# 添付資料　1

## 添付資料 1-3　3rd　Steering Committee

# Data Collection Survey on Parañaque Spillway in Metro Manila

## 3rd Steering Committee Meeting

January 23, 2018

Japan International Cooperation Agency

CTI Engineering International Co., Ltd. (CTII)
Nippon Koei Co., Ltd. (NK)
CTI Engineering Co., Ltd. (CTIE)

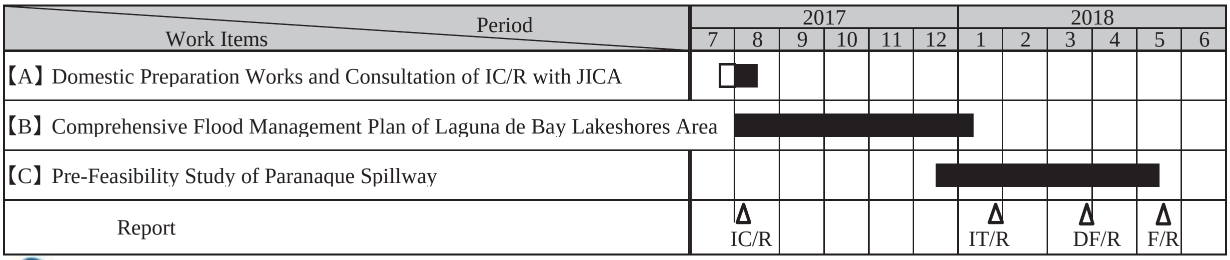


## ■ Topic

1. Schedule
2. Findings
3. Design Scale and Hydrological/Runoff Inundation Analysis
4. Full Menu of Comprehensive Flood Management Plan for Laguna de Bay Lakeshore Area
5. Comprehensive Flood Management Plan
6. Preliminary Environmental and Social Analysis

# 1. Schedule

- July 31,2017 : Started the Survey in the Philippines
- August 10-11,2017 : Site Investigation
- August 17,2017 : First Steering Committee
- November 03,2017 : Second Steering Committee
- January 23, 2018 : Third Steering Committee
- End of January, 2018 : Submission of Interim Report
- End of March, 2018 : Submission of Draft Final Report
- Middle of May, 2018 : Submission of Final Report




Source: JICA Survey Team



# 2. Findings

a. Past Flood Damage and Information

b. Relevant Development Plan

1) Laguna Lakeshore Expressway Dike Project (LLEDP as PPP)
2) LRT-1 Cavite Extension Project
3) Maynilad Water Supply Facilities Project at Muntinlupa City
4) North-South Railway Project (South Line)
5) The Mega Manila Subway Project
6) Power generation project by CBK Power Company

c. Hydrological Basic Data Collection

d. Water Quality of Manila Bay and Laguna de Bay

# 2. Findings, a. Past Flood Damage and Information

## 1) Summary of Climate and Damages in Major Flood

| Year | Water Level at Laguna de Bay (m) | Summary of Climate and Damages |
|---|---|---|
| 1972 | 14.03 | - Cause of Flood: Typhoon Gloring, Typhoon Eden, the tropical southwest monsoon<br>- More than 150 million US dollars' damage and casualties of 214 people [1] |
| 1978 | 13.58 | - Cause of Flood: Typhoon Kading<br>- More than 200 people died [1] |
| 1988 | 13.55 | - Cause of Flood: Typhoon Usang, Typhoon Yoning<br>- More than 404 people dead, 95 people missing, more than 1 million people lost their residences. [1] |
| 2009 | 13.85 | - Cause of Flood: Typhoon Ondoy, Typhoon Pepeng<br>- 38.3 billion US dollars' damage, 9.5 million people affected, 929 people dead, 736 people injured, 84 people missing. [2] |
| 2012 | 13.83 | - Cause of Flood: The tropical southwest monsoon, Typhoon Jose, Typhoon Haikui<br>- 565 million US dollars' damage, 625 thousand people affected, 2,563 houses totally damaged [3] |

Note: 1) Whole Philippines, 2) around Laguna de Bay, 3) in Metro Manila, Laguna, Rizal
Data Source: Annual Typhoon Report, US NAVY, Youngstown Daily Vindicator, Final Report on Tropical Storm "ONDOY"{Ketana} and Typhoon "PEPENG"{Parma}, Effects of Southwest Monsoon Enhanced by Typhoon Haikui, Sitrep No. 20 Effects of Southwest Monsoon Enhanced by Typhoon Haikui



# 2. Findings, b. Relevant Development Plan

## 1) Laguna Lakeshore Expressway Dike Project (LLEDP as PPP)

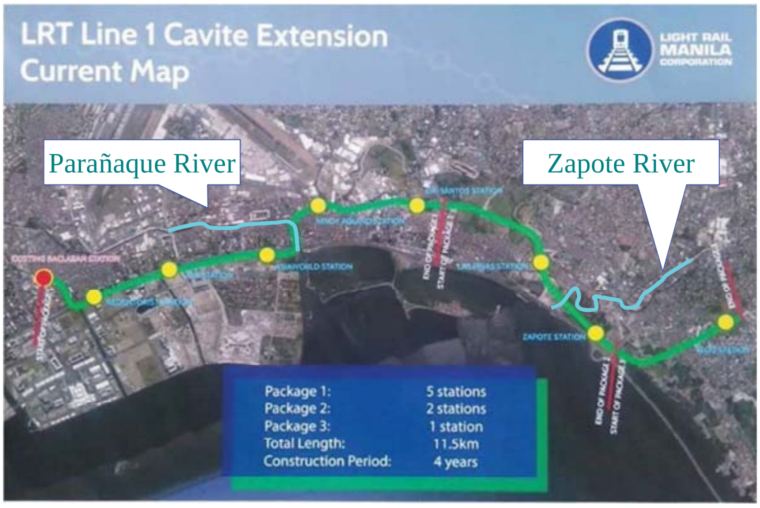

Component 1. Expressway-Dike: 47 km
Benefit: 64.9 billion pesos

Component 2. Reclamation: 700 ha
Benefit: 57.9 billion pesos

Source: LLEDP, a public-private partnership project (PPP), presentation to UK Transport Solutions

# 2. Findings , b. Relevant Development Plan

## 2) LRT-1 Cavite Extension Project




Source: LRMC

| Item | Contents |
|---|---|
| Budget | 64.9 billion pesos |
| Operation start | 2021 |
| Target Route Length | 11.5 km (from Baclaran to Bacoor, 10.5 km elevated) |
| Other construction/ procurement target | New station building, Rolling Stock (from Japan), expansion of existing depo, new depo |

Source: information from LRMC, summarized by JICA Survey Team

Since the LRT-1 line is planned to be elevated, there is basically no problem at an intersection of the spillway and the LRT-1 line. However, an attention should be paid on the relation between the position of the station building and the spillway.

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# 2. Findings , b. Relevant Development Plan

## 3) Water supply facilities construction project at Muntinlupa City by Maynilad


Source: Google Earth, Maynilad

| Item | Victoria Homes pump station | Putatan water treatment plant 2 |
|---|---|---|
| Budget | 250 million pesos | 6.75 billion pesos |
| Operation start | Already started | May 2018 |
| Construction target | Pumping station and adjustment reservoir | Water treatment facility |
| Intake Volume | - | 3.5 $m^3/s$ |

Source: information from Maynilad, summarized by JICA Survey Team

Since lowest elevation of the water intake for Putatan 2 is Water Level 10.5m, it is important to keep the lake water levels above the 10.5 m

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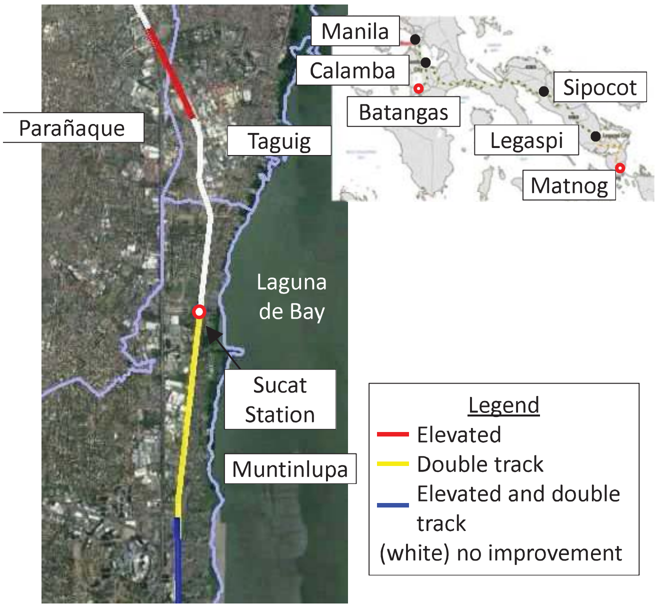
# 2. Findings , b. Relevant Development Plan

## 4) North-South Railway Project (South Line)




Source: information from DOTr, compiled by JICA Survey Team

| Item | Contents |
|---|---|
| Budget | 1,452 billion pesos (excluding land acquisition costs) |
| Operation start | 2022 |
| Target Route Length | 653 km (improvement of existing routes: 478 km, the extension of the route: 175 km) |
| Construction target | Railway track renovation, new station buildings, rolling stock, signalling systems, automatic ticket gate, depo, other equipment |

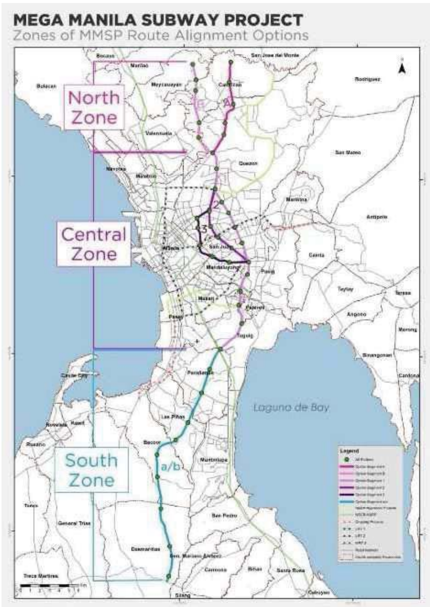
Source: information from DOTC, summarized by JICA Survey Team

If the spillway structure is designed at the surface of the ground or close, some consideration for the structure at the intersection and discussion with related organizations is required in the further study.



# 2. Findings , b. Relevant Development Plan

## 5) The Mega Manila Subway Project




Source: Information collection survey for the Mega Manila subway project

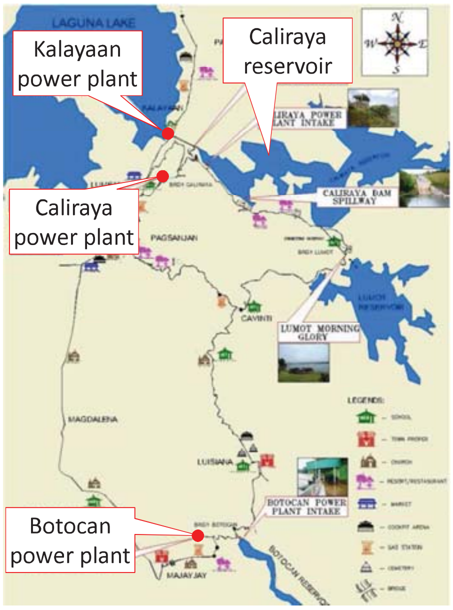
| Item | Contents |
|---|---|
| Design stage | Information collection survey done in 2015 |
| Budget | 3,570 billion pesos - 4,410 billion pesos |
| Construction period | About 5 years (carried out in two phases) |
| Construction target | Elevated structure, elevated station, underground structure, underground station, depo, railway track, rolling stock, signals etc. |

Source: information from DOTC, summarized by JICA Survey Team

Only if the spillway lay on the ground or at the close, some consideration for the structure and discussion with related organizations is required in the further study.

# 2. Findings , b. Relevant Development Plan

6) Power generation project by CBK Power Company




Source: CBKPCL brochure

| Item | Contents |
|---|---|
| Facility | Penstock (2 nos, dia: 5.5m to 6m, usually, a single operation), generators (total output of 685MW, 4 nos, usually two nos operation), small hydroelectric power system (for blackout, 1 nos, 1 MW), diesel generator (for blackout, 1 nos, 1 MW) |
| Character-istic | Highest water level at Laguna de Bay is designed at EL. 13.72 m and the lowest at EL. 10.12 m for the power plant. Water from Laguna de Bay is pumped up to Caliraya reservoir at every night |

Source: CBKPCL brochures, etc.

