No.

DEPARTMENT OF PUBLIC
WORKS AND HIGHWAYS
THE REPUBLIC OF THE
PHILIPPINES

Japan International
Cooperation
Agency

PROVINCIAL
GOVERNMENT
OF CAVITE

THE STUDY
ON
COMPREHENSIVE FLOOD MITIGATION
FOR CAVITE LOWLAND AREA
IN
THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

Volume 3: Adaptation to Climate Changes

February 2009

CTI ENGINEERING INTERNATIONAL CO., LTD.
in association with
NIPPON KOEI CO., LTD

GED
JR
09-016

Exchange Rate used in the Report is:

US$ 1.00 = PhP. 46.979 = JpY. 105.904
Jp¥ 1.00 = PhP. 0.4413

(as of 30th September 2008)

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PREFACE

In response to a request from the Government of the Republic of the Philippines, the Government of Japan decided to conduct a development study on Comprehensive Flood Mitigation for Cavite Lowland Area and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to the Philippines a study team headed by Mr. Makihiko Otogawa of CTI Engineering International Co., Ltd. in association with Nippon Koei Co., Ltd, between March 2007 and January 2009. In addition, JICA set up an Advisory Committee which examined the Study from specialist and technical point of view.

The Study Team held discussions with the officials concerned of the Government of the Philippines, and conducted field surveys at the study area. Upon returning to Japan, the Study Team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and promotion in the Philippines, and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Philippines for their close cooperation extended to the Study Team.

February, 2009
Ariyuki MATSUMOTO
Vice-President
Japan International Cooperation Agency

The Study on Comprehensive Flood Mitigation for Cavite Lowland Area in the Republic of the Philippines

February 2009

MR. ARIYUKI MATSUMOTO
Vice-President
Japan International Cooperation Agency
Tokyo, Japan

Ref.: **The Study on Comprehensive Flood Mitigation for Cavite Lowland Area in the Republic of the Philippines**

Subj.: **Final Report - Letter of Transmittal**

Dear Sir:

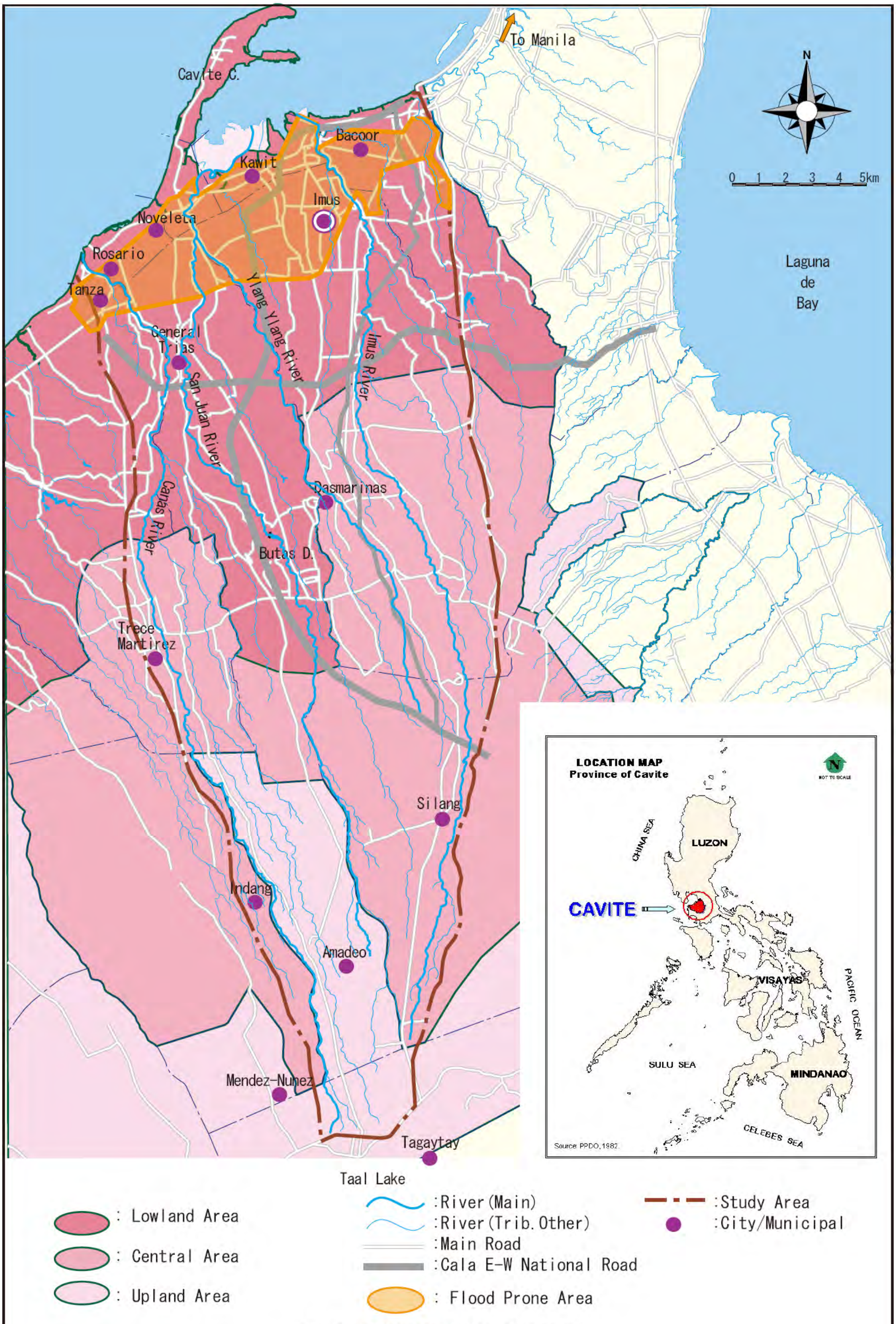
We are pleased to submit herewith the Final Report on "The Study on Comprehensive Flood Mitigation for Cavite Lowland Area" for your kind consideration. This report compiles the results of the Study in accordance with the contract between CTI Engineering International Co., Ltd. in association with Nippon Koei Co., Ltd. and the Japan International Cooperation Agency (JICA) during the period of March 2007 to February 2009.

During the Study, the Study Team formulated the master plan and conducted the feasibility study on comprehensive flood mitigation composed of applicable structural and non-structural measures for the Cavite Lowland Area based on the analysis of existing/future conditions and problems in the area. The report consists of Volume I: Master Plan Study, Volume II: Feasibility Study, Volume III: Adaptation to Climate Changes, and Volume IV: Appendix. The summaries of the master plan and feasibility studies are included in Volume I and Volume II respectively.

On this occasion the Study Team would like to express its sincere appreciation to JICA, the Ministry fo Foreign Affairs, and also to the officials concerned of the Government of the Republic of the Philippines, the Provincial Government of Cavite, and the Local Government Units (LGUs) concerned for the cooperation extended to the Team during the Study. We sincerely hope that the results of the Study will contribute to the solution and/or mitigation of flooding problems in the Cavite Lowland Area and that the amicable relationship between both our countries will further continue in the future.

Very truly yours,

MAKIHIKO OTOGAWA
Team Leader
The Study on Comprehensive Flood
Mitigation for Cavite Lowland Area



LOCATION MAP

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ABBREVIATIONS AND ACRONYMS

BDCC	Barangay Disaster Coordinating Council
CARP	Comprehensive Agricultural Reform Program
CCSR	Center for Climate System Research
CDCC	City Disaster Coordinating Council
CENRO	City Environment and Natural Resources Office
CEO	City Engineering Office
CPDO	City Planning and Development Office
DENR	Department of Environment and Natural Resources
DPWH	Department Public Works and Highways
EL.	Elevation
FMC	Flood Mitigation Committee
FWES	Flood Warning and Evacuation System
ICAS	Institute for Global Change Adaptation Science
IDI-Japan	International Development Institute, Japan
IEC	Information and Education Campaign
IPCC	The Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
MDCC	Municipality Disaster Coordinating Council
MENRO	Municipality Environment and Natural Resources Office
MEO	Municipality Engineering Office
MPDO	Municipality Planning and Development Office
MSL	Mean Sea Level
NAMRIA	National Mapping and Resource Information Authority
NIA	National Irrigation Authority
O&M	Operation and Maintenance
PAGASA	Philippine Atmospheric, Geophysical, and Astronomical Services Administration
PDCC	Provincial Disaster Coordinating Council
PENRO	Provincial Environment and Natural Resources Office
PEO	Provincial Engineering Office
PG-ENRO	Provincial Government-Environment and Natural Resources Office
PHUDO	Provincial Housing and Urban Development Office
PNP	Philippines National Police
PPDO	Provincial Planning and Development Office
SAFDZ	Strategic Agricultural and Fishery Department Zone
SRES	Special Report on Emission Scenarios
TIGS	Trans-disciplinary Initiative for Global Sustainability/Center
ha	Hectare

CHAP 1. THE STUDY AREA

1.1 Location and Topography of the Study Area

The Study Area is located eastern part of Cavite Province and close to the border of Metro Manila covering an area of about 407.4 km^2 in total (refer to Fig. 1). There exist three river basins in the Study Area, Imus, San Juan and Canas flowing into the Manila Bay. The catchment areas of these river basins are listed below:

Table 1 Major Rivers in the Study Area

Name of River Basin	Catchment Area (km2)	River Length (km)
Imus	115.5	45.0
San Juan	147.76	43.4
Canas	112.32	42.0
Residual	32.84	-
Total	407.4	

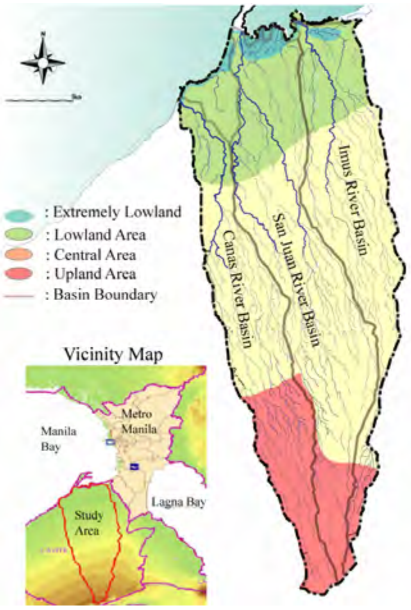


Fig. 1 General Map of Study Area

The Study Area forms a slope from the northern part as the top toward the southern coastal area, and it is topographically divided into four divisions, namely: (a) the extremely low land area, (b) the lowland area, (c) the central hilly area and (d) the upland mountainous area. The approximate extent, ground slope and ground elevation of each division are listed below:

Table 2 Topographic Features of the Study Area

Division	Extent (km^2)	Ground Slope (%)	Ground Elevation (EL. m)	City/Municipality Overlapped
Extremely Low Land Area	4.0	Almost Flat	EL. 0 to 2 m	Bacoor, Kawit, Noveleta, Rosario
Lowland Area	97.5	Less than 0.5%	EL. 2 to 30 m	Bacoor, Kawit, Noveleta, Rosario, General Trias, Imus, Tanza
Central Hilly Area	236.7	0.5% to 2%	EL. 30 to 400 m	Trece Martires City, Dasmarinas, Indang, Silang
Upland Mountainous Area	69.2	More 2%	EL. 400 to 650 m	Amadeo, Tagaytay
Total Area	407.4			

1.2 Flood Vulnerability of the Study Area

The Study Area is essentially vulnerable to flood overflow from rivers, inundation by stagnant storm rainfall and/or tidal flood because of the extremely low-lying ground elevation along the coastal area and insufficient flow capacity of river/drainage channels. In spite of the vulnerability, the intensive land development for residential subdivisions is being induced to the Study Area without adequate consideration for flood, and the recent flood damages in the river basins are deemed to exceed the tolerable level due to the following backgrounds:

(1) The natural flood-retarding basins are being reclaimed, and a considerable part of the ground is being covered with pavement. These decrease flood detention capacity of the river basins and increase the flood peak runoff discharge.

(2) The residential area spills over the habitual flood inundation area due to rapid increment of the population, which leads to significant increment of the flood damage potential.

(3) The areas along the downstream rivers are being densely packed with the houses. The houses are further constructed overhanging of the drainage channels. These houses in and around the river and drainage channels tend to dump a large volume of solid wastes into the river/drainage channels, which seriously reduce the channel flow capacity and deteriorates the river environment.

During the recent nine years from 2000 to 2008, the serious flood overflows from the rivers have occurred four times causing death of people and damages of many houses as shown Table 3 (refer to Photos-1 and 2). Some hundred thousand residents in the lowland area of the Study Area also suffer from the prolonged inundation of storm rainfall and/or high tide every year (refer to Photos-3 and 4). Such chronic inundation has affected not only the living conditions of the residents but also economic and social development in the Province.

Table 3 Recent Representative Flood Damage in the Study Area

Date	Name of Typhoon	Affected Area	Remarks
Oct. '00	Reming	Lowland Area (Bacoor, Noveleta, Rosario, Imus, Kawit etc.)	Death: 10 Affected population: 380,616
Jul. '02	Gloria	Lowland Area (Bacoor, Noveleta, Rosario, Imus, Kawit etc.)	Death: 0 Affected population: 173,075
Jul. '02	Inday	Lowland Area (Bacoor, Noveleta, Rosario, Imus, Kawit etc.)	Death: 1 Affected population: 168,025
Sep. '06	Milenyo	Lowland Area (Bacoor, Noveleta, Rosario, Imus, Kawit etc.) and General Trias	Death: 28, Missing: 18, Injured: 61, Evacuated: 28,322, Affected 196,904

Photo- 1 Flood Over-Flow from River Channel during Typhoon Reming Oct 2000 (Source: IDI-Japan)

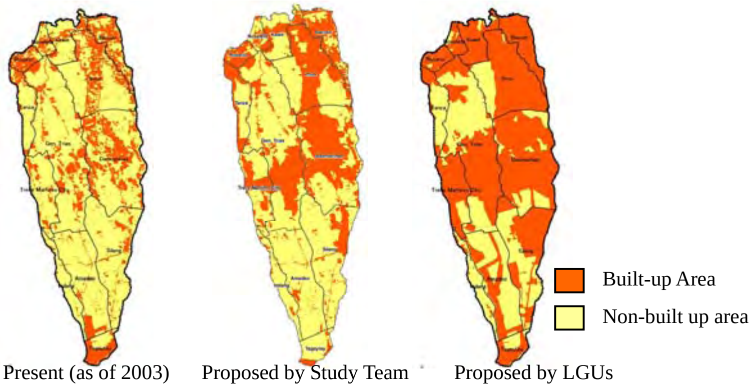
Photo- 2 Debris under Bridge after the Flood of Typhoon Reming Oct 2000 (Source: IDI-Japan)

Photo-3 Inland Flood due to Overflow of Drainage Channel (Taken by the Study Team in Aug. 2007)

Photo-4 Tidal Flood (Taken by the Study Team in Aug. 2007)

CHAP 2. INCREMENT OF FLOOD RUNOFF DISCHARGE DUE TO BASIN LAND DEVELOPMENT

One of the most serious issues on the flood mitigation in the Study Area is addressed to the current excessive urbanization. The built-up area (the residential, industrial, commercial and institutional area) as of 2003 covers about 26% of the entire Study Area, while the relevant local governments (one city and thirteen municipalities) have prepared a land zoning plan, where the share of built-up area in the Study Area is projected to increase to 65% in 2020 (refer to Fig. 2).



