CHAPTER 5 WATER LEVEL FLUCTUATION IN LAGUNA LAKE DURING FLOOD IN PASIG-MARIKINA RIVER

In order to examine the water level fluctuation of Laguna Lake, and validity of the flood management measures, related data is collected and analyzed such as flow regime of the water fluctuation data of Laguna Lake and both Manggahan Floodway and Napindan Channel during the floods, and the water level fluctuation analysis model of Laguna Lake is built based on the water level fluctuation characteristic of Laguna Lake as follows.

5.1 Characteristics of Water Level Fluctuation of Laguna Lake

5.1.1 Available Data

The available data regarding water level of Laguna Lake, rainfall in the basin, inflow discharge to Laguna Lake and flow regimes of Manggahan Floodway and Napindan Channel during floods (occurrence of reverse flow to/from Laguna Lake) are summarized in Table 5.1, Table 5.2, Figure 5.1 and Figure 5.2.

Table5.1 Availability of Hourly Rainfall and Water Level Data (EFCOS)

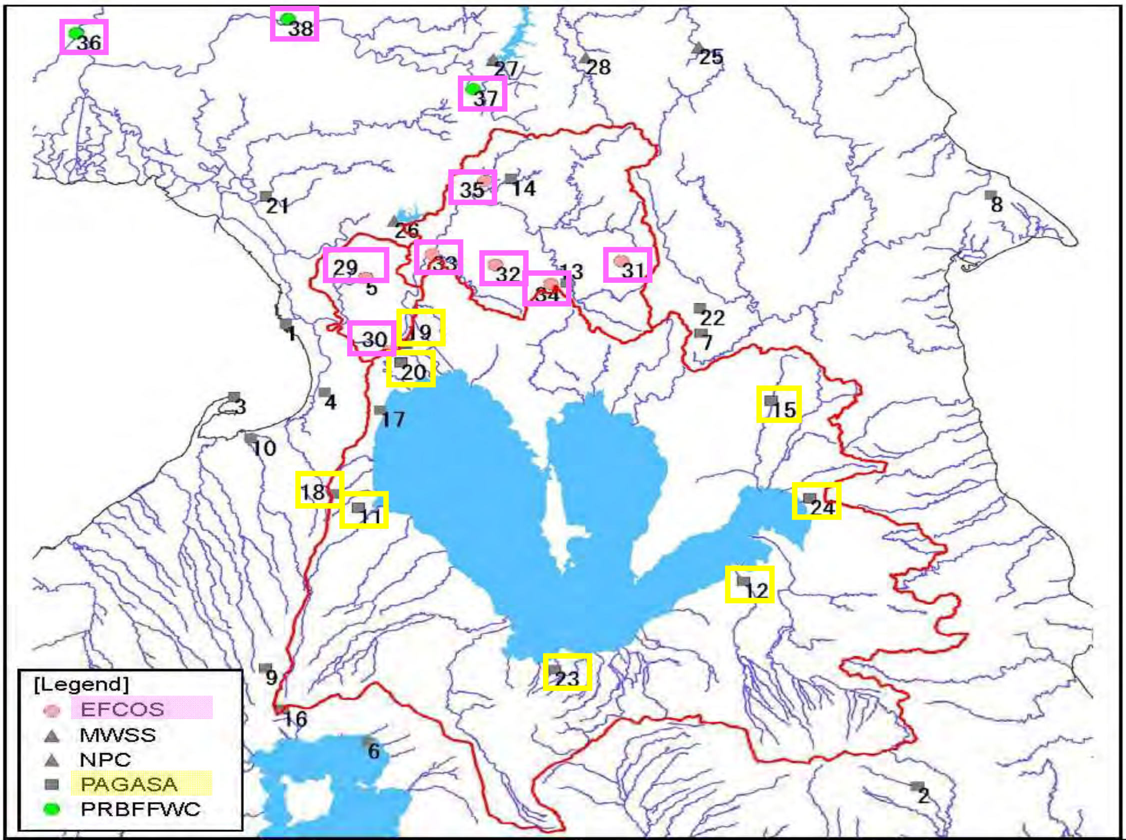
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Rainfall	Science Garden	×	×	×	×	×	×	×	×	×	○	○	○	○	○	○	○	△	×	×
	Napindan	×	×	×	×	×	×	×	×	×	○	○	○	○	○	△	×	×	×	×
	Mt.Campana	×	×	×	×	×	×	×	×	×	○	○	○	○	○	△	×	×	×	×
	Aries	×	×	×	×	×	×	×	×	×	○	○	○	○	○	○	○	○	○	△
	Nangka	×	×	×	×	×	×	×	×	×	○	○	○	○	○	○	△	△	○	△
	BosoBoso	○	○	○	○	○	△	○	○	○	○	○	○	○	○	○	○	△	○	△
	Mt.Oro	○	○	○	○	○	△	○	○	○	○	○	○	○	○	△	○	△	○	△
	Sulipan	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	Ipo dam	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	San Rafael	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Waterlevel	Rosario JS	○	○	○	○	○	△	○	○	○	○	○	○	○	○	△	△	○	○	△
	Rosario LS	○	○	○	○	○	○	○	○	○	○	○	○	△	○	×	×	×	×	×
	Napindan JS	○	○	○	○	○	○	△	○	○	○	○	○	○	○	×	×	△	×	×
	Napindan LS	○	○	△	△	○	○	○	○	○	○	○	○	△	○	×	×	×	×	×
	Nangka	×	×	×	×	×	×	×	×	○	○	○	○	○	○	○	△	△	○	△
	San Juan	×	×	×	×	×	×	×	×	○	○	○	○	○	○	○	△	△	○	△
	Montalban	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	△
	Sto.Nino	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	△
	Pandacan	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	△
	Fort Santiago	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	○	△
	Angono	△	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	△

Missing Data percentage ： ≧90% ⇒× Missing Data percentage ： ≧10% ＜90% ⇒△ Missing Data percentage ： ＜10% ⇒○

Table 5.2 Availability of Daily Rainfall Data (PAGASA)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Pakil	○	○	○	○	○	○	○	○	○	○	○	○	○
NAS	○	○	○	○	○	○	○	○	○	○	○	○	○
SanPedro	×	×	×	×	×	×	×	×	×	×	×	×	×
NPP	×	×	×	×	×	×	×	×	×	×	×	×	×
PasigElem	○	○	○	○	○	○	○	○	○	×	×	○	○
Tipas	×	×	×	×	×	×	×	×	×	×	×	×	×
StaMaria	○	○	○	○	○	○	○	○	×	×	×	○	○
StaCruz	○	○	○	○	○	○	○	○	△	△	○	○	○

Missing Data percentage ： ≧90% ⇒× Missing Data percentage ： ≧10% ＜90% ⇒△ Missing Data percentage ： ＜10% ⇒○



No	Station Name	No	Station Name	No	Station Name	No	Station Name
1	Port Area	11	San Pedro, Laguna	21	Polo, Valenzuela, M.M.	31	Mt.Campana
2	Tayabas Quezon	12	Sta Cruz Laguna	22	Bureau of Soil, Cuyambay, Tanay, Rizal	32	Aries
3	Sangley Point Cavite	13	Boso-Boso Antipolo Rizal (PAGASA)	23	NAS, UPLB, Los Banos	33	Nangka
4	NAIA	14	Sitio Tabak Montalban Rizal	24	Pakil, Laguna	34	BosoBoso (EFCOS)
5	Scienec Garden (PAGASA)	15	Macasipac, Sta. Maria, Laguna	25	Umiray	35	Mt.Oro
6	Ambulong Batangas	16	Tagaytay	26	La Mesa	36	Sulipan
7	Tanay (Radar)	17	Bagumbayan Taguig MM	27	Angat Dam	37	Ipo Dam
8	Infanta	18	NPP Research Bu.of Prison Muntinlupa	28	Matulid	38	San Rafael
9	Barrio Maitim Amadeo Cavite	19	Pasig Elem. Sch. Pasig MM	29	Science Garden (EFCOS)		
10	Mabolo Elem Sch. Bacoor Cavite	20	Tipas Taguig MM	30	Napindan		

Figure 5.1 Locations of Rainfall Gauging Stations

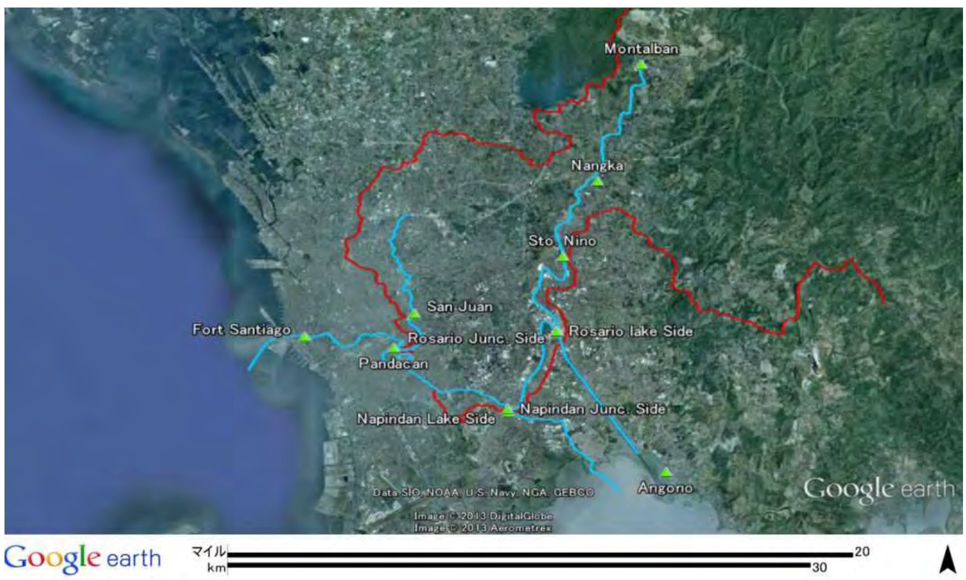


Figure 5.2 Locations of Water Level Gauging Stations

5.1.2 Monthly Fluctuation of Water Level

Secular change of monthly variation of water level at Anogono Station from 1994 to 2012 is summarized as follows.

- Water level of Laguna Lake becomes the lowest in the end of dry season in April or May and becomes the highest in late rainy season in September to January. (Refer to Figure 5.3) The average annual lowest and highest water levels are EL. 10.8m and EL. 12.4m, respectively.
- The average annual lowest water level is almost same as the mean sea level (MSL) of Manila Bay. It means that sea water intrusion to Laguna Lake occurs when high tide in the end of dry season.

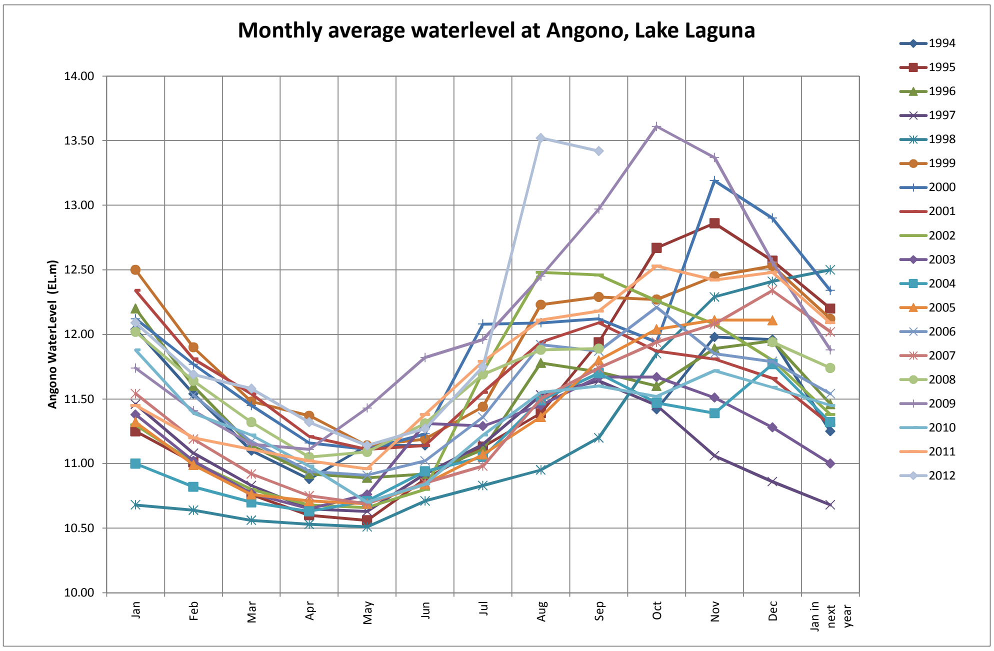


Figure 5.3 Monthly Variation of Water Level in Laguna Lake

5.1.3 Water Level Fluctuation during Floods

In order to identify flow regime of Manggahan Floodway and Napindan Channel during floods, difference of water levels of Rosario JS Station for Manggahan Floodway and Napindan JS Station for Napindan Channel against Angono Station are calculated. The hourly fluctuations are shown in Figure 5.4 and 5.5 and the fluctuations of daily mean water level is shown in Figure 5.6 and 5.7. It is noted that the positive number of difference means that water level of Angono is higher.

- Hourly hydrograph in 2004 in which two floods were occurred by the tropical cyclone Wennie in August and the typhoon Yoyong in December is analyzed. During flooding stage, water level of Rosario JS is more sensitive and always higher than Laguna Lake. It is expected that natural discharge to Laguna Lake through Manggahan Floodway always occurs during floods. On the other hand, clear correlation cannot be found between the water levels of Napindan JS and Laguna Lake. It is judged that natural diversion from Pasig River to Laguna Lake through Napindan Channel does not always occur. Using daily mean water level, this tendency is more emphasized.
- Since the hourly water level data of Typhoon Ondoy and Typhoon Pepeng are not available, calculation results using 2009 data is not utilized.

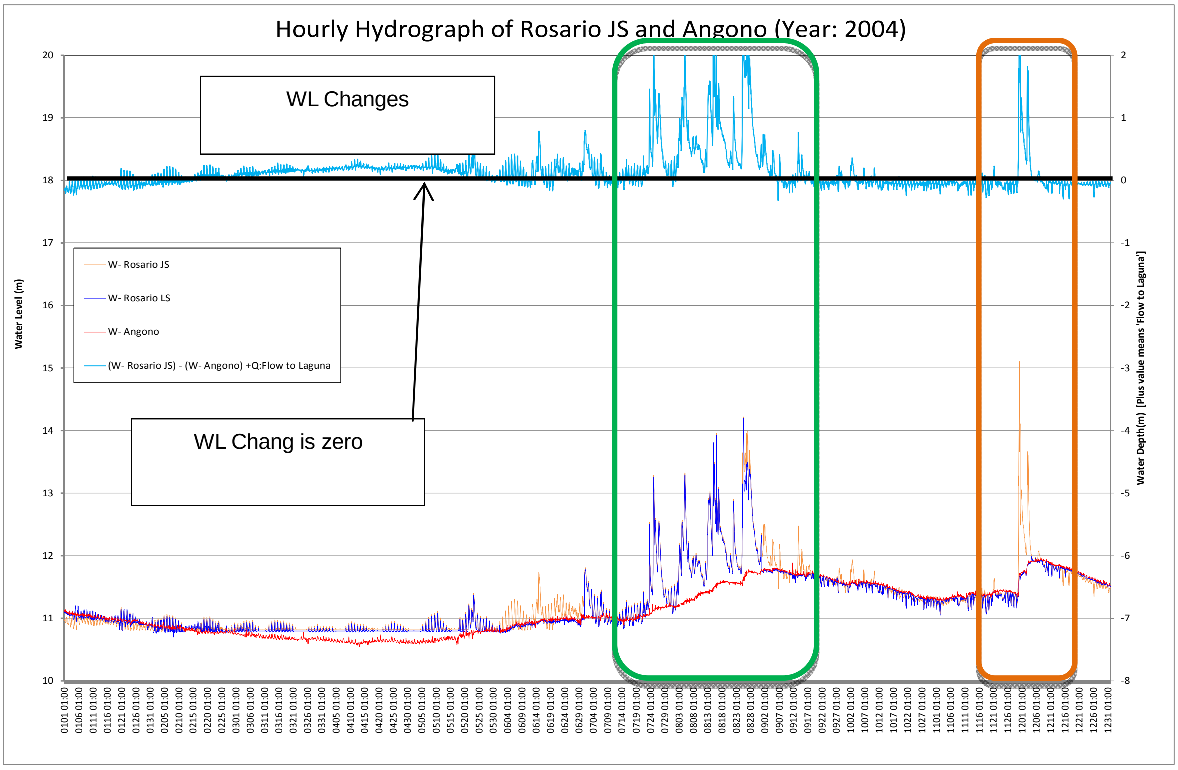


Figure 5.4 Hourly Hydrograph of Rosario JS and Angono (2004)

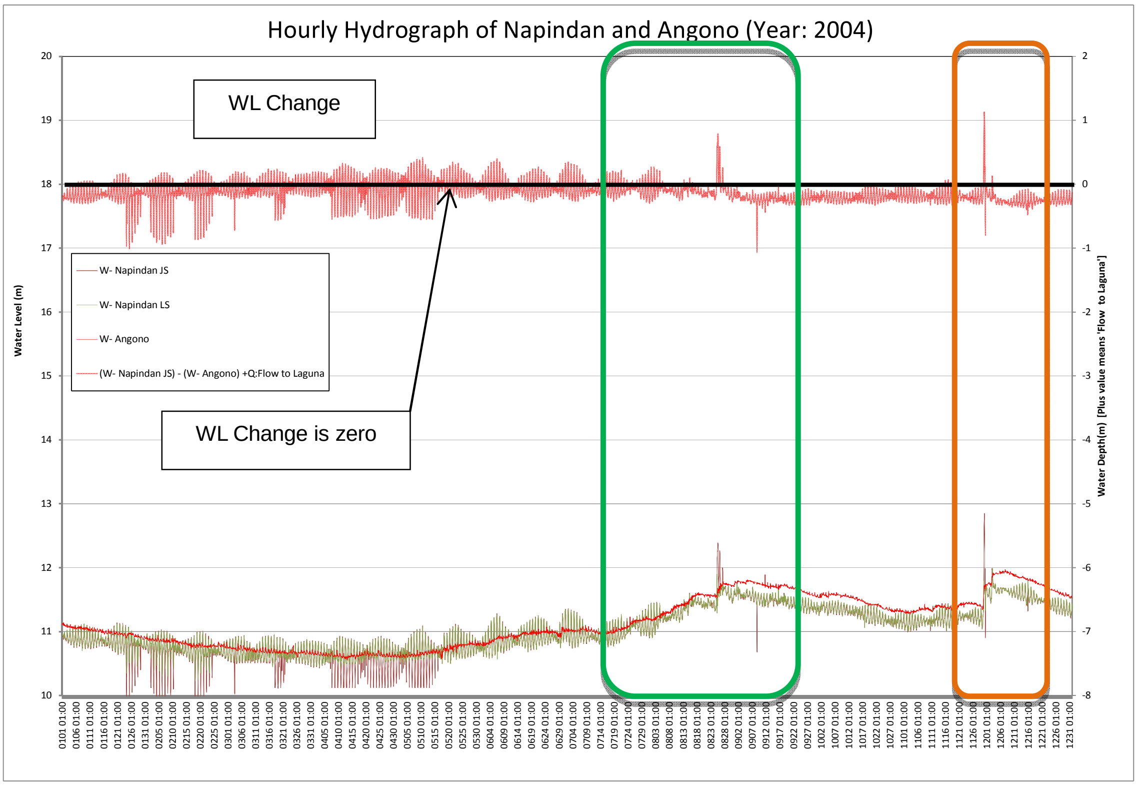


Figure 5.5 Comparison of Hourly Hydrograph Between Napindan JS and Angono (2004)

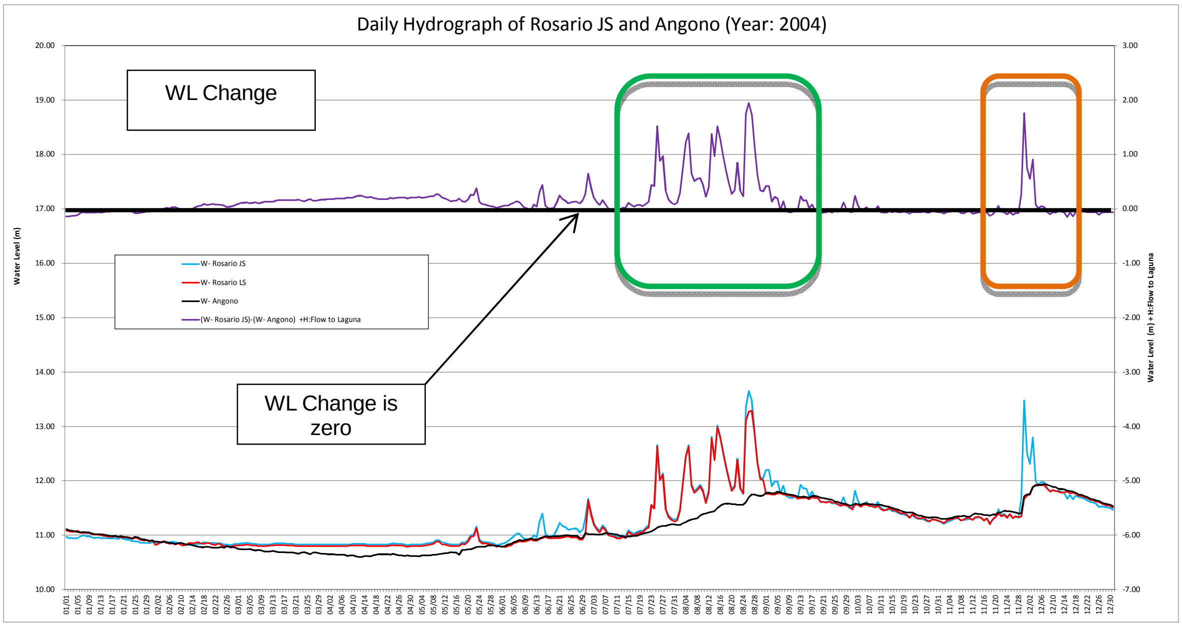


Figure 5.6 Comparison of Daily Mean Hydrograph between Rosario JS and Angono (2004)

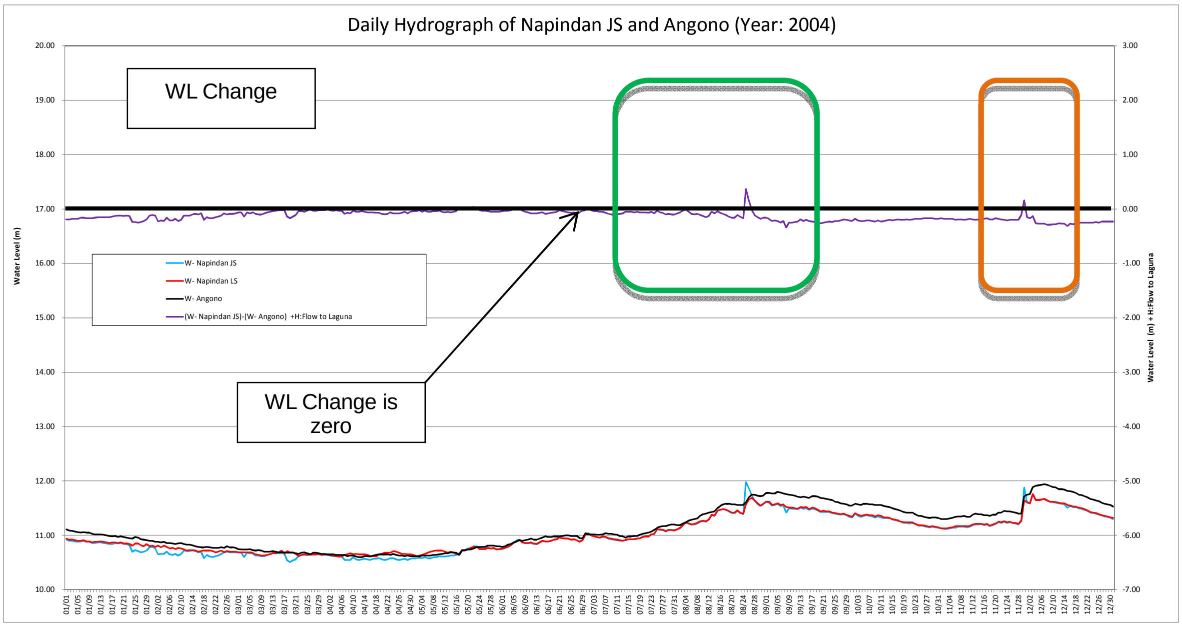


Figure 5.7 Comparison of Daily Mean Hydrograph Between Napindan JS and Angono (2004)

5.2 Water Level Fluctuation Model

5.2.1 Establishment of Analysis Model

(1) Objective of Modeling

The water level fluctuation model is established in order to analyze the followings.

- Validity regarding that reverse flow to Laguna Lake can be taken into account for flood management plan as proposed in the WB Study
- Effect of inflow from Manggahan Floodway to Laguna Lake to water level fluctuation of Laguna Lake
- Effect of Climate Change to water level fluctuation of Laguna Lake (Change of Evaporation and Rainfall)

(2) Basic Concepts

- To establish the long-term one dimensional model correlating the water level at Angono, inflow discharge from other tributaries, inflow through Manggahan Floodway, inflow and outflow through Napindan Channel, and evaporation from Lake surface
- Hourly fluctuation of water level is affected by tide level, however, it is considered that daily average can explain the trend of water level fluctuation. Thus, day is applied as the calculation unit of model.
- Inflow discharge from other tributaries is estimated by the rational formula.
- Since the gate operation record during floods is uncertain for Rosario Weir, it is assumed that gate is full open.
- Water level at Napindan Gate has no correlation between the water level of Laguna Lake, and Napindan Gate has not closed since 2008. Thus, for calibration, Napindan Gate is always open.

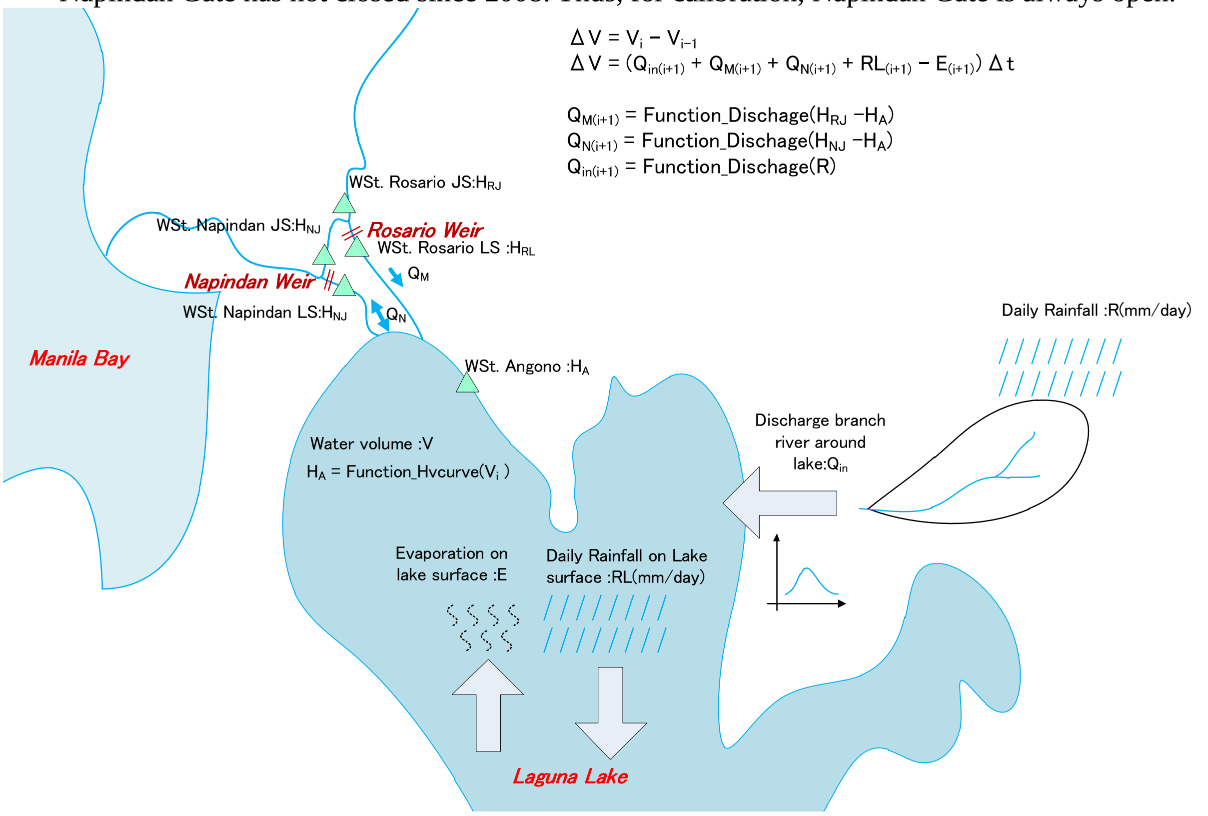


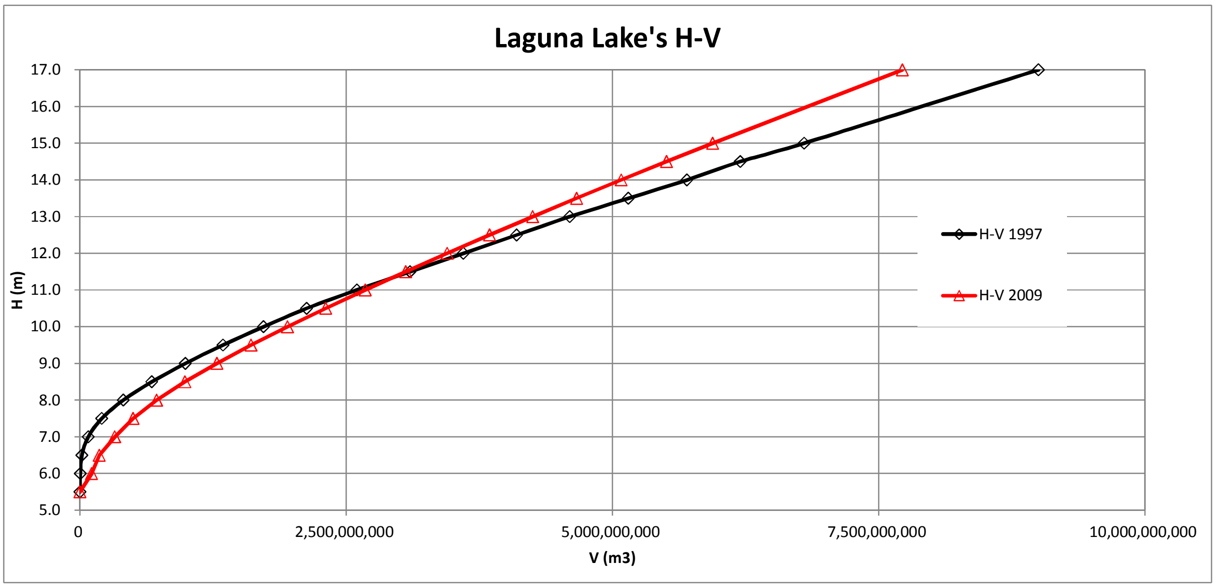
Figure5.8 Conceptual Figure of Water Level Fluctuation Analysis Model in Laguna Lake

(3) Model Verification

For verification of the model, 2004 observed data of which condition of data is good and 2009 in which Typhoon Ondoy occurred are used. The model parameters are evaluated and calibrated comparing observed and calculated water level of Laguna Lake.

(4) Applied H-V Curves of Laguna Lake

Available H-V curves of Laguna Lake are made in 1997 and 2009. Considering the basin characteristics such as construction of lake shore dyke and sedimentation induced by Typhoon Ondoy and Pepeng, the 2009 H-V curve is applied for 2009 data and the 1997 H-V curve is applied for 2004 data. It is noted that the WB Study applied 1997 data for whole period probably since 2009 H-V was not verified at that time.