There is no problem if the lake water level proposed by JICA flood management plan is higher than 10.12 m.



# 2. Findings, c. Hydrological Basic Data Collection

## 1) Daily Rainfall

28 rainfall gauging stations are in surrounding survey area. The longest observation record is "Port Area (PAGASA station)" and starting from 1949.

## 2) Hourly Rainfall

10 hourly rainfall station managed by EFCOS (since 2003) and 15 stations by ASTI (since 2015). EFCOS stations are only in Pasig-Marikina River Basin. The observation period is short which is not sufficient as the hourly data for the flood control plan.

## 3) River Water Level

10 river water level gauging stations in Pasig-Marikina River Basin (EFCOS stations)
6 river water level gauging stations in Laguna de Bay Basin (BRS stations)

## 4) Lake Water Level

4 lake water level gauging stations since 1946.

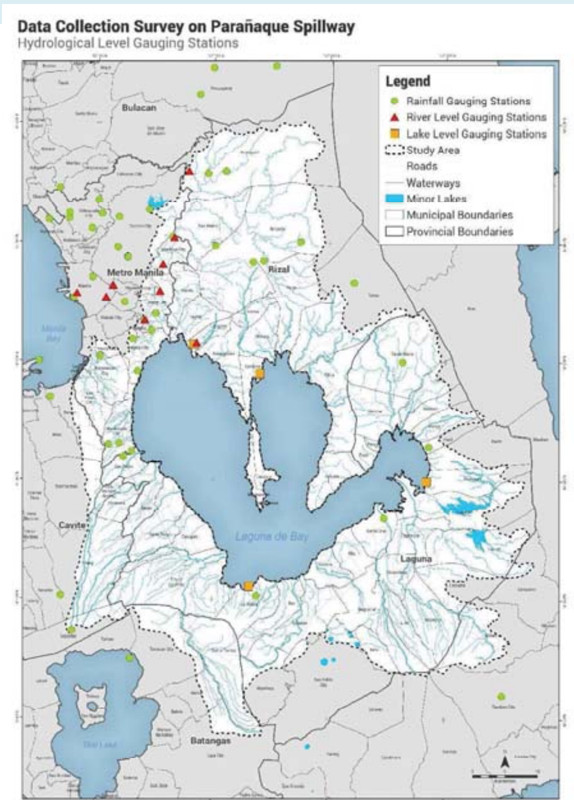
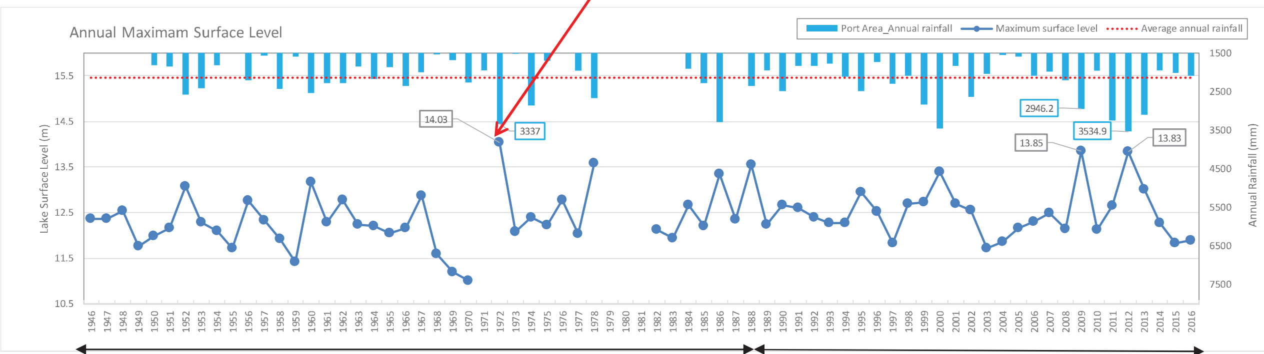



Figure 2.c.1 Location of Hydrological Gauging Stations

# 2. Findings, c. Hydrological Basic Data Collection

## 1) Observed Lake Water Level

The recorded maximum lake water level from 1946 to 2016 is shown in figure 2.c.2.
Maximum lake water level is 14.03m in 1972.




Data Source: LLDA

Figure 2.c.2 Recorded maximum lake water level



# 2. Findings, c. Hydrological Basic Data Collection

The maximum lake level for seventy-one (71) years from 1946 to 2016 was 14.03m in 1972 (before the construction of the Mangahan Floodway), and the lake level at the Typhoon Ondoy in 2009 was 13.85m. In addition, in the influence of monsoon rain in 2012, the lake level was 13.83m as same level as in 2009. Monsoon rain also influence raising lake level too.

Table 2.c.1 Top 10 - Year Maximum Lake Level

| No. | Year | Month | Day | Surface water level m | Typhoon or Cyclon | Date | |
|---|---|---|---|---|---|---|---|
| | | | | | | Start | End |
| 1 | 1972 | 8 | 3 | 14.03 | Tropical Storm Winnie | 1972/7/29 | 1972/8/3 |
| 2 | 2009 | 10 | 4 | 13.85 | Typhoon Ondoy | 2009/9/25 | 2009/9/30 |
| 3 | 2012 | 8 | 11 | 13.83 | 2012 Habagat | | |
| 4 | 1978 | 10 | 28 | 13.58 | Super Typhoon Rita | 1978/10/15 | 1978/10/29 |
| 5 | 1988 | 11 | 9 | 13.55 | Tropical Storm Tess | 1988/11/1 | 1988/11/6 |
| 6 | 2000 | 11 | 5 | 13.39 | Tropical Storm Bebinca | 2000/10/30 | 2000/11/7 |
| 7 | 1986 | 10 | 20 | 13.34 | Typhoon Ellen | 1986/10/11 | 1986/10/19 |
| 8 | 1960 | 10 | 15 | 13.17 | Typhoon Lola | 1960/10/8 | 1960/10/17 |
| 9 | 1952 | 10 | 30 | 13.08 | Typhoon Trix | 1952/10/15 | 1952/10/26 |
| 10 | 2013 | 10 | 3 | 13.01 | 2013 Habagat | | |

■1972/7/17 – 8/3 (18days) ■2009/9/25 – 9/26 (2days)

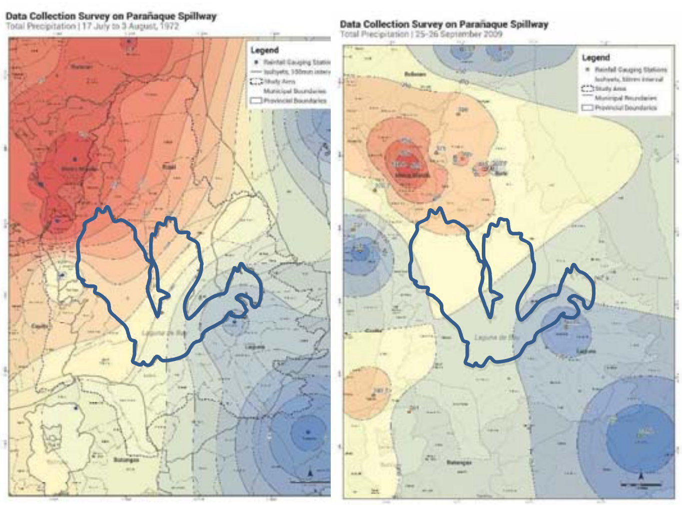



Figure 2.c.3 Isohyet line at the past flooding events

# 2. Findings, d. Water Quality of Manila Bay

- The oxygen is not enough for fishes. (less than 5mg/l)
- Fecal coliform of more than million times larger than the standard indicates the inflow of untreated human-waste.
- Toxic substances Chromium, Lead and Oil & Grease are found.

| Parameters (units) | 2016 Annual average | 2017 First half year average | Class SC Standard |
|---|---|---|---|
| Dissolved oxygen (mg/l) | **0.73** | **2.71** | > 5 |
| Total supended solid (mg/l) | 13 | 16 | < 80 |
| Color (TCU) | 12.64 | 16.33 | < 75 |
| Phosphate-phosphorus(mg/l) | **1.6** | 0.18 | < 0.5 |
| Nitrate Nitrogen (mg/l) | 1.34 | 1.26 | < 10 |
| Fecal Coliform (MPN*1/100ml) | **290 Million** | **2 Billion** | < 200 |
| Oil and Grease (mg/l) | - | **3.5***2 | < 2 |
| Chromium (mg/l) | - | **0.036***2 | < 0.01 |
| Cadmium (mg/l) | - | < 0.003*2 | < 0.005 |
| Mercury (mg/l) | - | < 0.0001*2 | < 0.002 |
| Lead (mg/l) | - | **0.27***2 | < 0.05 |

*1 Most Probable Number
*2 Observed in May 2017 only
Source: Statistical report Manila Bay bathing beaches monitoring (Monthly), DENR


Source: DENR
Figure 2.d.1 Observation Points

**Class SC**

1. *Fishery Water Class III - For the propagation and growth of fish and other aquatic resources and intended for commercial and sustenance fishing*
2. *Recreational Water Class II - For boating, fishing, or similar activities*
3. *Marshy and/or mangrove areas declared as fish and wildlife sanctuaries*

Source: DAO No.2016-08
salt water standard

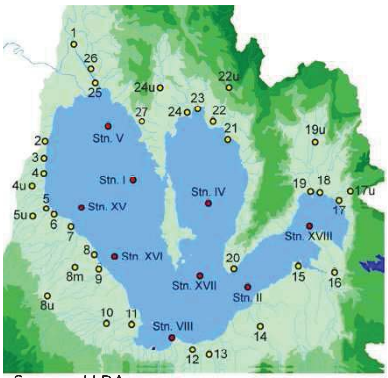


# 2. Findings, d. Water Quality of Laguna de Bay

- Almost all the parameters **pass** the **Class C** standard with the **exception** of **Ammonia**.(more than 0.05 mg/l)
- Exceedance of ammonia implicates the inflow of **untreated human and animal waste**.
- Water quality is far better than that of Manila Bay.

| Parameters (units) | 2016 Annual average | 2017 First half year average | Class C Standard |
|---|---|---|---|
| Dissolved oxygen (mg/l) | 8.1 | 8.36 | > 5 |
| Biochemical Oxygen Demand (mg/l) | 2 | 1.4 | < 7 |
| pH | 8.54 | 8.16 | 6.5 – 9.0 |
| Phosphate-phosphorus(mg/l) | 0.13 | 0.18 | < 0.5 |
| Nitrate Nitrogen (mg/l) | 0.2 | 1.26 | < 7 |
| Total Coliform (MPN/100ml) | 482 | 154 | < 5000* |
| Ammonia (mg/l) | **0.077** | **0.08** | < 0.05 |

*DAO No.34 standard (DAO2016-08 doesn't have standards)
Source: LLDA quarterly water quality reports (monthly data)




Source: LLDA
Figure 2.d.2 Observation Points

**Class C**

1. *Fishery Water for the propagation and growth of fish and other aquatic resources*
2. *Recreational Water Class II - For boating, fishing, or similar activities*
3. *For agriculture, irrigation, and livestock watering*

Source: DAO No.2016-08
fresh water standard

# 3. Design Scale and Hydrological/Runoff Inundation Analysis





# 3.1 Setting of Design Scale

The design scale is set by comprehensively evaluating the importance of the target basin, the actual condition of the past flood damages, the existing plan in the vicinity area and the design scale specified in the DPWH Standard Guideline 2015.

- ✓ For the **Pasig – Marikina River Basin** which is vicinity of this study, the design scale is a **100-year scale**. Typhoon Ondoy in 2009 brought massive damages to the Laguna de Bay Basin, and the basin average rainfall in the Marikina River Basin was 290.8mm (one day) which is equivalent to a 100-year scale.
- ✓ According to “Manual on Flood Control Planning 2003.3” which is prepared in the JICA Technology Cooperation Project -ENCA, the main eighteen (18) basins of the Philippines are specified including **Laguna de Bay in the Pasig-Laguna Bay Basin**.
- ✓ According to the DPWH Standard Guideline 2015, the design scales are specified for rivers and drainage In addition to the DPWH Standard Guideline, there is the memorandum of understanding in 2011 which specifies the design scales.
- ✓ The catchment area of Laguna de Bay is 3,280km$^2$, and the design scale in the DPWH Standard Guideline (Rivers) is a **100-year scale**.