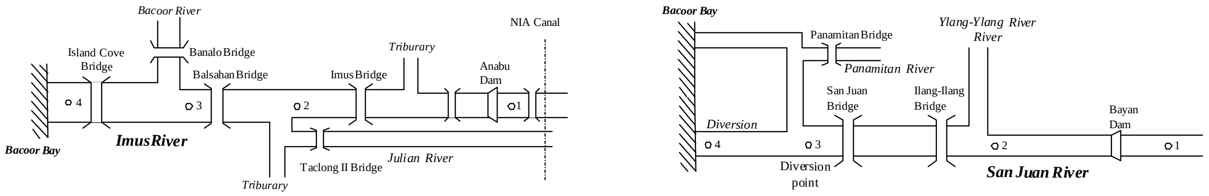
Present (as of 2003) Proposed by Study Team Proposed by LGUs

Fig. 2 Present and Proposed Land Zoning of Study Area

As the built-up area expands, the river catchment area covered with pavement, houses/buildings and other impermeable structures would increase. As the results, the storm rainfall tends to hardly penetrate into the ground and the surface flood runoff discharge increases.

According to the results of flood runoff simulation, the probable peak runoff discharge of 10-year return period under the present ratio of built-up area is estimated at 950 m^3/s and 650 m^3/s at the downstream end of Imus River and San Juan River, respectively. On the other hand, it would increase to 1,500 m^3/s for Imus River and 900 m^3/s for San Juan River, should the urbanized area expand and cover 65% of the entire Study Area as projected by the local government as shown in Fig. 3.

The JICA Study Team reviewed the contents and backgrounds of the zoning plan prepared by the local governments and concluded that the zoning plan is rather groundless judging from the simulated population and economic growth in the Study Area. The Team further delineated an alternative-zoning plan, which could promise the reasonable social and economic growth by the year 2020 and at the same time contribute to substantial reduction of the basin flood runoff discharge. The built-up area in the alternative-zoning plan is assumed to cover about 43% of the entire Study Area as shown in Fig. 2. The details of the proposed zoning plan are as described in subsection 7.1.



Point No.	Imus River			San Juan River		
	Present Urbanized Ratio	Urbanized Ratio in 2020 proposed in the Study	Urbanized Ratio in 2020 proposed by LGUs	Present Urbanized Ratio	Urbanized Ratio in 2020 proposed in the Study	Urbanized Ratio in 2020 proposed by LGUs
1	420	500	650	330	350	430
2	600	700	900	440	460	600
3	750	1,000	1,250	800	850	1,100
4	950	1,200	1,500	650	700	900

Fig 3 Increase of Probable Flood Runoff Discharge due to Urbanization in the River Basin

CHAP 3. CLIMATE CHANGE IN THE STUDY AREA

The Intergovernmental Panel on Climate Change (IPCC) has warned the climate changes associated with global warning. The climate changes include the rises of temperature, storm rainfall intensity and sea level, which could further aggravate the flood conditions of the Study Area. From this point of view, the impacts of climate-change in the Study Area are examined based on the results of assessment by IPCC as well as the long-term hydrological data observed in the Study Area.

3.1 Temperature Rise

The IPCC estimated the change of global temperature based on the Forth Special Report on Emission Scenarios (SRES), which describes several scenarios on the future global emission volume of greenhouse gas (such as carbon dioxide and nitrogen monoxide and methane gas) and sulphate. The IPCC estimated based on the SRES that the present global average temperature would most likely rise by 1.8 to 4.0°C at the end of the 21st Century as shown in Table 4 and Fig. 4.

The largest rise of the temperature would break out in the Scenario of A1FI, which assumes a future world of very rapid growth of the global economy and population together with the intensive use of the fossil fuel in the energy system. On the other hand, the smallest would be in the Scenario of B1, which projects a convergent world with the same global growth of population as in the A1FI storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies.

Table 4 Global Average Temperature Rise at the End of 21st Century

Scenario	Temperature Rise from Average of 1980-1999 to Average of 2090-2099 (°C)	
	Best Estimate	Likely Range
B1 scenario	1.8	1.1 – 2.9
A1FI scenario	4.0	2.4 – 6.4

Source:
IPCC 2007, Summary for Policymakers.

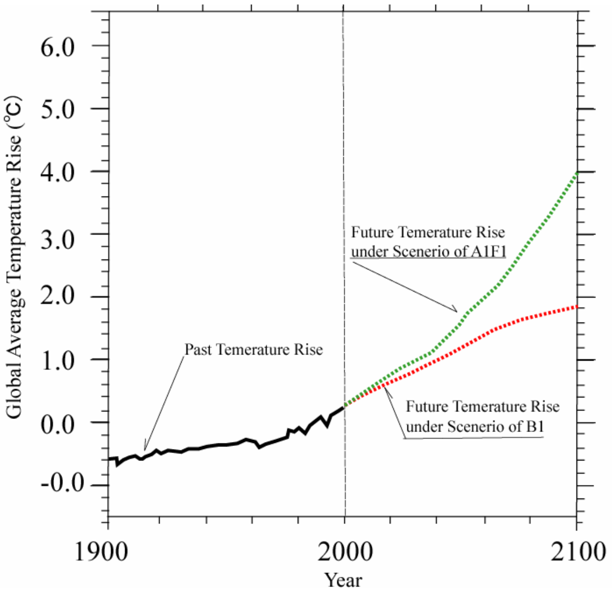


Fig. 4 Global Average Temperature Rise
(Consecutive Average Temperature Rise as the Base of Value in 1980-1999
Source: IPCC 2007, Summary for Policymakers)

The previous records of the temperature observed in the Study Area support the above global tendency of warming. The following figure shows difference of annual mean temperature from the average of 1974 to 2006 at Sangley Point Meteorological Gauging Station, which is locate adjacent to the Study Area. The annual mean temperature tends to continue to increase and higher temperature has been observed especially in the late of 1990s and in 2000s.

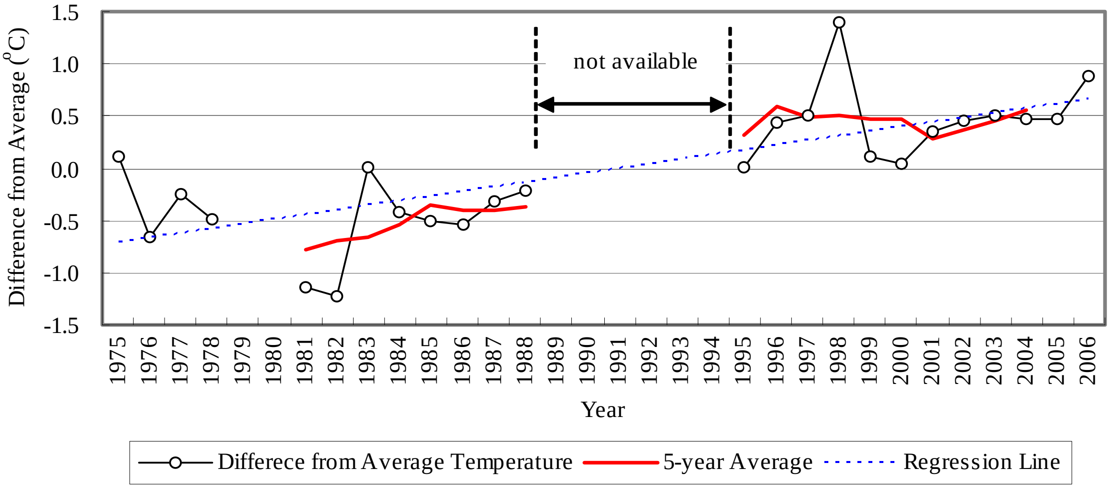


Fig. 5 Recorded Long-term Changes of Temperature in the Study Area
(Recoded at Sanglay Meteorological Station)

The TIGS/CCSR, the University of Tokyo simulated the relations between the aforesaid global average temperature rises and the local spatial average temperature rises in the Philippines, which covers an area of long. 116.0 to 126.0°E and lat. 9.0 to 19.0°N (the area of about 1,000km x 1,000km) as shown in Fig. 6. The simulation is made through a subset of models (twelve models) applied in the Forth Assessment Report of IPCC.

The above temperature rises are expressed as the averages of those at each mesh of 100km x 100km, and at the same time as the differences between the late 20th century (1981-2000) and the late 21st century (2081-2100) with assuming SRES A1B and B1.

According to the results of the above simulation, the local average temperature in the Philippines would rise by 1.1 to 2.3℃ in 2050 and further 1.5 to 3.5℃ in 2010 as shown in the following Table 5

Table 5 Future Local Average Temperature Rise in Philippines due to Global Warming

Scenario	Year	Global Average Temperature Rise (℃)*	Local Average Temperature Rise in Philippines (℃)**
B1 scenario	2050	1.2	1.1
	2100	1.8	1.5
A1FI scenario	2050	2.6	2.3
	2100	4.0	3.5

*: Estimated from Fig. 4
**: Estimated from Fig. 6

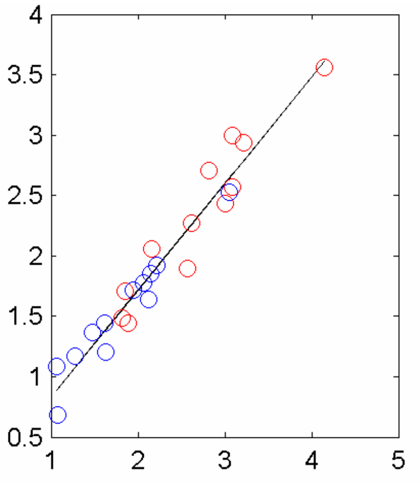


Fig. 6 Relation between Global Average Temperature Rise and Local Temperature Rise in the Philippines

Note: Red circles represent SRES A1B, while blue circles SRES B1. The local temperature rises in Philippines are expressed as the spatial average in the area of long. 116.0 to 126.0°E and lat. 9.0 to 19.0°N

3.2 Rise of Storm Rainfall Intensity

The IPCC projected that the global warning would possibly induce increment of the storm rainfall intensity causing more sever flood. In this connection, the aforesaid TIGS/CCSR simulated between the spatial-average changes of precipitable water and local temperature rises over the Philippines. This simulation is made in the same manner as that for the above relation between the global temperature rises and the local average temperature rises in the Philippines show in Fig. 6.

The results of the simulation are as shown in Fig. 7. According to the results of the simulations, the storm rainfall intensity in the Philippines would increase by 11 to 20% in 2050 and 14 to 29% in 2100 as shown in Table 6.

Table 6 Relation between Local Average Temperature Rise and Incremental Rate of Precipitable Water in Philippines

Scenario	Year	Temperature Rise (℃)	Increase Rate of Storm Rainfall Intensity (%)
B1 scenario	2050	1.1	11
	2100	1.5	14
A1FI scenario	2050	2.3	20
	2100	3.5	29

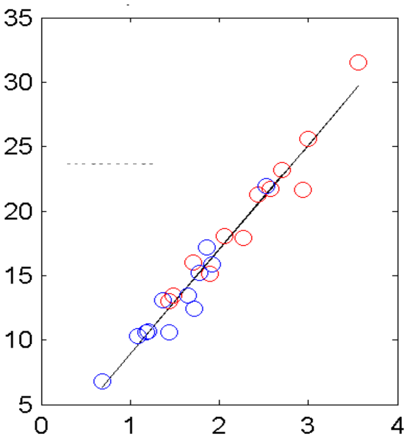


Fig.7 Relation between Local Average Temperature Rise and Incremental Rate of Precipitable Water in Philippines

Note: Red circles represent Scenario A1B, while blue circles Scenario B1. The incremental rise of precipitable water and temperature rise are expressed as the spatial average in the area of long. 116.0 to 126.0°E and lat. 9.0 to 19.0°N

Should the above incremental rate of precipitable water be assumed as the increment of storm rainfall intensity to the Study Area, the present return period of the storm rainfalls would be shortened and the probable flood runoff discharges in the Study Area would increase in the future as stated below:

- The probable two-day rainfall intensities would increase in the future due to global warming as shown in Table 7. For instance, the present rainfall intensity of 10-year return period is estimated at 295mm, while the intensities of same return period in 2050 would increase to 327mm under the B1 Scenario and/or 354mm under the A1FI Scenario, which are almost equivalent to the present rainfall intensities of 20 and 50-year return period, respectively.
- The present peak runoff discharge of 10-year return period at the downstream end of Imus River (catchment area of 115.5km^2), which is one of the major rivers in the Study Area, is 900m^3/s, while it could increase, in 2050, to 1,100m^3/s (24% increment) under B1 Scenario or 1,300m^3/s (48% increment) under the A1FI Scenario as shown in Fig. 8.

