REPUBLIC OF THE PHILIPPINES

DEPARTMENT OF
PUBLIC WORKS AND HIGHWAYS

THE DETAILED DESIGN STUDY FOR THE PASIG-MARIKINA RIVER CHANNEL IMPROVEMENT PROJECT (PHASE IV)

FINAL REPORT (PRIOR RELEASE VERSION)

VOLUME-1D
MAIN REPORT

AUGUST 2020

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI ENGINEERING INTERNATIONAL CO., LTD.
JAPAN WATER AGENCY
NIPPON KOEI CO., LTD.
CTI ENGINEERING CO., LTD.

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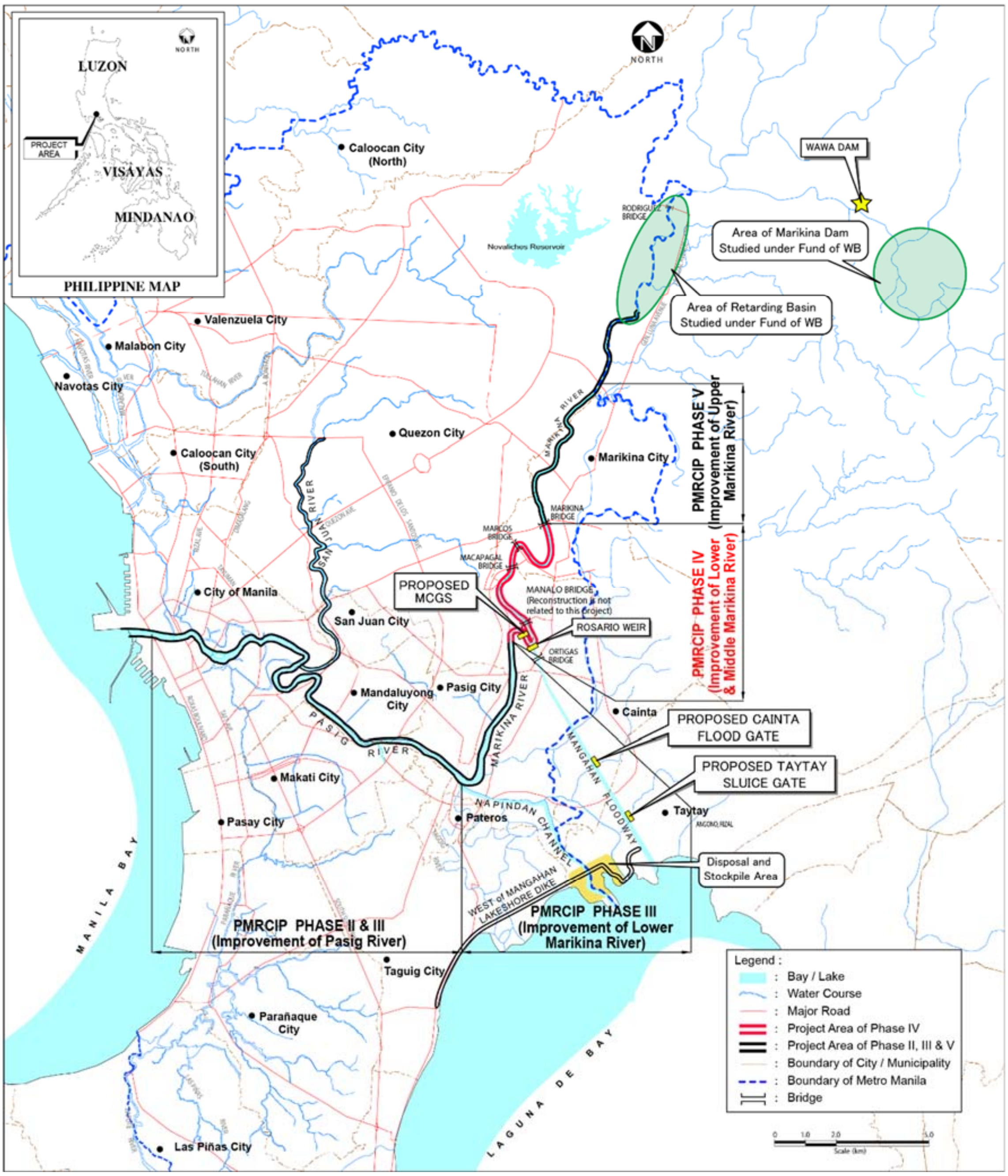
COMPOSITION OF FINAL REPORT

VOLUME-1A	:	MAIN REPORT (CHAPTER 1 to 6)
VOLUME-1B	:	MAIN REPORT (CHAPTER 7 / 7.1 to 7.3)
VOLUME-1C	:	MAIN REPORT (CHAPTER 7 / 7.4 to 7.6)
VOLUME-1D	:	MAIN REPORT (CHAPTER 8 to 12)
VOLUME-2	:	APPENDIX
VOLUME-3	:	APPENDIX FOR GEOTECHNICAL INVESTIGATION

EXCHANGE RATES USED IN THE REPORT:
PHP 1.0 = JPY 2.15
US $1.0 = JPY 108.9 = PHP 50.7
(November 2019)



PROJECT LOCATION MAP

THE DETAILED DESIGN STUDY
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ABBREVIATIONS AND ACRONYMS

1952MP	Formulation of Flood Control Plan in Pasig-Marikina River Basin
1975FS/DD	FS Study and Detailed Design for Manggahan Floodway
2002DD	Detailed Engineering Design of PMRCIP
2013III-DD	Detailed Design Study for the Pasig-Marikina River Channel Improvement Project (Phase III)
2015IV&V-FS	Feasibility Study on PMRCIP for Phase IV and V
AASHTO	American Association of State Highway and Transportation Officials
ABC	Approved Budget for the Contract
ACEL	Association of Carriers and Equipment Lessors
ACI	American Concrete Institute
ADB	Asian Development Bank
AIIB	Asian Infrastructure Investment Bank
ASD	Allowable Stress Method
ASDSS	Alloy-Saving Duplex Stainless Steel
ASTM	American Society for Testing and Materials
BAC	Bids and Awards Committee
BC	Box Culvert
B/C	Benefit-Cost Ratio
BDS	Bid Data Sheet
BM	Bench Mark
BOD	Bureau of Design
BOD	Biochemical Oxygen Demand
BOQ	Bill of Quantities
BQ Item	Item of Bill of Quantities
Brgy.	Barangay
BRS	Bureau Research Standards
BSDS	Bridge Seismic Design Specifications
CAAP	Civil Aviation Authority of the Philippines
CRID	Casing Ring bit Inner Drilling Down Hole Hammer
CTIE	CTI Engineering Co., Ltd.
CTII	CTI Engineering International Co., Ltd.
DAO	DENR Administrative Order
DD	Detailed Design
DENR	Department of Environment and Natural Resources
DFL	Design Flood Level
DHWL	Design High Water Level
DFR	Draft Final Report
DGCS	Design Guidelines, Criteria & Standards Volume 3: ‘Water Engineering Projects’
DHH	Down-the-Hole-Hammer
DND	Department of National Defense

DO	Department Order
DO	Dissolved Oxygen
D.O.77	Department Order 77
DOF	Department of Finance
DOST-ASTI	Advanced Science and Technology Institute of the Department of Science and Technology
DPWH	Department of Public Works and Highways
DUPA	Detailed Unit Price Analysis
EAM	Equivalent Area Method
ECC	Environment Compliance Certificate
EDC	Estimated Direct Cost
EFCOS	Effective Flood Control Operating System
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EIS	Environmental Impact Statement
EL.	Elevation
ELRD	Environmental Laboratory and Research Division
EMP	Environmental Management Plan
EMoP	Environmental Monitoring Plan
EPA	Environmental Protection Area
ESSD	Environmental Social Safeguards Division
F/C	Foreign Currency
FCIC	Flood Control Information Center
FCMC	Flood Control Management Cluster
FCSMO	Flood Control and Sewerage Management Office
FPM	Flood Plain Management
FMC	Flood Mitigation Committee
FMB	Forest Management Bureau of DENR
FP	Flamework Plan
FRIMP-CTI	Flood Risk Management Project for. Cagayan, Tagaloan and Imus Rivers
FR	Final Report
FS	Feasibility Study
FVR	Fidel Valdez Ramos
GC	General Conditions
GIS	Geographical Information System
GOP	Government of the Philippines
GPS	Global Positioning System
HCDRD	Housing, Community Development and Resettlement Department
HEC-RAS	Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System
ICB	International Competitive Bidding
ICC	Investment Coordination Committee
ICP	Infromation Campaign and Publicity

IR	Inception Report
IEE	Initial Environmental Evaluation
IFB	Invitation for Bids
ISF	Informal Settler Family
ITB	Instructions to Bidders
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JICA1990MP	The Study on Flood Control and Drainage Project in Metro Manila
JICA2011 Preparatory Study	The Preparatory Study for Pasig-Marikina River Channel Improvement Project (Phase III)
JICA2014Study	Data Collection Survey on Flood Management Plan in Metro Manila
JIS	Japanese Industrial Standards
JPY	Japanese Yen
JS	Junction Side
JV	Joint Venture
JWA	Japan Water Agency
KOIKA	Korea International Cooperation Agency
LA	Loan Agreement
LARRIPP	Land Acquisition, Resettlement, Rehabilitation and Indigenous Peoples' Policy
L/C	Local Currency
LCC	Life Cycle Cost
LGU	Local Government Unit
LiDAR	Laser Imaging Detection and Ranging
LLDA	Laguna Lake Development Authority
LRA	Land Registration Authority
LRFD	Load and Resistance Factor Design
LRT	Light Rail Transit
MCCB	Molded Case Circuit Breaker; MCCB
MCGS	Manggahan Control Gate Structure
MCM	million cubic meters
MDF/IDF	Main Distributing Frame / Intermediate Distribution Frame
MHHW	Mean Higher High Water Level
MHWL	Mean High Water Level
MLIT	Ministry of Land, Infrastructure, Transport and Tourism, Japan
MLLWL	Mean Lower Low Water Level
MLWL	Mean Low Water Level
MMDA	Metro Manila Development Authority
MOA	Memorandum of Agreement
MP	Master Plan
MRB	Medium Rise Building
MSL	Mean Sea Level

MSHHWL	Mean Spring Higher High Water Level
MSHWL	Mean Spring High Water Level
MWCI	Manila Water Company, Inc.
NCR	National Capital Region
NBCP	National Building Code of the Philippines
NEDA	National Economic and Development Authority
NETIS	New Technology Information System
NGO	Non-Governmental Organization
NHA	National Housing Authority
NHCS	Napindan Hydraulic Control Structure
NK	Nippon Koei Co., Ltd.
NPV	Net Present Value
NSCP	National Structural Code of the Philippines
OC	Open Channel
OCD	Office of Civil Defense
OCM	Overhead, Contingencies and Miscellanous
ODA	Official Development Assistance
OECF	Overseas Economic Cooperation Fund of Japan
OJT	On-the-Job Training
OPP	orthophenyl phenol
PAF	Project Affected Family
PAGASA	Philippine Atmospheric, Geophysical & Astronomical Services Administration
PAP	Project Affected Person
PC	Particular Conditions
PC	Personal Computer
PC	Prestressed Concrete
PCB	Polychlorinated Biphenyl
PD	Presidential Decree
PDB	Power Distribution Box
PLC	Programmable Logic Controller
PMC	Price Monitoring Committee
PR	Public Relations
PVC	Poly Vinyl Chloride
PHIVOLCS	Philippine Institute for Volcanology and Seismology
PHP	Philippine Peso
PIA	Public Information Agency
PMO	Project Management Office
PMRCIP	Pasig-Marikina River Channel Improvement Project
PNS	Philippine National Standard
POW	Program of Works
PRRC	Pasig River Rehabilitation Commission
PSD	Particle Size Distributions

RA	Republic Act
RAP	Resettlement Action Plan
RAM	River Area Management
RCP	Reinforced Concrete Pipe
RD	Record of Discussion
ROW	Right of Way
SAPROF	Special Assistance for Project Formation
SDGs	Sustainable Development Goal
SEA	Strategic Environmental Assessment
SNS	Social Networking Service
SP	Steel Pipe
SPSP	Steel Pipe Sheet Pile
SSP	Steel Sheet Pile
STA. Sta.	Station
STEP	Special Terms for Economic Partnership
STP	Sewerage Treatment Plant
SUS	Steel Special Use Stainless
SYW	Weldable hot rolled steel sheet piles
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TSP	Total Suspended Particles
TTS	Telegraphic Transfer Selling
TWG	Technical Working Group
UNDP	United Nations Development Programme
UPAO	The Urban Poor Affairs Office
UPMO	Unified Project Management Office
USACE	United States Army Corps of Engineers
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
VAT	Value Added Tax
WB	World Bank
WB2012MP	Master Plan for Flood Management in Metro Manila and Surrounding Areas
WB2018 UMD FS	Feasibility Study and Preparation of Detailed Engineering Design of the Proposed Upper Marikina Dam
WC	Water Code
WJ	Water Jet
WS	Workshop

Units of Measurement

mm	: millimeter
cm	: centimeter
mm	: millimeter
cm	: centimeter
m	: meter
km	: kilometer
g, gr	: gram
kg	: kilogram
t, ton	: metric ton
m^2	: square meter
ha, has	: hectare, hectares
km^2	: square kilometer
l, lt., ltr	: liter
m^3	: cubic meter
s, sec	: second
m, min.	: minute
h, hr	: hour
y, yr	: year
MW	: megawatt
mm/hr	: millimeter per hour
m/s	: meter per second
km/hr	: kilometer per hour
mg/l	: milligram per liter
m^3/s	: cubic meter per second
$m^3/s/km^2$	: cubic meter per second per square kilometer
%	: percent
ppm	: parts per million
x x	: symbol of multiplication (times)
≤ , ≥	: inequality sign (e.g. A≤B means that value A is less than or equal to value B.)
< , >	: inequality sign (e.g. A<B means that value A is less than value B.)
Y, Y, JPY	: Japanese Yen
P, P, PHP	: Philippine Peso
$	: US Dollar

CHAPTER 8 HYDRAULIC MODEL EXPERIMENT (SUMMARY)

The results of the Hydraulic Model Experiment completed in November 2019 are summarized in this chapter. The Main Report of Hydraulic Model Experiment has been prepared as a separate report "Hydraulic Model Experiment, October 2019".

8.1 Outlines of the Hydraulic Model Experiment

8.1.1 Introduction

There is an existing floodway in the vicinity of the MCGS which is the main target of this experiment, the Manggahan Floodway. Therefore, it is assumed that the diversion phenomenon will change with the flood control of MCGS. Although it is necessary to grasp the diversion discharge accurately to determine the appropriate specifications of the MCGS, it is difficult to predict the diversion discharge by desk study, because the diversion phenomenon is strongly influenced by the three-dimensional flow. Furthermore, although it is needed to install an energy dissipator at the downstream of the MCGS, it is difficult to determine the optimum scale of energy dissipating facilities by desk study, because complex flow such as hydraulic jump and plane vortex could be generated around the energy dissipating facilities.

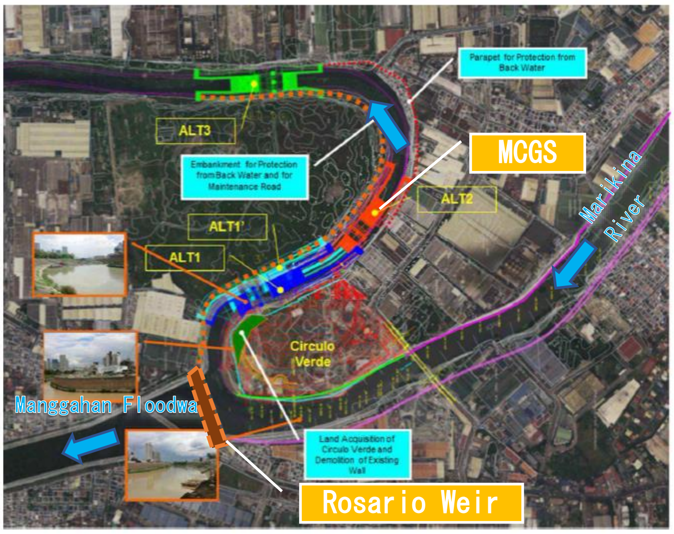
Therefore, in this detailed design study, the three-dimensional hydraulic model experiment, which can reproduce the diversion phenomenon and complex, flow around energy dissipating facilities is conducted to examine the optimum specifications of the MCGS, including the energy dissipator.

8.1.2 Purpose of the Hydraulic Model Test

The purpose of the hydraulic model experiment in the detailed design study for the implementation of Pasig-Marikina River Channel Improvement Project, Phase IV, are as listed below:

- To set the gate opening/width of MCGS that could ensure proper design discharge distribution during floods (To set the proper gate opening);
- To set the optimum river alignment and the gate opening/width of MCGS that could minimize turbulent flow at the upstream and downstream (To set the proper river shape);
- To confirm the relationship between the gate opening of MCGS and the discharge distribution of the Manggahan Floodway and the main river in flood conditions including design flood and excess flood (Confirmation of discharge distribution after construction); and
- To validate the temporary channel that could ensure the safety of the main river during the construction period (Confirmation of flood phenomenon during the construction period).

The objective area of the hydraulic model experiment is as shown in **Figure 8.1.1**.



Source: 2015IV&V-FS

Figure 8.1.1 Objective Area of Hydraulic Model Experiment

8.2 Results of Model Experiments

8.2.1 Diversion Characteristics of Existing Channel

The relationship of discharge between Marikina River (under the existing condition) and Manggahan Floodway is summarized in **Table 8.2.1**. As a result, diversion ratio for Marikina River is almost constant at about 20% under the existing condition (before SA#5 and #6 of the PMRCIP III (dredging of the Lower Marikina River)).

Under the existing channel, the diversion discharge to Marikina River, 585m^3/s, exceeds the design discharge, 500m^3/s, when inflow design flood discharge is 2,900m^3/s.

Table 8.2.1 Diversion Ratio of Existing Channel

Inflow Discharge (m^3/s)	Lower Marikina River (m^3/s)	Manggahan Floodway (m^3/s)	Diversion Ratio (%)	Remarks
2,147	437	1,710	20.3%	Maximum in past 5 years
2,900	585	2,315	20.2%	Design Flood Discharge
3,480	711	2,769	20.4%	Typhoon Ondoy (2014 JICA Study)
3,898	791	3,107	20.3%	Bank-full discharge (Upstream end of the model)

Source: Study Team

8.2.2 MCGS Specifications Determined by the Hydraulic Model Experiment

8.2.2.1 Specifications of MCGS Gates

The specifications of MCGS gates to achieve the designed diversion ratio under the condition of design flood discharge were determined as shown in **Table 8.2.2**.

Height of gate was determined as DFL EL.17.4m, in which condition discharge of Lower Marikina River does not increase significantly due to small amount of overflow from fully-closed gate even in excess flood.

Table 8.2.2 Gate Specifications Determined by the Hydraulic Model Experiment

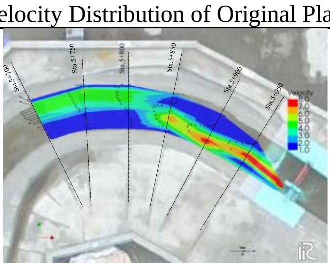
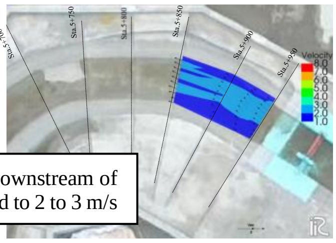
Narrower span gate		Long Span Gate	
Width	Crown Height	Width	Crown Height
11.7m	EL.17.4m（DFL）	28.3m	EL.17.4m（DFL）

Source: Study Team

8.2.2.2 Energy Dissipator and Bed Protection Works

It was confirmed that high flow velocity, about 8m/s, is generated at the downstream of MCGS under the condition of design discharge, 500m^3/s.

As a countermeasure, velocity at Sta.5+950 was reduced to 2 to 3m/s by improving the energy dissipator with the installation of L-type sill, 2.0m in height. Note, however, that this countermeasure restricts ships that could pass through the narrower span gate. Considering that this restriction will not be a great hindrance in navigation due to the wider span gate available for it in ordinary time, the priority shall be given to the improvement of flow condition.

Velocity Distribution of Original Plan	Velocity Distribution of Improved Plan (L-Type Sill, Sill Height +2.0m)
	

Source: 2015IV&V-FS

Figure 8.2.1 Velocity Distribution with Energy Dissipator (500m^3/s)

8.2.3 Diversion Characteristics of Planned Channel

Diversion characteristics of the channel after improvement by PMRCIP IV are as shown in **Table 8.2.3**.

Table 8.2.3 Diversion Ratio of Existing Channel Ratio of Planned Channel

Inflow Discharge (m^3/s)	Lower Marikina River (m^3/s)	Manggahan Floodway (m^3/s)	Diversion Ratio (%)	Remarks
2,900	488	2,512	16.8%	Design Flood Discharge
4,000	595	3,405	14.9%	Excess Flood (200-year flood)
4,000	1,140	2,860	28.5%	Only Long Span Gate Fully Opened
4,000	1,236	2,764	30.9%	2 Gates Fully Opened

Source: Study Team

8.2.4 Experiment at the Time of Construction

The water level and flow discharge at the section of the MCGS to be constructed had been confirmed by hydraulic software calculated in the computer. As a result, it has also been confirmed that discharge flow at 440m3/s which corresponding to the maximum discharge for the recent 5 years shall safely flow into the downstream stretch during the construction stage of the MCGS. In addition, it was confirmed that the water level corresponding to 440m3/s was EL+14.0m equivalent to water level at 10-year return period flood.

In the model experiments, the necessary dimensions of flow areas during construction stage were confirmed.

The construction steps confirmed by the hydraulic model experiments are shown in

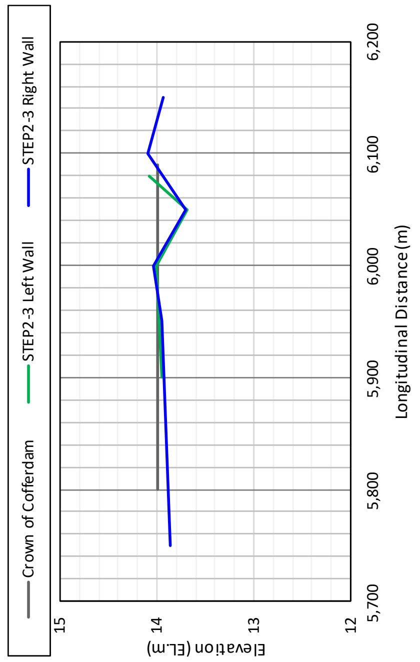
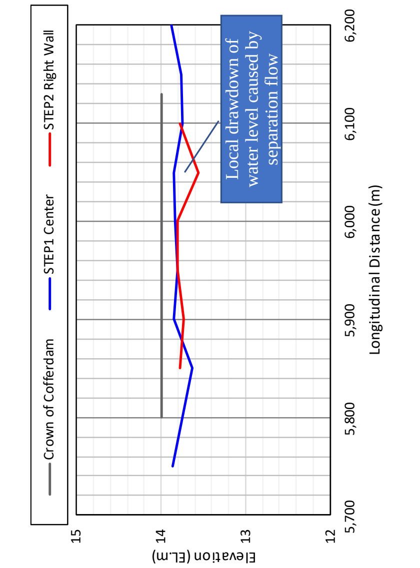
Table 8.2.4 Construction Steps confirmed by the Hydraulic Model Experiment

Construction Step	Concepts	Plan View of Temporary Channel
STEP1	Flow: Left Bank Construction: P2 and P3	Not Presented due the Closed Information
STEP2	Flow: Right Side between P2 and P3 Construction: P1	Not Presented due the Closed Information

Source: Study Team

As a result, Water level under the condition of target discharge for temporary cofferdam, 440m^3/s in both cases of STEP1 and STEP2, is below EL.14.1m.

Table 8.2.5 Water Levels and Flow Condition at 440m3/s in the Hydraulic Model Experiment

	Water Level Observed	Flow Line	Model Result
STEP2-3		Not Presented due the Closed Information	Not Presented due the Closed Information
STEP1		Not Presented due the Closed Information	Not Presented due the Closed Information

CHAPTER 9 NON-STRUCTURAL MEASURES AND OPERATION, MAINTENANCE AND MANAGEMENT RULES

9.1 Evaluation of Non-Structural Measures

The study team evaluated non-structural measures implemented in Phases II and III. The contents of non-structural measures for Phase IV were formulated by referring to the results.

9.1.1 Evaluation of Non-structural Measures Implemented in Phases II and III

The outline of non-structural measures implemented in Phase II and III and the results of the evaluation of past non-structural measures and requests for future activities are as described below.

9.1.1.1 Non-Structural Measures Implemented in Phases II and III

(1) Phase II

Before commencing Phase II, some issues such as the relocation of informal settlers along the Pasig-Marikina River and the complaints of residents along the river concerning the height of embankment (parapet wall) existed. Therefore, measures to mitigate flood damage were not implemented, and the following activities to foster understanding of the project were instead conducted.

(a) Development of Information Campaign and Publicity (ICP) plans;

(b) Conceptualization of design and preparation of information materials;

(c) Community-based explanatory discussions;

(d) Public hearing survey;

(e) Caravan operation involving schools, government officials, barangay officials;

(f) Development of community-based project motivators;

(g) Establishment of community-based information centers;

(h) Media exposure and public relation activities; and

(i) Continuous linkages with national/local government units.

(2) Phase III

The following non-structural measures were implemented in Phase III.

1) Information Campaign and Publicity (ICP)

The following information campaigns and communications activities were conducted in Phase III.

(a) Review of the existing ICP program prepared by the Consultant for Detailed Design;

(b) Conceptualization of design and preparation of information materials;

(c) Community-based explanatory discussion;

(d) Public hearing survey;

(e) Caravan operation involving schools, government officials, barangay officials;

(f) Development of community-based project motivators;

(g) Establishment of community-based information centers;

(h) Media exposure and public relation activities; and

(i) Continuous linkages with national/local government units.

Source: Study Team

Figure 9.1.1 ICP Activities in Phase III
(Left: Public hearing; Right: Caravan operation)

2) Establishment of Websites

Under Phase III, two websites were established: the website of the PMRCIP and the website of the Effective Flood Control Operation System (EFCOS). The former was established to provide information on the project, including the project's efforts to mitigate flood damage in the Pasig-Marikina River Basin, its history, mission, and vision. On the other hand, the latter was established to provide information on river water level observed at the EFCOS monitoring stations. **Figure 9.1.2** shows the main pages of each website**.**

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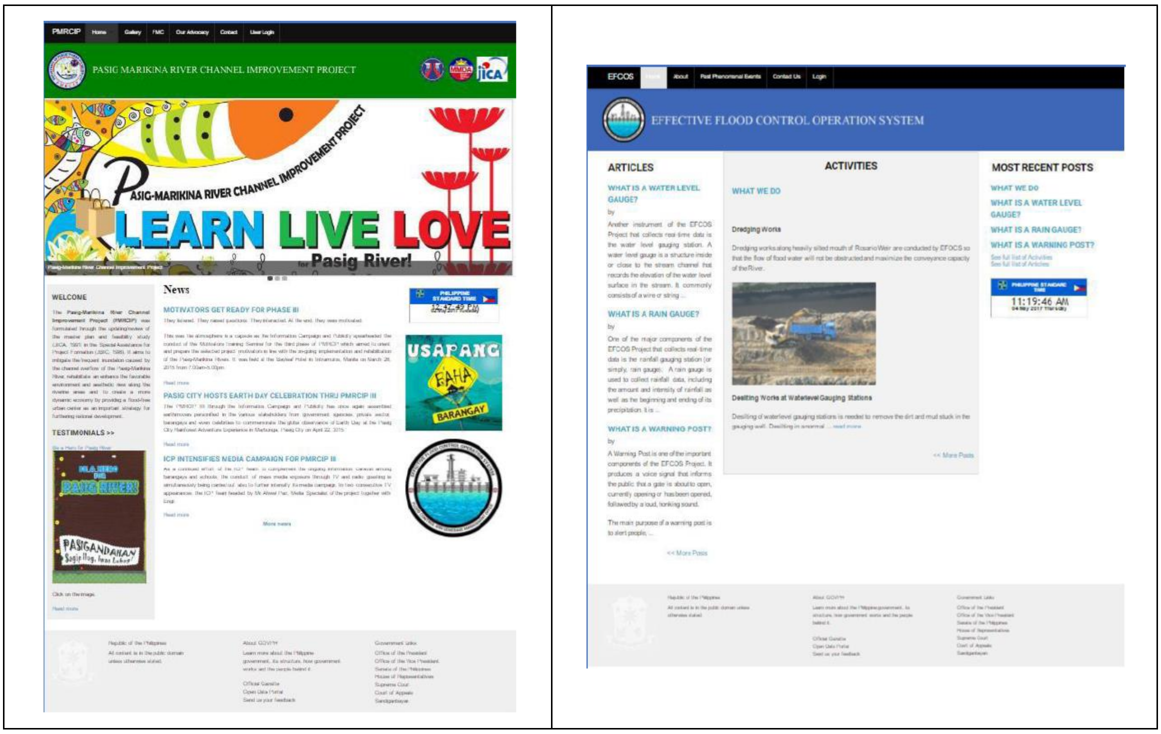


Source: Consulting Engineering Services for Assistance to Procurement of Civil Works and Construction Supervision on the JICA-Assisted Pasig-Marikina River Channel Improvement Project, Phase-III, Project Completion Report

Figure 9.1.2 Established Websites (Left: PMRCIP; Right: EFCOS)

3) Elaboration of Hazard Maps

Under Phase III, a pilot activity of hazard mapping was conducted in order to (1) enhance the capacity of selected barangays in Pasig City; (2) act as a model for other LGUs in the Pasig Marikina River Basin regarding the Disaster Risk Reduction Management (DRRM) through activities such as Community-Based Hazard Map development, evacuation drills, review and revision of action plan on DRRM; and (3) enhance the capacity on efficient and effective utilization of available information.

Two pilot barangays in Pasig City were selected to develop a community-based hazard map and conduct workshops and evacuation drills. Barangay Santolan was selected to develop a hazard map for general residents, and Barangay Ugong was selected to develop a hazard map for school children.

The activities include Workshop 1 ("Awareness Program"), Workshop 2 ("Map Exercise"), Evacuation Drill, and Training of Facilitators with the cooperation of Pasig City and Pilot Barangays. For the activities of school children in Barangay Ugong, Legaspi Memorial School was selected as a "Pilot School."

9.1.1.2 Evaluation of Implemented Non-structural Measures

(1) Questionnaire Survey

1) Survey Target

To get feedback on the non-structural measures implemented in Phase II and Phase III from the people related to these projects, the study team visited the organizations shown in **Table 9.1.1** and conducted a questionnaire survey.

Source: Study Team

Figure 9.1.3 Status of the Survey (Barangay Office)

Table 9.1.1 Survey Respondents

City	Barangay
Manila	1. Barangay 659-A
	2. Barangay 900
	3. Barangay 901
	4. Barangay 902
Makati	1. Barangay GUADALUPE VIEJO
	2. Barangay WEST REMBO
Mandaluyong	1. Barangay BARANGKAIBABA
	2. Barangay BARANGKAITAAS
	3. Barangay BARANGKA ILAYA
Pasig	1. Barangay PINEDA
	2 Barangay STA ROSA
	3 Barangay SAN JOSE
	4 Barangay BAGONG ILOG
	5 Barangay CANIOGAN
	6 Barangay MAYBUNGA
	7 Barangay ROSARIO

Source: Study Team

2) Question Items

The question items for the survey are as follows:

(a) Project Awareness: Are you aware or have heard about the Pasig-Marikina River Channel Improvement Project? If yes, where did you learn about this project?

(b) What is your impression of the project?

(c) Importance: Do you consider the project beneficial to you, your family, and the community?

(d) Evaluation of ICP activities conducted in Phases II and III (Five grades for relevance, effectiveness, impact, efficiency, and sustainability)

(e) Opinions and suggestions for future activities

(2) Hearing Survey

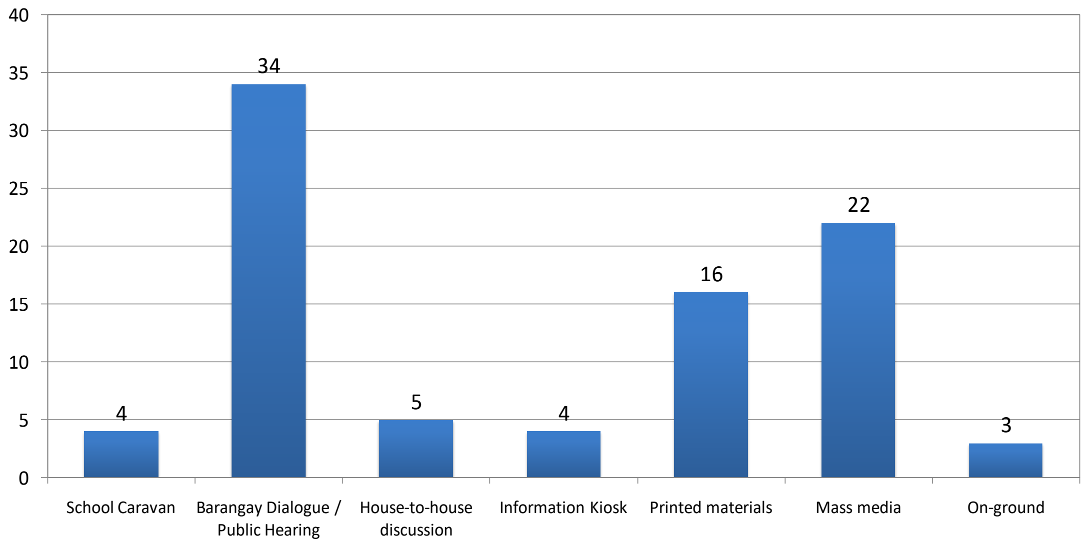
To seek public opinion regarding the non-structural measures implemented in Phase II and III, the study team held an explanatory meeting on April 12, 2019, at UPMO of DPWH, inviting officials from LGUs.

(3) Survey Results

1) Results of Questionnaire Survey

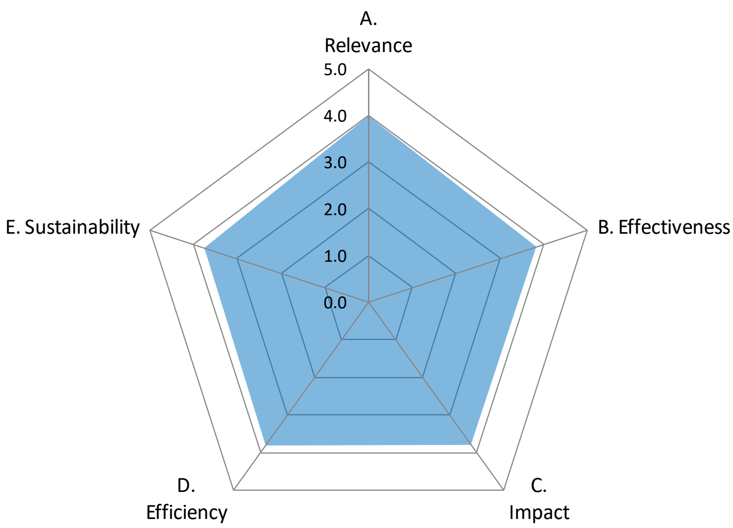
The results of the questionnaire survey are as below.

- 72% of respondents are aware of these projects. All of them answered that the projects were beneficial for themselves, their families, and communities.
- As shown in **Figure 9.1.4**, many respondents learned about the project through public hearings, barangay meetings, media advertising, and brochures.
- Figure 9.1.5 shows that the respondents' impression of each non-structural activity was generally positive. However, many of them associate the project with environmental measures such as water quality improvement and waste measures, as shown in Figure 9.1.6.
- Considering this fact, it is necessary to emphasize flood control as the main objective of the project in Phase IV.
- As for the future activities, there were requests from the respondents regarding the implementation of evacuation drills for local communities, training of river patrol and disaster response volunteers, and river cleaning activities.



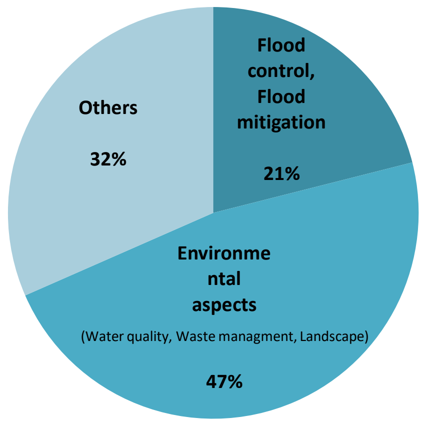
Source: Study Team

Figure 9.1.4 Where Did You Learn about This Project? (Multiple answers allowed)



Source: Study Team

Figure 9.1.5 Evaluation of ICP Activities Conducted in Phases II and III (Five grades for relevance, effectiveness, impact, efficiency, and sustainability)



Source: Study Team

Figure 9.1.6 Impression on the Projects

2) Results of Hearing Survey

As a result of the explanatory meeting with the LGUs regarding the outline of the next Phase IV project and past non-structural measures at UPMO of DPWH, participants expressed positive opinions on cooperation for the next project, including non-structural measures.

On the other hand, Marikina City, one of the LGUs related to Phase IV, requested not to construct embankment between Sta.12+500 and Sta.13+350 located right downstream of the Marikina Bridge since the city government is improving the riverside park in the same section. Although this matter is more of a structural concern, however, the explanatory meeting gave a venue for this issue to be discussed and considered. In this regard, DPWH, JICA, and the study team are still discussing the flood control measures in the said section. Under the circumstances, non-structural measures should be considered for floods in the future.

(4) Implementation Policy of Non-structural Measures Based on the Survey Results

Based on the above survey results, the JICA study team decided to implement non-structural measures in Phase IV according to the following policy.

(a) Scrutinize the results of the questionnaire survey and continue/expand the ICP activities to disseminate information to relevant organizations and residents in the Pasig-Marikina River Basin.

(b) Implement massive and extensive non-structural measures to mitigate flood damage.

(c) Reactivate the Flood Mitigation Committee (FMC) to facilitate consensus-building among the concerned member organizations and implement non-structural measures.

(d) Conduct activities aimed at tapping skills, talents in the spirit of volunteerism and by developing human resources for flood damage mitigation.

9.1.2 Flood Mitigation Committee (FMC) Reactivation Plan

9.1.2.1 Current Status of FMC

The FMC acts as the coordination body in handling issues relating to the PMRCIP implementation as well as Operation and Maintenance (O&M) of flood control facilities and controlling land encroachment and disorderly land development. The functions, roles, and responsibilities of the FMC are given below.

(a) Facilitate and assist in the PMRCIP implementation.

(b) Facilitate and assist in monitoring the O&M activities for the complemented facilities.

(c) Facilitate and assist in the introduction and operation of non-structural measures.

(d) Facilitate and assist in the resettlement and acquisition of Right-of-Way (ROW) activities for the project implementation.

(e) Monitor, coordinate, and take necessary actions for illegal activities such as encroachment, disorderly land development along the rivers in the Pasig-Marikina River Basin.

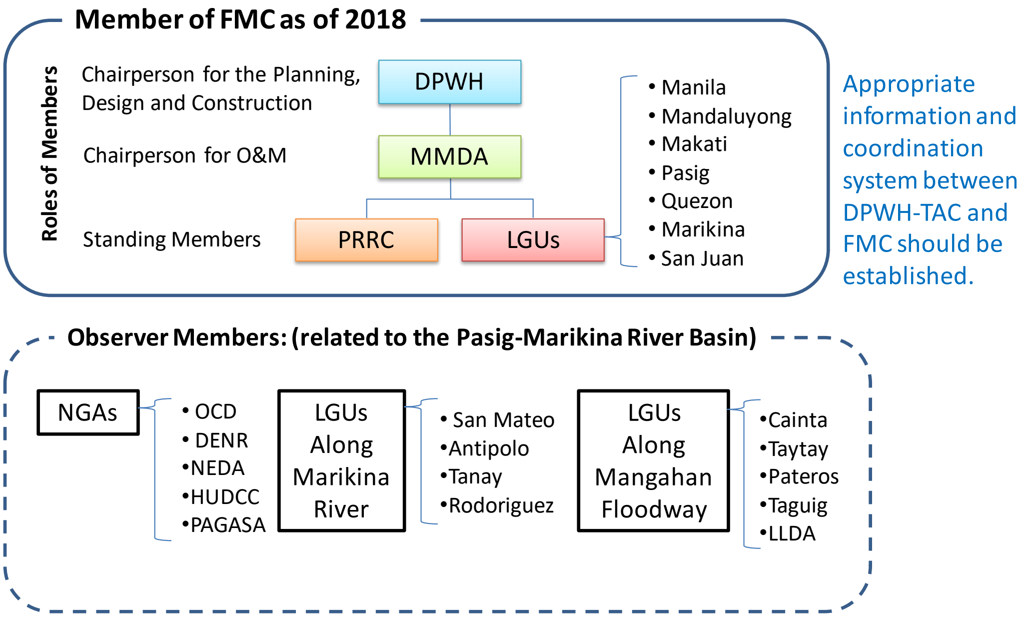
(f) Setup a "Query Window" for the project.

(g) Act as grievance and redress committee on ROW acquisition and other matters.

Since the establishment of the FMC in 2013, there has been no record of activities. To implement Phase IV smoothly, measures to reactivate this committee should be taken.

9.1.2.2 FMC Reactivation Plan

Figure 9.1.7 shows the current scheme of the FMC. Since related organizations should approve operation rules and maintenance management plan of flood control facilities and so on which would be prepared in Phase IV before implementing them, it is necessary to reactivate the FMC and facilitate consensus-building among member organizations. Specifically, as stipulated in the MOA at the time of the FMC formation, meetings for project progress briefing and opinion exchange should be convened regularly (at least once every three months) to raise awareness of the FMC and activate its activities. To strengthen the committee, the study team should encourage some observer members involved in Phase IV to participate in the FMC as formal members. Also, the study team should encourage the FMC to establish an appropriate information exchange and coordination system between the DPWH-TAC and the FMC in this consulting work.

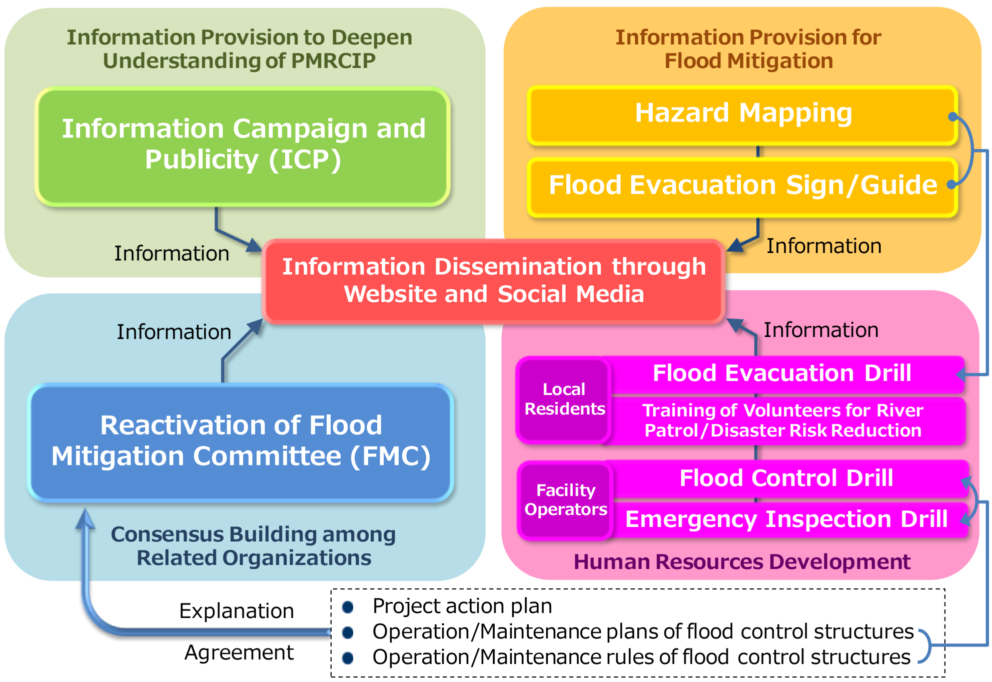


Source: Study Team

Figure 9.1.7 Scheme of Flood Mitigation Committee

9.1.3 Concept of Non-Structural Measures in Phase IV

Based on the above, non-structural measures in Phase IV are conceptualized as in **Figure 9.1.8**. The main objectives of non-structural measures for Phase IV are (1) to provide necessary information to relevant organizations and residents of the Pasig Marikina River Basin to foster their understanding of the project; (2) to provide necessary information for flood damage mitigation; (3) to build consensus among relevant organizations through the FMC; (4) to develop human resources for flood damage mitigation; and (5) to disseminate information regarding the above-mentioned activities through the internet and social media.



Source: Study Team

Figure 9.1.8 Concept of Non-structural Measures in Phase IV

9.1.3.1 Information Campaign and Publicity (ICP)

ICP is one of the fundamental non-structural components for the project. As in the past two phases, the ICP component complemented the smooth implementation alongside the structural component.

Before any non-structural measure or activity is undertaken, an organizational structure shall be created to compose the ICP team. The team will be headed by a media specialist, supported by a community organizer, a graphic artist, and a multi-media creator who will be working complementarily in carrying out the desired information campaign activities for Phase IV. Each one is specializing in his /her field of expertise, ensuring the delivery of work for this stage with their respective general job descriptions to be laid out in the implementation.

The activities of ICP to be conducted in Phase IV are as follows:

(1) Review of ICP Activities Implemented in Phases II and III

The study reports, work plans and results of the ICP conducted under Phases II and III have been collected and reviewed. Formulation/preparation of the ICP Plan based on these collected data and information will be conducted for target areas of Phase IV.

(2) Conceptualization of Design and Preparation of Information Materials

ICP materials with reference to past activities will be used.

(3) Community-based Explanatory Discussion

Meetings with local governments and barangays to publicize the project will be conducted.

(4) Public Hearings

Public hearings during the ICP caravan operations and other events to ask for opinions about the project will be conducted.

(5) Caravan Operation Involving Schools, Government Officials, Barangay Officials, and so on

ICP caravan operations at the offices of LGUs, educational institutions, Barangay offices and so on in the Pasig-Marikina River Basin that are related to Phase IV will be conducted to deepen participants' understanding of the project.

(6) Media Exposure and Public Relation Activities

Media exposure and publication of the project will be carried out.

(7) Continuous Linkages with National/Local Government Units (LGUs)

ICP meetings using ICP materials for continuous linkage with offices of national/local government units will be held.

9.1.3.2 Information Provision for Flood Damage Mitigation

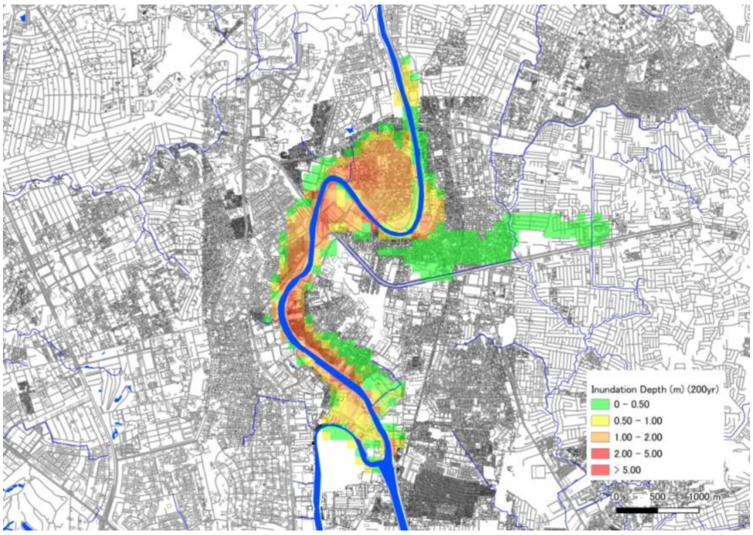
(1) Flood Hazard Map Preparation

1) Concept of Flood Hazard Map

Flood hazard maps are necessary for promoting flood evacuation activities in the Pasig-Marikina River Basin and providing essential data for the formulation of action plans concerning flood risk reduction in each LGU. The concept of the flood hazard map for Phase IV is a map that is (1) reliable, (2) easy to understand, and (3) user-friendly.

2) Preparation of Base Map

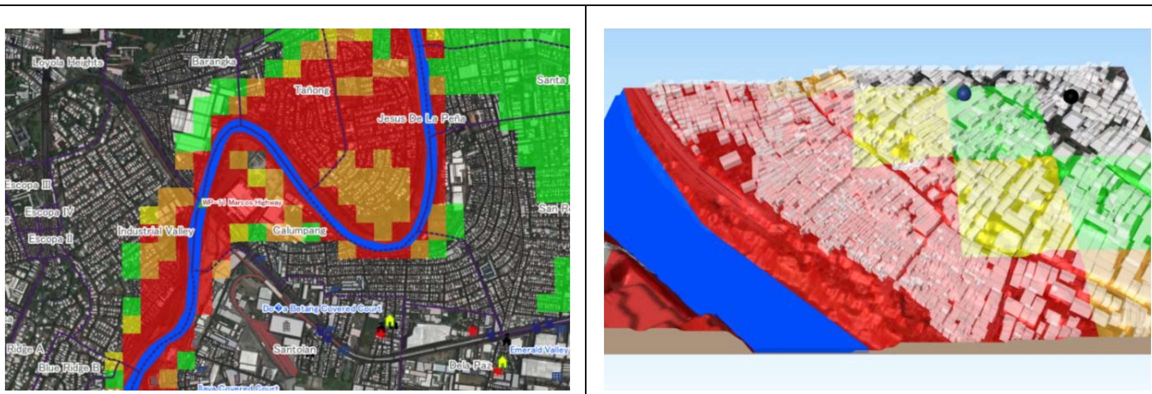
In this detailed design study, a base map for the flood hazard map was prepared using the GIS program. It is composed of a house map, a satellite image, Digital Elevation Model (DEM) data, facility information such as the location of evacuation centers prepared in Phase III, and the inundation analysis results conducted in this study. As for the inundation analysis, we assumed the precipitation caused by Typhoon Ondoy in 2009 that is equivalent for the return period of 200 years, and the analysis was carried out under the condition of the safe side without considering the freeboard of the embankment. The results of the flood analysis used are shown in **Figure 9.1.9**.



Source: Study Team

Figure 9.1.9 Result of Inundation Analysis (200-year Design Flood)

Figure 9.1.10shows the created base map. In addition to the general 2D map, the map also can be displayed in 3D so that the users can visually analyze the topographical differences and the location of high-rise buildings that are available for vertical evacuation sites in case of emergencies and examine the proper evacuation routes. This map should be provided to the department in charge of disaster prevention in each local government after completion of Phase IV, and the contents should be reviewed and revised, taking into account the progress of river improvement and changes in social conditions.



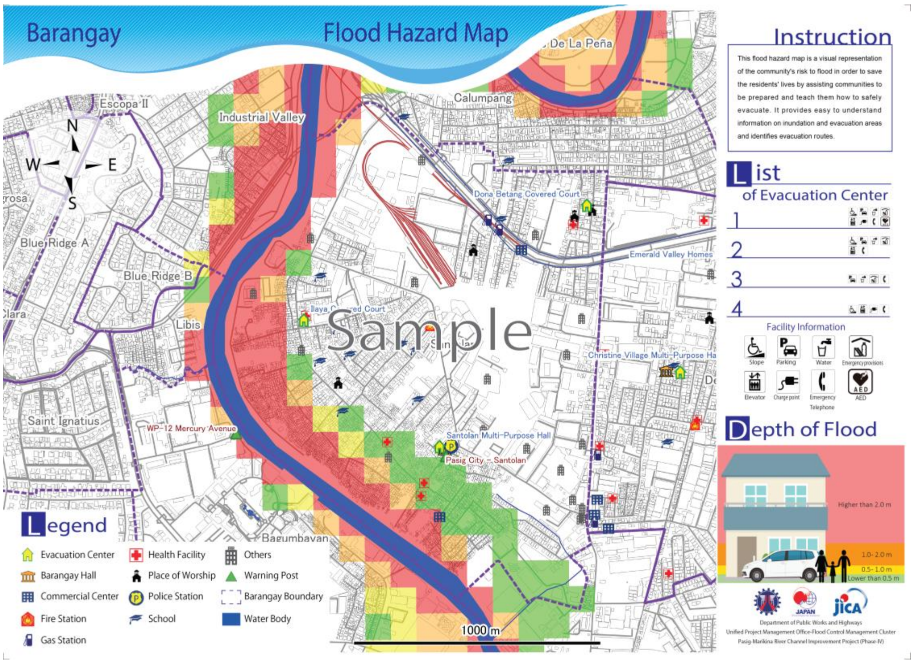
Source: Study Team

Figure 9.1.10 Base Maps (Left: 2D Map; Right: 3D Map)

3) Preparation of Draft Flood Hazard Map

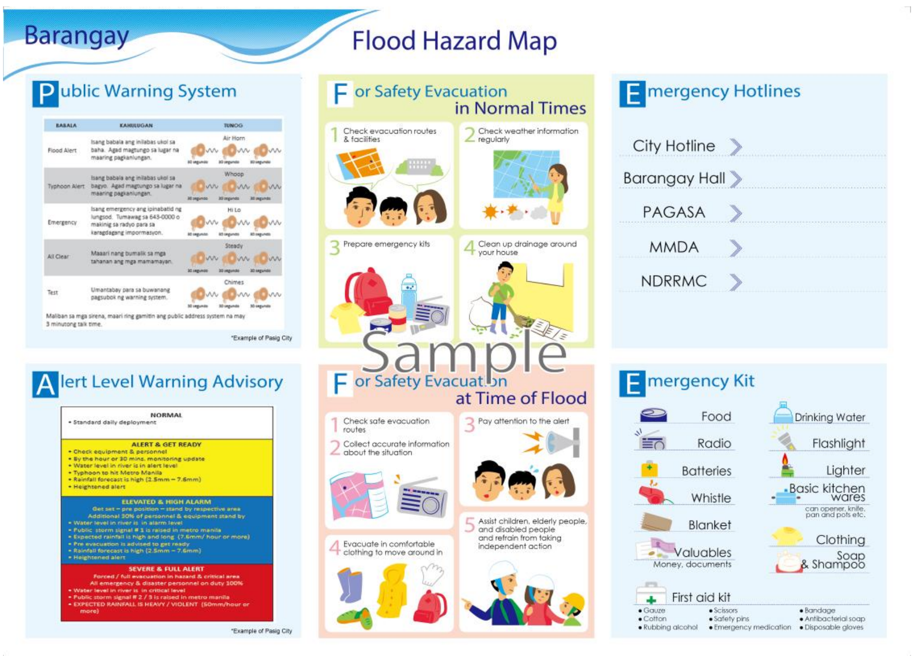
Figure 9.1.12and **Figure 9.1.12**shows the created draft flood hazard map. The hazard map consists of the base map and information and guidance related evacuation such as public warning system, warning advisory adopted by each local government, emergency hotline information, points to be noted during regular times, and a flood. To make each content understandable to users of a wide range of generations, make sure to use illustrations and diagrams as much as possible.

Also, in consideration of elderly and disabled people, information on the location of obstacles on evacuation routes, and barrier-free equipment at evacuation centers such as slopes and elevators are desirable to be included on the map.



Source: Study Team

Figure 9.1.11 A Draft Flood Hazard Map (Front Side)



Source: Study Team

Figure 9.1.12 A Draft Flood Hazard Map (Back Side)

4) Initiatives after Preparing Flood Hazard Map

After preparing the hazard map, hold briefing sessions and workshops to publicize it to the residents of each community, and deepen the user's understanding of the contents of the hazard map. It is also necessary to create a system in which the local government and residents can make effective use of the map together. To make the information on the map more reliable, regular updates by incorporating opinions from residents who understand the actual situation in each region through workshops and other opportunities are necessary. Besides, it is also recommended to incorporate region-specific information to the map.

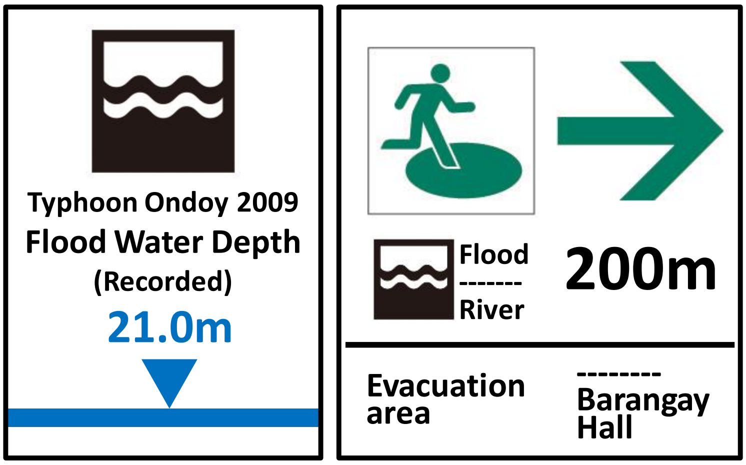
Furthermore, the created hazard maps are desirable to be uploaded to the PMRCIP's website to disseminate the information on flood damage mitigation in the project area. In addition, by showing flood analysis results before and after the project on the website, the effects of the project can be publicized widely.

(2) Flood Sign and Evacuation Guide

Installation of flood signs indicating the anticipated inundation depth at the time of flood and evacuation route guides to the evacuation facilities is one of the effective ways to promote awareness of flood risks in the local communities along the river and facilitate residents' safe evacuation. The signs shown in **Figure 9.1.13**indicate the inundation depth in the lowland area of Marikina City when Typhoon Ondoy made landfall in 2009. However, they have not been installed systematically throughout the inundated area at that time, and such activities need to be disseminated in the whole project area. **Figure 9.1.14**shows images of a flood sign, and an evacuation guide created referring the flood sign, and evacuation guide in Japan.

Source: Study Team

Figure 9.1.13 Signs of Inundation Depth in the Lowland Area of Marikina City (Typhoon Ondoy in 2009)



Source: JIS Z9098

Figure 9.1.14 Images of a Flood Sign and an Evacuation Guide

9.1.3.3 Reactivation of the FMC

In accordance with the FMC Reactivation Plan described in **7.1.2.2** above, the FMC activities were restarted under this consulting work as described below. In addition, the plenary meetings of the FMC will be held regularly to activate its activities.

Table 9.1.2 FMC Activities

Meeting	Schedule	Venue	Agenda
1st FMC Meeting (Working-Level Meeting)	7 Jun. 2019	DPWH Central Office	• Revival/Reactivation of the Flood Mitigation Committee (FMC) • Introduction of the PMRCIP PhaseIV • Presentation of non-structural measures to be conducted in the PMRCIP PhaseIV
2nd FMC Meeting	13 Aug. 2019	Quezon City	• Organization enhancement of the Flood Mitigation Committee (FMC) • Pasig-Marikina River Channel Improvement Project Phase-IV • A case study of the FMC activity in other river basins
3rd FMC Meeting	18 Nov. 2019	Quezon City	• Progress of the detailed engineering design study of the PMRCIP Phase IV • Flood control projects for Pasig-Marikina and Laguna Lake Basin in the past and future • Flood hazard map for PMRCIP Phase IV area
4th FMC Meeting	7 Feb. 2020	Quezon City	• Progress of the Detailed Engineering Design Study of the Pasig-Marikina River Channel Improvement Project (PMRCIP) Phase IV • Progress, Challenges and Future Plan of Resettlement and Update of Resettlement Action Plans (RAPs) • Operation Rule of Flood Control Structures in Pasig-Marikina and Laguna Lake Basin

Source: Study Team

(1) 1st FMC Meeting (Working-Level Meeting) on 7 June 2019

The FMC Working-Level Meeting was held on 7 June 2019 at the DPWH central office, with a total of 34 participants from member and observer organizations. During the meeting, DPWH gave a presentation on the background and outline of the FMC, and the JICA study team gave presentations on the outline of Phase IV and the results of the evaluation and the plan for non-structural measures. During the Q&A session, several inquiries were made regarding the resettlement of ISFs associated with the project's implementation. In addition, some observer members offered to join the FMC as formal members.

Source: Study Team

Figure 9.1.15 FMC Working-Level Meeting

(2) 2ndFMC Meeting on 13August 2019

The 2ndFMC Meeting was held on 13August 2019 in Quezon City, with a total of 108 participants from member and observer organizations. During the meeting, DPWH gave a presentation on the outline of the FMC activities, and the JICA study team gave presentations on the outline of Phase IV and the results of evaluation and the plan for non-structural measures. During the Q&A session, several inquiries were made regarding the specific information of construction works during Phase IV, the schedule of FMC, and the resettlement of ISFs associated with the project's implementation.

Source: Study Team

Figure 9.1.16 2nd FMC Meeting

(3) 3rdFMC Meeting on 18November 2019

The 3rdFMC Meeting was held on 18November 2019 in Quezon City, with a total of 77 participants from member and observer organizations. At the meeting, DPWH gave a presentation on the history of river improvement in the Pasig-Marikina River and Laguna Lake basin. JICA study team explained the progress of the detailed design study of Phase IV and outline of the draft flood hazard map for Phase IV and activities relating to hazard mapping. In the question and answer session, there were opinions and inquiries regarding the operation policy of each flood control facilities in the Pasig-Marikina River and Laguna Lake basin, basin management policy, resettlement, and selection of pilot sites of hazard mapping in the Phase IV project.

Source: Study Team

Figure 9.1.17 3rdFMC Meeting

(4) 4thFMC Meeting on

The 4thFMC Meeting was held on 7 February 2020 in Quezon City, with a total of 91 participants from member and observer organizations. At the meeting, after DPWH giving opening message, JICA study team gave a presentation on the history of river improvement in the Pasig-Marikina River and Laguna Lake basin and explained the progress of the detailed engineering design study of Phase IV, progress, challenges and future plan of resettlement and update of Resettlement Action Plans (RAPs) and operation rule of flood control structures in Pasig-Marikina and Laguna Lake basin. And also, challenges remaining after Phase IV project, such as flooding in East Manggahan district caused by rivers flowing into Manggahan Floodway and rising water level of Laguna Lake during floods, were provided. In the question and answer session, there were opinions and inquiries regarding resettlement and challenges remaining after Phase IV project. Next FMC and future will be held on a quarterly basis by DPWH.

Source: Study Team

Figure 9.1.18 4thFMC Meeting

9.1.3.4 Human Resources Development

(1) Human Resources Development of Residents

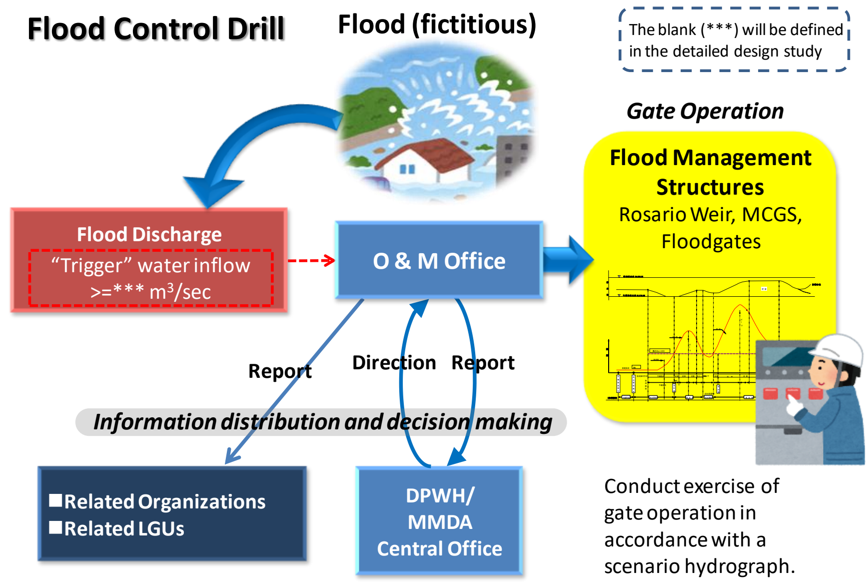
It is highly recommended to conduct flood evacuation drills for residents and training of volunteers for river patrol and disaster risk reduction under Phase IV, taking the request from the LGUs into consideration. The flood evacuation drill can be more practical and effective f hazard maps, flood signs, and evacuation guides prepared in the activities mentioned above are used. Issues identified during evacuation drills should be shared among the parties concerned, and used for facility development, review of evacuation routes, and updating flood hazard maps.

(2) Human Resources Development of Facility Operators

Since new flood control structures such as the MCGS, Cainta Floodgate, and Taytay Floodgate are expected to be constructed under Phase IV, it is necessary to conduct some exercises such as flood control drills and emergency inspection drills for DPWH and MMDA officials to enhance their O&M capacity after the completion of the facilities.

1) Flood Control Drill

Development of the MCGS and floodgates under Phase IV makes it possible to implement a comprehensive and integrated flood control operation of facilities, including those in the Pasig-Marikina River, the Manggahan Floodway and the Lake Laguna. However, to realize such operation, in addition to the construction of flood control facilities, strengthening the capacity of its operators is essential. Therefore, it is recommended to conduct exercises on the gate operation at each facility and information distribution among related organizations during the flood for facility operators, and improve their flood response capability.

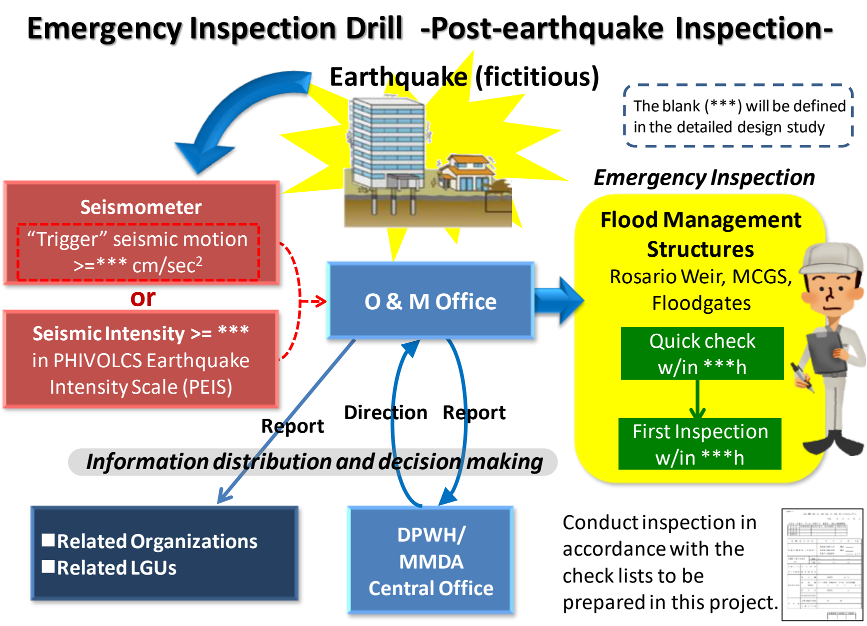


Source: Study Team

Figure 9.1.19 Outline of Flood Control Drill

2) Emergency Inspection Drill (Post-Earthquake Inspection)

MCGS and the floodgates to be constructed under Phase IV are designed to cope with a Level-2 earthquake that is expected to occur in the future. In response to such large-scale earthquakes, after completion of the facilities, emergency inspection drill of each facility and information distribution drill among relevant organizations against anticipated Level-2 earthquakes should be conducted. These drills improve operators' disaster response capability.



Source: Study Team

Figure 9.1.20 Outline of Emergency Inspection Drill (Post-Earthquake Inspection)

9.1.3.5 Information Dissemination through Website and Social Media

(1) Reactivation of the PMRCIP Website

Under Phase III, two websites were established: the EFCOS website, which provides information on river water level observed at the EFCOS monitoring stations in the Pasig-Marikina River Basin and the PMRCIP website, which provides essential information on the project, including the project's efforts to mitigate flood damage in the Pasig-Marikina River Basin, its history, mission, and vision.

The PMRCIP website is currently dysfunctional and needs to renew during Phase IV. **Table 9.1.3** and **Figure 9.1.21** show the contents and a draft image of the renewed website, respectively. Taking the situation that the PMRCIP website has been dysfunctional into consideration, news and event information related to the project need to be posted in cooperation with social media such as Facebook to simplify the updating procedure and make the website more sustainable.

Table 9.1.3 Contents of the Website of Phase IV

Classification	Contents
Public Relations	Outline of the PMRCIP Phase IV
	Effects of the project activities
	Project news and events (Link with Facebook)
Damage Mitigation	Activities of the Flood Mitigation Committee (FMC)
	Flood hazard map
	Hydrological information in the Pasig-Marikina River Basin

Source: Study Team

Source: Study Team

Figure 9.1.21 Image of Renewed Website (Draft)

(2) Information Dissemination through Social Media

Since the Facebook account, which opened under Phase III, is still available, information on the outline, progress status, and event of Phase IV should be disseminated, making the most use of this existing account.

Source: URL:https://ja-jp.facebook.com/pmrcip/

Figure 9.1.22 Existing PMRCIP Facebook Account

9.1.3.6 Action Plan of Non-Structural Measures in Phase IV

(1) Action Plan

Table 9.1.4-Table 9.1.7 show the action plan for realizing the above-mentioned non-structural measures in Phase IV, **Table 9.1.8** shows the timeline of each activity, and **Table 9.1.9** shows cost estimate of each activity.

Table 9.1.4 Information Provision to Deepen Understanding of PMRCIP

Strategy	Activities	Timeline	Related Organization(s)	Resource Requirement	Outputs
Impressive Information Campaign and Publicity (ICP)	Community-based Explanatory Discussion	2021 – 2025 (5years) As appropriate	･LGUs ･Barangays ･Schools	･Venue ･Facilitator ･Materials for discussion	･Raise of public awareness ･Opinions/suggestion from participants
	Public Hearings	2021 – 2025 (5years) As appropriate	･LGUs ･Barangays ･Schools	･Venue ･Facilitator ･Materials for hearing	･Raise of public awareness ･Opinions/suggestion from participants
	Caravan Operation	2021 – 2025 (5years) As appropriate	･Government ･Barangays ･Schools	･Venue ･Facilitator ･Materials for caravan operation	･Raise of public awareness ･Opinions/suggestion from participants
	Media Exposure and Public Relation Activities	2021 – 2025 (5years) As appropriate	･Media	･Publicity cost ･Media Specialist ･Materials	･Raise of public awareness
	Continuous Linkages with National/Local Government Units	2021 – 2025 (5years) As appropriate	･Government ･LGUs ･Barangays	･Coordinator	･Cooperation on the project
Information Dissemination through Website and Social Media	Reactivation of PMRCIP website and information dissemination	2021 – 2025 (5years) Update regularly	-	･Graphic Designer ･Multi-media Creator ･Materials for website and social media	･Raise of public awareness

Source: Study Team

Table 9.1.5 Information Provision for Flood Mitigation

Strategy	Activities	Timeline	Related Organization(s)	Resource Requirement	Outputs
Provision of Easy-to-follow Instructions for Flood Mitigation	Development of flood hazard map	･Preparation 2021 (1 year) *Hazard map will be used for evacuation drill	･LGUs ･Barangays ･Schools	･Result of flood analysis ･Map data ･GIS Operator ･Graphic Designer	･Hazard map
		･Workshop (update and upgrade the hazard map) 2022 (1 year)	･LGUs ･Barangays ･Schools	･Hazard map ･Venue ･Facilitator ･Workshop materials	･Updated hazard map ･Evaluation & Feedback from users
	Flood evacuation sign/ guide	･Preparation (location identification) 2021 (1 year) ･Installation 2022 (1 year)	･LGUs ･Barangays ･Schools	･Evacuation signs/guides ･Permission for installation from building/ structure owners ･Installation cost	･Evacuation signs/guides ･Evaluation & Feedback from users

Source: Study Team

Table 9.1.6 Consensus Building among Related Organizations

Strategy	Activities	Timeline	Related Organization(s)	Resource Requirement	Outputs
Reactivation of Flood Mitigation Committee (FMC)	FMC meeting	Jun 2019-2026 (once every 3 months or as necessary)	· FMC members · Observers · FMC Secretariat	· Venue · Facilitator	· Information sharing among member organizations · Cooperation on the project

Source: Study Team

Table 9.1.7 Human Resources Development

Strategy	Activities	Timeline	Related Organization(s)	Resource Requirement	Outputs
Conducting practical drills, training, and other related activities for local residents	Flood evacuation drill	2023– 2025 (3 years)	· LGUs · Barangays · Schools	· Hazard maps · Evacuation signs/guides · Venue · Facilitator · Training materials	· Improved evacuation system · Feedback on hazard map from participants
	Training of volunteers for river patrol/ disaster risk reduction	2023 – 2025 (3 years)	· LGUs · Barangays · Schools	· Hazard maps · Evacuation signs/guides · Venue · Facilitator · Training materials	· Trained volunteers for river patrol/ disaster risk reduction
Conducting practical drills for facility operators	Flood control drill	2025 (after completion of gate structures)	· DPWH · MMDA · LGUs	· Operation rule/manual · Venue · Facilitator · Training materials	· Trained facility operators · Improved disaster prevention system
	Emergency inspection drill (Post-earthquake inspection)	2025 (after completion of gate structures)	· DPWH · MMDA · LGUs	· Inspection guideline/manual · Venue · Facilitator · Training materials	· Trained facility operators · Improved disaster prevention system

Source: Study Team

Table 9.1.8 Timeline of Each Activity

ACTIVITIES	2019	2020	2021	2022	2023	2024	2025	2026
Consulting Services / Construction Works								
Detailed Engineering Design								
Consulting Services								
Construction Works								
Non-structural Measures								
Information Campaign and Publicity (ICP)								
Community-based Explanatory Discussion								
Public Hearings								
Caravan Operation								
Media Exposure and Public Relation Activities								
Continuous Linkages with National/Local Government Units								
Information Dissemination through Website and Social Media								
Reactivation of PMRCIP website and information dissemination					Update regularly			
Information Provision for Flood Mitigation								
Development of hazard map			Mapping		Revision & Update			
Hazard map workshop				Feedback Workshop				
Installation of flood evacuation sign/guide			Design & Production	Installation		Feedback		
Reactivation of Flood Mitigation Committee (FMC)								
Flood Mitigation Committee Meeting (Once/3 months)	● ● ●	● ● ● ●	● ● ● ●	● ● ● ●	● ● ● ●	● ● ● ●	● ● ● ●	● ● ● ●
Human Resources Development								
Local residents								
Flood evacuation drill								
Training of Volunteers for River Patrol/Disaster Risk Reduction								
Facility operators								
Flood control drill								
Emergency inspection drill								

Source: Study Team

Table 9.1.9 Cost Estimate of Non-Structural Measures in Phase IV

Item	Particulars	Unit	Quantity	Unit Cost	Amount
1.	**Manpower Expenses**				
	A. Strategic Communications / Media Specialist	man mo.	60	Offered by consultant of Construction Supervisor for PMRCIP-IV	
	B. Multimedia Creator (formerly Graphic Artist)	man mo.	60		
	C. GIS Operator	man mo.	60		
	D. Civil Engineer	man mo.	3		

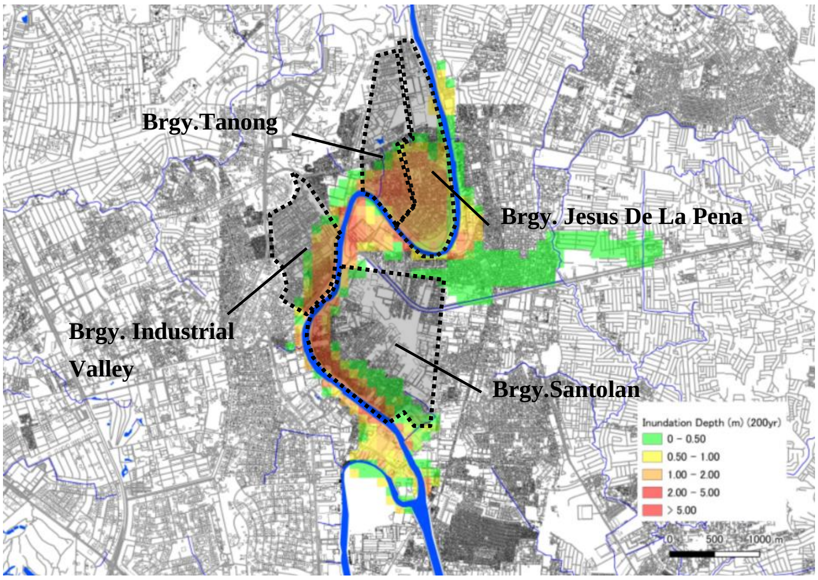
2.	**Conceptualize, Design and Produce Information Materials**					
	A. Printed Information Materials					
	1. Brochures (1,000copies/yr x 5 yrs)	copies	5,000	50.00	250,000.00
	2. Flyers (10,000/yr x 5 yrs)	copies	50,000	10.00	500,000.00
	3. Informational Posters (30/yr x 5yrs x 14brgys)	copies	2100	45.00	94,500.00
	4. Lampost Banners (100pcs./yr x 5 yrs)	pcs	500	350.00	175,000.00
	5. Billboards (1/yr x 5 yrs)	pcs	5	220,000.00	1,100,000.00
	6. Newsletters (2,000 issues/yr x 5 yrs)	issues	10,000	75.00	750,000.00
	7. Calendars (400pcs/yr x 5 yrs)	pcs	2,000	250.00	500,000.00
	B. Production of Multimedia Materials				
	1. Audio-Visual Presentations (AVPs) (5 materials/yr x 5 yrs)	materials	25	180,000.00	4,500,000.00
3.	**Conduct of Community-Based Explanatory Discussions**				
	A. Mounting of Regular Inter-Barangay Caucus (2times/5yrs x 5 yrs x 14brgys)	times	28	50,000.00	1,400,000.00
4.	**Public Hearing**				
	A. Mounting of Town Hall discussions, dialogues and caucuses (1time x 14brgys)	times	14	50,000.00	700,000.00
5.	**Caravan Operation in Schools, Barangays and Government Offices**				
	A. Schools				
	1. Conduct of symposium, forum, summit, etc. (2/5yrs x 5yrs x 14brgys)	times	28	80,000.00	2,240,000.00
	B. Barangays				
	1. Conduct of Information Dissemination in Headquarters and house-to-house talks (3/5yrs x 5yrs x 14brgys)	times	42	50,000.00	2,100,000.00
	C. Government Offices				
	1. Conduct of Inter-Agency and Inter-Governmental Alignment Meetings (1/yr x 5yrs)	times	5	30,000.00	150,000.00
6.	**Human Resources Training & Development**				
	A. Training of Pasig River Patrol volunteers (20 PRPs/brgy x 14brgys)	PRPs	280	1,500.00	420,000.00
	B. Conduct of Flood evacuation, emergency and control drill (1time/yr x 3yr x 4brgys)	times	12	80,000.00	960,000.00
7.	**Establishment of Community-Based Information Centers**				
	A. Setting Up of Information Kiosks in Barangays, Schools and Government Offices (2or3unit/brgy x 14brgys)	units	30	15,000.00	450,000.00
8.	**Undertake Mass Media Exposure and Public Relation Activities**				
	A. Production of Public Service Announcements (PSA) (1time/yr x 5yrs)	times	5	180,000.00	900,000.00
	B. PSA Ads Placement in Major Gov't and TV Stations (1/yr x 5yrs x 3 stations)	times	15	200,000.00	3,000,000.00
	C. Exposures in Major TV and Radio Programs (1/yr x 5yrs)	times	5	195,000.00	975,000.00
	D. Conduct of Press Conferences (1/yr x 5yrs)	times	5	300,000.00	1,500,000.00
	E. Press Releases in Major Dailies and Tabloids (1/yr x 5yrs)	times	5	125,000.00	625,000.00
9.	**Online Campaign via Website and Social Media**				
	A. Creation of Informational Campaign Strategies via Website, Social Media and Text lines (4/yr x 5yrs)	times	20	100,000.00	2,000,000.00
10.	**Continuous Linkages with National and Local Gov't Units**				
	A. Monthly meetings with Local Inter-Agency Committees (LIACs) (12/yr x 5yrs)	times	60	30,000.00	1,800,000.00
11.	**Flood Mitigation Information Campaign**				
	A. Development of Flood Hazard Map	1 lot	1	150,000.00	150,000.00
	B. Conduct of Training-Workshop in Schools and Barangays (4times/yr x 1yr x 4brgys)	times	16	75,000.00	1,200,000.00
	C. Installation of flood evacuation sign/guide (50piecies/brgy x 4brgys)	pieces	200	1,000.00	200,000.00

12.	**Reactivation of Flood Mitigation Committee (FMC)**				
	A. Conduct of Quarterly Meetings (4times/yr x 5yrs)	times	20	150,000.00	3,000,000.00
				Total	31,639,500.00

Source: Study Team

(2) Selection of Pilot Barangays

Among the above activities, the creation of flood hazard maps, the installation of flood signs and evacuation route signs, and the activities of human resource development for residents, such as flood evacuation drills, should be conducted after selecting pilot barangays. Based on the results of the flood analysis shown in **9.1.3.2** , the pilot area was selected from the area where the risk of inundation in the 200-year flood is expected to remain even after completion of Phase IV. Also, hearing surveys were conducted at the four barangay offices to confirm the intention to participate in the project, and the candidates of pilot barangay shown in **Figure 9.1.23** were finally selected.



Source: Study Team

Figure 9.1.23 Candidates of Pilot Barangay

- **Barangay Jesus De La Pena and Barangay Tanong (Marikina City)**

In the area between Sta.11 + 350 and Sta.13 + 350 where the Barangay Jesus De La Pena is located, Marikina City is improving the riverside park. Assuming that the dike in the above section won't be constructed, measures to mitigate flood damage by non-structural measures are required. According to a barangay officer who is in charge of disaster prevention, they are making an effort to prepare for and reduce the effects of disasters triggered by Typhoon Ondoy landed in 2009. After explaining the plan of this activity, they gave a very positive response regarding participation in the activities. Adjacent Barangay Tanong is also located in a high-risk flood area just like Jesus De La Pena. According to a barangay captain who has a responsibility of disaster prevention in the Barangay, they are often experienced in flood damage and are making an effort to reduce damage for preparing their flood map and evacuation rule, establishment of flood evacuation center, and so on. After explaining the plan of this activity, they gave a very positive response regarding participation in the activities in anticipation of improving the current.

- **Barangay Industrial Valley Complex (Marikina City)**

Since flood risk is expected to remain in the area along the Marikina River even after Phase IV, according to a barangay officer who is in charge of disaster prevention, they are making an effort to prepare for and reduce the effects of disasters triggered by Typhoon Ondoy landed in 2009. After explaining the plan of this activity, they gave a very positive response regarding participation in the activities.