# 3.1 Setting of Design Scale

## The design flood of rivers and the minimum capacity of drainages

| Type | | Target Level | 2011 Memorandum | 2015 DGCS[1] |
|---|---|---|---|---|
| River | Principal and Major Rivers (40 $km^2$ drainage area and above) | D.F.L.[2] | 50-year | 100-year |
| | | D.F.L. + Freeboard | 100-year | - |
| | For Smaller Rivers (below 40 $km^2$ drainage area) | D.F.L. | 25-year | 50-year |
| | | D.F.L. + Freeboard | 50-year | - |
| Drainage | Drainage Pipes[3], Esteros/creels, Pipe Culverts | D.F.L. | 15-year | 15-year |
| | | D.F.L. + Freeboard | 25-year | 25-year |
| | Box Culverts | D.F.L. | 25-year | 25-year |
| | | D.F.L. + Freeboard | 50-year | 50-year |
| | Drainage Channels | D.F.L. | - | 15-year |
| | | D.F.L. + Freeboard | - | 25-year |

1) Design Guidelines, Criteria and Standards, 2015 Vol. 3, 2) D.F.L.: Design Flood Level, 3) Minimum size of drainage pipes shall be 910 millimeters in diameter.

- In the absence of a risk assessment or master plan, above table provides design floods that can be adopted for different river sizes and drainages (referring to 2015 DGCS).



# 3.1 Setting of Design Scale

Table 3.1.1 Setting of Design Scale

| Classification | Evaluation Index | Design Scale | Setting Rationale |
|---|---|---|---|
| **Flood caused by the water level rise of Laguna de Bay** | Water Level | **100-year** | ・ Since Laguna de Bay is considered as one of the important basins in the Philippines, the design scale is set to a 100-year which is equivalent to the value of the Pasig - Marikina River Basin.<br>・ The water level observed data of Laguna de Bay has been accumulated over a long period of time as compared to the rainfall data. Therefore, the water level probability scale is adopted. |
| **Laguna de Bay Basin (21 River Basins)** | Rainfall | **【Rivers】**<br>A≧40km² : **50-year**<br>10km²≦A＜40km² : **25-year**<br>A≦10km² : **15-year** | ・ Since there are several rivers in 21 river basins located in the Laguna de Bay lakeshore Area, the design scale is set based on the basin area of each river.<br>・ The design scale used in DPWH Standard Guideline 2015 may be an excessive design scale, therefore, the design scale of each basin area is set based on the memorandum of 2011. |
| | | **【Drainage canal】**<br>Drainage canal : **15-year** | ・ This will be the design scale when internal water (drainage) countermeasures are targeted. |
| **Las Piñas・Parañaque District** | Rainfall | **【Rivers】**<br>A≧40km² : **50-year**<br>10km²≦A＜40km² : **25-year**<br>A≦10km² : **15-year** | ・ This will be the design scale when the external water countermeasures are targeted. |
| | | **【Drainage Canal】**<br>Drainage Canal : **15-year** | ・ This will be the design scale when internal water (drainage) countermeasures are targeted. |

# 3.2 Hydrological Statistical Analysis

## 1) Lake Water Level Statistical Analysis

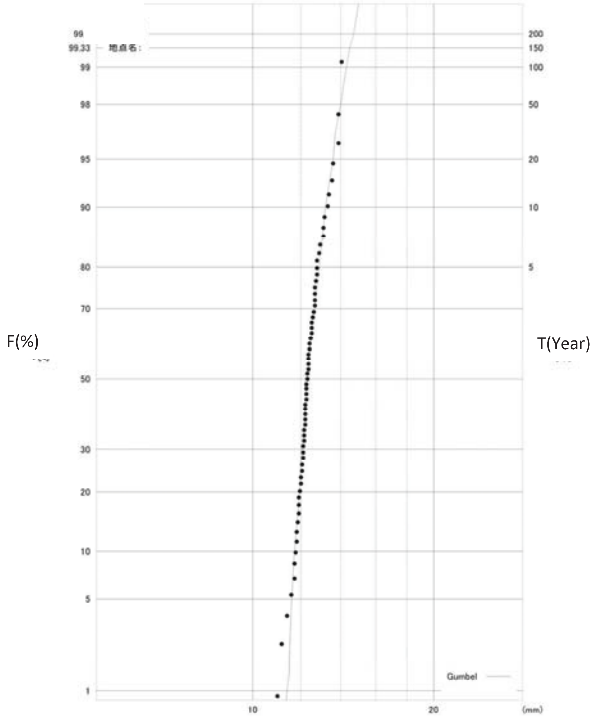
- Probable lake water level was computed using by annual maximum lake water level from 1946 to 2016.
- Lake water level in 100-year return period is at 14.3m.

Table 3.2.1 Probable Lake Water Level

| Return Period (year) | Water Level (m) |
|---|---|
| 2 | 12.3 |
| 3 | 12.6 |
| 5 | 12.9 |
| 10 | 13.2 |
| 20 | 13.6 |
| 30 | 13.7 |
| 50 | 14.0 |
| 80 | 14.2 |
| 100 | 14.3 |
| 200 | 14.7 |

SLSC[1]: 0.034
Probability analysis
Model: Gumbel

1) SLSC: Standard Least Squares Criterion
Source: JICA Survey Team




Source: JICA Survey Team

Figure 3.2.1 Result of Statistical Analysis



# 3.2 Hydrological Statistical Analysis

## 2) Rainfall Analysis in Lakeshore Area

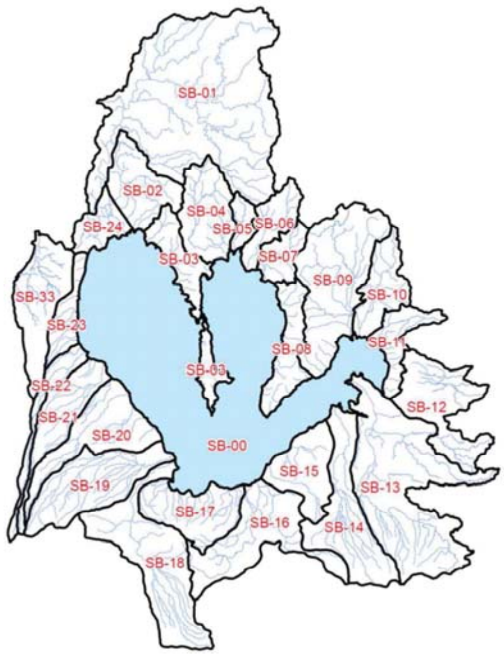
- Probable Basin Mean Rainfall in lakeshore area is shown in below table.
- Set one (1) day for design rainfall duration.

Table 3.2.2 Probable Basin Mean Rainfall in Lakeshore Area (mm/day)

| Sub-Basin ID | SB03 | SB04 | SB05 | SB06 | SB07 | SB08 | SB09 | SB10 | SB11 | SB12 | SB13 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Angono | Morong | Baras | Tanay | Pililla | Jala-jala | Sta. Maria | Siniloan | Pangil | Caliraya | Pagsanjan |
| Area($km^2$) | 86.6 | 95.9 | 21.7 | 52.2 | 40.4 | 70.6 | 202.2 | 71.7 | 50.1 | 128.8 | 301.2 |
| Statistical model | Gev | Gumbel | Gev | Gev | Gev | Gev | Gev | Gumbel | Gev | Gev | Gev |
| SLSC | 0.024 | 0.031 | 0.035 | 0.029 | 0.031 | 0.022 | 0.025 | 0.036 | 0.018 | 0.025 | 0.027 |
| 2 | 117.4 | 154.2 | 150.6 | 141.9 | 135.3 | 114.6 | 128.3 | 135.7 | 137.8 | 135.8 | 122.9 |
| 3 | 140.4 | 185.2 | 181.5 | 169.2 | 162.8 | 136.1 | 150.5 | 161.1 | 170.0 | 165.2 | 144.9 |
| 5 | 168.9 | 219.8 | 217.6 | 201.7 | 194.7 | 162.8 | 175.4 | 189.3 | 208.6 | 199.4 | 171.1 |
| 10 | 209.4 | 263.3 | 265.8 | 246.0 | 236.6 | 200.7 | 207.0 | 224.9 | 261.6 | 244.6 | 206.6 |
| 15 | 234.9 | 287.8 | 294.5 | 272.8 | 261.2 | 224.5 | 225.0 | 244.9 | 293.9 | 271.3 | 228.1 |
| 20 | 254.0 | 305.0 | 315.2 | 292.4 | 278.9 | 242.2 | 237.6 | 259.0 | 317.6 | 290.4 | 243.7 |
| 25 | 269.4 | 318.2 | 331.6 | 308.0 | 292.8 | 256.6 | 247.3 | 269.8 | 336.5 | 305.5 | 256.2 |
| 30 | 282.5 | 329.0 | 345.2 | 321.0 | 304.2 | 268.7 | 255.3 | 278.6 | 352.3 | 318.0 | 266.5 |
| 50 | 321.4 | 359.0 | 384.2 | 358.9 | 336.9 | 304.7 | 277.5 | 303.1 | 398.4 | 353.6 | 296.5 |
| 80 | 360.3 | 386.4 | 421.5 | 395.6 | 367.8 | 340.8 | 298.0 | 325.5 | 443.5 | 387.4 | 325.6 |
| 100 | 380.1 | 399.4 | 439.7 | 413.8 | 382.8 | 359.1 | 307.7 | 336.1 | 465.9 | 403.9 | 340.0 |

| Sub-Basin ID | SB14 | SB15 | SB16 | SB17 | SB18 | SB19 | SB20 | SB21 | SB22 | SB23 |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | Sta. Cruz | Pila | Calauan | Los Banos | San Juan | San Cristobal | Sta. Rosa | Binan | San Pedro | Muntinlupa |
| Area($km^2$) | 146.7 | 89.3 | 154.5 | 102.1 | 191.7 | 140.6 | 119.8 | 84.8 | 46 | 44.1 |
| Statistical model | Gev | Gev | Gev | Gev | SqrtEt | Gev | Gev | Gumbel | SqrtEt | Gev |
| SLSC | 0.025 | 0.017 | 0.029 | 0.019 | 0.035 | 0.024 | 0.022 | 0.027 | 0.027 | 0.025 |
| 2 | 120.6 | 115.8 | 138.3 | 146.2 | 138.5 | 127.2 | 113.9 | 109.3 | 105.5 | 101.4 |
| 3 | 142.6 | 139.0 | 164.5 | 175.8 | 167.5 | 152.4 | 138.7 | 133.2 | 128.9 | 124.9 |
| 5 | 168.8 | 167.3 | 193.8 | 209.2 | 202.5 | 182.4 | 166.4 | 159.9 | 157.3 | 155.8 |
| 10 | 204.6 | 207.0 | 230.9 | 251.9 | 250.7 | 223.1 | 201.6 | 193.3 | 196.5 | 202.9 |
| 15 | 226.3 | 231.7 | 252.0 | 276.4 | 279.9 | 247.7 | 221.5 | 212.2 | 220.3 | 234.3 |
| 20 | 242.2 | 250.1 | 266.8 | 293.7 | 301.1 | 265.6 | 235.6 | 225.5 | 237.7 | 258.7 |
| 25 | 254.8 | 264.8 | 278.3 | 307.1 | 318.0 | 279.8 | 246.4 | 235.7 | 251.5 | 279.0 |
| 30 | 265.4 | 277.3 | 287.6 | 318.0 | 332.0 | 291.7 | 255.3 | 244.0 | 263.0 | 296.5 |
| 50 | 296.1 | 313.9 | 313.8 | 348.8 | 372.6 | 326.1 | 280.0 | 267.1 | 296.2 | 350.5 |
| 80 | 325.9 | 350.4 | 337.8 | 377.4 | 411.6 | 359.4 | 302.8 | 288.2 | 328.2 | 407.5 |
| 100 | 340.7 | 368.7 | 349.3 | 391.0 | 430.6 | 375.9 | 313.7 | 298.2 | 343.8 | 437.4 |

Source: JICA Survey Team




Source: JICA Survey Team

Figure 3.2.2 Sub-Basin ID

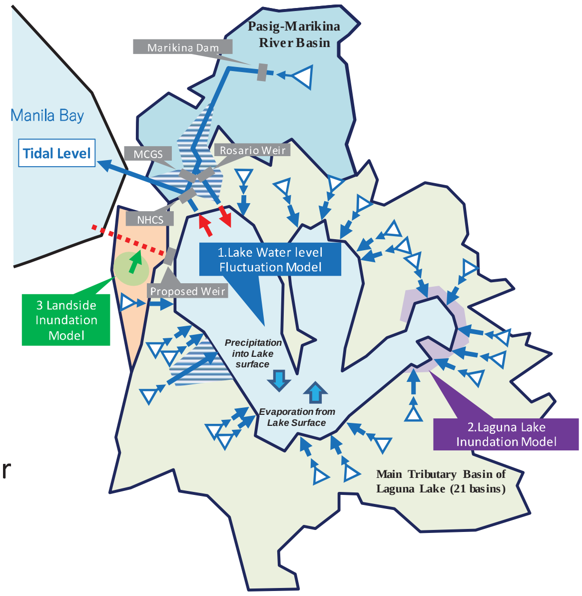
# 3.3 Outline of Analysis Model

## i) Lake Water Level Fluctuation Model

- To grasp the annual lake water level change
- Long-term Runoff analysis model using NAM and MIKE11 analysis model.
- The simulation period is daily calculation.
- Calibration and verification year is 2009 and 2012 which were recorded high lake water level.