Table 7 Future Increment of Probable Two-day Storm Rainfall

Scenario	Year	Increase Rate of Storm Rainfall (%)	Probable 2-day Storm Rainfall (mm)					
			2-year	5-year	10-year	20-year	50-year	100-year
Status Quo	2003	-	191	258	295	326	360	383
B1 Scenario	2050	11	212	286	327	362	400	425
	2100	14	218	294	336	372	411	437
A1FI Scenario	2050	20	229	310	354	391	432	460
	2100	29	246	333	380	421	465	494

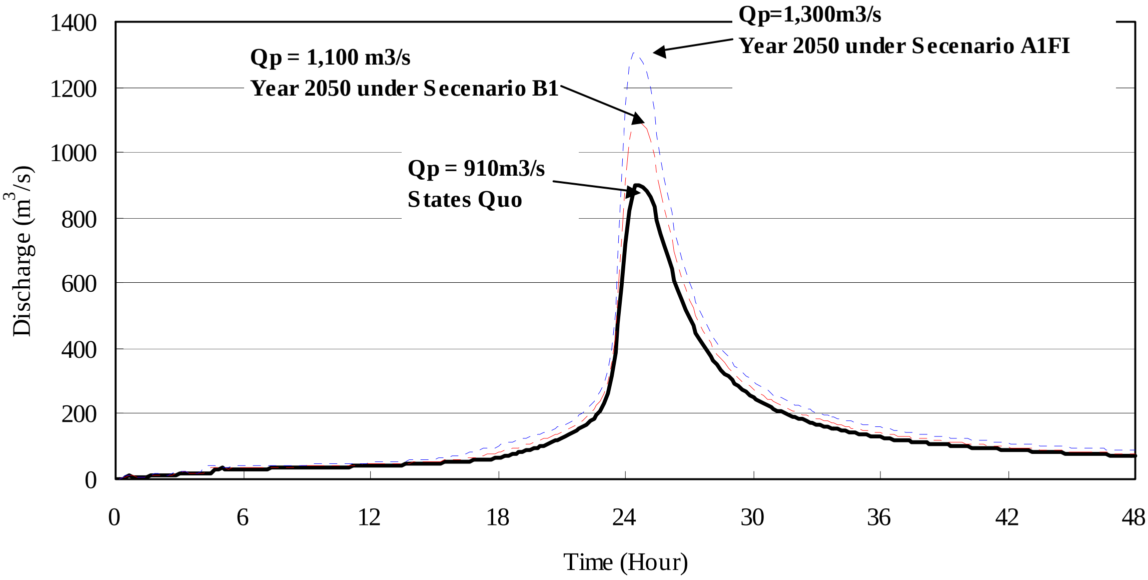


Fig. 8 Hydrograph of Probable Flood Runoff Discharge at the Downstream End of Imus River Basin (Note: The hydrograph is simulated on the premises of the present land use status as of 2003).

The available recording length of the past storm rainfall data in the Study Area is limited to a period of 1974-2006, and it is virtually difficult to prove the distinct tendency of the rise of the storm rainfall intensity through the observed data (refer to Fig. 9). Nevertheless, there is a strong possibility to increment the probable storm rainfall intensity in the longer time span due to the global warming as stated above, and it is necessary to monitor the change of the storm rainfall intensities in the future.

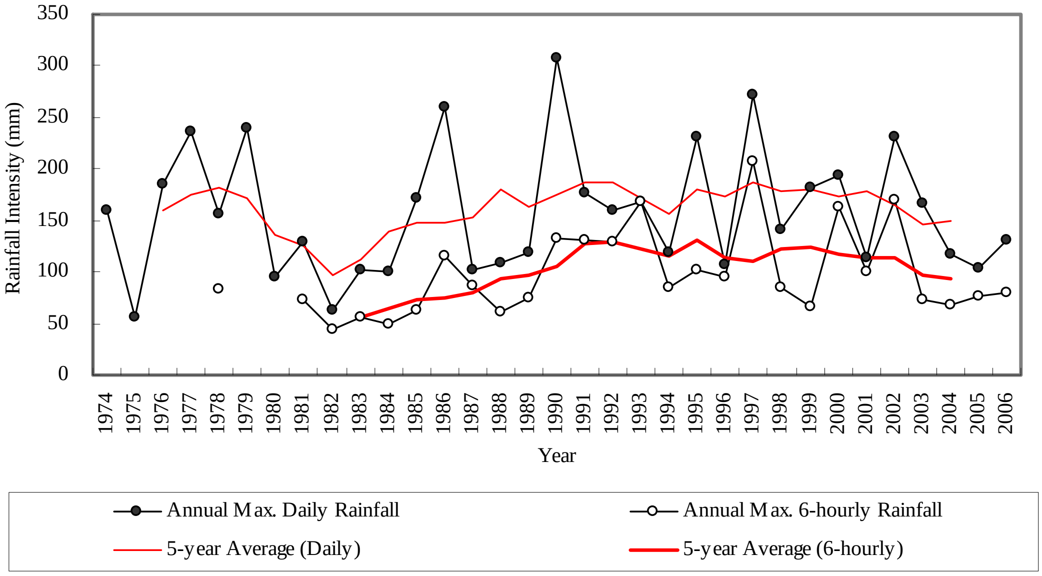


Fig. 9 Annual Maximum Daily and 6-hour Rainfall Observed in the Study Area (Observed at Sanglay Meteorological Gauging Station)

3.3 Sea Level Rise

The IPCC confirmed the global tendency in rise of sea level from the 19th to 20th century and estimated that the global average rate of sea level rises over 1961 to 2003 was about 1.8mm per year, while the rate was faster over 1993 to 2003: about 3.1 mm per year.

The IPCC further projected that the average sea level over 2090-2099 would rise by about 0.38cm at the maximum as compared with the average over 1980-2000 under the B1 Scenario and/or about 0.59cm under the A1BI Scenario (refer to Fig. 10 and Table 8).

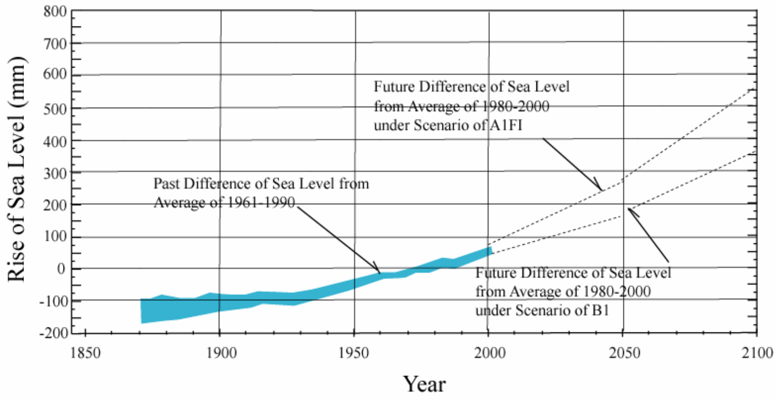


Fig.10 Global Average Sea Level Rise (Consecutive Average Sea Level Rise, Source: IPCC 2007, Summary for Policymakers)

Table 8 Future Global Average Sea Level Rise

(unit: cm)

Scenario	Year	Sea Level Rise due to Global Warming (cm)*	
		Min.	Max.
B1 scenario	2050	9	19
	2100	18	38
A1FI scenario	2050	13	29
	2100	26	59

*: Sea level rise from the average level of 1980-2000 (Source: IPCC 2007, Summary for Policymakers).

Fig.11 shows the trends in monthly sea levels at Manila South Harbor where the long-term sea level records are available near the Study Area. The records show that sea level has kept rising since 1996 up to the present. However, there is no constant increasing or decreasing trend in long term and the astronomical tide with a period of 19 years is deemed to be more predominant. In addition, datum planes had been adjusted at Manila South Harbor due to relocation of tidal gauge and land subsidence effect according to NAMRIA as of 2006. Therefore, it is difficult to conclude that sea level at Manila Bay has been rising due to global warming based on the available historical records. Nevertheless, there is a high confidence that the sea level would rise in a long-term rage due primarily to thermal expansion of the oceans and melting of glaciers and ice caps as projected by IPCC.

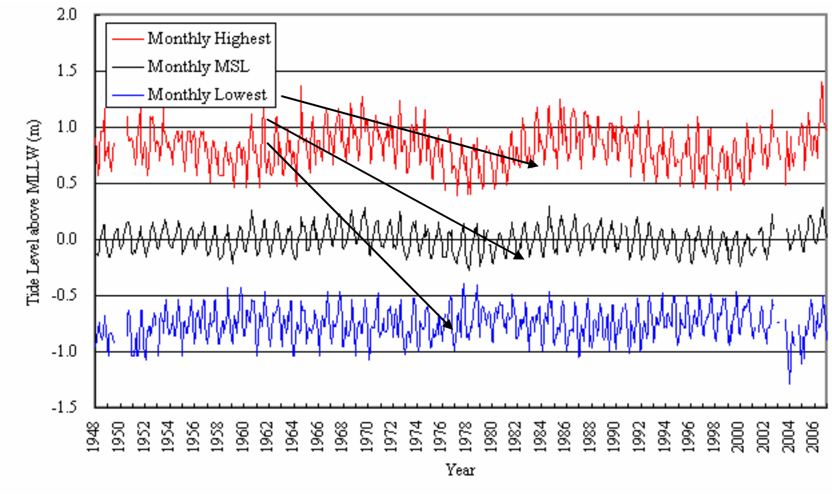


Fig. 11 Recorded Long-term Changes of Sea Level in Manila Bay (Recorded at Manila South Harbor)

CHAP 4. AGGRAVATION OF FLOOD CONDITIONS IN THE STUDY AREA

4.1 Aggravation by Urbanization of the Study Area and Rise of Storm Rainfall Intensity due to Climate Change

As described in the foregoing Chapters 2 and 3, the basin peak flood runoff discharge as well as the probable inundation areas will increase due to the urbanization of the Study Area and the climate change. The zoning plan is proposed to control the urbanized ration of the Study Area to 43% instead of the projected ratio of 65% prepared by the local government (refer to foregoing Chapter 2).

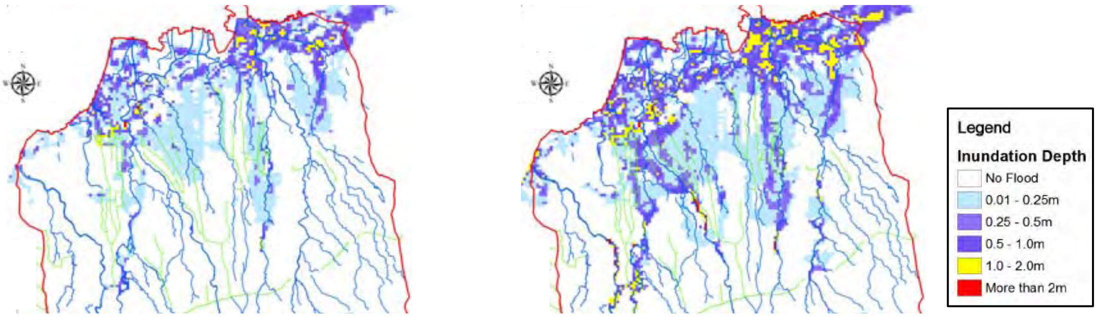
A variety of the structural flood mitigation measures are further proposed in the Study as described in the next Chap. 5. However, the design scale of these structural measures is limited to 10-year return period under the status quo of climate. The design scale would relatively drops and the future flood, which has the same recurrence probability as the present, would cause more serious damage as the climate change makes progress.

The flood inundation areas as well as numbers of houses/buildings to be inundated by the probable discharge of 10-year return period are estimated with assumption of the different scenarios of climate change and urbanized rations as shown in Table 9 and Fig. 12. For instance, the probable flood inundation area and number of houses/buildings under the status quo of climate and urbanized ratio of 43% as proposed in the Study are about 37 km^2 and 34 thousand, respectively. These potential flood damages could be wiped out by the aforesaid proposed flood mitigation measures. On the other hand, unless the proposed flood mitigation measures are induced, the probable flood inundation area would increase to about 48km^2 in 2050 under A1FI Scenario, even if the urbanized ration were maintained at 43% (see Case 4 in Table 9). It would further increase to 51km^2, if the urbanized ration expands to 65% as projected by the local government (see Case 7 in Table 9). The number of houses/buildings to be inundated by the flood would also increase from 22 thousand under the status quo of climate to 44 thousand and 74 thousand for the said two cases, respectively.

Table 9 Increase of Flooding Area and Number of Houses/Buildings Flooded due to Effects of Basin Urbanization and Global Warming (Probable Flood of 10-year Return Period)

Case No.	Scenario of Climate Change	Urbanized Ratio	Probable Flood Inundation Area (km^2)			Number of Houses/Buildings Inundated (thousand houses)		
			Flood Depth below 1m	Flood Depth above 1m	Total	Flood Depth below 1m	Flood Depth above 1m	Total
1	Status Quo	26%*	31.51	1.05	32.56	20.1	1.7	21.8
2	Status Quo	43%**	35.82	1.50	37.32	31.4	2.9	34.4
3	In 2050 under B1 Scenario		41.10	2.52	43.62	35.5	4.4	39.9
4	In 2050 under A1FI Scenario		44.64	3.54	48.18	38.4	5.9	44.3
5	Status Quo	65%***	41.05	2.45	43.50	56.4	7.2	63.6
6	In 2050 under B1 Scenario		43.92	2.97	46.89	60.1	8.5	68.6
7	In 2050 under A1FI Scenario		47.27	3.98	51.25	63.0	11.2	74.2

Note:
*: The present urbanized ratio as of 2003
**: The urbanized ratio in 2020 proposed by the JICA Study Team
***: The urbanized ratio in 2020 projected by the local governments



Present
(Case 1 in Table 9)

In 2050 under A1FI Scenario
(Case 7 in Table 9)

Fig. 12 Probable Inundation Area by the Flood of 10-year Return Period

4.2 Aggravation by Sea Level Rise and Storm Surge

NAMRIA has ever recorded the sea level of Manila Bay at Manila South Harbor gauging station since 1945. According to the record, the monthly mean highest sea level is EL. 0.80m. This monthly highest sea level would rise in 2050 because of the aforesaid global warming. As shown in the foregoing Table 8, the sea level would rise by 0.19m at the maximum in 2050 due to global warming under B1 Scenario and by 0.29m under A1FI Scenario. Assuming these sea level rises, the monthly highest sea level in 2050 would reach 0.91m (=EL. 0.80m + 0.19m rise) under B1 Scenario and 1.09m (=EL. 0.80m + 0.29m rise) under A1FI Scenario.