- **Barangay Santolan (Pasig City)**

  Typhoon Ondoy inundated a large area of this barangay in 2009, and flood risk is expected to remain in the area along the Marikina River even after Phase IV. This barangay was also a pilot barangay for flood hazard mapping and evacuation drill activities in Phase III. According to the information from a barangay officer who is in charge of disaster prevention at the barangay office, the flood hazard map created in Phase III is still in use. However, information of the map has not been updated since its creation. After explaining the plan of the activities in Phase IV, they recognized the necessity of updating the flood hazard map and gave a very positive response regarding participation in the activities. This barangay is also expected to play a role in sharing their experiences obtained during Phase III with other barangays and organizations.

9.2 Operation Rules for Weirs and Watergates

This section examines the basic concept for operation rules of the MCGS and the two floodgates to be constructed in this project, including an integrated operation method with the existing NHCS (Napindan Hydraulic Control Structure) and Rosario Weir.

The final drafts of the operation rules for the weirs and floodgates are shown at the end of this section in the following two parts.

- Rosario Weir, MCGS, and NHCS; and
- Two (2)Backflow Prevention Floodgates

9.2.1 Operation Rules for Existing Structures

The operation rules for the existing flood control structures in the Pasig-Marikina River, namely; the Rosario Weir at the inlet of the Manggahan floodway and the NHCS installed at the point where the Napindan Channel joins the Pasig River, are as described below.

9.2.1.1 Rosario Weir and NHCS (Napindan Hydraulic Control Structure)

(1) H-Q Curve at Sto. Niño (2014)

The H-Q curve at Sto. Niño, which was reviewed in the JICA 2014 study, is as shown in **Table 9.2.1** below.

Table 9.2.1 H-Q Curve at Sto. Niño (2014)

Condition	Relational Expression
H＜EL+14.0	$Q = 32.03 \times (H-10.80)^2$
H >EL+14.0	$Q = 25.65 \times (H-10.46)^2$

Q: flow rate; H: water level at Sto. Niño

Source: JICA 2014 Study

(2) Operation Rules

As in **Chapter 3**, the operation rules of the Rosario Weir and NHCS are as shown in **Table 9.2.2** below. Images of the operation rules identified in the EFCOS Office are given in the following **Figure 9.2.1**.

Table 9.2.2 Gate Rules for Rosario Weir and NHCS

<table>
<tr><th>Condition</th><th>Water Level at Sto. Niño</th><th>Rosario Weir</th><th colspan="2">NHCS</th></tr>
<tr><td rowspan="5">While the water level is rising</td><td>EL+13.80m</td><td>Open Gate No. 4</td><td rowspan="5">The main gates of NHCS shall be “closed” as soon as the opening of the Rosario Weir gates is notified.</td><td rowspan="10">Basically, the gates must be operated according to the rules on the left column, but there is information that the rules are not strictly followed for the NHCS.</td></tr>
<tr><td>EL+13.90m</td><td>Open Gate No. 5</td></tr>
<tr><td>EL+14.0~14.40m</td><td>Open Gate No. 3 & 6</td></tr>
<tr><td>EL+14.50~15.10m</td><td>Open Gate No. 2 & 7</td></tr>
<tr><td>EL+15.30m~Up</td><td>Open Gate No. 1 & 8</td></tr>
<tr><td rowspan="5">While the water level is dropping</td><td>EL+15.00m</td><td>Close Gate No. 1 & 8</td><td rowspan="5">The main gates of NHCS shall be “opened” as soon as the end of the gate closing operation of Rosario Weir is notified.</td></tr>
<tr><td>EL+14.50m</td><td>Close Gate No. 2 & 7</td></tr>
<tr><td>EL+14.00m</td><td>Close Gate No. 3 & 6</td></tr>
<tr><td>EL+13.80m</td><td>Close Gate No. 5</td></tr>
<tr><td>EL+13.60m</td><td>Close Gate No. 4</td></tr>
</table>

Source: Study Team added some information from MMDA-EFCOS Office.

GATE OPERATION REVISED RULE CURVE 2012

I. OPENING OF ROSARIO WEIR FLOODGATES

WATERLEVEL (M)	NO. OF GATES TO OPEN	GATE NO.	REMARKS
13.80 13.90	1 1	GATE 4 GATE 5	ISSUE WARNING TO ALL WARNING POST STATION
14.00-14.40	4	GATE 3 & 6	
14.50-15.10	6	GATE NO. 2 & 7	
15.30 - UP	8	GATE NO. 1 & 8	ALL GATES SHOULD BE OPEN AND REMAINED OPEN IF CONTINOUS RAINFALL IS BEING MONITORED UPSTREAM

II. CLOSING OF ROSARIO WEIR FLOODGATES

WATERLEVEL (M)	NO. OF GATES CLOSED	GATE NO.	REMARKS
15.00	2 gates	GATE 1 & 8	If there will be no rainfall monitored upstream gates should be randomly closed except for the last two gates which will be randomly closed when the elevation at Sto. Niño Station reached at 13.80m waterlevel at Rosario should be closely monitored due abnormalities of the difference in the elevation bet Sto Niño and Rosario J.S. when waterlevel is at its normal stage.
14.50	4 gates add 2 gates	GATE 2 & 7	
14.00	6 gates add 2 gates	GATE NO. 3 & 6	
13.80	7 gates add 1 gate	GATE NO. 5	
13.60	ALL GATES SHOULD BE CLOSED	GATE NO. 4	ALWAYS CHECK watelevel level at Rosario J.S. at the moment it was closed, if overtopping persists at the gate, open 1m height at one of the gates.

REFERENCE POINT : STO. NIÑO WATERLEVEL GAUGING STATION

Gate Operation Rule (Revised in 2012; English)

PALATUNTUNAN SA PAGBUBUKAS AT PAGSARA NG MGA TUBIG LAGUSAN

I. PAGBUBUKAS NG ROSARIO WEIR FLOODGATES

LEBEL NG TUBIG (m)	BILANG NG GATE NA BUBUKSAN	NUMERO NG GATE NA BUBUKSAN	PAALALA
13.80 13.90	1 (ISA) 2 (DALAWA)	GATE 4 GATE 5	PATUNUGIN ANG SIRENA HUDYAT BAGO MAGBUKAS NG GATE
14.00 - 14.40	4 (APAT)	GATE 3 & 6	
14.50 - 15.10	6 (ANIM)	Gates 2 & 7	
15.30 - PATAAS	8 (WALO)	Gates 1 & 8	PANATILIHING NAKABUKAS ANG MGA GATES KUNG MAY MALALAKAS NA ULAN SA BULUBUNDUKIN NG RIZAL AT KARATIG NA LUGAR

II. PAGSASARA NG ROSARIO WEIR FLOODGATES

LEBEL NG TUBIG (m)	BILANG NG GATE NA ISASARA	NUMERO NG GATE NA ISASARA	PAALALA
15.00	2 (isasara) 6 nanatiling nakabukas	Gate 1 & 8	KUNG WALANG MALALAKAS NA ULAN ANG NASUSUBAYBAYAN SA BUNDOK, MAHIGIPIT NA BANTAYAN ANG PAGBABA NG LEBEL NG TUBIG UPANG MAKAPAGSARA NG FLOODGATES AT MAIWASAN ANG PATULOY NA PAGPASOK NG TUBIG BAHA PAPUNTANG LAWA UPANG MAKAPAGIMBAK TAYO SA SUSUNOD NA ULAN
14.50	4 (nakasara) 4 nanatiling nakabukas	Gate 2 & 7	
14.00	6 (nakasara) 2 nanatiling nakabukas	Gates 3 & 6	
13.80	7 (nakasara) 1 nanatiling nakabukas	Gate No. 5	
13.60	LAHAT NG GATE DAPAT NAKASARA NA	Gate No. 4	PALAGIANG TINGNAN AT OBSERBAHAN ANG LEBEL NG TUBIG SA ROSARIO JS KUNG NAKASARA ANG LAHAT NG GATES DAHIL MAARING UMAPAW ANG TUBIG SA MGA GATE. KUNG ITO'Y UMAPAW, MAAARING BUKSAN NG ISANG METRO ANG ISA SA MGA GATE

PINAGBASEHAN NG LEBEL: ESTASYON NG STO. NIÑO SA TULAY NG MARIKINA

LAHAT NG IMPORMASYON PATUNGKOL SA PAGSASARA AT PAGBUBUKAS NG MGA FLOODGATES AY IPAGBIGAY ALAM SA MGA NAKATATAAS NG ATING TANGGAPAN AT SA FLOOD CONTROL INFORMATION CENTER

Gate Operation Rule (Revised in 2012; Tagalog)

2012 REVISED GUIDLINE IN THE OPEING OF GATES AT ROSARIO WEIR

REFERENCE POINT: STO. NIÑO WATERLEVEL GAUGING STATION

STARTING ELEVATION	TOTAL RAINFALL UPSTREAM	FORECAST ELEVATION		GATES TO OPEN AT RANDOM	GATE OPERATION		WHAT TO DO FIRST	REMARKS
		LOW	HIGH		OPEN	CLOSE		
13.50 ALARM	NO RAINFALL MONITORED AT ALL EFCOS RAINFALL GAUGING STATION			ALL GATES CLOSED	0	8	ISSUE WARNING BEFORE OPENING ALL GATES	If there is no rainfall event yet Sto. Niño reads elevation 13.8m keep all gates closed
13.70 ALERT								If there is rainfall event follow the random opening of gates
13.80 CRITICAL	LIGHT 10-30	13.90	14.4	OPEN G4 OPEN G5 OPEN G3 & G6	1 2 4	7 6 4	ISSUE SEVERE WARNING AT ALL WARNING POST STATION	**FIRST ALARM IN MARIKINA LGU (15.00)**
	LIGHT-MOD 30-50	14.50	15.10	OPEN G2 & G7 OPEN G8	6 7	2 1		**SECOND ALARM MARIKINA LGU (16.00)**
	MODERATE 50-70	15.30	15.90	OPEN G1	8	0		
	MOD-HEAVY 70-90	16.00	16.60		**ALL GATES OPEN**			**FORCE EVACUATION AT MARIKINA (17.00)**
	HEAVY 90-100	16.70	16.90					

Guidelines for Opening Gates (Revised in 2012)

FLOOD OPERATION RULE

PRECAUTION STAGE

During the precaution stage all gates are usually closed but then an announcement is given to people within the floodway channel as a precautionary measure.

- This stage occurs when the waterlevel at Sto. Niño is more than its alert level of 13.0m corresponding to 150 cu. m. discharge when the average rainfall intensity that falls in Sto. Niño Station is more than 30 mm or in case the waterlevel at Montalban exceeds 22.4m corresponding to 100 cu. m. per second.

CAUTION STAGE

When caution stage starts, some floodgates are open causing the sudden increase of floodwater to flow in the floodway channel. Warning consisting a siren warning and speaker warning is issued around 30 minutes before opening the floodgates to provide enough time for people inside the channel to stay away from the channel.

- The Napindan HCS is closed and the Rosario Weir is operated only to store the flood water from Marikina River into Laguna Lake.
- This stage occurs when the waterlevel at Sto. Niño reach critical level 1 hence, two floodgates are open.
- But when the waterlevel comes up halfway between critical level 1 and 2 four floodgates are open simultaneously

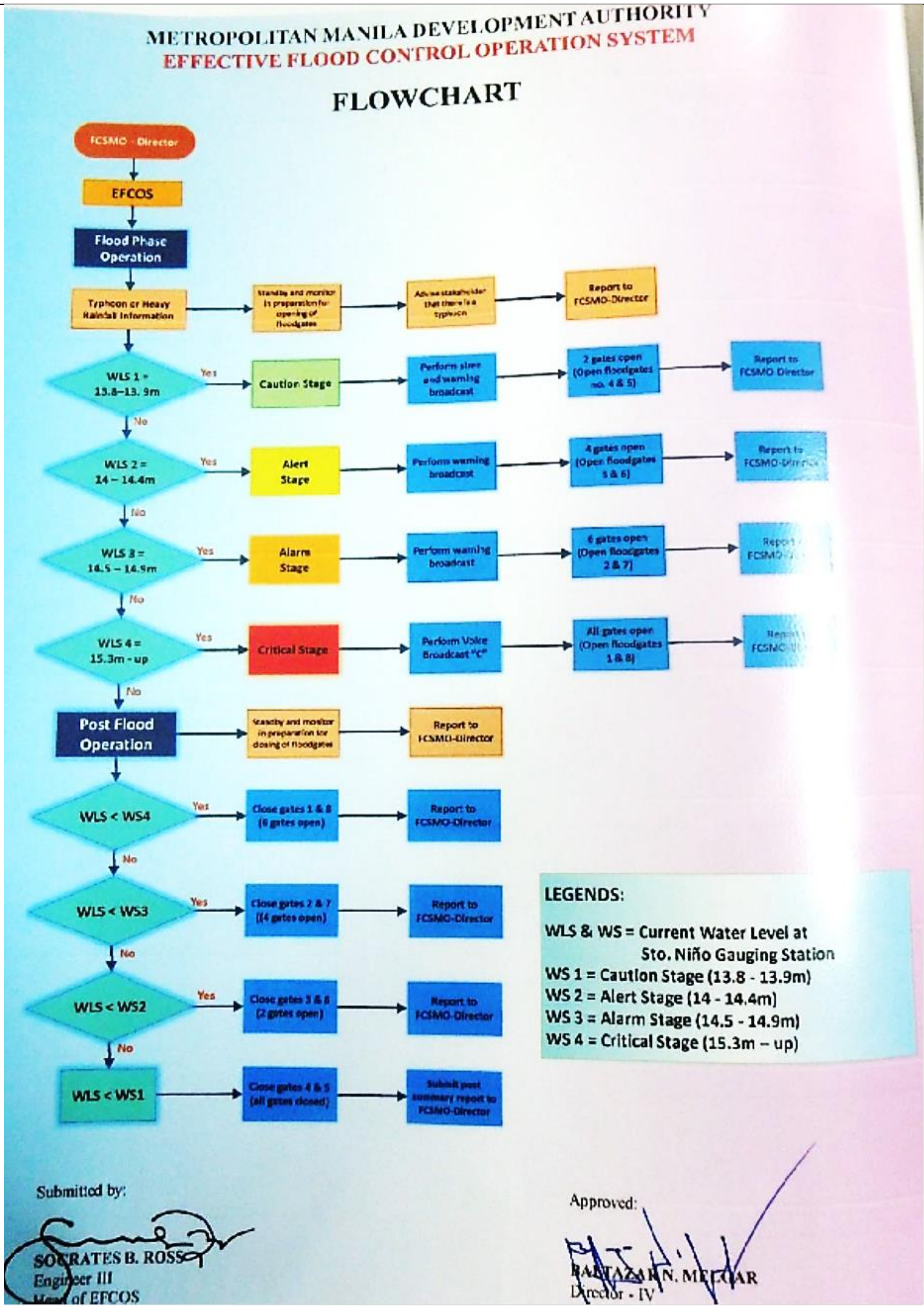
EMERGENCY STAGE

During emergency stage, the floodway stream is expected to rise due to bigger flood waters from Marikina River.

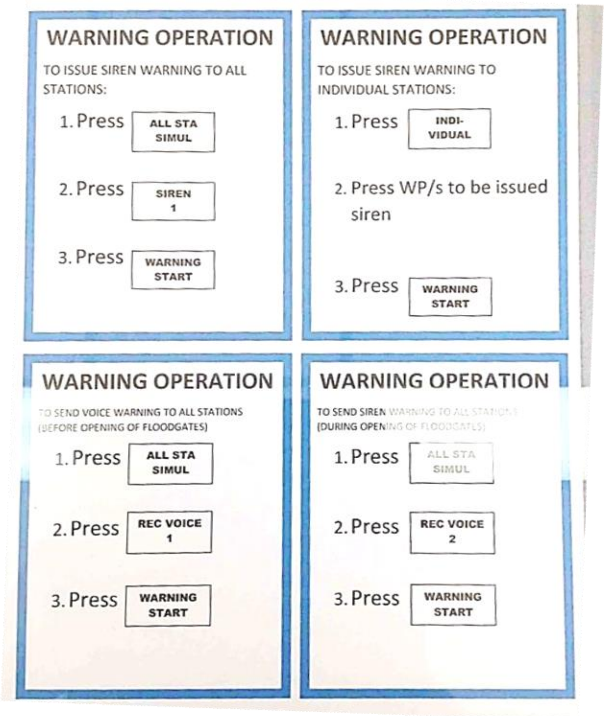
- This stage occurs when the waterlevel at Sto. Niño exceeds critical level 2, both Napindan HCS and Rosario Weir are operated to store flood water into Laguna Lake. When the floodwater into Manggahan Floodway has increased informative warning is issued as decided upon by Headquarters at Rosario.

Note: Tidal level (Fort Santiago) has to be considered during operation.

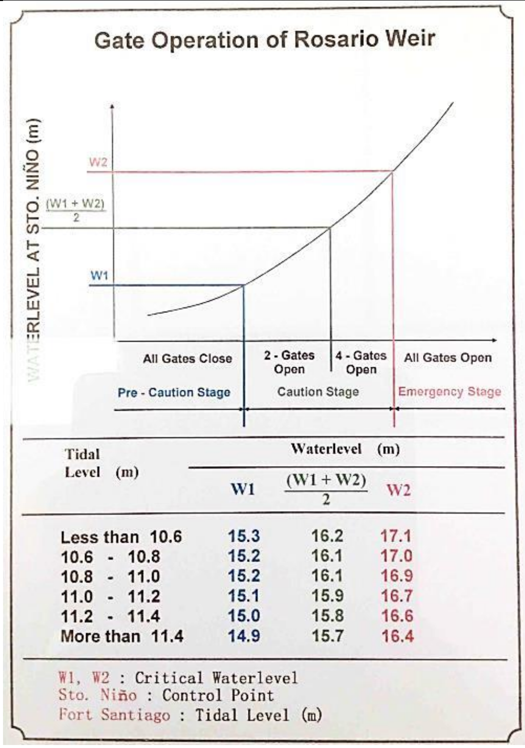
Operation Rules of Gates and Discharge Warning Systems in the event of a Flood



Flowchart of Gates and Discharge Warning Systems in the event of a Flood

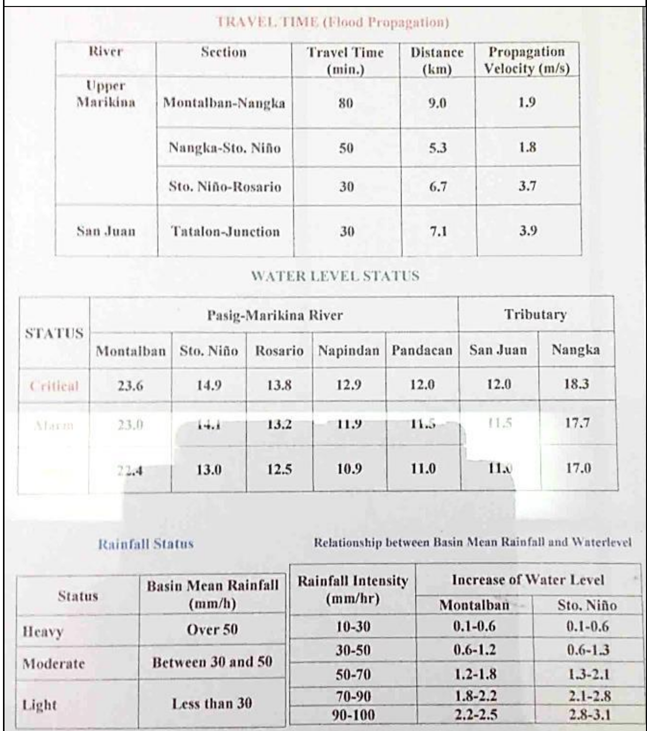


Operation Method of Flood Warning



Tidal Level (m)	Waterlevel (m) W1	(W1 + W2)/2	W2
Less than 10.6	15.3	16.2	17.1
10.6 - 10.8	15.2	16.1	17.0
10.8 - 11.0	15.2	16.1	16.9
11.0 - 11.2	15.1	15.9	16.7
11.2 - 11.4	15.0	15.8	16.6
More than 11.4	14.9	15.7	16.4

Correlation between the reference water level corresponding to the tide and the number of open gates



TRAVEL TIME (Flood Propagation)

River	Section	Travel Time (min.)	Distance (km)	Propagation Velocity (m/s)
Upper Marikina	Montalban-Nangka	80	9.0	1.9
	Nangka-Sto. Niño	50	5.3	1.8
	Sto. Niño-Rosario	30	6.7	3.7
San Juan	Tatalon-Junction	30	7.1	3.9

WATER LEVEL STATUS

STATUS	Pasig-Marikina River					Tributary	
	Montalban	Sto. Niño	Rosario	Napindan	Pandacan	San Juan	Nangka
Critical	23.6	14.9	13.8	12.9	12.0	12.0	18.3
Alarm	23.0	14.1	13.2	11.9	11.5	11.5	17.7
	22.4	13.0	12.5	10.9	11.0	[illegible]	17.0

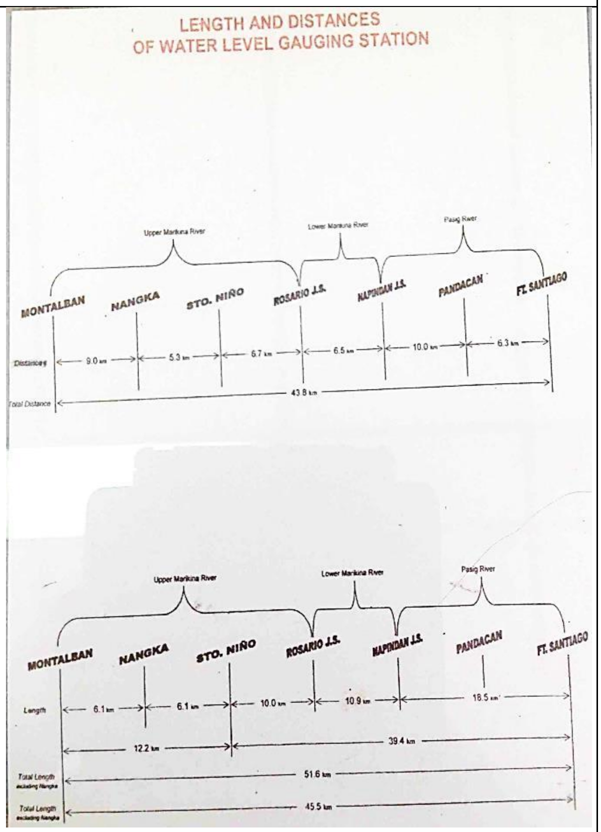
Rainfall Status

Status	Basin Mean Rainfall (mm/h)
Heavy	Over 50
Moderate	Between 30 and 50
Light	Less than 30

Relationship between Basin Mean Rainfall and Waterlevel

Rainfall Intensity (mm/hr)	Increase of Water Level Montalban	Sto. Niño
10-30	0.1-0.6	0.1-0.6
30-50	0.6-1.2	0.6-1.3
50-70	1.2-1.8	1.3-2.1
70-90	1.8-2.2	2.1-2.8
90-100	2.2-2.5	2.8-3.1

Standard flood arrival time and reference water level & rainfall



Distance between water level observation points

Source: EFCOS Office

Figure 9.2.1 Images of Operation Rules of Rosario Weir

(3) Conversion of Operation Rules to Flow Rates in Terms of Water Level

The Operating Rules of Rosario Weir according to water level are shown in (2) above. By being combined with the H-Q at Sto. Niño shown in (1), the Operating Rules of Rosario Weir in terms of water level are converted to those in terms of flow rate as shown in **Table 9.2.3**.

Table 9.2.3 Gate Operation Rules of Rosario Weir in Terms of Flow Rate

Condition	Flow Rate at Sto. Niño	Rosario Weir
While the water level is rising	288 m^3/s	Open Gate No.4
	308 m^3/s	Open Gate No.5
	328 ~ 398 m^3/s	Open Gate No.3 & 6
	419 ~ 552 m^3/s	Open Gate No.2 & 7
	601 m^3/s	Open Gate No.1 & 8
While the water level is dropping	529 m^3/s	Close Gate No.1 & 8
	419 m^3/s	Close Gate No.2 & 7
	328 m^3/s	Close Gate No.3 & 6
	288 m^3/s	Close Gate No.5
	251 m^3/s	Close Gate No.4

Source: Study Team

(4) Organizing the Gate Operation of Rosario Weir

Summarizing (1) to (3) above, the operation of the Rosario Weir can be as follows.

All gates are normally "Fully Closed" for the following reasons:

- To maintain the flow rate of the lower Marikina River (to maintain normal river function); and
- To control the water level of Laguna Lake only by NHCS located downstream.

On the other hand, during floods, the gates are operated as follows:

- The gates start to open when the flow rate at Sto. Niño increases to 300 m^3/s;
- As the flow rate at Sto. Niño increases to 600 m^3/s, all 8 gates are fully open;
- When the flow rate at Sto. Niño decreases to 530 m^3/s, the gates start to close;
- When the flow rate at Sto. Niño decreases to 250 m^3/s, all 8 gates are closed completely (Transition to a normal phase).

(5) Warning Broadcast at the Rosario Weir

According to information from the EFCOS Office, they are possible to send the following messages 1 to 4 at present. Both broadcasts are sent in the order English and Tagalog.

<MESSAGE 1>(duration: 50 seconds)
This is a discharge warning from the Rosario Master Control Station.
The release of flood water through the Rosario floodgates will now commence.
The surge of water will become swift.
The public is advised not to go near the floodway channel to avoid risks.

Ito ay babalamulasa Rosario Master Control Station.
Angpagpapalabas ng tubigbahasatubiglagusan ng Rosario ay sisimulanna.
Ito ay maaasahangmagdudulot ng mabilis at malakasnapag-agos ng tubig.
Pinapayuhananglahatnalumikasmulasatubiglagusan ng upangmaiwasananganumangsakuna.
Maramingsalamatpo!

<MESSAGE 2>(duration: 52 seconds)
This is a discharge warning from the Rosario Master Control Station.
The release of flood water shall now commence through the Rosario Floodgates.
The level of water will soon rise and its flow will gradually become swift.

The public is advised not to go near the floodway channel for your safety.

Ito ay babalamulasa Rosario Master Control Station.
Sinimulannaangpagpapalabas ng tubigbahasatubiglagusan ng Rosario.
Inaasahanangmalakasnapagdaloy ng tubig at pagtaas ng sukatnito
Pinapayuhananglahatnalumikasmulasatubiglagusan ng upangmaiwasananganumangsakuna.
Maramingsalamatpo!

<MESSAGE 3>(duration: 43 seconds)
This is a discharge warning from the Rosario Master Control Station.
All the Rosario floodgates are now open.
The public's attention is called to caution as flood may occur.
Distance from the floodway channel is advised for your safety.

Ito ay babalamulasa Rosario Master Control Station.
Angtubiglagusan ay kasalukuyangnakabukas
Subalitmaaaaringmagkaroonmuli ng tubigbaha.
Ipinakikiusapsalahatnalumikasmulasatubiglagusan para sainyongkaligtasan.
Maramingsalamatpo!

<MESSAGE 4>(duration: 42 seconds)
This is a discharge warning from the Rosario Master Control Station.
The floodgates of Rosario have now been closed.
However, the public is requested to remain cautious and to keep away from the floodway channel due to possible occurrence of flood.

Ito ay babalamulasa Rosario Master Control Station.
Angtubiglagusan ay nakasarana.
Subalitmaaaaringmagkaroonmuli ng tubigbaha.
Ipinakikiusapsalahatnalumikasmulasatubiglagusan para sainyongkaligtasan.
Maramingsalamatpo!

9.2.1.2 Other Structures

As mentioned in 3.2.2.4, the pumping stations managed by MMDA are installed in Pasig River Basin. Even when the water level in the Pasig River is high, inland water can be drained (unless the facility is submerged). The largest drainage capacity among these pumping stations is 19.0 m^3/s of San Andres Pumping Station installed just before the Pasig River joins the San Juan River, the right tributary.

At each pumping station, the water level at the start and end of operation are defined. It is expected that such pumping stations on the riverside will also be effective in the event of flood. However, no operation is done to stop the drainage pump when the water level of the Pasig River rises up to, e.g., DFL.

9.2.1.3 Evaluation on Operation of the Existing River Structures

(1) Rosario Weir

The JICA Study Team has evaluated that there are few problems because the time and effort for gate operation are reduced as much as possible and the water level in the upstream rises as little as possible during floods. However, it is necessary to consider more efficient operation rules that link the two facilities, since the MCGS will be completed through the Phase IV Project.

(2) NHCS

Essentially, this structure was constructed to develop water resources, i.e., desalinate Laguna Lake. Since some people using the Laguna Lake oppose closing of the gates, they are normally "fully open".

On the other hand, according to the facility manager (MMDA), the gates are "fully closed" in conjunction with the operation of Rosario Weir in the event of flood, but there is information that accurate operation is not carried out. Since the MCGS has not yet been constructed, there is a tendency of more flows than planned in the Lower Marikina River during floods. Therefore, the reason for this operation may be to prevent additional water into the Lower Marikina and Pasig River and reduce the load on them by diverting floods to the Laguna Lake in two places.

This study will focus on the following:

- Whether operation of the NHCS would be necessary or not, as the flow to the lower Marikina River will be controlled upstream by the MCGS.

(3) Warning Broadcast

The breakdown of the four messages sent during the operation of the Rosario Weir consists of two (just) before the starting of the full opening, one after the full opening of the all gates, and one after the full closing of the all gates. The reason why there are two types of broadcasts before the start of the full opening operation maybe due to an operational assumption that opens several gates in succession when the water rise of the Marikina River is too rapid or for some reason the initial operation is delayed, although the rule is opening one or two gates at a time.

This study will improve the following problems:

- There are no pre-operational broadcasts even though the closing operation causes water level fluctuations upstream and downstream of the weir; and
- There is no broadcast in the event of an excessive flood

(4) Pumping Stations

The pumping stations along the Pasig River are not operated to stop the drainage pump when the main river water level exceeds DFL. Since this operation may lead to increasing the risk of flooding along the riverside, the following change of operation is required:

- Add the outside water level as well as the inside one to the reference for stopping the drainage pump.

9.2.2 Basic Concept of Operation Rules for MCGS and Floodgates

9.2.2.1 Fundamental Principles of the Operation

There are no guidelines in the Philippines that illustrate the basic operation rules applicable to the MCGS and the floodgates, etc. Therefore, the fundamental principles of the operation are based on the following Japanese standards and similar examples of diversion weirs and sluices:

- Technical standards for dam and weir facilities (March 2016, MLIT, Japan)
- Standards for the preparation of operation rules for river management facilities (March 9, 2012, Notification by Director, River Environment Division, Water and Disaster Management Bureau, MLIT, Japan)

9.2.2.2 Operational Plan

(1) H-Q Curve at Sto. Niño (After the Completion of Phase IV Project)

As discussed in Chapter 3, the completion of the Phase IV project will increase the flow capacity of the Marikina River, so the new H-Q curve at the Sto. Niño, which is necessary for the operation planning, changes as shown in **Table 9.2.4**.

Table 9.2.4 H-Q Curve at Sto. Niño (after the Completion of Phase IV Project)

Condition	Relational Expression
H : any water level	$Q = 26.263 \times (H-10.373)^2$

Q: flow rate; H: water level at Sto. Niño

Source: Study Team

(2) Definition of Flood Phase

Based on the data provided by the EFCOS Office, each stage corresponding to the water level observed at Sto. Niño is determined according to the following concept.

1) Non-Flood Phase

When the water level at Sto. Niñois less than EL +13.0m, it is considered as Non-Flood Phase and normal operation is performed.

2) Flood Phase

(a) Precaution Stage

The flood phase begins when the water level at Sto. Niño reaches EL +13.0m under certain conditions, such as when heavy rainfall is observed. However, when applied to the H-Q curve shown in (1), the flow rate corresponding to the same water level is expected to increase from 150 m^3/ s to 180 m^3/ s.

At this stage, although the weirs and floodgates are not operated, it is said to be a stage to call attention to people in Manggahan Floodway. The increase in baseline flow means that the frequency of reaching this condition is expected to decrease slightly after the completion of the Phase IV project.

(b) Caution Stage

The operation of the weirs and floodgates begins when the water level at Sto. Niño reaches EL +13.8m. The baseline water level is the same as the current one, and the corresponding flow rate is 300 m^3/ s.

(c) Alert Stage

When the water level at Sto. Niño reaches EL +14.0m, this stage starts. The baseline water level is the same as the current one, and the corresponding flow rate is 350 m^3/ s.

(d) Alarm Stage

When the water level at Sto. Niño reaches EL +14.5m, this stage starts. The baseline water level is the same as the current one, and the corresponding flow rate is 450 m^3/ s.

(e) Critical Stage

When the water level at Sto. Niño reaches EL +15.2m, this stage starts. Although it is set to EL +15.3m according to the current rule, it is cut down by 10 cm so as not to change the corresponding flow rate of 600 m^3/ s due to the operation of MCGS described later.

3) Excessive Flood Phase

When the water level at Sto. Niño reaches the design water level (DFL) of EL +21.17m, it is considered that the Excessive Flood Phase has started. Although this phase does not appear in the documents provided by EFCOS, unlike the previous phase, the river water level exceeds the DFL. As an Emergency Stage that requires the utmost vigilance, this stage requires accurate information to the residents.

If the flow rate then decreases and the water level at Sto. Niño falls below EL +21.17m, the steps shown in 2) will be followed in reverse.

4) Post-Flood Phase

If the river flow decreases and the water level at Sto. Niño falls below EL +13.8m, it will move to the Post-Flood Phase. The flow rate is the same level as in 2) (a), and it is still a stage that needs caution as it may shift to the Flood Phase again, depending on how it rains in the future.

If the flow rate decreases further and the water level at Sto. Niño falls below EL +13.0m, the phase proceeds to 1).

(3) Operation up to Planned Scale Floods

1) MCGS

As a result of the Phase IV Project, river channels upstream of the MCGS will have a flow area that can flow up to 2,900 m^3/s safely. On the other hand, the Lower Marikina River downstream of the

MCGS and the Manggahan Floodway already have the ability to safely run down 500 m^3/s and 2,400 m^3/s, respectively.

Therefore, if the flow of 2,900 m^3/s or less runs from the upstream, it is necessary to operate the MCGS so that the flow rate to the Lower Marikina River where the planned flow rate is less will not exceed 500 m^3/s.

Based on the consideration in **Subsection 8.2.2**, the MCGS will have a composite structure of large and small spans. The length of the small span is determined so that the flow rate of 500 m^3/s to the Lower Marikina River can be ensured at the time of DFL when the flow rate at Sto. Niño reaches 2,900 m^3/s.

The basic concept of operation is shown below.

(a) The operation corresponds to the current operation of the Rosario weir.

- When the flow of the Marikina River increases, the wider gate of MCGS is closed in accordance with opening the Rosario Weir based on the water level observed at the Sto. Niño. The reverse is true when the flow rate decreases.

(b) The wider gate of MCGS begins to be closed with sufficient time, so that, when the gate is fully closed, the amount of natural flow to the Lower Marikina River (the rate that flows if there is no MCGS at the time of diverting) cannot reach 500$m^3/$ s.

- If MCGS is closed just before reaching the design flow rate of 2,900 $m^3/$ s at the diversion point, the flow rate to the Lower Marikina River is more than the design flow rate of 500 $m^3/$ s due to the natural diversion ratio with the Manggahan Floodway. For this reason, assuming that MCGS does not exist, the time point when the flow rate into the Lower Marikina River reached 500 $m^3/$ s was set as a guide.
- According to the results of the hydraulic model experiment, when the MCGS is fully opened, the diversion ratio between the Lower Marikina River and the Manggahan Floodway is about 37:63 at the design flow rate of 2,900 $m^3/$ s, and is about 31:69 at the excessive flood flow rate of 4,000 m^3/s. This result shows that the smaller the flow rate, the larger the ratio tends to flow into the Lower Marikina River. Here, if the flow is diverted in half, the wider gate of MCGS needs to be fully closed when the flow rate at the diversion point with Manggahan Floodway reaches 1,000 $m^3/$ s.
- The speed at which the wider gate of MCGS closes is 0.3m/s, and it takes about 38 minutes from full open to full close. It is necessary to allow for a time lag for water level data observation (maximum 10 minutes) and 5 minutes for discharge warning. On the other hand, it takes 30 minutes for the flood to reach the diversion point from Sto. Niño. Therefore, it is necessary to determine whether the wider gate is "fully closed" or not (38 + 10 + 5 - 30 =)23 minutes or more before the Sto. Niño flow rate reaches 1,000 $m^3/$ s. The equivalent flow rate at Sto. Niño is about 670 $m^3/$ s from the hydrograph shown in **Section 3.4**.
- In comparison with the operation flow of Rosario Weir shown in **Table 9.2.3**, the wider gate of MCGS begin to be closed when the flow rate at Sto. Niño reaches 600 $m^3/$ s.

Based on the examination above, the operation rule of the MCGS is shown in the **Table 9.2.5**below, in accordance with that of Rosario Weir.

Table 9.2.5 Proposed Operation Rules of MCGS and Rosario Weir (up to the DFL)

Facilities	Non-Flood Phase	Flood Flow Rate at Sto. Nino (increasing phase)	
		300 m^3/s ~ 600 m^3/s	600m^3/s ~ 2,900m^3/s
MCGS	All gates fully open	All gates fully open	Wider gate fully closed, narrower one fully open (Flow discharge is controlled of up to 500 m^3/s)
Rosario Weir	All gates fully closed	Opening gates sequentially	All gates fully open

Source: Study Team

2) Floodgates to Prevent Backward Flow

The basic operation of the floodgates should be as shown in **Table 9.2.6**.

Table 9.2.6 Proposed Basic Operation Rules for Two Floodgates

Condition	Cainta Floodgate	Taytay Floodgate
Normal	Fully open	Fully open
When the water level of the river/creek and drainage inside the embankment are higher than that of the Manggahan Floodway	Fully open	Fully open
When the water level in the Manggahan Floodway is higher than that of the river/creek and drainage inside the embankment	Fully closed	Fully closed
When the gates are fully closed and the water level inside the embankment becomes higher than that of the Manggahan Floodway	Fully open	Fully open

Source: Study Team

(4) Operation in Excessive Scale Floods

1) MCGS

The planned flow rate of 2,900 m^3/s before the completion of the Marikina Dam and the upstream retarding basins is estimated to be 1/30 to 1/20 based on hydrological analysis, so that excessive flooding is likely to occur. When the Marikina Dam and the upstream retarding basins are completed, the 50 km river channel of the Pasig-Marikina River, excluding the most upstream portion, will be protected from external flooding to a level of 1/100 return period, reducing the probability of occurrence of an excessive flood. However, the necessity of specifying the operation method in the event of excessive floods remains unchanged.

The operation differs depending on where the load in the case of an excessive flood is sought. Taking the load in the case of an excessive flood into consideration, the possible 3options are shown below:

Case 1) The excess is to be loaded only on the main (Pasig-Marikina) river

Case 2) The excess is to be loaded only on the (Manggahan) Floodway

Case 3) The excess is to be loaded on both the main river and the Floodway

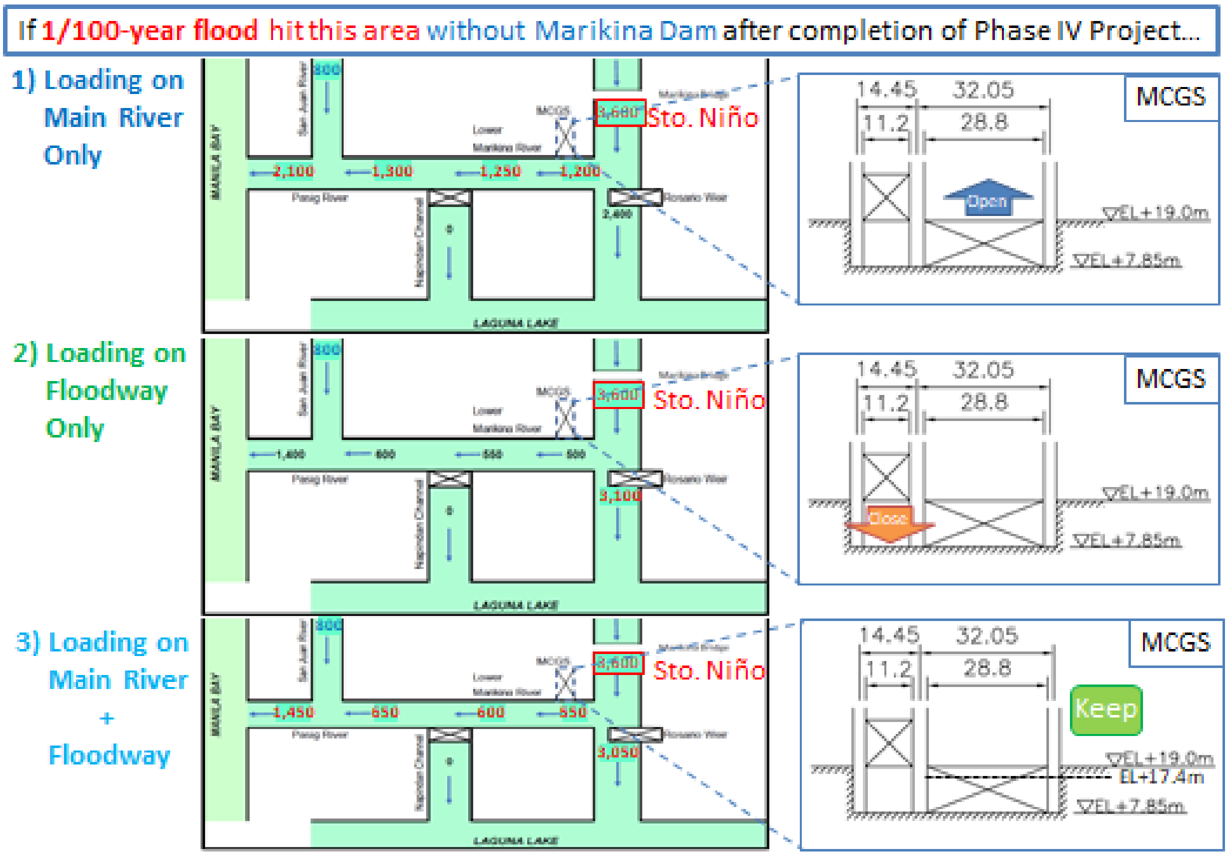
Regarding Case 3, the following two (2) cases are further assumed. This is because the height of the gate pillars can be suppressed and their design can be made more economical, if the height of the gate can be lowered.

Case 3-1) The top height of the fully closed wider gate of MCGS matches the elevation of the dike crown so that overflow cannot be allowed

Case 3-2) The top height of the fully closed wider gate of MCGS matches the design high water level so that overflow of the excess can be allowed

For each plan, we organized the advantages and disadvantages, calculated the estimated damage due to inundation, and then discussed with DPWH.

Images of flow distribution diagram and MCGS gate operation of each plan when the flow rate at Sto. Niño is assumed to be 3,600 m^3/s are shown in **Figure 9.2.2**, and the results of the comparative study are shown in **Table** 9.2.7.However, since the discussion was conducted before hydraulic model experiment, the gate span length shown is different from the final plan.



Source: Study Team

Figure 9.2.2 Images of Flow Distribution Diagram and MCGS Gate Operation in Excessive Floods

Table 9.2.7 Results of the Comparative Study on Operation in Excessive Floods

Case No.	1		2		3-1		3-2*	
Concept	**Loading on Main River Only**		**Loading on Floodway Only**		**Loading on Main River (little) + Floodway (much)**		**Loading on Main River (much) + Floodway (little)**	
Additional operation of MCGS	Necessary	3	Necessary	3	Not necessary	1	Not necessary	1
Water level rising in Lower Marikina River	Significantly	3	None	1	Slightly	1	Slightly	1
Water level rising in Manggahan Floodway	None	1	Moderately	2	Slightly to Moderately	2	Slightly to Moderately	2
Vibration of MCGS gate	On wider gate	2	On narrower gate	2	None	1	None	1
Inundation Damage (Million PHP)	214,087		134,736		135,304			

Legend) 1: Preferable2: Average3:Not preferable
Source: Study Team

Each item in **Table 9.2.7**is explained as follows.

- Regarding whether MCGS requires additional operations, both Case 1 and Case 2 require additional opening or closing operations to achieve each objective. Therefore, if any damage such as inundation occurs, the human responsibility for the operation may be questioned. On the other hand, Case 3 can be realized without any additional operations.
- Regarding the water level rise in the Lower Marikina River, it has been found that in Case 1, the water level in the Lower Marikina River rises significantly, and it is calculated that the flood water will overflow the embankment. Such an event is NOT acceptable by the Philippine side. On the other hand, in Case 2, the water level does not rise compared to the planned flood, and in Case 3, though the water level rises, it falls within the design dike level.
- Regarding the water level rise in Manggahan Floodway, In Case 1, the water level does not rise compared to the planned flood, and even in Case 2 and Case 3, though the water level rises, it falls within the design dike level. This is because the flow capacity of the Manggahan Floodway is much larger than that of the Lower Marikina River, so that the amount of water level rise in the Manggahan Floodway cannot have much as that in the main river.
- Regarding the gate vibration of MCGS, vibration occurs in Case 1 and Case 2 where the lower end of the gate is in water, but in Case 3, this phenomenon does not occur.
- Regarding the inundation damage, in Case 1, as the water level rises over the design dike level, inundation occurs along the Pasig River and the Lower Marikina River, and the damage is the largest. Although there is almost no difference between Case 2 and Case 3, a slightly larger amount of water flows down the Marikina River in Case 3, so that the flooded area could expand on the Pasig River after the San Juan River merger where the dike height does not reach the design dike level.

As a result of the study team describing a comparative study table, DPWH has determined that Case 3 is the most desirable. Therefore, the operation policy of MCGS in excessive floods is as follows:

- Not change from the operation rules up to the design flood scale

In addition, from the results of hydraulic model experiments, even when a flow rate of 4,000 m^3/s flowed down the Marikina River, the flow rate difference between Case3-1 and 3-2 is less than 10 m^3/s. Based on this, the Study Team decided to adopt Case 3-2.

Therefore, in the event of excessive flooding, not only the increase in the water level flowing down from the fully open narrower gate of MCGS, but also a slight flow down to the Lower Marikina River due to overflow from the top of the fully closed wider gate will be allowed.

2) Floodgates to Prevent Backward Flow

The operation of the floodgates is basically conducted by the water level in the Manggahan Floodway and that of the river/creek and drainage inside the embankment, so the operation rules are not changed even in the case of an excessive flood.

9.2.2.3 Warning Broadcast

The new contents of the broadcast by the Study Team are proposed below. It is recommended that the same content be broadcasted in Tagalog after English for all broadcasts as it is now.

(1) Rosario Weir

For broadcasting other than during gate operation, the current four types of messages will be reorganized into four types: precaution stage / before opening gates when the river flow increases / emergency stage / before closing gates when the river flow decreases. For the emergency stage, the message will be slightly stronger than others.

1) Warning Broadcast R1: (At Precaution Stage)

"This is a discharge warning from the Rosario Master Control Station.
Release of flood water through the Rosario floodgates will commence soon.

The surge of water will occur when the release commences.
The public is advised not to go near the floodway channel for your safety."

2) Warning BroadcastR2: (Before Opening the Gates during the River Flow Increases)

"This is a discharge warning from the Rosario Master Control Station.
The further release of flood water shall now commence through the Rosario floodgates.
The level of water will soon rise and its flow will gradually become swift.
The public is advised not to go near the floodway channel for your safety."

3) Warning BroadcastR3: (At Emergency Stage)

"This is a discharge warning from the Rosario Master Control Station.
All the Rosario floodgates are now open and flood water has been increasing.
The public requires caution as flood may occur.
Keeping away from the floodway channel is advised to avoid risk to the maximum."

4) Warning BroadcastR4: (Before Closing the Gates during the River Flow Decreases)

"This is a discharge warning from the Rosario Master Control Station.
Decrease of flood water through the Rosario floodgates will now commence.
The level of water will soon drop but its flow can change swiftly.
The public is advised not to go near the floodway channel for your safety."

5) Warning Broadcast during Gate Operation

"The gate is being operated. Please be careful. " ---[repeat]---

(2) MCGS

Unlike the Rosario Weir, since the broadcast is directed toward the Lower Marikina River where there is always water flow, there is no need for a precautionary broadcast. Therefore, there are three types of broadcasting for other than during gate operation: before closing the wider gate when the river flow increases / emergency stage / before opening the wider gate when the river flow decreases. It is the same as the Rosario Weir that a slightly stronger message is broadcasted in the emergency stage.

1) Warning BroadcastM1: (Before Closing the Wider Gate during the River Flow Increases)

"This is a discharge warning from the Rosario Master Control Station.
Restricting of flood water shall now commence through the Manggahan Control Gate Structure.
The flow of water will change swiftly when the restriction commences.
The public is advised not to go near the river channel for your safety."

2) Warning BroadcastM2: (At Emergency Stage)

"This is a discharge warning from the Rosario Master Control Station.
The flow is restricted by the Manggahan Control Gate Structure, but flood water has been increasing.
The public requires caution as flood may occur.
Keeping away from the river channel is advised to avoid risk to the maximum."

3) Warning BroadcastM3: (Before Opening the Wider Gate during the River Flow Decrease)

"This is a discharge warning from the Rosario Master Control Station.
The restriction of flood water through the Manggahan Control Gate Structure will end soon and its flow can change swiftly.
The public is advised not to go near the river channel for your safety."

4) Warning Broadcast during Gate Operation

"The gate is being operated. Please be careful. " ---[repeat]---

(3) Floodgates to Prevent Backward Flow

For broadcasts other than during the gate operation, there are two types before the gate closing operation and before the gate opening operation.

1) Warning BroadcastF1: (Before Closing the Gates)

"This is a discharge warning from the Rosario Master Control Station.
The flood water is coming through the floodway and the water level has risen.
The gates will be soon closed to prevent backflow from the floodway.
The public is advised not to go near the floodgates for your safety."

2) Warning BroadcastF2: (Before Opening the Gates)

"This is a discharge warning from the Rosario Master Control Station.
Release of flood water to the floodway shall now commence by opening the gates.
The flow of water will vary swiftly when the discharge commences.
The public is advised not to go near the floodgates for your safety."

3) Warning Broadcast during Gate Operation

"The gate is being operated. Please be careful. " ---[repeat]---

9.2.3 Need to Operate the NHCS

9.2.3.1 Policy for Considering the Operation

Normally (in non-flood phase) the MCGS is fully open, and there is no change in the river situation compared with before the construction. Therefore, any change in the operation of the NHCS is not considered necessary.

On the other hand, with the construction of the MCGS, the flow to the Lower Marikina River will be controlled as described in the previous section in the event of flood. Therefore, the necessity of operating the NHCS shall be considered, while there is information that the NHCS has not been actively operated so far.

According to previous studies[1], it has been found that the water level at the inflow of the Manggahan Floodway (that is, the upstream of Rosario Weir) is always higher than that in Laguna Lake, while there is no clear height relationship between the water level at the confluence with Napindan Channel (that is, the downstream of NHCS) and that in Laguna Lake. Therefore, whether the water level at the confluence with Napindan Channel or that in Laguna Lake is higher should be considered separately.

9.2.3.2 Operational Plan

(1) When the water level in Laguna Lake is higher than that at the main river confluence with Napindan Channel

As discussed in **Subsection 9.2.2**, in the event up to the design flood scale in the main river, the combined operation of the MCGS and the Rosario Weir will ensure that flows in the Lower Marikina River and Manggahan Floodway are adjusted to an appropriate level.

If there is not enough room for the main river to accept additional inflow in this adjusted state, it should be avoided that new inflow from the Laguna Lake side to the main river increases the flow rate in the Pasig River. The situation where there is not enough room for the main river is consistent with the operation water level of MCGS, where the water level at Sto. Niño is EL +15.2m or more, that is, the flow rate at Sto. Niño is 600 m^3/ s or more. The timing is recommended for easy understanding when to operate.

Therefore, the condition for closing gates of the NHCS is as follows:

- When the water level at Sto. Niño is EL +15.2m or more and there is a necessity to suppress additional inflow from Laguna Lake to the main river

Even in the event of an excessive flood on the Pasig-Marikina River, the above operation is applied because there is no more room.

[1]Data collection survey on flood management plan in Metro Manila: final report, May 2014, JICA

(2) When the water level in Laguna Lake is lower than that at the main river confluence with Napindan Channel

In the event up to the design flood scale in the main river, the flow rate in the Lower Marikina River and Manggahan Floodway is adjusted to an appropriate state by the cooperative operation of MCGS and Rosario Weir. However, when the water level in Laguna Lake is lower than that at the confluence with the Napindan Channel, if the gates of NHCS are open, flood water flows into Laguna Lake through not only Manggahan Floodway but also Napindan Channel.

In the event up to the design flood scale, since the main river is controlled to an appropriate flow rate, there is no need to divert the flood to Laguna Lake from the NHCS. However, as mentioned in Chapter 3, the existing flow capacity of the Pasig River is not sufficient in the downstream of the confluence with the San Juan River. In addition, if the main river reaches the DFL, it is recommended to stop operation of the pumping stations along the Pasig River. Therefore, it is effective to keep the main river flow as little as possible to prevent inundation along the Pasig River.

On the other hand, since flood flows into the Laguna Lake from the Pasig River when the NHCS is open, the water level in Laguna Lake slightly rises. From the viewpoint of ensuring the safety of residents along the shoreline of Laguna Lake, when the water level exceeds EL +11.5m, which is the elevation to start operation of the pumping stations along the shoreline of the Lake, the inflow from the main river to Lake Laguna should be limited to the Manggahan Floodway and be minimized. Therefore, the condition for allowing inflow from the Napindan Channel is until the water level of Laguna Lake reaches EL +11.5m.

Based on the above, the conditions under which the closing operation of the NHCS is required are as follows.

- When the water level on the Laguna Lake side reaches EL +11.5m or more and there is a necessity to suppress inflow from the main river

Even in the event of an excessive flood on the Pasig-Marikina River, the “opening” operation of the NHCS is recommended because the significance of utilizing the capacity of Laguna Lake can be found. However, since the water level of Laguna Lake would be also rising under the condition that the main river is over-flooded, it is assumed that the NHCS could be almost closed.

As a reference, it has been reported that more than 500 people in the upper reaches were killed when Typhoon Ondoy hit the Manila metropolitan area in September 2009. On the other hand, in the lower reaches of the area, about 3,100 m^3/s of flood was intercepted by the Manggahan Floodway and the Napindan Channel, and the flow rate of the downstream part (Pasig River) after division was reduced to almost 600[2] m^3/s or 800[1] m^3/s, i.e., close to the planned flow rate. Although the inundation damage in the area along the shoreline of Laguna Lake was large with the diversion of flood, the damage to the population and assets concentrated along the Pasig River were spared.

(3) Summary of Concept for the Operation of NHCS

Thus, the operation of NHCS in the event of floods is recommendable as shown in **Table 9.2.8**.

Table 9.2.8 Proposed Basic Operation Rules for NHCS

Condition		NHCS
When the water level in Laguna Lake is higher than that at the main river confluence with Napindan Channel	When the water level at Sto. Niño is EL +15.2m or more and there is a necessity to suppress additional inflow from Laguna Lake to the main river	Fully closed
When the water level in Laguna Lake is lower than that at the main river confluence with Napindan Channel	When the water level on the Laguna Lake side reaches EL +11.5m or more and there is a necessity to suppress inflow from the main river	Fully closed
Cases other than the above at the time of flood		Fully open

Source: Study Team

[2]Guide todisaster management measures in Japan, p.11, Cabinet Secretariat / Disaster Management Bureau, Cabinet Office, Government of Japan

9.2.4 Operation Rules

9.2.4.1 Rosario Weir, MCGS, and NHCS

The concept of operation procedure is shown in **Table 9.2.9**, followed by final draft of operation rules.

Table 9.2.9 Concept of Operation Procedure of Rosario Weir, MCGS, and NHCS

Flow Rate at Sto.Nino	Water Level at Sto.Nino	Operational Phase and Stage	when WL (L: Laguna Lake side) < WL (C: Confluence side)			Other than the Left
			Napindan HCS	Rosario Weir	Manggahan Control Gate Structure (MCGS)	Napindan HCS
Q < $180m^3/s$	H < EL+13.0m	Non-Flood Phase		Close all 8 gates	Open all 2 gates	
Q > $180m^3/s$	H > EL+13.0m	Flood Phase Precaution Stage		(for the people in the floodway, if necessary) Broadcast R1(15min)		
Q > $300m^3/s$	H > EL+13.8m	Caution Stage	Open all 4 gates	Siren and Warning Broadcast R2(30min) Open No.4&5 gates sequentially (Gate operation: 18 minutes +)		Open all 4 gates
Q > $350m^3/s$	H > EL+14.0m	Alert Stage	However, Close all 4 gates if WL(L)>EL+11.5m	Warning Broadcast R2(5 min) if any interval Open No.3&6 gates simultaneously (Gate operation: 18 minutes)		
Q > $450m^3/s$	H > EL+14.5m	Alarm Stage		Warning Broadcast R2(5 min) if any interval Open No.2&7 gates simultaneously (Gate operation: 18 minutes)		
Q > $600m^3/s$	H > EL+15.2m	Critical Stage		Warning Broadcast R2(5 min) if any interval Open No.1&8 gates simultaneously (Gate operation: 18 minutes)	Siren and Warning Broadcast M1(5 min) Close Wider Gate fully (Gate operation: 38 minutes)	Close all 4 gates (32 minutes)
Q > $2,900m^3/s$	H > EL+21.17m	Excessive Flood Phase Emergency Stage		Warning Broadcast R3(20 min) Open all 8 gates	Warning Broadcast M2(20 min) Close Wider Gate and Open Narrower Gate	
Q < $2,900m^3/s$	H < EL+21.17m	Flood Phase Critical Stage				
Q < $550m^3/s$	H < EL+15.0m	Alarm Stage		Warning Broadcast R4(5 min) Close No.1&8 gates simultaneously (Gate operation: 18 minutes)	Siren and Warning Broadcast M3(5 min) Open Wider gate fully (Gate operation: 38 minutes)	Open all 4 gates (32 minutes)
Q < $450m^3/s$	H < EL+14.5m	Alert Stage		Warning Broadcast R4(5 min) if any interval Close No.2&7 gates simultaneously (Gate operation: 18 minutes)	Open all 2 gates	
Q < $350m^3/s$	H < EL+14.0m	Caution Stage		Warning Broadcast R4(5 min) if any interval Close No.3&6 gates simultaneously (Gate operation: 18 minutes)		
Q < $300m^3/s$	H < EL+13.8m	Post Flood Phase		Warning Broadcast R4(5 min) if any interval Close No.5&4 gates sequentially (Gate operation: 18 minutes +)		
Q < $180m^3/s$	H < EL+13.0m	Non-Flood Phase		Close all 8 gates		

Note : **Flood Phase** operation starts under the following conditions: if average rainfall (Sto.Nino) > 30 mm/hr, or flow rate (Montalban) > 100 m^3/s
Gate operation velocity = 0.3 m/min, Gate operation time = Lifting height / Operation velocity

Source: Study Team

Operation Rules on

Rosario Weir, Manggahan Control Gate Structure, and Napindan Hydraulic Control Structure

Table of contents

Chapter 1 General Rules

(Intent)

Article 1

The operation of the Rosario Weir and the Manggahan Control Gate Structure (hereinafter both referred to as “the Weirs”) on the Marikina River, and the Napindan Hydraulic Control Structure (hereinafter referred to as “the Watergate”) on the Napindan Channel shall be as stipulated in these operation rules.

In this operation rule, Napindan Hydraulic Control Structure handles only operations related to flood protection.

(Purpose of operation)

Article 2

The operation of the Weirs and the Watergate aims to protect the floods along the Marikina and Pasig rivers by diverting flow of the Marikina river to the Manggahan floodway (and possibly to the Napindan Channel) during floods.

(Definition of terms)

Article 3

In this operation rule, “local control operation” refers to an operation that is performed while visually checking situation of the rivers, river use, and hinterlands, etc. at the local control house in the Weirs/Watergate, and “remote operation” refers to an operation that is performed in the operation room in the EFCOS Office building while observing the video footage and water level data.

(Basic policy of operation)

Article 4

1. The operation of the Weirs shall be done on local control operation as the main method. However, if the situation does not allow doing so, then remote operation shall be adopted instead. The operation of the Watergate is done on local control operation.

2. The basic policy for the operation of the Weir is as follows.

(1) When the water level of Marikina River measured at Sto. Niño Observatory (hereinafter referred to as “Sto. Niño water level”) is less than EL + 13.8 meters, all the water flows down to the Lower Marikina River.

(2) When the Sto. Niño water level is more than EL + 13.8m and less than EL + 21.17m (the design flood level), the flow of the Lower Marikina River is controlled to 500m^3/ s as the maximum or less.

(3) In case of (2) above, even when the Sto. Niño water level reaches EL + 21.17 meters or more, the flood flow is diverted as it is to the Marikina River and the Manggahan Floodway without doing any

additional operations.

3. The basic policy for operation of the Watergate is as follows.

(1) When the Sto. Niño water level is EL + 13.8 meters or more, the inflow and outflow through the Napindan Channel is controlled according to the water level of Pasig-Marikina River and Lake Laguna.

Chapter 2 Operation Method of the Weirs/Watergate, and others

(Operation method of the Weirs during floods)

Article 5

1. If the Sto.Niño water level is EL + 13.8 meters or more, the Head of EFCOS (hereinafter referred to as "the Head") shall operate the Rosario Weir as specified below.

(1) Open the gates of the Weirs in the following order. The figures in bracket indicate the Sto. Niño water level at the time of operation.
   a. Gate 4 (EL + 13.8 meters)
   b. Gate 5 (EL + 13.9m)
   c. Gates 3 and 6 (EL + 14.0 to +14.4 meters)
   d. Gates 2 and 7 (EL + 14.5 to +15.1 meters)
   e. Gates 1 and 8 (EL + 15.2 meters or more)

(2) When closing a gate opened in the Weirs, the operation is done in the following order. The figure in the bracket indicates the Sto. Niño water level at that time of operation.
   a. Gates 1 and 8 (EL + 15.0 meters)
   b. Gates 2 and 7 (EL + 14.5 meters)
   c. Gates 3 and 6 (EL + 14.0 meters)
   d. Gate 5 (EL + 13.8 meters)
   e. Gate 4 (EL + 13.6 meters)

2. When the Sto. Niño water level is EL + 13.8 meters or more, the Head shall operate the Manggahan Control Gate Structure as specified in the following procedure.

(1) The gates of the weirs are kept open fully until the Sto. Niño water level reaches EL + 15.2 meters.

(2) When the Sto. Niño water level reaches EL + 15.2 meters, Gate 1 (the wider gate) is closed fully.

(3) When the Sto. Niño water level falls below EL + 15.0 meters, all the gates are fully opened.

3. In the case of the preceding items 1&2, the water levels upstream and downstream of the Weirs should not be affected by sudden fluctuations.

(Method of operation the Watergate during floods)

Article 6

1. If the Sto. Niño water level is more than EL + 13.8 meters, and the water level measured at the upstream and downstream of the Napindan Hydraulic Control Structure is higher on the downstream side (the confluence point with the Marikina River), Napindan Hydraulic Control Structure shall be operated as specified below.

(1) All the water gates are fully open until the water level upstream (Laguna Lake side) reaches EL + 11.5 meters.

(2) When the water gate level upstream (Laguna Lake side) reaches EL + 11.5 meters, all gates are fully closed.

(3) When the gates are fully closed and the water level on the upstream (Laguna Lake side) is higher than

that on the downstream side (confluence point with the Marikina River), the following procedure should be done.

2 If the Sto. Niño water level is more than EL + 13.8 meters, and the water level measured at the upstream and downstream of the Napindan Hydraulic Control Structure is higher on the upstream side (Laguna Lake side), this structure shall be operated as specified below. .

(1) Open all gates until the Sto. Niño water level reaches EL + 15.2 meters.
(2) When the above level reaches EL + 15.2m, all gates are fully closed.
(3) If the gate is fully closed and the Sto. Niño water level falls below EL + 15.2 meters, all gates are fully opened.

3. In the case of the preceding items 1&2, the water levels upstream and downstream of the Weirs should not be affected by sudden fluctuations.

(Operation method during normal stage of water)
Article 7
When the water level of Sto. Niño is less than EL + 13.8 meters, the Head shall fully close all the gates of the Rosario Weir and fully open all the gates of the Manggahan Control Gate Structure, so that the water can flows down according to the preceding in Article 4- 2-(1).

(Special cases of operation methods)
Article 8
When there is an accident or under other unavoidable circumstances, the Head shall be allowed to operate the Weirs by other methods than the prescribed ones in the preceding Article 5 to 7, as far as necessary.

(Notification and communication)
Article 9
1. The Head shall notify relevant organizations in advance if it is deemed that operating or not operating the Weir/Watergate will bring a serious impact on public interests.
2. The Head shall notify the public in advance if it is deemed that operating or not operating the Weirs/Watergate will bring a risk of harming upstream or downstream.

(Records related to operations and others)
Article 10
The Head shall record the following items when operating the Weirs/Watergate.

(1) Date and time of start and end of operation
(2) Weather and hydrological conditions
(3) Name and opening degree of the operated gate
(4) Notifications performed during or without operation
(5) Reason for the operation when it is applied to Article 8
(6) Other matters to be referenced

Chapter 3 Alert System

(Implementation of alert system)
Article 11
When a situation falls under one of the following items and the Sto.Niño water level reaches EL + 13.0 meters, the Head shall regard it as the flood phase to immediately go into the flood alert.

(1) When the rainfall at Sto. Niño reaches an average rainfall intensity of 30 millimeters (equivalent to the water level rise of 0.6 meters per hour).
(2) When the water level of the Marikina River measured at the Montalban Observatory (hereinafter referred to as "Montalban water level") reaches EL + 22.4 meters.

(Measures in the alert system)

Article 12

The Head shall take the following measures in the alert system.

(1) To ensure necessary systems such as personnel who can properly operate the Weirs/Watergate.
(2) To inspect and maintain the Weirs/Watergate and the machinery and equipment necessary to operate them (including test operation of the backup generators).
(3) To maintain close observation of meteorological and hydrological conditions necessary for the management of the Weirs/Watergate, communication with related organizations, and collection of information.
(4) Other measures necessary for the management of the Weirs/Watergate.

(Cancellation of warning system)

Article 13

The Head shall lift the alert system when the flood is over or when there is no risk of reaching floods.

Chapter 4 Miscellaneous

(Inspection and maintenance)

Article 14

The Head shall inspect and maintain the Weirs/Watergate, and the machines and equipment for operating them, and keep them in good condition at all times.

(Observation)

Article 15

The Head shall observe the Sto. Niño and Montalban water levels, the water levels immediately upstream and downstream of the Weirs/Watergate, the diversion flow by the Weirs and other items necessary to operate the Weirs/Watergate.

(Creation and maintenance of records)

Article 16

The Head shall create and maintain records concerning matters related to the management of the Weirs/Watergate.

Supplementary Provisions

These operation rules will take effect from XX / XX, 20XX.

9.2.4.2 Floodgates to Prevent Backward Flow

The concept of operation procedure is shown in **Table 9.2.10**, followed by final draft of operation rules.

Table 9.2.10 Concept of Operation Procedure of Floodgates to Prevent Backward Flow

Condition & Broadcast	Cainta Floodgate	Taytay Floodgate
Normal	Open all 2 gates	Open all 3 gates
When WL (Inside the embankment) > WL (Manggahan Floodway)	Open all 2 gates	Open all 3 gates
When WL (Manggahan Floodway) > WL (Inside the embankment) Siren (only Cainta) and Warning Broadcast F1 (5 min)	Close all 2 gates	Close all 3 gates
During the gates are fully closed, when WL (Inside the embankment) > WL (Manggahan Floodway) Siren (only Cainta) and Warning Broadcast F2 (5 min)	Open all 2 gates	Open all 3 gates

Source: Study Team

Operation Rules on

Cainta Floodgate and Taytay Sluiceway

Table of contents

Chapter 1 General Rules

(Intent)

Article 1

The operation of the Cainta Floodgate (hereinafter referred to as “the Floodgate”) in the Cainta River, and the Taytay Sluiceway (hereinafter referred to as “the Sluiceway”) in the Taytay Creek shall be as stipulated in these operating rules.

(Purpose of operation)

Article 2

The purpose of the operation of the Floodgate and the Sluiceway is as follows.

(1) The operation of the Cainta Floodgate aims to prevent the backflow of floods in the Manggahan floodway to the Cainta River.

(2) The operation of the Taytay Sluiceway aims to prevent the backflow of floods in the Manggahan floodway to the Taytay Creek.

(Definition of terms)

Article 3

In this operation rule, “local control operation” refers to an operation that is performed while visually checking the situation of the rivers, river use, and hinterlands at the local control house in the Floodgate/Sluiceway, and “remote operation” refers to an operation performed in the operation room in the EFCOS Office building while observing the video footage and water level data.

(Basic policy of operation)

Article 4

The operation of the Floodgate/Sluiceway shall be done on local control operation as the main method, but if the situation does not allow doing so, then remote operation shall be adopted instead.

Chapter 2 Operation Method of the Floodgate/Sluiceway

(Operation method during flood)

Article 5

1 The Head of EFCOS (hereinafter referred to as “the Head”) shall operate the Flood gate/Sluiceway as specified in each of the following items when floods are flowing down the Manggahan Floodway.

(1) Open fully the gates of the Floodgate and Sluiceway until the back flow from the Manggahan Floodway to the Cainta River or Taytay Creek begins.

(2) When the backflow from the Manggahan Floodway to the Cainta River or Taytay Creek begins, the Floodgate/Sluiceway should be fully closed.

(3) During the gates of the Floodgate/Sluiceway are fully closed, if the water level on the up-stream side of the Floodgate/Sluiceway becomes higher than that on the downstream side, they should be fully opened.

2. In the case of the preceding item, the water levels upstream and downstream of the Floodgate/Sluiceway should not be affected by sudden fluctuations.

(Operating method during normal stage of water)

Article 6

The Head shall keep the gates fully open when there is no flood in the Manggahan Floodway.

(Special cases of operation methods)

Article 7

When there is an accident or under other unavoidable circumstances, the Head shall be al-lowed to operate the Floodgate/Sluiceway by a method other than the prescribed ones in the Article 5 to 6, as far as necessary.

(Notification and communication)

Article 8

1. The Head shall notify relevant organizations in advance if it is deemed that operating or not operating the Floodgate/Sluiceway will bring a serious impact on public interests.

2. The Head shall notify the public in advance if it is deemed that operating or not operating the Floodgate/Sluiceway will bring a risk of harming upstream or downstream.

(Records related to operations and others)

Article 9

The Head shall record the following items when operating the Floodgate/Sluiceway.

(1) Date and time of start and end of operation

(2) Weather and hydrological conditions

(3) Name and opening degree of the operated gate

(4) Notifications performed during or without operation

(5) Reason for the operation when it is applied to Article 7

(6) Other matters to be referenced

Chapter 3 Alert System

(Implementation of alert system)

Article 10

When a situation falls under one of the following items and the Sto. Niño water level reaches EL + 13.0 meters, the Head shall regard it as the flood phase to immediately go into the flood alert.

(1) When the rainfall at Sto. Niño reaches an average rainfall intensity of 30 millimeters (equivalent to the water level rise of 0.6 meters per hour).

(2) When the water level of the Marikina River measured at the Montalban Observatory (hereinafter referred to as "Montalban water level") reaches EL + 22.4 meters.

(Measures in the alert system)

Article 11

The Head shall take the following measures in the alert system.

(1) To ensure necessary systems such as personnel who can properly operate the Flood-gate/Sluiceway.

(2) To inspect and maintain the Floodgate/Sluiceway and the machinery and equipment necessary to operate them (including test operation of backup generators).

(3) To maintain close observation of meteorological and hydrological conditions necessary for the management of the Floodgate/Sluiceway, communication with related organizations, and collection of information.

(4) Other measures necessary for managing the Floodgate/Sluiceway.

(Cancellation of warning system)

Article 12

The Head shall lift the alert system when the flood is over or when there is no risk of reaching floods.

Chapter 4 Miscellaneous

(Inspection and maintenance)

Article 13

The Head shall inspect and maintain the Floodgate/Sluiceway, and the machinery and equipment for operating them, and keep them in good condition at all times.

(Observation)

Article 14

The Head shall observe the Sto. Niño and Montalban water levels, concerning the water levels immediately upstream and downstream of the Floodgate/Sluiceway and other items necessary for operating them.

(Creation and maintenance of records)

Article 15

The Head shall create and maintain records concerning matters related to the management of the Floodgate/Sluiceway.

(Management commitment)

Article 16

The Metro Manila Development Authority (MMDA) shall conclude a delegation agreement with the Department of Public Works and Highways (DPWH), the owner, regarding matters concerning the management of the Floodgate and Sluiceway.

Supplementary Provisions

These operating rules will take effect from XX / XX, 20XX.

9.3 Organization and Maintenance Management Plan

9.3.1 Study Policy for Organization and Maintenance Management Plan

9.3.1.1 Need to Draw up Organization and Maintenance Management Plan

To properly fulfill the function of facilities over the long term, it is necessary to ensure the appropriateness, reliability, and safety of operation of each facility such as MCGS and the two floodgates to be constructed in this project as well as the existing structures such as Rosario Weir.

Therefore, it is necessary to make a maintenance plan for each facility including the following items:

- Basic data collection, patrol and inspection methods (monitoring) to grasp the conditions of the facilities on a daily basis, during operation, and when abnormal events occur;
- Methods to maintain the functions of facilities(functional maintenance measures); and
- Recording method of the above activities (maintenance record).

The maintenance management plan shall include not only a maintenance plan described above but also a plan on organizational management structure for determining the size and budget of the organization which implements maintenance management.

9.3.1.2 Standards, Guidelines, etc. to be Applied

The maintenance management plan for the MCGS, the two backflow prevention floodgates, etc. shall be examined by dividing them into civil engineering and building structures such as steel sheet piles and weirs, mechanical facilities such as gates, and electrical and telecommunication facilities necessary to operate them, referring to the following standards and guidelines and similar existing facilities. However, since the terms used in each standard and guideline are very different from each other, the unification of terms in multiple sectors was considered as much as possible when compiling the plan.

As all of the following standards are written in Japanese, please refer also to the "MANUAL ON MAINTENANCE OF FLOOD CONTROL AND DRAINAGE STRUCTURES" (DPWH-Flood Control and Sabo Engineering Center, 2005), which was prepared with Japan's aid.

(1) General

The concept of maintenance management of the entire facilities to be developed in Phase IV project was based on the following standards.

- Technical Standards on River and Erosion Control [Maintenance Management Section (river edition)] (March 2015: Ministry of Land, Infrastructure, Transport and Tourism, Japan)
- Guideline to the Development of the Life Extending Plan of River Structures (March 2017: Ministry of Land, Infrastructure, Transport and Tourism, Japan)

(2) Civil Engineering and Building Structures

The following guideline was taken into account in the formulation of the inspection plan of civil structures (including building structures such as weir piers). The above 'Guideline to the Development of the Life Extending Plan of River Structures' was referred to in the development of maintenance and renewal plans.

- Guideline for Inspection and Evaluation of River Management Facilities such as Embankments and River Channels (April 2019, Ministry of Land, Infrastructure, Transport and Tourism, Japan)

(3) Mechanical Equipment

The following standards and procedures were referred to in the formulation of inspection, maintenance, and renewal plans of mechanical equipment.

- Technical Standards for Equipment of Dams and Weirs (March 2016: Ministry of Land, Infrastructure, Transport and Tourism, Japan)
- Manual for Inspection, Maintenance and Renewal of Gate Equipment for Rivers (March 2015:

Ministry of Land, Infrastructure, Transport and Tourism, Japan)

- Standard Procedure for Inspection and Maintenance of Gate Equipment for Rivers (March 2016: Ministry of Land, Infrastructure, Transport and Tourism, Japan)

(4) Electrical and Telecommunication Facilities

The following standards and guidelines were referred to in the formulation of inspection, maintenance, and renewal plans for electrical and telecommunication facilities.

- Guidelines for the Development of Maintenance Management Plans for Electrical and Telecommunication Facilities (March 2018: Ministry of Land, Infrastructure, Transport and Tourism, Japan)
- Standards for Inspection of Electrical and Telecommunication Equipment (November 2016: Ministry of Land, Infrastructure, Transport and Tourism, Japan)
- Standards for Inspection of Electrical and Telecommunication Equipment (November 2017: Japan Water Agency)

9.3.2 Maintenance Management Plan

The concept of maintenance management of the facilities to be developed in this project is shown below.

9.3.2.1 Basics

(1) Basic Policy for Maintenance Management

Maintenance management after completion of Phase IV project should be conducted in an appropriate and comprehensive manner by the following **monitoring** and **functional maintenance measures**.

- Conducting data collection and patrols at an appropriate time and frequency commensurate with the content of the completed facilities, and taking necessary measures such as removal of obstacles and dredging to maintain their functions; and
- Carrying out inspections at an appropriate time and frequency commensurate with each component of the completed facility, and taking necessary measures such as maintenance when any deterioration or abnormality such as damage or corrosion is identified.

In particular, the organization responsible for the O&M of MCGS and the two floodgates shall maintain and manage the facilities appropriately, efficiently and effectively, to keep their good running condition.

To achieve the above, the organization responsible for O&M of the facilities shall establish a sufficient system and ensure the necessary budget for the long term.

(2) Principles of Inspection and Maintenance

Inspection and maintenance shall be conducted in a rational manner, taking into consideration the purpose, function, and characteristics of the target facilities, and the expected service life of the installed facilities. “Controlled operation” shall be carried out periodically in order to confirm the series of functions.

In addition, in order to grasp the state of the target facilities and to cope with the situation, the facilities shall be monitored in a manner corresponding to their purpose, function, and installation environment. In particular, in the operation of equipment, efforts shall be made to grasp the occurrence of abnormalities by, for example, predicting the failure occurrence paying attention to changes in instruments and indicator lights.

(3) Ensuring functions and safety during inspections and maintenance

When operating the equipment from the necessity in inspection and maintenance, the impact by operation on the main body and related equipment of weirs and sluices, surrounding revetment, upstream and downstream rivers, etc., shall be considered. In particular, when it is necessary to change the flow of water by operation, alternative measures shall be taken to complement the change.

Since it is inevitable that the inspection and maintenance are carried out in the condition that the equipment is used (that is, loaded), safety measures for the work shall be considered. In particular, when inspection and maintenance, disassembling or power switching operation of the opening/closing devices, etc. are carried out while the gate body is suspended, certain measures shall be taken to prevent self-weight drop.

Furthermore, safety and workability, as well as implementation methods, shall be considered in selecting cranes, other machines and equipment, temporary materials such as work scaffolds while inspection and maintenance are being performed.

9.3.2.2 Monitoring

(1) Type of Monitoring

In the maintenance management, it is fundamental to grasp the state of river channels and facilities, and to implement countermeasures according to the results. Items to be carried out to grasp the state of rivers are classified into collection of basic data, river patrols, inspections before the rainy season and after a flood, and inspections of facilities.

1) Collection of basic data

Observing hydrological and hydraulic data such as precipitation, water level, and flow rate, surveying plane or longitudinal and cross sections, and collecting data on river channel conditions such as riverbed materials shall be carried out.

In the Phase IV project, especially, since the cross-section is secured by excavation and dredging of the river channel, it is recommended to check for local deep digging or sedimentation by longitudinal and cross-sectional surveys every five years. If digging or sedimentation is found, it is essential to conduct additional detailed investigations.

2) River patrol

For the purpose of grasping the status of river channels and facilities, and discovering illegal acts in river areas, river patrol shall be conducted in the round. Hereinafter, "patrol" refers to this river patrol.

3) Pre-rainy season inspection

Before the rainy season (in principle, every April), changes in river channels and facilities from the previous inspection shall be checked. Civil engineering and building structures, mechanical equipment, and electrical equipment, excluding telecommunication equipment, shall be subject to the "Annual inspection (or every 12 months inspection.)" during this season.

4) Inspection after a flood

In the event of a flood, earthquake, etc., which were exceeding the specified scale, temporary inspections of river channels and facilities shall be conducted with due considerations to safety. Hereinafter, this type of inspection is referred to as "extraordinary inspection".

It is recommended that the following guides be used for the implementation of extraordinary inspections.

- For floods, when the water level at Sto. Niño observes a critical level: EL +15.2 m or more
- For earthquakes, when the vicinity of Phase IV project area observes equivalent to or greater than VI (Japanese seismic intensity of lower 5) of the Philippine Institute of Volcanology and Seismology

5) Inspection of facilities

It is important to grasp the status of facilities with machinery and telecommunications equipment such as weirs, water gates and sluiceways, by inspecting them at an appropriate time and frequency. Hereinafter, inspections performed periodically are referred to as "periodic inspection", which includes "monthly inspection (However, it is not always held every month.)" and "yearly inspection". Inspections performed when facilities are in operation are called "operation check".

(2) Differences between Patrols and Inspections

The purpose of **patrol** is to patrol rivers periodically and systematically and to grasp abnormalities and changes in the round. The purpose of **inspection** is to discover, observe and measure abnormalities and changes in the functions of each facility. Actions requiring prompt initial response upon detection, such as responding to a tort, shall be included in the scope of patrols. Since the contents and accuracy required for grasping the state of rivers are different between river patrols and inspections, it is necessary to carry out appropriately according to the purpose.

(3) Types of Patrol and Inspection

The types of patrols and inspections for civil engineering and building structures, mechanical equipment, and, electrical and telecommunication facilities (electrical equipment and telecommunication one) are summarized in **Table 9.3.1** below.

Table 9.3.1 Types of Patrol and Inspection

<table>
<tr><th rowspan="2">Category</th><th rowspan="2">Patrol</th><th colspan="2">Periodic Inspection</th><th rowspan="2">Operational Check</th><th rowspan="2">Extraordinary Inspection</th></tr>
<tr><th>Monthly</th><th>Yearly*</th></tr>
<tr><td>Civil Engineering and Building Structures</td><td>Monthly</td><td>-</td><td>April</td><td>-</td><td>After Events
(Floods, Earth-quakes, etc.)</td></tr>
<tr><td>Mechanical Equipment</td><td>-</td><td>Rainy season: Every month
Dry season: Every 3 months</td><td>April</td><td>During Operation</td><td>After Events
(Floods, Earth-quakes, etc.)</td></tr>
<tr><td>Electrical Equipment</td><td rowspan="2">-</td><td rowspan="2">Anytime
every 3 or 6 months</td><td>April</td><td rowspan="2">Daily
(weekdays)</td><td rowspan="2">After Events
(Floods, Earth-quakes, etc.)</td></tr>
<tr><td>Telecommunication Equipment</td><td>Anytime</td></tr>
</table>

* In principle, Yearly Inspection shall be carried out before Rainy Season except for Telecom Equipment.
Source: Study Team

(4) Patrol and Inspection of Civil Engineering and Building Structures

1) Patrol

The main activities of the patrol are as follows.

