 were used for the river channel and floodplain, respectively.

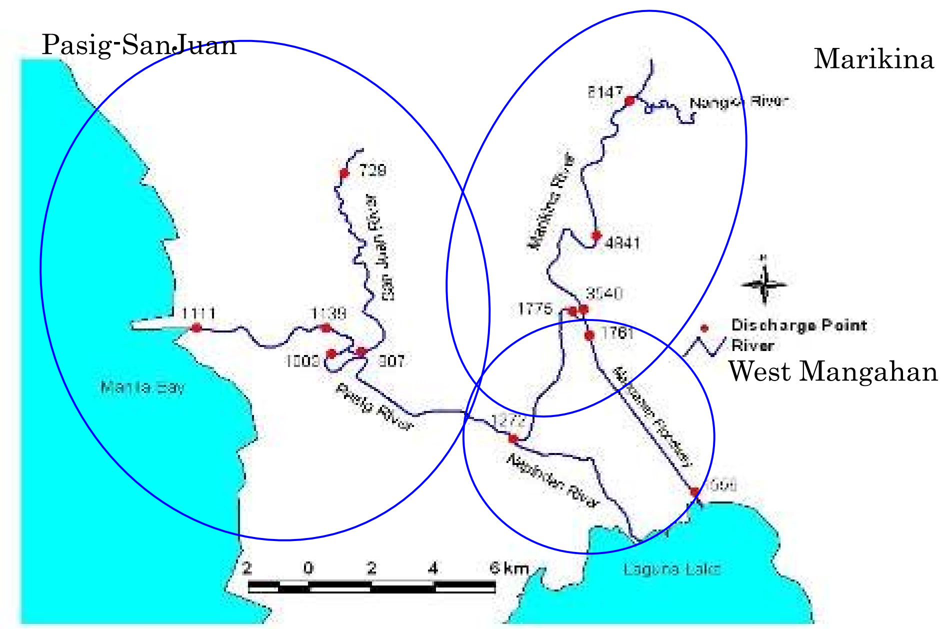

Figure 2-5 Pasig-Marikina River System

The flood runoff simulation model of the Pasig-Marikina River system is illustrated in Fig. 2-6. Flood runoff is computed using the NAM Model, which is one of the simulation components of the MIKE 11 model. Its computation mechanism is similar to the Tank Model. Flood inundation simulation is done directly by the MIKE 11 model using flood runoff computed by the NAM Model for the Marikina River basin. In the Pasig River basin simulation, flood runoffs of the Pasig, and San Juan rivers and the outflow of the Marikina River are given to the Pasig model as upstream boundary conditions.

The model parameters of the NAM Model were calibrated by adjusting the model to match the November 2004 flood at St. Nino station. The model calibration results are shown in Fig. 2-7.

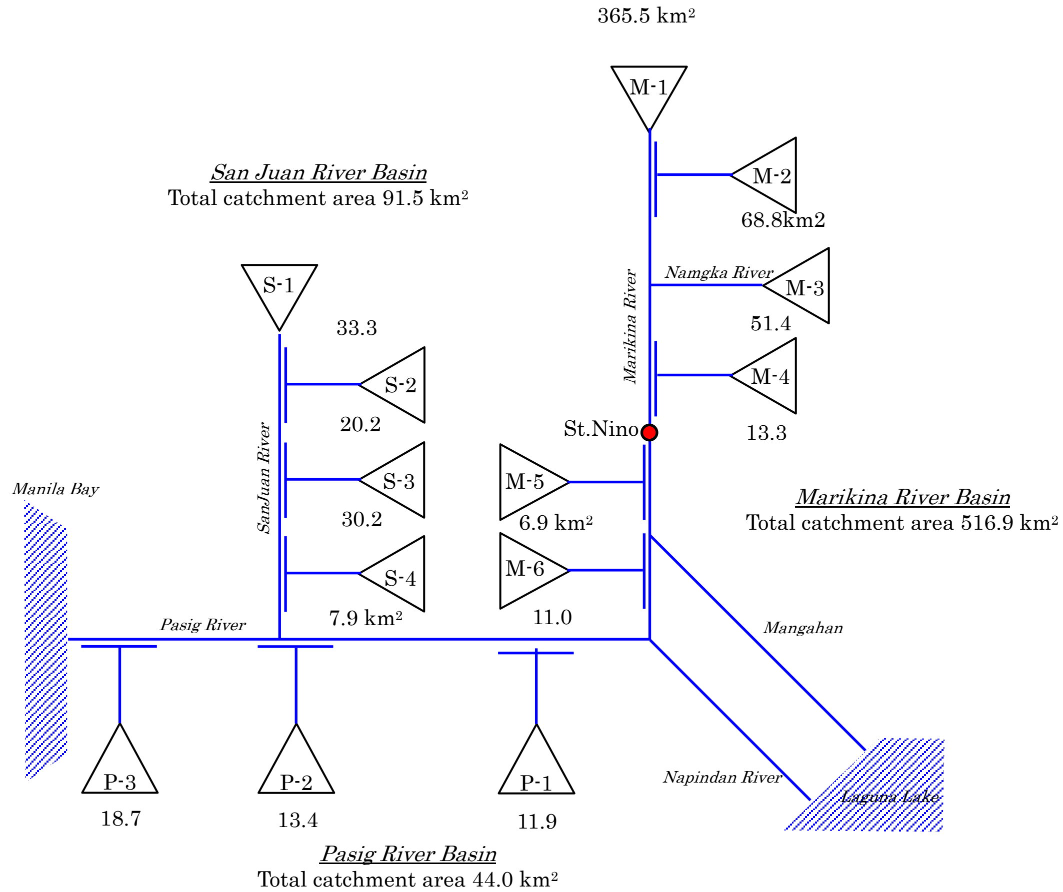

Figure 2-6 Flood Runoff Simulation Model (NAM model)

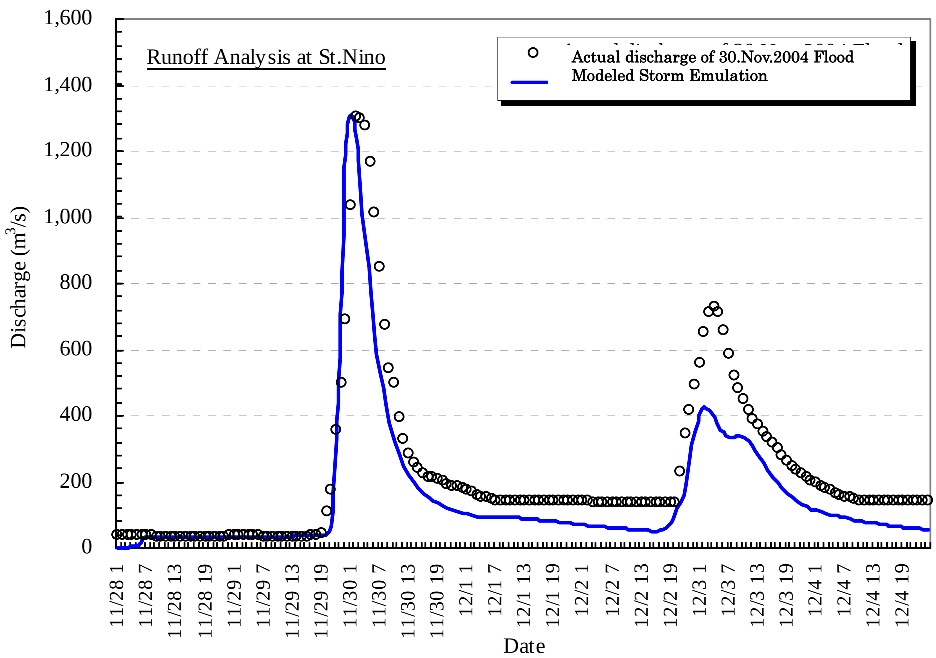

Figure 2-7 Model Calibration Results for November 2004 Flood at St. Nino on the Pasig-Marikina River System

2.2.3 Pasig and San Juan River Basin

Overbanking floodwater spreads out toward the northern low-lying area in a stretch of the Pasig River. A two-dimensional unsteady flow model is appropriate for this stretch. The following basic data are used for the hydraulic simulation:

- A Digital Elevation Model (DEM) was adopted, based on a 100 m grid, using data produced by the Pasig-Marikina River Improvement Project. The DEM elevations along the river course were adjusted based on cross-sectional survey results from that project.
- The floodplain's roughness coefficient was determined using land uses and principal values from Japan as reference points; dry fields have a coefficient of 0.060; roads, 0.047; and other uses, 0.030. A coefficient of 0.030 was used for the Pasig and San Juan River channels.
- Large-scale pumping stations are incorporated into the model as flood control facilities.

In the Pasig River system storm surge and flood peaks can be treated experimentally as independent phenomena. Thus the lower boundary condition of Pasig River flooding is the tidal fluctuation at MSHHW without storm surge as tabulated in Table 2-5. Since the tidal peak with storm surge exceeds the height of the design dike crown and storm surge can be regarded as an independent phenomenon from flood peak, the tidal hydrograph shown in Fig. 2-8 was used to simulate flood inundation as the lower boundary condition. The tidal hydrograph was adjusted so that its peak coincides with the flood runoff peak as presented in Fig. 2-8. In addition, the storm surge hydrographs for the simulation cases enumerated in Table 2-5 are shown in Fig. 2-9.

Table 2-5 Relevant Meteo-hydrological Data in Simulation Cases

Simulation Case		Temperature Rise (°C)	Sea Level Rise (cm)	Increase in Rainfall Rate (%)	Sea Level Conditions without Storm Surge [A] (EL.m)	Sea Level Conditions with Storm Surge (EL.m)
1	Status quo	0	0	0	11.40 (=11.4+0)	12.31 (=A1+0.91)
2	B1 with storm level at status quo	1.17	19	9.4	11.59 (=11.4+0.19)	12.50 (=A2+0.91)
3	B1 with strengthened storm level	1.17	19	9.4	11.59 (=11.4+0.19)	12.59 (=A3+1.00)
4	A1FI with storm level at status quo	1.80	29	14.4	11.69 (=11.4+0.29)	12.60 (=A4+0.91)
5	A1FI with strengthened storm level	1.80	29	14.4	11.69 (=11.4+0.29)	12.69 (=A5+1.00)

Note 1) Projected temperature rise in the Philippine is about 90 % of global temperature rise.
2) Increase in rainfall rate is estimated at around 8 % per degree Kelvin of temperature rise.
3) In the no-storm surge sea level condition column, the first term indicates the Mean Spring High High Water level in Manila Bay; and the second term indicates sea level rise by global warming. In the sea level condition with storm surge column, the second term indicates tidal deviation due to storm surge. The figures in the table are the local values for the mouth of the Pasig River.

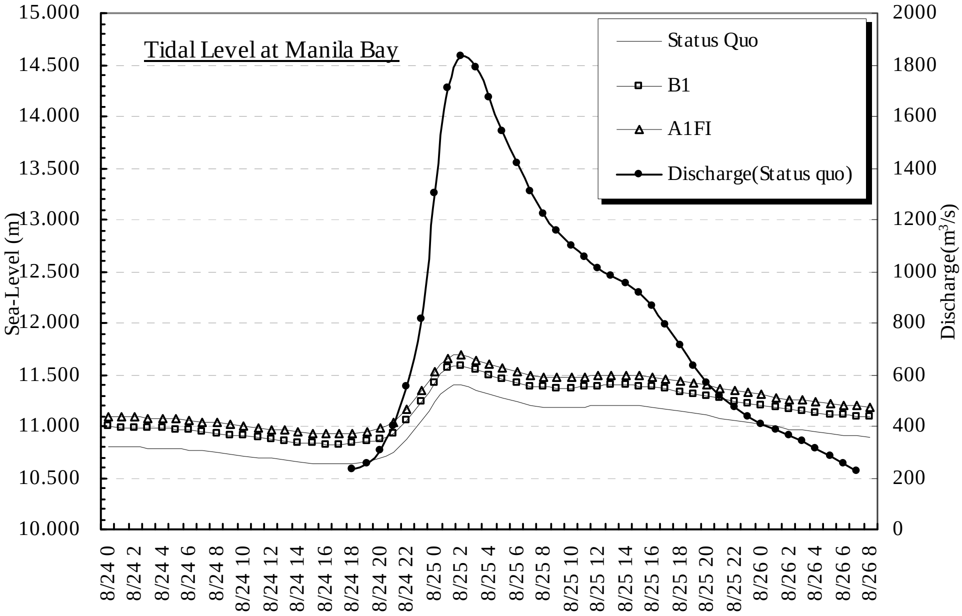

Figure 2-8 Tidal Hydrograph for Simulation of Flood Inundation in the Pasig River

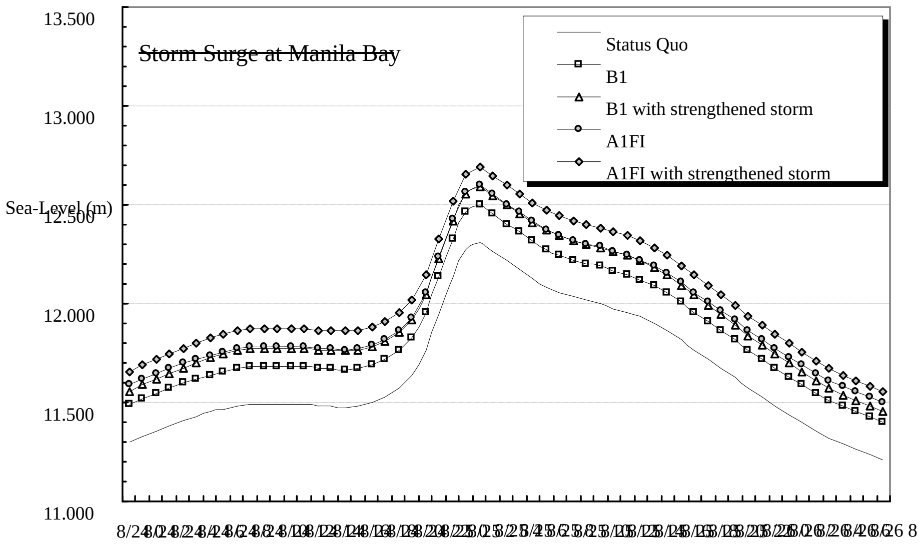

Figure 2-9 Tidal Hydrograph of Storm Surge at the Pasig River mouth

As described earlier for the Marikina River Basin, the boundary conditions for the Pasig River, including flood runoff inflows are summarized in Fig. 2-10.

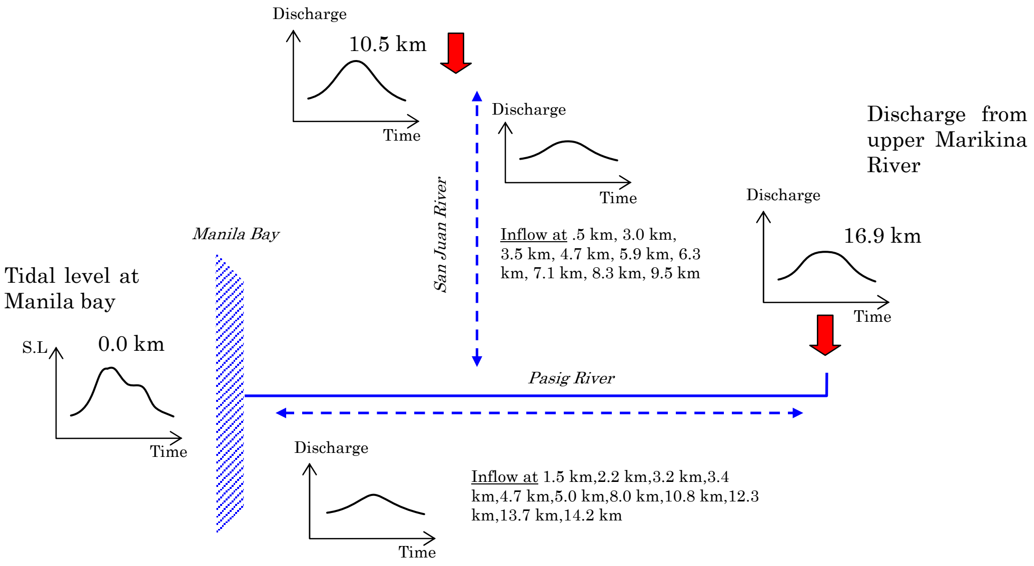

Figure 2-10 Boundary Conditions for Simulation of Flood Inundation of the Pasig River

2.2.4 West of Mangahan Area

The West of Mangahan drainage area has flat topography and is a typical interior-flood-prone area along the Laguna de Bay Lake. In that area, there are several drainage channels and rivers. Storm rainfall and high water levels in the lake bring on floods, and storm water runoff is stranded due to the high water. To improve the drainage conditions, projects employing a combination of a lakeshore dike to prevent inflow from the lake, and pumping stations to discharge the storm water runoff have been proposed. In due consideration of these conditions, a pond model was employed for flood inundation simulation in this area.

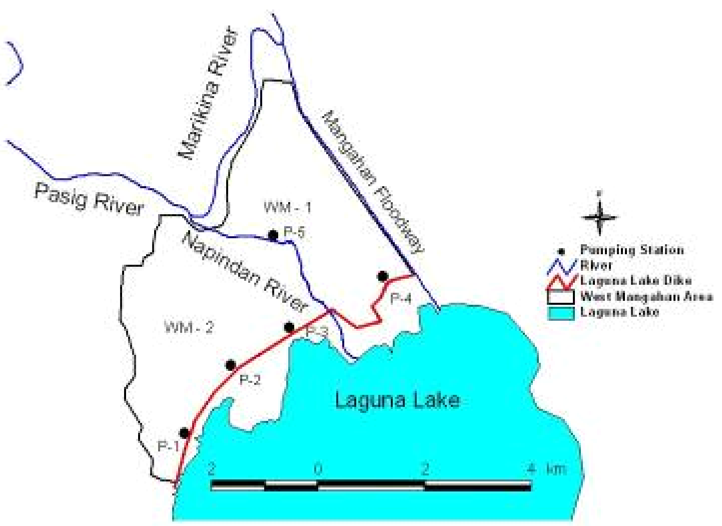

Figure 2-11 West of Mangahan Drainage Area

The drainage area is divided into two basins, WM-1 and WM-2, as illustrated in Figure 2-11. Flood runoff is computed using the rational formula in the same manner as for drainage improvement plans. The estimates are summarized below, and flood hydrographs are shown in Figure 2-12.

Table 2-6 Rational Formula Parameters and Results of Flood Runoff Simulation

	WM-1	WM-2
Area	13.49 km^2 From DEM elevation data	25.52 km^2 From DEM elevation data
Runoff Coefficient*	0.5	0.5
Flow Velocity*	0.90 m/s	0.90 m/s
Concentration Time	110 min Longest channel length = 5800 m 5800 m/0.9 m/s /60 s/min=107.4 min	160 min Longest channel length = 8700 m 8700m/0.9 m/s/ 60 s/min = 161.1 min
Boundary Condition (Rainfall)	Existing: probability 1/10 B1: probability 1/10 × 9.4％ increase A1FI: probability 1/10 × 11.4％ increase	
Peak Discharge)	Status quo: 111.9 m^3/s B1: 122.0 m^3/s A1FI: 128.1 m^3/s	Status quo: 176.2 m^3/s B1: 192.1 m^3/s A1FI: 201.6 m^3/s

*Detailed Engineering Design of the North Laguna Lakeshore Urgent Flood Control and Drainage Project

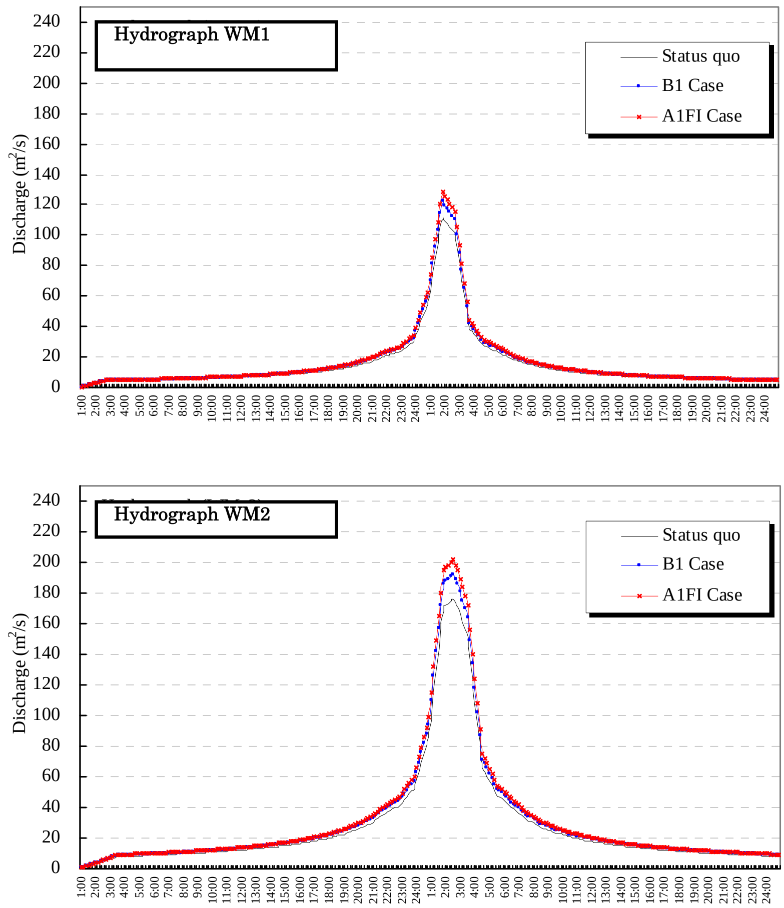

Fig. 2-12 Flood Hydrographs for the West of Mangahan Area

For the pond model, the water level-area-storage volume (H-A-V) relationship was developed using a digital elevation model (DEM) as shown in Fig. 2-13.

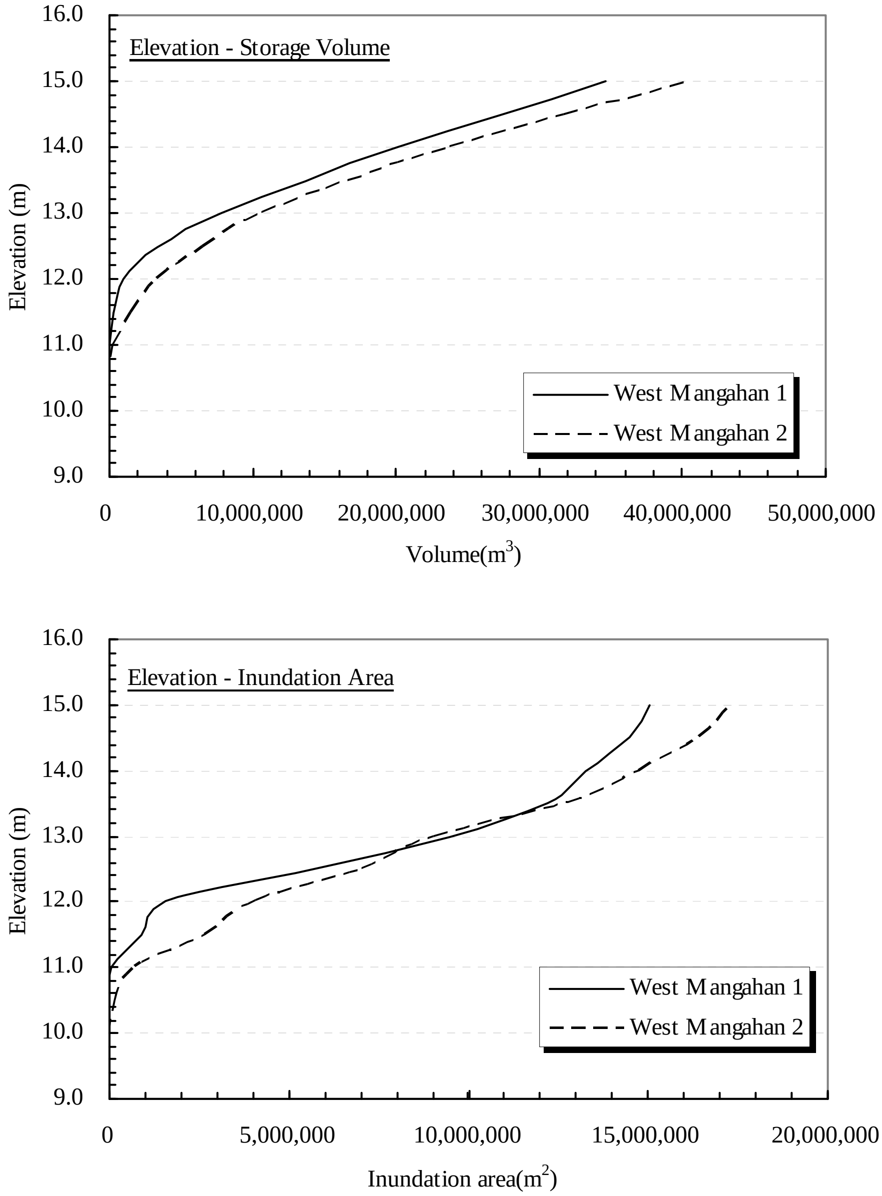

Figure 2-13 Water Level-Area-Storage Volume (H-A-V) Relationship in the area West of Mangahan

2.2.5 KAMANAVA Area

The KAMANAVA area experiences storage-type floods. The model shown in Fig. 2-14 was constructed to simulate storage type inundation. In the KAMANAVA area, there are several esteros (primary open drainage channels), drainage mains (closed or piped channels) and outfalls to rivers. Floods are brought on by storm rainfall and high tides in Manila Bay. Storm water runoff is stranded due to the high tide. Improvement of the drainage condition by employing a combination of a ring levee (polder dike) to prevent inflow from Manila Bay and pumping stations to discharge the storm water runoff is proposed. The MOUSE-DHI program was used in the planning stages of the KAMANAVA Project, and the same model was used in this study assuming the conditions outlined above.

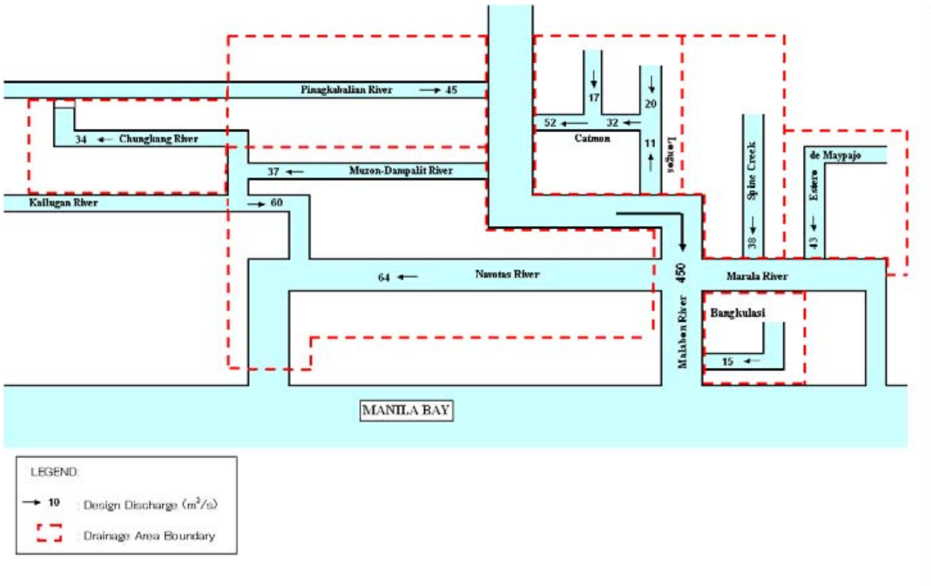

Figure 2-14 Schematic Diagram of KAMANAVA Area Flood Analysis

The KAMANAVA drainage Area is divided into seven hydraulically independent sub-drainage areas as shown below:

Table 2-7 KAMANAVA Area Sub-Drainage Basins

Name of Drainage Area		Area (ha.)
1	Bangkulasi	75.4
2	Catmon	355.5
3	Spine	173.1
4	Maypajo	241.2
5	North Navotas	475.5
6	Dampalit	233.1
7	South Pinagkabalian	254.6
Total		1,808.4

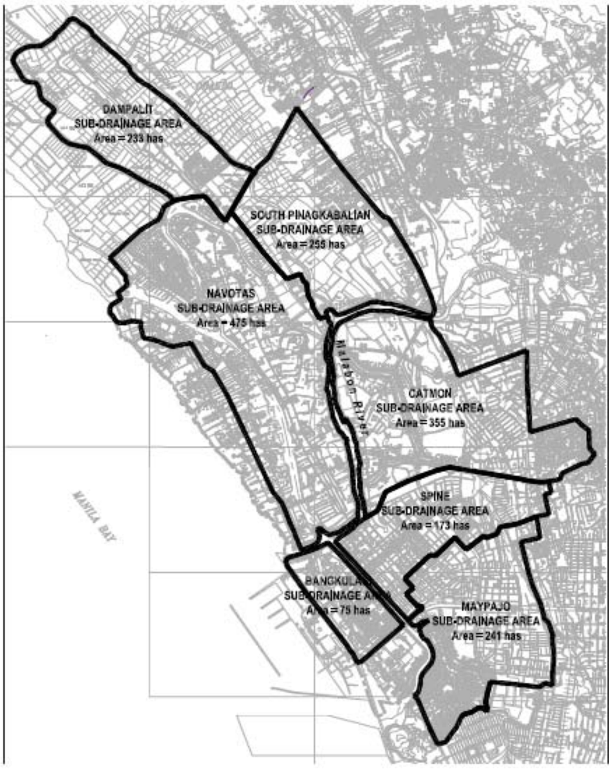

Figure 2-15 KAMANAVA Area Sub-Drainage Basins

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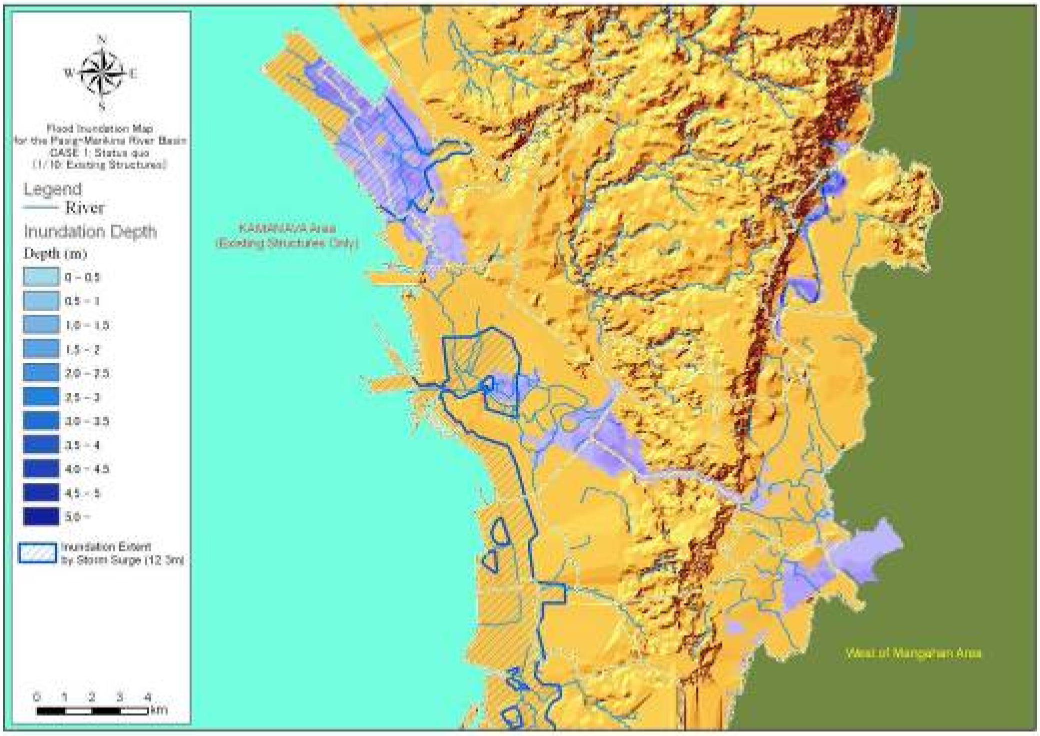
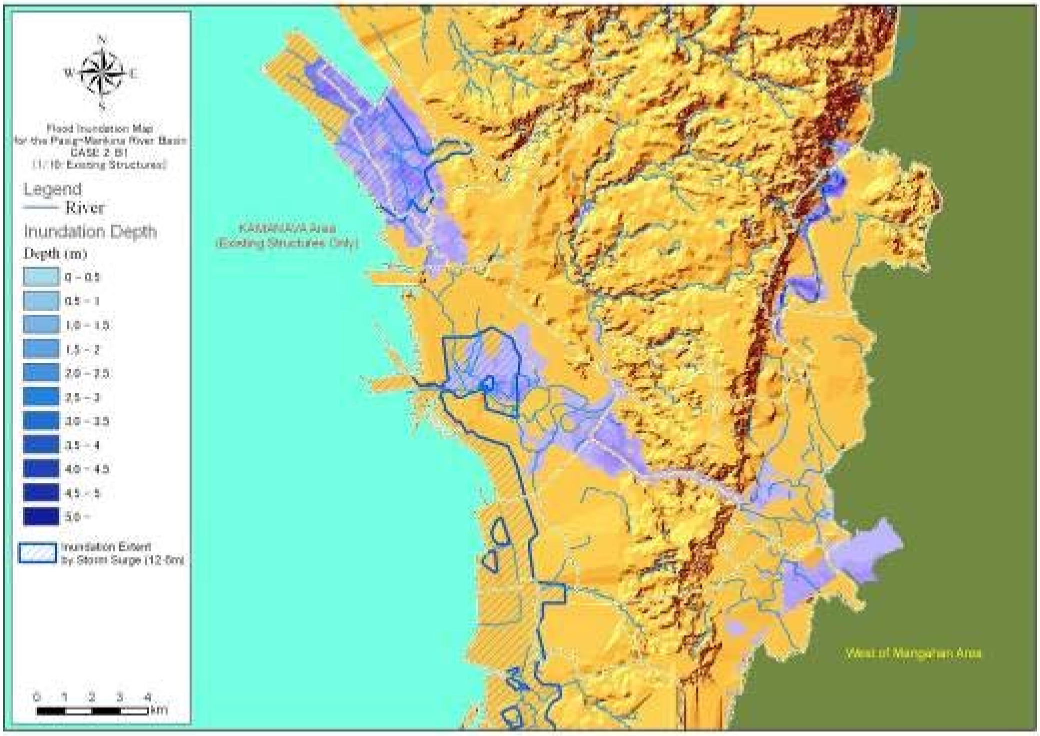
Based on the hydrodynamic analysis described above, the study produced simulation maps showing the different spatial spreads and inundation depths of flooding expected in the metropolis due to the different climate-hydrologic-infrastructure scenarios （Figure 2-16）. Another set of simulation maps illustrate the inundation duration（Figure 2-17）.

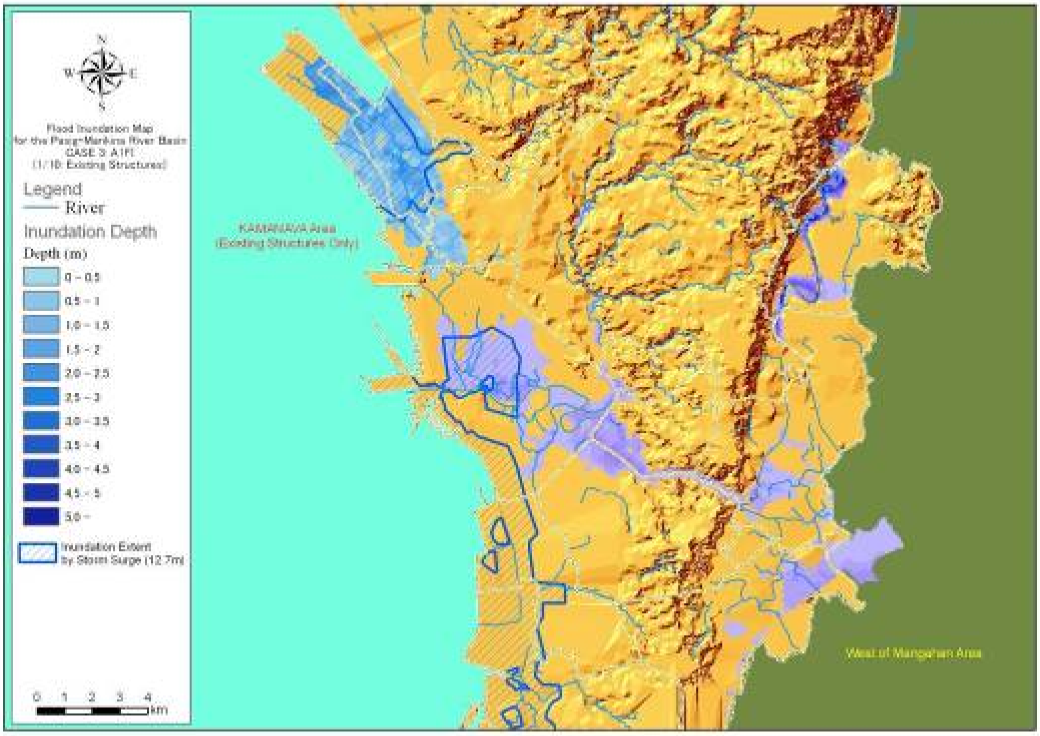


Case 1 (10-year Flood)-1: Status quo with Existing Structures

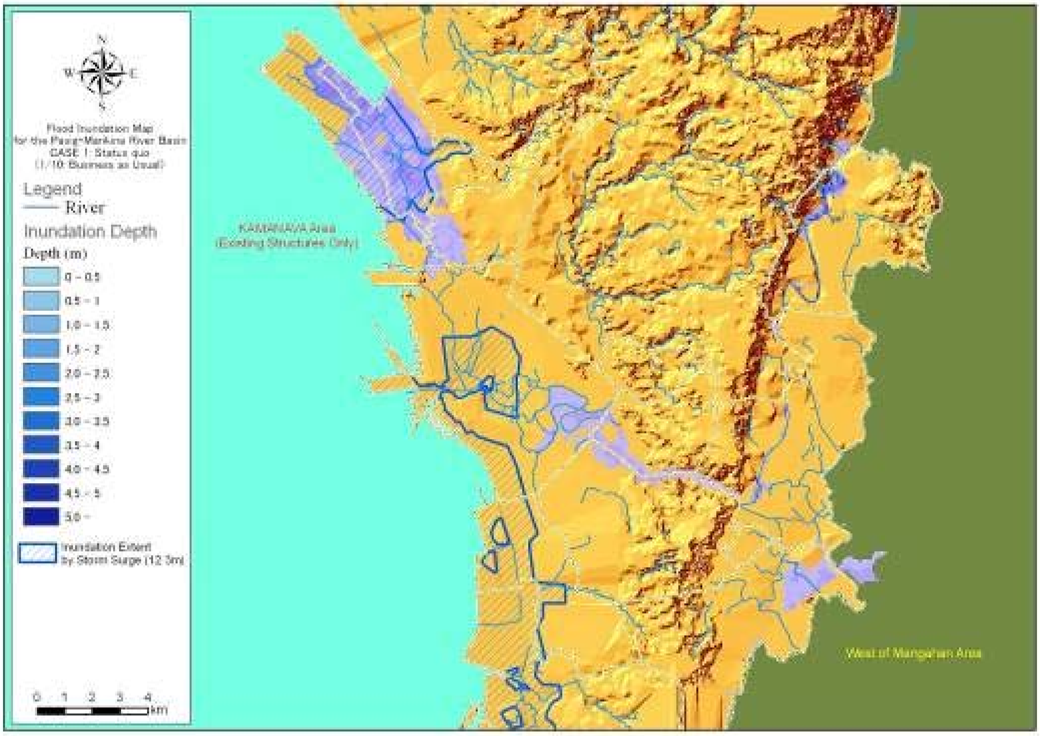


Case 1 (10-year Flood)-2: B1 with Existing Structures

Figure 2-16 (1/9) Flood Inundation Map

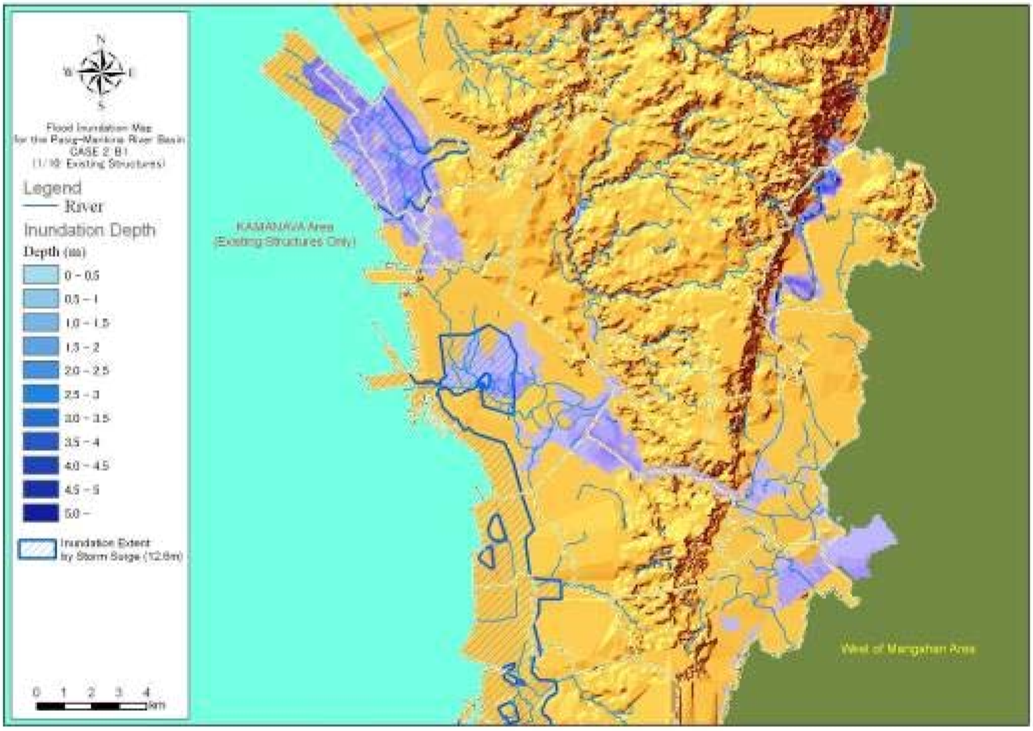


Case 1 (10-year Flood)-3: A1FI with Existing Structures

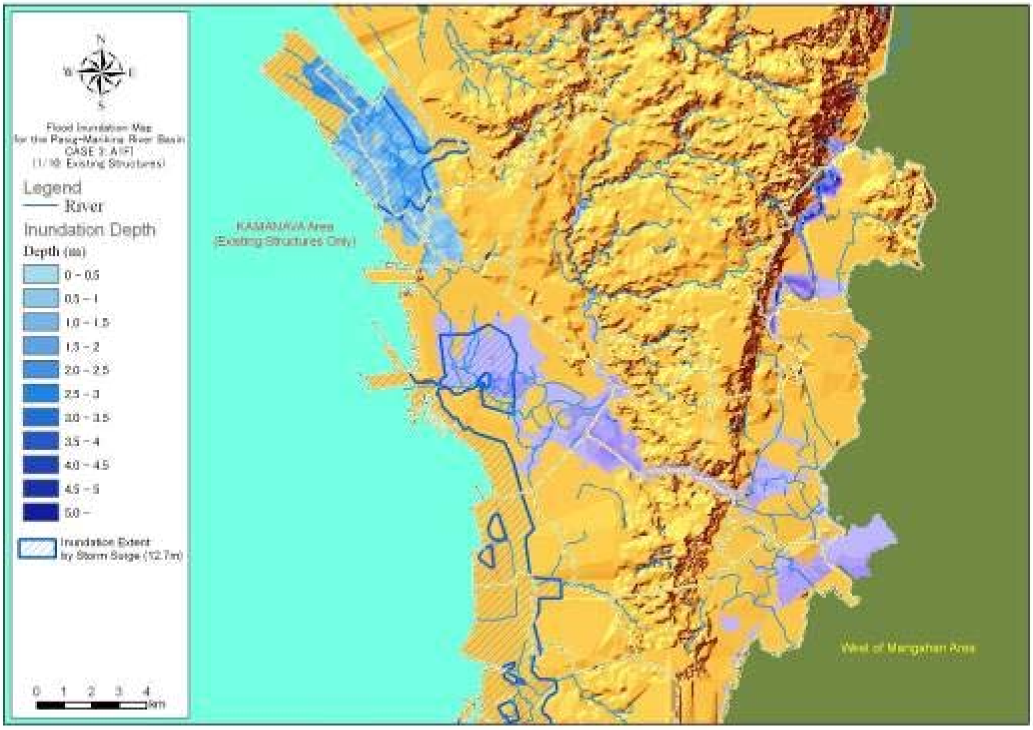


Case 1 (10-year Flood)-4: Status quo with Improvements as per the 1990 Master Plan