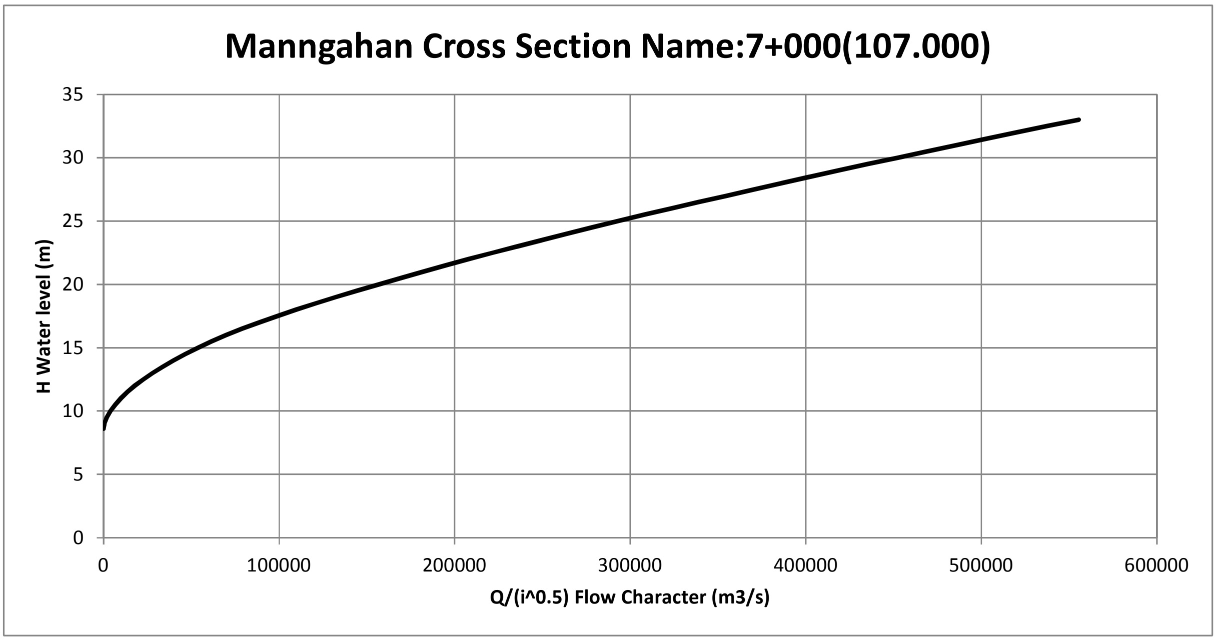
Source: Master Plan for Flood management in Metro manila and Surrounding Area Final Draft Master Plan Report, Mar 2012, The World Bank

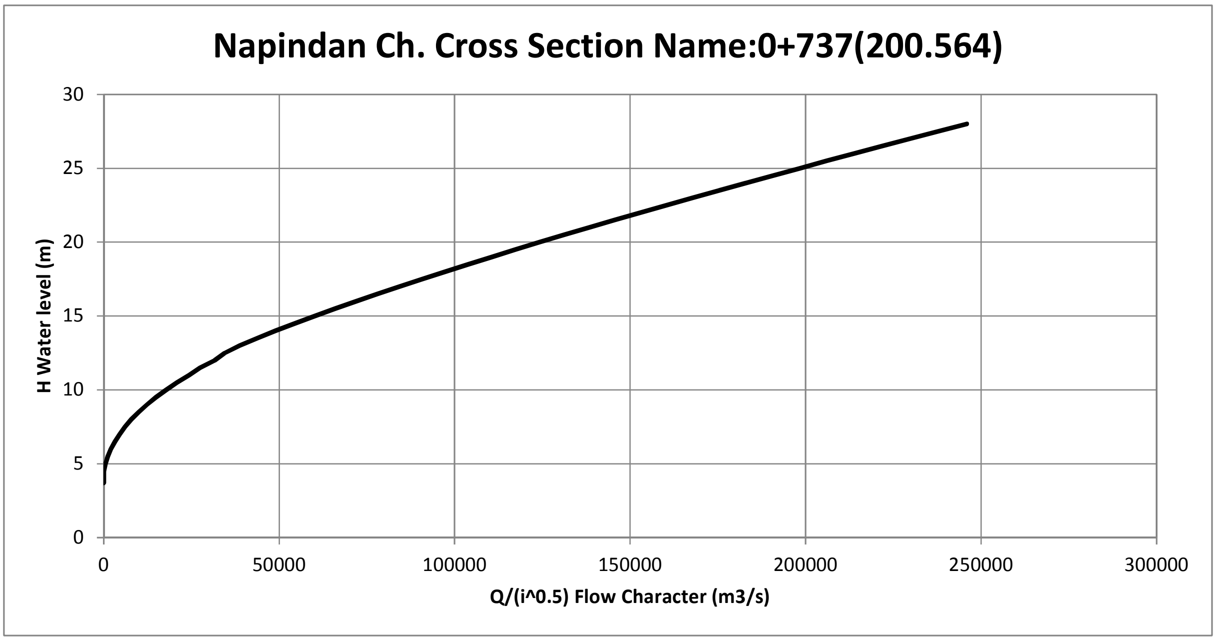
Figure5.9 Laguna Lake H-V Curve

(5) Cross Section Property of Manggahan Floodway and Napindan River

For long term flow regime of Manggahan Floodway and Napindan Channel, cross section property is an important factor to determine discharges as well as difference of water level between Laguna Lake and Pasig-Marikina River since riverbed slopes of both channel are gentle. It is more dominant than gate control of Rosario Weir and NHCS.

The cross section properties shown in Figure 5.10 are selected as typical cross section properties which fluctuation of discharge against fluctuation of water level is low.





Source: JICA Study

Figure 5.10 Applied Cross-sectional Properties

(6) Inflow Rivers to Laguna Lake

Out of 38 sub basins of Pasig-Marikina River Basin which was set by the WB Study, the 23 sub-basins of which rivers directly flows into Laguna Lake are selected as shown in Table 5.3.

Table 5.3 Summary of Inflow Rivers to Laguna Lake

SB_ID	NAME	Area (km2)	Longest Flow Path L_r(km)	Elevetion Difference dH(m)	Time of Concentration TC(hr)	Lag Time (hr)	MajorRivers
SB - 00	Laguna Lake Surface	870.27	-	-	-	-	
SB - 01	Marikina	538.08	-	-	-	-	Marikina, Wawa
SB - 02	*Mangahan*	*91.02*	*4.8*	*55*	*1.14*	*0.68*	*Mangahan, Cainta (Baho), Buli, Mahaba*
SB - 03	*Angono*	*86.41*	*6.1*	*74*	*1.08*	*0.65*	*Angono*
SB - 04	*Morong*	*98.78*	*23.1*	*124*	*3.25*	*1.95*	*Morong*
SB - 05	*Baras*	*22.71*	*9.2*	*127*	*1.59*	*0.95*	*Baras*
SB - 06	*Tanay*	*53.44*	*18.7*	*393*	*2.04*	*1.22*	*Tanay*
SB - 07	*Pililla*	*41.19*	*12.3*	*162*	*1.66*	*1.00*	*Pililla*
SB - 08	*Jala - jala*	*73.12*	*3.5*	*57*	*0.80*	*0.48*	*Jala-Jala*
SB - 09	*Sta.Maria*	*204.90*	*26.0*	*275*	*3.52*	*2.11*	*Sta.Maria*
SB - 10	*Siniloan*	*74.31*	*18.3*	*449*	*2.46*	*1.48*	*Romero*
SB - 11	*Pangil*	*54.14*	*12.4*	*288*	*1.77*	*1.06*	*Pangil*
SB - 12	*Caliraya*	*128.84*	*16.2*	*36*	*2.56*	*1.54*	
SB - 13	*Pagsanjan*	*311.76*	*54.1*	*581*	*5.88*	*3.53*	*Pagsanjan*
SB - 14	*Sta.Cruz*	*148.35*	*32.2*	*675*	*3.77*	*2.26*	*Sta.Cruz*
SB - 15	*Pila*	*90.55*	*13.1*	*92*	*2.08*	*1.25*	*Bancabanca*
SB - 16	*Calauan*	*154.82*	*28.1*	*238*	*3.40*	*2.04*	*Bay*
SB - 17	*LosBanos*	*102.83*	*7.0*	*358*	*1.05*	*0.63*	*Maulauen*
SB - 18	*SanJuan*	*191.77*	*39.1*	*393*	*4.33*	*2.60*	*SanJuan*
SB - 19	*San Cristobal*	*140.66*	*33.4*	*511*	*3.76*	*2.26*	*SanCristobal*
SB - 20	*Sta.Rosa*	*120.30*	*25.3*	*417*	*2.85*	*1.71*	*Sta.Rosa*
SB - 21	*Binan*	*86.03*	*31.7*	*468*	*3.38*	*2.03*	*Biñan*
SB - 22	*SanPedro*	*46.09*	*33.0*	*527*	*3.21*	*1.93*	*SanPedro*
SB - 23	*Muntinlupa*	*43.53*	*5.1*	*34*	*0.98*	*0.59*	*PasongDiablo*
SB - 24	*Taguig*	*45.29*	*2.4*	*8*	*0.69*	*0.41*	*NapindanChannel*
SB - 31	Pasig	102.56	-	-	-	-	Pasig, SanJuan
SB - 32	CoreArea	73.46	-	-	-	-	
SB - 33	Paranaque - LasPinas	115.97	-	-	-	-	Parañaque, Zapote
SB - 34	Malabon - Tullahan	90.06	-	-	-	-	Tullahan
SB - 35	Meycauayan	171.23	-	-	-	-	Meycauayan, Marilao
SB - 36	Bulacan	390.89	51.0	211	6.52	3.91	Bulacan, Sta.Maria
SB - 37	BulacanCoastalArea	67.14	-	-	-	-	Meycauayan
B-103	*Laguna Lake Model Catchment*	*2,410.84*					

Source: Master Plan for Flood management in Metro manila and Surrounding Area Final Draft Master Plan Report, Mar 2012, The World Bank

(7) Evaporation of a Laguna Lake

Since the area of Laguna Lake surface is wide as same as the catchment area of lake, rainfall and evaporation from the lake is large enough to be included in the simulation. The area scale of Laguna Lake surface and the area total of inflow river to Laguna Lake is almost equal, therefore, it is considered that the lake surface evaporation other than rain drops on the lake surface cannot be disregarded.

Refereeing to the WB Study, actual evaporation amount (E) modeled after the instrumental evaporation (E_0) of Los Banoz is applied.

$$E = \alpha_1 E_0 \qquad P < 0.5mm/day$$
$$E = \alpha_1 \alpha_2 E_0 \qquad P \geqq 0.5mm/day$$
$$\text{Given } \alpha_1 = 0.6, \alpha_2 = 0.5$$

Table 5.4 Instrumental Evaporation (E_0) and Monthly Mean Value (mm/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.38	5.70	6.72	7.90	7.31	5.66	4.66	4.50	4.48	4.38	4.19	3.80

Source: Master Plan for Flood management in Metro manila and Surrounding Area Final Draft Master Plan Report, Mar 2012, The World Bank

(8) Rainfall Data

The applied rainfall stations are 6 stations consisting Pakil, NAS, PasigElem, StaMaria, and StaCruz which are continuously observed since 2000 under PAGASA, and Boso-Boso station under EFCOS to complement northern part of the basin.

Table 5.5 Data Availability of Adopted Rainfall Stations operated by PAGASA

Station	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Pakil	○	○	○	○	○	○	○	○	○	○	○	○	○
NAS	○	○	○	○	○	○	○	○	○	○	○	○	○
SanPedro	×	×	×	×	×	×	×	×	×	×	×	×	×
NPP	×	×	×	×	×	×	×	×	×	×	×	×	×
PasigElem	○	○	○	○	○	○	○	○	○	×	×	○	○
Tipas	×	×	×	×	×	×	×	×	×	×	×	×	×
StaMaria	○	○	○	○	○	○	○	○	×	×	×	○	○
StaCruz	○	○	○	○	○	○	○	○	△	△	○	○	○

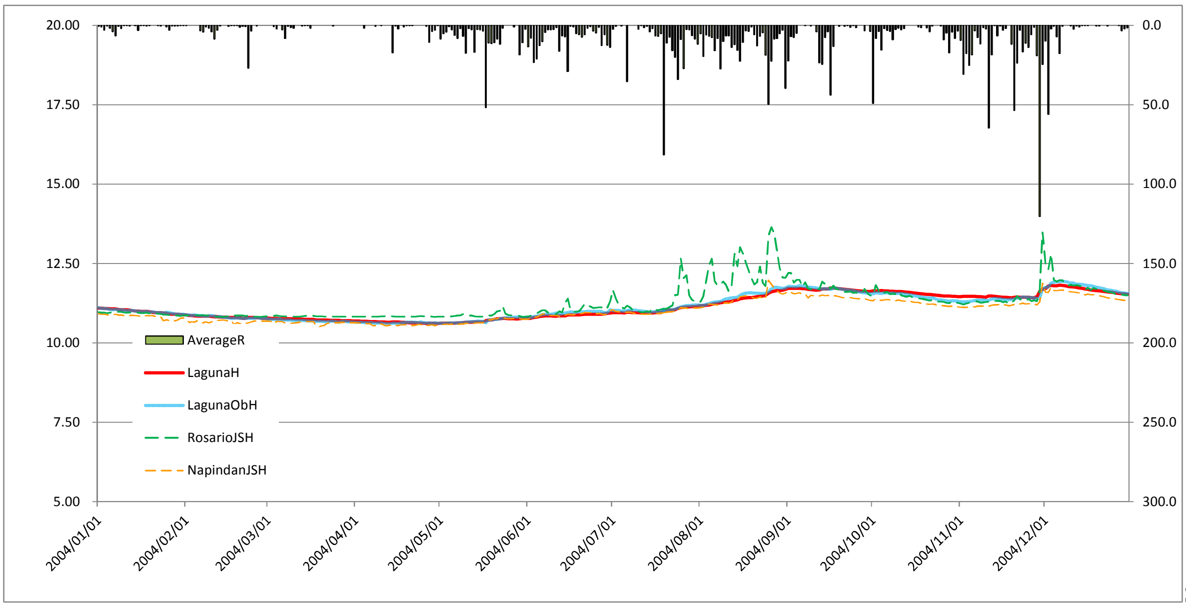
※ Missing Data percentage : ≧90% ⇒× Missing Data percentage : ≧10% ＜90% ⇒△
Missing Data percentage : ＜10% ⇒○

5.2.2 Analysis Results of Laguna Lake Water Level

(1) Result of Simulation

The numerical simulation was performed with the conditions mentioned above.

As shown in Figure 5.11, simulated water level of Laguna Lake well follows the observed water level showing good reproducibility of the model.



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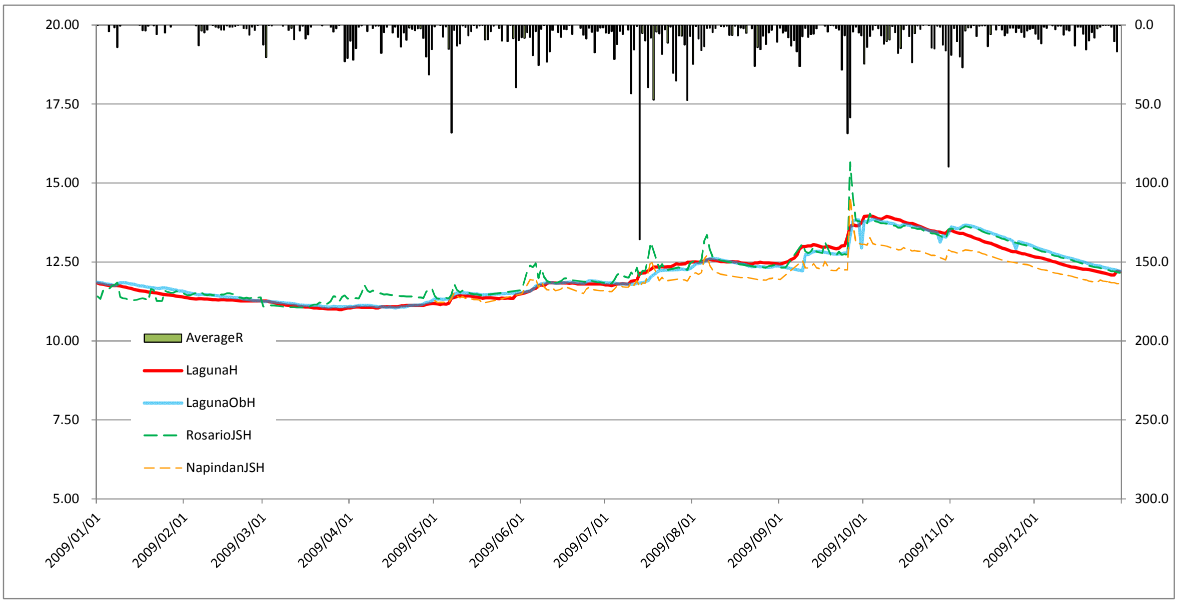
Source: JICA Study

Figure-5.11(1) Results of Laguna Lake Water Level Simulation (case of 2004 year)



Source: JICA Study

Figure-5.11(2) Results of Laguna Lake Water Level Simulation (case of 2009 year)

(2) Water Level Fluctuation during Typhoon Ondoy and Pepeng Invasion

Typhoon Ondoy passed through the basin from the east to the west from September 25 to 26, 2009 and Typhoon Pepeng passed the northern part of Luzon Island from east to west with straying in October 3 to 10. The water level of Laguna Lake recorded 13.9m, which is the highest level after Manggahan Floodway construction.

The water levels of Laguna Lake, Rosario JS and Napindan JS during the two typhoons invasion are shown in Figure 5.14. As shown in the figure, water level of Laguna Lake remarkably rose during Typhoon Ondoy and rose again due to Typhoon Pepeng before the water level had fallen after Typhoon Ondoy. Total inflow to Laguna Lake was bigger by Typhoon Ondoy, and water levels of both Rosario JS and Napindan JS were higher than Laguna Lake resulting reverse flow to the lake through Napndan Channel. Based on the analysis of other floods, the situation that the water level of Napindan JS is higher than the lake during floods is very unique case while Rosario JS usually becomes higher than Laguna Lake.

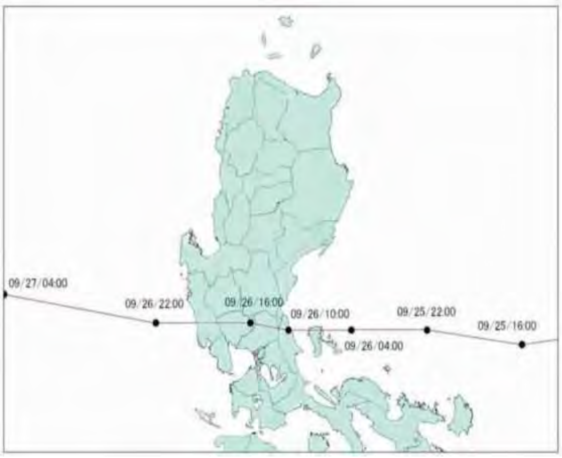
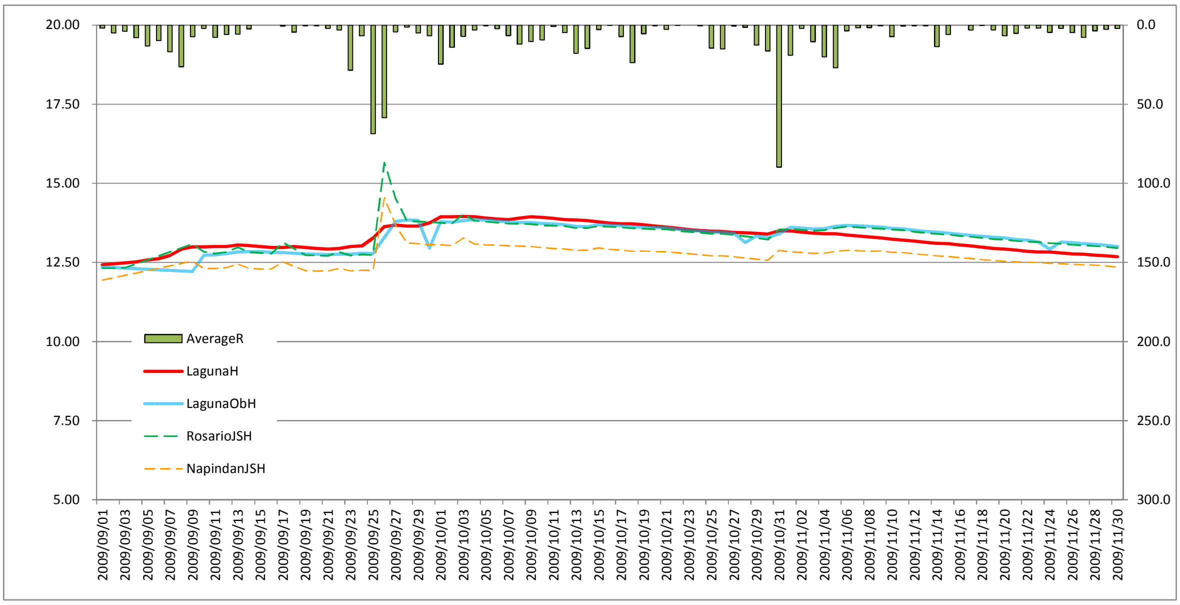


Figure5.12 Best Track of Ondoy typhoon (T2009-16)

Figure5.13 Best Track of Pepeng Typhoon (T2009-17)



Source: JICA Study

Figure 5.14 Water Level Fluctuation during Typhoon Ondoy Typhoon and Typhoon Pepeng

5.2.3 Validity of Including reverse flow (Napindan Waterway) of Laguna in Flood Measure Plan

Based on observed data in 2004 and analysis results in 2004 and 2009, water level of Rosario JS is always higher than Laguna Lake during floods. On the other hand, water level of Napindan JS is lower than Laguna Lake in many cases. Although it becomes higher than Laguna Lake occasionally depending of tidal level, its uncertainty is high to expect as flood control function and it is not recommended to include this phenomena as a flood control measure.

5.2.4 Influence of inflow from Pasig-Marikina River to Water Level Fluctuation of Laguna Lake

As discussed in section 4.3.1 (2), 82 % of inflow to Languna Lake during Typhoon Ondoy is came from Laguna Lake Basin, while only 10 % comes through Manggahan Flood way and 8 % comes through Napindan Channel. Based on this simulation results, it is judged that influence of inflow from Pasig-Marikina River is very small to water level fluctuation of Laguna Lake.

5.2.5 Impact of Climate Change

Using the established model, water level of Laguna Lake in 2040 is estimated considering the effects of climate change.

(1) Model Parameter of Climate Change

In connection with the climate change currently explained by AR4 of IPCC, it is considered as temperature, rain, and a tide level as an influenced natural phenomena. Among them, although it is thought that it has the indirect influence of a tide level, it is not influenced directly in Laguna Lake. Temperature is also an indirect influence derived from meteorological influence. Change of precipitation and evaporation of the surface of the lake are the most significant impacts.

(2) Temperature Rise Influence on Rainfall

The increase ratio of precipitation in Manila and the emission scenario by IPCC is examined.

<Emission Scenario>

Out of the several scenarios which reported in the IPCC 4th Assessment Report in 2000, the A1B scenario which assumes realistic social and physical conditions is applied.

<Total Amount of Earth Temperature Rise>

The total amount of earth average temperature rises after 100 years (2000 standard) in this scenario is estimated as 2.8K as optimal value as shown in Table 5.6.

If secular change of temperature rise is linier, temperature rise in 2040 will be set to 1.1K (=2.8K/100*40). However, A1B scenario shown in Figure 5.15 is curvilinear form. Therefore, the total amount of earth average temperature rises in 2040 is set to 1.3K by direct reading of the graph.

Table 5.6 Rise Prediction of Global Average Ground Temperature and Sea Level Rise Prediction in End of the 21st Century

Scenarios[a)]	Changes in Temperature (difference of year 2090-2099 based on the year 1980-1999 (℃))[C)]		Sea Level Rise (difference of year 2090-2099 based on the year 1980-1999 (℃)) Forecast range by models (exclusive of mechanical changes of rapid ice discharge)
	Best estimate value	Likely forecast range	
Steady at the consistence of 2000[b)]	0.6	0.3-0.9	No data
B1 scenario	1.8	1.1-2.9	0.18-0.38
A1T scenario	2.4	1.4-3.8	0.20-0.45
B2 scenario	2.4	1.4-3.8	0.20-0.43
A1B scenario	2.8	1.7-4.4	0.21-0.48
A2 scenario	3.4	2.0-5.4	0.23-0.51
A1FI scenario	4.0	2.4-6.4	0.26-0.59

Source: Summary on IPCC 4th Assessment Report (Official Edition)

Note: a) Scenarios are six SRES marker scenarios. CO2 conversion consistence (see p.823, 1st working group report of 3rd assessment report) corresponding to the radiative forcing by man-made greenhouse gas and aerosol are SRES marker scenarios of B1, A1T, B2, A1B, A2 and A1FI, and approximately 600, 700, 800, 850, 1250, 1550ppm respectively.

b) Composition of values of steady at the consistence of 2000 is obtained only by air-sea coupling system model (AOGCM).

c) Temperature is the best estimate value and forecast range of uncertainty obtained by models belonging to various hierarchies regarding constraints by observed values and composite degrees. Changes of temperature are presented as the differences between1980-1999. To present the changes between 1850-1899, 0.5℃ will be added.

<Forecast Scenarios (Reference)>

These scenarios do not include the additional global warming measures

■A1 "Growth-oriented Society Scenario"

・World's economy will develop more and great innovation will be come up.

A1FI: Value on Fossil Energy Resources

A1T: Value on Non-Fossil Energy Resources

A1B: Value on Balance of Energy Resources

■A2 " Pluralistic Society Scenario"

・World's economy and politics will be divided into blocks, and trading and movement of people/technologies will be restricted.

・World's economy will grow slower, and concerns for environment will be relatively scarce.

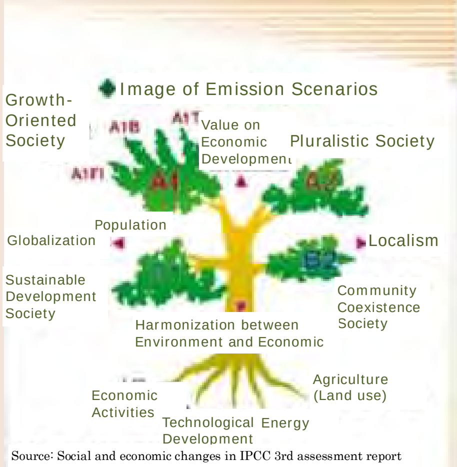
■B1 "Sustainable Development Society Scenario"

・Environmental protection and economic development will be promoted at the same time.

■B2 "Community Coexistence Scenario"

・Value on the problem solution in the communities and fairness of world, and economic development will be somewhat slow.

・Environmental issues will be resolved within each community.



Source: Social and economic changes in IPCC 3rd assessment report

Source: Ministry of Environment "Global Warming

Source: Summary on IPCC 4th Assessment Report (Official Edition)

Greenhouse Gas Emission Scenarios 2000-2100 (without Additional Climate Policies) and Forecast of Surface Temperature

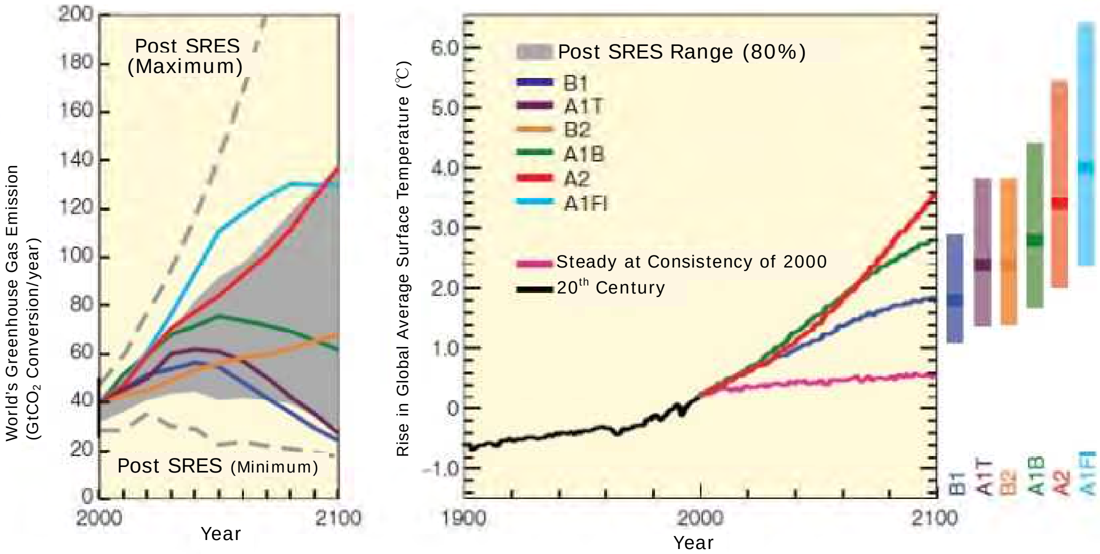


Figure SPM.5. ***Left Figure***: amount of greenhouse emission (CO2 conversion) without additional climate policies: six SRES marker scenarios (colored lines), 80% tile of recent scenarios (post SRES) publicized after SRES (range with grey colored). Dot lines are overall range of results of post SRES scenario. CO2, CH4, N2O and CFC are included in emission amount. ***Right Figure***: solid lines show rise in global average surface temperature continued from the condition of 20th century in models of A2, A1B, B1 scenarios. These forecasts are considered with the effects of short-lived greenhouse gas and aerosol. Pink line represents the simulation of air-sea coupling system model (AOGCM) which is sustained steadily at the atmospheric concentration of year 2000, but the scenario. Right belt of the figure indicates best estimation value (horizontal line of each belt) and forecast spread of high possibility from 2090-2099 of 6 SRES scenarios. All temperatures were comparison with 1980-1999.

Source: Summary on IPCC 4th Assessment Report (Official Edition)

Figure 5.15 Forecast Scenarios in IPCC 4th Assessment Report

<Amount of Temperature Rises and Rate of Precipitation Increase in Manila>

Since the amounts of temperature rises by all the Earth climate change models are all the Earth surface average value, it is necessary to adjust to the area for examination by downscaling. The method of downscaling examines the relation between the amount of global temperature rises and the temperature rises of a local climate model by all the earth climate change models. There is the result of research which considered the relation with the amount of temperature rises in a local climate model according to the major cities until now. The same method also in this study. According to this method, it becomes the amount of rises of 0.883K in Manila to the amount 1.0K of temperature rises of all the earth climate change models. (Refer to Figure 5.16 Inclination of the regression line)

Furthermore, the amount of local temperature rises and the relation of the precipitation rate of increase are also shown. According to the relation, rainfall increases by 8.094% to the amount 1.0K of temperature rises. (Refer to Figure 5.17 inclination of the line)

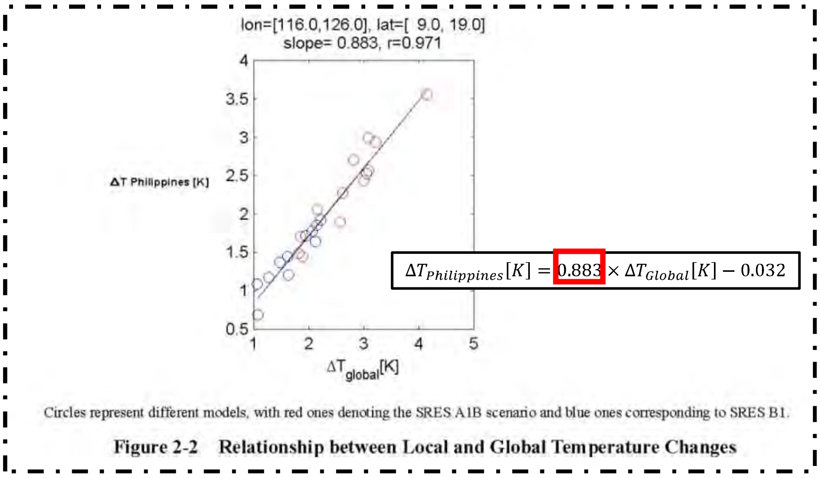
The amount of temperature rises of Manila in 2040 was set to 1.15K from these relations, and the rainfall rate of increase became 9.3%. (Refer to Table 5.7) .

Table 5.7 Rainfall Increment Volume

	Value	Remarks
Global mean temperature increase $\Delta T_{global}[K]$	1.3K	A1B 2040 from 2000
$\Delta T_{local}/\Delta T_{global}$	0.883	On Figure- 5.16
Local mean temperature change $\Delta T_{local}[K]$	1.15K	
$\frac{1}{\Delta T_{local}} \frac{\Delta P_{local}^{extreme}}{P_{local}^{present,extreme}} [\%/K]$	8.094%/K (0.081)	On Figure- 5.17
Change of precipitation $\Delta P_{local}^{extreme}/P_{local}^{present,extreme}[\%]$	9.3%	

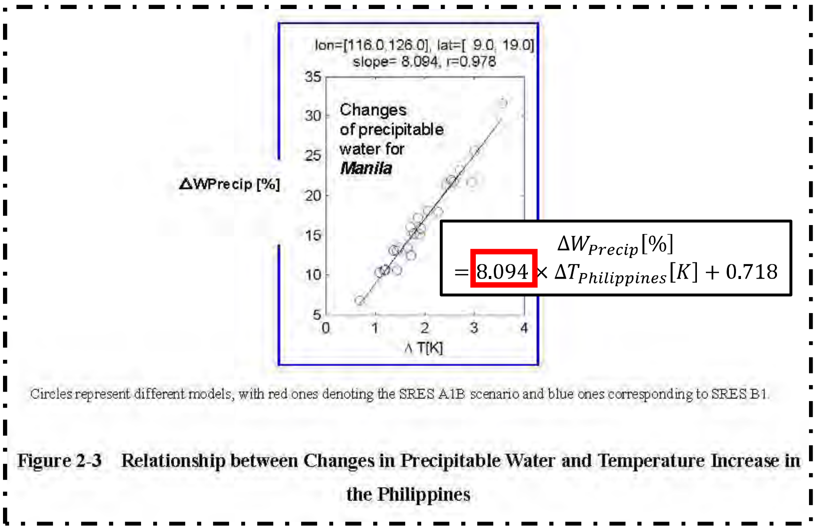
$\Delta T_{global} \equiv T_{global}^{future} - T_{global}^{present}$

$\Delta P \equiv P^{future} - P^{Present}$



Source: Impacts of Climate Change upon Asian Coastal Area: The Case of Metro Manila, JICA

Figure 5.16 Relation between Amount of Temperature Rises by Earth Models, and Amount of **Temperature Rises in Philippines**



Source: Impacts of Climate Change upon Asian Coastal Area: The Case of Metro Manila, JICA

Figure 5.17 Amount of Temperature rises, and Relation of Rainfall Rate of Increase

(3) Influence on Lake Surface Evaporation

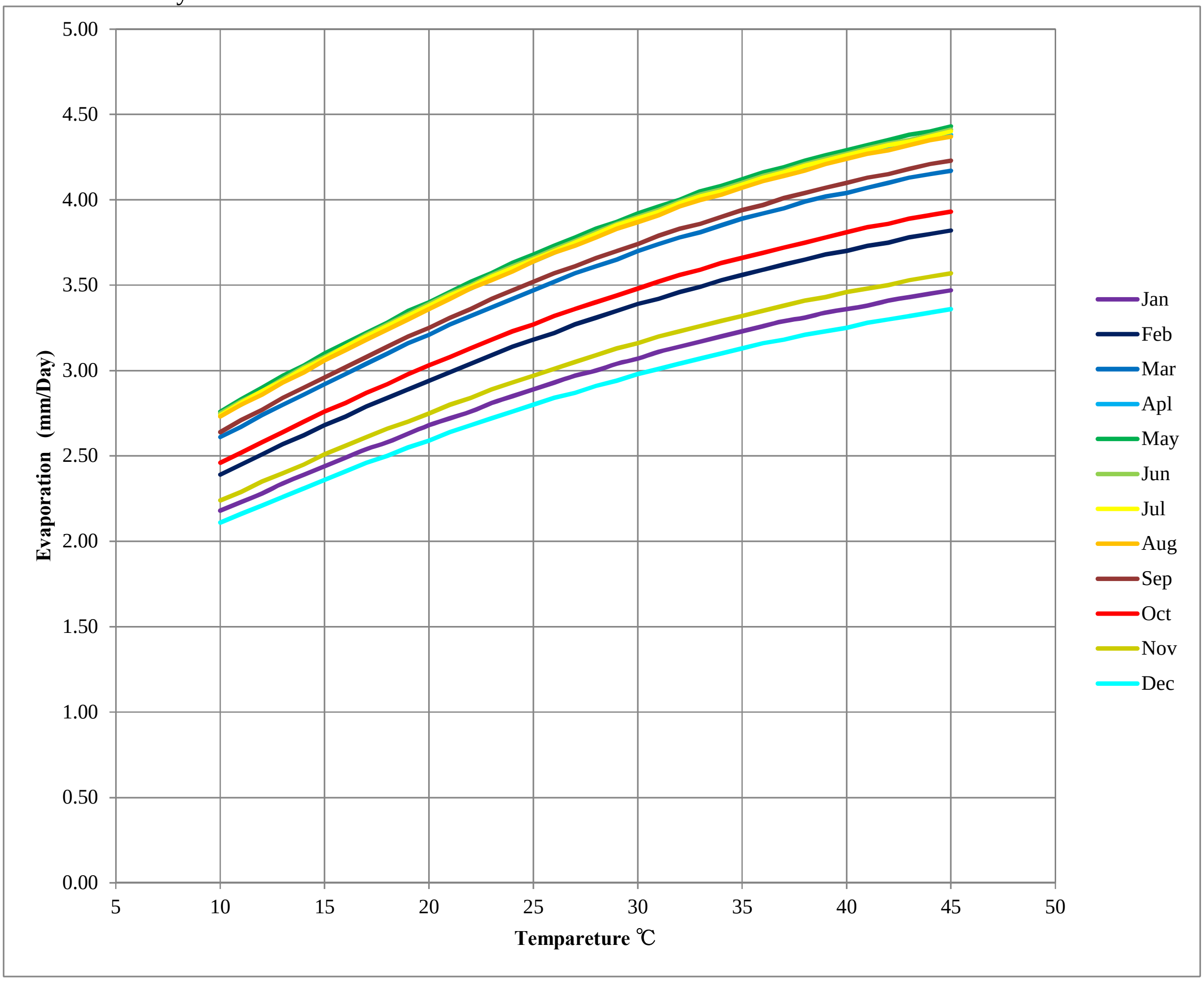
The relation between the temperature rise of Manila (N 14.533333") and the amount of evaporation was estimated. For estimation, Makkink Method is applied by which evaporation is estimated by temperature (evaporation of water) and sunshine (outer atmosphere amount of insolation by earth revolution and latitude). The relation between temperature and evaporation is as shown Figure 5.18 and amount of evaporation change per temperature change is summarized in Table 5.8.