The sea level could further occasionally rise due to storm surge. The University of Ibaraki (ICAS) simulated the possible largest sea level rise of the Manila Bay inflicted by the storm surge. The simulation is based on the recorded wind velocities/directions of nine typhoons and the undulating depth of seabed. As the results of simulation, the maximum rise of sea level caused by the storm surge is estimated at about 91cm.

Assuming the above monthly mean highest sea levels added by the sea level rise by the storm surge, the monthly highest sea level could reach 1.71m under status quo, while those in 2050 under B1 and A1FI Scenario would be 1.90m and 2.00m, respectively as shown in Table 10.

The recorded highest sea level at the aforesaid Manila South Harbor gauging station is EL. 1.41m, which is most likely due to storm surge. This recorded maximum does not incorporate with the wind wave height, and assuming the approximate wave height of about 50cm, which often occurs in Manila Bay during a typhoons, the instantaneous maximum sea level at the time of the recorded highest sea level could be equal to the range of the above-mentioned monthly sea levels in 2050 (i.e. EL. 1.90m to 2.00m). In another word, the sea level in equivalent to the recorded maximum could more often occur in 2050.

Table 10 Present and Future Sea Level of Manila Bay

Scenario	Mean Monthly Highest Sea Level	Monthly Highest Sea Level Intensified by Storm Surge
State Quo	EL. 0.80m (Average of recorded sea levels)	EL. 1.71m (=EL. 0.80m + 0.91m /2)
In 2050 under B1 Scenario	EL. 0.99m (=EL. 0.80m + 0.19m /1)	EL. 1.90m (=EL. 0.80m + 0.19m + 0.91m /2)
In 2050 under A1FI Scenario	EL. 1.19m (=EL. 0.80m + 0.29m /1)	EL. 2.00m (=EL. 0.80m + 0.29m + 0.91m /2)

/1: The maximum rise of sea level by climate change
/2: The maximum rise of sea level by storm surge.

A considerable part (about 900ha) of the Study Area along the coast has the low ground elevation below EL. 1m as shown in Fig. 13. The ground elevation of EL. 1m is only 20cm higher than the present mean monthly highest sea level. Due to such low ground level, the coastal area currently suffers from the chronic tidal flood damage (see the foregoing Photo-4).

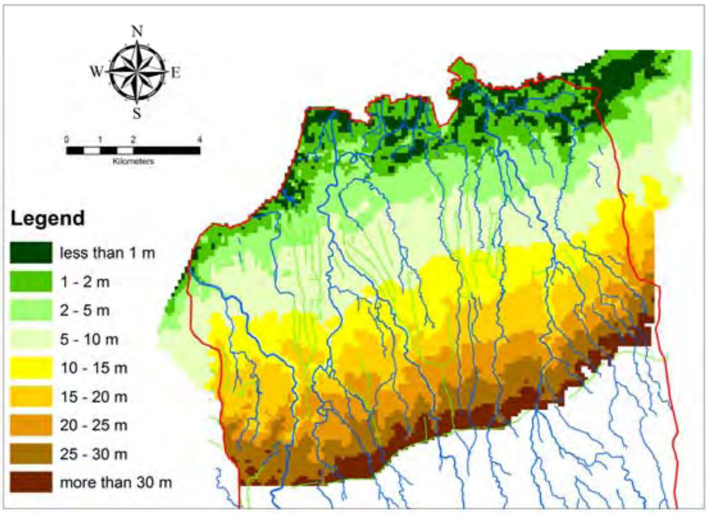


Fig. 13 Ground Elevation in the Lower Reaches of Study Area

Moreover, the area is exposed to the risk of the storm surge. Such storm surge is an unusual occurrence, but once it occurs, the damage could be more serious than that by the usual astronomical high tide. The recent storm surge occurred in the Study Area on 01 October 2007. According to the field survey by the Study Team, the storm surge caused the maximum inundation depth of about 70cm and the coastal area was buried under the heap of sediment of about 2m deep (see Photo-5). It is herein noted that this heaps of sediment of 2m deep suggests the seal level rise of more than 2m, which is almost equal to or even possibly exceeds the recorded highest seal level of Manila Bay, while no house was seriously damaged by such extremely high tide. This inconsistent phenomenon has not been unsolved.

Inundation Caused by Storm Surge
on 01 Oct 2007

Heaps of Sediments on the Coast
after Storm Surge

Photo-5 Conditions of Storm Surge on 01 October 2007

CHAP 5. PROPOSED STRUCTURAL FLOOD MITIGATION PLAN

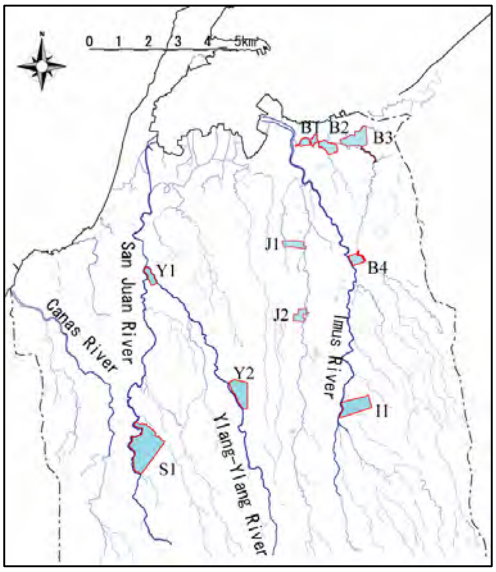
The proposed structural flood mitigation plan is divided into three major components, namely; (a) construction of the offsite flood-retarding basin together with partial river channel improvement, (b) improvement of inland drainage channel together with the coastal dike/tidal gates and (c) construction of onsite flood regulation pond at each of new subdivision of more than five hectors. The details of these components of the structural flood mitigation plan are as described below:

5.1 Construction of Offsite Flood Retarding Basin and Partial River Improvement

The river channel improvement and construction of flood diversion channel have been conventionally adapted as the principal measures against the flood overflow from the river in Philippines. However, the area along the downstream river stretches in the Study Area is densely packed with houses, and it is virtually difficult to adapt such conventional measures due to extremely large number of house evacuations required. From this point of view, adapted is the offsite flood-retarding basin together with the minimum partial river channel improvement (refer to Fig. 14), The proposed design level is set to cope with the probable flood of 10-year return period flood taking the financial affordability for the project cost and the economic viability into account.

The offsite flood-retarding basin could be constructed in the less populated agricultural land/grassland in middle reaches and adapted as the principal flood mitigation measure. The flood peak discharge could be reduced by temporally retarding the flood runoff discharge in the offsite flood-retarding basin. The number of proposed flood-retarding basins is ten covering an area of about 200ha in total.

The partial river channel improvement is further proposed as supporting measure to lift up the extremely small cannel flow capacity at the bottlenecks of the river channels in the lower reaches of the offsite flood-retarding basins. The partial river improvement would be made within the downstream stretch of 14.7km.



Location

Description	Quantity
Design Scale	10-year return Period
Offsite Flood Retarding Basin	10 basins with 203ha of the site in total
Partial River Improvement	To be made within a stretch of 14.7km

Fig. 14 Proposed Offsite Flood Retarding Basin and Partial River Improvement

5.2 Inland Drainage Improvement and Protection against Tidal Flood

The drainage channel improvement work and construction of coastal dike together with tidal gate/flap gate are proposed in order to mitigate the inundation by storm rainfall and the tidal flood (refer to Fig. 15). The proposed drainage channel improvement work includes improvement of existing drainage channels with a length of 4.1km in length, construction of new drainage channel of 1.5km in total, construction of interceptors of 2.7km, offsite flood detention ponds of 52ha in total and 18 flap gates.

The offsite flood detention pond functions to collect and temporally store the storm rainfall so as to reduce the burden of the downstream drainage channel, while the flap gates are constructed at the outlet point of the drainage channel in order to prevent seawater and/or river water from reversely flowing into the drainage channel. The proposed design level for the drainage improvement work is set to cope with the probable flood of 2-year return period flood taking the financial affordability for the project cost, the available land for construction works and the economic viability into account.

The costal dike of 4.1km in length is also proposed along the shoreline in order to protect the costal low land area against the tidal flood. The tidal gates are further constructed at nine sites, where the costal dike cross the rivers/the creeks, so as to facilitate drainage of the inland storm water to the sea during a low tide and the present navigation between the sea and rivers. The crown level of the tidal dike is set at EL. 2.41m, which is one meter higher than the recorded highest sea level (refer to Fig. 16).

Description	Quantity
Design Level of Drainage Improvement	2-year return period
Length for Improvement of Existing Drainage Channel	3.9 km
Length for Construction of New Drainage Channel	2.6 km
Length for Construction of New Interceptor	2.7km
Number of Tidal Gate	9 units
Number of Flap Gates	18 units
Number and Area of Offsite Flood Detention Pond	52 ha in total

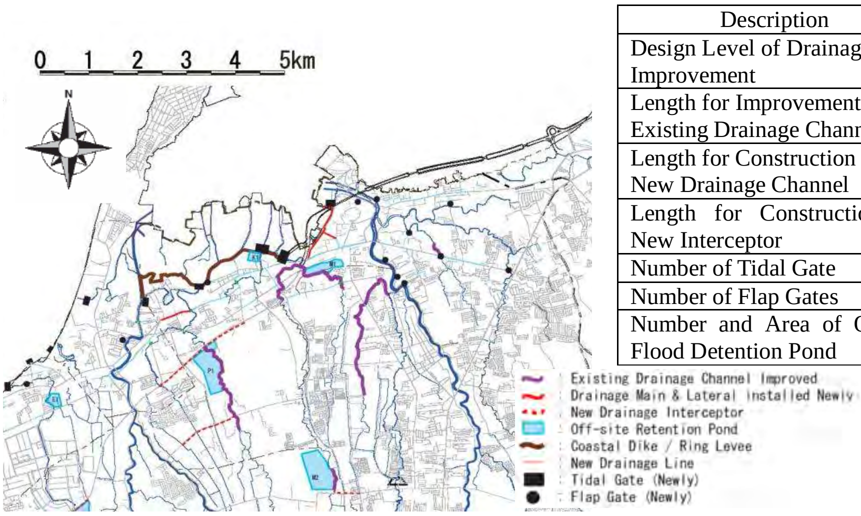


Fig. 15 Proposed Inland Drainage Improvement and Protection Work against Tidal Flood

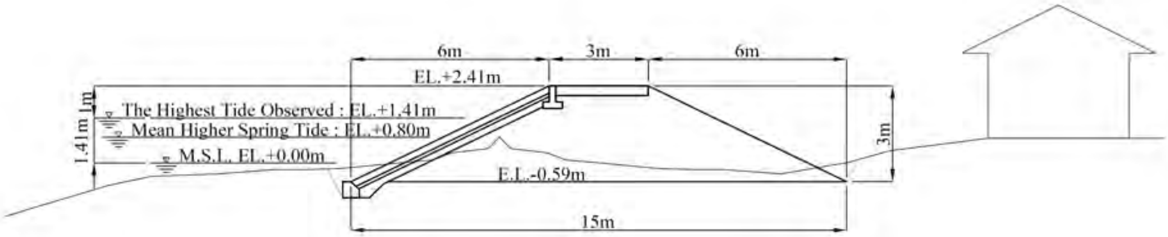


Fig. 16 Typical Cross Section of Proposed Coastal Dike

5.3 Construction of Onsite Flood Regulation Pond within the Compound of new subdivision

As described above, the intensive land development for residential estate is currently in progress in the middle and upper reaches of the Study Area. As the Study Area is covered with the road pavement, houses/buildings and other impermeable structures by the land development, the storm rainfall would more hardly penetrate into the ground, which leads to increment of the basin peak flood runoff discharge. In order to offset such increment of the flood runoff discharge, enforcement of an ordinance is proposed to obligate the land developer to construct an onsite flood regulation pond at every new subdivision of five hectors or larger. The onsite flood regulation pond is designed to occupy 3% of the entire extent of subdivision and offset the peak flood runoff discharge of 20-year return period or shorter return period. The conceptual drawing of the onsite flood regulation pond is as illustrated in Fig. 17. During a flood, the onsite flood regulation pond function as an impounding pond, while it could be used as the amenity space such as the sport ground during a non-flood time (refer to Photo-6).

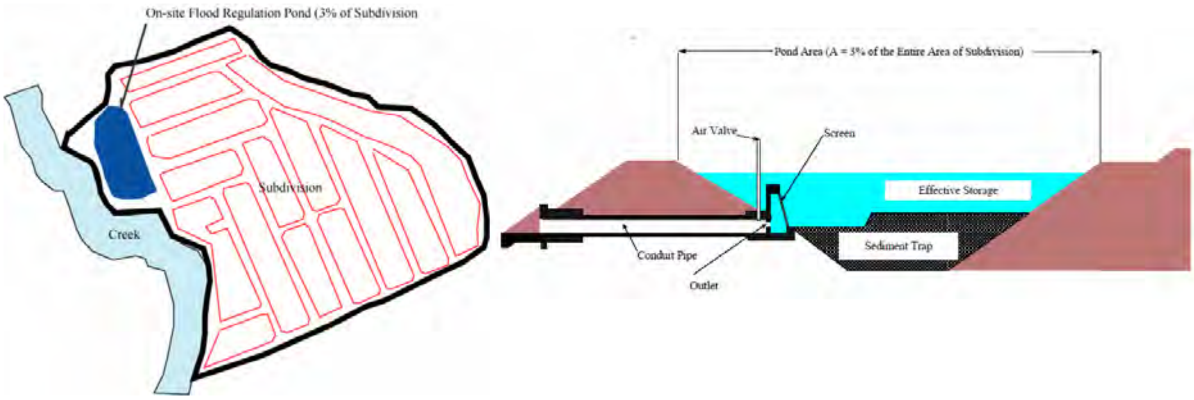


Fig. 17 Conceptual Drawing of Proposed Onsite Flood Regulation Pond

Photo-6 Existing Onsite Flood Regulation Pond

CHAP 6. ADAPTATION OF STRUCTURAL MEASURES AGAINST CLIMATE CHANGES

6.1 Basic Concept for Adaptation of Measures against Climate Changes

As described above, the design scales of the proposed flood mitigation structures are set at 10-year return period against the flood overflow from the rivers and 2 year return period for inland drainage improvement. Estimation of these design scales is based on the past annual maximum rainfall intensities recorded in the Study Area. Design of the crown level of coastal dike against the tidal flood is also based on the recorded highest sea level.