Figure 2-16 (2/9) Flood Inundation Map

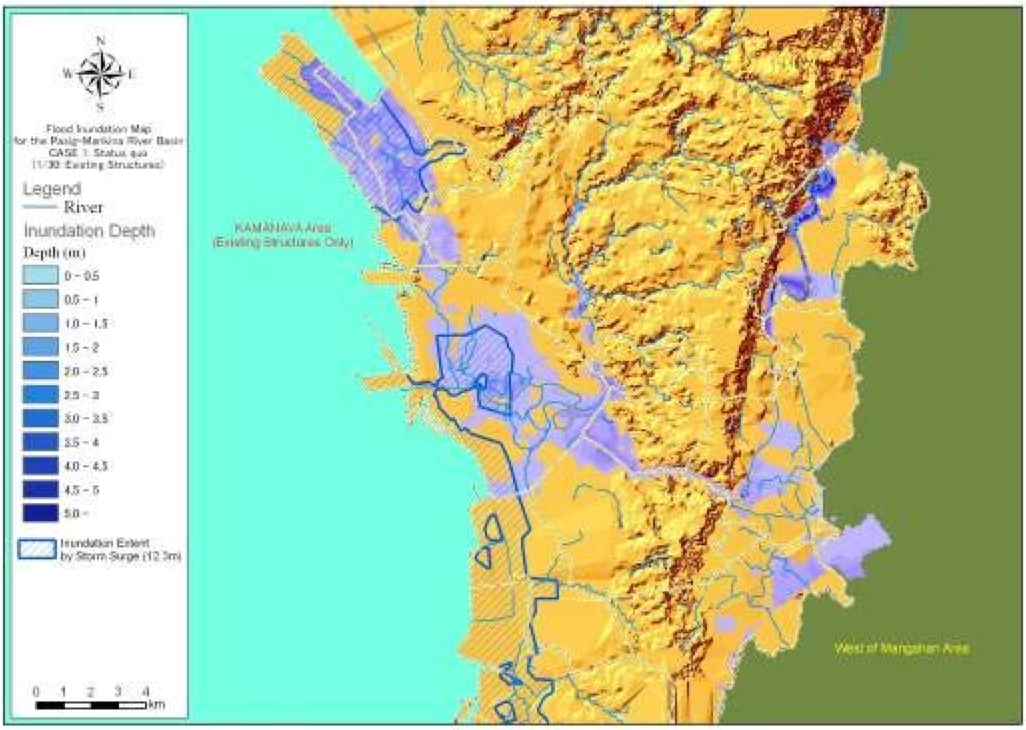


Case 1 (10-year Flood)-5: B1 with Improvements as per the 1990 Master Plan

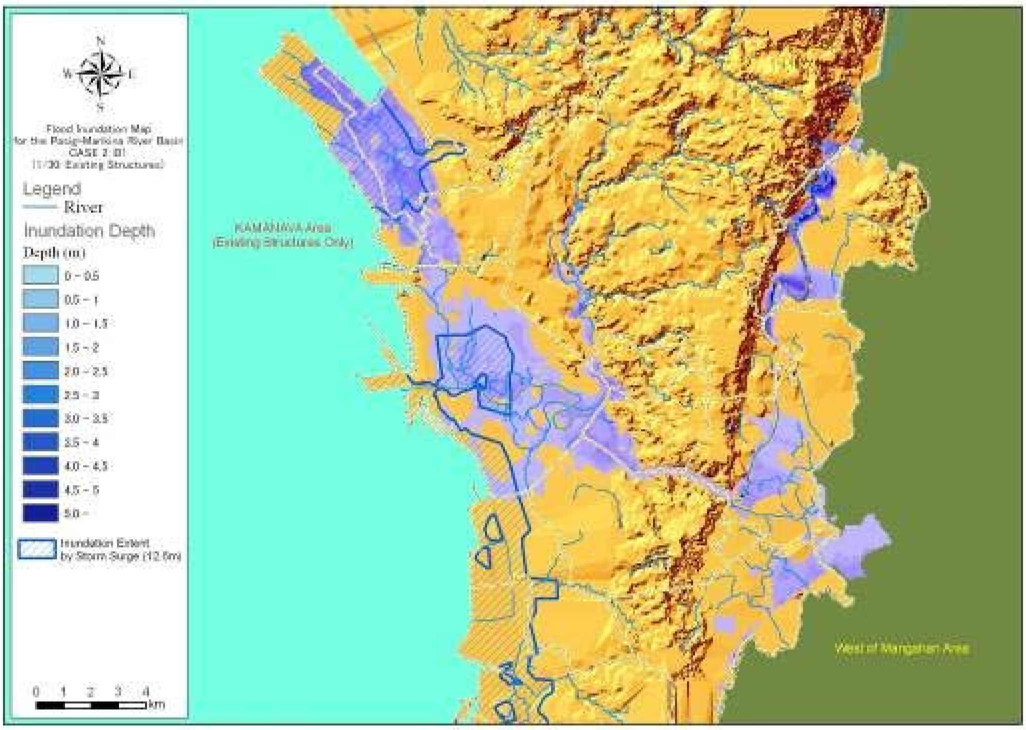


Case 1 (10-year Flood)-6: A1FI with Improvements as per the 1990 Master Plan

Figure 2-16 (3/9) Flood Inundation Map

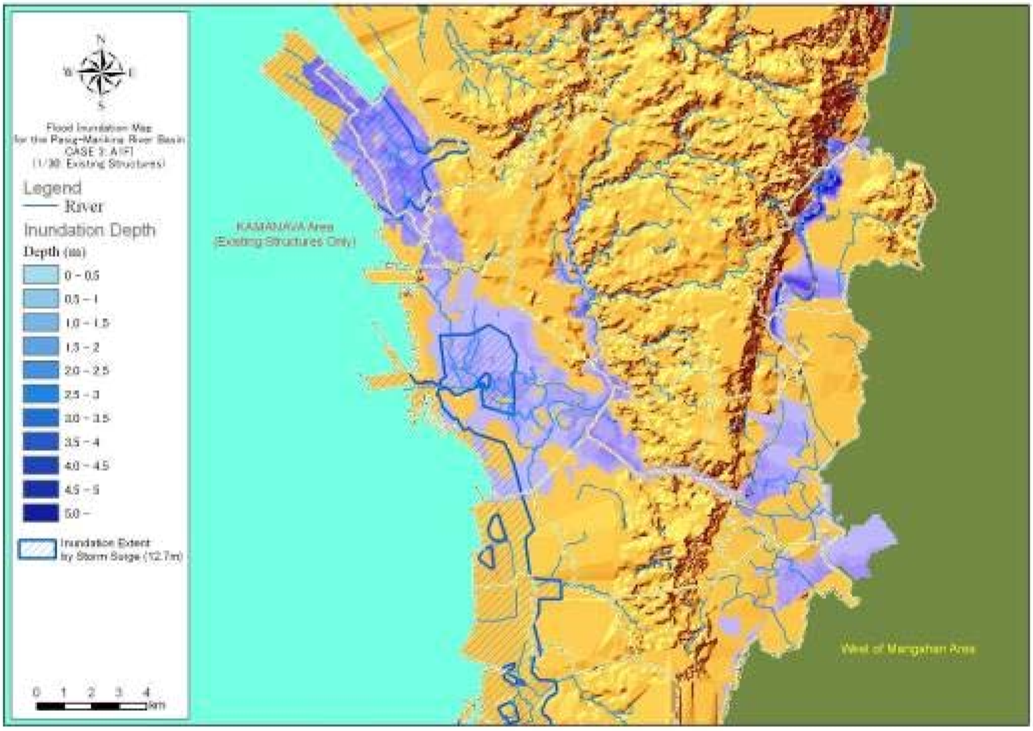


Case 2 (30-year Flood)-1: Status quo with Existing Structures

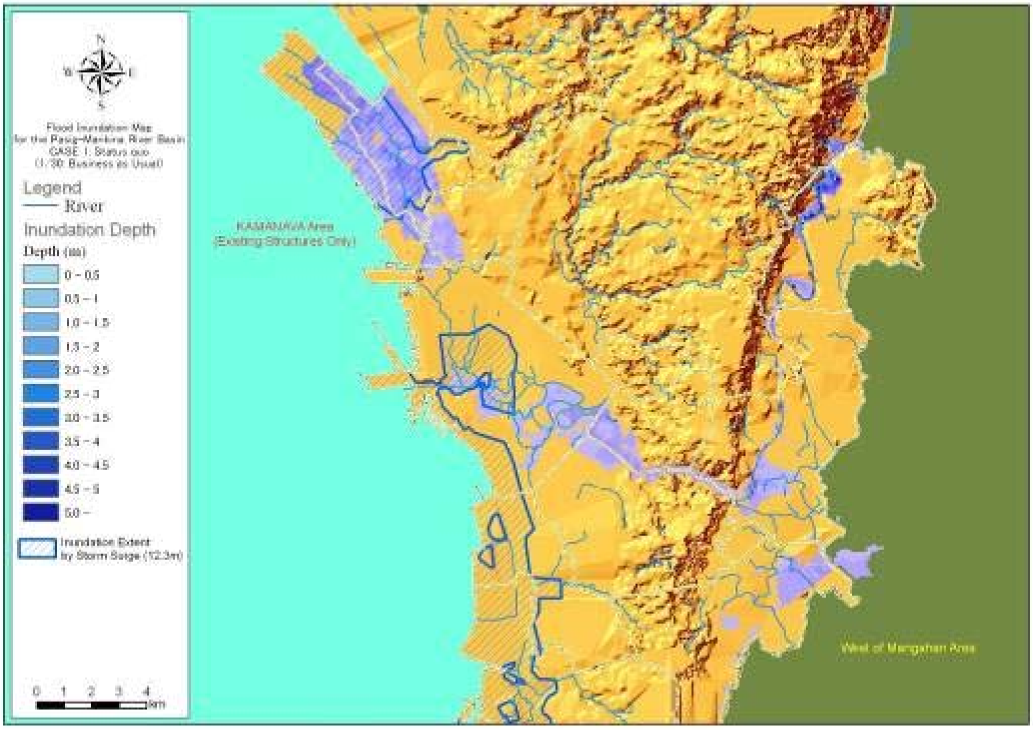


Case 2 (30-year Flood)-2: B1 with Existing Structures

Figure 2-16 (4/9) Flood Inundation Map

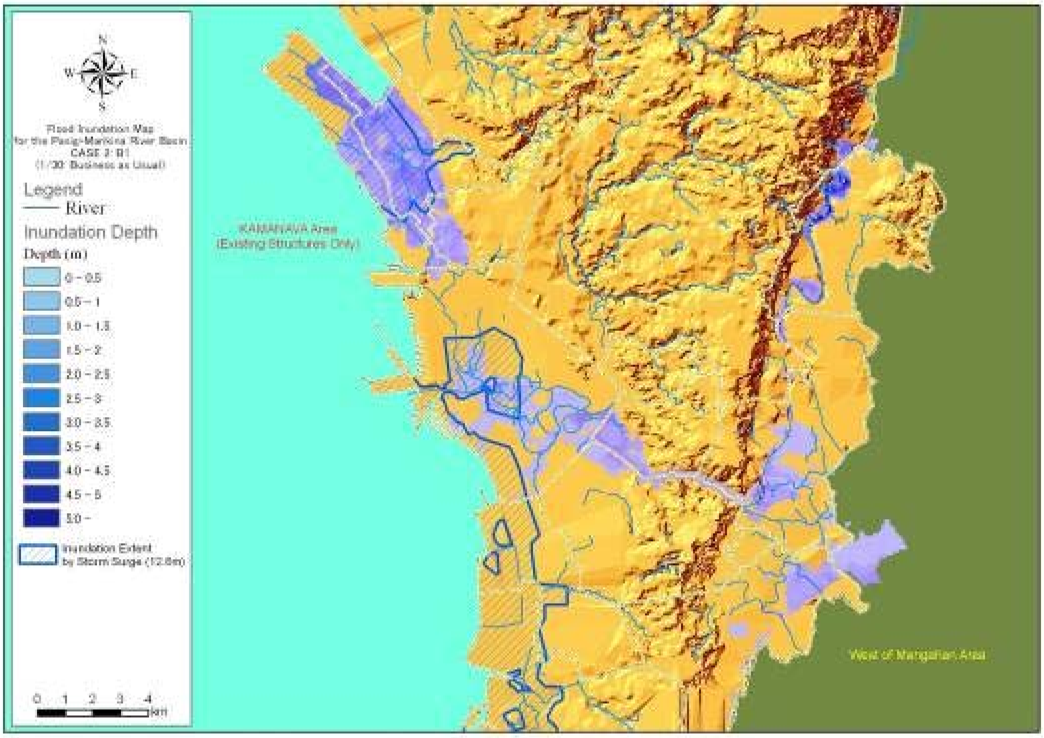


Case 2 (30-year Flood)-3: A1FI with Existing Structures

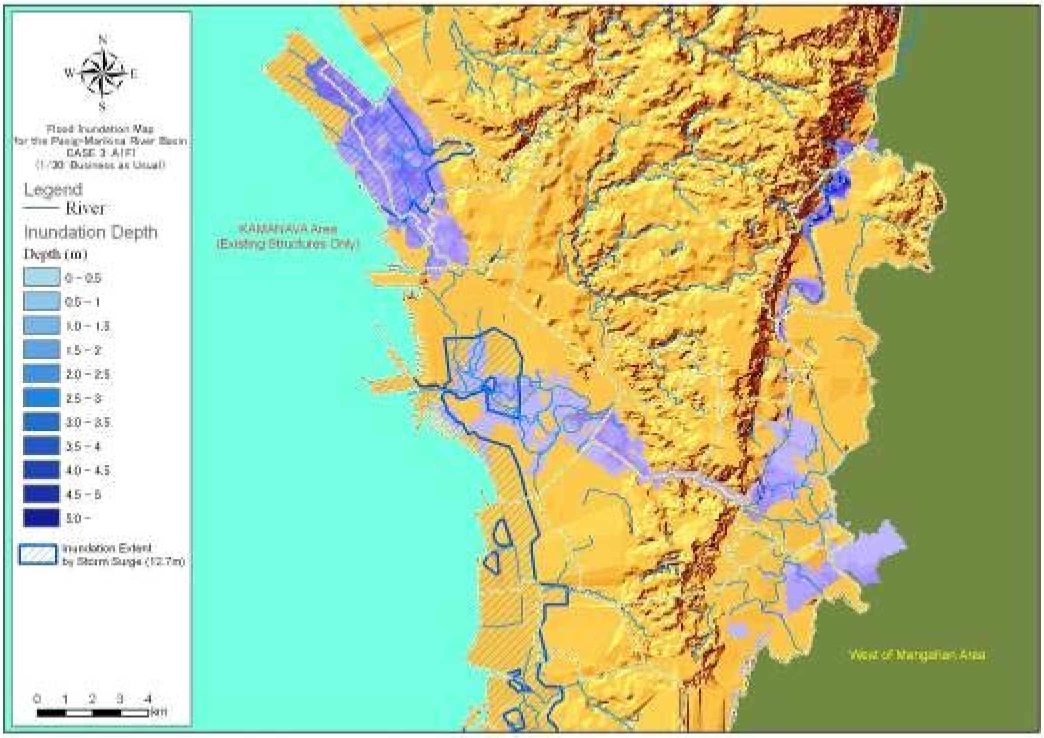


Case 2 (30-year Flood)-4: Status quo with Improvements as per the 1990 Master Plan

Figure 2-16 (5/9) Flood Inundation Map

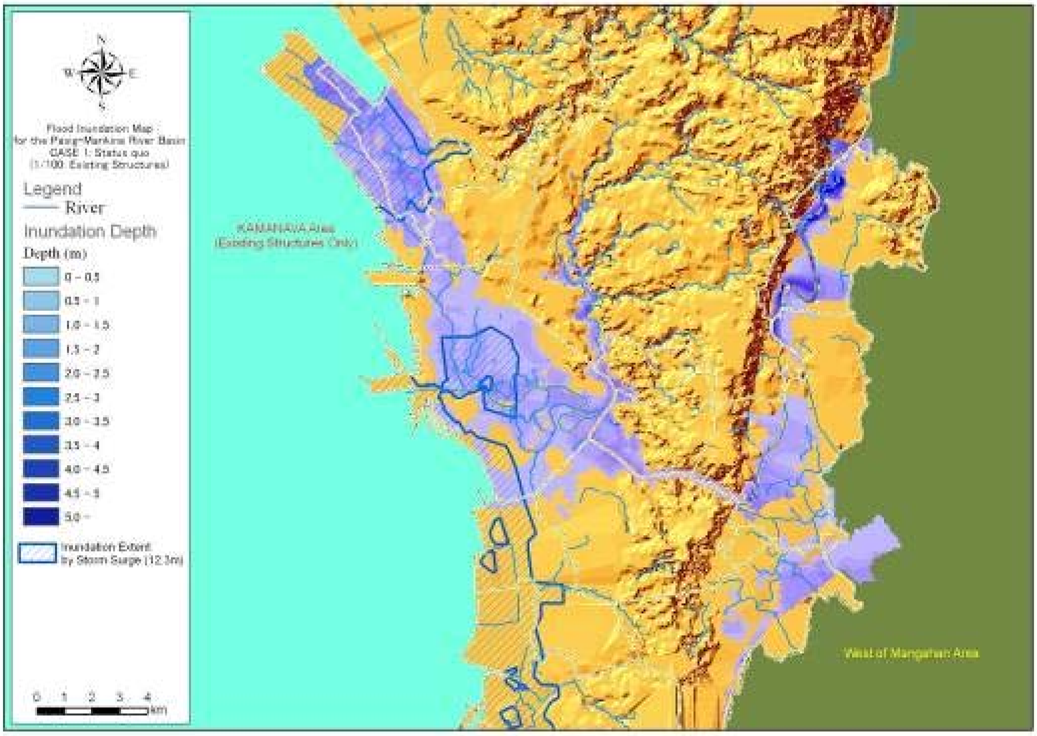


Case 2 (30-year Flood)-5: B1 with Improvements as per the 1990 Master Plan

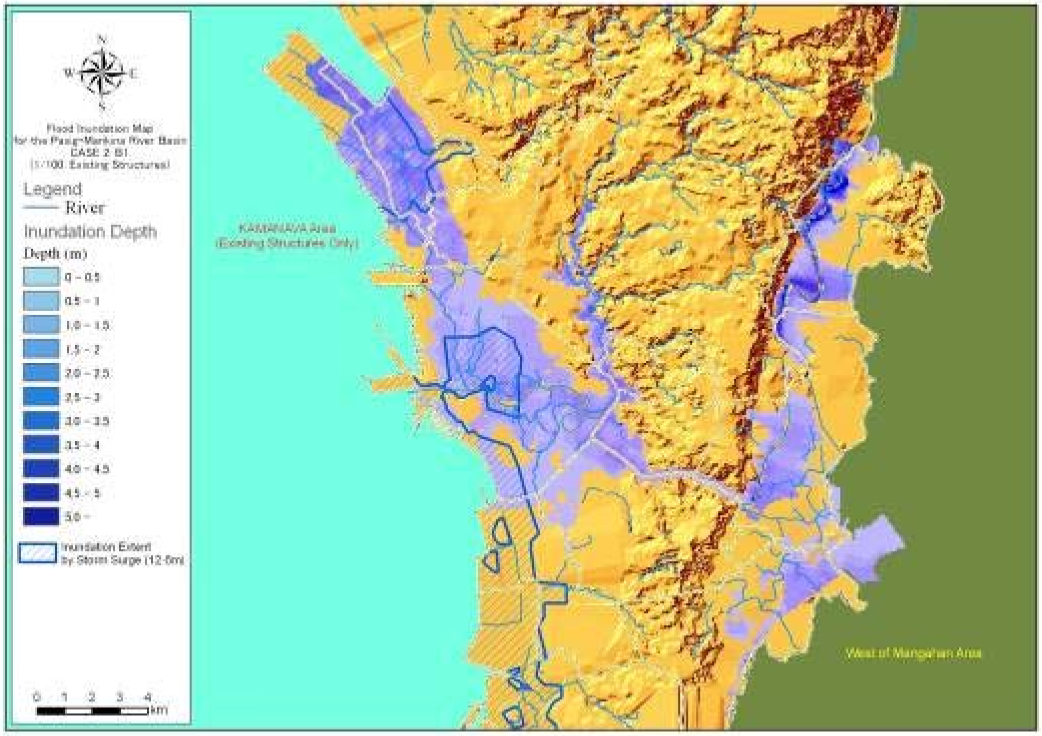


Case 2 (30-year Flood)-6: A1FI with Improvements as per the 1990 Master Plan

Figure 2-16 (6/9) Flood Inundation Map

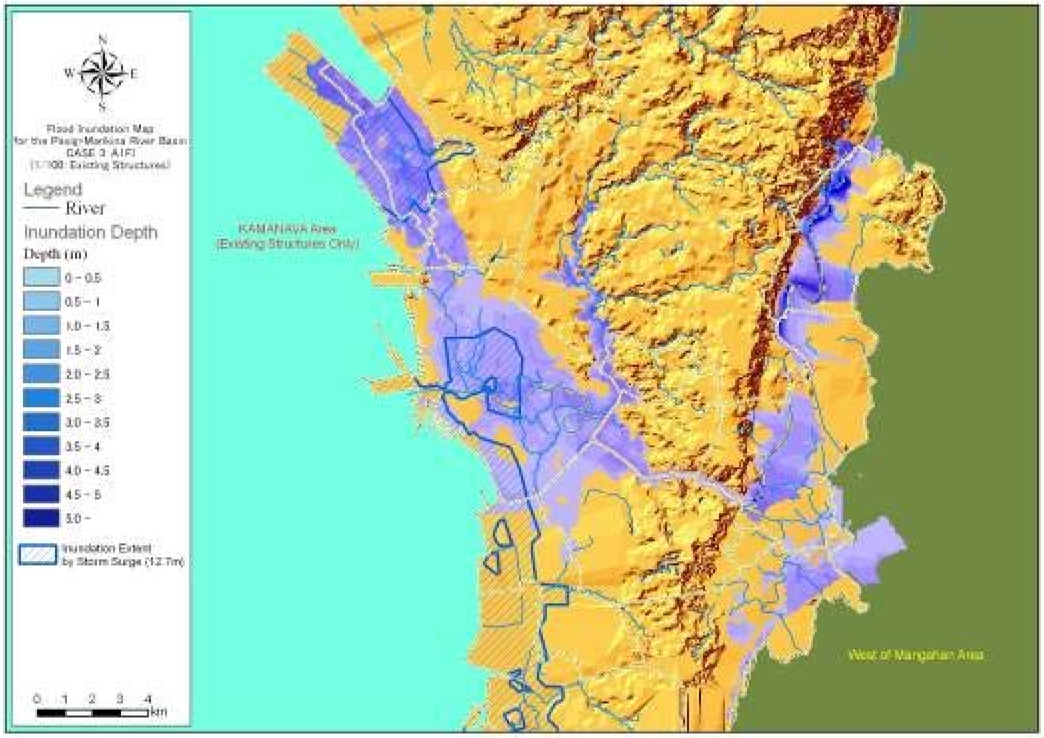


Case 3 (100-year Flood)-1: Status quo with Existing Structures

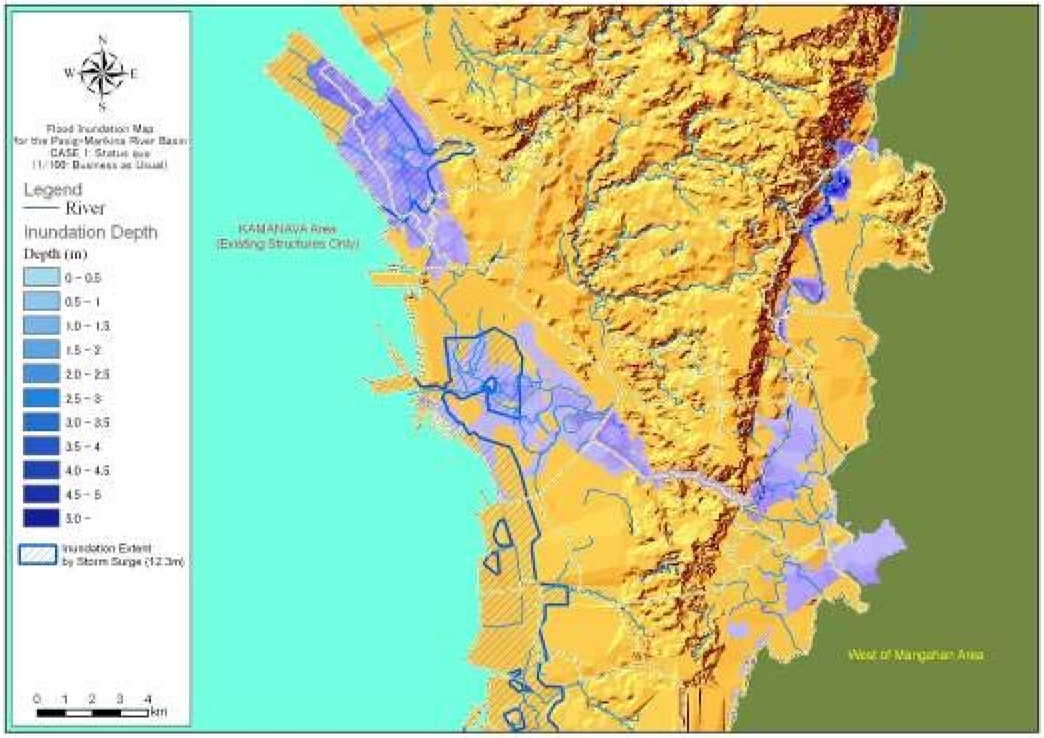


Case 3 (100-year Flood)-2: B1 with Existing Structures

Figure 2-16 (7/9) Flood Inundation Map

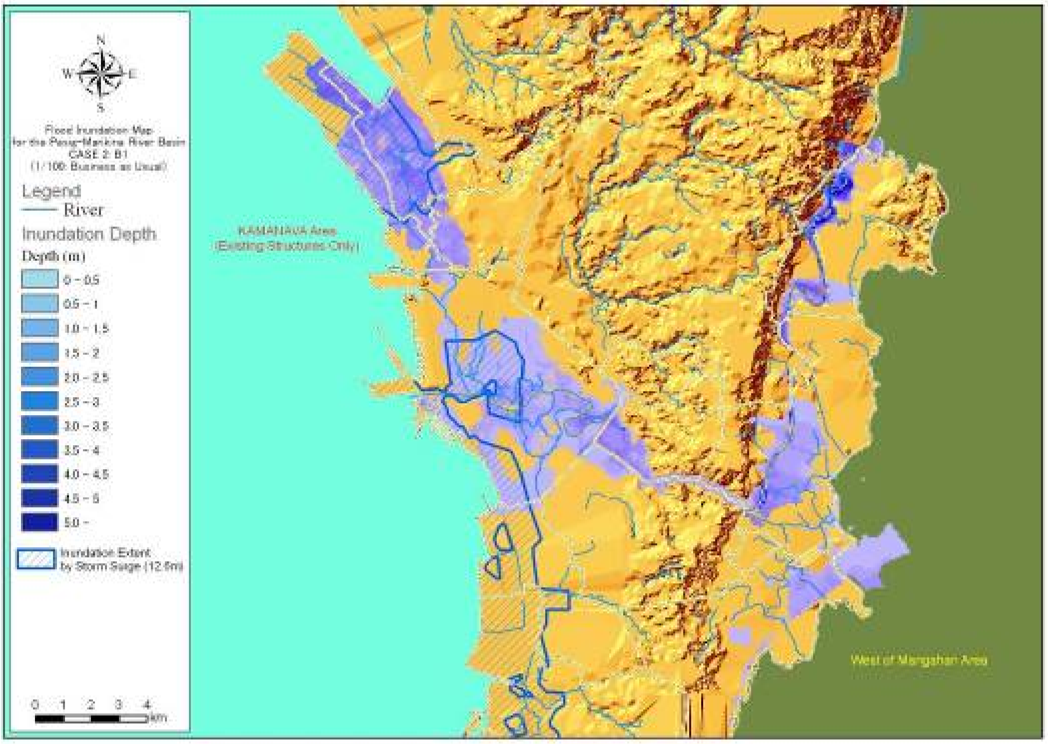


Case 3 (100-year Flood)-3: A1FI with Existing Structures

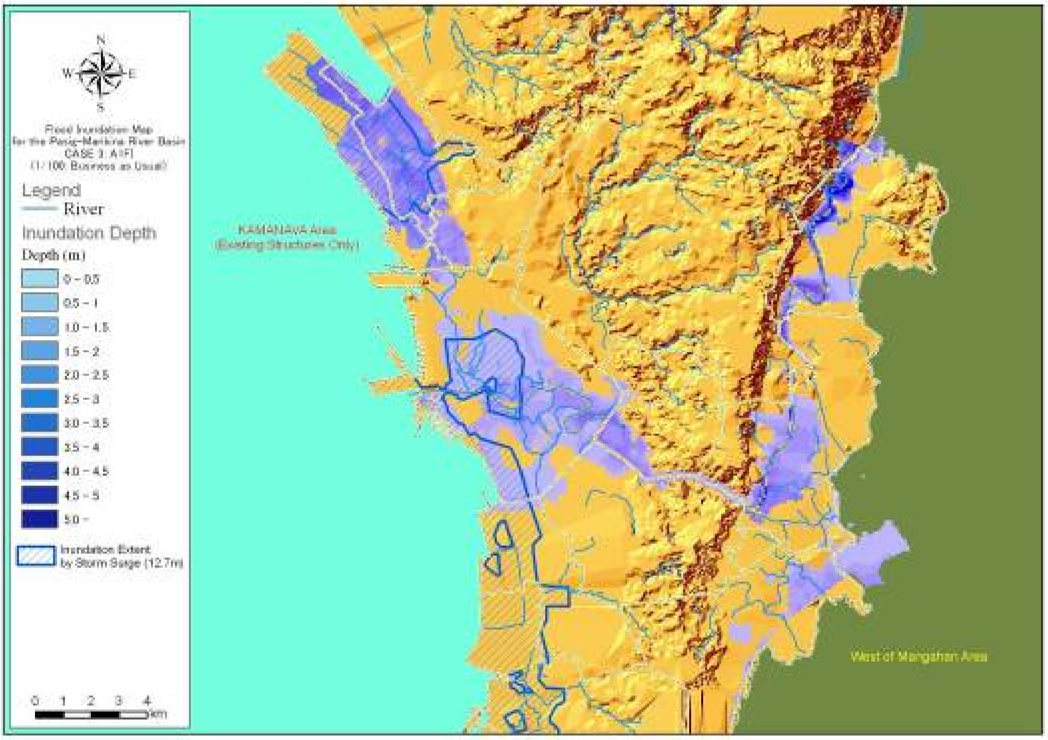


Case 3 (100-year Flood)-4: Status quo with Improvements as per the 1990 Master Plan

Figure 2-16 (8/9) Flood Inundation Map

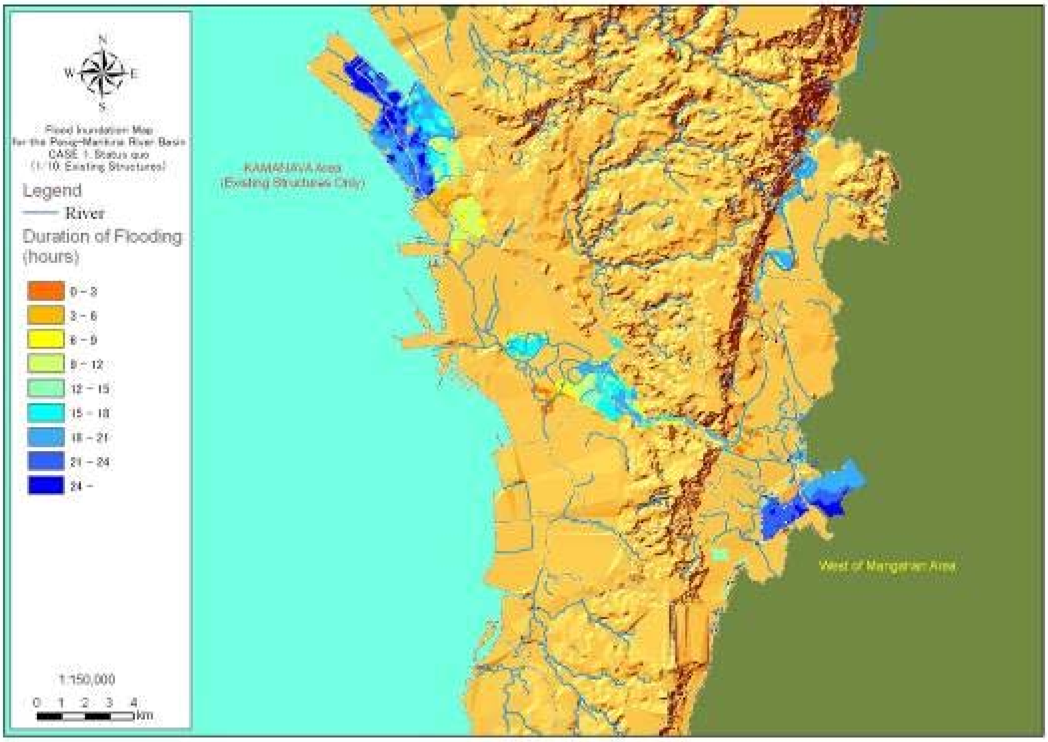


Case 3 (100-year Flood)-5: B1 with Improvements as per the 1990 Master Plan

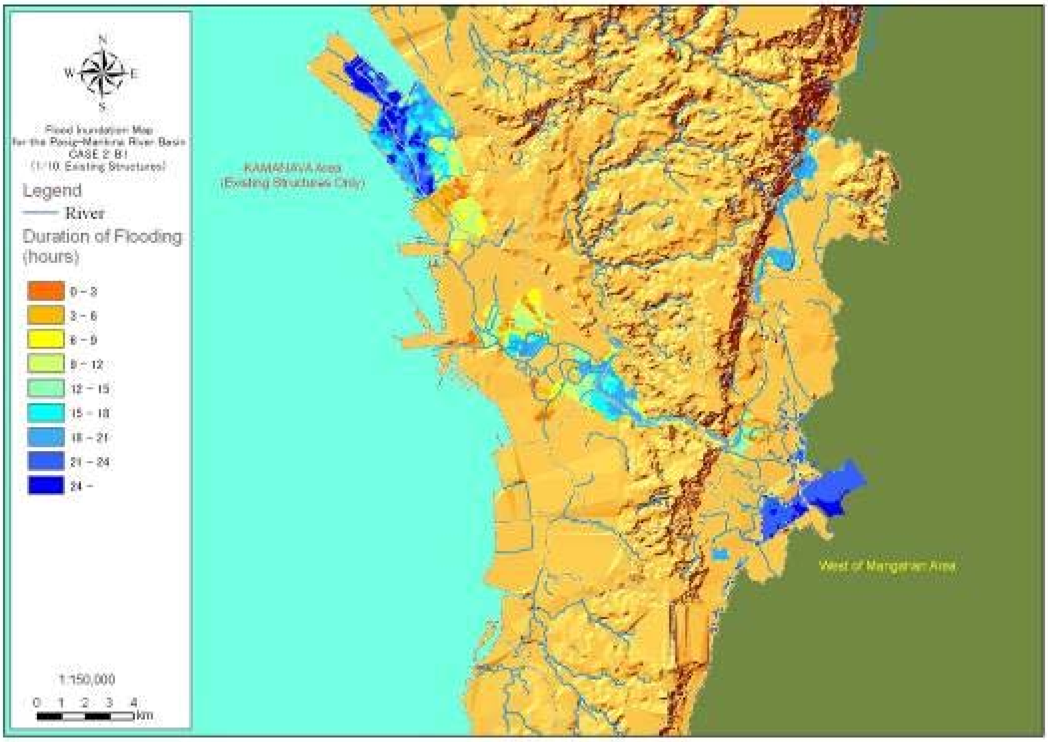


Case 3 (100-year Flood)-6: A1FI with Improvements as per the 1990 Master Plan

Figure 2-16 (9/9) Flood Inundation Map

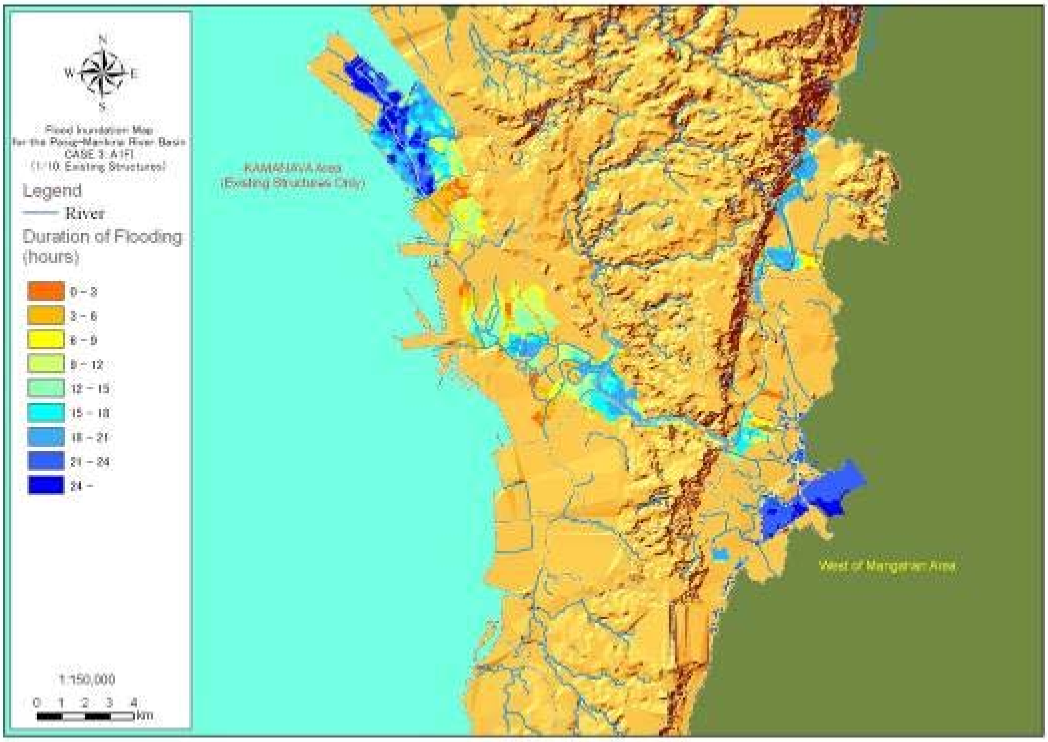


Case 1 (10-year Flood)-1: Status quo with Existing Structures

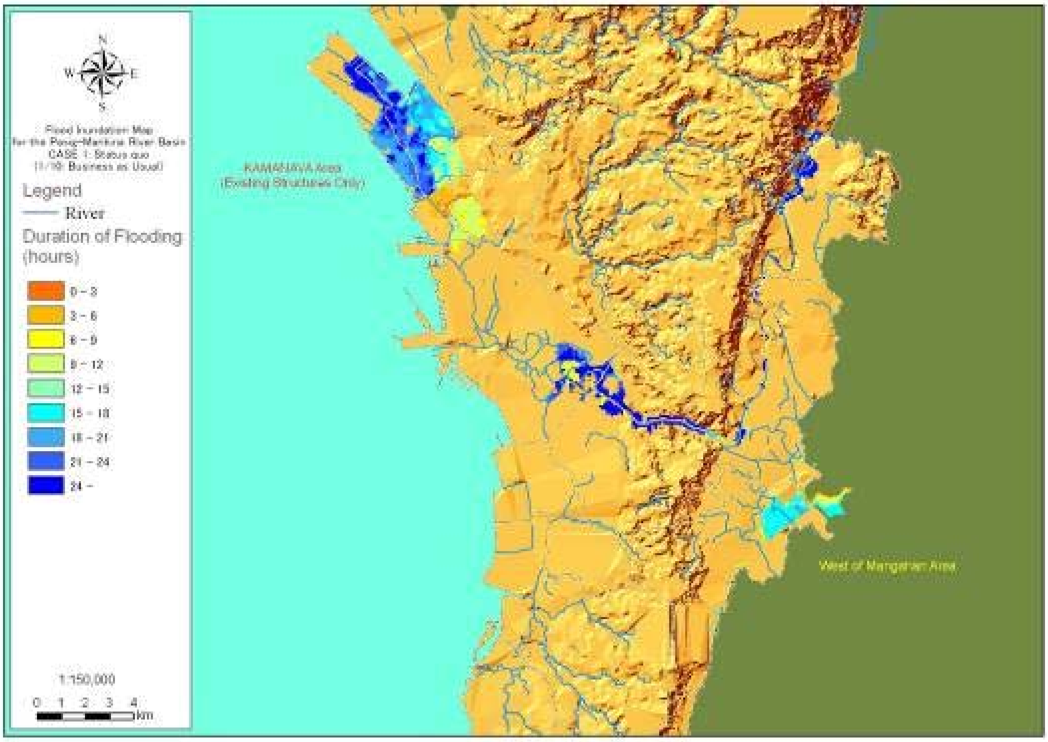


Case 1 (30-year Flood)-2: B1 with Existing Structures

Figure 2-17 (1/9) Duration of Flooding

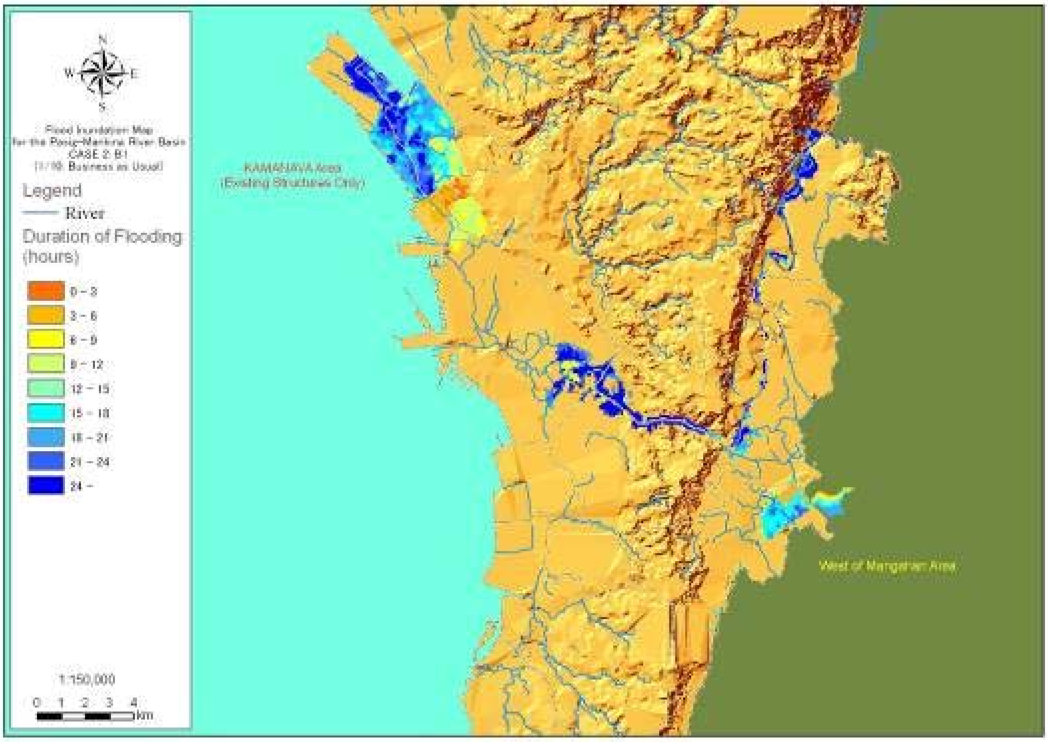


Case 1 (10-year Flood)-3: A1FI with Existing Structures

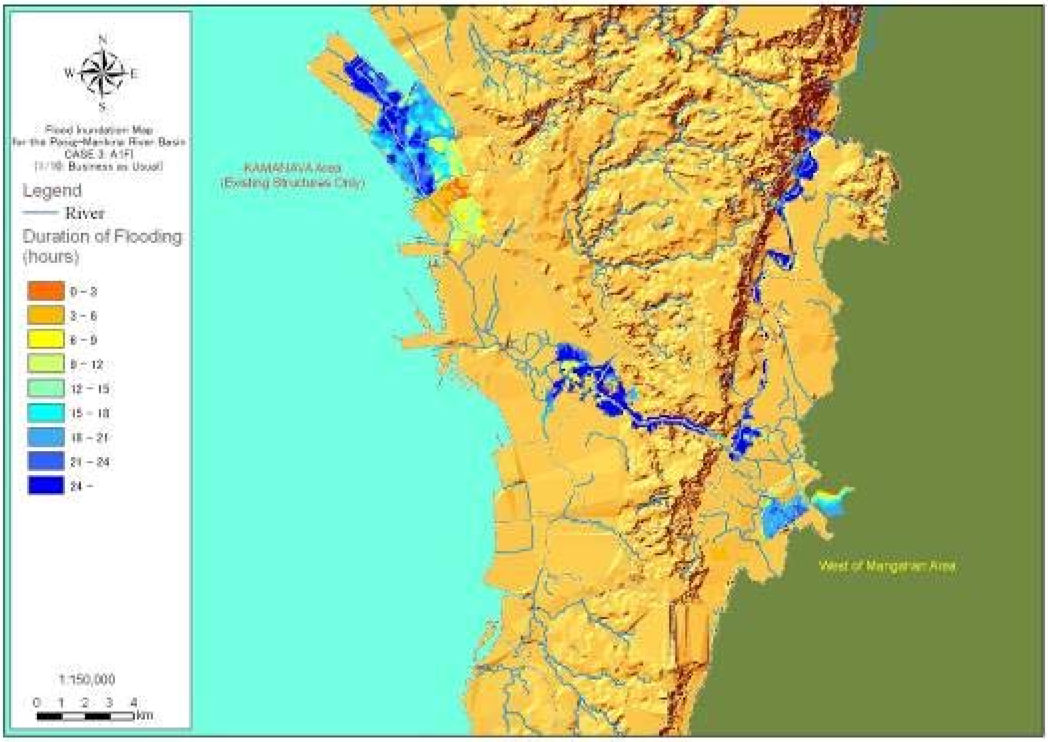


Case 1 (10-year Flood)-4: Status quo with Improvements as per the 1990 Master Plan