Evaporation will increase by 7.1% per 1 degree at the maximum in March - August, and by 4.5% per 1 degree as annual average value. As the results, evaporation rate of increase becomes 5.2% in 2040 since the temperature rises is estimated as 1.15 degree.

Table 5.8 Amount of Monthly Evaporation change to 1 ℃of Temperature Rises (Manila)

	Unit	EMAK Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Anuualy Average
Eby Makkink Method														
Max	mm/day/1℃	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.05	0.07
Min	mm/day/1℃	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ave	mm/day/1℃	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05
Pan Evaporation at Los Banos														
Present	mm/day	4.38	5.70	6.72	7.90	7.31	5.66	4.66	4.50	4.48	4.38	4.19	3.80	5.31
Future(Max)	mm/day	4.64	6.04	7.19	8.45	7.82	6.06	4.99	4.82	4.79	4.64	4.44	3.99	5.66
Future(Min)	mm/day	4.47	5.81	6.85	8.06	7.46	5.77	4.75	4.59	4.57	4.47	4.27	3.88	5.41
Future(Average)	mm/day	4.56	5.93	6.99	8.30	7.68	5.94	4.89	4.73	4.70	4.56	4.36	3.95	5.55
Rate of Future and Present														
Max	%	5.9	6.0	7.0	7.0	7.0	7.1	7.1	7.1	6.9	5.9	6.0	5.0	6.5
Min	%	2.1	1.9	1.9	2.0	2.1	1.9	1.9	2.0	2.0	2.1	1.9	2.1	2.0
Ave	%	4.1	4.0	4.0	5.1	5.1	4.9	4.9	5.1	4.9	4.1	4.1	3.9	4.5

Source: JICA Study



Source: JICA Study

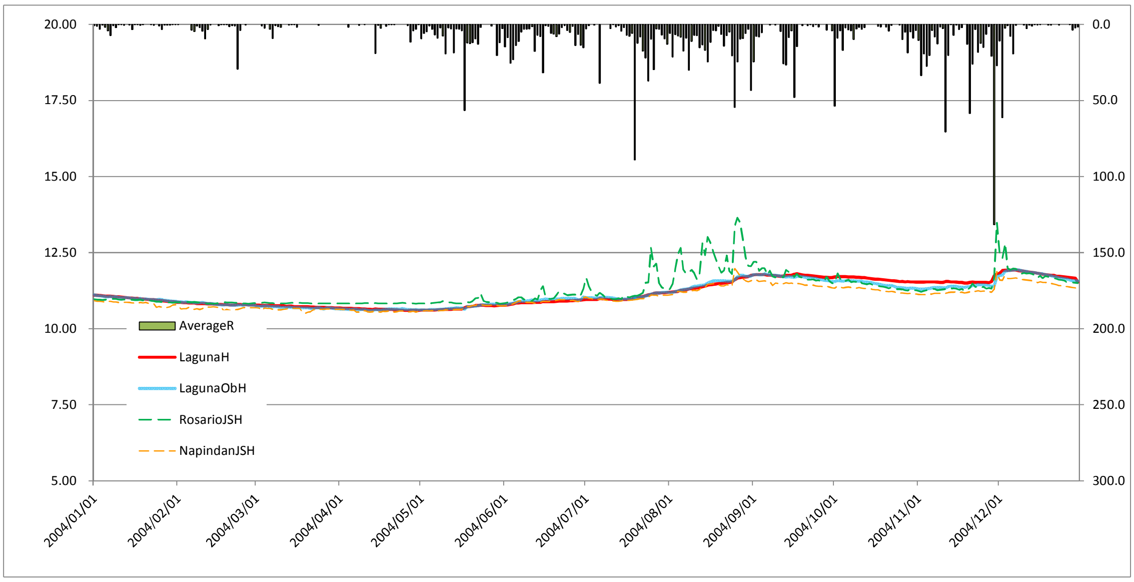
Figure 5.18 Relation between the monthly temperature in Manila, and an amount of evaporation (Makkink method)

(4) Influence on Laguna Lake accompanying a climate change

Based on the aforementioned assumptions of rainfall and evaporation increases, water level of Laguna Lake is estimated for 2040.

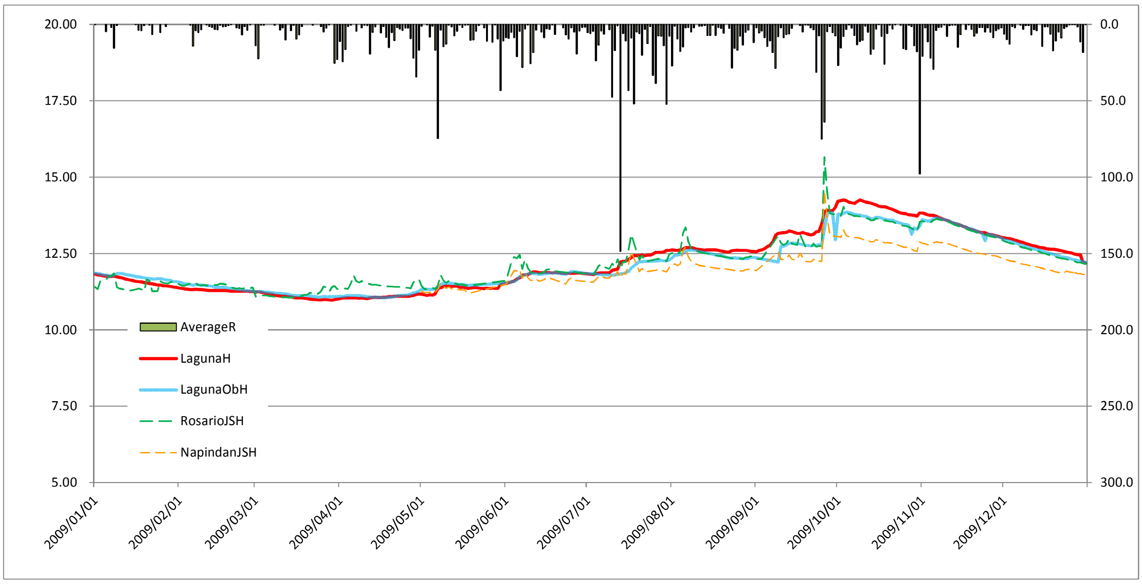
As a result, 11.82 m of simulated high water level in 2004 becomes 11.93 m (+0.11 m) and 13.96 m of simulated high water level during Typhoon Ondoy invasion in 2009 becomes 14.25 m (+0.29m).

At the observed water level base, 11.94m in 2004 becomes 12.05m and 13.85m in 2009 becomes 14.14m.



Source: JICA Study

Figure 5.19 (1) Result of Laguna Lake Water Level Analysis (2004 Year, Climate Condition in **2040 Year)**



Source: JICA Study

Figure 5.19 (2) Result of Laguna Lake Water Level Analysis (2009 Year, Climate Condition in 2040 Year)

5.3 Examination Validity of Flood Management Measures

Based on the aforementioned examination, validity of the proposed flood management measures in this Study which discussed in Chapter 4 is confirmed in the aspect of effect to the water level of Laguna Lake.

(1) Include reverse flow (Napindan Channel) to Laguna Lake in a flood measure plan.

- In Napindan JS, the water level may become higher than Laguna Lake in some cases. However, the uncertainty of the flood regulation from a relation with a tide level is high, and it is not recommended to consider as a flood management measure.

(2) Factor of a Laguna Lake water level rise

- The factor of a water level rise of Laguna Lake can be judged from the comparison result of amount of flood discharge. It is that the rainfall to the inflow river and the surface of Laguna Lake occupies about 80%.
- Balance of Marikina river catchment area: about 538 km2 and Laguna Lake surface of lake area: about 870km^2, inflow river (excluding Pasig-Marikina River) catchment area about 2,410km^2.
- The influence of Pasig-Marikina River is small as a factor of a water level rise of Laguna Lake.

5.4 Remarks on Effect of Global Warming

Countermeasure against lake water rise is currently on-going. It is found that simulated highest water level of the lake becomes EL. 14.25m increasing 0.29m as an effect of global warming. It is recommended to take another countermeasures such as heightening by parapet wall and so on.

CHAPTER 6 CLIMATE CHANGE EFFECT

6.1 Change of Flood Safety Degree

Increase of discharge and decline of flood safety degree are confirmed.

As discussed in Section 5.2.5, rainfall will increase about 10% in 2040 as a climate change impact, and rise of water level in Laguna Lake is expected to 29 cm as maximum. Besides, it is estimated based on the 4th IPCC report that tide level in Manila Bay rises about 22 cm.

Change of probable discharge is analyzed by simulation with inputting such increases as shown in Table 6.1. It is noted that river conditions as of Phase IV completion is applied for evaluation.

Table 6.1 Boundary Conditions by Climate Change

Simulation case	Temperature rise (℃)	Increased rate of rainfall(%)	Sea-level-rise (cm)	Laguna Lake-Water-level-rise(cm)
No Climate Change (Present conditon（2013）)	0	-	-	-
After Climate Change* (2040)	1.3	9.3	22	29

Note:Climate Change Scenario:A1B
Sea-level-rise: 22cm≒48cm(2100)/2.8K(2100)×1.3K(2040)
Laguna Lake water-level-raise: from Chapter 5
Source: JICA Study Team

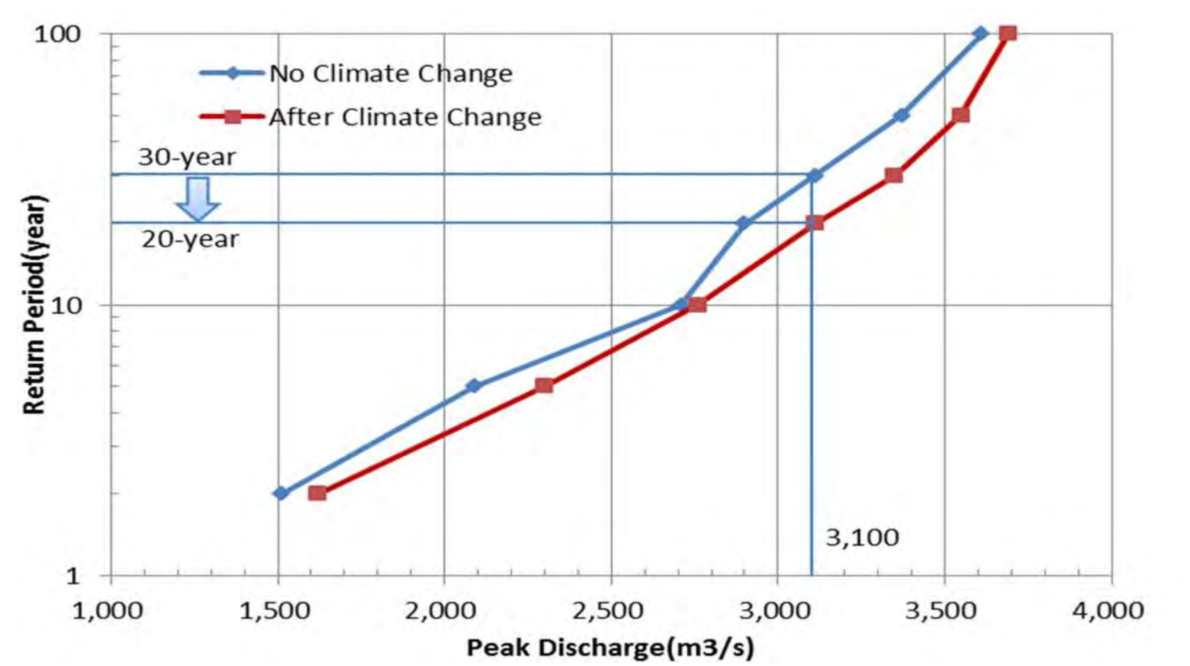
Probable peak discharges at Sto.Nino is shown in Table 6.2. Peak discharges increase about 17 % for 1/30 years flood and about 10 % for 1/100 years flood.

Therefore, safety degree of 1/30 years decline to 1/20 years and 1/100 years decline to 1/60 years.

Table 6.2 Probable Peak Discharges at Sto.Nino Station

Return Period	(A)No Climate Change (Present condition)	(B)After Climate Change	(C)=(B)-(A)	(B)/(A)
2	1,510	1,620	110	107%
5	2,090	2,300	210	110%
10	2,710	2,760	50	102%
20	2,900	3,110	210	107%
30	3,100	3,350	250	108%
50	3,370	3,550	180	105%
100	3,610	3,690	80	102%

Source: JICA Study Team



Source: JICA Study Team

Figure 6.1 Relation between Probability and Peak Discharge

6.2 Change of Inundation by Climate Change after Phase IV Project Completion

Changes of inundation for 1/30 years flood and 1/100 years flood by the climate change under the conditions after Phase IV Project completion.

The simulation results are summarized in Table 6.3 and shown in Figure 6.2 to 6.5. Inundation areas increase about 1.26 times for 1/30 years flood and about 1.12 times for 1/100 years flood. On the other hand, inundation depths decrease about 15 cm for 1/30 years flood and about 9 cm for 1/100 years flood due to spread of inundation areas induced by increase of discharges.

Table 6.3 Impact of Climate Change

Return Period (year)	Content	(A)No Climate Change (Present condition (2013))	(B)After Climate Change* (2040)	(B)-(A)	(B)/(A)
30	Inundation Area (km^2)	10.38	15.03	4.65	1.45
	Average Inundation Depth(m)	2.87	2.36	-0.51	0.82
100	Inundation Area (km^2)	26.54	31.53	4.99	1.19
	Average Inundation Depth(m)	1.69	1.62	-0.08	0.96

Source: JICA Study Team

[Phase IV Completed: 1/30 Years Flood]

Source: JICA Study Team

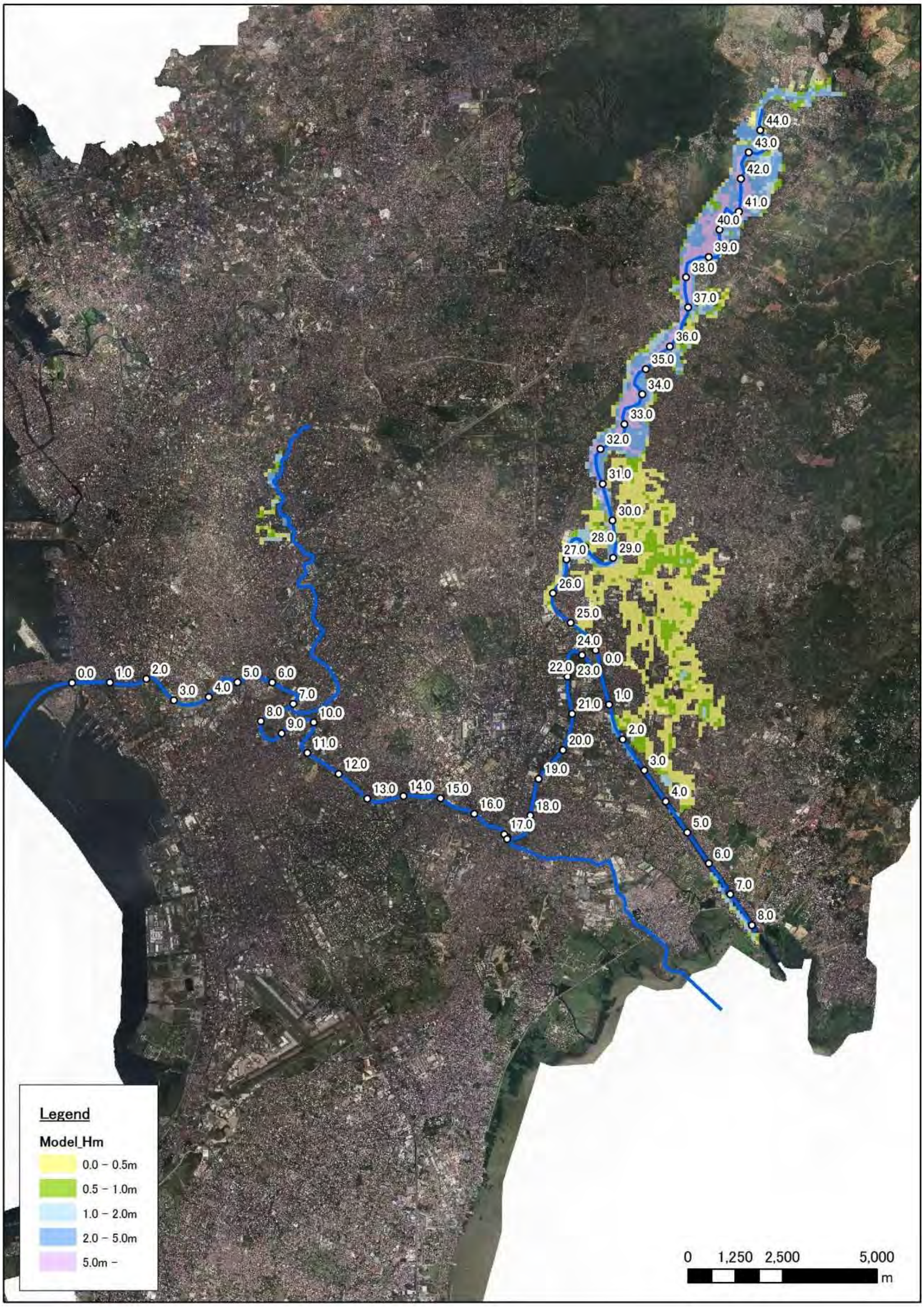
Figure 6.2 Inundation Area by 1/30 Years Flood Without Climate Change Effect

[Phase IV Completed: 1/30 Years Flood with Climate Change]

Source: JICA Study Team

Figure 6.3 Inundation Area by 1/30 Years Flood With Climate Change Effect

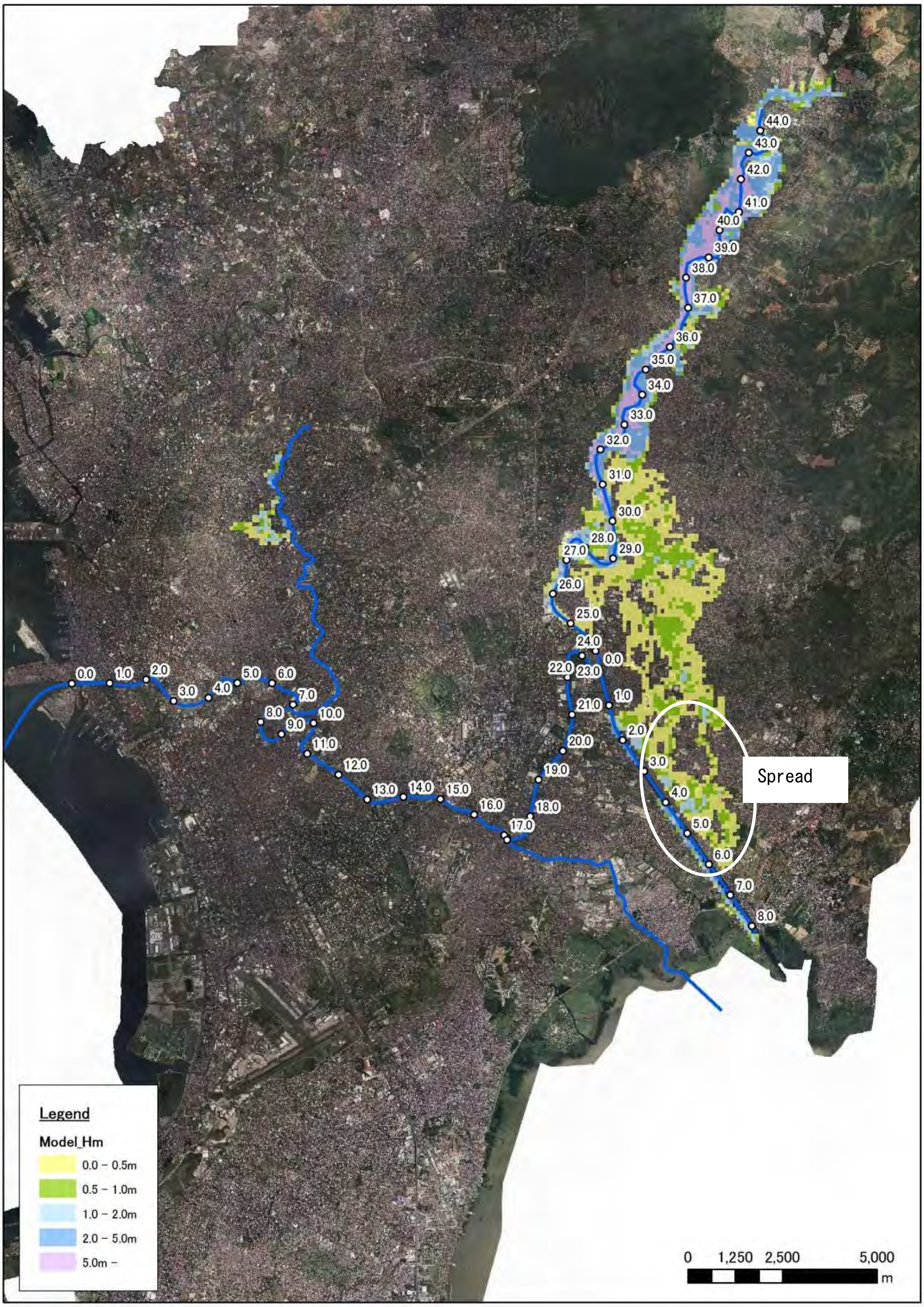
[Phase IV Completed: 1/100 Years Flood]



Source: JICA Study Team

Figure 6.4 Inundation Area by 1/100 Years Flood Without Climate Change Effect

[Phase IV Completed: 1/100 Years Flood with Climate Change]



Source: JICA Study Team

Figure 6.5 Inundation Area by 1/100 Years Flood With Climate Change Effect

6.3 Adaptation Measures against Climate Change

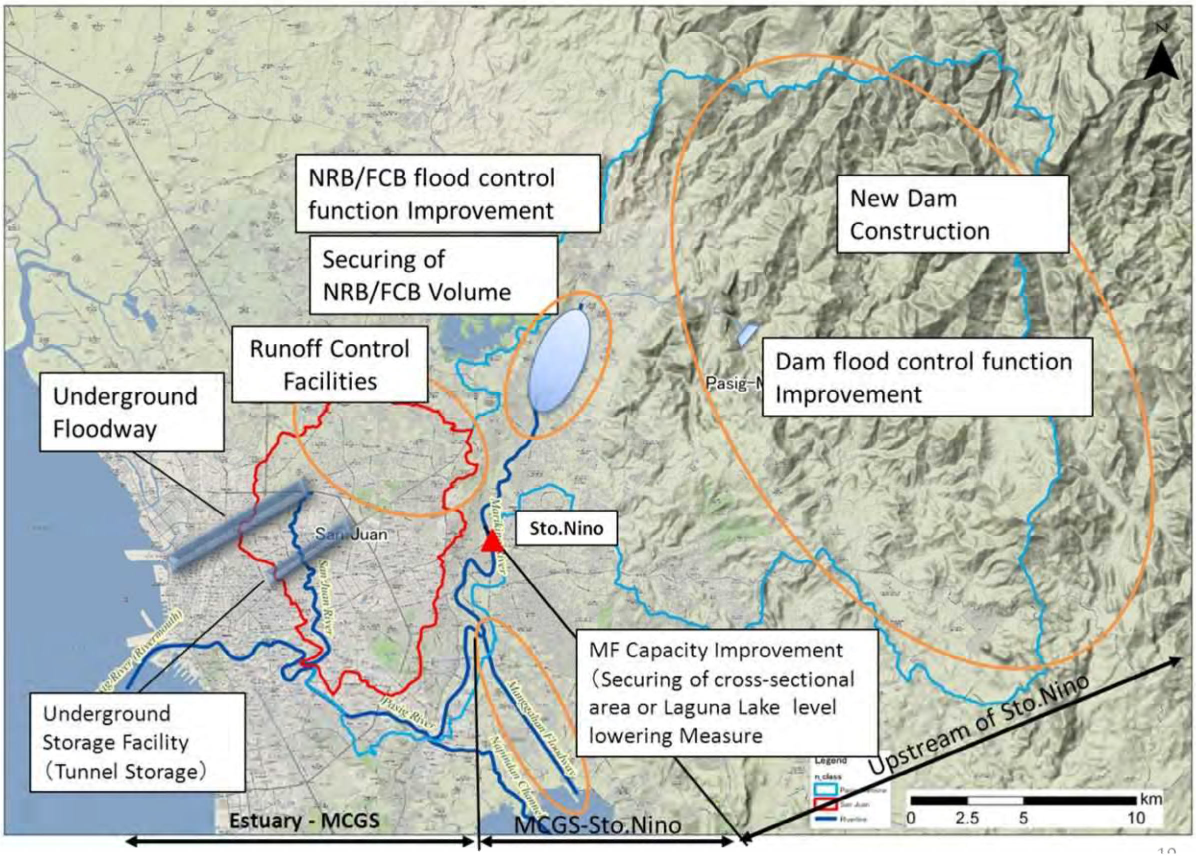
It is expected that peak discharge at Sto.Nino increases about 10 %. Both structural and non-structural measures are required to adapt the climate change.

6.3.1 Structural Measures

Possible structural adaptation measures for the alternatives of flood management measures are listed in Table 6.4 and 6.5.

The adaptation structural measures can be categorized into the measures upstream and downstream of MCGS. And the measures upstream of MCGS can be divided into the measures for flood control facilities upstream of Sto.Nino and increase of diversion discharge to Laguna Lake. As the measures upstream of Sto.Nino, increase of capacities of retarding basins, improvement of flood control function of dam and additional dam. The increase of diversion discharge can be achieved by increase of flow capacity of Manggahan Floodway such as dredging, and new floodway construction.

The adaptation measures downstream of MCGS is mainly the measures to reduce inflow discharge from San Juan River such as underground floodway, underground storage and runoff control facilities such as retarding storage, rainwater storage and infiltration facilities.



Source: JICA Study Team

Figure 6.6 Possible Structural Adaptation Measures

Table 6.4 Available Structural Adaptation Measures for Alternatives A-1 to A-3

Alternative	A-1	A-2-1	A-3	A-2-2
Upper Upper Marikina River	Dam + Natural Retarding Basin	Channel Improvement + Dam	Channel Improvement + Dam + Retarding Basin	Channel Improvement + Dam*
(1)Upstream of Sto.Nino				
Heightening of Dam	○	○	○	○
Improvement of Spillway	○	○	○	○
New Dam Construction	○	○	○	○
Secure of Capacity of Retarding Basin	○	–	○	–
Improvement of Overflow Dyke	○	–	○	–
(2)MCGS-Sto.Nino				
Improvement of Channel and Manggahan Floodway	○	○	○	○
Reduce of WL of Laguna Lake	○	○	○	○
(3)Downstream of MCGS				
Runoff Control Facilities	○	○	○	○
Underground Floodway	○	○	○	○
Underground Storage	○	○	○	○

*: Improvement of Retarding Function is also conducted.
Source: JICA Study Team

Table 6.5 Available Structural Adaptation Measures for Alternatives O-1 to B-3

Alternative	O-1	O-2	B-1	B-2-1	B-3	B-2-2
Upper Upper Marikina River	Dam + Natural Retarding Basin	Channel Improvement + Dam	Dam + Retarding Basin	Channel Improvement + Dam*	Channel Improvement + Dam + Retarding Basin	Channel Improvement + Dam*
(1)Upstream of Sto.Nino						
Heightening of Dam	○	○	○	○	○	○
Improvement of Spillway	○	○	○	○	○	○
New Dam Construction	○	○	○	○	○	○
Secure of Capacity of Retarding Basin	○	–	○	–	○	–
Improvement of Overflow Dyke	○	–	○	–	○	–
(2)MCGS-Sto.Nino						
Improvement of Channel and Manggahan Floodway	○	○	○	○	○	○
Reduce of WL of Laguna Lake	○	○	○	○	○	○
(3)Downstream of MCGS						
Runoff Control Facilities	○	○	○	○	○	○
Underground Floodway	○	○	○	○	○	○
Underground Storage	○	○	○	○	○	○

*: Improvement of Retarding Function is also conducted.
Source: JICA Study Team

6.3.2 Non-Structural Measures

Change of inundation conditions based on comparisons of inundations with and without climate change for 1/30 years flood and 1/100 flood is summarized as follows.

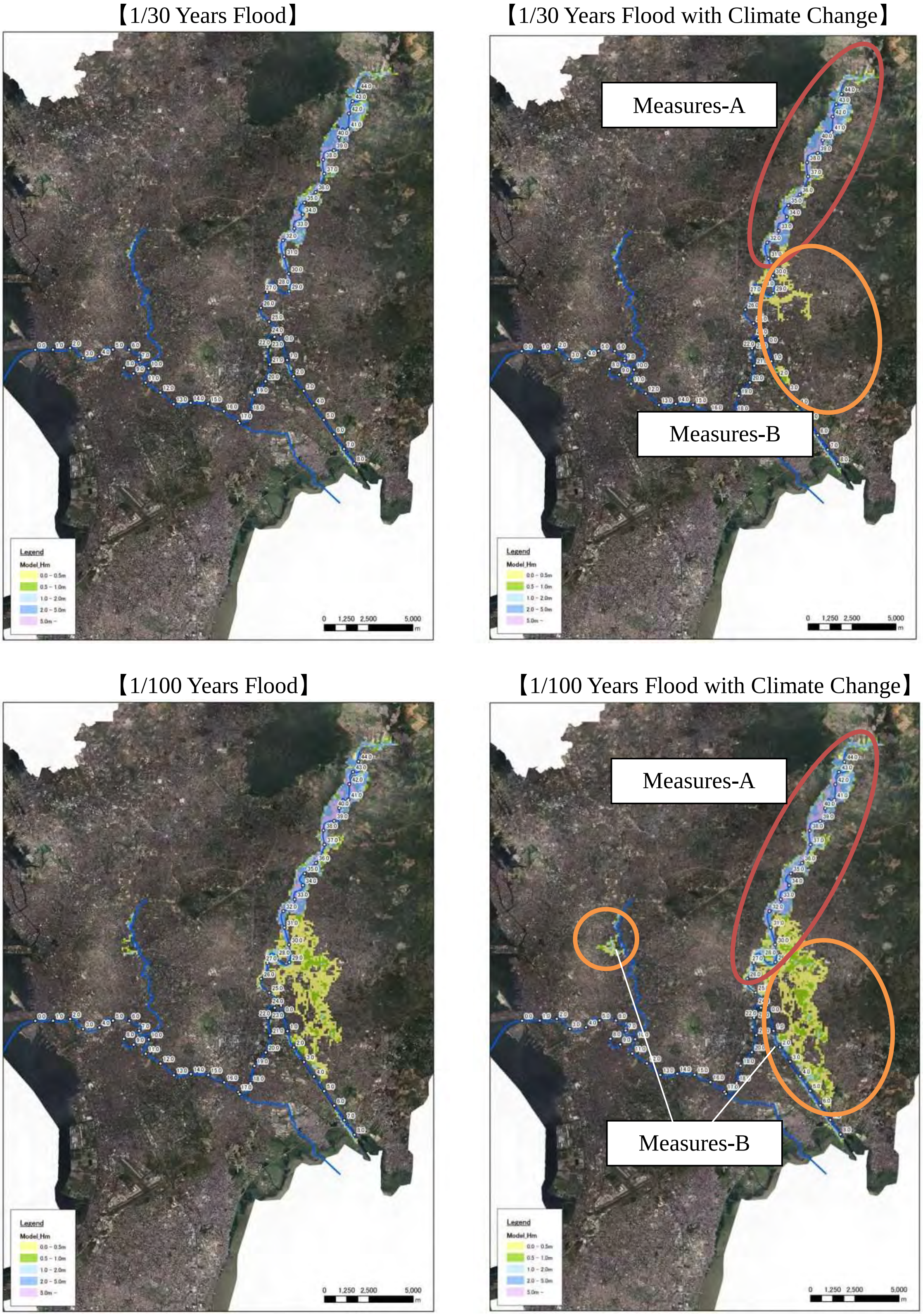
- Inundation depth increase upstream area of confluence of Nangka River.
- Inundation depth and inundation area increase between MCGS and confluence of Nangka River.
- Inundation area increases in San Juan River Basin between the river mouth and MCGS.