## ii) Lakeshore Area Runoff Inundation Analysis

- To grasp inundation area and flood river discharge in lakeshore area relating lake water level raising and probable rainfall.
- Short-term Rainfall Runoff Inundation Model (RRI model) used in lakeshore area.
- The simulation period is hourly calculation.




Source: JICA Survey Team

Figure 3.3.1 Conceptual Diagram of the Analysis Model in Laguna de Bay Basin



# 3.4 Lake Water Level Analysis ,Runoff Inundation Analysis (Long-Term Analysis)

## 3) Analysis of Factors and Trends of Lake Water Level Rise

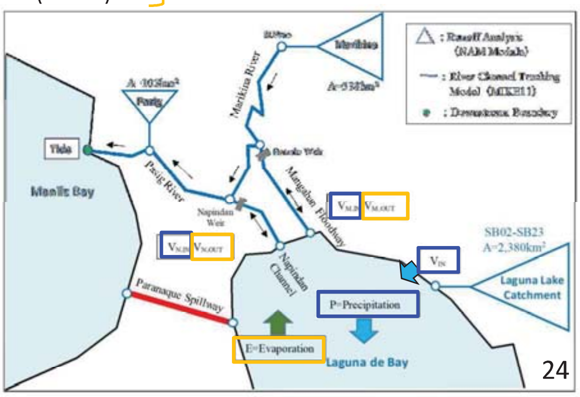
- Based on the calculation results of 2009, the factors of water level rise in Laguna de Bay are examined. The water level rise at the time of Typhoon Ondoy in 2009 is summarized below.

【Breakdown of Inflow and Outflow of Laguna de Bay ※Total Amount of 25 to 28 September 2009】

| | | Ratio to Inflow V | |
|---|---|---|---|
| Inflow from the Laguna de Bay Basin | $V_{IN}$ | =736.0 MCM (**64.6%**) | Inflow from lakeshore area is most influence to lake level raising. |
| Inflow from the Mangahan Floodway | $V_{M,IN}$ | =181.0 MCM (15.9%) | **Inflow V=1,139.8 MCM** |
| Inflow from the Napindan Channel | $V_{N,IN}$ | = 11.8 MCM (1.0%) | |
| Rainfall to the Laguna de Bay Lake Surface | $V_R$ | =211.0 MCM (18.5%) | |
| | | Ratio to outnflow V | |
| Evapotranspiration from the Laguna de Bay Lake Surface | $V_{EVA}$ | = 4.7 MCM (7.0%) | |
| Outflow from the Napindan Channel | $V_{N,OUT}$ | = 53.8 MCM (80.4%) | **outflow V =66.9 MCM** |
| Outflow from the Mangahan Floodway | $V_{M,OUT}$ | = 8.4 MCM (12.6%) | |

- $\Delta V = \underbrace{V_{IN} + V_{M,IN} + V_{N,IN} + V_R}_{\text{Inflow V}} - \underbrace{(V_{EVA} + V_{N,OUT} + V_{M,OUT})}_{\text{outflow V}}$
  = 1,139.8 – 66.9
  = **1,072.6 MCM (1.11m water level up)**
  1m water level up ≒965MCM

2009/9/25 WL=12.77m (Observed)
2009/9/28 WL=13.81m(Observed)
ΔL=1.04m

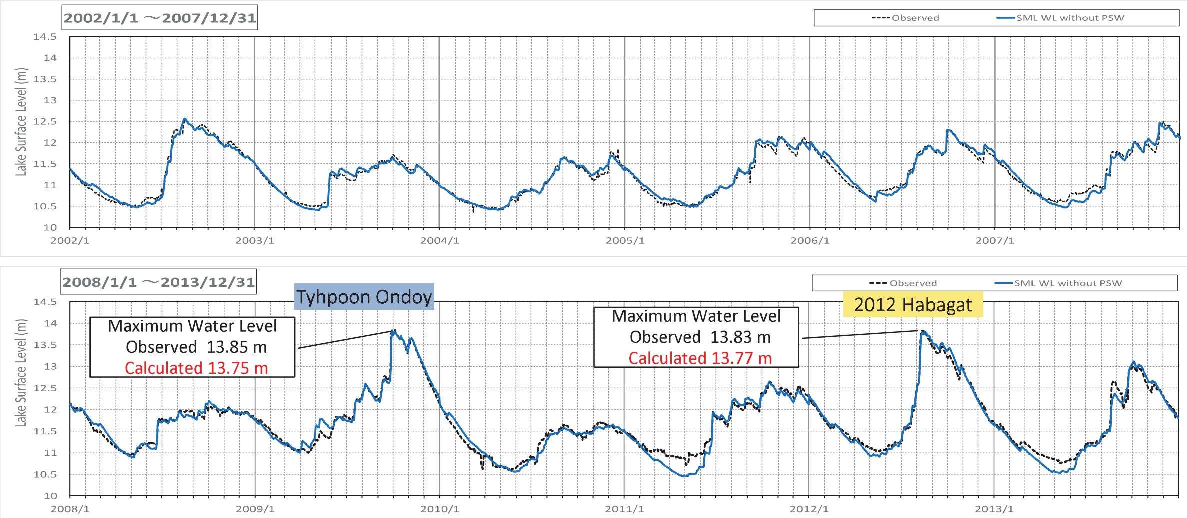


# 3.4 Lake Water Level Analysis ,Runoff Inundation Analysis (Long-Term Analysis)

## 4) Long-term Reproduction Calculation Results (2002 to 2013)

＜Long-term Reproduction Calculation Results＞

- Based on the 12-year long-term reproduction calculation results from 2002 to 2013, it is concluded that the long-term water level fluctuation of Laguna de Bay is reproduced well.
- The water level rise in 2009 and 2012 as well as the water level reduction after flooding are also reproduced well. In addition, the water level fluctuation in the drought years (2004, 2005, 2008, and 2010) is also well reproduced.




Source: JICA Survey Team

Figure 3.4.1 Results of Long-term Reproduction Calculation



# 3.5 Runoff/Inundation Analysis in Lakeshore Area (Short-Term Analysis)

## 1) Target Basin

- The evaluation on countermeasures against floods in lakeshore area, target basins are twenty (20) basins (excluding the Caliraya Basin (SB-12)).

Table 3.5.1 Target Basin

| Basin-ID | Name | Area (km$^2$) |
|---|---|---|
| SB-03 | Angono | 86.6 |
| SB-04 | Morong | 95.9 |
| SB-05 | Baras | 21.7 |
| SB-06 | Tanay | 52.2 |
| SB-07 | Pililla | 40.4 |
| SB-08 | Jala-jala | 70.6 |
| SB-09 | Sta.Maria | 202.2 |
| SB-10 | Similoan | 71.7 |
| SB-11 | Pangil | 50.1 |
| SB-13 | Pagsanjan | 301.2 |
| SB-14 | Sta.Cruz | 146.7 |
| SB-15 | Pila | 89.3 |
| SB-16 | Calauan | 154.5 |
| SB-17 | Los Banos | 102.1 |
| SB-18 | San Juan | 191.7 |
| SB-19 | San Cristobal | 140.6 |
| SB-20 | Sta.Rosa | 119.8 |
| SB-21 | Binan | 84.8 |
| SB-22 | San Pedro | 46.0 |
| SB-23 | Muntinlupa | 44.1 |


Source : Survey Team created based on Google Earth

Figure 3.5.1 Scope of Runoff/Inundation Analysis in the Laguna de Bay Basin

# 3.5 Runoff/Inundation Analysis in Lakeshore Area (Short-Term Analysis)

## 2) Rainfall-Runoff-Inundation Model (RRI)

- ☐ Rainfall Ruoff Inundation Model : Outline of RRI Model

  - The RRI model is the distributed runoff calculation model which is capable of the river channel tracking calculation and the inundation analysis. At least it requires two information such as the DEM data (elevation) and the flow direction of river to express the basin, it is possible to develop the runoff inundation analysis model.
  - The RRI Model is the distribution model which integrally analyzes from the river runoff to inundation by using rainfall as an input data. By analyzing the rainfall runoff and the inundation phenomenon on the same two-dimensional computation grid, it is possible to express the runoff inundation phenomenon in the lowland that is difficult to reproduce by a general distributed runoff model. For the mountainous region with the valley plain, it is possible to analyze with the high calculation accuracy by appropriately setting the calculation grid size.

- ☐ Observed Data (Rainfall and Cross-section Data) in Lakeshore area

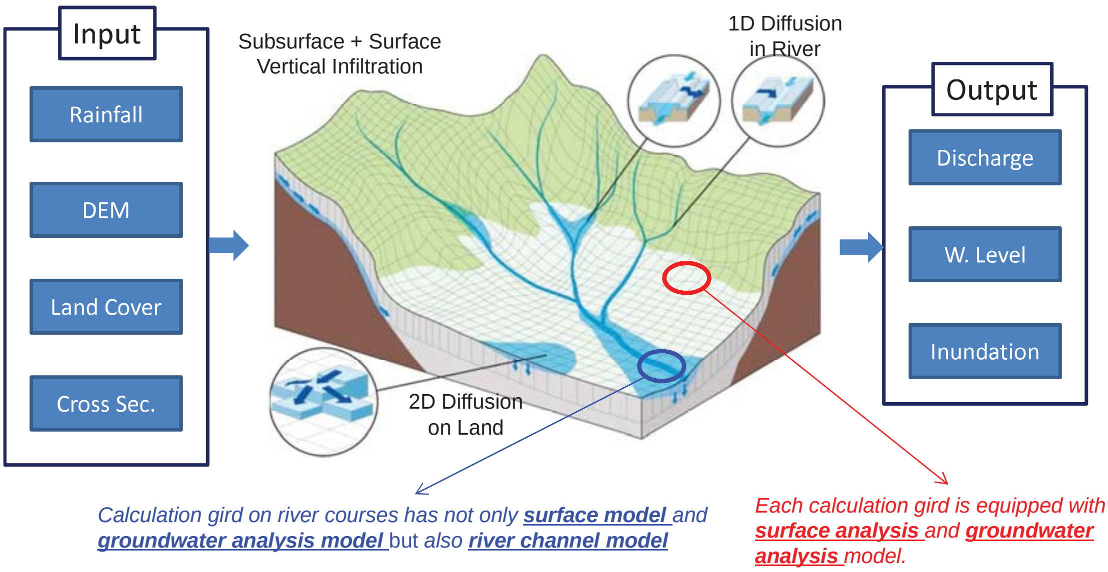
  - Rainfall Data is insufficient
    →Only 8 daily rainfall gauging stations in lakeshore area (SB-03 to SB23)
  - No Cross-section Data



# 3.5 Runoff/Inundation Analysis in Lakeshore Area (Short-Term Analysis)

## 2) Rainfall-Runoff-Inundation Model (RRI)

- ☐ Conceptual diagram of RRI Model is shown in following figure. Basically, RRI Model can simulate river discharge/water level and inundation area




Source: JICA Survey Team

### 3) Input data for RRI

a. Rainfall Data
   The basin mean rainfall (BMR) is estimated at each basin using daily rainfall observed data. Daily rainfall data from 1951 to 2016 is used to estimate BMR. However the observation situation changes every year, BMR is calculated by selecting site where daily rainfall data of 1 year exists in each year and conducted by Thiessen Polygon.

a. DEM Data
   The flood plain elevation data is prepared by using ifSAR (5m elevation data).

a. Land Cover
   Land cover is prepared base on Landsat2016 Satellite data

a. Cross Section
   Automatic estimation by RRI Model (estimated from the relational formula of catchment area, river width and depth) is conducted. Then, the estimated value is adjusted based on the field survey results or aerial photographs.