Figure 2-17 (2/9) Duration of Flooding

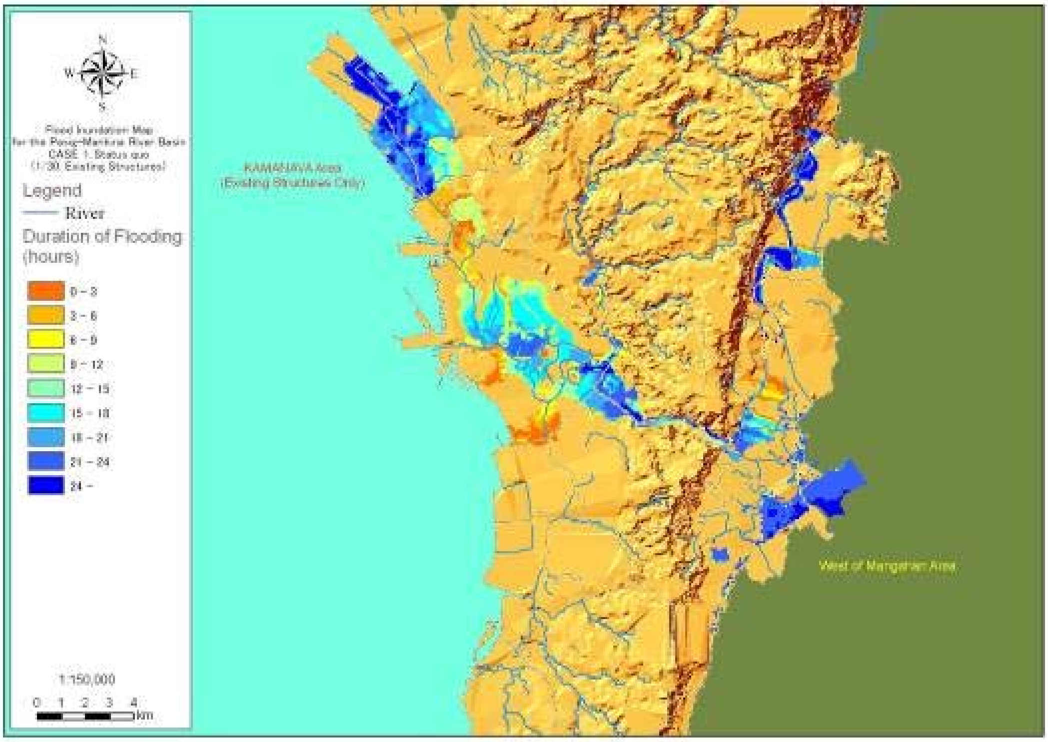


Case 1 (10-year Flood)-5: B1 with Improvements as per the 1990 Master Plan

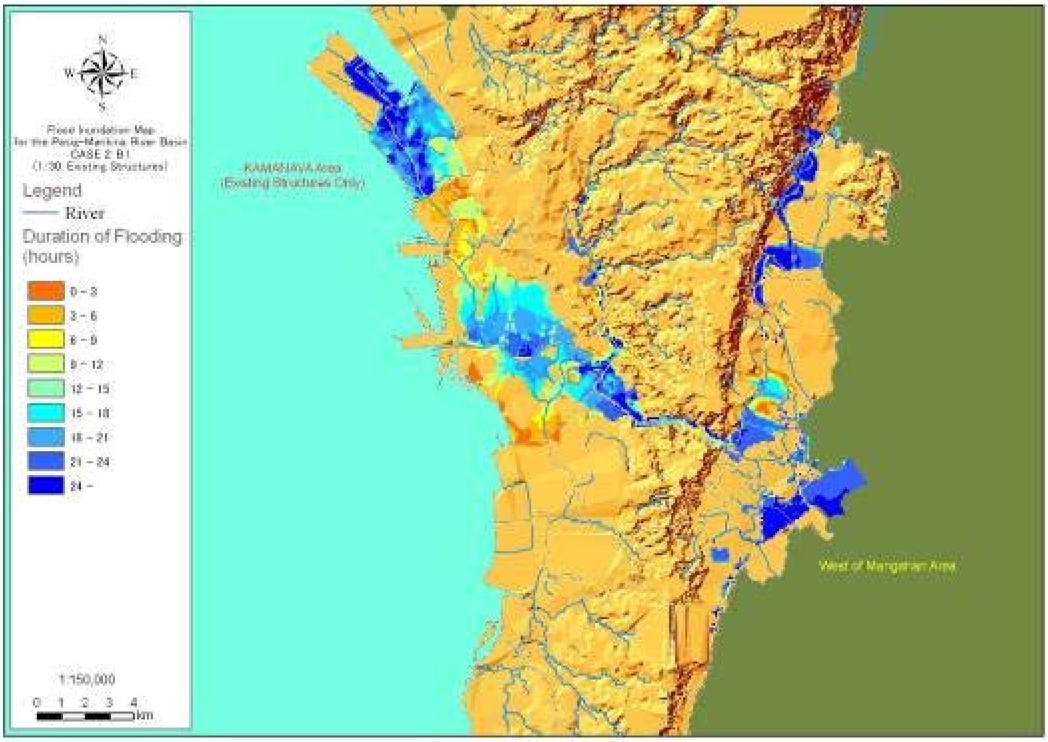


Case 1 (10-year Flood)-6: A1FI with Improvements as per the 1990 Master Plan

Figure 2-17 (3/9) Duration of Flooding

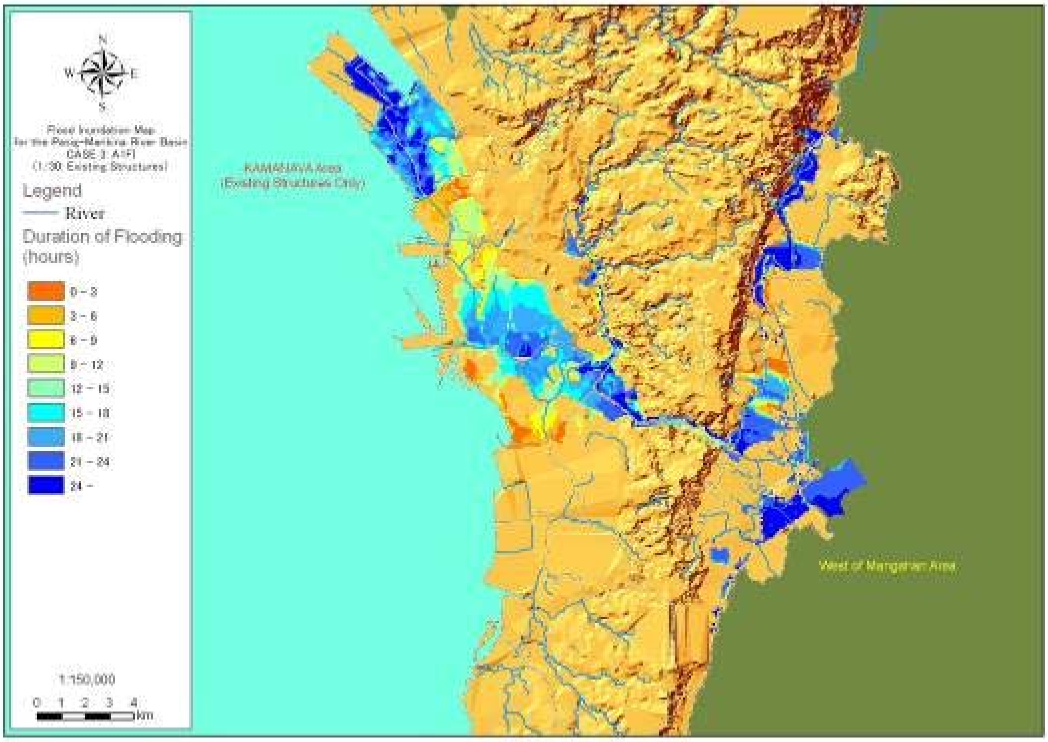


Case 2 (30-year Flood)-1: Status quo with Existing Structures

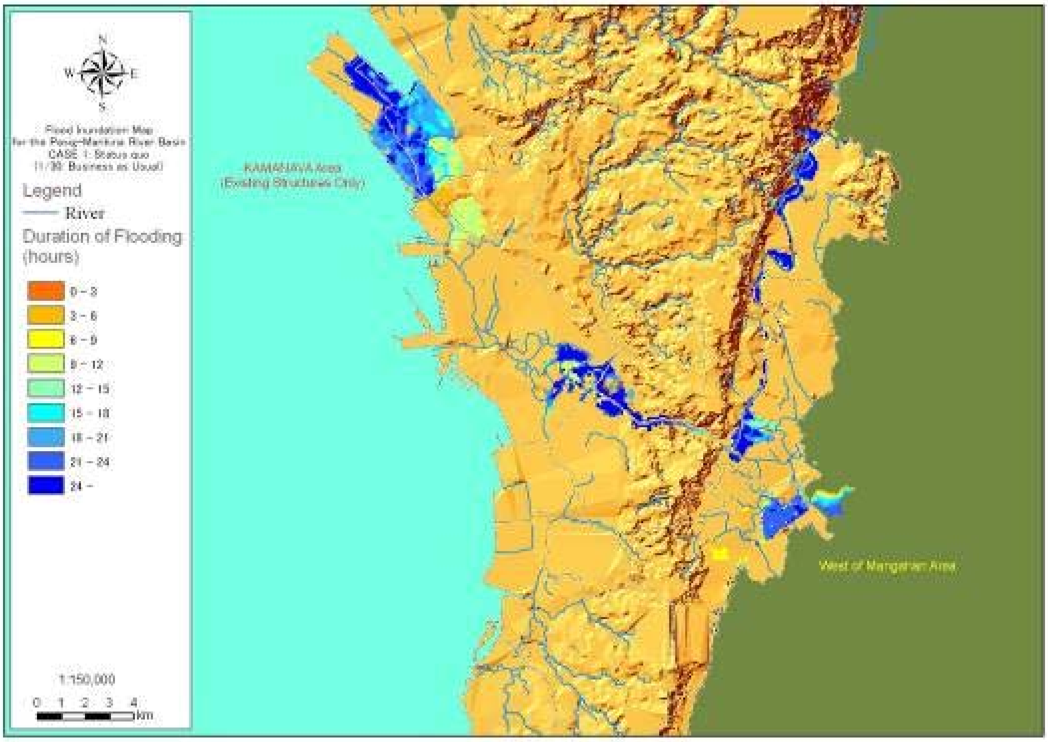


Case 2 (30-year Flood)-2: B1 with Existing Structures

Figure 2-17 (4/9) Duration of Flooding

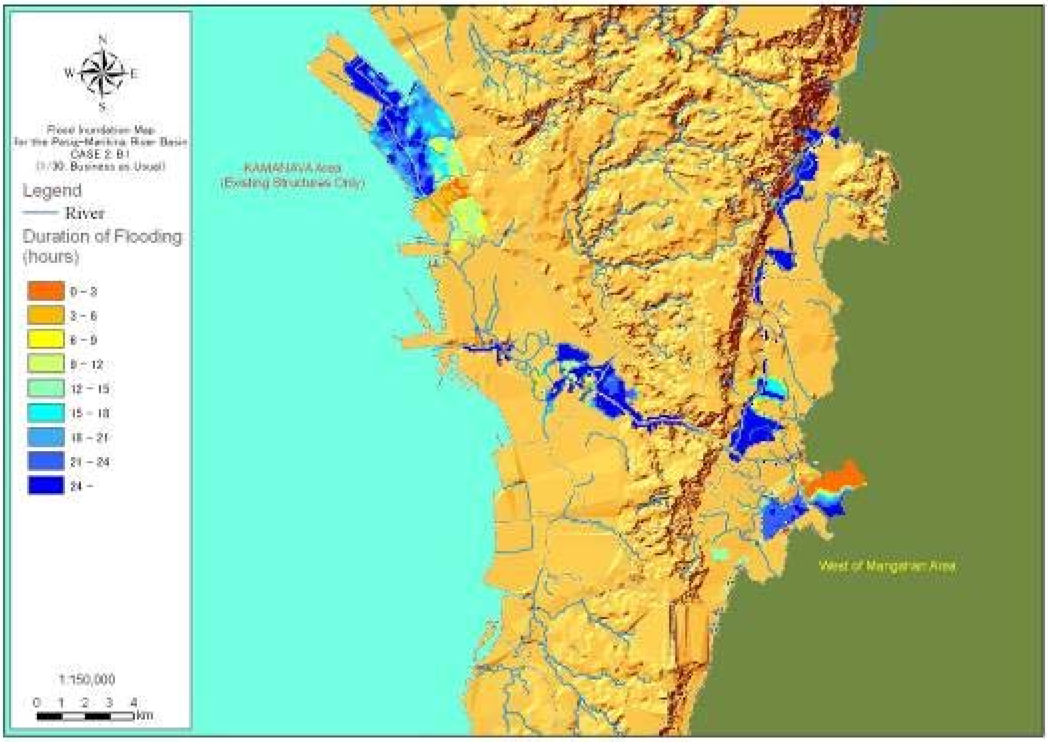


Case 2 (30-year Flood)-3: A1FI with Existing Structures

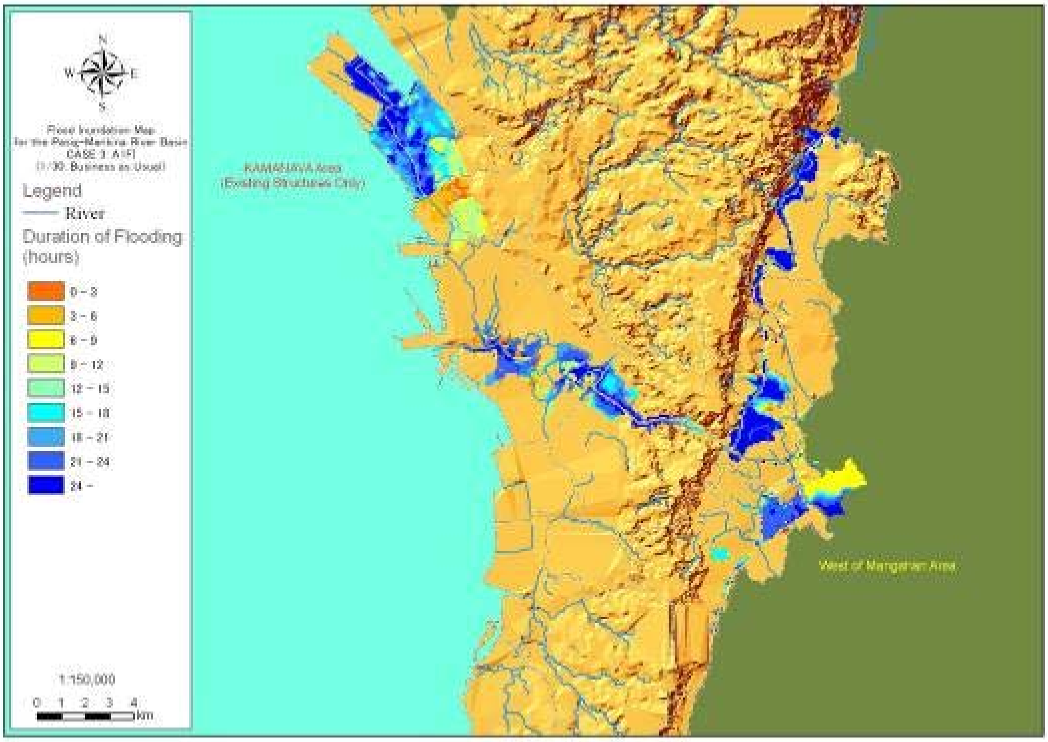


Case 2 (30-year Flood)-4: Status quo with Improvements as per the 1990 Master Plan

Figure 2-17 (5/9) Duration of Flooding

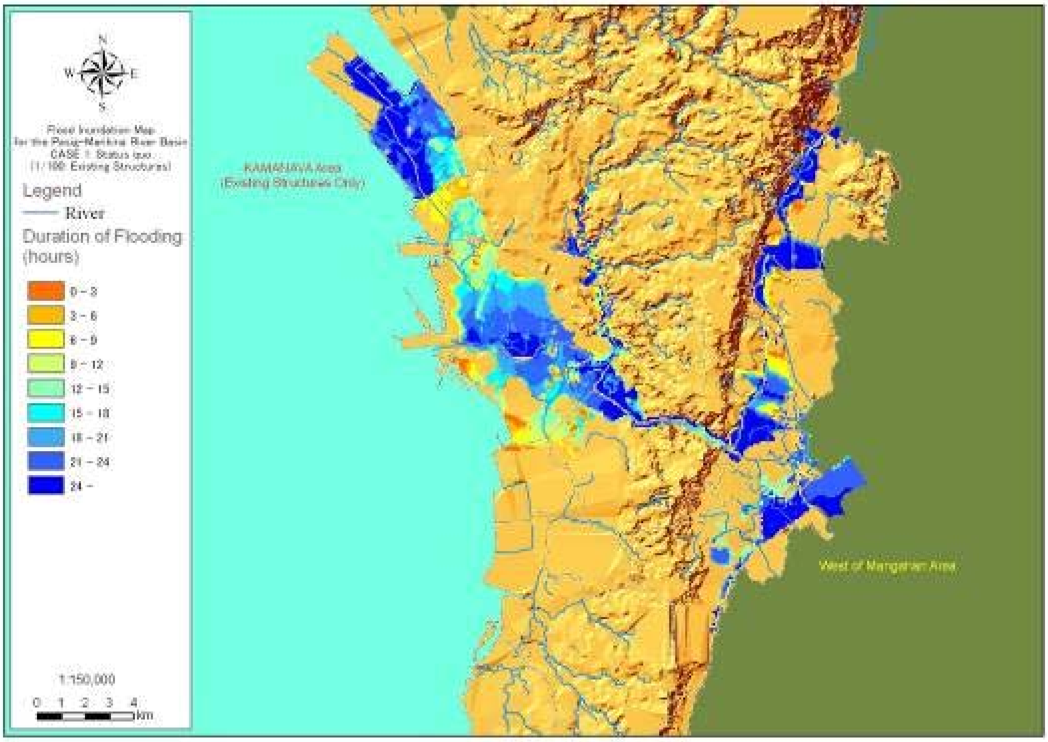


Case 2 (30-year Flood)-5: B1 with Improvements as per the 1990 Master Plan

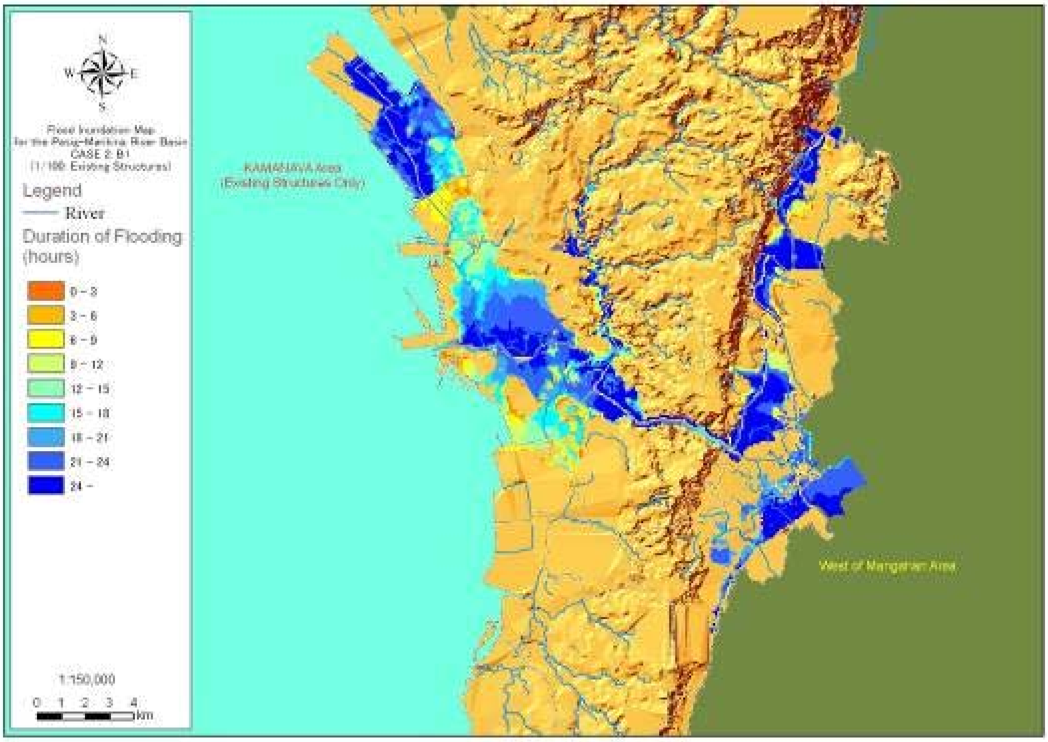


Case 2 (30-year Flood)-6: A1FI with Improvements as per the 1990 Master Plan

Figure 2-17 (6/9) Duration of Flooding

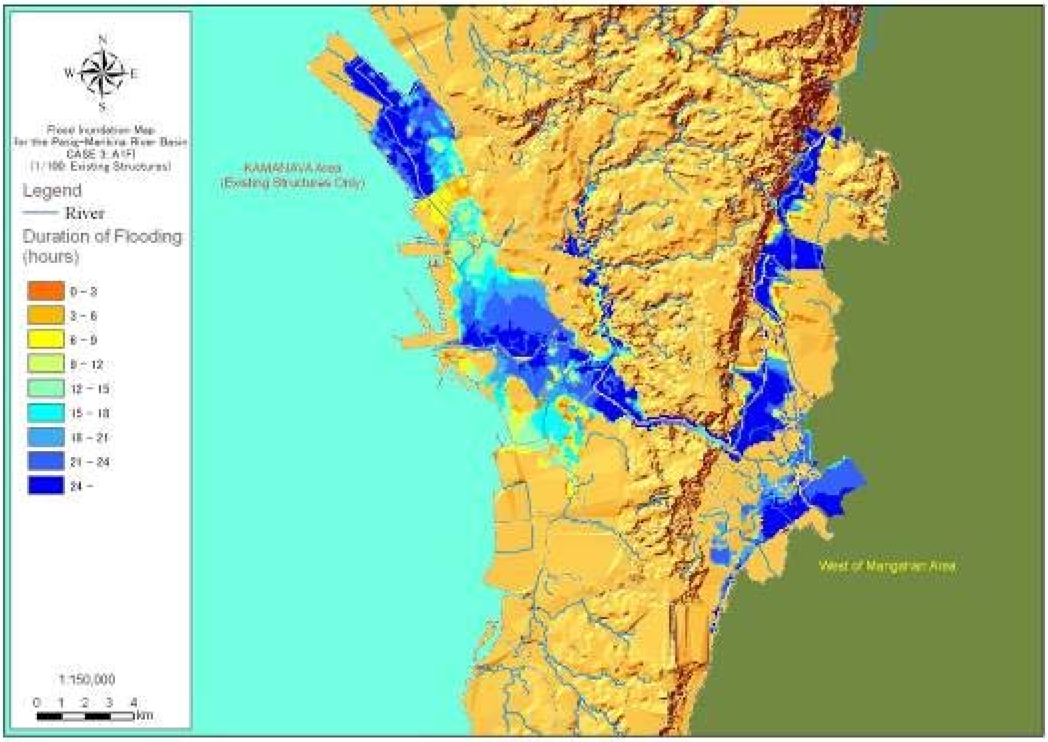


Case 3 (100-year Flood)-1: Status quo with Existing Structures

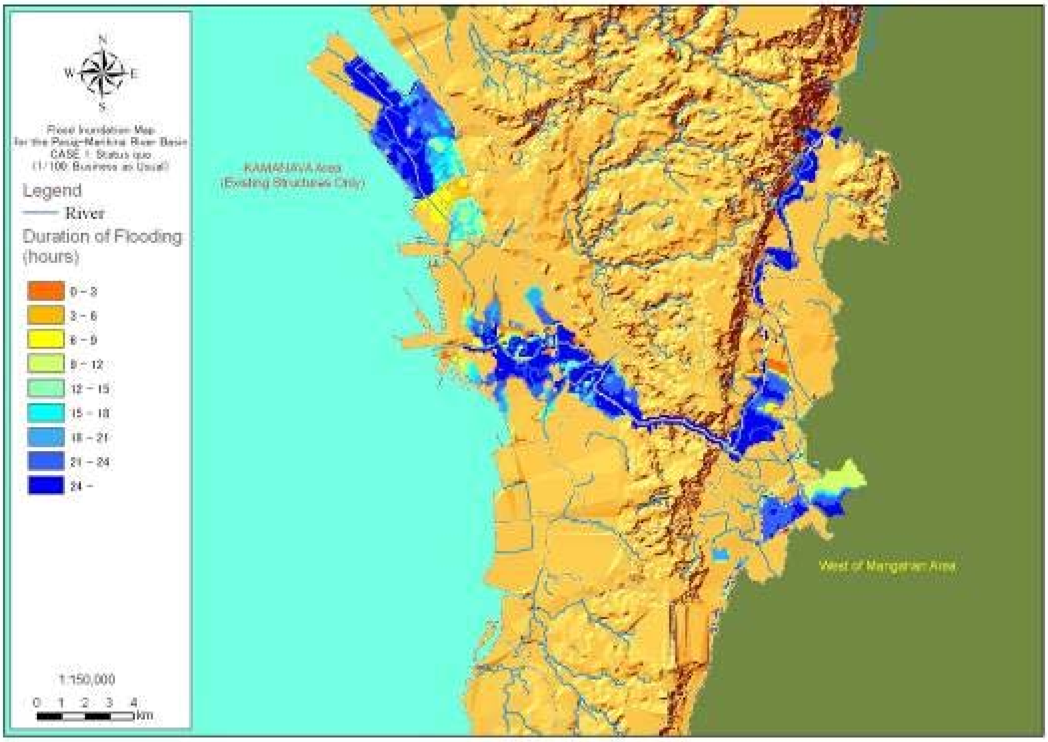


Case 3 (100-year Flood)-2: B1 with Existing Structures

Figure 2-17 (7/9) Duration of Flooding

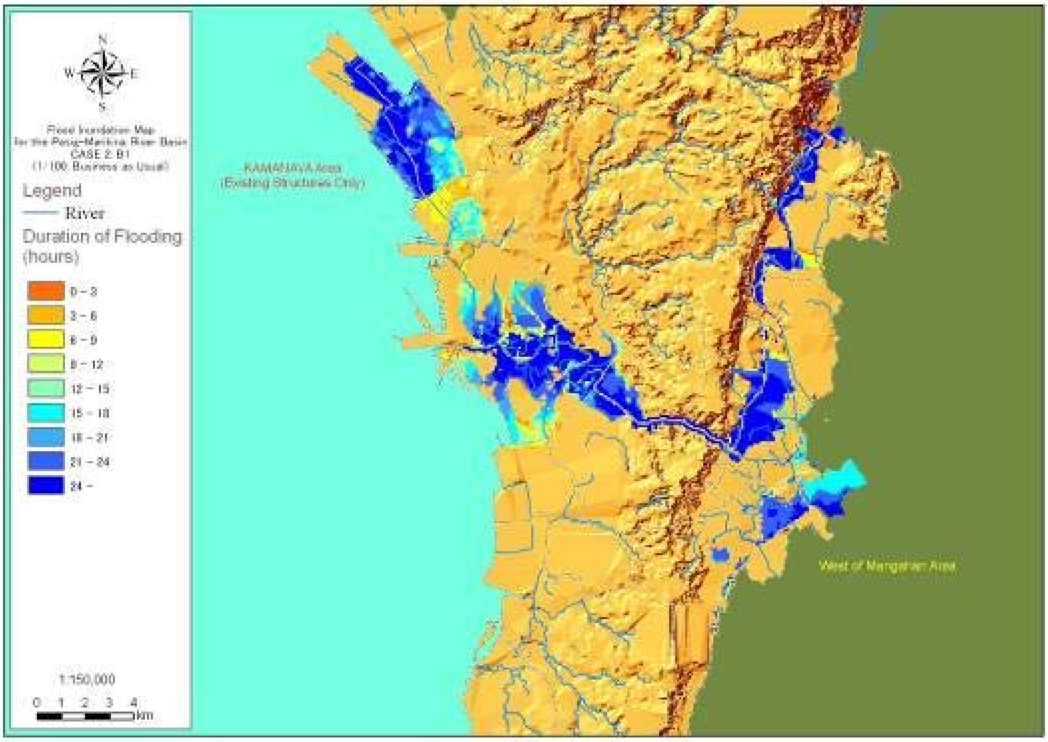


Case 3 (100-year Flood)-3: A1FI with Existing Structures

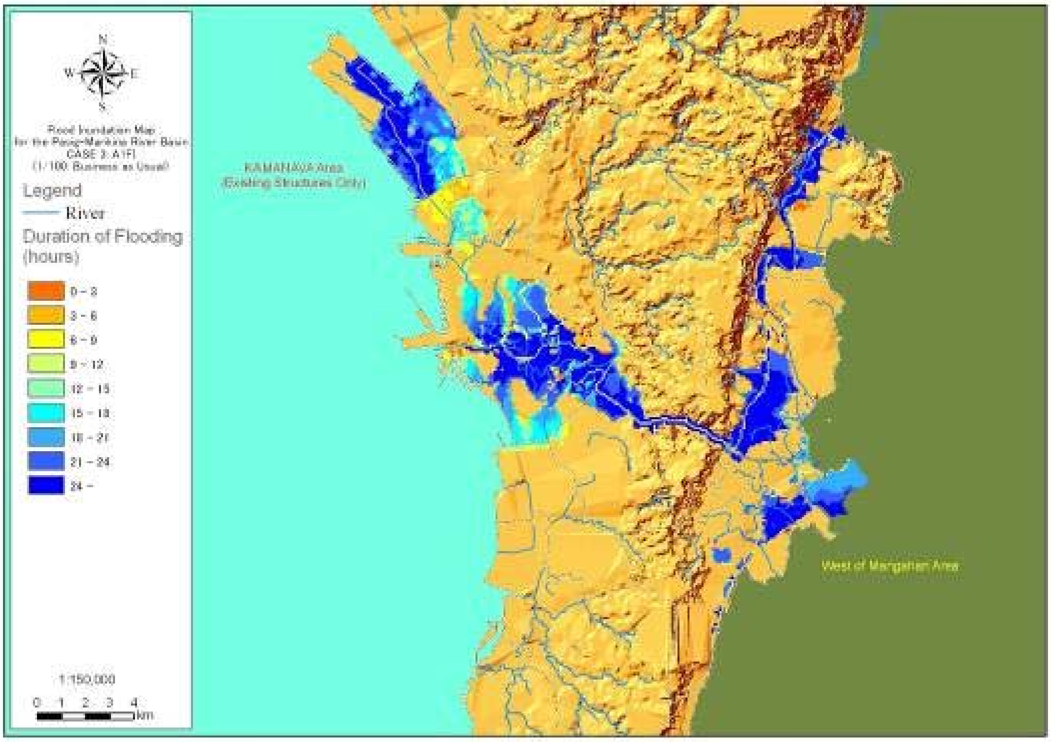


Case 3 (100-year Flood)-4: Status quo with Improvements as per the 1990 Master Plan

Figure 2-17 (8/9) Duration of Flooding



Case 3 (100-year Flood)-5: B1 with Improvements as per the 1990 Master Plan



Case 3 (100-year Flood)-6: A1FI with Improvements as per the 1990 Master Plan

Figure 2-17 (9/9) Duration of Flooding

Chapter 3 Methodology Part Two: Socio-Economic Analysis to identify tangible damages avoided by implementation of planned flood control projects

3.1 General framework

This chapter describes the socioeconomic impact analyses used to understand the characteristics and magnitude of the damage caused by floods expected in year 2050, including damage caused by climate change. The benefits of flood control projects, measured as the damage avoided by implementing them, are estimated based on the SQ, B1, and A1FI climate scenarios, assuming two infrastructure conditions, the "existing infrastructure (EX)" and "1990 Master Plan (MP)". The MP condition assumes the completion of infrastructure improvements planned based on current climate conditions[1], while the EX condition assumes that present infrastructure conditions remain unchanged until the year 2050. The scenarios are further classified into three levels by the return periods (10, 30 and 100 years) of the design floods. In total, there are 18 (3 climate scenarios X 2 infrastructure states X 3 return periods) scenarios to be considered.

3.2 Benefits

3.2.1 Benefit characteristics

Benefits, for the sake of this analysis are taken to be the future aggregate-level flood damage avoided by implementing flood control infrastructure improvements. The types of benefits included in this study go beyond conventional flood impact assessments that deal with direct losses only. For example, in conventional analyses of direct losses, damage to buildings is converted into monetary terms based on simple information such as flood depth and building use. Such direct impacts are limited to damage caused by physical contact of the floodwater with humans, property and other objects.

Flooding, however, interacts with the patterns of human activities in the metropolis in more complex ways. Not all tangible losses are direct, because floods not only affect structures themselves but also their contents and the activities undertaken within them. Examples of such losses are disruption of traffic and business. Such secondary impacts are damages induced by the direct impacts and may occur outside the flood event in space or time. In addition, there are intangible impacts such as health hazards. Table 3-1 itemizes the types of damage incurred by flooding.

[1] Details of the infrastructure plan as per the 1990 Master Plan depend on the return period. For example, for a return period of 30 years, the flood infrastructure scenario does not include the Marikina Dam, but the scenario for a 100-year return period does assume its completion.

Table 3-1 Tangible and Intangible Flood Losses and Damages

Form of Flood Damage or Loss	Tangible Loss		Intangible Loss (Currently not possible to measure in monetary terms)	
	Private Sector	Public Sector	Private Sector	Public Sector
Direct	• Cost of cleaning, repairing, or replacing residential, commercial, and industrial buildings, contents and land. • Cost of cleaning, repairing or replacing contents and cost of lost crops and livestock.	• Cost of repairing or replacing roads, bridges, culverts and dams. • Cost of repairing damage to stormwater systems, sanitary sewerage systems and other utilities. • Cost of restoring parks and other public places.	• Loss of life. • Health hazards. • Psychological stress endured during and after flooding.	• Disruption of normal community activities. • Loss of archaeological sites.
Indirect	• Cost of temporary evacuation and relocation. • Lost wages. • Lost production and sales. • Incremental cost of transportation. • Cost of post-flood floodproofing. • Cost of purchasing and storing flood response equipment and materials.	• Incremental costs to governmental units as a result of flood response measures. • Cost of post-flood engineering and planning studies and of implementing structural and non-structural management measures. • Cost of purchasing and storing flood response equipment and materials.	• Reluctance by individuals to inhabit flood-prone areas, thereby depreciating riverine or flood prone area property values by an unknown amount. • Psychological stress caused by possibility of future floods.	• Reluctance by business interests to continue development of flood-prone commercial and industrial areas, adversely affecting the community tax base.

Source: Adapted from Southeastern Wisconsin Regional Planning Commission (1976) and Green et al., (1983)

In this report, direct and tangible losses are first assessed, such as damage to buildings and roads. Direct impacts on public utilities such as the power supply and railways are discussed in this chapter but not included in the estimates of total damage due to difficulties in value aggregation. Indirect and tangible losses are then assessed where possible with available data. For indirect and tangible losses, this report combines the incremental cost of transportation (vehicle operating cost (VOC) and incremental time costs), lost wages and lost sales brought about by the flooding. The intangible losses (in this report, health hazards) are presented separately in the next chapter. Figure 3-1 shows the process of impact assessment in schematic form.

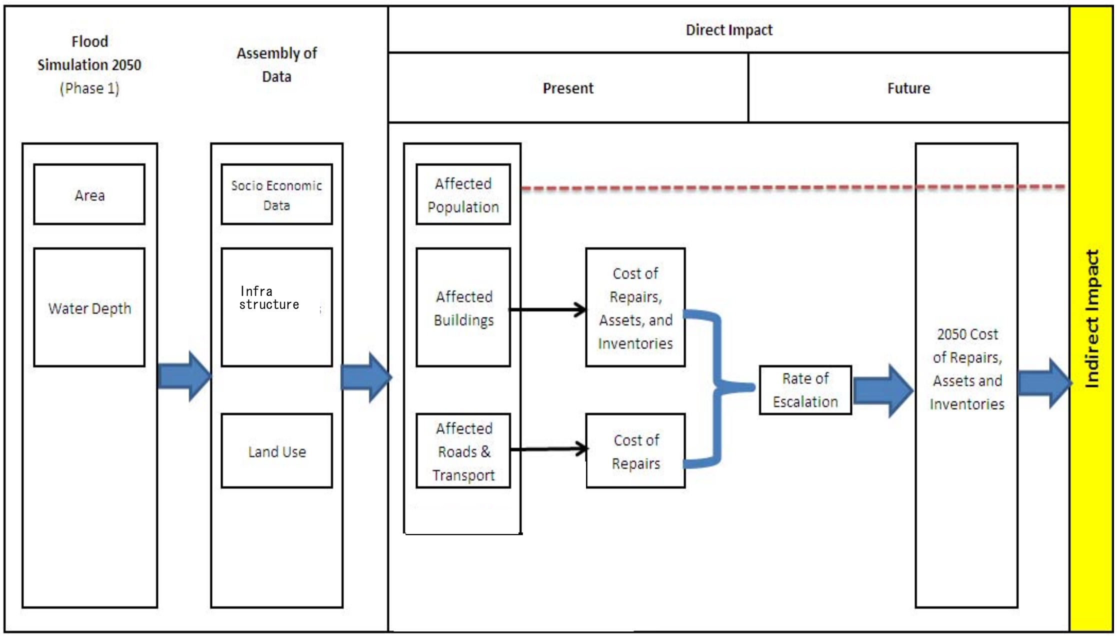


Figure 3-1 Impact Assessment Flowchart

3.2.2 Base data

This section shows the base data related to assessing direct impacts on population, buildings, the power supply, railroads, water, roads, and vehicles. The analysis relies on extensive GIS data collected as shown in the list below. The basic parameters for analyzing the impacts of climate change in the metropolis are the spatial spread, water depth, and duration of flooding, which rely heavily on GIS analysis.