- Check whether there are relatively large-scale changes that can be visually confirmed in the riverbank, sedimentation in the river channel, vegetation, dikes, revetment works, weirs, floodgates, etc.; and
- Check whether there are any torts or violations concerning the occupancy of land or the installation of structures in the river.

Patrols shall be basically conducted as follows.

(a) Patrollers move efficiently by utilizing vehicles, motorcycles, bicycles, etc., and the situation of the river should be sufficiently grasped by observing a target from the opposite riverbank as necessary.
(b) The patrols are conducted with special attention to the places where abnormalities have been confirmed.
(c) When it is judged that the abnormality found by the patrol may interfere with the function of the facility, individual inspection shall be carried out in order to examine countermeasures
(d) When any activities that require permission are performed without it, or when any prohibited activities are discovered, the patroller should understand the situation and take necessary measures.

2) Periodic inspection

Inspections of river channels and facilities before the rainy season (in principle, every April) shall be carried out by visual inspection on foot or by other appropriate methods for all of them, taking into consideration the conditions of their structure, maintenance, and repair of the facilities, the river where the facilities are installed, the topography or meteorology, etc.

The way to move to the inspection object should be selected according to the situation of the road for maintenance, such as by vehicles, motorcycles, bicycles, or on foot. In addition, personnel with experience in maintenance technology should be used to conduct appropriate inspections in accordance with the characteristics of rivers.

One of the civil engineering structures to be installed in the Phase IV project is a steel sheet pile revetment. It is important to grasp the condition of steel, because the corrosion of the materials is an important factor affecting the safety of sheet pile revetments. It is necessary to pay special attention to the state of corrosion in the zone near the water surface where wet and dry are repeated.

3) Extraordinary inspection

Extraordinary inspections conducted after a flood or earthquake exceeding a certain scale shall be visually carried out, paying attention to damage to facilities and changes in river channels, etc. In the event of a flood of a scale exceeding the design flood level (DFL), more detailed inspections of the damage to embankment, etc. shall be conducted, depending on the situation.

Since the collapse of steel sheet piles is directly linked to the collapse of embankments or riverbanks, it is necessary to check whether there is any change in the situation after floods and earthquakes.

4) Concept of action items

The items are divided into 4 types of river channel, dike/revetment (along a high-water channel), steel sheet pile (along a low-water channel), and flood control gate facilities, and main check items were arranged in each classification.

Since patrols are the basis for understanding the state of rivers and facilities, they are to be conducted monthly, and other inspection items are to be conducted yearly before the rainy season.

As for these classification methods and implementation items, the contents organized in "MANUAL ON MAINTENANCE OF FLOOD CONTROL AND DRAINAGE STRUCTURES" (2005) were taken into consideration as much as possible.

A list of items to be patrolled and inspected for civil engineering and building structures is shown in **Table 9.3.2**.

Table 9.3.2 Inspection items for Civil Engineering and Building Structures

Categories/Major Check Items	Type of Monitoring (Patrol & Periodic Inspection)												After	Remarks
Civil and Architectural Structures	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Event	
River Channel														
Overflow (from Channel)													E	After Large Floods
Severe Erosion/Slide/Collapse of Riverbank	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
River Width Reduction by Sediment Deposition				Y									E	
Riverbed Rise/Sand Bar by Sediment Deposition				Y									E	
Vegetation and Aquatic Plant				Y										
Water Quality (Turbidity/Color)	P	P	P	P	P	P	P	P	P	P	P	P		
Harmful Acts (along Channel)*	P	P	P	P	P	P	P	P	P	P	P	P	E	
River Longitudinal & Cross-sectional Survey														Every 5 years
Dike / Revetment (along High-Water Channel)														
Overflow (from Dike/Revetment)													E	After Large Floods
Erosion/Slide/Collapse	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
Crack/Bulge/Damage	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
Gap/Displacement of Joint				Y									E	
Degradation				Y									E	
Seepage				Y									E	
Massive Vegetation				Y										
Harmful Acts (on Dike)**	P	P	P	P	P	P	P	P	P	P	P	P	E	
Steel Sheet Piles (along Low-Water Channel)														
Deformation/Bulge/Damage	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
Inclination/Uneven Settlement	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
Gap/Displacement of Joint				Y									E	
Degradation/Corrosion				Y									E	
Subsidence by Runaway of Backfill Soil	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
Flood Control Gate Structure														
Deformation/Damage	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
Inclination/Uneven Settlement	P	P	P	P,Y	P	P	P	P	P	P	P	P	E	
Degradation/Corrosion				Y									E	
Shape of Surrounding Dike Crest/Slope				Y									E	
Gap/Displacement of Joint with Dike/Revetment				Y									E	
Scouring of Upstream/Downstream Riverbeds				Y									E	
Sediment Deposition in the Upstream Channel				Y									E	

P: Patrol Y: Yearly Inspection before Rainy Season
E: Extraordinary Inspection after Events (Floods, Earthquakes, etc.)

* Harmful Acts (along Channel) include 1)structure construction or earth work, 2)illegal usage such as fish pond, water intake, mooring, quarrying, etc. and 3)garbage dumping

** Harmful Acts (on Dike) include 1)cultivation at the dike foot, 2)illegal usage such as public and private facilities, temporary building, piling, excavation, etc. and 3)garbage dumping

Source: Study Team

(5) Inspection of Mechanical Equipment

1) Periodic inspection 1: Monthly inspection

Monthly inspections shall be carried out to check the presence or absence of abnormalities in each part of the facility, the occurrence of failures, and the functions of each part. Test runs should be conducted with the gate in the load state in principle (controlled operation), and the status and operation of the facility are checked. In this case, the load under the load state is not a design opening/closing load (full load) but an actual load as much as possible in consideration of the characteristics of the river gate.

In facilities where it is difficult to conduct controlled operation inspections, visual inspections shall be conducted to check for abnormalities in the external appearance and changes since the previous inspection, depending on the conditions of use or shutdown of the facilities. In particular, pay attention to the sedimentation on guide frames, the existence of any obstacles to the opening and closing of gate leaves, the condition of related facilities, the confirmation of safety, water leakage in the watertight portion, the display of the meter, the condition of oiling grease and lubrication, painting abnormality, etc.

2) Periodic inspection 2: Yearly inspection

Yearly inspections shall be carried out for the purpose of ensuring the reliability of the facilities and the maintaining their functions by carrying out more detailed inspection and measurement of each part than the monthly inspections. In the implementation, it is necessary to appropriately perform understanding changes, maintenance from the viewpoint of preventive maintenance, and other measures, through comparison with the previous periodic inspection and maintenance records.

In yearly inspections, trends should be managed by not only visual inspection, palpation, and auscultation but also by various measurements, and defects should be detected reliably, and inspection records should be analyzed (checking historical records) to enable responses several years in the future (maintenance forecast). A monthly inspection at the month in which a yearly inspection was conducted can be omitted.

3) Operational check

At the time of operational check, in order to confirm the function and safety of the opening and closing operation, the state and operation whether there are any obstacles at the start of operation, and any abnormalities or changes during and at the end of operation shall be confirmed. As a general rule, this should be done each time gates are operated.

4) Extraordinary inspection

Extraordinary inspections shall be carried out immediately when there is a possibility that any abnormalities occur in facilities and equipment due to factors such as floods, earthquakes, lightning strikes, etc., exceeding a certain scale. It is to check whether there are any particular abnormalities over the whole facilities by mainly visual inspection methods according to the purpose, function, installation environment, etc., of the relevant facilities.

5) Concept of action items

After roughly classifying into three types of gate leaf/guide frame, hoist, and local control panel, the main check items in each part were arranged, while the hoist was subdivided according to the components such as an electric motor, a brake, and a reducer, taking into consideration the wire rope winch type which is a typical gate equipment to be developed in the phase IV project.

Monthly inspections shall be conducted every month during the rainy season (from May to October) and every 3 months during the dry season (from November to April). Yearly inspections shall be conducted in April before the rainy season. Items such as confirmation of internal state that cannot be carried out even in yearly inspections shall be carried out by periodic maintenance (to be described later) by suppliers, which is carried out in a longer term.

A list of inspection items for mechanical equipment is shown in **Table 9.3.3**. However, since these inspection items are not exhaustive, it is essential to manage them appropriately based on the maintenance procedures provided by suppliers when the equipment is installed.

Table 9.3.3 Inspection items for Mechanical Equipment

Categories/Major Check Items*	Type of Monitoring (Periodic Inspection)												After Event	Remarks
Mechanical Equipment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Gate Leaf & Guide Frame														
Deformation of Metal/Rubber				Y										
Damage of Metal/Rubber	M			Y	M	M	M	M	M	M			E	
(Pitting) Corrosion of Metal				Y										
Wear of Wheels (Roller/Sheave) and Bearings				Y										
Rotating State of Wheels (Roller/Sheave) and Bearings	M			Y	M	M	M	M	M	M				
Water Leak through Watertight Rubber				Y										
Deterioration of Watertight Rubber				Y										
Supply State of Lubricant Oil	M			Y	M	M	M	M	M	M				
Cracks in the Weld														Periodic Maintenance
Reduction of Steel Plate Thickness														
Hoist (Electric Motor)														
Abnormal Vibration/Sound/Heat	M			Y	M	M	M	M	M	M				
Current/Voltage	M			Y	M	M	M	M	M	M			E	
Insulation Resistance				Y										
Opening/Closing Speed				Y										
State of the Components														Periodic Maintenance
Hoist (Brake)														
Cleanliness Level	M			Y	M	M	M	M	M	M				
Operating State	M			Y	M	M	M	M	M	M				
Gap between Brake Lining and Drum				Y										
Thickness of Brake Lining				Y										
Damage of Drum				Y										
Insulation Resistance				Y										
State of the Components														Periodic Maintenance
Hoist (Reducer)														
Abnormal Vibration/Sound/Heat	M			Y	M	M	M	M	M	M				
Leak of Lubricant Oil	M			Y	M	M	M	M	M	M			E	
Quantity/State of Lubricant Oil				Y										
Damage/Wear of Gear				Y									E	
Tooth Contact of Gear				Y										
Backlash of Gear				Y										
State of the Components														Periodic Maintenance
Hoist (Driving Force Transmission Part)														
Operating State	M			Y	M	M	M	M	M	M				
Abnormal Vibration/Sound/Heat	M			Y	M	M	M	M	M	M				
Leak of Lubricant Oil	M			Y	M	M	M	M	M	M			E	
Quantity/State of Lubricant Oil				Y										
State of the Components														Periodic Maintenance
Hoist (Gate Driving Part)														
Deformation/Damage of Drum/Drum Shaft				Y										
Wear of Rope Groove on Drum				Y										
Loose/Drop-out of Rope Terminal of Drum				Y									E	
Damage of Sheave/Bearing	M			Y	M	M	M	M	M	M			E	
Wear of Sheave/Bearing				Y										
(Pitting) Corrosion of Sheave/Bearing				Y										
Rotating State of Sheave/Bearing	M			Y	M	M	M	M	M	M				
Supply State of Lubricant Oil	M			Y	M	M	M	M	M	M				
Deformation of Wire Rope	M			Y	M	M	M	M	M	M			E	
Foreign Substances adhered to Wire Rope	M			Y	M	M	M	M	M	M				
Rust/Wear/Break of Wire Rope				Y										
State of the Components														Periodic Maintenance
Hoist (Protective Device)														
Loose of Lock Nut in Rope Terminal Adjusting Device	M			Y	M	M	M	M	M	M				
Drop-out of Pin from Wire Rope Socket				Y										
Difference of Rope Length on the left and right				Y										
Supply State of Lubricant Oil				Y										
Deformation/Damage of Limiting Switch	M			Y	M	M	M	M	M	M			E	
Operating State of Limiting Switch	M			Y	M	M	M	M	M	M				
Hoist (Gate Opening Meter)														
Matching of Actual Head and Pointer Display	M			Y	M	M	M	M	M	M				
Local Control Panel														
Operating Test of Switch/Relay	M			Y	M	M	M	M	M	M				
Abnormal Sound of Switch/Relay	M			Y	M	M	M	M	M	M				
Set Value of 3E Relay/Timer	M			Y	M	M	M	M	M	M				
Indicator Lighting (Lamp Test)	M			Y	M	M	M	M	M	M			E	
Contact Welding/Discoloration of Switch				Y										
Operation Test by Opening/Closing/Changing Gates				Y										
Voltage of Power Supply Terminal of PLC				Y										
Age of Built-in Battery of PLC				Y										
Adjustment of Zero Point/Span of PLC				Y										
Operating/Telecom State through PLC				Y										
Wiring State/Terminal Loose in the Panel				Y									E	
Check of Spare Parts				Y										

M: Monthly Inspection with "Controlled Operation"

Y: Yearly Inspection before Rainy Season

E: Extraordinary Inspection after Events (Floods, Earthquakes, etc.)

* The items shown here are just examples. As for specific items, follow the maintenance procedure manual provided by a supplier.

Source: Study Team

(6) Inspection of Electrical and Telecommunication Facilities

1) Periodic inspection

Periodical inspections are carried out for the purpose of grasping (monitoring) the status necessary for early detection of signs of problems, systematic introduction of maintenance or repair, and determining an appropriate time for maintenance of aging facilities or equipment, etc. These inspections shall be implemented at an appropriate frequency for each device, taking the following points into consideration.

- Appearance, damage, abnormal sound, unusual odor, heat generation, smoke generation, etc.
- Situation in the electrical and control rooms
- Display status of the indicator lamp
- Whether or not the indicated value of the measuring instrument is within the normal range

In addition, yearly inspections on generation equipment shall be conducted with controlled operation.

2) Operational check (Daily inspection)

Since many of the devices that make up electrical and telecommunication facilities are in operation at all times, daily checks, replacement and replenishment of consumables shall be carried out by checking and grasping the operation status on a daily basis.

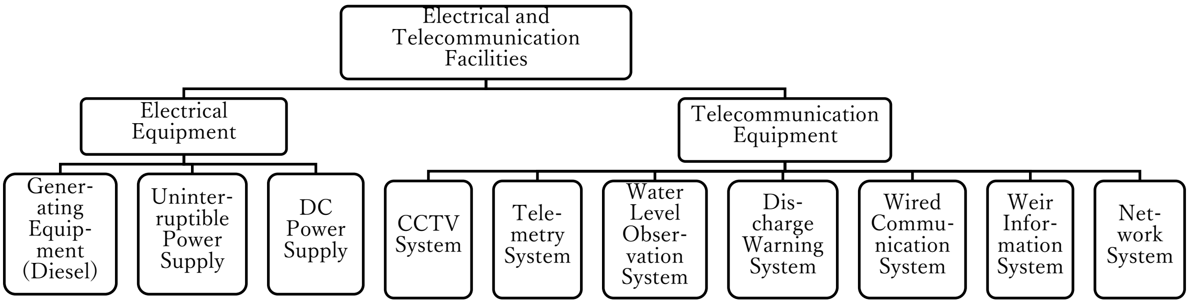
When operating the gates, the status shall be appropriately grasped through monitoring equipment such as CCTV, remote control panel, monitoring panel, etc., and the status of electrical and telecommunication facilities on the machine side shall be checked in a timely manner.

3) Extraordinary inspection

Extraordinary inspections shall be conducted to confirm the operational and installation status of facilities and equipment in the event of floods, earthquakes, lightning strikes, etc., exceeding a certain scale.

4) Concept of action items

In the Phase IV project, the facilities to be replaced or newly installed were classified as follows, and the necessary facilities were further subdivided and the main check items in each were arranged.



Monthly inspections shall be carried out at a frequency determined for each component of the equipment, for example, for three months or six months. Yearly inspections shall be carried out in April before the rainy season for electrical facilities, mainly power generating equipment. However, yearly inspections for telecommunication facilities (including attached power supply) are acceptable for the facility manager to select an appropriate time instead of setting a fixed time. Items such as parts replacement and disassembly adjustment, which cannot be carried out even in yearly inspection, shall be carried out by periodic maintenance (to be described later) by suppliers in a longer term.

The followings are lists of items to be inspected for electrical and telecommunication equipment: **Table 9.3.4** and **Table 9.3.5** respectively. However, since inspection items are not exhaustive, it is essential to manage them appropriately based on the maintenance procedures provided by suppliers when the equipment is installed.

Table 9.3.4 Inspection items for Electrical Equipment

Categories/Major Check Items*		Type of Monitoring												After Event	Remarks
Electrical Equipment		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Generating Equipment [Diesel] (Engine)														E	
	Status of fan belt, brush, air filter, super charger, etc.	3			3			3			3				
	Draining fuel/lubricant filters				(Y)										
	Status of air-starting system (lubricant, pipe arrangement, electric/manual valve., etc.)				(Y)										
	Status of cooling system(piping, electric/manual valve, etc.)				(Y)										
	Status of fuel system(daily tank, piping, etc.)				(Y)										
	Measurement of No. of rotations, lubricantion oil pressure/temperature, cooling water pressure/temperature, etc.				(Y)										
	Status of system operations of air-starting, cooling, fueling, and lubricant				(Y)										
	Cleaning of parts and units				(Y)										
	Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Generating Equipment [Diesel] (Generator)														E	
	Status of coils and iron cores				(Y)										
	(With brush) Status of brush wear and slip ring condition	3			3			3			3				
	(Without brush) Status of exciter, rectifier, etc.				(Y)										
	Status of oil leakage from parts of packing, sliding bearing, and terminals	3			3			3			3				
	Status of metal and sliding bearing				(Y)										
	Measurement of insulation and ground resistance				(Y)										
	Cleaning of parts and units				(Y)										
	Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Generating Equipment [Diesel] (DC Power Panel)														E	
	Measurement of input/output voltage, current, storage battery voltage, etc.				(Y)										
	Measurement of voltage and electrolyte specific gravity for each battery cell				(Y)										
	Testing of automatic changeover on charging				(Y)										
	Operation test of protection circuit and alert circuit				(Y)										
	Measurement of internal resistance of battery cells				(Y)										
	Cleaning rectifiers and storage batteries				(Y)										
	Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Generating Equipment [Diesel] (Flue/Silencer)														E	
	Status of flues and silencers				(Y)										
	Status of insulation protection around through-holes and water stoppage				(Y)										
	Draining of silencer				(Y)										
	Confirmation of no flammable materials in the vicinity				(Y)										
	Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Generating Equipment [Diesel] (Generator/Control Panel)														E	
	Status of circuit breakers, relays, capacitors, etc.				(Y)										
	Status of main circuit, control circuit, etc.				(Y)										
	Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Uninterruptible Power Supply (less than 20kVA)														E	
	Status of display abnormality / failure display	D	D	D	D	D	D	D	D	D	D	D	D		
	Status of storage battery				Y										
	Status of fan				Y										
	Cleaning and others of equipment body				Y										
	Documents and spare parts/units				Y										
	Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
DC Power Supply Equipment														E	
	Status of abnormality/failure display	D	D	D	D	D	D	D	D	D	D	D	D		
	Status of internal status of equipment				Y										
	Measurement of insulation resistance				Y										
	Status of input/output characteristics				Y										
	Status of storage battery				Y										
	Cleaning and others of equipment body				Y										
	Status of documents and spare parts/units				Y										
	Parts replacement, Disassembly to fix parts/units														Periodic Maintenance

D: Daily Inspection

(Implementation can be replaced with another month)
- 3: Every 3 Months Inspection
- 6: Every 6 Months Inspection
- Y: Yearly Inspection (Every 12 Months Inspection)

(Y): Yearly Inspection with Controlled Operation before Rainy Season

E: Extraordinary Inspection after Events (Floods, Earthquakes, etc.): <Check of Installation Status / Operation, etc.>

* The items shown here are just examples. As for specific items, follow the maintenance procedure manual provided by a supplier.

Source: Study Team

Table 9.3.5 Inspection items for Telecommunication Equipment

Categories/Major Check Items*	Type of Monitoring												After Event	Remarks
Telecommunication Equipment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
CCTV System (Control Device)													E	
Status of operation of switch, mouse, and keyboard	D	D	D	D	D	D	D	D	D	D	D	D		
Measurement of power supply voltage				Y										
Status of control equipment				Y										
Status of display				Y										
Cleaning and others of equipment body				Y										
Status of documents and spare parts/units				Y										
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
CCTV System (Local Device)													E	
Status of looseness of pole, installation base, paint, and bolts				Y										
Status of power supply voltage				Y										
Status of camera device, and equipment on local operation side (wiper, glass plane, connectors, cables, etc.)				Y										
Cleaning or others of camera equipment, and equipment				Y										
Status of documents and spare parts/units				Y										
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Telemeter System (Monitor Station)													E	
Status of display of abnormality/failure	D	D	D	D	D	D	D	D	D	D	D	D		
Status of print record	D	D	D	D	D	D	D	D	D	D	D	D		
Measurement of voltage, current, frequency, S/N, etc.				Y										
Status of system functions				Y										
Status of received data				Y										
Re-examination of propagation line				Y										
Status of aerial wire				Y										
Status of connection of terminals				Y										
Status of interlocking sensor and recorder				Y										
Cleaning of the equipment body				Y										
Status of documents and spare parts/units				Y										
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Telemeter System (Observation Station)													E	
Measurement of voltage, current, frequency, S / N, etc.				Y										
Status of operation of each observation equipment				Y										
Re-examination of propagation line				Y										
Status of aerial wire				Y										
Status of connection of terminals				Y										
Status of interlocking sensor and recorder				Y										
Cleaning of the equipment body				Y										
Parts replacement, Disassembly to fix parts/units				Y										
Replace or disassembly parts/units and adjustment														Periodic Maintenance
Water Level Observation System (Water Level Gauge)													E	
Status of loose connections on terminal board, damage, etc.				Y										
Calibration of A/D converter, etc.				Y										
Status of recorder				Y										
Status of connection part				Y										
Status of cleaning equipment and installation				6						6				
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Discharge Warning System (Monitor Station)													E	
Status of abnormality / failure display	D	D	D	D	D	D	D	D	D	D	D	D		
Status of print record	D	D	D	D	D	D	D	D	D	D	D	D		
Measurement of voltage, current, frequency, power for received input, S/N, etc.				6						6				
Status of Max. frequency deviation and unnecessary width intensity				Y										
Status of system functions (inspection control, sound generation, & printer control)				6						6				
Status of alarm control (siren, simulated sound, broadcast, rotating light, etc.)				Y										
Re-examination of propagation line				6						6				
Status of aerial wire				Y										
Status of connection of terminals				Y										
Status of interlocking of sensor and recorder				Y										
Cleaning of equipment body				6						6				
Status of documents and spare parts/units				Y										
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Discharge Warning System (Warning Station)													E	
Measurement of voltage, current, frequency, power for received input, S/N, etc.				6						6				
Status of Max. frequency deviation and unnecessary width intensity				Y										
Status of alarm control (siren, simulated sound, broadcast, rotating light, etc.)				Y										
Re-examination of propagation line				6						6				
Status of aerial wire				Y										
Status of connection of terminals				Y										
Status of operation of siren, speaker, microphone, and revolving light				6						6				
Cleaning of equipment body				6						6				
Status of documents and spare parts/units				Y										
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance

Categories/Major Check Items*	Type of Monitoring												After	Remarks
Telecommunication Equipment (continued)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Event	
Wired Communication System (Optical Transmission Device)													E	
Alarm history and display of faults	D	D	D	D	D	D	D	D	D	D	D	D		
Status of utilizing monitoring equipment	D	D	D	D	D	D	D	D	D	D	D	D		
Status of connection of terminals				Y										
Cleaning of equipment body				Y										
Weir Information System (Information Processing Device)													E	
Measurement of CPU utilization				6						6				
Measurement of network load				6						6				
Measurement of memory utilization				6						6				
Status of documents and spare parts/units				Y										
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Weir Information System (Input/Output Interface)													E	
Measurement of voltage				6						6				
Measurement of Input/output level				Y										
Status of connection part				Y										
Cleaning of surface of equipment and status of fan operation	D	D	D	D	D	D	D	D	D	D	D	D		
Cleaning of inside of equipment and status of installation				Y										
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Weir Information System (Input/Output Relay Device)													E	
Measurement of voltage and others				6						6				
Status of protector and lightning arrester				6						6				
Status of auxiliary relay				Y										
Status of connection part				Y										
Cleaning of inside of equipment and status of its installation				Y										
Cleaning of surface of equipment body	D	D	D	D	D	D	D	D	D	D	D	D		
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Weir Information System (Monitoring Control Console)													E	
Status of protection of switches				Y										
Status of voltage				6						6				
Status of indicators (Lamp test)	D	D	D	D	D	D	D	D	D	D	D	D		
Cleaning of inside of equipment and status of its installation				Y										
Cleaning of surface of equipment body	D	D	D	D	D	D	D	D	D	D	D	D		
Parts replacement, Disassembly to fix parts/units														Periodic Maintenance
Weir Information System (Display)													E	
Status of protection of switches	D	D	D	D	D	D	D	D	D	D	D	D		
Status of voltage				Y										
Status of indicators (Lamp test)				Y										
Status of connection part and equipment body				Y										
Network System (Router Switch)													E	
Status of terminals connection				Y										
Cleaning of equipment body				Y										

D: Daily Inspection
(Implementation can be replaced with another month) 3: Every 3 Months Inspection
6: Every 6 Months Inspection
Y: Yearly Inspection (Every 12 Months Inspection)
(Y): Yearly Inspection with Controlled Operation before Rainy Season
E: Extraordinary Inspection after Events (Floods, Earthquakes, etc.):
<Check of Installation Status / Operation, etc.>

* The items shown here are just examples. As for specific items, follow the maintenance procedure manual provided by a supplier.

Source: Study team

9.3.2.3 Functional Maintenance Measures

(1) Civil Engineering and Building Structures

1) Measures based on patrol and inspection results

Based on the results of periodic or post-flood longitudinal and cross-sectional surveys, or patrols and inspections, if it is judged that changes in the flow capacity and/or the ones in the river bed that affect the safety of the facility may interfere with river management, appropriate measures shall be taken, such as excavation and dredging of the river bed, or construction of a consolidation and filling of scouring areas.

When any abnormalities such as damage or deterioration of the civil engineering or building structure of a facility have been identified through patrols and inspections, the following necessary measures shall be taken to ensure the efficient maintenance and repair of the facility.

(a) When cracks, deterioration of concrete, subsidence, etc. are found through inspections, and there is a risk that the functions to be maintained by each facility may decline, investigate the cause by continuously grasping the state (inspecting).

(b) Referring to past damage and/or abnormal occurrence cases of the facilities and structures of the same type, if it is judged from the state of the facility's abnormality due to inspections, etc. that a serious problem may occur with the functional maintenance of the facilities, necessary measures shall be taken.

In implementing the measures, long-term costs should be considered through consideration of measures to extend the service life of the facilities. When renewing the facilities, qualitative improvements should be considered, such as the preservation and creation of the natural ecosystem of the river and various landscapes taken into consideration of the location and the surrounding environment of the facilities, and consideration for harmony with local life, history, and culture.

2) Large-scale repair

It is considered that the strength of properly constructed concrete will not decrease due to deterioration for several decades.

On the other hand, steel materials are used for the low-water revetment works and the local control houses. Since the steel materials deteriorate after several decades and it is considered that they cannot perform the functions expected at first, large-scale repair or replacement will be required. For the stairs to access the local control house and the access bridge, since SS materials, which are general-purpose ones, are used, there is a necessity to paint at a shorter interval.

In addition, the roof of the generator building needs to be waterproofed periodically.

Based on the above concept, the cycles of large-scale repair in civil engineering and building structures are shown in Table 9.3.6.

Table 9.3.6 Large-Scale Repair Cycles for Civil Engineering and Building Structures

Category	Subcategory	Location	Paint Repainting	Replacement	Remarks
Steel Parts	Staircase, louvers, etc.	MCGS, Cainta	12 years	35 years	Handrail (Material: GI Pipe) is excluded from painting.
	Access bridge, louvers, etc.	Taytay	12 years	35 years	Handrail (Material: GI Pipe) is excluded from painting.
Local Control House	Roof sheet	MCGS, Cainta, Taytay	-	35 years	Material: Galbarium steel sheet
Generator Building	Roof waterproofing	MCGS, Cainta	12 years		Replacing the waterproof coating
Low-water Revetment	Steel sheet piles	River	50 years		Large-scale repairs (Partial replacement, etc.)

Source: Study Team

(2) Mechanical Equipment

1) Maintenance

Maintenance shall be carried out in consideration of the function and purpose of the facilities, installation environment, operating conditions, characteristics of the facilities and equipment, etc., and a proper and reasonable maintenance plan shall be formulated for the purpose of maintaining or restoring the functions and ensuring reliability.

Maintenance can be divided into "maintenance at the time of inspection" and "periodic maintenance".

Maintenance at the time of inspection means cleaning, refueling and greasing, simple adjustment and replacement of mechanic and electric parts by hand tools, etc. performed after or during inspection for the purpose of maintaining the function of the equipment. It is basically carried out as a part of the inspection work, and necessary maintenance based on the inspection result is also included.

Periodic maintenance means maintenance work entrusted to suppliers at a predetermined time for the purpose of maintaining the functions of equipment and preventing damage and abnormal occurrences. Periodic maintenance includes cleaning, refueling and greasing, periodic replacement, disassembly adjustment (overhaul), painting, etc. This allows for longer use at less cost than frequent renewals, thus reducing lifecycle costs.

Cleaning, oiling and greasing are indispensable to keep the machine elements constituting the equipment in the normal condition, and since they are the most basic maintenance, they must be surely carried out based on the operation manual of the equipment.

2) Replacement and renewal

Replacement and renewal involves the reinstallation of new equipment or devices in order to ensure the normal function of the facilities in the following cases:

- When it is judged that the reliability and safety cannot be maintained due to deterioration in the functions of the facilities compared to when they were newly installed in spite of proper maintenance management of the facilities; or
- When it is determined that the equipment constituting the facilities has become unable to obtain stable functions and performance due to deterioration such as aging and has reached the end of its life.

It is important to implement replacement and renewal in a planned and economical manner at an appropriate time according to the importance of the target facilities, equipment, and devices. Therefore, replacement and renewal plans must be formulated and implemented systematically from a long-term perspective, taking into account the life cycle costs of the equipment. For replacement and renewal, measures such as the use of standard products and general-purpose products should be taken as much as possible to reduce costs.

To replace and renewal cycles for mechanical equipment is shown in Table 9.3.7. The table was prepared assuming the following conditions.

(a) Basically, the equipment and devices that make up each facility are replaced and/or renewed in a unit to some extent.
(b) Since the material of the gate leaf is alloy saving duplex stainless steel, it is considered that the replacement and renewal years are longer than described. However, since there is no record, the same value as the conventional SS material was applied.
(c) It should be kept in mind that the figures in "replacement and renewal cycles" are the estimated number of years that can be expected if necessary inspections and maintenance, including periodic maintenance carried out with being entrusted to suppliers, are surely carried out properly. If the level of inspections and maintenance cannot be secured, it is impossible to use the equipment up to the years described.

Table 9.3.7 Replacement and Renewal Cycles for Mechanical Equipment

Equipment and Devices			Category	MCGS		Cainta	Taytay	Replacement and Renewal: Standard number of years
				No. 1 (Wider)	No. 2 (Narrower)			
			Number of gates	1 Gate	1 Gate	2 Gates	3 Gates	
Gate leaf(pergate)	Gate leaf structure		Renewal	1 set	1 set	1 set	1 set	58 years
	Main roller	Roller	Replacement	4 units	4 units	4 units	4 units	58 years According to the gate leaf structure
		Roller shaft	Replacement	4 sticks	4 sticks	4 sticks	4 sticks	
		Bearing metal	Replacement	4 sets	4 sets	4 sets	4 sets	
	Auxiliary roller		Replacement	4 sets	4 sets	4 sets	4 sets	
	Sheave attached to gate leaf		Replacement	2 units	2 units	2 units	-	
	Watertight rubber		Replacement	L = 48 m	L = 31 m	L = 31 m	L = 9 m	21 years

Equipment and Devices			Category	MCGS		Cainta	Taytay	Replacement and Renewal: Standard number of years
				No. 1 (Wider)	No. 2 (Narrower)			
			Number of gates	1 Gate	1 Gate	2 Gates	3 Gates	
Wire rope winch type Hoist (per stand)	Main electric motor		Replacement	2 units	1 unit	1 unit	-	39 years
	Hydraulic push-up brake		Replacement	4 units	2 units	2 units	-	55 years According to the sheave in machine stand
	Centrifugal brake		Replacement	4 units	1 unit	1 unit	-	
	Switching device		Replacement	2 units	1 unit	1 unit	-	
	Reducer		Replacement	2 units	1 unit	1 unit	-	
	Open gear		Replacement	2 sets	1 set	1 set	-	
	Sheave in machine stand		Replacement	2 sets	1 set	1 set	-	55 years
	Bearing		Replacement	2 sets	1 set	1 set	-	55 years According to the sheave in machine stand
	Shaft coupling		Replacement	2 sets	1 set	1 set	-	
	Wire rope		Replacement	L = 80 m 2 ropes	L = 120 m 1 rope	L = 190 m 1 rope	-	35 years (Waiting)
	Wire rope terminal adjusting device		Replacement	2 sets	1 set	1 set	-	55 years According to the sheave in machine stand
Rack type Hoist body			Renewal	-	-	-	1 set	34 years
Control Equipment (per gate)	Limiting switch		Replacement	2 sets	1 set	1 set	-	43 years
	Gate opening meter		Replacement	2 units	1 unit	1 unit	-	43 years
	Local control panel (per panel)	Entire panel	Replacement	1 panel (self-supporting)	1 panel (self-supporting)	1 panel (self-supporting)	1 panel (mounting on switch)	35 years
		Relays	Replacement	1 set	1 set	1 set	1 set	35 years Replacement of the entire panel
		Switches	Replacement	1 set	1 set	1 set	1 set	

Source: Study Team

(3) Electrical and Telecommunication Facilities

1) Maintenance

In maintenance, the replacement and adjustment of deteriorated parts specified in advance for each facility shall be systematically carried out, while utilizing the results of inspection and facility diagnosis, and the maintenance and recovery of facility functions shall be attempted by performing prompt and appropriate repairs to any failures or malfunctions that occur.

The maintenance of electrical and telecommunication facilities is also divided into "maintenance at the time of inspection" and "periodic maintenance".

Maintenance at the time of inspection means cleaning, simple adjustment and replacement of parts by hand tools, etc. performed after or during inspection for the purpose of maintaining the function of the equipment. It is basically carried out as a part of the inspection work, and necessary maintenance based on the inspection result is also included.

Periodic maintenance means maintenance work entrusted to suppliers at predetermined times for the purpose of further extending the life of equipment that reaches the end of its service life under normal inspection and maintenance. The periodic maintenance includes replacement of deteriorated parts, disassembly adjustment (overhaul), etc. Although not applicable to all facilities and equipment, periodic maintenance can reduce the life cycle cost because it can be used longer than the design life at less cost than frequent renewals.

2) Renewal

Many of the facilities and equipment that make up electrical and telecommunication facilities have shorter design life than civil engineering and building structures, and mechanical equipment. Although it is possible to extend the life of the facilities by carrying out thorough maintenance, including the periodical maintenance mentioned above, frequent renewals are required while facilities are operated.

For the equipment and devices that comprise electric and telecommunication facilities are shown in **Table 9.3.8**.

The "Location" column includes the existing EFCOS-related systems where equipment and devices to be replaced in the Phase IV project are installed, as well as the newly installed MCGS and two backflow prevention floodgates. In addition, the renewal period which is based on the assumption of prolonged life through appropriate maintenance including periodic maintenance was set as "Expected Life".

Table 9.3.8 Renewal Cycles of Electric and Telecommunication Equipment

Location	Equipment	Device	Quantity	Design Life	Expected Life
MCGS	Generating equipment	Diesel engine	3 units	20	25
	Uninterruptible power supply	Uninterruptible power supply	3 units	15	19
	Electronic equipment	Water level observation equipment (water level gage)	1 set	8	15
	Discharge warning system	Siren	1 unit	13	16
		Speaker	4 units	13	16
		Sound collection microphone	4 units	13	16
		Warning light	4 units	13	16
		Warning device	2 sets	13	16
		Control monitor	1 set	13	16
	CCTV equipment	Camera device	4 units	11	13
		Local device for camera	4 units	11	13
		Control unit	1 set	11	13
	Weir information system	Monitor and control unit	1 set	8	16
	Wired communication system	Optical transmission device	1 set	12	12
	Network system	Router switch	1 set	5	8

Location	Equipment	Device	Quantity	Design Life	Expected Life
CAINTA	Generating equipment	Diesel engine	2 units	20	25
	Uninterruptible power supply	Uninterruptible power supply	3 units	15	19
	Electronic equipment	Water level observation equipment (water level gage)	1 set	8	15
	Discharge warning system	Siren	1 unit	13	16
		Speaker	2 units	13	16
		Sound collection microphone	2 units	13	16
		Warning light	2 units	13	16
		Warning device	1 set	13	16
		Control monitor	1 set	13	16
	CCTV equipment	Camera device	4 units	11	13
		Control unit	1 set	11	13
	Weir information system	Monitor and control unit	1 set	8	16
	Wired communication system	Optical transmission device	1 set	12	12
	Network system	Router switch	1 set	5	8
TAYTAY	Generating equipment	Diesel engine	1 unit	20	25
	Uninterruptible power supply	Uninterruptible power supply	1 unit	15	19
	Electronic equipment	Water level observation equipment (water level gage)	1 set	8	15
	Discharge warning system	Speaker	2 units	13	16
		Sound collection microphone	2 units	13	16
		Warning light	2 units	13	16
		Warning device	1 set	13	16
		Control monitor	1 set	13	16
	CCTV equipment	Camera device	5 units	11	13
		Control unit	1 set	11	13
	Weir information system	Monitor and control unit	1 set	8	16
	Wired communication system	Optical transmission device	1 set	12	12
	Network system	Router switch	1 set	5	8
ROSARIO MASTER CONTROL STATION	Generating equipment	Diesel engine	2 units	20	25
		fuel tank	2 tanks	20	25
	Uninterruptible power supply	Uninterruptible power supply	1 unit	15	19
	DC power supply	DC power supply	2 units	15	19
	Weir information system	Monitor and control unit	1 set	8	16
	Electronic equipment	Information display device	2 units	8	10
		Large display unit (plasma display)	1 unit	8	10
		Operating terminal	2 units	8	10

Location	Equipment	Device	Quantity	Design Life	Expected Life
		Information processing device	1 set	8	10
		Printer	3 units	8	10
		GPS receiver	1 unit	8	10
	Discharge warning system	Control monitor	1 set	13	16
	Telemetry system	Telemeter monitoring device	1 set	13	16
		Antenna device	1 set	13	16
	Wired communication system	Optical transmission device	1 set	12	12
	Network system	Router switch	1 set	5	8
		NTP Server	1 unit	8	10
ANTIPOLO RELAY STATION	Power receiving and transforming equipment	Insulation transformer	1 set	20	30
	Generating equipment	Automatic switching control panel	1 set	20	25
PAGASA (SCIENCE GARDEN) STATION	Telemetry system	Antenna device	1 set	13	16
	DC power supply	DC power supply	1 unit	15	19
NAPINDAN HCS MONITOR STATION	Telemetry system	Radio equipment	1 unit	13	16
STO NIÑO WATER LEVEL GAUGE STATION	Telemetry system	Telemeter device	1 unit	13	16

Source: Study Team

(4) Financial Plan for Maintenance

Based on the concept of (1) - (3) above, the medium- to long-term costs required for large-scale repair, replacement, and renewal of civil engineering and building structures, mechanical equipment, and electrical and telecommunication facilities were calculated. The target period is 60 years, when the renewal of the gates, which is the main equipment constituting the facilities, will be completed. Costs were calculated based on the following conditions:

- Maintenance management expenses required annually in each sector were booked at the same amount every year.
- For civil engineering and building structures, the cost for the large-scale repair shown in **Table 9.3.6**was booked in addition to longitudinal and cross-sectional surveys every five years.
- For mechanical equipment, in addition to the replacement and renewal costs shown in **Table 9.3.7**, periodic maintenance costs were recorded as necessary. The indication for the periodic maintenance is around half of the standard number of years.
- For electrical and telecommunication facilities, in addition to the renewal costs shown in **Table 9.3.8**, periodic maintenance costs were recorded as necessary. The guideline for the periodic maintenance is when the "intermediate maintenance" indicated in the Standards for Inspection of Electrical and Telecommunication Equipment (Japan Water Agency) is recommended.

The medium- to long-term maintenance financial plan for the facilities to be developed in the Phase IV project is shown in **Table 9.3.9**.

Table 9.3.9 Medium- and Long-term Financial Plan for Maintenance

[Financial Plan for Maintenance] Black letters: Inspection, Maintenance ([ ] shows the number of years since the new establishment or the last renewal.)

Blue letters: Large-scale repair, Replacement, Renewal

Unit: Thousand Pesos

Fiscal Year	2026		2027		2028		2029		2030	
Elapsed Years	1		2		3		4		5	
Civil Engineering and Building Structures	(Not accounted)		Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
	※Due to defect warranty period								River Surveying	500
	Subtotal	**0**	**Subtotal**	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,500**
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	Subtotal	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	Subtotal	**1,000**	**Subtotal**	**1,000**	**Subtotal**	**1,000**	**Subtotal**	**1,000**	**Subtotal**	**1,000**
Total Amount (thousand pesos)	**Total**	**3,000**	**Total**	**6,000**	**Total**	**6,000**	**Total**	**6,000**	**Total**	**6,500**
Total Amount (thousand yen)	**Total**	**6,240**	**Total**	**12,480**	**Total**	**12,480**	**Total**	**12,480**	**Total**	**13,520**

Fiscal Year	2031		2032		2033		2034		2035	
Elapsed Years	6		7		8		9		10	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
									River Surveying	500
	Subtotal	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,500**
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	Subtotal	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
			[7]Periodic Maint. of CCTV syst.	7,940	[8]Periodic Maint. of Weir Info. syst.	16,360	[9]Periodic Maint. of UPS	2,660	[10]Renewal of Info. processing device	7,500
							[9]Periodic Maint. of Water level obs. eqpt.	3,880	[10]Periodic Maint. of DC power supply	1,500
							[9]Periodic Maint. of Telemetry syst.	7,240	[10]Periodic Maint. of Discharge warning syst.	9,340
	Subtotal	**1,000**	**Subtotal**	**8,940**	**Subtotal**	**17,360**	**Subtotal**	**14,780**	**Subtotal**	**19,340**
Total Amount (thousand pesos)	**Total**	**6,000**	**Total**	**13,940**	**Total**	**22,360**	**Total**	**19,780**	**Total**	**24,840**
Total Amount (thousand yen)	**Total**	**12,480**	**Total**	**28,995**	**Total**	**46,509**	**Total**	**41,142**	**Total**	**51,667**

Fiscal Year	2036		2037		2038		2039		2040	
Elapsed Years	11		12		13		14		15	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
	[11]Painting of Staircase, louvers, etc. (MCGS)	3,700	[12]Painting of Staircase, louvers, etc. (Cainta)	2,200	[13]Painting of Access bridge, etc.(Taytay)	1,100			River Surveying	500
	[11]Waterproofing on Generator bldg.roof(MCGS)	200	[12]Waterproofing on Generator bldg.roof(Cainta)	200						
	Subtotal	**6,900**	**Subtotal**	**5,400**	**Subtotal**	**4,100**	**Subtotal**	**3,000**	**Subtotal**	**3,500**
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	Subtotal	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**	**Subtotal**	**2,000**
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
			[12]Renewal of Optical transmission device	7,400	[13]Renewal of CCTV syst.	39,700	[14]Renewal of Weir Info. syst.	81,800	[15]Renewal of Water level obs. eqpt.	19,400
			[12]Periodic Maint. of Generating eqpt.(All)	11,040						
	Subtotal	**1,000**	**Subtotal**	**19,440**	**Subtotal**	**40,700**	**Subtotal**	**82,800**	**Subtotal**	**20,400**
Total Amount (thousand pesos)	**Total**	**9,900**	**Total**	**26,840**	**Total**	**46,800**	**Total**	**87,800**	**Total**	**25,900**
Total Amount (thousand yen)	**Total**	**20,592**	**Total**	**55,827**	**Total**	**97,344**	**Total**	**182,624**	**Total**	**53,872**

Fiscal Year	2041		2042		2043		2044		2045	
Elapsed Years	16		17		18		19		20	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
									River Surveying	500
	Subtotal	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,000**	**Subtotal**	**3,500**
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	[16]Periodic Maint. of Hoist(MCGS-Wider)	21,780	[17]Periodic Maint. of Hoist(Cainta)	15,800	[18]Periodic Maint. of Hoist (MCGS-Narrower,Taytay)	7,980	[19]Replacement of Water-tight rubber(MCGS-Wider)	2,400	[20]Replacement of Watertight rubber (Cainta)	2,300
							[19]Periodic Maint. of Gate leaf(MCGS-Wider)	199,000	[20]Periodic Maint. of Gate leaf(Cainta)	51,000
	Subtotal	**23,780**	**Subtotal**	**17,800**	**Subtotal**	**9,980**	**Subtotal**	**203,400**	**Subtotal**	**55,300**
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	[16]Renewal of Telemetry syst.	36,200	[17]Renewal of Discharge warning syst.	46,700	[18]Renewal of UPS	13,300	[19]Renewal of DC power supply	7,500	[10]Renewal of Info. processing device	7,500
									[7]Periodic Maint. of CCTV syst.	7,940
	Subtotal	**37,200**	**Subtotal**	**47,700**	**Subtotal**	**14,300**	**Subtotal**	**8,500**	**Subtotal**	**16,440**
Total Amount (thousand pesos)	**Total**	**63,980**	**Total**	**68,500**	**Total**	**27,280**	**Total**	**214,900**	**Total**	**75,240**
Total Amount (thousand yen)	**Total**	**133,078**	**Total**	**142,480**	**Total**	**56,742**	**Total**	**446,992**	**Total**	**156,499**

Fiscal Year	2046		2047		2048		2049		2050	
Elapsed Years	21		22		23		24		25	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
					[23]Painting of Staircase, louvers, etc. (MCGS)	3,700	[24]Painting of Staircase, louvers, etc. (Cainta)	2,200	River Surveying	500
					[12]Waterproofing on Generator bldg.roof(MCGS)	200	[12]Waterproofing on Generator bldg.roof(Cainta)	200	[25]Painting of Access bridge, etc.(Taytay)	1,100
	Subtotal	3,000	Subtotal	3,000	Subtotal	6,900	Subtotal	5,400	Subtotal	4,600
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	[21]Replacement of Watertight rubber(MCGS-Nrwer, Taytay)	3,800								
	[21]Periodic Maint. of Gate leaf (MCGS-Narrower, Taytay)	39,400								
	Subtotal	45,200	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
			[8]Periodic Maint. of Weir Info. syst.	16,360	[23]Renewal of Generating eqpt. (Rosario)	6,000	[24]Renewal of Generating eqpt.(MCGS)	30,000	[25]Renewal of Generating eqpt.(Cainta, Taytay)	19,200
					[8]Periodic Maint. of Water level obs. eqpt.	3,880	[12]Renewal of Optical transmission device	7,400	[9]Periodic Maint. of Telemetry syst.	7,240
	Subtotal	1,000	Subtotal	17,360	Subtotal	10,880	Subtotal	38,400	Subtotal	27,440
Total Amount (thousand pesos)	**Total**	**49,200**	**Total**	**22,360**	**Total**	**19,780**	**Total**	**45,800**	**Total**	**34,040**
Total Amount (thousand yen)	**Total**	**102,336**	**Total**	**46,509**	**Total**	**41,142**	**Total**	**95,264**	**Total**	**70,803**

Fiscal Year	2051		2052		2053		2054		2055	
Elapsed Years	26		27		28		29		30	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
									River Surveying	500
	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,500
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	[13]Renewal of CCTV syst.	39,700	[9]Periodic Maint. of UPS	2,660	[9]Periodic Maint. of DC power supply	1,500	[15]Renewal of Weir Info. syst.	81,800	[15]Renewal of Water level obs. eqpt.	19,400
			[10]Periodic Maint. of Discharge warning syst.	9,340					[10]Renewal of Info. processing device	7,500
	Subtotal	40,700	Subtotal	13,000	Subtotal	2,500	Subtotal	82,800	Subtotal	27,900
Total Amount (thousand pesos)	**Total**	**45,700**	**Total**	**18,000**	**Total**	**7,500**	**Total**	**87,800**	**Total**	**33,400**
Total Amount (thousand yen)	**Total**	**95,056**	**Total**	**37,440**	**Total**	**15,600**	**Total**	**182,624**	**Total**	**69,472**

Fiscal Year	2056		2057		2058		2059		2060	
Elapsed Years	31		32		33		34		35	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
									River Surveying	500
	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,500
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
			[32]Replacement of wire rope(MCGS-Wider)	8,100	[33]Replacement of wire rope(Cainta)	3,900	[34]Renewal of Hoist (Taytay)	5,700	[35]Replacement of wire rope(MCGS-Narrower)	2,000
			[32]Replacement of Local control panel(MCGS-Wider)	5,700	[33]Replacement of Local control panel(Cainta)	8,400			[35]Replacement of Local control panel(MCGS-Narrower)	4,200
			[16]Periodic Maint. of Hoist(MCGS-Wider)	21,780	[16]Periodic Maint. of Hoist(Cainta)	15,800			[17]Periodic Maint. of Hoist(MCGS-Narrower)	6,840
	Subtotal	2,000	Subtotal	37,580	Subtotal	30,100	Subtotal	7,700	Subtotal	15,040
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	[15]Renewal of Telemetry syst.	36,200			[7]Periodic Maint. of CCTV syst.	7,940	[17]Renewal of Discharge warning syst.	46,700		
	Subtotal	37,200	Subtotal	1,000	Subtotal	8,940	Subtotal	47,700	Subtotal	1,000
Total Amount (thousand pesos)	**Total**	**42,200**	**Total**	**41,580**	**Total**	**42,040**	**Total**	**58,400**	**Total**	**19,540**
Total Amount (thousand yen)	**Total**	**87,776**	**Total**	**86,486**	**Total**	**87,443**	**Total**	**121,472**	**Total**	**40,643**

Fiscal Year	2061		2062		2063		2064		2065	
Elapsed Years	36		37		38		39		40	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
	[36]Replacement of Roof sheet, staircase, etc.(MCGS)	50,000	[37]Replacement of Roof sheet, staircase, etc.(Cainta)	35,700	[38]Replacement of Roof sheet, access bridge, etc.(Taytay)	4,100			River Surveying	500
	[13]Waterproofing on Generator bldg.roof(MCGS)	200	[13]Waterproofing on Generator bldg.roof(Cainta)	200						
	Subtotal	53,200	Subtotal	38,900	Subtotal	7,100	Subtotal	3,000	Subtotal	3,500
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
					[19]Replacement of Water-tight rubber(MCGS-Wider)	2,400	[19]Replacement of Watertight rubber(Cainta)	2,300	[19]Replacement of Water-tight rubber(MCGS-Nrwer、Taytay)	3,800
					[19]Periodic Maint. of Gate leaf(MCGS-Wider)	199,000	[19]Periodic Maint. of Gate leaf(Cainta)	51,000	[19]Periodic Maint. of Gate leaf (MCGS-Narrower、Taytay)	39,400
	Subtotal	2,000	Subtotal	2,000	Subtotal	203,400	Subtotal	55,300	Subtotal	45,200
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	[18]Renewal of UPS	13,300	[18]Renewal of DC power supply	7,500	[13-15]Periodic Maint. of Generating eqpt.(All)	11,040	[13]Renewal of CCTV syst.	39,700	[10]Renewal of Info. processing device	7,500
	[12]Renewal of Optical transmission device	7,400	[8]Periodic Maint. of Weir Info. syst.	16,360	[8]Periodic Maint. of Water level obs. eqpt.	3,880			[9]Periodic Maint. of Telemetry syst.	7,240
	Subtotal	21,700	Subtotal	24,860	Subtotal	15,920	Subtotal	40,700	Subtotal	15,740
Total Amount (thousand pesos)	**Total**	**76,900**	**Total**	**65,760**	**Total**	**226,420**	**Total**	**99,000**	**Total**	**64,440**
Total Amount (thousand yen)	**Total**	**159,952**	**Total**	**136,781**	**Total**	**470,954**	**Total**	**205,920**	**Total**	**134,035**

Fiscal Year	2066		2067		2068		2069		2070	
Elapsed Years	41		42		43		44		45	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
									River Surveying	500
									[45]Large-scale repair of Revetment(CP1 zone)	274,000
	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	277,500
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	[41]Replacement of Electric motor(MCGS-Wider)	2,100	[42]Replacement of Electric motor(Cainta)	800	[43]Replacement of Electric motor(MCGS-Narrower)	800				
	[41]Replacement of Limiting switch/Gate opening meter (MCGS-Wider)	1,400	[42]Replacement of Limiting switch/Gate opening meter(Cainta)	800	[43]Replacement of Limiting switch/Gate opening meter (MCGS-Narrower)	800				
	Subtotal	5,500	Subtotal	3,600	Subtotal	3,600	Subtotal	2,000	Subtotal	2,000
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
					[9]Periodic Maint. of Discharge warning syst.	9,340	[15]Renewal of Weir Info. syst.	81,800	[15]Renewal of Water level obs. eqpt.	19,400
									[9]Periodic Maint. of UPS	2,660
	Subtotal	1,000	Subtotal	1,000	Subtotal	10,340	Subtotal	82,800	Subtotal	23,060
Total Amount (thousand pesos)	Total	9,500	Total	7,600	Total	16,940	Total	87,800	Total	302,560
Total Amount (thousand yen)	Total	19,760	Total	15,808	Total	35,235	Total	182,624	Total	629,325

Fiscal Year	2071		2072		2073		2074		2075	
Elapsed Years	46		47		48		49		50	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
	[46]Large-scale repair of Revetment(CP2 zone-1)	343,000	[47]Large-scale repair of Revetment(CP2 zone-2)	343,000	[48]Large-scale repair of Revetment(CP3 zone-1)	279,000	[49]Large-scale repair of Revetment(CP3 zone-2)	279,000	River Surveying	500
					[12]Painting of Staircase, louvers, etc. (MCGS)	3,700	[12]Painting of Staircase, louvers, etc. (Cainta)	2,200	[50]Large-scale repair of Revetment(CP3 zone-3)	279,000
					[12]Waterproofing on Generator bldg. roof(MCGS)	200	[12]Waterproofing on Generator bldg. roof(Cainta)	200	[12]Painting of Access bridge, etc.(Taytay)	1,100
	Subtotal	346,000	Subtotal	346,000	Subtotal	285,900	Subtotal	284,400	Subtotal	283,600
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000	Subtotal	2,000
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	[9]Periodic Maint. of DC power supply	1,500	[16]Renewal of Telemetry syst.	36,200	[25]Renewal of Generating eqpt. (Rosario)	6,000	[25]Renewal of Generating eqpt.(MCGS)	30,000	[25]Renewal of Generating eqpt.(Cainta, Taytay)	19,200
	[7]Periodic Maint. of CCTV syst.	7,940			[12]Renewal of Optical transmission device	7,400			[10]Renewal of Info. processing device	7,500
	Subtotal	10,440	Subtotal	37,200	Subtotal	14,400	Subtotal	31,000	Subtotal	27,700
Total Amount (thousand pesos)	Total	358,440	Total	385,200	Total	302,300	Total	317,400	Total	313,300
Total Amount (thousand yen)	Total	745,555	Total	801,216	Total	628,784	Total	660,192	Total	651,664

Fiscal Year	2076		2077		2078		2079		2080	
Elapsed Years	51		52		53		54		55	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
									River Surveying	500
	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,500
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
			[18]Periodic Maint. of Hoist(Taytay)	1,140	[53]Renewal of Hoist (MCGS-Wider)	108,900	[54]Renewal of Hoist (Cainta)	79,000	[55]Renewal of Hoist (MCGS-Narrower)	34,200
	Subtotal	2,000	Subtotal	3,140	Subtotal	110,900	Subtotal	81,000	Subtotal	36,200
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	[17]Renewal of Discharge warning syst.	46,700	[13]Renewal of CCTV syst.	39,700	[9]Periodic Maint. of Weir Info. syst.	16,360	[9]Periodic Maint. of Water level obs. eqpt.	3,880	[19]Renewal of UPS	13,300
	Subtotal	47,700	Subtotal	40,700	Subtotal	17,360	Subtotal	4,880	Subtotal	14,300
Total Amount (thousand pesos)	**Total**	**52,700**	**Total**	**46,840**	**Total**	**131,260**	**Total**	**88,880**	**Total**	**54,000**
Total Amount (thousand yen)	**Total**	**109,616**	**Total**	**97,427**	**Total**	**273,021**	**Total**	**184,870**	**Total**	**112,320**

Fiscal Year	2081		2082		2083		2084		2085	
Elapsed Years	56		57		58		59		60	
Civil Engineering and Building Structures	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000	Structure Repair/Dredging	3,000
									River Surveying	500
	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,000	Subtotal	3,500
Mechanical Equipment	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000	Refueling & Greasing, Simple adjustment	2,000
			[58]Renewal of Gate leaf (MCGS-Wider)(1)	497,500	[58]Renewal of Gate leaf (MCGS-Wider)(2)	497,500	[59]Renewal of Gate leaf (Cainta)	255,000	[60]Renewal of Gate leaf (MCGS-Narrower,Taytay)	197,000
	Subtotal	2,000	Subtotal	499,500	Subtotal	499,500	Subtotal	257,000	Subtotal	199,000
Electrical and Telecommunication Facilities	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000	Simple adjustment, Replacement of parts	1,000
	[19]Renewal of DC power supply	7,500			[6]Periodic Maint. of CCTV syst.	7,940	[15]Renewal of Weir Info. syst.	81,800	[15]Renewal of Water level obs. eqpt.	19,400
	[9]Periodic Maint. of Telemetry syst.	7,240					[8]Periodic Maint. of Discharge warning syst.	9,340	[12]Renewal of Optical transmission device	7,400
									[10]Renewal of Info. processing device	7,500
	Subtotal	15,740	Subtotal	1,000	Subtotal	8,940	Subtotal	92,140	Subtotal	35,300
Total Amount (thousand pesos)	**Total**	**20,740**	**Total**	**503,500**	**Total**	**511,440**	**Total**	**352,140**	**Total**	**237,800**
Total Amount (thousand yen)	**Total**	**43,139**	**Total**	**#######**	**Total**	**#######**	**Total**	**732,451**	**Total**	**494,624**

Source: Study Team

9.3.2.4 Maintenance Record

(1) Basic Policy

In order to steadily carry out the maintenance management of facilities, such as the state grasp, analysis and evaluation, and repair and renewal, it is necessary to firstly ensure the preparation and renewal of river ledgers, which are the basic information of the facilities, and at the same time to accurately grasp and record various information concerning the maintenance management of the facilities, such as the inspection results and the evaluation results of soundness, as well as to consolidate important information and advance the creation of a database.

(2) At the time of Completion

The person responsible for the DPWH-UPMO, which will carry out this project, shall organize the records and documents regarding the design, manufacture, and construction of each facility and equipment necessary for flood control and maintenance before the start of service of this facility, and shall prepare the completed and maintenance documents, etc. The project manager will surely hand them over to the person responsible for the management of the MCGS and the two backflow prevention floodgates.

(3) After Starting Management

The person responsible for the management of the MCGS and the two backflow prevention floodgates shall prepare, preserve and manage a management book consisting of a facility ledger and a maintenance ledger in order to implement systematic and efficient maintenance.

The equipment ledger shall contain the installation year and main specifications of the facilities, and the maintenance ledger shall contain the history of patrol, inspection, maintenance, and renewal carried out at the equipment, accidents and failures, and the history of taken measures. The items described in the maintenance ledger are important information for the subsequent maintenance management and should be properly organized and stored.

9.3.3 Organizational Management Structures

9.3.3.1 Organizations for Project Implementation and Maintenance

The implementing agency of this project and the manager for each structure are as shown in **Table 9.3.10**.

Table 9.3.10 Proposed Organizations for Project Implementation and Maintenance

Structures	Detailed Design (2019) up to Completion (2026)	Two years after completion (until 2028)	Management Phase (after 2029)
Rosario Weir	MMDA-FCSMO		
NHCS	MMDA-FCSMO		
MCGS	DPWH-UPMO-FCMC	DPWH-UPMO-FCMC	MMDA-FCSMO
Floodgates	DPWH-UPMO-FCMC	DPWH-UPMO-FCMC	DPWH-Region IV-A
Dikes and Revetments	DPWH-UPMO-FCMC	DPWH-UPMO-FCMC	MMDA-FCSMO

Source: Study Team

The DPWH-UPMO will manage the project. Two years after the completion of construction, the organization for O&M will be transferred to MMDA, except for the two floodgates not located in Metro Manila.

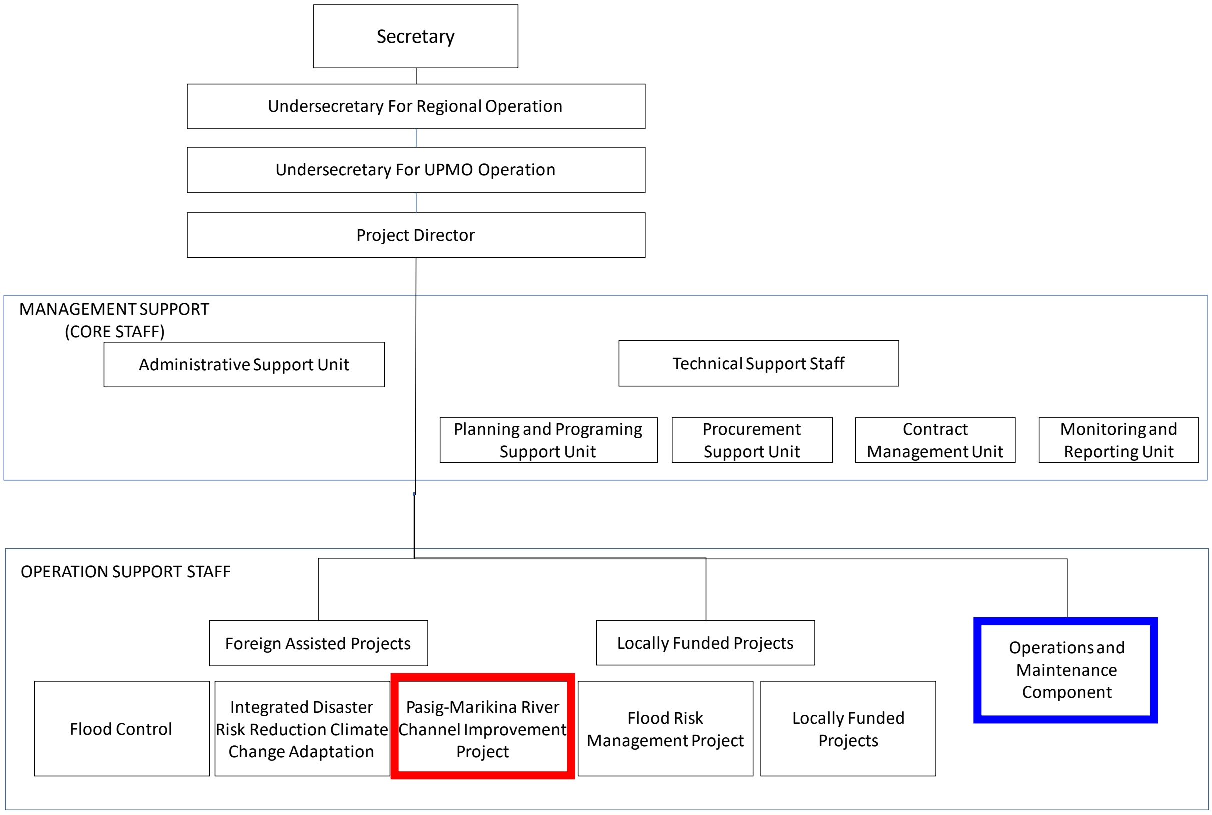
However, with regard to the two floodgates, it is desirable that MMDA will integrally manage (especially operate) them together with the other facilities to be developed in this project. In consultation with the Study Team, MMDA indicated that they would be able to manage if the staff and budget could be secured. DPWH will bear the cost and entrust their management to the MMDA (EFCOS Office) and will coordinate the details before the actual management starts.

9.3.3.2 Current Status of Organizational Structures for Flood Mitigation

This section provides basic information on the organizations associated with the MCGS, the two backflow prevention floodgates, and river channel improvement facilities to be constructed under this project.

(1) DPWH

The DPWH-UPMO-FCMC will carry out this project and manage the facilities for two years after the completion of construction. Its organizational structure is shown in **Figure 9.3.1**, and it consists of about 70 engineers as a whole.



Source: DPWH

Figure 9.3.1 Organizational Chart of DPWH-UPMO-FCMC

The section enclosed in red will be responsible for project implementation, and the section enclosed in blue will be responsible for management.

The management of the two backflow prevention floodgates will be transferred to DPWH Region IV-A two years after the completion of construction. As mentioned in the previous section, however, the actual management will be coordinated in the direction of entrusting to MMDA.

(2) MMDA

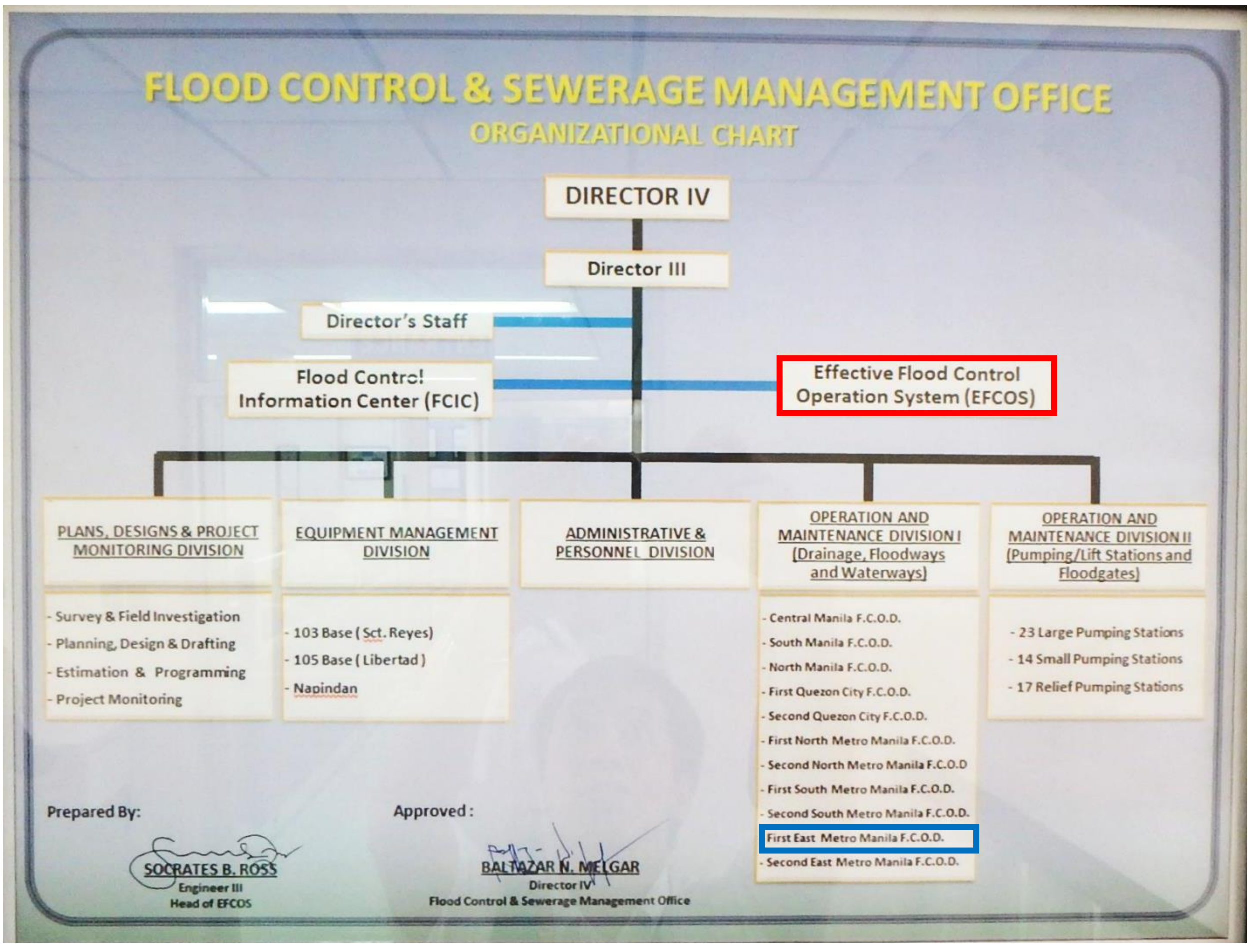
The section of MMDA related to this project is FCSMO (Flood Control and Sewerage Management Office). FCSMO implements flood mitigation and drainage measures divided into several areas.

1) Organizational Structure of FCSMO

The organizational chart of FCSMO is shown in **Figure 9.3.2**.

The operation and maintenance of NHCS and Rosario Weir, and the maintenance of EFCOS itself are conducted by the EFCOS Office, an organization in the FCSMO. The EFCOS Office was originally in DPWH, but it was transferred to MMDA in 2002, including the personnel belonging to it.

In addition to the river channels, dikes and revetments which are the target of this project, the management of drainage channels in the basin is to be implemented by the **First East Metro Manila Flood Control Operation District (FEMMFCOD)** in the FCSMO. The FEMMFCOD has jurisdiction over the main stream of Marikina River from the junction with the Nangka River(the border between Metro Manila and Rizal Province), which is a tributary, to the junction with the Napindan Channel(starting point of the Pasig River).The jurisdiction crosses Marikina City and Pasig City as the LGUs.



Source: MMDA

Figure 9.3.2 Organizational Chart of MMDA-FCSMO

The section enclosed in red will be responsible for the operation and maintenance of MCGS, NHCS and Rosario Weir, and section enclosed in blue will be responsible for the maintenance management of dikes and revetment.

2) Annual Budget for FCSMO

The annual budget for FCSMO in fiscal year 2019 is shown in **Table 9.3.11**.

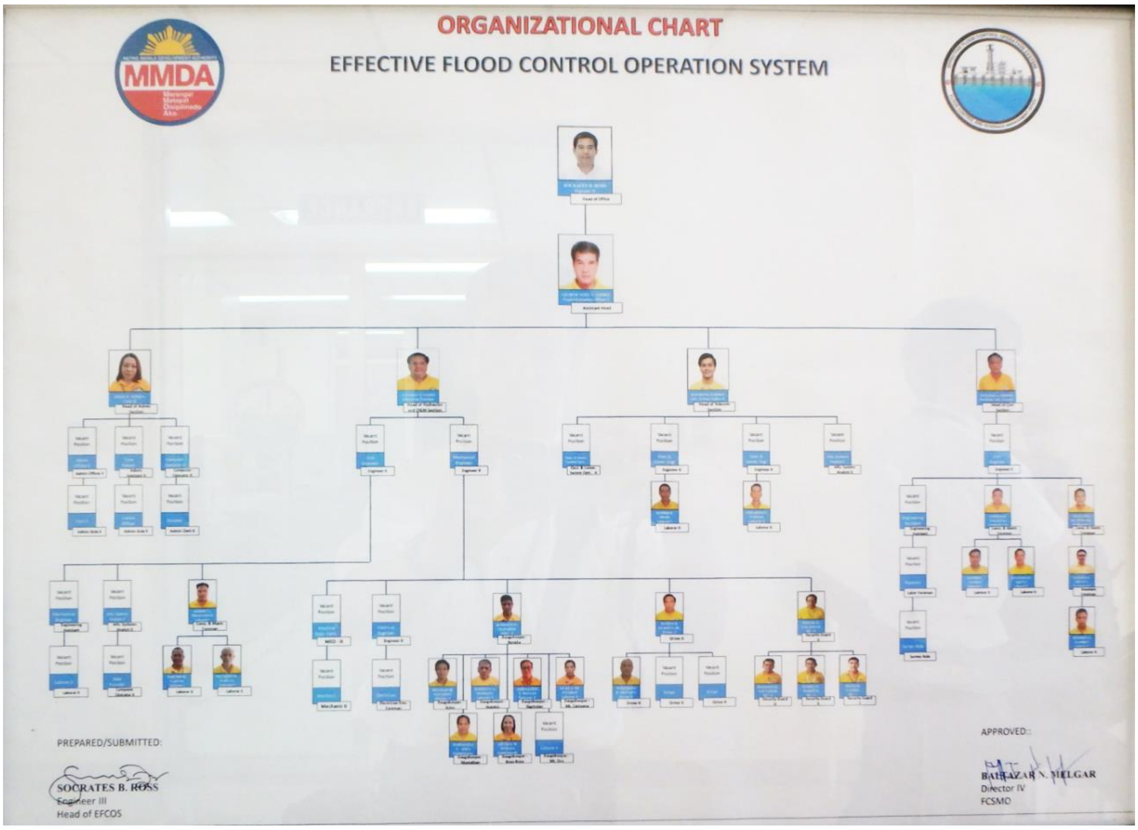
Table 9.3.11 Annual Budget for MMDA-FCSMO (Fiscal Year 2019)

Category	Covered Range	Budget	
Maintenance and Other Operating Expenses	Metro Manila	PHP288,559,000	JPY600,202,720
Capital Outlays (rehabilitation, dredging, etc.)	Metro Manila	PHP1,477,436,000	JPY3,073,066,880
	First East Metro Manila Flood Control Operation District	PHP103,635,000	JPY215,560,800

Source: MMDA; Yen equivalent was calculated by the JICA Study Team

3) Personnel and Machinery of EFCOS

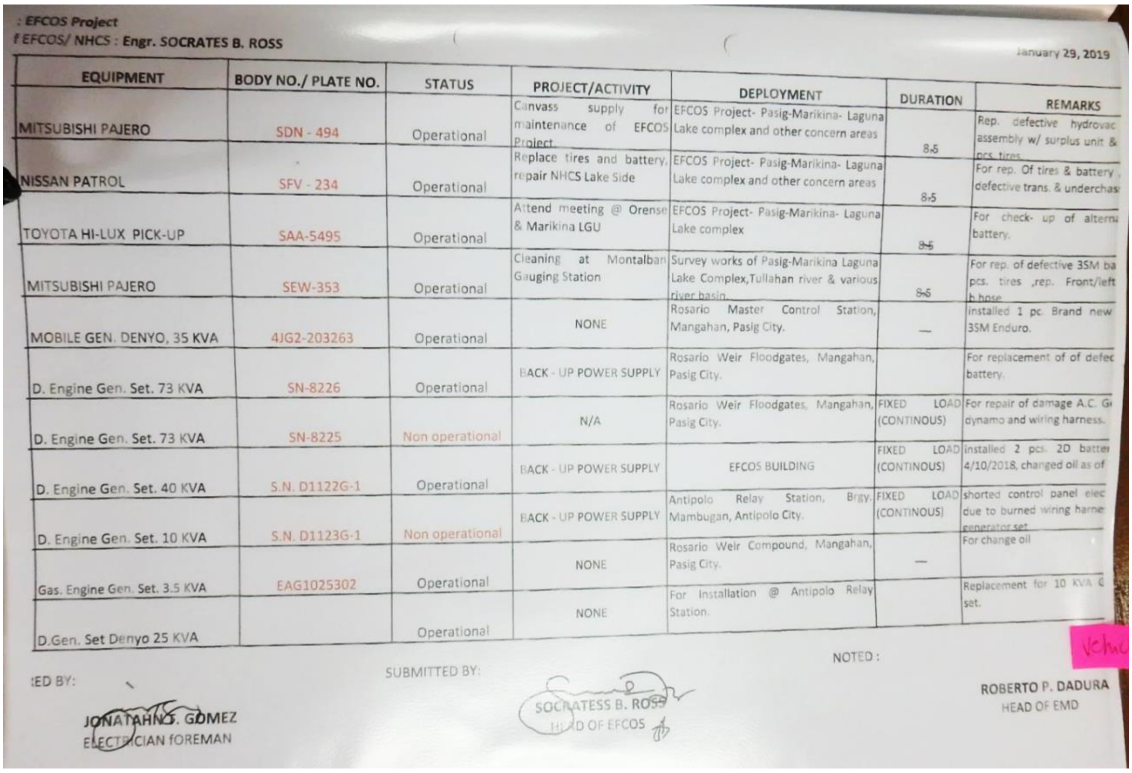
The organizational chart of the EFCOS Office currently operating and maintaining the EFCOS itself, the NHCS and the Rosario Weir is shown in **Figure 9.3.3**. Although the total number of personnel is about 30, more personnel will be needed, judging from the large number of posts described as "Vacant Position" in the chart.



Source: MMDA-EFCOS Office

Figure 9.3.3 Organizational Chart of MMDA-FCSMO-EFCOS

Machinery owned by the EFCOS Office is shown in **Figure 9.3.4**.Three (3) passenger cars, one (1) pickup truck, and seven (7) generators have been confirmed.



: EFCOS Project
f EFCOS/ NHCS : Engr. SOCRATES B. ROSS

January 29, 2019

EQUIPMENT	BODY NO./ PLATE NO.	STATUS	PROJECT/ACTIVITY	DEPLOYMENT	DURATION	REMARKS
MITSUBISHI PAJERO	SDN - 494	Operational	Canvass supply for maintenance of EFCOS Project	EFCOS Project- Pasig-Marikina- Laguna Lake complex and other concern areas	8-5	Rep. defective hydrovac assembly w/ surplus unit & pcs. tires
NISSAN PATROL	SFV - 234	Operational	Replace tires and battery, repair NHCS Lake Side	EFCOS Project- Pasig-Marikina- Laguna Lake complex and other concern areas	8-5	For rep. Of tires & battery, defective trans. & underchas
TOYOTA HI-LUX PICK-UP	SAA-5495	Operational	Attend meeting @ Orense & Marikina LGU	EFCOS Project- Pasig-Marikina- Laguna Lake complex	8-5	For check- up of altern battery.
MITSUBISHI PAJERO	SEW-353	Operational	Cleaning at Montalban Gauging Station	Survey works of Pasig-Marikina Laguna Lake Complex,Tullahan river & various river basin.	8-5	For rep. of defective 3SM ba pcs. tires ,rep. Front/left b hose
MOBILE GEN. DENYO, 35 KVA	4JG2-203263	Operational	NONE	Rosario Master Control Station, Mangahan, Pasig City.	—	installed 1 pc. Brand new 3SM Enduro.
D. Engine Gen. Set. 73 KVA	SN-8226	Operational	BACK - UP POWER SUPPLY	Rosario Weir Floodgates, Mangahan, Pasig City.		For replacement of of defec battery.
D. Engine Gen. Set. 73 KVA	SN-8225	Non operational	N/A	Rosario Weir Floodgates, Mangahan, Pasig City.	FIXED LOAD (CONTINOUS)	For repair of damage A.C. G dynamo and wiring harness.
D. Engine Gen. Set. 40 KVA	S.N. D1122G-1	Operational	BACK - UP POWER SUPPLY	EFCOS BUILDING	FIXED LOAD (CONTINOUS)	installed 2 pcs. 2D batter 4/10/2018, changed oil as of
D. Engine Gen. Set. 10 KVA	S.N. D1123G-1	Non operational	BACK - UP POWER SUPPLY	Antipolo Relay Station, Brgy. Mambugan, Antipolo City.	FIXED LOAD (CONTINOUS)	shorted control panel elec due to burned wiring harne generator set
Gas. Engine Gen. Set. 3.5 KVA	EAG1025302	Operational	NONE	Rosario Weir Compound, Mangahan, Pasig City.	—	For change oil
D.Gen. Set Denyo 25 KVA		Operational	NONE	For Installation @ Antipolo Relay Station.		Replacement for 10 KVA G set.

ED BY: JONATHAN S. GOMEZ
ELECTRICIAN FOREMAN

SUBMITTED BY: SOCRATES B. ROSS
HEAD OF EFCOS

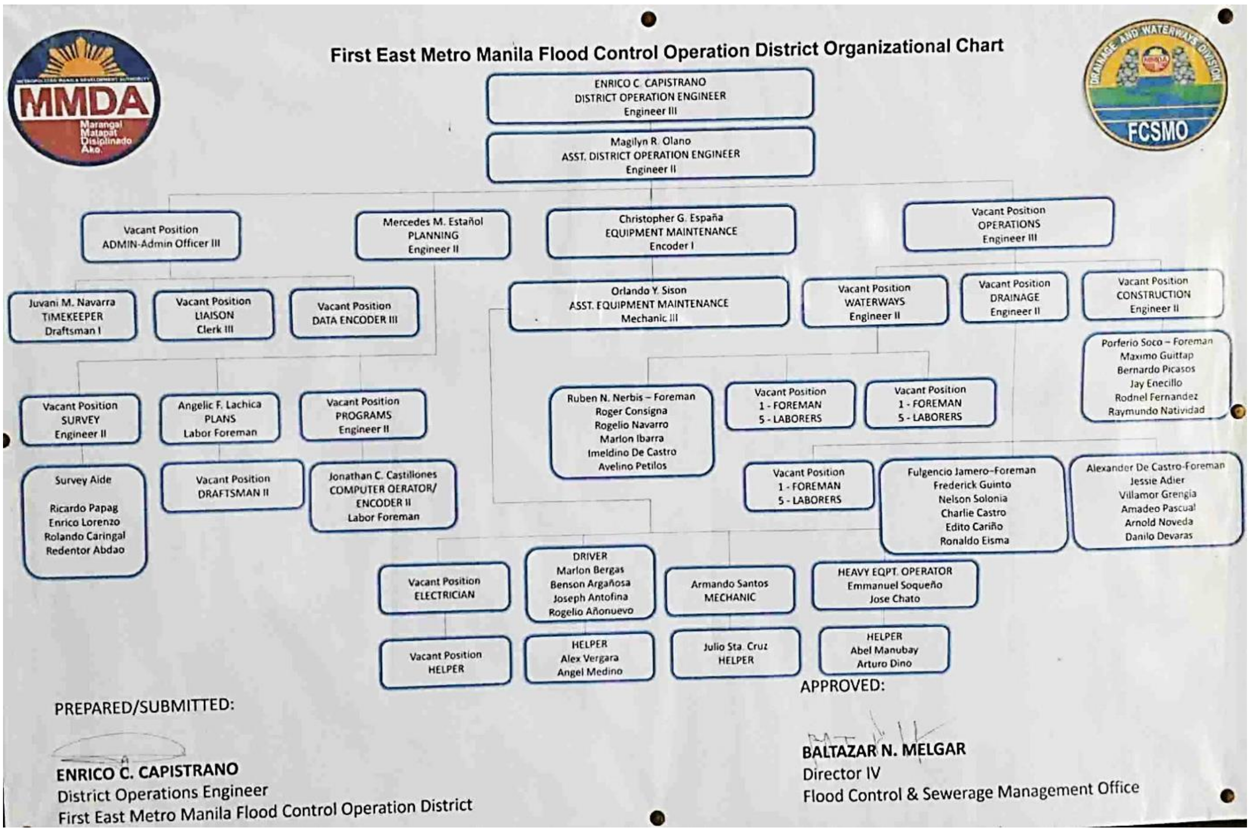
NOTED : ROBERTO P. DADURA
HEAD OF EMD

Source: MMDA-EFCOS Office

Figure 9.3.4 Machinery owned by MMDA-FCSMO-EFCOS

4) Personnel and Machinery of First East Metro Manila Flood Control Operation District

The organizational chart of the First East Metro Manila Flood Control Operation District in the FCSMO, which is carrying out maintenance management of drainage channels and rivers in Marikina City and Pasig City, is shown in **Figure 9.3.5**. Although the total number of employees is about 50, more personnel will be needed, judging from the large number of posts described as "Vacant Position" in the chart.