However, the present probable rainfall intensities as well as the sea levels would possibly rise in the future due to the climate-change, which would relatively lower the safety level designed for the flood mitigation structures.

For instance, the present design scale of 10-year return period against the flood overflow would decline to 6-year return period in 2050 under B1 Scenario or 3-yaer return period under A1FI Scenario as shown in Fig. 18. From this point of view, adaptation of measures against climate changes is preliminarily proposed in the Study.

The climate changes are likely to gradually take place during several decades and the precise degrees of climate changes would be hardly predicted due to uncertainties in the future trend of emission of the greenhouse/sulphate and the limited reliabilities of the climate simulation models. On the other hand, the largely excessive design scale to absorb the climate-changes is hardly adapted due to the limited affordable budget for project implementation and minimum requirement of house relocations.

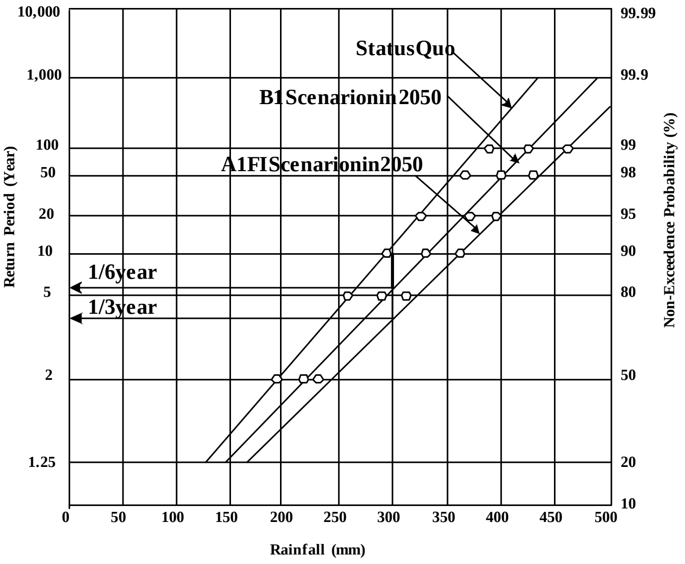


Fig. 18 Relationship between the Two-day Storm Rainfalls and Recurrence Probabilities

In order to meet the above contradictions, the following practical scenarios and methodologies are adapted for the measures against the climate-change:

- The stage-wise expansion of the flood mitigation capacity of the structures in accordance with the aggravation of flood inflicted by the climate change,
- The minimum flood damage in the event of the flood scale, which exceeds the design level of the flood mitigation structures, and
- The minimum risk in destruction of the flood mitigation structures in the event of the flood scale, which exceeds the design level of the flood mitigation structures.

6.2 Adaptation against Flood Overflow from Rivers

The structural measures against the flood overflow from the rivers include the offsite flood-retarding basins, the partial river channel improvement and the on-site flood regulation. The structural size of the offsite flood-retarding basin together with the partial river channel improvement aims at preventing the flood runoff discharge from overflowing from the river channels. On the other hand, the onsite flood regulation pond is to be constructed at every new subdivision so as to offset the increment of flood runoff discharge induced by development of the subdivision. Adaptations for these structural measures against the flood overflow from rivers are as enumerated hereinafter.

6.2.1 Minimization of River Channel Improvement

The mitigation of the flood overflow from rivers could be achieved by combination of river channel improvement (for increase of river channel flow capacity) and construction of basin flood detention structures such as offsite flood retarding basin and onsite flood regulation pond (for increase of basin flood detention capacity). However, the proposed measures minimized the river channel improvement taking the under-mentioned particular features of the Study Area into account. Instead, the basin flood detention structure is adapted as the principal measure against flood overflow from the river. The proposed river channel improvement is limited to construction of river dike of less than 1.5m above the hinter ground level and dredging of existing riverbed along the estuary sections, which is affected by high tide and hardly protected by any other flood mitigation measure.

- The areas along the downstream river channels in particular are densely packed with the houses. In spite of such dense houses and frequent flood overflows from the river channel, the number of casualties in the Study Area due to flood overflow has been rather small (refer to Table 3).
- The small number of causalities could be attributed to the condition such that most of the existing river bank elevation in the Study Area is almost same as the hinterland ground level (refer to Photo-7). Due to such low elevation of riverbank, the river discharge could gradually spill into the hinterland when the river water level exceeds the riverbank level.

Photo-7 Existing River Channels in the Study Area

- The basin flood detention structures function to minimize elevating of the river dike. Unless the basin flood detention structures are constructed in the upper reaches, the design discharge for the downstream river channel improvement remarkably increases and the crown level of the river dike has to be far higher than the ground level. Destruction of such extremely high river dike could possibly occur, once the river water level exceeds the dike crown level, which leads to rushing out of the river discharge within a short period and the disastrous damages including a large number of death calamities. The risk of dike destruction would possibly increase in the future due to increment of storm rainfall intensity inflicted by the climate-change. Moreover, it is virtually difficult to step-wisely elevate the height of river dike in order to increase the channel flow capacity in accordance with the rise of storm rainfall intensities inflicted by climate-change.

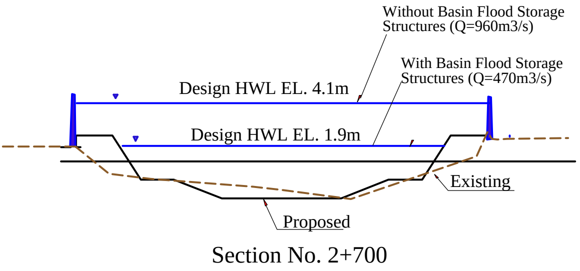


Fig. 19 Standard Cross-sections with and without Basin Flood Retention Structure (Case for Elevating of River Dike)

For instance, the proposed basin flood detention structures in Imus river basin could reduce the design discharge of river channel improvement for the downstream section (1+500 to 3+2000) from 970m^3/s to 470m^3/s. This reduction of design discharge could lower the design high water level for river improvement to be almost equal to the hinterland ground level. On the other hand, unless the basin flood detention structures are constructed, the design high water level needs to be about 3 to 4m higher than the hinterland ground level, which is judged to be out of tolerable range (refer to Figs. 17 to 18.

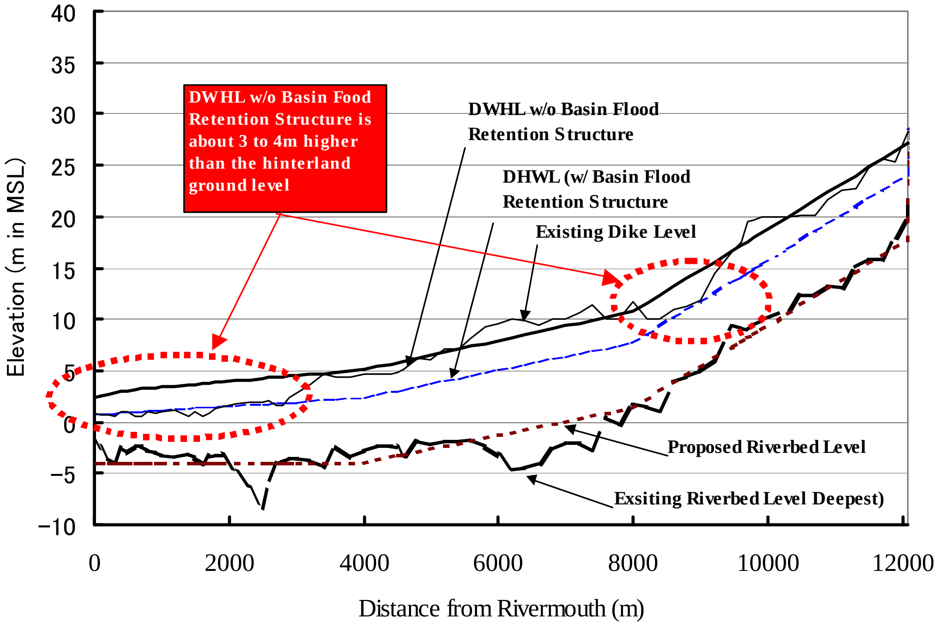


Fig. 20 Longitudinal Profile of Design High Water Levels (DHWL)
with and without Basin Flood Detention Structure
(Case for Elevating River Dike)

- Instead of elevating of river dike, widening of the river channel could be considered as another option for increasing of the river channel. The river channel improvement could be made through solely dredging of the existing of riverbed not requiring channel widening, when the basin flood detention structures are constructed in the upper reaches. On the other hand, unless any basin flood detention structures are constructed in the upper reaches, the downstream river channel improvement would require rather large extent of right of way. For instance, the downstream of Imus river channel needs widening by about 30 to 40m, when the basin flood detention structure is not constructed as shown in Fig. 21.

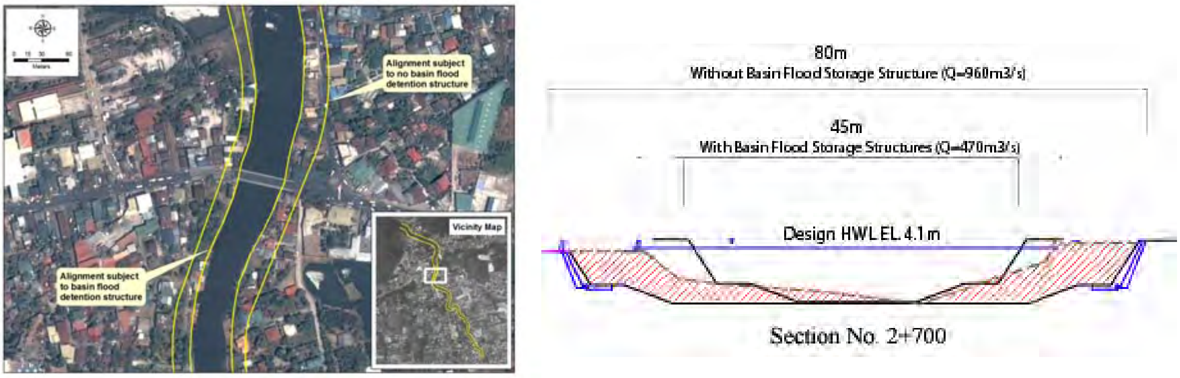


Fig. 21 Alignment and Standard Cross-Sections with and without Basin Flood Detention Structure
(Case foe Channel Widening)

Due to the dense houses along the downstream river stretches and the aforesaid large extent of channel width required, the option of channel widening would require a large number of house relocations. According to aerial photo interpretation, the number of house relocations for river channel improvement is limited to 260 in case of construction of the basin flood detention structures in the upper reaches, while it would increase to 1,960 houses in case of no basin flood detention structure as shown in Table 11. Due to this large number of house relocation required, the option of channel widening is evaluated to be not feasible.

Table 11 Number of House Relocations Required for River Channel Improvement

River Basin	River Channel	Number of House Relocations Required to Channel Improvement	
		With Basin Flood Detention Structure*	Without Basin Flood Detention Structure
Imus	Main Stream	60	650
	Bacoor	30	450
	Jurian	90	400
San Juan	Main Stream	40	460
Total		260	1,960

6.2.2 Reservation of Supplementary Flood Detention Capacity for Offsite Flood Retarding Basin

As described above, the offsite flood-retarding basin is the principal structure for mitigation of river overflow flood and its design flood control capacity is set to meet the probable flood of 10-year return period. In order to reserve the land for step-wise expansion of the offsite flood-retarding basin, which would be required to cope with the climate-change, proposed is the "Urban Growth Development Ordinance". The Ordinance specifies the three zones in the Study Area; namely: Zone A, Zone B (composed of Zone B1 and B2) and Zone C. These zonings in the lower reaches of the Study Area as well as location of the proposed flood retarding basins are as shown in Fig. 22 (Details of the zoning plan for the entire Study Area are as described in subsection 7.1).

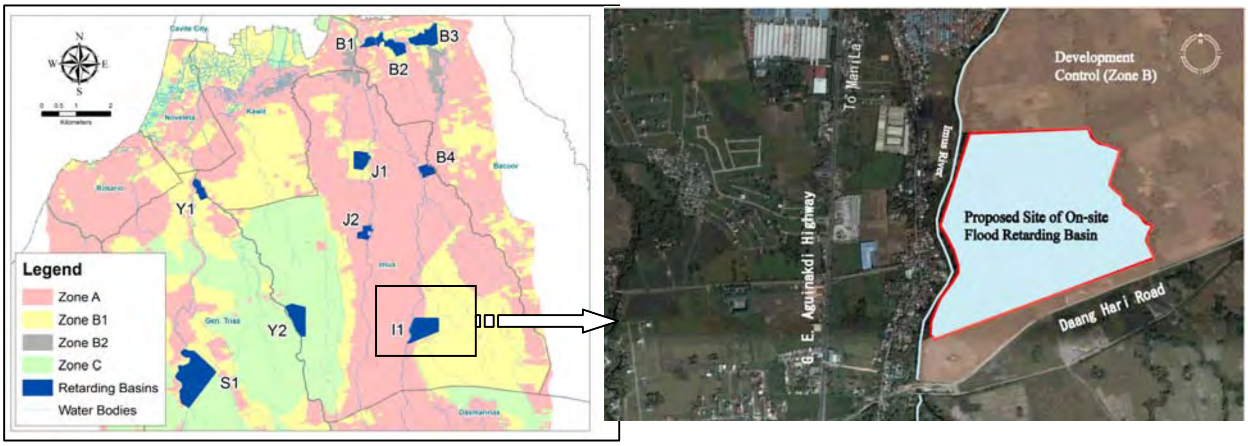


Fig. 22 Land Zoning in the Lower Reaches of Study Area

Definition of the above Zone A, B and C are as described below:

- Zone A is designated as the Development Promotion Zone, which is either the existing built-up area or the future projected built-up area to be positively developed.
- Zone B is designated as the Development Control Zone, where the land development is not allowed before 2020 and it is subject to monitor and control by the local government (cities/municipalities) even after 2020. Zone B is further divided into Zone B1 and B2. Of them, Zone B1 is the existing

agricultural land/grassland, which is out of the under-mentioned the priority agricultural conservation area/environmentally critical area but far from the existing road or other public service facilities, and not preferable for urbanization. Zone B2 is the present built-up area but lies over the flood hazard area[1], where the redevelopment of the existing built area including unoccupied land should be strictly controlled. The allowable development in Zone B2 would be limited to construction of flood proof structures such as the piloty houses/buildings and car parking space.