Table 3-2 List of GIS Data Targeted for Collection

Field	Item	Data Collected
Electricity / Power	Generation	Location of generation facilities, boundaries, year of completion, generation volumes, cost of generation
	Distribution	Location of distribution towers, boundaries, height of towers, year of completion, distribution volume
	Transformation	Location of transformer facilities, boundaries, year of completion, throughput volume
	Distribution network, etc.	Distribution route (polyline) and coverage, materials, year installed, distribution line capacities
Transportation and Traffic	Road	Alignment, ROW and width of carriageways, height of embankments, surface materials, year of completion, traffic volume by vehicle type
	Railway[2/]	Alignment, ROW and track line, height of embankments, year completed, transport capacity
	Bridge	Location, shape line, boundaries, width, girder height, structure, material, year completed, traffic volume by vehicle type
	Port, Airport[2/], etc.	Location, boundary, year completed, number of carriers/airplanes, volume of cargo handling, number of warehouses, capacity of warehouses
Water Supply and Drainage	Purification plant	Location, boundaries, area, year completed, volume of water intake/distribution
	Water pipe	Line shape, diameter, material, year completed, elevation of pipe
	Pumping station	Location, boundaries, area, year completed, capacity
	Distribution network, etc.	Distribution route, capacity of distribution
Flood Control	Discharge channel	Line shape, year completed, material, capacity
	Pumping station	Location, boundaries, area, year completed, capacity
	Embankment	Line shape, boundary, height, thickness, type of soil
	Drainage network, etc.	Drainage route, capacity of drainage
Public health	Waste management	Location of waste management facility, boundaries, area, method of treatment, collection route, place for collection, number and capacity of collection vehicles
	Healthcare center	Location, number of beds, number of staff
	Hospital, etc.	Location, boundaries, number of beds and number of staff
Ordinal Building and Infrastructures [1/]	Industrial use	Location, utilization, electricity usage
	Commercial use	Location, utilization, electricity usage
	Residential use, etc.	Location, electricity usage
Others[1/]	Community Disaster Management Facility	Location, facility, stock on hand, capacity
	Meeting hall	Location, boundaries, capacity
	Religious facility, etc.	Location, boundaries, type, capacity

[1/] Information was collected for the flood-affected areas only.

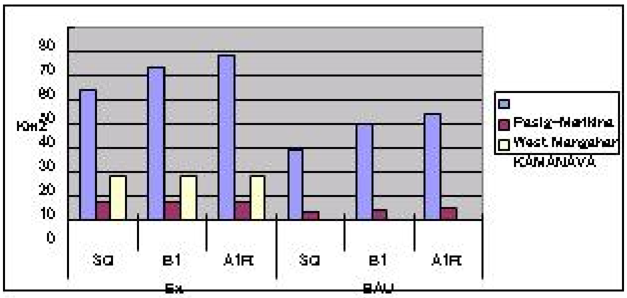
3.3 Affected area and population

3.3.1 Affected area

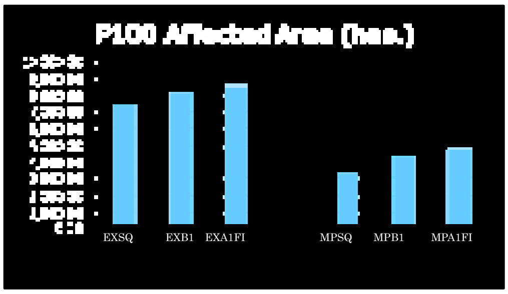
Table 3-3 shows the maximum area of inundation due to a 100-year return period flood under different climate and infrastructure conditions.

Table 3-3 Areas of Study Sites Inundated by Simulated 100-year Return Period Flood (km^2)

	Ex			MP		
	SQ	B1	A1FI	SQ	B1	A1FI
Pasig-Marikina River basin	53.73	63.19	67.97	29.14	40.09	44.14
West of Mangahan	10.65	11.09	11.42	7.79	8.16	8.3
KAMANAVA	18.24	18.24	18.24	-	-	-



(a) By site and scenario



(b) Total inundated area by scenario

Figure 3-2 Areas Inundated by 100-year Return Period Simulation

As expected, less area is affected under the MP conditions than with the current infrastructure (EX). Under the SQ, B1, and A1FI scenarios, the local government units (LGUs) in the Pasig Marikina River basin (particularly the municipalities of Manila, Mandaluyong, and Marikina) and the KAMANAVA area are more prone to floods than the West of Mangahan area, as shown in Fig. 3-3.

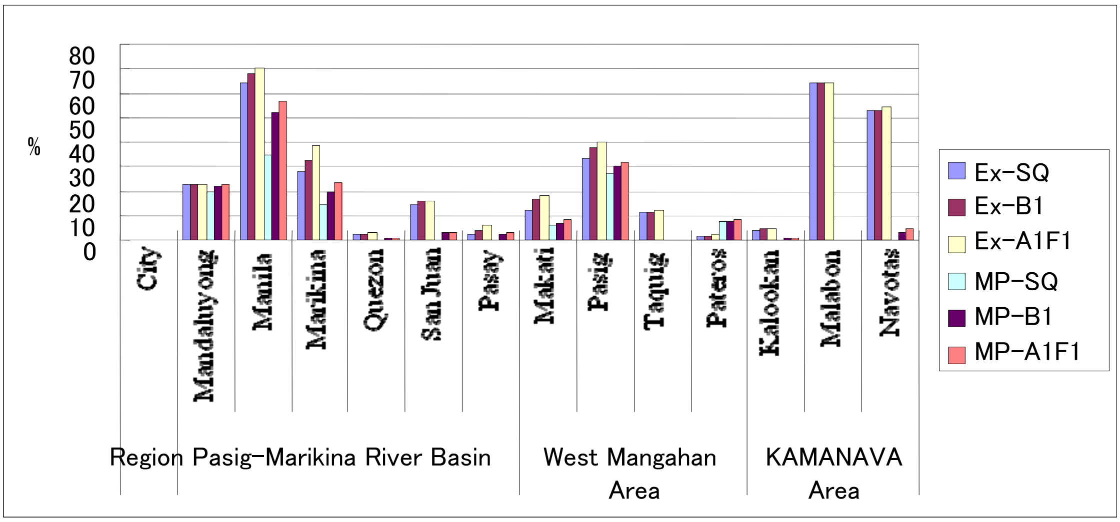
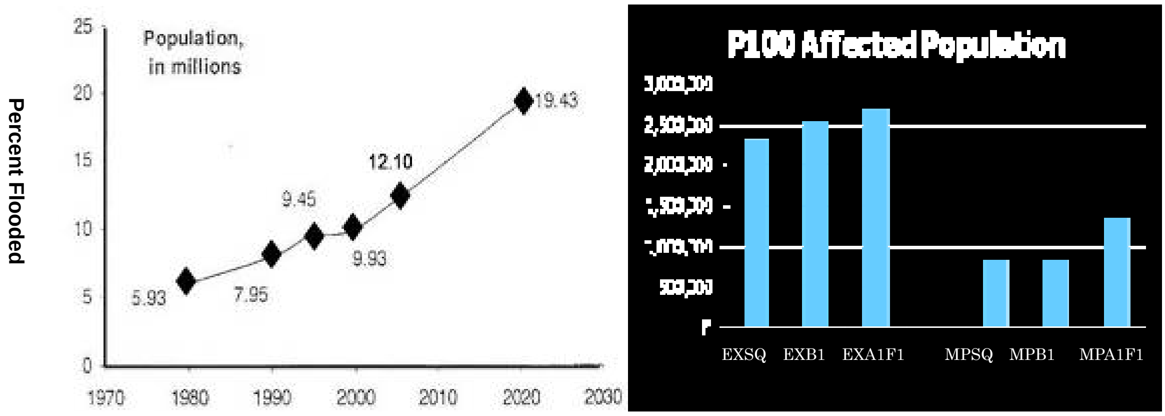


Figure 3-3 Flooding Rates of Affected Areas in Metro Manila

3.3.2 Affected Population

The population of Metro Manila has been growing rapidly, from 5.93 million in 1980 to 7.95 million in 1990 and 9.93 million in 2000.



(a) (b)

Figure 3-4 (a) Metro Manila Population Trends (1970-2020), (b) Population Affected in SQ, B1, and A1FI Scenarios for EX and MP conditions

The population of the cities and municipalities comprising the study areas are presented in Table 3-4 below.[2] In general, while the population of the Pasig-Marikina river basin is decreasing, the populations of the area West of Mangahan and the KAMANAVA area are increasing rapidly due to rapid commercialization and increased settlement. In the Pasig-Marikina River basin, all the cities' growth rates are negative, except for Marikina and Quezon, where the rates are quite high. In the cities that compose the commercial centers of Metro Manila, such as Mandaluyong, Manila, Makati, and San Juan, the population is expected to decrease. Meanwhile, in the West of Mangahan and KAMANAVA areas, population influx is taking place. The population density in Navotas is by far the highest (88,617 persons/km^2) in the national capital region. The population is expected to have increased rapidly in Taguig (52.4%) and Pasig (18%) in the area West of Mangahan and in Kalookan (24.7%) in the KAMANAVA area in the period from 2000 to 2010.

[2] Based on National Statistics Office, 2000 and Detailed Engineering Design of Pasig-Marikina River Channel Improvement Project, 2000.

Table 3-4 Changes in Population Growth Rates in Study Areas[3]

Region	City	Census Population (2007)	Population Density (persons/km^2)	Population Growth Rate (%) (1990-2000)	Population Growth Rate (%) (2000-2010)
Pasig-Marikina River basin	Mandaluyong	305,576	10,711	1.16	-0.8
	Manila	1,660,714	41,282	-0.13	-15.1
	Marikina	424,610	10,056	2.35	20.5
	Quezon	2,679,450	13,080	2.67	8.1
	San Juan	125,338	11,315	-0.75	-16.9
	Pasay	NA	NA	NA	-0.5
West of Mangahan	Makati	510,383	14,878	-0.18	-3.2
	Pasig	397,679	38,851	2.42	18.0
	Pateros	57,407*	5,520	1.11	NA
	Taguig	340,227	13,869	5.77	52.4
	Taytay	198,183*	5,108	5.83	NA
KAMANAVA	Kalookan	1,378,856*	21,104	4.43	24.7
	Malabon	363,681*	14,481	1.93	14.5
	Navotas	245,344*	88,617	2.08	10.3
	Valenzuela	568,928*	10,328	3.62	NA

(Source: National Statistics Office)

3 CTI Engineering International Co. Ltd., "Study on Climate Impact Adaptation and Mitigation in Asian Coastal Mega Cities: Case of Manila," June 2008, pp. 35-36.

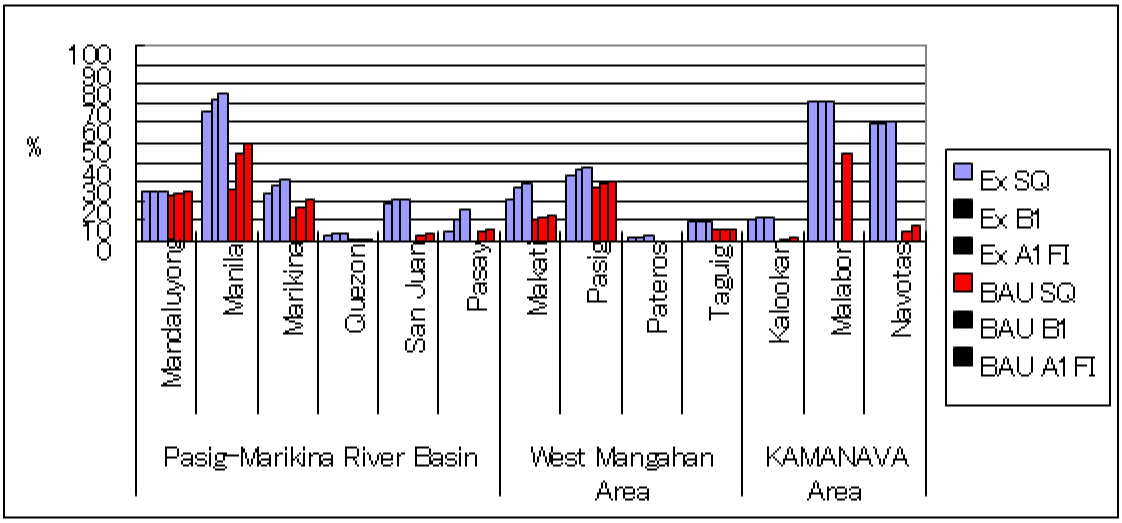


Figure 3-5 Percentages of Population Affected in Metro Manila Local Governments by 100-Year Flooding under SQ, B1, and A1FI Scenarios with EX and MP Infrastructure Conditions

Based on the affected cities' year 2007, the percentages affected by flooding were compared under the SQ, B1, and A1FI scenarios with EX and MP infrastructure conditions (Fig. 3-5). The population of Manila in the Pasig-Marikina River basin and Malabon and Navotas in the KAMANAVA area are more prone to floods than are other Metro Manila cities and municipalities.

3.4 Direct building impacts

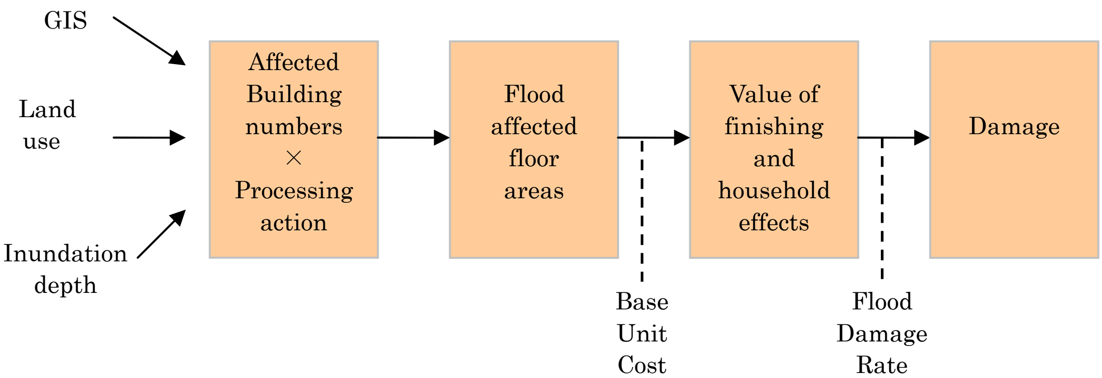


Figure 3-6 Damage to buildings: Flowchart

The authors inventoried buildings affected by flooding by building height. Structures located in areas with floodwater less than 8 inches (20cm) deep were considered for further impact estimation. Flood-affected floor areas of structures were calculated based on the buildings' footprints.

Table 3-5 Inundated Floor Areas in Metro Manila (100-Year Flood)

(Existing Infrastructure)

Climate Scenario	Land Use	Inundated Floor Areas (m^2) by Water Depth (P100, EX)									
		Water Depths with Present Land Use					Water Depths with Future Land Use				
		20 cm to 50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m	<50 cm	50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	>9 m
Status Quo	Residential	1,825,925	6,624,579	259,954	19,719	198	1,561,807	6,523,200	213,135	25,754	-
	Commercial	561,611	1,192,165	9,818	27,554	534	1,001,849	2,312,735	18,719	11,258	534
	Institutional	303,515	657,157	2,893	-	-	315,143	597,179	3,523	582	-
	Industrial	398,711	1,989,335	29,410	12,622	-	181,406	977,637	21,590	29,239	-
B1	Residential	1,488,290	9,071,261	289,572	46,598	256	850,632	8,081,618	223,221	38,021	-
	Commercial	471,270	1,624,147	14,427	27,554	15,038	1,165,249	4,059,993	31,747	2,589	15,038
	Institutional	184,700	925,930	2,893	-	-	245,698	1,102,962	2,941	582	-
	Industrial	294,114	2,655,751	26,308	10,021	-	119,962	1,064,117	21,590	27,554	-
A1FI	Residential	1,747,771	10,127,129	325,131	51,077	751	1,181,815	8,791,215	241,259	41,177	701
	Commercial	441,927	1,898,583	16,274	27,554	15,038	1,152,368	4,744,357	40,053	322	17,305
	Institutional	144,796	1,037,482	5,249	-	-	178,354	1,247,366	4,726	582	-
	Industrial	347,281	2,891,794	25,365	14,456	2,267	117,535	1,156,340	12,524	34,254	-

(As per 1990 Master Plan)[1]

Climate Scenario	Land Use	Inundated Floor Areas (m^2) by Water Depth (P100, MP)									
		Water Depths in Present Land Use					Water Depths in Future Land Use				
		20 cm to 50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m	<50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m
Status Quo	Residential	622,660	2,149,855	168,607	19,896	33	494,960	2,316,001	124,441	25,754	-
	Commercial	327,619	282,205	7,842	27,554	-	698,063	684,963	12,570	8,992	-
	Institutional	175,938	308,002	3,562	-	4,372	226,198	391,260	-	582	7,185
	Industrial	461,558	1,137,983	37,980	29,614	2,780	113,667	362,089	6,991	43,507	-
B1	Residential	927,401	2,739,498	167,638	32,306	331	622,189	2,835,434	117,667	31,875	981
	Commercial	509,926	520,704	7,151	27,554	-	1,112,457	1,284,863	15,785	8,194	-
	Institutional	225,356	421,335	1,967	-	2,893	264,368	555,860	1,786	582	5,706

Climate Scenario	Land Use	Inundated Floor Areas (m^2) by Water Depth (P100, MP)									
		Water Depths in Present Land Use					Water Depths in Future Land Use				
		20 cm to 50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m	<50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m
	Industrial	276,333	1,356,389	19,082	28,816	2,780	77,022	378,426	6,690	43,507	-
A1FI	Residential	1,048,617	3,180,302	192,363	46,678	331	711,451	3,193,996	146,915	38,267	981
	Commercial	622,941	622,237	7,151	27,554	-	1,140,501	1,445,776	15,785	8,194	-
	Institutional	276,010	475,502	1,967	-	2,893	281,583	585,019	1,786	582	2,941
	Industrial	268,455	1,600,375	19,868	27,130	15	64,407	437,330	6,690	41,822	-

[1/] No simulation for KAMANAVA area in this table

Table 3-6 Inundated Floor Areas in Metro Manila, (30-Year Flood)

(Existing Infrastructure)

Climate Scenario	Land Use	Inundated Floor Areas (m^2) by Water Depth (P30, EX)									
		Water Depths in Present Land Use					Water Depths in Future Land Use				
		20 cm- 50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m	Less than 50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m
Status Quo	Residential	1,726,740	3,640,676	137,428	3,358	165	1,292,795	3,530,545	104,768	3,520	-
	Commercial	536,294	357,341	30,011	-	534	1,220,328	965,783	10,574	2,267	534
	Institutional	236,669	313,495	2,893	-	-	217,356	420,078	6,287	-	-
	Industrial	360,007	1,089,694	27,075	4,195	-	154,410	460,389	38,422	-	-
B1	Residential	1,651,974	5,531,078	179,761	15,955	165	1,037,077	5,183,963	136,221	16,693	-
	Commercial	596,236	754,877	30,653	-	534	1,368,919	1,895,124	13,545	2,267	534
	Institutional	299,988	473,622	2,893	-	-	490,496	528,712	6,287	-	-
	Industrial	475,019	1,569,391	27,075	2,267	-	130,730	740,060	38,422	-	-
A1FI	Residential	1,621,789	6,429,553	210,206	15,824	165	931,262	5,976,304	165,568	16,562	-
	Commercial	577,434	955,035	9,550	17,877	534	1,328,662	2,409,263	17,913	-	534
	Institutional	305,820	573,724	2,893	-	-	492,204	633,285	6,287	-	-
	Industrial	352,714	1,887,437	28,056	-	-	132,764	833,619	17,319	17,877	-

(As per 1990 Master Plan)[1]

Flood Scenario	Land Use	Inundated Floor Areas (m^2) by Water Depth (P30, MP)									
		Water Depths in Present Land Use					Water Depths in Future Land Use				
		20 cm-50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m	Less than 50 cm	>50 cm to 3 m	>3 m to 6 m	>6 m to 9 m	<9 m
Status Quo	Residential	384,225	985,517	102,071	786	-	397,778	1,103,144	79,144	1,669	-
	Commercial	64,186	78,423	27,895	-	-	151,782	206,626	15,463	-	-
	Institutional	28,264	80,408	96	2,893	-	25,803	52,670	582	5,706	-
	Industrial	180,199	418,605	30,382	10,348	-	54,552	104,682	32,540	7,567	-
B1	Residential	422,999	1,400,147	116,706	6,867	-	440,441	1,491,325	84,463	11,702	-
	Commercial	166,636	145,823	28,253	-	-	253,874	328,649	15,499	322	-
	Institutional	125,858	144,530	96	2,893	-	188,324	150,673	-	6,287	-
	Industrial	283,575	572,621	18,840	22,039	-	78,998	174,730	25,839	14,268	-
A1FI	Residential	455,971	1,656,144	134,065	8,670	-	510,660	1,728,679	93,534	15,416	-
	Commercial	243,563	192,689	28,253	-	-	458,569	420,344	17,824	322	-
	Institutional	144,608	190,306	96	2,893	-	159,798	204,081	-	6,287	-
	Industrial	402,318	637,210	19,942	22,039	-	63,247	169,087	4,234	5,706	-

[1/] No simulation for KAMANAVA in this table

Assumptions for costs were derived from past infrastructure and flood studies for Metro Manila as follows:

(i) The cost of buildings is based on LGUs' recent schedule of base unit costs, which is usually less than fair market value;

(ii) The value of assets and stocks/inventories of commercial, institutional and industrial buildings is based on the National Statistics Office's data for establishments.

The base costs assigned for residential, commercial, institutional and industrial buildings are given in Table 3-7 through Table 3-10, respectively.

Table 3-7 Schedule of Base Unit Costs for Residential Buildings

(Php/mi^2)

Type*	Residential Condo		Apartment Bldg.		Single Dwelling		Duplex/ Townhouse		Boarding House		Median Construction Cost	Finishing (25%)	Household Effects (35%)
1A	15,500	16,000	12,200	12,600	9,700	10,000	8,700	9,100	7,300	7,500			
1B	14,500	15,000	11,400	11,800	9,000	9,300	8,000	8,300	6,500	6,900	9,200	2,300	4,025
1C	13,500	14,000	10,600	11,000	8,300	8,600	7,300	7,600	5,900	6,200			
IIA	11,500	12,000	9,000	6,400	6,600	7,000	5,800	6,100	4,400	4,700			
IIB	10,500	11,000	8,200	8,600	5,900	6,200	5,100	5,400	3,700	4,000	6,150	1,538	2,691
IIC	9,500	10,000	7,400	7,800	5,200	5,500	4,400	4,700	3,000	3,300			
IIIA	-	-	-	-	3,600	4,000	3,500	3,800	2,400	2,700	2,550	638	1,116

Source: Assessor's Office City of Malabon (most updated schedule of base unit cost)

Note: * **I. Reinforced Concrete** (A= structural steel and reinforced concrete columns and beams with the remainder being the same as IB; B= Columns, beams, walls, floors and roofs all reinforced concrete; C= Same as "B" but walls are hollow block reinforced concrete or the building has tile roofing); **II. Mixed Concrete** (A= Concrete columns, beams, and walls but wooden floor joists, flooring, roof framing and galvanized iron (GI) roofing even if walls are hollow concrete hollow blocks. Kitchen, toilet and bathroom are on reinforced concrete slabs; B= Concrete columns and beams but hollow block walls and GI roofing; C= Concrete columns and wooden beams, hollow block walls, wooden floor joists, floors and roof framing and GI roofing. Second floor walls are wooden.); **III. Strong Materials** (A=First grade wooden structural framing, flooring, walls, and GI roofing)

Table 3-8 Schedule of Base Unit Costs for Commercial Buildings

(Php/mi^2)

Type[1]	Commercial Bldg.		Shopping Bldg.		Theater, Convention Hall		Restaurant		Median Construction Cost	Durable Assets[2]	Stocks[2]
1A	14,200	14,700	8,500	8,900	13,200	13,700	10,700	11,000	11,100	27,750	333,000
1B	13,200	13,700	7,800	8,100	12,200	12,700	10,100	10,500			
1C	12,200	12,700	7,100	7,400	11,200	11,700	9,400	9,700			
IIA	10,200	10,700	5,600	5,900	9,200	9,700	7,800	8,100	7,750	19,375	232,500
IIB	9,200	9,700	4,800	5,300	8,200	8,700	7,400	7,700			
IIC	8,200	8,700	4,100	4,600	7,200	7,700	6,600	7,000			
IIIA							5,400	6,000	5,700	14,250	171,000

Source: Assessor's Office City of Malabon (most updated schedule of base unit cost)

[1/] **I. Reinforced Concrete** (A= Structural steel and reinforced concrete columns and beams, the remainder being the same as IB; B= Columns, beams, walls, floors and roofs all reinforced concrete; C= Same as "B" but walls are hollow block reinforced concrete or the building has tile roofing); **II. Mixed Concrete** (A= Concrete columns, beams, and walls but wooden floor joists, flooring, and roof framing and galvanized iron (GI) roofing even if walls are concrete hollow blocks. Kitchen, toilet and bathroom are on reinforced concrete slabs; B= Concrete columns and beams but hollow block walls and GI roofing; C= Concrete columns and wooden beams, hollow block walls, wooden floor joists, floors and roof framing and GI roofing. Second floor walls are wooden.); **III. Strong Materials** (A=First grade wooden structural framing, flooring, walls, and GI roofing).

[2/] Based on NSO Data on the Value of Assets per Establishment from "Pasig-Marikina River Channel Improvement Project," Volume II, DPWH, 2002

Table 3-9 Schedule of Base Unit Cost for Institutional Buildings

(Php/mi²)

Type[1]	Office Bldg		Hospitals		Schools		Church/ Chapel		Median Construction Cost	Durable Assets[2]	Stocks[2]
1A	11,800	12,200	12,700	13,100	10,100	10,400	11,400	11,800	11,000	2,970	1,100
1B	11,000	11,400	11,900	12,300	9,400	9,700	10,600	11,000			
1C	10,200	10,600	11,100	11,500	8,700	9,000	9,800	10,200			
IIA	8,700	9,100	9,100	9,500	6,900	6,500	7,900	6,300	7,500	2,025	750
IIB	7,900	8,300	8,300	8,700	6,200	6,500	7,100	7,500			
IIC	7,100	7,500	7,500	7,900	5,500	5,800	6,300	6,700			
IIIA					3,900	4,300			4,100	1,107	410

Source: Assessor's Office City of Malabon (most updated schedule of base unit cost)

[1/] **I. Reinforced Concrete** (A= Structural steel and reinforced concrete columns and beams, with the remainder being the same as IB; B= Columns, beams, walls, floors and roofs all reinforced concrete; C= Same as "B" but walls are hollow block reinforced concrete or the building has tile roofing); **II. Mixed Concrete** (A= Concrete columns, beams, and walls but wooden floor joists, flooring, and roof framing and galvanized iron (GI) roofing even if walls are concrete hollow blocks. Kitchen, toilet and bathroom are on reinforced concrete slabs; B= Concrete columns and beams but hollow block walls and GI roofing; C= Concrete columns and wooden beams, hollow block walls, wooden floor joists, floors, and roof framing and GI roofing. Second floor walls are wooden.); **III. Strong Materials** (A=First grade wooden structural framing, flooring, walls, and GI roofing).

[2/] Based NSO Data on the Value of Assets per Establishment from the "Pasig-Marikina River Channel Improvement Project," Volume II, DPWH, 2002.

Table 3-10 Schedule of Base Unit Cost for Industrial Buildings

(Php/mi^2)

Type[1]	Industrial Bldg		Warehouse		Cold Storage		Factory		Median Construction Cost	Durable Assets[2]	Stocks[2]
1A	7,200	7,500	5,700	6,000	7,800	8,000	5,900	6,200			
1B	6,500	6,800	5,000	5,700	7,100	7,400	5,200	5,500	6,050	26,620	22,990
1C	5,800	6,100	4,300	4,600	6,400	6,700	4,500	4,800			
IIA	4,300	4,600	3,400	3,700	4,900	5,200	3,800	4,100			
IIB	3,600	3,900	2,800	3,200	4,200	4,500	3,200	3,500	3,550	15,620	13,490
IIC	2,900	3,200	2,200	2,400	3,500	3,800	2,500	2,600			
IIIA			1,700	2,000			1,800	2,100	1,900	8,360	7,220

Source: Assessor's Office City of Malabon (most updated schedule of base unit cost)

1/ **I. Reinforced Concrete** (A= Structural steel and reinforced concrete columns and beams, with the remainder the same as IB; B= Columns, beams, walls, floors and roofs all reinforced concrete; C= Same as "B" but walls are hollow block reinforced concrete or the building has tile roofing); **II. Mixed Concrete** (A= Concrete columns, beams, and walls but wooden floor joists, flooring, and roof framing and galvanized iron (GI) roofing even if walls are concrete hollow blocks. Kitchen, toilet and bathroom are on reinforced concrete slabs; B= Concrete columns and beams but hollow block walls and GI roofing; C= Concrete columns and wooden beams, hollow block walls, wooden floor joists, floors, and roof framing and GI roofing. Second floor walls are wooden.); **III. Strong Materials** (A=First grade wooden structural framing, flooring, walls, and GI roofing).

2/ Based on NSO Data on the Value of Assets per Establishment from the "Pasig-Marikina River Channel Improvement Project," Volume II, DPWH, 2002

In the flood damage estimates, no building replacement costs (or construction costs) were imputed since there is no certainty that structures will be destroyed without data on the rate or strength of floodwater flow. Rather, the cost of repairing finishings and the cost of damage to assets and stocks are utilized. Moreover, conservative estimates for mixed concrete type structures (IIA, IIB, and IIC) were used in the calculations. Table 3-11 gives the applicable damage rates based on the "Manual for Economic Study on Flood Control" by the Ministry of Construction of Japan, which was cited in a recent Metropolitan Manila Development Authority drainage study.

Table 3-11 Flood Damage Rates by Building Use and Inundation Depth

Building Use	Cost Item	<50 cm	100-200 cm	200-300 cm	>300 cm
Residential	Finishings	0.0920	0.119	0.580	0.834
	Household Effects	0.1450	0.326	0.928	0.991
Business Entities[1] (Commercial, Institutional, and Industrial)	Assets	0.2320	0.453	0.966[1]	0.966
	Stocks	0.1280	0.267	0.897[1]	0.897[1]

Source: Adapted from the Manual for Economic Study on Flood Control, May 2000, Ministry of Construction (presently the Ministry of Land, Infrastructure and Transport), Japan

1/ maximum rate given is for depths of 200-299 cm. The same rates are applied to institutional and industrial entities.

Finally, damage to buildings is aggregated as follows. First, the most common flood depth of a municipality was identified based on the table of water depths and affected buildings in each local government unit. Next, damages to buildings were added up, totaling the cost of damages calculated based on land use and water depth by municipality. In doing so, damage to upper floors of buildings was not included if the flood water level did not reach those floors. Table 3-12 shows the results of these calculations for the B1 climate scenario, 100-year flood, and existing flood infrastructure.

Table 3-12 Damage to Buildings Under Climate Scenario B1 (P100, EX)

Cost Damage by Land Use by Water Depth (P100, EX, scenario B1)

LGU	Present Land Use	Cost of Damage by Land Use by Water Depth (P100,EX,scenarioB1) (Php)				
		Water Depth				
		< 50cm	> 50cm-3m	> 3m-6m	> 3m-6m	> 9m
City of Manila	Residential	458,871,983	2,218,086,727	-	-	-
	Commercial	12,829,768,532	62,934,702,340	-	-	-
	Institutional	85,211,132	779,225,777	-	-	-
	Industrial	584,334,016	7,246,785,689	-	-	-
Kalookan City	Residential	11,420,810	553,786,169	-	-	-
	Commercial	85,796,443	3,625,925,522	-	-	-
	Institutional	-	36,377,236	-	-	-
	Industrial	-	1,244,840,764	-	-	-
Makati City	Residential	51,325,762	305,509,110	-	-	-
	Commercial	317,684,124	957,244,378	-	-	-
	Institutional	4,155,136	14,835,559	-	-	-
	Industrial	82,692,396	832,063,852	-	-	-
Malabon City	Residential	12,708,866	1,940,384,831	-	-	-
	Commercial	-	5,948,445,847	-	-	-
	Institutional	-	25,682,551	-	-	-
	Industrial	-	3,817,242,409	-	-	-
Mandaluyong City	Residential	11,860,678	511,910,593	4,623,023	-	-
	Commercial	156,245,105	5,420,204,871	-	-	-
	Institutional	6,101,740	54,695,679	-	-	-
	Industrial	35,338,442	2,828,435,193	-	-	-
Marikina City	Residential	70,403,978	813,731,088	720,533,379	182,079,947	1,009,209
	Commercial	27,227,758	9,723,568,010	1,674,279,791	-	3,417,742,461
	Institutional	1,289,294	54,434,100	-	-	-
	Industrial	78,813,374	1,553,133,116	39,792,848	74,156,262	-
Navotas City	Residential	9,526,326	1,079,356,548	-	-	-
	Commercial	-	788,389,545	-	-	-
	Institutional	417,459	36,107,267	-	-	-
	Industrial	14,471,419	2,619,099,989	-	-	-
Pasay City	Residential	32,008,380	11,327,104	-	-	-
	Commercial	167,408,981	-	-	-	-
	Institutional	3,154,649	54,695	-	-	-

	Industrial	-	-	-	-	-
Pasig City	Residential	77,066,151	1,285,579,675	99,240,996	-	-
	Commercial	1,125,494,098	13,471,786,766	-	-	-
	Institutional	481,233	90,806,032	-	-	-
	Industrial	728,798,360	6,588,915,429	150,607,258	135,690,038	-
Municipality of Pate	Residential	98,698	746,602	-	-	-
	Commercial	-	-	-	-	-
	Institutional	-	-	-	-	-
	Industrial	-	-	-	-	-
Quezon City	Residential	34,227,574	554,597,131	132,353,340	1,957,280	-
	Commercial	1,264,946,203	10,527,905,103	1,543,602,532	6,262,050,639	-
	Institutional	1,290,157	35,389,087	7,755,013	-	-
	Industrial	40,027,218	1,054,449,276	524,898,586	61,632,501	-
San Juan City	Residential	9,551,284	231,211,819	24,690,726	-	-
	Commercial	168,797,336	1,679,725,537	60,894,389	-	-
	Institutional	2,402,508	36,355,740	-	-	-
	Industrial	-	561,617,611	-	-	-
Taquig City	Residential	12,239,904	111,921,467	-	-	-
	Commercial	-	-	-	-	-
	Institutional	-	-	-	-	-
	Industrial	9,200,823	10,699,152	-	-	-

3.5 Direct impact on roads and VOC

For roads and traffic, the sections of the road network (existing and planned) that are potentially affected by flooding were identified. Then, related maintenance costs on flood-affected roads and VOCs were assessed.

Floods will inundate roads and make them unusable. Water depths above 26 cm will render roads impassable to most vehicles. Table 3-13 gives the road lengths affected by flooding under existing and master plan conditions for the 100-year flood. As expected, in both cases, more roads are affected under scenario A1FI than B1, while fewer road sections are affected in the master plan conditions than with the existing infrastructure.

Table 3-13 Affected Length of Road by Inundation Depth

Existing Infrastructure	Road Length by Inundation Depth (km)						
	8-20 cm		21-50 cm		Above 50 cm		Total
	Major	Minor	Major	Minor	Major	Minor	
Status Quo	4.5	3.9	22.1	23.8	31.9	39.8	125.9
B1	5.4	9.7	13.6	15.1	47.9	55.6	147.3
A1FI	5.3	6.9	14.6	18.2	53.6	60.3	158.9

Master Plan Infrastructure	Road Length by Inundation Depth (km)						
	8-20 cm		21-50 cm		Above 50 cm		Total
	Major	Minor	Major	Minor	Major	Minor	
Status Quo	3.78	4.33	6.40	10.45	7.45	13.42	45.82
B1	7.24	8.15	9.54	15.73	12.07	20.82	73.55
A1FI	9.45	9.05	12.62	16.28	14.97	25.63	87.99

Table 3-18 lists the flooding effects on the future Metro Manila transportation network envisioned in the transportation Master Plan of the Metro Manila Urban Transportation Integration Study (MMUTIS) under existing and planned flood infrastructure conditions.

Table 3-14 Future Road Network Affected Under SQ, B1, and A1FI Scenarios (EX and MP Conditions)

(Status Quo)

	Affected Length (SQ Scenario)(km)						Total Length(km)	
	Depth 0.08 m-0.20 m		Depth 0.21 m-0.50 m		Depth above 0.51 m			
	Commited	Proposed	Commited	Proposed	Commited	Proposed	Commited	Proposed
Road	-	0.25	-	1.33	-	3.91	-	5.48
Rail	2.50	-	5.37	-	6.08	-	13.95	-
Expressway	-	0.45	0.24	1.48	4.20	5.14	4.44	7.07

(B1)

	Affected Length (B1 Scenario)(km)						Total Length(km)	
	Depth 0.08 m-0.20 m		Depth 0.21 m-0.50 m		Depth above 0.51 m			
	Commited	Proposed	Commited	Proposed	Commited	Proposed	Commited	Proposed
Road	-	1.01	-	1.20	-	5.18	-	7.39
Rail	2.66	0.04	5.03	0.35	9.57	-	17.26	0.39
Expressway	-	1.83	-	1.35	4.44	6.03	4.44	9.21

(A1F1)

	Affected Length (A1FI Scenario)(km)						Total Length(km)	
	Depth 0.08 m-0.20 m		Depth 0.21 m-0.50 m		Depth above 0.51 m			
	Commited	Proposed	Commited	Proposed	Commited	Proposed	Commited	Proposed
Road	-	1.00	-	1.16	-	5.82	-	7.98
Rail	1.46	-	6.64	0.22	10.53	0.27	18.63	0.49
Expressway	-	0.68	0.08	2.79	4.44	7.14	4.52	10.61

1/Based on MMUTIS Transport Network

3.5.1 Maintenance Cost of Flood-Affected Roads

Basic assumptions for calculating the maintenance costs of flood-affected roads were derived from road feasibility studies done by the Department of Public Works and Highways (DPWH), which deals with asphalt and concrete pavement on generally flat terrain. In these conditions, routine maintenance cost is set at 50,000 Php/km while periodic maintenance cost is 972 Php/vehicle unit. This study determined the total length of major and minor roads that will be affected by floods brought about by 30- and 100-year return period flooding, (Tables 3-15 and 3-16) but traffic volumes were only established for major roads. Annual Average Daily Traffic (AADT) on those roads was converted to Vehicle Units using DPWH factors as shown in Table 3-17.

Table 3-15 Present Network Roads Affected by 100-Year Flooding by LGU (km)

	LGU	Depth: 8-20cm		Depth: 21-50cm		Depth: Above50cm		Total		
		Major	Minor	Major	Minor	Major	Minor	Major	Minor	Total
Status Quo	Marikina			0.05		0.23		0.28	0	0.28
	Pasig	0.29	0.32	1.55	2.56	3.26	3.26	5.1	6.14	11.24
B1	Marikina	0.12	0.62	0.09	2.03	0.28		0.49	2.65	3.14
	Pasig	0.21	0.45	2.11	1.49	4.85	5.35	7.17	7.29	14.46
A1F1	Marikina	0.29	0.44	0.76	2.32	0.34	0.73	1.39	3.49	4.88
	Pasig	0.52	0.18	1.87	0.74	5.5	6.55	7.89	7.47	15.36

Table 3-16 Present Network Roads Affected by 30-Year Flooding by LGU (km)

	LGU	Depth: 8-20cm		Depth: 21-50cm		Depth:Above50cm		Total		
		Major	Minor	Major	Minor	Major	Minor	Major	Minor	
Status Quo	Marikina					0.13		0.13	0	0.13
	Pasig	0.39	0.2	0.84	0.31	0.97	0.32	2.2	0.83	3.03
B1	Marikina					0.13		0.13	0	0.13
	Pasig	0.73	1.42	1.11	1.19	1.66	0.63	3.5	3.24	6.74
A1F1	Marikina	0.1				0.13		0.23	0	0.23
	Pasig	0.44	0.84	1.75	2.58	2.18	1.15	4.37	4.57	8.94

Table 3-17 DPWH Traffic Conversion Factors

Vehicle Type	Vehicle Unit Equivalent
Car/Van/Pick-up	0.4
Jeepney	0.7
Tricycle	0.2
Buses and Trucks	2.5

The total maintenance cost is given by:

MC = L* RMC + VU*PMC,

Where: MC — Maintenance Cost

L — Total length of flood-affected roads(in km)

RMC — Routine maintenance cost/km

VU — Total Vehicle Units

PMC — Periodic maintenance cost/VU

3.5.2 Vehicle Operating Cost

Vehicle operating cost (VOC) is based on vehicles' running cost, fixed cost, and time cost. It can be measured either in cost per distance (Peso/km) or cost per time (Peso/hour) of vehicle operation. VOC increases when vehicles traverse roads in bad condition, including flooded roads. The time element is disregarded since there is no available information on alternate routes used to avoid flooded areas. Table 3-18 shows the Inundation Unit Cost for vehicles in Metro Manila.