Source: MMDA

Figure 9.3.5 Organizational Chart of MMDA-FCSMO-First East Metro Manila Flood Control Operation District

Machinery owned by the First East Metro Manila Flood Control Operation District is shown in **Figure 9.3.6**. One (1) pickup truck, one (1) dump truck, one (1) dredging machine, and two (2) drainage pumps have been confirmed.

Republic of the Philippines
Office of the President
METROPOLITAN MANILA DEVELOPMENT AUTHORITY
FLOOD CONTROL & SEWERAGE MANAGEMENT OFFICE
EQUIPMENT MANAGEMENT DIVISION
EQUIPMENT DAILY UTILIZATION REPORT
As of: June 3, 2019

FCSMO-FEMM-EDUR-2019-6-3

OFFICE	UNIT	EQUIPMENT	BODY NO. / PLATE NO.	PROJECT/ACTIVITY	DEPLOYMENT	DURATION	REMARKS
FCSMO	District First East Metro Manila FCOD	KIA DOUBLE CAB	FE-SV-O7/SGZ-221	Inspection & Project Monitoring service	Pasig, Marikina & other concern area's	1 week	> Defective body/cab & upholstery
		2 TONNER DUMPTRUCK	SDG-630	Hauling & Crew service	Pasig, Marikina & other concern area's	1 week	
		3 TONNER DUMPTRUCK	FE-3DT-O2/SEB-815				> Defective Engine, body/cab & upholstery
		3 TONNER DUMPTRUCK	SEB-947	Hauling & Crew service	Pasig, Marikina & other concern area's	1 week	> Defective body/cab, upholstery & Electrical Wiring
		AMPHIBIOUS EXCAVATOR	FE-AE-01	Dredging	Estero De San Antonio Abad, Manila	1 week	
		WATERPUMP (ROBIN 5.0)	1167754	Standby	FEMMFCOD		
		FLOATING PUMP (HONDA 3.0)	GJAAT-1024013	Standby	FEMMFCOD		

CHRISTOPHER G. ESPAÑA
DISPATCHER

ENGR. ENRICO C. CAPISTRANO
D.O.E. FEMMFCOD

Source: MMDA

Figure 9.3.6 Machinery Owned by MMDA-FCSMO- First East Metro Manila Flood Control Operation District

9.3.3.3 Expansion of Organizational Management Structure

(1) DPWH

With regard to DPWH Region IV-A, which will possess the two floodgates for the prevention of backflow and constructed in this project, a necessary system for the procedures shall be ensured so that the management entrusting to MMDA can proceed smoothly.

(2) MMDA

1) EFCOS Office

To properly operate and maintain the facilities such as the MCGS to be newly constructed in this project, the existing Rosario Weir and NHCS, and the two backflow prevention floodgates which will be entrusted with management from DPWH in cooperation with each other, it is proposed that the operation and maintenance structure of the EFCOS Office of MMDA will be expanded as shown in **Table 9.3.12**.

In addition, taking into consideration the current system where MMDA has not received a large budget, it is assumed that if large-scale repair is required in each facility in the future, support from the DPWH, a national organization, will also be required.

Table 9.3.12 New Personnel required for MMDA-FCSMO-EFCOS (Clerical and Technical positions)

Designation	Common Works	Works Specific to Each Designation		Current Staff	Additional Staff
		Mainly in the Rainy Season	Mainly in the Dry Season		
Clerk	Operation, patrol and inspection, simple maintenance (structure)	Budget request and expenditure including Rosario Weir and NHCS		1	2
Civil Engineer		Hydrological analysis and records, Public relations	Maintenance Works (dredging, repair of the structures)	2	2
Architectural Engineer		Record of operation, Public relations	Maintenance Works (buildings and equipment)	1	2
Mechanical Engineer	Operation, inspection, simple maintenance (equipment)	Troubleshooting (mainly gates)	Maintenance Works (gate equipment)	1	3
Electrical Engineer		Troubleshooting (mainly electrical/observation)	Maintenance Works (electrical and observation equipment)	2	2
Telecom Engineer		Troubleshooting (mainly telecom)	Maintenance Works (telecom equipment)	1	3

Current staff: The actual number of staff as of 2019
Additional staff: The number of staff to be added to the actual number as of 2019
Source: Study Team

Although **Table 9.3.12** includes neither Head / Deputy Head of EFCOS nor gauge keepers of each observing station, drivers, workers, etc., the number of these personnel shall be increased and machinery shall be replenished as necessary. In addition, since only security guards are currently stationed at NHCS, it is recommended that all security guards be replaced with the above-mentioned engineers and that a proper maintenance system be in place. The concept of the number of personnel including the improvement from the current situation is as follows:

(a) Clerk

MCGS and two backflow prevention floodgates are newly constructed by the Phase IV project. In order to promote efficient and effective maintenance, the maintenance budget required every year must be accurately recorded and executed. For that purpose, the number of the clerks shall be expanded to two (2), making the system a total of three (3).

(b) Civil Engineer

Although there are only two dredgers at present, in consideration of the new increase of three concrete river crossing structures, the number of the engineers shall be increased to two (2), making the system a total of four (4). One person each will be assigned to Rosario Weir, MCGS, NHCS, and two backflow prevention floodgates.

(c) Architectural Engineer

There is only one engineer at present. However, since the new river crossing structures with a steel roof, steel stairs, etc. and the generator buildings will be developed, the number of the engineers shall be increased to two (2), making the system a total of three (3). One person each will be assigned to the EFCOS Office and Rosario Weir, MCGS and two backflow prevention floodgates, and NHCS. This shall include the maintenance of buildings such as the generator building attached to each facility.

In addition, the architectural engineers are responsible for the maintenance of accompanying equipment such as water supply and drainage system and air conditioning installed in each building, in cooperation with the mechanical engineers.

(d) Mechanical Engineer

There is only one welder at present. However, since the NHCS gate facilities are not maintained sufficiently at present, and three river crossing structures with gate facilities are to be developed, the number of the engineers who understand the mechanism shall be increased to three (3), making the system a total of four (4).One person each will be assigned to Rosario Weir, MCGS, NHCS, and two backflow prevention floodgates.

In addition, the mechanical engineers are responsible for the maintenance of the owned machinery and the accompanying equipment such as water supply and drainage system and air conditioning installed in each building, in cooperation with the architectural engineers.

(e) Electrical Engineer

Although there are two engineers at present, it is necessary to maintain the water level gauges installed upstream and downstream of the three new river crossing structures as well as the structures themselves. Therefore, the number of the engineers shall be increased to two (2), making the system a total of four (4).One person each will be assigned to EFCOS Office and Rosario Weir (Master Control Station), MCGS, NHCS, and two backflow prevention floodgates (including water level gauges upstream and downstream of each weir and floodgate, and power generation equipment).

(f) Telecommunication Engineer

Although there is only one engineer at present, it is necessary to monitor and maintain three river crossing structures from the EFCOS Office without fail. Therefore, the number of the engineers shall be increased to three (3), making the system a total of four (4).One person each will be assigned to EFCOS Office and Rosario Weir (Master Control Station), MCGS, NHCS, and two backflow prevention floodgates (including water level gauge stations upstream and downstream of each weir and floodgate).

When the Study Team coordinated the personnel system at the time of flooding with the EFCOS Office, the Office proposed to the Study Team that, although the two backflow prevention floodgates would be usually unmanned, if a flood was expected, the Office would have three personnel wait at the Cainta Floodgate in advance and engage in operations including the Taytay Sluiceway. It is assumed that the Head of the Office will appoint the three personnel from among the civil, architectural, mechanical, electrical, and telecommunication engineers who are in charge of the two backflow prevention floodgates, and they will wait on site.

Even in the management phase, it is important for the MMDA to be accountable and to continuously gain the understanding of residents by disseminating information to the public about the history of each facility and its effects. The role has been reflected in the above-mentioned system table (“Public relations” by Civil and Architectural Engineers).It is desirable for MMDA to operate efficiently by taking over the websites, etc., rehabilitated in this project as mentioned in **Section 7.1**.

2) First East Metro Manila Flood Control Operation District

Personnel and machinery need to be expanded also in the First East Metro Manila Flood Control

Operation District of MMDA to properly maintain the river improvement facilities developed in this project.

In addition to continuing to maintain the river channel with a total length of about 8 km, it is necessary to coordinate and cooperate with local LGUs to newly maintain the revetments and dikes, including steel sheet piles. It is proposed to expand the number of personnel by about three (3).

Regarding the machinery, since they do not currently have any passenger cars, it is recommended to place the cars for the purpose of conducting patrols efficiently.

9.4 Progress of Project Explanation to Related Organizations

The outline of explanatory meetings with related organizations up to the end of June 2019 is given below.

9.4.1 LGUs

The outline of explanatory meetings with the LGUs is shown in **Table 9.4.1**.

Table 9.4.1 Meetings with LGUs

Date	Venue	Meeting Agenda
April 16, 2019	Marikina City Engineering Office Marikina City River Parks Development Office	Project and survey description
April 24, 2019	Pasig City Engineering Office	Project and survey description
April 30, 2019	Pasig City Engineering Office	Outline of embankment and drainage pumping stations to be constructed by Pasig City
May 3, 2019	Quezon City Housing, Community Development and Resettlement Department	Relocation of ISFs associated with the project
May 14, 2019	Pasig City Engineering Office	Outline of embankment and drainage pumping stations to be constructed by Pasig City
July 17, 2019	Cainta Municipality	Courtesy and project description
July 18, 2019	Taytay Municipality	Courtesy and project description
Sept 10, 2019	Pasig City Engineering Office	Description and discussion on embankment design
Nov 11, 2019	Conference Room, Pasig Mayor	Project description

Source: Study Team

9.4.2 Related Organizations

9.4.2.1 MMDA

The outline of explanatory meetings with MMDA is shown in **Table 9.4.2**.

Table 9.4.2 Meetings with MMDA

Date	Venue	Meeting Agenda
March 22, 2019	EFCOS Office	Courtesy call of JICA President(dry run)
April 9, 2019	EFCOS Office	Courtesy call of JICA President
April 12, 2019	EFCOS Office NHCS MMDA Head Office	Current situation of Rosario Weir, EFCOS System, and Napindan Control Gate Metro Manila Crisis Office
April 23, 2019	Antipolo Sto. Niño PAGASA	Current situation of EFCOS System
May 16, 2019	EFCOS Office	Current situation of Rosario Weir and MCGS construction site
June 19, 2019	EFCOS Office	Description of the project, design concepts and operation & maintenance plan of MCGS, etc.
June 20, 2019	MMDA Head Office	Description of the project, design concepts and operation & maintenance plan of MCGS, etc.
Aug 15, 2019	MMDA Head Office	Description and discussion on design policy of local house and generator house of flood gate structures
Aug 20, 2019	EFCOS Office	Description and discussion on design policy of local house and generator house of flood gate structures
Aug 29, 2019	EFCOS Office	Description and discussion on design policy of generators for flood gate structures
Nov 7, 2019	EFCOS Office	Description and discussion on operation rules for flood gate structures

Source: Study Team

9.4.2.2 LLDA

The outline of explanatory meetings with LLDA is shown in **Table 9.4.3**.

Table 9.4.3 Meetings with LLDA

Date	Venue	Meeting Agenda
April 26, 2019	LLDA Office	Confirmation of possible site of landfill
June 11, 2019	LLDA Office	• Project description, possible landfill site • Request for participation in the FMC as formal member • O&M of facilities in Pasig-Marikina River Basin associated with water level of Lake Laguna.
Dec 12, 2019	LLDA Deputy Secretary's Office	Report on the start of an Environmental Impact Assessment (EIA) survey for possible landfill site

Source: Study Team

CHAPTER 10 SOCIO-ENVIRONMENTAL CONSIDERATIONS AND RESETTLEMENT PLANS

10.1 Socio-Environmental Considerations

10.1.1 Review of EIS, EMP and EMoP

In 1998, the DPWH prepared an environmental impact assessment report (EIS) covering all of the Pasig-Marikina River Channel Improvement projects (Phase-II to V) and submitted it to the Department of Environment and Natural Resources (DENR), which issued an environmental conformity certificate (ECC)) in the same year. In Phase-IV, the DPWH prepared a Supplemental EIS (published in August 2018), an updated version of the 1998 EIS, due to the changes in social and environmental conditions around the project site. The Supplemental EIS consisted of an environmental management plan (EMP) and an environmental monitoring plan (EMoP) based on the performance in Phase-III. This was because no major environmental management issue has been reported in Phase-III. The review results on the main items are as summarized below.

(1) Air Quality

There was some concern regarding the concentration of construction dust (TSP), NO_2 and SO_2, but they have not exceeded the standard values in Phase-III. In Phase-IV, the implementation of appropriate mitigation and monitoring plans shall be decided in line with the results of EMP and EMoP.

(2) Water Quality

Water pollution by domestic wastewater in the Pasig and Marikina rivers has been confirmed. In Phase-III, water pollution by the construction activities was unsure. The effect of turbid water due to dredging was assumed, but the area affected by flowing water was limited, and there will be no effect on the downstream areas. The dredging method was examined to see if dredging can be carried out without diffusion of turbid water. Water pollution by domestic wastewater in the Manggahan Floodway was also confirmed, and there was some concern that soil and sand may flow out, although the scale of construction is small. Consensus must be formed with the Laguna Lake Development Authority (LLDA), which manages the lake located downstream.

(3) Sediment and Soil

The results of the dredged soil sampling survey in Phase-III show that hazardous substances were seldom detected in the sediment of the Marikina River. There were no factories or other facilities that may generate hazardous substances in the area covered by Phase-IV and the upstream area, and no hazardous substance was used in the construction work. For this reason, it is believed that there will be no soil contamination by hazardous substances. To confirm this in Phase-IV, sediment testing for hazardous substances shall be performed (refer to **Section 10.1.3.1** for details).

(4) Wastes

A new disposal site for dredged soil has been planned. Once the possible site is determined, an EIA is to be performed to obtain the ECC. The contamination of dredged soil could be confirmed in the treatment process, but the contamination risk is considered to be low as described in item (3) above (refer to **Section 10.1.3.2** for disposal site).

(5) Noise and Vibration

There were houses and busy roads around the construction area, and the baseline noise has already exceeded the environmental standard value in the country. The impact can be avoided by maintaining a safe distance between the construction sites and the surrounding structures. However, since it is assumed that structures may be located nearby, the impacts shall be confirmed through monitoring and additional measures taken as necessary. During the construction works, the method with small effect of noise and vibration shall be adopted (waterjet method, etc.). As for vibration, since the baseline value was not confirmed in the Supplemental EIS, it should be measured and grasped before the construction. In Phase-III, no complaint due to construction vibration has been reported.

(6) Protected Areas and Ecosystems

The project sites are urbanized, and no protected area, rare terrestrial or aquatic organisms requiring protection has been identified in the EIS. However, in order to properly conserve watershed ecosystems, monitoring shall be carried out, especially for aquatic organisms, including rare and non-rare species.

The Marikina River is connected to Laguna Lake through the Manggahan Floodway in normal time. It is assumed that there will be no major impact if the water level increases during floods, but it is necessary to objectively show that there will be no impact, and the understanding and agreement of the local residents and the LLDA shall be obtained.

It is considered that most of the trees were planted by the residents, and tree-cutting will be required for bank protection and embankment construction. As described in **Subsection 10.1.4.2**, the number of trees to be felled shall be determined through a tree inventory survey, and greening measures including tree planting shall be implemented in accordance with the laws and regulations of the Philippines, as conducted in Phase-III.

10.1.2 Revision and Update of EIS, EMP and EMoP

Based on the results of the sediment survey, the dredged soil disposal site and the inventory survey for the cutting of trees, the EMP and EMoP shall be updated. In addition, items and activities necessary for mitigation measures and monitoring plans shall be added in a timely manner, taking into account the opinion of stakeholders including the Environmental and Social Safeguard Department (ESSD) which oversees environmental and social considerations of the DPWH, as well as the DENR and relevant local governments.

10.1.3 Support on the Implementation of Socio-Environmental Considerations for Dredged Soil

10.1.3.1 Riverbed Sediment Survey

This section describes the sampling methods for riverbed sediment, soil and river water.

(1) Sampling Method

1) Measurement of Water Level and Sediment Thickness

When doing sampling, prior to taking sediment samples, water characteristics, especially river water level and sediment thickness were measured and recorded. The objective is to determine the river water level and sediment accumulation depth at each sampling site and to determine whether a large barge can be operated as it is or through easy dredging throughout the middle reaches of the Marikina River in the design area. A calibrated metal measuring stick was used to measure the depth of water. Measurements were performed at all sampling points and recorded together with the sampling date and time.

2) Particle Size Distribution Test

The basic characteristics of samples, such as color and texture, were observed and recorded at the sites. More detailed geological results of the riverbed shall be compiled separately in a geological survey report.

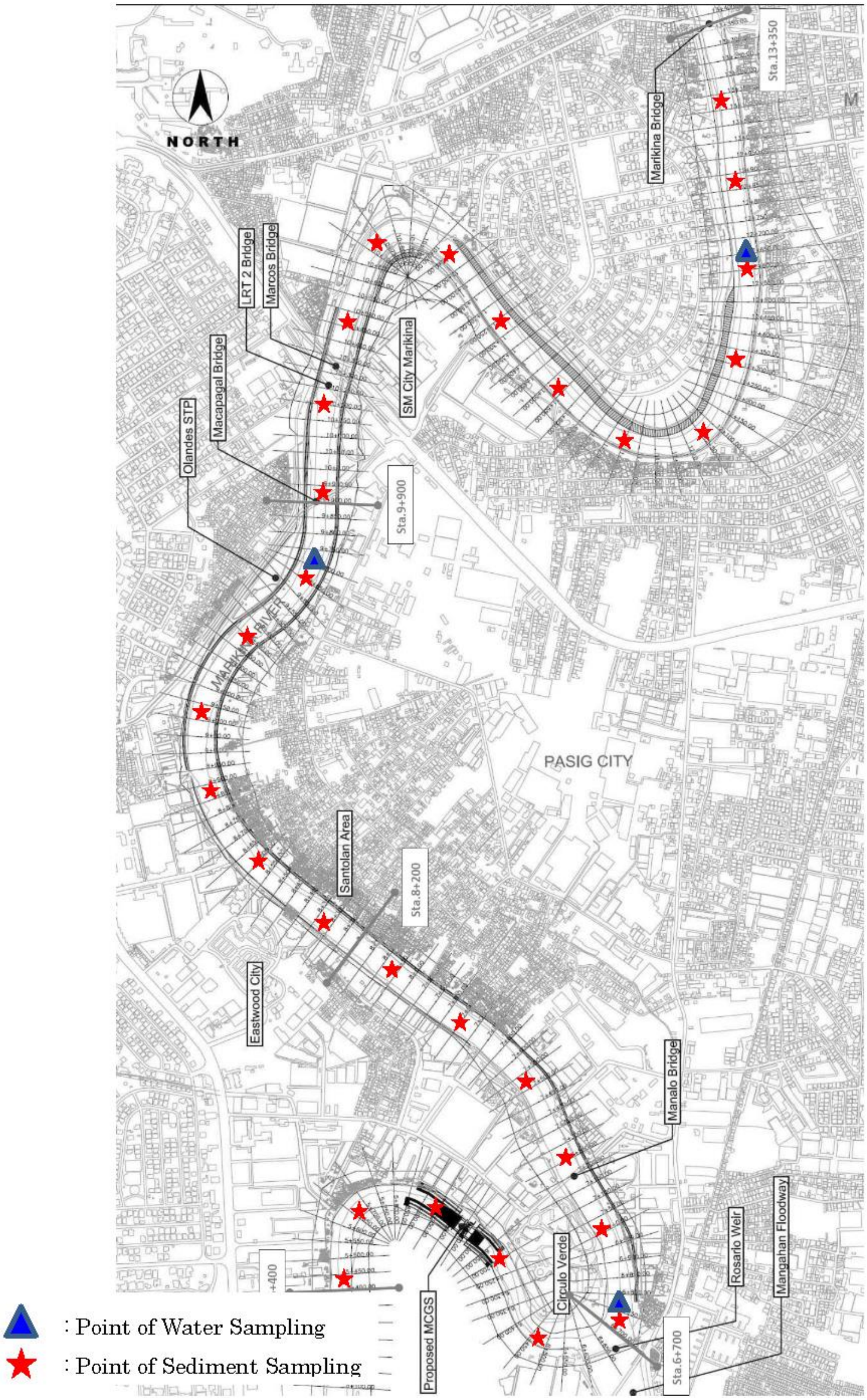
3) Sampling of Riverbed Sediment

As a part of the prior monitoring in the project (Phase-IV), in order to investigate and evaluate the toxicity of riverbed sediment dredged or excavated, a verification study on dredged and excavated soil to be treated by dredging was conducted. Thirty-two (32) riverbed sediment samples were collected along the lower reaches of the Marikina River. The samples consisted of five (5) samples of surface sediment and 27 samples of deep-layer sediment (mixture of sediment from the surface to a depth of 2 m). The sampling points, together with the geographic coordinates and type of sample are as summarized in **Table 10.1.1**. Also, locations of the sediment collection points are as shown in **Figure 10.1.1** and **Figure 10.1.2**.

Table 10.1.1 List of Sampling Type and Location

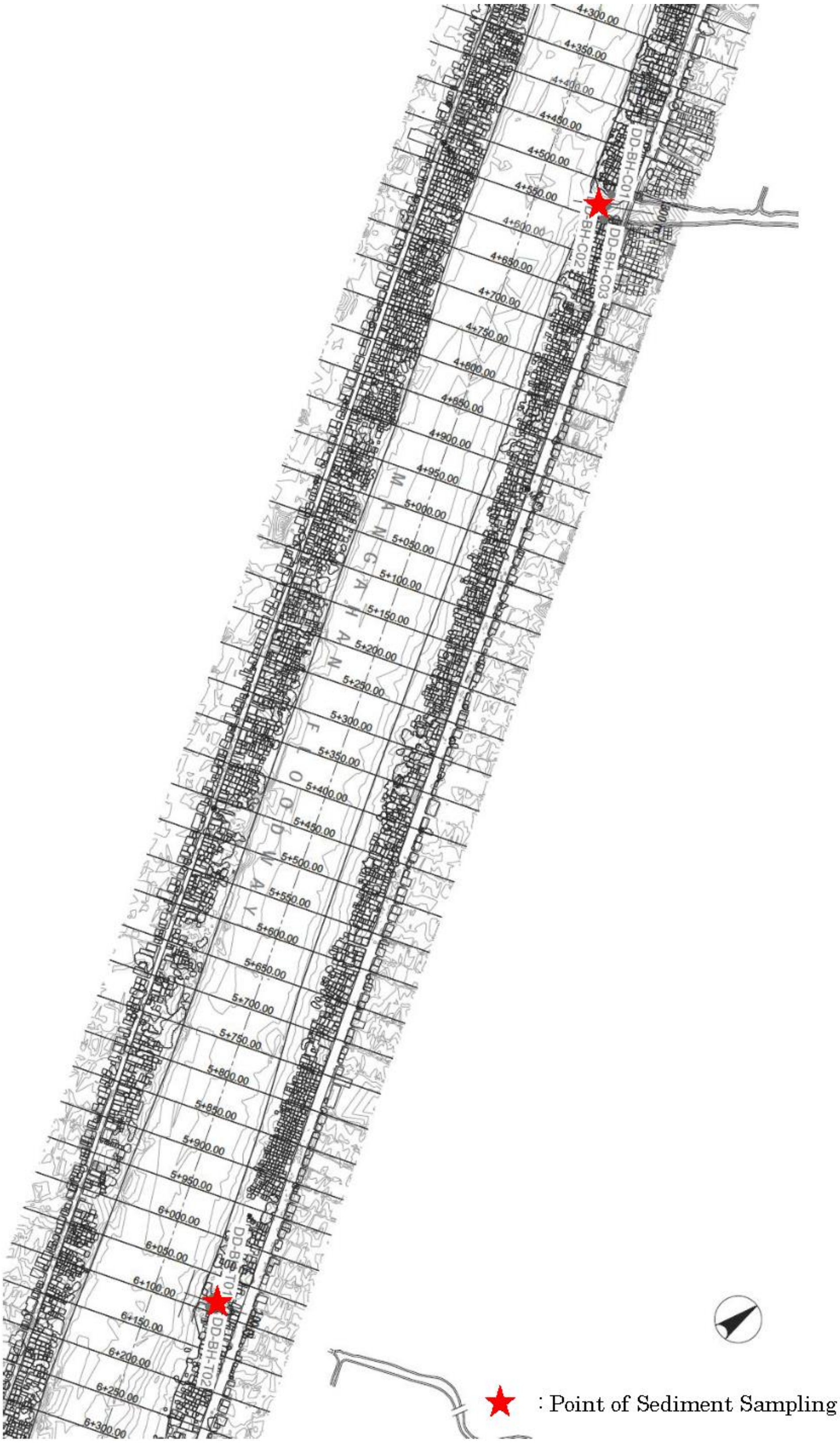
No.	Location	Sample Type	No.	Location	Sample Type
1	Marikina Sta.5 + 400	surface layer	17	Marikina Sta.9 + 670	deep layer
2	Marikina Sta.5 + 670	surface layer	18	Marikina Sta.9 + 930	deep layer
3	Marikina Sta.5 + 930	surface layer	19	Marikina Sta. 10 + 200	deep layer
4	Marikina Sta.6 + 200	surface layer	20	Marikina Sta. 10 + 470	deep layer
5	Marikina Sta.6 + 470	surface layer	21	Marikina Sta. 10 + 730	deep layer
6	Marikina Sta.6 + 730	deep layer	22	Marikina Sta. 11 + 000	deep layer
7	Marikina Sta. 7 + 000	deep layer	23	Marikina Sta. 11 + 270	deep layer
8	Marikina Sta.7 + 270	deep layer	24	Marikina Sta. 11 + 530	deep layer
9	Marikina Sta.7 + 530	deep layer	25	Marikina Sta. 11 + 800	deep layer
10	Marikina Sta.7 + 800	deep layer	26	Marikina Sta. 12 + 070	deep layer
11	Marikina Sta.8 + 070	deep layer	27	Marikina Sta. 12 + 330	deep layer
12	Marikina Sta.8 + 330	deep layer	28	Marikina Sta. 12 + 600	deep layer
13	Marikina Sta.8 + 600	deep layer	29	Marikina Sta. 12 + 870	deep layer
14	Marikina Sta.8 + 870	deep layer	30	Marikina Sta. 13 + 130	deep layer
15	Marikina Sta.9 + 130	deep layer	31	Manggahan Floodway (Cainta Creek)	deep layer
16	Marikina Sta.9 + 400	deep layer	32	Manggahan Floodway (Taytay Creek)	deep layer

Source: Study Team



Source: Study Team

Figure 10.1.1 Sediment Sampling Points (Marikina River)



Source: Study Team

Figure 10.1.2 Sediment Sampling Points (Manggahan Floodway)

In the deep layer, river sediment was collected to a depth of 2 m using an Ekman-Birge grab sampler. The collected sediment was scooped-up three times at the same point and mixed to prepare a sediment sample for the analysis. The first sampling was the representative of surface sediments, the second sampling was the representative of intermediate sediments, and the third sampling was the representative of deep sediments. Each scoop was used to collect representative sediment, remove dust and solid waste through a sieve, and mixed together to make them uniform. The representative sediment was then collected again and transferred to the labeled sample container. Sampling points in the Marikina River were approximately 200 to 300 m apart, and samples were taken from a total of 30 points. A total of two samples were taken from the construction sites of the two backflow prevention gates, one sample each.

4) Collection of River Water Samples

The most updated survey of water quality in the Marikina River was conducted. Sampling sites for collecting river water are as indicated in **Figure 10.1.1,** together with those for riverbed sediment survey.

A Van Dorn water sampler was used to sample river water. Three river water samples were taken from 3 different locations, i.e., upstream (SW-1), midstream (SW-2) and downstream (SW-3) of the midstream portion of the Marikina River. Water samples were taken at intermediate depths. Enough samples were taken with a Van Dorn water sampler, and all sample containers previously labeled from the water sampler nozzle were filled with sample water. They were then placed in a cooler box with ice and shielded and cooled during sampling and transferred to the laboratory. During sampling, on-site measurements of pH, temperature, electrical conductivity, and river flow rate were performed.

(2) Analysis Method

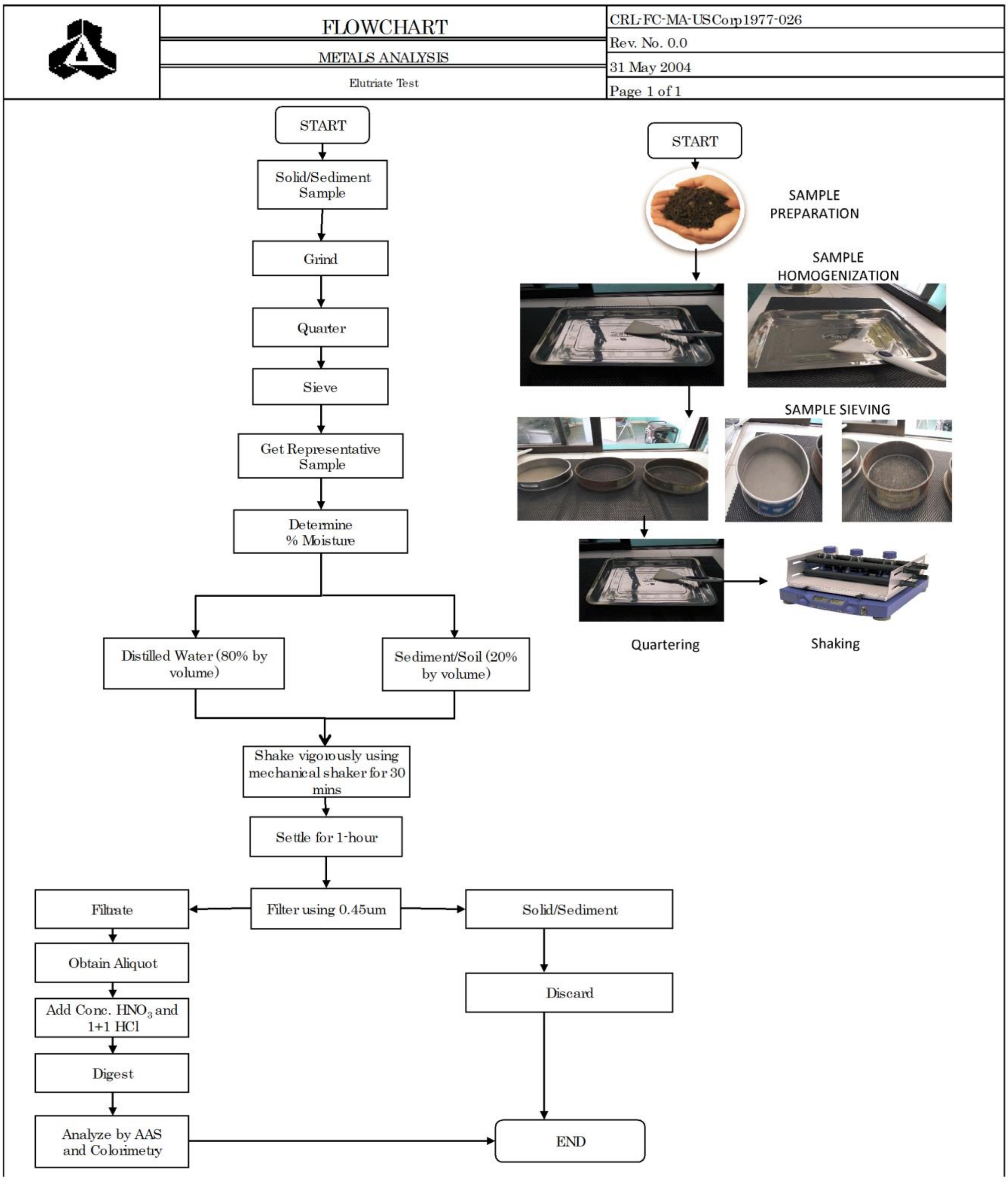
The analysis method of this survey consists of the following items.

(a) Leaching tests for sediment: Elutriate Test and TCLP Test

(b) Water quality analysis method

Sediment and soil samples from 32 sites were analyzed in both leaching tests such as Elutriate and TCLP (Toxicity Characteristic Leaching Procedure) tests.

The Elutriate test is an extraction method to predict the potential release of contaminants from riverbed sediment at dredging sites and when dredged material is exposed to water or rainwater at a dump site. This method was originally developed by the U.S. Army Corps of Engineers, and it simulates the conditions that occur during dredging operations by testing whether the target material is released. The test methods include sample preparation, homogenization, sieving, quartering, shaking, water determination, filtration, decomposition, and analytical procedures (refer to **Figure 10.1.3**). The amount of elution sample required for the chemical analysis varies depending on the number and nature of the analysis performed. In the project, the elutriate test was conducted for 8 items: cadmium (Cd), hexavalent chromium (Cr^{6+}), lead (Pb), total mercury (T-Hg), arsenic (As), free cyanide (CN-), organophosphorus pesticides (OPP), and polychlorinated biphenyls (PCB).

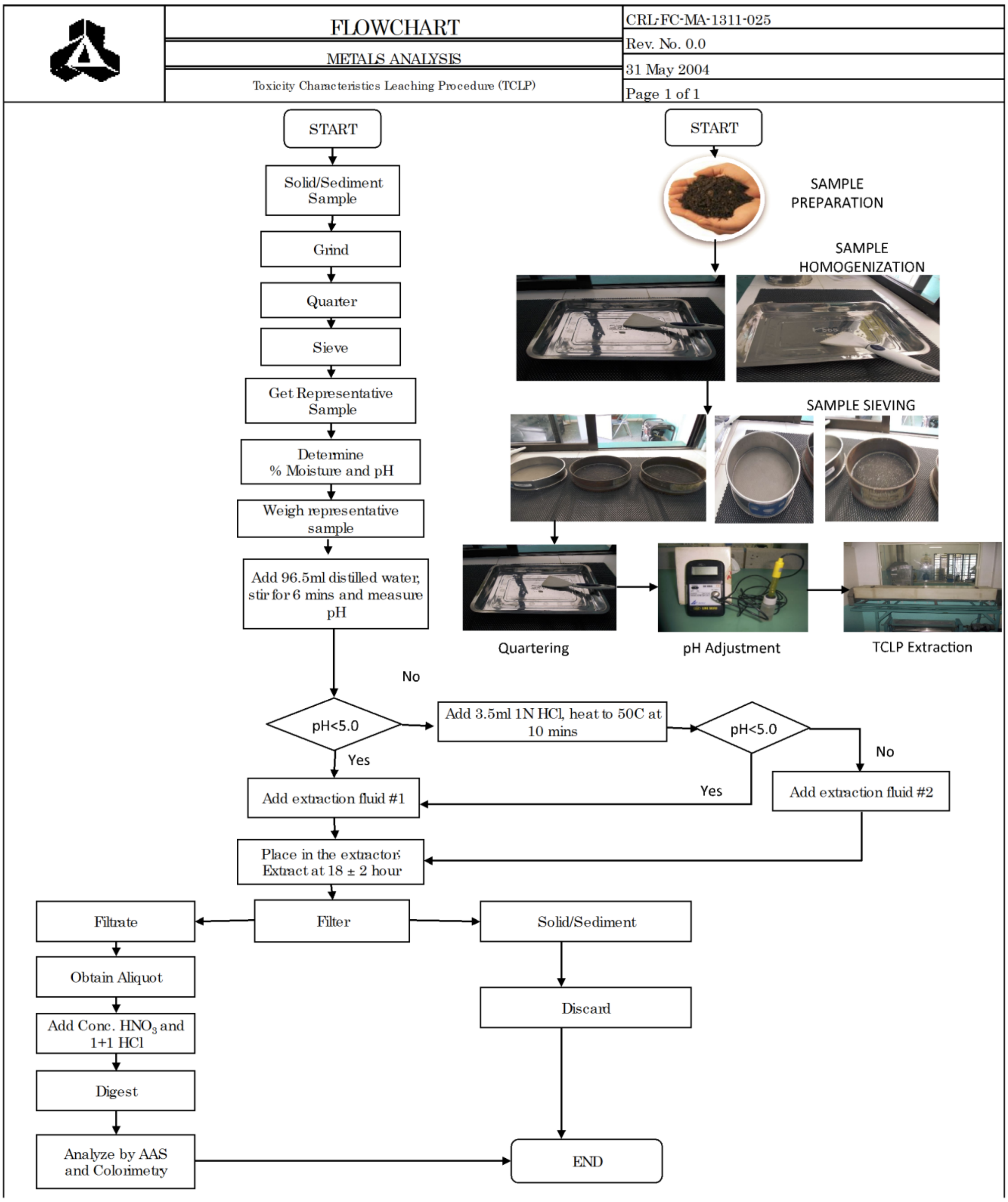


Source: U.S. Army Corps of Engineers

Figure 10.1.3 Flowchart of Elutriate Test

The TCLP test, on the other hand, is an extraction method for chemical analysis that simulates emissions at a disposal site. The purpose of this test is to determine whether the waste to be disposed has hazardous properties and whether the waste will require further treatment prior to disposal.

The extraction method is described in Method 1311 of the USEPA Method for Solid Waste Evaluation (SW-846). The TCLP consists of four basic methods: preparation of the sample, leaching, preparation of the eluate for analysis, and analysis of the eluate (refer to **Figure 10.1.4**). The five (5) items for the eluate analysis included cadmium (Cd), total chromium (T-Cr), lead (Pb), total mercury (T-Hg) and arsenic (As).



Source: U.S. Army Corps of Engineers

Figure 10.1.4 Flowchart for TCLP Test Process

Table 10.1.2 shows a list of measurement items and applicable analysis methods.

Table 10.1.2 Measurement Items and Applicable Analytical Methods

Measurement Item	Analytical Method	Sediment and Soil Analysis		Water Quality Analysis
		Elutriate Test	TCLP Test	
Arsenic (As), mg/L	SDDC spectrophotometry	✓		✓
Arsenic (As), mg/L	Hydride generation atomic absorption spectrometry		✓	
Cadmium (Cd), mg/L	Flame atomic absorption spectrometry	✓	✓	✓
Lead (Pb), mg/L	Flame atomic absorption spectrometry	✓	✓	✓

Measurement Item	Analytical Method	Sediment and Soil Analysis		Water Quality Analysis
		Elutriate Test	TCLP Test	
Mercury (Hg-total), mg/L	Cold vapor atomic absorption spectrometry	✓	✓	✓
Copper (Cu), mg/L	Flame atomic absorption spectrometry			✓
Cyanogen (CN-free), mg/L	Ion selective electrode method	✓		✓
hexavalent chromium (Cr^{6+}), mg/L	Di-phenyl carbazide colorimetric assay	✓		✓
Total chromium (T-Cr), mg/L	Flame atomic absorption spectrometry		✓	
Polychlorinated biphenyl (PCB), μg/L	EPA 8082 A	✓		
Organophosphorus pesticides, μg/liter	EPA 8141	✓		✓
Coliform Count, MPN/100 mL	Multiple tube fermentation			✓
pH (Onsite)	Electric measuring method			✓
Temperature (Onsite), °C	Laboratory and field measurements			✓
Chromaticity, PCU	Visual comparison			✓
Turbidity, NTU	Turbid metric method			✓
Electrical conductivity, μS/cm	Conductivity measuring method			✓
DO (Onsite), mg/L	Membrane electrode method			✓
BOD, mg/L	Modified Winkler sodium azide			✓
Total Evaporation Residue, mg/L	Gravimetric measurement			✓
Methylene Blue Active Substance (surfactant), mg/L	Chloroform extraction and colorimetric assay			✓
Phenol, mg/l	Chloroform extraction and colorimetric assay			✓
Total Suspended Particulate Matter, mg/L	Gravimetric measurement			✓
Oil, mg/L	Petroleum ether extraction method			✓
Chloride Ion, mg/l	Silver titration method			✓
Free Cyanide, mg/L	Ion selective electrode			✓
Nitric Acid Nitrogen, mg/L	Brucine method			✓
Phosphoric Acid Phosphorus, mg/L	Tin chloride method			✓
Salinity (NaCl conversion), mg/L	Conversion from the titration method			✓

Note: Check mark ("✓") indicates an item to be analyzed.
Source: Study Team

As noted above, characteristics of soil samples from landfills were analyzed in both Elutriate and TCLP tests. Measurement items were the same as those of sediment samples.

The Particle Size Distribution (PSD) test for riverbed sediment samples was also carried out by extracting 5 sites from 32 places. Water is used in calculating dry weight.

A trial treatment of the sediment with cement and lime was also planned. This was done to determine the most effective mixing ratio to improve dredged mud and sediment into the appropriate filler. The improved samples were then analyzed again in a leaching test to determine if the cement/lime mixture was effective in containing the contaminants after discarded. It should be noted that even if the original sediment is safe, the mixture may be contaminated due to the mixture of cement and lime. Another objective is to double-check that the analytical results are still below the baseline after mixing for physical stabilization.

For water quality analysis, water samples from the lower reaches of the Marikina River were tested for copper (Cu), cadmium (Cd), hexavalent chromium (Cr^{6+}), lead (Pb), total mercury (T-Hg), free cyanide (CN^-), arsenic (As), and organophosphorus pesticides (OPP), as well as basic parameters such as color, water temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended particulate matter (TSS), total dissolved solid (TDS), anionic surfactants, oil, nitric acid nitrogen, phosphorous phosphorus, phenol, coliform count, chloride ion and salt conductivity (refer to **Table 10.1.2**).

(3) Evaluation of Sediment Analysis Results and Survey Results

The results of sediment survey conducted by the local contractor are shown in **Table 10.1.3** and **Table 10.1.4**. All the substances tested by the both methods were undetected or under the standard values.

Table 10.1.3 Results of TCLC Test

Sampling Stn	As, mg/L	Cd, mg/L	Pb, mg/L	Hg, mg/L	Cr, mg/L
SS01	<0.008	<0.001	<0.005	<0.0002	<0.005
SS02	<0.008	<0.001	<0.005	<0.0002	<0.005
SS03	<0.008	<0.001	<0.005	<0.0002	<0.005
SS04	<0.008	<0.001	<0.005	<0.0002	<0.005
SS05	<0.008	<0.001	<0.005	<0.0002	<0.005
SS06	0.02	<0.001	<0.005	<0.0002	0.009
SS07	<0.008	0.002	<0.005	<0.0002	0.0074
SS08	0.01	<0.001	<0.005	<0.0002	<0.005
SS09	<0.008	0.002	<0.005	<0.0002	<0.005
SS10	<0.008	0.004	<0.005	<0.0002	0.006
SS11	<0.008	0.002	<0.005	<0.0002	<0.005
SS12	<0.008	0.002	<0.005	<0.0002	<0.005
SS13	<0.008	<0.001	<0.005	<0.0002	0.007
SS14	0.02	<0.001	<0.005	<0.0002	0.02
SS15	0.01	<0.001	<0.005	<0.0002	0.02
SS16	<0.008	<0.001	<0.005	<0.0002	<0.005
SS17	<0.008	<0.001	<0.005	<0.0002	<0.005
SS18	<0.008	<0.001	<0.005	<0.0002	<0.005
SS19	<0.008	<0.001	<0.005	<0.0002	<0.005
SS20	<0.008	<0.001	<0.005	<0.0002	0.01
SS21	<0.008	0.001	<0.005	<0.0002	<0.005
SS22	<0.008	0.001	<0.005	<0.0002	<0.005
SS23	<0.008	<0.001	<0.005	<0.0002	0.005
SS24	0.02	<0.001	<0.005	0.0004	0.008
SS25	0.02	<0.001	<0.005	<0.0002	0.02
SS26	0.01	<0.001	<0.005	<0.0002	<0.005
SS27	<0.008	0.002	<0.005	<0.0002	0.02
SS28	<0.008	0.001	<0.005	<0.0002	0.01
SS29	0.01	<0.001	<0.005	<0.0002	0.009
SS30	0.02	<0.001	<0.005	<0.0002	0.009
SS C01	0.01	<0.001	<0.005	<0.0002	0.01
SS T01	0.01	<0.001	<0.005	<0.0002	0.007

Sampling Stn	As, mg/L	Cd, mg/L	Pb, mg/L	Hg, mg/L	Cr, mg/L
Regulatory Limit	1	0.3	1	0.1	5

Source: Study Team

Table 10.1.4 Results of Elutriate Test

Sampling Stn	As, mg/L	Cd, mg/L	Pb, mg/L	Hg, mg/L	Cr^{+6}, mg/L	Free CN, mg/L	PCB, ug/L	OPP, ug/L
SS01	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS02	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS03	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS04	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS05	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS06	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS07	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS08	0.009	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS09	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS10	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS11	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS12	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS13	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS14	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS15	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS16	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS17	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS18	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS19	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS20	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS21	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS22	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS23	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS24	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS25	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS26	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS27	<0.008	<0.001	<0.005	<0.002	<0.002	0.02	<0.25	<0.20
SS28	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS29	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS30	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS C01	<0.008	<0.001	<0.005	<0.002	<0.002	<0.004	<0.25	<0.20
SS T01	<0.008	<0.001	<0.005	<0.002	<0.002	0.02	<0.25	<0.20
DENR Reg Limit	0.02	0.005	0.05	0.002	0.01	0.1	0.5	---

Source: Study Team

From these results, we can determine that the heavy metal concentrations in the target sediment of Phase IV are within the reference value, same as the case in Phase III.

(4) Evaluation of Water Quality Analysis Results and Survey Results

The results of water quality analysis from the three sites are shown in **Table 10.1.5**. Sampling and analysis were performed simultaneously with the sediment analysis described above.

The results were compared with the reference values of Class-C (see **Table 10.1.6**) specified by DENR.

Biological Oxygen Demands, or BODs were above the reference value (7) at two of the three sampling points (upstream and midstream). Dissolved Oxygens, or DOs were also below the reference value (5) at two locations (upstream and downstream). Total Suspended Solids, or TSSs which indicate degrees of turbidity also exceeded the standard value (80) at two locations (upstream and middle).

In addition, regarding the number of E. coli, based on DENR Administrative Order No. 34 (1990), the total number of E. coli must not exceed 5,000 MPN/100 ml in the average monitoring period of three months. It greatly exceeded this allowable average value. It should be noted that the total E. coli count results are very high. Bacterial contamination can be caused by domestic household wastewater, commercial wastewater from various tributaries, and even industrial wastewater.

The results of this study are to be added to the evaluation of the same sediment analysis test conducted in Phase III.

Table 10.1.5 Results of Water Quality Test

Parameters, units	Regulatory Limits	WS1	WS2	WS3
As, mg/L	0.02	<0.008	<0.008	<0.008
Cd, mg/L	0.005	<0.001	<0.001	<0.001
Cu, mg/L	0.02 (b)	0.004	0.006	<0.003
Pb, mg/L	0.05	<0.005	<0.005	<0.005
Hg, mg/L	0.002	<0.0002	<0.0002	<0.0002
Total coliform, MPN/100 mL	- (5,000)	240,000	540,000	2,400,000
pH, onsite	6.5 - 9.0	7.4	7.4	7.4
temperature, onsite, oC	25 - 31 (t)	33.3	29.3	29.7
color, TCU	75	25	50	40
turbidity, NTU	-	22	32	29
conductivity, µS/cm	-	462	501	491
BOD, mg/L	7	8	28	4
TDS, mg/L	-	267	297	302
MBAS, mg/L	1.5	0.4	1	0.8
TSS, mg/L	80	158	63	39
Oil & Grease, mg/L	2	0.74	0.58	0.75
Chloride, mg/L	350	23	30	28
Cr+6, mg/L	0.01	<0.002	<0.002	<0.002
Free CN, mg/L	0.1	<0.004	<0.004	<0.004
DO, onsite	5 min (e)	2	7	1
NO3 - N, mg/L	7	0.4	0.1	0.2
Phosphate - P, mg/L	0.5	0.5	0.3	0.5
Salinity as NaCl, mg/L	-	38	50	46
Organic phenols		ND	ND	ND
OPP		ND	ND	ND

Source: Study Team

Table 10.1.6 Water Usage and Classifications (Fresh Surface Water)

Classification	Beneficial Use
Class AA	Public Water Supply Class 1 This class is intended primarily for waters having watersheds which are uninhabited and otherwise protected and which require only approved disinfection in order to meet the National standards for Drinking Water (NSDW) of the Philippines.
Class A	Public Water Supply Class 2 For sources of water supply that will require complete treatment (coagulation, sedimentation, filtration, and disinfection) in order to meet the NSDW.
Class B	Recreational Water Class 1 For primarily contact recreation such as bathing, swimming, skin diving, etc. (particularly those designated for tourism purpose.)
Class C	a) Fishery Water for the propagation and growth of fish and other aquatic resources. b) Recreational water class 2 (boating, etc) c) Industrial Water supply class 1 (from manufacturing processes after treatment)
Class D	1. For agriculture, irrigation, live stocks watering, etc.) 2. Industrial Water supply class 2 (e.g. cooling, etc.) 3. Other inland waters by their quality belong to this classification.

Source: DENR Administrative Order No. 34 Series of 1990

(5) Evaluation of Particle Size Distribution (PSD) Test Results

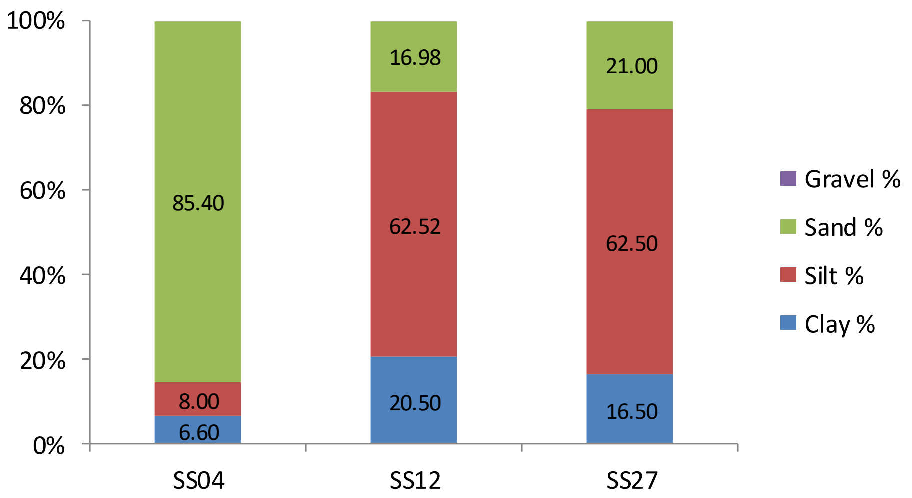
The particle size distribution test was conducted at the following three points, taking into account the sediment test results and the construction site for the planned structure. The test results are shown in **Table 10.1.7** and **Figure 10.1.5**.

1) SS04-Marikina Sta.6+200、2) SS12-Marikina Sta.8+330、3) SS27-Marikina Sta.12+330

Table 10.1.7 Results of Particle Size Distribution (PSD) Test

Sample ID	Clay %	Silt %	Sand %	Gravel %
SS04	6.60	8.00	85.40	0.00
SS12	20.50	62.52	16.98	0.00
SS27	16.50	62.50	21.00	0.00

Source: Study Team



Source: Study Team

Figure 10.1.5 Results of Particle Size Distribution (PSD) Test

The results showed that SS04 had the highest percentage of sand particles (about 85%), and SS12 and SS27 contained almost the same amount of silt (about 63%). Also, since SS04 is mostly sand, the soil at this location would not hold much moisture. Since SS12 and SS27 are both silt soils, they tend to solidify and form a hard crust, especially in dry conditions.

(6) Evaluation and Discussion of Results for the Construction Phase

The concentrations of all sediment samples collected in the middle- and down-stream sections of Marikina River were lower than the standards set by the Philippine government. This indicates that the sediment in the area is not harmful and may not produce significant levels of toxicity in river water during dredging. In addition, according to the analysis results, the concentrations of heavy metals extracted from the sediment sample in the TCLP test were very small or not detected by the analyzer generally used, that is, the concentrations shall be below the method detection limit. They were not at a significant concentration level exceeding the hazardous waste regulation values (DAO 2004-36/ RA6969). Compared to the regulatory limits for hazardous wastes, the observed concentrations were much lower than the reference values, and it is assumed that those concentrations would give no affections to the planned landfill site and the surrounding environment. In water quality, heavy metals and other harmful inorganic and organic substances were not present at concentrations considered harmful. Therefore, we consider that the dredged sludge (sediment) collected in the middle and downstream sections of Marikina River is safe for use for embankment and landfill purposes.

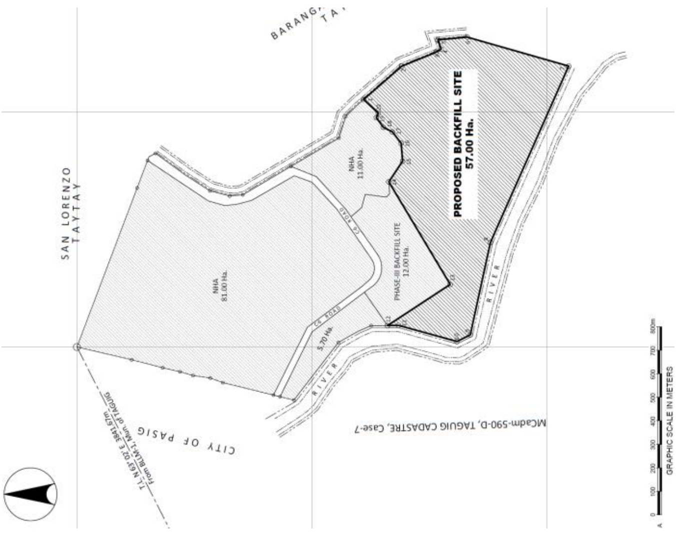
Based on the above considerations and the fact that there would be no source likely to affect the design/ project site of the project and the upstream area, we evaluate that there are also no special environmental considerations in Phase IV.

10.1.3.2 Dredged Soil Disposal Site

The assumed amount of disposed soil to be dredged and excavated due to river channel expansion work in this project is likely about 1.5 million m^3. It is necessary to prepare a specific land to dispose of this large amount of sediment. Therefore, DPWH consulted with the local government and the Laguna Lake Development Authority (LLDA), which has many idle lands, and received a proposal to use a 57 ha of idle land located in the barangay San Juan in Taytay Municipality (refer to **Figure 10.1.6)**.

After discussions with LLDA and related organizations, approval was given for conducting an Environmental Impact Assessment (EIA) on the idle land. For this reason, an EIA study has been commenced since November 2019 to obtain an Environmental Compliance Certificate (ECC) for the use of this land as a landfill site from the Department of Environment and Natural Resources (DENR).

LINES	BEARING	DISTANCE
1-2	S 41d9' E	215.11m
2-3	S 22d12' E	158.55m
3-4	S 30d11' E	24.63m
4-5	N 70d33' E	42.55m
5-6	S 5d9' E	125.63m
6-7	S 15d55' W	448.90
7-8	N 66d5' W	820.62m
8-9	N 77d41' W	402.63
9-10	N 26d22' W	63.67
10-11	N 15d25' E	257.08
11-12	N 0d51' W	47.31
12-13	S 33d21' E	318.93
13-14	N 59d6' E	508.75
14-15	S 56d2' E	105.96
15-16	N 85d7' E	76.61
16-17	N 52d24' E	60.85
17-18	N 26d53' E	43.32
18-19	N 54d0' E	50.49
19-20	S 65d55' E	20.90
20-1	N 42d53' E	85.60



Source: Study Team, based on the data from LLDA

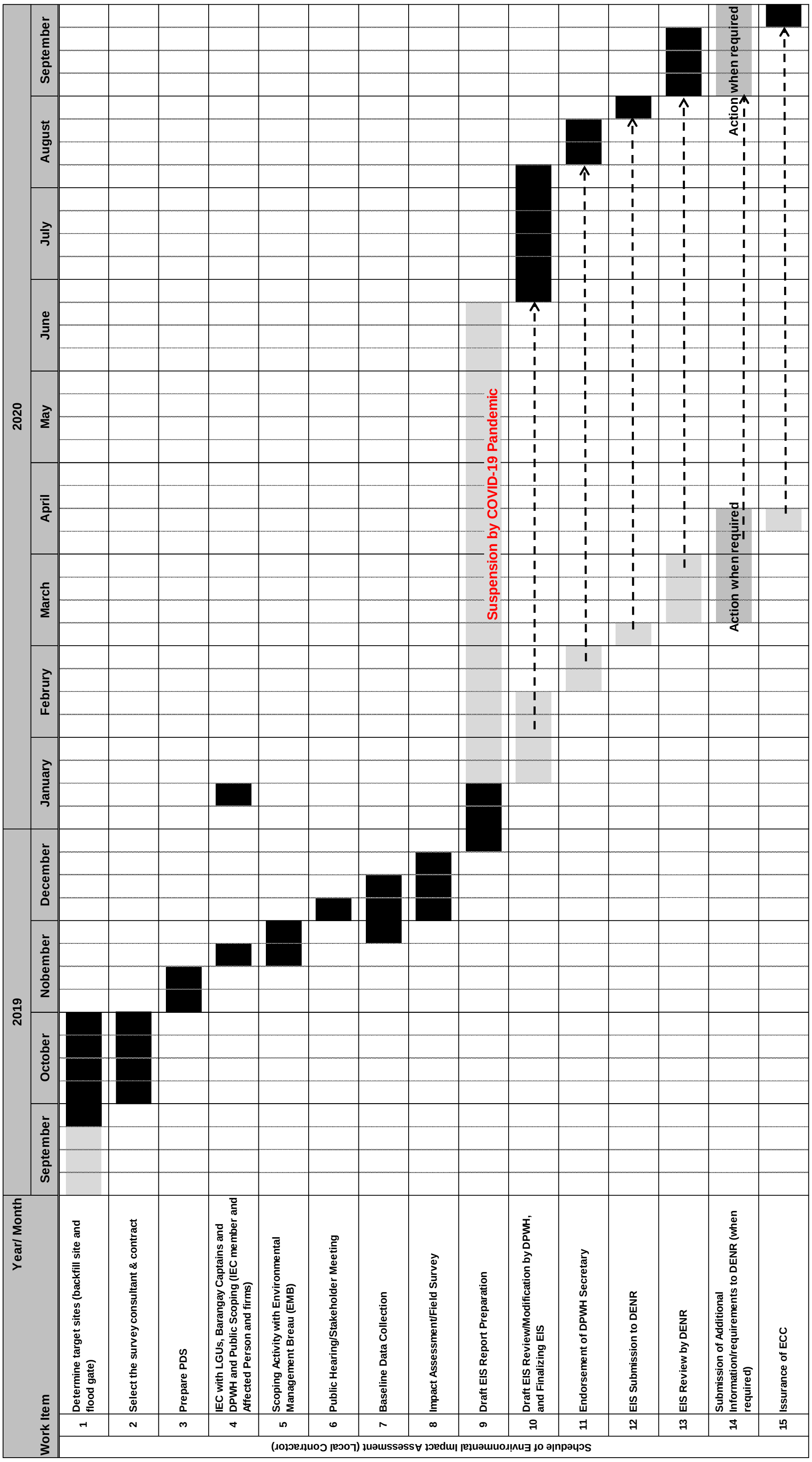
Figure 10.1.6 Potential Landfill Site for Sediment Disposal
(LLDA-managed District in Barangay San Juan, Taytay Municipality)

(1) Progress of the EIA Study

Although the EIA study had been delayed due to the COVID-19 cases since March 2020, the Study Team prepared a draft EIA report and submitted it to DPWH-ESSD in June 2020. The draft report was undertaken the first review by ESSD late July 2020, and will be finalized after considerations. As shown in **Figure 10.1.7**, the acquisition of ECC is expected to be around September 2020, after this survey is scheduled to complete.

(2) EIA Study Pre-screening and Scoping Results

The local subcontractor has conducted the pre-screening and scoping, and based on the results, is undertaking EIA studies under the guidance of DENR.



Source: Study Team

Figure 10.1.7 ECC Acquisition Schedule for Landfill Site

(3) Results of EIA Pre-screening and Pre-scoping

The pre-screening and pre-scoping were conducted by the local subcontractor and the EIA survey implemented with guidance by DENR. Based on the results of EIA survey, outlines of the environmental and social considerations for the landfill site and floodgate were summarized in Table 10.1.8 and Table 10.1.9, respectively.

Table 10.1.8 Outline of Environmental and Social Baseline (Backfill Site)

LAND

1. Land Use and Classification

- The proposed Backfill site is situated along the shores of Laguna Lake within Lupang Arenda in Taytay, Rizal.
- **Based on the Comprehensive Land Use Plan (CLUP) of Taytay, the site is considered Agricultural SAFDZ.**
- **The proposed site does not fall within any declared Environmentally Critical Area (ECA).**
- **The site is not covered by any tenurial instrument.**
- **There are no visually significant landforms, landscapes, or structures in the proposed project area that can potentially be affected by the project activities.**

2. Geology/Geomorphology

- The project location is susceptible to liquefaction, has very high flood susceptibility, and is susceptible to flood greater than 2 meters.

3. Terrestrial Ecology

- There are no important species (flora and fauna) identified in the project area.

WATER

1. Competition in Water Use

- Around 24-30m^3 of water per day will be used for the proposed backfill area. Both projects will source its water from Manila Water Company, Inc.

2. Water Quality

- All parameters in the surface water (sampling the station in the proposed floodgate) passed DAO 2016-08 Class C.
- There are no groundwater sources in the study area.

AIR

1. Meteorology

- The proposed project area belongs to Type I climate under the Modified Coronas Classification (MCC)[1] with two pronounced seasons: dry from November to April and wet the rest of the year.
- Temperature is highest in May and lowest in January.
- Rainfall is highest in July and lowest in April.
- The surface winds in the area are southwest monsoons from July to September while the northeast monsoon comes during the months of December to February.
- An average of 5 cyclones passes by every 3 years.

2. Ambient Air Quality and Noise

- Results of ambient air quality monitoring in all 3 stations (except PM$_{10}$ near the proposed backfill site) below DENR standards.
- **Noise levels near the road are above the NPCC standards; noise levels in the morning and daytime in the community near the proposed backfill site are below NPCC standards.**

3. Vibration

- Observed vibrations at the project area indicates that the vibrations levels from a low of 80 VdB to a high 86 VdB. These are caused by large vehicles plying the roads near the project area.

PEOPLE

- Water supply sources are supplied by MWCI (Level III), but there are still households using Levels I & II water supply[2].
- There are informal settler families (ISFs) that will be resettled from the proposed backfill site.
- A right-of-way action plan (RAP) will be prepared for the affected ISFs.

Source: Study Team

[1] The MCC uses the sum of average monthly rainfall to define four climatic zones. Type I and III: There are rainy season and dry season. Type II and IV: There is a rainy season, but no dry season.

[2] Level I: Stand-alone water points (hand pumps, shallow wells, rainwater collectors, etc.) that supply an average of 15 households within 250 m. Level II: Water supply with an average of 4 to 6 households of common water (wells, spring systems, etc.) within 25 m. Level III: Water supply by piping private water areas (eg houses) based on water demand of 100 L or more per person per day.

Table 10.1.9 Outline of Environmental and Social Baseline (Floodgate)

LAND

1. Land Use and Classification

- The proposed floodgate will be located beside the existing San Francisco Bridge in East Bank Road along Cainta River which is classified as part of road network and buffer zone.
- The proposed project area does not fall within any declared ECA.
- There are no visually significant landforms, landscapes, or structures in the proposed project areas that can potentially be affected by the project activities.

2. Geology/Geomorphology

- The project locations are susceptible to liquefaction.
- The project locations are very high flood susceptibility.
- The project locations are susceptible to flood greater than 2 meters.

3. Terrestrial Ecology

- There are no important species (flora and fauna) identified in the project area.

WATER

1. Competition in Water Use

- Around 2 m^3 of water per day will be used for the proposed floodgate. Water will be sourced from MWCI.

2. Water Quality

- There are no groundwater sources in the study area.

AIR

1. Meteorology

- The proposed project area mainly belongs to Type I climate under the modified Coronas classification with two pronounced seasons: dry from November to April and wet the rest of the year.
- Temperature is highest in May and lowest in January.
- Rainfall is highest in July and lowest in April.
- The surface winds in the area are southwest monsoons from July to September while the northeast monsoon comes during the months of December to February.
- An average of 5 cyclones passes by every 3 years.

2. Ambient Air Quality and Noise

- Results of ambient air quality monitoring in all 3 stations are below DENR standards.
- Noise levels near the road are above the NPCC standards; noise levels in the morning and daytime in the community near the proposed backfill site are below NPCC standards.

3. Vibration

- Observed vibrations at the project area indicates that the vibrations levels from a low of 80 VdB to a high 86 VdB. These are caused by large vehicles plying the roads near the project area.

PEOPLE

- Water supply sources are supplied by MWCI (Level III), while there are still households using Levels I & II water supply.
- There are informal settler families (ISFs) that will be resettled.
- A right-of-way action plan (RAP) will be prepared for the affected ISFs.

Source: Study Team

(4) Draft Environmental Management Plan (EMP)

Results from the EIA survey is used for developing an Environmental Management Plan (EMP) after revisions and the EMP is used for management and monitoring for the environmental and social considerations during the project implementation. Table 10.1.10 shows a draft EMP for the backfill site and the floodgate at the pre-construction, during construction, in operation and decomposition periods. The draft EMP will be approved and implemented after ECC issuance by DENR.

Table 10.1.10 Draft EMP (Backfill Site and Cainta Floodgate)

Project Phase/ Environmental Aspect	Environmental Component likely to be Affected	Potential Impact	Options for Prevention or Mitigation or Enhancement	Responsible Entity	Cost (PHP)*	Guarantee/ Financial agreements
A. Pre-Construction Phase (Backfill Site for Dredged Sediments and Floodgate)						
A1. Acquisition of the applicable permits and licenses **A1.1 Regulatory**	People, Land, Water, Air	Disclosure of project components and activities	▪ Submission of complete requirements for the processing of all permits	DPWH	P 5,000 per permit	Pre-construction expenses

Project Phase/ Environmental Aspect	Environmental Component likely to be Affected	Potential Impact	Options for Prevention or Mitigation or Enhancement	Responsible Entity	Cost (PHP)*	Guarantee/ Financial agreements
compliance						
A2. Procurement & planning **A2.1 Local sourcing of labor and materials**	People	Increase in employment opportunities and livelihood programs	▪ Priority will be given to the barangays within the primary impact zones ▪ Local labor requirements shall be posted in barangay halls and other public places	DPWH	P 5,000	Pre-construction expenses
A3. Resettlement of affected ISFs	People	Resettlement of existing ISFs living within the project areas	▪ Prepare a Right-of-Way Action Plan for the affecter ISFs ▪ Provide relocation of qualified ISFs ▪ Provide financial assistance to ISFs that will be displaced economically	DPWH/NHA	Will be provided in the ARAP to be prepared for the proposed projects	Pre-construction expenses
B. Construction Phase (Backfill Site for Dredged Sediments and Floodgate)						
B1. Construction of Temporary Jetty and Slope Protection (Backfill Site for Dredged Sediments)	Water	Possible siltation and increase of turbidity on the nearby surface water	▪ Regular removal of silt and sediments ▪ Establishment of siltation ponds, silt traps and erosion barriers	DPWH	P 50,000	Contractor's MOA
B1.1. Earth-movement and civil works	Air	Generation of dust	▪ Minimize/prevent unnecessary earth-movement ▪ Regular watering of construction sites that will generate dust ▪ Avoid long exposure of excavated soil piles to strong winds by applying canvass covers ▪ Control vehicle speed to lessen dust suspension	DPWH	P 30,000	Contractor's MOA
B1.2 Operation of equipment	Land	Ground vibration	▪ Notify nearby residents about the activity of using heavy equipment ▪ For hauling trucks, comply with road weight limit standards to avoid ground vibration	DPWH	P 30,000	Contractor's MOA
	Air	Generation of air emissions & noise	▪ Proper and regular maintenance of heavy equipment ▪ Perform noisy activities during daytime	DPWH	P 50,000	Contractor's MOA
B1.3 Influx of construction workers	Land, Water	Generation of solid wastes	▪ Solid Waste Management Plan ▪ Segregation of solid waste according to recyclable and non-recyclables ▪ Hauling of discarded/recyclable items by duly-licensed traders	DPWH LGU	P 15,000	Contractor's MOA
	Water	Generation of domestic wastewater	▪ Follow basic housekeeping policies ▪ Provision of sanitation facilities (i.e. toilets, showers, etc.)	DPWH	P 30,000	Contractor's MOA
	People	Increased occupational safety and health risks	▪ All personnel are required to wear proper PPE ▪ All civil and electro-mechanical works will be supervised by trained engineers ▪ First-aid stations, safety equipment and signage shall be made available on working areas	DPWH	P 50,000	Contractor's MOA
	People	Health hazards from	▪ Implement dust control management	DPWH	P 100,000	Contractor's MOA

Project Phase/ Environmental Aspect	Environmental Component likely to be Affected	Potential Impact	Options for Prevention or Mitigation or Enhancement	Responsible Entity	Cost (PHP)*	Guarantee/ Financial agreements
		dust emissions	▪ Provide PPEs for dust emissions ▪ Provide on-site medical services in case of emergency ▪ Provide adequate buffer zone and perimeter fence to protect passersby			
	People	Generation of employment, taxes and additional income	▪ Prioritize hiring of qualified residents of the host communities ▪ Prioritize purchasing of local items, if applicable, within the host communities	DWPH LGU	P 5,000	Contractor's MOA, LGU MOA
B2. Construction and Site Development (Floodgate) **B2.1. Earth-movement and civil works**	Land	Generation of construction spoils and debris	▪ Provision of disposal area ▪ Segregation of debris according to recyclable and non-recyclables ▪ Hauling of debris items by duly licensed traders	DPWH	P 50,000	Contractor's MOA
	Water, Land	Possible siltation and increase of turbidity on the nearby surface water	▪ Regular removal of silt and sediments ▪ Establishment of siltation ponds, silt traps and erosion barriers	DPWH	P 50,000	Contractor's MOA
	Air	Generation of dust	▪ Minimize/prevent unnecessary earth-movement ▪ Regular watering of construction sites that will generate dust ▪ Avoid long exposure of excavated soil piles to strong winds by applying canvass covers ▪ Control vehicle speed to lessen dust suspension	DPWH	P 30,000	Contractor's MOA
B2.2 Operation of equipment	Land	Ground vibration	▪ Notify nearby residents about the activity of using heavy equipment ▪ For hauling trucks, comply with road weight limit standards to avoid ground vibration	DPWH	P 30,000	Contractor's MOA
	Air	Generation of air emissions & noise	▪ Proper and regular maintenance of heavy equipment ▪ Installation of mufflers ▪ Perform noisy activities during daytime	DPWH	P 50,000	Contractor's MOA
	Land, Water	Generation of hazardous wastes (e.g. used oil)	▪ Provision of storage area ▪ Collect, store and dispose wastes in safe and sealed containers ▪ Treatment and dispose wastes through accredited treaters	DPWH	P 100,000	Contractor's MOA
B2.3 Influx of construction workers	Land, Water	Generation of solid wastes	▪ Solid Waste Management Plan ▪ Segregation of solid waste according to recyclable and non-recyclables ▪ Hauling of discarded/recyclable items by duly-licensed traders	DPWH LGU	P 15,000	Contractor's MOA
	Water	Generation of domestic wastewater	▪ Follow basic housekeeping policies ▪ Provision of sanitation facilities (i.e. toilets, showers, etc.)	DPWH	P 30,000	Contractor's MOA

Project Phase/ Environmental Aspect	Environmental Component likely to be Affected	Potential Impact	Options for Prevention or Mitigation or Enhancement	Responsible Entity	Cost (PHP)*	Guarantee/ Financial agreements
	People	Increased occupational safety and health risks	▪ All personnel are required to wear proper PPE ▪ All civil and electro-mechanical works will be supervised by trained engineers ▪ First-aid stations, safety equipment and signage shall be made available on working areas	DPWH	P 50,000	Contractor's MOA
	People	Health hazards from dust emissions	▪ Implement dust control management ▪ Provide PPEs for dust emissions ▪ Provide on-site medical services in case of emergency ▪ Provide adequate buffer zone and perimeter fence to protect passersby	DPWH	P 100,000	Contractor's MOA
	People	Generation of employment, taxes and additional income	▪ Prioritize hiring of qualified residents of the host communities ▪ Prioritize purchasing of local items, if applicable, within the host communities	DWPH LGU	P 5,000	Contractor's MOA, LGU MOA
C. Operations Phase (Backfill Site for Dredged Sediments and Floodgate)						
C1. Transport and Unloading Dredged Materials and Site Development (Backfill Site for Dredged Sediments) **C1.1. Earth-movement**	Water	Possible siltation and increase of turbidity on the nearby surface water	▪ Regular removal of silt and sediments ▪ Installation of barriers, covers in the dredge materials prior to transport	DPWH	P 50,000	Contractor's MOA
	Air	Generation of dust	▪ Regular watering of construction sites that will generate dust ▪ Avoid long exposure of excavated soil piles to strong winds by applying canvass covers ▪ Control vehicle speed to lessen dust suspension	DPWH	P 30,000	Contractor's MOA
C1.2 Operation of equipment	Land	Ground vibration	▪ Notify nearby residents about the activity of using heavy equipment ▪ For hauling trucks, comply with road weight limit standards to avoid ground vibration	DPWH	P 30,000	Contractor's MOA
	Air	Generation of air emissions & noise	▪ Proper and regular maintenance of heavy equipment ▪ Perform noisy activities during daytime	DPWH	P 50,000	Contractor's MOA
C1.3 Influx of workers	Land, Water	Generation of solid wastes	▪ Solid Waste Management Plan ▪ Segregation of solid waste according to recyclable and non-recyclables ▪ Hauling of discarded/recyclable items by duly-licensed traders	DPWH LGU	P 15,000	Contractor's MOA
	Water	Generation of domestic wastewater	▪ Follow basic housekeeping policies ▪ Provision of sanitation facilities (i.e. toilets, showers, etc.)	DPWH	P 30,000	Contractor's MOA
	People	Increased occupational safety and health risks	▪ All personnel are required to wear proper PPE ▪ First-aid stations, safety equipment and signage	DPWH	P 30,000	Contractor's MOA

Project Phase/ Environmental Aspect	Environmental Component likely to be Affected	Potential Impact	Options for Prevention or Mitigation or Enhancement	Responsible Entity	Cost (PHP)*	Guarantee/ Financial agreements
			shall be made available on working areas			
	People	Health hazards from dust emissions	▪ Implement dust control management ▪ Provide PPEs for dust emissions ▪ Provide on-site medical services in case of emergency ▪ Provide adequate buffer zone and perimeter fence to protect passersby	DPWH	P 100,000	Contractor's MOA
	People	Generation of employment, taxes and additional income	▪ Prioritize hiring of qualified residents of the host communities ▪	DWPH LGU	P 5,000	Contractor's MOA, LGU MOA
C2. Floodgate Operations **C2.1. Operations**	Air	Generation of noise	▪ Proper and regular maintenance of heavy equipment	Floodgate Operator	P 20,000 per month	EMP & ECC
	Water	Generation of domestic wastewater	▪ Installation of 3-chamber septic tanks ▪ Regular monitoring of effluent discharges	Floodgate Operator	P 500,000	EMP & ECC
	Land	Generation of solid wastes from worn-outs stacks	▪ Installation of material recovery facility (MRF) ▪ Observe proper storage of materials	Floodgate Operator	P 100,000	EMP & ECC
	Land, Water	Generation of hazardous wastes (used oil)	▪ Provision of storage area ▪ Collect, store and dispose wastes in safe and sealed containers ▪ Treatment and dispose wastes through accredited treaters	Floodgate Operator	P 100,000	EMP & ECC
C2.2 Floodgate repair and maintenance	Land, Water	Generation of solid wastes	▪ Implement a Solid Waste Management Plan ▪ Segregation of solid waste according to recyclable and non-recyclables ▪ Hauling of discarded/recyclable items by duly licensed traders	Floodgate Operator LGU	P 5,000 per month	EMP & ECC
	Land, Water	Generation hazardous wastes (used oil, busted bulbs)	▪ Provision of storage area ▪ Collect, store and dispose wastes in safe and sealed containers ▪ Treatment and dispose wastes through accredited treaters	Floodgate Operator	P 10,000 per month	EMP & ECC
C2.3 Influx of floodgate operators/workers	Land, Water	Generation of solid wastes	▪ Solid Waste Management Plan ▪ Segregation of solid waste according to recyclable and non-recyclables ▪ Hauling of discarded/recyclable items by duly licensed traders	Floodgate Operator LGU	P 5,000 per month	EMP & ECC
	Water	Generation of domestic wastewater	▪ Follow basic housekeeping policies ▪ Provision of sanitation facilities (i.e. toilets, showers, etc.)	Floodgate Operator	P 10,000	EMP & ECC
	People	Increased occupational safety and health risks	▪ All personnel are required to wear proper PPE ▪ All operation works will be supervised by trained officers ▪ First-aid stations, safety equipment and signage shall be made available on	Floodgate Operator	P 50,000	EMP & ECC

Project Phase/ Environmental Aspect	Environmental Component likely to be Affected	Potential Impact	Options for Prevention or Mitigation or Enhancement	Responsible Entity	Cost (PHP)*	Guarantee/ Financial agreements
			working areas			
	People	Generation of employment	▪ Prioritize hiring of qualified residents of the host communities ▪ Prioritize purchasing of local items, if applicable, within the host communities	Floodgate Operator LGU	P 5,000	EMP & ECC, Labor Code
C3. Generator Building and Control House (Floodgate) **C3.1 Operation and maintenance of equipment**	Air	Generation of air and noise emissions	▪ Proper and regular maintenance of generator sets and motor vehicles ▪ Installation of mufflers	Floodgate Operator	P 50,000 per quarter	EMP & ECC
	Land, Water	Generation of hazardous wastes	▪ Provision of storage area ▪ Collect, store and dispose wastes in safe and sealed containers ▪ Treatment and dispose wastes through accredited treaters	Floodgate Operator		EMP & ECC
C3.2 Influx of workers and employees	Land, Water	Increase in solid and liquid waste generation	▪ Solid Waste Management Plan ▪ Segregation of solid waste according to recyclable and non-recyclables ▪ Hauling of discarded/recyclable items by duly licensed traders ▪ Follow basic housekeeping policies ▪ Provision of sanitation facilities (i.e. toilets, showers, etc.)	Floodgate Operator LGU	P 20,000 per month	EMP & ECC
	People	Potential occupational safety and health risks	▪ All personnel are required to wear proper PPE ▪ All operations works will be supervised by trained officers ▪ First-aid stations, safety equipment and signage shall be made available on working areas	Floodgate Operator	P 100,000	EMP & ECC
	People	Generation of employment	▪ Prioritize hiring of qualified residents of the host communities ▪ Prioritize purchasing of local items, if applicable, within the host communities	Floodgate Operator	P 5,000	EMP & ECC, Labor Code
D. Abandonment Phase (Backfill Site for Dredged Sediments and Floodgate)						
D1. Equipment Pullout and Property Turnover (Backfill Site for Dredged Sediments)	Land	Possible subsidence of backfill site	▪ Limit use of light structures until site is stable	Landowner/ DPWH	To be determined	To be determined
	Air	Generation of dust due to lack of green cover	▪ Regular sprinkling in the area ▪ Conduct monitoring	Landowner/ DPWH	To be determined	To be determined
	Water	Possible contamination due to moisture leakage	▪ Conduct monitoring and repair, if necessary	Landowner/ DPWH	To be determined	To be determined
D2. Floodgate Decommissioning **D2.1 Pull-out of equipment**	Air	Generation of air emission and noise	▪ Proper and regular maintenance of heavy equipment ▪ Installation of mufflers ▪ Perform noisy activities during daytime	To be determined	To be determined	To be determined
D2.2 Demolition of floodgate facilities	Land, Water	Generation of solid wastes and other scraps	▪ Solid Waste Management Plan ▪ Segregation of solid waste according to recyclable and non-recyclables	To be determined	To be determined	To be determined

Project Phase/ Environmental Aspect	Environmental Component likely to be Affected	Potential Impact	Options for Prevention or Mitigation or Enhancement	Responsible Entity	Cost (PHP)*	Guarantee/ Financial agreements
			▪ Hauling of discarded/recyclable items by duly licensed traders			
	Land, Water	Generation of hazardous wastes	▪ Provision of storage area ▪ Collect, store and dispose wastes in safe and sealed containers ▪ Treatment and dispose wastes through accredited treaters	To be determined	To be determined	To be determined
D2.3 Decommissioning of floodgate equipment	Land, People	Sale of vessels or possible turn over to LGU	▪ Possible sale or donation to LGU	To be determined	To be determined	To be determined
D2.4 Termination of employees' contract	People	Loss of employment	▪ Provide 6 months' notice about the impending termination of employment ▪ Provide compensation for affected personnel ▪ If possible, provide re-training of personnel in preparation for other job openings	To be determined	To be determined	To be determined
**** - Estimates only***						

Source: Study Team

10.1.4 Pre-confirmation of Tree Inventory Survey

In accordance with the Philippine laws and regulations, it is mandatory to carry out inventory surveys of trees to be cut down by construction work. The following describes the research policy in accordance with the latest Philippine laws and regulations and guidelines.

10.1.4.1 Related Legislation

According to Department Administrative Order No. 2000-21 (DAO No. 2000-21) issued by the Department of Environment and Natural Resources (DENR) on February 28, 2000, implementation of a tree inventory survey is mandatory in order to obtain a tree cutting permit. This Department Order is based on Republic Act No. 7161 (RA 7161) and its detailed enforcement regulations, deforestation taxes in volumetric units of trees and non-arboreal materials. This tree inventory survey shall be carried out by a registered forest inspector (Forester) and shall be confirmed by the competent DENR office.

In addition, the cutting of coconut tree, which is one of the non-arboreal species, requires a cutting permit as stipulated in RA 8048.

Tree inventory survey and actual logging practices shall be conducted in accordance with DENR-FMB Technical Bulletin No. 3 and DAO 16-2018.

10.1.4.2 Method of Tree Inventory Survey

(1) Flow of Tree Inventory Survey

The tree inventory survey is carried out as follows:

1) Determine the study area.