- Zone C covers the priority agricultural conservation area, where any land development is legally prohibited, unless it promotes public interests. The priority agricultural conservation area includes the areas specified as the Strategic Agricultural and Fishery Department Zone (SAFDZ), the areas specified in the Comprehensive Agricultural Reform Program (CARP) and the existing NIA irrigation area. The steep slope area of more than 15% is further included into the Zone C as the environmentally critical area.

The Provincial Government intends to enforce the above Ordinance, and upon enforcement, land development would not be made in Zone B and Zone C before the year 2020 and/or strictly controlled even after 2020. The extents of Zone B and C are 9,148ha and 14,183ha,respectively (refer to the Table.12 in the under-mentioned Subsection 7.1.1). Hence, an area of about 23,000ha in total is reserved as the non-built-up area in the Study Area. A part of such reserved non built-up area could be used as the land for step-wise expansion of the impounding area of the retarding basins to cope with the future climate-change.

Of ten proposed offsite flood-retarding basins, that of Code I1, which is the principal flood mitigation measure for Imus River, is sampled for estimating its supplementary impounding area required to the future climate change. As shown in Table 12, the proposed impounding area of the offsite flood-retarding basin of Code I1 is estimated at 45ha, which is required to minimize the downstream channel improvement works as described in the foregoing subsection 6.2.1.

This impounding area is subject to the peak river flow discharge of 430m^3/s at just inlet point of the offsite flood-retarding basin, while the peak discharge would increase, in 2050, to 550m^3/s under B1 Scenario and/or 690m^3/s under A1FI Scenario. Due to such increment of the peak river flow discharges, the impounding area of the offsite flood-retarding basin would need to expand to 75ha in 2050 under B1Scenario and/or 100ha under A1FI Scenario as shown in Table 12.

Thus, the impounding area of the Code I1 to cope with the climate change would need to be about 1.9 times of the proposed retarding basin under B1 Scenario and 2.5 times under A1F1 Scenario. The impounding area of the whole proposed offsite flood retarding basins is about 220 ha, while the impounding area to climate change is quite roughly estimated to be in a rage of about 420 to 550ha assuming the said incremental ratio for Code I1.

Table 12 Required Impounding Area for Offsite Flood Retarding Basin Code. No. I1
(Design Scale: 10-year Return Period Flood)

Description	Peak River Discharge before Retarding	Peak River Discharge after Retarding	Reduction of Peak Discharge	Required Storage Volume	Required Area
Proposed in the Study	430 m^3/s	250 m^3/s	180 m^3/s	1.73 (10^{6}m^3)	40ha
Required in 2050 under B1 Scenario	550 m^3/s	250 m^3/s	300 m^3/s	3.01 (10^{6}m^3)	75ha
Area Required in 2050 under A1FI Scenario	690 m^3/s	250 m^3/s	440 m^3/s	4.06 (10^{6}m^3)	100ha

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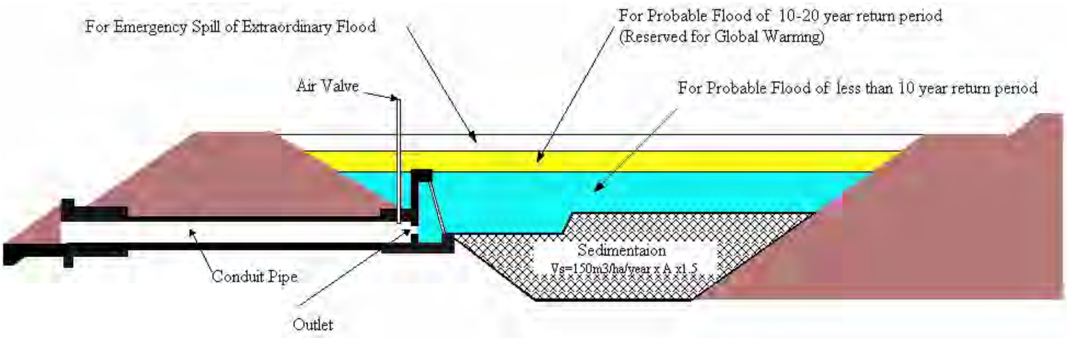
[1] The flood hazard area is assumed as the present probable inundation area by the flood of 2-year return period.

6.2.3 Reservation of Supplementary Flood Detention Capacity of Onsite Flood Regulation Pond

As described above, the design scale of flood mitigation structures against the river overflow is set at 10-year return period, and the same design scale shall be adapted to the on-site flood regulation pond. However, the design scale would be relatively reduced due to the climate-change, while it is virtually difficult to reserve the supplementary space for expansion of the onsite flood regulation pond within the premises of the subdivision to cope with the future climate-change.

In order to maintain the flood control capacity even under the future conditions of the climate-change, the onsite flood regulation pond is designed to complementarily possess the flood control capacity to offset the increment of the probable peak runoff discharge of 20-year return period as shown Fig. 23. The onsite flood regulation pond with the supplementary flood control capacity is deemed to cope with the most likely climate-change simulated as the condition in 2050 under B1 Scenario.



Fig, 23 Conceptual Longitudinal Section of Proposed Onsite Flood Regulation Pond

6.3 Adaptation against Sea Level Rise and Storm Surge

The extension of coastal road (called R1 Extension) of about 5.3km is now being constructed in the offshore of the Study Area as shown in Fig. 24. R1 Extension runs about 800m at maximum from the shoreline, and the sea between R1 extension and shoreline is being reclaimed. The top elevation of the R1 Extension is EL. 4.0m or higher, while the possible highest sea level is estimated at EL. 2.00m, which would possibly break out in 2050 due to complex factors of sea level rise by climate-change under the A1FI Scenario and the storm surge (refer to Table 10). Thus, the R1 extension would amply function as the costal dike and protect the inland against the storm surge.

Fig. 24 Extension of Coastal Road and Reclamation Work

The eastern part of coastal area along Bacoor Bay in particular is out of the area walled in by the above R1 Extension, while it has an extremely low ground elevation below EL. 1m suffering the habitual tidal flood. In order to cope with this issue, the coastal dike of 3.9 km in length (the dike of CD-1, CD-2 and CD-3 in Fig. 25) together with tidal gate is proposed along the eastern part of coastal area (refer to subsection 5.2).

The crown level of the proposed costal dike is designed at EL. 2.41m, which could cope with the aforesaid the possible highest sea level of EL. 2.00m in 2050 under the A1FI Scenario.

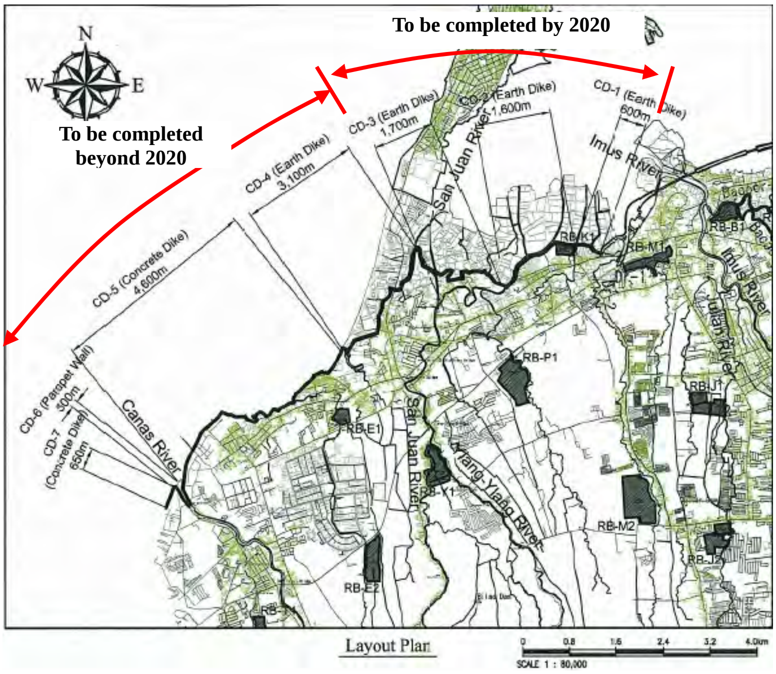
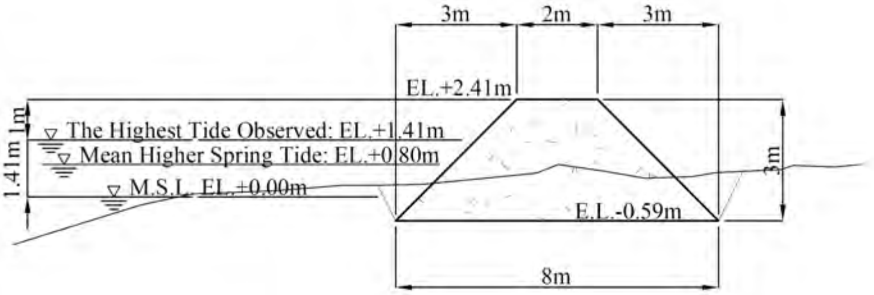


Fig. 25 Alignment of Proposed Costal Dike

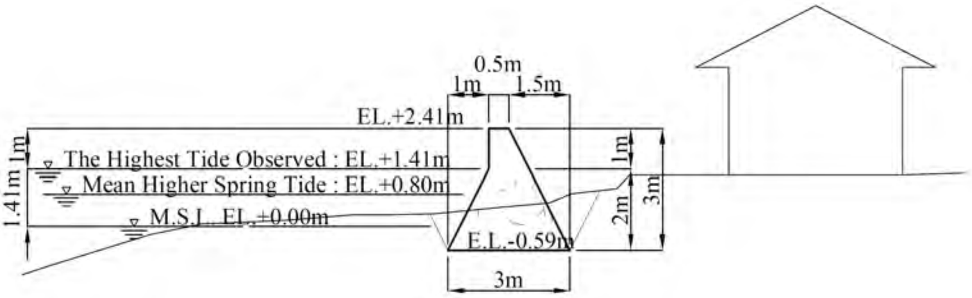
It is herein noted that there still remains the shoreline of about 8.8km not covered with the costal dike. The current tidal flood along this shoreline is less serious than that covered with the proposed costal dike, and the construction of costal dike was not programmed within the target project completion year 2020. Nevertheless, a considerable part of the shoreline has the ground elevation of the shoreline below EL. 1.0m, and suffers from the occasional storm surge and/or high tide. Tidal flood would be further aggravated by the sea level rise due to climate-change. In order to cope with such sea level rise in particular, the supplementary costal dike of about 8.8km in length (CD4, 5, 6 and 7 in Fig. 25) is conceived on the premises that its completion would be beyond the year 2020. The crown level of the supplementary costal dike is assumed at EL. 2.41m in the same way as the aforesaid proposed coastal dike of CD-1, 2 and 3.

As described above, the crown level of all proposed costal dike is set at 0.41m higher than the possible highest sea level in 2050 simulated under the A1FI Scenario. Nevertheless, there are still uncertainties in the simulated sea levels for the climate change, and the possibility of the extraordinary tidal level, which exceeds the crown level of the proposed costal dike, could not be denied. When the extraordinary high tide occurs, the costal dike might possibly be collapsed by the overtopping waves. In order to prevent the coastal dike from such collapsing, the following structural design are made:

- The costal dikes of CD-1 to CD-4 are placed at inland fishpond/vacant land, where difficulties are not foreseeable in step-wisely elevating the dike crown level in accordance with rise of the tidal level. In order to facilitate such step-wise elevating of the dike, the earth dike with the front concrete revetment is proposed (refer to Fig. 16).
- The costal dike of CD-5 to CD-7 needs to be placed along sea shoreline and hardly to have the step-wise elevating of the dike height because of difficulties in land acquisition. Moreover, the coastal dike is exposed to the direct and usual strong wave beasts. In order to prevent the coastal dike from collapsing by the overtopping wave and/or the wave beats, the costal dike of CD-5 to CD-6 is to be the concrete dike made of the massive concrete. The coastal dike for CD-7 is placed along the river mouth and needs to be constructed at the extremely limited space, and it is designed as the parapet type dike with massive concrete. The typical cross-sections of the said concrete dike and parapet wall are as shown in Fig. 26.



Coastal Dike of CD-5 to CD6: Concrete Dike



Coastal Dike of CD-7: Parapet Wall

Fig. 26 Typical Cross Section of Concrete Coastal Dike and Parapet Wall

6.4 Adaptation against Inland Flood

The inland drainage system is proposed to cope with the rainfall intensity of 2-year return period under the present climate conditions. However, the short-term rainfall intensity in the Study Area would rise due to the climate-change: the one-hour rainfall intensity of 2-year return period is 54.3mm, while it would increase, in 2050, to 60.3mm under the B1 Scenario and 65.2mm under A1FI Scenario as shown in Table 13. As the results of rise of short-term rainfall intensity, the low land area of the Study Area would be inundated even by the rainfall intensity of less than 2-year return period.

Table 13 Rise of Probable One-our Storm Rain Intensity Inflicted by Climate Change

Scenario	Probable One-hour Rainfall Intensity		
	2-year	5-year	10-year
Status Quo	54.3	71.7	82.1
In 2050 under B1 Scenario	60.3	79.6	91.1
In 2050 under A1FI Scenario	65.2	86.0	98.5

*: Incremental rate of rainfall intensities are derived from the figures shown in the foregoing Table 6.