Table 3-18 Inundation Unit Cost for Vehicles in Metro Manila

Road Condition	Public Mode (Peso/km/vehicle)	Private Mode (Peso/km/vehicle)
Good/Fair	9,614	11,795
Inundated(Bad)	14,316	16,962
Incremental Flooding Cost	4,702	5,167

The annual VOC on roads with good to fair condition can be calculated as:

$TVOC_G = \{(AADT_{Pb} * VOC_{GPb}) + (AADT_{Pr} * VOC_{GPr})\} * L * 365$ days,

Where:

$TVOC_G$ – Total vehicle operating cost(good condition)

$AADT_{Pb}$ – Public vehicle traffic (in AADT)

VOC_{GPb} – VOC – public mode, good condition

$AADT_{Pr}$ – Private vehicle traffic (in AADT)

VOC_{GPr} – VOC – private mode, good condition

L – Length of road (km)

The total VOC on roads during flooded days can be computed as:

$TVOC_B = \{(AADT_{Pb} * VOC_{BPb}) + (AADT_{Pr} * VOC_{BPr})\} * L * NF$,

Where:

$TVOC_B$ – Total vehicle operating cost(good condition)

$AADT_{Pb}$ – Public vehicle traffic (in AADT)

VOC_{BPb} – VOC – public mode, good condition

$AADT_{Pr}$ – Private vehicle traffic (in AADT)

VOC_{BPr} – VOC – private mode, good condition

L – Length of road (km)

NF – Number of flooded days in a year

Damage attributable to VOC is the difference between $TVOC_G$ and $TVOC_B$

3.6 Indirect impact on travel time

Another impact of inundated roads can be translated into travel delay costs, which are the product of extra time spent traveling multiplied by unit costs. Travel time unit costs vary depending on the type of trip, travel conditions, and traveler preferences as shown in Fig. 3-7.[4]

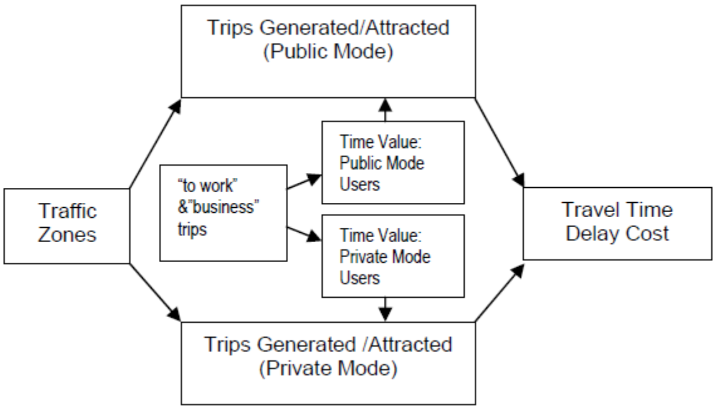
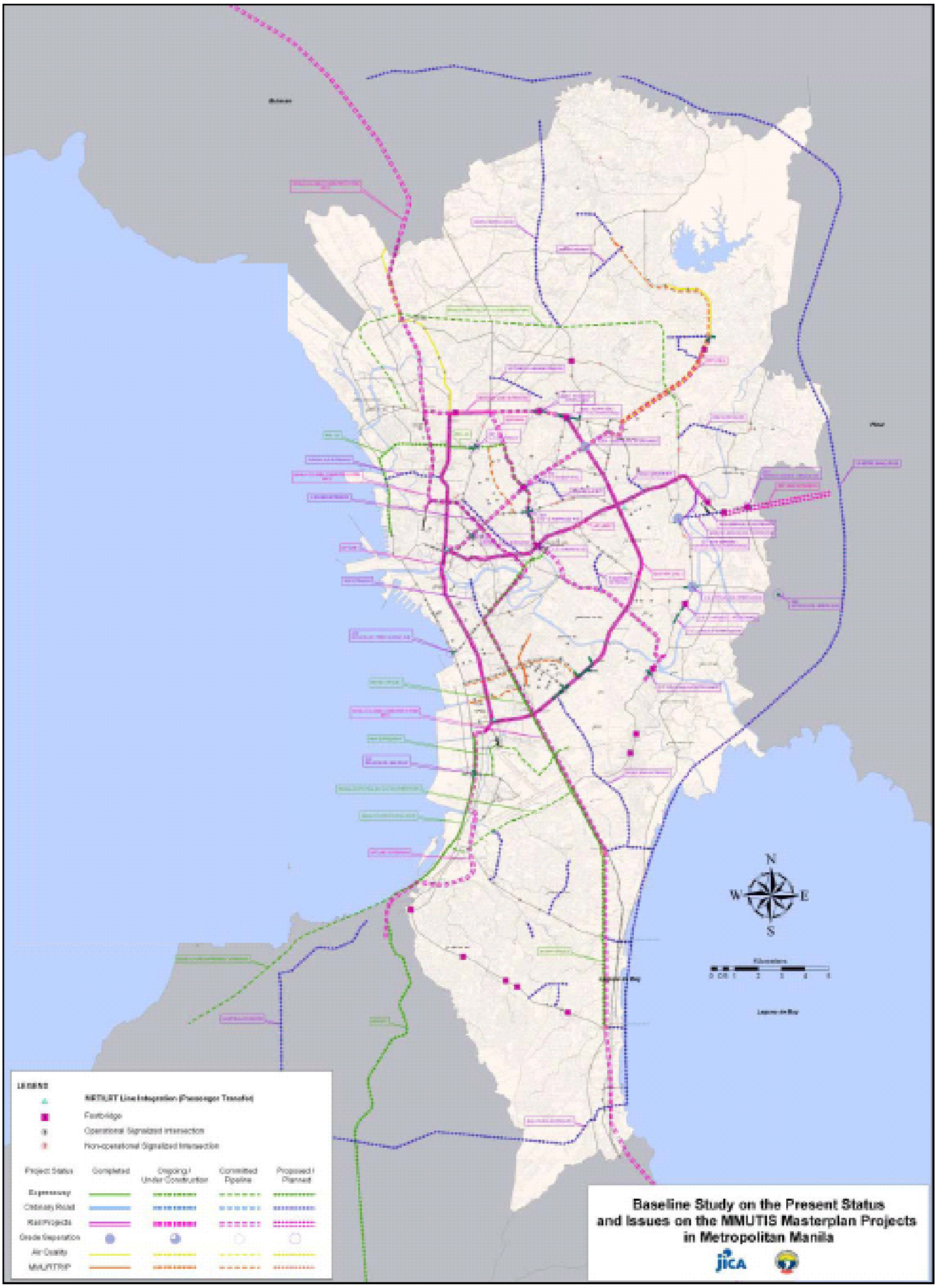


Figure 3-7 Travel Delay Costs

Figure 3-8 below illustrates the transportation infrastructure master plan for Metro Manila, on which travel time delay calculations were based.

[4]Kenneth Small, Cliford Winston, and J. Yan, "Uncovering the Distribution of Motorists' Preferences for Travel Time and Reliability: Implications for Road Pricing," University of Irvine, 2005. retrieved at <www.socsci.uci.edu/~ksmall/Value%20of%20time%20note.pdf.>



Source: MMDA-JICA Baseline Study on the Present Status and Issues on the MMUTIS Master plan

Figure 3-8 Metro Manila Transportation Infrastructure, 2015

There are two ways to quantify time costs. The first starts with the number of passengers counted at the roadside during the 1999 MMUTIS. The number of road trips in the metropolis was recorded during the 1999 MMUTIS based on a metropolis-wide Person Trip Survey. This information allowed trip data by transportation mode for each LGU zone to be created. Table 3-19 gives the number of trips generated and attracted to each LGU by public and private transportation modes.

Table 3-19 Trips Generated and Attracted by LGU, 1999

LGU	Generation			Attraction		
	Public Mode[1]	Private Mode[2]	Total Trips	Public Mode[1]	Private Mode[2]	Total Trips
City of Manila	2,107,588	803,715	2,911,303	2,123,166	798,571	2,921,737
Kalookan City	1,119,707	249,607	1,369,314	1,116,425	245,808	1,362,233
Las Piñas City	473,072	128,461	601,533	468,587	128,523	597,110
Makati City	804,786	474,891	1,279,677	810,382	463,654	1,274,036
Malabon City	365,452	84,032	449,484	362,822	89,222	452,044
Mandaluyong City	451,882	169,308	621,190	448,586	157,830	606,416
Marikina City	349,082	146,314	495,396	346,093	150,925	497,018
Muntinlupa City	544,349	117,259	661,608	539,842	122,818	662,660
Navotas City	192,807	50,049	242,856	188,634	52,295	240,929
Parañaque City	483,152	269,687	752,839	478,343	285,485	763,828
Pasay City	517,955	185,027	702,982	514,495	186,419	700,914
Pasig City	568,051	282,966	851,017	567,986	286,429	854,415
Pateros	65,940	8,884	74,824	65,012	12,069	77,081
San Juan City	118,930	70,968	189,898	116,865	73,748	190,613
Quezon City	2,906,580	1,239,448	4,146,028	2,912,567	1,225,501	4,138,068
Taguig City	394,253	60,536	454,789	400,295	61,093	461,388
Valenzuela City	496,615	243,127	739,742	493,927	241,251	735,178
Total	11,960,201	4,584,279	16,544,480	11,954,027	4,581,641	16,535,668

1/ Public mode includes Train, Bus, Jeepney, and Tricycle.
2/ Private mode includes Car, Taxi, Truck, and Others.
Source: MMUTIS

Passengers are classified into those using public and private transportation, with the modal share being determined by household income based on data collected in the 1999 person-trip survey. The average income of public mode users, which was calculated to be P45.45/hour, was multiplied by the counted number of public mode passengers to obtain their aggregate travel time cost per hour. The travel time delay cost for private mode users, on the other hand, is better ascertained based on their perceived time value, which was estimated to be P81.30/hour based on an interview survey conducted in 2002.[5] Trips with financial bearing are generally made by income-earning individuals. These trips can be derived from the MMUTIS data on "to work" and "business" purpose trips tabulated by the Person Trip Survey. Considering this information, the number of trips can further be refined, resulting in 14 percent of total public trips and 5 percent of private trips being classified as "to work" and "business" trips.

Table 3-20 shows the year 2002 per-hour time values of trip makers. It should be noted that not all flood-affected areas had roadside traffic counts and therefore cost changes determined by this method cannot be directly related to flooding scenarios.

5 JICA-DPWH, "The Development of the Public-private Partnership Technique for the Metro Manila Urban Expressway Network," March, 2002.

Table 3-20 Time Value of Trip Makers (Pesos/hour)

Mode Type	2002 Php/hr
Private	81.30
Public	45.45

Table 3-21 Passengers' Travel Delay Costs Based on 1999 Roadside Counts

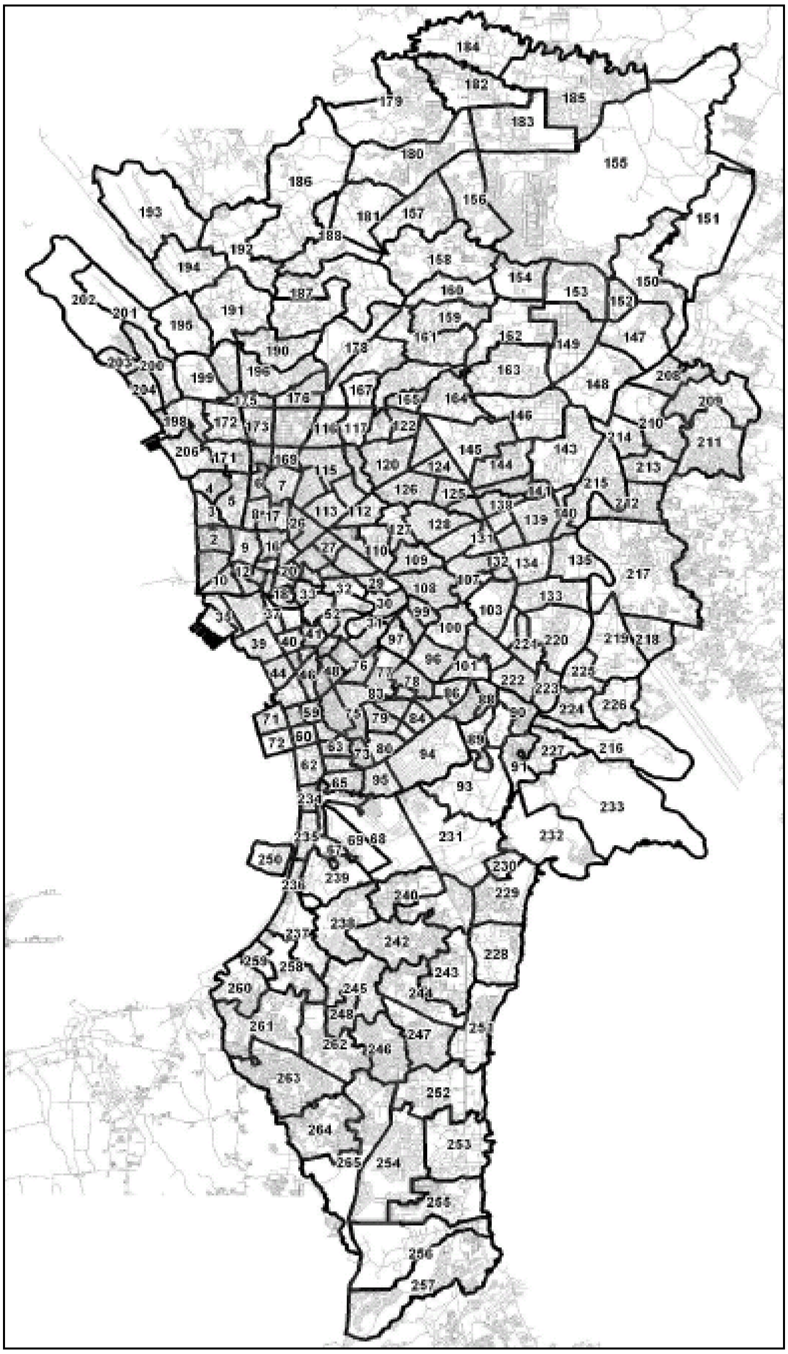
(Php / hour)

City	No. of Trips		Cumulative Travel Time Delay Cost (per hour)	
	Public Mode	Private Mode	Public Mode	Private Mode
Manila	1,045,199	804,406	9,500,859	13,079,642
Quezon City	990,984	534,542	9,008,045	8,691,653
Makati	595,196	426,961	5,410,332	6,942,386
Mandaluyong	441,798	247,367	4,015,944	4,022,187
Marikina	115,169	77,803	1,046,886	1,265,077
Pasig	233,418	157,591	2,121,770	2,562,430
San Juan	108,698	104,849	988,065	1,704,845
Total	**3,530,462**	**2,353,519**	**32,091,900**	**38,268,219**

Source: MMUTIS

In this regard, the second method of quantifying costs, which relates to the area's traffic zones (Fig. 3-9) and the number of generated and attracted trips recorded during the MMUTIS, is useful. Its area-based method grasps the transportation conditions better, as all inundated areas are overlain on traffic zones used in past transport studies.[6] Traffic zones and their corresponding trips are segmented into 265 zones in the MMUTIS, which are converted to the 185 zoning system of the Public-Private Partnership of the Metro Manila Urban Expressway Network (PPP-MMUEN).

[6] JICA, JICA Update of Manila Studies of Urban Transport (JUMSUT, 1984), MMUTIS (1999), and PPP-MMUEN (2003). Traffic zones and their corresponding trips are given in Appendix 5.3.1 in terms of the 265 zoning system in MMUTIS converted to the 185 zoning system of PPP-MMUEN



Source: JICA-MMUTIS 1999

Figure 3-9 Traffic Zones in Metro Manila

This report adopts the second method in quantifying travel delay costs.[7] The private-mode trips generated by and attracted to the zones are summed up for each city and refined considering only the income-earning trip-makers. Using the travel time values given in Table 3-20 and the number of trips, the cumulative travel time delay cost is calculated for 2002 for all flood scenarios.

Cumulative travel time delay costs (per hour) in Metro Manila for the SQ, B1, and A1FI scenarios with

[7] JICA studies: JUMSUT in 1984, MMUTIS in 1999, and PPP-MMUEN in 2003.

both existing and master plan conditions are summarized below. The number of hours the effects will span was estimated from flood duration data to obtain the aggregate time delay cost.

3.7 Affected residents' income loss

3.7.1 Formal residents

The number of residents or households affected by floods is difficult to measure. However, the number of residential buildings affected can be counted. Hence, the number of households was assumed based on the number of buildings. The incomes were based on the per capita income data from the National Statistics Office (NSO).

Table 3-22 gives the flood-affected residential buildings below 12 meters in height in each local governmental unit. 1.5 families were assumed for each of these residential building. Formal residents were calculated by multiplying the number of affected residential buildings by 1.5 families and 750 Philippine Pesos per day, which is the 2002 per capita household income. Figures for 2008 and 2050 are derived by applying 5% growth per year.

Table 3-22 Flood-Affected Residential Buildings (P100, EX, SQ)

(100-Year Flooding, Status Quo Climate, Existing Infrastructure)

LGU	Flood-Affected Buildings
	Less Than 12 m Tall
City of Manila	66,057
Kalookan City	9,356
Makati City	7,593
Malabon City	32,876
Mandaluyong City	6,227
Marikina City	12,721
Navotas City	23,384
Pasay City	953
Pasig City	19,059
Municipality of Pateros	20
Quezon City	6,600
San Juan City	2,102
Taguig City	4,104
Total	191,052

3.7.2 Informal Residents

Table 3-23 gives the number of affected informal residential structures and income loss per day from each local governmental unit. Two families are assumed per structure. The number of informal settlers was calculated by multiplying the number of affected informal residential structures by 2 families and 266 Philippine Pesos per day, which is poverty threshold household income based on National Statistical Coordination Board (NSCB) data. Figures in 2008 and 2050 are derived by applying 5% growth per year.

Table 3-23 Informal Residents' Income Loss (P100, EX)

(100-Year Flooding, Existing Infrastructure)

LGU	Daily Income Loss to Informal Residents					
	Status Quo Flood Level		B1 Flood Level		A1FI Flood Level	
	Number of Structures	Income Loss/ day (Php)	Number of Structures	Income Loss/ day (Php)	Number of Structures	Income Loss/ day (Php)
City of Manila	2,620	1,393,840	4,063	2,161,516	4,294	2,284,408
Kalookan City	1,864	991,648	1,870	994,840	1,871	995,372
Makati City	1	532	1	532	1	532
Malabon City	2,425	1,290,100	2,425	1,290,100	2,425	1,290,100
Mandaluyong City	8	4,256	8	4,256	8	4,256
Marikina City	-	-	-	-	-	-
Navotas City	2,712	1,442,784	2,712	1,442,784	2,712	1,442,784
Pasay City	249	132,468	299	159,068	349	185,668
Pasig City	97	51,604	150	79,800	245	130,340
Municipality of Pateros	-	-	-	-	-	-
Quezon City	1,393	741,076	1,403	746,396	1,416	753,312
San Juan City	5	2,660	5	2,660	5	2,660
Taguig City	-	-	-	-	-	-
Total	11,374	6,050,968	12,936	6,881,952	13,326	7,089,432

3.8 Income (sales) loss to affected firms

A 2008 survey conducted by the NSO on the Income of Flood Affected Firms provided information on business income (sales) losses due to past floods. Income loss was approximated by loss in sales, as it is difficult to identify the cost of sales. The income losses were averaged by economic activity and multiplied by the number of buildings by use. The results are shown in Table 3-24. The building counts included the number of floors and the assumption was made of one firm per floor. Table 3-25 gives the estimated income losses incurred by firms

Table 3-24 Income (Sales) Losses by Number of Employees

Sector	Average Income Loss				
	All	Number of Employees per Firm			
		10-19	20-49	50-99	100 <
Total	459,780	3,205,583	345,000	1,630,417	2,308,824
Manufacturing	513,611	623,333	206,250	159,167	1,158,824
Construction	242,857	-	50,000	800,000	-
Wholesale /Retail Trade; Repair Services	253,571	-	30,000	228,750	800,000
Hotels and Restaurants	121,250	70,000	53,750	150,000	250,000
Transport, Storage and Communications	816,357	2,512,250	5,000	292,500	50,000
Financial Intermediation	-	-	-	-	-
Health and Social Work	50,000	-	-	-	50,000

Table 3-25 Income (Sales) Losses by Climate Scenario (Php)

Economic Activity	P30			P100		
	Status Quo	B1	A1Fi	Status Quo	B1	A1Fi
Commercial	235,869,171	315,841,154	339,832,748	435,028,313	488,021,795	537,161,205
Industrial	539,710,329	941,771,542	1,096,354,644	1,505,431,365	1,476,401,675	1,573,651,138
Institutional	13,875,000	14,925,000	15,600,000	22,824,071	28,397,679	32,147,679
Transport/Utilities	-	-	-	-	-	-
Total	789,454,500	1,272,537,695	1,451,787,392	1,963,283,749	1,992,821,148	2,142,960,022

3.9 Summary tables

Finally, we show the tables for "damage cost"(Tables 3-26 to 28) as well as "avoided damage" (Tables 3-29 to 31). The latter refers to the damage that can potentially be reduced by adaptation measures.

Table 3-26 Damage assessment (2008 Php): 100-year return period

Cost in 2008 Pesos		SQ EX	SQ MP	B1 EX	B1 MP	A1FI EX	A1FI MP
Damage to buildings	Residential	3,688,647,788	1,045,670,772	6,022,893,816	1,326,288,039	7,517,544,912	2,101,690,472
	Commercial	37,699,327,245	15,298,341,749	63,871,514,594	25,506,211,401	68,021,524,157	37,713,082,264
	Institutional	298,785,692	158,994,559	485,447,235	173,893,911	1,874,981,233	253,765,175
	Industrial	8,650,623,155	5,694,313,706	16,556,719,073	5,532,356,399	17,850,618,995	9,193,023,327
Maintenance cost on flood affected roads	Current roads	8,143,240	3,010,272	9,677,159	4,831,659	10,443,791	5,780,183
	Future roads	360,001	360,001	485,467	485,467	524,226	524,226
VOC		50,729,576	22,855,337	62,246,103	36,684,130	68,001,872	43,885,751
Travel time cost		706,986,380	277,477,558	1,082,134,984	197,675,748	1,420,426,406	340,173,579
Firms' loss of business	Assets (this is already included in damages to buildings)						
	Sales	13,403,412,143	6,567,976,899	14,085,687,162	7,745,705,319	14,639,854,088	8,339,388,091
Residents' income loss	Formal residents	214,933,500	67,473,375	230,942,250	95,140,125	481,092,750	105,586,875
	Informal residents	6,050,968	584,668	6,881,952	1,247,540	7,089,432	2,091,824
Total		64,727,999,688	29,137,058,896	102,414,629,796	40,620,519,739	111,892,101,862	58,098,991,768

2008 METRO Manila GRDP

468,382,396,000	*Source: National Statistical Coordination Board

		SQ EX	SQ MP	B1 EX	B1 MP	A1FI EX	A1FI MP
% of GRDP		14%	6%	22%	9%	24%	12%

EX: Existing infrastructure, MP: Continuing 1990 Master plan

Table 3-27 **Damage assessment (2008 Php): 30-year return period**

Cost in 2008 in Pesos		P30 SQ EX	P30 SQ MP	P30 B1 EX	P30 B1 MP	P30 A1FI EX	P30 A1FI MP
Damage to buildings	Residential	1,802,689,882	399,849,739	3,660,228,253	549,439,668	4,210,760,389	637,339,590
	Commercial	22,710,938,518	2,273,492,105	35,692,199,142	7,069,333,943	39,538,199,655	10,143,817,110
	Institutional	158,250,637	23,533,947	270,248,699	85,001,479	334,199,868	96,920,697
	Industrial	4,216,676,982	1,330,430,240	9,932,796,023	2,657,311,465	11,606,388,976	3,456,942,255
Maintenance cost on flood affected roads	Current road	5,286,655	1,102,956	6,846,841	1,937,811	7,482,737	2,313,418
	Future road	244,376	244,376	302,185	302,185	329,119	329,119
VOC		40,138,658	8,374,141	51,984,296	14,712,729	56,812,303	17,564,506
Travel time cost		374,633,321	31,760,926	421,032,785	74,184,136	573,888,428	85,170,808
Firms' loss of business	Assets (this is already included in damages to buildings)						
	Sales	10,756,786,447	3,281,670,824	11,832,564,006	4,515,810,393	12,434,679,407	5,075,470,880
Residents income loss	Formal residents	93,848,625	39,640,500	184,246,875	49,636,125	196,321,500	51,926,625
	Informal residents	4,731,076	92,036	5,367,880	111,188	5,750,388	118,636
Total		40,164,225,177	7,390,191,790	62,057,816,985	15,017,781,123	68,964,812,770	19,567,913,643

2008 METRO Manila GRDP							
468,382,396,000	*Source: National Statistical Coordination Board						
% of GRDP		9%	2%	13%	3%	15%	4%

EX: Existing infrastructure, MP: Continuing 1990 Master plan

Table 3-28 **Damage assessment (2008 Php): 10-year return period**

Cost in 2008 in Pesos		P10 SQ EX	P10 SQ MP	P10 B1 EX	P10 B1 MP	P10 A1FI EX	P10 A1FI MP
Damage to buildings	Residential	785,486,988	320,880,033	842,295,372	491,606,130	595,395,243	546,225,294
	Commercial	8,641,501,748	610,789,400	9,658,314,207	1,611,046,487	13,750,520,244	2,326,289,074
	Institutional	66,863,814	20,189,999	91,707,535	37,209,916	96,826,650	37,268,296
	Industrial	2,890,401,496	1,173,449,757	2,414,697,965	1,461,799,749	1,756,641,760	1,346,409,219
Maintenance cost on flood affected roads	Current road	1,162,100	346,199	1,587,787	463,132	2,632,955	543,277
	Future road	44,014	30,219	44,014	31,532	91,969	38,102
VOC		8,823,186	2,628,501	12,055,195	3,516,306	19,990,575	4,124,802
Travel time cost		33,199,847	8,380,787	45,754,992	11,655,307	71,672,669	13,646,330
Firms' loss of business	Assets (this is already included in damages to buildings)						
	Sales	2,816,137,180	2,704,662,851	2,961,770,824	2,822,212,152	3,044,628,088	2,881,793,868
Residents' income loss	Formal residents	32,629,500	20,444,625	49,763,250	26,401,500	49,437,000	29,098,125
	Informal residents	85,652	51,072	151,620	51,072	255,892	72,352
Total		15,276,335,523	4,861,853,444	16,078,142,760	6,465,993,284	19,388,093,046	7,185,508,737

2008 METRO Manila GRDP

468,382,396,000 *Source: National Statistical Coordination Board

% of GRDP	3%	1%	3%	1%	4%	2%

EX: Existing infrastructure, MP: Continuing 1990 Master plan,

Table 3-29 Gross summary of costs used to calculate EIRR/NPV by adaptation option: P100*

Cost in 2008 in Pesos		P100 SQ EX	P100 SQ MP	P100 B1 EX	P100 B1 MP	P100 A1FI EX	P100 A1FI MP
Damage to buildings	Residential	2,032,678,209	1,045,670,772	3,581,994,723	1,326,288,039	4,938,356,848	2,101,690,472
	Commercial	33,658,358,514	15,298,341,749	56,812,993,791	25,506,211,401	60,548,031,143	37,713,082,264
	Institutional	265,215,324	158,994,559	419,111,179	173,893,911	1,804,114,489	253,765,175
	Industrial	5,098,786,299	5,694,313,706	11,390,565,953	5,532,356,399	12,481,231,557	9,193,023,327
Maintenance cost on flood affected roads	Current road	7,971,703	3,736,418	9,912,070	5,940,825	10,906,505	7,051,890
	Future road	434,377	434,377	603,324	603,324	668,553	668,553
VOC		50,729,576	22,855,337	62,246,103	36,684,130	68,001,872	43,854,503
Travel time cost		24,425,094	6,777,512	27,511,321	10,015,447	29,685,666	13,027,249
Firms' loss of business	Assets (this is already included in damages to buildings)						
	Sales	9,783,823,274	6,567,976,899	10,275,458,777	7,630,789,127	10,744,074,387	8,076,336,098
Residents' income loss	Formal residents	705,577,500	236,156,813	781,020,000	280,705,500	1,097,884,125	413,874,000
	Informal residents	11,632,180	2,046,338	15,771,140	3,661,224	21,847,644	5,192,320
Total		51,857,476,996	29,109,794,526	83,647,021,228	40,603,026,930	92,141,704,102	57,981,565,022

*Excludes KAMANA (Kalookan City, Malabon City, and Navotas City)

P100: 100-year return period flooding, EX: Existing infrastructure, MP: Continuing 1990 Master plan

Table 3-30 Gross summary of costs used to calculate EIRR/NPV by adaptation option: P30*

Cost in 2008 in Pesos		P30 SQ EX	P30 SQ MP	P30 B1 EX	P30 B1 MP	P30 A1FI EX	P30 A1FI MP
Damage to buildings	Residential	1,202,929,707	399,849,739	1,771,762,946	549,439,668	1,959,651,541	637,339,590
	Commercial	20,932,089,898	2,273,492,105	30,719,386,579	7,069,333,943	32,989,928,809	10,143,817,110
	Institutional	143,657,338	23,533,947	229,101,560	85,001,479	274,926,260	96,920,697
	Industrial	3,077,487,378	1,330,430,240	5,931,104,691	2,657,311,465	6,805,462,975	3,456,942,255
Maintenance cost on flood affected roads	Current roads	4,529,898	1,301,698	6,348,277	2,370,511	7,163,107	2,890,857
	Future roads	286,073	286,073	350,715	350,715	390,884	390,884
VOC		29,783,652	8,374,141	41,028,315	14,712,729	45,856,321	17,564,506
Travel time cost		21,013,412	2,973,744	12,842,005	4,939,334	13,602,174	4,901,852
Firms; loss of business	Assets (this is already included in damages to buildings)						
	Sales	7,408,308,883	3,281,670,824	8,084,550,478	4,515,810,393	8,686,665,879	5,075,470,880
Residents' income loss	Formal residents	187,697,250	79,281,000	166,826,250	74,454,188	492,358,500	103,853,250
	Informal residents	2,139,704	184,072	2,477,790	166,782	8,137,472	237,272
Total		33,009,923,195	7,401,377,583	46,965,779,605	14,973,891,206	51,284,143,921	19,540,329,151

*P30: Exclude KAMANA (Kalookan City, Malabon City, and City, and Navotas City)

P30: 30-year return period flooding, EX: Existing infrastructure, MP: Continuing 1990 Master plan

Table 3-31 Gross summary of costs used to calculate EIRR/NPV by adaptation option: P10*

Cost in 2008 in Pesos		P10 SQ EX	P10 SQ MP	P10 B1 EX	P10 B1 MP	P10 A1FI EX	P10 A1FI MP
Damage to buildings	Residential	0	0	0	0	0	0
	Commercial	0	0	0	0	0	0
	Institutional	0	0	0	0	0	0
	Industrial	0	0	0	0	0	0
Maintenance cost on flood affected roads	Current roads	0	0	0	0	0	0
	Future roads	0	0	0	0	0	0
VOC		0	0	0	0	0	0
Travel time cost		0	0	0	0	0	0
Firms' lost business	Assets (this is already included in damages to buildings)						
	Sales	438,472,844	326,998,515	584,106,488	444,547,816	666,963,752	504,129,532
Residents' income loss	Formal settlers	48,944,250	30,666,938	74,644,875	39,602,250	74,155,500	43,647,187
	Informal settlers	128,478	76,608	227,430	76,608	383,838	108,528
Total		487,545,572	357,742,061	658,978,793	484,226,674	741,503,090	547,885,248

*P10: Exclude KAMANA (Kalookan City, Malabon City, and Navotas City)

P10: 10-year return period flooding, EX: Existing infrastructure, MP: Continuing 1990 Master plan

3.10 Impacts on other public infrastructures and utilities

3.10.1 Power

This report identifies the critical parts of the existing power infrastructure that are vulnerable to floods based on information from power-related companies. The potentially affected facilities and related costs are presented and a rough estimate of the losses caused by power outages is calculated.

In the Philippines, the production, transmission and distribution of power are handled by three main entities: the National Power Corporation (NAPOCOR), the National Transmission Corporation (TRANSCO) and Meralco. NAPOCOR is mainly responsible for energy production, while TRANSCO handles the main transmission and Meralco distributes energy to end-users.

Of the three TRANSCO substations in the Metro Manila area, two, as shown in Fig. 3-10, could be affected by flooding. One of these, the Araneta substation, is located within an area of Quezon City that has an estimated water depth of about 2 meters in the simulated flood. The company claims, however, that the substation is on higher ground and would not be affected by flooding. Meralco, on the other hand, has approximately 117 substations that serve the metropolis. Similar to Araneta, most of these substations are located on high ground and only a few would be affected even if water depths reach 6 meters. However, once water reaches ground level, these substations automatically shut down for a few hours until the water has receded and switching equipment has fully dried out.

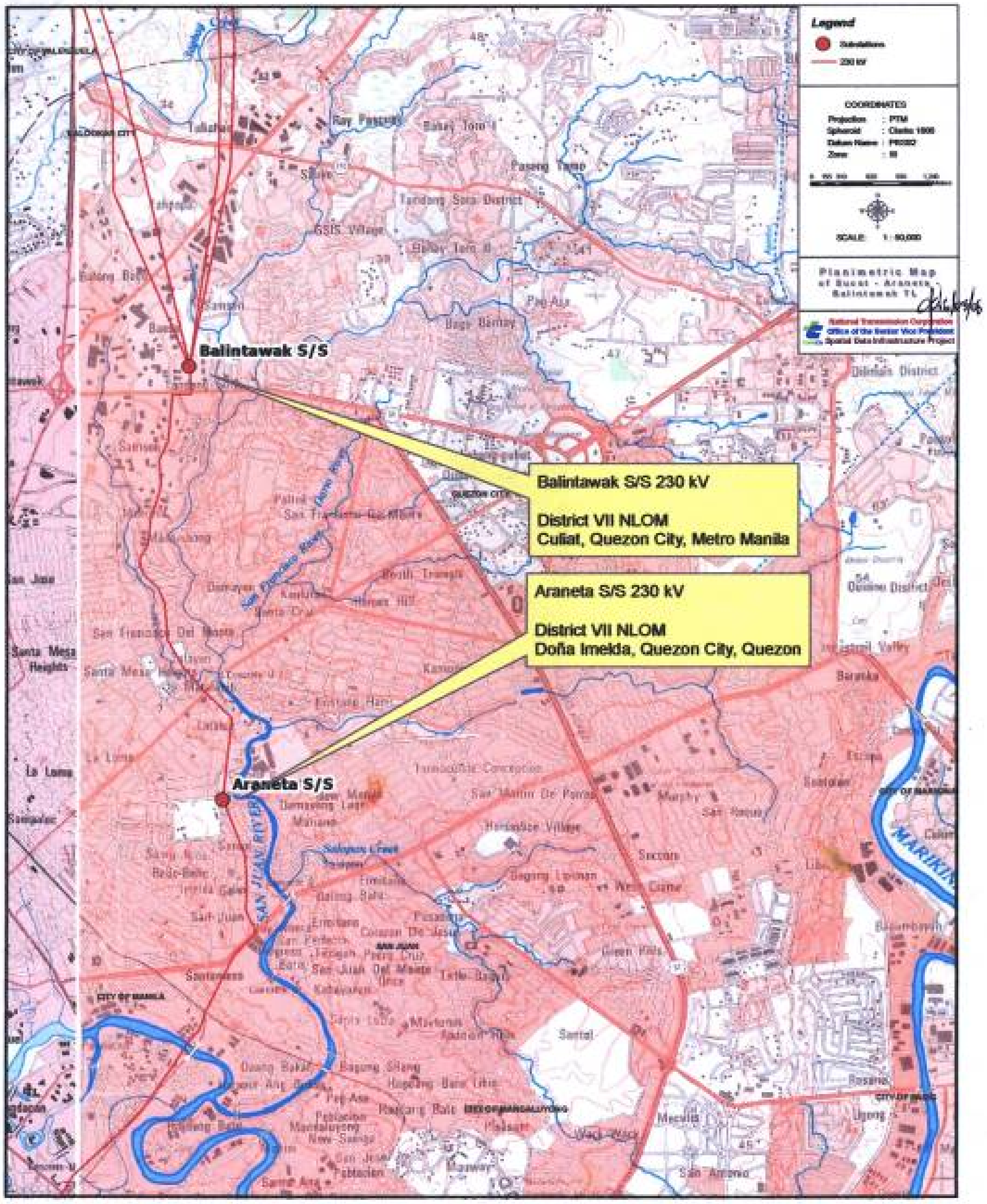


Figure 3-10 Flood-affected TRANSCO substations in Metro Manila

Table 3-32 below presents Meralco substations potentially vulnerable to floods and their corresponding service areas. The potentially vulnerable areas are concentrated in Pasay, Manila, and Taguig.

Table 3-32 Affected Power Distribution Infrastructure

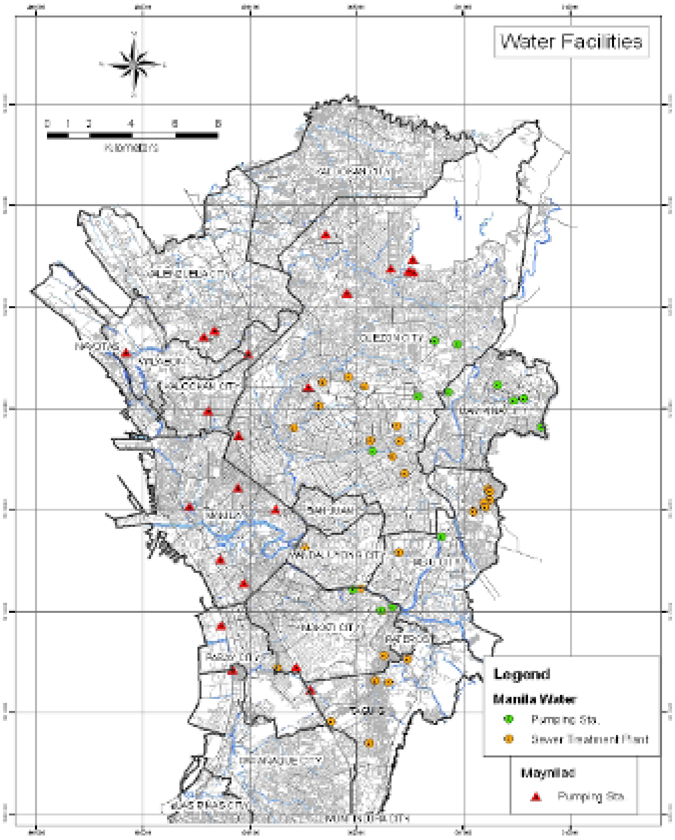
Rise in Flood Water Level (m)	Substations	Elevation (m)[1]	Affected Areas	Planned Projects
1	CBP 1-A (at Mall of Asia, Pasay City)	0.61	Pasay City Paranaque City	• Expansion of CBP 1-A Substation (2009) • Development of NAIA Substation
6	North Port (at Antipolo St., Tondo, Manila)	4.00	Manila South Kalookan Navotas	• Installation of 83 MVA at Balintawak Substation (5th Bank) • Development of South Port Substation • Development of Nagtahan Substation (2012)
	Capasco (at Napindan Road, Taguig)	4.88	CAPASCO Taguig	
	Taguig (at Elisco Road, Taguig)	4.88	Taguig City Pateros Makati City Pasig City Mandaluyong City	• Development of Santolan Substation (2006) • Development of Fort Bonifacio Global City Substation (2009) • Expansion of Hillcrest Substation • Expansion of Manggahan Substation • Expansion of BF-Paranaque Substation (2010)
	Paco (at Quirino Hiway, Sta. Ana, Manila	5.79	Malate, Manila Sta. Ana, Manila San Andres, Manila Paco, Manila Ermita, Manila Makati City	• Expansion of Paco Substation (2010) • Development of South Port Substation • Development of Nagtahan Substation (2012)
	Pasay (at EDSA near Tramo, Pasay City	6.10	Pasay City Paranaque City Makati City	• Unloading of Pasay 23U (2011) • Unloading of Paranaque 17ZJ (2011) • Complete conversion of Pasay Substation • Complete conversion of Paranaque Substation • Complete conversion of Makati Substation

Source: Network Asset Performance Management Office, Meralco, May 2008
1/ Elevation based on Google Earth Elevation

The substations listed in Table 3-32 were located on the flood simulation maps for both depth and duration of inundation. The Meralco substation identified as most vulnerable is CBP1-A at the Mall of Asia in Pasay City alongside Manila Bay. Other substations are not vulnerable because their corresponding elevations exceed the possible simulated flood depths. The maximum duration of flooding at CBP1-A was identified as eight hours.

3.10.2 Water

Information from water supply companies was used to attempt to identify the critical parts of the existing water infrastructure that are vulnerable to floods. Provision of potable water to households in Metro Manila is carried out by two concessionaries under contract with the Manila Waterworks and Sewerage System (MWSS). Manila Waters Company serves the eastern part of the metropolis while Maynilad Water Services, Inc. serves the western part (Fig. 3-11).



Source: Manila Waters Company and Maynilad Water Services, Inc., May 2008

Figure 3-11 Water supply facilities in Metro Manila

According to interviews with the water supply companies, flooding is not a concern for these water providers as they claim that their pipes are positively charged. This means the pressure in the pipes is strong thereby preventing infiltration of dirty water or other contaminants. They also claim that their facilities, such as pumping stations, are above flood levels. There is no record of flooding incidents in their databases. It is, therefore, not possible to assume any detailed damage to the functioning of the water system due to flooding. Households that depend on wells, however, can be affected by flooding.

3.10.3 Rail

Rail operations are vulnerable to floods. There are three major urban elevated rails operating within Metro Manila: the Light Rail Transit Line (LRT1), the Metro Rail Transit Line 2 (MRT2), and the Metro Rail Transit 3 (MRT3). The routes and stations of each line are given below in Table 3-33.

Since Meralco provides power for urban rails and the power rectifier substations (RSS) of all urban rails are located at ground level, the entire transportation system in Metro Manila is greatly influenced by power cuts caused by intensified flooding.

Table 3-33 Urban Rail System in Metro Manila

Urban Rail System	Description
LRT 1 (Metrorail / Yellow Line)	Length: 15 kilometers Route : Manila to Caloocan City; Manila to Pasay City: Monumento, 5th Avenue, Ricardo Papa, Jose Abad Santos, Blumentritt, Tayuman, Bambang, Doroteo Jose, Carriedo, Central, United Nations Avenue, Pedro Gil, Quirino Avenue, Vito Cruz, Sen. Gil Puyat, Libertad, EDSA Pasay, Baclaran Year Constructed: 1981 to 1985
MRT 2 (Megatren / Purple Line)	Length: 13.8 kilometers Route : Manila to San Juan, Quezon City, and Pasig City: Santolan, Katipunan, Anonas, Cubao, B.G.Belmonte, Gilmore, J. Ruiz, V. Mapa, Pureza, Legarda, C.M.Recto Year Constructed: 1997 to 2003
MRT 3 (EDSA MRT III / Blue Line)	Length: 16.9 kilometers Route : Pasay City to Makati City, Mandaluyong City, and Quezon City: Taft Avenue, Magallanes, Ayala, Buendia, Guadalupe, Boni, Shaw, Ortigas, Santolan-Annapolis, Cubao, Kamuning, Quezon Avenue, North Avenue Year Constructed: 1996 to 2000

Table 3-34 lists the substations potentially affected by flooding. Under the SQ and A1FI scenarios, LRT 1 is partially paralyzed due to discontinued operation of substations RSS 3 and 7. If RSS 5 and 6 also shut down, the entire line will stop.

Table 3-34 Flood-affected RSS Supporting Urban Rail Transport[8]

RSS No. & Location (LRT Line 1)	"Status Quo" Flood Depth	"A1F1" Flood Depth
3 - Buendia Station	0.45 m	0.65 m
5 - Central Station	0.42 m	0.62 m
6 - D. Jose Station	0.55 m	0.79 m
7 - Blumentritt Station	0.26 m	0.50 m

Source: Light Rail Transit Authority

Converting this effect into monetary terms would mean an income loss of 4.7 M Php per day for the line.[9] However, we have not included this number in the damage cost as the effect of LRT 1 shutting down may also be accounted for through loss of daily income.

8 Any impact on RSS nos. 5 and 6 would paralyze the entire line.
9 ALMEC, pp. 4-17. This is based on the reported 2007 Income of the LRT Line 1 of P 1.707.67 M with 360 operating days.

Chapter 4 Methodology Part Three: Intangible Risk Analysis (Health)[1]

4.1 Introduction

This section aims to characterize and quantify human health risks associated with exposure to pathogens present in floodwater as an example of an intangible risk related to flooding in Metro Manila. Here, exposure scenarios based on different inundation levels are developed in which direct and indirect contact with water are assumed to occur.

4.2 Data and Methodology

4.2.1 Data

In this study, the authors combined GIS population density and flood inundation (Status Quo and A1FI climate scenarios, existing flood control infrastructure) data and then calculated the level of relevant risk. The GIS data include city boundaries as of 2003 within Metro Manila, grouped together by District; population statistics based on the 2000 census conducted by the National Statistics Office; and flood inundation GIS data, based on different climate scenarios.[2]

The US Environment Research Institute's (ERSI) ArcGIS 9.2 software was used to match population with district boundaries. The output of that process, a shapefile, contains Metro Manila district boundaries as of 2000 matched with year 2000 population. Based on this shapefile, a population density (people/hectare) map was created. The GIS inundation data was then used to create inundation maps. The minimum flood level (in meters) of the Status Quo and A1FI climate scenarios form the basis for the maps. Risk, depending on different exposure scenarios, was assessed according to inundation levels and the results were matched with the inundation map to create a new map of potential risk at different locations.