2) Measure, mark and confirm the quantity of all tree species and crops in the survey area (Young trees with trunk diameter of 4 to 15 cm shall be included in the inventory investigation).

(a) Number all trees and identify their locations by GPS;

(b) Describe common name, diameter at breast height, total height, number of species, and location;

(c) Separate tree lists for non-arboreal species (e.g. bamboo, banana, coconut, etc.). Non-arboreal species include: affected crop species, crop owners, annual crop yields on affected cropland, average crop yields, market classification of crops, number of employees growing the crop concerned, average value of the crop (price), and survey of average annual household income;

(d) Identify fruit tree information (age, fruit owner, average yield, average annual income from fruit trees);

(e) Spray, paint with a brush, or mark with a metal tag;

(f) Position and take pictures with a camera with GPS function;

(g) Make another list of coconuts based on RA 8048;

(h) Review the capacity by tree species under DENR-FMB Technical Bulletin No. 3, as of October 31, 2012;

(i) Create a tree inventory ledger classified by tree species and trunk diameter;

(j) Create a tree layout map; and

(k) Create a photo album, etc.

(2) How to Create an Inventory Ledger

The confirmation method indicated in “h” above uses the following equation.

Dipterocarp species:

$V = 0.00005171 \times (D^2 \times H)$

Non-Dipterocarp species:

$V = 0.00005.204 \times (D^2 \times H)$

Where:

V: Volume of target tree species (m^3)

D: Trunk diameter at breast height (cm)

H: Tree height (m)

10.1.4.3 Survey Results

The implementation of the tree inventory survey started in December 2019 after completion of the basic design and completed in March 2020.

The results were submitted to DPWH and summarized below.

(1) Along Marikina River

1) Results of Tree Inventory Survey

A total of 2,066 trees were assessed on both East and West bank of the Marikina River’s project area. Specifically, East bank consists of 372 individual tree species while the West bank of the river contains 1,694 trees. (See **Table 10.1.11** and **Figure 10.1.8**)

Table 10.1.11 Summary of Results of Tree Inventory Survey along Marikina River

No.	Common Name	Nos.	No.	Common Name	Nos.
1	Narra	391	40	Royal Palm	7
2	Mahogany	303	41	Balete	7
3	Mangga	141	42	Auri	7
4	Yemane	99	43	Langka	6
5	Rain Tree	95	44	Fringon	6
6	Aratilis	81	45	River Red Gum	6
7	African Tulip	66	46	Banaba	6
8	Molave	63	47	Bayabas	6
9	Ipil-ipil	62	48	Hawili	6
10	Bitaog	61	49	Alim	6
11	Kalumpit	53	50	Atsuete	6
12	Bignai	49	51	Golden Shower	5

No.	Common Name	Nos.	No.	Common Name	Nos.
13	Bagras	48	52	Calamansi	5
14	Kupang	37	53	Malunggai	5
15	Fire Tree	31	54	Eucalyptus	4
16	Tuai	27	55	Nangka	4
17	Salisi	26	56	Tibig	4
18	Neem Tree	26	57	Mc Arthur Palm	4
19	Bangkal	24	58	Cacao	3
20	Miscellaneous	23	59	Avocado	3
21	Dit	20	60	Puso-puso	2
22	Talisay	16	61	Atis	2
23	Katuray	15	62	Niog-niogan	1
24	Anabiong	15	63	Himbabao	1
25	Mangium	12	64	Bo GTree	1
26	Duhat	12	65	Kamagong	1
27	Kaimito	12	66	Ayangile	1
28	Santol	11	67	Katap	1
29	Kulibangbang	11	68	Gakakan	1
30	Rimas	11	69	Bagalunga	1
31	American Kapok	11	70	Balimbing	1
32	Kalumpang	11	71	Eugenia	1
33	Eucalyptus Sweet Gum	10	72	Bani	1
34	Kamachile	10	73	Fishtail Palm	1
35	Guyabano	10	74	Agoho	1
36	Indian Lanutan	9	75	Terminalia sp.	1
37	Sampalok	9	76	Cadle Tree	1
38	Dao	7	77	Jathropa	1
39	Ilang-Ilang	7	78	Is-is	1

Source: Study Team

Source: Study Team

Figure 10.1.8 Location of Trees Surveyed along Marikina River

2) Results of Crop Inventory Survey

In terms of crops, the project area consist of 50 different crop species assessed from 8 farms along both of the riverbanks. Aside from the 15 coconut trees, different crops such as bamboos (84 clumps), banana (50 individual) and various vegetable crops were also noted in the area.

Table 10.1.12 Summary of Results of Crop Inventory Survey along Marikina River

No.	Common Name	No.	Common Name	No.	Common Name
1	Coconut	18	Kalabasa	35	Papaya
2	Banana	19	Kamatis	36	Patola
3	Bamboo	20	Kamias	37	Pechay
4	Alugbati	21	Kamote	38	Petsay
5	Ampalaya	22	Kamoteng Kahoy	39	Saing
6	Atis	23	Kangkong	40	Saluyot
7	Balinghoi	24	Kastanas	41	Sanglai
8	Banana	25	Lemon Grass	42	Sili
9	Bayabas	26	Lettuce	43	Sitau
10	Binunga	27	Luyang Dilau	44	Squash

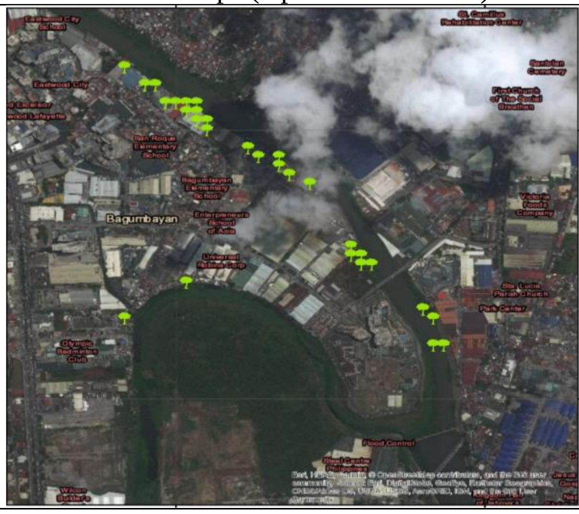
No.	Common Name	No.	Common Name	No.	Common Name
11	Corn	28	Malunggai	45	Suha
12	Cucumber	29	Malunggay	46	Talbos
13	Duhat	30	Mixed	47	Talbos
14	Eggplant	31	Mustasa	48	Talong
15	Gabi	32	Nangka	49	Tanglad
16	Isis	33	Niyog	50	Upo
17	Kakauate	34	Okra		

Source: Study Team

For Coconut

Other Crops (Upstream Sections)

Other Crops (Middle stream Sections)



Other Crops (Downstream Sections)

Source: Study Team

Figure 10.1.9 Location of Crops Surveyed along Marikina River

3) Proposed Compensation Works during Construction Stage

A predicted compensation cost for the affected trees and coconut crops were determined with the guide of relevant policies and regulations. This shows that 736 trees are applicable for earth-balling, 132, 250 tree seedlings and 15 coconut seedlings are projected for the replacement on the trees and coconuts to be subjected for cutting. In addition, an amount of Php. 1,500.00 must be provided to the Philippine Coconut Authority as an application fee for the compensation of the affected coconuts. The concerned CENRO (DENR-NCR) will issue the Tree Cutting Permit and/or Earthballing permit which will indicate the exact number of trees to be cut and number of seedlings to compensate based on the analysis of the appropriate infrastructure plan on the result of their ocular inspection.

(2) Along the Manggahan Floodway for Cainta and Taytay Floodgates

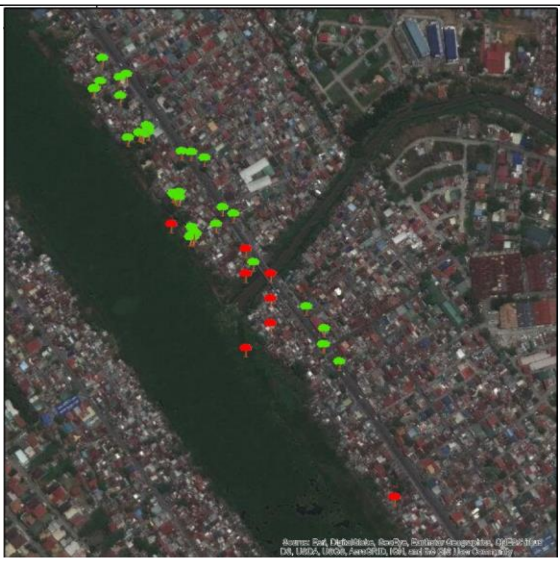
1) Results of Tree Inventory Survey

A total of 315 trees representing 35 species were surveyed; 121 trees were accounted in Taytay area which dominated by Bangkal, Aratilis, and Mangga. Similar species dominated in Cainta area of 194 trees. Narra recorded the highest total basal area and volume followed by Mangga and Bangkal in Taytay while Bangkal, Mangga and Aratilis in Cainta. Most of the trees are found near flood fringe, which may be due to soil moisture that gives favorable condition to the trees. For trunk diameter, majority are small diameter (5-15cm) which indicates that inventoried trees have not yet reach matured stage.

Table 10.1.13 Summary of Results of Tree Inventory Survey along Manggahan Floodway

Site in Cainta Floodgate			Site in Taytay Sluicegate		
No.	Common Name	Nos.	No.	Common Name	Nos.
1	Bangkal	47	1	Aratilis	45
2	Aratilis	46	2	Bangkal	28
3	Mangga	16	3	Mangga	8
4	Talisay	12	4	Narra	7
5	Malunggay	10	5	Malunggay	6
6	Guava	7	6	Balete	4
7	Balete	6	7	Guava	4
8	Botong	6	8	Talisay	3
9	Sampalok	4	9	Hawili	2
10	Miscellaneous	4	10	Makopa Alim	2
11	Fire Tree	3	11	Katuray Atsuete	1
12	Guyabano	3	12	Caimito	1
13	Caimito	3	13	Avocado	1
14	Ipil-Ipil	3	14	Duhat	1
15	Narra	3	15	Alagaw	1
16	Santol	3	16	Guyabano	1
17	Tuba-tuba	2	17	Santol	1
18	Hawili	2	18	Indian Lanutan	1
19	Duhat	2	19	Ipil-Ipil	1
20	Atsuete	1	20	Botong	1
21	Avocado	1	21	Mangkono	1
22	Alagaw	1	22	Rain Tree	1
23	Binunga	1			
24	Cacao	1			
25	Indian Lanutan	1			
26	Kalumpit	1			
27	Kamachile	1			
28	Kamias	1			
29	Nangka	1			
30	Salisi	1			
31	Yemane	1			
	Total	194		Total	121

Source: Study Team

	
View for Site of Cainta Floodgate	View for Site of Taytay Sluiceway

Source: Study Team

Figure 10.1.10 Location of Trees Surveyed along Manggahan Floodway

2) Results of Crop Inventory Survey

In terms of crops, the Taytay area consists of 16 different crop species; bananas (147 individuals) and various vegetable crops were noted in the area while Cainta has 18 different species of crops. Bamboo (7 clumps), banana (65 individuals), and other various vegetable crops were accounted in the area. A total of 12 coconut trees were surveyed in both areas; 3 are found in Taytay and 9 are located in Cainta.

Table 10.1.14 Summary of Results of Crop Inventory Survey along Manggahan Floodway

Site in Cainta Floodgate		Site in Taytay Sluicegate	
No.	Common Name	No.	Common Name
1	Papaya	1	Talbos ng Kamote
2	Talbos ng Kamote	2	Banana
3	Kangkong	3	Sili
4	Bamboo	4	Kamatis
5	Banana	5	Gabi
6	Talong	6	Papaya
7	Gabi	7	Talong
8	Mutasa	8	Kamote
9	Kalamansi	9	Ampalaya
10	Alugbati	10	Tanglad
11	Ampalaya	11	Okra
12	Kamatis	12	Patola
13	Patola	13	Kalabasa
14	Okra	14	Upo
15	Kamote	15	Munggo
16	Squash	16	Coconut
17	Sugarcane		
18	Kamoteng Kahoy		

Source: Study Team

Distribution of Coconut Trees (Cainta)

Distribution Coconut Trees (Taytay)

Distribution of Other Crops (Cainta)

Distribution of Other Crops (Taytay)

Source: Study Team

Figure 10.1.11 Location of Crops Surveyed along Manggahan Floodway

3) Proposed Compensation Works during Construction Stage

Indicative total of 11,300 seedlings will be replaced for the affected 122 trees. Of the 122 trees, 18 are planted trees which corresponds to the replacement of 900 (preferably indigenous species) seedlings while the 104 naturally grown trees and premium species shall be replaced by 10,400 (strictly indigenous species) seedlings. There 193 tees classified as healthy and with DBH<15cm suggested for earth-balling. In terms of coconut, a total 12 coconut trees accounted in both survey areas, hence, estimated 12 seedlings for the replacement. An indicative amount of Php 1,200.00 application fee and additional Php.200.00 for processing fee must be provided to the PCA Regional Office.

10.1.5 Capacity Improvement Support Seminar of the DPWH in Environmental and Social Considerations

In order that the DPWH can conduct appropriate monitoring activities (including methods for monitoring terrestrial and aquatic organisms) of the project in line with the EMP and EMoP, half-day training web-seminar (workshop) was conducted for staff members of the ESSD and the UPMO-FCMC of the DPWH, on July 28, 2020.

In the web-seminar, a workshop was also held: (1) to promote the capacity building of DPWH personnel through this seminar with regard to the environmental monitoring report (quarterly in the prescribed format), which is required to be submitted to JICA, and (2) to decide on how to report the status of environmental and social considerations in the Project Status Report.

10.1.6 Review of the EIS for the Main Riverine

The supplemental EIS for the main riverine was already approved by the DENR, and reviewed trough the survey by the Study Team. The Study Team decides no or few amendments are required for the EIS at the moment because of: the environmental condition has not been changed since the period of the EIS preparation with the results from surveys for riverbed sediment and tree inventory.

10.2 Resettlement Plan

The project involves the acquisition of approximately 12.4 ha of land and the relocation of seven (7) utilities, as well as the relocation of 9,327 Informal Settler Families, or ISFs. The procedure for land acquisition and resettlement under the project is based on the resettlement plan prepared in accordance with the domestic procedures and the JICA Guidelines for Environmental and Social Considerations. No particular oppositions to the implementation of the project have been confirmed during the residents' consultations concerning the project.

As of June 2020, in parallel with the detailed design, the Study Team has been supporting the revision of the above-mentioned Resettlement Action Plan (RAP) developed by DPWH, but the number of non-regular residents to be resettled shall be clarified. The outline of the confirmation survey is shown below. No specific oppositions to the project have been confirmed at present in the consultations with the residents.

10.2.1 Review of Resettlement Action Plan (RAP) and Assistance of Required Works

10.2.1.1 Confirmation of Compensation Policy for Current Resettlement Action Plan and Budget Based on the Current Plan

The affected entities by the Project are divided into two categories as follows:

1. Residents and businesses along the main river and around the structure that suffer direct loss of land and property due to river improvement and construction of river structures.
2. Informal residents living inside Manggahan Floodway which are indirectly affected by the implementation of this Project.

DPWH has formulated the following two RAPs for the implementation of this Project:

- Resettlement Action Plan for Marikina River;
- Resettlement Action Plan for Manggahan Floodway

These two RAPs were prepared in principle according to JICA's Guidelines for Environmental and Social Considerations. A comparison of the legal basis, provisions and implementation policies of the resettlement plan with the JICA Guidelines is provided in Chapter 2 of each RAP. This section summarizes and clarifies the current RAP, especially the compensation conditions and their budget.

(1) RAP for Marikina River

1) Land Acquisition

In the current RAP, the land along the river is used as the basis for paying the property tax, using the land unit price called BIR Zonal Value and the fair market value unit price at the time of general land sales (Fair Market Value). These purchase costs have been estimated at PHP 18.6 billion and PHP 45.5 billion, respectively (the land purchase cost of the resettlement site is recorded separately as ISF transfer cost). However, in accordance with Republic Act 10752 enacted in 2016, it will only be acquired at market prices and <u>will need to be modified within this study</u>.

2) Compensation for Structure

Based on the current unit price of construction materials, labor and equipment, etc., the price is estimated at PHP 18,000 per m^2 of building, and about PHP 129 million is calculated as compensation for buildings affected by the project. This study will support the review of the area of the affected buildings and the compensation unit price.

3) Income Rehabilitation Assistance for Affected Business

Due to the impact of the Project on land and buildings, the current RAP requires business compensation for seven shops. Based on DPWH's 2007 Land Acquisition, Resettlement, Rehabilitation and Indigenous Peoples' Policy (LARRIPP (2007)), the RAP sets from PHP 15,000 per to PHP 105,000 per shop. In this Study, since the business unit price of DPWH is extremely low, consideration will be given to river channel design so that project area (ROW) that does not require business compensation as much as possible is taken account of.

4) Cost for Relocating the Informal Settlers

71 ISFs (277 people) are in the Project area and need to be relocated. Costs required for relocation are estimated at PHP 450,000 for relocation site and house preparation, PHP 18,000 for relocation subsidies, and PHP 10,000 for transportation and meals for relocation, totaling PHP 32 million are included in the current RAP.

However, as of November 2019, the ISFs that directly affect the business of these 71 households are included in a separate city-wide riverside ISFs relocation project implemented by Quezon City with the NHA. This situation is described in detail in section 10.2.1.2.

(2) RAP for Manggahan

The RAP in the Manggahan Floodway, which is currently being prepared by DPWH, is intended for residents in Cainta and Taytay Municipalities. On the other hand, relocation within the Floodway within Pasig City is not included in the DPWH-prepared RAP, as it was previously implemented by a ISFs' resettlement program for the ISFs currently living along the Floodway in Pasig City.

1) Land Acquisition, Compensation for Structures and Income Rehabilitation Assistance for Affected Business

Since only the informal settlers currently living in the Floodway are indirectly affected by the project, land acquisition costs, compensation for structures and income rehabilitation assistance required for the project will not occur.

2) Cost for Relocating the Informal Settlers

Based on the tagging and census survey conducted by NHA from 2016 to 2017, the resettlement costs of informal settlers in the Floodway in Cainta and Taytay Municipalities are shown in **Table 10.2.1**.

Table 10.2.1 Resettlement Costs for Informal Settlers in Manggahan Floodway

Unit: PHP

Item	Cainta	Taytay
Number of Confirmed Households	9,256	4,269
Number of Entitled Households for Relocation Assistance	7,483	3,382
Resettlement Costs		
Preliminary activities and studies	99,830,000	80,820,000
Social preparation	74,830,000	33,820,000
Parcellary survey and subdivision plan survey		10,000,000
Conduct of EIA to acquire ECC	5,000,000	5,000,000
Conduct of tree inventory to acquire tree cutting permit		2,000,000
Land development planning (incl. topographic survey and geotechnical study)	20,000,000	30,000,000
Procurement of Resettlement Site	300,000,000 175,000,000	167,500,000
Resettlement Site Development Costs	86,893,400	298,171,000

Item	Cainta	Taytay
Resettlement Housing Development Cost	2,956,800,000	1,328,500,000
Demolition/ Hauling Cost	286,495,000	149,646,000
Transfer of Informal Settlers to Resettlement Housing	59,864,000	27,056,000
Rehabilitation Assistance	18,900,000	11,235,000
Total	3,983,782,400	2,143,748,000

Source: RAP for Manggahan Floodway (DPWH, 2018)

10.2.1.2 RAP for Marikina River

This section describes the current activities and related status of the RAP for Marikina River, which is a plan to acquire land along the main river where the river channel is to be rehabilitated and to relocate buildings and irregular residents.

(1) Relocation Plan for Informal Settler Families (ISFs) along the River Channel in Quezon City (on the Right Bank of the Main River)

In DPWH's RAP for Marikina River developed in 2018, relocation is required for 71 ISFs living along the river on the right bank at Sta.5 + 750 to Sta.8 + 700 from the lower to the middle stream of the target section, and a relocation plan has been being compiled.

1) ISFs Relocation Program along Marikina River by the National Housing Authority (NHA) and Quezon City

The relocation of the 71 ISFs indicated in the latest RAP for Marikina River mentioned above was implemented by the National Housing Authority (NHA) in 2015, to all the ISFs along the Marikina River in Quezon City that need to be relocated, and was designed based on the results of the Tagging and Census survey. The NHA survey identified 438 ISFs along the Marikina River in Quezon City, of which 71 needed to be relocated for business.

At the moment, NHA and Quezon City have been planning a relocation program for all ISFs (438 households) along the Marikina River in Quezon City

In 2018, NHA officially announced to Quezon City that it would have access to a relocation site for 481 households located in Baras Municipality, Rizal Province as the document shown in **Figure 10.2.1**.

Office of the President
NATIONAL HOUSING AUTHORITY

CERTIFICATION

To Whom It May Concern:

This is to certify that there are **Four Hundred Eighty One (481) available housing units** within **St. Joseph Residences 1** located in **Barangay Pinugay, Baras, Rizal**, to accommodate the ISFs residing along Marikina River from Brgy. Bagumbayan (Upper Stream), Tawiran and Mercury Ave) Quezon City.

This certification is being issued this **17th day of August 2018** for whatever legal purpose this may serve.

ENGR. LORENZO D. PINEDA
Manager
BN 2/SV9 & 10 Rizal Housing Projects

Noted by:

AR. SUSANA V. NONATO
Regional Manager, Region 4

Source: Quezon City

Figure 10.2.1 Image of Document on the Relocation of ISFs along the Marikina River in Quezon City Issued by the NHA

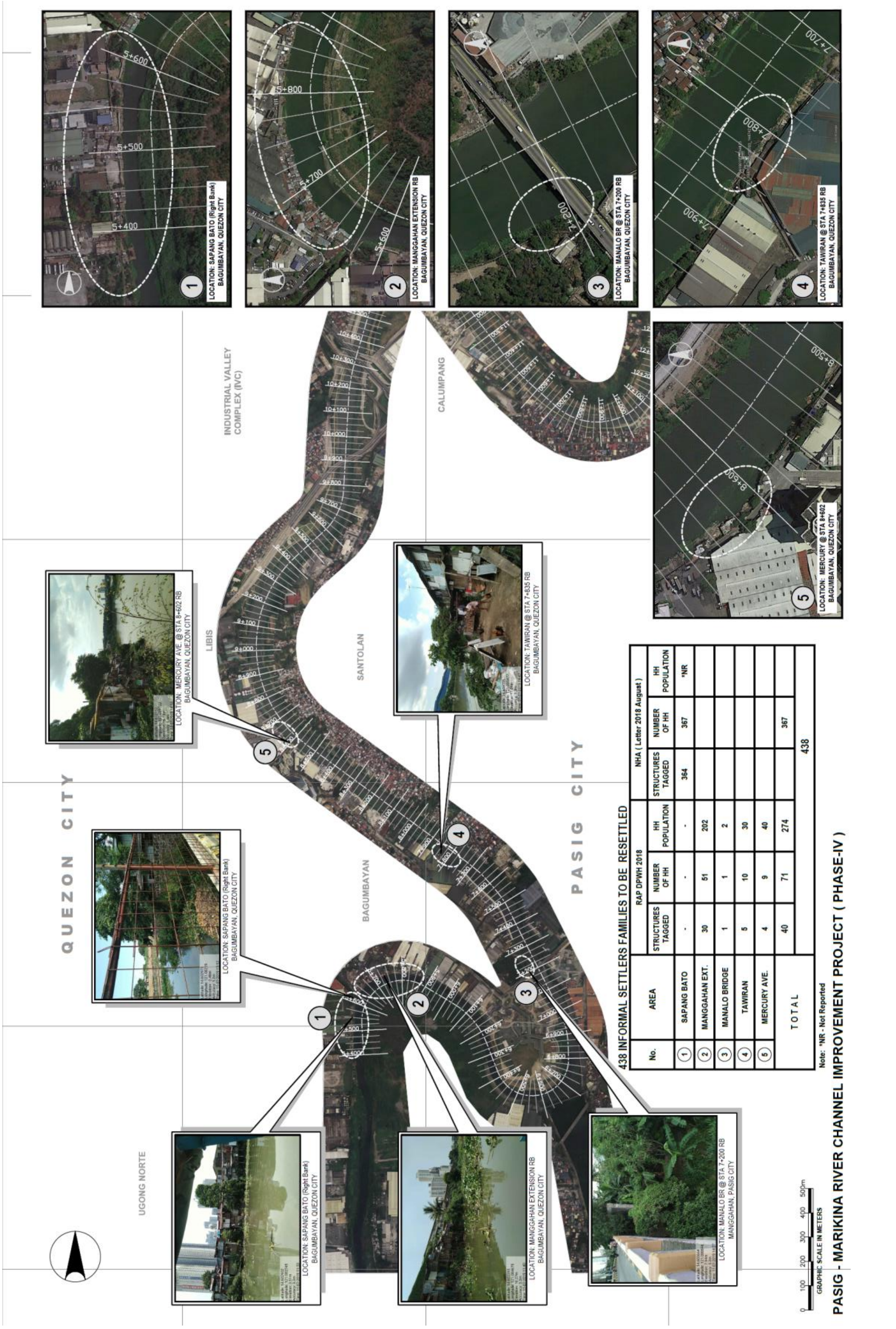
2) Relationship between 438 ISFs Targeted by NHA and Quezon City and 71 ISFs Requiring Relocation in the Project

Figure 10.2.2 and **Table 10.2.2** indicate the relationship between the 438 ISFs to be relocated along the Marikina River, which the NHA and Quezon City independently promote, and the ISFs targeted for this Project.

Table 10.2.2 Status of ISFs along the Marikina River in Quezon City

Area Name	Station Point	No. of ISFs	Position of ISFs in this Project	
Sapang Bato	Sts.5+400~5+700	367	This area is not included in the plan due to: - Only the dredging work is implemented in the FS, and does not affect ISFs. - At the time of 2015, improvement of drainage channels had already been planned to relocate ISFs in the area.	
Manggahan Ext.	Sta.5+700~5+900	51	ISFs directly affected by the project	Total: 71 ISFs
Manalo Bridge	Sta.7+200~7+300	1		
Tawiran	Sta.7+700~7+900	10		
Merury Ave.	Sta.8+600~8+700	9		
All Areas	All (only on right bank)	438		

Source: Study Team



Source: Study Team

Figure 10.2.2 Location Confirmation Map of ISFs along Marikina River in Quezon City

3) Riverbank Improvement after ISFs Relocation in Sapang Bato District by Quezon City

DPWH, in consultation with Quezon City, decided to include riverbank development (bank protection) after the relocation of ISFs, which was not included in the previous project relocation plan, for the following reasons;

- Creating the environment where ISFs will not return to the area:
- Because the opposite bank (left bank) sets the project ROW based on the request from the riverbank landowner, it is desirable to set the ROW that clearly positions the right bank on the river including the riverbank (In the proposed FS, no ROW was set in the area.)

DPWH conditionally changed the policy of setting the ROW down to the riverbank in order to implement river maintenance management in cooperation with MMDA. The condition is that Quezon City will relocate the ISFs, and in order to manage rivers appropriately in the future, the revetment of this area by the Project and the setting of ROWs will be conducted in the Parcellary Survey after the detailed design.

4) Issues and Response Policies in this Project

The details of the transfer from NHA to Quezon City are the relocation site of Brgy. Pinugay, located in Baras Municipality, Rizal Province. To implement the relocation, a Memorandum of Agreement (MOA) between Quezon City and Baras Municipality is required, but as of August 2020, it has not been signed yet.

According to the Housing, Community Development and Resettlement Department (HCDRD) and the Mayor's Office, which are in charge of the relocation activities in Quezon City, and as mentioned above, the MOA on the relocation will be made in Quezon City and Baras Municipality in the future and relocate 438 households. Quezon City already confirmed the resettlement site on October 17, 2019. MOA has also been drafted, but no conclusion has been reached on the sharing of responsibilities between the two entities (especially follow-up activities to the ISFs after the relocation), nor no conclusion has been reached. .

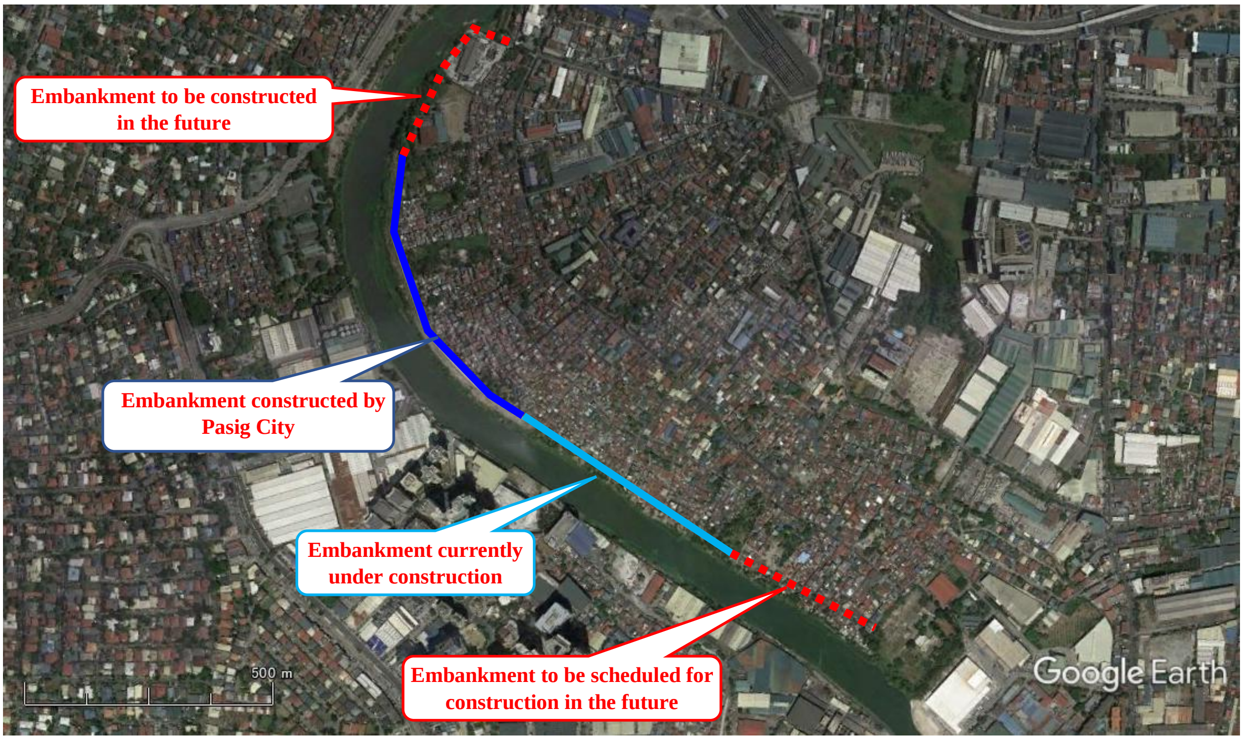
Therefore, if Quezon City and Baras Municipality conclude the MOA earlier, the relocation will be implemented before the Project. Conversely, if the conclusion of the MOA between the municipalities is delayed, DPWH will need to implement the relocation project based on the RAP for Marikina River targeting 71 ISFs. It is necessary to determine the timing of this determination. If the relocation program by Quezon City and Baras Municipality would not be implemented, the relocation of 367 ISFs in the Sapang Bato Area will need to be redesigned for dredging only without revetment (return to the plan at the time of FS in 2015).

(2) Relocation of ISFs in Pasig City

1) Status of Implementation of ISFs Relocation

In Pasig City, Brgy. Santolan is the area where the ISFs affecting the project reside. In this area, Pasig City itself has been carrying out embankment construction, and for this purpose, the relocation of ISFs affecting the construction has been going on. Therefore, the RAP for Marikina River produced by the DPWH does not include the relocation plan for this area.

As of January 2020, the embankment project with the above relocation is under construction with the “Emergency embankment currently under construction”' section shown in **Figure 10.2.3**, and the embankment from Sta.8 + 900 to Sta.7 + 850 has been already stretched.



Source: Google Earth, with information from Pasig City

Figure 10.2.3 Progress of Embankment Construction by Pasig City

It was because that the interim elections held on May 13, 2019 resulted in the replacement of the ex-mayor of Pasig City who had been carrying out the embankment work to the new mayor (Mr. Victor Ma. Regis N. Soto).

For this reason, DPWH-UPMO-FCMC, the executing agency of the construction, paid tribute to the new mayor twice in September and November 2019, and requested understanding of the Project, implementation of the flood control project by Pasig City itself and cooperation with the Project, and continuous implementation of the relocation project for the ISFs along the river channel to a safe place.

The attitude of the Flood Control Section of the Construction Bureau of Pasig City is as follows.

- The City Bureau of Construction will proceed with the planned and remaining embankment improvement projects in the future, but make adjustments so that the contents of this project, which is planned by DPWH, will not overlap in the future.

2) Number of ISFs in Sections where Embankment Project have been Remained

As shown in **Figure 10.2.3**, the remaining sections of the embankment Project section where the project has not been completed include the two sections, the upstream end and the downstream end of the Project section. Of these, the ISFs stay in the downstream end section in Pasig City and the embankment construction site of this Project. There are 248 ISFs living in this section, according to an official of Home Construction Bureau of Pasig City.

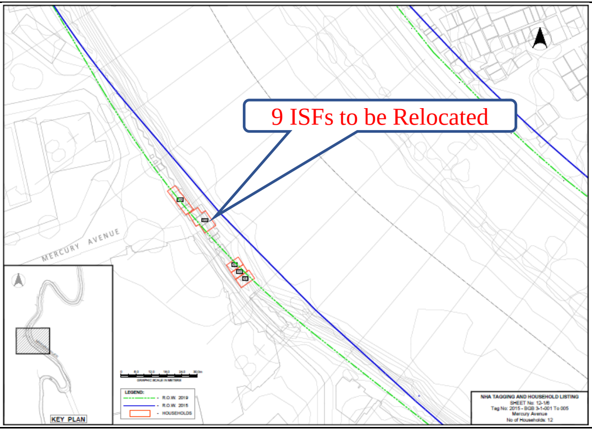
3) Issues and Response Policies in this Project

The ISFs in Santolan Area who had been involved in flood control projects by Pasig City have been relocated to Morong Municipality in Rizal Province, where NHA developed.

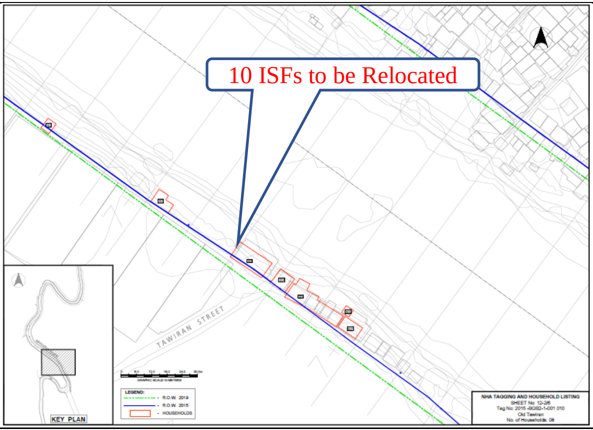
DPWH needs to encourage the Housing Construction Authority of Pasig City to complete the resettlement before the Project is implemented, as the relocation of 248 ISFs in the Santolan Area is not yet proceeding.

(3) Detailed Location Map of ISFs Residence in the Section where this Project is Implemented

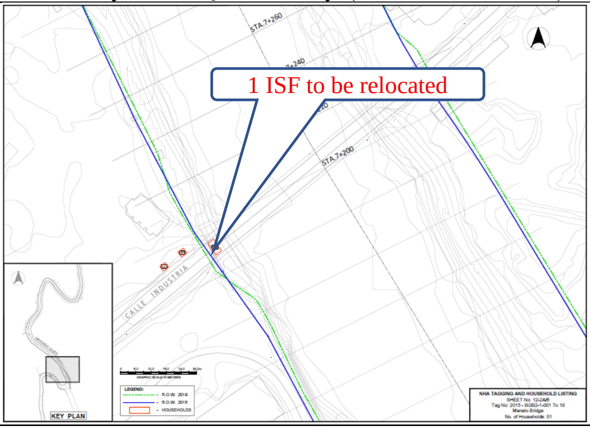
As for the ISFs settlements shown in **Figure 10.2.2**, the NHA conducted a detailed survey in 2015. The results are shown in **Figure 10.2.4**.



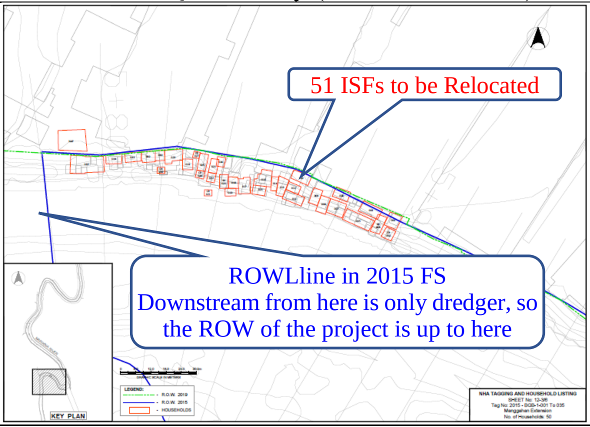
Mercury Ave., Quezon City (Sta.8+600~8+700)



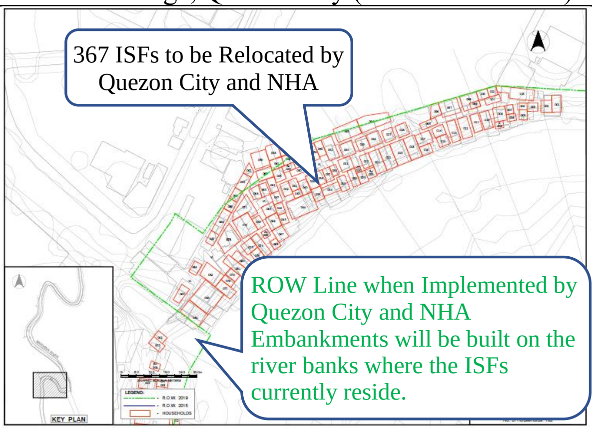
Tawiran, Quezon City (Sta.7+700~7+900)

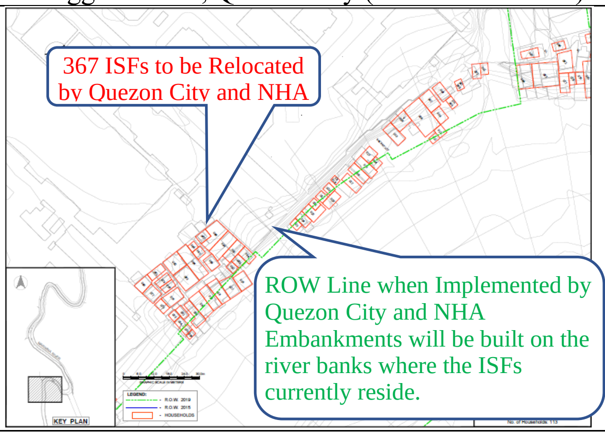


Manalo Bridge, Quezon City (Sta.7+200~7+300)

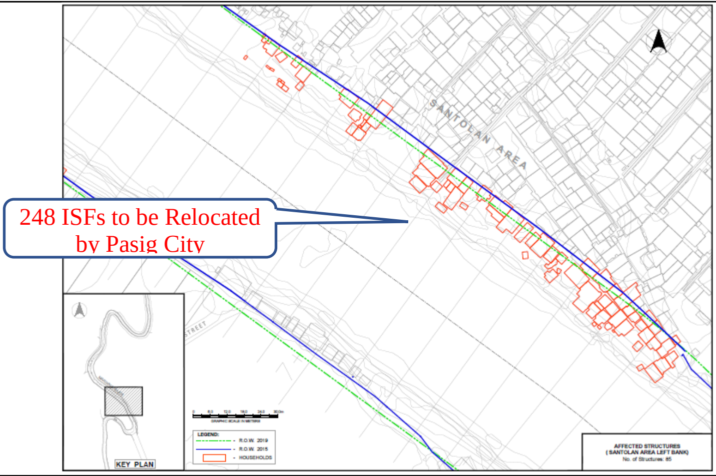


Manggahan Ext., Quezon City (Sta.5+700~5+900)





Sapang Bato, Quezon City (Sts.5+400~5+700)



Santolan Area, Pasig City (Sta.7+600~7+900)

Source: Prepared by the Study Team based on NHA Survey Results

Figure 10.2.4 Confirmation Map of ISFs Living in the Project Area

10.2.1.3 RAP for Manggahan Floodway

(1) Relocation of ISFs inside Manggahan Floodway in Cainta and Taytay Municipalities

1) Coordination activities between the National Housing Authority (NHA) and the DPWH

(a) Preparation of Memorandum of Understanding for Development of Relocation Sites between the National Housing Authority (NHA) and the DPWH

In February 2019, a memorandum of understanding for the development of relocation sites was made between the National Housing Authority (NHA) and the DPWH regarding the ISFs inside Manggahan Floodway in Cainta and Taytay municipalities and concluded in November 2019.

The original memorandum stated that DPWH will prepare PHP 5,514,816,000 (approximately 11 Billion JPY) for relocation of the 10,865 ISFs in the two municipalities, which would be delivered to the NHA for the implementation of the relocation project. In fact, however, the above amount was changed to PHP 6.0 billion and then concluded. **Table 10.2.3** shows the division of responsibilities of the DPWH and the NHA under the MOA.

Table 10.2.3 Division of Responsibilities between DPWH and NHA in Phase-IV (Draft)

DPWH	NHA
• Detailed design and construction of structural measures for the Phase IV projects • Implementation of parcellary survey • Support to NHA's surveys and confirmation surveys of relocation targets for Project-Affected-Families (PAFs) • Preparation and renewal of resettlement action plan (RAP) • Transfer of PHP 5,514,816,000 to NHA for land acquisition, construction of middle-rise building (MRB) and other expenses. • Implementation of detailed design for the development of relocation areas inside municipalities. • Implementation of the development work on the relocation areas inside the municipalities. • Provision to NHA of a list of priority zones for the removal and disposal of buildings in the Floodway. • Assistance to the NHA in obtaining the necessary applications. • Approval on the rearrangement of area transferred from the NHA.	• Confirmation of the transfer of funds from DPWH for the acquisition of transferred land and the construction of medium rise building (MRB). • Implementation of identification, relocation/ replacement and social preparation support activities for the eligible households in cooperation with relevant municipalities. • Confirmation and coordination of parcellary survey. • Land acquisition and housing construction. • Implementation of relocation and migration projects within 60 months. • Submission of monthly transferred fund use report to DPWH. • Liquidation of transfer funds. • Submission of annual business financial report. • Return of removal site inside the Floodway to DPWH.

Source: Study Team

(b) Issues for Implementation of Resettlement between NHA and DPWH

As noted above, the MOU on the implementation of relocation between NHA and DPWH was signed on November 11, 2019. To facilitate this conclusion, workshops on the relocation were held on September 25 and October 3, 2019 among stakeholders of NHA and DPWH, and opinions were exchanged.

In these two workshops, it was confirmed that the relocation project was planned based on the fundamental conditions shown in **Table 10.2.4**, based on the claims of the NHA.

Table 10.2.4 Fundamental Conditions for Relocation Plan

Item	Fundamental Condition	Cainta	Taytay
Type of Relocation Site	Housing Complex (H.C.)	Housing Complex	Housing Complex
No. of Target Families	All: 10,865 Families	Approx. 3,600	Approx. 7,500
No. of Families per H.C.	12 Families/ story×5 stories = 60 Families, 24m^2/ Family	48	48
No. of Required H.C.		75	157
Unit Construction Cost per H.C.	PHP 40 Million (2019~2020) PHP 42 Million (2021~2023)		
Required Area for Relocation Site	7 Buildings/ ha	10 has	23 has
Unit Cost for Relocation Site	Market Value	PHP 3,500/m^2	PHP5,000/m^2

Source: Study Team

As a result of the above, the necessary budget for each year shown in **Table 10.2.5** was estimated, including social support activities for irregular residents. The required budget is supposed to be PHP 12 billion, which greatly exceeds PHP 5.5 billion that DPWH estimates in the project implementation plan (I/P) and has been approved by NEDA, or PHP 6 billion specified in the MOA with NHA.

Table 10.2.5 Budget for Relocation of ISFs in Manggahan Floodway by DPWH-NHA Joint Workshop (NHA Implementation Project)

Activity Item	Annual Budget (PHP mil)					Total
	2019	2020	2021	2022	2023	
A. Advance Activity						
1. Land Acquisition						
1.1 Taytay	400					
1.2 Cainta	1,250					
2. Social Assistance	250					
3. Revised Household Survey	100					
Sub-total 1	2,000					2,000
B. Development of Relocation Site						
1. Construction of Housing Complex in Taytay		400	840	840	1,050	
2. Construction of Housing Complex in Cainta		1,600	3,360	1,554		
Sub-total 2		2,000	4,200	2,394	1,050	9.644
Total	2,000	2,000	4,200	2,394	1,050	11,644 12,000

Source: DPWH-UPMO-FCMC

Therefore, it is necessary to consider the following two items in the RAP revision based on the MOA and two workshops by DPWH and NHA stakeholders:

- The implementation phase of the relocation of DPWH at PHP 5.5 billion approved by NEDA as a project cost or at PHP 6 billion specified in the MOA; and
- The final resettlement plan at PHP 12 billion, which the NHA estimated to be necessary for

ISFs in the Floodway in Cainta and Taytay Municipalities.

2) Activities by Cainta and Taytay Municipalities

At the time of the courtesy calls to the mayors, the Urban Poor Affairs Office (UPAO) and the Municipal Assessor conducted by DPWH after the mid-term election on May 13, 2019, both Municipalities showed an agreement to cooperate with the resettlement of ISFs in the Floodway in collaboration with DPWH and NHA.

(2) Unique Activities for Relocation for ISFs inside Manggahan Floodway in Pasig City

1) Present Condition

Pasig City has already implemented the relocation of ISFs in the Floodway in the city. Specifically, relocation of about 2,000 ISFs on the left bank of the Floodway has been completed. Currently, about 2,798 ISFs on the right bank (West Manggahan) have been remained. Prior to the mid-term election in May 2019, 900 ISFs were scheduled to be relocated by 2019, based on the relocation plan approved by the former mayor, and the rest by 2020 (Refer to **Table 10.2.6**).

Therefore, the relocation of ISFs in the Floodway in Pasig City has not been included in the contents of the current RAP for Manggahan Floodway.

Table 10.2.6 Pasig City's Relocation Plan for ISFs on the Right Bank of Manggahan Floodway before the Midterm Election in May 2029

Items to be considered	Targets and Considerations	Remarks
Number of Target Families	Year 2019: 900 out of a total of 2,798 target ISFs Year 2020: Remaining ISFs	Reconfirmation required
Relocation Site	Morong Municipality in Rizal Province	Same as the left bank (Santolan Area)
Start of Relocation	After the midterm election on May 13, 2019	Reconfirmation is necessary because the mayor changed
Scheduled End of Relocation	December 2019	

Source: Based on interviews with Pasig City by the Study Team

However, due to the results of the mid-term election held on May 13, 2019, the former mayor who had promoted this relocation project was rejected and the new mayor was appointed in July 2019. According to city officials, the relocation of ISFs in the Floodway under the new mayor has been delayed.

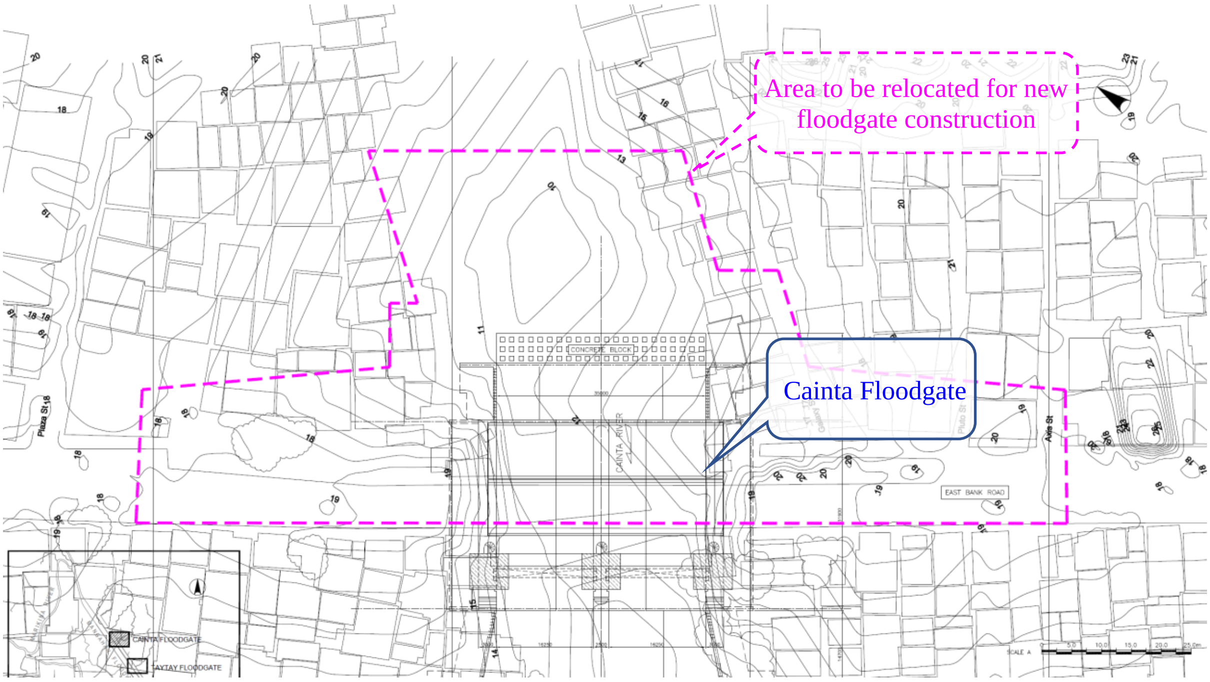
DPWH paid courtesy calls to the new mayor in August and November 2019, requesting to understand the project and continue the relocation of ISFs along the main river and Floodway required for the Project.

2) Policy of Housing Authority of Pasig City

In meetings between DPWH and Pasig City Housing Construction Bureau, the Bureau stated that the explanation has been and will be continued within the city administration in order to obtain the understanding of the new mayor, and that DPWH will continue to conduct courtesy activities.

(3) Relocation of Residents inside the Embankments for Cainta Floodgate Construction

The basic design report of this detailed design was formally submitted and approved on October 9, 2019 after discussions with DPWH. Based on this result, in the construction work of Cainta Floodgate, it was revealed that not only the ISFs already included in the current RAP inside the Floodway but also the residents living inside the embankments within the framework shown in **Figure 10.2.5** including the formal residents would be necessary.



Source: Study Team

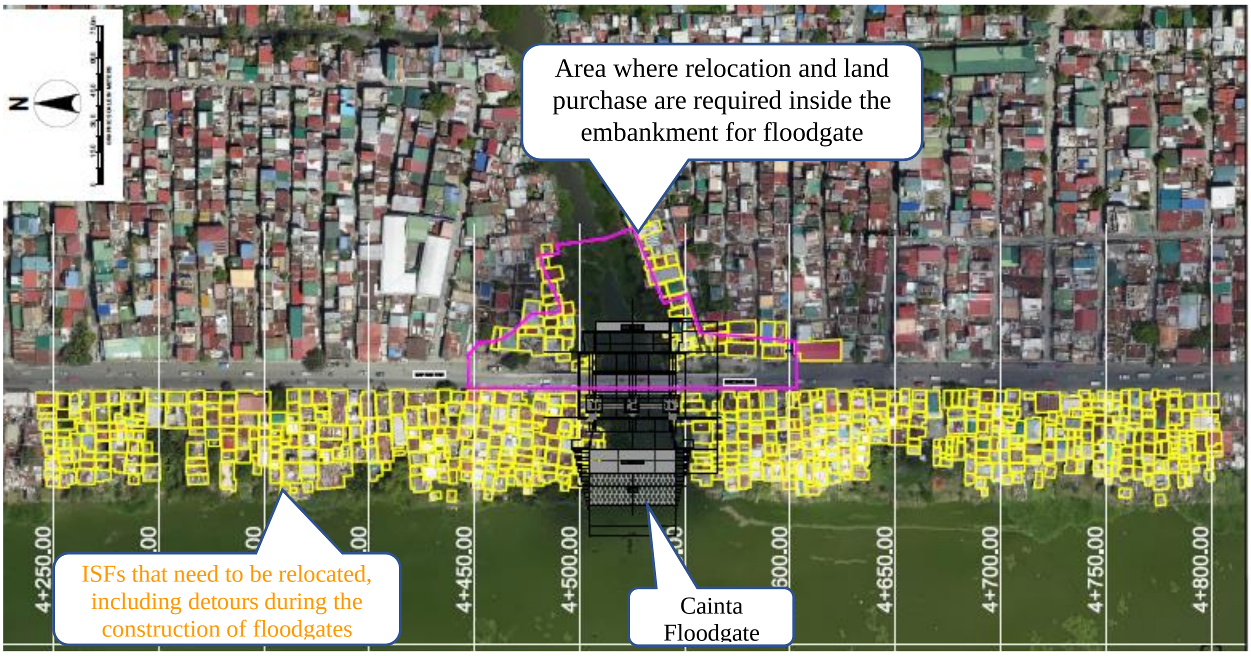
Figure 10.2.5 General Plan View of Cainta Floodgate Construction

After confirming the results in advance with the EMB of the DENR's regional office, it was instructed that an EIA study was required. Therefore, in this study, environmental impact studies have been carried out for the construction of the Cainta Floodgate and the sediment landfill site shown in Section 10.1.3.2 to obtain Environmental Compliance Certificates thru subcontracted EIA survey.

(4) Revision Support Policy for RAP for Manggahan Floodway

Based on the conditions (1) to (3) above argued, DPWH decided to revise and finalize the relocation plan for ISFs residing in the Manggahan Floodway according to the following policy:

- The updated RAP prepares the implementation plan in three phases:
  - The relocation necessary for the construction of Cainta Floodgate and Taytay Gutter is implemented as Phase 1, with the top priority (refer to **Figure 10.2.6** and **Figure 10.2.7**);
  - Relocation of residents and land acquisition required for the construction of Cainta Floodgate are included in RAP for Manggahan Floodway and implemented in Phase 1 (refer to **Figure 10.2.5** and **Figure 10.2.6**);
  - Phase 2 is the implementation of relocation based on NEDA-approved PHP.5.5 billion or PHP.6 billion listed in MOA with NHA. The target of this Phase 2 is mainly the residents who may be affected before and after the implementation of this Project; and
  - Relocation of ISFs living in all floodways not included until Phase 2 is implemented as Phase 3.
- For the relocation of ISFs in the Floodway within Pasig City, DPWH periodically works to promote the resettlement.



Source: Study Team

Figure 10.2.6 Necessary Relocation Area for Construction of Cainta Floodgate

Source: Study Team

Figure 10.2.7 Necessary Relocation Area for Construction of Taytay Sluice Gate

10.2.2 Assistance of Review and Update of Resettlement Action Plan (RAP)

From here on, the RAP will be revised in consultation with the DPWH on the new information and proposed measures to address the issues described in **Section 10.2.1**.

10.2.3 Support for Preparation of Parcellary Survey Implementation Plan

10.2.3.1 Information Service System on Landowners in Accordance with a MOU between DPWH and the Land Registration Authority (LRA)

Since January 10, 2018, the DPWH had been receiving land registration information from the Land Registration Authority (LRA) to promote the progress of the works by DPWH, although it is for a fee (refer to **Table 10.2.7**).

At present, required data has been being requested through the DPWH-UPMO-FCMC for the entire design target section. The parcellary survey is expected to save time and costs because the survey will compensate insufficient information when the requested data is obtained.

Table 10.2.7 Costs of Purchasing Land Registration Data under the Memorandum between DPWH and LRA

Land Registration Information	Units	Unit Price (PHP)	Remarks
Parcel registration information	Subdivisions	728.0	
Alignment 40 m-range registration information	km	38,236	4 hectares
Alignment 60 m-range registration information	km	57,354	6 hectares
Alignment 75 m-range registration information	km	71,692	7.5 hectares
Alignment 100 - range registration information	km	95,590	10 hectares
Alignment 125 m-range registration information	km	119,487	12.5 hectares
Alignment 150 m-range registration information	km	143,385	15 hectares

Source: Memorandum of Agreement (MOA) between the Department of Public Works and Highway (DPWH) and the Land Registration Authority (LRA)

10.2.3.2 Contents of Parcellary Survey

A parcellary survey is usually conducted after the completion of detailed design in order to identify the necessary land area for securing the right to use land for the project (Right-of-Way), buildings and other assets affected by the project, and residents who own or use the affected buildings.

The items to be carried out in the parcellary survey are shown in **Table 10.2.8**.

Table 10.2.8 Works and Surveys to be carried out in Parcellary Survey

Work and survey items	Specific work and investigation	
Confirmation of land information with relevant organizations	The Assessor's Office	Tax declaration of Real Property
		Tax Map to determine the owner and address
		Land Classification
	The affected Landowners	Tax declaration of Real Property
		Copy of the Transfer Certificate of Title (TCT)
		Tax Clearance
		Pictures taken by the Consultant/Geodetic Engineer
	The Registry of Deeds	Certified copy of the Transfer Certificate of Title (TCT)
	The Land Management Services (LMS)	Cadastral Map
		Technical Description of Lot
		Lot Plan in standard LMS Form
Survey	Plan View Drawing	Plan View Drawing of Project-Affected Areas
		Description of Land Alignment Required for the Project
		Description of Land Information
		Identification of the Land Area Required for the Project

Source: Study Team

10.2.3.3 Preparatory Activities for Parcellary Survey

Currently, DPWH is requesting the Study Team to support the implementation of "Land information confirmation activities to related organizations", which is one of the survey items of the Parcellary Survey, in this detailed design for the following reasons. .

- It is planned to conduct a Parcellary Survey after detailed design, but it will take half a year to conduct the Parcellary Survey; and
- Land appraisal can be conducted by a government bank based on the information from the Land Registration Authority (LRA) mentioned above.

The current survey, on the other hand, utilizes the directly hired specialized staff, etc., to conduct the following surveys, and to assist in quickly obtaining the results of the Parcellary Survey after detailed design.

- Partial land surveying and collection of property tax information from tax-related bureaus such as Cities of Marikina, Pasig, and Quezon;
- Pre-collection of land registration information at city-related bureaus; and
- Reflection of the above information into topographic maps created by the survey.

Republic of the Philippines
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
CENTRAL OFFICE
Manila

November 28, 2019

ASSESSORS OFFICE
Marikina City Hall
Shoe Avenue, Sta. Elena,
Marikina City

SUBJECT : REQUEST FOR RESEARCH (TAX DECLARATION)

Dear Sir/Madam:

This has reference to the proposed Pasig-Marikina River Channel Improvement Project, Phase IV (PMRCIP-IV) funded by JICA Loan No. PH-P271.

In this regard, may we respectfully request for the copy of Tax declaration of the listed areas (please refer to the attached list marked as ***Annex A***). The purpose of the research is to create the parcellary map of the affected area/s of the above-mentioned project and will not be used for other purpose.

Further, the bearer of this letter is Mr. Glenn Ballester. He is duly appointed by DPWH to procure the attached research list.

We humbly ask for your kind assistance.

Respectfully yours,

ALEJANDRO A. SOSA
Project Manager III
UPMO-Flood Control Management Cluster

MARIKINA MULTI PURPOSE CADASTRE MCAD- 583			
BRGY,CALUMPANG		BRGY,SAN ROQUE	BRGY,JOSE DE LA PENA
817	924	2409	LRC-5683
818	925	2244	BLK 47
819	926	2292	BLK 42
820	927		BLK 28
821	928		BLK 20
822	971		BLK 4
823	972		
824	970		
825	969		
826	968		
832	967		
831	966		
830	965		
829	964		
828	963		
843	962		
844	961		
845	977		
846	978		
847	979		
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912	958		
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920			

Source: DPWH-UPMO-FCMC

Figure 10.2.8 Letter of Request for Property Tax Information from DPWH to Marikina City, as of November 28, 2019

10.2.4 Support for Holding Regular Consultation Meetings among DPWH, Related Organizations and PAFs

Since the commencement of this basic design in March 2019, no consultation meetings have been held. After the midterm elections, the JICA Study Team started supporting the DPWH in holding regular consultation meetings among the DPWH, relevant municipalities, relevant central government agencies and community groups.

The JICA Study Team has currently been discussing with the DPWH the preparation of a manual to implement the regular consultation meetings, including the following items:

- Clarification of the purpose of consultation meetings to be held;
- Manner of selecting members to be invited to each consultation meeting (conference) clarifying the purpose and division of roles;

- Manner to disseminate information in regular and special consultation meetings, including the division of roles; and
- Manner to prepare the minutes of meetings, the list of attendees, and the division of roles.

10.2.5 Support to Initiated Activities on Resettlement

At present, there is no resettlement activity to be initiated. Once the activities commence, the JICA Study Team will provide support to the following activities of the DPWH:

- Provision of various procedural documents to Project-Affected Families (PAFs) in order to enable the PAFs to receive compensation, subsidies, and transfer benefits, allowances or support funds;
- Provision of a basic mechanism for consultation and process of complaints to PAFs, including relocation site visits and interview surveys, to confirm living conditions in the relocation site;
- Advice for improvement of living conditions to related organizations based on the above survey;
- Support for the DPWH to revise the RAPs for the project based on the results of monitoring of relocation activities; and
- Information collection and monitoring of the relocation project by Pasig City, which is not included in the RAPs activities of the project.

CHAPTER 11 DESIGN CRITERIA

11.1 Objectives of the Design Criteria

This chapter describes a detailed design approach for river structures along the Pasig-Marikina River. The design and calculation basically conform to the design standards of the Philippines. In case there are no design method guidelines or design criteria, or if it is regarded to be safer or appropriate considering the characteristics of the project site, the globally accepted code and standard will be applied. Based on these criteria, design load, safety factors at stability calculation, allowable stress of materials, design method and necessary parameters for river revetments, drainage channels, civil engineering/gate facilities and telecommunication equipment of the Manggahan Control Gate Structure (MCGS) are determined.

For the MCGS, sluiceways and weirs, seismic design for Level 1 and Level 2 ground motions will be applied. Therefore, methodologies and analysis methods regarding seismic design will be described in this chapter.

11.2 Technical Codes and Criteria

This project is implemented based on the Yen Loan Agreement and the international bidding system. Therefore, the materials and construction techniques implemented in this project shall follow the Philippines, Japan, and major international codes and standards. The main technical codes and criteria applied and/or to be applied in the design of this project are as shown in **Table 11.2.1**.

Table 11.2.1 Technical Codes

No.	Technical Codes	Countries
1	National Building Code of the Philippines (NBCP)	Philippines
2	National Structural Code of the Philippines VOL. I (NSCP)	Philippines
3	National Structural Code of the Philippines VOL. II (NSCP)	Philippines
4	Design Guidelines Criteria and Standards Vol. I-VI (DGCS), 2015	Philippines
5	JICA-DPWH/Technical Standards and Guidelines for Design of Flood Control Structures	Philippines
6	DPWH LRFD Bridge Seismic Design Specifications (BSDS)	Philippines
7	DPWH Design Guidelines Criteria and Standards, Volume I and II, 1984	Philippines
8	Rules and Regulations of DPWH: (a) D.O.77 Series of 2018, Revised Guidelines in the Preparation of Detailed Engineering Design, "As-Staked", Revised, and "As-Built" Plans for Highway, Bridge and Water Projects (b) D.O.143 Series of 2017, Revised Standard Pay Item List for Infrastructure Projects (c) D.O.139 Series of 2014, Guidelines on River Dredging Operations for Flood Control (d) DPWH Standard Specifications (the Latest Version) (e) All other applicable codes (f) Philippine National Standard (PNS) (g) Technical Standards and Guidelines for Design of Flood Control Structures (h) Standard Specification for Highways, Bridges and Airports	Philippines
9	Japanese Industrial Standard (JIS)	Japan
10	Specifications for Highway Bridges I Common	Japan
11	Specifications for Highway Bridges IV Substructures	Japan
12	Specifications for Highway Bridges V Seismic Design	Japan
13	Road Earthwork Guideline	Japan
14	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc.	Japan
15	Technical Criteria for River Works: Practical Guide for Planning [I]	Japan
16	Guideline of River Planning Study	Japan
17	River Earthwork Manual	Japan
18	The Collection of The Collection of Hydraulic Formulae (Japan Society of Civil Engineers)	Japan
19	Structural Design Guide for Groundsill	Japan
20	Design for Weirs (Japan Dam Engineering Center)	Japan
21	Guideline for Flexible Sluiceway	Japan
22	Dynamical Design Method of Revetment	Japan
23	Civil Engineering Structure Design Manual – Sluiceway -	Japan
24	Performance Based Seismic Design Criteria for River Structures	Japan
25	Manual for Adjoining Works of Urban Railway Structures	Japan
26	Pile Foundation Design Manual	Japan
27	Standard Specifications for Concrete Structures [Design]	Japan
28	Technical Specification for Dams and Weirs in Japan (Draft)	Japan

No.	Technical Codes	Countries
29	Design Guideline for Floodgate and Sluiceway Gate	Japan
30	Technical Data of Remote Operation Systems for Floodgates and Sluiceways	Japan
31	Guidelines for Telecommunications Facility Design	Japan
32	Design and Construction Guidelines of Lightning Damage Measures	Japan
33	Management System Guidelines for Water and Lock Gates against Tsunami and Storm Surge (Ver.3.0)	Japan
34	Design Guidelines of Disaster Recovery Works	Japan
35	Technical Standard for Design and Construction of Gabion Revetment	Japan
36	Standard of Temporary Cofferdams	Japan
37	Technical Data of Vacuum Dewatering Method with Geotextile Tube ; High Grade Soil Research Consortium	Japan
38	Standard Design (MLIT, Japan)	Japan
39	Standards and Guidelines of American Concrete Institute (ACI)	U.S.A
40	Standards and Guidelines of American Association of State Highway and Transportation Officials (AASHTO)	U.S.A
41	ASTM International (ASTM).	U.S.A
42	U.S Army Corps of Engineer : Hydraulic Design Criteria	U.S.A

Source: Technical Codes Enumerated by Study Team

11.3 Basics of Design Method

11.3.1 Basics

Structures will be designed with maximum stress generated by the combination of the largest loads that affect structures. Concrete and steel structures are designed by the allowable stress design method (ASD)[1].

11.3.2 Embankments and Revetments

11.3.2.1 Embankments (Earth Dikes)

As described in **Chapter 5**, embankments should be earth dikes if there is enough space on the site. In the case of non-soil levees, there is a foundation soil under the structure. Here, the basic design method is shown, including the examination method of this foundation soil.

(1) Embankment Materials

It is difficult to obtain high-quality soil material from construction sites along rivers. Therefore, embankment materials (which satisfy the conditions below) will be purchased from other places.

- Soil with mixed particle sizes
- Maximum particle size is 10 to 15 cm or less
- Fine particles (less than 0.075 mm) contains at least 15% of soil material (less than 75 mm)
- Soil with low content of silt
- Soil with not too many of fine particles (particles less than 0.075 mm)

Table 11.3.1 Preferable Soils for Embankment Materials[2]

Soils			Soil Features	Measures
Coarse-grained soil	Gravel	O	Very high permeability	Permeability and vegetation control
	Gravelly Soil	O		
	Sand	O	High permeability Higher risk of slope failure	Permeability control
	Sandy Soil	O		
Fine-grained soil	Silt	O	(Measures are needed in some cases) Under wet condition, workability becomes low and compaction may not be effective.	-Decrease of moisture by drying -Ground improvement with soil improvement additives
	Clayey Soil	O		
	Volcanic Ash Clayey Soil	O		

Source: Technical Standards and Guidelines for Design of Flood Control Structures DPWH (JICA June 2010)

(2) Extra Banking

The extra banking height of the dike at the time of embankment works shall be as follows; However,

[1] DPWH Design Guidelines Criteria and Standards (Vol. II) 4.1Design Methodology / NSCP Vol. II Bridges (ASD) 8.14.1 Design Methods

[2] Technical Standards and Guidelines for Design of Flood Control Structures DPWH (JICA June 2010)

if the supporting ground of the embankment is weak, the amount of consolidation shall be calculated, and the calculated amount will be added to the extra banking height.

Table 11.3.2 Extra Banking According to Dike Height[3]

Embankment Height	Foundation Materials			
	Normal Soil		Sand / Gravel	
	Extra Banking Materials			
	Normal Soil (cm)	Sand / Gravel (cm)	Normal Soil (cm)	Sand / Gravel (cm)
≤ 3 m	20	15	15	10
3m – 5m	30	25	25	20
5m – 7m	40	35	35	30
≥7 m	50	45	45	40

Source: Study Team based on Technical Standards and Guidelines for Design of Flood Control Structures DPWH (JICA June 2010)

(3) Freeboard[4]

Freeboard according to the DFL is set as follows:

Table 11.3.3 DFL and Freeboard

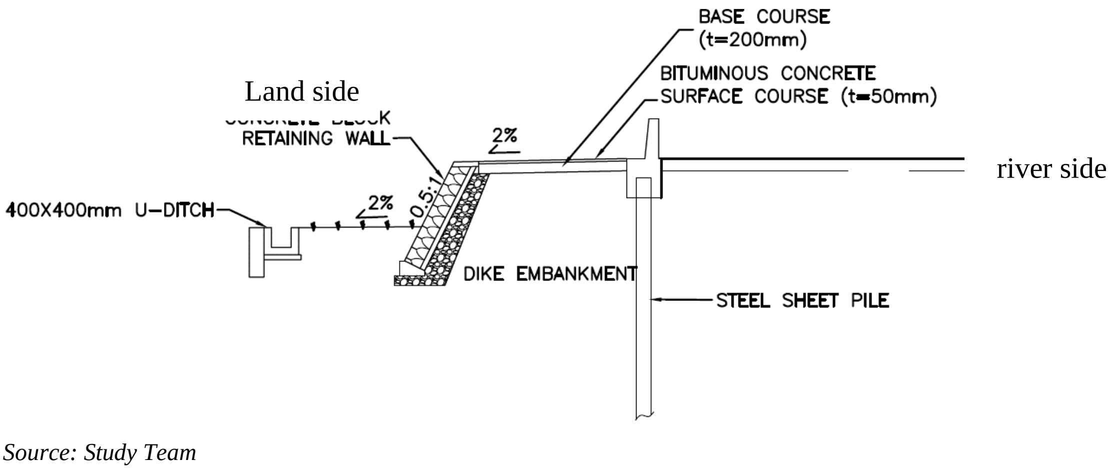
DFL (m^3/s)	Freeboard (m)
＜200	0.6
200-500	0.8
500-2000	1.0
2000-5000	1.2
5000-10000	1.5
≥10000	2.0

Source: DPWH Design Guidelines Criteria and Standards (Vol. III) 5.3.2.2

(4) Slope Protection[5]

A simple protective work by dry masonry with a height of 0.50 to 1.00 m will be installed to protect the slope of the dike on the land side.

Similarly, concrete block slope protection with a drainage facility will be provided to the land side of a non-soil levee as illustrated below.



Source: Study Team

Figure 11.3.1 Image of Slope Protection (Example of a Non-Soil Levee)

[3] Technical Standards and Guidelines for Design of Flood Control Structures DPWH (JICA June 2010)
[4] Cabinet Order Concerning Structural Standards for River Administration Facilities, etc., Chapter20.
[5] Technical Standards and Guidelines for Design of Flood Control Structures DPWH (JICA June 2010)

(5) Bank Paving

The top width and paving composition of the embankment, as well as the landscape design, will be determined based on discussions with DPWH and LGU, taking into consideration existing facilities such as the riverine promenade.

1) Paving Materials (Reference)

For materials of macadam paving, coarse aggregate classified as Item 200 consisting of hard durable particles such as crushed stone, natural gravel, and fillers or natural crushed sand will be used. The particle size properties of the material are as shown below:

Table 11.3.4 Grain Size Distribution[6]

Sieve Analysis		Item 200
Percentage Passing [%]	50 mm	100
	25 mm	55 ~ 85
	10 mm	40 ~ 75
	0.075 mm	0 ~ 12

Source: Standard Specifications for Public Works and Highways, Aggregate Sub-Base Course

2) Handrail (Reference)

Handrails shall be penetrated into a concrete foundation, using a pier spacing of 2.00 m, 1.10 m of height, and a two-step round beam. If metallic handrail is applied, the piers and beams will be fixed by welding to prevent theft. Also, the steel piers and beams will be galvanized.

(6) Settlement of Dike

Total Settlement (S_T) = Elastic Settlement + Consolidation Settlement

1) Immediate Settlement (Elastic Settlement) [7]

Immediate settlement is calculated with the aid of the following formula, on the assumption that the ground is elastic.

$$Sx = \sum_{i=1}^{n} \frac{-3ai \cdot qi}{Em \cdot \pi} \log \cdot \sin\left(\tan^{-1}\frac{ai}{H}\right) \cdot \left\{1.0 - \frac{0.75}{\pi}\left[\left(1+\frac{x}{ai}\right)\log\left|1+\frac{x}{ai}\right| + \left(1-\frac{x}{ai}\right)\log\left|1-\frac{x}{ai}\right|\right]\right\}$$

Where,

Sx	: Immediate settlement on x (m)
q_i	: Load of embankment (kN/m^2)
E_m	: Modulus of deformation of the ground (kN/m^2)
$2a_i$	: Load width (m)
H	: Depth for considering the effect of immediate settlement (m)
n	: Number of uniform loads
x	: Distance from the center of the ach uniform load (m)

2) Consolidation Settlement[8]

(a) Height of Consolidation Settlement

Consolidation settlement is examined on the basis of the result of soil investigation by using Terzaghi's Consolidation Theory, as described below:

$$S_c = \frac{e_0 - e_1}{1 + e_0} \cdot H$$

In the case of cohesive soil in a normal consolidation state, the following equation may be used.

---

[6] Standard Specifications for Public Works and Highways, Aggregate Sub-Base Course
[7] Design Guideline for Flexible Sluiceway 5.3.2 Immediate Settlement
[8] River Earthwork Manual 3.2.3 Settlement of Weak Ground

$$S_c = \frac{C_c}{1+e_0} \cdot \log_{10} \frac{p_0 + \Delta p}{p_0} \cdot H$$

When the Coefficient of volume compressibility is used, the following equation is applied.

$$S_c = m_v \cdot \Delta p \cdot H$$

Where,

S_c : Total consolidation settlement (m)
e_0 : Initial void ratio of cohesive soil
e_1 : Initial void ratio after embankment; it is obtained by applying $p_0 + \Delta p$ of the central depth of the compressive stratum to the e~logp curve obtained in the consolidation examination.
C_c : Compressive index of compressive stratum
H : Thickness of compressive stratum (m)
p_0 : Effective soil cover pressure before embankment (kN/m^2)
Δp : Increased compressive stress (kN/m^2)
m_v : Coefficient of volume compressibility (m^2/kN)

(b) Consolidation Time

t = Tv*d^2 / Cv

Where,

t : Time until consolidation index U
Tv : Time factor to U
D : Drainage distance (m)
Cv : Consolidation coefficient

(7) Seepage under Dike

Calculation of seepage is done with Lane's Creep Theory (see also **Subsection 11.5.4.1**)

L = v + 1/3 * h

Where,

L : Creep path length (m)
v : Vertical creep path length (m)
h : Horizontal creep path length (m)

(8) Slope Stability

Slope stability will be checked by the slip-circle method shown in **Subsection 11.5.3** .

11.3.2.2 Non-Soil Levees

(1) Basics of Flood Protection Wall

To ensure the safety against sliding and overturning, the flood protection wall which has a non-soil levee structure shall be designed to satisfy the following conditions.

(2) Safety against Sliding

Minimum safety factor against sliding is assessed referring to "**Subsection 11.5.1** Sliding."

(3) Safety against Overturning

Safety assessment against overturning is conducted referring to "**Subsection 11.5.2** Overturning."

(4) Safety against Supporting

Safety assessment against supporting is conducted referring to "**Subsection 11.5.6** Direct Foundation."

11.3.2.3 Revetments (Stone Pitching / Dry Masonry)

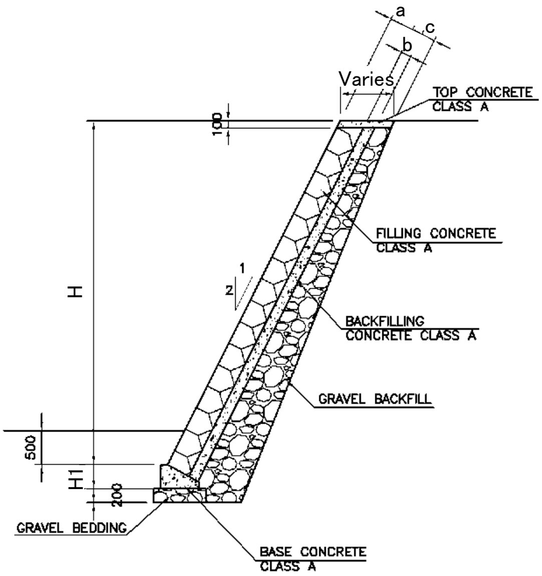
(1) Concrete Block Retaining Wall

1) Structural Specifications

The concrete block retaining wall is basically composed of precast blocks, embedded concrete, back-fill concrete, a foundation, a top concrete, and back-filling materials. The block's weight shall be 350 kg/m^2 or more, and the concrete strength shall be 18N/mm^2 following DPWH Standard Pay Item 1728 Concrete Block Slope Protection. The back-filling material shall be macadam (DPWH Standard Pay Item 1707 Aggregate Base Course Grade A). The maximum diameter of the macadam is 50mm.

For stability analysis of concrete block retaining walls, stability against overturning, sliding and bearing capacity shall be checked.

Figure 11.3.2 and **Table 11.3.5** are the specifications of the concrete block retaining wall for river revetment adopted by MLIT. They are used as a reference value when calculating the stability of the retaining wall.



Source: Standard Design (MLIT, Japan)

Figure 11.3.2 Standard Structure of a Concrete Block Retaining Wall

Table 11.3.5 Standard Design of Concrete Block Retaining Walls

Height H (m)	Foundation Height H1 (mm)	Slope Length L (mm)	Thickness of Concrete Block a (mm)	Thickness of Backfill Concrete d (mm)	Thickness of Backfill, c (mm)	
					C (mm)	D (mm)
1.00	300	1118	350	100	300	412
1.50	300	1677	350	100	300	457
2.00	300	2236	350	100	300	501
2.50	300	2795	350	100	300	546
3.00	300	3354	350	100	300	591
3.50	350	3913	350	150	300	635
4.00	350	4472	350	150	300	680
4.50	350	5031	350	150	300	725
5.00	350	5590	350	10	300	770

Source: Standard Design (MLIT, Japan)

2) Applicable Conditions of Concrete Block Retaining Walls

Concrete block retaining walls are applicable if:

- The planned height is in the middle of the values in the above table of standard design, the standard design immediately above the planned height will be applied.
- The distance between expansion joints of foundation concrete is 10 m or less.
- The foundation ground is weak, the concrete foundation of the retaining wall shall be supported by steel sheet piles at soft spots.

No drainage pipe (hard PVC pipe diameter 50 mm (VP pipe)) shall be provided below the water level of the river side revetment. However, if the water level is low enough (such as at the land side of the river), a drainage pipe will be provided per 2-3 m^2 of the wall surface.

Maximum wall height shall be 5m or less. If the height exceeds 5m, stability shall be secured by stability analysis.

(2) Gravity-Type Retaining Wall

Stability analysis of gravity type retaining wall is conducted for sliding, overturning, and bearing capacity (refer to **Subsection 11.6.1** and **Subsection 11.6.2**).

11.3.3 Maintenance Road

Maintenance roads for each section determined by the criteria in **Chapter 5** shall be designed based on the following settings (see image in **Figure 11.3.1**).

11.3.3.1 Road Width

The passage of vehicles is considered, the road width shall be 3.0 m or more.

11.3.3.2 Transverse Gradient

If the width of the management road is less than 3 m, transverse shall be a one-sided slope to the land side of the river. If the width exceeds 3 m, it shall be sloped on both sides from the road center. The gradient shall be 2% for both cases.

11.3.3.3 Pavements

Maintenance road on embankments shall be paved to prevent seepage of rainwater into the dike. In consideration of the influence of consolidation of foundation, a two-layer simple paving with 5 cm asphalt layer on the 20 cm road base macadam will be applied.

11.3.4 Revetment for Low Water Channel

11.3.4.1 Steel Sheet Pile Revetments (SSPs)

(1) Selection of SSP Type

SSPs include hat-shaped SP-10H to SP-50H (four types) and U-shaped SP-II to SP-VIL. In addition, there is also a hat-shaped + H SSP, which is a joint structure of hat-shaped SP with H steel. The strength of the hat-shaped + H SSP compares favorably with a steel pipe sheet pile.

When selecting the SSP type, allowable stress shown in the following (7) and (8) and the allowable displacement against external force shall be satisfied.

(2) Joint Efficiency[9]

For stress calculation, the joint efficiency per unit width of SSP revetment (αI) (with sufficient embedded length of pile and concrete coping provided) is generally set as αI = 0.8 for the joint efficiency with respect to the second moment of area (I), and αz = 1.0 for the joint efficiency with respect to the cross-section coefficient (z).

If the embedded pile length is calculated by the Chang's formula, the sectional moment of inertia shall be assumed as αI = 1.0.

For the hat-type SSP, it is not necessary to reduce the modulus of section by joint efficiency.

[9] Design Guidelines of Disaster Recovery Works Part3 Reference Cahper1(6) Corrosion Protection and Joint Efficiency of SSP

(3) Loads

SSPs are designed against the loads enumerated below:

- Earth pressure
- Hydraulic pressure
- Seismic load
- Surcharge load

1) Earth Pressure

Earth pressure is calculated using a Coulomb's formula for lateral earth pressure; both for active and passive pressure[10].

2) Hydraulic Pressure

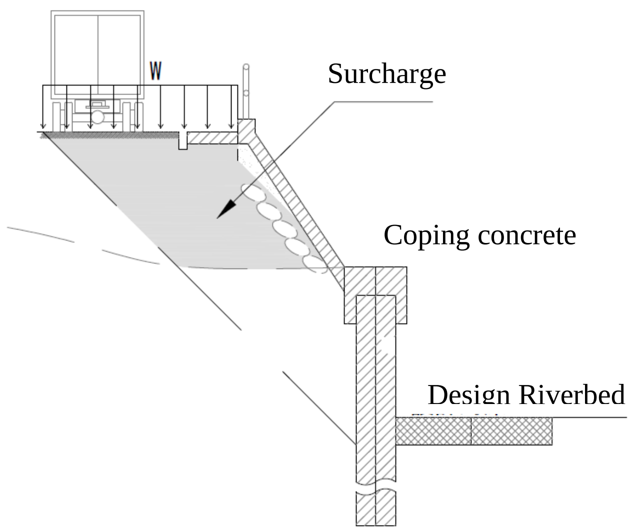
Hydrostatic pressure of high-water level from the river side, and residual water pressure occurring from the landside after flood will be considered. Residual water pressure is calculated using 2/3 of the height from the design flood height to the average water level as the water surface[11].