As non-structural measures, evacuation system improvement, hazard map and landuse regulation, and conservation of retarding function of basins are considered. Non-structural adaptation measures are examined in the JICA Study as shown in Table 6.6.

Non-structural measures shall be implemented according to change of inundation conditions induced by the climate change. Proposed locations where the non-structural measures shall be implemented is shown in Figure 6.6.

Table 6.6 Proposed Non-Structural Adaptation Measures

<table>
<tr><th colspan="3">Adaptation Measures</th><th>Measures against Increase of Inundation Depth (A)</th><th>Measures against Increase of Inundation Area (B)</th></tr>
<tr><td rowspan="9">Evacuation System and Preparedness</td><td rowspan="4">Preparedness</td><td>Improvement of Hazard Map and Dissemination</td><td>○</td><td>○</td></tr>
<tr><td>Review of Evacuation Routs and Refugees</td><td>○</td><td>○</td></tr>
<tr><td>Review of Emergency Relief Goods</td><td>○</td><td>○</td></tr>
<tr><td>Review of Warning Criteria</td><td>−</td><td>−</td></tr>
<tr><td rowspan="2">Information System</td><td>Improvement of Information System</td><td>−</td><td>○</td></tr>
<tr><td>Improvement of Information Board</td><td>−</td><td>○</td></tr>
<tr><td rowspan="3">Monitoring & Warning</td><td>Improvement of Warning Posts</td><td>−</td><td>○</td></tr>
<tr><td>Installation of CCTV</td><td>−</td><td>○</td></tr>
<tr><td>Installation of Simple Monitoring System</td><td>−</td><td>−</td></tr>
<tr><td colspan="2" rowspan="3">Landuse Regulation</td><td>Landuse Regulation by LGU</td><td>○</td><td>○</td></tr>
<tr><td>Heightening of Road and Housing Area</td><td>○</td><td>○</td></tr>
<tr><td>Regulations for conservation of retarding function</td><td>○</td><td>○</td></tr>
</table>



Source: JICA Study Team

Figure 6.7 Possible Non-Structural Adaptation Measures

CHAPTER 7 CONCLUSION AND RECOMMENDATION

The works in this Study can be broadly categorized into the followings.

(a) Establishment of hydrological and hydrodynamic flood simulation model with appropriately selected dataset in consideration of the future climate change

(b) Reevaluation of technical validity of the proposed structural measures in Pasig-Marikina River Basin under the WB Study

(c) Examination of flood management measures against 1/30 and 1/100 years probable floods and proposal of direction of flood management measures

The conclusion and recommendations of the Study are as follows.

7.1 Conclusion

The results and conclusions of above mentioned work categories are summarized as follows.

7.1.1 Establishment of Hydrological and Hydrodynamic Flood Simulation Model with Appropriately Selected Dataset in Consideration of Future Climate Change

Flood analysis model is established integrating runoff analysis model (WEB-DHM Model), river hydraulic model (one dimensional unsteady flow model) and inundation analysis model (two dimensional unsteady flow model). Since the detailed elevation data named LiDAR data, the latest river section survey, vegetation and landuse data, and timely and spatially varied hydrological data are utilized, accurate model against various types of flood including Typhoon Ondoy is established. Besides, H-Q equation is recalculated based on the detailed section data and discharges are estimated.

<u>Flood Analysis Model</u>

WEB-DHM Model is applied for runoff analysis since it can analyze hydrologic cycle among atmosphere, vegetation and soils with high accuracy reflecting the change of runoff pattern by changing of vegetation and landuse of a basin, and time and spatial variations of meteorology.

For river hydraulic model and inundation model, one-dimensional unsteady flow analysis model and two dimensional unsteady flow analysis model are applied, respectively, since effect of water level of Laguna Lake, effects of past and planned river improvement works, and effects of natural or artificial retarding basin can be properly reflected.

<u>Verification of Model by Various Types of Floods</u>

The river basin includes the center of Metro Manila in the downstream reach, and the river improvement works have been implemented to secure the safety against 1/30 years probable floods with assuming various types of floods. For examination of flood management measures against 1/100 years probable flood as the future target, various patterns of hyetographs such as high intensity with short period rainfall and long period rainfall including Typhoon Ondoy are utilized for calibration and verification of the model to improve the reproducibility of model.

<u>Estimation of Discharge by New H-Q Equation</u>

Observed water level and discharge date is required for calibration of model parameters. However, there is no recent observed discharge data. H-Q equations have been formulated by previous studies, however, accuracy of high water level is uncertain because there is no observed discharge data. Thus, H-Q equation is re-formulated by non-uniform flow calculation based on the river section data combining LiDAR data and latest survey data, and detailed parameters.

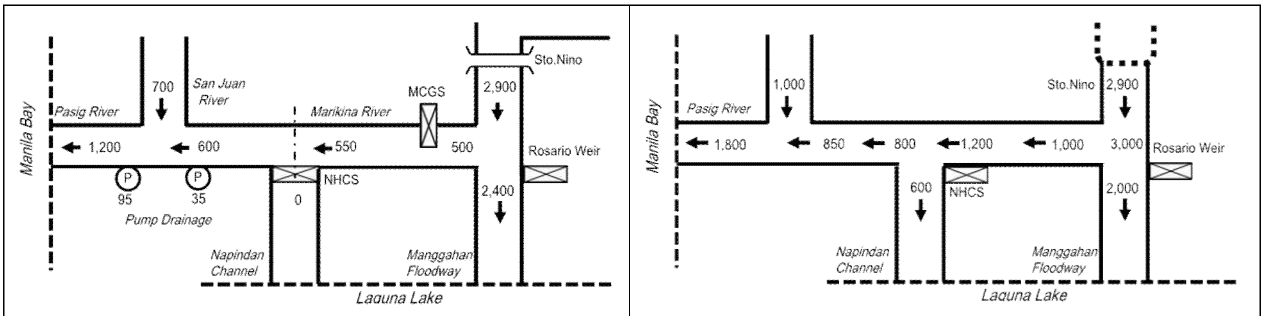
7.1.2 Reevaluation of Technical Validity of Proposed Structural Measures in Pasig-Marikina River Basin under the WB Study

Design discharges of PMRCIP based on the JICA Master Plan in 1990 and the WB Study are shown in Figure 7.1.

PMRCIP proposed diversion to Lower Marikina with 500m^3/s controlling by MCGS and shut down of

NHCS during flood. On the other hand, the WB proposed that the diversion to Manggahan Floodway was controlled by Rosario Weir only without construction of MCGS, and natural diversion to Napindan Channel with NHCS open was expected.

Based on the analysis utilizing the established flood analysis model with referring the various types of design hyetographs estimated by "the Study of Water Security Master Plan for Metro Manila and its Adjoining Areas" and the results of water level fluctuation analysis of Laguna Lake by this Study, technical validity of these proposals are reevaluated as follows.



PMRCIP | The WB Plan

Source: Preparatory Study for Pasig-Marikina Channel Improvement Project (Phase III)

Source: Master Plan for Flood Management in Metro Manila and Surrounding Areas, the World Bank

Figure 7.1 Design Discharge of PMRCIP and the WB Study

(1) Necessity of MCGS Diversion Function

The Study concludes that the proposed flood management measures by the Study including the MCGS function based on the JICA Master Plan is more effective than flood management measures without MCGS, in aspects of reliability, feasibility and step-wise improvement of flood safety. The features of flood management measures with MCGS are as follows.

<Reliability>

Various types of flood discharges can be securely diverted though Manggahan Flood way by the function of MCGS. As the results, Laguna Lake can be fully utilized as flood control facilities, and flood risk in lower reach can be reduced by controlling flood discharge to the downstream. This flood risk reduction in lower reach also works against excess floods or climate change impacts.

<Feasibility>

The flood management measures with MCGS function is more feasible since it does not reinvestment to the river sections where the river improvement works has been already implemented such as re-improvement of PMRCIP, reconstruction of existing bridges and re-improvement of Napindan Channel.

<Step-wise Improvement of Flood Safety>

With MCGS, the flood control works can be implemented separately by the upstream and downstream of MCGS since the discharge to downstream can be regulated by MCGS. Thus, improvement works can be implement in upstream sections with maintaining the safety against 1/30 years probable floods in the downstream of MCGS.

Besides, during the course of improvement of each section such as Lower Marikina and Upper-upper Marikina, flood safety can be improved step-wise without temporary decrease of flood safety of the Basin.

(2) Operation of NHCS

The water level fluctuation analysis in Laguna Lake reveals that the water level at the inlet of Manggahan Floodway (Rosario Weir) is always higher than Laguna Lake while there is no clear correlation between the water levels at the confluence of Napindan Channel and Pasig River (NHCS) and Laguna Lake. It is also founded that impact of inflow discharge from Pasig-Marikina River to water level fluctuation in Laguna Lake is small. Thus, it is concluded that NHCS shall be closed during floods to mitigate increase of flood risk in Pasig-Lower Marikina Basin by preventing discharge from Laguna Lake to Pasig River.

- By closing NHCS, discharge from Laguna Lake to Pasig River is blocked in case the water level of lake is higher than the river, resulting uncertainty of flood management is eliminated.
- In case of natural diversion from Pasig River to Laguna Lake is expected in the flood management plan by opening NHCS, uncertainty of the plan remains since diversion will not occur if the water level of lake is higher than the river. Besides, there are many issues in this option such as a possibility to increase of flood risk in Pasig-Lower Marikina Basin against excess floods, necessity of reinvestment in PMRCIP (Phase II) section, large scale dredging and re-improvement of Napindan Channel which requires large scale land acquisition.

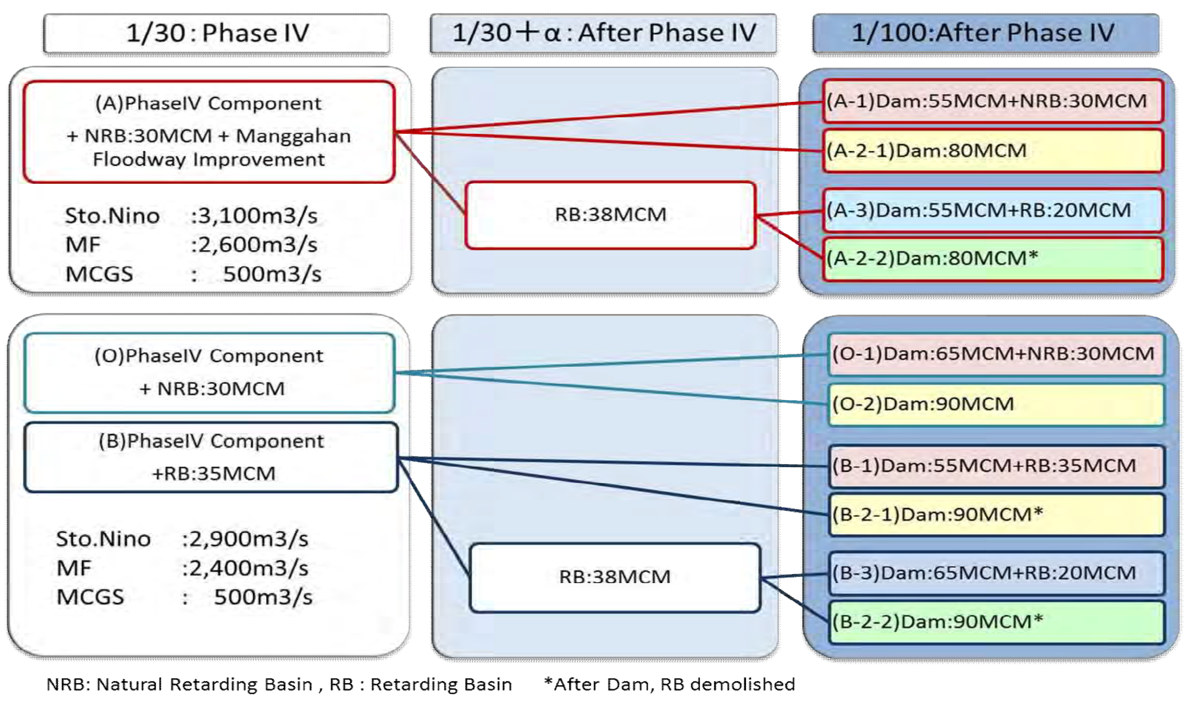
(3) Dredging of Pasig River

Under the alternative "Without MCGS and NHCS opening", design discharge in Pasig River becomes 1,800m^3/s which is about 1.5 times of the design discharge by PMRCIP of 1,200m^3/s. To flow this discharge large scale dredging is required to deepen the riverbed about 2 to 3 m below the design riverbed in the master plan. Tremendous amount of maintenance cost is also required to maintain the riverbed.

In this Study, design discharge with 1/100 years return period becomes 1,400m^3/s which is 200m^3/s increase than the previous plan. However, it is within the flow capacity of channel if the riverbed is dredged until the design riverbed level. And scale of dredging works is also small which can be treated as a river maintenance works.

7.1.3 Flood Management Measures for 1/30 and 1/100 Years Probable Floods

Review of hydrology with the latest data, 1/30 years probable flood discharge is estimated at 3,100m^3/s at Sto.Nino which is larger than the design discharge of PMRCIP at 2,900m^3/s. As alternatives for 1/30 years probable flood management, 2 alternatives are proposed as well as the PMRCIP plan (Alt-O: Phase IV only), one is enhancement of Manggahan Floodway (Alt-A: Phase IV + Manggahan Floodway) and the other is enhancement of retarding basin (Alt-B: Phase IV + Retarding Basin). And combining "dam" or "dam + retarding basin" options, 10 alternatives for 1/100 years probable flood management are also proposed with step-wise development scenarios from 1/30 probable flood management measures, consisting of 4 alternatives from Alt-A, 2 alternatives from Alt-O and 4 alternatives from Alt-B. (Refer to Figure 7.1) Economic feasibility is confirmed for all alternatives. By applying one of these alternatives, the flood management in Pasig-Marikina River can adapt to impacts of climate change with various options.



Source: JICA Study Team

Figure 7.2 Alternatives and Phased Development Scenarios

7.2 Recommendations

7.2.1 Necessity of Further Studies

This Study is conducted using the various data and information from the previous studies. Thus, it is recommended to conduct further investigations, studies and designs such as follows.

- Optimal Location and Scale of Dam
- Scale and Capacity of Retarding Basin, Area of Natural Retarding Basin
- Design Flood Discharge in Phase IV Section and HWL
- Area of Channel Excavation of Manggahan Floodway

7.2.2 Restoration and Improvement of Manggahan Floodway

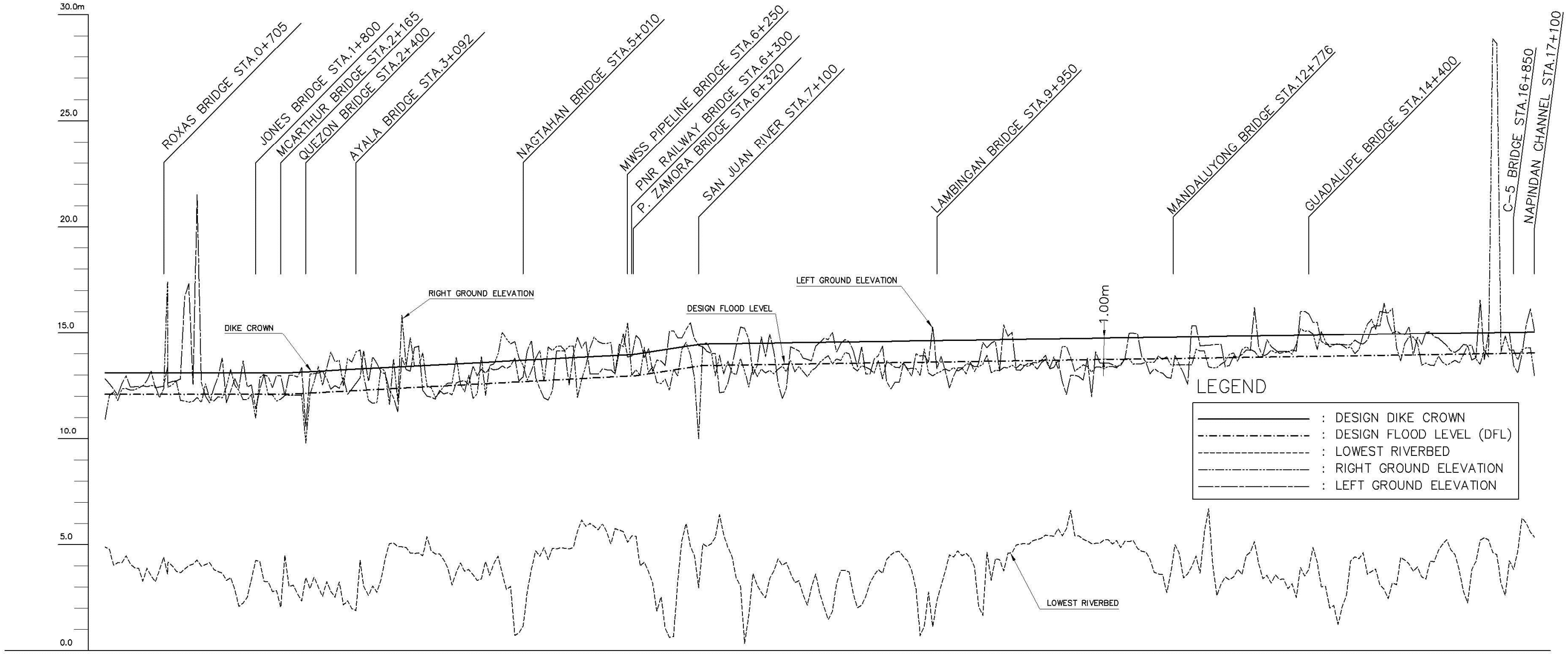
Manggahan Flood way was completed in 1988 with the design discharge of 2,400m^3/s. However, flow area has been reduced mainly due to houses in river course and sedimentation. To divert flood discharge to Manggahan Floodway by MCGS, restoration of its function is a precondition. Resettlement and dredging shall be implemented to restore the original capacity.

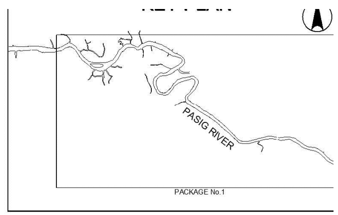
In case of the design discharge at Sto.Nino is 3,100m^3/s, flow capacity of Manggahan Floodway shall be increased to 2,600m^3/s with additional 200m^3/s. Considering excess floods and climate change impacts, capacity improvement of Manggahan Floodway is required. Enlargement of flow capacity of Manggahan Floodway by excavation is relatively easy since earth dyke is applied from Laguna Lake to 5km point.

7.2.3 Retention of Natural Retarding Function and Necessity of Detailed Investigation of Retarding Basin

The alternatives for 1/100 years probable flood management measures can be divided into “dam” options and “dam + retarding basin” options. Even if a “dam” option is selected, the current natural retarding function shall be maintained since the dam project needs long time. It is needed to fix the area of natural retarding basin and to regulate land use to maintain the natural retarding function.

APPENDIX I: Figure





DESIGN D.F.L. SLOPE: LEVEL L=2.160km — (12.100) — i=1/4800 L=4.190km — (12.973) — i=1/1680 L=0.800km — (13.450) — i=1/17000 L=9.980km — (14.036)

DESIGN RIVER BED SLOPE: (blank)

STATION NUMBER (Km)	PARTIAL DISTANCE (Km)	ACCUMU-LATIVE DIST. (Km)	LOWEST RIVER BED	MEAN RIVER BED	LEFT GROUND ELEV.	RIGHT GROUND ELEV.	DESIGN RIVER BED	D.F.L.	DESIGN DIKE CROWN
0.000	0.000	0.000	4.891		12.820	10.931		12.100	13.100
0.200	0.200	0.200	4.141		12.611	12.351		12.100	13.100
0.400	0.200	0.400	3.881		12.100	12.401		12.100	13.100
0.600	0.200	0.600	3.251		12.100	12.491		12.100	13.100
0.800	0.200	0.800	4.011		12.701	12.541		12.100	13.100
1.000	0.200	1.000	4.011		17.311	11.731		12.100	13.100
1.200	0.200	1.200	4.061		12.011	12.591		12.100	13.100
1.400	0.200	1.400	3.661		13.791	11.931		12.100	13.100
1.600	0.200	1.600	2.091		12.381	12.271		12.100	13.100
1.800	0.200	1.800	4.261		11.41	11.010		12.100	13.100
2.000	0.200	2.000	2.791		12.411	12.081		12.100	13.100
2.200	0.200	2.200	3.031		12.991	12.061		12.109	13.109
2.400	0.200	2.400	3.451		10.561	9.791		12.150	13.150
2.600	0.200	2.600	2.561		13.191	12.521		12.192	13.192
2.800	0.200	2.800	3.241		12.381	13.701		12.234	13.234
3.000	0.200	3.000	1.901		12.611	14.081		12.275	13.275
3.200	0.200	3.200	3.061		13.861	11.681		12.317	13.317
3.400	0.200	3.400	5.051		12.311	11.611		12.359	13.359
3.600	0.200	3.600	4.861		13.261	13.451		12.400	13.400
3.800	0.200	3.800	4.471		12.291	14.031		12.442	13.442
4.000	0.200	4.000	4.564		12.279	12.179		12.484	13.484
4.200	0.200	4.200	3.699		12.637	13.843		12.525	13.525
4.400	0.200	4.400	3.589		13.434	11.918		12.567	13.567
4.600	0.200	4.600	3.552		13.315	13.448		12.609	13.609
4.800	0.200	4.800	2.888		13.303	14.693		12.650	13.650
5.000	0.200	5.000	1.151		12.911	13.451		12.692	13.692
5.200	0.200	5.200	4.450		12.363	14.148		12.734	13.734
5.400	0.200	5.400	4.794		14.116	14.340		12.775	13.956
5.600	0.200	5.600	4.861		13.945	14.361		12.817	13.817
5.800	0.200	5.800	6.022		13.051	14.277		12.859	13.859
6.000	0.200	6.000	5.589		13.251	14.474		12.900	13.900
6.200	0.200	6.200	5.603		14.945	14.330		12.942	13.942
6.400	0.200	6.400	3.997		14.651	12.991		13.003	14.003
6.600	0.200	6.600	1.866		13.700	12.659		13.123	14.123
6.800	0.200	6.800	0.659		15.098	13.284		13.242	14.242
7.000	0.200	7.000	4.919		15.471	13.938		13.361	14.361
7.200	0.200	7.200	4.909		14.114	14.499		13.453	14.453
7.400	0.200	7.400	5.438		12.199	13.061		13.465	14.465
7.600	0.200	7.600	3.051		15.265	13.775		13.477	14.477
7.800	0.200	7.800	3.093		13.452	12.933		13.489	14.489
8.000	0.200	8.000	3.755		14.104	13.065		13.500	14.500
8.200	0.200	8.200	3.651		14.326	13.679		13.512	14.512
8.400	0.200	8.400	2.156		13.731	12.923		13.524	14.524
8.600	0.200	8.600	2.062		14.730	13.771		13.536	14.536
8.800	0.200	8.800	3.777		14.481	13.683		13.548	14.548
9.000	0.200	9.000	2.033		13.391	13.199		13.559	14.559
9.200	0.200	9.200	3.561		13.759	13.093		13.571	14.571
9.400	0.200	9.400	4.524		12.353	13.499		13.583	14.583
9.600	0.200	9.600	4.239		13.252	13.302		13.595	14.595
9.800	0.200	9.800	1.150		13.903	14.212		13.606	14.606
10.000	0.200	10.000	3.062		13.867	13.175		13.618	14.618
10.200	0.200	10.200	4.700		13.351	13.199		13.630	14.630
10.400	0.200	10.400	3.956		13.162	13.401		13.642	14.642
10.600	0.200	10.600	3.321		14.499	13.116		13.653	14.653
10.800	0.200	10.800	4.589		14.829	13.334		13.665	14.665
11.000	0.200	11.000	5.045		13.447	13.436		13.677	14.677
11.200	0.200	11.200	5.302		13.570	13.693		13.689	14.689
11.400	0.200	11.400	5.751		13.696	13.310		13.700	14.700
11.600	0.200	11.600	5.411		12.989	13.180		13.712	14.712
11.800	0.200	11.800	5.040		11.983	13.133		13.724	14.724
12.000	0.200	12.000	5.221		13.570	13.410		13.736	14.736
12.200	0.200	12.200	5.161		13.761	13.766		13.748	14.748
12.400	0.200	12.400	4.681		13.871	13.530		13.759	14.759
12.600	0.200	12.600	3.621		13.161	13.901		13.771	14.771
12.800	0.200	12.800	4.991		13.921	13.480		13.783	14.783
13.000	0.200	13.000	3.971		15.330	13.480		13.795	14.795
13.200	0.200	13.200	6.701		14.400	13.391		13.806	14.806
13.400	0.200	13.400	3.471		13.390	13.641		13.818	14.818
13.600	0.200	13.600	3.601		13.970	14.191		13.830	14.830
13.800	0.200	13.800	4.101		14.290	13.871		13.842	14.842
14.000	0.200	14.000	3.571		14.181	14.051		13.853	14.853
14.200	0.200	14.200	3.151		14.181	13.981		13.865	14.865
14.400	0.200	14.400	3.831		15.890	15.090		13.877	14.877
14.600	0.200	14.600	3.041		14.450	14.561		13.889	14.889
14.800	0.200	14.800	2.101		14.440	14.400		13.900	14.900
15.000	0.200	15.000	4.341		14.511	14.191		13.912	14.912
15.200	0.200	15.200	3.851		15.341	15.171		13.924	14.924
15.400	0.200	15.400	3.201		14.991	16.141		13.936	14.936
15.600	0.200	15.600	4.071		15.301	14.791		13.948	14.948
15.800	0.200	15.800	3.381		15.011	13.561		13.959	14.959
16.000	0.200	16.000	5.011		14.561	13.601		13.971	14.971
16.200	0.200	16.200	3.781		14.201	13.561		13.983	14.983
16.400	0.200	16.400	4.221		13.811	13.761		13.995	14.995
16.600	0.200	16.600	4.627		15.000	28.865		14.006	15.006
16.800	0.200	16.800	4.241		15.000	14.181		14.018	15.018
17.000	0.200	17.000	6.037		15.394	14.272		14.030	15.030
17.100	0.100	17.100	5.354		15.096	12.976		14.036	15.036

ELEVATION – METERS

NOTES:

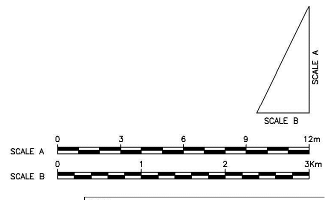
1.DESIGN DISCHARGE DISTRIBUTION:

REFER TO SHEET No. PR-GE/GN-02 ON ITEM IV UNDER GENERAL NOTES FOR RIVER STRUCTURE.

2.DESIGN VELOCITY: VARIES PER SECTION,

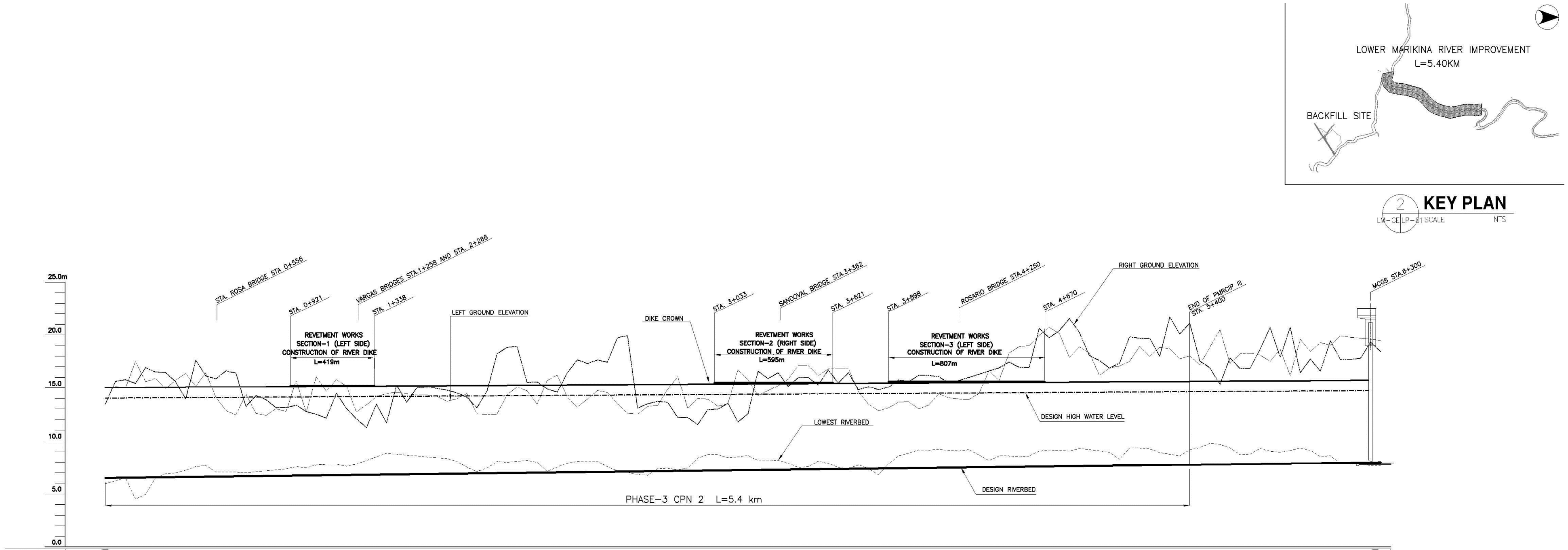
Vmin= 0.55m/s
Vmax= 2.70m/s

3. APPROX. RIVER CATCHMENT AREA AT RIVER MOUTH= 621km²



Source: Detailed Desgin of PMRCIP (III)

ANNEX Figure 4.1.1 Design Longitudinal Profile for Phase III Project (Pasig River)



		0.000	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200	2.400	2.600	2.800	3.000
DESIGN H.W.L. SLOPE		14.036															i=1/9000 L=6.300km
DESIGN RIVER BED SLOPE																	
ELEVATION - METERS	RIGHT GROUND ELEV.	13.475	16.930	13.947	16.619	13.880	12.770	13.078	11.695	15.090	14.120	18.843	14.905	17.305	19.941	13.645	12.961
	LEFT GROUND ELEV.	0.000	15.610	16.380	12.873	12.415	12.722	15.205	14.469	14.340	14.460	14.345	15.720	13.940	12.615	14.875	13.935
	MEAN RIVER BED																
	LOWEST RIVER BED	5.960	4.955	7.220	7.070	7.170	7.460	7.605	8.860	8.505	7.520	7.995	7.125	8.095	7.035	7.425	8.730
	DESIGN DIKE CROWN	15.036	15.058	15.080	15.103	15.125	15.147	15.169	15.192	15.214	15.236	15.258	15.280	15.303	15.325	15.347	15.369
	D.F.L.	14.036	14.058	14.080	14.103	14.125	14.147	14.169	14.192	14.214	14.236	14.258	14.280	14.303	14.325	14.347	14.369
	DESIGN RIVER BED	6.500	6.547	6.593	6.640	6.686	6.733	6.779	6.826	6.872	6.919	6.965	7.012	7.058	7.105	7.151	7.198
PARTIAL DISTANCE (Km)		0.000	0.205	0.200	0.198	0.201	0.200	0.201	0.200	0.200	0.200	0.201	0.203	0.202	0.201	0.201	0.204
CROSS SECTION STATION NUMBER		0.000	0.205	0.405	0.603	0.804	1.005	1.205	1.405	1.606	1.806	2.007	2.209	2.412	2.612	2.814	3.018
ACCUMULATIVE DIST. (Km)		0.000	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200	2.400	2.600	2.800	3.000
PARTIAL DISTANCE (Km)		0.000	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
DESIGN STATION NUMBER		0.000	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200	2.400	2.600	2.800	3.000

		3.200	3.400	3.600	3.800	4.000	4.200	4.400	4.600	4.800	5.000	5.200	5.400	5.600	5.800	6.000	6.200
DESIGN H.W.L. SLOPE																	14.736 17.400
DESIGN RIVER BED SLOPE																	
ELEVATION - METERS	RIGHT GROUND ELEV.	12.570	15.160	16.715	15.121	15.605	15.480	16.605	16.925	21.542	16.878	19.679	21.105	17.850	20.710	17.735	17.690
	LEFT GROUND ELEV.	15.785	15.845	16.815	13.464	13.694	14.064	16.646	19.000	17.890	16.905	17.995	18.035	17.330	17.525	18.440	19.780
	MEAN RIVER BED																
	LOWEST RIVER BED	8.640	7.895	7.885	7.395	8.870	9.130	8.155	8.610	9.060	8.945	9.275	9.175	9.360	9.040	9.130	7.960
	DESIGN DIKE CROWN	15.392	15.414	15.436	15.458	15.480	15.503	15.525	15.547	15.569	15.592	15.614	15.636	15.658	15.680	15.703	15.725
	D.F.L.	14.392	14.414	14.436	14.458	14.480	14.503	14.525	14.547	14.569	14.592	14.614	14.636	14.658	14.680	14.703	14.725
	DESIGN RIVER BED	7.244	7.291	7.337	7.384	7.430	7.477	7.523	7.570	7.616	7.663	7.709	7.756	7.802	7.849	7.895	7.942
PARTIAL DISTANCE (Km)		0.202	0.200	0.201	0.201	0.199	0.199	0.200	0.199	0.200	0.200	0.200	0.201	0.211	0.223	0.207	
CROSS SECTION STATION NUMBER		3.220	3.420	3.621	3.822	4.022	4.221	4.421	4.620	4.820	5.021	5.221	5.422	5.632	5.855	6.061	
ACCUMULATIVE DIST. (Km)		3.200	3.400	3.600	3.800	4.000	4.200	4.400	4.600	4.800	5.000	5.200	5.400	5.600	5.800	6.000	6.200
PARTIAL DISTANCE (Km)		0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
DESIGN STATION NUMBER		3.200	3.400	3.600	3.800	4.000	4.200	4.400	4.600	4.800	5.000	5.200	5.400	5.600	5.800	6.000	6.200