The proposed inland drainage system is to allow the inundation depth of 0.25m at maximum. On the premises of the allowable inundation depth, the inland drainage system in the western part of the Study Area is proposed to consist of flap gates at the downstream end of the existing drainage channel and one interceptor together with inland regulation pond, while any enlargement of the existing drainage channel is not proposed in the area as shown in Fig. 27. Assuming the above rise of short-term rainfall intensity, however, the inundation depth of more than 0.25m would gradually break out in the western part of the Study Area. The proposed drainage system for the eastern part of the Study Area could not also meet the rise of the short-term rainfall intensity. In order to cope with these aggravations of the inland flood, the following approaches of either enlargement of drainage channels or pumping drainage are drawn up:

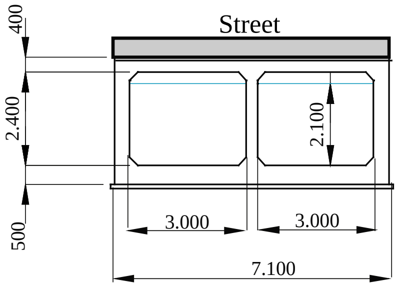


Fig. 27 Concept of Drainage Main under Street

- **Western Part of the Study Area:** A substantial part of this area has the relatively high ground elevation above EL. 2m and the gravity drainage could be made. On the other hand, the shoreline is densely packed with the houses, and the site for construction of regulation pond attached to the pumping station is hardly secured along the shoreline. From these points of view, the gravity drainage through enlargement of drainage channels is conceived to cope with the rise of rainfall intensity by the climate change. The available space for enlargement of the drainage channel is principally placed under the existing streets. The box culverts are to be step-wisely constructed under the streets as the drainage main to collect the storm rainwater according to the rise of the storm rainfall by the climate change. The box culvert of 2.1m in depth and 6m in width would need to run along the streets of 3.5km in total to cope with the 2-year return period in 2050 under A1FI Scenario (refer to Fig. 28). These structural dimensions are subject to allowable inundation depth of 0.25m. In addition, construction of the coastal dike of about 8.8km is projected as described in the foregoing subsection 6.3.

- **Eastern Part of the Study Area**: A substantial part of this area has the extremely low ground level of less than EL. 1m, and it is difficult to drain the storm rainfall through the box culverts under the streets, which are as adapted in the above western part of the Study Area. On the other hand, the downstream end of this area is currently used as the fishpond, which could be used as the regulation pond attached to the drainage pumping station. From these points of view, the pumping drainage is conceived as an adaptable measure to cope with the rise of the storm rainfall intensity by the climate change. The pumping station would be placed at the downstream end of the western part of the Study Area as shown in Fig. 28, and its pumping capacity would need to step-wisely increase in accordance with the rise of the storm rainfall. The pumping capacity in the year 2050 would be 13m^3/s for B1 Scenario and 16m^3/s for A1FI Scenario.

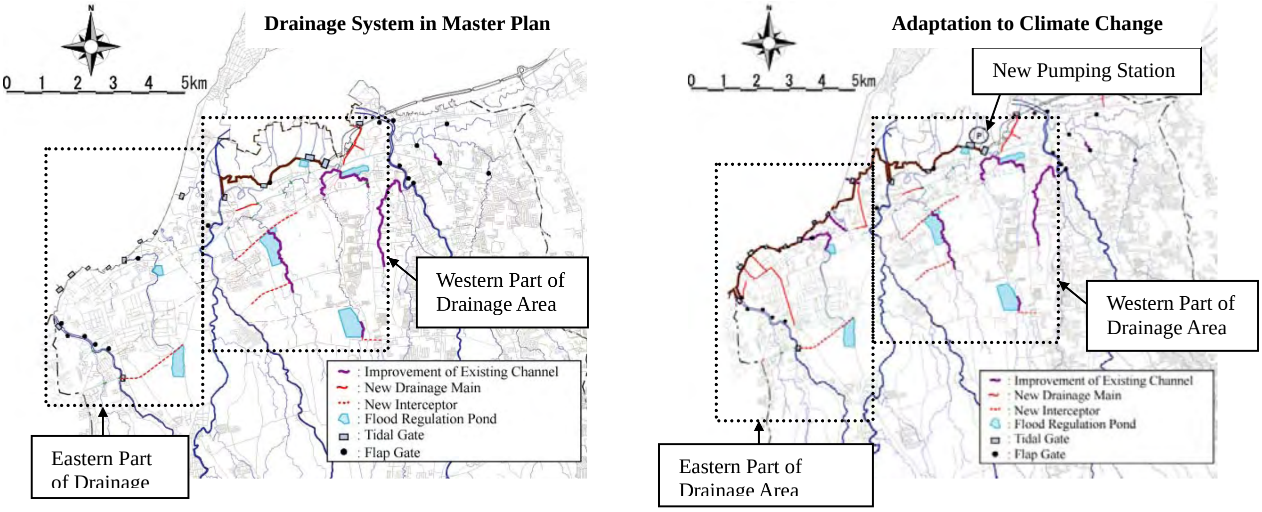


Fig. 28 Drainage System Proposed in Master Plan and Adaptation to Climate Change

CHAP 7. ADAPTATION OF NON-STRUCTURAL MEASURES AGAINST CLIMATE-CHANGE

The aggravation of flood/storm surge intensified by the climate change is hardly solved solely by the aforesaid adaptation of structural measures, and it is indispensable to adapt the non-structural measures such as proper land use control in the river basin, establishment of flood warning and evacuation system and organization setup for flood management in order to minimize the aggravation of flood. Hence, the adaptation of non-structural measures is preliminarily proposed as described hereinafter.

7.1 Land Use Control

7.1.1 Control of Excessive Land Development

The onsite flood regulation pond is to be constructed at every new subdivision. Accordingly, it could strengthen the basin flood detention capacity as the urbanized area expands and function to offset the increment of the basin peak runoff discharge caused by expansion of the urbanized area. However, the design flood control capacity of the onsite flood regulation pond is limited to cope with the probable flood runoff discharge of 20-year return period as described in the foregoing subsection 5.3.

Due to the limited flood control capacity, the potential damage by the probable flood of more than 20-year return period would increase as the urbanized area expands. On the other hand, it is virtually difficult to freeze the growth of the urban development. In order to adjust this dilemma, the zoning plan for the Study Area is proposed through enforcement of “Urban Growth Management Ordinance”.

This Ordinance facilitates to control the ongoing excessive land development in the Study Area, which leads to the extremely large increment of the flood runoff discharge and flood damage potentials. At the same time, it functions to reserve the available land for expansion of offsite flood retarding basin as described in the foregoing subsection 6.2.2.

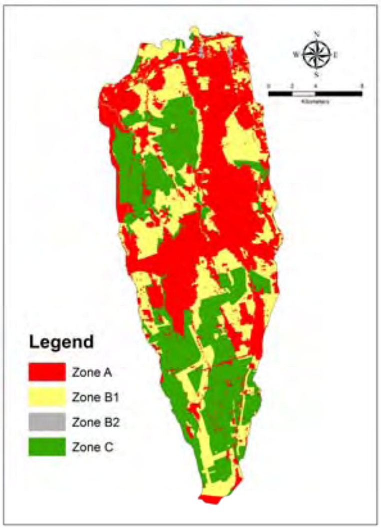


Fig. 29 Zoning Plan of the Study Area

Zoning is made taking the complex factors into account such as: (a) present land use status, which includes the extent of the existing built-up area, and the extent of the conservation area for agricultural product specified by law, (b) population growth by the year 2020, (c) existing urban development plan prepared by the local governments, (d) status of applications from land developers and (e) the high flood risk area. The zoning plan for the entire Study area is as shown in Table 14 and Fig. 29.

Upon enforcement of the zoning pan, the sporadic land development would be strictly controlled in Zone B and at the same time, any land development would be prohibited in Zone C until the year of 2020. Such land use control would contribute to minimizing of the basin flood runoff discharge and the flood damage potentials in the high flood risk areas and be useful against aggravation of the flood conditions caused by the climate changes.

The zoning would be revised after 2020 in accordance with the socio-economic changes as well as the climate-changes. However, once the zoning system is firmly established, the revision of the system would be properly and smoothly made.

Table 14 Zoning Plan for the Study Area by the Year 2020

Zone	Present/Projected Land Use Status	Area (ha)	Share	Remarks
Zone A	Residential	14,561	35.7%	Projected land use status by 2020
	Industrial	1,426	3.5%	
	Institutional	407	1.0%	
	Commercial	1,019	2.5%	
	Sub-total	**17,413**	**42.7%**	
Zone B	Agricultural	2,462	6.0%	Present land use status as of 2003, a part of which may be shifted to the built-up area on the premises of screening by the local government
	Grassland/Open Area	3,145	7.7%	
	Tree Plantation	2,856	7.0%	
	Water Bodies	665	1.6%	
	Unclassified	20	0.0%	
	Sub-total	**9,148**	**22.5%**	
Zone C	Agricultural	12,861	31.6%	Projected land use status, which is to be conserved until 2020
	Grassland/Open Area	1,004	2.5%	
	Tree Plantation	249	0.6%	
	Water Bodies	68	0.2%	
	Unclassified	1	0.0%	
	Sub-total	**14,183**	**34.8%**	
Total		**40,744**	**100.0%**	

7.1.2 Control of Encroachment into River Area

The intensive encroachment into the river area is raised as another principal issue in the land use control relevant to the flood management. Philippines Presidential Decree No. 1067 prescribes that the water body of the river together with the river corridor within the distance of 3m in urban area, 20m in agricultural area and 40 m in forest area from the edge of the water body should be designated as the river area, where nobody is allowed to reside. In spite of such prescription, there exist a large number of informal and formal dwellers in the essential river area. Moreover, encroachment of the houses to the riverside tends to be more intensive as the urban population increases.

The intensive encroachment is made along the downstream stretches of about 28km in length, and the number of the encroachment houses in the river area is estimated at about 500 houses (refer to Fig. 30). These houses are exposed to the high risk of the flood, while any structural flood mitigation measure is hardly applied to them due to the topographic conditions as well as the legislative constraint. In order to cope with these issues, the plan for relocation of the illegal structures in the river area as well as the management of the river area posterior to relocation is proposed as described in the under-mentioned Items (1) to (4).

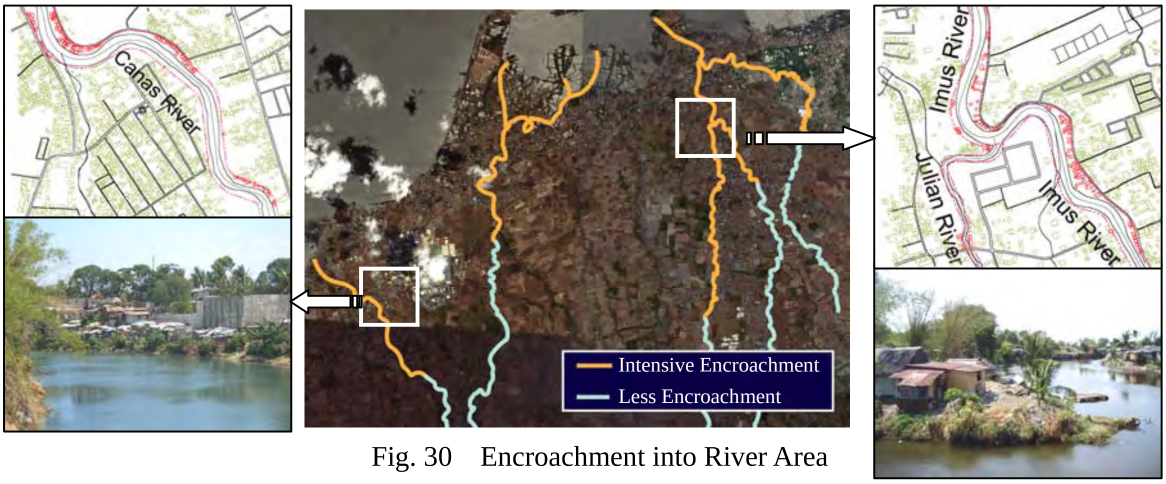


Fig. 30 Encroachment into River Area

(1) Re-clarification of Boundary of River Area

There exist the arterial and/or secondary roads, which form the river dike, running along a part of river sections of Imus, San Juan and Canas. The parapet walls of less than 1.5m in height are further constructed along a part of downstream stretch of the rivers. The riverine area confined by these roads and/or the parapet wall could be defined as the river area. However, substantial parts of the downstream section of the rivers have no definite riverbank, and their flow widths largely change depending on the magnitudes of the discharge, which leads to the uncertainty of the river area's boundary. From this viewpoint, the following boundaries together with installation of boundary makers such as pegs are proposed in order to re-clarify the extent of the river area:

- The Water Body: the riverine area confined by the river dike/bank, if they exist, should be defined as the water body. In case of difficulties in recognizing clear river dike/bank, the water body should be assumed as the width of the water flow section in the non-flood time.
- The River Corridor: In accordance with Presidential Decree No. 1067, the river corridor should have the widths of 3m in the urban area, 20m in the agricultural area and 40m in the forest area from the outward bound of the above water body.

(2) Development and Updating of Database of the River Area

The database of the river area should be developed as the base of maintenance and management of river area. The objective of the database would need to cover the information on updated number and location of houses in the river area as well as the major river structures such as the river dike/revetment, river bridges and dams/weirs for irrigation intake. The JICA Study Team currently supports the counterpart agencies (the Provincial Government of Cavite) to develop the objective database.

(3) Relocation of Informal Dwellers in River Area

A Task Force of "Provincial Drive against Professional Squatting and Squatting Syndicates" has been organized in Cavite Province to relocate the illegal houses in the government owned land and/or other public places. The Task Force has prepared a relocation program and development of a relocation site of about 85ha in total is now in progress to accommodate the informal dwellers to be relocated. This relocation program is not necessarily addressed to the dwellers in the river area, but proposed to incorporate them.

(4) Readjustment of Land Use in the River Area

The readjustment of land use in the river area is proposed to promote public interest on the environment of the river area, ensuring the safety river flow of flood and refraining re-occupancy of the river area after relocation of houses. The proposed land uses of the river area are such as the river-park, sport ground, river walk lanes, and biotope.

(5) Maintenance and Management of River Area

The necessary plans for maintenance and management of river area are proposed including: those for preparation/execution of river patrol, information and education campaign (IEC) for promotion of proper environment of river area.

7.2 Establishment of Flood Waning and Evacuation System (FWES)

A substantial part of the study area is currently exposed to the risk of river overflow even in the event of a probable flood of 2-year return period, and any structure for flood mitigation could not stamp out the flood calamity, since the flood is natural phenomenon and its scale could certainly exceed the design scale of the flood mitigation structure. The future flood calamities would be further aggravated due to not only climate-changes but also complex factors such as the expansion of the urban population, the progress of encroachment to the flood hazard area and the increment of peak discharge by the expansion of the built-up area.