# 4. Full Menu of Comprehensive Flood Management Plan for Laguna de Bay Lakeshore Area





# 4.1 Concept of Comprehensive Flood Management Plan

Proposal of Evaluation Items

| No. | Evaluation Items | Indicators of Evaluation Items |
|---|---|---|
| 1 | Reduction in Disaster Risk | Water level reduction amount, inundation area, inundation period, damage amount, assumed disaster-affected population |
| 2 | Disaster Risk Management | Amount of damage potential |
| 3 | Adaptation to Climate Change | Extensibility of measures, vulnerability to excessive flood events. |
| 4 | Impact on Natural Environment and Social Environment | Project costs, number of relocation, land expropriation, construction period, difficulty of maintenance and management, influence on water quality, influence of construction work, and influence on the area |

Possible Menu of Flood Control Management Plan

| Water Level Rise Control | Inundation Damage Reduction | Non-Structural Countermeasures |
|---|---|---|
| ✓ **Dredging of the Napindan Channel and the Mangahan Floodway**<br>✓ **Construction of the Parañaque Spillway**<br>✓ **Construction of the Pacific Ocean Spillway** | ✓ Construction of the lake shore dyke system (includes the installation of the inland water drainage facility, Pumping Station, Backwater Levee, etc.) | ✓ Implementation of the lake shore management plan<br>✓ Establishment of the Laguna de Bay Disaster Prevention Committee<br>✓ Land use regulation<br>✓ Establishment of warning system<br>✓ Preparation of flood area map |

# 4.2 Study on Drainage Capacity Improvement of Napindan Channel and Mangahan Floodway

i. Existing Condition of Napindan Channel

The length is approximately 6 km and no longitudinal slope. It flows down due to the difference water level between the Laguna de Bay and Pasig River.

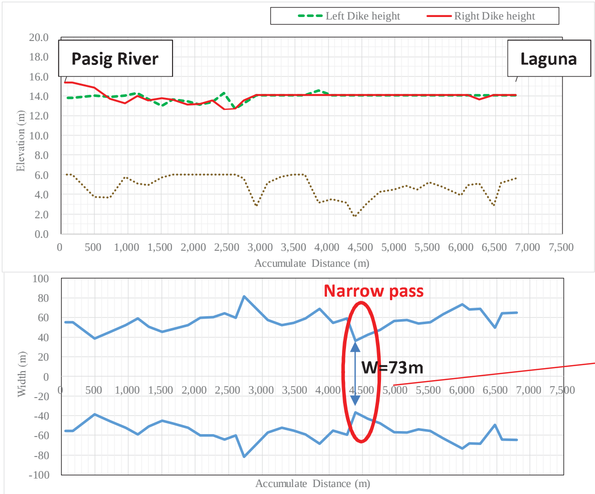
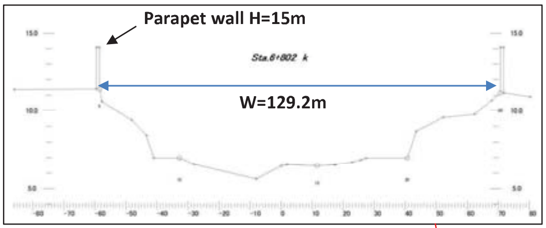



Figure 4.2.1 Longitudinal Profile of Napindan Channel (upper diagram) Width (bottom diagram)





Source：Survey Team created based on Google Earth



# 4.2 Study on Drainage Capacity Improvement of Napindan Channel and Mangahan Floodway

ii. Existing Condition of Mangahan Floodway

- Mangahan Floodway was constructed in 1988 and already about 30 years is passed. Cross-sectional survey was carried out 3 times from after completion until present.
- The riverbed sedimentary condition of Mangahan Floodway is shown in below. Regarding to the secular change of riverbed, due to the falling sediment from the Marikina River, the riverbed height tends to rise year by year.
- Also, in Mangahan Floodway, ISFs (Informal Settler Families) are present in flood and impede cross section area.

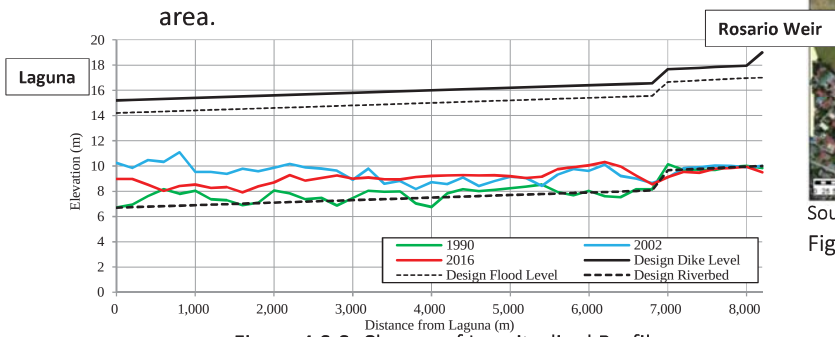
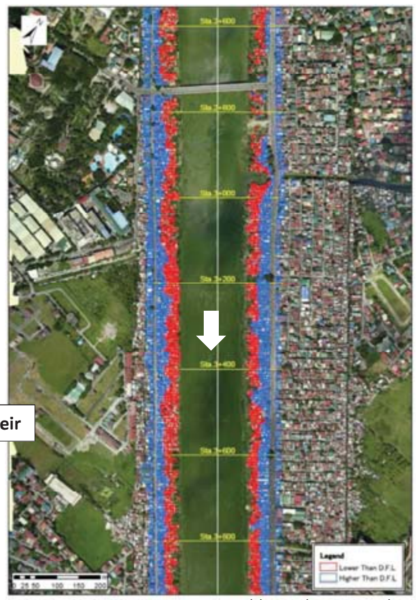



Figure 4.2.2 Change of Longitudinal Profile



Source：Survey Team created based on Google Earth

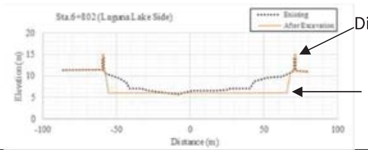
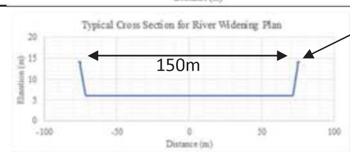
Figure 4.2.3 Distribution Condition of ISFs along Mangahan Floodway

# 4.2 Study on Drainage Capacity Improvement of Napindan Channel and Mangahan Floodway

iii. Study Case

- The effect of Laguna de Bay water level change due to excavation of Napindan channel, river channel widening, and dredging of Mangahan Floodway was investigated in following cases..

Table 4.2.1 Study Case on Napindan Channel and Mangahan Floodway

| Case | Napindan Channel | Mangahan Floodway | Remarks |
|---|---|---|---|
| 0 | Existing condition<br>(cross section of 2002) | Existing condition<br>(cross section of 2002) | ・Comparison case<br>・100-year return period case<br>lake water level=14.3m |
| 1 | Riverbed＝**6.0m Excavation**<br>Dike height＝**15.0m**<br>Width＝Existing width | Existing condition<br>(cross section of 2002) | <br>Dike height=15m<br>River bed=6m |
| 2 | Riverbed＝**6.0m (Excavation)**<br>Width=**150m (Widening)**<br>Dike height＝15.0m | Existing condition<br>(cross section of 2002) | <br>150m<br>Dike height=15m<br>• River widening until 150m in all sections. |
| 3 | Existing condition<br>(cross section of 2002) | **Dredging to Design Cross section**<br>(execution section in 1988) | ・Mangahan Floodway has been sedimented from construction cross section in 1988 and river capacity impede occurred due to ISFs living in river (flood plan).<br>・Water level exceeds DFL when peak flow is 2,400m$^3$/s in existing cross section. |
| 4 | Riverbed＝**6.0m (Excavation)**<br>Dike height＝**15.0m**<br>Width＝Existing width | **Dredging to Design Cross section**<br>(execution section in 1988) | |

Source: JICA Survey Team



# 4.2 Study on Drainage Capacity Improvement of Napindan Channel and Mangahan Floodway

iv. Summary of Results

- The results from Case 1 to Case 4 are summarized in below table. The case where the effect is most effective in declining Laguna lake level is case 2 widening plan of the Napindan channel, and the maximum water level of Laguna Lake is reduced by 20 cm.

Table 4.2.2 Summary of Results

| Case | Napindan Channel | Mangahan Floodway | Lake Water Level | Change amount |
|---|---|---|---|---|
| 1 | Riverbed＝**6.0m Excavation**<br>Dike height＝**15.0m** | Existing condition<br>(cross section of 2002) | Case-0* : 14.3m<br>Case-1 : 14.25m | -5cm |
| 2 | Riverbed＝**6.0m (Excavation)**<br>Width=**150m (Widening)** | Existing condition<br>(cross section of 2002) | Case-0 : 14.3m<br>Case-2 : 14.1m | **-20cm** |
| 3 | Existing condition<br>(cross section of 2002) | **Dredging to Design Cross section**<br>(execution section in 1988) | Case-0 : 14.3m<br>Case-3 : 14.3m | None |
| 4 | Riverbed＝**6.0m (Excavation)**<br>Dike height＝15.0m | **Dredging to Design Cross section**<br>(execution section in 1988) | Case-0 : 14.3m<br>Case-4 : 14.25m | -5cm |

* Result of 100-year return period

■ Case-2 Napindan Channel 150m widening
- Maximum lake water level is decreasing 20 cm from 14.3m (case-0:100-year return period) to 14.1m
- Maximum daily average discharge, flows from Napindan channel to Pasig River, is increasing to 408 m$^3$/s from 337m$^3$/s (case-0).

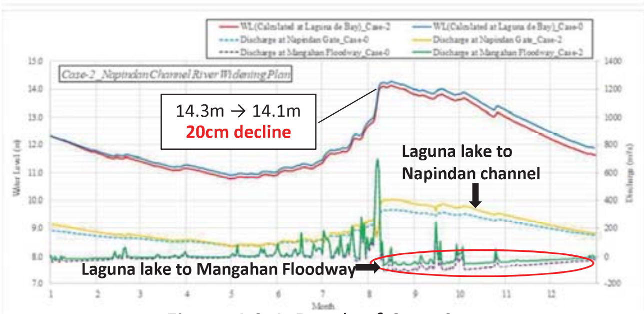
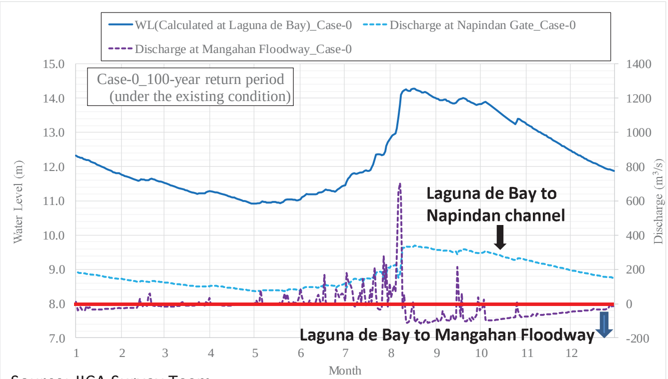



Figure 4.2.4 Result of Case-2

# 4.2 Study on Drainage Capacity Improvement of Napindan Channel and Mangahan Floodway

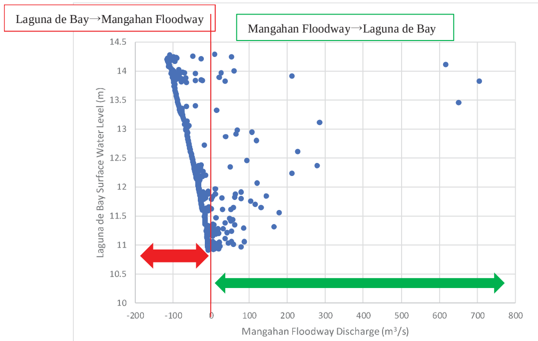
v. Relationship Between Lake Level and Outflow of Mangahan Floodway

- According to the previous result, prior flow before flood and flow thorough Mangahan Floodway and Napindan channel after flood is effective to decline lake water level.
- When the water level at Sto.Nino decline to 15.0m, gates are closed in existing operation rules of Rosario weir. Therefore, lake water level is still high, if water level in Marikina River is decreasing, outflow from Laguna de Bay cannot be expected. It is assumed that it is necessary to re-considering the gate operation rule of Rosario weir and Napindan weir after flood.