Source: Detailed Desgin of PMRCIP(III)

ANNEX Figure 4.1.2 Design Longitudinal Profile for Phase III Project (Lower Marikina River)

APPENDIX II: Table

ANNEX Table 4.4.1 Breakdown of Project Costs for Each Alternative (2012 Price)

(O)Phase IV (1/30(as of 2002)) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	Total
Pasig River Dredging	1,200m3/s	-	-	-	-	-	-	-
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	4,063.0
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	2,899.2
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	4,303.3
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	4,687.0
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	4,179.4
Upper Upper Marikina River	NRB	-	-	-	-	-	-	-
Dam		-	-	-	-	-	-	-
Toral		14,804.5	129.6	2,031.9	518.5	817.2	1,830.2	20,131.9

(A)PhaseIV+Mangahan Floodway (1/30(as of 2013)) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	Total
Pasig River Dredging	1,300m3/s	993.0	-	158.9	34.8	49.7	123.7	1,360.1
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	4,063.0
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	2,899.2
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	4,303.3
Mangahan Floodway	2,600m3/s	3,625.2	99.2	580.0	130.4	181.3	461.6	5,077.7
Upper Marikina River	3,100m3/s	3,291.1	17.2	452.4	112.6	188.0	406.2	4,467.5
Upper Upper Marikina River	NRB	-	-	-	-	-	-	-
Dam		-	-	-	-	-	-	-
Toral		16,288.7	138.2	2,264.6	570.7	893.0	2,015.6	22,170.8

(B)PhaseIV+Retarding Basin (1/30(as of 2013)) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	Total
Pasig River Dredging	1,300m3/s	993.0	-	158.9	34.8	49.7	123.7	1,360.1
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	4,063.0
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	2,899.2
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	4,303.3
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	4,687.0
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	4,179.4
Upper Upper Marikina River	NRB	-	-	-	-	-	-	-
	RB 5MCM	1,543.5	1,250.0	247.0	99.1	77.2	325.3	3,542.1
Dam		-	-	-	-	-	-	-
Toral		17,341.0	1,379.6	2,437.8	652.4	944.1	2,279.2	25,034.1

ANNEX Table 4.4.2 Breakdown of Project Costs for Each Alternative (2012 Price)

A-1:Dam&NRB (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	*Total*
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,600m3/s	3,625.2	99.2	580.0	130.4	181.3	461.6	*5,077.7*
Upper Marikina River	3,100m3/s	3,291.1	17.2	452.4	112.6	188.0	406.2	*4,467.5*
Upper Upper Marikina River	NRB	-	21,814.8	-	763.5	-	2,257.8	*24,836.1*
Dam	Dam 55MCM	8,396.6	-	1,343.5	293.9	419.8	1,045.4	*11,499.2*
Toral		*25,678.3*	*21,953.0*	*3,767.0*	*1,662.9*	*1,362.4*	*5,442.4*	*59,866.0*

A-2-1:Dam (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	*Total*
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,600m3/s	3,625.2	99.2	580.0	130.4	181.3	461.6	*5,077.7*
Upper Marikina River	3,100m3/s	3,291.1	17.2	452.4	112.6	188.0	406.2	*4,467.5*
Upper Upper Marikina River	Cl 3,100m3/s	1,475.1	34.6	236.1	52.8	73.8	187.3	*2,059.7*
	NRB	-	21,780.2	-	763.5	-	2,257.8	*24,801.5*
Dam	Dam 80MCM	9,261.0	-	1,481.8	324.1	463.1	1,153.0	*12,683.0*
Toral		*28,017.8*	*21,953.0*	*4,141.4*	*1,745.9*	*1,479.5*	*5,737.3*	*63,074.9*

A-3:Dam&RB (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	*Total*
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,600m3/s	3,625.2	99.2	580.0	130.4	181.3	461.6	*5,077.7*
Upper Marikina River	3,100m3/s	3,291.1	17.2	452.4	112.6	188.0	406.2	*4,467.5*
Upper Upper Marikina River	RB 20MCM	2,873.0	2,000.0	459.7	172.6	143.6	570.7	*6,219.6*
	Cl 3100m3/s	1,475.1	34.6	236.1	52.8	73.8	187.3	*2,059.7*
	NRB	-	19,780.2	-	763.5	-	2,257.8	*22,801.5*
Dam	Dam 55MCM	8,396.6	-	1,343.5	293.9	419.8	1,045.4	*11,499.2*
Toral		*30,026.4*	*21,953.0*	*4,462.8*	*1,888.3*	*1,579.8*	*6,200.4*	*66,110.7*

A-2-2:Dam* (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	*Total*
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,600m3/s	3,625.2	99.2	580.0	130.4	181.3	461.6	*5,077.7*
Upper Marikina River	3,100m3/s	3,291.1	17.2	452.4	112.6	188.0	406.2	*4,467.5*
Upper Upper Marikina River	Cl 3,100m3/s	1,475.1	34.6	236.1	52.8	73.8	187.3	*2,059.7*
	NBR	-	19,780.2	-	763.5	-	2,257.8	*22,801.5*
	RB 8MCM	2,469.6	2,000.0	395.1	158.5	123.5	520.5	*5,667.2*
Dam	Dam 80MCM	9,261.0	-	1,481.8	324.1	463.1	1,153.0	*12,683.0*
Toral		*30,487.4*	*21,953.0*	*4,536.5*	*1,904.4*	*1,603.0*	*6,257.8*	*66,742.1*

*After Dam, RB demolished

ANNEX Table 4.4.3 Breakdown of Project Costs for Each Alternative (2012 Price)

O-1:Dam&NRB (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	*Total*
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	*4,687.0*
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	*4,179.4*
Upper Upper Marikina River	NRB	-	21,814.8	-	763.5	-	2,257.8	*24,836.1*
Dam	Dam 65MCM	8,767.1	-	1,402.7	306.8	438.4	1,091.5	*12,006.5*
Toral		*25,557.6*	*21,944.4*	*3,752.4*	*1,658.4*	*1,354.9*	*5,426.8*	*59,694.5*

O-2:Dam (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	*Total*
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	*4,687.0*
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	*4,179.4*
Upper Upper Marikina River	Cl 2,900m3/s	1,379.9	32.4	220.8	49.4	69.0	175.1	*1,926.6*
	NBR	-	21,782.4	-	763.5	-	2,257.8	*24,803.7*
Dam	Dam 90MCM	9,631.4	-	1,541.0	337.1	481.6	1,199.1	*13,190.2*
Toral		*27,801.8*	*21,944.4*	*4,111.5*	*1,738.1*	*1,467.1*	*5,709.5*	*62,772.4*

ANNEX Table 4.4.4 Breakdown of Project Costs for Each Alternative (2012 Price)

B-1:Dam&RB (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	Total
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	*4,687.0*
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	*4,179.4*
Upper Upper Marikina River	NRB	-	20,564.8	-	763.5	-	2,257.8	*23,586.1*
	RB 5MCM	1,543.5	1,250.0	247.0	99.1	77.2	325.3	*3,542.1*
Dam	Dam 55MCM	8,396.6	-	1,343.5	293.9	419.8	1,045.4	*11,499.2*
Toral		*26,730.6*	*21,944.4*	*3,940.2*	*1,744.6*	*1,413.5*	*5,706.0*	*61,479.3*

B-2-1:Dam* (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	Total
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	*4,687.0*
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	*4,179.4*
Upper Upper Marikina River	CI 2,900m3/s	1,379.9	32.4	220.8	49.4	69.0	175.1	*1,926.6*
	NBR	-	20,532.4	-	763.5	-	2,257.8	*23,553.7*
	RB 5MCM	1,543.5	1,250.0	247.0	99.1	77.2	325.3	*3,542.1*
Dam	Dam 90MCM	9,631.4	-	1,541.0	337.1	481.6	1,199.1	*13,190.2*
Toral		*29,345.3*	*21,944.4*	*4,358.5*	*1,837.2*	*1,544.3*	*6,034.8*	*65,064.5*

*After Dam, RB demolished

B-3:Dam&RB (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	Total
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	*4,687.0*
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	*4,179.4*
Upper Upper Marikina River	RB 20MCM	2,873.0	2,000.0	459.7	172.6	143.6	570.7	*6,219.6*
	CI 2,900m3/s	1,379.9	32.4	220.8	49.4	69.0	175.1	*1,926.6*
	NBR	-	19,782.4	-	763.5	-	2,257.8	*22,803.7*
Dam	Dam 65MCM	8,767.1	-	1,402.7	306.8	438.4	1,091.5	*12,006.5*
Toral		*29,810.5*	*21,944.4*	*4,432.9*	*1,880.4*	*1,567.5*	*6,172.6*	*65,808.3*

B-2-2:Dam* (1/100) unit:million peso

Section	Contents	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	Price contingency cost	Total
Pasig River Dredging	1,400m3/s	1,986.0	-	317.8	69.6	99.3	247.3	*2,720.0*
Pasig River Phase2	Phase2	3,033.2	10.9	371.2	107.5	170.8	369.4	*4,063.0*
Lower Marikina River	Phase3	2,164.4	7.7	264.9	76.7	122.0	263.5	*2,899.2*
MCGS	MCGS	3,181.8	3.2	437.2	108.7	181.2	391.2	*4,303.3*
Mangahan Floodway	2,400m3/s	3,346.3	91.6	535.4	120.3	167.3	426.1	*4,687.0*
Upper Marikina River	Phase4	3,078.8	16.2	423.2	105.3	175.9	380.0	*4,179.4*
Upper Upper Marikina River	CI 2,900m3/s	1,379.9	32.4	220.8	49.4	69.0	175.1	*1,926.6*
	NBR	-	19,782.4	-	763.5	-	2,257.8	*22,803.7*
	RB 8MCM	2,469.6	2,000.0	395.1	158.5	123.5	520.5	*5,667.2*
Dam	Dam 90MCM	9,631.4	-	1,541.0	337.1	481.6	1,199.1	*13,190.2*
Toral		*30,271.4*	*21,944.4*	*4,506.6*	*1,896.6*	*1,590.6*	*6,230.0*	*66,439.6*

*After Dam, RB demolished

ANNEX Table 4.5.1 Result of Economic Evaluation（Case① Alternative Plan O）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging			-	-	-	-
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	-	-	-	-	-	-
Dam	-	-	-	-	-	-
Total	*11,695.6*	*73.9*	*2,418.0*	*502.9*	*760.0*	*15,450.3*

ANNEX Table 4.5.2 Result of Economic Evaluation（Case② Alternative Plan A）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	784.5	-	189.1	33.8	46.2	*1,053.5*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,863.9	56.5	690.2	126.5	168.6	*3,905.7*
Upper Marikina River	2,600.0	9.8	538.4	109.2	174.8	*3,432.2*
Upper Upper Marikina River	-	-	-	-	-	-
Dam	-	-	-	-	-	-
Total	*12,868.1*	*78.8*	*2,694.9*	*553.6*	*830.5*	*17,025.8*

ANNEX Table 4.5.3 Result of Economic Evaluation（Case③ Alternative Plan B）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	784.5	-	189.1	33.8	46.2	*1,053.5*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	-	-	-	-	-	-
	1,219.4	733.2	293.9	96.1	71.8	*2,414.4*
Dam	-	-	-	-	-	-
Total	*13,699.4*	*807.1*	*2,901.0*	*632.8*	*878.0*	*18,918.3*

ANNEX Table 4.5.4 Result of Economic Evaluation（ Case④ Alternative Plan A-1）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,863.9	56.5	690.2	126.5	168.6	*3,905.7*
Upper Marikina River	2,600.0	9.8	538.4	109.2	174.8	*3,432.2*
Upper Upper Marikina River	-	12,434.4	-	740.6	-	*13,175.0*
Dam	6,633.3	-	1,598.8	285.1	390.4	*8,907.6*
Total	*20,285.9*	*12,513.2*	*4,482.7*	*1,613.0*	*1,267.0*	*40,161.8*

ANNEX Table 4.5.5 Result of Economic Evaluation（ Case⑤ Alternative Plan A-2-1）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,863.9	56.5	690.2	126.5	168.6	*3,905.7*
Upper Marikina River	2,600.0	9.8	538.4	109.2	174.8	*3,432.2*
Upper Upper Marikina River	1,165.3	19.7	281.0	51.2	68.6	*1,585.9*
	-	12,414.7	-	740.6	-	*13,155.3*
Dam	7,316.2	-	1,763.3	314.4	430.7	*9,824.6*
Total	*22,134.1*	*12,513.2*	*4,928.3*	*1,693.5*	*1,375.9*	*42,645.0*

ANNEX Table 4.5.6 Result of Economic Evaluation（ Case⑥ Alternative Plan A-3）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,863.9	56.5	690.2	126.5	168.6	*3,905.7*
Upper Marikina River	2,600.0	9.8	538.4	109.2	174.8	*3,432.2*
Upper Upper Marikina River	2,269.7	1,173.1	547.0	167.4	133.5	*4,290.7*
	1,165.3	19.7	281.0	51.2	68.6	*1,585.9*
	-	11,241.7	-	740.6	-	*11,982.2*
Dam	6,633.3	-	1,598.8	285.1	390.4	*8,907.6*
Total	*23,720.9*	*12,513.2*	*5,310.7*	*1,831.7*	*1,469.2*	*44,845.7*

ANNEX Table 4.5.7 Result of Economic Evaluation（Case⑦ Alternative Plan A-2-2）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,863.9	56.5	690.2	126.5	168.6	*3,905.7*
Upper Marikina River	2,600.0	9.8	538.4	109.2	174.8	*3,432.2*
Upper Upper Marikina River	1,165.3	19.7	281.0	51.2	68.6	*1,585.9*
	-	11,241.7	-	740.6	-	*11,982.2*
	1,951.0	1,173.1	470.2	153.7	114.9	*3,862.8*
Dam	7,316.2	-	1,763.3	314.4	430.7	*9,824.6*
Total	*24,085.0*	*12,513.2*	*5,398.4*	*1,847.3*	*1,490.8*	*45,334.7*

ANNEX Table 4.5.8 Result of Economic Evaluation（Case⑧ Alternative Plan O-1）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	-	12,434.4	-	740.6	-	*13,175.0*
Dam	6,926.0	-	1,669.2	297.6	407.7	*9,300.5*
Total	*20,190.5*	*12,508.3*	*4,465.4*	*1,608.6*	*1,260.1*	*40,032.9*

ANNEX Table 4.5.9 Result of Economic Evaluation（Case⑨ Alternative Plan O-2）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	1,090.1	18.5	262.8	47.9	64.2	*1,483.4*
	-	12,416.0	-	740.6	-	*13,156.6*
Dam	7,608.8	-	1,833.8	327.0	447.9	*10,217.5*
Total	*21,963.4*	*12,508.3*	*4,892.7*	*1,686.0*	*1,364.4*	*42,414.8*

ANNEX Table 4.5.10 Result of Economic Evaluation（Case⑩ Alternative Plan B-1）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	-	11,701.2	-	740.6	-	*12,441.8*
	1,219.4	733.2	293.9	96.1	71.8	*2,414.4*
Dam	6,633.3	-	1,598.8	285.1	390.4	*8,907.6*
Total	*21,117.2*	*12,508.3*	*4,688.8*	*1,692.3*	*1,314.6*	*41,321.1*

ANNEX Table 4.5.11 Result of Economic Evaluation（Case⑪ Alternative Plan B-2-1）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	1,090.1	18.5	262.8	47.9	64.2	*1,483.4*
	-	11,682.8	-	740.6	-	*12,423.4*
	1,219.4	733.2	293.9	96.1	71.8	*2,414.4*
Dam	7,608.8	-	1,833.8	327.0	447.9	*10,217.5*
Total	*23,182.8*	*12,508.3*	*5,186.6*	*1,782.1*	*1,436.2*	*44,096.0*

ANNEX Table 4.5.12 Result of Economic Evaluation（Case⑫ Alternative Plan B-3）

(million pesos)

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	2,269.7	1,173.1	547.0	167.4	133.5	*4,290.7*
	1,090.1	18.5	262.8	47.9	64.2	*1,483.4*
	-	11,242.9	-	740.6	-	*11,983.5*
Dam	6,926.0	-	1,669.2	297.6	407.7	*9,300.5*
Total	*23,550.3*	*12,508.3*	*5,275.2*	*1,824.0*	*1,457.8*	*44,615.5*

ANNEX Table 4.5.13 Result of Economic Evaluation（ Case⑬ Alternative Plan B-2-2）

（million pesos）

Section	Direct construction cost	Compensation cost	Engineering service cost	Administration cost	Physical contingency cost	*Total*
Pasig River Dredging	1,568.9	-	378.2	67.5	92.3	*2,107.0*
Pasig River Phase2	2,396.2	6.2	441.7	104.3	158.8	*3,107.3*
Lower Marikina River	1,709.9	4.4	315.2	74.4	113.5	*2,217.4*
MCGS	2,513.6	1.8	520.3	105.4	168.5	*3,309.7*
Mangahan Floodway	2,643.6	52.2	637.1	116.7	155.6	*3,605.2*
Upper Marikina River	2,432.3	9.2	503.6	102.1	163.6	*3,210.8*
Upper Upper Marikina River	1,090.1	18.5	262.8	47.9	64.2	*1,483.4*
	-	11,242.9	-	740.6	-	*11,983.5*
	1,951.0	1,173.1	470.2	153.7	114.9	*3,862.8*
Dam	7,608.8	-	1,833.8	327.0	447.9	*10,217.5*
Total	*23,914.4*	*12,508.3*	*5,362.9*	*1,839.7*	*1,479.3*	*45,104.5*

ANNEX Table 4.5.14 Cash Flow（Case① Alternative Plan O）

(10^6PESOS)

Year		BENEFIT ①	②	③	④	⑤	⑥	⑦	⑧	B/C	B-c
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				3,863	3,863	11	11	3,874	3,874		-3,874
2015				3,863	3,359	22	20	3,885	3,378		-3,378
2016				3,863	2,921	34	25	3,896	2,946		-2,946
2017				3,863	2,540	45	30	3,908	2,569		-2,569
2018	1	23,915	13,673			45	26	45	26		13,648
2019	2	23,915	11,890			45	22	45	22		11,868
2020	3	23,915	10,339			45	19	45	19		10,320
2021	4	23,915	8,991			45	17	45	17		8,974
2022	5	23,915	7,818			45	15	45	15		7,803
2023	6	23,915	6,798			45	13	45	13		6,785
2024	7	23,915	5,911			45	11	45	11		5,900
2025	8	23,915	5,140			45	10	45	10		5,131
2026	9	23,915	4,470			45	8	45	8		4,461
2027	10	23,915	3,887			45	7	45	7		3,880
2028	11	23,915	3,380			45	6	45	6		3,374
2029	12	23,915	2,939			45	6	45	6		2,933
2030	13	23,915	2,556			45	5	45	5		2,551
2031	14	23,915	2,222			45	4	45	4		2,218
2032	15	23,915	1,932			45	4	45	4		1,929
2033	16	23,915	1,680			45	3	45	3		1,677
2034	17	23,915	1,461			45	3	45	3		1,458
2035	18	23,915	1,271			45	2	45	2		1,268
2036	19	23,915	1,105			45	2	45	2		1,103
2037	20	23,915	961			45	2	45	2		959
2038	21	23,915	835			45	2	45	2		834
2039	22	23,915	726			45	1	45	1		725
2040	23	23,915	632			45	1	45	1		631
2041	24	23,915	549			45	1	45	1		548
2042	25	23,915	478			45	1	45	1		477
2043	26	23,915	415			45	1	45	1		415
2044	27	23,915	361			45	1	45	1		361
2045	28	23,915	314			45	1	45	1		313
2046	29	23,915	273			45	1	45	1		273
2047	30	23,915	237			45	0	45	0		237
2048	31	23,915	207			45	0	45	0		206
2049	32	23,915	180			45	0	45	0		179
2050	33	23,915	156			45	0	45	0		156
2051	34	23,915	136			45	0	45	0		136
2052	35	23,915	118			45	0	45	0		118
2053	36	23,915	103			45	0	45	0		102
2054	37	23,915	89			45	0	45	0		89
2055	38	23,915	78			45	0	45	0		77
2056	39	23,915	68			45	0	45	0		67
2057	40	23,915	59			45	0	45	0		59
2058	41	23,915	51			45	0	45	0		51
2059	42	23,915	44			45	0	45	0		44
2060	43	23,915	39			45	0	45	0		39
2061	44	23,915	34			45	0	45	0		34
2062	45	23,915	29			45	0	45	0		29
2063	46	23,915	25			45	0	45	0		25
2064	47	23,915	22			45	0	45	0		22
2065	48	23,915	19			45	0	45	0		19
2066	49	23,915	17			45	0	45	0		17
2067	50	23,915	15			45	0	45	0		14
		1,195,751	104,733	15,450	12,682	2,360	283	17,811	12,964		91,769
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.635						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		91,769						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		8.1						

Note : Benefit of 1/20 is applied to this case owing to the design flood discharge of 2,900m^3/s is reevaluated as 1/20 years flood as previously mentioned.

ANNEX Table 4.5.15 Cash Flow （Case② Alternative Plan A)

(10^6PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,256	4,256	12	12	4,269	4,269		-4,269
2015				4,256	3,701	25	22	4,281	3,723		-3,723
2016				4,256	3,218	37	28	4,294	3,247		-3,247
2017				4,256	2,799	50	33	4,306	2,831		-2,831
2018	1	25,671	14,677			50	28	50	28		14,649
2019	2	25,671	12,763			50	25	50	25		12,738
2020	3	25,671	11,098			50	21	50	21		11,077
2021	4	25,671	9,651			50	19	50	19		9,632
2022	5	25,671	8,392			50	16	50	16		8,376
2023	6	25,671	7,297			50	14	50	14		7,283
2024	7	25,671	6,345			50	12	50	12		6,333
2025	8	25,671	5,518			50	11	50	11		5,507
2026	9	25,671	4,798			50	9	50	9		4,789
2027	10	25,671	4,172			50	8	50	8		4,164
2028	11	25,671	3,628			50	7	50	7		3,621
2029	12	25,671	3,155			50	6	50	6		3,149
2030	13	25,671	2,743			50	5	50	5		2,738
2031	14	25,671	2,385			50	5	50	5		2,381
2032	15	25,671	2,074			50	4	50	4		2,070
2033	16	25,671	1,804			50	3	50	3		1,800
2034	17	25,671	1,568			50	3	50	3		1,565
2035	18	25,671	1,364			50	3	50	3		1,361
2036	19	25,671	1,186			50	2	50	2		1,184
2037	20	25,671	1,031			50	2	50	2		1,029
2038	21	25,671	897			50	2	50	2		895
2039	22	25,671	780			50	2	50	2		778
2040	23	25,671	678			50	1	50	1		677
2041	24	25,671	590			50	1	50	1		589
2042	25	25,671	513			50	1	50	1		512
2043	26	25,671	446			50	1	50	1		445
2044	27	25,671	388			50	1	50	1		387
2045	28	25,671	337			50	1	50	1		336
2046	29	25,671	293			50	1	50	1		293
2047	30	25,671	255			50	0	50	0		254
2048	31	25,671	222			50	0	50	0		221
2049	32	25,671	193			50	0	50	0		192
2050	33	25,671	168			50	0	50	0		167
2051	34	25,671	146			50	0	50	0		145
2052	35	25,671	127			50	0	50	0		126
2053	36	25,671	110			50	0	50	0		110
2054	37	25,671	96			50	0	50	0		96
2055	38	25,671	83			50	0	50	0		83
2056	39	25,671	72			50	0	50	0		72
2057	40	25,671	63			50	0	50	0		63
2058	41	25,671	55			50	0	50	0		55
2059	42	25,671	48			50	0	50	0		48
2060	43	25,671	41			50	0	50	0		41
2061	44	25,671	36			50	0	50	0		36
2062	45	25,671	31			50	0	50	0		31
2063	46	25,671	27			50	0	50	0		27
2064	47	25,671	24			50	0	50	0		24
2065	48	25,671	21			50	0	50	0		21
2066	49	25,671	18			50	0	50	0		18
2067	50	25,671	16			50	0	50	0		16
		1,283,543	112,423	17,026	13,975	2,601	312	19,627	14,286		98,136
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.626						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		98,136						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		7.9						

ANNEX Table 4.5.16 Cash Flow (Case③ Alternative Plan B)

(10^6 PESOS)

Year		BENEFIT ①	②	③	④	⑤	⑥	⑦	⑧	B/C	B-c
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,126	4,126	12	12	4,138	4,138		-4,138
2015				4,126	3,588	24	21	4,150	3,609		-3,609
2016				4,126	3,120	36	27	4,162	3,147		-3,147
2017				4,528	2,977	49	32	4,578	3,010		-3,010
2018				402	230	50	29	453	259		-259
2019				402	200	52	26	454	226		-226
2020				402	174	53	23	455	197		-197
2021				402	151	54	20	456	172		-172
2022				402	132	55	18	457	150		-150
2023	1	25,671	7,297			55	16	55	16		7,282
2024	2	25,671	6,345			55	14	55	14		6,332
2025	3	25,671	5,518			55	12	55	12		5,506
2026	4	25,671	4,798			55	10	55	10		4,788
2027	5	25,671	4,172			55	9	55	9		4,163
2028	6	25,671	3,628			55	8	55	8		3,620
2029	7	25,671	3,155			55	7	55	7		3,148
2030	8	25,671	2,743			55	6	55	6		2,737
2031	9	25,671	2,385			55	5	55	5		2,380
2032	10	25,671	2,074			55	4	55	4		2,070
2033	11	25,671	1,804			55	4	55	4		1,800
2034	12	25,671	1,568			55	3	55	3		1,565
2035	13	25,671	1,364			55	3	55	3		1,361
2036	14	25,671	1,186			55	3	55	3		1,183
2037	15	25,671	1,031			55	2	55	2		1,029
2038	16	25,671	897			55	2	55	2		895
2039	17	25,671	780			55	2	55	2		778
2040	18	25,671	678			55	1	55	1		677
2041	19	25,671	590			55	1	55	1		588
2042	20	25,671	513			55	1	55	1		512
2043	21	25,671	446			55	1	55	1		445
2044	22	25,671	388			55	1	55	1		387
2045	23	25,671	337			55	1	55	1		336
2046	24	25,671	293			55	1	55	1		293
2047	25	25,671	255			55	1	55	1		254
2048	26	25,671	222			55	0	55	0		221
2049	27	25,671	193			55	0	55	0		192
2050	28	25,671	168			55	0	55	0		167
2051	29	25,671	146			55	0	55	0		145
2052	30	25,671	127			55	0	55	0		126
2053	31	25,671	110			55	0	55	0		110
2054	32	25,671	96			55	0	55	0		96
2055	33	25,671	83			55	0	55	0		83
2056	34	25,671	72			55	0	55	0		72
2057	35	25,671	63			55	0	55	0		63
2058	36	25,671	55			55	0	55	0		55
2059	37	25,671	48			55	0	55	0		48
2060	38	25,671	41			55	0	55	0		41
2061	39	25,671	36			55	0	55	0		36
2062	40	25,671	31			55	0	55	0		31
2063	41	25,671	27			55	0	55	0		27
2064	42	25,671	24			55	0	55	0		24
2065	43	25,671	21			55	0	55	0		21
2066	44	25,671	18			55	0	55	0		18
2067	45	25,671	16			55	0	55	0		16
2068	46	25,671	14			55	0	55	0		14
2069	47	25,671	12			55	0	55	0		12
2070	48	25,671	10			55	0	55	0		10
2071	49	25,671	9			55	0	55	0		9
2072	50	25,671	8			55	0	55	0		8
		1,283,543	55,894	18,918	14,698	3,137	328	22,056	15,026		40,868
		EIRR	$\Sigma(B - C)/\Sigma(1 + io)^{t-1}=0$		0.280						
		NPV	$\Sigma(B - C)/\Sigma(1 + i)^{t-1}$		40,868						
		B/C	$\Sigma(B/(1 + i)^{t-1})/\Sigma(C/(1 + i)^{t-1})$		3.7						

ANNEX Table 4.5.17 Cash Flow （Case④ Alternative Plan A-1)

(10^6PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,520	4,520	13	13	4,533	4,533		-4,533
2015				4,520	3,930	26	23	4,546	3,953		-3,953
2016				4,520	3,418	39	30	4,559	3,447		-3,447
2017				7,606	5,001	62	40	7,668	5,042		-5,042
2018				3,087	1,765	71	40	3,157	1,805		-1,805
2019				3,087	1,535	80	40	3,166	1,574		-1,574
2020				3,087	1,334	89	38	3,175	1,373		-1,373
2021				3,087	1,160	98	37	3,184	1,197		-1,197
2022				3,087	1,009	107	35	3,193	1,044		-1,044
2023				891	253	109	31	1,000	284		-284
2024				891	220	112	28	1,002	248		-248
2025				891	191	114	25	1,005	216		-216
2026				891	166	117	22	1,008	188		-188
2027	1	28,937	4,703			117	19	117	19		4,684
2028	2	28,937	4,090			117	17	117	17		4,073
2029	3	28,937	3,556			117	14	117	14		3,542
2030	4	28,937	3,092			117	12	117	12		3,080
2031	5	28,937	2,689			117	11	117	11		2,678
2032	6	28,937	2,338			117	9	117	9		2,329
2033	7	28,937	2,033			117	8	117	8		2,025
2034	8	28,937	1,768			117	7	117	7		1,761
2035	9	28,937	1,537			117	6	117	6		1,531
2036	10	28,937	1,337			117	5	117	5		1,331
2037	11	28,937	1,163			117	5	117	5		1,158
2038	12	28,937	1,011			117	4	117	4		1,007
2039	13	28,937	879			117	4	117	4		875
2040	14	28,937	764			117	3	117	3		761
2041	15	28,937	665			117	3	117	3		662
2042	16	28,937	578			117	2	117	2		576
2043	17	28,937	503			117	2	117	2		501
2044	18	28,937	437			117	2	117	2		435
2045	19	28,937	380			117	2	117	2		378
2046	20	28,937	330			117	1	117	1		329
2047	21	28,937	287			117	1	117	1		286
2048	22	28,937	250			117	1	117	1		249
2049	23	28,937	217			117	1	117	1		216
2050	24	28,937	189			117	1	117	1		188
2051	25	28,937	164			117	1	117	1		164
2052	26	28,937	143			117	1	117	1		142
2053	27	28,937	124			117	1	117	1		124
2054	28	28,937	108			117	0	117	0		108
2055	29	28,937	94			117	0	117	0		94
2056	30	28,937	82			117	0	117	0		81
2057	31	28,937	71			117	0	117	0		71
2058	32	28,937	62			117	0	117	0		62
2059	33	28,937	54			117	0	117	0		53
2060	34	28,937	47			117	0	117	0		47
2061	35	28,937	41			117	0	117	0		40
2062	36	28,937	35			117	0	117	0		35
2063	37	28,937	31			117	0	117	0		31
2064	38	28,937	27			117	0	117	0		27
2065	39	28,937	23			117	0	117	0		23
2066	40	28,937	20			117	0	117	0		20
2067	41	28,937	18			117	0	117	0		17
2068	42	28,937	15			117	0	117	0		15
2069	43	28,937	13			117	0	117	0		13
2070	44	28,937	12			117	0	117	0		11
2071	45	28,937	10			117	0	117	0		10
2072	46	28,937	9			117	0	117	0		9
2073	47	28,937	8			117	0	117	0		8
2074	48	28,937	7			117	0	117	0		7
2075	49	28,937	6			117	0	117	0		6
2076	50	28,937	5			117	0	117	0		5
		1,446,833	36,023	40,162	24,504	6,879	547	47,041	25,050		10,973
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.176						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		10,973						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.4						

ANNEX Table 4.5.18 Cash Flow （Case⑤ Alternative Plan A-2-1)

(10^6PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,520	4,520	13	13	4,533	4,533		-4,533
2015				4,520	3,930	26	23	4,546	3,953		-3,953
2016				4,520	3,418	39	30	4,559	3,447		-3,447
2017				7,959	5,233	63	41	8,022	5,274		-5,274
2018				3,439	1,966	73	42	3,512	2,008		-2,008
2019				3,439	1,710	83	41	3,522	1,751		-1,751
2020				3,439	1,487	93	40	3,532	1,527		-1,527
2021				3,439	1,293	103	39	3,542	1,332		-1,332
2022				3,439	1,124	113	37	3,552	1,161		-1,161
2023				982	279	116	33	1,098	312		-312
2024				982	243	118	29	1,101	272		-272
2025				982	211	121	26	1,104	237		-237
2026				982	184	124	23	1,107	207		-207
2027	1	28,937	4,703			124	20	124	20		4,683
2028	2	28,937	4,090			124	18	124	18		4,072
2029	3	28,937	3,556			124	15	124	15		3,541
2030	4	28,937	3,092			124	13	124	13		3,079
2031	5	28,937	2,689			124	12	124	12		2,677
2032	6	28,937	2,338			124	10	124	10		2,328
2033	7	28,937	2,033			124	9	124	9		2,025
2034	8	28,937	1,768			124	8	124	8		1,760
2035	9	28,937	1,537			124	7	124	7		1,531
2036	10	28,937	1,337			124	6	124	6		1,331
2037	11	28,937	1,163			124	5	124	5		1,158
2038	12	28,937	1,011			124	4	124	4		1,007
2039	13	28,937	879			124	4	124	4		875
2040	14	28,937	764			124	3	124	3		761
2041	15	28,937	665			124	3	124	3		662
2042	16	28,937	578			124	2	124	2		575
2043	17	28,937	503			124	2	124	2		500
2044	18	28,937	437			124	2	124	2		435
2045	19	28,937	380			124	2	124	2		378
2046	20	28,937	330			124	1	124	1		329
2047	21	28,937	287			124	1	124	1		286
2048	22	28,937	250			124	1	124	1		249
2049	23	28,937	217			124	1	124	1		216
2050	24	28,937	189			124	1	124	1		188
2051	25	28,937	164			124	1	124	1		164
2052	26	28,937	143			124	1	124	1		142
2053	27	28,937	124			124	1	124	1		124
2054	28	28,937	108			124	0	124	0		108
2055	29	28,937	94			124	0	124	0		94
2056	30	28,937	82			124	0	124	0		81
2057	31	28,937	71			124	0	124	0		71
2058	32	28,937	62			124	0	124	0		62
2059	33	28,937	54			124	0	124	0		53
2060	34	28,937	47			124	0	124	0		47
2061	35	28,937	41			124	0	124	0		40
2062	36	28,937	35			124	0	124	0		35
2063	37	28,937	31			124	0	124	0		31
2064	38	28,937	27			124	0	124	0		27
2065	39	28,937	23			124	0	124	0		23
2066	40	28,937	20			124	0	124	0		20
2067	41	28,937	18			124	0	124	0		17
2068	42	28,937	15			124	0	124	0		15
2069	43	28,937	13			124	0	124	0		13
2070	44	28,937	12			124	0	124	0		11
2071	45	28,937	10			124	0	124	0		10
2072	46	28,937	9			124	0	124	0		9
2073	47	28,937	8			124	0	124	0		8
2074	48	28,937	7			124	0	124	0		7
2075	49	28,937	6			124	0	124	0		6
2076	50	28,937	5			124	0	124	0		5
		1,446,833	36,023	42,645	25,598	7,289	571	49,934	26,169		9,854
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.173						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		9,854						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.4						