3) Seismic Load[12]

Seismic load is expressed as the increase in earth pressure. The earth pressure coefficient during earthquake is also computed using Mononobe-Okabe's formula revising Coulomb's formula, where horizontal seismic coefficient kh is set at 0.20[13].

4) Surcharge

Surcharge is a load which acts on the land side above the SSPs. Surcharge load due to vehicle traffic shall be 10kN/m^2 in normal condition and 5kN/m^2 in seismic condition[14]. For the area where pedestrians occupy, the surcharge load shall be 5kN/m^2. Soil and other weight above the coping concrete shall be added to the surcharge load if ground height is higher than the coping concrete (**Figure 11.3.3**).



Source: Study Team

Figure 11.3.3 Upper Load Range Acting on an SSP

10 Design Guidelines of Disaster Recovery Works Part3 Reference Cahper1 2-8 SSP Revetments 2 Earth Pressure
11 Design Guideline for Flexible Sluiceway 7.13 Shielding Wall Design
12 Design Guidelines of Disaster Recovery Works Part3 Reference Cahper2 2-8 SSP Revetments 7 Example of SSP Calculation
13 National Structural Code of the Philippines VOL.Ⅱ (NSCP) 21.6.2.2 (A)Free-Standing Abutment
14 Design Guidelines of Disaster Recovery Works Part3 Reference Cahper1 2-8 SSP Revetments 1 Soil Properties

(4) Load Combinations

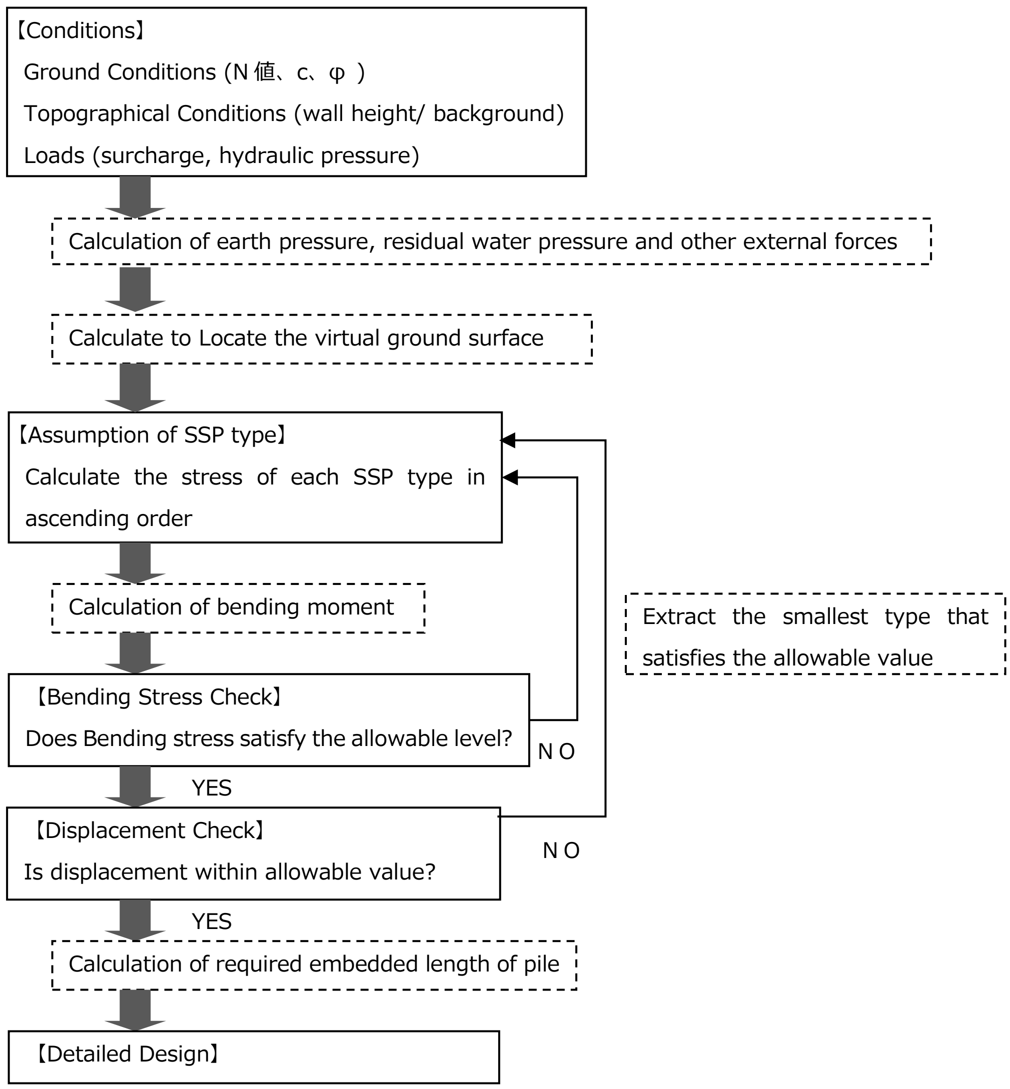
SSPs are designed using the following load combinations:

- Normal condition：For the active earth pressure and residual water pressure from the land side, 100% of the surcharge is considered.
- Seismic condition：For the active earth pressure under seismic condition from the land side, 50% of the surcharge is considered.[15]。
- Flood condition：For the active earth pressure from land side, while design flood water pressure acts from river side, 50% of the surcharge is considered.
- Water level under flood condition：Designed Floodwater Level is applied.
- Normal water level：Mean water level calculated by the observed data at Rosario J.S and Sto. Niño from 1994 to 2016.

(5) Stability Analysis

The method of selecting a wall based on stability analysis follows the flow in **Figure 11.3.4**. As the SSP becomes larger, the construction cost becomes higher and the interference width to the background increases because the wall thickness becomes thicker. Therefore, the smallest type of sheet pile which meets the safety requirement against the design load shall be adopted.

[15] Design Guidelines of Disaster Recovery Works Part3 Reference Cahper2 2-8 SSP Revetments 7 Example of SSP Calculation



Source: Study Team

Figure 11.3.4 Selection of SSP by Stability Calculation

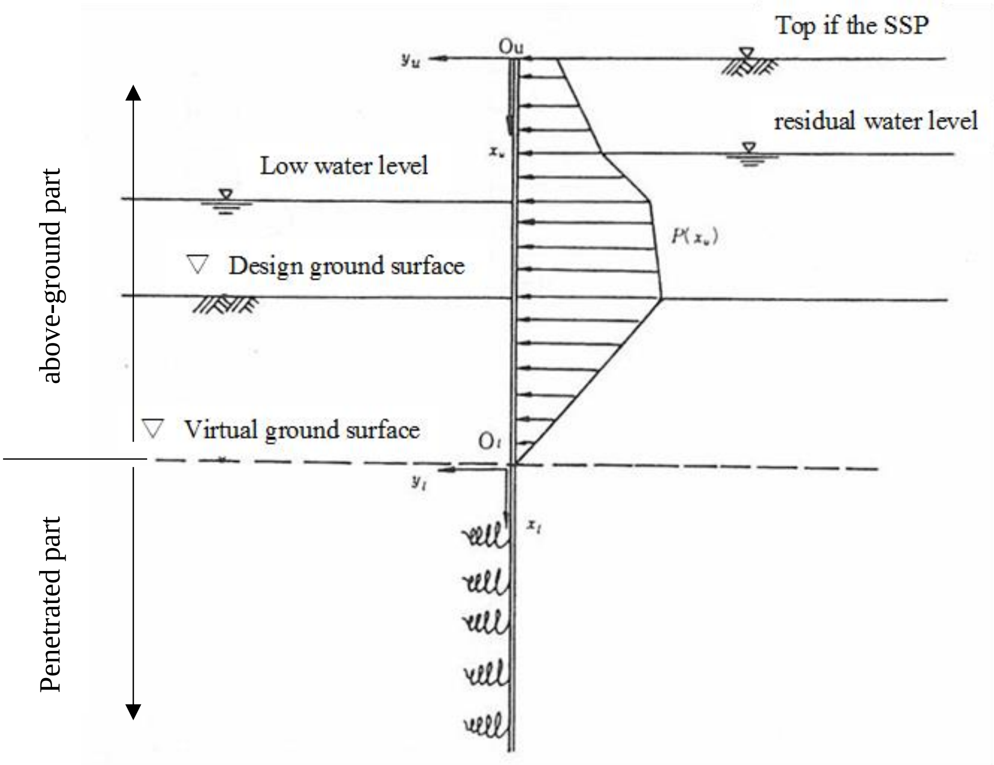
(6) Structural Calculation and Analysis

SSP is designed as a cantilever supported by soil below an imaginary riverbed[16].

SSP revetment supports lateral load such as earth pressure by lateral support force of the intruded ground and flexural rigidity of the wall. The target external forces are lateral load (horizontal load) such as lateral soil pressure and water pressure. Vertical load will not be considered. Therefore, penetration of SSP is not regarded as a friction pile or support pile, but it shall be designed to withstand lateral load (Calculated as = 3 / β).

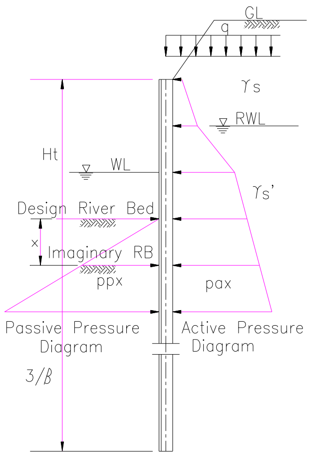
The Chang's equation will be applied for the structural calculation. In Chang's equation, when the SSP is divided into the upper part and the lower part with the virtual riverbed (A position where the sum of the active earth pressure strength and the residual hydraulic pressure equals the passive earth pressure strength) as the boundary as shown in **Figure 11.3.5**, it is assumed that the ground reaction force of the penetrated part is linear with respect to the displacement amount.

[16] Design Guidelines of Disaster Recovery Works Part3 Reference Cahper1 2-8 SSP Revetments 3 Outline of Design Method



Source: Design Guidelines of Disaster Recovery Works Part3 Reference Cahper1 2-8 SSP Revetments

Figure 11.3.5 Virtual Ground Surface and Sheet Pile



Source: Study Team

Figure 11.3.6 Structure and Loads of a Sheet Pile

1) Calculation of penetration depth

The depth of sheet pile embedment from the riverbed, l_d, is determined using the following formula:

l_d = $x + 3/\beta$

Where,

X = distance from a design riverbed to a level where passive earth pressure becomes equal with the active earth pressure:

β = $(K_H\, D / 4Es\, I)^{0.25}$

K_H = coefficient of lateral subgrade reaction[17]

$$K_H = K_{H0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

Where,

K_{H0} : the coefficient of horizontal subgrade reaction (kN / m³) corresponds to the value of a flat plate loading test with a 0.3 m-diameter rigid disk. When it is estimated from deformation coefficients obtained by various soil tests or investigations, it is calculated by the following equation.

$$K_{H0} = \frac{1}{0.3}\alpha E_0$$

B_H : Converted load width of foundation orthogonal to the direction of loads action (=10 m). For the case of a pile foundation, $\sqrt{D/\beta}$

D : load width of foundation orthogonal to the direction of loads action (m)

$1/\beta$: The depth (m) of the ground expected to have horizontal resistance. The depth shall be less than the effective penetration depth of the foundation.

β : Characteristic value of foundation $\sqrt[4]{\frac{K_H B}{4EI}}$ (m^{-1})
EI : Flexural rigidity of foundation (kN・m^2)
B : Width of SSP
Es : Yang's modules for SSP
I : Moment of inertia of area of SSP per unit width

2) Calculation of Maximum Moment

Formulae to analyze maximum moment and displacement of SSP (Chang's Formulae) are as follows:

$$M_{MAX} = M \cdot \emptyset_m$$

Where,

M : Bending moment of the imaginary riverbed

$$\emptyset_m = \frac{\sqrt{(1+2\cdot\beta\cdot h_0)^2+1}}{2\cdot\beta\cdot h_0}\cdot \exp\left(-tan^{-1}\frac{1}{1+2\cdot\beta\cdot h_0}\right)$$

M_{MAX} : Maximum bending moment (kN・m) (t・m)

$$\beta = \sqrt[4]{\frac{K_h\cdot B}{4\cdot E\cdot I}\ (m^{-1})}$$

K_h : Coefficient of lateral soil reaction (kN/m^3) (kg/cm^3)
B : Unit calculation width=1.0m = 100cm
E : Young Modulus = 2.0×10^8 (kN/m^2) = 2.1×10^6 (kg/cm^3)
I : Geometric moment of inertia = (m^4)
h_0 : Distance between imaginary riverbed and point of application force

3) Calculation of Deflection

$$\delta = \delta_1 + \delta_2 + \delta_3$$

Where,

[17] Specifications for Highway Bridges IV Substructures p285

δ : Deflection at top of a steel sheet pile (m) (cm)

δ_1 : Deflection on imaginary riverbed (m) (cm)

$$= \frac{(1+\beta \cdot h_0)\cdot P}{2 \cdot E \cdot I \cdot \beta^3}$$

δ_2 : Deflection by incline (m) (cm)

$$= \frac{(1+2+\beta \cdot h_0)\cdot P \cdot H}{2 \cdot E \cdot I \cdot \beta^2}$$

δ_3 : Deformation by bending of sheet pile (deflection as a cantilever) (m) (cm)

$$= \frac{B \cdot H^3}{6 \cdot E \cdot I} \cdot \sum (3-\alpha_i)\cdot \alpha_i^2 \cdot P_i = \frac{B \cdot H^3}{E \cdot I} \cdot \sum q_i$$

H : Height of steel sheet pile from imaginary riverbed to top (m)

P : Total lateral force (kN) (t)

α_i : ratio of force point to total height from imaginary riverbed

q_i : Deformation coefficient

(7) Allowable Stress

In this project, SYW 295 and SM 490 H-shaped steel will be used. The allowable stress of SYW 295 (SYW 390) for design calculation is 180 (235) N/mm^2 [18]. Similarly, the allowable stress of the SM 490 H-shaped steel is 185 N/mm^2. The allowable stress is set to 185 N/mm^2 in consideration that the tensile strength of the H-shaped steel placed on the land side is dominant strength of the SSP with H-shaped steel.

The seismic load works only temporarily during earthquake. Considering this point, the allowable stress level during an earthquake shall be increased by 50%. Therefore, the allowable stress levels (seismic) applied to SSPs and H-shaped SSPs shall be set as 270 N / mm^2 and 277.5 N / mm^2, respectively.

(8) Allowable Displacement

In addition to satisfying material strength, the allowable displacement of SSPs shall be 50 mm at normal condition.

In the case of an earthquake, the allowable displacement shall be increased by 50% because the period of time in which the seismic load acts is temporary. Therefore, the type of SSP shall be decided so that the amount of displacement at normal state is less than 50 mm and that during an earthquake is less than 75 mm[19]. If SSP does not resist against external force and circular slip, or there is fear of scouring, foot protection structures such as ripraps or gabions in front of SSP shall be installed.

The thickness of SSP shall consider corrosion allowance in 2 mm. It is assumed that the corrosion will process by 0.02 mm per year (actual value) during the entire service time of 50 years[20].

(9) Differences Between Hat-Shaped SSP, Hat + H-Shaped SSP and Normal SSP Design

Difference between Hat-shaped SSP, Hat + H-shaped SSP and normal SSP are as follows.

- As for allowable stress of H-shaped steel composite SSP, the smaller steel sheet pile or H-shaped steel shall be applied.
- Since the allowable stress of H-shaped steel is smaller than SSP, allowable stress for normal state shall be 140 N / mm^2 for SS400, SM400, SHK400M and 185 N / mm^2 for SM490, SHK490M respectively.

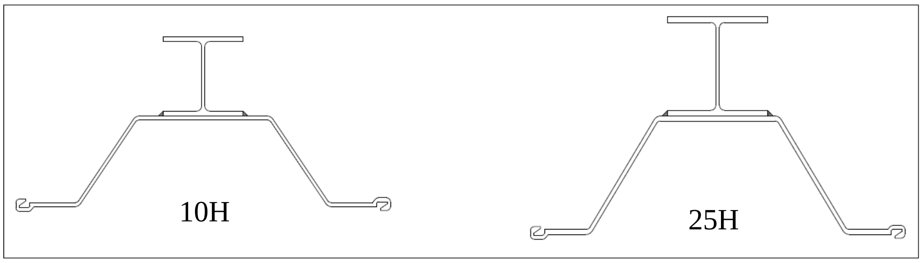
[18]Design Guidelines of Disaster Recovery Works Part3 Reference Cahper1 2-8 SSP Revetments 1 Earth Properties

[19]Design Guidelines of Disaster Recovery Works Part3 Reference Cahper2 2-8 SSP Revetments 7 Example of SSP Calculation

[20] Association of Steel Pipe Piles; Steel Sheet Pile – From Design to Construction, Standards on Allowable Corrosion and Corrosion Protection Method of SSP

- In case Hat-type SSP and Hat + H-shaped SSP (composite SSP with H-shaped steel) are connected to the edge of sheet pile, rigidity will not to be reduced, and the joint efficiency is calculated as 1.0 (cf. for normal SSP, 0.8 for moment of inertia of area).
- For the selection of composite SSP with H-shaped steel, the material cross-section shall be chosen referring not only to the minimum requirement for the external force, allowable stress and allowable displacement, but also economic efficiency.

Design methods other than those described in the above three points shall be designed based on the flow (1) to (7).



Source: Study Team

Figure 11.3.7 Images of Hat + H-Shaped SSPs

11.3.4.2 Foot Protection

(1) Design of Foot Protection Around Bridge Pier

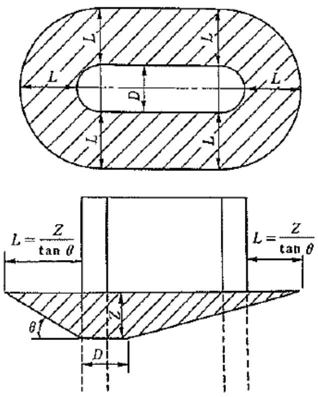
In determining the depth of embedment of a bridge pier, the scour depth around a bridge pier must be calculated. The scour depth around the pier is given by the following function.

$$\frac{Z}{D} = f\left(\frac{h_0}{D},\ \frac{h_0}{d_m},\ F_r\right)$$

Where,

Z	:	Maximum Scour Depth (m)
D	:	Bridge Pier Width (m)
h_0	:	Average Water Depth (m)
d_m	:	Average Size of Riprap (m)
F_r	:	Froude Number

The area of scouring around pier and estimated schematic is as follows.



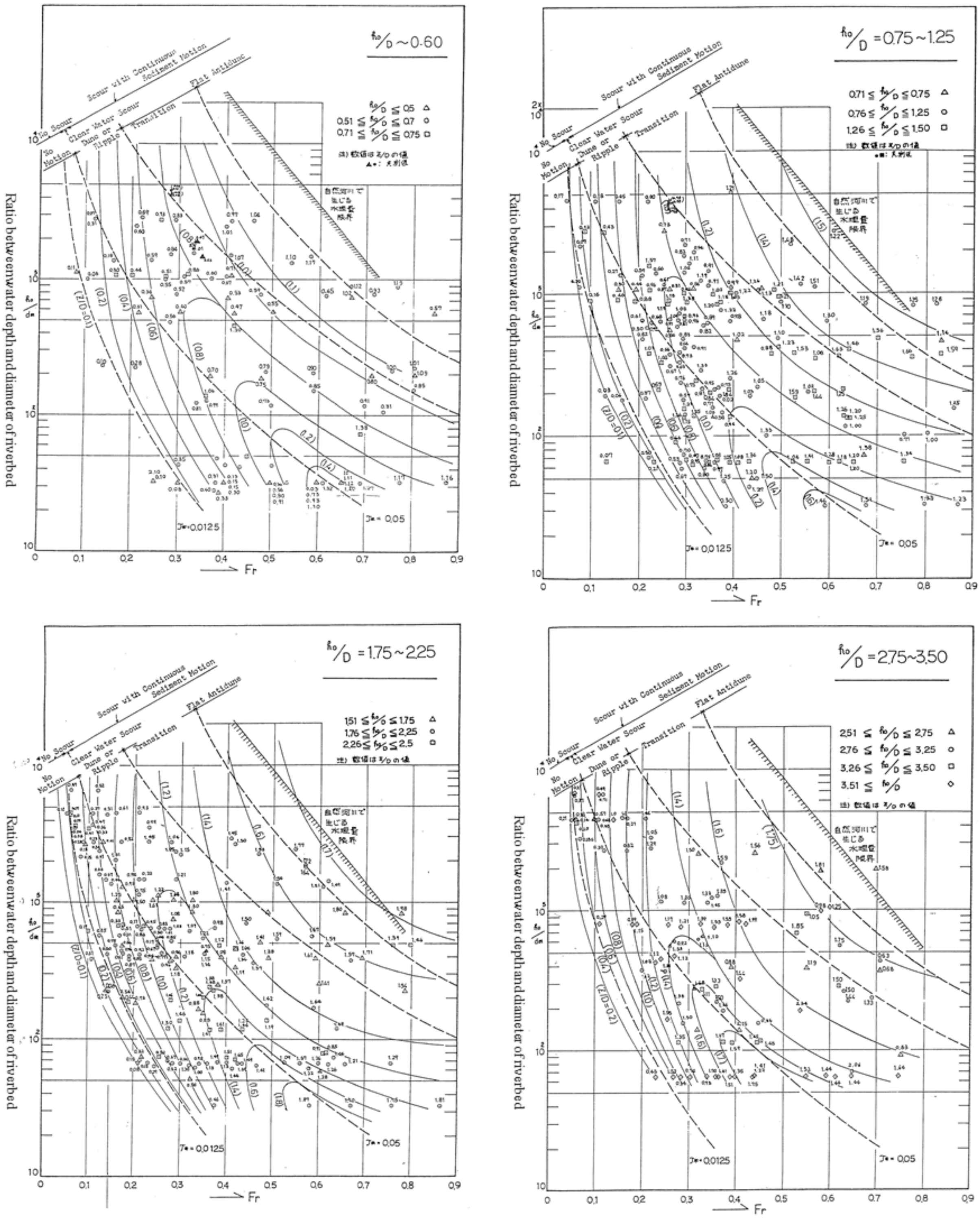
Source: "Hydraulic Study on Prediction and Countermeasures of Local Scouring Depth by Bridge Pier (Published by Public Works Research Institute, Japan -1982)"

Figure 11.3.8 Area of Scouring around Pier and Estimated Schematic

Where, L : Scour Range (m)

θ : Angle of Repose in Water (°)

By dividing h0 / D into four, the estimated scour depth is given as follows.



Source: "Hydraulic Study on Prediction and Countermeasures of Local Scouring Depth by Bridge Pier (Published by Public Works Research Institute, Japan -1982)"

Figure 11.3.9 Estimated Scour Depth

(2) Gabion Mattress

1) Applicable Rivers / River Sections[21]

Gabion mattress shall be applied for stability (foot protection) of SSPs and against scouring of piers. However, the river area where gabion mattress is applicable is only limited for rivers/river sections excluding the following:

- Where the river water is pH 5 or less.
- Where annual average of chloride ion concentration is 450 mg / l or more.
- Where riverbanks and substrates consist of black organic matter mixed soil or peat.
- Where substrates consist of rolling stones.

According to the survey for the Phase IV section, the target river area does not include any of the above conditions. Therefore, the gabion mattress is basically applicable. However, further investigations about pH and chloride ion concentration will be required.

2) Gabion Mattress against Scouring around Pier

A 0.5 m thick gabion mattress is used to prevent scouring of the piers. The gabion mattress will be placed flatly in the range of 2.00 m around the pier. If the current riverbed under the pier is higher than the planned riverbed height, the mattress will be gradually adjusted to the riverbed with 2:1 gradient. The upper end of the gabion mattress slope shall correspond to the design riverbed height.

3) Grain Size of Filling Materials

The grain size of filling materials will be calculated by the following formula:

$$V_o = (1+\alpha) \cdot V_m$$

$$\alpha = B / 2r$$

Where,

V_o : Representative velocity (m/s)
V_m : Average velocity (m/s)
α : Correction coefficient due to the effect of meander
B : Width of the low flow channel (m)
r : Radius of curvature of the river channel (m)

The representative velocity is obtained by the non-uniform flow calculation under the condition of the design flood of 2,900m^3/s. The following equation calculates the minimum grain size of the filling material. Then, the calculated grain size will be compared with the grain size in **Table 9.3.7** and that with the larger diameter will be adopted.

$$D_m \geqq \frac{V_0^2}{(6.0 + 5.75\log_{10}\frac{H_d}{k})^2 \cdot \tau_{*sd} \cdot s \cdot g}$$

$$\tau_{*sd} = \tau_{*d} \times \cos\theta \sqrt{1 - \frac{\tan^2\theta}{\tan^2\phi}}$$

Where,

D_m : Grain diameter
H_d : Design water level (m)
τ_{*sd} : Dimensionless critical tractive force on slope
τ_{*d} : Dimensionless critical tractive force on flat bed (=0.10)
s : Underwater specific gravity of filling materials (usually 1.65)
θ : Gradient of slope (degree)
k : Roughness (=2.5D) (m)

[21] Technical Standard for Design and Construction of Gabion Revetment

g : Gravitational acceleration (m/s^2)

4) Specifications of Gabion Mattress[22]

Specifications of gabion mattress will be based on the Table shown below. Besides, according to the material available at the project site, and comparison with the approved specifications of DPWH, appropriate specifications shall be applied.

Table 11.3.6 Structural Specifications of Gabion Mattress

Thickness of mattress				50 cm
Grain size of filling materials				15~20 cm (17.5 cm)
Structure	Mesh	Upper lid		6.5 cm
		Body		10.0 cm
	Diameter of Wire Mesh	Mesh	Upper lid	5.0mm dia.
			Body	4.0mm dia.
		Frame	Upper lid	6.0mm dia.
			Body	6.0mm dia.
	Material of Wire Mesh	Tensile strength		$\geq$ 290 N/mm^2
		Plating remaining amount		$\geq$ 30 g/m^2
		Frictional resistance		Friction coefficient > 0.90
	Intervals of Partition	Flat Bed		$\leq$ 2.0 m
		Slope		$\leq$ 1.5 m
		Apron		$\leq$ 1.5 m
		Side Wall		$\leq$ 2.0 m
	Mesh Shape			Rhombus
	Angle of Partition			Perpendicular to the slope surface

Source: Study Team

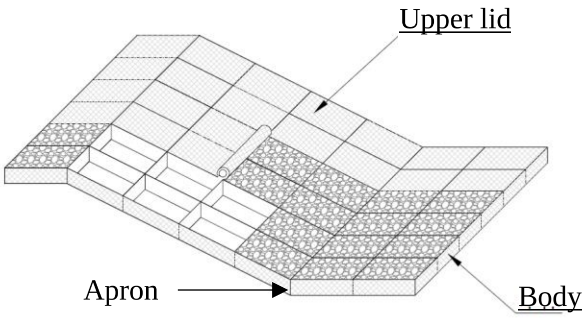


Figure 11.3.10 Sample Installation of Gabion Mattress on Slope

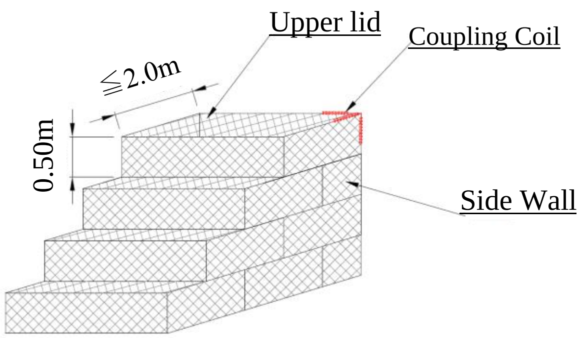


Figure 11.3.11 Sample Installation of Multistage Gabion Mattress

[22] Technical Standard for Design and Construction of Gabion Revetment

(3) Riprap[23]

1) Layout

In principle, gabion mattress shall be used for foot protection. However, riprap will be installed in places where gabion mattress is difficult to be set. The minimum crest width of riprap is 2.0 m; the front slope is 2: 1 (H: V) or gentler. Similarly, the minimum thickness of riprap is 0.75m.

2) Size of Riprap

To resist the flow velocity during flood, size of riprap shall be determined by the formula of "Traction-Weak Integrity Model" according to "Dynamical Design Method of Revetment[24]". It is assumed that the tractive force acting on the riprap does not exceed the threshold of riprap movement. The relationship between the representative flow velocity V_0 and the riprap size is determined as follows[25]:

(a) Riprap on Flat Bed

$$D_m = \frac{1}{E_1^2 \cdot 2g\left[\frac{\rho_s}{\rho_w} - 1\right]} V_0^2$$

Where,

D_m : Average size of riprap (m)
V_0 : Representative flow velocity (m/s)
ρ_s : Density of riprap (kg/m^3)
g : Gravitational acceleration (m/s^2)
ρ_w : Water density (kg/m^3) (ca.2.65as usual)
E_1 : Experimental factor of magnitude of turbulence

As the experimental factor E_1, in the case of a relatively small turbulent flow, E_1 = 1.2 is usually used. In the case of a large turbulent flow, the value of E_1 = 0.86 is proposed.

(b) Riprap on Slope with Inclination Angle of θ[26]

Diameter of riprap will be decided as the value $K \cdot D_m$, obtained by multiplying particle diameter D_m by slope correction coefficient K.

$$K = \frac{1}{cos\theta\sqrt{1 - \frac{tan^2\theta}{tan^2\varphi}}}$$

Where,

ϕ : ac. 38°for natural rock, ca.41°for macadam.

However, minimum grain size of riprap will be 30cm.

11.3.5 Drainage Channel/Drainage Works/Sluiceway

11.3.5.1 Basic Principles

Drainage facilities are broadly classified into drainage works and sluiceway, which are distinguished under the following conditions:

23 Technical Standards and Guidelines for Design of Flood Control Structures DPWH (JICA June 2010) 2.5.1 Basic Concept
24 Dynamical Design Method of Revetment (Japan,2007) 5-3-3 Verification Method for Each Structural Model
25 U.S. Army Corps of Engineer: Hydraulic design criteria, chart 712-4, 1970
26 U.S. Army Corps of Engineer: Hydraulic design criteria, chart 712-4, 1970

- Drainage works are installed in sections where the DFL is lower than the present ground and where non-soil levees below the DFL are not necessary.
- Sluiceways are installed in sections where the DFL is higher than the present ground and where non-soil levees below DFL are necessary.

The drainage is composed of a U-ditch, collector pipes, manholes, and flap gates. Flap gates will be installed if there is a point lower than the DFL in the drainage network area.

The design criteria of sluiceway are described in **Subsection 11.3.6 .**

11.3.5.2 Design Overview of Drainage Works

(1) U-ditch

U-ditch will be installed to collect small amounts of drainage from private households and rainwater from roofs as well as from surface drainage behind revetment. The minimum cross section of a U-ditch shall be 0.3 m x 0.3 m.

(2) Manhole and Outlet

The diameter of an outlet is set based on the amount of discharge from the catchment area. For the sake of maintenance, the mouth of manhole shall at least be 0.60 m x 0.60. Manhole covers shall be made of reinforced concrete to prevent theft. If a manhole is deeper than 1.0 m, foot hooks will be installed.

11.3.5.3 Planning Conditions

(1) Design Precipitation

Based on the Design Guidelines, Criteria and Standards, Volume III – Water Engineering Projects, 2015 of DPWH (hereinafter “Drainage Guidelines”) which specifies urban drainage planning and design, design precipitation shall correspond to the rainfall of 25-year probability. Inasmuch as PMRCIP Phase III complies with the Drainage Guideline, the Phase IV Design shall also comply with the Drainage Guideline and adopt the rainfall of 25-year probability as the design precipitation.

(2) Minimum Diameter of Drainage Pipe

The minimum diameter of drainage pipes shall be 910 mm as specified in the Drainage Guidelines.

(3) Calculation of Design Runoff

1) Rational Formula

Design runoff will be calculated using the following rational formula in accordance with the Drainage Guidelines.

$$Q = \frac{CIA}{360}$$

Where,

Q	: Design runoff (m^3/sec)
C	: Runoff coefficient
I	: Rainfall intensity (mm/hr)
A	: Catchment area (ha)

2) Runoff coefficient

Runoff coefficient is determined by the weighted average over the entire catchment area according to the following table in the Drainage Guidelines.

Table 11.3.7 Values of 'c' Recommended for Rational Formula

Land Use	Runoff Coefficient	
	Minimum	Maximum
Residential Area - Densely built	0.50	0.75
Residential Area – Not Densely built	0.30	0.55
City Business District	0.70	0.95
Light Industrial Areas	0.50	0.80
Heavy Industrial Areas	0.60	0.90
Parks, Playgrounds, Cemeteries, unpaved open spaces and vacant lots	0.20	0.30
Concrete or Asphalt Pavement	0.90	1.00
Gravel Surfaced Road and Shoulder	0.30	0.60
Rocky Surface	0.70	0.90
Bare Clay Surface (faces of slips, etc.)	0.70	0.90
Forested Land (sandy to clay)	0.30	0.50
Flooded or Wet Paddies	0.70	0.80

Source: Drainage Guidelines (DPWH,2015) 3.4.1.2 Runoff Coefficient (C)

$$C = \frac{A_1C_1+A_2C_2+A_3C_3+A_4C_4+\cdots\cdots A_NC_N}{A_T}$$

Where,

$C_1 \sim C_N$: Runoff coefficient of each land use type
$A_1 \sim A_N$: Area of each land use type
A_T : Catchment area

3) Rainfall Intensity

Rainfall intensities adopt those shown in the Definitive Plan. The coefficients of rainfall and the rainfall intensity equation are as follows:

$$I = \frac{a}{Tc^n + b}$$

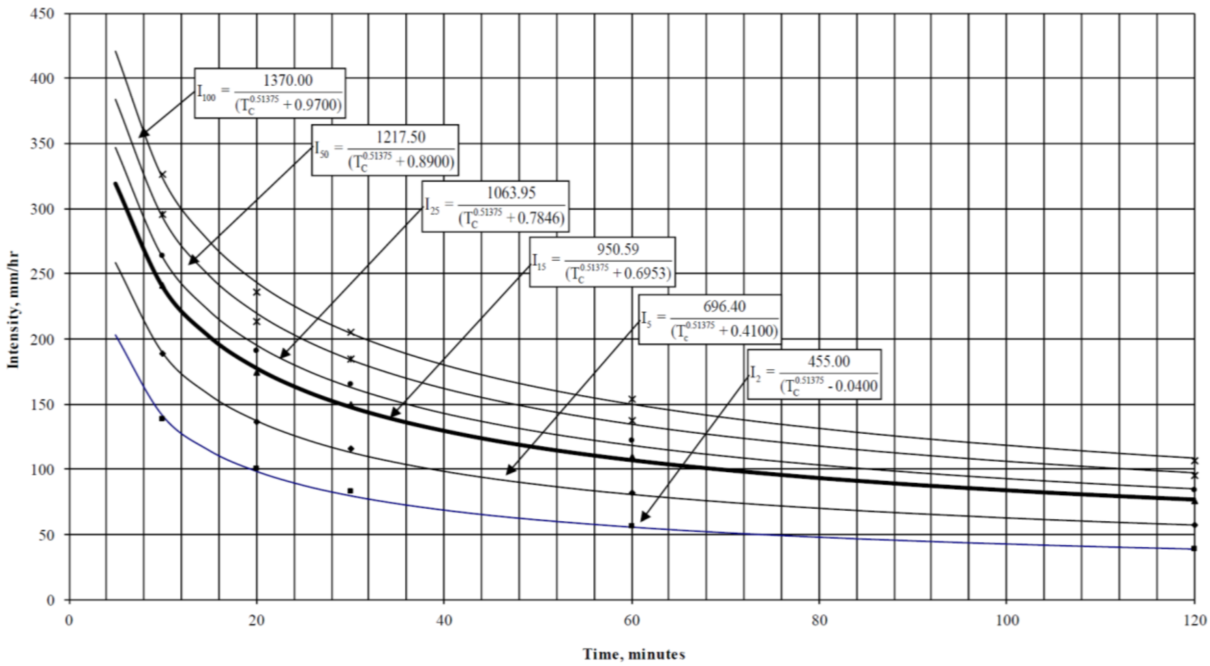
Where,

I : Rainfall intensity (mm/hr)
Tc : Concentration time (min)
n,a,b : Coefficients

Table 11.3.8 Precipitation Return Period Coefficients

Return Period	Port Area		
	a	b	n
2	455.00	-0.0400	0.51375
5	696.40	0.4100	0.51375
10	858.40	0.6100	0.51375
15	950.59	0.6953	0.51375
20	1015.44	0.7519	0.51375
25	1063.95	0.7846	0.51375
50	1217.50	0.8900	0.51375
100	1370.00	0.9700	0.51375

Source: JICA Study Team



Source: Study Team

Figure 11.3.12 Rainfall Intensity and Return Period

According to the Drainage Guidelines, the "concentration time (Tc) in urban area should not be less than 5 minutes".

The concentration time of this project is calculated by the following calculation method as shown in the Drainage Guidelines.

Concentration time (Tc)＝Overland Flow (t_o)＋Curb and Gutter Flow (t_g)＋Drain Flow (t_d)

The calculation methods are shown in **Table 11.3.9**.

Table 11.3.9 Equations for Estimating the Time of Concentration in Urban Areas

Category	Formulae	Remarks
Overland Flow	$t_o = \frac{107n^*L^{1/3}}{S^{1/5}}$	t_o = overland flow travel time (minutes) L：Overland sheet flow path length (m) L = Overland sheet flow path length (m) -For steep slopes (> 10%), L ≤ 50 m -For moderate slopes (< 5%), L ≤ 100 m -For mild slopes (< 1%), L ≤ 200 m n* = Horton's roughness value for the surface S = slope of overland flow surface (%)
Curb and Gutter Flow	$t_g = \frac{L}{40\sqrt{S}}$	t_g = curb and gutter flow time (minutes) L = length of curb gutter flow (m) S = longitudinal slope of gutter (%)
Drain Flow	$t_d = \frac{nL}{60R^{2/3}S^{1/2}}$	t_d = travel time in minutes n：Manning's roughness R = Hydraulic Radius (m) S = Friction Slope (m/m) L = Length of Reach (m)

Source: Drainage Guidelines (DPWH,2015)

Table 11.3.10 Horton's Surface Roughness

Land Use	Horton's Roughness (n*)
Paved	0.0150
Bare Soil	0.0275
Poorly Grassed	0.0350
Average Grassed	0.0450
Densely Grassed	0.0600

Source: Drainage Guidelines (DPWH,2015)

11.3.5.4 Design Condition for Drainage Facilities

(1) Determination of Drainage Size

According to the Drainage Guidelines, drainage cross sections are calculated using the Manning's Equation.

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2}$$
$$Q = A \times V$$

Where,

Q : Flow volume (m^3/sec)
V : Velocity (m/sec)
A : Area of flow (m^2)
n : Coefficient of roughness
R : Hydraulic mean depth (m)
S : Gradient

The coefficient of roughness adopts the values indicated in the Drainage Guidelines (**Table 11.3.11**). Cross section of sluiceway will be determined by one-dimensional varied flow calculation after the final planned drainage volume is determined.

Table 11.3.11 Manning's Roughness Coefficient

Land Use	Horton's Roughness (n*)
Pasture, short grass, no brush	0.030
Pasture, tall grass, no brush	0.035
Cultivated land-no crop	0.030
Cultivated land, nature field crops	0.045
Scrub & scattered brush	0.050
Wooded	0.120

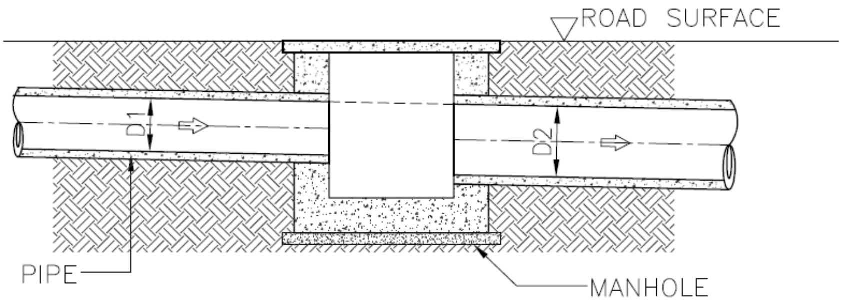
Source: Drainage Guidelines (DPWH, 2015)

(2) Flow Velocity in Pipe

According to the Drainage Guidelines, the minimum flow velocity in the pipe shall be 0.8 m/sec, considering that the drainage pipe will neither be exhausted nor blocked by sediment. As for the maximum flow velocity, an extremely high flow velocity (5.0 m/sec) is shown in the Drainage Guidelines, however, it will be designed within the range of 1.0 to 1.8 m/sec, which is regarded as an ideal range of flow velocity in this project.

(3) Connection of the Collector Pipe

In this design, the pipe top connection is applied to smoothen the water flow according to the Drainage Guidelines.



Source: Study Team

Figure 11.3.13 Image of the Pipe Top Connection

(4) Allocation of Manholes

Manholes to connect collector pipes will be placed, in accordance with the Drainage Guidelines, at locations where pipe ridges meet, where maintenance required, where pipe diameter changes, or where direction and slope of pipe changes. The maximum distance between manholes shall be 50 m.

11.3.6 Sluiceway

11.3.6.1 Structural Design

(1) Design Principles[27]

The sluiceway shall be designed not to disturb the flow below the DFL, as well as not to significantly affect the riverine structures and river management facilities nearby, while properly considering prevention of scouring of riverbeds and high-water beds adjacent to the sluiceway.

The most suitable structure type of sluiceway shall be selected, considering the amount of residual settlement and the characteristics of the foundation ground. To minimize negative effects of adjacent embankment, a flexible sluiceway shall be adopted, if the residual settlement is larger than ca.5cm.

Table 11.3.12 Structure Types of Sluiceway

Structures	Flexible Structure	Rigid Structure
Measures for residual settlement	Allow subsistence of the body	Do not allow subsistence of the body
Foundation	Flexible foundation	Rigid Foundation
Coupling Joint	Collar joint Flexible joint Elastic joint	Collar joint Flexible joint Elastic joint
Deflection properties of Longitudinal direction of the sluiceway	With deflection properties	With/ Without deflection properties
Displacement properties of Longitudinal direction of the sluiceway	Structure of free displacement / Elastic structure	
Column, Gate, Bridge	Structure adaptable to inclination	

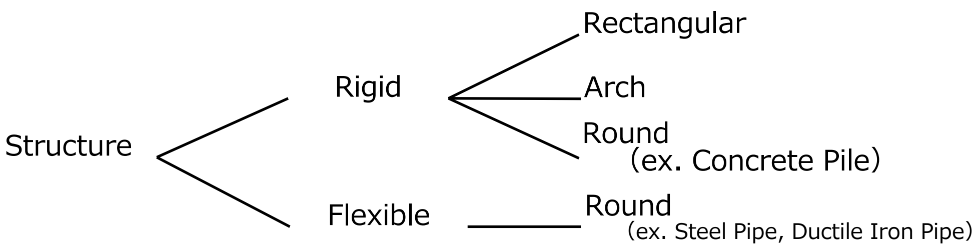
Source: Study Team

(2) Structure Type Selection[28]

1) Box Culvert of Sluiceway

The longitudinal structure of box culvert shall be selected in consideration of the cross-sectional structure of the box and the structural characteristics of the coupling joint.

[27] Design Guideline for Flexible Sluiceway 2.4.1 Selection of Sluiceway Structure
[28] Design Guideline for Flexible Sluiceway 2.4.2 Selection of Box Culvert Structure



Source: Study Team

Figure 11.3.14 Box Culvert Types

In this project, a rectangular box made of cast-in-place concrete is adopted for the reasons given below.

- Although there is a precast concrete for round type in the Philippines, it is difficult to secure water tightness and deformation characteristics at the joint between the boxes when using it as a sluiceway.
- If a steel pipe is used, welding is required at joints, resulting in poor workability.
- In case of cast-in-place concrete, it is difficult to construct a round box culvert.

2) Coupling Joint[29]

An appropriate type of joint, which adequately meet the following features, shall be selected: (a) Water tightness to the water pressure inside and outside the box; (b) Deformation capacity corresponding to the displacement between joints; and (c) Capacity for transmission of the sectional force of adjacent spans.

Table 11.3.13 Coupling Joint Types

Types	Deformation Characteristics	Design Model
Flexible Joint	Transmission of the cross-sectional force is small, since the interstice, bending angle and gaps between joints are hardly restrained.	Free
Collar Joint	It restrains the joint gap, but hardly restricts the interstice and bending angle. Thus, only the sheer force is transmitted	Hinge model (Free in axial direction)
Elastic Joint	There is transmission of cross-sectional force according to the size of joint spring and displacement between spans.	Spring in axial direction Shear spring, Bending spring

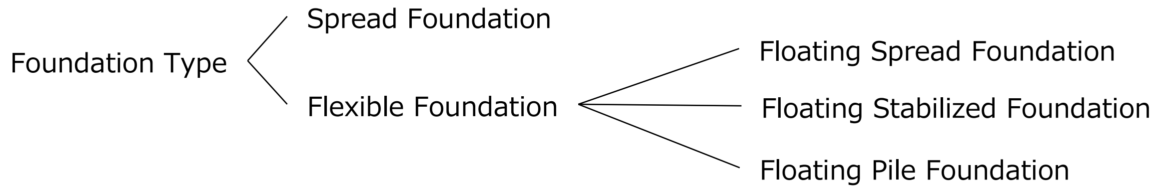
Source: Guideline for Flexible Sluiceway, Table 1-2-5.

3) Foundation Structure[30]

The foundation type of sluiceway shall be selected in consideration of the amount of residual settlement of the ground, structural characteristics of sluiceway, and influences on the surrounding embankment. In principle sluiceway should be designed with a direct foundation.

The acceptable amount of residual settlement of the direct foundation shall be ca.5 cm or less. If the residual settlement exceeds 5 cm, or in case it exceeds even after ground improvement measures, it is recommended to apply flexible foundation.

[29] Design Guideline for Flexible Sluiceway 2.4.3 Selection of Joint Structure
[30] Design Guideline for Flexible Sluiceway 2.4.4 Foundation Structure



Source: Study Team

Figure 11.3.15 Foundation Types

(3) Sluiceway Main Body

1) Cross Section

The cross-section of the main body shall not hinder the removal of sediments and other maintenance activities. The inside height of box culvert shall consider the following clearance.

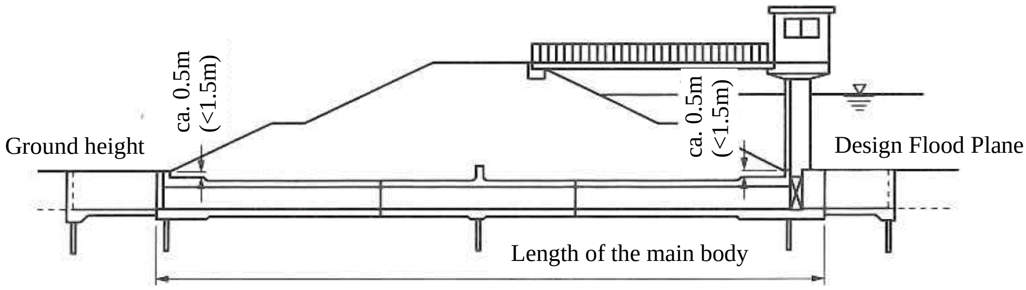
Table 11.3.14 Clearance of Box Culvert

Design Flood (m^3/s)	Clearance (m)
< 50	0.3
≥ 50	0.6

Source: Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Chapter 6 Table 6.1 P.244

2) Length of the Main Body[31]

In principle, the length of the main body shall be designed to extend to the planned embankment surface of both river and land side. Invasion of the embankment cross-section should be minimum. Similarly, it is desirable to set the height from the top end of the box culvert to the top of the breast wall to 1.5 m or less. Besides, it shall be around 0.5 m in height to regard as a retaining wall.



Source: Guideline for Flexible Sluiceway 6.1.3Figure 1-6-2

Figure 11.3.16 Length of Main Body

3) Structure of Ends[32]

The end of the main body shall be safe against the load of the columns and the breast wall. On the land side, A groove for stop log will be installed. For reduction of thickness due to the groove, appropriate reinforcement measures will be required.

4) Column[33]

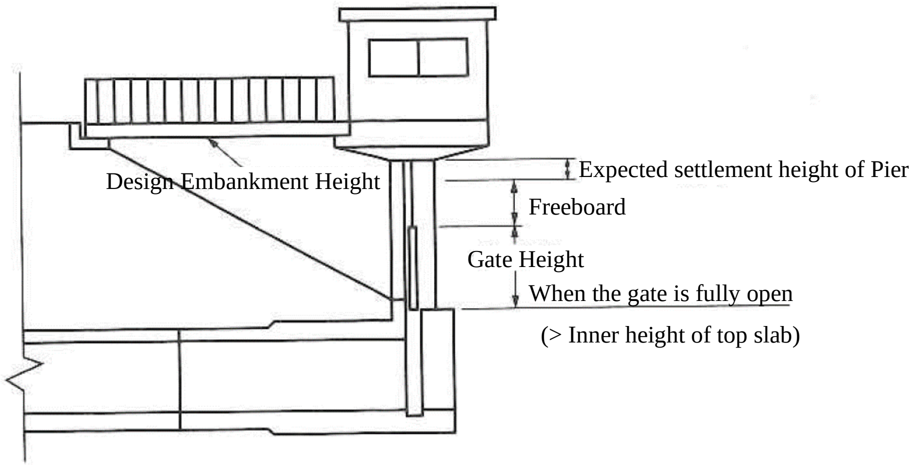
A column of a sluiceway shall have a structure which can open and close the gate smoothly and is able to reduce the resistance of running water to minimum.

The height of the column is determined by adding the height of the gate and the height necessary for the management of the gate when the gate is fully open.

31 Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.1.2.2 Box Culvert Length

32 Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.1.2.4 Structure of Box Ends

33 Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.1.3 Column



Source: Guideline for Flexible Sluiceway 6.1.7 Figure 1-6-5

Figure 11.3.17 Freeboard at the Gate is fully Open

5) Gate[34]

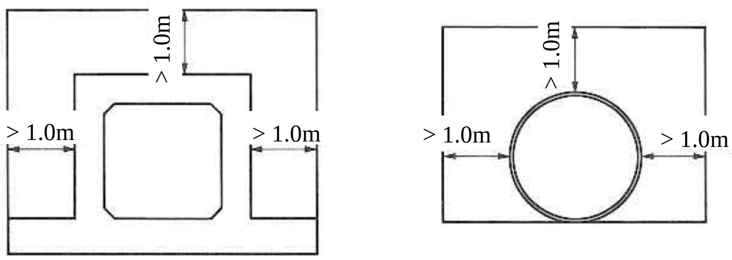
A gate shall be designed to be able to open and close smoothly, to have sufficient water tightness and to have a structure that does not cause any critical problem with flowing water. In addition, the lower end of the gate fully open shall be higher than the top of the box culvert.

6) Operation deck[35]

An operation deck for installing hoists shall be provided on the columns. In addition, the operation floor shall be designed as an integral structure with piers.

7) Seepage Cut-off Wall[36]

Except for the case where the ground height behind the embankment is high enough to be safe against seepage, seepage cut-off wall shall be provided. The shielding wall is an integral structure with the box culvert. The width of the wall shall be at least 1 m.



Source: Guideline for Flexible Sluiceway 6.1.9 Figure 1-6-6

Figure 11.3.18 The Area which Shielding Wall shall Cover

8) Breast Wall[37]

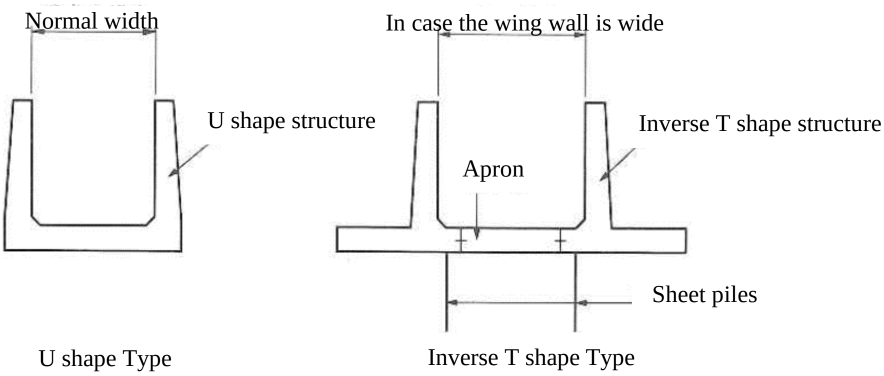
The breast wall shall be designed as an integrated structure with the main body to prevent movement and suction of soil particles in the embankment, as well as to avoid collapse of the embankment due to damage of wing walls.

[34] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I]8.2.1.6 Gate
[35] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I]8.2.1.4 Gate Operation Desk
[36] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.1.5 Water Shielding Wall
[37] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.2 Brest Wall and Wing Wall

(4) Wing Wall[38]

1) Wing Wall Structure

In principle, the wing wall shall be separate from the main body and cover the area of embankment to be fully protected. The structure of the wing wall shall generally be U-shaped as shown in the figure below, however, if it is not suitable to use the U-shaped type, such as the wing wall is relatively wide, an inverse T-shape type may be applied.

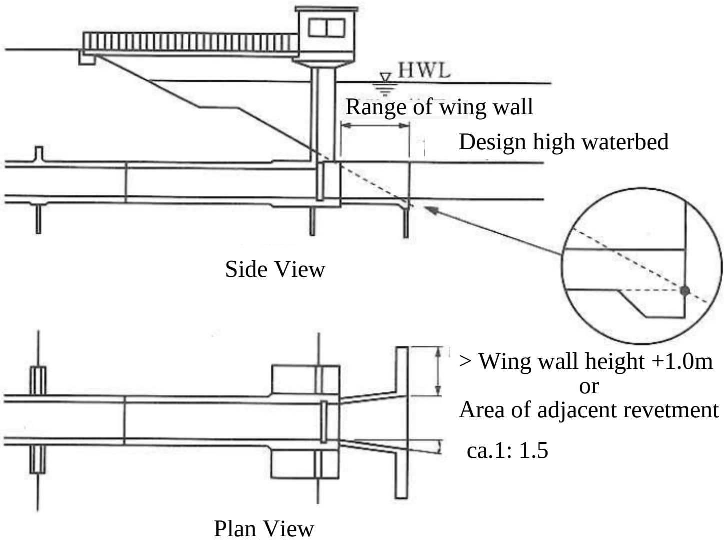


Source: Guideline for Flexible Sluiceway 6.2 Figure 1-6-10

Figure 11.3.19 Wing Wall Structure

2) Length of Wing Walls Shall Cover

The purpose of the wing wall is to protect the adjacent embankment. In principle, the wing wall shall be provided to the range beyond the dike cross-section. In general, the mouth shall be gradually extended at the rate of 1:5, however, it will be determined according to the condition of the construction site.



Source: Guideline for Flexible Sluiceway 6.2 Figure 1-6-11

Figure 11.3.20 Length of Wing Walls

(5) Connecting Water Channel

The river side connecting water channel shall be designed to minimize the impact on the embankment during a flood event. In general, the connecting water channel shall be placed perpendicular to the embankment normal line.

[38] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.2 Brest Wall and Wing Wall

(6) Sealing Works[39]

To prevent sediment movement and suction under the sluiceway, sealing works shall be installed at appropriate points.

(7) Foundation[40]

The foundation shall be able to adapt to the structural characteristics of the box culvert and the ground displacement. In principle, the direct foundation shall be adopted.

(8) Bed Protection Work[41]

In principle, bed protection works shall be designed to be flexible. Also, it is desirable to be designed in harmony with the river environment.

(9) Other Facilities

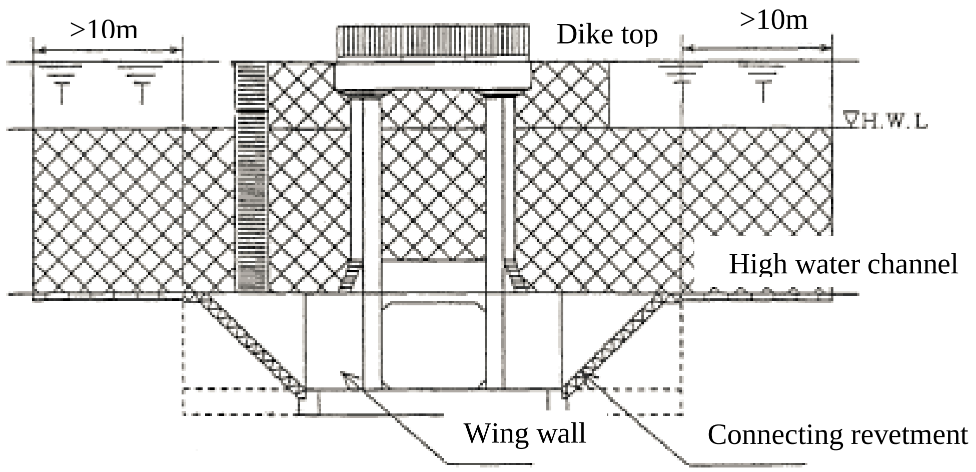
1) Adjacent Revetments

In consideration of the site conditions and the shape of the main body, revetments will be installed in an appropriate range according to the following standards[42].

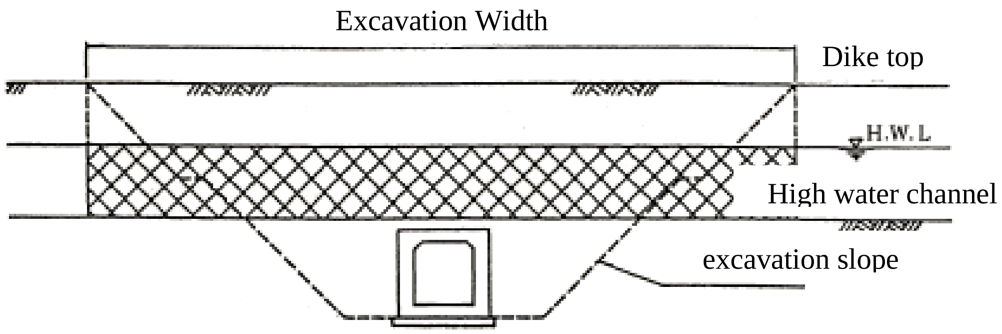
The revetment of riverbank adjacent to a sluiceway shall be provided up to the DFL, whichever is wider: 10m each from both ends of the sluiceway, or the excavated section of the dike for the sluiceway construction.

However, it is not necessary to comply with the above-mentioned rule if the characteristics of construction site and planned structure (e.g. A small sluiceway in which cross sectional area is less than 0.5 m^2).

[39] Technical Criteria for River Works: Practical Guide for Planning. [Design][I] 8.2.4 Sealing Work
[40] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.5 Foundation
[41] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.6 Bed Protection Work
[42] Technical Criteria for River Works: Practical Guide for Planning. [Planning] 8.2.7 Revetment near Weir and Other Structures



Required width of revetment according to the Article 25, Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. (MLIT, JAPAN)



Required width of revetment according to the dike excavation

Source: Study Team

Figure 11.3.21 Area of Adjacent Revetments

2) Protection Works for Flood Plain[43]

In consideration of the river environment, flood plain protection works shall be designed with a structure capable of preventing scouring of the high-water channel by running water.

3) Maintenance Bridge[44]

The width of the bridge (for management of the sluiceway) shall be at least 1.0 m.

11.3.6.2 Load[45]

A sluiceway shall be designed for the following loads:

- Self-weight
- Effect of foundation displacement
- Static hydraulic pressure

[43] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.8 Protection Work for High Water Channel

[44] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.2.9.1 Management Bridge

[45] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 8.3.1 Loads

- Uplift
- Seismic force

Table 11.3.15 Load Types Considered to Lateral Calculation of Box Culvert

Load Types		Lateral Calculation of Box Culvert
Dead Load	Self-Weight of Box Culvert	○
Live Load	Vehicle Load	○
Earth Pressure	Vertical earth pressure, horizontal earth pressure	○
Hydraulic Pressure	Underground water pressure	Consider by condition
	Internal water pressure etc.	Consider by condition

Source: Guideline for Flexible Sluiceway 7.2 Figure 1-7-1

Table 11.3.16 Load Types Considered to Longitudinal Calculation of Box Culvert

Load Types		Model for Longitudinal Calculation of Box Culvert	
		Beam on Elastic Foundation	Beam on Elastic Foundation considered Deformation of Foundation Ground
Dead Load	Self-weight (Incl. column・breast wall)	○	○
	Inland water weight	○	○
Effect of Ground Deformation	Ground settlement	×	○
	Lateral Displacement	×	Consider by condition
Live Load	Vehicle Load	○	Consider by condition
Earth Pressure	Vertical earth pressure,	○	×
	Earth Pressure on Breast Wall	○	○
Hydraulic Pressure		○	○
Influence of negative skin friction of a Pile		Consider by condition	Consider by condition
Prestress Force	PC Box Culvert	Consider by condition	Consider by condition
Seismic Load		○	○

Source: Guideline for Flexible Sluiceway 7.2 Figure 1-7-2

11.3.6.3 Foundation Ground Analysis

(1) Immediate Settlement (Elastic Settlement)

Immediate settlement is calculated with the aid of the following formula, on the assumption that the ground is elastic.

The calculation method is the same as river dike (See **Subsection 11.3.2.1 (6) 1)**)

(2) Consolidation Settlement

Consolidation settlement is examined based on the result of soil investigation by using Terzaghi's Consolidation Theory.

The calculation method is the same as river dike (See **Subsection 11.3.2.1 (6) 2)**)

(3) Lateral Displacement[46]

Lateral displacement is generally calculated as horizontal displacement caused by shear deformation of the ground after embankment.

[46] Design Guideline for Flexible Sluiceway 5.3.3 Lateral Displacement

11.3.6.4 Design Method

(1) Cross Sectional Calculation of Box Culvert[47]

In case of cross-sectional direction, the calculation model is the box frame on which the external force is acting as well as the usual box culvert. In the calculation, the most dangerous cross section for each span is selected and considered to be safe for each load condition.

(2) Longitudinal Calculation of Box Culvert[48]

1) Basic Principles

The longitudinal calculation will be conducted considering the characteristics of structure and foundation type of the sluiceway, as well as the effect of residual settlement in the foundation ground. The design loads for the structure shall act to produce the most unfavorable cross-sectional force or displacement. In addition, the amount of relative settlement and the relative horizontal displacement between the main body and the ground should be within the allowable values. Similarly, the ground reaction force of the main body must be within the allowable bearing capacity of the ground.

Calculation of the longitudinal direction of the main body is explained as follows:

- The main body on direct foundation will be modeled as "beams on elastic foundation"
- The main body with flexible structure may be designed by the following two methods according to the relative rigidness considering the influence of the ground displacement.

1. To design the box body as an elastic beam
2. To design the box body as a rigid body

2) In Case of Rigid Body[49]

When the residual settlement of the ground is less than 5.0 cm, the following equation will be used.

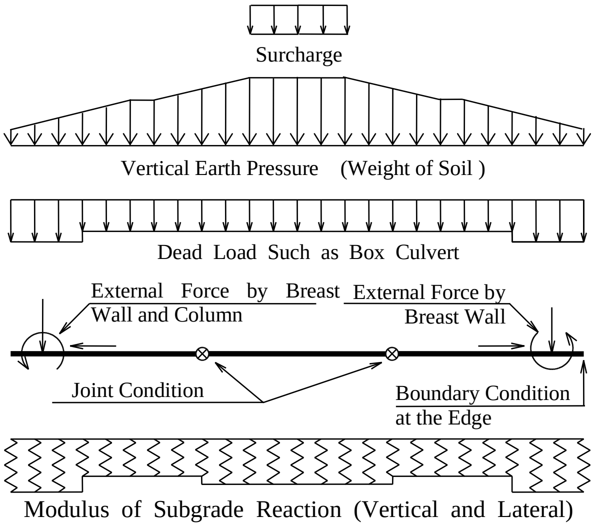
$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v\cdot w=q \quad \text{(Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s\cdot u=p \quad \text{(Displacement in axial direction of box culvert)}$$

Where,

w	: Displacement of box culvert (Swag：m)
k_v	: Modulus of subgrade reaction in vertical direction (kN/m^3)
B	: Width of box culvert (m)
EI	: Rigidness of box culvert (kN・m^2)
q	: Vertical external force (kN/m^2)
u	: Displacement on axial direction of box culvert (m)
k_s	: Modulus of lateral shear subgrade reaction (kN/m^3)
U	: Circumference of box culvert (m)
EA	: Rigidness of box culvert in axial direction (kN)
p	: External force in axial direction (kN/m^2)

47 Design Guideline for Flexible Sluiceway 7.5 Cross Sectional Calculation of Box Culvert
48 Design Guideline for Flexible Sluiceway 7.6 Longitudinal Calculation of Box Culvert
49 Design Guideline for Flexible Sluiceway 7.6 Longitudinal Calculation of Box Culvert



Source: Guideline for Flexible Sluiceway 7.6.2 Figure 1-7-16

Figure 11.3.22 Calculation Model of a Beam on Elastic Foundation

3) In Case of Flexible Body[50]

When the residual settlement of the ground is more than 5.0 cm, the following equation will be applied in order to consider the displacement of the ground.

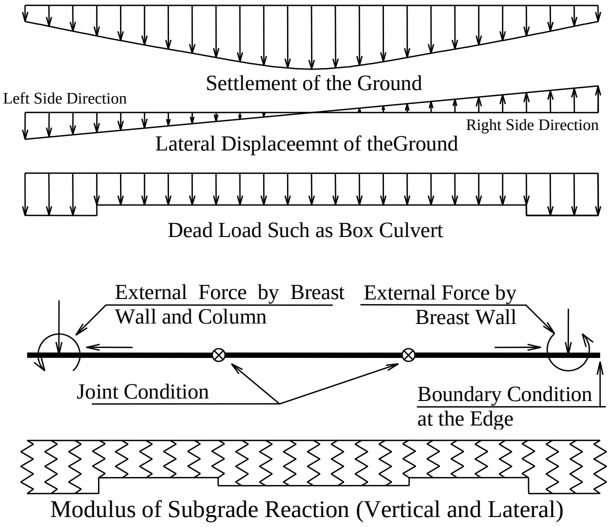
$$\frac{EI}{B}\cdot\frac{d^4w}{dx^4}+k_v(w-w_g)=q \quad \text{(Swag)}$$

$$\frac{EA}{U}\cdot\frac{d^2u}{dx^2}+k_s(u-u_g)=p \quad \text{(Displacement in axial direction of Box culvert)}$$

Where,

w	: Displacement of box culvert (Swag : m)
w_g	: Displacement of the ground (residual settlement : m)
k_v	: Modulus of subgrade reaction in vertical direction (kN/m³)
B	: Width of box culvert (m)
EI	: Rigidness of box culvert (kN・m²)
q	: Vertical external force (kN/m²)
u	: Displacement on axial direction of box culvert (m)
w_g	: Displacement of ground (lateral displacement : m)
k_s	: Modulus of lateral shear subgrade reaction (kN/m³)
U	: Circumference of box culvert (m)
EA	: Rigidness of box culvert in axial direction (kN)
p	: External force in axial direction (kN/m²)

[50] Design Guideline for Flexible Sluiceway 7.6 Longitudinal Calculation of Box Culvert



Source: Guideline for Flexible Sluiceway 7.6.2 Figure 1-7-17

Figure 11.3.23 Calculation Model of a Beam on Elastic Foundation in Consideration of Ground Displacement

(3) Design of Joint[51]

The joints are designed to satisfy the following functions:

- Water tightness against water pressure inside and outside the box culvert is ensured
- The displacement of the joint is within the deformation capacity of the joint.
- The cross-sectional force of the joint is safe for the load capacity of the joint

(4) Design of Breast Wall[52]

The wall and floor slabs of the breast wall are, in principle, designed as cantilevers fixed to the main body.

(5) Design of Column[53]

The column is designed with the top of the box as the fixed end, the frame in the lateral direction and the cantilever in the longitudinal direction.

(6) Design of Seepage Cut-off Wall[54]

The shielding wall prevents water infiltration (roofing) between the box culvert and the embankment, or piping by seepage along the weak point of the soil. In consideration of the water shielding at the connecting point between the box culvert and the shielding wall, the structure shall be designed to be safe against the force transmitted from the main body or the water shielding work itself.

(7) Design of Management Bridge[55]

In principle, the management bridge shall be designed as a simple beam.

(8) Design of Gates/Gate Stop/Hoist[56]

The gate, gate stop, and hoist of the floodgate shall be designed to ensure the water control function.

[51] Design Guideline for Flexible Sluiceway 7.6.7 Design of Joint
[52] Design Guideline for Flexible Sluiceway 7.7 Design of Brest Wall
[53] Design Guideline for Flexible Sluiceway 7.8 Design of Column
[54] Design Guideline for Flexible Sluiceway 7.9 Design of Water Shielding Wall
[55] Design Guideline for Flexible Sluiceway 7.10 Design of Management Bridge
[56] Design Guideline for Flexible Sluiceway 7.11 Design of Gates/Gate Stop/Switchgear / Technical Specification for Dams and Weirs in Japan (Draft) 3 Design of Gate, Gate Stop and Fixed Part

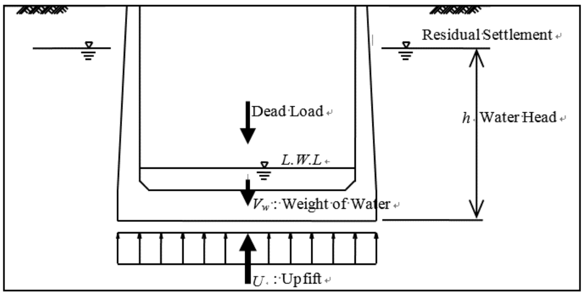
(9) Design of Wing Wall[57]

The wing wall is separated from the bushing body and designed as a freestanding structure. Stability check is required as shown in the following table.

Table 11.3.17 Stability Calculation Case of Wing Wall

Condition	Sliding (safety ratio)	Overturning (e: eccentric distance of load)	Maximum ground reaction force
Normal	Fs=1.5	$\lvert e \rvert \leqq \frac{B}{6}$ B : Width of Bottom Slab	Within allowable bearing capacity in normal condition
Normal (in case with uplift)	Fs=1.2	$\lvert e \rvert \leqq \frac{B}{3}$ B : Width of Bottom Slab	
Seismic			Within allowable bearing capacity in seismic condition

Source: Guideline for Flexible Sluiceway 7.11 Table 1-7-13



Source: Guideline for Flexible Sluiceway 7.11 Figure 1-7-39

Figure 11.3.24 Method of Uplift Analysis

(10) Design of Sealing Works[58]

Sealing works shall be designed to be safe against the effects of seepage such as roofing. See **11.5.4** for the method of seepage analysis.

11.3.7 Floodgate (Cainta Floodgate and Taytay Floodgate)

11.3.7.1 Structural Design

(1) Design Principles[59]

The floodgate shall be designed not to disturb the flow below the Design Floodwater Level, as well as not to significantly affect the riverine structures and river management facilities nearby, while properly considering for preventing scouring of riverbeds and high-water beds adjacent to the sluiceway.

(2) Main Body of Floodgate

1) Type[60]

There are three major types of floodgate: box-type, U-type, and inverse-T type. For a relatively small facility, a frame structure is favorable. Thus, from a small-scale facility, the form is adopted in the order of Box-type < U-type < Inverse T-type.

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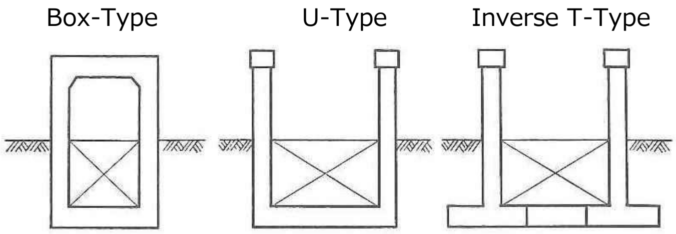
57 Design Guideline for Flexible Sluiceway 7.12 Design of Wing Wall

58 Design Guideline for Flexible Sluiceway 7.13 Design of Sealing Works

59 Technical Criteria for River Works: Practical Guide for Planning. [Design][1] 9.1 Basic of Floodgate Design

60 Technical Criteria for River Works: Practical Guide for Planning. [Design] [1] 9.2.1 Body of Floodgate



- Box Type ～12m
- U-Type・・・・・12～20m
- Inverse T-Type・・・20m～

Source: Guideline Checklist for Permitted Structures' Technical Review (MLIT, Japan)

Figure 11.3.25 Three major types of floodgate

2) Columns[61]

The top height of the columns for a vertical rising gate is determined by the total height of the gate itself and any necessary for the gate management, which is added to the height of the bottom the gate when the gate is fully open. In principle, the clearance when the gate is fully raised should be at least 1 m.

3) Floor Slab[62]

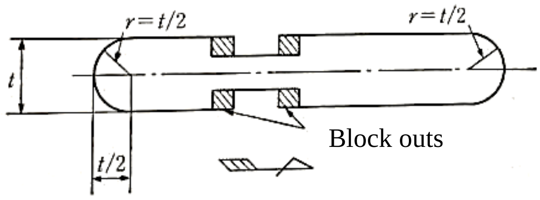
A floor slab shall be designed to be able to support a load of upper structures, to keep water tightness of the gate, as well as to serve as an apron between piers.

4) Piers[63]

Piers shall be designed to safely transmit the upper load and the water pressure at the time of flooding to the floor slab.

The cross-sectional shape of the central rod of the vertical rising gate is often designed as semicircular at both upstream and downstream ends (see **Figure 11.3.26**) to reduce the resistance to flowing water and to ensure the safety against it. The width and length of the piers are determined from the width of the control bridge, the size of the gate stop and the hoist, as well as the stability calculation.

The block out of the gate stop shall be considered so that materials for gate stop is able to be easily installed.



Source: Technical Criteria for River Works: Practical Guide for Planning [I] P63

Figure 11.3.26 Horizontal Cross Section of Piers

5) Gate[64]

The gate of sluiceway shall be designed to be able to open and close at high water events, to have enough water tightness, as well as not to hinder high water flow.

In principle, when the sluiceway gate is closed, the top of the gate (the case with the curtain wall, the top of the curtain wall) shall be higher than the crone of the dike connected to the floodgate.

When the gate is fully open, the bottom of the gate (the case with the curtain wall, the bottom of the curtain wall) shall be higher than H.W.L of the river traversed by the sluiceway added to the height

[61] Technical Criteria for River Works: Practical Guide for Planning. [Design] [1] 7.2.1.1.4 Column
[62] Technical Criteria for River Works: Practical Guide for Planning. [Design] [1] 7.2.1.1.2 Bottom Slab
[63] Technical Criteria for River Works: Practical Guide for Planning. [Design] [1] 7.2.1.1.3 Pier
[64] Technical Criteria for River Works: Practical Guide for Planning. [1] 9.2.1.6 Gate

determined by Article 20 of the Structural Ordinance. In addition, it is not lower than the top of the higher side of the embankments at that site.

6) Breast Wall[65]

Since the role of a breast wall is to prevent movement and suction of soil particles between the main body and embankments, as well as to prevent an immediate collapse of the embankments due to damages of the wing walls, etc., the height of the breast wall needs to be high as possible. Therefore, the height of the breast wall shall be designed by subtracting the revetment thickness from the planned embankment cross-section.

According to the Technical Criteria for River Works: Practical Guide for Planning [Design][I] Width of the Breast Wall[66] will be more than half of the height of the breast wall.

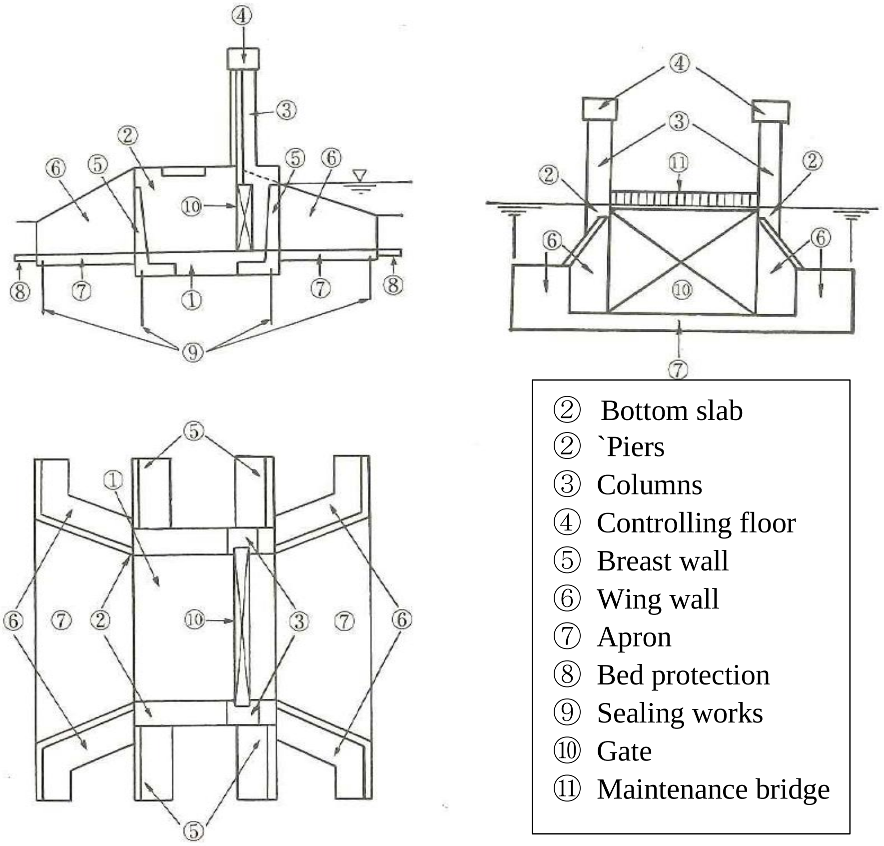
(3) Wing Walls

1) Length of wing wall[67]

The length of wing wall is designed referring to the Technical Criteria for River Works: Practical Guide for Planning [Design][I] Part 9 Floodgate. Thus, wing walls will be provided to the extent beyond the planned embankment section.

2) Horizontal Projection of Wing Walls

The horizontal projection of wing walls shall follow the figure below as cited in the Technical Criteria for River Works: Practical Guide for Planning [Design][I].



Source: Technical Criteria for River Works: Practical Guide for Planning. [Design][I] P108

Figure 11.3.27 Horizontal Projection of Wing Walls

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[65] Technical Criteria for River Works: Practical Guide for Planning. [I] 9.2.2.1 Breast Wall

[66] Technical Criteria for River Works: Practical Guide for Planning. [I] 9.2.2.1 Breast Wall

[67] Technical Criteria for River Works: Practical Guide for Planning. [I] 9.2.2.2 Wing Wall

(4) Sealing Works[68]

Appropriate water sealing works shall be installed, in order to prevent sediment movements and suction of soil by scouring under the floodgate.

1) Seepage Analysis

Seepage analysis is conducted based on Lane's Creep Theory.

2) Vertical Sealing Works

- Design Water Level：Flood (gate closed)
- Length of cut-off sheet pile[69]: If the length of the cut-off sheet pile is longer than 1/2 of the distance between sheet-piles, another measure shall be considered such as extending the apron length.

3) Horizontal Sealing Works

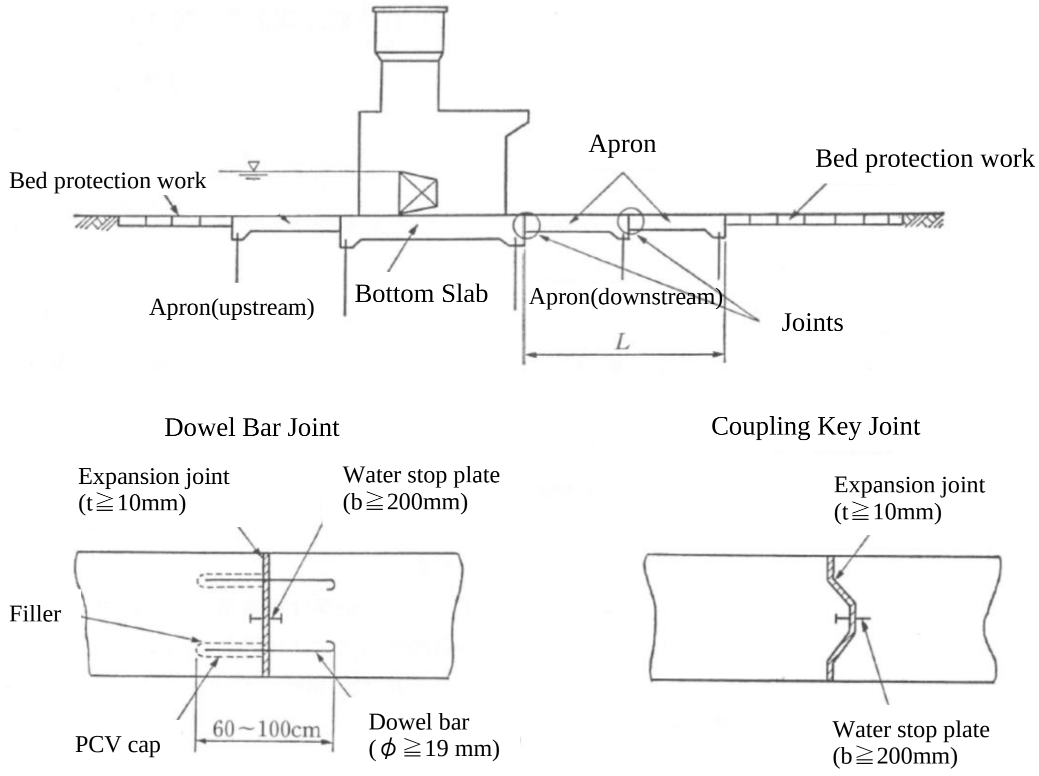
- Design Water Level：Flood (gate closed)
- Length of cut-off sheet pile：Same as the vertical sealing works.

(5) Apron[70]

Aprons shall be installed on the upper and lower sides of the main body. Aprons shall have a necessary length and structure to keep the sluiceway body safe[71].

Since the floodgate in this project will be designed to resist the Level 2 earthquake, a dowel bar will be installed at joints between the main body and wing wall so that gaps or steps will not be generated by the earthquake. The design of dowel bars shall refer to the Technical Criteria for River Works: Practical Guide for Planning [Design][Ⅰ] Part 7 Weir.