4.2.2 Risk Assessment

Quantifiable risk assessment was initially developed to assess human health risks associated with exposure to chemicals (Hass, 1999). In its simplest form, it consists of four steps, namely:

- Hazard assessment
- Exposure assessment
- Dose-response analysis
- Risk characterization

[1] This Chapter is based on the findings of Tran Thi Viet Nga and Fukushi, K. (2008) "Infected Risk Assessment with Exposure to Pathogens in the Flood Water- Case of Metro Manila".
[2] Flood inundation data from Chapter 2.

4.2.2.1 Hazard assessment

A human health risk assessment was conducted to evaluate the risk associated with pathogen (E. coli) exposure in the flooding areas for the following scenarios: (1) Inundation depths of 0-50 cm; (2) Inundation depths of 50-100 cm; (3) Inundation depths of 100-200 cm, and (4) Inundation depths above 200 cm. These scenarios are chosen based on the classification of “human interactions” set in the Flood Fighting Act, Japan, 2001:

Table 4-1 Classification of Inundation Depth

Level	Inundation depth	Human interaction
I	0-50 cm	Most houses will stay dry and it is still possible to walk through the water
II	50-100 cm	There will be at least 50 cm of water on the ground floor
III	100-200 cm	The ground floor of houses will be flooded
IV	> 200 cm	Both the first floor and often the roof will be covered by water

Note: Classification based on Flood Fighting Act, Japan, 2001

In this analysis, exposure scenarios according to inundation levels were developed in which direct and indirect contact with water was assumed to occur. Probabilities of gastrointestinal infection were estimated based on established dose-response relationships for the indicator pathogen (E. coli), which is present in floodwater. Due to data limitations, the *E. coli* concentration in contaminated surface water from a previous study (Nga, 1999) was used to evaluate the risk. Ingestion was assumed to be the exposure route. Figure 4-1 shows the exposure mechanism schematically.

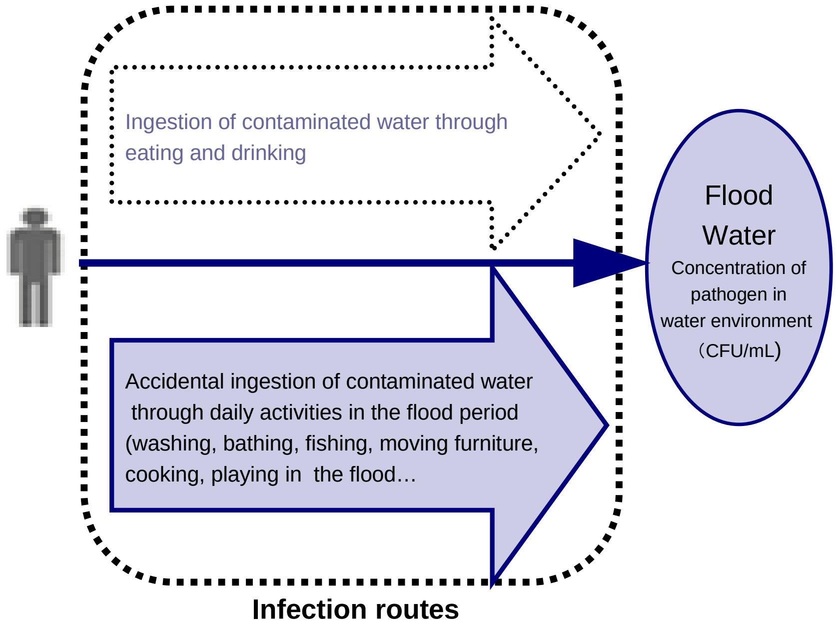


Figure 4-1 Infection routes through direct and indirect contact with contaminated floodwater

4.2.2.2 Exposure Assessment

Various groups of people have different vulnerabilities, experiences, coping behaviors and responses to flooding among due to gender, age, job, lifestyle and other factors. Because of data constraint the analysis here focuses on age. The Metro Manila population was divided in to four groups, namely a) 0 to 4 year-olds, b) 5 to 14 year-olds, c) 15-59 year-olds, and d) those above 60 years old, based on the 2000 census conducted by the National Statistics Office (NSO, 2000). The proportion of each age group is displayed in Fig. 4-2. Daily activities and behaviors of each age group were examined and studied through a literature review to determine the amount of time people would spend in water in the event of a flood. Default ingestion intake values were derived from the U. S. Environmental Protection Agency (USEPA) Risk Assessment Guidance for Superfund (RAGS). For each exposure scenario, risk was first calculated for a single exposure event.

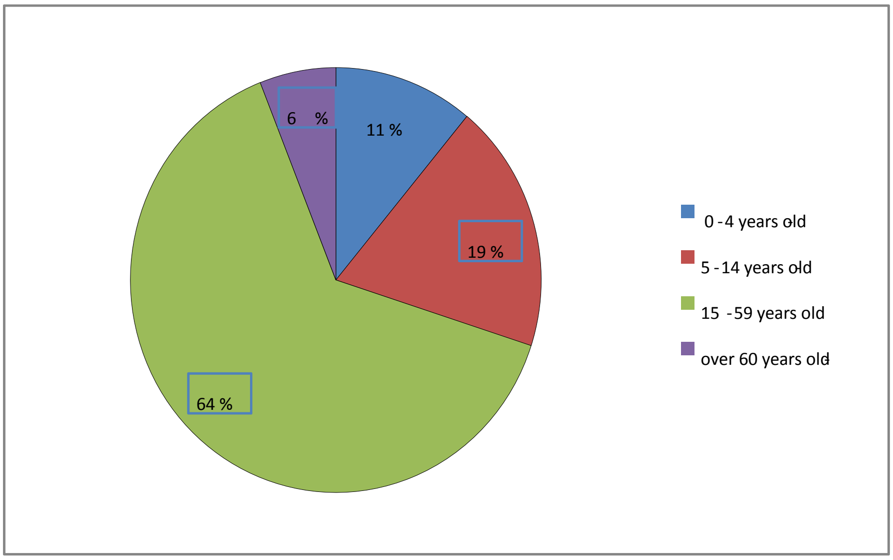


Figure 4-2 Distribution of Age in Metro Manila

Source: NSO, 2000 Census of Population and Housing

(1) Inundation depth of 0-50 cm

Direct floodwater contact in this scenario occurs primarily while walking on roads. For this assessment, it was assumed that in one day the total time spent outdoors for the age groups of 4 years and under, 5-14 years, 15-59 years and over 60 years old are 2, 4, 4, and 1 hour, respectively, with the assumption that 50% of total outdoor time would be spent in water. Since the inundation depth is less than 50 cm, water-contact activities would likely only occur during walking on flooded streets.

The potential route of pathogen exposure is indirect ingestion of floodwater as result of hand-to mouth activities. Hand to mouth transfer may be significant for the baby group (< 4-years old) who spend time playing with water. In this analysis, the mean incidental ingestion rate was assumed to be 50 ml/hour for babies (less than 4 years old) and 10 ml/hour for children (5-14), adults (15-59), and seniors (over 60 years old). These values are derived from the USEPA's Risk Assessment Guidance for Individuals Exposed to Surface Water During Wading.

(2) Inundation depths of 50-100 cm

At this depth, people would likely be in water whenever they go out, so it was assumed that 100% of the time outdoors would be spent in the water. The exposure route is again indirect ingestion from moving in floodwater. Floodwater may also be used for bathing or washing personal belongings.

(3) Inundation depths of 100-200 cm

In this scenario, the water contact time was assumed to be the same as in scenario (2) since water would be everywhere. However, at this inundation depth, it is likely that people would have to swim or do swimming-like activities to travel from place to place. Because children (5-14) would have opportunities to play and swim in the water repeatedly, creating multiple exposure events in a day, it was assumed that incidental ingestion of floodwater could be considerably higher for them than that experienced by other age groups. Some studies have indicated that non-adults ingest about twice as much water as adults during swimming activities (Dufour, 2006). In this assessment, the incidental ingestion rate as assumed to be 100 ml/hour for children, and 50 ml/hour for adults.

(4) Inundation depths of above 200 cm

At this depth, both the first floor and often the roof will be covered by water. With high frequency water contact by people staying in flooded houses, it was assumed that incidental ingestion of floodwater could be considerably higher compared to usual swimming. For the purposes of this assessment, it was assumed the ingestion rate was 200 ml/hr for children and 100 ml/hour adults.

4.2.2.3 Dose-response Model

The single-exposure illness rate was calculated for *E. coli* using the following equation (Hass, 1989) :

$$P(d) = 1 - \left[1 + \frac{d}{N_{50}} \left(2^{1/\alpha} - 1 \right) \right]^{-\alpha}$$

With Risk = probability of infection;

N_{50} = medium infectious dose (N_{50}=8,6 x 10^7)

α = slope parameter (α=0,1778)

4.2.2.4 Infectious Risk Calculation

Figure 4-3 summarizes the flow of the risk analysis. First, we segment the year 2000 population at the city and municipality level based on age. Time allocation for different types of outdoor activities was assumed for each age group, based on Nga (1999) (see Table 4-2). This, combined with the inundation depth from the flood maps produces the floodwater contact time. Ingestion intake values were derived from USEPA data. Further, using the dose-response model shown above, the single exposure illness rate was calculated for each city and municipality. The risk was multiplied by the population to calculate the number of people expected to be affected. Finally, the annual risk for each age category was estimated.

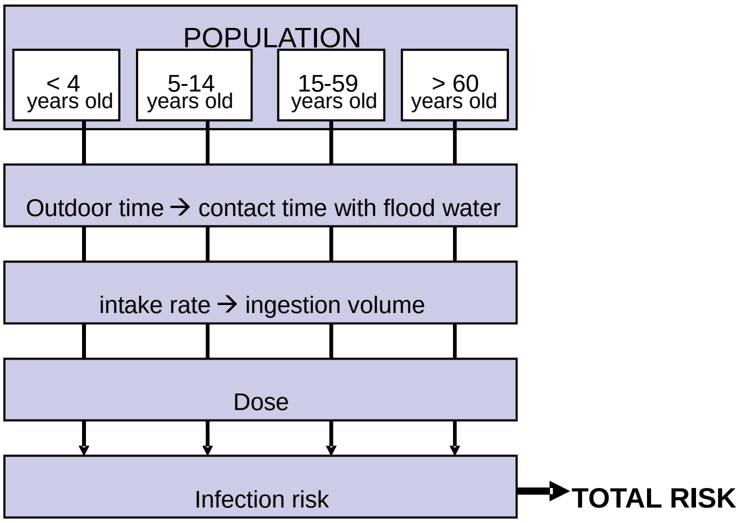


Figure 4-3 Flowchart for Risk Calculation

Table 4-2 Assumptions used in risk calculations

Parameter	Symbol	Unit	Distribution/notes
E. coli Concentration	C_E	MPN/100 ml	A mean value of 30,000 MPN/100 mL (18,000-50000) was taken as the *E. coli* concentration in flood water (Nga, Master's thesis, 1999)
Water Ingestion Rate during walking		ml/hour	
Age <4			50 ml/h
Age 5-14			10 ml/h
Age 15-59			10 ml/h
Age >60			10 ml/h
Water Ingestion Rate during swimming		ml/hour	
Age 5-14			100 ml/h
Age 15-59			50 ml/h
Time spent outdoors	T	hours/day	
Age <4			Assumed 1 hour
Age 5-14			Assumed 4 hours
Age 15-59			Assumed 4 hours
Age >60			Assumed 1 hours
Fraction of outdoor time spent in water	F	%	Assumed, varies according to inundation levels
Dose-response model (Hass equation)			

N_{50}	8.6 x 10^7
α	0.1778

4.3 Results and Discussions

4.3.1 Flood Identification

Figure 4-4 shows that among the 17 cities and municipalities in Metro Manila, the western coastal district of Manila City has highest population density, more than 500 people per hectare. The areas in the south and northeast have lowest population density, less than 110 people per hectare.

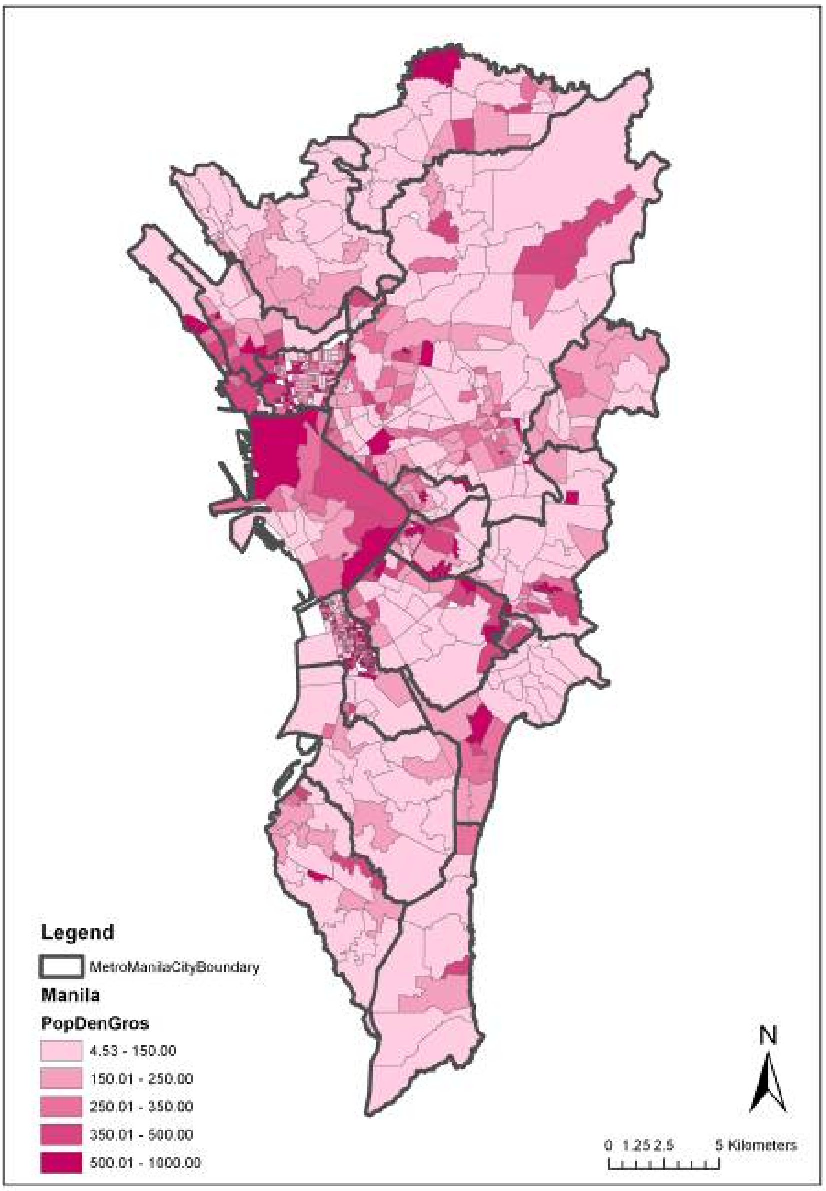


Figure 4-4 Population density map of Metro Manila

Map was created by overlaying city boundary polygons on classified population densities in ArcMap 9.2

The GIS inundation data was then used to create inundation maps. We used the minimum level (in meters) of the Status Quo and A1FI climate scenarios to produce the map shown in Figure 4-5. Areas showing serious flooding with high inundation levels and high population densities are Manila City, Quezon City, Pasig City, Markina City, San Juan and Mandaluyong City.

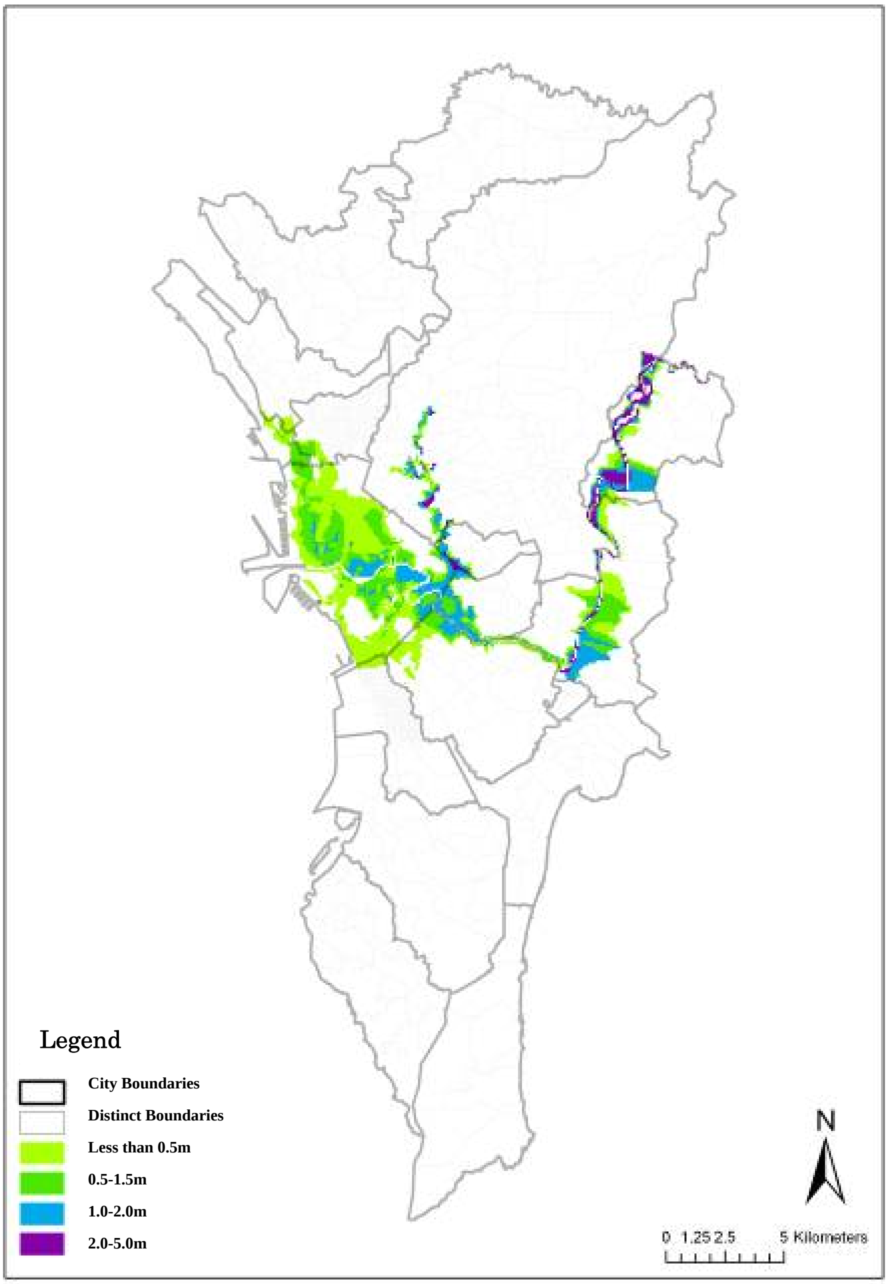


Figure 4-5 Status Quo Climate Metro Manila Inundation Map

Map produced in ArcMap 9.2 by overlaying district boundaries on classified minimum inundation levels of (1) < 50 cm; (2) 50-100 cm; (3) 100-200 cm, and (4) > 200 cm.

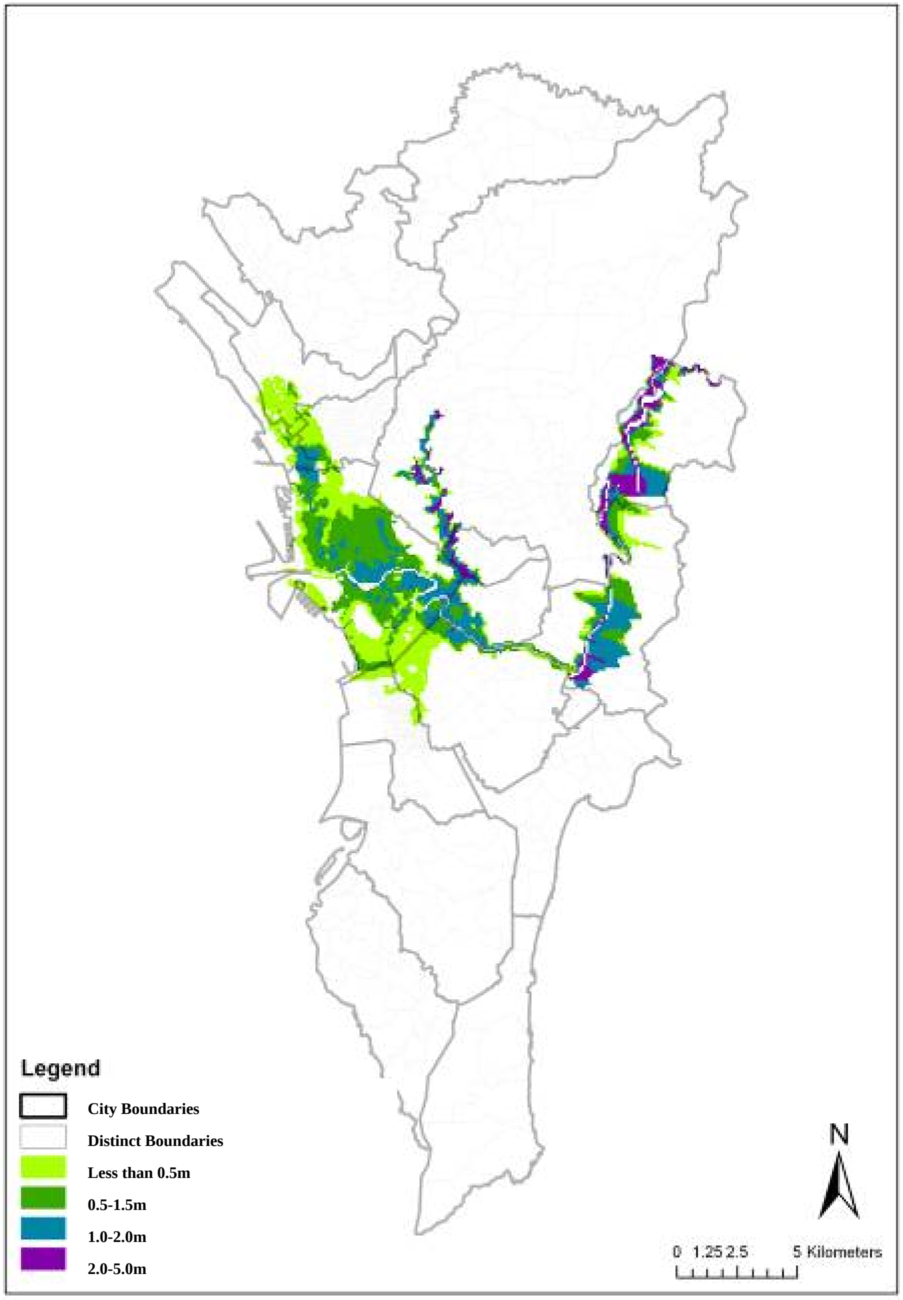


Figure 4-6 A1F1 Climate Metro Manila Inundation Map

Map created in ArcMap 9.2 by overlaying district boundaries on minimum inundation classifications of (1) < 50 cm; (2) 50-100 cm; (3) 100-200 cm, and (4) > 200 cm.

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4.3.2 Exposure Assessment and Estimated Risk of Infection

4.3.2.1 Daily risk

Figures 4-7 and 4-8 show the infection risk throughout Metro Manila for the Status Quo and A1FI scenarios. Figures 4-9 and 4-10 show the number of people infected in each scenario.

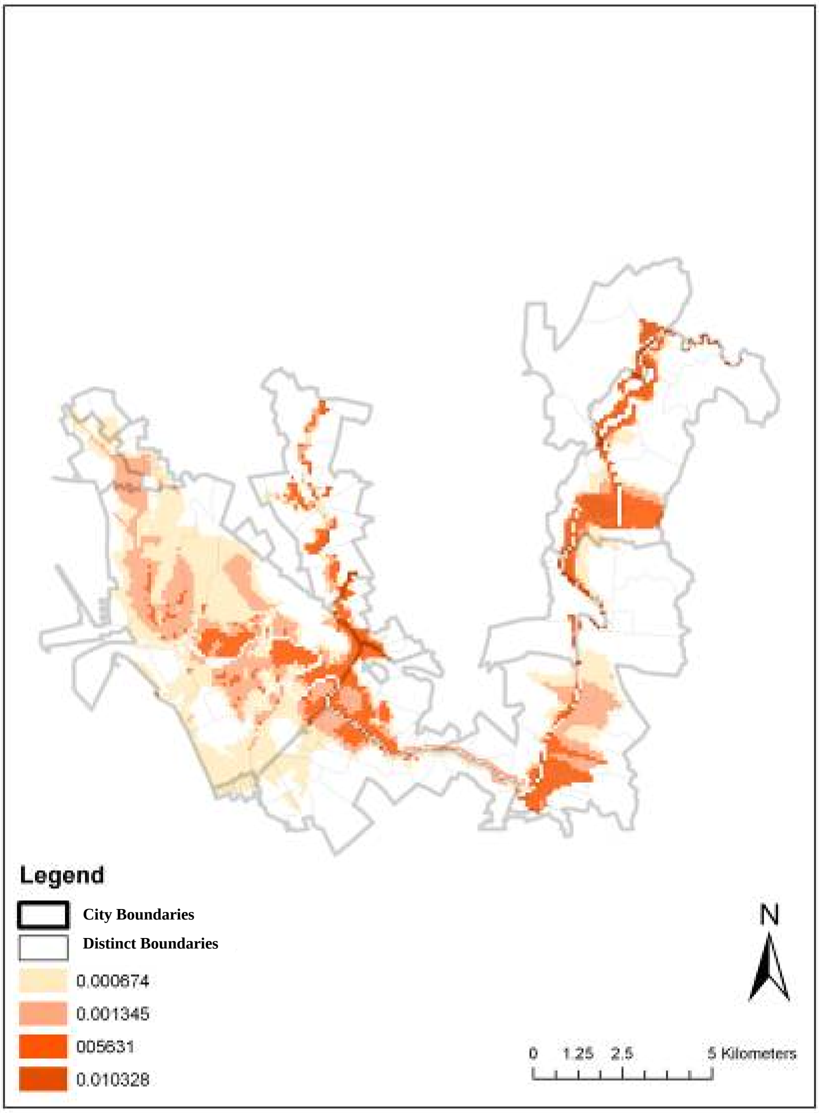

Figure 4-7 Distribution of estimated daily risk of infection via incidental ingestion of flood water (Status-quo climate scenario) in Metro Manila.

Map created in ArcMap 9.2 by overlaying district boundaries on risk classifications.

Daily risks of gastrointestinal illness via incidental ingestion for the Status Quo scenario were 0.000674, 0.001345, 0.005631 and 0.010328 for inundations of 0-50 cm, 50-100 cm, 100-200 cm, and above 200 cm, respectively.

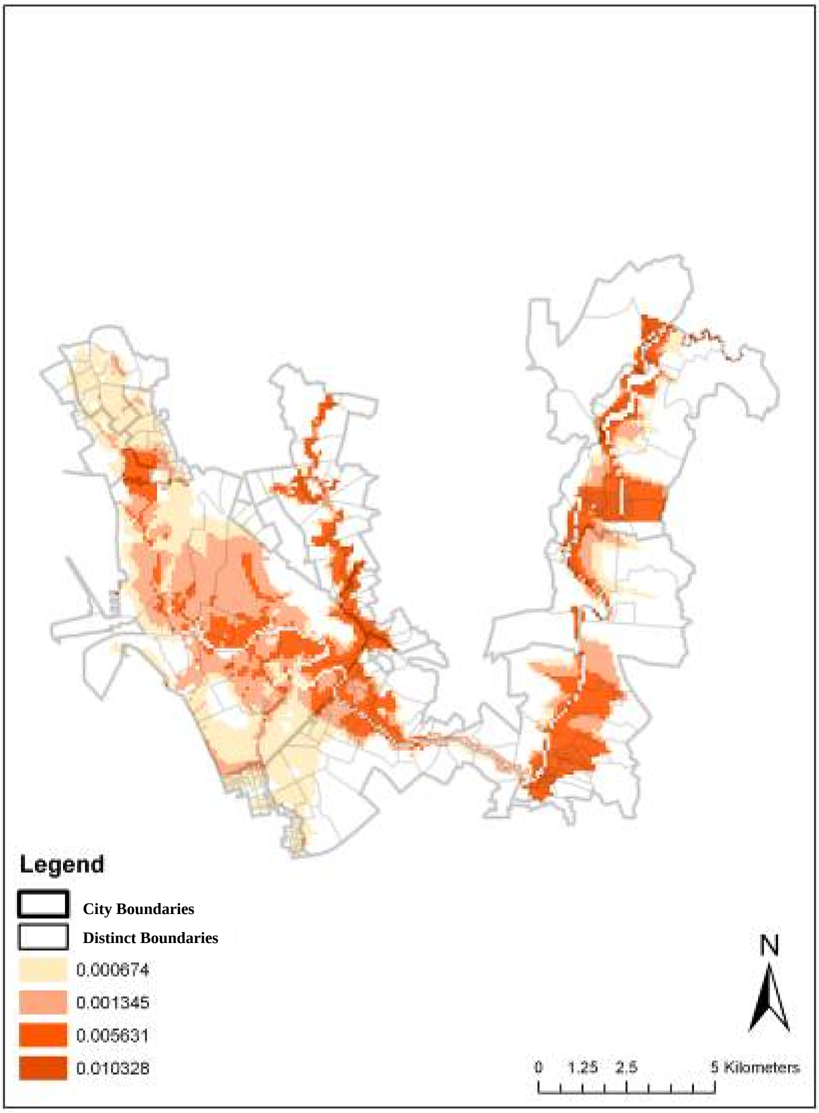

Figure 4-8 Estimated daily risk of infection via incidental ingestion of flood water (A1FI climate scenario) in Metro Manila.

Map created in ArcMap 9.2 by overlaying district boundaries on risk classifications. The risk of infection was calculated using the mean *E. coli* exposure level of 30,000 MPN/100 ml from contaminated surface water data (Nga, 1998). Daily risks of gastrointestinal illness via incidental ingestion for the A1FI climate scenario were 0.000674, 0.001345, 0.005631 and 0.010328 for inundations of 0-50 cm, 50-100 cm, 100-200 cm, and above 200 cm, respectively.

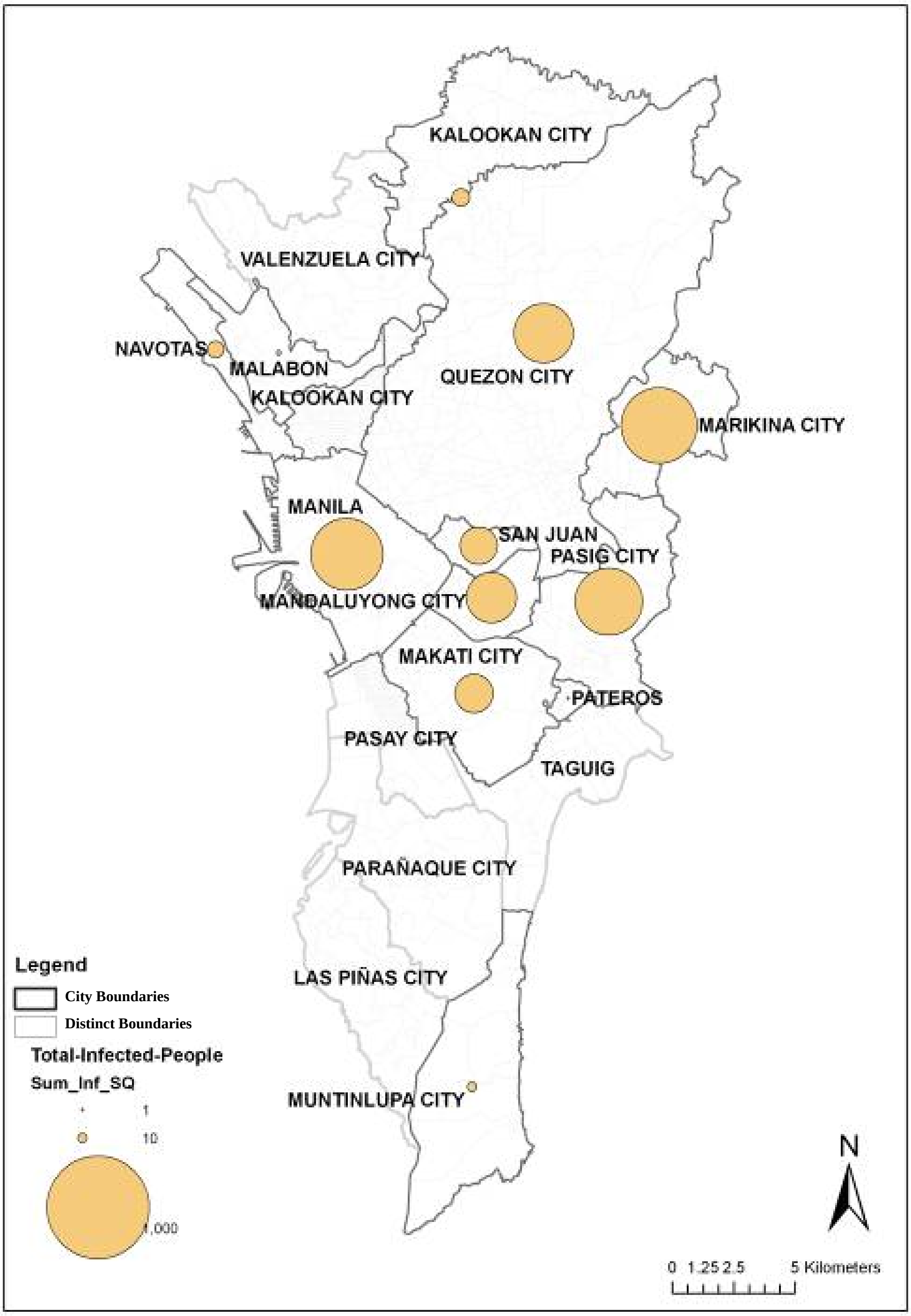

Figure 4-9 Number of infected people due to gastrointestinal illness via incidental ingestion of flood water in Metro Manila (Status-Quo climate).

Map created in ArcMap 9.2 by overlaying risk classification map on population density map

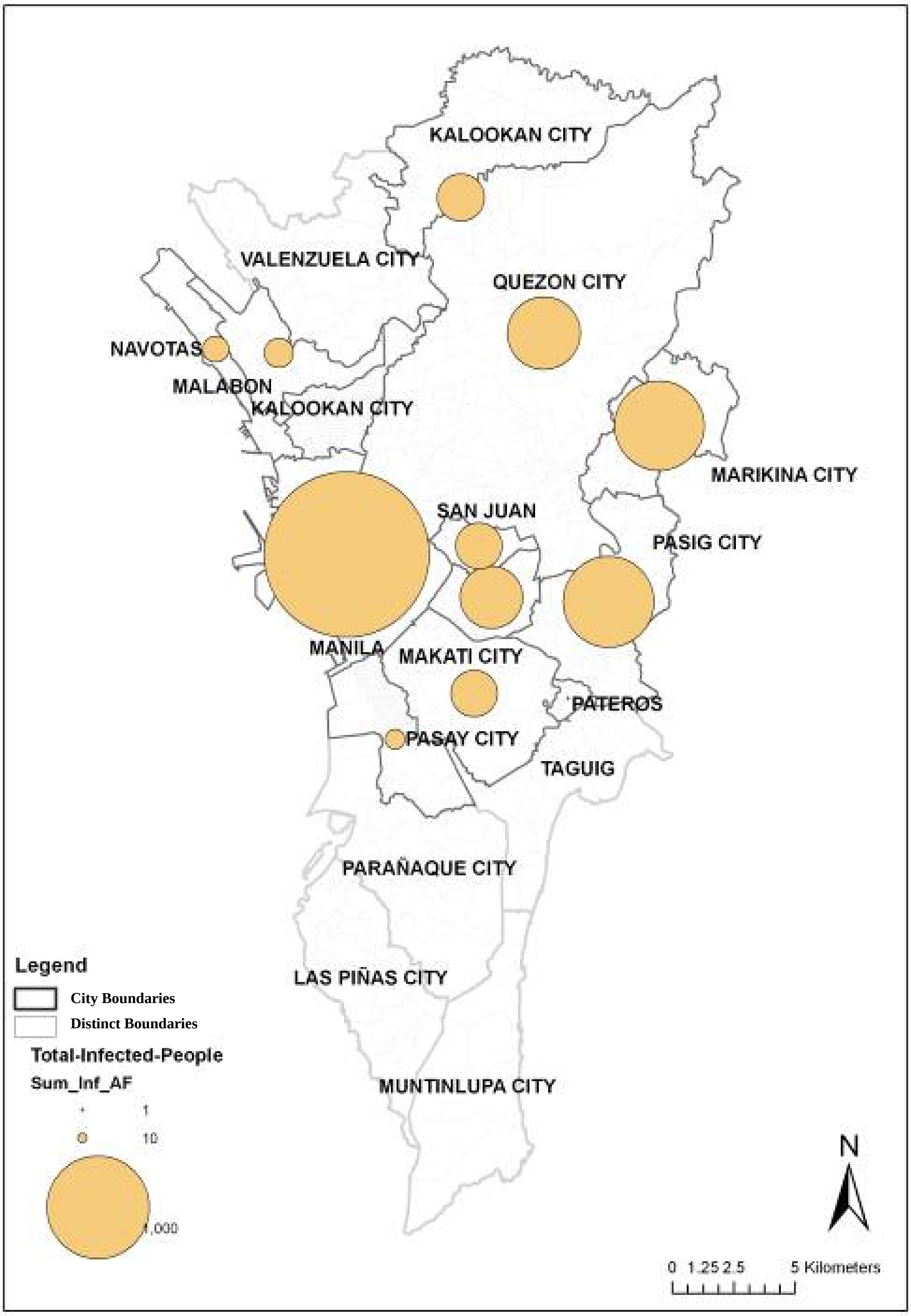

Figure 4-10 Number of infected people due to gastrointestinal illness via incidental ingestion of flood water in Metro Manila (A1FI climate).

Map created in ArcMap 9.2 by overlaying risk classification map on population density map Table 4-3 shows the expected daily infections due to different flooding for conditions for each local government.

Table 4-3 Expected Number of people infected per day in Metro Manila by inundation level for Status-Quo and A1FI flooding

Local Government Unit	Population	Infected people (based on SQ inundation data year 2003)					Infected people (based on A1FI inundation data year 2003)				
		0-50 cm	50-100 cm	100-200 cm	>200 cm	Total (persons)	0-50 cm	50-100 cm	100-200 cm	>200 cm	Total (persons)
Manila City	1581082	60	114	316	11	500	275	729	1487	86	2576
Mandaluyong City	278474	6	28	200	10	244	5	22	318	31	377
Marikina City	391170	16	16	135	383	550	19	35	208	494	756
Pasig City	505058	11	55	270	97	433	13	56	489	225	783
Quezon City	2173831	14	21	118	186	339	15	21	198	270	504
San Juan	117680	3	5	70	57	135	2	3	62	138	205
Kaloocan City	1177604	21	9	0	-	30	57	45	112	-	215
Malabon	338855	3	0	0	-	3	69	12	0	-	81
Navotas	230403	17	10	0	-	27	29	9	29	-	66
Makati City	444867	36	28	77	-	141	66	31	103	-	207
Pasay City	354908	10	-	-	-	10	32	6	-	-	38
Pateros	57407	-	-	1	-	1	-	-	1	-	1
Valenzuela City	485433	-	-	-	-	-	-	-	-	-	-
Las Piñas City	472780	-	-	-	-	-	-	-	-	-	-
Muntinlupa City	379310	-	-	-	-	-	-	-	-	-	-
Parañaque City	449811	-	-	-	-	-	-	-	-	-	-
Taguig	467375	-	-	-	-	-	-	-	-	-	-

4.3.2.2 Estimation of Annual risk

According to Zoleta-Nantes (2000), 18 to 20 floods occur annually in Metro Manila. In this analysis, one flood will count as one exposure, and we assume that one exposure will be one day long. The annual risk based on a single exposure was estimated as in Hass (1999) and is shown in Table 4-4:

$$P_{annual} = 1 - [1 - P(d)]^n$$

Where n: number of exposures per year

Table 4-4 Single exposure and annual risk by age group due to pathogen exposure during flooding

Group of Age	Risk	Inundation depth (cm)			
		< 50	50-100	100-200	>200
0-4	daily risk	0.001491	0.002968	0.005879	0.005879
	total risk	0.029407	0.057715	0.111231	0.111231
5 to 14	daily risk	0.000598	0.001194	0.005879	0.011536
	total risk	0.011898	0.023615	0.111231	0.207095
15 to 59	daily risk	0.000598	0.001194	0.005879	0.011536
	total risk	0.011898	0.023615	0.111231	0.207095
>60	daily risk	0.000150	0.000299	0.001491	0.001491
	total risk	0.002992	0.005972	0.029407	0.029407
Total	daily risk	0.000674	0.001345	0.005631	0.010328
	total risk	**0.013398**	**0.026556**	**0.106796**	**0.187491**

4.4 Conclusion

The risk of contracting gastrointestinal illness due to *E. coli* from incidental ingestion of flood water in Metro Manila over the course of a year is 0.013398, 0.026556, 0.106796, and 0.187491 for inundation levels of less than 50 cm, from 50-100 cm, from 100-200 cm, and above 200 cm, respectively. The risk of gastrointestinal illness is highest for the group from 4 -15 years old.

While the health risks associate with *E. coli* in this assessment are considerable, the risk of gastrointestinal illness may actually be significant higher because other potentially pathogenic microorganisms might be present in flood water that affect especially the young, the old and those have frequent contact with water. Further, as with any risk assessment, there are many sources of uncertainty in the analysis.

Chapter 5 Vulnerabilities of selected segments of the society and economy

5.1 Introduction

This chapter presents the results of analyses conducted to identify vulnerabilities of selected segments of the society and economy. The first section covers an analysis at the household level, focusing on the experiences of those living in areas affected by flooding, typhoons, and tidal surges in the current climate. The household level respondents found difficulty in effectively distinguishing the difference between typhoon events, as well as distinguishing between floods, typhoons, and tidal surges. Therefore, the impacts discussed in the household section combine the effects of floods, typhoons, and tidal surges. The second section covers an analysis of businesses at the firm level, focusing on their experience in Typhoon Milenyo (2006) and other flood events.

5.2 Metro Manila: Urban development, environment and socio-economic characteristics

Metro Manila is the center of the Philippines' political, economic and socio-cultural activities. Its strategic location by Manila Bay and the mouth of the Pasig River led its growth and development as the country's capital city. Being near a river and a good harbor made possible the development and expansion of the city and its suburbs over the last 30 years.

Over time, with large in-migration and rapid population growth, the city expanded to the suburbs, and surrounding municipalities, including swampy areas, areas near or above esteros or water canals, areas along the river or earthquake fault lines, and other sites that are risky for habitation. A large part of the development occurring in informal settlements is unregulated. Thus, in Metro Manila, many structures are built in dangerous areas near the seashore, in flood zones, or on unstable ground that is prone to landslides.