ANNEX Table 4.5.19 Cash Flow （Case⑥ Alternative Plan A-3)

(10^6PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,520	4,520	13	13	4,533	4,533		-4,533
2015				4,520	3,930	26	23	4,546	3,953		-3,953
2016				4,520	3,418	39	30	4,559	3,447		-3,447
2017				8,387	5,515	64	42	8,451	5,557		-5,557
2018				3,867	2,211	75	43	3,942	2,254		-2,254
2019				3,867	1,923	86	43	3,954	1,966		-1,966
2020				3,867	1,672	98	42	3,965	1,714		-1,714
2021				3,867	1,454	109	41	3,976	1,495		-1,495
2022				3,867	1,264	120	39	3,987	1,303		-1,303
2023				891	253	123	35	1,013	288		-288
2024				891	220	125	31	1,016	251		-251
2025				891	191	128	27	1,019	219		-219
2026				891	166	131	24	1,021	191		-191
2027	1	28,937	4,703			131	21	131	21		4,682
2028	2	28,937	4,090			131	18	131	18		4,071
2029	3	28,937	3,556			131	16	131	16		3,540
2030	4	28,937	3,092			131	14	131	14		3,078
2031	5	28,937	2,689			131	12	131	12		2,677
2032	6	28,937	2,338			131	11	131	11		2,328
2033	7	28,937	2,033			131	9	131	9		2,024
2034	8	28,937	1,768			131	8	131	8		1,760
2035	9	28,937	1,537			131	7	131	7		1,530
2036	10	28,937	1,337			131	6	131	6		1,331
2037	11	28,937	1,163			131	5	131	5		1,157
2038	12	28,937	1,011			131	5	131	5		1,006
2039	13	28,937	879			131	4	131	4		875
2040	14	28,937	764			131	3	131	3		761
2041	15	28,937	665			131	3	131	3		662
2042	16	28,937	578			131	3	131	3		575
2043	17	28,937	503			131	2	131	2		500
2044	18	28,937	437			131	2	131	2		435
2045	19	28,937	380			131	2	131	2		378
2046	20	28,937	330			131	1	131	1		329
2047	21	28,937	287			131	1	131	1		286
2048	22	28,937	250			131	1	131	1		249
2049	23	28,937	217			131	1	131	1		216
2050	24	28,937	189			131	1	131	1		188
2051	25	28,937	164			131	1	131	1		164
2052	26	28,937	143			131	1	131	1		142
2053	27	28,937	124			131	1	131	1		124
2054	28	28,937	108			131	0	131	0		108
2055	29	28,937	94			131	0	131	0		94
2056	30	28,937	82			131	0	131	0		81
2057	31	28,937	71			131	0	131	0		71
2058	32	28,937	62			131	0	131	0		61
2059	33	28,937	54			131	0	131	0		53
2060	34	28,937	47			131	0	131	0		46
2061	35	28,937	41			131	0	131	0		40
2062	36	28,937	35			131	0	131	0		35
2063	37	28,937	31			131	0	131	0		31
2064	38	28,937	27			131	0	131	0		27
2065	39	28,937	23			131	0	131	0		23
2066	40	28,937	20			131	0	131	0		20
2067	41	28,937	18			131	0	131	0		17
2068	42	28,937	15			131	0	131	0		15
2069	43	28,937	13			131	0	131	0		13
2070	44	28,937	12			131	0	131	0		11
2071	45	28,937	10			131	0	131	0		10
2072	46	28,937	9			131	0	131	0		9
2073	47	28,937	8			131	0	131	0		8
2074	48	28,937	7			131	0	131	0		7
2075	49	28,937	6			131	0	131	0		6
2076	50	28,937	5			131	0	131	0		5
		1,446,833	36,023	44,846	26,737	7,662	596	52,508	27,334		8,689
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.170						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		8,689						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.3						

ANNEX Table 4.5.20 Cash Flow （Case⑦ Alternative Plan A-2-2)

(10^6 PESOS)

Year		BENEFIT									
		①	②	③	④	⑤	⑥	⑦	⑧	B/C	B-c
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,520	4,520	13	13	4,533	4,533		-4,533
2015				4,520	3,930	26	23	4,546	3,953		-3,953
2016				4,520	3,418	39	30	4,559	3,447		-3,447
2017				8,407	5,528	64	42	8,471	5,570		-5,570
2018				3,888	2,223	75	43	3,963	2,266		-2,266
2019				3,888	1,933	87	43	3,974	1,976		-1,976
2020				3,888	1,681	98	42	3,985	1,723		-1,723
2021				3,888	1,461	109	41	3,997	1,503		-1,503
2022				3,888	1,271	120	39	4,008	1,310		-1,310
2023				982	279	123	35	1,106	314		-314
2024				982	243	126	31	1,109	274		-274
2025				982	211	129	28	1,112	239		-239
2026				982	184	132	25	1,114	208		-208
2027	1	28,937	4,703			132	21	132	21		4,682
2028	2	28,937	4,090			132	19	132	19		4,071
2029	3	28,937	3,556			132	16	132	16		3,540
2030	4	28,937	3,092			132	14	132	14		3,078
2031	5	28,937	2,689			132	12	132	12		2,677
2032	6	28,937	2,338			132	11	132	11		2,328
2033	7	28,937	2,033			132	9	132	9		2,024
2034	8	28,937	1,768			132	8	132	8		1,760
2035	9	28,937	1,537			132	7	132	7		1,530
2036	10	28,937	1,337			132	6	132	6		1,331
2037	11	28,937	1,163			132	5	132	5		1,157
2038	12	28,937	1,011			132	5	132	5		1,006
2039	13	28,937	879			132	4	132	4		875
2040	14	28,937	764			132	3	132	3		761
2041	15	28,937	665			132	3	132	3		662
2042	16	28,937	578			132	3	132	3		575
2043	17	28,937	503			132	2	132	2		500
2044	18	28,937	437			132	2	132	2		435
2045	19	28,937	380			132	2	132	2		378
2046	20	28,937	330			132	2	132	2		329
2047	21	28,937	287			132	1	132	1		286
2048	22	28,937	250			132	1	132	1		249
2049	23	28,937	217			132	1	132	1		216
2050	24	28,937	189			132	1	132	1		188
2051	25	28,937	164			132	1	132	1		164
2052	26	28,937	143			132	1	132	1		142
2053	27	28,937	124			132	1	132	1		124
2054	28	28,937	108			132	0	132	0		108
2055	29	28,937	94			132	0	132	0		94
2056	30	28,937	82			132	0	132	0		81
2057	31	28,937	71			132	0	132	0		71
2058	32	28,937	62			132	0	132	0		61
2059	33	28,937	54			132	0	132	0		53
2060	34	28,937	47			132	0	132	0		46
2061	35	28,937	41			132	0	132	0		40
2062	36	28,937	35			132	0	132	0		35
2063	37	28,937	31			132	0	132	0		31
2064	38	28,937	27			132	0	132	0		27
2065	39	28,937	23			132	0	132	0		23
2066	40	28,937	20			132	0	132	0		20
2067	41	28,937	18			132	0	132	0		17
2068	42	28,937	15			132	0	132	0		15
2069	43	28,937	13			132	0	132	0		13
2070	44	28,937	12			132	0	132	0		11
2071	45	28,937	10			132	0	132	0		10
2072	46	28,937	9			132	0	132	0		9
2073	47	28,937	8			132	0	132	0		8
2074	48	28,937	7			132	0	132	0		7
2075	49	28,937	6			132	0	132	0		6
2076	50	28,937	5			132	0	132	0		5
		1,446,833	36,023	45,335	26,881	7,739	600	53,074	27,481		8,542
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.170						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		8,542						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.3						

ANNEX Table 4.5.21 Cash Flow （Case⑧ Alternative Plan O-1)

(10^6PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,389	4,389	13	13	4,402	4,402		-4,402
2015				4,389	3,817	26	22	4,415	3,839		-3,839
2016				4,389	3,319	38	29	4,428	3,348		-3,348
2017				7,515	4,941	60	40	7,575	4,981		-4,981
2018				3,126	1,787	69	40	3,195	1,827		-1,827
2019				3,126	1,554	78	39	3,204	1,593		-1,593
2020				3,126	1,351	87	38	3,213	1,389		-1,389
2021				3,126	1,175	97	36	3,222	1,211		-1,211
2022				3,126	1,022	106	35	3,232	1,056		-1,056
2023				930	264	108	31	1,038	295		-295
2024				930	230	111	27	1,041	257		-257
2025				930	200	114	24	1,044	224		-224
2026				930	174	116	22	1,047	196		-196
2027	1	28,937	4,703			116	19	116	19		4,684
2028	2	28,937	4,090			116	16	116	16		4,073
2029	3	28,937	3,556			116	14	116	14		3,542
2030	4	28,937	3,092			116	12	116	12		3,080
2031	5	28,937	2,689			116	11	116	11		2,678
2032	6	28,937	2,338			116	9	116	9		2,329
2033	7	28,937	2,033			116	8	116	8		2,025
2034	8	28,937	1,768			116	7	116	7		1,761
2035	9	28,937	1,537			116	6	116	6		1,531
2036	10	28,937	1,337			116	5	116	5		1,332
2037	11	28,937	1,163			116	5	116	5		1,158
2038	12	28,937	1,011			116	4	116	4		1,007
2039	13	28,937	879			116	4	116	4		875
2040	14	28,937	764			116	3	116	3		761
2041	15	28,937	665			116	3	116	3		662
2042	16	28,937	578			116	2	116	2		576
2043	17	28,937	503			116	2	116	2		501
2044	18	28,937	437			116	2	116	2		435
2045	19	28,937	380			116	2	116	2		378
2046	20	28,937	330			116	1	116	1		329
2047	21	28,937	287			116	1	116	1		286
2048	22	28,937	250			116	1	116	1		249
2049	23	28,937	217			116	1	116	1		216
2050	24	28,937	189			116	1	116	1		188
2051	25	28,937	164			116	1	116	1		164
2052	26	28,937	143			116	1	116	1		142
2053	27	28,937	124			116	1	116	1		124
2054	28	28,937	108			116	0	116	0		108
2055	29	28,937	94			116	0	116	0		94
2056	30	28,937	82			116	0	116	0		81
2057	31	28,937	71			116	0	116	0		71
2058	32	28,937	62			116	0	116	0		62
2059	33	28,937	54			116	0	116	0		53
2060	34	28,937	47			116	0	116	0		47
2061	35	28,937	41			116	0	116	0		40
2062	36	28,937	35			116	0	116	0		35
2063	37	28,937	31			116	0	116	0		31
2064	38	28,937	27			116	0	116	0		27
2065	39	28,937	23			116	0	116	0		23
2066	40	28,937	20			116	0	116	0		20
2067	41	28,937	18			116	0	116	0		17
2068	42	28,937	15			116	0	116	0		15
2069	43	28,937	13			116	0	116	0		13
2070	44	28,937	12			116	0	116	0		11
2071	45	28,937	10			116	0	116	0		10
2072	46	28,937	9			116	0	116	0		9
2073	47	28,937	8			116	0	116	0		8
2074	48	28,937	7			116	0	116	0		7
2075	49	28,937	6			116	0	116	0		6
2076	50	28,937	5			116	0	116	0		5
		1,446,833	36,023	40,033	24,224	6,849	540	46,882	24,765		11,259
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.177						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		11,259						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.5						

ANNEX Table 4.5.22 Cash Flow （Case⑨ Alternative Plan O-2)

(10^6PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,389	4,389	13	13	4,402	4,402		-4,402
2015				4,389	3,817	26	22	4,415	3,839		-3,839
2016				4,389	3,319	38	29	4,428	3,348		-3,348
2017				7,851	5,162	61	40	7,912	5,202		-5,202
2018				3,462	1,979	71	41	3,533	2,020		-2,020
2019				3,462	1,721	81	40	3,543	1,762		-1,762
2020				3,462	1,497	91	40	3,553	1,536		-1,536
2021				3,462	1,301	101	38	3,563	1,340		-1,340
2022				3,462	1,132	112	36	3,573	1,168		-1,168
2023				1,022	290	115	33	1,136	323		-323
2024				1,022	253	117	29	1,139	282		-282
2025				1,022	220	120	26	1,142	246		-246
2026				1,022	191	123	23	1,145	214		-214
2027	1	28,937	4,703			123	20	123	20		4,683
2028	2	28,937	4,090			123	17	123	17		4,072
2029	3	28,937	3,556			123	15	123	15		3,541
2030	4	28,937	3,092			123	13	123	13		3,079
2031	5	28,937	2,689			123	11	123	11		2,677
2032	6	28,937	2,338			123	10	123	10		2,328
2033	7	28,937	2,033			123	9	123	9		2,025
2034	8	28,937	1,768			123	8	123	8		1,760
2035	9	28,937	1,537			123	7	123	7		1,531
2036	10	28,937	1,337			123	6	123	6		1,331
2037	11	28,937	1,163			123	5	123	5		1,158
2038	12	28,937	1,011			123	4	123	4		1,007
2039	13	28,937	879			123	4	123	4		875
2040	14	28,937	764			123	3	123	3		761
2041	15	28,937	665			123	3	123	3		662
2042	16	28,937	578			123	2	123	2		576
2043	17	28,937	503			123	2	123	2		500
2044	18	28,937	437			123	2	123	2		435
2045	19	28,937	380			123	2	123	2		378
2046	20	28,937	330			123	1	123	1		329
2047	21	28,937	287			123	1	123	1		286
2048	22	28,937	250			123	1	123	1		249
2049	23	28,937	217			123	1	123	1		216
2050	24	28,937	189			123	1	123	1		188
2051	25	28,937	164			123	1	123	1		164
2052	26	28,937	143			123	1	123	1		142
2053	27	28,937	124			123	1	123	1		124
2054	28	28,937	108			123	0	123	0		108
2055	29	28,937	94			123	0	123	0		94
2056	30	28,937	82			123	0	123	0		81
2057	31	28,937	71			123	0	123	0		71
2058	32	28,937	62			123	0	123	0		62
2059	33	28,937	54			123	0	123	0		53
2060	34	28,937	47			123	0	123	0		47
2061	35	28,937	41			123	0	123	0		40
2062	36	28,937	35			123	0	123	0		35
2063	37	28,937	31			123	0	123	0		31
2064	38	28,937	27			123	0	123	0		27
2065	39	28,937	23			123	0	123	0		23
2066	40	28,937	20			123	0	123	0		20
2067	41	28,937	18			123	0	123	0		17
2068	42	28,937	15			123	0	123	0		15
2069	43	28,937	13			123	0	123	0		13
2070	44	28,937	12			123	0	123	0		11
2071	45	28,937	10			123	0	123	0		10
2072	46	28,937	9			123	0	123	0		9
2073	47	28,937	8			123	0	123	0		8
2074	48	28,937	7			123	0	123	0		7
2075	49	28,937	6			123	0	123	0		6
2076	50	28,937	5			123	0	123	0		5
		1,446,833	36,023	42,415	25,271	7,242	564	49,657	25,835		10,189
		EIRR	$\Sigma(B - C)/\Sigma(1 + io)^{t-1}=0$		0.174						
		NPV	$\Sigma(B - C)/\Sigma(1 + i)^{t-1}$		10,189						
		B/C	$\Sigma(B/(1 + i)^{t-1})/\Sigma(C/(1 + i)^{t-1})$		1.4						

ANNEX Table 4.5.23 Cash Flow （Case⑩ Alternative Plan B-1)

(10^{6}PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,389	4,389	13	13	4,402	4,402		-4,402
2015				4,389	3,817	26	22	4,415	3,839		-3,839
2016				4,389	3,319	38	29	4,428	3,348		-3,348
2017				7,756	5,100	61	40	7,817	5,140		-5,140
2018				3,367	1,925	71	40	3,437	1,965		-1,965
2019				3,367	1,674	80	40	3,447	1,714		-1,714
2020				3,367	1,456	90	39	3,457	1,495		-1,495
2021				3,367	1,266	100	38	3,467	1,303		-1,303
2022				3,367	1,101	110	36	3,477	1,137		-1,137
2023				891	253	112	32	1,003	285		-285
2024				891	220	115	28	1,006	249		-249
2025				891	191	118	25	1,008	217		-217
2026				891	166	120	22	1,011	189		-189
2027	1	28,937	4,703			120	20	120	20		4,683
2028	2	28,937	4,090			120	17	120	17		4,073
2029	3	28,937	3,556			120	15	120	15		3,541
2030	4	28,937	3,092			120	13	120	13		3,079
2031	5	28,937	2,689			120	11	120	11		2,678
2032	6	28,937	2,338			120	10	120	10		2,329
2033	7	28,937	2,033			120	8	120	8		2,025
2034	8	28,937	1,768			120	7	120	7		1,761
2035	9	28,937	1,537			120	6	120	6		1,531
2036	10	28,937	1,337			120	6	120	6		1,331
2037	11	28,937	1,163			120	5	120	5		1,158
2038	12	28,937	1,011			120	4	120	4		1,007
2039	13	28,937	879			120	4	120	4		875
2040	14	28,937	764			120	3	120	3		761
2041	15	28,937	665			120	3	120	3		662
2042	16	28,937	578			120	2	120	2		576
2043	17	28,937	503			120	2	120	2		500
2044	18	28,937	437			120	2	120	2		435
2045	19	28,937	380			120	2	120	2		378
2046	20	28,937	330			120	1	120	1		329
2047	21	28,937	287			120	1	120	1		286
2048	22	28,937	250			120	1	120	1		249
2049	23	28,937	217			120	1	120	1		216
2050	24	28,937	189			120	1	120	1		188
2051	25	28,937	164			120	1	120	1		164
2052	26	28,937	143			120	1	120	1		142
2053	27	28,937	124			120	1	120	1		124
2054	28	28,937	108			120	0	120	0		108
2055	29	28,937	94			120	0	120	0		94
2056	30	28,937	82			120	0	120	0		81
2057	31	28,937	71			120	0	120	0		71
2058	32	28,937	62			120	0	120	0		62
2059	33	28,937	54			120	0	120	0		53
2060	34	28,937	47			120	0	120	0		47
2061	35	28,937	41			120	0	120	0		40
2062	36	28,937	35			120	0	120	0		35
2063	37	28,937	31			120	0	120	0		31
2064	38	28,937	27			120	0	120	0		27
2065	39	28,937	23			120	0	120	0		23
2066	40	28,937	20			120	0	120	0		20
2067	41	28,937	18			120	0	120	0		17
2068	42	28,937	15			120	0	120	0		15
2069	43	28,937	13			120	0	120	0		13
2070	44	28,937	12			120	0	120	0		11
2071	45	28,937	10			120	0	120	0		10
2072	46	28,937	9			120	0	120	0		9
2073	47	28,937	8			120	0	120	0		8
2074	48	28,937	7			120	0	120	0		7
2075	49	28,937	6			120	0	120	0		6
2076	50	28,937	5			120	0	120	0		5
		1,446,833	36,023	41,321	24,877	7,067	555	48,388	25,432		10,591
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.175						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		10,591						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.4						

ANNEX Table 4.5.24 Cash Flow （Case⑪ Alternative Plan B-2-1)

(10^6PESOS)

Year		BENEFIT								B/C	B-c
		①	②	③	④	⑤	⑥	⑦	⑧		
		BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
2014				4,389	4,389	13	13	4,402	4,402		-4,402
2015				4,389	3,817	26	22	4,415	3,839		-3,839
2016				4,389	3,319	38	29	4,428	3,348		-3,348
2017				8,131	5,346	62	41	8,193	5,387		-5,387
2018				3,742	2,139	73	42	3,815	2,181		-2,181
2019				3,742	1,860	84	42	3,826	1,902		-1,902
2020				3,742	1,618	95	41	3,837	1,659		-1,659
2021				3,742	1,407	106	40	3,847	1,446		-1,446
2022				3,742	1,223	116	38	3,858	1,261		-1,261
2023				1,022	290	119	34	1,141	324		-324
2024				1,022	253	122	30	1,144	283		-283
2025				1,022	220	125	27	1,147	247		-247
2026				1,022	191	128	24	1,150	215		-215
2027	1	28,937	4,703			128	21	128	21		4,682
2028	2	28,937	4,090			128	18	128	18		4,071
2029	3	28,937	3,556			128	16	128	16		3,540
2030	4	28,937	3,092			128	14	128	14		3,079
2031	5	28,937	2,689			128	12	128	12		2,677
2032	6	28,937	2,338			128	10	128	10		2,328
2033	7	28,937	2,033			128	9	128	9		2,024
2034	8	28,937	1,768			128	8	128	8		1,760
2035	9	28,937	1,537			128	7	128	7		1,531
2036	10	28,937	1,337			128	6	128	6		1,331
2037	11	28,937	1,163			128	5	128	5		1,157
2038	12	28,937	1,011			128	4	128	4		1,006
2039	13	28,937	879			128	4	128	4		875
2040	14	28,937	764			128	3	128	3		761
2041	15	28,937	665			128	3	128	3		662
2042	16	28,937	578			128	3	128	3		575
2043	17	28,937	503			128	2	128	2		500
2044	18	28,937	437			128	2	128	2		435
2045	19	28,937	380			128	2	128	2		378
2046	20	28,937	330			128	1	128	1		329
2047	21	28,937	287			128	1	128	1		286
2048	22	28,937	250			128	1	128	1		249
2049	23	28,937	217			128	1	128	1		216
2050	24	28,937	189			128	1	128	1		188
2051	25	28,937	164			128	1	128	1		164
2052	26	28,937	143			128	1	128	1		142
2053	27	28,937	124			128	1	128	1		124
2054	28	28,937	108			128	0	128	0		108
2055	29	28,937	94			128	0	128	0		94
2056	30	28,937	82			128	0	128	0		81
2057	31	28,937	71			128	0	128	0		71
2058	32	28,937	62			128	0	128	0		61
2059	33	28,937	54			128	0	128	0		53
2060	34	28,937	47			128	0	128	0		46
2061	35	28,937	41			128	0	128	0		40
2062	36	28,937	35			128	0	128	0		35
2063	37	28,937	31			128	0	128	0		31
2064	38	28,937	27			128	0	128	0		27
2065	39	28,937	23			128	0	128	0		23
2066	40	28,937	20			128	0	128	0		20
2067	41	28,937	18			128	0	128	0		17
2068	42	28,937	15			128	0	128	0		15
2069	43	28,937	13			128	0	128	0		13
2070	44	28,937	12			128	0	128	0		11
2071	45	28,937	10			128	0	128	0		10
2072	46	28,937	9			128	0	128	0		9
2073	47	28,937	8			128	0	128	0		8
2074	48	28,937	7			128	0	128	0		7
2075	49	28,937	6			128	0	128	0		6
2076	50	28,937	5			128	0	128	0		5
		1,446,833	36,023	44,096	26,073	7,523	582	51,619	26,654		9,369
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.172						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		9,369						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.4						

ANNEX Table 4.5.25 Cash Flow （Case⑫ Alternative Plan B-3)

(10^6PESOS)

	BENEFIT									
	①	②	③	④	⑤	⑥	⑦	⑧	B/C	B-c
	BENEFIT	PRESENT VALUE	COST	PRESENT VALUE	MAINTENANCE	PRESENT VALUE	COST	PRESENT VALUE		
			4,389	4,389	13	13	4,402	4,402		-4,402
			4,389	3,817	26	22	4,415	3,839		-3,839
			4,389	3,319	38	29	4,428	3,348		-3,348
			8,279	5,444	62	41	8,341	5,485		-5,485
			3,890	2,224	74	42	3,963	2,266		-2,266
			3,890	1,934	85	42	3,975	1,976		-1,976
			3,890	1,682	96	42	3,986	1,723		-1,723
			3,890	1,462	108	40	3,997	1,503		-1,503
			3,890	1,272	119	39	4,009	1,310		-1,310
			930	264	122	35	1,052	299		-299
			930	230	124	31	1,054	261		-261
			930	200	127	27	1,057	227		-227
			930	174	130	24	1,060	198		-198
1	28,937	4,703			130	21	130	21		4,682
2	28,937	4,090			130	18	130	18		4,071
3	28,937	3,556			130	16	130	16		3,540
4	28,937	3,092			130	14	130	14		3,078
5	28,937	2,689			130	12	130	12		2,677
6	28,937	2,338			130	10	130	10		2,328
7	28,937	2,033			130	9	130	9		2,024
8	28,937	1,768			130	8	130	8		1,760
9	28,937	1,537			130	7	130	7		1,531
10	28,937	1,337			130	6	130	6		1,331
11	28,937	1,163			130	5	130	5		1,157
12	28,937	1,011			130	5	130	5		1,006
13	28,937	879			130	4	130	4		875
14	28,937	764			130	3	130	3		761
15	28,937	665			130	3	130	3		662
16	28,937	578			130	3	130	3		575
17	28,937	503			130	2	130	2		500
18	28,937	437			130	2	130	2		435
19	28,937	380			130	2	130	2		378
20	28,937	330			130	1	130	1		329
21	28,937	287			130	1	130	1		286
22	28,937	250			130	1	130	1		249
23	28,937	217			130	1	130	1		216
24	28,937	189			130	1	130	1		188
25	28,937	164			130	1	130	1		164
26	28,937	143			130	1	130	1		142
27	28,937	124			130	1	130	1		124
28	28,937	108			130	0	130	0		108
29	28,937	94			130	0	130	0		94
30	28,937	82			130	0	130	0		81
31	28,937	71			130	0	130	0		71
32	28,937	62			130	0	130	0		61
33	28,937	54			130	0	130	0		53
34	28,937	47			130	0	130	0		46
35	28,937	41			130	0	130	0		40
36	28,937	35			130	0	130	0		35
37	28,937	31			130	0	130	0		31
38	28,937	27			130	0	130	0		27
39	28,937	23			130	0	130	0		23
40	28,937	20			130	0	130	0		20
41	28,937	18			130	0	130	0		17
42	28,937	15			130	0	130	0		15
43	28,937	13			130	0	130	0		13
44	28,937	12			130	0	130	0		11
45	28,937	10			130	0	130	0		10
46	28,937	9			130	0	130	0		9
47	28,937	8			130	0	130	0		8
48	28,937	7			130	0	130	0		7
49	28,937	6			130	0	130	0		6
50	28,937	5			130	0	130	0		5
	1,446,833	36,023	44,616	26,410	7,616	589	52,231	26,999		9,024
	EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.171						
	NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		9,024						

ANNEX Table 4.5.26 Cash Flow （Case⑬ Alternative Plan B-2-2)

$(10^6 PESOS)$

Year		BENEFIT ① BENEFIT	② PRESENT VALUE	③ COST	④ PRESENT VALUE	⑤ MAINTENANCE	⑥ PRESENT VALUE	⑦ COST	⑧ PRESENT VALUE	B/C	B-c
2014				4,389	4,389	13	13	4,402	4,402		-4,402
2015				4,389	3,817	26	22	4,415	3,839		-3,839
2016				4,389	3,319	38	29	4,428	3,348		-3,348
2017				8,299	5,457	62	41	8,362	5,498		-5,498
2018				3,910	2,236	74	42	3,984	2,278		-2,278
2019				3,910	1,944	85	42	3,995	1,986		-1,986
2020				3,910	1,690	97	42	4,007	1,732		-1,732
2021				3,910	1,470	108	41	4,018	1,511		-1,511
2022				3,910	1,278	119	39	4,029	1,317		-1,317
2023				1,022	290	122	35	1,144	325		-325
2024				1,022	253	125	31	1,147	284		-284
2025				1,022	220	128	28	1,150	247		-247
2026				1,022	191	131	25	1,153	216		-216
2027	1	28,937	4,703			131	21	131	21		4,682
2028	2	28,937	4,090			131	19	131	19		4,071
2029	3	28,937	3,556			131	16	131	16		3,540
2030	4	28,937	3,092			131	14	131	14		3,078
2031	5	28,937	2,689			131	12	131	12		2,677
2032	6	28,937	2,338			131	11	131	11		2,328
2033	7	28,937	2,033			131	9	131	9		2,024
2034	8	28,937	1,768			131	8	131	8		1,760
2035	9	28,937	1,537			131	7	131	7		1,530
2036	10	28,937	1,337			131	6	131	6		1,331
2037	11	28,937	1,163			131	5	131	5		1,157
2038	12	28,937	1,011			131	5	131	5		1,006
2039	13	28,937	879			131	4	131	4		875
2040	14	28,937	764			131	3	131	3		761
2041	15	28,937	665			131	3	131	3		662
2042	16	28,937	578			131	3	131	3		575
2043	17	28,937	503			131	2	131	2		500
2044	18	28,937	437			131	2	131	2		435
2045	19	28,937	380			131	2	131	2		378
2046	20	28,937	330			131	1	131	1		329
2047	21	28,937	287			131	1	131	1		286
2048	22	28,937	250			131	1	131	1		249
2049	23	28,937	217			131	1	131	1		216
2050	24	28,937	189			131	1	131	1		188
2051	25	28,937	164			131	1	131	1		164
2052	26	28,937	143			131	1	131	1		142
2053	27	28,937	124			131	1	131	1		124
2054	28	28,937	108			131	0	131	0		108
2055	29	28,937	94			131	0	131	0		94
2056	30	28,937	82			131	0	131	0		81
2057	31	28,937	71			131	0	131	0		71
2058	32	28,937	62			131	0	131	0		61
2059	33	28,937	54			131	0	131	0		53
2060	34	28,937	47			131	0	131	0		46
2061	35	28,937	41			131	0	131	0		40
2062	36	28,937	35			131	0	131	0		35
2063	37	28,937	31			131	0	131	0		31
2064	38	28,937	27			131	0	131	0		27
2065	39	28,937	23			131	0	131	0		23
2066	40	28,937	20			131	0	131	0		20
2067	41	28,937	18			131	0	131	0		17
2068	42	28,937	15			131	0	131	0		15
2069	43	28,937	13			131	0	131	0		13
2070	44	28,937	12			131	0	131	0		11
2071	45	28,937	10			131	0	131	0		10
2072	46	28,937	9			131	0	131	0		9
2073	47	28,937	8			131	0	131	0		8
2074	48	28,937	7			131	0	131	0		7
2075	49	28,937	6			131	0	131	0		6
2076	50	28,937	5			131	0	131	0		5
		1,446,833	36,023	45,105	26,554	7,692	592	52,797	27,146		8,877
		EIRR	$\Sigma(B-C)/\Sigma(1+io)^{t-1}=0$		0.171						
		NPV	$\Sigma(B-C)/\Sigma(1+i)^{t-1}$		8,877						
		B/C	$\Sigma(B/(1+i)^{t-1})/\Sigma(C/(1+i)^{t-1})$		1.3						

APPENDIX Ⅲ： Technical Working Group Material

September 6, 2013

Japan International Cooperation Agency

Department of Public Works and Highway (DPWH)

DATA COLLECTION SURVEY ON FLOOD MANAGEMENT PLAN IN METRO MANILA

Summary of Draft Final Report

September , 2013

Yachiyo Engineering Co., Ltd.

1

OBJECTIVE

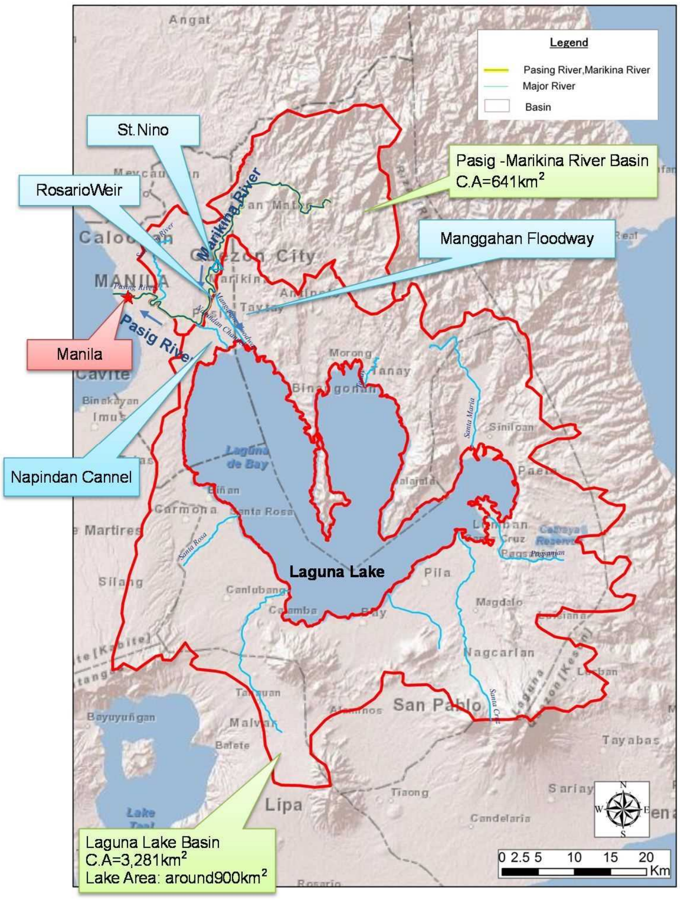
- To re-examine the technical validity of the proposed structural measures in Pasig-Marikina River Basin under the WB Study
- by utilizing the hydrological and hydrodynamic flood simulation model which is to be refined and updated with appropriately selected dataset
- in consideration of the future climate change;
- thereby bridging the concept planning and the actual implementation of projects.