68 Technical Criteria for River Works: Practical Guide for Planning. [I] 9.2.4 Sealing Works
69 Technical Criteria for River Works: Practical Guide for Planning. [I] Ref.1.4 Design of Sealing Works
70 Technical Criteria for River Works: Practical Guide for Planning. [I] 9.2.3 Apron
71 Technical Criteria for River Works: Practical Guide for Planning. [I] 7.2.2 Apron



Source：Technical Criteria for River Works: Practical Guide for Planning. [Design][Ⅰ] P66

Figure 11.3.28 Apron Joints

(6) Bed Protection Work

1) Length

In principle, bed protection works should be designed to retain bending properties and to meet the required length in accordance with Dynamical Design Method of Revetment (Japan,2007).

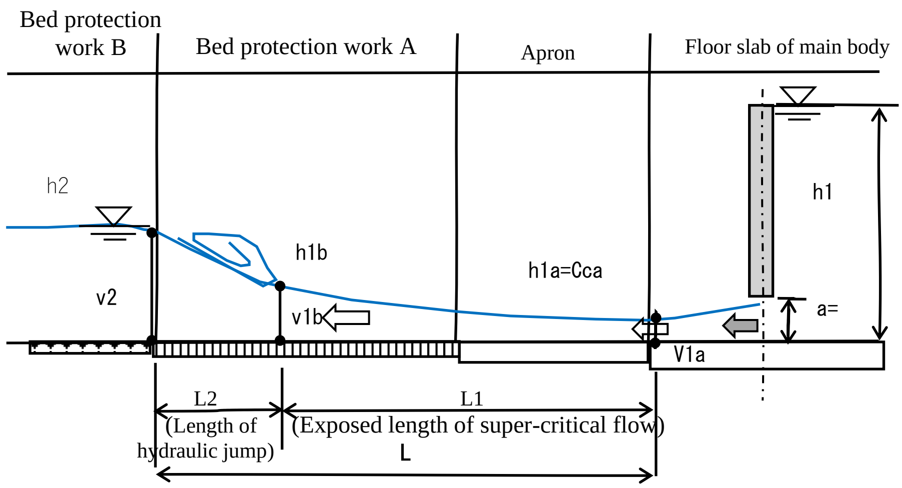
The length of the bed protection work will be set as follows.

- Length of the bed protection work A

＝ Exposed length of super-critical flow (L_1) + Length of hydraulic jump (L_2) － Length of Apron

- Length of the bed protection work B

＝ (3～5)×Water depth of downstream (h_2)



Source: Edited by Study Team Referring to the Collection of The Collection of Hydraulic Formulae (Japan Society of Civil Engineer)

Figure 11.3.29 Horizontal Projection of Wing Walls

2) Block Weight (If used)

According to the Dynamical Design Method of Revetment (Japan,2007), calculation of block weight will be carried out using the "Sliding-Overturning-Layered Model" as follows:

$$W = a\left(\frac{\rho_w}{\rho_b-\rho_w}\right)^3 \cdot \frac{\rho_b}{g} \cdot \left(\frac{V_d}{\beta}\right)^6$$

Where,

W : Minimum block weight to not move
V_d : Representative flow velocity (m/s)
a, β : Coefficients according to block shape (See **Table 11.3.18**)
ρ_b : Block density (kgf・s^2/m^4)
ρ_w : Water density =102 (kgf・s^2/m^4)

Table 11.3.18 Coefficients *a* and *β* of concrete blocks

Block Type	Specific gravity of model block	$a \times 10^{-3}$	β
A：Symmetrical protrusion Type	ρ_b/ρ_w=2.22	1.2	1.5
B：Flat Type	ρ_b/ρ_w=2.03	0.54	2.0
C：Triangular pyramid Type	ρ_b/ρ_w=2.35	0.83	1.4
D：Three-point support type	ρ_b/ρ_w=2.35	0.45	2.3
E：Rectangular type	ρ_b/ρ_w=2.09	0.79	2.8

Source: Dynamical Design Method of Revetment (Japan, 2007)

(7) Other Facilities

1) Adjacent Revetments

In consideration of the site conditions and the structure of the main body, revetments will be constructed in an appropriate range, according to the following standards[72].

Except for the site where the substrate consists of bedrock, the upstream revetment adjacent to the floodgate shall be installed until the longer of 10 m from the upstream end of the weir or 5 m from the upstream end of the bed protection work. Similarly, downstream revetment shall be provided at

72 Technical Criteria for River Works: Practical Guide for Planning. [I] 8.2.2.2 Adjacent Revetments

least until the longer of 15 m from the downstream end of apron or 5 m from the downstream end of the bed protection work.

2) Protection works for the high-water channel

The structure is common with that of the sluiceway. (see **Subsection 11.3.6.1 (9) 2)**)

3) Management Bridge[73]

The width of the management bridge shall be determined in consideration of the width necessary for the maintenance of the sluiceway, the passage width for managing the embankment, etc.

11.3.7.2 Load

The floodgate will be designed considering the following loads.

- Self-weight
- Static hydraulic pressure
- Uplift
- Seismic load
- Thermal force
- Residual hydraulic pressure
- Earth pressure
- Wind load
- Active load

Load such as static hydrostatic pressure shall be determined based on the following water level conditions.

Table 11.3.19 Design Water Levels

Water Levels / Types of Floodgates	Design Water Levels	
	External water level	Internal water level
Floodgate installed for backwater protection of tributary with levee which height is determined by DFL of the main channel	External H.W. L (Design High Tide Level in the high tide section)	Bottom Height of Gate or H.W.L of internal water
Floodgate installed for backwater protection of tributary with levee which height is determined by DFL of the tributary	External H.W. L (Design High Tide Level in the high tide section)	Bottom Height of Gate or H.W.L of internal water
Floodgate installed at diversion point	External H.W. L (Design High Tide Level in the high tide section)	Bottom Height of Gate

Source: Technical Criteria for River Works: Practical Guide for Planning. [Design][I] P114

11.3.7.3 Design Methods

(1) Stability Analysis[74]

The sluiceway body shall be designed to ensure the required safety for sliding, overturning and bearing capacity against the design load. In principle, the calculation flow and methods shall be based on the following descriptions.

1) Assumption of Geometries

The shape and dimensions of the major units such as the gate operation room, operation console, columns, piers, floor slab, etc., are to satisfy the specifications of the floor height, span length, portal height, and bridge width decided in advance. The weight of the body is determined based on the above-mentioned assumption.

[73] Technical Criteria for River Works: Practical Guide for Planning. [I] 9.2.6.1 Management Bridge

[74] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] P83

2) Assumption of weight of gate, hoist, gate stop, bridge and other accessories

To assume the weight of the gate, hoist, and gate stop, it is calculated with the bed height, span length, gate height, and design water level decided in advance. Similarly, the weight of the bridge is calculated according to other examples and reference designs such as standard designs.

If there are other accessories which may affect stability calculations, their weights shall also be taken into account.

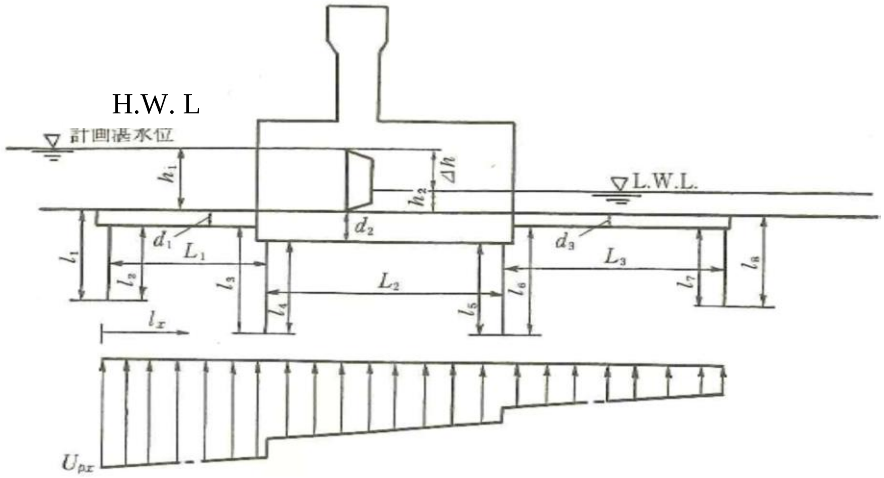
3) Load Calculations

- Vertical load: The weight of facilities, such as the sluiceway main body and bridge, will be calculated according to the assumed shape and dimensions. For end piers, soil weight behind will be considered if necessary.
- Seismic load: The horizontal force will be calculated by multiplying the weight of each part by the design seismic coefficient. Hydraulic pressure, however, shall be calculated by Westergaard's equation (**Subsection 11.4.5.3**).
- Earth pressure: As a rule, earth pressure is calculated by the Coulomb equation, both in case of ordinary and earthquake (**Subsection 11.4.4**).
- Wind load: All projected planes above the water surface or above the ground. wind load shall be taken into consideration.
- Uplift: uplift is calculated by the following formulae.

$$U_{px} = \left(h_2 + \Delta h \frac{\sum l - lx}{\sum l} + d_1 \right) \cdot W_0$$

Where,

U_{px} : Uplift at any point (kN/m^2)
Δh : Water level difference between upstream and downstream ($h_1 - h_2$) (m)
lx : Seepage length from the upper edge to any point (m)
$\sum l$: The entire seepage length (m)
W_0 : Unit weight of water (kN/m^3)
d_1 : The thickness of the bottom slab or apron at any point (m)



Source: Technical Criteria for River Works: Practical Guide for Planning [Design] [I] P66

Figure 11.3.30 Calculation of Uplift

4) Safety analysis of sliding, overturning and bearing capacity

The sliding, overturning, and bearing capacity of ground are examined under the load conditions of **Subsection 11.3.7.2** , and the safety factor is designed to be higher than those of shown in **Subsection 11.5** .

(2) Stress Calculation

1) Columns[75]

The stress of the column is calculated against the design load by obtaining the moment and the axial force as a cantilever or a portal-shape rigid frame according to the shape of the column.

2) Piers[76]

The stress of weir pier is calculated against the design load by obtaining the moment and the axial force as a cantilever fixed with the bottom slab.

3) Bottom Slab[77]

The stress of the bottom slab is calculated against the design load by obtaining the moment and the axial force as a cantilever fixed with the weir pier, or a beam on elastic foundation according to the shape of the bottom slab.

1. Stress calculation of floor slab in case of inverse T type

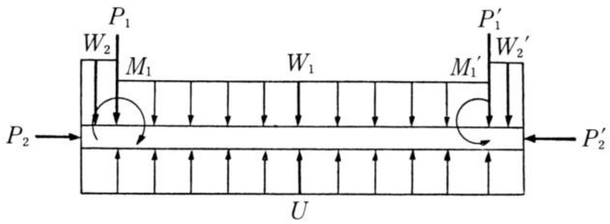
   If the structure of the main body is inverse T type, stress calculation against the given load conditions shall be conducted by separating the floor slab of the weir piers and middle slab. The floor slab of the weir piers shall be calculated cantilever as fixed with the weir pier, while the middle slab as a slab on an elastic foundation.

2. Stress calculation of floor slab in case of U Type

   If the structure of the main body is U type, stress calculation shall be conducted. The bottom slab will, in principle, be regarded as a slab on an elastic foundation.

   - The case of the direction perpendicular to flow

   Against the load conditions shown in Figure below, stress is calculated by obtaining moment and axial force as a slab on the elastic foundation.



Load Acting on the Bottom Slab (perpendicular to flow)

Where,

U	: Uplift
P_1, P'_1	: Vertical force from pier
P_2, P'_2	: Horizontal force from pier
W_1	: Water weight
W_2, W'_2	: Sediment weight
M_2, M'_2	: Moment from pier

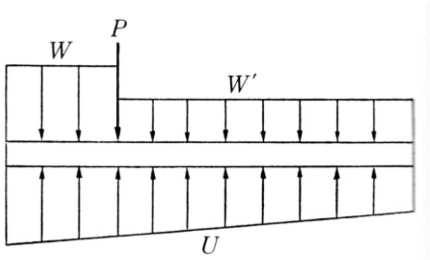
[75] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] P90
[76] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] P91
[77] Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] P92

- The case of direction horizontal to flow

Against the load conditions shown in Figure below, stress is calculated by obtaining moment and axial force as a slab on the elastic foundation.

Where,

U : Uplift
W_2, W'_2 : Water weight downstream of the weir
P : Gate weight



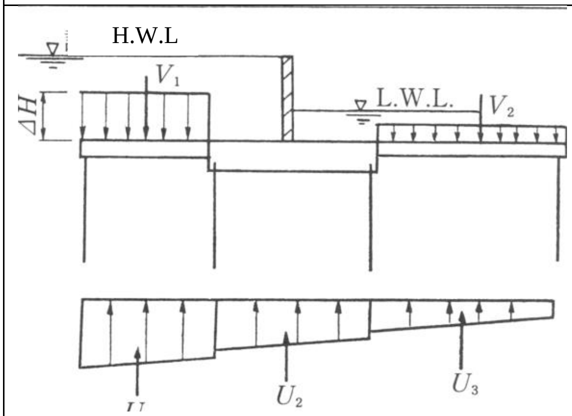
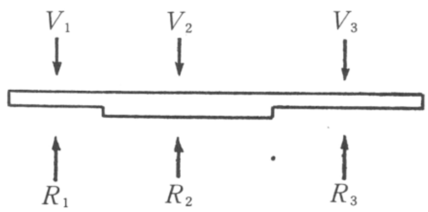
Load Acting on the Bottom Slab (horizontal to flow)

Source: Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] P92

4) Apron[78]

Aprons shall be designed to be a safe structure against loads such as water weight and uplift.

Table 11.3.20 Loads for Calculation of Apron Stability

In case of flood	In case of construction (bearing capacity analysis)
 V_1,V_2 : water weight, apron weight U_1,U_2,U_3 :Uplift	 V : Apron weight (without buoyancy) R : Foundation reaction

Source: Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] P93

11.3.8 Weir (MCGS)

11.3.8.1 Structural Design

(1) Design Principles[79]

The weir shall be designed to be safe against running water below the DFL. The weir should not significantly disturb the structure and function of embankments and adjacent river management facilities. Similarly, it should not disrupt the flooding flow below the DFL. Besides, the weir shall be

78 Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] P92
79 Technical Criteria for River Works: Practical Guide for Planning [Design] [I] 7.1 Design of Weir

designed in consideration of the prevention of scouring of riverbeds and high-water beds near the weir, as well as operability, landscape, and economy.

(2) Main Body of Weir

See Design for Floodgate (**Subsection 11.3.7.1 (2)**).

(3) Sealing Work[80]

In principle, the shieling work is a concrete cut-off structure or a steel sheet pile structure. The shielding work will be designed to reduce the hydraulic gradient of the seepage water caused by the water level difference between the upstream and downstream, as well as to prevent the soil movement and sanction. It is also necessary to consider the seepage along the retaining wall of the weir. The seepage analysis method is the same as that of the floodgate

In addition, shielding works shall be continuously installed with the floor slab, apron, and the other connected parts of the weir.

(4) Apron

See Apron Design for Floodgate (**Subsection 11.3.7.1 (5)**).

(5) Bed Protection Work

See Bed Protection Work Design for Floodgate (**Subsection 11.3.7.1 (6)**).

(6) Revetment[81]

1) Adjacent Revetment

In consideration of the site conditions and the structure of the main body, revetments will be constructed in an appropriate range, according to the following standards[82].

Except for the site where the substrate consists of bedrock, the upstream revetment adjacent to the weir shall be installed until the longer of 10 m from the upstream end of the weir or 5 m from the upstream end of the bed protection work. Similarly, downstream revetment shall be provided at least until the longer of 15 m from the downstream end of apron or 5 m from the downstream end of the bed protection work.

(7) Other Facilities

1) Protection Works for the High-Water Channel

See Protection Work Design for Floodgate (**Subsection 11.3.7.1 (7) 2)**).

2) Management Bridge[83]

In principle, a management bridge will be installed on the weir. The width of the bridge shall be determined in consideration of the width necessary for the maintenance of the weir, the road width of the connected embankment and so on.

11.3.8.2 Loads

The weirs will be designed considering the following loads.

- Self-Weight
- Hydraulic Pressure
- Mud Pressure
- Uplift
- Seismic Force
- Seismic Water Pressure

80 Technical Criteria for River Works: Practical Guide for Planning [Design] [I] 7.2.3 Sealing Work
81 Technical Criteria for River Works: Practical Guide for Planning [Design] [I] 7.2.6 Revetment
82 Technical Criteria for River Works: Practical Guide for Planning. [Planning] 8.2.2 Revetment near Weir and Other Structures
83 Technical Criteria for River Works: Practical Guide for Planning. [Design] [I] 7.2.8.1 Management Bridge

- Thermal Force
- Wave Pressure
- Residual Water Pressure
- Earth Pressure
- Wind Pressure
- Active Load

11.3.8.3 Design Methods

(1) Stability Analysis

See Stability Analysis of Floodgate (**Subsection 11.3.7.3 (1)**).

(2) Stress Calculation

See Stress Calculation of Floodgate (**Subsection 11.3.7.3 (2)**).

11.4 Loads

11.4.1 Load Type

All facilities of the project are designed against combination of the loads enumerated below:

- Dead Load (Dead weight of structures)
- Surcharge (incl. active/collision load and dynamic load from equipment)
- Earth Pressure
- Hydrostatic Pressure
- Uplift
- Seismic Load
- Wind Load
- Thermal Force
- Loads During Construction

11.4.2 Dead Load

11.4.2.1 Normal Condition

Table 11.4.1 Unit Weight of Materials

Materials	Unit Weight	Unit
Concrete: Reinforced /Pre-stressed	24	kN/m^3
Concrete: Plain	23.5	kN/m^3
Mortar	21	kN/m^3
Structural Steel	77	kN/m^3
Cast Iron	71	kN/m^3
Stone Masonry	22	kN/m^3
Timber	8	kN/m^3
Water	9.8	kN/m^3
Soil：dry (not disturbed)	Ref. **Subsection 11.6.1.1**	kN/m^3
：wet (compacted)		kN/m^3
：saturated		kN/m^3
sand／gravel (compacted)	19	kN/m^3

Source: DPWH Design Guidelines Criteria and Standards (Vol. II) 3.11Dead Load、NSCP Vol. II Bridges (ASD) 3.3 Dead Load / Specifications for Highway Bridges I Common 2.2.1 Dead Load

11.4.2.2 Seismic Condition

Seismic load is calculated using the seismic coefficient method. According to the NSCP, the seismic coefficient[84] is recommended to consider a half of the acceleration coefficient[85]. As seen in the **Figure 11.4.1**, the acceleration coefficient (A) in the Manila (zone 4) is 0.40. Thus, Kh = A / 2 = 0.4 / 2 = 0.2.

The already completed projects in the Pasig-Marikina river also followed this method.

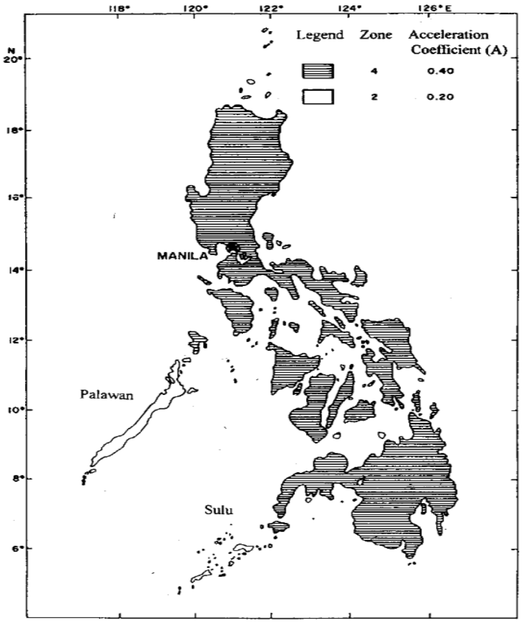


Figure 21.3 Seismic Zone Map of the Philippines

Source: NSCP II Bridges (ASD) 21.3.5 Site Effects

Figure 11.4.1 Acceleration Coefficients in the Philippines

On the other hand, the horizontal seismic coefficient described in the DSGS is used. This method calculates designed horizontal seismic coefficient using the distance attenuation formula of Fukushima and Tanaka[86] as follows:

$$\log_{10} A = 0.41M - \log_{10}(R+0.032*10^{0.4M}) - 0.0034R + 1.30$$

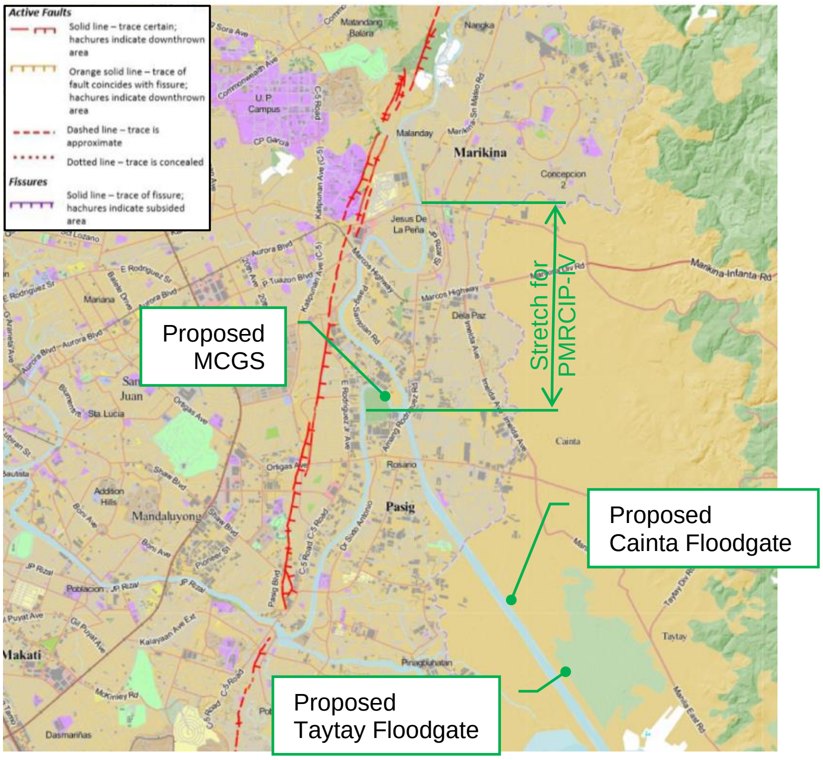
Where,

A = Average peak acceleration (cm/sec^2)
R = Distance from epicenter (km)
M = Magnitude

Depending on the foundation soil characteristics, a correction factor is applied to the average peak acceleration (hard soil: 0.87, moderate soil: 1.07, soft soil: 1.39).

As a result of applying this formula in the project area, the designed horizontal seismic coefficient A is 0.76 at the MCGS (R = 1.3 km, medium soil). This value is larger than the horizontal seismic coefficient for the Level 2 earthquake at the site described in the BSDS (= 0.6[87]). Therefore, the horizontal design seismic coefficient for medium-sized earthquakes targeted by this design shall be 0.2.

[84] NSCP Vol. II Bridges (ASD) 21.3.5 Site Effects
[85] NSCP Vol. II Bridges (ASD) 21.6. Foundation and Abutment Design Requirements
[86] DGCS Vol.2a Annex A: Seismicity
[87] BSDS Appendix.3B Spectral Acceleration Maps for Level 2 Earthquake Ground Motion 3B-8



Source: The PHIVOLCS Fault Finder

Figure 11.4.2 Valley Fault System

11.4.3 Surcharge Load

11.4.3.1 If Erath Cover is 4m or more

Surcharge load composed of the following loads shall be loaded on the most damaging part of the structure. If earth cover is 4m or more, the live load of 10kN/m^2 shall be considered. If there is no automobile traffic the pedestrian load shall be q = 5kN / m^2.

As the load acting on the side surface of the structure, q = 10kN / m^2 (normal) and q = 5kN / m^2 (seismic) are applied.

Table 11.4.2 Surcharge

Type	Normal	Seismic	Unit
Upper load	10	5	kN/m^2
Pedestrian load	5.0	0	kN/m^2

Source: Guideline of Earth Works of Box Culvert 4-2-3 Live Load and Impact

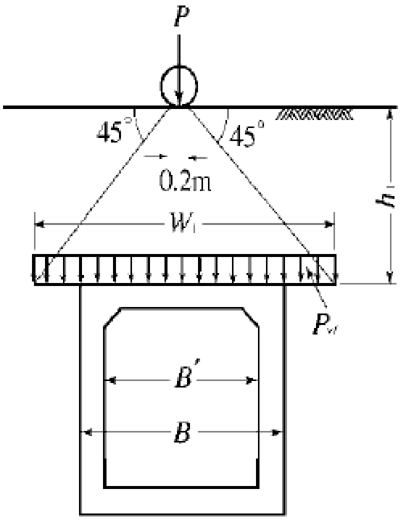
11.4.3.2 If Erath Cover is less than 4m

In case that a vehicle and heavy machinery passes through the structure, the rear wheel of 100kN will act on the structure if the earth cover is 4m or less. Impact factor shall be 0.3.

Rear wheel Load : P_{l1} = (2 x Rear wheel (kN)) / Width of vehicle x (1+Impact factor)[88]

= (2 x 100) / 2.75 x (1+0.30) = 94.5 kN/m

[88] Road Earthwork Guideline (Culvert) 4-2-3 Live Load and Impact



Source: Guideline of Earth Works of Box Culvert (Japan, 2010)5-2 Load

Figure 11.4.3 Concentrated Load and Its Distribution with Earth Cover of 4m or Less [89]

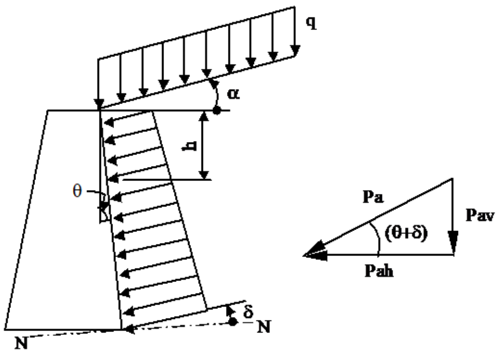
In case that the earth cover is 4m or more, a uniform load of 10 kN/m^2 shall be adopted. Whereas, in case that no vehicle except pedestrians pass through, a pedestrian load of 5 kN/m^2 shall be adopted.

The Lateral Pressure will be q=10kN/m^2 (normal) and q=5kN/m^2 (seismic) in spite of the height of embankment.

11.4.4 Earth Pressure

11.4.4.1 Earth Pressure Acting on Movable Wall

Earth pressure acting on movable walls is calculated by the following Coulomb's coefficient[90]:



Source: Study Team

Figure 11.4.4 Active Earth Pressure

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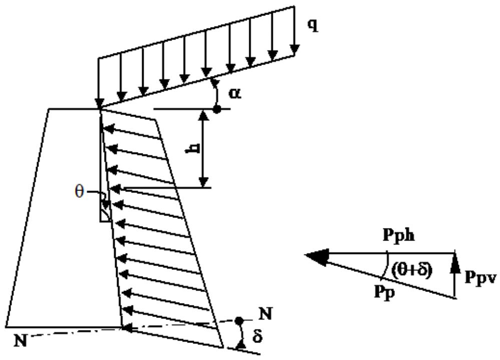
[89] Road Earthwork Guideline (Culvert) 5-2 Load

[90] NSCP Vol. II Bridges (ASD) 5.5.2 Earth Pressure and Surcharge Loadings



Source: Study Team

Figure 11.4.5 Passive Earth Pressure

For Sandy Soil:

P_a = Ka γh + Ka q

P_p = Kp γh + Kp q

For Clayey Soil

$$P_a = K_a \gamma h - 2c\sqrt{K_a} + K_a q$$

$$K_a = \frac{cos^2(\varphi - \theta)}{cos^2\theta \cos(\theta + \delta)\left[1 + \sqrt{\frac{\sin(\theta + \delta)\sin(\varphi - \alpha)}{\cos(\theta + \delta)\cos(\theta - \alpha)}}\right]^2}$$

$$P_p = K_p \gamma h + 2c\sqrt{K_p} + K_p q$$

$$K_p = \frac{cos^2(\varphi + \theta)}{cos^2\theta \cos(\theta + \delta)\left[1 - \sqrt{\frac{\sin(\theta - \delta)\sin(\varphi + \alpha)}{\cos(\theta + \delta)\cos(\theta - \alpha)}}\right]^2}$$

Where,

P_a	: Active earth pressure (kN/m²)
P_p	: Passive earth pressure (kN/m²)
γ	: Unit weight of soil (kN/m³)
K_a	: Coefficient of active earth pressure
K_p	: Coefficient of passive earth pressure
h	: Earth depth to acting point of earth pressures (m)
c	: Soil cohesion (kN/m²)
q	: Surcharge load in normal condition (kN/m²)
φ/ϕ	: internal friction angle of soil (degree)
θ	: angle between back side surface of wall and vertical plane (degree)
α	: angle between ground surface and horizontal plane (degree)
δ	: angle of wall friction (degree)

11.4.4.2 Earth Pressure under Seismic Condition[91]

Lateral earth pressure due to earthquake is calculated by the Mononobe-Okabe formula based on the Coulomb's theory in consideration of seismic factor.

Pea = K_{ea} γ h – 2c $\sqrt{K_{ea}}$ + K_{ea} q'

[91] NSCP Vol. II Bridges (ASD) 5.5.4 Seismic Pressure

$$Kea = \frac{\cos^2(\phi - \theta_o - \theta)}{\cos\theta_o \cos^2\theta \cos(\theta + \theta_o + \delta)\left(1 + \sqrt{\frac{\sin(\phi + \delta)\sin(\phi - \alpha - \theta_o)}{\cos(\theta + \theta_o + \delta)\cos(\theta - \alpha)}}\right)^2}$$

$$Pep = Kep\ \gamma\ h - 2c\sqrt{K_{ep}} + Kep\ q'$$

$$Kep = \frac{\cos^2(\phi - \theta_o + \theta)}{\cos\theta_o \cos^2\theta \cos(\theta - \theta_o + \delta)\left(1 - \sqrt{\frac{\sin(\phi - \delta)\sin(\phi + \alpha - \theta_o)}{\cos(\theta - \theta_o + \delta)\cos(\theta - \alpha)}}\right)^2}$$

Where,

Pea : Active earth pressure under Seismic Condition (kN/m²)
Pep : Passive earth pressure under Seismic Condition (kN/m²)
γ : Unit weight of soil (kN/m³)
h : Earth depth to acting point of earth pressures (m)
c : Soil cohesion (kN/m²)
ϕ/φ : internal friction angle of soil (degree)
θ : angle between back side surface of wall and vertical plane (degree)
α : angle between ground surface and horizontal plane (degree)
δ : angle of wall friction (degree)
Kea : Coefficient of active earth pressure under Seismic Condition
Kep : Coefficient of passive earth pressure under Seismic Condition
q' : Surcharge load in Seismic Condition (kN/m²)
θo : Angle expressed by formula shown below (degree)

$$\tan\theta_o = \frac{Kh}{1 - Kv}$$

Kv : seismic coefficient in vertical direction
Kh : seismic coefficient in horizontal direction

11.4.4.3 Wall Friction Angle[92]

The following values will be used as wall friction angles.

Table 11.4.3 Wall Friction Angles

Type of friction	Wall friction angle (δ)	
	Normal Condition (δ)	Seismic Condition (δ_E)
Soil and Concrete	$\emptyset/3$	0
Soil and Soil	$\emptyset$	$\emptyset/2$

Note: ϕ: internal friction angle of soil (degree)
Source: Specifications for Highway Bridges IV Substructures p-49

11.4.4.4 Earth Pressure Acting on Fixed Wall

Earth pressure applied to the breast wall fixed to the pier of the floodgate, or to the U-shaped type wing wall shall be in accordance with the following principles.

Table 11.4.4 Types of Earth Pressure Acting on the Breast Wall and Wing Wall

Type	Normal	Seismic
Breast Wall	Earth pressure at rest	Active earth pressure (seismic)
Wing Wall (U-shaped Type)	Earth pressure at rest	Earth pressure at rest (seismic)
Wing wall (Inverse-T type)	Active earth pressure	Active earth pressure (seismic)

Source: Guideline for Flexible Sluiceway P-50

The end of the box culvert, which connects to the wing wall is likely to displace during an earthquake. Thus, an active earth pressure is considered in case of an earthquake in the breast wall design.

92 Specifications for Highway Bridges IV Substructures p49

When it is certain that the displacement of the box is restricted during an earthquake since the main body is one span or such, it is preferable to use the static earth pressure during the earthquake.

As for the wing wall of inverse-T type, the active earth pressure may be considered for both normal and seismic condition, since rotation displacement will not be bound[93].

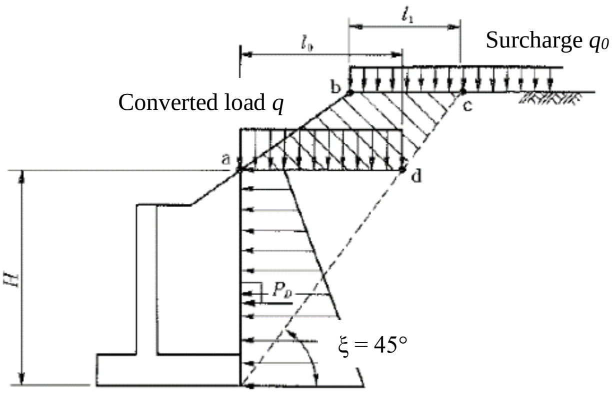
The earth pressure at rest acting on the breast wall and wing wall is obtained as follows.

$$P_{hd} = K_0(\gamma \cdot h + q_0)$$

Where,

P_{hd} : Horizontal earth pressure strength of any depth (kN/m^2)
K_0 : Coefficient of earth pressure at rest (= 0.5 as usual)
γ : Unit weight of soil (kN/m^3)
h : Depth (m)
q_0 : Surcharge (kN/m^2)

Assuming that the area of influence of the soil slope behind the wall is $\xi = 45°$as shown in the figure below, the earth weight and surcharge of this area may be converted into the design load[94].



Source: *Guideline for Flexible Sluiceway P-51*

Figure 11.4.6 Converted Load of Soil behind the Wall

11.4.5 Hydraulic Pressure

11.4.5.1 Static Hydrostatic Pressure

Hydrostatic pressure acting on the structure is calculated by the following formula:

$$Ph = \gamma_w h$$

Where,

Ph : Hydrostatic pressure at "h" (kN/m^2)
h : Water depth (m)
γ_w : Unit weight of water (9.8kN/m^3)

11.4.5.2 Residual Water Pressure[95]

In case the water level is different between the front side and rear side of the wall, residual water level shall be considered.

<u>HWL < GL</u>

1. GWL < WL $RWL = (HWL - WL) \times 2/3$
2. GWL > WL $RWL = (HWL - GWL) \times 2/3$

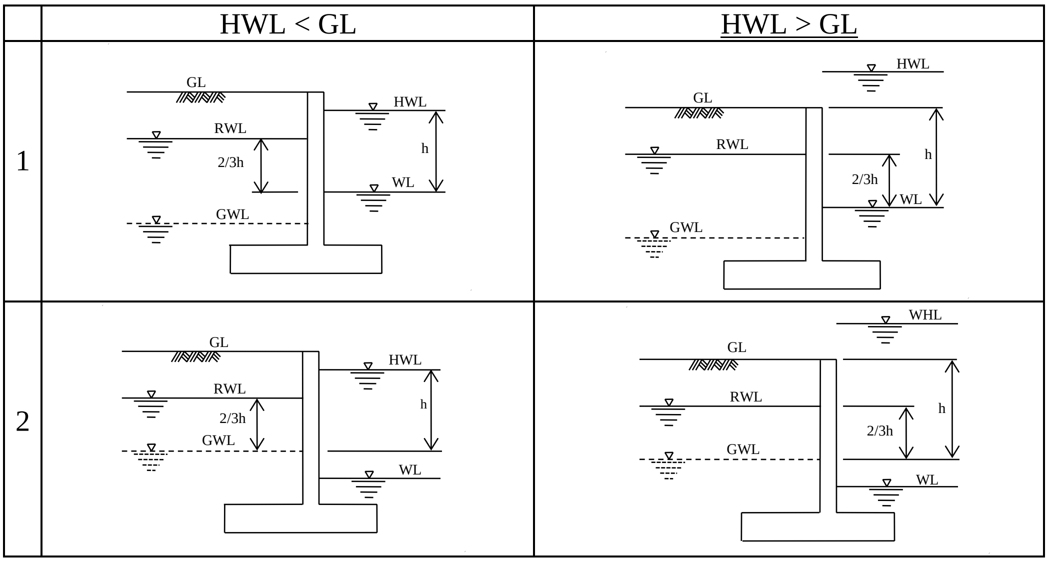
[93] Source: Guideline for Flexible Sluiceway P-50
[94] Source: Guideline for Flexible Sluiceway P-50
[95] Design Guideline for Flexible Sluiceway P54

HWL > GL

1. GWL < WL $RWL = (GL - WL) \times 2/3$
2. GWL > WL $RWL = (GL - GWL) \times 2/3$

Where,

RWL	:	Residual Water Level
HWL	:	High Water Level
GWL	:	Natural Ground Level
WL	:	Water Level in Front Side
GL	:	Ground Level behind the Structure



Source: Guideline for Flexible Sluiceway P-54

Figure 11.4.7 Determination of Residual Water Level (Normal Condition)

11.4.5.3 Dynamic Hydraulic Pressure during Earthquake[96]

Dynamic water pressure caused by earthquake acting on the wall structure facing on one side only is calculated by the following Westergaard's formula:

$$Pp = Kp\ \gamma\ h + Kp\ q$$

$$P = \frac{7}{12} Kh\, \gamma_w\, b\, H^2$$

$$hg = \frac{2}{5} H$$

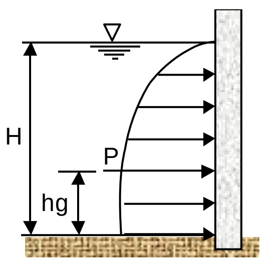


Figure 11.4.8 Dynamic Water Pressure on Wall

P : Dynamic water pressure caused by earthquake (kN)

K_h : Coefficient of horizontal earthquake factor

96 Specifications for Highway Bridges V Seismic Design 6.2.5 Seismic Hydraulic Pressure

γ_w : Unit weight of water (kN/m³)
b : Width of wall structure (m)
H : Water depth (m)
h_g : Dynamic water pressure acting depth caused by earthquake (m)

11.4.6 Uplift (Buoyancy)[97]

Uplift pressure shall be considered in the design of structures fully or partially submerged. All resultant buoyancy acting on the structure is calculated as follows:

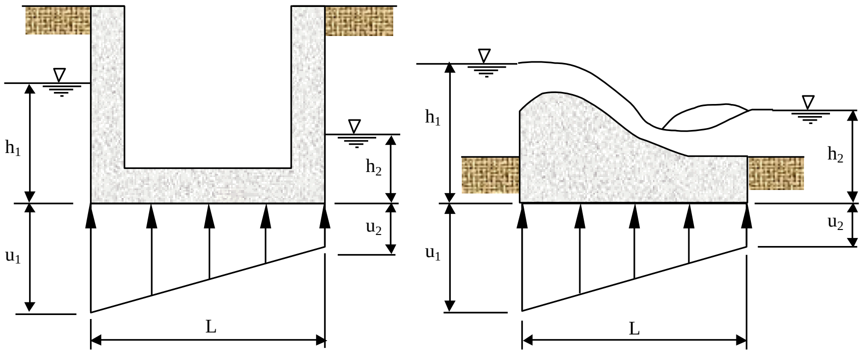


Figure 11.4.9 Uplift (Buoyancy)

$$U = \frac{1}{2}(U_1 + U_2)\,L\,\gamma w$$

Where,

U : Total uplift (kN/m)
U_1 : Buoyancy at upstream side (kN/m²) ($U_1 = 9.8\ h_1$)
U_2 : Buoyancy at downstream side (kN/m²) ($U_2 = 9.8\ h_2$)
L : Bottom width of structure (m)
γ_w : Unit weight of water (9.8 kN/m³)

11.4.7 Wind Load

(1) In case of Civil Structure

1) Study Concept

In DGCS Vol.3Water Engineering is not specifying the wind load. Hence, wild load is set in reference to the following standards.

- DGCS vol.5 Bridges (The Philippines)
- Guideline for Flexible Sluiceway (Japan)

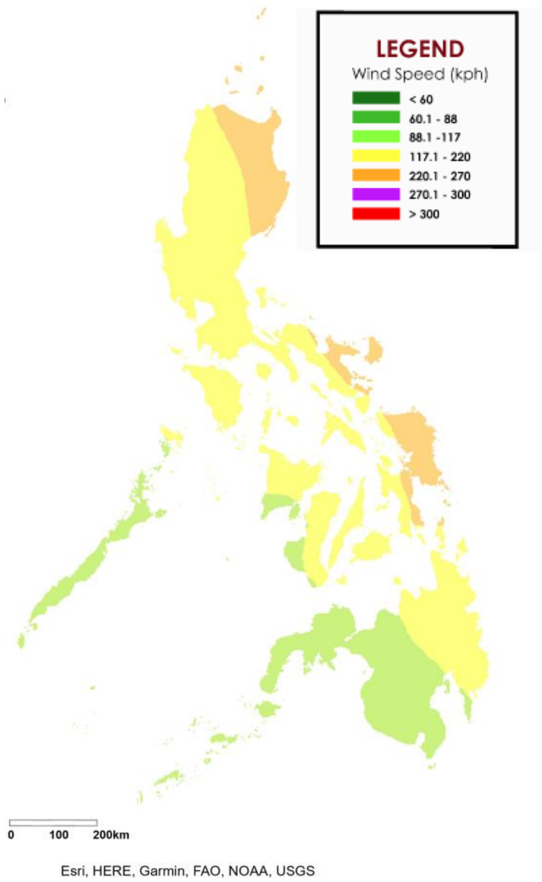
Guideline for Flexible Sluiceway in Japan is specifying the same wind load as the one given to the bridge substructure[98]. Generally, in Japan, the wind load specified in this guideline has been adopted in the design of river structure such as sluiceways, weirs and floodgates. Hence, also in this detailed design study, wind load would be determined in reference to the one for bridge substructures.

2) Determination of Basic Wind Speed

According to DGCS vol.5 Bridges Design, Basic Wind Map indicated by PAGASA can be referred for the wind velocity above 10 m height or above design water level which is used in the calculation of design wind velocity[99]. The wind speed distribution in 50 years return period(**Figure 11.4.10**) published by PAGASA is almost same as Basic Wind Map(**Figure 11.4.11**) introduced in DGCS vol.6 Public Buildings and Other Related Structures (NSCP also shows the same map) and the basic

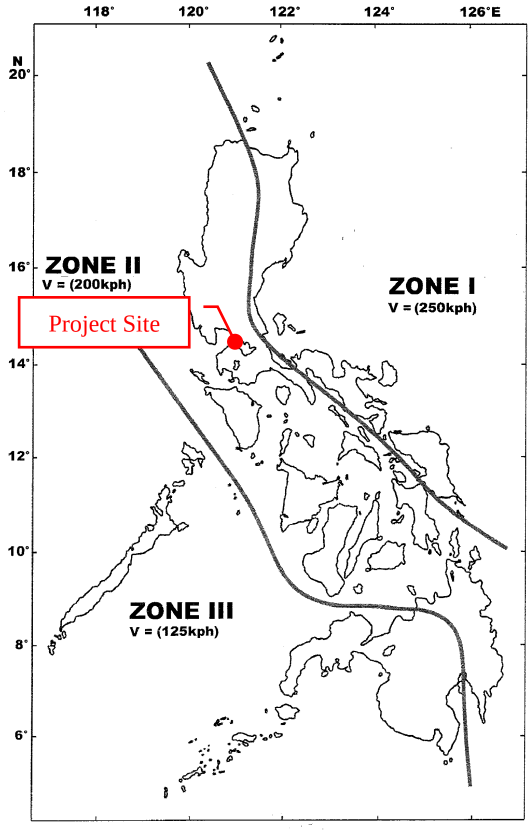
[97] Specifications for Highway Bridges I Common 2.2.8 Uplift Pressure
[98] Guideline for Flexible Sluiceway 3.12 Wind Load and Specifications for Highway Bridges I Common 2.2.9 Wind Load (5)
[99] DGCS Volume 5 - Bridge Design 10.13.1 Horizontal Wind Pressure

wind speed at the project site is 200 km/h. Accordingly, 200 km/h is adopted for basic wind speed. In addition, this basic wind speed is as same as the one adopted for the design of building structure in this study.



Source : PAGASA Web Page

Figure 11.4.10 Wind Hazard Map(50-year Return Period)



Source : NSCP vol. II, 2010 (Same contents as DGCS vol.6)

Figure 11.4.11 Basic Wind Speed

3) Calculation of Wind Load

DGCS vol.5 Bridges Design specifies 1.9 kN/m^2 at 160 km/h of basic wind speed for wind load given to bridge substructures[100]. On the other hand, Guideline for Flexible Sluiceway specifies 2.94 kN/m^2 at basic design wind speed 40 m/s (=144 km/h) as the wind load[101]. **Table 11.4.5** shows the wind load considering the extra based on the basic wind speed 200 km/h.

Table 11.4.5 indicates that the wind load considering the extra based on the basic wind speed 200 km/h in accordance with Guideline for Flexible Sluiceway (Japan) is larger. Considering that strong typhoons attack the Philippine more frequently than Japan, application of a larger wind load than it used in japan is appropriate. Therefore, considering the extra based on the basic wind speed 200 km/h to the wind load specified in Guideline for Flexible Sluiceway (Japan), 4.17 kN/m^2 would be adopted in this design.

Table 11.4.5 Wind Load Considering the Extra Based on the Basic Wind Speed 200 km/h

	DGCS, Philippine		Guideline for Flexible Sluiceway (Japan)	
Wind Speed (km/h)	160	**200**	144	**200**
Wind Load (kN/m^2)	1.9	**2.38**	3.0	**4.17 (Adopted)**

Source : JICA Study Team

100 DGCS Volume 5 - Bridge Design 10.13.1.1 Wind Pressure on Structures: WS

101 Guideline for Flexible Sluiceway 3.12 Wind Load and Specifications for Highway Bridges I Common 2.2.9 Wind Load (5)

(2) In case of Building Structure[102]

Wind load is calculated in accordance with the DGCS vol.6 Public Buildings and Other Related Structures and NSCP vol. II (2010).

$q_z = 47.3 \times 10^{-6} \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2 \cdot I_w$

where:

qz	: Velocity Pressure
K_d	: wind directionality factor in NSCP Table 207-2
K_z	: velocity pressure exposure coefficient evaluated at height z
K_{zt}	: topographic factor as defined in NSCP Section 207.5.7
V	: basic wind speed as defined in NSCP Section 207.5.4
I_w	: importance factor as defined in NSCP Section 207.5.5

For rigid buildings of all heights: $p = q \cdot G \cdot C_p - q_i \cdot (GC_{pi})$

For flexible buildings: $p = q \cdot G_f \cdot C_p - q_i \cdot (GC_{pi})$

where:

p :	Wind Load
q :	q_z for windward walls evaluated at height z above the ground
q :	q_h for leeward walls, side walls and roofs evaluated at height h
qi :	q_h for windward walls, leeward walls, and roofs of enclosed buildings and f_{pr} negative internal pressure evaluation in partially enclosed buildings
qi :	q_z for positive internal pressure evaluation in partially enclosed buildings where height is defined as the level at the highest opening in the building that could affect the positive internal pressure
G, G_f :	gust effect factor from NSCP Section 207.5.8 (See discussion in NSCP Section 207.5.12.2)
C_p :	external pressure coefficient from NSCP Figure 207-6 or 207-8
(GC_{pi}) :	internal pressure coefficient from NSCP Figure 207-5; q and q_i shall be evaluated using exposure defined in NSCP Section 207.5.6.3. Pressure shall be applied simultaneously on windward and leeward walls and on roof surface as defined in NSCP Figures 207-6 and 207-8.

11.4.8 Thermal Force[103]

The design of the structure should consider stress and movement due to temperature fluctuations. Careful attention shall be paid to the difference between the temperature in air and the internal stress of the mass concrete structure.

In general, the temperature range is as follows:

Steel structure : 17.8 ºC ~48.9ºC

Concrete structure : Temperature rise =16.7ºC; Temperature fall =22.2ºC

Based on the above, the thermal force is set as follows.

$$Thermal\ Force\ Nt = Ab \times Ec \times \varepsilon \times \Delta t$$

Here,

Ab	: Area of the structure (m^2)
Ec	: Modulus of elasticity (21,383.7N/m^2)
ε	: Coefficient of linear expansion (10.8×10^{-6})

[102] DPWH Design Guidelines Criteria and Standards vol. 6 4.2.7 Wind Load

[103] DPWH Design Guidelines Criteria and Standards (Vol. II) 3.16 Thermal Forces

Δt : Range of thermal fluctuation (ºC: +16.7 ºC, -22.2 ºC)

11.4.9 Gate Operation Load

Gate operation load shall be considered in the design of piers and operation deck. Besides the "normal" load that occurs in regular gate operation, the "maximum" load is given to protect the facility when an abnormality occurs in the hoist. The "maximum" load is 300% of "normal."

In this design, however, only normal load is considered, because abnormalities in the hoisting mechanism are extremely rare events, and there is no concept in the gate-pier design to increase the allowable value for abnormal loads.

11.4.10 Load Combinations and Allowable Stress[104]

11.4.10.1 Load Combinations

All structures shall be designed for the largest stresses resulting from the worst combination of loads that may act on the structure at any given condition. For safety reasons, each component of the structure shall be in proportion to bear the critical combination of these forces:

Group I	: Normal condition	: D + L + I + E + H + U + F + O (+T if consider thermal force)
Group II	: Wind condition I	: D + E + H + U + F + W (+T if consider thermal force)
Group III	: Wind condition II	: Group I + 0.3W + WL + LF (+T if consider thermal force)
Group VII	: Seismic condition	: D + Ee + H + U + V + He

Where,

D	: Dead load
L	: Live load
I	: Impact/ dynamic effect of live load
E	: Earth pressure
H	: Hydrostatic pressure
U	: Uplift
W	: Wind load on structure
WL	: Wind load on live load
LF	: Longitudinal force from live load
V	: Seismic load
F	: Flowing water pressure
Ee	: Earth pressure due to earthquake
He	: Dynamic water pressure due to earthquake
T	: Thermal force
O	: Gate operation load

Source: DPWH Design Guidelines Criteria and Standards Vol. II 3.2.1 Loading Combinations
NSCP Vol. II Bridges, Section 3, 3.22 COMBINATIONS OF LOAD

11.4.10.2 Extra Factors in Allowable Stress

The allowable stress will be increased according to the combination of loads listed above. Regarding the extra factor during earthquakes, the concrete structure shall conform to the Philippine design standard, and thus, 33% of Group IV will be applied. For the SSP revetments, design methods and safety evaluations will be carried out following Japanese standards “Specifications for Highway Bridges” and “Design Guidelines of Disaster Recovery Works”. To maintain the consistency from design to inspection, the extra factor of the Specifications for Highway Bridges shall be used, and thus, it shall be 50% in the seismic case.

The following extra factors in allowable stresses shall be applied to the load combinations listed above.

[104] DPWH Design Guidelines Criteria and Standards (Vol. II) 3.1 Loads

Table 11.4.6 Extra Factors in Allowable Stress

DPWH Design Guidelines Criteria and Standards Vol. II[105]	Group I	none (25%*)
	Group II	25% (40%*)
	Group III	25% (40%*)
	Group VII	33%
Specification for Highway Bridges, Part IV, Road Association of Japan: Substructure 4.1 General [106]	Normal	none
	Seismic	50%
Road Earthwork Guideline, Temporary Works[107]	Temporary work	50%

* If thermal force is considered to design a structure

Source: Study Team referring to DGCS / Specifications for Highway Bridges

11.5 Stability Analysis

11.5.1 Sliding

Minimum safety factor against sliding should be as follows[108],[109]。 :

$$SF = \frac{\text{Total Vertical forces x f}}{\text{Total Horizontal Force}}$$

SF ≥ 1.50 : in Normal Condition
SF ≥ 1.20 : in Seismic and Wind Condition

Where, f is as follows:

Concrete to rock base	;	f = 0.7
Concrete to boulder or cobble base	;	f = 0.6
Concrete to sandy base	;	f = 0.6
Concrete to clayey base	;	f = 0.5

11.5.2 Overturning

For stability of structures against overturning, the following conditions should be satisfied[110],[111]:

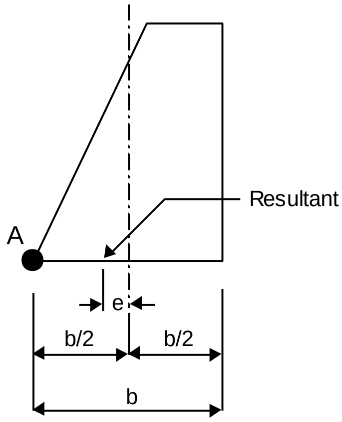
$$e = \left|\frac{b}{2} - \frac{M}{N}\right| \le \frac{b}{6} \quad : \quad \text{in Normal Condition}$$

$$e = \left|\frac{b}{2} - \frac{M}{N}\right| \le \frac{b}{3} \quad : \quad \text{in Seismic, Wind and Flood Condition}$$

Where,

b : Width of base (m)
M : Total moment about point A (kN・m)
N : Total vertical forces (kN)
e : Eccentricity (m)

[105] DPWH Design Guidelines Criteria and Standards Vol. II 3.1 Loads
[106] Specifications for Highway Bridges IV Substructures 4.1 Common
[107] Road Earthwork Guideline (Temporary Works) 2-6 Allowable Stress
[108] NSCP Vol. II Bridges (ASD) 5.5.5 Structural Dimensions and External Stability
[109] Road Earthwork Guideline (Retaining Wall) 2-1-3 Stability Analysis
[110] NSCP Vol. II Bridges (ASD) 5.5.5 Structural Dimensions and External Stability
[111] Road Earthwork Guideline (Retaining Wall) 2-1-3 Stability Analysis



Source: Study Team

Figure 11.5.1 Point of Resultant Force

11.5.3 Stability of Slope

Minimum safety factor against slope failure calculated by the slip-circle method as indicated below should be as follows[112]:

$$SF = \frac{\sum\{cl+(W-ub)\cdot \cos\alpha \cdot \tan\phi\}}{\sum W \cdot \sin\alpha}$$

Where,

SF	: Safety Factor
u	: pore water force of a slip surface (kPa)
W	: Weight of slice (kN/m)
c	: Cohesion of soil (kPa)
l	: Arc length (m)
ϕ	: Angle of shear resistance (degree)
b	: Slice width (m)

$SF \geq 1.2$ in Normal Condition[113]
$SF \geq 1.0$ in Seismic Condition

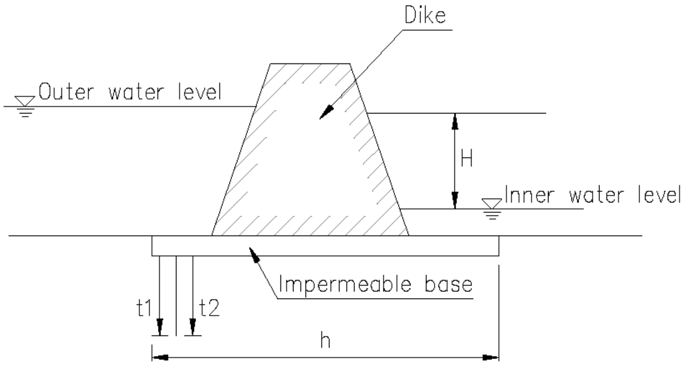
According to the DGCS 2015 Vol. IVI, the safety factor is SF=1.5. However, the design of river structures in the Pasig-Marikina river have been conducted with SF=1.2 (1.0 for seismic) by the Modified Fellenius method as indicated in the Japanese Road Earthwork Guideline. It is not desirable to apply different safety levels along the same river. Therefore, FS=1.2 shall be used in this project. It is also acknowledged that a safety factor of 1.2 has historically been applied to river structures in Japan and there are no significant problems observed until the present.

11.5.4 Seepage/Piping

11.5.4.1 Seepage/Piping Analysis[114]

For relatively impervious embankments, where seepage or piping is more likely to occur under the structure, seepage analysis according to the Lane's Creep Theory shall be conducted.

[112] DPWH Design Guidelines Criteria and Standards (Vol. IV) 7.6.3 Stability Calculations
[113] Technical Criteria for River Works: Practical Guide for Planning [Design] [I] 2.3.2 Seepage Analysis
[114] Design Guideline for Flexible Sluiceway 7.13 shielding Wall Design



Source: Study Team

Figure 11.5.2 Model of Creep Distance

$$C \leq \frac{\left(\sum H\right)/3 + \sum V}{\Delta H}$$

Where:

C	: Creep Ratio
H	: Horizontal path length (m)
V	: Vertical path length (m)
ΔH	: Hydraulic head or the difference between headwater and tail water (m)

Table 11.5.1 Creep Ratio

Material	Ratio[1/]
very fine sand or silt	8.5
fine sand	7.0
medium sand	6.0
coarse sand	5.0
fine gravel	4.0
medium gravel	3.5
coarse gravel including cobbles	3.0
boulders with some cobbles and grave	2.5
soft clay	3.0
medium clay	2.0
hard clay	1.8

Source: Guideline for Flexible Sluiceway 7.13 Shielding Wall Design

11.5.4.2 Measures against Seepage/Piping[115]

As a result of the seepage analysis, if the countermeasure is necessary, the following measures will be applied.

(1) Pavement of upstream slope and apron
(2) Impervious sealing work
(3) Vertical cut-off wall

The above measures lengthen the seepage and creep path, to reduce the risk of piping and release the lifting pressure. Besides, the following measures may be considered to lower the infiltration line in the embankment and prevent the embankment collapse.

(1) Embankment foot drain
(2) Pipe drain

[115] Guide of Structural Analysis of River Embankment 4.4.3 Selection of Reinforcement Method

11.5.5 Consolidation Settlement

Consolidation settlement is examined on the basis of the result of soil investigation by using Terzaghi's Consolidation Theory[116]:

For calculation, see the formulae of **Subsection 11.3.2.1 (6) 2)**)

11.5.6 Direct Foundation

Allowable bearing capacity (Qa) is obtained by the ultimate bearing capacity using the safety factor shown below[117],[118].

$$Qa = \frac{Qu}{SF}$$

SF = 3 (normal)
SF = 2 (seismic)

Ultimate bearing capacity of foundation ground is calculated with the formula below.

$$Qu = A'\left\{\alpha\, k\, c\, N_c + k\, q\, N_q + \frac{1}{2}\gamma_1\, \beta\, B'\, N_r\right\}$$

Where,

Qu : Ultimate bearing capacity (kN)
A' : Effective loading area on footing (m^2) (Refer to following **Figure 11.5.3**)
α , β : Shape factor of foundation as shown in the following table

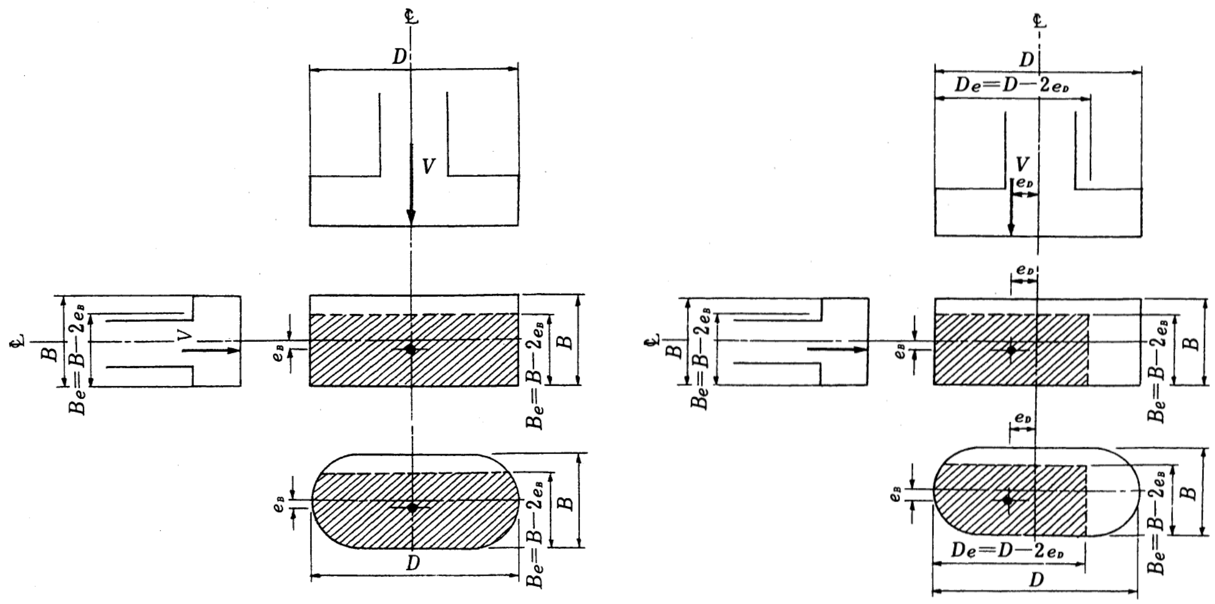
Table 11.5.2 Shape Factor of Foundation

Shape of Foundation	α	β
Zonation	1.0	1.0
Circle or Square	1.3	0.6
Rectangle or ellipse	1+0.3B'/L'	1-0.4B'L'

Source: Specifications for Highway Bridges IV Substructures Table 10.3.3

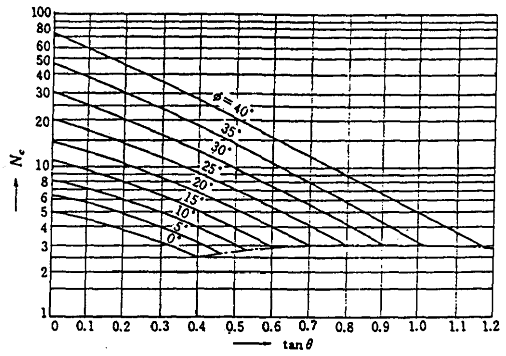
C : Cohesion of foundation ground (kN/m^2)
q : Surcharge (kN/m^2)
= $\gamma_2 \cdot Df$
γ_1, γ_2 : Unit weight of soil of bearing ground (kN/m^3)
B',L' : Width and length of effective loading areas as shown in the following figure
B' = $B - 2e_H$
L' = $L - 2e_L$
e : Distance from center of footing to point of resultant force on footing as illustrated in the following figure (m)
Df : Depth from ground surface to bottom of footing (m)
K : Coefficient (1+0.3 x Df'/B)
Df' : Effective embedded depth of foundation (m)
Nc, Nq, Nr: Bearing capacity factors (refer to **Figure 11.5.4**)

116 River Earthwork Manual 3.2.3 Settlement of Soft Ground
117 NSCP Vol. II Bridges (ASD) 4.4.7.1 Bearing Capacity
118 Specifications for Highway Bridges IV Substructures 10.3.1 Allowable Bearing Capacity of Foundation Ground

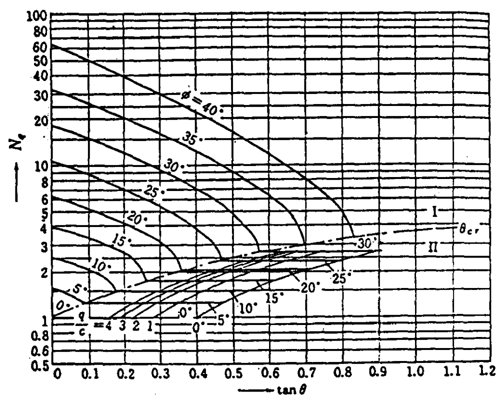


Source: Specifications for Highway Bridges, Volume IV Substructures, Japan Road Association, 2012, Table 10.3.4, 10.3.5

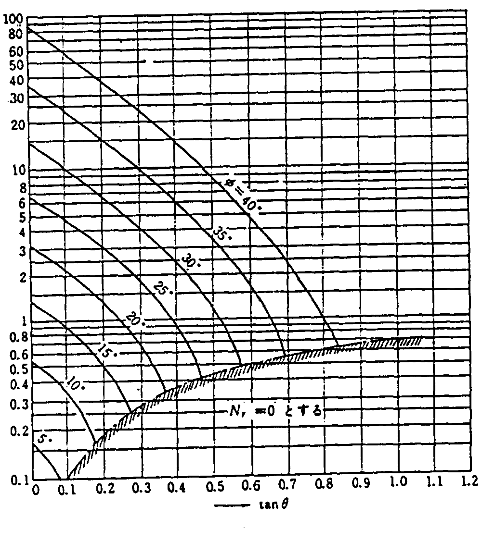
Figure 11.5.3 Effective Loading Area on Footing



Graph for Bearing Capacity Factor Nc



Graph for Bearing Capacity Factor Nq



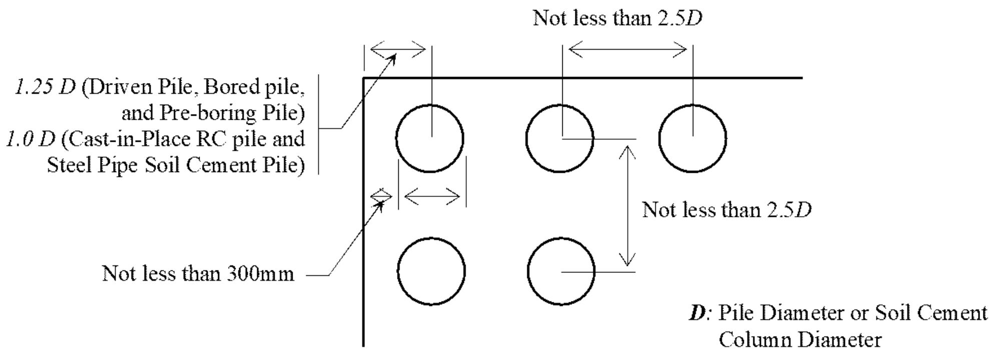
Graph for Bearing Capacity Factor Nr

Source: Specifications for Highway Bridges, Volume IV Substructures, Japan Road Association, 2012, Table 10.3.1, 10.3.2, 10.3.3

Figure 11.5.4 Graphs for Bearing Capacity Factor

11.5.7 Pile Foundation

11.5.7.1 Pile Allocation



Source: Specifications for Highway Bridges, Volume IV Substructures, Japan Road Association, 2012, Figure 12.3.1, BSDS 5-16

Figure 11.5.5 The Minimum Distance Between Pile Centers and Footing Edges.

11.5.7.2 Allowable Axial Bearing Capacity

Allowable axial bearing capacity of a pile is calculated by the following formula[119].

$$Ra = \{q_d A + U \sum (1_i f_i)\} / SF$$

Where,

Ra	:	Allowable bearing capacity of pile (kN)
q_d	:	Ultimate bearing capacity per unit area at the pile tip (kN/m^2)
A	:	Area of pile tip (m^2)
U	:	Perimeter of pile (m)
1_i	:	Depth of soil layer (m)
Fi	:	Maximum skin friction of each layer: (kN/m^2) (see).

Table 11.5.3 Skin Friction of Pile

Table C5.4.3.3-5 Maximum Shaft Resistance Intensity (kN/m^2)

Ground Type / Pile Installation Method	Sandy Soil	Cohesive Soil
Driven Pile Method (including Vibro-Hammer Method)	$2N$ (≤ 100)	c or $10N$ (≤ 150)
Cast-in-place RC pile method	$5N$ (≤ 200)	c or $10N$ (≤ 150)
Bored Pile Method	$2N$ (≤ 100)	$0.8\ c$ or $8N$ (≤ 100)
Pre-bored Pile Method	$5N$ (≤ 150)	c or $10N$ (≤ 100)
Steel Pipe Soil Cement Pile Method	$10N$ (≤ 200)	c or $10N$ (≤ 200)

Source: BSDS p5-24

Where,

C	:	Soil cohesion
N	:	N-value
SF	:	Safety factor shown below.

[119] Specifications for Highway Bridges IV Substructures 12.4 9.5.7.1 Allowable Axial Bearing Capacity

Table 11.5.4 Safety Factor

Load Condition	Safety Factor	
	Bearing Pile	Friction Pile
Normal	3	4
Seismic	2	3

Source: Excerpt from Specifications for Highway Bridges IV Substructures Table 12.4.1

<u>A bearing pile</u> is a pile mainly supported by its resistance produced by the soil characteristics on which the pile tip touches.

<u>A friction pile</u> is a pile mainly supported only by the friction of the ground contact with the pile surface along the penetrated section of the pile.

In the case of a cast-in-place support pile, the ultimate bearing capacity per unit area at the pile tip is calculated using the following figure. (This figure is applied to cohesive, sand and gravel soil.)

In this design, the case of open-ends steel pipe piles shown below is applied to calculate the ultimate bearing capacity.

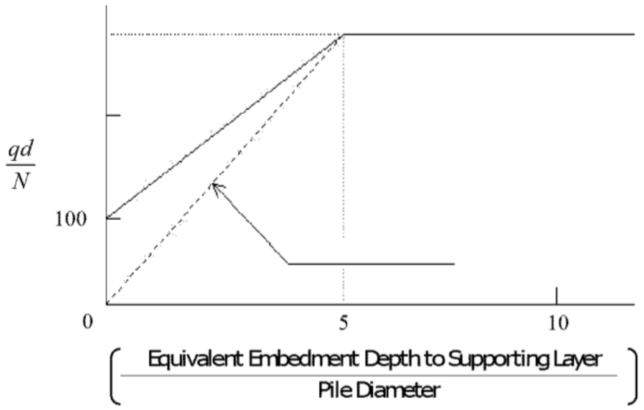
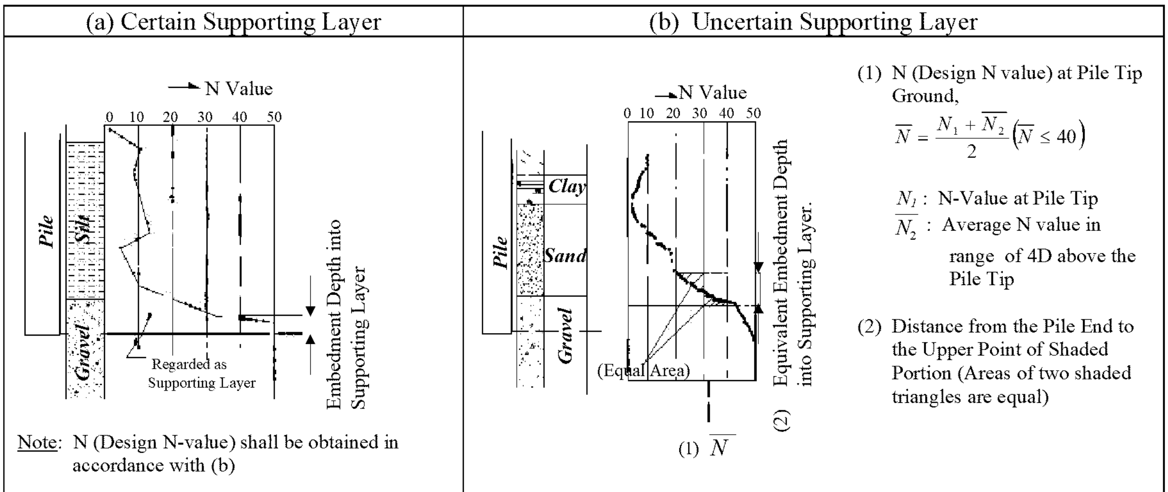


Figure C5.4.3.3-1 Evaluation Chart for Ultimate End Bearing Capacity Intensity (q_d)

Source: Specifications for Highway Bridges IV Substructures Table 12.4.2, BSDS p5-19

Figure 11.5.6 Evaluation Chart of the Ultimate End Bearing Capacity Intensity (q_d)



Remarks	In determining the equivalent embedment depth into a supporting layer, soil properties in boring logs and the distribution of *N* values shall be carefully examined, and (a) or (b) in the above shall be selected.

Figure C5.4.3.3-2 Determination Method of Equivalent Embedment Depth into Supporting Layer

Source: Specifications for Highway Bridges IV Substructures Table 12.4.3, BSDS p5-19

Figure 11.5.7 Determination Method of Equivalent Depth into Supporting Layer

The N value to calculate the ultimate bearing capacity is determined as follows.

$$N = \frac{N_1 + N_2}{2}$$

Where,

N_1 : SPT N-value at pile tip

N_2 : SPT N-value in the range of 4D upwards from the pile tip

D : Diameter of circular pile or side length of square pile (m)

For cast-in-place piles, the ultimate bearing capacity (q_d) is shown in the following table.

Table 11.5.5 Ultimate Bearing Capacity of Cast-in-Place Piles

Soil Type	Ultimate Bearing Capacity, qd: (kN/m²)
Sandy and Sand Soil (N>30)	3,000
Hard Clayey Soil	$3q_u$

Source: Excerpt from Specifications for Highway Bridges IV Substructures Table 12.4.1

Where,

q_u : Unconfined compression strength (kN/m²)

11.5.7.3 Allowable Drawing-out Strength of Pile[120]

The allowable drawing out strength of a pile shall be calculated by the following equation.

Pa = Pu / SF + W

Where,

Pa : Allowable drawing out strength at the pile tip (kN)
P_u : Drawing out strength determined by soil characteristics (kN)
P_u : $U \sum (1_i \quad f_i)$
W : Effective weight of pile (kN)

Safety factor is shown below;

SF = 6 (normal)
SF = 3 (seismic)

11.5.7.4 Allowable Lateral Bearing Capacity

(1) Pile Tip under the Ground

$$H_a = \frac{kD}{\beta}\delta_\alpha$$

(2) Pile Tip above the Ground

$$H_a = \frac{4EI\beta^3}{1+\beta h}\delta_\alpha$$

$$\beta = \sqrt[4]{\frac{kD}{4EI}}$$

Where,

Ha : Allowable horizontal bearing capacity of piles (kN)
k : Horizontal ground reaction force coefficient (kN/cm³)

[120] Specifications for Highway Bridges IV Substructures 12.4.2 Allowable Drawing-out Strength of a Pile

D	:	Pile diameter (cm)
E	:	Modulus of elasticity of pile (kN/cm^2)
I	:	Sectional moment of inertia of pile (cm^4)
h	:	Pile height above ground (cm)
β	:	Characteristic value of pile (cm^{-1})
δ_α	:	Allowable displacement of pile (cm)

11.5.7.5 Allowable Pile Displacement[121]

(1) Water gates and weirs

For water gates and weirs, maximum allowable lateral displacement shall be 1cm[122].

(2) Other structures

The allowable displacement of the pile foundation structure is as follows.

Table 11.5.6 Allowable Pile Displacement

Displacement Type	Normal / Seismic
Lateral Displacement	In principle, 1% of Foundation Footing Width (15mm < δa < 50mm)

Source: Specifications for Highway Bridges Ⅳ Substructures 9.2 Basics of Design P.270

11.5.7.6 Axial Spring Constant

The axial spring constant of pile (Kv) may be obtained by the following equation[123] :

$$K_v = a \times \frac{A_p E_p}{L}$$

a is specified as follows.

0.014 (L/D)+ 0.72 (driven pile (driven by hammer))
0.031 (L/D)-0.15 (cast-in-place pile)

Where,

Kv	: Axial spring constant of pile (kN/m)
A_p	: Net cross-sectional area of pile (mm^2)
E_p	: Young's modulus of pile (kN/mm^2)
L	: Pile length (m)
D	: Pile diameter (m)

11.5.7.7 Pile Reaction Force and Foundation Displacement

The pile reaction force and the displacement of the foundation will be calculated by the displacement method. However, if the pile foundation is relatively hard, a simple displacement method may be used.

121 Specifications for Highway Bridges IV Substructures 9.2 Design Basics
122 Technical Criteria for River Works: Practical Guide for Planning. [Design] [1] 7.2.4 Foundation
123 Specifications for Highway Bridges ⅣSubstructures 12.6 Spring Constant of Pile

11.6 Material Characteristics

11.6.1 Soil Coefficients/Property

11.6.1.1 Unit Weight of Soil

The soil factor will be determined by laboratory tests. If there is no data available, the following values for unit weight will be applied:

Table 11.6.1 Unit Weight of Soil

Type of Soil		Wet (kN/m^3) *1	
		Loose	Compacted
Natural Foundation	Sand or Gravel	18	20
	Sandy soil	17	19
	Clayey soil	14	18
Embankment	Sand or Gravel	20	
	Sandy soil	19	
	Clayey soil	18	

*Note *1: Values to be utilized for design will be determined based on the results of geological investigation per representative N-value of each soil type as per USGS*
Source: Specifications for Highway Bridges IV Substructures Table 2.2.4

11.6.1.2 Cohesion of Cohesive Soil

Cohesion of cohesive soil shall be determined by tri-axial test or unconfined compression test. When using an unconfined compression test, the following formula can be used to estimate the cohesion of soft clay[124]:

$$c = \frac{q_u}{2}$$

Where,

c : Cohesion (kN/m^2)
qu : Unconfined compression strength (kN/m^2)

If there is no data available, cohesion can be estimated by using “N” value as follows:

c = 6N ~ 10N

11.6.1.3 Internal Friction Angle of Sandy Soil

The internal friction angles of Sandy Soil shall be determined either by direct shear test, unconfined compression test or tri-axial test. For sandy soil or if there is no data available, it can be estimated by the following formula[125]:

$$\phi = 15 + \sqrt{15N} \leq 45^\circ \quad \text{: for N>5}$$

Where,

ϕ : Internal friction angle (degree)
N : N-value by standard penetration test

11.6.1.4 Coefficient of Lateral Reaction of Foundation Ground

For the design of pile foundation, coefficient of lateral reaction of soil can be estimated by using the following method[126]:

[124] Road Earthwork Guideline (Retaining Wall) 1-4-2 Setting of Design Constants
[125] Road Earthwork Guideline (Retaining Wall) 1-4-2 Setting of Design Constants
[126] Specifications for Highway Bridges IV Substructure 9.6.2 Coefficient of Reaction of Foundation Ground

$$K_H = K_{H0}\left(\frac{B_H}{0.3}\right)^{-3/4}$$

Where,

K_H : coefficient of lateral reaction of soil (kN/m^3)

K_{H0} : coefficient of lateral reaction of soil (kN/m^3) equals to a value of plate bearing test with rigid circular plate of a diameter of 30cm, and it can be estimated by the following equation with a modulus of deformation: E_0 obtained by various soil tests and investigations:

$$K_{H0} = \frac{1}{0.3}\alpha\, Eo$$

Where,

α : coefficient given by the table below

Eo : modulus of deformation of soil for design obtained by soil test or equation as shown in table below.

B_H : converted loading width of foundation in load action direction (m)

Table 11.6.2 Relation Between E_0 and α

Modulus of Deformation Eo (kN/m^2)	α value	
	Normal, Storm	Seismic
A half of modulus of deformation obtained by repeating curves in plate bearing test with rigid circular plate of a diameter of 30cm	1	2
Modulus of deformation measured in borehole horizontal loading test	4	8
Modulus of deformation obtained by test pieces in unconfined compression test or tri-axial test	4	8
Modulus of deformation estimated by Eo= 2800N with N-value in Standard Penetration Test	1	2

Source: Specification for Highway Bridges, Part IV, Substructure: 9.5.2 Coefficient of Reaction of Foundation Ground

11.6.1.5 Compression Index

The compression index of the ground or foundation ground is determined by the compression tests. However, if data is not available, it may be calculated by the following equation[127]。

Cc = 0.009 (LL -10)

Or,

Cc = 0.0054 (2.6 w - 35)

Where,

Cc : Compression index
LL : Liquid limit (%)
w : Natural moisture ratio (%)

11.6.1.6 Permeability

Permeability of soil and foundation ground is determined based on in-situ or indoor permeability tests;, however, it may also be calculated by the following Hazen equation or the table of Creager in the table below.

k = C (0.7 +0.03 t) $D10^2$

[127] Road Earthwork Guideline (Retaining Wall) 1-4-2 Setting of Design Constants

Where,

k	: Coefficients of Permeability (cm/sec)
D_{10}	: Diameter of 10% of soil grain pass (cm)
t	: Temperature (°C)
C	: Coefficient (50 ~ 100)

The coefficients of permeability of various soil types are shown in **Table 11.6.3**.

Table 11.6.3 Coefficients of Permeability (Creger's Table)

Soil Type	D_{10} (mm)	k (cm/s)
Clayey	0.05	3.0×10^{-6}
Fine Silt	0.01	1.0×10^{-5}
Coarse Silt	0.02 0.05	4.0×10^{-5} 2.8×10^{-4}
Micro Sand	0.06 0.10	4.0×10^{-4} 1.7×10^{-3}
Fine Sand	0.12 0.25	2.6×10^{-3} 1.4×10^{-2}
Medium Sand	0.30 0.50	2.2×10^{-2} 7.5×10^{-2}
Coarse Sand	0.60 1.00	1.1×10^{-1} 3.6×10^{-1}

Source: Creger's Table

11.6.2 Steel Sheet Pile (SSP)

11.6.2.1 Selection of SSP Type

The type of sheet pile shall be determined in consideration of the stress and displacement in each section not to meet an allowable stress and displacement against outer loads. SSPs consist of Hat-shape SP-10H and SP-25H, and U-shape SP-IA to SP-VIL. In case that the calculated stress and/or displacement SSP revetment are/is not less than the allowable value, combined SSP with H-Beam shall be applied to secure the strength of SSP revetment and not to meet an allowable stress and displacement.

11.6.2.2 Section Efficiency

As shown in **Table 11.6.4**, the 20% reduction of rigidness (e.g., Moment of Inertia of Area: I x 0.8) is applied to U-shape SSP. This reduction is caused by the joint efficiency of U-shape SSP during bending load. On the other hand, there is no reduction of rigidness for Hat-shape SSP due to their connecting structural characteristic between SSPs.

Table 11.6.4 Moment of Inertia of Area and Efficient Ratio in SSP Wall

Item	Classification of Calculation	Efficient Ratio of Sectional Factor	
		Hat-shape	U-shape
Moment of Inertia of Area	Calculation of Penetration Depth	Full cross section is effective (100%)	
	Calculation of Dispalcement and Sectional Force	Full cross section is effective (100%)	80% of full cross section is effective
Sectional Factor	Stress Calculation	Full cross section is effective (100%)	

Source: Cantilever Steel Sheet Pile Design Manual, 2007 Dec.

11.6.2.3 Structure

When SSP with H-Beam is employed as SSP revetment, welding structure is to be applied.

11.6.2.4 Types and Properties of SSP and H-Beam

As mentioned previously, SSP should conform to SYW295 specified in JIS A-5523 or equivalent with minimum yield strength (Fy) of 295MPa. General specifications of SSP of SYW295 defined in JIS A-5523 are shown in **Table 11.6.5**.