Socio-economic forces like land use practices, infrastructure development, building standards, codes and practices, urban development policies and programs have greatly shaped the settlement and building patterns of the city. These forces generate an environment that poses high risks to residents and infrastructure alike, especially in low-lying flood-prone areas.

A large portion of the population does not have job or housing security. Moreover, the 2008 Philippine Asset Reform Report Card estimated that only 61% of households in Metro Manila have sufficient basic services, as most of the informal settlements do not have access to the water supply or sewage facilities of the Manila Waterworks Sewage and Sewerage System (MWSS). The metropolis has an estimated housing backlog of 4 million, about a third of its population.

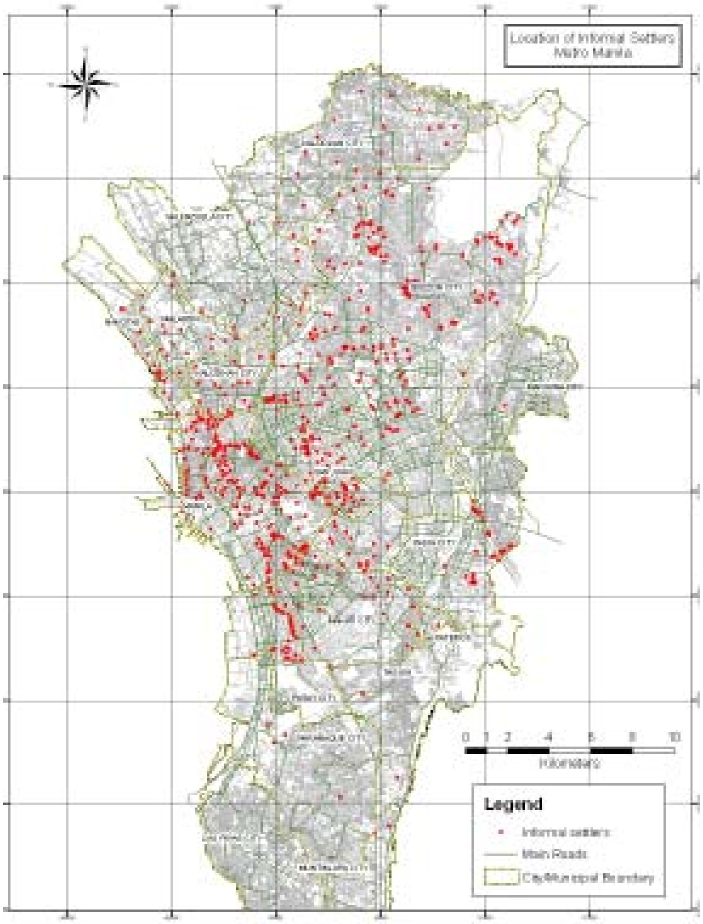

Figure 5-1 Informal Settlements in Metro Manila, 2007

5.3 Household Level Effects[1]

5.3.1 Objectives and Methodology

The objective of this section is to assess the current strategies and modes of survival of residents in flood-prone areas undergoing climate change, with particular focus on vulnerable groups in three flood-prone areas of Metro Manila, namely, 1) the Pasig-Marikina River Basin, 2) the West Mangahan area, and 3) the KAMANAVA area.

5.3.2 Methodology

A team from Ateneo de Manila University conducted preliminary fieldwork in the communities and cities of KAMANAVA (Kalookan, Navotas, and Valenzuela), Cainta, Taytay, Marikina, Pasig and

[1] This section is based on the findings of Porio, E. (2008) "Vulnerability, Adaptation and Resilience to Flood and Climate Change-Related Risks among Riverline Communities in Metro Manila".

West of Mangahan to finalize the research framework and sampling design of the study. [2]

After the field reconnaissance, the study selected poor urban communities from the KAMANAVA (Kaloocan, Malabon, Navotas and Valenzuela) area, the Pasig-Marikina river basin, and the area West of Mangahan because of their frequent experiences of flooding and regular tidal and storm surges.

The study conducted household interviews in the following communities of the KAMANAVA area: (1) San Agustin and (2) Longos in Malabon, (3) Navotas West, (4) Bangkulasi and (5) Bagumbayan South, and (6) West Navotas in Navotas, and (7) Barangay 28 in Caloocan City. In the Marikina-Pasig River Basin, the study chose the following communities: (1) Rosario, (2) Bagong Ilog, and (3) Ugong in Pasig City and (4) Tumana in Marikina City. Lastly, in the West of Mangahan area, the following sites were selected: In Taguig City, the barangays (districts) of (1) Ibayo Tipas (2) Calzada, and (3) Napindan, and in Pasig City, (4) San Joaquin. The study interviewed a total of 300 households (100 in each of the river basins) located in low-lying areas of these barangays along the Pasig River System and its connecting tributaries

The study utilized a systematic sampling strategy with a random start (e.g., every 5 households depending on the sampling area population) in selecting the 300 sample household respondents.

5.3.3 Environmental and social characteristics of the study sites

As mentioned earlier, the households in the study live in three flood-prone areas of Metro Manila, namely, 1) the Pasig-Marikina River Basin, 2) the West Mangahan area, and 3) the KAMANAVA area. These households are also located in low-lying areas, mostly wetlands and swamplands around the following river systems and their tributaries: the Pasig-Marikina River, the Napindan River in West Mangahan, and the Malabon and Tullahan Rivers in the KAMANAVA area, which are connected to the sea (Manila Bay) and Laguna de Bay Lake. Thus, aside from their being flood-prone, these areas also suffer the effects of heavy monsoon rains, typhoons, and in KAMANAVA and West Mangahan, regular tidal surges. Most of the surveyed households belong to informal slums or squatter settlements, with no security of tenure in their housing and no adequate access to basic services like water, electricity, sewerage and drainage systems.

[2] The flood data maps supplied to the research group needed field validation by local officials and residents in the flood-prone areas as communities along the river basins varied in terms of levels of flood experience, from none to very frequent. Because of this variation, it was very hard to determine the levels of risks in relation to the flood map. Most of the interviews were also conducted during the dry season, which may have made the respondents not so conscious of the risks generated by heavy monsoon rains, typhoons and floods.

Because of their location, the sample communities selected here are prone to floods from typhoons and heavy monsoon rains from June to November, Metro Manila's traditional rainy season. Meanwhile, throughout the year, the KAMANAVA area is particularly susceptible to the effects of sea level rise (SLR) through tidal surges. During the last few years, the residents have observed changes in the climate patterns like typhoons and heavy monsoon rains continuing past the end of the expected rainy season, into December or January or beginning early, in May.

5.3.4 Socio-economic and demographic characteristics of households

The study surveyed a total of 300 households in communities located in the three river basins. The respondents were mostly female (86%) as they were the ones available and more willing to be interviewed, compared to male household members. Their ages ranged from 18 to 92 years old, with a median age of 42 years old. They were mostly legally married (61%), or had live-in/cohabitation arrangements (20%), while the rest were widowed or separated (14%), or single (4%). Their mean household income was Php 10,033 per month and the median monthly household income was Php 8,000. Of the communities surveyed, the barangays of West Navotas and San Joaquin in Pasig and Ibayo Tipaz in Taguig had the lowest monthly median income of Php 8,000 while Longos in Malabon and Bangkulasi in Navotas with Php 23,250 and Php 18,000, respectively, had higher median income levels. Most of the poorest households, whose members were old, widowed or separated, had no income and who were dependent on food support given by their children or relatives came from these low-income communities.

Most of the respondents had obtained an average of 8.5 years of schooling, i.e., reached high school. Only respondents from Malabon had attained some college education, with an average of 11.20 years in school. This low education level explains their low levels of formal employment, with most of them deriving their sources of income from the informal sector, and therefore having low household income levels. Tables 5-1, 5-2, and 5-3 give breakdowns of the survey respondents' age, civil status, and education, respectively.

Table 5-1 Age of respondent by area

			Area			Total
			KAMANAVA	Pasig-Marikina River Basin	West Mangahan	
Age of respondent	20 and below	Count	3	1	3	7
		% within Area	3.0%	1.0%	3.0%	2.3%
	21 to 30 years old	Count	7	22	27	56
		% within Area	7.0%	22.0%	27.0%	18.7%
	31 to 40 years old	Count	19	32	27	78
		% within Area	19.0%	32.0%	27.0%	26.0%
	41 to 50 years old	Count	43	29	24	96
		% within Area	43.0%	29.0%	24.0%	32.0%
	51 to 60 years old	Count	17	7	12	36
		% within Area	17.0%	7.0%	12.0%	12.0%
	61 to 70 years old	Count	9	8	4	21
		% within Area	9.0%	8.0%	4.0%	7.0%
	70 and over years old	Count	2	1	3	6
		% within Area	2.0%	1.0%	3.0%	2.0%
Total		Count	100	100	100	300
		% within Area	100.0%	100.0%	100.0%	100.0%

Table 5-2 Civil status of respondent by area

			Area			Total
			KAMANAVA	Pasig-Marikina River Basin	West Mangahan	
Civil status of respondent	Single	Count	9	0	4	13
		% within Area	9.0%	.0%	4.0%	4.3%
	Married, living with spouse	Count	58	64	62	184
		% within Area	58.0%	64.0%	62.0%	61.3%
	Widow/widower	Count	13	11	10	34
		% within Area	13.0%	11.0%	10.0%	11.3%
	Separated	Count	6	1	1	8
		% within Area	6.0%	1.0%	1.0%	2.7%
	Live-in	Count	14	24	23	61
		% within Area	14.0%	24.0%	23.0%	20.3%
Total		Count	100	100	100	300
		% within Area	100.0%	100.0%	100.0%	100.0%

Table 5-3 Education by area

			Area			Total
			KAMANAVA	Pasig-Marikina River Basin	West Mangahan	
Education of respondent	Some elementary	Count	15	11	10	36
		% within Area	15.0%	11.0%	10.0%	12.0%
	Elementary graduate	Count	20	9	31	60
		% within Area	20.0%	9.0%	31.0%	20.0%
	Some high school	Count	17	27	15	59
		% within Area	17.0%	27.0%	15.0%	19.7%
	High school graduate	Count	22	41	34	97
		% within Area	22.0%	41.0%	34.0%	32.3%
	Some college	Count	19	8	8	35
		% within Area	19.0%	8.0%	8.0%	11.7%
	College graduate	Count	7	4	2	13
		% within Area	7.0%	4.0%	2.0%	4.3%
Total		Count	100	100	100	300
		% within Area	100.0%	100.0%	100.0%	100.0%

5.3.5 Effects of Typhoons, Floods, and Storm/Tidal Surges

Of the 300 households interviewed, about two-thirds reported that they had been affected in the past by floods (two-thirds), storm/tidal surges (almost one-half), and typhoons (almost three-fourths). The respondents found it difficult to effectively distinguish different typhoon events, as well as between floods, typhoons, and tidal surges. Therefore, in the section reporting household survey results the impacts of floods, typhoons, and tidal surges are combined.

Table 5-4 Percentages of respondents affected by flooding by area

			Affected by flooding		Total
			Yes	No	
Area	KAMANAVA	Count	81	19	100
		% of Total	27.0%	6.3%	33.3%
	Pasig-Marikina River Basin	Count	49	51	100
		% of Total	16.3%	17.0%	33.3%
	West of Mangahan	Count	67	33	100
		% of Total	22.3%	11.0%	33.3%
Total		Count	197	103	300
		% of Total	65.7%	34.3%	100.0%

5.3.5.1 Effects on Basic Services

Sewage, Garbage, Drainage, and Toilets

Slightly more than one-fourth (27 %) of the households have substandard toilets (antipolo type or dug latrines) or none at all (they discharge direct to the river or sea or use their neighbor's toilets). These same households reported that floods and storm/tidal surges affected their toilets. Of those who have toilets, about 27 % complained that during times of flooding, their toilets become clogged with waste overflowing to their floor and they are forced to relieve themselves in the river/sea or in a neighbor's toilet that is located far from the flooded area. They complained that during floods and tidal/storm surges their neighborhoods smell very bad and become quite dirty with floating garbage, plastic bags, and human waste. Aside from the smell, dirt and environmental pollution, they also complained that sometimes, huge worms or snakes emerge from their toilets, sewers, and/or drainage pipes.

The respondents also complained about garbage carried by the floods and the tidal/storm surges clogging the nearby canals and drainage channels. The residents of the KAMANAVA area, particularly in San Agustin, Malabon and Bagumbayan South in Navotas complained that garbage, mostly plastic bags, from other communities of the metropolis float near or under their floors. According to the residents, this continuous flow of garbage discourages them from disposing of their own trash properly because even if they do, their environment is still littered with garbage from other people in other communities. Yet this polluted environment does not prevent children from swimming in these waters, especially during heavy rains.

Electricity

Only 39 % of households have their own electric meter while 42 % of them buy their electricity from their neighbor at a higher price. Meanwhile, 10 % of them admitted obtaining electricity through illegal connections (i.e., stealing, using jumpers) from their neighbors and almost 9 % do not have electricity at all and use oil lamps and candles for light. Candles and oil or gas lamps heighten the risks faced by these households, as these are often the cause of fires in informal settlements. Those who do have electric connections complained that during typhoons and floods, they often experience energy fluctuations, "brown-outs", and their electricity sources sometimes "ground out". During these times, the barangay police (tanod) ask them to shut off their electricity as a safety precaution.

Water

Almost one-third (32.3 %) of the households have a direct supply of piped water while the remaining two-thirds (65.2 %) buy their water from suppliers or neighbors who have MWSS water connections or have artesian or dug wells. Slightly less than one-fourth (23 %) of them have their water supply affected when there are floods and storm/tidal surges. They then have to buy potable water from water suppliers, who in turn, increase their prices. Thus, during floods and water surges, household expenditures on water, as well as food commodities and transportation increase.

Sickness

Owing to the inadequate supply of potable water and compromised sanitation, a substantial number of the respondents reported that they or their household members have become sick from the typhoons, monsoon rains, and floods. The respondents reported losing from 2 to 98 days in the last rainy season because they were sick and had to stay home or could not report for work or pursue their business/livelihood activities. They complained that they themselves or their household members suffered from skin itchiness/allergies, psoriasis, athlete's foot, fever, colds, diarrhea, typhoid, dengue, and the resurgence of primary complex or TB infections among children and the elderly. Of those who suffered from flooding, the respondents themselves or their household members were sick an average of 12 days.

Loss of income and assets

Those who were absent from work reported that they could not get out of their place nor could they cross the river or streets or find transportation to their schools or place of work. During floods, the transportation available (non-motorized tricycles and pedi-cabs) are not only few but also charge higher fares (the driver may charge double the usual fare, for example Php 50 for a Php 25 tricycle fare). Those who were unable to pursue their work or livelihoods said that business slowed down during floods or it was impossible to vend or pursue their work and earn their livelihood during high monsoon rains, typhoons, or floods. Some of the respondents also choose not to leave their homes when floods or high tidal surges occur because they worry about their household appliances or clothing getting wet and being destroyed. They lost between 1 and 15 days of income, averaging 4 days, losing an average Php 925, with the median being Php 500, during floods or tidal surges when they could not go to work. Whether they work inside their homes, within the barangay, or in the city, typhoons and floods still negatively affect them. If they work at home, their work is disrupted because of the dirty water coming onto their floors. If they work outside the home, they cannot get out of their house, through the street or get transportation to their place of work.

Those who were not able to work or pursue their livelihood activities reported losing earnings ranging from Php 98 to Php 2,000 (average Php 1,081; median Php 500) in the last rainy season. Aside from losses in earnings, the respondents also reported losses or damages to their household appliances (refrigerators, TVs, washing machines, bed mattresses, roofs, cabinets, radios, electric fans, water dispensers, etc.). The costs of these household assets ranged from Php 2 pesos to Php 50,000, with the average household loss being Php 4615 in the last rainy season.

School Absences

The parents in the study complained that their children also suffered from the monsoon rains, typhoons and floods. About one-third of the children had had to be absent from their classes, tremendously affecting their academic performance. The respondents reported that their children were unable to go school for roughly 4 days in the last rainy season. Among the communities surveyed, the respondents from Napindan and Calzada in Taguig City reported the most days missed (7) while those from Longos, Malabon reported the least (1.5 days). The respondents as a whole reported that their children could not go to school for an average of 5 days because of floods.

Disaster preparation

In preparation for floods and typhoons, residents store food supplies and other necessities; they gather and put their household appliances and things on top of tables, shelves or in high places in their homes so that water will not reach them. A few of them evacuate and go to neighbors' or relatives' homes when the weather becomes bad and they expect their homes to be flooded.

In the KAMANAVA area, where there are regular tidal/storm surges, residents have adapted by putting their clothes, furniture, and appliances in high places in their homes. Some of them have devised platforms that they raise when water surges come.

A very small percentage (5%) of the respondents said that after the occurrence of typhoons and floods, some community officials, religious leaders or associations came to their aid. They received food, relief goods, medicine, housing materials, and instructions. Their barangay officials instructed them to be careful.

The barangay officials in IbayoTipas, Calzada, and Napindan in Taguig reported that they vigilantly watch the rise of water during floods to decide if they need to evacuate vulnerable residents to nearby schools. In the case of Ibayo Tipas, the barangay officials evacuate the residents in slum/squatter settlements to a nearby structure that is an extension of a bakery owned by the barangay captain's mother. She helps the evacuees with food and clothing for the wet children.

Support Network Availability

When asked what kind of support they received from their relatives, neighbors, friends and community officials, the respondents showed a high level of reliance on informal networks. Those who were able to get support from their relatives, friends and neighbors borrowed money for subsistence, medicine, hospitalization, and school expenses. They also asked their support networks to watch over their houses, children, or possessions during floods, typhoons and tidal surges.

More importantly, the interviews with key information sources revealed that the poor and vulnerable households who do not have a wide network of friends, relatives or neighbors who can provide support are also not able to access much support from formal institutions like the health clinic or social work department of the local government unit.

5.3.6 Coping Strategies

5.3.6.1 Households: Water-based Lifestyle

Coping with the risks of storm/tidal surges and floods has been a key survival strategy for most residents. They seem to have gotten used to constant flooding in their premises. According to some residents, they have adjusted to a "water-based lifestyle". They have gotten used to the floods and regular rise of dirty water.

Residents have adjusted to flooding or to water rising onto their floors, streets, and surroundings. Their perception or consciousness of risks or dangers posed by these risks is not very high. They say "Hindi ka naman namamatay dahil sa baha!" (You do not die from floods or rising waters here!). For example, the risk of catching an infection like leptospirosis, a deadly disease contracted through contact with rat urine, is not high in their consciousness. The risks of catching a disease or infection from floodwater that can compromise their health does not seem to be very well recognized among the respondents.

5.3.6.2 Local solutions/coping strategies

The local governments of Metro Manila have been finding innovative solutions to their flooding-related problems. These solutions range from short-term to long-term strategies.

Navotas

In 2005 in the community of Bangkulasi, the Navotas mayor installed a "bombastic" (water pump) to the delight of the residents who used to suffered from constant flooding and had to use mini-boats made of Styrofoam to cross the streets and the river. In fact, during the field interviews, these "styro" boats could still be seen hanging in the respondents' houses. As a water diversion technique, the pump drains the flooded barangay of water but other barangays nearby that do not have a “bombastic” installed are then more likely to be flooded.

Barangay Bagongbayan South (BBS), which is located near Bangkulasi, started having more and higher floods three years ago when Bangkulasi’s “bombastic” was installed. Floods that used to reach the knees of BBS residents now reached their waists. This particularly affects the poor urban settlers at the mouth of the river flowing towards Manila Bay. The garbage carried by the river from different parts of the metropolis often floats into the houses of the residents during tidal surges and floods during heavy monsoon rains and typhoons. Owing to the rising water level, houses near the river are totally covered by water. These houses are connected by bamboo or wood bridges which pose hazards such as the risk of falling into piles of debris and dirty, murky water to children and adults walking at night as there are no lights.

Malabon

Most of the houses in Barangay San Agustin are located on the bank of the mouth of the river before it joins Manila Bay. Some homes are on stilts over the water. During the last few years, some have added another story or two to their housing structures to escape the rising waters. A cemented sea wall, which some use as a wall for their lean-to-housing structures serves as a pathway for the community but many people have fallen from it and drowned, especially during floods.

Pasig City

The residents in Barangay Rosario, in Pasig City, reported that in the past, tidal waters did not reach the school and that tidal surges would only be up to their knees but for the last few years it has been reaching their waists. In Rosario, whenever the water rises because of monsoon rains, typhoons and tidal surges, residents have to put their appliances on top of tables, cabinets, or on movable platforms that they hoist with ropes.

To cope with the rising waters, residents have built multiple level housing structures. Most of these have rooms as rental units for people who work in nearby factories. But these multiple-level structures also make the residents helpless during floods as they can be isolated and cannot go out. During floods, residents reported that sludge and human wastes get inside the lower floors. This causes respiratory and water-borne diseases.

Taguig City

Taguig has always been flooded, being a swampy area facing Laguna de Bay. To a certain extent, a dike built several years ago along the Napindan River has protected the residents in nearby areas from floods and tidal/storm surges. But it has also prevented the drainage of sewage and other wastes to the river as well compromising the free flow of the of household/community drainage system.

Heightening the impacts of floods and tidal/storm surges on the poor urban communities in the area is the continuous building of middle-class residential and industrial structures in the swampy areas of this city. The construction intensifies the flow of silt and clogging of substandard drainage channels because of the fill materials used to strengthen the land.

Napindan

Building riprap or river walls to stem tidal surges and floods from monsoon rains or typhoons is one of the strategies adopted by residents in Purok 5 and other communities along the Napindan River. The residents have also built mini-ports or landing areas for boats transporting goods across the river and for access to dry places where they can travel to their places of work. To mitigate the destructive tendencies of floods, some better-off residents have raised their ground floors and/or built second or third floors onto their homes.

During floods, some residents stay at home and wait for the floods to subside. Others intentionally do not go to work but fish after the floods as they can make more money catching the milkfish that wash out or escape from nearby fishponds in Laguna Lake than they can at their regular jobs.

Ibayo Tipas and Calzada

Residents in this area have constructed makeshift bamboo bridges to connect one household to another. They also have formed warning groups or networks that alert residents to rising water or floods or the coming of storms. The barangay officials have also organized groups, which if needed, can coordinate and facilitate the evacuation of residents to nearby schools.

Marikina

Among the local governments of Metro Manila, Marikina has been one of the most successful in constructing flood mitigation structures with the help of external assistance. In 1992, the Marikina government reported a total of 6.36 square kilometers of flooded area but in 2004 this was reduced to 4.40 square kilometers. What did the LGU do to achieve this reduction?

- The LGU made concreting of roads a priority to reduce the amount of sand, pebbles, and mud entering the drainage system.
- Improvements were made to major outfalls. Rehabilitation and new construction now allows flooded areas to recede faster and in the process, reduce flood damage and other impacts.

- Regular massive dredging operations are undertaken allowing faster discharge of floodwaters from residential subdivisions to creeks and rivers.
- Obstructions such as squatters' shantytowns/informal settlements along rivers, creeks and drainage channels have been demolished waterways.
- The LGU has improved existing water diversion channels.

In particular, Marikina has constructed river barriers and relocated squatters living along the Marikina River. It has also cleared canals and constructed up-to-standard drainage systems.

Like most cities in Metro Manila, Marikina is characterized by rapid population growth due to in-migration and high fertility. It has witnessed increasing densities in residential and industrial sectors and decreasing agricultural land uses. But the local government is regulating these forces through close monitoring of people settling in danger zones and regulation of residential subdivision construction and industrial establishments that can cause pollution.

5.3.6.3 Characteristics of the Vulnerable Population

In summary, the surveyed households have a high level of social vulnerability given their common characteristics:

- All live in low-lying and/or swampy/wetlands, vulnerable to floods and storm/tidal surges.
- The monthly median income is Php 8,000, which translates into only about Php 44/day (less than US$ 1/day per person, given the current rate of exchange and consumer price index) per person for food in a typical six-member household.
- Most people live in slum/squatter settlements with no security of tenure in their housing, and inadequate sources of water, electricity, health services, drainage and sanitation.
- Of these 300 households, two-thirds regularly suffer damages due to typhoons floods, and tidal/storm surges such as loss of income, health, and household assets. They have no access to adequate basic services like potable water, toilet and sanitation facilities, electricity, and endure inconveniences like evacuation or having to use their neighbor's toilet or a waterway as a toilet due to typhoons, floods and tidal/storm surges.

The study found a strong interaction between the environmental or ecological vulnerability of communities along the river systems (Pasig-Marikina, Malabon-Tullahan and Napindan) and the social vulnerability of the residents in these areas' poor urban households. Thus, the effects on poor households of climate changes like intensified typhoons, floods and storm/tidal surges are heightened by the location of their homes and their low socio-economic status (i.e., low income, no housing tenure, inadequate access to water, electricity, and drainage/sewage systems).

Among the urban poor, the very poorest are extremely vulnerable because they have no alternatives for where to build or relocate their houses, find alternative jobs, or schools for their children. As reported in the community survey, those who are elderly, sick, disabled or dependent on others have less capacity to cope with the impacts of climate change. They are least able to cope with the losses suffered from frequent typhoons, floods or tidal surges such as sickness, loss of income, inability to pursue their livelihood, and loss of household assets. Women also bear the brunt of taking care of sick children and of their homes during floods.

More importantly, the capacity to cope with these disasters is also weakened by the inability of their local and national governments to provide necessary infrastructure and services or to repair and restore existing ones. Among the local governments in the study, only Marikina and Navotas seem to have actively responded with infrastructure development and innovation in order to stem the effects of floods and other impacts of climate change.

5.4 Effects on Business a the Firm Level[3]

5.4.1 Objectives

The National Statistics Office (NSO) was commissioned by JICA to conduct the 2008 Survey on Impact of Floods on Establishments (SIFE) in Metro Manila. The 2008 SIFE aimed to provide data on flood risks and impacts on socio-economic vulnerability in selected areas in the National Capital Region (NCR) or Metro Manila. In order to identify the vulnerability experienced by firms, The SIFE focused on typhoon "Milenyo" which passed near Metro Manila in 2006 in addition to flood risks in general under the current climate. Specifically, the SIFE asked for data on:

- Firms' general situation in regard to flood risks
- Direct damages to firms' physical assets
- Sources of financing for rehabilitation of fixed assets and inventories
- Impacts indirectly induced by the above damages such as production, profit, employment, etc
- Current and future measures adopted by firms in response to flood risks, and
- Formal and informal roles of local communities in mitigating the impact of floods.

[3] This section is based on the findings of National Statistics Office, Republic of the Philippines. (2008) "2008 Survey on Impact of Floods on Establishments, Final Report"

5.4.2 SIFE Areas

The 2008 SIFE covered four areas. The first three areas were determined according to the causes of flooding. These areas are: the Pasig-Marikina Area where flooding is caused by the overflow of the Pasig-Marikina River; the KAMANAVA Area where flooding is caused mainly by the rise in sea level; and the West Manggahan Area where flooding is due to the overflow of Laguna de Bay lake. The fourth area, Other Barangays, is located in KAMANAVA but is not identified as part of the KAMANAVA Area for the purpose of this study. It consisted of flood-prone barangays reported by Local Government Units, the National Statistics Office - National Capital Region (NSO-NCR) field offices, and the websites of the Citizen's Disaster Response Center and Philippine newspapers archives.

The SIFE covered sample establishments from 47 barangays. There were 28 total barangays from the Pasig-Marikina Area (4 barangays from Marikina, 10 from Pasig, and 14 from KAMANAVA). For the KAMANAVA Area, the total number of barangays was 22 and for the West Mangahan Area, 7. Ten barangays were surveyed for the Other Barangays category.

The 2008 SIFE covered establishments with Average Total Employment (ATE) of 10 and over. The survey canvassed only formal businesses in the following seven sectors of the amended 1994 Philippine Standard Industrial Classification (PSIC):

- Manufacturing
- Construction
- Wholesale and Retail Trade, Repair of Motor Vehicles, Motorcycles and Personal and Household Goods
- Hotels and Restaurants
- Transport, Storage and Communications
- Financial Intermediation and Health and Social Work

5.4.3 Profile of Respondents

In the different target areas, the number of responding establishments were: 179 in the Pasig-Marikina Area; 66 in the KAMANAVA Area; 58 in the West Mangahan Area; and 76 in Other Areas. By sector, 53.9% of the total responding establishments engaged in manufacturing; 13.4% in wholesale and retail trade; 5.2% in transport, storage and communications; and 4.5% in health and social work. Hotels and restaurants, construction, and financial intermediation were also represented (Table 5-5). Overall, the great majority (74.2%) of the respondent establishments were corporations and the nationality of the stockholders or owners were overwhelmingly Filipinos (97.0%).

Table 5-5 Distribution of Establishments by 1994 PSIC Major Division by Area: 2008 SIFE

SIFE Survey Areas	Total Number of Establishments	Number of Establishments by 1994 PSIC Major Divisions						
		D	F	G	H	I	J	N
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ALL ESTABLISHMENTS	286	168	12	43	23	16	5	19
PASIG-MARIKINA BGYS	179	106	9	24	14	12	3	11
KAMANAVA BGYS	66	43	2	11	1	4	2	3
WEST MANGAHAN BGYS	58	38	2	9	1	3		5
OTHER BARANGAYS	76	41	1	14	9	4	1	6

PSIC Divisions: D - manufacturing, F - Construction, G - Wholesale and Retail Trade, Repair of Motor Vehicles, Motorcycles and Household Goods, H - Hotels and Restaurants, I - Transport, Storage, and Communication, J --Financial Intermediation, N - Health and Social Work

5.4.4 General Situation with regard to Flood Risks

The highest average number of times establishments experienced flooding was 40 times during 2005-2007 in the Pasig-Marikina and KAMANAVA Areas. In the West Mangahan Area, the maximum average yearly number of times establishments experienced flooding has decreased from 11 in 2005 to 8 in 2007. Most respondents reported having flooding no more than five times yearly from 2005 to 2007 in the Pasig-Marikina, West Mangahan area, and Other areas. The highest maximum number of days establishments stopped operation in any of the four areas was 14, reported by establishments in the West Mangahan area. Most establishments had one to two days of work stoppage. Table 5-6 summarizes the flood-caused work stoppages by area.

Table5-6 Number of affected firms and days of work stoppage by area

Area	Obs.	Affected firms (over the past 3 years)		Stopped days		
		No.	%	Mean	Min	Max
Pasig - Marikina Bgys	86	28	32.6	1.0	0.5	2
Kamanava Bgys	66	37	56.1	2.3	0.5	9
West Mangahan Bgys		29	50.0	1.8	0.1	14
Other Barangays	76	40	52.6	1.8	0.5	7
All Establishments	286	134	46.9	1.8	0.1	14

5.4.5 Magnitude of Damages to the Establishments Caused by Typhoon Milenyo

5.4.5.1 Description of Typhoon MILENYO

When typhoon Milenyo hit the Philippines before noon of 27 September 2006, everything in its path felt the fury of the heavy rains and strong winds. The hardest hit areas were the Bicol region and Southern Tagalog provinces as water supply, electricity and landline communication were cut off. Landslides were very common. Human lives were lost. Other lives were dramatically saved. Houses were buried or washed away. Rivers overflowed. Planted crops were destroyed.

PAG-ASA, the Philippine weather bureau, raised signal no. 3 when typhoon Milenyo hit Metro Manila at around 10:00 am. It carried with it maximum winds of 130 kph and gusts of up to 160 kph. At about 4:00 pm of that day, the typhoon signal was lowered to no. 2. While the metropolis also suffered from the wrath of Milenyo, the damages to lives and property were in many cases caused by the strong winds that brought debris from uprooted trees, pieces of galvanized iron sheets, and fallen electric poles and billboards resulting to power outage and unavailability of water supply in almost all parts of the metropolis. Operation of the overhead train system (MRT and LRT) also stopped. Two runways of the Ninoy Aquino International Airport faced closure for five hours.

The government declared all schools and offices closed on that day and the day after. Many private firms including large business establishments also stopped operation for the day as they sent home their employees. The high degree of damages, if any, was the main reason why some firms remained closed the following day.

5.4.5.2 Number of Days Establishments Temporarily Stopped Operation

About 165 of the 233 establishments that were affected by typhoon Milenyo reported to have temporarily stopped operation, for periods ranging from 0.08 days to 7 days, during the onslaught of the typhoon. The number of days that these establishments temporarily stopped operating varied according to the major industry division in which they operated.

Table 5-7 Number of Establishments that Temporarily Stopped Operation Due to Typhoon MILENYO and the Minimum and Maximum Days of Stoppage by Area and Main Economic Activity: 2008 SIFE

SIFE Survey Areas	1994 PSIC Major Division	Number of Establishments that Temporarily Stopped Operation	Minimum Number of Days with Stopped Operation	Maximum Number of Days with Stopped Operation
(1)	(2)	(3)	(4)	(5)
ALL ESTABLISHMENTS		165	0.08	7.00
	D - Manufacturing	104	0.08	7.00
	F - Construction	8	0.50	2.00
	G - Wholesale and Retail Trade; Repair of Motor Vehicles, Motorcycles and Personal and Household Goods	22	0.50	3.00
	H - Hotels and Restaurants	12	0.50	2.00
	I - Transport , Storage and Communications	9	1.00	4.00
	J - Financial Intermediation	3	0.30	3.00
	N - Health and Social Work	7	0.50	2.00

5.4.5.3 Reasons Cited For Effects on Business Operation

The survey results showed that business operations were definitely affected by the strong winds that came with the typhoon, which lasted for roughly five hours. From among the many possible reasons why business operation was affected by typhoon Milenyo, the 233 affected sample establishments, in the following order, pointed out three main reasons:

- Shortage of electricity/power outage (73.8 %)
- Insufficient number of employees who reported to work (66.1 %)
- Sales of goods and services were lower than the usual level (46.8 %).

The inability of establishments to deliver finished goods and the inability of suppliers to deliver raw materials and supplies were considered to be other main causes affecting business operations.

Table 5-8 Reasons why business operations were affected by typhoon Milenyo

Reasons	No. of reasons cited by firms	Cause of damage				
		Flooding within premise	Flooding within 50 km Meters	Flooding within 5 km Radius	Strong wind	Others
Problems delivering products	97	11	13	44	24	1
Low Sales	109	17	26	31	20	5
Problems receiving raw materials	65	5	16	25	13	
Employee shortage	154	15	27	53	47	1
Machines/Equipment	24	13	1		5	2
Inventory Damage	38	13	1	4	4	5
Cancelled orders	25	3	3	9	5	2
Electrical power outage	172	10	5	8	137	4
Damages to Telecommunication/Internet	53	1	1	3	32	1
Water Shortage	9		2	1	3	1
Others	11	3		1	3	2

5.4.5.4 Employees Who Did Not Report to Work

Nearly half (49%) of the affected establishments reported that from 1% to 50% of their employees did not report to work immediately after typhoon Milenyo hit the country. Over 20% reported that at least 50% of their workforce did not report to work the following day after typhoon Milenyo hit Metro Manila. This was expected as many parts of Metro Manila, including the flood-prone areas, were still having transportation problems and power outages. In addition, many employees needed to remain at home to repair their houses.

Table 5-9 Reasons for employees' absence from work

Area	Area	＜Reason＞				
		Unavailability of Transportation	Health Problems	Trouble Securing Food	House Repairs	Other
Pasig - Marikina Bgys	148	93	6	6	66	30
Kamanava Bgys	55	46	2	3	30	8
West Mangahan Bgys	43	33	4	4	13	13
Other Barangays	60	46	2	1	13	1

Note: One firm may cite more than one reason, so the number of affected firms does not equal the number of the reasons of work absence

5.4.5.5 Amount of Sales Lost

The temporary stoppage of business operation in 165 establishments during the onslaught of typhoon Milenyo certainly brought loss in sales. Sectors that depend on the daily patronage of customers for their income, like hotels and restaurants and transport, storage and communication, were one of the hardest hit. Losses in sales ranged from a low of Php 5,000 to a maximum of Php 5,000,000. A maximum of Php 10 million in sales was reported to be lost in a manufacturing establishment when typhoon Milenyo hit Metro-Manila.

Table 5-10 Sales and asset loss caused by typhoon Milenyo by Area (Php)

Area	Obs.	Loss in	
		Income	Assets
Pasig - Marikina Bgys	86	480,194	254,582
		(47)	(75)
Kamanava Bgys	66	364,359	268,461
		(39)	(55)
West Mangahan Bgys	58	245,317	816,147
		(30)	(43)
Other Barangays	76	229,238	113,247
		(40)	(60)
All Establishments	286	341,719	325,099
		(156)	(233)

Note: Number of affected firms is given in parentheses

Table 5-11 Sales and asset loss caused by typhoon Milenyo by Sector (Php)

Area	Obs.	Loss in	
		Income	Assets
Manufacturing	168	402,589	509,969
		(97)	(139)
Construction	12	218,750	31,982
		(8)	(11)
Wholesale and Retail Trade	43	227,429	57,891
		(21)	(33)
Hotels and Restaurants	23	102,773	22,310
		(11)	(21)
Transport,Storage and Communications	16	598,050	141,083
		(10)	(12)
Financial Intermediation	5	50,000	0
		(3)	(4)
Health and Social Work	19	78,333	33,744
		(6)	(13)
All Establishments	286	341,719	325,099
		(156)	(233)

Note: Number of affected firms is given in parentheses

5.4.5.6 Damaged assets (fixed assets and inventories)

About 93 of the 286 establishments interviewed reported that their fixed assets and inventories were damaged by typhoon Milenyo. Establishments engaged in the manufacturing sector experienced the highest prevalence of damage with 80.7%, while the lowest belonged to the transport storage and communications sector with 57.1%.

5.4.5.7 Sources of Financing for the Rehabilitation of Fixed Assets and Inventories Damaged by Typhoon Milenyo

Out of the 286 establishments interviewed, 65 establishments reported that they used their own funds to pay for flood damages, 11 obtained loans from private banks, and 12 establishments got money from their insurance policies. There were three establishments who reported that they received assistance from their parent companies located in Metro Manila. Establishments located in the four study areas got their financing from the same sources. In all areas, the highest percentage of financing came from the establishments' own funds, followed by insurance and loans from formal private banks.

5.4.5.8 Flood Countermeasures Undertaken by Establishments

Changing Business Location

For all establishments, 74 out of 286 establishments or 25.6% of establishments changed locations as a flooding countermeasure. The maximum number of moves was four. Financial intermediation had the highest percentage offices that moved with 80.0% while hotel and restaurant establishments had the smallest percentage with 8.7%.

Adding Fill to Land Within Premises

There were 67 establishments or 23.4% that had refilled some or all of the land within their premises in the last five years. The number times that fill had been added varied from one to seven times. Establishments situated in the KAMANAVA area had the highest percentage (51.5%) and had refilled their land a maximum of seven times.

Increasing the Number of Stories in Buildings

Only 19 out of 286 establishments interviewed or 6.6% had increased the number of stories of any of their buildings in the last five years. The highest percentage was by establishments in the KAMANAVA area with 10.6%, while Other Barangays had the lowest with only 3.9%. There were 12 establishments or 4.2% reporting that they still planned to increase the number of stories in any of their buildings.

Other Measures to Minimize the Effects of Flooding

In 2008, 36 establishments protected their vital records. Thirty-one implemented safe storage of hazardous materials. Twenty-eight said that they were maintaining sufficient inventories of raw materials and supplies and had installed disaster prevention plans. Only 17 establishments had prepared for transportation in emergencies and installed disaster recovery plans. Among other measures taken by establishments to minimize the effects of flooding included installation of motor, electric, or automatic submerged pumps; cleaning or declogging of drainage, building their own drainage systems or open canals, and improving or repaired their drainage systems.

5.4.5.9 Measures Managed by Private Community-Based Organizations to Mitigate the Damages Caused by Floods

Level of Awareness and Preparatory Measures Undertaken by Private Community-Based Organizations to Mitigate Damages Caused by Floods

About 15.7% of establishments were aware of preparatory measures undertaken by private community-based organizations. By area, the level of awareness was highest among establishments based in the West Mangahan area at 24.1%, followed by those in Pasig-Marikina with 17.9 %.

The most common type of preparatory measures to mitigate damages caused by floods undertaken by private community-based organization were preparation of emergency transportation and construction of dikes, reported by 18 and 15 establishments, respectively. Firms also reported that private organizations had undertaken cleaning and improvement of canals, drainage and sewage systems.

Types of Cooperative Activities that Exists Among Establishments to Restore the Normal Business Environment after Flooding Occurs

There were several cooperative activities that existed among the establishments to restore the normal business environment after occurrence of flooding. The top three activities were:

- Repair of damages to public infrastructure
- Provision of loans or assistance for recovery
- Lending of machines, equipment and tools

Nine establishments mentioned cleaning and declogging of drainage and canals as other type of cooperative activities.

Types of Assistance Provided by Business Organizations

Of the 286 surveyed establishments, only 23, or 8.0% were aware of any type of assistance provided by business organizations to mitigate damages caused by floods. By area, the level of awareness was highest for establishments in Pasig-Marikina (11.2%) and the lowest in Other Barangays (2.6%). The types of assistance from business organizations respondents mentioned were:

- Conducting training or seminars
- Lending of machines, equipment and tools
- Provision of loans or assistance for recovery
- Dredging of rivers near the vicinity of the establishment
- Immediate supply of raw materials and supplies
- Repair of damages to public infrastructure.

5.4.5.10 Countermeasures for Floods Undertaken by Government Agencies

Type of Government Agencies Providing Assistance

Of the responding establishments, 175 reported awareness of assistance provided by the Local Government Units (LGUs) and 68 knew of assistance provided by national government agencies (NGAs). Of the 141 establishments in thee Pasig-Marikina barangays that were aware of government assistance, 132 were aware of assistance from LGUs and 33 knew of NGAs' assistance.

Types of Assistance

Of the 68 establishments that were aware that assistance was available from national government agencies to mitigate the effects of flooding, 55 stated that the assistance was in the form of repair of damages to public infrastructure and 29 listed construction of dikes. Nine mentioned provision of loans or assistance for recovery and five cited drainage cleaning and improvement. Similarly, repair of damaged infrastructure (140), construction of dikes (66), cleaning, construction, and improvement of drainage or sewerage systems (41) were among the types of help cited by the 175 establishments that were aware of assistance provided by LGUs to mitigate effects of flooding.

Chapter 6 Adaptation Options and Economic Evaluation

6.1 Introduction

This Chapter first describes the methodology employed to derive the adaptation options and their corresponding costs. The adaptation options are selected with the objective of eliminating, as much as possible[1], the floods shown in the previously presented flood simulations. Next, the results of economic evaluation, Economic Internal Rate of Return (EIRR) and Net Present Value (NPV) are presented by combining the adaptation options (cost side) with the damages that can be avoided (benefit side) shown in Chapter 3.

6.2 Deriving adaptation options

6.2.1 Flood levels to be examined

The target flood level is set in accordance with the safety level of existing flood control infrastructure projects in the target areas. If the difference between the target flood level and the safety level of existing flood control projects is too large, the effects of infrastructural improvements such as river improvement, diking systems and drainage facilities cannot be examined through hydraulic simulation. In this context, the target flood level is determined as shown in Table 6-1. In the case of the Pasig-Marikina river basin, a 100-year return period target flood level was possible (an exceptional case) because the 1990 Master Plan covered such hydraulic analysis.