FRAMEWORK

- Counterpart in Philippines Side: DPWH
- Study Area: Pasig-Marikina River Basin & Laguna Lake Basin

2

STUDY AREA



3

WORK FLOW

1.Data Collection
- Topography (LiDAR Data)
- Landuse, Soil, Vegetation
- Hydrological Data
- Flood Disaster Record

→

2.Establishment of Flood Analysis Model
- Runoff Model (WEB-DHM)
- River Hydraulic Model
- Inundation Analysis Model

→ **Verification of Model**

↓

3.a Exam of Rainfall Analysis Results

↓

3.b Basic Design Discharge

3.c Planning Conditions

↓

3.d Design Flood Discharge & WL

↔ **4. WL Fluctuation Analysis in Laguna Lake**
- Validity of Reverse Flow
- Inflow from Manggaran to Lake ⇒ WL Fluctuation

↓

3.e Validity of Proposed Measures

↓

5.Climate Change Effect
- Change of Safety Degree
- Adaptation Measures

4

1. Comparison with WB Study

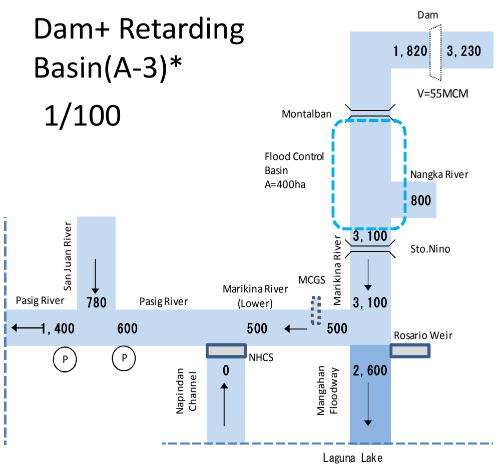
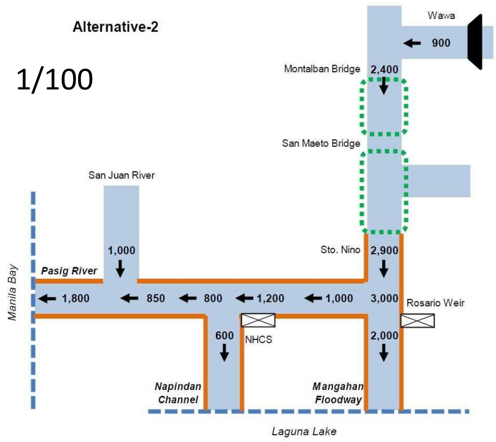
1-1 Floods Utilized for Anlaysis

- In this Study, 7 observed floods including Typhoon Ondoy are selected while the WB selected only Typhoon Ondoy.

	This Study	WB
Design Hyetograph	7 Actual Hyetograph (including Ondoy)＋Middle-peak Fictional Hyetograph	Ondoy ＋Middle-peak Fictional Hyetograph
Rainfall Duration	1day	2days
Design Rainfall	1/100:285.5mm/day	1/100:439mm/2days (Marikina Basin)
Period of Rainfall Analysis	1951-2012 (6 Stations)	1976-2010 (6 Stations)

1-2 Proposed Project Components

- 1/100 Flood Discharge Allocation(Comparison with WB Study)

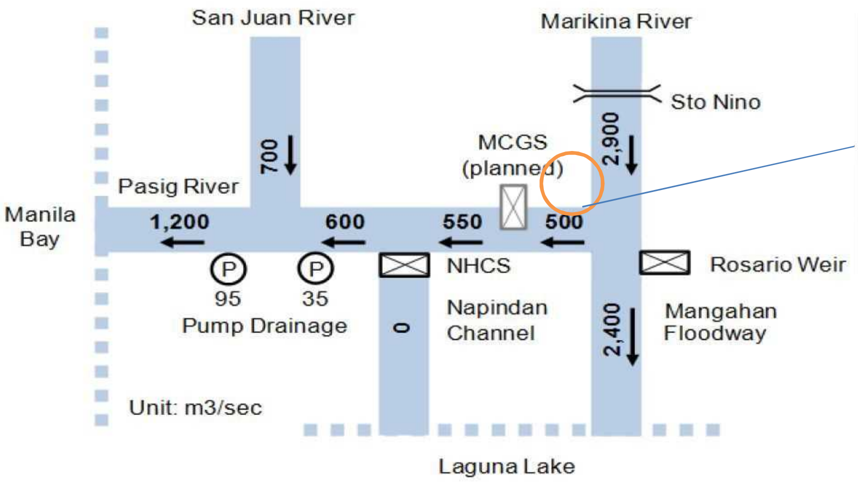
	This Study	WB : Alternative-2
Flood Discharge Allocation	Dam+ Retarding Basin(A-3)* 1/100 	
Phase II, III	No change	To need re-improve Pasig River, Lower Marikina River, Napindan Channel
Phase IV	Almost No change	Without MCGS

Phase II, III: without MCGS and San Juan River Improvement
Phase IV: Existing project components
*One of Alternatives

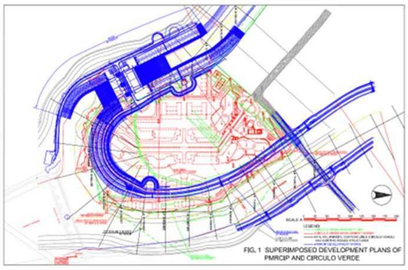
2. Phase IV Components

2-1 Consideration of Urban Development along Marikina River

- **Discharge Allocation for PMRCIP Project (1/30：as of 2002)**
  - Urban Development Project is on-going and changes river section near Rosario. However, it can be adjusted by Phase IV Project.



Source: Preparatory Survey on Pasig-Marikina River Channel Improvement Project (Phase III) (JICA/DPWH,2011)



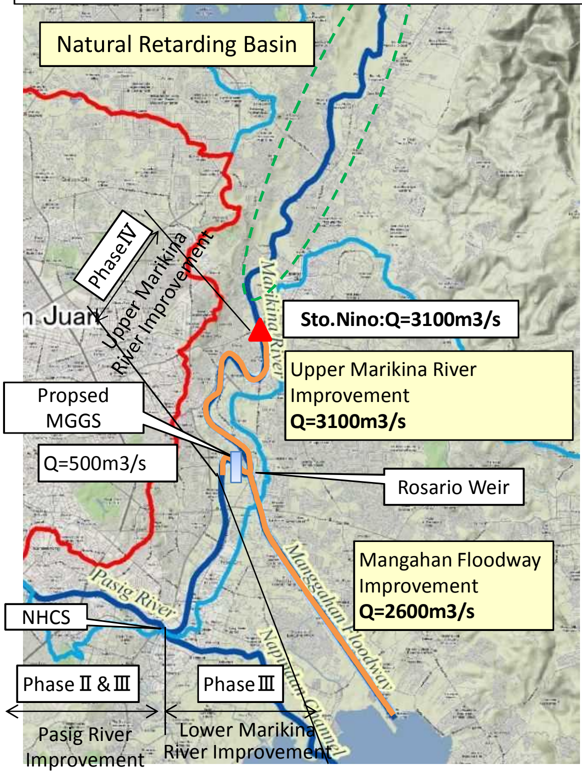
2. Phase IV Components

2-2 Basic Design Discharge of 1/30 Years Flood

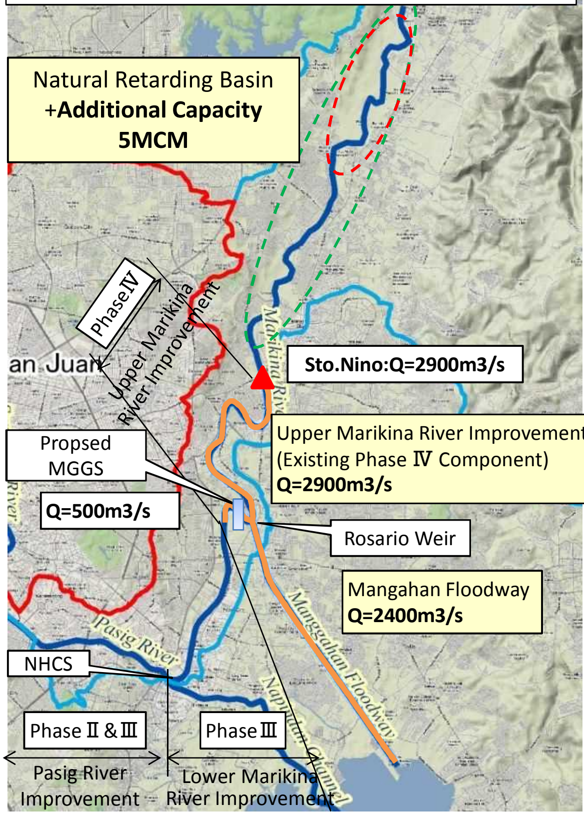
	D/D 2002(1/30 as of 2002)	This Study(1/30 as of 2013)
Design Hyetograph	Middle-peak Fictional Hyetograph	7 Actual Hyetograph (including Ondoy)＋Middle-peak Fictional Hyetograph（Maximum:Ondoy）
Design Rainfall	1/30 :401mm/2days (Period of Rainfall Analysis:1903-1999, 1 Station)	1/30：232.4mm/day (Period of Rainfall Analysis:1951-2012,6 Stations)
Flood Analysis Model	Lumped System Model Storage Function Model Quasi-Linear Model	Distributed System Model River Basin :WEB-DHM Model River Course: 1-D Unsteady Flow Model Flood plain: 2-D Unsteady Flow Model
Basic Design Discharge	**Sto.Nino:2,900m3/s**	**Sto.Nino:3,100m3/s** （With Retarding Function）

2-3 Flood Management Measures for 1/30 Years Flood

Phase IV with Heightening + Improvement of Manggahan Floodway



Improvement of Retarding Basin



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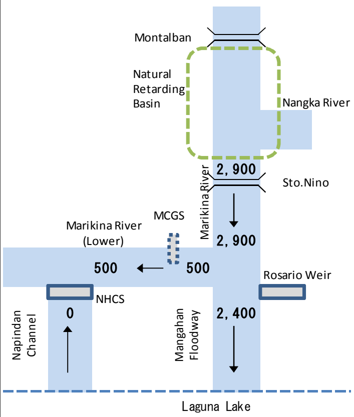
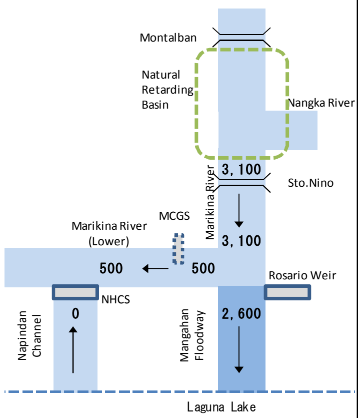
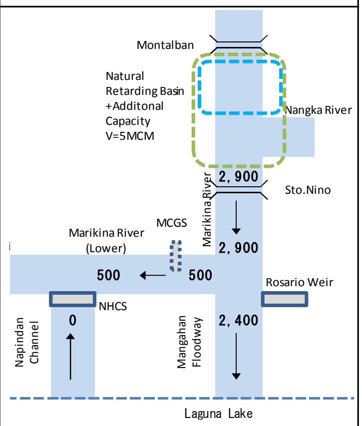
2. Phase IV Components

2-4 Alternatives Phase IV Components

	O: Phase IV Only	A: Phase IV + Manggahan FW	B: Phase IV + Retarding Basin
Sto.Nino	2900m3/s 1/30 (as of 2002)	3100m3/s 1/30(as of 2013)	2900m3/s 1/30(as of 2013)
Discharge Allocation			
Phase IV Section	Original Components	Heightening of Dyke 0.5m + Improvement of Manggahan FW	Original Components
Upstream of Phase IV Section	Current Natural Ret. Basin	Current Natural Ret. Basin	Natural + Enhancement V=5MCM

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2-5 Flood Management Measures for 1/100 Years Flood

- **Phased Improvement Scenario**

- 1/100 Years Flood Management by “Dam” or “Dam + Retarding Basin”
- “Dam + Retarding Basin” can be implemented stepwise.

1/100
・Dam+NRB
・Dam
・Dam+RB

1/30+α
・RB

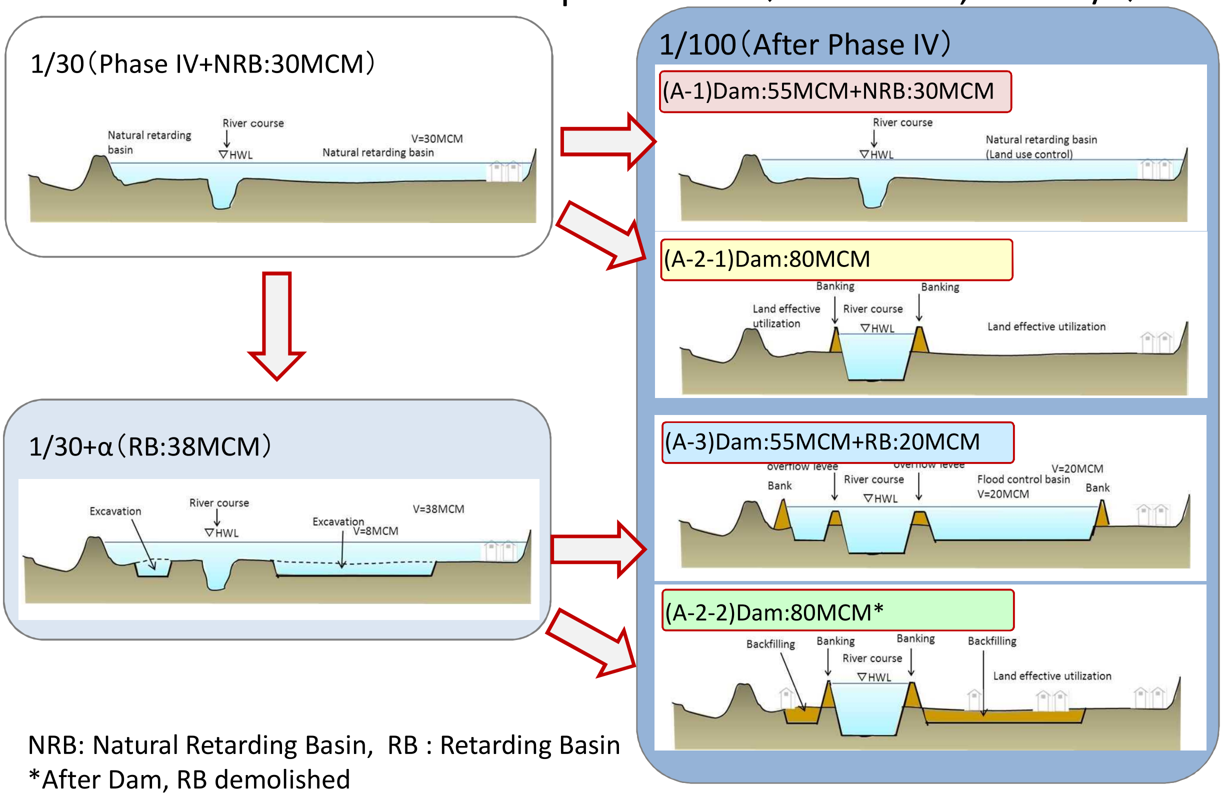
1/30（Phase IV）

・O:Original Phase IV Component +NRB
・A:O+Hightenning Dyke ＋Manggahan Floodway Improvement
・B:Original Phase IV Component +RB

NRB: Natural Retarding Basin
RB : Retarding Basin

2-5 Development Scenarios for 1/100 Years Flood Management

- **Alternatives for Phased Improvement（Sto.Nino:3,100m3/s）**



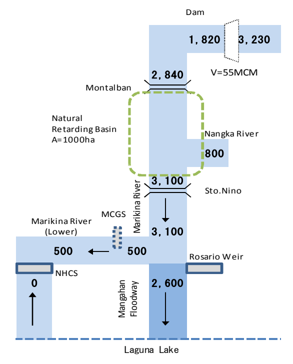
NRB: Natural Retarding Basin, RB : Retarding Basin
*After Dam, RB demolished

2-5 Development Scenarios for 1/100 Years Flood Management

- Alternatives for 1/100 Years Flood Management Measures (Sto.Nino:3,100m3/s)

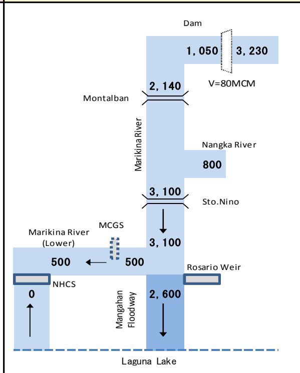
1/30 : Phase IV	1/30＋α : After Phase IV	1/100:After Phase IV
(A)PhaseIV Component + NRB:30MCM + Manggahan Floodway Improvement Sto.Nino :3,100m3/s MF :2,600m3/s MCGS : 500m3/s		(A-1)Dam:55MCM+NRB:30MCM (A-2-1)Dam:80MCM
	RB:38MCM	(A-3)Dam:55MCM+RB:20MCM (A-2-2)Dam:80MCM*

(A-1) Dam & NRB



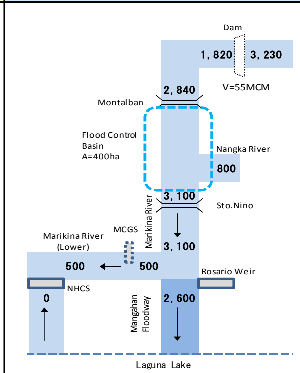
Dam : V=55MCM
NRB : V=30MCM
A=1000ha

(A-2-1) Dam



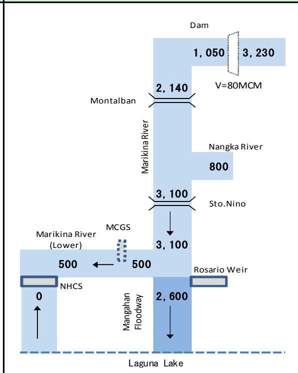
Dam: V=80MCM
RB : —

(A-3) Dam & RB



Dam : V=55MCM
RB : V=20MCM
A=400ha

(A-2-2) Dam*



Dam: V=80MCM
RB : —

NRB: Natural Retarding Basin , RB : Retarding Basin *After Dam, RB demolished

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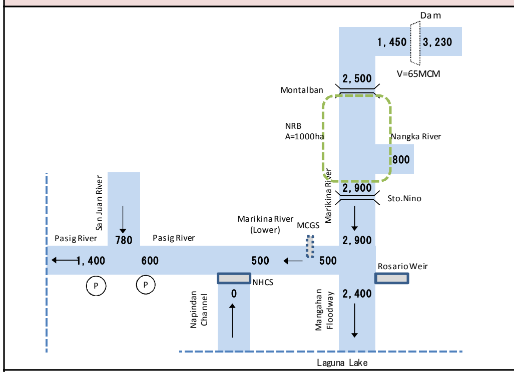
2-5 Development Scenarios for 1/100 Years Flood Management

- Alternatives for 1/100 Years Flood Management Measures (Sto.Nino:2,900m3/s)

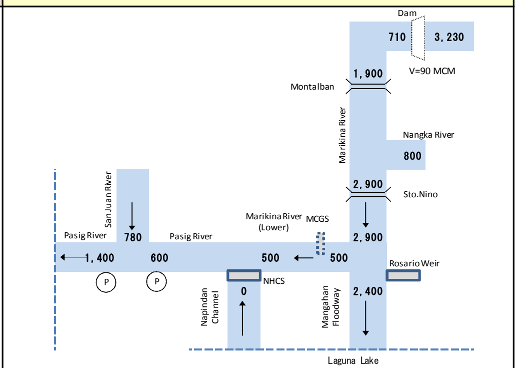
1/30 : Phase IV	1/30＋α : After Phase IV	1/100:After Phase IV
(O)PhaseIV Component + NRB:30MCM Sto.Nino :2,900m3/s MF :2,400m3/s MCGS : 500m3/s		(O-1)Dam:65MCM+NRB:30MCM (O-2)Dam:90MCM

(O-1) Dam & NRB



Dam : V=55MCM
NRB : V=30MCM
A=1000ha

(O-2) Dam



Dam: V=80MCM
RB : —

NRB: Natural Retarding Basin , RB : Retarding Basin *After Dam, RB demolished

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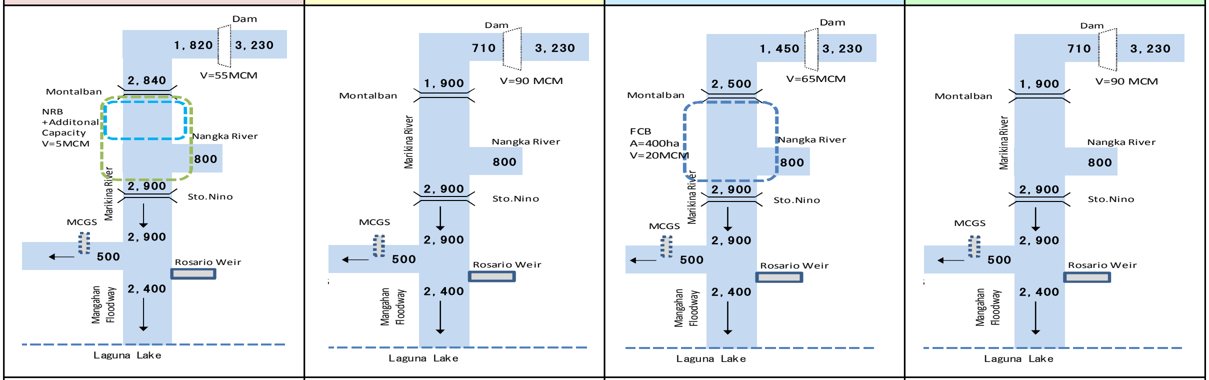
2-5 Development Scenarios for 1/100 Years Flood Management

- Alternatives for 1/100 Years Flood Management Measures（Sto.Nino:2,900m3/s）

1/30 : Phase IV	1/30＋α : After Phase IV	1/100:After Phase IV
(B)PhaseIV Component +RB:35MCM Sto.Nino :2,900m3/s MF :2,400m3/s MCGS : 500m3/s	RB:38MCM	(B-1)Dam:55MCM+RB:35MCM (B-2-1)Dam:90MCM* (B-3)Dam:65MCM+RB:20MCM (B-2-2)Dam:90MCM*

(B-1) Dam & RB	(B-2-1)Dam*	(B-3) Dam & RB	(B-2-2)Dam*
Dam : V=55MCM RB: : V=35MCM	Dam: V=90MCM RB : —	Dam : V=65MCM RB : V=20MCM A=400ha	Dam: V=90MCM RB : —



NRB: Natural Retarding Basin , RB : Retarding Basin *After Dam, RB demolished

2-5 Flood Management Measures for 1/100 Years Flood

- Phased Improvement scenario

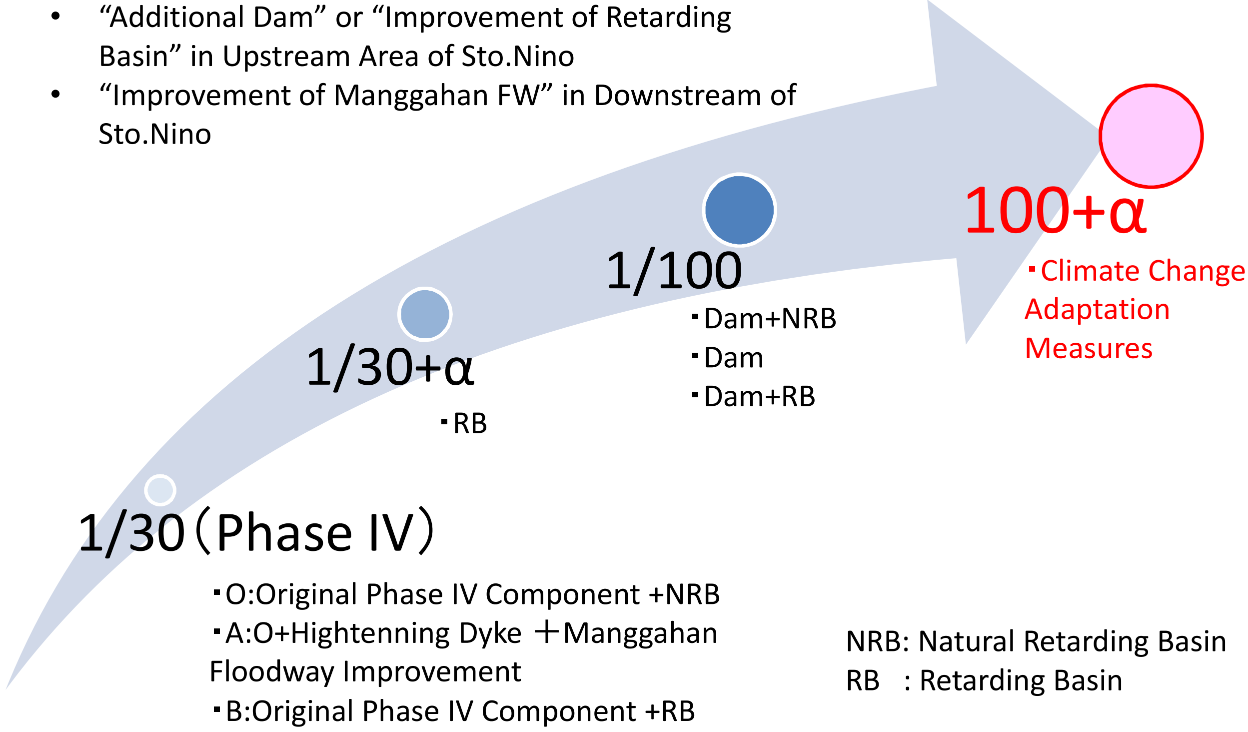
1/30 : Phase IV	1/30＋α : After Phase IV	1/100:After Phase IV
(A)PhaseIV Component + NRB:30MCM + Manggahan Floodway Improvement Sto.Nino :3,100m3/s MF :2,600m3/s MCGS : 500m3/s	RB:38MCM	(A-1)Dam:55MCM+NRB:30MCM (A-2-1)Dam:80MCM (A-3)Dam:55MCM+RB:20MCM (A-2-2)Dam:80MCM*
(O)PhaseIV Component + NRB:30MCM		(O-1)Dam:65MCM+NRB:30MCM (O-2)Dam:90MCM
(B)PhaseIV Component +RB:35MCM Sto.Nino :2,900m3/s MF :2,400m3/s MCGS : 500m3/s	RB:38MCM	(B-1)Dam:55MCM+RB:35MCM (B-2-1)Dam:90MCM* (B-3)Dam:65MCM+RB:20MCM (B-2-2)Dam:90MCM*

NRB: Natural Retarding Basin , RB : Retarding Basin *After Dam, RB demolished

3. Adaptation Measures for Climate Change

- Step Up Options of Adaptation Measures for Climate Change

- "Additional Dam" or "Improvement of Retarding Basin" in Upstream Area of Sto.Nino
- "Improvement of Manggahan FW" in Downstream of Sto.Nino



NRB: Natural Retarding Basin
RB : Retarding Basin

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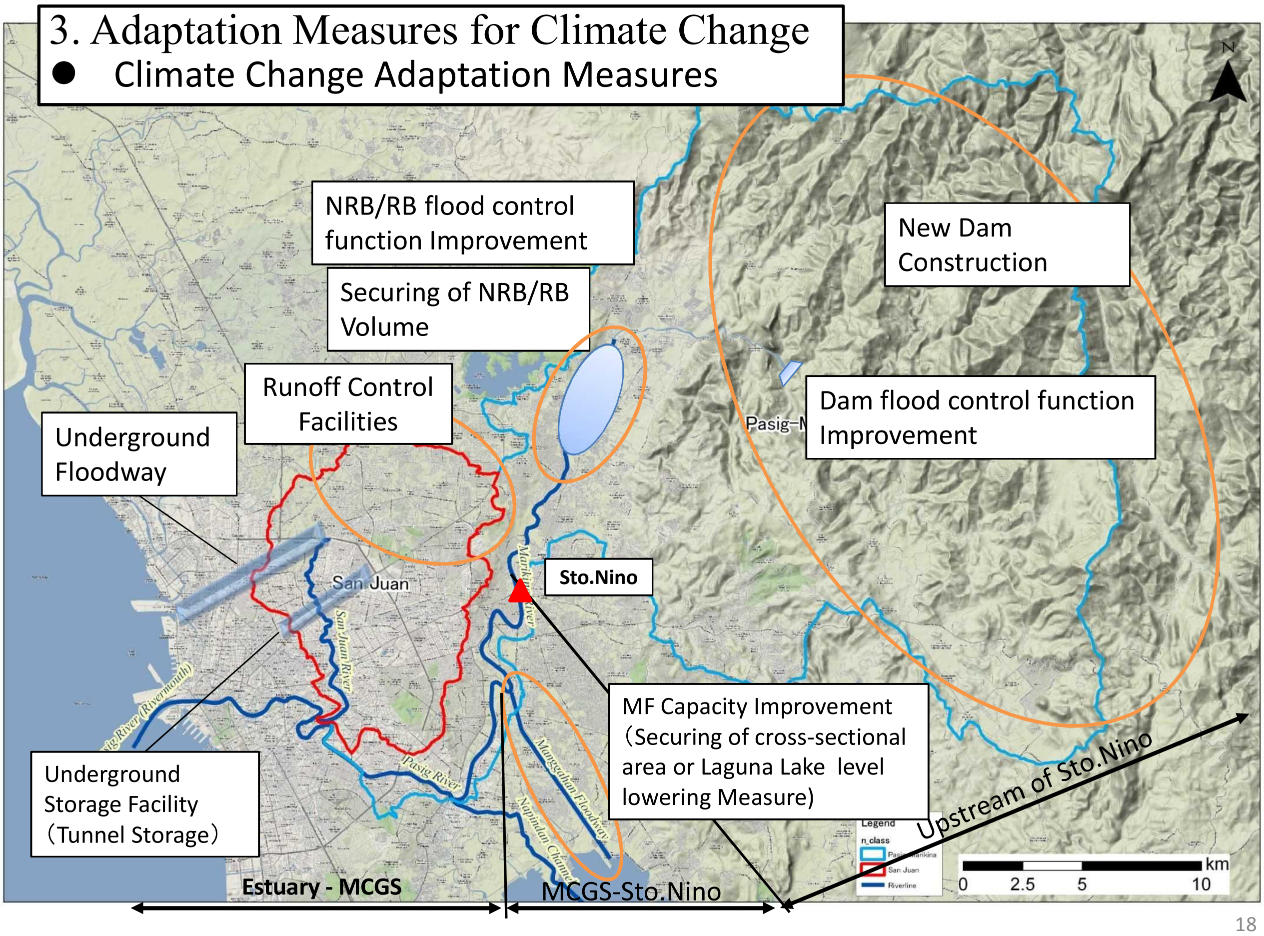
3. Adaptation Measures for Climate Change

- Climate Change Adaptation Measures



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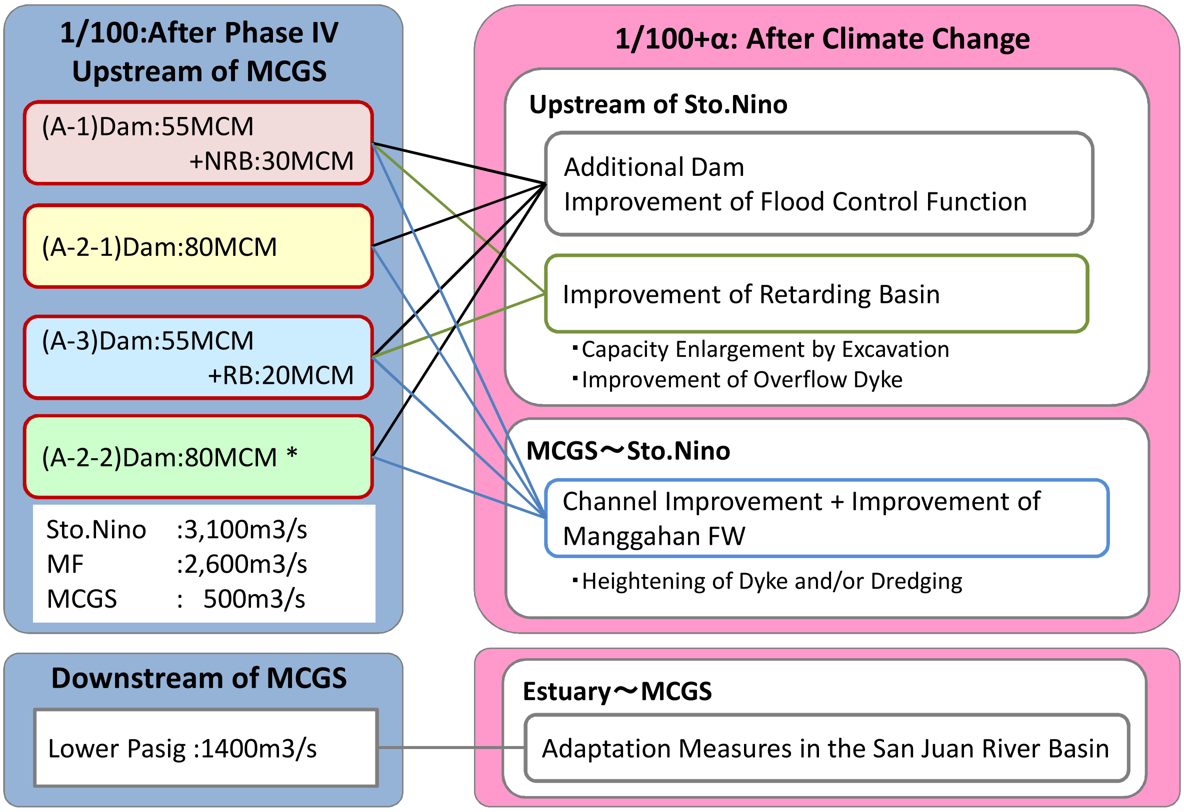
3. Adaptation Measures for Climate Change

- Climate Change Adaptation Measures



4. Points of The Study

4-1 Comparison with WB Study

（1） Floods Utilized for Analysis

- This Study selects 7 observed floods including Typhoon Ondoy.