Source: JICA Survey Team

Figure 4.2.5 Lake water level and discharge of Case0




Source: JICA Survey Team

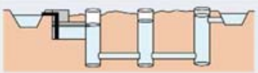
Figure 4.2.6 Relationship between Lake Level and Outflow of Mangahan Floodway (Case-0)



# 4.3 Study on Parañaque Spillway

## 1) Comparison of Spillway Types

Source: JICA Survey Team

| Case | Underground Spillway Type | | Open-cut Spillway Type | |
|---|---|---|---|---|
| | Case 1: Non-pressure Tunnel | Case 2: Siphon Type | Case 3: Open Channel Type | Case 4: Box Culvert Type |
| **Figure** |  |  |  |  |
| **Concept** | Tunnel connects existing rivers and/or channels with some tunnels under the road and/or hills. The most general type of the spillway. | Tunnel is planned deeper than fifty (50) m from the surface.*1 Siphon discharges excess water using the pressure difference caused by the water head. | Open channel type makes the construction cost relatively less. However, it comes with the issues of large compensation for land acquisition and number of the relocation of the existing facilities. | The top of the channel proposed in Case 3 is covered applying the box culvert structure. The top area can be utilized as a road, a park and so on. |
| **Tentative Evaluation for Parañaque Spillway** | Water head difference between Laguna de Bay and Manila Bay is so small that the earth covering thickness at the top of the tunnel with gravity flow of water is not sufficient. **Not adequate** | Siphon will do without pump drainage. **Adequate** | Compensation for land acquisition and relocation of houses are the big issues. Project cost can be high considering the amount of compensations. **less adequate but possible** | This case has the same issues with Case 3. In addition, the high construction cost and the high maintenance cost make this type almost infeasible. **Not adequate** |

*1: IRR of RA 10752 (yr. 2016) states that the government shall not be prevented from use of such private and government lands by surface owners or occupants, if such entry and use are made more than fifty (50) m from the surface.

# 4.3 Study on Parañaque Spillway

## 2) Possible Spillway Route


Source: JICA Survey Team

| Route | Location | Length*1 | Depth |
|---|---|---|---|
| A | Bicutan – Parañaque | 7.8km | 50m |
| B | Bagumbayan – Parañaque | 7.6km | 50m |
| C | Sucat – Parañaque | 8.5km | 30m |
| D | Sucat – Zapote | 9.6km | 50m |
| E | Alabang – Zapote | 12.5km | 30m |

Source: JICA Survey Team

Note *1: Measured by Google Earth because of No Survey Data

> "The government or any of its authorized representatives shall not be prevented from entry into and use of such private and government lands by surface owners or occupants, if such entry and use are made more than fifty (50) meters from the surface."
> (from Section 11 in "Implementing Rules and Regulations of Republic Act No. 10752" in 2016)



# 4.3 Study on Parañaque Spillway

## 3) Comparison (Summary) of Possible Spillway Route

| Route | A | B | C | D | E |
|---|---|---|---|---|---|
| Inlet | Bicutan | Bagumbayan | Sucat | Sucat | Alabang |
| Outlet | Parañaque | Parañaque | Parañaque | Zapote | Zapote |
| Route Map |   |   |   |   |   |
| Depth | 50 m | 50 m | 30 m | 50 m | 30 m |
| Length | 7.8 km | 7.6 km | 8.5 km | 9.6 km | 12.5 km |
| Problem & Issue | • Negative Influence for LPPCHEA<br>• Insufficient Capacity of Outlet River | • Negative Influence for LPPCHEA<br>• Access Road to Inlet Site | • Negative Influence for LPPCHEA<br>• Sectional Surface Rights | • Relatively High Cost | • Highest Cost<br>• Sectional Surface Rights (Partially) |
| Evaluation | Possible | Not Good/ Some Problems | Not Good/ Some Problems | Possible | Difficult/ Impossible |

Source: JICA Survey Team

# 4.3 Study on Parañaque Spillway

## 4) Study on Design Discharge (Inner Diameter 12 m, 15 m)

Design Discharge = 200 m3/s
Water Level at Laguna Lake = 14.0 m
Water Level at Manila Bay = 10.5 m
Spillway Length = 10,000 m

10% Reduction of Spillway

Source: JICA Survey Team

| Diameter (m) | Area (m2) | Invert (m) | 10% Reduction Area (m2) | Conversion Diameter (m) | Roughness Coefficient | Inlet fe | Outlet fo | Velocity *1 v (m/s) | Total Loss ht (m) | Calculated Discharge (m3/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 15.00 | 176.715 | 5.00 | 157.749 | 14.172 | 0.015 | 0.50 | 1.00 | 2.626 | 3.499 | 414.221 |
| 14.00 | 153.938 | 5.00 | 137.150 | 13.215 | 0.015 | 0.50 | 1.00 | 2.524 | 3.499 | 346.119 |
| 13.00 | 132.732 | 5.00 | 117.947 | 12.255 | 0.015 | 0.50 | 1.00 | 2.417 | 3.499 | 285.022 |
| 12.00 | 113.097 | 5.00 | 100.135 | 11.291 | 0.015 | 0.50 | 1.00 | 2.304 | 3.499 | 230.700 |
| 11.00 | 95.033 | 5.00 | 83.706 | 10.324 | 0.015 | 0.50 | 1.00 | 2.185 | 3.499 | 182.901 |
| 10.00 | 78.540 | 5.00 | 68.648 | 9.349 | 0.015 | 0.50 | 1.00 | 2.059 | 3.499 | 141.345 |

Water Level at Laguna Lake = 12.5 m
Water Level at Manila Bay = 10.5 m

10% Reduction of Spillway

| Diameter (m) | Area (m2) | Invert (m) | 10% Reduction Area (m2) | Conversion Diameter (m) | Roughness Coefficient | Inlet fe | Outlet fo | Velocity *1 v (m/s) | Total Loss ht (m) | Calculated Discharge (m3/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 15.00 | 176.715 | 5.00 | 157.749 | 14.172 | 0.015 | 0.50 | 1.00 | 1.963 | 2.000 | 309.639 |
| 14.00 | 153.938 | 5.00 | 137.150 | 13.215 | 0.015 | 0.50 | 1.00 | 1.886 | 2.000 | 258.732 |
| 13.00 | 132.732 | 5.00 | 117.947 | 12.255 | 0.015 | 0.50 | 1.00 | 1.806 | 2.000 | 213.060 |
| 12.00 | 113.097 | 5.00 | 100.135 | 11.291 | 0.015 | 0.50 | 1.00 | 1.722 | 2.000 | 172.453 |
| 11.00 | 95.033 | 5.00 | 83.706 | 10.324 | 0.015 | 0.50 | 1.00 | 1.633 | 2.000 | 136.722 |
| 10.00 | 78.540 | 5.00 | 68.648 | 9.349 | 0.015 | 0.50 | 1.00 | 1.539 | 2.000 | 105.659 |

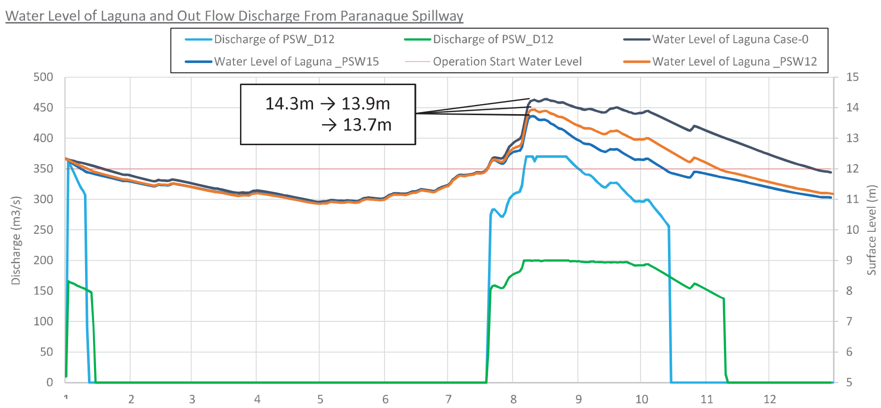


# 4.3 Study on Parañaque Spillway

## 4) Study on Design Discharge (Inner Diameter 12 m, 15 m)

| Case | Inner Diameter | Maximum Discharge | Highest Lake Water Level | Inundated Period with the lake water level at 12.5 m or higher |
|---|---|---|---|---|
| Case -0 | - | - | 14.3 m (100-year return period) | 120 days |
| PSW_D15 | 15.0 m | 370 m³/s | 13.7 m (-0.6 m, 30-year return period) | 50 days (- 70 days) |
| PSW_D12 | 12.0 m | 200 m³/s | 13.9 m (-0.4 m, 50-year return period) | 75 days (- 45 days) |

| Case | Inner Diameter (m) | Length of Spillway (km) | Estimated Construction Cost (million Peso) | Estimated Annual Average Flood Damage Reduction (million Peso) | EIRR |
|---|---|---|---|---|---|
| PSW D15 | 15.0 | 10 | 55,000 to 75,000 | 4,300 | 6.6 ～ 8.0% |
| PSW D12 | 12.0 | 10 | 35,000 to 50,000 | 3,200 | 7.3 ～ 9.1% |



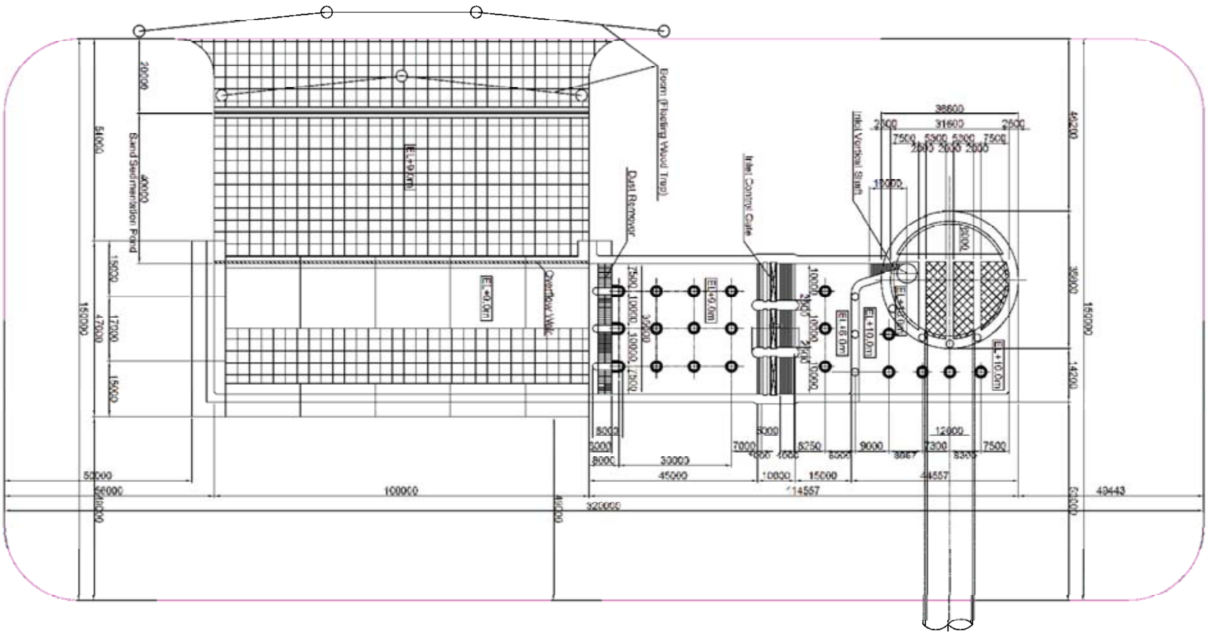

Inner Diameter of 12.0 m with Maximum Discharge of 200m³/s was selected for Parañaque Spillway