Table 6-1 Target Flood Level to be examined (return period in years)

River Basin/Drainage Area	Design Level for Flood control project	Target Flood Level
Pasig-Marikina River Basin	30-year	100-year
KAMANAVA Area	10-year	10-year
West of Mangahan Area	10-year	10-year

6.3 Structural measures to be examined

For preventing flood damage caused by climate change, structural measures like dam construction and dike raising are considered for each river basin/drainage area.

[1] Note that for the KAMANAVA and West of Mangahan Areas, total elimination is impossible because of the low elevation. Rather, pumping capacity improvement is considered to minimize the duration of flooding.

6.3.1 Pasig-Marikina River Basin

Case 1: Improvement of embankments without the Marikina Dam (P30)

In order to prevent overbanking-type flooding from the river, raising the embankment was considered. The necessary additional embankment height can be determined by trial calculations of the embankment heights until the overbanking flow is eliminated. This case is subject to the condition that the Marikina dam is not constructed.

Case 2: Improvement of embankment with Marikina Dam (P100, P30)

The method described above was also used to examine how much the embankments would need to be raised assuming that the Marikina dam is in operation.

6.3.2 West of Mangahan and KAMANAVA Area

For the West of Mangahan and KAMANAVA areas, the pump capacity required to keep flooding depths under an allowable inundation of 30 cm was determined. When the usual local runoff drainage plan for the interior areas was applied, all of the rainwater could not be drained due to excessive cost for the benefit achieved. In this study, allowable inundation depths of around 30 cm are assumed because only negligible damages would occur with such inundation and it would be possible to evacuate residents under those conditions.

6.3.3 Storm Surge barrier for the coastal area

For preventing overflow from the Manila Bay caused by typhoon-induced storm surge, the necessary height of storm surge barrier was examined.

6.4 Adaptation options

6.4.1 Pasig Marikina River Basin

As a result of hydraulic analysis, the necessary increased embankment heights were calculated as shown in Table 6-2. Raising the embankments approximately 0.5 m would relieve the flood damage.

Table 6-2 Adaptation Measures for Climate Change – Raising Embankments

Return Period: 30 years

Scenario	Case	River	Increased Embankment Height	Length
B1	Without Marikina dam	Pasig	-	-
		San Juan	-	-
		Marikina	+ 0.5 m	16,400 m
	With Marikina Dam	Pasig	-	-
		San Juan	-	-
		Marikina	Less than + 0.5 m	16,400 m
A1FI	Without Marikina dam	Pasig	+ 0.2 m	25,380 m
		San Juan	-	-
		Marikina	+ 0.5 m	16,400 m
	With Marikina Dam	Pasig		
		San Juan	-	-
		Marikina	Less than + 0.5 m	16,400 m

Return Period: 100 years

Scenario	Case	River	Increased Embankment Height	Length
B1	With Marikina Dam	Pasig	+ 0.4 m	27,250 m
		San Juan	-	-
		Marikina	+ 0.5 m	16,400 m
A1FI	Ditto	Pasig	+ 0.6 m	28,690 m
		San Juan	-	-
		Marikina	+ 0.5 m	16,400 m

6.4.2 KAMANAVA Area

In the KAMANAVA area, the storm water drainage plan is designed for a 10-year return period and the total planned drainage pump capacity is 44 cubic m^3/s. In order to mitigate the expected increase in flooding volume caused by climate change, pump capacity increases should be considered. The necessary capacity increases estimated by the pond model analysis for the KAMANAVA area are tabulated in Table 6-3.

Table 6-3 Necessary Pumping Capacity Increases (KAMANAVA)

Unit: m^3/s

Scenario	Return Period	Capacity for Master plan	Necessary Pump Capacity	Additional Capacity
B1	1/10	44 (10-year return period)	73	29
	1/30		81	37
	1/100		90	46
A1FI	1/10		83	39
	1/30		94	50
	1/100		105	61

6.4.3 West of Mangahan Area

In the West of Mangahan area, drainage plan is also designed for a 10-year return period and the total planned drainage pump capacity is 72 m^3/s. In order to mitigate the expected increase in flooding volume caused by climate change, pump capacity increases should be considered here as well. The necessary capacity increases estimated by the pond model analysis for the West of Mangahan area are tabulated in Table 6-4.

Table 6-4 Necessary Pumping Capacity Increases (West of Mangahan)

Unit: m^3/s

Scenario	Return Period	Capacity for Master plan	Necessary Pump Capacity	Additional Capacity
B1	1/10	72 (10-year return period)	86	14
	1/30		99	27
	1/100		105	33
A1FI	1/10		94	22
	1/30		115	43
	1/100		125	53

6.4.4 Storm Surge

In order to calculate the necessary height and length of storm surge barriers, the elevation along the coastal area and storm surge water levels were compared. The necessary height and length of barriers determined in this way are shown in Table 6-5.

Table 6-5 Improvement of Storm Surge Barrier

Scenario	Storm Surge Level	Length	Average Required Embankment Height Increase
SQ	12.31 m	26,200 m	0.59 m
B1	12.59 m	27,700 m	0.83 m
A1FI	12.69 m	28,600 m	0.91 m

6.5 Cost Estimation

6.5.1 Construction Cost of components related to the 1990 Master plan

In order to conduct economic analyses for measures used to adapt to climate change, construction cost units used in the 1990 Master Plan[2] were reviewed. Construction costs in Japanese Yen, estimated in 1990, were converted to present values using Japanese deflator figures.

6.5.1.1 Pasig Marikina River

1) Return Period: 100 years

Construction costs estimated in 1990 are shown in Table 6-6, with details for the Marikina dam given in Table 6-7. According to the 1990 conversion rate, 1 Philippine peso was equivalent to 6.20 Yen. To roughly estimate capital costs, 40% of direct costs are assumed to be attributable to administration cost, as 40% is empirically used in other similar projects in the Philippines.

[2] Flood Control and Drainage Projects in Metro Manila (JICA, 1990)

Table 6-6 Works Required by 1990 Master Plan

Pasig Marikina River Improvements (100-year)

Items	Civil Works (mil. Php)	Land Acquisition and others (mil. Php)	Total (mil. Php)	Direct Cost Yen (2007)*	Capital Cost
River Mouth/San Juan C	646	60	706	4,625,610,000	6,475,850,000
San Juan C./ Napindan	212	45	257	1,683,830,000	2,357,360,000
Napindan C./ M.C.G.S.	39	24	63	412,770,000	577,880,000
M.C.G.S / Mangahan C.	24	18	42	275,180,000	385,250,000
Mangahan C./ Sta. 7+425	26	12	38	248,970,000	348,560,000
M.C.G.S.	183	1	184	1,205,540,000	1,687,760,000
San Juan River	580	177	757	4,959,760,000	6,943,660,000
	1,710	337	2,047	13,411,660,000	18,776,320,000
Mangahan C./ Nangka C.	497	334	831	5,444,600,000	7,622,440,000
Nangka C./ Rodoriger B.	218	517	735	4,815,620,000	6,741,870,000
Marikina Dam	675	125	800	5,241,490,000	7,338,090,000
	1,390	976	2,366	15,501,700,000	21,702,380,000
Total	3,100	1,313	4,413	28,913,360,000	**40,478,700,000**

*According to Japanese deflator for construction costs (base year: 2000), the present value for 1990 is 96.1 for a base value of 100 and 2007 is 101.6. For converting 1990 construction costs to 2007 costs, direct costs should be multiplied by a factor of 101.6/96.1.

Table 6-7 Details of Construction Cost for Marikina Dam (1990)

Marikina Dam

Dam Height	70	m
Direct Cost (1990)	800	Mil. Php
	4,957,746,000	Yen
Direct Cost (2007)	5,241,490,000	Yen
Capital Cost *	7,338,090,000	Yen

*added administration cost

2) Return Period: 30 years

Construction costs for the 30-year return period were converted to present values as described above. Construction costs estimated for JICA's 2002 Department of Public Works and Highways Detailed Design (DPWH D/D) are shown in Table 6-8. According to the conversion rate for 2002, 1 Philippine peso was equivalent to approx 2.6 Yen

Table 6-8 Works Required for 2002 Detailed Design

Capital Cost for Pasig Marikina River Improvement (30 Year) (Mil. Php)

1	Main Construction Cost	8,355
2	Compensation Cost	2,362
3	Administration Cost	292
4	Engineering Service	657
	Total	11,666

Reference:2002 JICA-DPWH D/D

Japanese Yen(2002)	30,004,952,000
Japanese Yen(2007)	31,558,000,000

6.5.2 Improvement costs for components not included in the 1990 Master plan

6.5.2.1 Cost of Increasing Embankment Height

Additional cost estimation for improvements along the Pasig-Marikina River produced the rough costs for parapet walls shown in Table 6-9 below.

Table 6-9 Construction Cost for Parapet Walls (2008)

Parapet Wall **Rate:** 1.913

H	Concrete			Reinforcing Bar			Anchor Bar			Concrete Chipping			Total Cost (Php/m)	Total Cost (Yen/m)
(m)	Volume (m^3/m)	Unit Cost (Php/m^3)	Cost (Php/m)	Weight (t/m)	Unit Cost (Php/t)	Cost (Php/m)	Weight (kg/m)	Unit Cost (Php/kg)	Cost (Php/m)	Area (m^2/m)	Unit Cost (Php/m^2)	Cost (Php/m)		
0.41 ~ 0.5	0.113	7,000	788	0.010	65,000	645	4.972	500	2,486	0.5	500	250	5,000	9,600
0.91 ~ 1	0.250	7,000	1,750	0.016	65,000	1,015	4.972	500	2,486	0.5	500	250	6,000	11,500
1.41 ~ 1.5	0.413	7,000	2,888	0.023	65,000	1,512	4.972	500	2,486	0.5	500	250	8,000	15,400

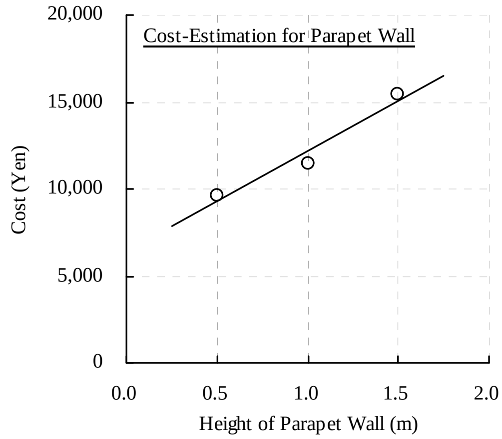

Figure 6-1   Relationship between Height of Parapet Wall and Construction Cost (Yen)

The unit price of adding additional height to embankments is obtained by assuming a linear relationship between the height and the unit price for a parapet wall, as shown above in Fig. 6-1. For instance, the cost for raising an embankment by 50 cm is calculated as follows.:

11,500 Yen/m (cost for 1.0 m high wall) – 9600 Yen/m (cost for 0.5 m high wall) = 1,900 Yen/m

6.5.2.2 Cost of Increasing Drainage Pump Capacity

If existing pumps are improved to enhance drainage capacities, the cost is approximately 50,000,000 yen per m^3/s, while constructing a new pump station costs approximately 100,000,000 yen per m^3/s. These units were employed to make rough cost estimates for increasing drainage pump capacities.

6.5.3 Cost estimation for improvement work

6.5.3.1 Pasig-Marikina River Basin

Table 6-10 presents rough cost estimates for improvements based on necessary height increases and unit prices.

Table 6-10 Costs of Measures for Adaptation to Climate Change

Return Period: 30 years

Scenario	Dam	River	Raising of Embankment	Capital Cost (Yen)	Total Cost (Yen)
B1	None	Pasig	-	0	89,550,000
		San Juan	-	0	
		Marikina	+ 0.5 m	89,550,000	
	Marikina Dam	Pasig	-	0	7,427,640,000
		San Juan	-	0	
		Marikina	Less than + 0.5 m	89,550,000	
		Dam Construction Cost		7,338,090,000	
A1FI	None	Pasig	+ 0.2 m	67,510,000	157,060,000
		San Juan		0	
		Marikina	+ 0.5 m	89,550,000	
	Marikina Dam	Pasig		0	7,427,640,000
		San Juan		0	
		Marikina	Less than + 0.5 m	89,550,000	
		Dam Construction Cost		7,338,090,000	

Return Period: 100 years

Scenario	Dam	River	Raising Embankment	Capital Cost (Yen)	Total Cost (Yen)
B1	Marikina Dam	Pasig	+ 0.4 m	148,070,000	237,620,000
		San Juan		0	
		Marikina	+ 0.5 m	89,550,000	
A1FI	Marikina Dam	Pasig	+ 0.6 m	231,720,000	321,270,000
		San Juan		0	
		Marikina	+ 0.5 m	89,550,000	

*Master plan for the 100-year return period originally included the construction of Marikina Dam.

6.5.3.2 KAMANAVA Area

Rough cost estimates based on necessary additional pump capacity are shown in Table 6-11.

Table 6-11 Additional Pump Capacity Costs

Scenario	Return Period	Pump Capacity for Master Plan (m^3/s)	Necessary Pump Capacity(m^3/s)	Additional Capacity (m^3/s)	Capital Cost (yen)
B1	10 years	44 (10-year return period)	73	29	1,450,000,000
	30 years		81	37	1,850,000,000
	100 years		90	46	2,300,000,000
A1FI	10 years		83	39	1,950,000,000
	30 years		94	50	2,500,000,000
	100 years		105	61	3,050,000,000

*unit price:50,000,000 yen / m^3/s

6.5.3.3 West of Mangahan

Rough cost estimates based on necessary additional pump capacity are shown in Table 6-12.

Table 6-12 Additional Pump Capacity Costs

Scenario	Return Period	Pump Capacity for Master Plan (m^3/s)	The Necessary Pump Capacity(m^3/s)	Additional Capacity (m^3/s)	Capital Cost (yen)
B1	10 years	72 (10-year return period)	86	14	700,000,000
	30 years		99	27	1,350,000,000
	100 years		105	33	1,650,000,000
A1FI	10 years		94	22	1,100,000,000
	30 years		115	43	2,150,000,000
	100 years		125	53	2,650,000,000

*unit price:50,000,000 yen / m^3/s

6.5.3.4 Storm Surge Barriers

For raising storm surge barriers, rough estimates of costs based on the necessary additional height, length and unit cost, are given in Table 6-13.

Table 6-13 Construction Costs for Storm Surge Barrier

Scenario	H.H.W.L Elev. (m)	Length (m)	Height (m)	Unit (yen /m)	Direct Cost (yen)	Capital Cost (yen)
SQ	12.31	26,200	0.6	2,700	70,740,000	99,040,000
B1	12.59	27,700	0.8	4,300	119,110,000	166,750,000
A1FI	12.69	28,600	0.9	5,100	145,860,000	204,200,000

H.H.W.L. – Highest High Water Level calculated for each climate scenario

6.6 Economic evaluations

The objective of this section is to derive the cost and benefit streams for determining the Economic Internal Rate of Return (EIRR) and Net Present Value (NPV) for a range of possible adaptation investments proposed specifically for the Pasig-Marikina River basin area, the West of Mangahan area, and the KAMANAVA area of Metro Manila.

6.6.1 Methodology for EIRR and NPV calculation

The major components needed to calculate the economic internal rate of return (EIRR) and net present value (NPV) of an infrastructure project are the following:

1) Project Costs, consisting of construction cost, engineering service cost, land acquisition and compensation (if needed), project management cost, and physical and price contingencies.

2) Investment Schedule, showing how the investment will be distributed during the implementation period of the project (i.e., initial investment) and over its project life (i.e., for improvements or maintenance). The durable life of an infrastructure project is usually assumed to be 50 or 60 years if properly maintained. In this analysis, the construction period is 5 years starting from 2010 and project life is expected to last until 2060. Investments after the completion of the Master Plan are assumed to start from 2014. No maintenance cost was included in the analysis.

3) Project Benefits - these are the benefits (i.e., avoided damages) attributable to the investment. We estimated the most direct benefits and the ones possible for quantification although there are still various social benefits that are not quantifiable. The benefits are estimated in terms of building/asset damage, road damage, VOC, travel time, income loss (for both firms and households), etc. Benefits are usually subject to an inflation/deflation rate for economic cash flows over the

project life to take into account projected changes based on past economic performance.

4) Discount rate - According to the National Economic and Development Authority of the Philippines, the discount rate used to judge the economic feasibility of projects is 15%. This rate is used as the discount rate in the NPV calculation.

6.6.4 Deriving EIRR and NPV for adaptation options

Economic evaluation of the adaptation projects given in the previous sections of this Chapter and the benefits (avoided damages) provided in Chapter 3 requires several calculation steps. It is important to note that the total gross avoided damages determined in Chapter 3 do not directly feed in to the EIRR and NPV annual benefit flows. This is because there are three geographical areas, and depending on the return period and adaptation investments, only the relevant benefits are considered. For example, embankment improvements on the Pasig-Marikina River do not affect the coast side KAMANAVA area, thus such improvements do not benefit the KAMANAVA area.

Each damage item was converted to 2008 and 2050 values using a 5% growth rage per annum. For example, affected floor area was calculated using year 2000 DPWH base unit costs. These values were converted to 2008 or 2050 values with the 5% growth rate.

The benefit side of the cash stream for EIRR and NPV was then calculated by taking the integral of the probability distribution function plotting 10-year, 30-year and 100-year return period damages for each climate/infrastructure scenario as shown in Figure 6-2.

Two different cases were considered in the analysis:

1) Improvements that take the infrastructure from its existing state (EX) to the full adaptation level (the difference between EX and full adaptation lines in the figure)
2) Further improvements above those in the 1990 master plan level (MP) to achieve the full adaptation level (the difference between MP and full adaptation lines in the figure)

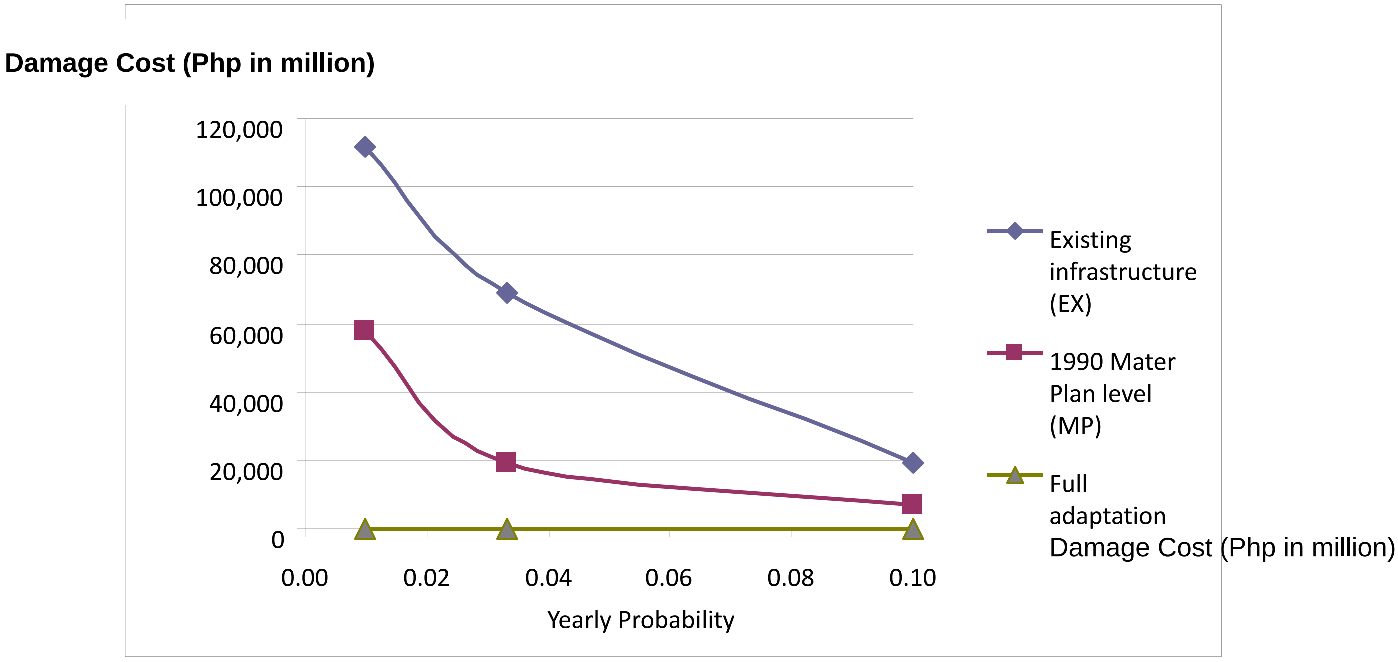

Figure 6-2 Comparison of damage costs for different adaptation levels and probabilities

Third, the adaptation costs given in the previous sections were combined with the benefit stream (damages avoidable) for each climate/infrastructure/return period scenario. P100 adaptation structures are assumed to prevent P30 and P10 floods. Careful matching was conducted between adaptation measures and avoided damages since flood control structures intended for specific areas cannot prevent floods in other areas, as mentioned before.

Significant deviations in estimates can arise when calculating the damages to high-rise buildings. Conventional methods do not specify how to value buildings' higher floors. In this study, we assumed that the value of upper floor areas remains intact while the fixtures of the affected floors are damaged depending on the flood depth. Similarly, the income and activities of residents and firms in upper floors are assumed to be unaffected. In this sense, the benefit numbers are on the conservative side.

Adaptation options for the P30 return period are divided into those that do no include the Marikina dam and those that do. Without the dam, the necessary investments for embankments and pumping increase. The Master Plan for the 100-year return period has always included the Marikina dam. Table 6-14 presents the economic analyses for each scenario/return period/adaptation level combination, and Table 6-15 lists the priorities by which the adaptation measures were compared.

Table 6-14 EIRR and NPV Results

	Cases	EIRR	NPV 15% (Php)	Adaptation cost in 2008 (Php)	Duration (days)
1	P100 SQ EX wD	18%	3,735,417,996	13,501,553,721	5
2	P100 SQ MP wD	N/A	4,747,146,081	0	3.5
3	P100 B1 EX wD	23%	10,119,764,171	13,604,450,310	5
4	P100 B1 MP wD	140%	7,578,065,582	102,896,589	3
5	P100 A1FI EX wD	24%	11,941,808,517	13,640,673,269	6.5
6	P100 A1FI MP wD	141%	10,393,996,079	139,119,548	4
7	P30 SQ EX wD	16%	791,013,521	14,121,102,133	2
8	P30 SQ EX nD	18%	2,921,383,920	10,943,489,020	2
9	P30 SQ MP wD	19%	1,194,339,182	3,177,613,113	1.5
10	P30 SQ MP nD	N/A	3,324,709,581	0	1.5
11	P30 B1 EX wD	20%	5,615,755,728	14,232,087,722	3
12	P30 B1 EX nD	23%	7,746,126,127	11,054,474,609	3
13	P30 B1 MP wD	26%	3,506,324,553	3,216,390,949	2
14	P30 B1 MP nD	174%	5,636,694,952	38,777,837	2
15	P30 A1FI EX wD	21%	7,041,428,985	14,248,304,696	4
16	P30 A1FI EX nD	24%	9,152,200,101	11,099,925,438	4
17	P30 A1FI MP wD	31%	5,498,525,059	3,216,390,949	2
18	P30 A1FI MP nD	160%	7,609,296,174	68,011,692	2
19	P10 SQ EX nD	49%	209,952,438	42,887,291	1.5
20	P10 SQ MP nD	*N/A because Master Plan beyond EX does not exist.			
21	P10 B1 EX nD	10%	(349,951,115)	1,003,222,253	1.5
22	P10 B1 MP nD	*N/A because Master Plan beyond EX does not exist.			
23	P10 A1FI EX nD	8%	(581,704,127)	1,409,166,226	1.5
24	P10 A1FI MP nD	*N/A because Master Plan beyond EX does not exist.			

Note: P10, P30, and P100 are the 10, 30, and 100-year return period flooding levels. SQ, B1, and A1FI are the climate scenarios, EX and MP denote existing and master plan infrastructure conditions. wD and nD denote the presence or absence of the Marikina Dam, respectively.

Table 6-15 Adaptation priorities for NPV and EIRR comparisons (without Marikina dam)

Adaptation Project Priority	NPV	EIRR
1st priority	**Prepare for P30 flooding under A1FI climate (p30 A1FI EX nD)** First, continue investments under the current Master Plan in the Pasig-Marikina river basin and then add additional investments for full adaptation	**Prepare for P30 flooding under B1 climate (p30 B1 MP nD)** Additional adaptation investments for full adaptation (provided that the current Master Plan in the Pasig-Marikina river basin is completed on time)
2nd priority	**Prepare for P30 flooding under A1FI climate (p30 A1FI MP nD)** Additional adaptation investments for full adaptation (provided that the current Master Plan in the Pasig-Marikina river basin is completed on time)	**Prepare for P30 flooding under A1FI climate (p30 A1FI MP nD)** Additional adaptation investments for full adaptation (provided that the current Master Plan in the Pasig-Marikina river basin is completed on time)
3rd priority	**Prepare for P30 flooding under B1 climate (p30 B1 EX nD)** First, continue investments under the current Master Plan in the Pasig-Marikina river basin and then add additional investments for full adaptation	**Prepare for P10 flood under status quo climate (p10 SQ EX nD)** Continue investments necessary under the status quo climate in the KAMANAVA and West of Mangahan flood control project areas

Table 6-16 (for reference) Adaptation priorities for NPV and EIRR comparisons (including cases with the Marikina dam)

Priority of the adaptation projects	NPV	EIRR
1st priority	**Prepare for P100 flood under A1FI climate (p100 A1FI EX wD)** First, continue investments under the current Master Plan in the Pasig-Marikina river basin and then add additional investments for full adaptation, including the Marikina Dam	**Prepare for P30 flood under B1 climate (p30 B1 MP nD)** Additional adaptation investments for full adaptation (provided that the current Master Plan in the Pasig-Marikina river basin is completed on time)
2nd priority	**Prepare for P100 flood under A1FI climate (p100 A1FI MP wD)** Additional adaptation investments for full adaptation including the Marikina Dam (provided that the current Master Plan in the Pasig-Marikina river basin is completed on time)	**Prepare for P30 flood under A1FI climate (p30 A1FI MP nD)** Additional adaptation investments for full adaptation (provided that the current Master Plan in the Pasig-Marikina river basin is completed on time)
3rd priority	**Prepare for P100 flood under B1 climate (p100 B1 EX wD)** First, continue investments under the current Master Plan in the Pasig-Marikina river basin and then add additional investments for full adaptation, including the Marikina Dam	**Prepare for P100 flood under A1FI climate (p100 A1FI MP wD)** Additional adaptation investments for full adaptation including the Marikina Dam (provided that the current Master Plan in the Pasig-Marikina river basin is completed on time)

6.7 Discussion of adaptation priorities based on economic evaluations

The ranking of the EIRR evaluation and the ranking of the NPV evaluation show different results, but they are common in suggesting that filling the infrastructure gap identified under the current

Master Plan (for the status quo climate) is the first and foremost priority. If maximizing the avoided damages is most important, following the NPV results is preferable, but if investment efficiency is more of a concern, following the EIRR results would be better. The decision also depends on the level of return period that is targeted.

Assuming no dam in the adaptation options, the NPV results prioritize investments to protect the city from the 30-year return period under the A1FI climate scenario. The recommended investment package is to first continue investments under the current Master Plan in the Pasig-Marikina river basin and then add additional investments for full adaptation to the A1FI scenario. This suggests that the flood control investments in the Pasig-Marikina river basin to fill the gap between the existing infrastructure and the Master Plan are priority investments in the process to adapt to climate change. This is the option currently chosen by the Government of the Philippines, by implementing the Pasig- Marikina Flood Control Project Phase II to avoid damages from 30-year flooding.

The EIRR results prioritize additional investments to prepare for P30 flood under the B1 climate scenario after the Master Plan components for the current climate are completed. The recommended progression is to invest in additional adaptation projects for full adaptation for the B1 scenario, provided that the current Master Plan in Pasig-Marikina river basin is completed before the projects are undertaken. This also suggests that the flood control investments in the Pasig-Marikina river basin to fill the gap between the existing infrastructure and the Master Plan are prerequisites to adapt to climate change. It is important to note that preparing for 10-year flooding in the status quo climate comes in third place. This suggests that additional investments to the KAMANAVA and West of Mangahan areas under the status quo climate are important. In fact, some KAMANAVA area municipalities are introducing their own pumping stations ("bombastics") in limited numbers.

The above discussion confirms that the on-going flood control projects in Metro Manila are integrated components of adaptation to climate change. At least in the case of Metro Manila, adaptation investments are not a completely new additional effort, but a continuation of the on-going flood control efforts both in terms of planning and financing.

Chapter 7: Summary and policy discussions

7.1 Introduction

This chapter summarizes the main contents of Chapters 1 to 6 and discusses policy measures to adapt to climate change. The policy recommendations are based on the findings in this report as well as dialogues with Metro Manila communities and local governments.

7.2 Summary of previous chapters

7.2.1 Chapter 1

Climate models supporting the IPCC's Fourth Assessment Report (AR4) indicate that climate change is likely to increase local temperatures and local precipitation in monsoon regions in Asia, where the number of large cities is increasing and existing large urban areas are expanding, particularly along the coasts.

Metro Manila, typical of Asian coastal megacities, was chosen as a case study to comprehensively simulate impacts of future climate change and identify necessary policy actions. Metro Manila maintains its premiership as the economic center of the Philippines holding the headquarters of domestic and international business establishments. At the same time, since Metro Manila is in a low-lying area, facing the sea, a lake and two river systems, it is prone to disastrous flooding.

There are several flood types in Metro Manila: storage, overbanking, and interior flooding. The following three areas are each vulnerable to one of these: the KAMANAVA (Kalookan, Malabon, Navotas, and Valenzuela) area is susceptible to storage type flooding, the Pasig-Marikina river basin often experiences overbanking, and the West Mangahan area is prone to interior flooding.

The KAMANAVA area is low and flat with elevations ranging from around sea level to two to three meters above mean sea level. Flooding in the KAMANAVA area is caused by a combination of overflow of the Malabon-Tullahan River and inadequate local drainage aggravated by high tides in Manila Bay. A JICA-financed flood control project, the KAMANAVA Area Flood Control and Drainage System Improvement Project, has a 10-year return period design scale.

The Pasig-Marikina River System has a catchment area of 651 km^2, composed of the 10 cities and municipalities of Mandaluyong, Manila, Marikina, Quezon, San Juan, Antipolo, Cainta, Rodriguez, San Mateo and Pasay. The section of the river system between the river mouth (Manila Bay) and the confluence point with the Napindan Channel is called the Pasig River, and the section of the river system upstream from the Napindan confluence is the Marikina River. Excess flood runoff overflows the riverbanks of the Pasig and Marikina rivers. A JICA-funded flood control project known as the Pasig-Marikina River Channel Improvement Project has been formulated based on a 30-year return period.

The Marikina River's excess runoff water is diverted to the Laguna de Bay Lake through the Mangahan Floodway during floods to protect the Metro Manila city core. The total area west of the Mangahan Floodway facing Laguna Lake is 39 km^2, covering the five cities of Makati, Pasig, Pateros, Taguig, and Taytay. The topography of the West Mangahan drainage area is flat, and it is a typical interior-flood-prone area. Floods are assumed to be brought on by storm rainfall and high water levels in the lake.

7.2.2 Chapter 2

This report is based on global climate projections provided by the IPCC's Fourth Assessment Report. Two scenarios, B1 and A1FI, from the IPCC's Special Reports on Emissions Scenarios (SRES) were adopted and compared with the status quo (SQ) scenario. A target year of 2050 was set as the halfway mark of the IPCC SRES. Simulated spatial spreads of flooding under scenarios SQ, B1, and A1FI in the year 2050 were used as the bases of impact analyses.

In spite of various uncertainties, in this study we translated global climate scenarios to regional climate scenarios, a process called "downscaling". Scenarios B1 and A1FI of the IPCC SRES scenarios provide a basis for discussing changes in local temperature and precipitation in Metro Manila, based on which hydrological conditions such as river overflow and storm surge are projected. The study produced flood simulation maps that show different spatial spreads and flooding inundation depths in the metropolis, depending on the climate-hydrologic infrastructure scenario.

7.2.3 Chapter 3

Chapter 3 discusses socio-economic impact analyses conducted to understand the characteristics and the magnitude of the damage of floods expected in the year 2050. The benefit side of the analysis is the aggregate-level damage avoidable through adaptation. The types of benefits included in this study go beyond conventional flood impact assessments that deal only with direct losses such as buildings.

In this report, direct and tangible losses are first assessed, as is performed in conventional flood control project analyses. Then, indirect and tangible losses are assessed where possible with available data. For indirect, tangible losses, this report combines the incremental cost of transportation (VOC and time costs), lost wages and income (sales) triggered by flood. Intangible losses (in this report, health hazards) are presented separately in Chapter 4.

If infrastructure improvement were halted now, assuming the A1FI climate scenario, flood damages could be up to 24% of GRDP under 100-year flooding conditions. If infrastructure improvement based on 1990 Master Plan is implemented and the B1 climate scenario is assumed, the damages due to 100-year flooding would be only 9% of GRDP. For a 30-year return period, the above percentages are 15% and 3% respectively.

7.2.4 Chapter 4

Chapter 4 characterizes and quantifies human health risks associated with exposures to pathogens present in floodwater, as an example of intangible risks related to flooding in Metro Manila. Here, exposure scenarios based on different inundation levels were developed in which direct and indirect contacts with water were assumed to occur.

The risk of gastrointestinal illness due to E. Coli from incidental ingestion of floodwater in Metro Manila is calculated for different flood depths. The number of infected people is estimated to be high in densely populated flood areas such as the city of Manila, Pasig city, and Marikina city.

7.2.5 Chapter 5

This chapter presents the results of the analyses undertaken to identify the vulnerabilities of selected segments of society and the economy. The first section covers a household level analysis focusing on the experiences of those living in areas affected by flooding, typhoons, and tidal surges in the current climate. The second section covers a firm-level analysis of businesses, focusing on their experiences in Typhoon Milenyo (2006) and other flood events.

The urban poor who live in flood-prone areas consist of recent migrants from outside Metro Manila. Their choice of where to live coincides with the vulnerability of their livelihoods. The interviewed households have an income level of less than 1 USD a month per person, and most of them live in slums and squatter settlements with no security of tenure nor adequate access to water, electricity, health services, drainage, or sanitation services. Among those residents, two-thirds regularly suffer losses (income, health, household assets), and inconvenience (evacuation, having to use rivers or creeks for toilet, etc.) due to flooding.

Many establishments in flood-prone areas of Metro Manila have had to temporarily halt their operations, especially during Typhoon Milenyo in 2006. The three main reasons for the work stoppage were a shortage of electricity or power outages (mainly due to strong winds), an insufficient number of workers reporting to work, and low sales. The main reason for employees' absence from work was unavailability of transportation, which can be related to flooding.

7.2.6 Chapter 6

This Chapter first describes the methodology used to derive the adaptation options and their corresponding costs. The adaptation options were selected, guided by the objective of eliminating, as much as possible, the floods shown in the previously presented flood simulations. Finally, the results of economic evaluations based on Economic Internal Rate of Return (EIRR) and Net Present Value (NPV) are presented.

The ranking of improvements based on EIRR and NPV evaluations differ, but they are common in suggesting that filling the infrastructure gap identified under the current Master Plan (for the status quo climate) is the first and foremost priority. If maximizing the avoided damages is most important, following the NPV results is preferable, but if investment efficiency is a larger concern, following the EIRR results is recommended. The decision also depends on the targeted return period.

If construction of the Marikina dam is not considered in the adaptation options, NPV calculations prioritize investments to protect the city from 30-year return period flooding under the A1FI climate scenario. The recommended investment package is to first continue investments under the current Master Plan in the Pasig-Marikina river basin and then add additional investments toward full adaptation for the A1FI scenario. This suggests that the flood control investments in the Pasig-Marikina river basin aimed at filling the gap between the existing infrastructure and the Master Plan are priority investments in the process to adapt to climate change. This is the strategy currently chosen by the Government of the Philippines as they implement the Pasig- Marikina Flood Control Project Phase II to avoid damages from 30-year return period floods.

The EIRR analysis prioritizes additional investments to prepare for 30-year flooding under the B1 climate scenario after the Master Plan components for the current climate are completed. The recommended flow of investment is to fund additional adaptation investments for full adaptation for the B1 scenario, provided that the current Master Plan in the Pasig-Marikina river basin is completed before those projects are undertaken. This also suggests that flood control investments in the Pasig-Marikina river basin to fill the gap between the existing infrastructure and the Master Plan are prerequisites to adapting to climate change. It is important to note that preparing for 10-year flooding under the status quo climate comes in third place. This suggests that additional investments to the KAMANAVA and West of Mangahan areas under the status quo climate are important. In fact, some KAMANAVA area municipalities are introducing their own pumping stations ("bombastics") in limited numbers.

The above discussion confirms that the ongoing flood control projects in Metro Manila are integrated components of adaptation to climate change. At least in the case of Metro Manila, adaptation investments are not a completely new additional effort, but a continuation of ongoing flood control efforts both in terms of planning and financing.

7.3 Policy discussions

7.3.1 New flood control infrastructure

As described in Chapter 6, new flood control infrastructure is required to adapt to the flood situation in 2050 assuming climate change. Our analysis suggests that filling the infrastructure gap in responding to the current climate is the first and foremost priority. As a next adaptation priority, additional flood control investments in the Pasig-Marikina river basin were identified. This investment consists mainly of raising embankments along the Pasig-Marikina River.

7.3.2 Fine-tuning and improvement of the existing flood control infrastructure

Although the above economic evaluations highlight the priority of currently implemented flood control infrastructure investment, discussions with communities and local governments also call for an assessment of the design of existing structures to better respond to the new hydrodynamics to be faced by flood prone communities.

1) KAMANAVA area

The KAMANAVA Area Flood Control and Drainage System Improvement Project has a 10-year return period design scale.
However, recent observations by residents and barangay officials in the area (e.g. Barangay Bangkulasi, Barangay Bagonbayan South) suggest that tides are reaching unprecedented levels, especially when combined with floods from the upstream sections of the Malabon-Tullahan River or with storm surges. As a remedial response, the barangay captains are introducing drainage pumps, locally known as “bombastics” in their respective areas to remove floodwater. However, as neighboring barangays are just discharging water to each other, this remedial response is not significantly reducing water levels in the respective areas.

Therefore, an additional assessment is necessary to understand the relatively recent hydrodynamics, which may not necessarily be due to climate change, and consider local policies that can create solutions that benefit all of the neighboring areas. In conducting the assessment, a close coordination with the National Government (DPWH) is necessary to assure technical consistency between DPWH-led infrastructure projects (the KAMANAVA Area Flood Control and drainage under national roads), and local government initiatives (pumping, drainage under local roads, land use, social housing, etc.)

2) Pasig-Marikina river basin

Marikina city is located alongside the Marikina River. With strong political leadership, it has successfully strengthened its capacity to cope with flooding. First, under the Pasig-Marikina River Channel Improvement Project Phase I, the city government successfully relocated almost 10,000 households that were squatting along the Marikina River. Now both sides of the river are cleared and pleasant walkways and bikeways where families come to enjoy walking, have been constructed together with dike structures. Drainage of the riverbed is regularly conducted. The city planning office has a comprehensive information database of the hydrodynamics of the city area, allowing for setting design standards for local drainage infrastructure projects. Marikina is the only city that can demand that the DPWH conform to the city’s design standards when the DPWH constructs drainage facilities under national roads.

Despite this excellent performance, the city of Marikina is not prepared for climate change. According to this study’s flood simulation, because of its steep topography, Marikina is one of the areas worst affected by climate change. The types of structures or policies necessary to cope with climate change at the local level have yet to be identified by the city government. As chapter 6 suggests, at the Metro Manila level, improvement of river embankments to protect against B1 climate scenario conditions is a priority for adapting to climate change.

3) West of Mangahan area

The city of Taguig stretches alongside Laguna de Bay Lake. Some large scale development projects brought high rise condominiums and shopping centers to the southern part of the city, while the swampy areas in the northern part are a mix of middle income and low income residential areas, with some remaining paddies and fishing areas. The West of Mangahan flood control project consists of a long road dike alongside the lake and several pumping stations. Floods are assumed to be brought on by storm rainfall and high water levels in the lake.

Flood simulations in this study, however, show that when taking climate change into consideration, the risk of intensive rain in the inner urban area will increase, causing water to flow from the inner urban area to Laguna Lake. With the presence of the road dike, this will lead to flooding in the northern part of the city of Taguig. In this case, additional pumping structures will be necessary to permit the water to flow both ways.

Partly due to the completion of the road dike, the city of Taguig is busy evaluating unsolicited development plans in the areas previously used as paddies and fishing fields. However, these plans typically do not accompany drainage plans or flood mitigation plans. For the city of Taguig assessment of the hydrodynamics of the area (with climate change considered) and development of land use plans that have appropriate drainage and flood mitigation plans in addition to the appropriate evaluation of environmental considerations is urgent.

7.3.3 Other policy areas for consideration

1) Capacity building (city planning)

As described in 7.3.2, cities' capabilities of coping with flooding problems under the status quo climate differ widely. In particular, assessing the local hydrodynamics, building design standards for drainage systems, land use planning and enforcement, and social housing, including resettlement, seem to be the key areas in adapting to climate change. As is already done among cities and municipalities in Metro Manila, continuous upgrading of technical capabilities (including recruiting) as well as learning from examples of excellent management such as in the case of Marikina, are fundamental to the improvement of city level capabilities, along with the obvious importance of strong political leadership.

2) Capacity building (disaster preparedness)

As described in 5.3.6, the local governments in Metro Manila have been finding innovative solutions to their flooding and other related problems. However, as is evident in the case of ad hoc installations of water pumps ("bombastics"), solutions designed for a particular area may be counterproductive to a coordinated, collective solution. It is urgent to communicate to the local governments the necessity for coordinated, collective solutions and to instill strong leadership in the existing coordinating mechanisms (through HUDCC, MMDA or other councils).

Interviews with local communities show that many local governments are active in monitoring water levels, conducting evacuations, and providing shelter (including food and medicine) in the case of disasters. However, interviews with poor urban households reveal that many of them are left with minimum care, so they opt to adopt "water based lifestyles" in which they cope with the flooding any way they can. This includes adding floors to their structures and raising their appliances up onto movable platforms. More importantly, interviews with key information sources revealed that the poor and vulnerable households who do not have a wide network of relatives, neighbors, or friends who can support them, are also unable to access much support from formal institutions like health clinics run by local government units' social workers. Effective methods of intervention to help these segments of the society should be strengthened, with the help of capable stakeholders such as NGOs operating in the area of disaster management.

3) Adaptation in combination with mitigation

During discussions with the MMDA (Metro Manila Development Authority), it was pointed out that they are expecting a new study assessing mitigation effects. The MMDA is leading the efforts to control traffic in Metro Manila. These efforts are expected to increase the mitigation measures that will be taken by the government of the Philippines. Assessment of the combined efforts covering both mitigation and adaptation for a given city is our next research topic.

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