In order to minimize the incremental flood calamities, the plan for flood warning and evacuation system (FWES) for the Study Area is proposed with referring to the current activities and resources of the local government and communities. The proposed FWES should be adapted as the base to cope with the future possible climate-change, and the necessary stage wise modification for it would be made in accordance with the degree of the climate-changes.

7.2.1 Objective Area for FWE

The Typhoon Milenyo, which occurred in 2006, is estimated to have caused the maximum recoded flood having a recurrence probability of about 100-year return period, and its extent of flooding area could be regarded as the present possible maximum flood risk area. From this point of view, the objective areas for FWE are preliminarily assumed as those, which may be submerged with the depth of more than 50cm by the scale of Typhoon Milenyo. In accordance with this assumption, the flood risk area of 1,283 ha together with the eligible flood evacuation centers is proposed as shown in Fig. 31.

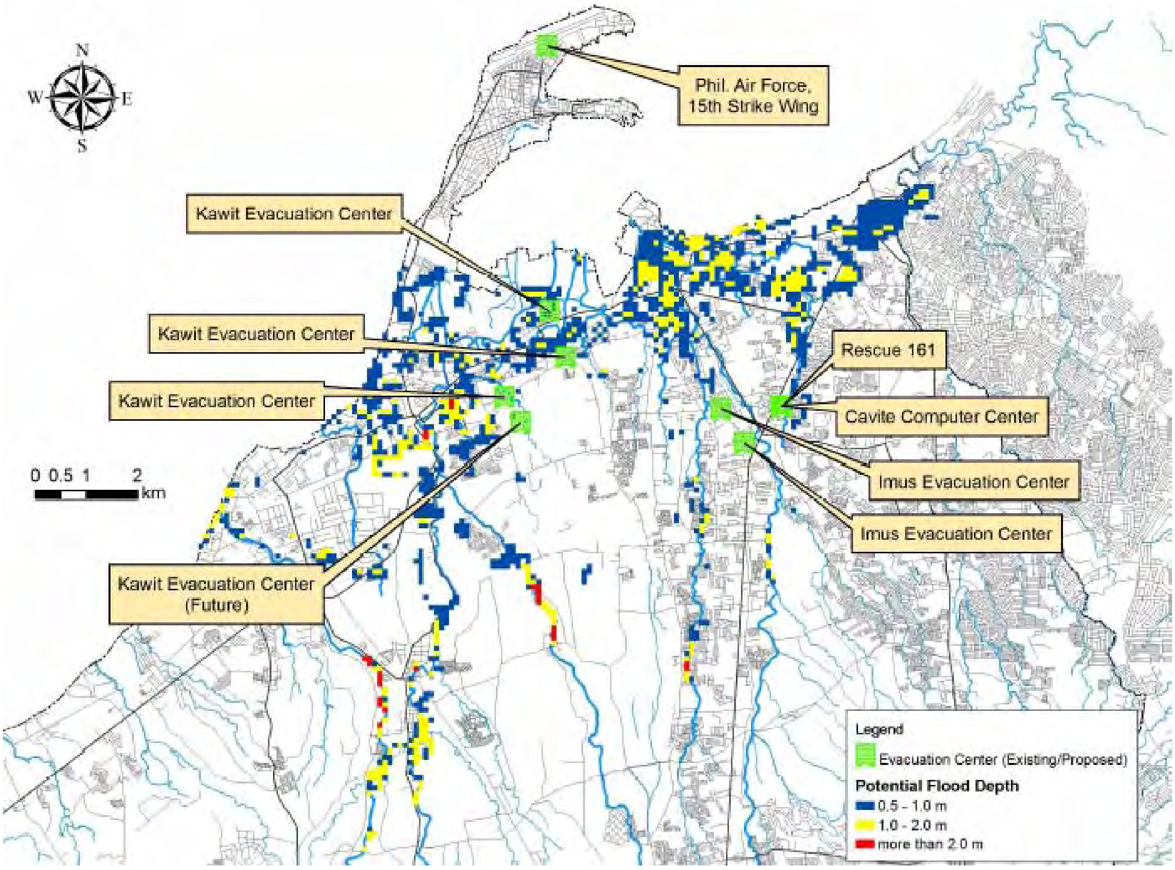


Fig. 31 Objective Areas of Flood Warning and Evacuation and Eligible Flood Evacuation Centers

7.2.2 Proposed Stage-wise Flood Warning and Evacuation

The information on the flood warning and evacuation is to be made based on evaluation of the weather conditions and/or the hydrological conditions such as river water levels and rainfall intensities. The earlier information would facilitate the more effective flood evacuation for the residents, while it may cause more misleadingness in determination of issuance of flood warning and evacuation. The frequent misleadingness would raise a decline in concern of residents about information on flood warning and evacuation. In order to release the earlier information for flood warning and evacuation and at the same time to minimize such misleading, the stage-wise flood warning and evacuation is proposed as listed in Table 15.

Table 15 Proposed Stage-wise Flood Warning and Evacuation

Stage	Hydrometeorological Conditions for Initiation of the Stage	Required Actions
Stage 1 (Standby)	• Public Storm Warning Signal No.1 is released by PAGASA*	• To convene all members for FWE. • To start measurement of river water level and rainfall intensity • To start collection of weather conditions
Stage 2 (Alert Stage)	• Public Storm Warning Signal No.2 is released by PAGASA, or • Accumulated 5-minute rainfall intensity reaches 12.3mm (2-year return period)	• To confirm available human resources, equipment and materials for flood warning and evacuation. • To start river patrol
Stage 3 (Warning Stage)	• Public Storm Warning Signal No.3 is released by PAGASA, • Accumulated 30-minute rainfall intensity reaches 38.8mm (2-year return period), or • River water revel reach the designated level	• To issues warnings • To position the necessary equipment, material and personnel for flood evacuation.
Stage 4 (Evacuation Stage)	• Public Storm Warning Signal No. 4 is released by PAGASA, or • Accumulated 60-minute rainfall intensity reaches 38.8mm (2-year return period) • River water revel reach the designated level	• To issues order of flood evacuation • To guide the residents to the evacuation centers

*: Philippines Atmospheric Geological & Astronomical Service Administration under Department of Service and Technology

7.2.3 Measures for Monitoring of Flood Conditions

As shown in the above Table 15, the accumulated rainfalls and the river water levels are proposed as the boundaries to initiate each of stages for the flood warning and evacuations.

The river water levels are to be monitored at the seven bridge sections and the critical river water levels are marked on the pier of the bridges as shown in Photo-8.

Photo-8 Example of River Water Level Indicator for Flood Warning and Evacuation

As for monitoring of the rainfall intensities, the typing gauging equipment is proposed as the measures at three locations in the Study Area. This rainfall gauging equipment could be simply and easily installed with low procurement cost (i.e., around 80,000 pesos/unit).

7.2.4 Communication Network for FWES

The proposed FWES is executed by the local disaster coordination councils at the provincial, city/municipality and barangay level through cooperation with civic and non-government organizations. The chief executive elected for the local government such as the provincial governor or the mayor acts as chairperson of the local disaster coordinating council. The disaster operation center is also established for each level of the disaster coordinating councils to undertake the actual operation for flood warning and evacuation in accordance with the directions by the chief executives.

The river basins in the Study Area cover the several cities and municipalities, and therefore, the provincial disaster coordination council (PDCC) would undertake the monitoring on the flood conditions over the entire jurisdiction area, and the Provincial Governor as the chairperson of the PDCC would issue the flood warning and/or direct the flood evacuation. On the other hand, the city/municipal disaster coordinating council (CDCC/MDCC) as well as barangay disaster coordinating council (BDCC) would stand for the frontline for the actual operation for dissemination of the messages for flood warning and evacuation among the residents. The BDCC would also undertake monitoring of the river water levels during the flood and report to the PDCC.

The eligible communication route among the government and no-government organizations relevant to flood waning and evacuation as well as the residents is proposed as shown in Fig. 32 taking the aforesaid present disaster communication system as well as the necessary flow of information to achieve the aforesaid step-wise flood warning and evacuation into account.

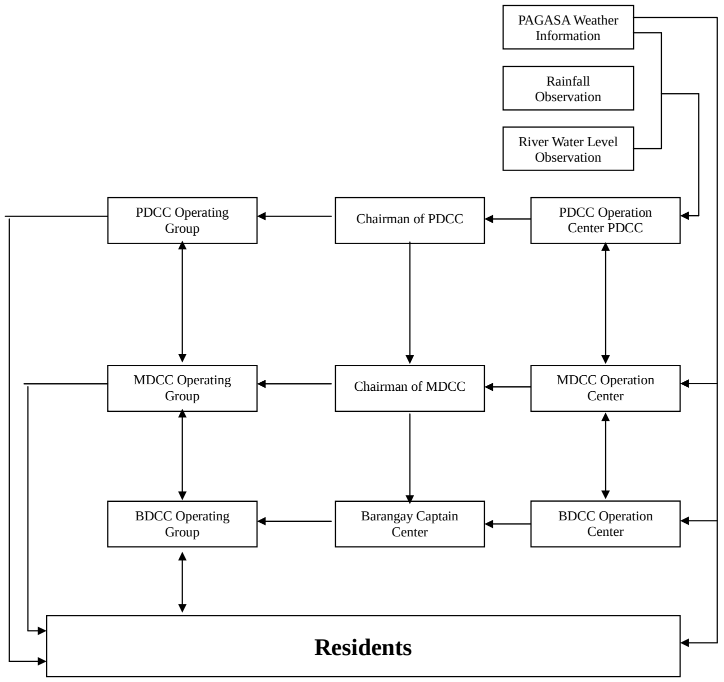


Fig.32 Proposed Communication Flow for Operation of Flood Warning and Evacuation

7.2.5 Evacuation Center and Evacuation Route

The Provincial Government of Cavite and two municipalities, namely Imus and Kawit have preliminarily identified the existing nine public places in and around the entire Study Area as the definite evacuation centers and further conceived the public elementary/secondary schools as the potential centers. The locations of the said public places identified as the evacuation centers are as shown in Fig. 31. However, details of these candidates of the evacuation centers as well as the eligible evacuation routes have not been clarified yet. Moreover, most of the barangays (the minimum government administrative unit in Philippines) as well as the municipalities other than Imus and Kawit in the Study Area have not designated any definite flood evacuation center in their respective jurisdiction yet.

Under the above current situations, each of the municipalities and the barangays are required to determine the definite evacuation centers and evacuation routes and disseminate them among the residents through the flood risk map developed in advance. In order to defuse the methodologies/knowledge on establishment of the evacuation centers and evacuation routes and development of the flood hazard map, the JICA Study Team has commenced the study on a pilot project in August 2008. In the study, the eligible evacuation centers/evacuation routes are clarified for the several pilot barangays and at the same time, the flood hazard map for the barangays are developed in collaboration with the communities based on the results of flood simulation.

7.3 Organization Setup for Flood Management and Monitoring of Climate-change

Aside from the project execution body for flood mitigation structures, the Flood Mitigation Committee (FMC) is proposed to undertake the particular tasks required for flood management of the Study Area. The FMC consists ten permanent members, who represent the local government units relevant to flood management for the Study Area as shown in Table 16.

The principal roles of the FMC are oriented to coordination with the relevant government agencies and communities for promotion of the proposed non-structural flood mitigation plans, which include those for (a) information and education campaign for clean-up dive of rivers/drainage channels, (b) land use control against the excessive land development in the river basins and encroachment into the river areas, and (c) flood warning and evacuation. In this connection, FMC shall invite other relevant agencies/personnel as collaborators, such as heads of schools, representatives of NGOs and statesmen, for the agenda and the ends to be discussed and executed arbitrarily.

The FMC would further undertake monitoring of the climate-change in collaboration with two cooperating agencies, namely PAGASA and NAMRIA. PAGASA functions to monitor and provide the data on climate changes including those of temperature and rainfall intensities both for short-term and long-term in the Study Area as well as the entire country of Philippines through its meteorological gauging stations. NAMRIA also functions to monitor and provide the date on the changes of sea level of Manila Bay. The FMC should collect all of the climate data as well as sea level data related to the Study Area and at the same time, it should acquire the updated results of the analysis by IPCC. Based on these integrated information, the FMC should evaluate the climate-changes, which may aggravate the flood conditions in the Study Area.

Table 16 Proposed Members of Flood Mitigation Committee (FMC)

Designation	Personnel and Organization	Principal Role	Relevant Organizations to be Coordinated
Chairperson	Provincial Planning and Development Coordinator (PPDC)	• Coordinate and guide the overall activities of FMC • Guide the necessary control of the excessive land development • Guide the necessary conservation of the agricultural land	• Provincial Land Use Committee • PPDO • CPDO/MPDOs
Secretariat	Provincial Planning and Development Office (PPDO)	• Act as the secretariat of the FMC	
Vice-chairperson	District Engineer of DPWH in Tress Martires City	• Assist the chairperson for coordination and guidance of the overall activities of FMC • Coordinate and implement land acquisition and construction of the proposed flood mitigation facilities • Coordinate and implement the O&M of the flood mitigation facilities	• DPWH
Member	Provincial Director of Philippine National Police (PNP)	• Coordinate and guide the flood warning and evacuation works • Coordinate and guide the control of encroachment to the river area	• PNP
Member	Head of PG-Environmental and natural Resources Office (PG-ENRO)	• Coordinate and guide the OPLAN LINIS (IEC for cleanup drive of the waterways)	• CENRO/MENROs
Member	Head of Provincial Housing and Urban Development Office	• Coordinate and implement the control of encroachment to the river area	• PHUDO • Task Force for Relocation of Informal Dwellers)
Member	Head of Provincial Engineering Office (POE)	• Coordinate and implement land acquisition and construction of the proposed flood mitigation facilities • Coordinate and implement the O&M of the flood mitigation facilities	• PEO • C/MEOs
Member	Representative from District Office of DENR in Tress Martires City	• Coordinate and guide the OPLAN LINIS (IEC for cleanup drive of the waterways) • Coordinate and guide the watershed management	• DENR
Member	Representative from District Office of NIA in Naic, Cavite	• Guide the necessary conservation of the agricultural land	• NIA
Member	Provincial Action Officer of the Gov. Service Office	• Coordinate and guide the activities relevant to flood warning and evacuation a	• PDCC • CDCC/MDCCs • BDCCs