Source: JICA Survey Team

# 4.3 Study on Parañaque Spillway

5) Plan Drawing (Draft)

i) Inlet Plan



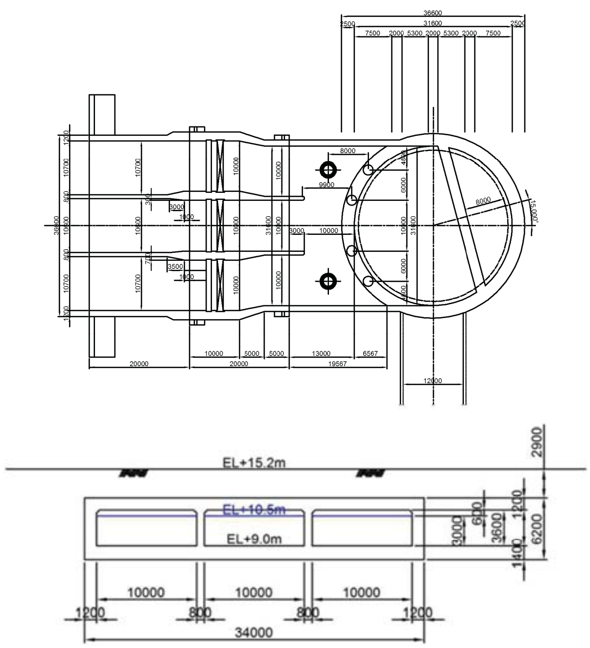
Source: JICA Survey Team



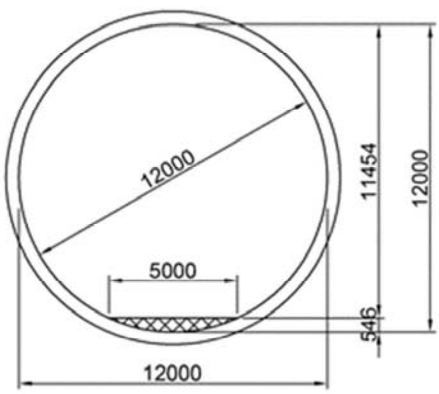
# 4.3 Study on Parañaque Spillway

5) Plan Drawing (Draft)

ii) Outlet Plan




iii) Tunnel Cross Section

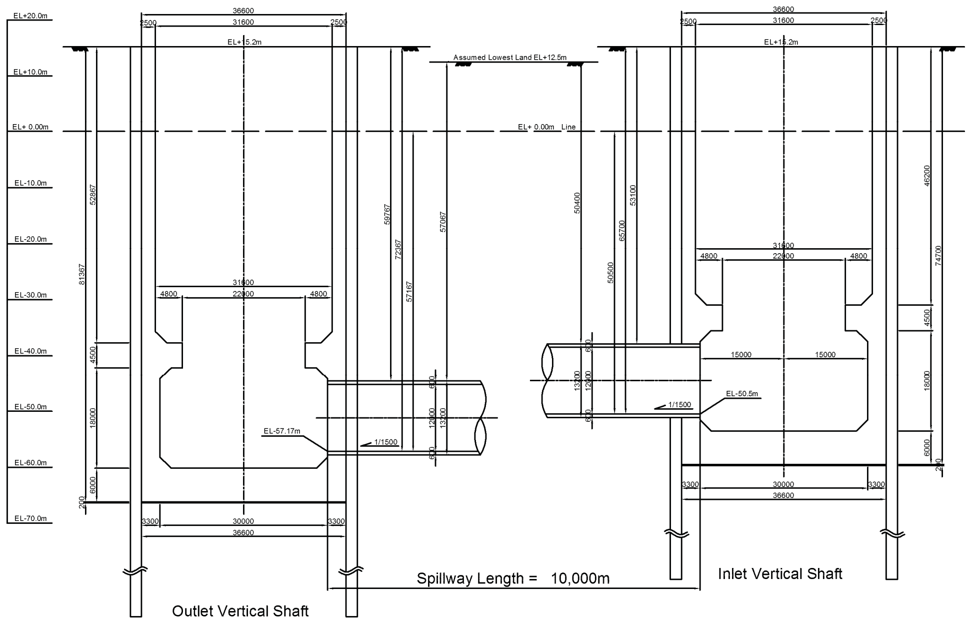



Source: JICA Survey Team

# 4.3 Study on Parañaque Spillway

## 5) Plan Drawing (Draft)

### iv) Cross Section of Vertical Shaft (Inlet & Outlet)



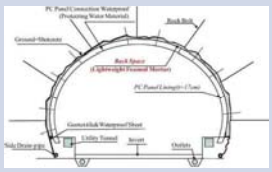

Source: JICA Survey Team



# 4.3 Study on Parañaque Spillway

## 6) Construction Method

The hilly area where the Parañaque Spillway is proposed is made from Guadalupe Formation of Pleistocene. It can be assumed that soft rock such as volcanic clastic rock, lapilli tuff are widely spread.

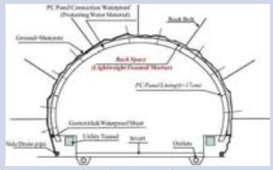
| Item | Shield Tunneling Method | NATM |
|---|---|---|
| **Photo and Figure** |   Source: http://www.ktr.mlit.go.jp/edogawa/gaikaku/index.html |   Source: Tunnelling and Underground Space Technology, Volume 47, 2015 |
| **Outline of Method** | Tunneling method using a **shield machine to keep stability of the ground**. Shield machine is driven coping with earth and water pressure at the cutting face by filling the chamber with slurry or excavated muddy soil. | Use of **ground supporting function of the area surrounding the excavation. Shotcrete, rock-bolts, steel rib supports**, and other methods are used for stabilization. |
| **Applicable Geological Conditions** | Generally, it is applicable in **alluvium, diluvium and very soft Neocene ground**. It has flexibility to accommodate variations in ground conditions. Recently, there have been some cases of applications in hard rock. | Generally, it is applicable to **ground of hard rock and Neocene soft rock.** It can be used even in diluvium formations depending on ground conditions of the project. |
| **Advantages and Disadvantage** | A closed-face type shield usually requires to auxiliary measures except for at the departure and arriving portions. It is possible to achieve standard progress rate of around 350 m/month. Compared to NATM, the construction cost will become **high due to costly shield machine and segments.** | **Construction Cost will be less than half of shield tunneling method if auxiliary measures are not required**. Auxiliary measures are needed in case of the appearance of the unforeseeable soft soil condition and/or large amount of water flow. As a result, construction cost will be significantly increased |

Source: JICA Survey Team

## 4.3 Study on Parañaque Spillway

### 6) Construction Method

The hilly area where the Parañaque Spillway is proposed is made from Guadalupe Formation of Pleistocene. It can be assumed that soft rock such as volcanic clastic rock, lapilli tuff are widely spread.

| Item | Shield Tunneling Method | NATM |
|---|---|---|
| Photo and Figure |   Source: http://www.ktr.mlit.go.jp/edogawa/gaikaku/index.html |   Source: Tunnelling and Underground Space Technology, Volume 47, 2015 |
| Outline of … | Tunneling method using a shield machine to keep … | Use of ground supporting function of the area … |
| Advantages and Disadvantage | A closed-face type shield usually requires to auxiliary measures except for at the departure and arriving portions. It is possible to achieve standard progress rate of around 350 m/month. Compared to NATM, the construction cost will become high due to costly shield machine and segments. | Construction Cost will be less than half of shield tunneling method if auxiliary measures are not required. Auxiliary measures are needed in case of the appearance of the unforeseeable soft soil condition and/or large amount of water flow. As a result, construction cost will be significantly increased |

NATM, which is generally cheaper than Shield Tunneling Method, is possibly applicable to the Parañaque Spillway project. However, geological data is presently not enough, especially permeability of the rock foundation.

Hence, in the Survey, both the Shield Tunneling Method and NATM are studied.

Source: JICA Survey Team



## 4.3 Study on Parañaque Spillway

### 7) Possibility of Pacific Ocean Spillway


Source: JICA Survey Team based on Google Earth Data

Figure 3.e.1 Route Plan of Pacific Spillway

Total Length of Pacific Spillway L= 20.6km
Tunnel Length Lt=20.0km

(Hydraulic Condition of Pacific Ocean)
- Mean Sea Level（MSL） EL+10.80m
- Mean High Water（MHW） EL+11.46m
- Mean Low Water（MLW） EL+10.17m

Case-1: Pressure Type Tunnel
- Design Discharge Qd=200m3/s
- Section Increase Ratio 10%
- Design Inner Diameter D=13.5m

*Tunnel Diameter increases up to 13.5m and Length of Tunnel increases more than 10km. Therefore, not feasible.

Case-2: Open Channel Type Tunnel
- Slope Gradient i=1/(20,000/(14.0-10.8-0.1))= 1/6,452= 1/6,500
- Design Discharge Qd=260m3/s（130% of Planning Discharge）
- Design Inner Diameter D=14.0m, Water Depth H=9.2m

(Impossible due to the Water Depth of Laguna de Bay)

Alternative Plan-1: 2 Tunnels of Dia. =10.5m, Water Depth =8.0m (Also Impossible)
Alternative Plan-2: 3 Tunnels of Dia. = 9.5m, Water Depth =6.4m (Cost is Expensive.)

Therefore, Pacific Ocean Spillway is not feasible compared with Parañaque Spillway.

## 4.4 Lake Water Level Analysis ,Runoff Inundation Analysis (Long-Term Analysis)

### 1) Effect of Water Level Reduction by the Construction of Parañaque Spillway

＜ Operation Starting Water Level ＝ 12.0m ＞

- Regarding the peak water level, a maximum water level decrease of 0.55 m in 2009, and the water level lowering effect of 0.24 m on a 12-year average.
- The duration that water level is over 12.5m is shortened from 110 days to 46 days (42% reduction) in 2009, from 108 days to 63 days (58% reduction) in 2012, and from 62 days to 15 days (24% reduction) in 2013.
- Laguna de Bay is utilized as resource of drinking and irrigation water, and fishery. The operation starting water level 12.0m does not affect those water utilization functions. .

Table 4.4.1 Long-term Prediction Calculation Results, Operation Starting Water Level ＝ 12.0m

| Year | Maximum Water level | | | | Days of more than 12.5m | | |
|---|---|---|---|---|---|---|---|
| | Observed | SML | | | | | |
| | | [1] | [2] | [3]=[1]-[2] | [4] | [5] | [6]=[4]-[5] |
| | | WL without PSW | With PSW | Difference | WL without PSW | With PSW | Days |
| 2002 | 12.55 | 12.57 | 12.29 | 0.28 | 8 | 0 | 8 |
| 2003 | 11.72 | 11.64 | 11.64 | 0.00 | 0 | 0 | 0 |
| 2004 | 11.85 | 11.69 | 11.69 | 0.00 | 0 | 0 | 0 |
| 2005 | 12.15 | 12.12 | 12.03 | 0.10 | 0 | 0 | 0 |
| 2006 | 12.30 | 12.30 | 12.27 | 0.03 | 0 | 0 | 0 |
| 2007 | 12.49 | 12.47 | 12.33 | 0.14 | 0 | 0 | 0 |
| 2008 | 12.14 | 12.19 | 12.10 | 0.10 | 0 | 0 | 0 |
| 2009 | 13.85 | 13.84 | 13.29 | 0.55 | 110 | 46 | 64 |
| 2010 | 12.12 | 12.12 | 11.64 | 0.48 | 0 | 0 | 0 |
| 2011 | 12.65 | 12.65 | 12.22 | 0.43 | 17 | 0 | 17 |
| 2012 | 13.83 | 13.80 | 13.50 | 0.30 | 108 | 63 | 45 |
| 2013 | 13.01 | 13.11 | 12.66 | 0.45 | 62 | 15 | 47 |
| **Min** | **11.72** | **11.64** | **11.64** | **0.00** | **0** | **0** | **0** |
| **Ave** | **12.56** | **12.54** | **12.31** | **0.24** | **25** | **10** | **15** |
| **Max** | **13.85** | **13.84** | **13.50** | **0.55** | **110** | **63** | **64** |