（2） Proposed Project Components

- This Study confirmed that 1/100 years Flood Management is possible as Original Master Plan shows by putting countermeasures in Upper-Upper Marikina after completion of Phase-IV.
- This Study confirmed that large scale re-improvement in Phase I - III sections is not necessary.

4-2 Phase IV Components

- This Study proposed various alternatives of the phased development scenario to 1/100 years flood management. These alternatives are useful for selection of final optimum components.

4-3 Adaptation Measures for Climate Change

- This Study proposed various step-up options of Adaptation Measures for Climate Change. These options are useful for selection of final adaptation measures.

APPENDIX Ⅳ: Explanatory Material to Secretary
February 13, 2014

Minutes of Meeting between JICA & WB

- Both parties acknowledged the importance of proceeding with Phase IV including MCGS subject to:
  - Full timelines of processing of Phase IV and upstream measures will be prepared.
  - Subsequent studies (both Phase IV and upstream measures) will be conducted.
  - The result of those studies will be commonly used for the best optimized flood management structures within the basin.
- Decision of DPWH taking into account parameters and aspects including but not limited to economic cost, time, benefit, social and environmental aspect, protection of asset and goods, strategic political choices etc. should be the most respected.

1

Japan International Cooperation Agency

Department of Public Works and Highway (DPWH)

DATA COLLECTION SURVEY ON FLOOD MANAGEMENT PLAN IN METRO MANILA

Summary of Draft Final Report

February, 2014

Yachiyo Engineering Co., Ltd.

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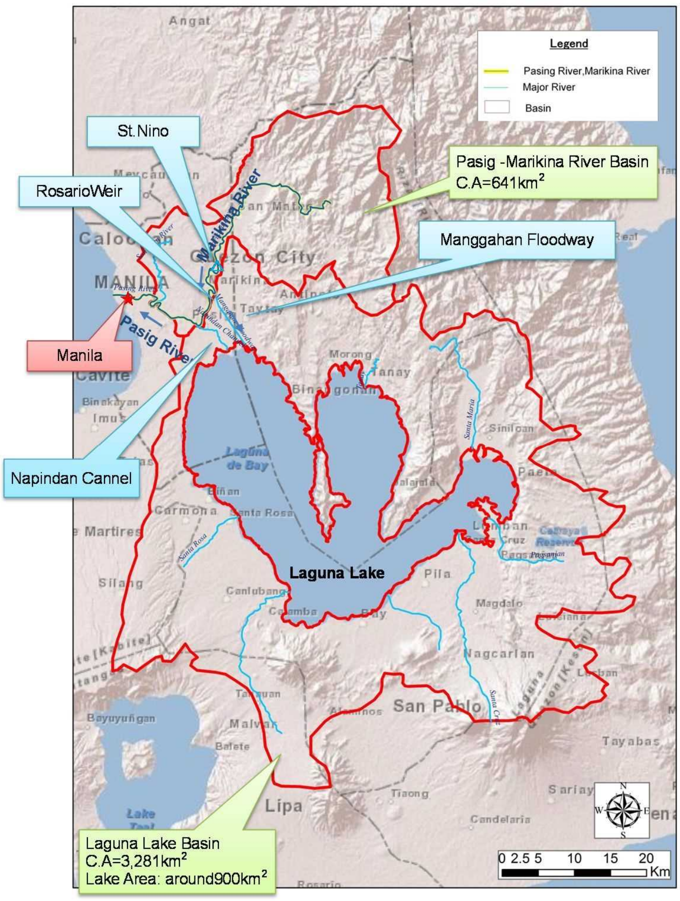
OBJECTIVE

- To re-examine the technical validity of the proposed structural measures in Pasig-Marikina River
- by utilizing the hydrological and hydrodynamic flood simulation model which is to be refined and updated with appropriately selected dataset
- in consideration of the future climate change;
- thereby bridging the concept planning and the actual implementation of projects.

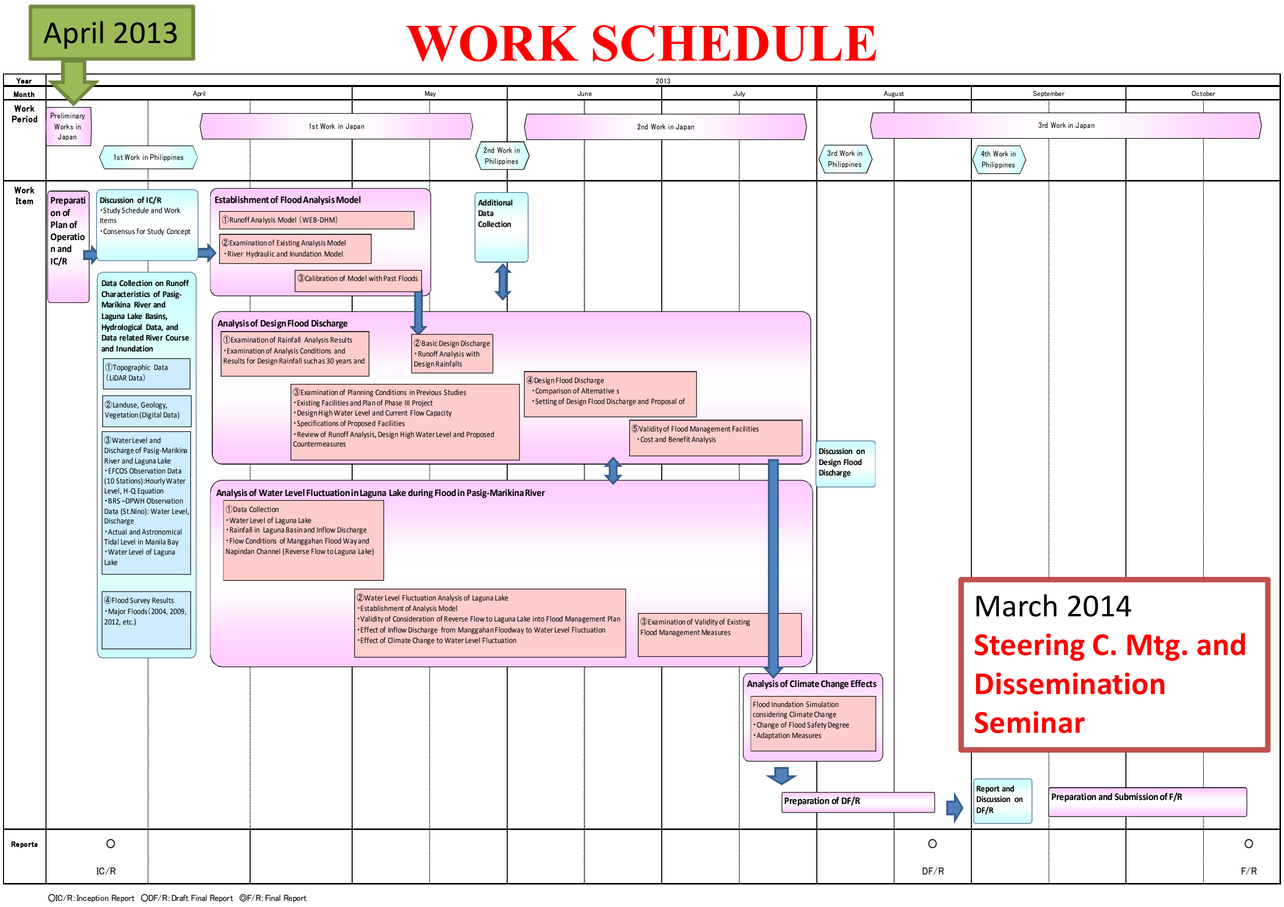
FRAMEWORK

- Counterpart in Philippines Side: DPWH
- Study Area: Pasig-Marikina River Basin & Laguna Lake Basin

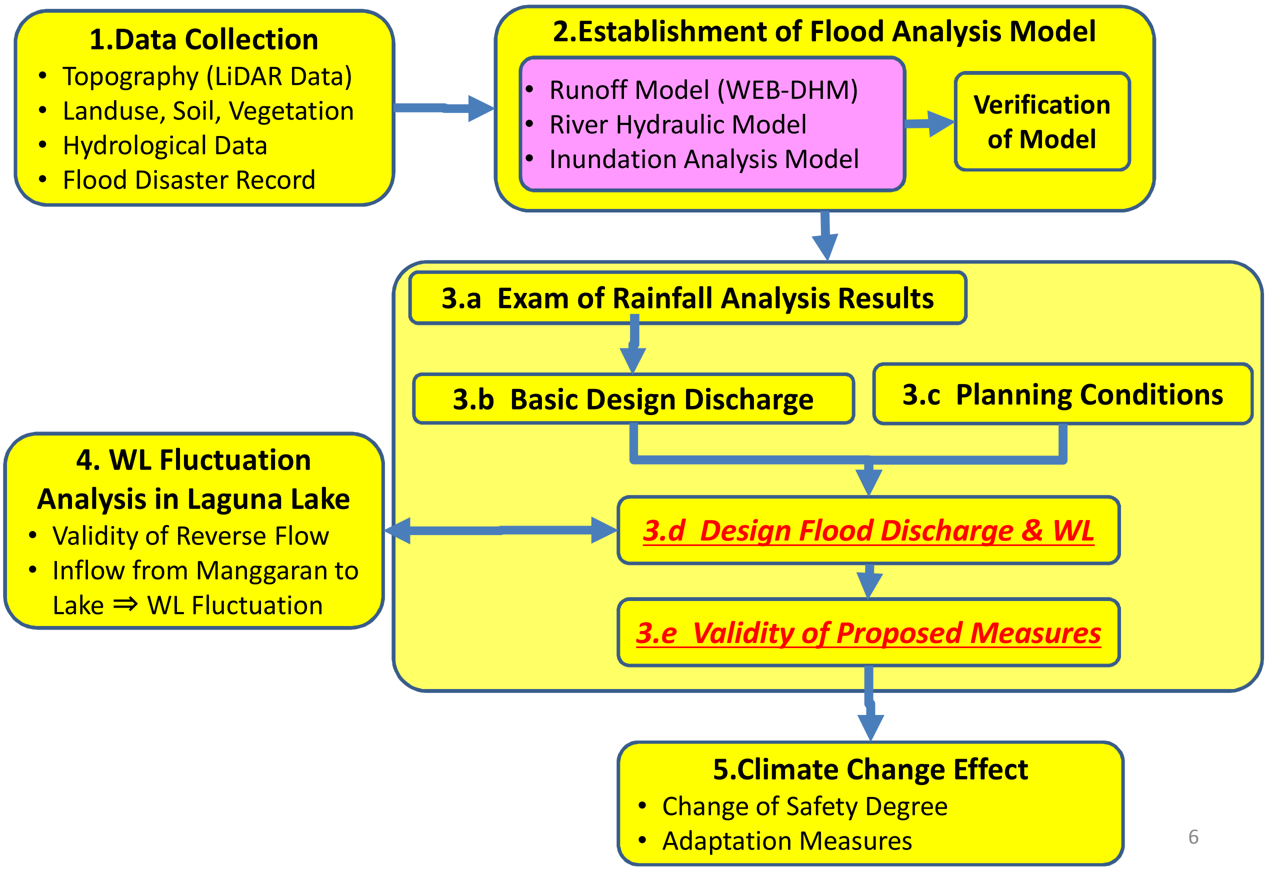
STUDY AREA



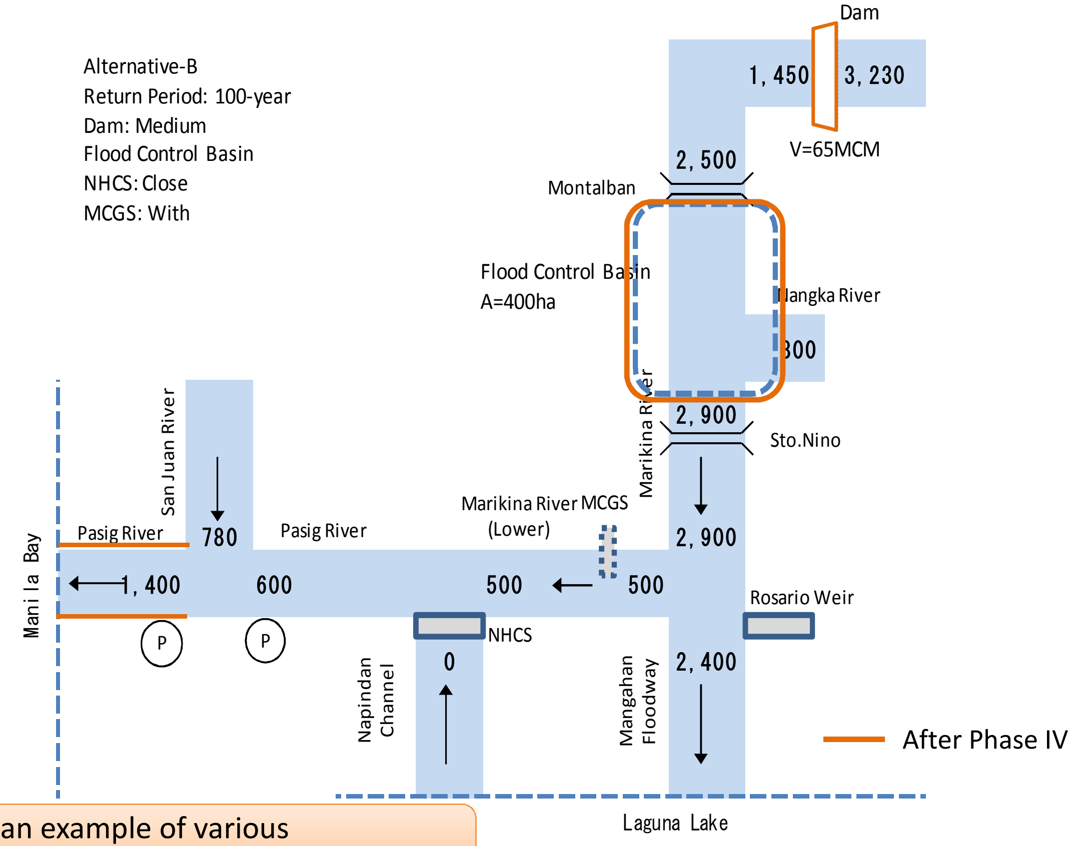
WORK SCHEDULE



WORK FLOW



6.Proposed Discharge Allocation of this Study (1/100 scale, plan B-3*)



*This is just an example of various improvement scenario proposed in this study.

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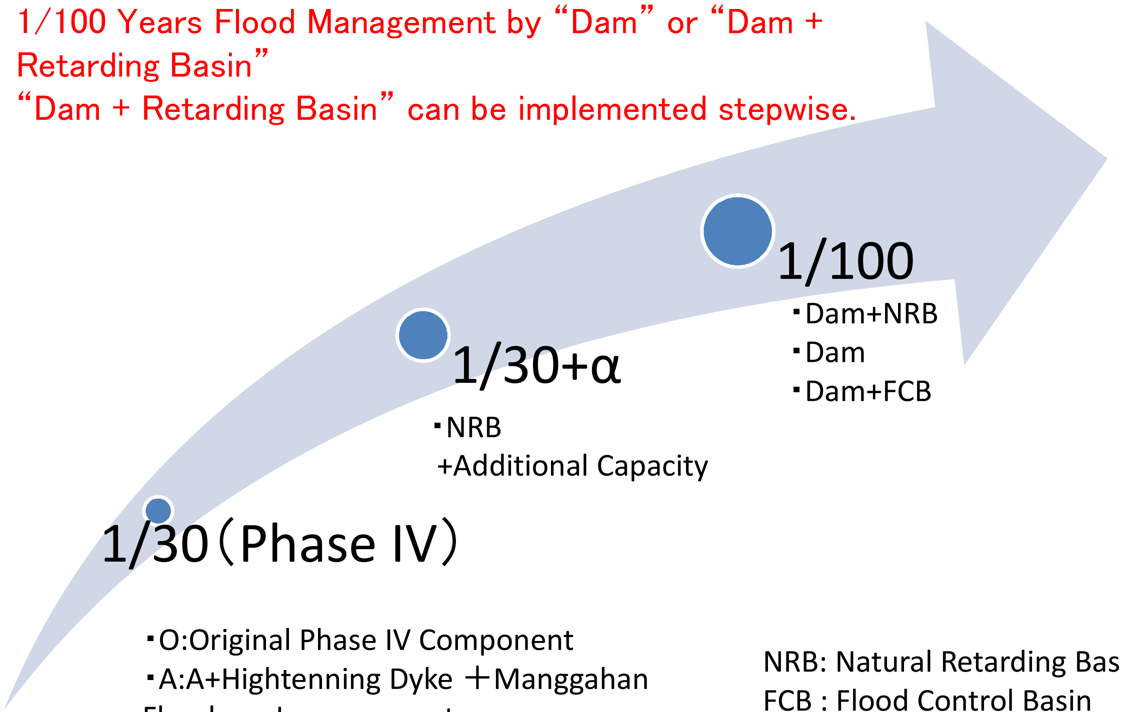
2-5 Flood Management Measures for 1/100 Years Flood

- Phased Improvement Scenario

- 1/100 Years Flood Management by "Dam" or "Dam + Retarding Basin"
- "Dam + Retarding Basin" can be implemented stepwise.



・O:Original Phase IV Component
・A:A+Hightenning Dyke ＋Manggahan Floodway Improvement
・B:A+NRB+Additional Capacity

NRB: Natural Retarding Basin
FCB : Flood Control Basin

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2-5 100年洪水への対応確認

- Phased development scenario

1/30 : Phase IV	1/30＋α : After Phase IV	1/100:After Phase IV
(A)PhaseIV Component + NRB + Manggahan Floodway Improvement		(A-1)Dam:55MCM+NRB
		(A-2-1)Dam:80MCM
	NRB+ Additional Capacity 5MCM	(A-3)Dam:55MCM +FCB20MCM
		(A-2-2)Dam:80MCM
Sto.Nino :3100m3/s MF :2600m3/s MCGS :500m3/s		

	1/30＋α : After Phase IV	
(O)PhaseIV Component + NRB		(O-1)Dam:65MCM+NRB
		(O-2)Dam:90MCM
(B)PhaseIV Component + NRB + Additional Capacity 5MCM		(B-1)Dam:65MCM+NRB +Additional Capacity 5MCM
		(B-2-1)Dam:80MCM
	NRB+ Additional Capacity 8MCM	(B-3)Dam:65MCM +FCB20MCM
		(B-2-2)Dam:90MCM
Sto.Nino :2900m3/s MF :2400m3/s MCGS :500m3/s		

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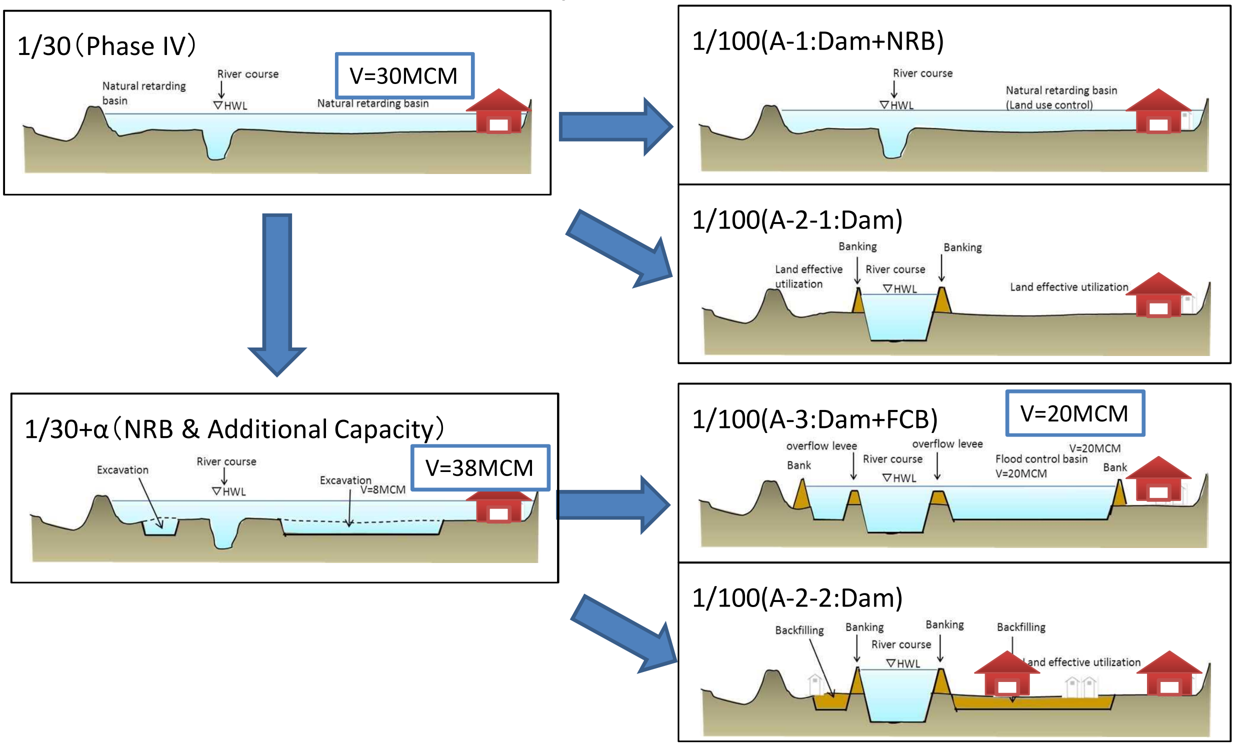
2-5 Development Scenarios for 1/100 Years Flood Management

- Alternatives for Phased Improvement（Sto.Nino:3100m3/s）



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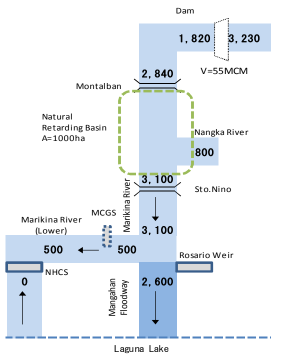
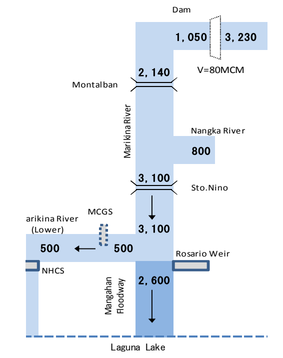
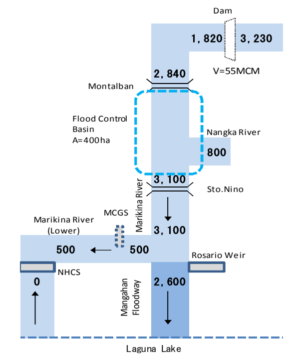
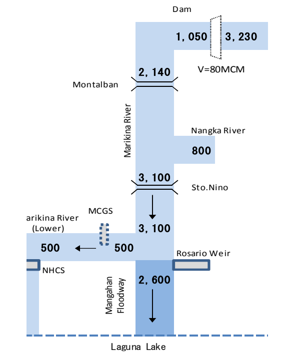
2-5 Development Scenarios for 1/100 Years Flood Management

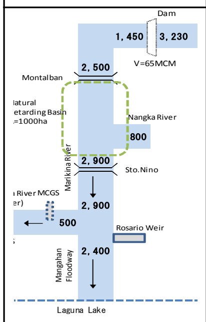
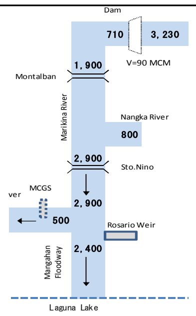
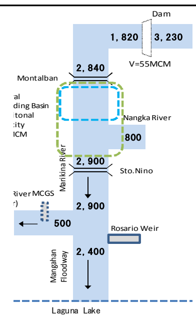
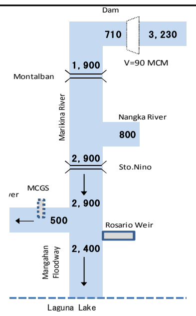
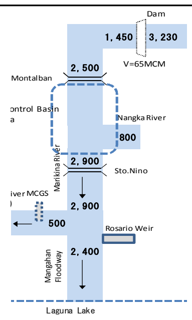
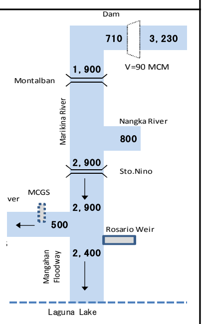
- Alternatives for 1/100 Years Flood Management Measures (Sto.Nino:3100m3/s)

(A-1) Dam & NRB	(A-2-1) Dam	(A-2) Dam & FCB	(A-2-2) Dam
			
Dam : V=55MCM NRB : V=30MCM A=1000ha	Dam: V=80MCM	Dam : V=55MCM FCB : V=20MCM A=400ha	Dam: V=80MCM

NRB: Natural Retarding Basin
FCB: Flood Control Basin

2-5 Development Scenarios for 1/100 Years Flood Management

- Alternatives for 1/100 Years Flood Management Measures (Sto.Nino:2900m3/s)

(O-1) Dam & NRB	(O-2) Dam	(B-1)Dam & NRB+Additional Capapcity	(B-2-1)Dam	(B-3)Dam & FCB	(B-2-2)Dam
					
Dam : V=65MCM NRB : V=30MCM A=1000ha	Dam: V=90MCM	Dam : V=65MCM NRB:V=35MCM Additional Capacity : V=5MCM	Dam: V=90MCM	Dam : V=65MCM FCB : V=20MCM A=400ha	Dam: V=90MCM

NRB: Natural Retarding Basin
FCB: Flood Control Basin

2-6 Adaptation Measures for Climate Change

● Step Up Options of Adaptation Measures for Climate Change

- "Additional Dam" or "Improvement of Retarding Basin" in Upstream Area of Sto.Nino
- "Improvement of Manggahan FW" in Downstream of Sto.Nino

1/100+α
・Climate Change Adaptation Measures

1/100
・Dam+NRB
・Dam
・Dam+FCB

1/30+α
・NRB +Additional Capacity

1/30 (PhaseⅣ)
・O:Original PhaseⅣ Component
・A:A+Hightenning Levee +Mangahan Floodway Improvement
・B:A+NRB+Additional Capacity

NRB: Natural Retarding Basin
FCB : Flood Control Basin

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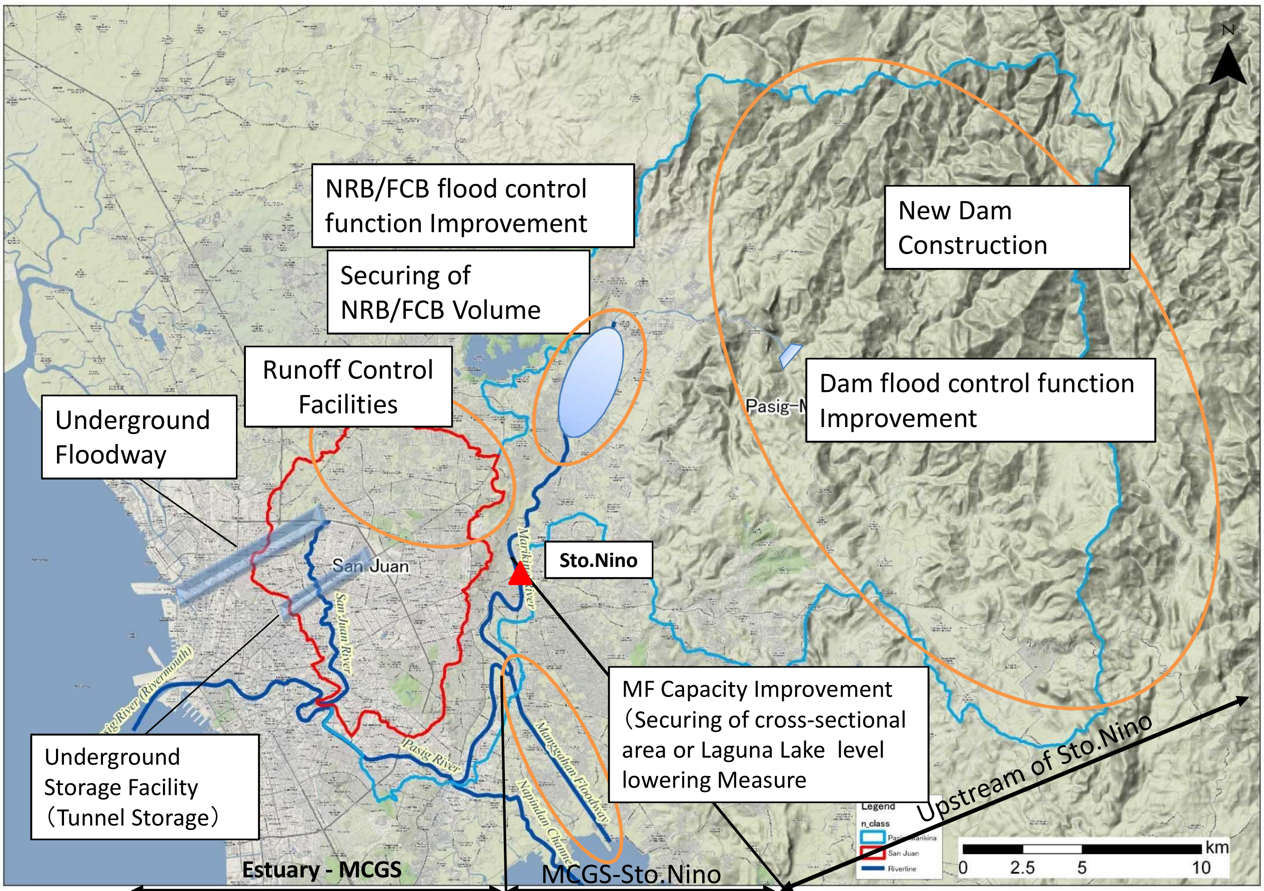

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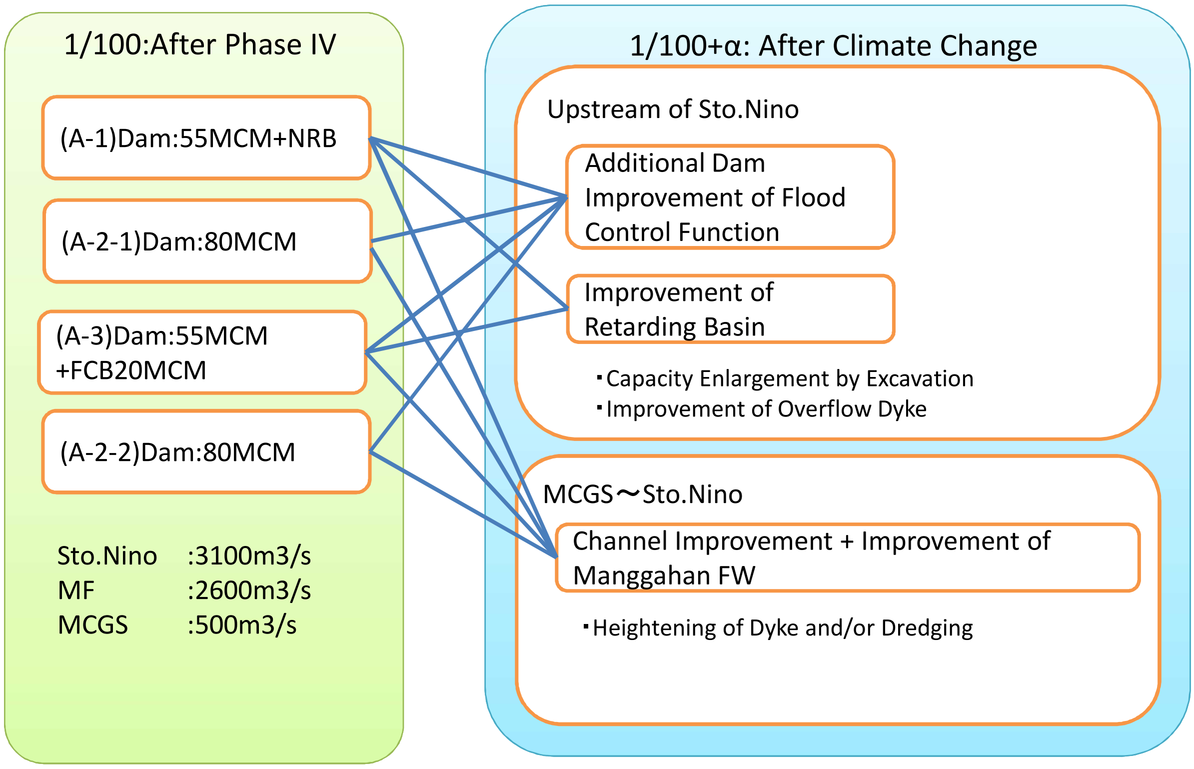
2-6 Adaptation Measures for Climate Change

- Climate Change Adaptation Measures



Minutes of Meeting between JICA & WB

- Both parties acknowledged the importance of proceeding with Phase IV including MCGS subject to:
  - Full timelines of processing of Phase IV and upstream measures will be prepared.
  - Subsequent studies (both Phase IV and upstream measures) will be conducted.
  - The result of those studies will be commonly used for the best optimized flood management structures within the basin.

- Decision of DPWH taking into account parameters and aspects including but not limited to economic cost, time, benefit, social and environmental aspect, protection of asset and goods, strategic political choices etc. should be the most respected.

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Recommendations

- Further flood management works in Pasig-Marikina River Basin shall be implemented based on the results of this study, including:
  - rainfall analysis,
  - hydrological model,
  - hydrodynamic model,
  - inundation model,
  - design flood discharge, and
  - component combination plans with different facility scale under step-wise approach.
- Restoration works of Manggahan Floodway shall be proceeded as soon as possible.

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Thank you

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