**[Parañaque Spillway]**
Design Discharge : 200m³/S
Floodway length : it is considered as 10km.
Pipe Diameter : 12.0m
Inflow Gate : 10.0m x 3 sluice gates

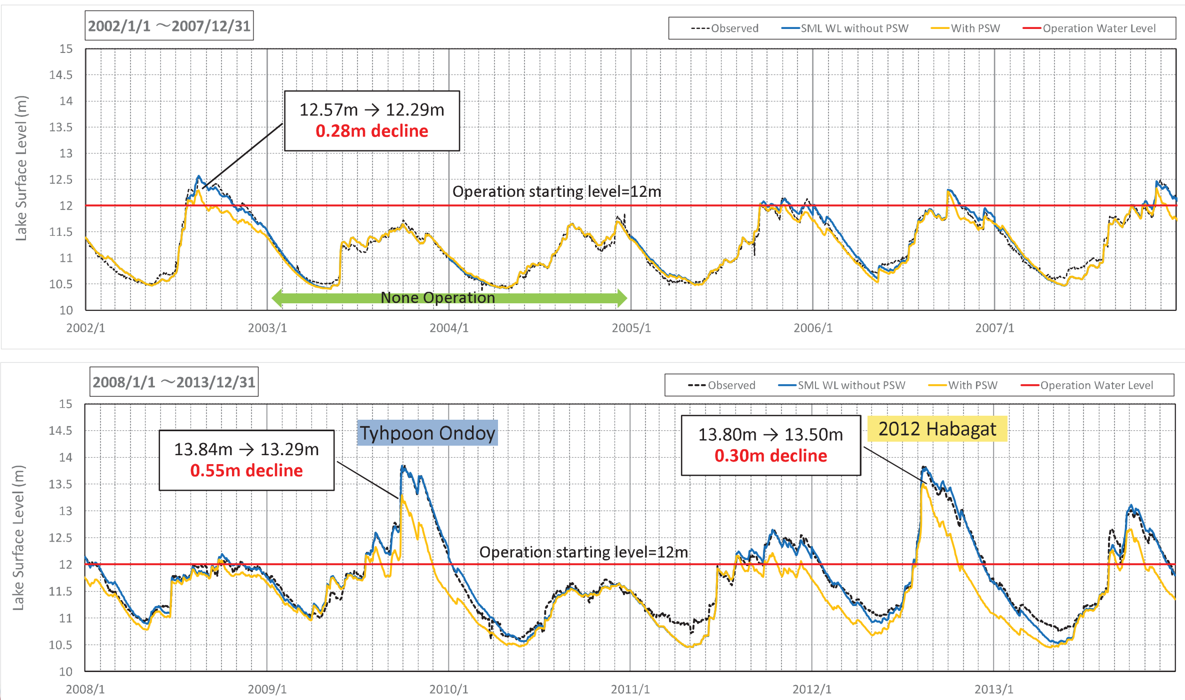
Source: JICA Survey Team



## 4.4 Lake Water Level Analysis ,Runoff Inundation Analysis (Long-Term Analysis)

### 1) Effect of Water Level Reduction by the Construction of Parañaque Floodway

＜ Operation Starting Water Level ＝ 12.0m ＞




Source: JICA Survey Team

Figure 4.4.1 The results map of the long-term prediction calculation

# 4.4 Lake Water Level Analysis ,Runoff Inundation Analysis (Long-Term Analysis)

## 1) Analysis Results of Water Level Fluctuation by Probability Scale

- Calculation conditions in the water level fluctuation analysis by probability scale are summarized below.

Table 4.4.2 Calculation Conditions for Water Level Fluctuation by Probability Scale

| Items | Setting Value | Basis |
|---|---|---|
| The Operation Starting Water Level of the Parañaque Spillway | **12.0m** | ● Based on the calculation results that set the operation starting water level of three patterns, the case with 12.0 m was adopted because it has the effect in water level reduction and less influence even in drought years. |
| Design Water Level Waveform | Actual water level waveform in **2012** | ● Based on the calculation results with the operation starting water level ＝ 12.0m, the water level lowering effect in 2009 and 2012 was confirmed.<br>☐ **In 2009**<br>with Parañaque Spillway =13.84m<br>without Parañaque Spillway =13.29m **0.55m decline**<br>☐ **In 2012**<br>with Parañaque Spillway =13.80m<br>without Parañaque Spillway =13.50m **0.30m decline**<br>● As mentioned above, the waveform of 2012 has less water level reduction effect by the Parañaque Floodway. In considering the effect by the probability scale, the safety review is conducted by adopting the 2012 water level waveform. |
| Calculation Period | **1 year** | ● The calculation period is set as 1 year and the water level fluctuation throughout the year is examined and evaluated. |

Source: JICA Survey Team



# 4.4 Lake Water Level Analysis ,Runoff Inundation Analysis (Long-Term Analysis)

## 2) Analysis Results of Water Level Fluctuation by Probability Scale

- The water level of the 100-year probability scale is 14.3 m without the Parañaque Floodway (Present Condition), whereas it is 14.0 m with the Parañaque Floodway, and the water level lowering effect of **30 cm** is confirmed.
- The 3 to 5 year probability scale has 10 cm reduction, the 10 to 20 year probability scale is 20 cm reduction and the 30 to 50 year probability scale has 30 cm water level reduction effect.
- For the case with the Parañaque Floodway, since the preliminary operation is started before a major flood events, there is a possibility that it may be lower than the predicted maximum water level calculated by the probability scale calculation.

Table 4.4.3 Outline of the Maximum Water Level of Laguna de Bay by Probability Scale (Operation Start Water Level ＝ 12.0m)

| Probability | Case-5 | Case-6 | Decline (m) | Days of more than 12.5m | | |
|---|---|---|---|---|---|---|
| | Without PSW*1 | With PSW*1 | | Without PSW*1 (day) | With PSW*1 (day) | Reduction (%) |
| 200 | 14.7 | 14.3 | 0.4 | 141 | 93 | 66 |
| 100 | 14.3 | 14.0 | 0.3 | 124 | 79 | 64 |
| 50 | 14.0 | 13.7 | 0.3 | 116 | 70 | 60 |
| 30 | 13.7 | 13.4 | 0.3 | 103 | 53 | 51 |
| 20 | 13.6 | 13.4 | 0.2 | 97 | 49 | 51 |
| 10 | 13.2 | 13.0 | 0.2 | 74 | 26 | 35 |
| 5 | 12.9 | 12.8 | 0.1 | 62 | 18 | 29 |
| 3 | 12.6 | 12.5 | 0.1 | 18 | 0 | 0 |
| 2 | 12.3 | 12.3 | 0.0 | 0 | 0 | 0 |

Source: JICA Survey Team
*PWS: Parañaque Spillway

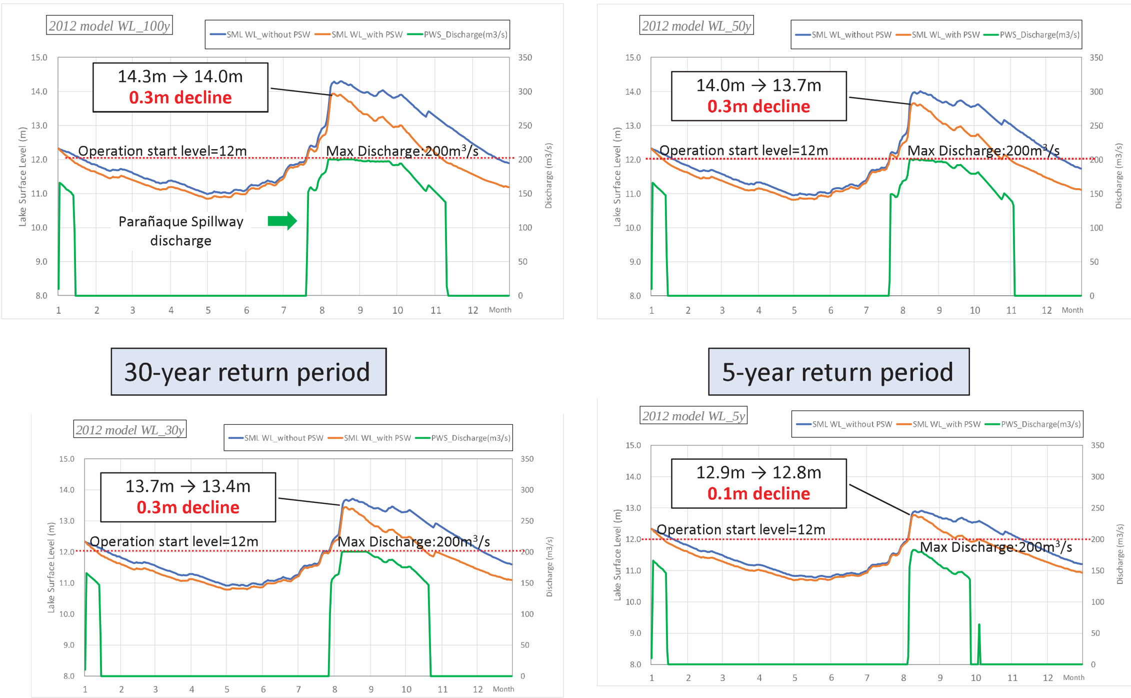
# 4.4 Lake Water Level Analysis ,Runoff Inundation Analysis (Long-Term Analysis)

100-year return period

50-year return period

30-year return period

5-year return period




Source: JICA Survey Team

Figure 4.4.2 Analysis Results of Water Level Fluctuation

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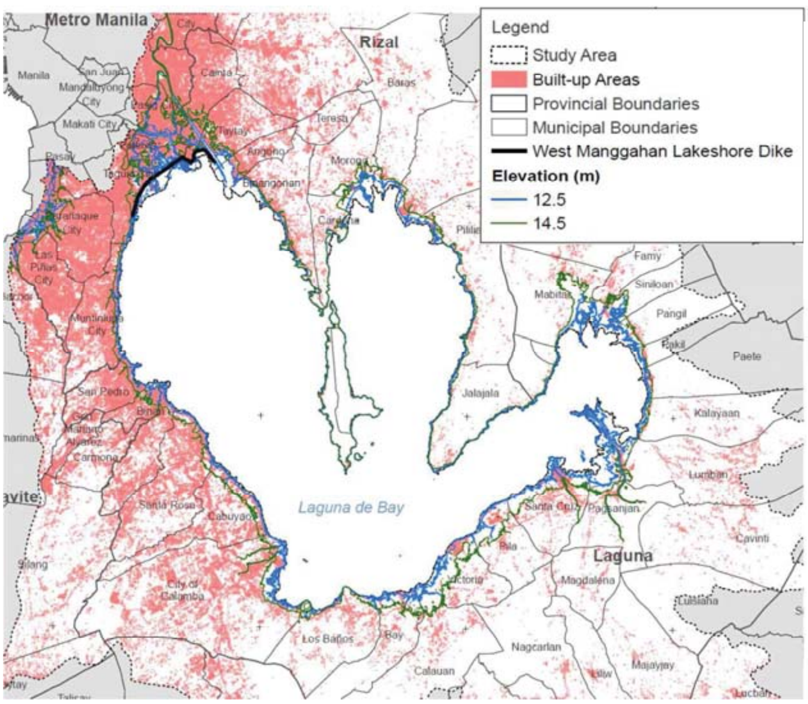
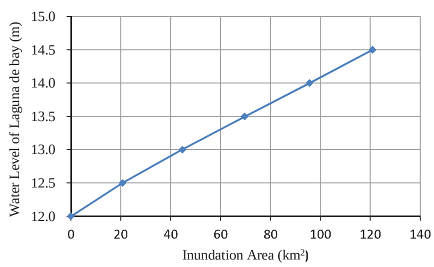
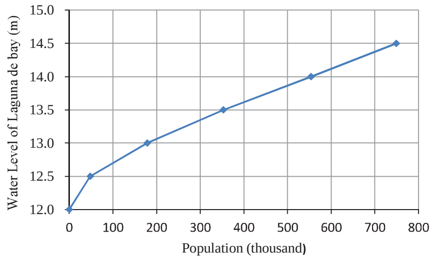
# 4.5 Study on Lakeshore Dike

## 1) Condition of Lakeshore Area




Inundation Area (Water Level >12.0m)




Population (Water Level >12.0m)

Source: JICA Survey Team

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