Table 11.6.5 Properties of SSP

Type of SSP	Dimension (mm)			Per 1.0m (original condition)				Per 1.0m (after corrosion)	
	W	h	t	A (cm^2)	I (cm^4)	Z (cm^3)	Weight (kg/m)	I' (cm^4/m)	Z' (cm^3/m)
U-Shape									
SP-I_A	400	85	8.0	113.0	4500	529	89	3420	402
SP-II_W	600	130	10.3	131.2	13000	1000	103	10500	810
SP-III_W	600	180	13.4	173.2	32400	1800	136	27500	1530
SP-IV_W	600	210	18.0	225.5	56700	2700	177	49900	2380
SP-V_L	500	200	24.3	267.6	63000	3150	210	57300	2870
SP-VI_L	500	225	27.6	306.0	86000	3820	240	79100	3510
Hat-Shape									
SP-10H	900	230	10.8	122.2	10500	902	96	8300	713
SP-25H	900	300	13.2	160.4	24400	1610	126	20000	1320
SP-45H	900	368	15.0	207.8	45000	2450	163	38300	2080
SP-50H	900	370	17.0	236.3	51100	2760	186	44500	2400

I', Z' : are consider 2mm allowable corrosion depth (1mm at each side)
Source: Steel Sheet Pile Association Data

Applicable combinations of SSP and H-Beam and expected values of strength of combined SSP are shown in **Table 11.6.6.**

Table 11.6.6 Combinations of SSP and H-Beam

SSP	H-Beam	Per 1.0m: Original condition I (cm^4/m)	Original condition Z (cm^3/m)	After corrosion I' (cm^4/m)	After corrosion Z' (cm^3/m)	Weight (kg/m^2)
SP-10H	400x200x9x22	114000	3250	95900	2820	202
	450x200x12x25	145000	4070	128000	3580	226
	450x250x9x22	154000	4160	131000	3630	225
	450x250x12x28	177000	5050	152000	4500	261
	500x200x12x25	180000	4480	154000	3950	232
	500x250x12x28	212000	5560	183000	4960	266
	550x200x12x28	213000	4920	182000	4330	237
	550x250x12x28	252000	6090	217000	5430	271
	600x200x12x28	262000	5720	226000	5070	252
	600x250x12x28	295000	6640	255000	5920	276
	650x200x12x28	305000	6220	262000	5510	257
	650x250x12x28	342000	7200	296000	6420	282
	700x200x12x28	353000	6780	304000	6020	264
	700x250x12x25	375000	7330	323000	6480	275
	750x250x12x25	429000	7900	369000	6980	281
	750x250x14x28	462000	8730	401000	7810	305
	800x250x16x28	537000	9710	467000	872	324
	850x250x14x25	563000	9470	486000	8390	305
	900x250x16x28	681000	11200	593000	9990	338
SP-25H	450x250x12x28	228000	5890	198000	5250	290
	500x250x12x28	268000	6380	233000	5690	295
	550x250x12x28	312000	6900	271000	6160	301
	600x250x12x28	360000	7440	314000	6640	306
	600x300x12x28	396000	8410	345000	7530	330
	650x250x12x28	414000	8010	360000	7140	311
	700x250x14x28	484000	8950	422000	8010	329
	700x300x14x28	529000	10000	463000	9010	353
	750x250x14x28	548000	9590	479000	8580	335
	750x300x14x28	600000	10700	526000	9650	359
	750x300x16x32	649000	11900	573000	10800	391
	800x250x16x28	632000	10600	553000	9530	354
	800x300x14x28	676000	11500	593000	10300	365
	800x300x16x32	732000	12800	647000	11600	398
	850x250x16x28	709000	11400	621000	10200	361
	850x300x16x32	821000	13600	726000	12400	405
	900x250x16x28	792000	12100	694000	10900	368
	900x300x16x32	917000	14500	811000	13100	412
	1000x300x16x32	1130000	16300	998000	14800	426

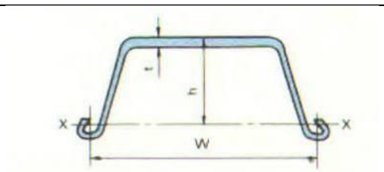
Source: Steel Sheet Pile Association Data

Strength properties of SSPs are shown in the **Table 11.6.7**.

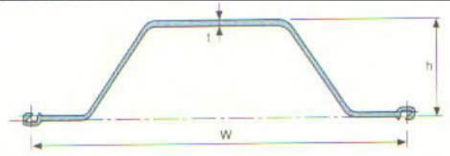
Table 11.6.7 Strength of SSPs

Type	Yield Point (fy) (N/mm^2)	Tensile Strength (N/mm^2)	Allowable Tensile Strength (N/mm^2)
SYW 295	295 or more	490 or more	180
SYW 390	390 or more	540 or more	235

Source: Steel Sheet Pile Association Data



U-Shape SSP



Hat-Shape SSP

Source: Study Team

Figure 11.6.1 SSP Types

11.6.3 Concrete and Reinforcing Bar

11.6.3.1 Materials

(1) Concrete

Concrete is classified according to compressive strength, coarse aggregate maximum size, and target members/ structures.

Table 11.6.8 Composition and Strength of Concrete for Use in Structures

Class of Concrete	Minimum Compressive Strength of 150×300mm Concrete Cylinder Specimen at 28 days (MN/m^2)	Designed Size of Coarse Aggregate(mm)	Target Members/Structures
A	20.7	50	Main Structures (Slab, Beam, Girder, Pier, Box Culvert etc.)
B	16.5	50	Small structure with few or no reinforcing bars
C	20.7	19	Thin RC Members (<20cm) RC Pile etc.
P	37.7	—	Prestressed Concrete
E	29.4	25	Precast RC Pile
F	11.8	40	Leveling Concrete
Seal	20.7	37.5	Underwater Concrete

Source: DPWH Standard Specifications for Public Works and Highways Vol.2 405.1.2 Classes and Uses of Concrete

Allowable stress of concrete will be obtained as below.

(2) Reinforcing Bar

The minimum yielding strength of the reinforcing bars shall be decided in accordance with the specifications of PNS for round bars and deformed bars for RC structures[128].

[128] National Structural Code of the Philippines VOL.II (NSCP) Bridges (ASD), 8.15.2 Allowable stress

Table 11.6.9 Specifications of Reinforcing Bars

Nominal Diameter (mm)*1	Nominal Perimeter (mm)	Nominal Cross Section (mm^2)	Unit Weight (kg/m)
10	31.4	78.540	0.617
12	37.7	113.1	0.888
16	50.3	201.06	1.578
2016	62.8	314.16	2.466
25	78.5	490.88	3.853
28	88	615.75	4.834
32	100.5	804.25	6.313
36	113.1	1017.88	7.99

Source：Philippine National Standard Steel bars for concrete reinforcement – specification 6.2 Dimension and mass tolerance

11.6.3.2 Physical Constants

(1) Young Modulus[129]

The Young modulus (Ec) of concrete will be $4{,}700\sqrt{f'_c}$ (Mpa) for normal concrete. In the case of a steel material which does not give prestress, Young modulus (Es) shall be 200,000 Mpa.

Therefore, for concrete, f'c = 20.7 MPa, which corresponds to the Class A concrete, young modulus ratio n=Es / Ec=9.

(2) Coefficient of Linear Expansion

Following the DGCS vol.15, the coefficient of linear expansion is set as 10.8×10^{-6}.

11.6.4 Allowable Stress

(1) Concrete

According to NSCP, allowable stress of concrete will be obtained by the following equations.

Table 11.6.10 Allowable Stress of Concrete (N/mm²)

Type of Stress			Plain Concrete	Reinforced Concrete
Flexure	Compressive Stress due to Bending		0.40f'c	0.40f'c
	Tensile Stress due to Bending		0.21fr	—
	Modulus of Rupture (fr)		0.70√f'c	0.70√f'c
	Bearing Stress		0.30f'c	0.30f'c
Shear	Beam, Cantilever slab, foundation		0.08√f'c	0.08√f'c
	Axial Stress	Compression Member	0.08√f'c	0.08√f'c
		Tension Member	0.075〔1+0.6(N/Ag)〕√f'c	0.075〔1+0.6(N/Ag)〕√f'c

f'c =minimum compressive strength of 150×300mm Concrete cylinder specimen at 28 days (MN/m^2), N=axial stress, Ag = amount of reinforcing bar

Source: NSCP Vol. II Bridges (ASD), 8.15.2 Allowable stress, 8.15.2.1 Concrete

Thus, allowable stress of reinforced concrete in this design are set as shown in **Table 11.6.11**.

129 National Structural Code of the Philippines VOL.II (NSCP) Bridges (ASD) 8.7 Modulus of Elasticity and Poisson's Ratio

Table 11.6.11 Allowable Stress of Reinforced Concrete

Stress Type \ Allowable Stress in Design (N/mm²)		20.7 Class A
Compression	Bending Compression (N/mm²)	8.28 *
	Axial Compression (N/mm²)	6.21 *
Shear	If shear stress is borne by concrete only τa (N/mm²)	0.36 *
	If shear stress is borne by concrete and diagonal tension rebar τa2 (N/mm²)	1.6 ★
	Punching shear stress τa3 (N/mm²)	0.85 ★

Note: When the haunch is not provided, it is desirable to set the member thickness so that the bending compression stress of concrete is about 3/4 of the allowable stress[130].

Source: Specifications for Highway Bridges IV Substructures, p.157 ** Ref.* ***Table 11.6.12***

Table 11.6.12 Allowable Stress of Reinforced Concrete Members of Class A

Class A Concrete			Reinforced Concrete		
f'c(N/mm²) =	20.7	Equations	Normal	Wind Load (+25%)	Seismic (+33%)
Bending	Bending compression (fc)	0.40f'c	8.28	10.35	11.01
	Bending tension (ft)	0.21fr	-	-	-
	Bearing stress (fb)	0.30f'c	6.21	7.76	8.25
Shear	Beam, cantilever, and foundation (Vc)	0.08√f'c	0.36	0.45	0.47
	Axial force (for compressive members) (Vc)	0.08√f'c	0.36	0.45	0.47

Source: Edited by the Study Team referring to NSCP Vol. II Bridges (ASD), 8.15.2 Allowable stress, 8.15.2.1 Concrete

(2) Reinforcing Bar

Grade 420 is used for this design. The allowable stress of reinforcing bar grade 420 is shown in **Table 11.6.13**.

Table 11.6.13 Allowable Stress of Reinforcing Bar (1)

Stress Type \ Allowable stress (N/mm²)			Grade420(60)
Tension	The basic value free from impact load and seismic load	Normal member	168
		Submerged member	168
	The basic value which combines impact load and seismic load		168
Compression			168

Source: Edited by the Study Team referring to NSCP Vol. II Bridges (ASD), 8.15.2 Allowable stress

Table 11.6.14 Allowable Stress of Reinforcing Bar (2)

Allowable stress of reinforcing bars (N/mm²)	Grade 420		
	Normal	Wind load (+25%)	Seismic (+33%)
Tension	168.0	210.0	223.4
Yielding	415.0	518.7	551.9

Source: Edited by the Study Team referring to NSCP Vol. II Bridges (ASD), 8.15.2 Allowable stress

11.6.4.2 Minimum Thickness of RC Members

The minimum thickness of major reinforced concrete members shall be 200 mm for double bars and 150 mm for single bars[131]

[130] Road Earthwork Guideline (Culverts) 5-7(7)3) Haunch

[131] National Structural Code of the Philippines VOL.II (NSCP) Bridges (ASD) 8.21 Spacing limits for reinforcement, 8.22 Protection against corrosion

11.6.5 Prestressed Concrete

11.6.5.1 Strength of Concrete (For Structures other than Bridges[132])

Stresses in concrete immediately after prestress transfer (before time-dependent prestress losses) shall not exceed the following:

(a) Extreme fiber stress in compression ……………………………………..…… 0.60 f'ci

(b) Extreme fiber stress in tension except as permitted in (c) ……………………… $\sqrt{f_{ci}}$ / 4

(c) Extreme fiber stress in tension at ends of simply supported members………… $\sqrt{f_c}$ /2

Where computed tensile stresses exceed these values, bonded auxiliary reinforcement (non-prestressed or prestressed) shall be provided in the tensile zone to resist the total tensile force in concrete computed with the assumption of an uncracked section.

Stresses in concrete at service loads (after allowance for all prestress losses) shall not exceed the following:

(a) Extreme fiber stresses in compression …………………………………………… 0.45 f'c

(b) Extreme fiber stresses in tension in pre-compressed tensile zone………………… $\sqrt{f_c'}$ /2

(c) Extreme fiber stress in tension in pre-compressed tensile zone of members (except two-way slab systems), where analysis based on transformed crack sections and on bilinear moment deflection relationships show that immediate and longtime depletions comply with requirements of NSCP Vol. I sec. 5.9.5.4, and where cover requirements comply with NSCP Vol. I sec 5.7.7.3.2 ……………………………………………………………………………………………….. $\sqrt{f_c'}$

Permissible stresses in prestressed concrete of the foregoing sections are permitted to be exceeded if shown by test or analysis that performance will not be impaired.

11.6.5.2 Prestressing Steel (For Structures other than Bridges)

Tensile stress in prestressing tendons shall not exceed the following:

(a) Due to tendon jacking force ………………………………………… 0.94 fpy

But not greater than the lesser of 0.80 fpu and the maximum value recommended by the manufacturer of prestressing tendons or anchorages.

(b) Immediately after prestress transfer ………………………………………… 0.82 fpy

But not greater than 0.74 fpu

(c) Post tensioning tendons, at anchorages and couplers, immediately after tendon anchorage ………………………………………………………………………………… 0.70 fpu

11.6.6 Structural Steel

Structural steels with minimum yield strength (Fy) =245/295 MPa are specified in JIS A-5526 (for SHK400/ SHK400M / SHK490M) and in JIS G-3101 (SS 400) respectively. In addition, the allowable stress of structural steel shall conform to that of presented in JIS and other standards.

The allowable stresses of structural steels such as SM400, SMA 400 and SM 490 are as follows.

[132] NSCP Vol. I Buildings, Towers and other vertical structures (Ver. 1992) 5.18 Prestressed Concrete

Table 11.6.15 Allowable Strength of Structural Steel[133]

Categories	SS400 SM400 SMA400 SHK400 (M)	SM490 SHK490M
Yielding point (fy)	245	295
Allowable tensile strength (Axial Direction)	140	185
Allowable compressive strength (Axial Direction)	140	185
Allowable bending-tensile strength	140	185
Allowable bending-compressive strength	140	185
Allowable shear strength	80	105

Source: Study Team *(N/mm²)*

Table 11.6.16 Physical Properties of Structural Steel[134]

Class	Grade	Yielding point (fy)	Tensile strength
Normal Steel	230	230	390
	275	275	480
	415	415	620
Welding Steel	230W	230	390
	275W	415	480
	415W	275	550

Source: Philippine National Standard (PNS 49:200) *(N/mm²)*

11.6.7 Bar Arrangement Rules

(1) Concrete Covering Depth of Reinforcing Bars

The minimum concrete cover depth is shown in **Table 11.6.17**.

Table 11.6.17 Minimum Concrete Cover[135]

Conditions		Minimum concrete cover (Depth from outer rebar surface) (mm)
Concrete cast against and permanently exposed to earth		75
Concrete exposed to earth or weather	Primary reinforcement	50
	Stirrups, ties and spirals	40
Concrete deck slabs in mild climates	Top reinforcement	50
	Bottom reinforcement	25
Concrete not exposed to weather or in contact with ground	Primary reinforcement	40
	Stirrups, ties and spirals	25
Concrete piles cast against and/or permanently exposed to earth		50

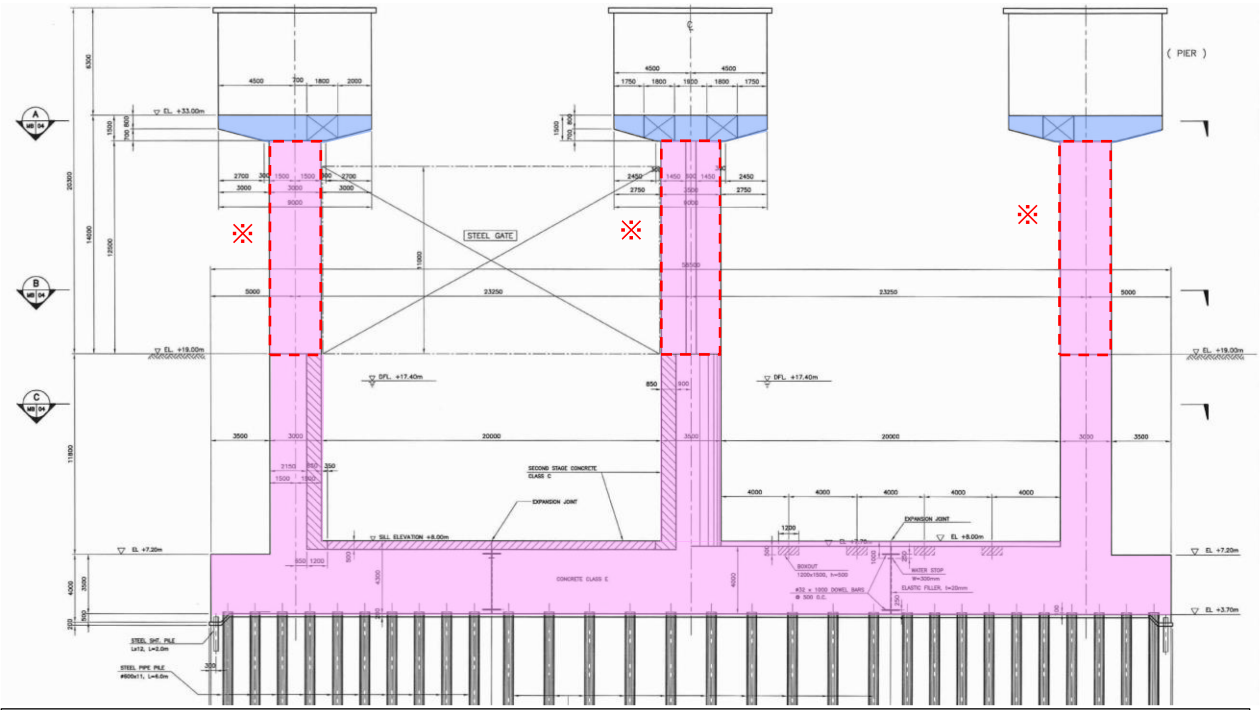
Source: NSCP Vol. II Bridges (ASD) 8.22

The minimum concrete cover depth is shown in **Table 11.6.17**. For the design of Watergates and weirs, each part belongs to whether "concrete cast against and permanently exposed to earth" or "concrete exposed to earth or weather". As an example, the distinction of these parts is illustrated in **Figure 11.6.2**.

133 Specifications for Highway Bridges IV Substructures 4.4 Allowable Strength of Structural Steel
134 Philippine National Standard (PNS 49:2002)
135 NSCP Vol. II Bridges (ASD) 8.22 Protection Against Corrosion

■ : Concrete cast against and permanently exposed to earth

■ : Concrete exposed to earth or weather



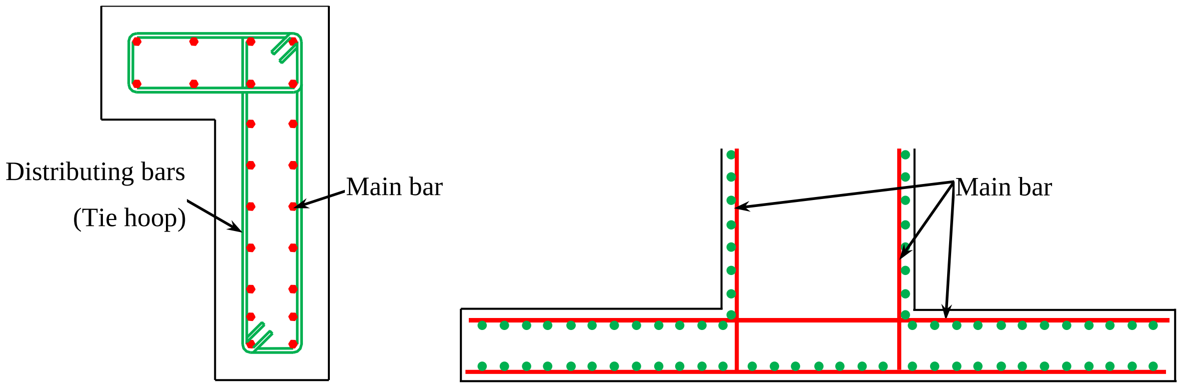
※ According to its position, the main rebar of the column should have a cover of 50 mm as a member that is exposed to bad weather. However, the column needs to resistant against the Level 2 earthquakes. Besides, some concrete exfoliations in the Rosario weir were observed. Considering these factors, the concrete cover depth for the outermost reinforcing bars in the column is set to be 75 mm as " Concrete cast against and permanently exposed to earth"

Source: Study Team

Figure 11.6.2 Distinction of Parts According to the Concrete Cover Depth

(2) Bar Arrangements

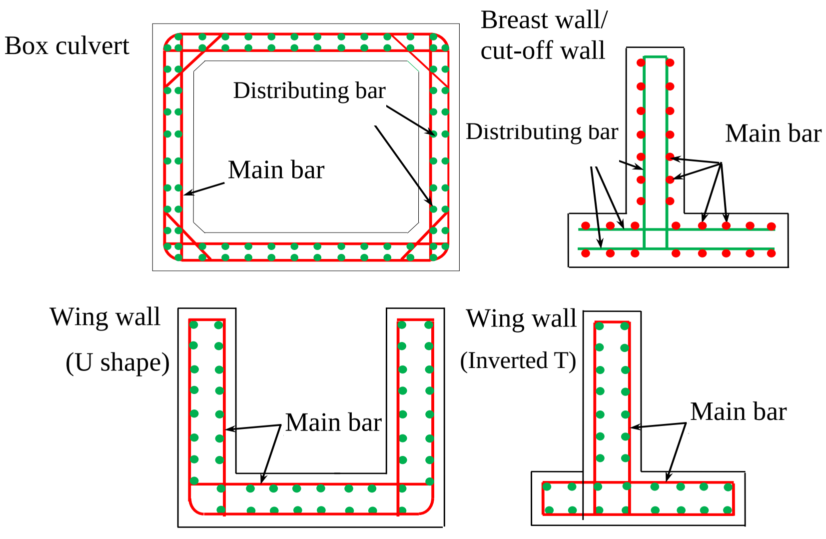
The reinforcing bars of columns, piers, and operation deck of water gates are recommended to allocate following by the rule of " main bars on the inside, and the distribution bars on the outside" to minimize damage by a large-scale earthquake. This rule is applied to this design. The bar arrangements at the column and bottom slab are as shown in **Figure 11.6.3**.



Source: Study Team

Figure 11.6.3 Bar Arrangement Image of the Columns and Bottom Slab of the Central Pier

The bar arrangements for other parts (except for columns and piers) are shown below.



Source: Study Team

Figure 11.6.4 Basic Bar Arrangement of Parts Except for Column and Piers

The basic distance between bars is 250mm (Required diameter: D25 or more, pitch: 125mm)

(3) Distributing Bar (Tie Hoop)

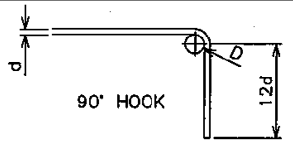
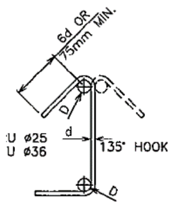
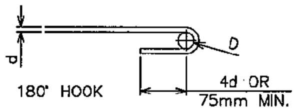
Unlike main bars, compression bars and distribution bars cannot determine the required amount of bars from structural calculations.

The "Civil Engineering Structure Design Manual -Sluiceway -" standardized the bar arrangement of compression bars and distribution bars, which cannot determine the required amount from structural calculations, as placing 1/6 or more amount of the main bar. Following this standard, this design applies 1/6 or more of the main bar to decide the amount of distribution bars.

(4) Hook

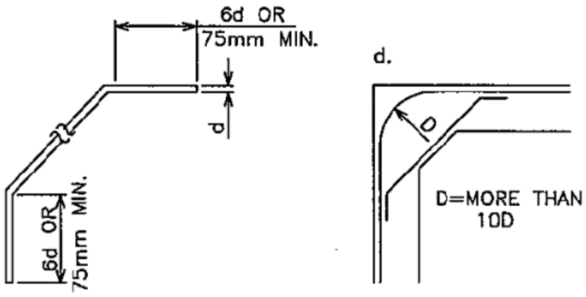
Reinforcing bar hooks conform to the Philippine Standards (**Table 11.6.18**). Shear reinforcing bars and intermediate reinforcing bars to improve seismic performance shall have hooks with an acute angle of 135 degrees.

Table 11.6.18 Hook of Rainforcing Bars

Case	Bending Profile of Hook	
	Distance from the edge of the bending point	Image
Right angle hook	Twelve (12) times the diameter of the bar	
Acute angle hook	Six (6) times the diameter of the reinforcing bar or 75 mm, whichever is greater	
Half circle hook	Four (4) times the diameter of the reinforcing bar or 75 mm, whichever is greater	

Source: Study Team

Figure 11.6.5 shows the hook of the haunch that is placed in the lateral main bar of the box culvert.



Source: Study Team

Figure 11.6.5 Hook of Reinforcing Bar around the Haunch

(1) Standard Bar Arrangements in this Design

The five patterns of bar arrangements are set in this design. These five types are distinguished considering the characteristics of the location in the structure and the seismic resistance of columns and beams (**Table 11.6.19**). Concrete cover for each diameter and each type are summarized in **Table 11.6.20**. The grounds for the classification are shown in Figures from **Figure 11.6.6** to **Figure 11.6.10**.

Table 11.6.19 Standard Bar Arrangements (Five Types)

Pattern	Conditions	Target part of the Watergates, sluices, and weir	notes
A	Concrete cast against and permanently exposed to earth	Box culvert Breast wall, wing wall, connecting wall (L2 seismic design is not required)	
B	Concrete cast against and permanently exposed to earth	Bottom slab of the direct foundation, apron (L2 seismic design is required)	
C	Concrete cast against and permanently exposed to earth ⇒ Required Level 2 seismic design	Piers and columns (L2 seismic design is required)	Distribution bars are allocated outside the main bars (tie loop)
D	Concrete exposed to earth or weather	Operation deck	
E	Concrete cast against and permanently exposed to earth	Bottom slab of weir, water gate and pile foundation	

Source: Study Team

Table 11.6.20 Concrete Covers for each Bar Diameters (Five Types)

Target part / Main bar	No.A	No.B	No.C	No.D	No.E
	Box culvert Breast wall, Wing wall, Connecting wall	Bottom slab of the direct foundation, Apron	Piers and Columns	Operation deck	Bottom slab of weir, Water gate and Pile foundation
D16	90	100	110	70	210
D20	90	100	110	70	210
D25	90	110	130	70	220
D28	90	110	130	70	220
D32	100	120	140	80	220
D36	100	120	140	80	220
D40	100	130	160	100	230
D50	100	130	160	100	230

Source: Study Team

■Pattern.A

【Concrete cast against and permanently exposed to earth】

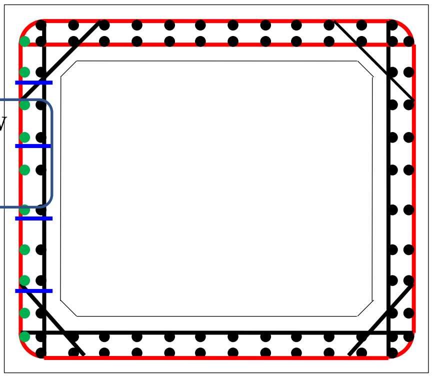
Box culvert, breast wall, wing wall, connecting wall (L2 seismic design is not required)

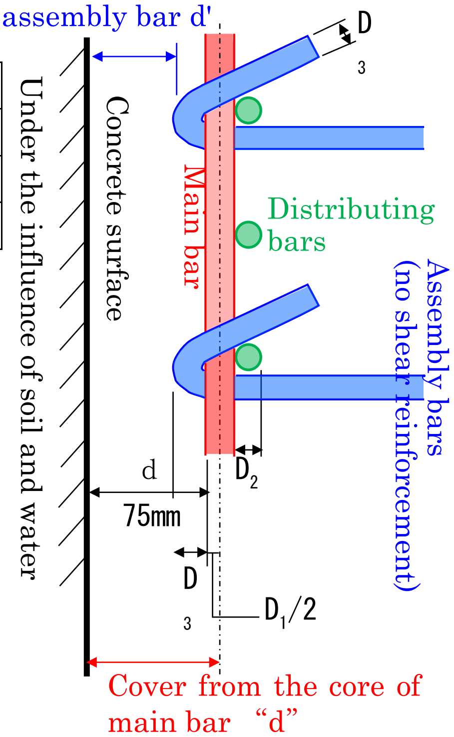
Pattern	Minimum cover from the bar surface C (mm)	Assembly bar D3(mm) (no shear reinforcement)	Main bar D1 (mm)	Cover from the core of the main bar d (mm)	Cover from the core of assembly bar d' (mm)
1	75	D12	D16	83	63
2	75	D12	D16	83	63
3	75	D12	D20	85	63
4	75	D12	D20	85	63
5	75	D12	D25	87.5	63
6	75	D16	D25	87.5	59
7	75	D12	D28	89	63
8	75	D16	D28	89	59
9	75	D16	D32	91	59
10	75	D20	D32	91	55
11	75	D16	D36	93	59
12	75	D20	D36	93	55
13	75	D20	D40	95	55
14	75	D25	D40	95	50
15	75	D25	D50	100	50
16	75	D28	D50	100	47

【Cover from the core of main bar *d* (mm)】

If diameter of the main bar is D16 or D20	90	mm
If diameter of the main bar is D25 or D28	90	mm
If diameter of the main bar is D32 or D36	100	mm
If diameter of the main bar is D40 or D50	100	mm

See enlarged view on the right





Source: Study Team

Figure 11.6.6 The Ground of Concrete Cover Setting of Main Bars

■Pattern.B

【Concrete cast against and permanently exposed to earth】

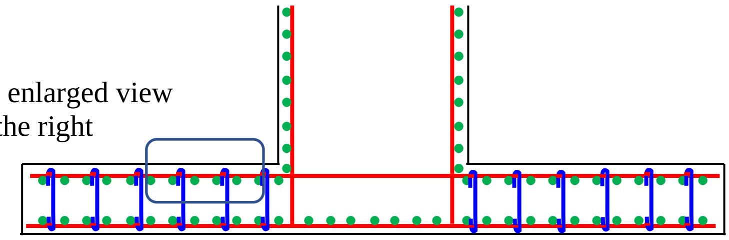
Bottom slab of the direct foundation, apron (L2 seismic design is required)

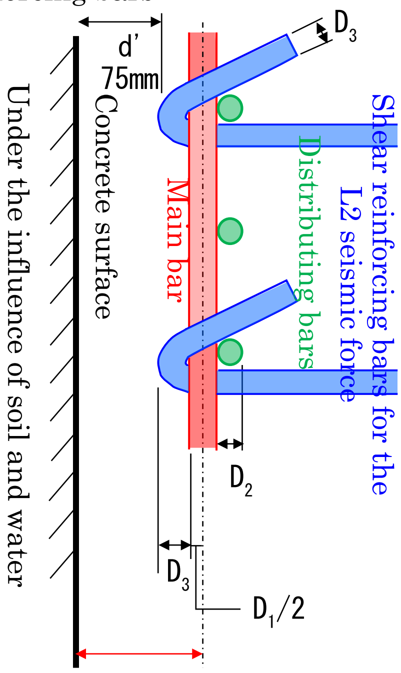
Pattern	Minimum cover from the bar surface C (mm)	Shear reinforcing bar D_3 (mm)	Main bar D_1 (mm)	Cover from the core of main bar d (mm)
1	75	D12	D16	95
2	75	D12	D16	95
3	75	D12	D20	97
4	75	D12	D20	97
5	75	D12	D25	99.5
6	75	D16	D25	103.5
7	75	D12	D28	101
8	75	D16	D28	105
9	75	D16	D32	107
10	75	D20	D32	111
11	75	D16	D36	109
12	75	D20	D36	113
13	75	D20	D40	115
14	75	D25	D40	120
15	75	D25	D50	125
16	75	D28	D50	128

【Cover from the core of main bar *d* (mm)】

If diameter of the main bar is D16 or D20	100	Mm
If diameter of the main bar is D25 or D28	110	Mm
If diameter of the main bar is D32 or D36	120	Mm
If diameter of the main bar is D40 or D50	130	Mm

See enlarged view on the right





Source: Study Team

Figure 11.6.7 The Ground of Concrete Cover Setting of Main Bars

■Pattern.C

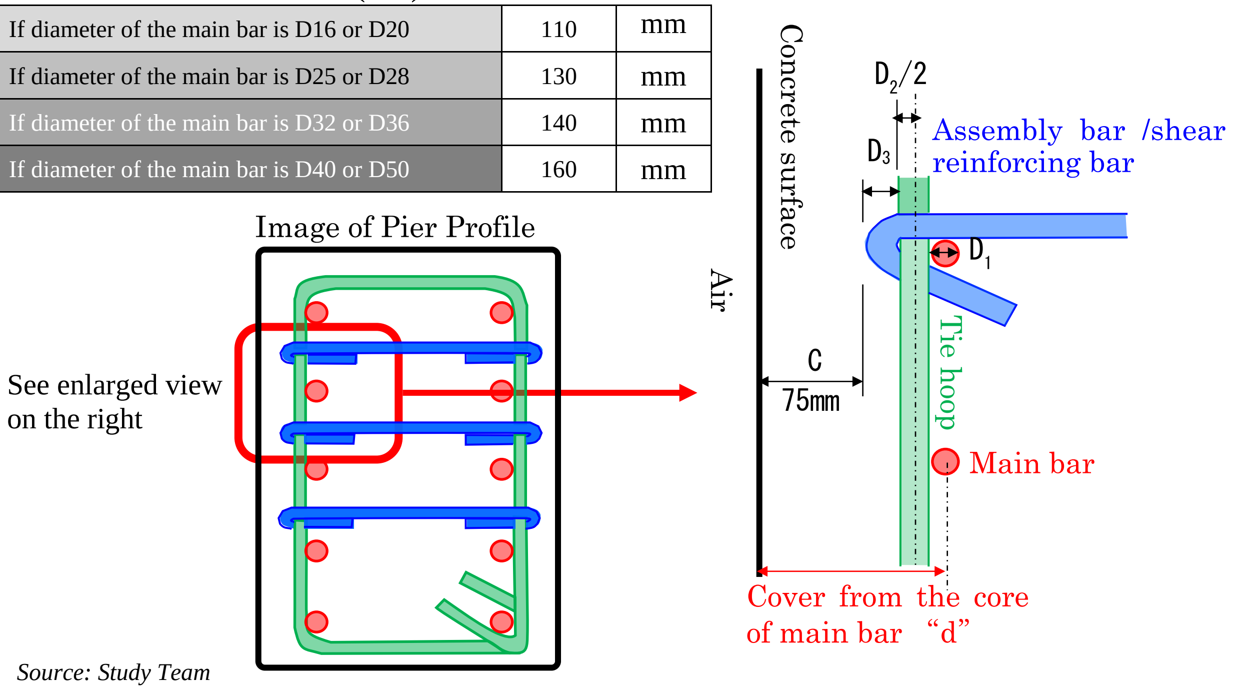
【Concrete cast against and permanently exposed to earth】

Piers and columns (L2 seismic design is required)

Pattern	Minimum cover from the surface of shear reinforcing bars C (mm)	Shear reinforcing bar D_3 (mm)	Tie hoopD_2 (mm)	Main bar D_1 (mm)	Cover of the tie hoop (mm)	Cover from the core of main bar d (mm)
1	75	D12	D12	D16	93	107
2	75	D12	D12	D16	93	107
3	75	D12	D10	D20	93	109
4	75	D12	D12	D20	93	109
5	75	D12	D12	D25	93	111.5
6	75	D16	D16	D25	99	119.5
7	75	D12	D12	D28	93	113
8	75	D16	D16	D28	99	121
9	75	D16	D16	D32	99	123
10	75	D20	D20	D32	105	131
11	75	D16	D16	D36	99	125
12	75	D20	D20	D36	105	133
13	75	D20	D20	D40	105	135
14	75	D25	D25	D40	112.5	145
15	75	D25	D25	D50	112.5	150
16	75	D28	D28	D50	117	156

【Cover from the core of main bar *d* (mm)】

If diameter of the main bar is D16 or D20	110	mm
If diameter of the main bar is D25 or D28	130	mm
If diameter of the main bar is D32 or D36	140	mm
If diameter of the main bar is D40 or D50	160	mm



Source: Study Team

Figure 11.6.8 The Ground of Concrete Cover Setting of Main Bars

■Pattern.D

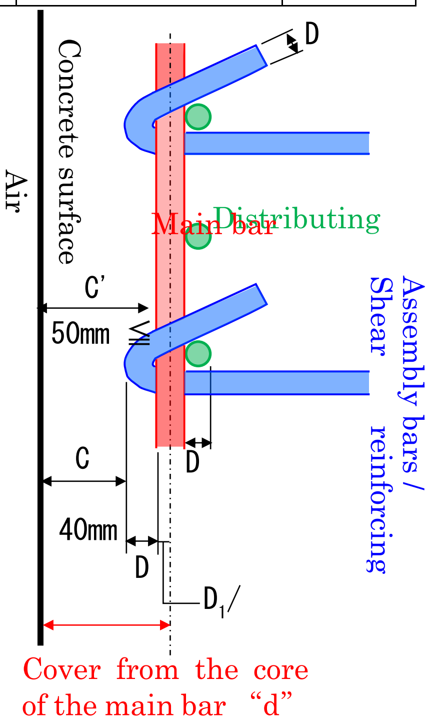
【Concrete exposed to earth or weather】

Operation Deck

Pattern	Minimum cover from the surface of shear reinforcing bars C (mm)	Assembly bar etc. D_3 (mm)	Main bar D_1 (mm)	Distributing bar D_2 (mm)	Cover from the core of the main bar d (mm)=C+D_3+D_1/2	Cover from the main bar surface C' (mm) =d−D_1/2
1	40	D12	D16	D12	60	52
2	40	D12	D16	D12	60	52
3	40	D12	D20	D12	62	52
4	40	D12	D20	D12	62	52
5	40	D12	D25	D12	64.5	52
6	40	D16	D25	D16	68.5	56
7	40	D12	D28	D12	66	52
8	40	D16	D28	D16	70	56
9	40	D16	D32	D16	72	56
10	40	D20	D32	D20	76	60
11	40	D16	D36	D16	74	56
12	40	D20	D36	D20	78	60
13	40	D20	D40	D20	80	60
14	40	D25	D40	D25	85	65
15	40	D25	D50	D25	90	65
16	40	D28	D50	D28	93	68

【Cover from the core of main bar *d* (mm)】

If diameter of the main bar is D16 or D20	70	mm
If diameter of the main bar is D25 or D28	70	mm
If diameter of the main bar is D32 or D36	80	mm
If diameter of the main bar is D40 or D50	100	mm



Source: Study Team

Figure 11.6.9 The Ground of Concrete Cover Setting of Main Bars

■Pattern.E

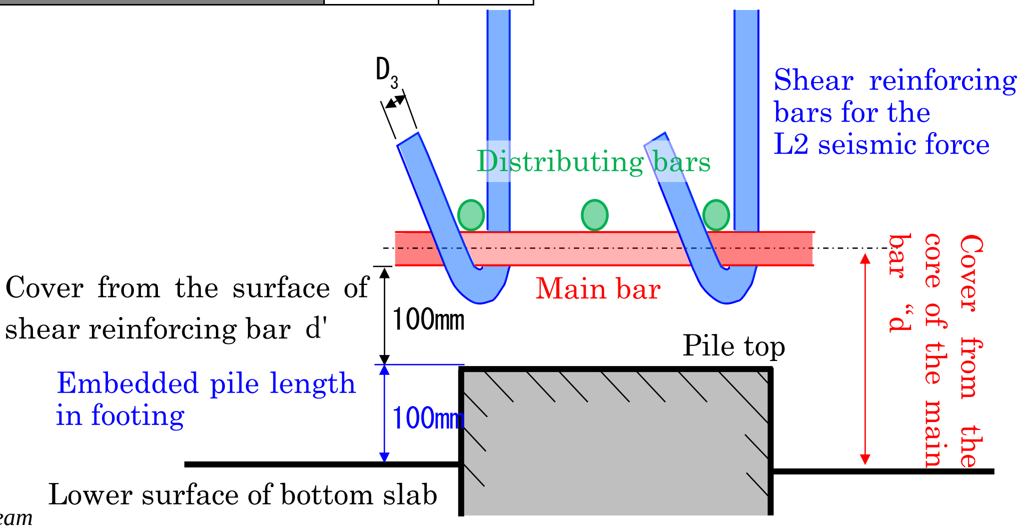
【Concrete cast against and permanently exposed to earth】

Bottom slab of weir, water gate and pile foundation

Pattern	Embedded pile length in footing (mm)	Minimum cover from the main bar surface C (mm)	Shear reinforcing bar D_3 (mm)	Main bar D_1 (mm)	Cover from the core of the main bar d (mm)
1	100	100	D12	D16	208
2	100	100	D12	D16	208
3	100	100	D12	D20	210
4	100	100	D12	D20	210
5	100	100	D12	D25	212.5
6	100	100	D16	D25	212.5
7	100	100	D12	D28	214
8	100	100	D16	D28	214
9	100	100	D16	D32	216
10	100	100	D20	D32	216
11	100	100	D16	D36	218
12	100	100	D20	D36	218
13	100	100	D20	D40	220
14	100	100	D25	D40	220
15	100	100	D25	D50	225
16	100	100	D28	D50	225

【Cover from the core of main bar *d* (mm)】

If diameter of the main bar is D16 or D20	210	mm
If diameter of the main bar is D25 or D28	220	mm
If diameter of the main bar is D32 or D36	220	mm
If diameter of the main bar is D40 or D50	230	mm



Source: Study Team

Figure 11.6.10 The Ground of Concrete Cover Setting of Main Bars

11.7 Liquefaction Analysis

11.7.1 Sandy Layer Requiring Liquefaction Assessment

The liquefaction which occurs in the saturated sandy soil layer significantly affects the behavior of the structure during an earthquake. Thus, liquefaction assessment will be carried out to identify the risk of liquefaction of the soil layer under (around) the planned structure. The assessment will be conducted using F_L (=resistance Factor against Liquefaction), which is calculated by using the information of grain size test obtained from boring data and cyclic triaxial test.

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The determination of liquefaction risk will be based on the Philippines' BSDS and the Japanese "Performance Based Seismic Design Criteria for River Structures." If the FL is less than 1.0, it is regarded that liquefaction may occur during the earthquake.

The liquefaction evaluation is conducted, at which satisfies all the following conditions.

1) Saturated soil layer with depth less than 20 m below the ground surface and having ground water level higher than 10 m below the ground surface.
2) Soil layer containing a fine content (FC) of 35% or less, or soil layer having plasticity index, I_P, less than 15, even if FC is larger than 35%.
3) Soil layer having a mean particle size (D_{50}) of less than 10 mm and a particle size at 10% passing (D_{10}) (on the grading curve) is less than 1 mm.

Source: BSDS, DPWH, P6-3

11.7.2 Assessment of Liquefaction

For soil layers which needs liquefaction assessment, the resistance factor against liquefaction F_L shall be calculated using the following formula for Level 1 and Level 2 earthquake ground motions. If the F_L is 1.0 or less, it is considered that the soil layer has a potential of liquefaction [136][137][138]. The evaluation formula and the assessment criteria are the same in both guidelines in the Philippines and Japan. However, in this study, considering the data availability of the ground conditions and previous earthquakes at the project site, external force is set according to Philippine BSDS. According to the BSDS, $k_{hgL}= F_{pga}PGA$ for Level 2 earthquake motions.

$$F_L = R/L$$
$$R = c_w R_L$$
$$L = r_d k_{hg} \sigma_v / \sigma'_v$$
$$r_d = 1.0 - 0.015x$$
$$\sigma_v = r_{t1} h_w + r_{t2}(x - h_w)$$

[136] Performance Based Seismic Design Criteria for River Structures I. p26 (Only for the level2 earthquake motion)
[137] Specifications for Highway Bridges V Seismic Design p141
[138] BSDS 6.2.3 Assessment of Soil Liquefaction p6-2

$$\sigma'_v = r_{t1}h_w + r'_{t2}(x - h_w)$$
$$C_w = 1.0 \quad \text{(for Level 1 earthquake motion)}$$
$$C_w = \begin{cases} 1.0 \ (R_L \leq 0.1) \\ 3.3R_L + 0.67 \ (0.1 < R_L \leq 0.4) \\ 2.0 \ (0.4 < R_L) \end{cases} \quad \text{(for Level 2 earthquake motion)}$$

Here,

F_L : Liquefaction resistance factor.
R : Dynamic shear strength ratio
L : Seismic shear stress ratio
C_w : Modification factor on earthquake ground motion.
R_L : Cyclic triaxial shear stress ratio
r_d : Reduction factor of seismic shear stress ratio, in terms of depth.
k_{hgL} : Design horizontal seismic coefficient at the ground surface (k_{hgL} = Fpga PGA)
F_{pga} : Site coefficient for peak ground acceleration
PGA : Peak ground acceleration coefficient on rock
σ_v : Total overburden pressure (kN/m^2)
σ'_v : Effective overburden pressure (kN/m^2)
x : Depth from the ground surface (m)
r_{t1} : Unit weight of soil above the ground water level (kN/m^3)
r_{t2} : Unit weight of soil below the ground water level (kN/m^3)
r'_{t2} : Effective unit weight of soil below the ground water level (kN/m^3)
h_w : Depth of the ground water level (m)

Cyclic triaxial shear stress ratio R_L shall be calculated by the following equation.

$$R_L = \begin{cases} 0.0882\sqrt{N_a/1.7} & (N_a < 14) \\ 0.0882\sqrt{N_a/1.7} + 1.6 \times 10^{-6} \cdot (N_a - 14)^{4.5} & (14 \leq N_a) \end{cases}$$

Here,

<For sandy soil>

$$N_a = c_1 N_1 + c_2$$
$$N_1 = 170N/(\sigma'_v + 70)$$
$$c_1 = \begin{cases} 1 & (0\% \leq FC < 10\%) \\ (FC + 40)/50 & (10\% \leq FC < 60\%) \\ FC/20 - 1 & (60\% \leq FC) \end{cases}$$
$$c_2 = \begin{cases} 0 & (0\% \leq FC < 10\%) \\ (FC - 10)/18 & (10\% \leq FC) \end{cases}$$

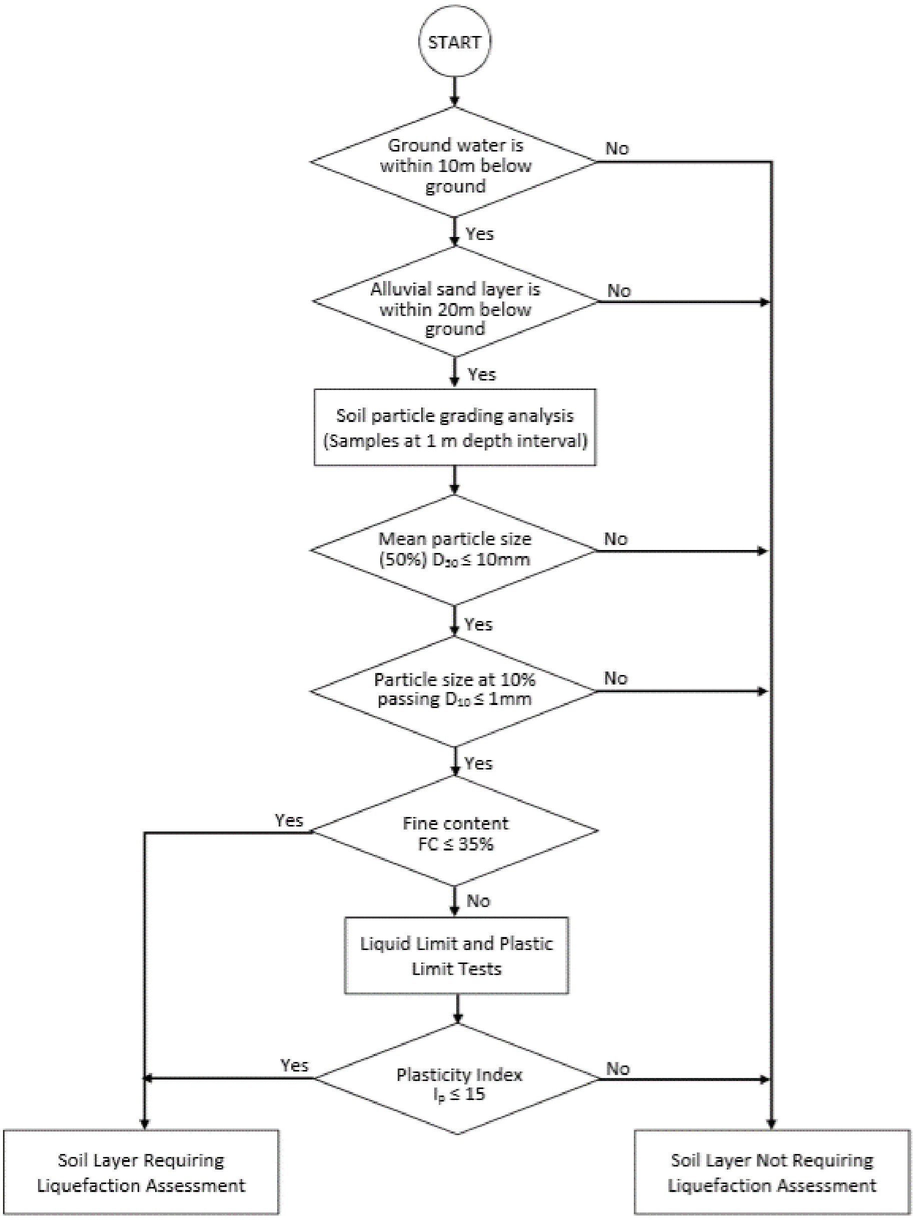
<For gravelly soil>

$$N_a = \{1 - 0.36 log_{10}(D_{50}/2)\}N_1$$

Here,

R_L : Cyclic triaxial shear stress ratio
N : N-value obtained from the standard penetration test
N_1 : Equivalent N value corresponding to effective overburden pressure of 100 kN/m^2
N_a : Modified N value taking into account the effects of grain size
c_1、c_2 : Modification factors of N value on fine content
FC : Fine content, (%) (percentage by mass of fine soil passing through the 75μm mesh)
D_{50} : Mean grain diameter (mm)

Figure 11.7.1 shows the determination flow of the liquefaction assessment.



Source: BSDS 6.2.3 Assessment of Soil Liquefaction p6-5

Figure 11.7.1 Determination of Necessity for Liquefaction Assessment of Soil Layer

11.7.3 Reduction of Geotechnical Parameters of Sandy Layer Causing Liquefaction

For sandy layers that have the potential for liquefaction, the geotechnical parameters should be reduced according to the liquefaction resistance factor F_L, the depth from the ground surface, and the dynamic shear strength ratio R. The geotechnical parameters to be reduced are the coefficient of subgrade reaction, the upper limit of the ground reaction force, and the maximum peripheral friction force[139].

Geotechnical parameters of a sandy layer causing liquefaction and affecting the structure will be obtained as the product of geotechnical parameters without liquefaction and the coefficient D_E in the **Table 11.7.1**[140].

For the case of $D_E = 0$, the geotechnical parameters (shear modulus and strength) shall be regarded as 0 in seismic design.

139 Performance Based Seismic Design Criteria for River Structures I. Common p27

140 Specifications for Highway Bridges V Seismic Design p141

Table 11.7.1 Reduction Factor DE for Geotechnical Parameters

Regime of F_L	Depth from Present Ground Surface x (m)	Dynamic Shear Strength Ratio R	
		$R \leq 0.3$	$0.3 < R$
$F_L \leq 0.3$	$0 \leq x \leq 10$	0	1/6
	$10 < x \leq 20$	1/3	1/3
$1/3 < F_L \leq 2/3$	$0 \leq x \leq 10$	1/3	2/3
	$10 < x \leq 20$	2/3	2/3
$2/3 < F_L \leq 1$	$0 \leq x \leq 10$	2/3	1
	$10 < x \leq 20$	1	1

Source: Specifications for Highway Bridges V Seismic Design p142 Table-8.2.2、BSDS 6.2.4 Reduction of Geotechnical Parameters p6-7

11.7.4 Horizontal Seismic Coefficients for the Liquefaction Assessment

In principle, the embankments, special levees, small sluices and Steel Sheet Pile (SSP) revetments are assessed at Level 1 earthquake motion that is same as designed and constructed in Phases II and III projects.

In BSDS, liquefaction is judged only for Level 2 earthquake motions. BSDS uses F_{pga} *PGA* for design horizontal seismic coefficient considering liquefaction, and the values shown in **Table 11.7.2** based on the relationship between PGA and ground type are given as F_{pga}[141].

Table 11.7.2 Site Coefficient for Peak Ground Acceleration (F_{pga})

Ground Type	Peak Ground Acceleration Coefficient（PGA）					
	PGA≤0.10	*PGA*=0.20	*PGA*=0.30	*PGA*=0.40	*PGA*=0.50	*PGA*≥0.80
I	1.2	1.2	1.1	1.0	1.0	1.0
II	1.6	1.4	1.2	1.0	0.9	0.85
III	2.5	1.7	1.2	0.9	0.8	0.75

Source: BSDS 3.5.3 Site Factors p3-32

Although BSDS does not specify the seismic coefficients at the time of Level 1 earthquake motion, PGAs equivalent to Level 1 earthquake (100-year return period) are shown[142]. On the other hand, the design seismic coefficients of Level 1 earthquake specified by Japanese standards (Performance-Based Seismic Design Criteria for River Structures, Technical Criteria for River Works: Practical Guide for Planning (TCR), Specifications for Highway Bridges) are based on existing earthquakes in Japan.

To take into account the geology and earthquake characteristics of this project site, the BSDS method based on the ground type and PGA at the site is more suitable. Therefore, the horizontal seismic coefficient used for level 1 ground motion to assess liquefaction will be calculated as F_{pga} PGA according to the method of BSDS for level 2 ground motion.

The design horizontal seismic coefficients of the structure at the time of Level 1 earthquake shall comply with NSCP regulations[143] (Refer Chapter9 9.4.2.2).

Table 11.7.3 shows the ground motion and method to set design horizontal seismic coefficients for liquefaction judgment of ground directly under structures.

141 BSDS 3.5.3 Site Factors p3-32
142 BSDS 3.5.3 APPENDIX 3A: SPECTRAL ACCELERATION MAPS FOR LEVEL 1 EARTHQUAKE GROUND MOTION (100-YEAR RETURN PERIOD) p3A-1
143 NSCP Vol. II Bridges (ASD) 21.6. Foundation and Abutment Design Requirements

Table 11.7.3 Horizontal Seismic Coefficients for Ground under Each Structure

Structures	Embankment	Special Levee	SSP Revetment	Small Sluice	Large Sluice (> 2m x 2m)	Weir	Floodgate
Earthquake motion applied to liquefaction assessment	Level 1	Level 1	Level 1	Level 1	Level 1 Level 2	Level 1 Level 2	Level 1 Level 2
Horizontal Seismic Coefficients※1	0.20	0.20	0.20	0.20	0.20 Fpga PGA	0.20 Fpga PGA	0.20 Fpga PGA

Source: Study Team *※1 For the horizontal seismic coefficients, refer to* ***11.4.2.2***

11.8 Design Methods and Countermeasures against Liquefaction

11.8.1 General Countermeasures

The liquefaction countermeasures for structures are broadly classified as follows.

1. Measures to prevent the liquefaction itself

- to improve the ground property to resist against the liquefaction.
- to control critical conditions such as excess pore water pressure and ground deformation, which may induce liquefaction

2. Measures to reduce the damage of a structure while allowing liquefaction

Table 11.8.1 and **Table 11.8.2** show the main liquefaction countermeasures for 1 and 2, respectively. Countermeasures shall be selected considering applicability, effectiveness, reliability and cost efficiency of each construction site.

Table 11.8.1 Characteristics of Countermeasures (1. Measures to Prevent the Liquefaction Itself)

Measures (Major Construction Methods)			Summary of the Measures	Notes	Construction Characteristics			Applicability			Cost	No. of Application
					Noise and Vibration	Ground Deformation	Ground water Cutoff	Grain Size	Depth of the Liquefaction Layer	Applicable Depth (m)		
Counterweight Fill / Soil Replacement			-It consolidates the foot of the slope with a fill or replace liquefiable ground with non-liquefiable material. -No vibration, no noise, but need to obtain new site.	-Ensure the safety of embankment during excavation. -Need examination of lateral displacement of the surrounding ground due to the counterweight.	small	small	-	-	effective to a shallow layer	liquefaction layer of ca. 3m	economical	normal
Foundation Soil Improvement Measures	Vibration Compaction Method	Sand Compaction Pile Method	- It penetrates a steel pipe-casing into the ground and presses the sand to form a sand pile when pulling out. Simultaneously the surrounding ground is compressed sideways. -Also applicable to clayey ground	-Lateral displacement will occurs in the surrounding ground; the range of influence shall be examined.	large	large	-	caution to fine particles	even effective to a thick soil layer	30	economical	many
		Vibrating Rod Method	- It compacts the ground by vibration press-fitting using a special press-fitting rod while filling with sand gravel from the ground surface.	-Lateral displacement may occur in the surrounding ground; the range of influence shall be examined.	large	large	-	caution to fine particles	even effective to a thick soil layer	20	economical	normal
		Vibro-flotation Method	- It compacts the ground by a high-frequency vibrator etc. -Less noise and vibration, less deformation of the surrounding ground compared to other compaction methods	-Lateral displacement may occur in the surrounding ground; the range of influence shall be examined.	middle	small	-	caution to fine particles	even effective to a thick soil layer	20	economical	normal
	Silent Compaction Method	Compaction Grouting Method	- It compacts the ground by pressing the soil mortar with extremely low fluidity into the ground using the boreholes to construct the solid ground. -The equipment is small and applicable diagonally.	-Construction management is necessary to keep the continuous consolidated body. -Lateral displacement may occur in the surrounding ground; the range of influence shall be examined.	small	small	may prevent ground water flow	not applicable to large boulders	even effective to a thick soil layer	to a depth of a boring capacity	normal	small
		Super Lime Pile Method	- It penetrates a spiral casing to install piles of hard burned lime mixed material, and statically compacts the sandy ground by the expansion pressure of the pile. -Also applicable to the clayey ground.	-Lateral displacement may occur in the surrounding ground; the range of influence shall be examined. -The drilled hole shall be properly filled.	small	small	-	not applicable to large boulders	even effective to a thick soil layer	15	economical	small

Measures (Major Construction Methods)			Summary of the Measures	Notes	Construction Characteristics			Applicability			Cost	No. of Application
					Noise and Vibration	Ground Deformation	Ground water Cutoff	Grain Size	Depth of the Liquefaction Layer	Applicable Depth (m)		
Structural Measures	Drain Method	Gravel Drain Method	-It penetrates a casing auger to create a macadam pile in the ground to ensure vertical drainage and dissipate excess pore water pressure.	-The compaction type requires measures against vibration. -If the compaction type is not used, some subsidence may occur after the earthquake.	small	small	-	not applicable to large boulders	not effective to a thick layer	25	normal	many
Structural Measures	Drain Method	Plastic Drain Method	- It places a plastic board drain in the ground to ensure the vertical drainage and dissipate excess pore water pressure. -Applicable to narrow areas	-Horizontal drainage is required at the drainage outlet. -If installed in the riverside, a seepage check is necessary. -Some subsidence may occur after the earthquake.	small	small	-	not applicable to large boulders	not effective to a thick layer	25	normal	normal
Structural Measures	Consolidation Method	Deep Mixing Method	- It consolidates the ground by mixing stabilizer such as cements.	-lateral displacement or uplift will occur in the ground; the range of influence shall be examined.	small	middle	may prevent ground water flow	not applicable to large boulders	even effective to a thick soil layer	30	normal	many
Structural Measures	Consolidation Method	Jet Grouting Method	- It consolidates the ground by spraying cement grout at high pressure from the tip nozzle of the borehole.	-Proximity construction is possible with double pipe & triple pipe methods. -Need management to prevent a cavity under the bottom slab.	small	depends on the method	may prevent ground water flow	not applicable to large boulders	even effective to a thick soil layer	to a depth of a boring capacity	expensive	small
Structural Measures	Consolidation Method	Injection Method	- It consolidates the ground by spraying cement grout at high pressure from the tip nozzle of the borehole.	-Depending on the ground conditions, it may not be possible to obtain a homogeneous and consolidated solid body.	small	small	may prevent ground water flow	caution to fine particles	even effective to a thick soil layer	to a depth of a boring capacity	expensive	small
Structural Measures	Method using Steel	SSP or Steel Pile Sheet Pile (SPSP)	- It prevents lateral displacement and sliding of the embankment.	-If installed by a vibration method, it is necessary to examine the ground subsidence. -Groundwater and seepage flow need to be checked	depends on the method	small	may prevent ground water flow	caution to boulders	applicable to a shallow layer	liquefactio n layer of ca. 5m	normal	normal
Structural Measures	Method using Steel	SSP (SPSP) with Drain Function	- It dissipates excess pore water pressure during liquefaction to prevent shear deformation. -Passive earth pressure resistance of sheet piles can be expected. -Effective against liquefaction, lateral displacement and sliding.	-If installed by a vibration method, it is necessary to examine the ground subsidence.	depends on the method	small	may prevent ground water flow	caution to boulders	applicable to a shallow layer	liquefactio n layer of ca. 5m	normal	small

Source: Edited by study team based on Design and Construction of Countermeasures against Liquefaction of River Banks, Design and Construction of Countermeasures against Liquefaction of River Banks (Design: Methods using Steel), and Guideline for Flexible Sluiceway

Table 11.8.2 Characteristics of Countermeasures (2. Measures to Reduce the Damage of a Structure While Allowing the Liquefaction)

Measures (Major Construction Methods)		Summary of the Measures	Notes	Construction Characteristics		Cost	No. of Application
				Noise and vibration	Groundwater Cutoff		
Strengthening of the Foundation	Pile Foundation	- It supports the structure with the pile foundation penetrated the solid ground to prevent the displacement and settlement of the structure due to liquefaction.	-If applied without ground improvement, piles may be pulled out during liquefaction, and ground height may become uneven.	depends on the method	-	expensive	normal
	Soil Improvement by Piles	- It designs reinforcement piles, revetments, and foundations assuming liquefaction	-It may be less effective to a large-scale liquefaction. -It is necessary to estimate the expected ground displacement accurately in order to design appropriately.	depends on the method	-	normal	normal
Prevention of Uplift	Lift Prevention Pile/Anchor	- It supported by solid ground provide adequate pull-out resistance.	-Since the ground may become uneven after liquefaction, enough attention should be paid to structures that are integrated with embankments (ex. sluice).	depends on the method	-	normal	normal
	Increase the Weight of Underground Structure	- It reduces the amount of uplift due to liquefaction by self-weight.	-It may be less effective for a large-scale liquefaction. -It is necessary to estimate the expected ground displacement accurately in order to design appropriately.	small	-	normal	normal
Following the Ground Deformation	Flexible Joint	-They are installed in the structure to make it follow the ground displacement.	-A design is required that accurately estimates the expected ground displacement and control it within the allowable displacement.	small	-	normal	many
Prevention of Ground Deformation after Liquefaction	Geogrid Method	- It is a mattress under the foundation which distribute the load of the upper structure and increase shear resistance within the mattress.	-Embankment materials should be properly managed (quality control, construction control). -The method is relatively new, and long-term application results are not yet available. -Repair is difficult because is difficult to remove the upper soil after installation.	small	-	economical	normal
	SSP Coffering Method	- It prevents lateral displacement of the foundation ground by surrounding embankment or structures with SSPs.	-The method is said to be effective against tension cracks that reach to the foundation ground within the embankment. -Extra land acquisition is needed -The cost is relatively high.	depends on the method	may prevent the groundwater flow	expensive	small

Source: Edited by study team based on Design and Construction of Countermeasures against Liquefaction of River Banks, Design and Construction of Countermeasures against Liquefaction of River Banks (Design: Methods using Steel), and Guideline for Flexible Sluiceway

11.8.2 Embankment

11.8.2.1 Design Method

The stability of the embankment against liquefaction is assessed by using the arc slip method considering the excess pore water pressure Δu produced by an earthquake motion[144].

The formula for calculating the slip safety factor F_{sd} during an earthquake is as follows. It considers only the excess pore water pressure increment[145]:

$$F_{sd} = \frac{\sum(c' l + (W - u_0 b - \Delta u b)\cos\alpha \tan\varphi'}{\sum W \sin\alpha}$$

Here,

c'、 φ' : Soil cohesion for effective stress (kN/m^2)and internal friction angle (°)

W : Total gravity of each segment (kN/m)

l : Length of arc slip at each segment (m)

b : Width of each segment (m)

u_0 : Pore water pressure generated by normal groundwater (kN/m^2)

Δu : Pore water pressure generated by earthquake motion (kN/m^2)

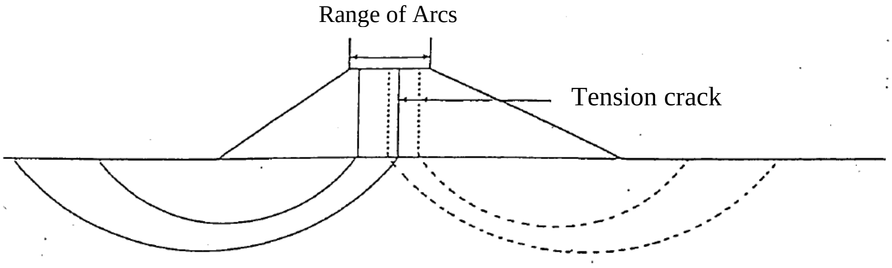
α : The angle between the connecting direction of the sliding arc of each segment and the horizontal plane (°)

In the arc slip calculation, an arc shall pass through the crown as shown in the **Figure 11.8.1**, and a tension crack shall occur in the embankment above the groundwater level.

A tension crack will be considered due to the following reasons.

1. There are many unclear points regarding the strength constant (c, φ) of the embankment
2. There is no significant difference between the safety factor with and without considering a tension crack.

Slip through the embankment slope is ignored. In addition, a vertical slip line is assumed in the embankment, and the resistance moment at this part is not considered.



Source: Design and Construction of Countermeasures against Liquefaction of River Banks p12

Figure 11.8.1 Shape of Arc Slip by Seismic Stability Calculation

In principle, "Design and Construction of Countermeasures against Liquefaction of River Banks" does not allow ground subsidence due to liquefaction, and set safety factor Fs as always 1.0 using the Δu method146.

On the other hand, in the TCR, describes safety factor FS as below:

Ideally, a seismic analysis shall be able to assess the amount of deformation of embankment after an

[144] Design and Construction of Countermeasures against Liquefaction of River Banks p12
[145] Design and Construction of Countermeasures against Liquefaction of River Banks p12
[146] Design and Construction of Countermeasures against Liquefaction of River Banks p16

earthquake. However, practical methods to evaluate the deformation are not yet established.

The realistic alternative is to assume the amount of embankment deformation from the relations between the amount of subsidence and the seismic safety factor. To calculate the seismic safety factor, the arc slip method based on the seismic coefficient method is applicable which is widely applied to stability assessments of soil structures. Table 1.2.3 shows the empirical relations between the amount of settlement at the crown top and the safety factor obtained from the damage cases of river embankments （TCR p16）.

In principle, this design does not allow subsidence due to liquefaction, and use will use Fs = 1.0 as a safety threshold.

However, in case additional measures such as ground improvement are necessary in order to prevent the safety factor from falling below Fs=1.0, the safety factor in Table 1.2.3 will be used to the assessment. The safety factor shall be chosen within the range of subsidence that the top embankment height does not fall below DFL and consider integrity with the adjacent embankment in the upstream and downstream.

Table 11.8.3 The relations between seismic safety factors and amounts of subsidence (maximum)

Seismic Safety Factor *Fsd*		Amount of settlement
kh	Δu	
1.0< Fsd	1.0< Fsd	0
0.8 < Fsd ≤1.0	0.8 < Fsd ≤1.0	(embankment height)×0.25
Fsd ≤0.8	0.6 < Fsd ≤0.8	(embankment height)×0.50
-	Fsd ≤0.6	(embankment height)×0.75

Source: Technical Criteria for River Works: Practical Guide for Planning [I] p16

11.8.2.2 Countermeasures

The following countermeasures against liquefaction under embankment are considerable.

As for the measures to prevent the liquefaction itself, all methods listed in Table 11.8.1 are options for consideration. For the measures to reduce the damage of a structure while allowing the liquefaction, the methods to prevent ground deformation after liquefaction shown in Table 11.8.2 may be applicable.

Countermeasures shall be selected considering applicability, effectiveness, reliability and cost efficiency of the construction site.

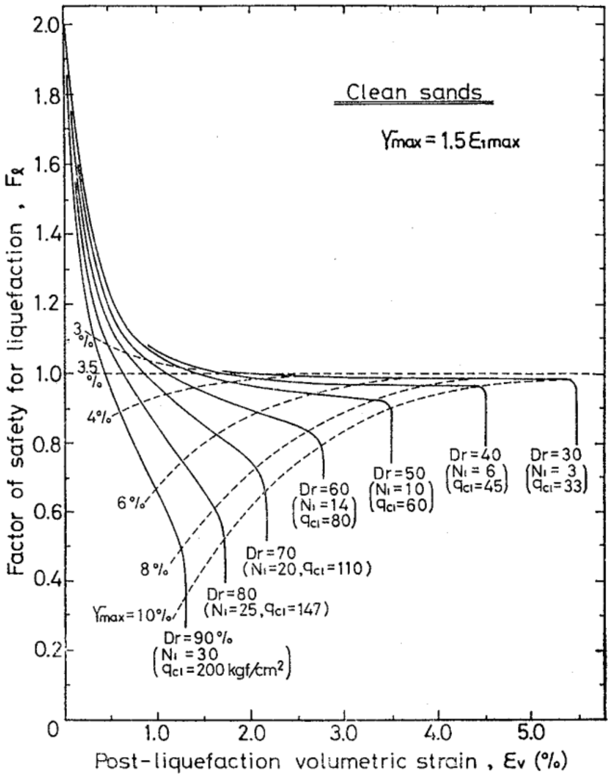
11.8.3 Sluice

11.8.3.1 Design Method

If the foundation ground of a sluice liquefies, the strength and supporting capacity of the foundation ground will decline. It may endanger the stability of the structure. For a sandy layer that is determined to liquefy after the liquefaction assessment (**11.7.2**), the geotechnical parameters of the layer shall be reduced according to the instruction of **11.7.3** . The seismic performance of box culvert will use the modified parameters[147]. In addition, suitable countermeasures shall be adopted as necessary.

Figure 11.8.2 shows the relationship between the volumetric strain associated with the excess pore water pressure dissipation obtained from the experiment. In this figure, the volumetric strain can be obtained from F_L. The amount of ground subsidence can be obtained by multiplying this by the thickness of the liquefied layer

[147] Performance Based Seismic Design Criteria for River Structures IV Floodgate, Sluiceway and Weir p9



Source: K Ishihara and M Yoshimine, Evaluation of Settlements in Sand Deposits Following Liquefaction during Earthquakes, Soils and Foundations, Volume32, Issue 1 pp.173-188

Figure 11.8.2 Chart for Determining Volumetric Strain as Functions of Safety Factor[148]

11.8.3.2 Countermeasures

A sluice is built across the river embankment and thus, has the same function as an embankment. Therefore, the countermeasures against liquefaction shall be designed so that it works against ground subsidence.

When only the seismic performance of the sluice is improved, the stability of the structure is maintained against liquefaction. However, it may cause a secondary disaster due to a gap generated between the bottom slab of the structure and foundation. Therefore, the goal of liquefaction countermeasures for a sluice is to ensure the seismic resistance of the adjacent embankment and to prevent the secondary disaster by controlling the ground liquefaction and fluidization while allowing some displacement of the ground[149].

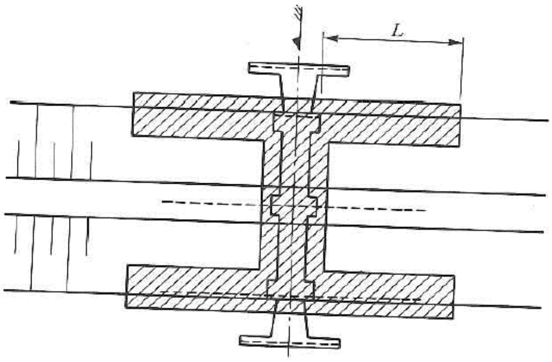
The most reliable measure is to improve the ground under the box culvert to prevent liquefaction. In this case, compacting or consolidating methods are effective. When adopting the consolidation method, note that only the constructed part becomes hard, and the connectivity with the adjacent ground might be worse. Thus, the boundary should be appropriately treated.

<u>In principle, the minimum depth of a liquefaction measure should be up to the bottom end of the liquefaction layer.</u> Furthermore, it should cover the horizontal range where the stability of the improvement material itself and the adjacent embankment against an arc-slip during an earthquake are secured.

The figure below shows the recommended range of countermeasures for embankment around the sluice necessary to ensure the stability against arc-slip during an earthquake. Also, when the consolidation method is used, the improved part may move upward, which may cause adverse effects such as embankment cracks around the improved part. Thus, the boundary should be appropriately treated. **Table 11.8.1** and **Table 11.8.2** show the other liquefaction countermeasures. Countermeasures shall be selected considering applicability, effectiveness, reliability and cost efficiency of the construction site.

[148] K Ishihara and M Yoshimine, Evaluation of Settlements in Sand Deposits Following Liquefaction during Earthquakes, *Soils and Foundations*, Volume32, Issue 1 pp.173-188

[149] Guideline for Flexible Sluiceway p322



L: The length of seepage cut-off SSP+2m or 10m, whichever is longer

Source: Guideline for Flexible Sluiceway p323

Figure 11.8.3 Recommended Range of Liquefaction Measures for Embankment around the Sluice

11.8.4 Floodgate and Weir

11.8.4.1 Design Method

When the foundation ground of a floodgate or a weir liquefies, there is a risk that the strength and bearing capacity of the foundation ground declines and may jeopardize the stability of the structure.

For sandy layers that are determined to liquefy by the liquefaction assessment shown in the section **11.7.2** , the changes in the geotechnical parameters of the soil layer shall be appropriately taken into account following the instruction of **11.7.3** . Based on the changed parameters, the seismic performance of columns, piers and box culverts shall be checked[150]. Countermeasures shall be considered as necessary.

If liquefaction occurs, the plasticity may be considered in the foundations of columns and piers when checking yielding during an earthquake[151].

If the soil layer has a potential of liquefaction, seismic performance evaluation both in the case with and without liquefaction shall be performed. Then, the more critical result of the two cases shall be used. The reason to check both cases is that the behaviors of the ground and structures at the time of liquefaction are complex, and even if liquefaction occurs, it may not become as the expected behavior in the seismic performance evaluation[152].

11.8.4.2 Countermeasures

The principle of countermeasures of floodgates and weirs is the same as that of sluices (**11.8.2.2**). The measures shall prevent the subsidence of the foundation ground that will jeopardize the stability of the structure. For the general countermeasures, foundation improvement measures listed in **Table 11.8.1**, or measures shown in **Table 11.8.2** are applicable.

11.8.5 SSP Revetment

11.8.5.1 Design Method

For sandy layers that are determined to liquefy by the liquefaction assessment shown in the section **11.7.2** , the changes in the geotechnical parameters of the soil layer shall be appropriately taken into account following the instruction of **11.7.3** .To consider the ground deformation caused by the changed geotechnical parameters due to liquefaction, the deformation of the surrounding ground including the SSP will be statically assessed to calculate deformation and the sectional force of the SSP[153].

150 Performance Based Seismic Design Criteria for River Structures IV Floodgate, Sluiceway and Weir p9
151 Performance Based Seismic Design Criteria for River Structures IV Floodgate, Sluiceway and Weir p12
152 Performance Based Seismic Design Criteria for River Structures IV Floodgate, Sluiceway and Weir p13
153 Performance Based Seismic Design Criteria for River Structures III. Non-soil Embankment p14

In the seismic performance evaluation of SSP revetments, soil deformation due to liquefaction caused by earth/water pressure or changes in geotechnical properties accompanying liquefaction will be considered[154].

To calculate SSP deformation due to liquefaction, "a gradual increase component of earth/water pressure" will be considered. Similarly, "a vibration component of earth/water pressure" will be applied to calculate the cross-sectional force of SSP[155].

<Gradual increase component of earth / water pressure>

$p_s = K_A \sigma_v$ (surface non-liquefaction layer)

$p_s = \sigma_v$ (liquefaction layer)

Here,

p_s : Gradual increase component of earth / water pressure (kN/m^2)

K_A : Coefficient of active earth pressure（normal）

σ_v : Total loading pressure (kN/m^2)

<Vibration component of earth / water pressure>

$p_d = \alpha_d \gamma_{NL} k_{hg} \sqrt{(H_{NL} + H_L)x}$ (surface non-liquefaction layer)

$p_d = \alpha_d K_{NL} k_{hg} \sqrt{(H_{NL}{}' + H_L)x'}$ (liquefaction layer)

$\alpha_d = 0.40 \cdot log\rho - 0.40$ ($0 \leq \alpha_d \leq 1.0$)

$$\rho = \frac{EZ_a}{\gamma_L (H_{NL} + H_L)^3}$$

Here,

p_d : Vibration component of earth / water pressure (kN/m^2)
α_d : Correction factor based on the relative rigidness of the sheet pile
γ_{NL} : Unit volume weight of soil of surface non-liquefaction layer (kN/m^3)
k_{hg} : Level 2 horizontal seismic coefficient on the ground surface
H_{NL} : Thickness of surface non-liquefaction layer (m)
H_L : Thickness of liquefaction layer (m)
x : Depth from the ground surface(m)
γ_L : Unit volume weight of soil in liquefaction layer (kN/m^3)
$H_{NL}{}'$: Converted depth from the ground surface (m) calculated by the following formula.

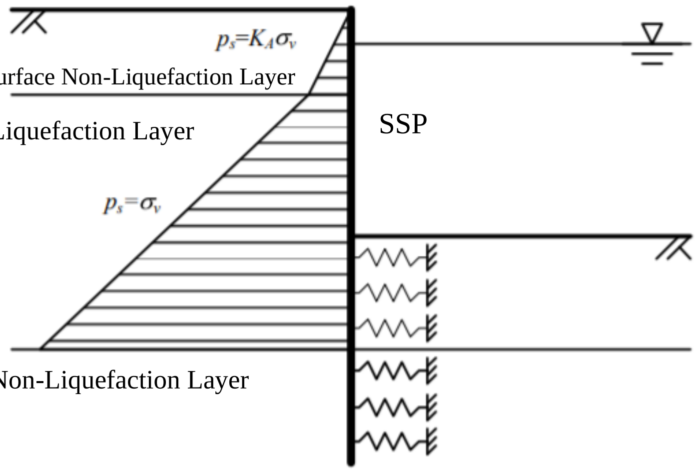
HNL′=HNLγNL/γL

x' : Converted depth from the ground surface (m) calculated by the following formula.

x′=x−(HNL−HNL') =x−(1−γNL/γL) HNL

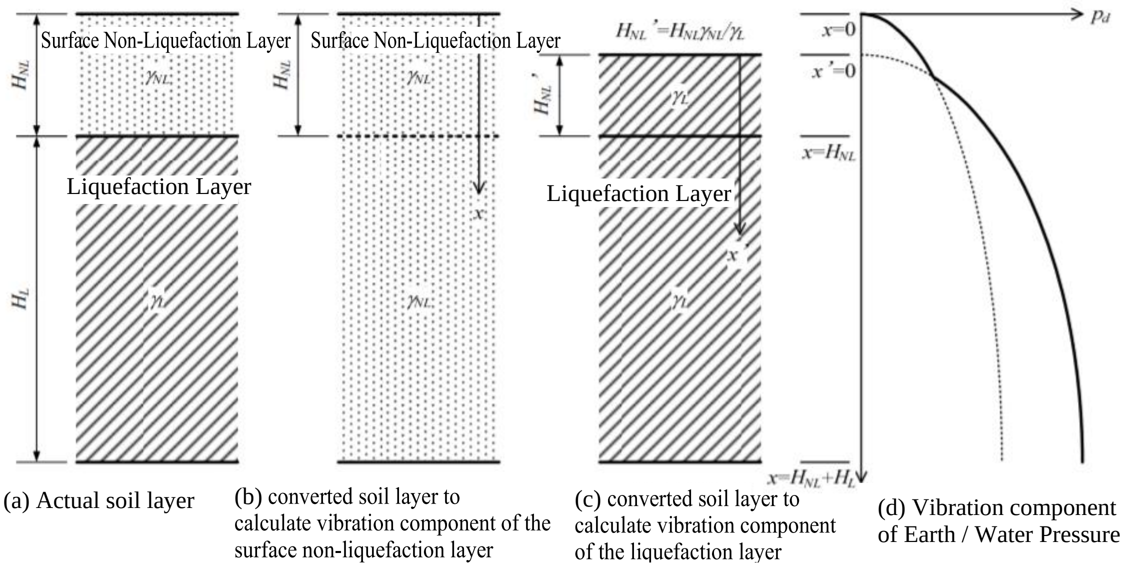
ρ : Relative rigidness of sheet pile
E : Elastic modulus of sheet pile (kN/m^2)
Z_a : Section modulus (m^3/m) of sheet pile per unit width (1m)

[154] Performance Based Seismic Design Criteria for River Structures III. Non-soil Embankment p9
[155] Performance Based Seismic Design Criteria for River Structures III. Non-soil Embankment p12



Source: Performance Based Seismic Design Criteria for River Structures III. Non-soil Embankment p13

Figure 11.8.4 Gradual Increase Component of Earth / Water pressure Acting on the SSP Revetment



Source: Performance Based Seismic Design Criteria for River Structures III. Non-soil Embankment p14

Figure 11.8.5 Vibration component of Earth / Water Pressure Acting on the SSP Revetment

11.8.5.2 Countermeasures

The main countermeasure is to reduce the subsidence of the ground which will affect the stability of the SSP revetment. The applicable methods are the same as those of the embankment, that are shown in **Table 11.8.1**.

11.8.6 Special Levees (Concrete Parapets)

11.8.6.1 Design Method

For sandy layers that are determined to liquefy by the liquefaction assessment shown in the section **11.7.2** , the changes in the geotechnical parameters of the soil layer shall be appropriately taken into account following the instruction of **11.7.3** .

The stress generated in the structure shall be checked that is less than the allowable stress. Also, the stress generated in the foundation shall be less than the allowable stress. Also, it shall have enough bearing capacity and be safe against sliding and overturning. The subsidence of the foundation shall be less than the allowable degree.

11.8.6.2 Countermeasures

The main countermeasure is to reduce the subsidence of the foundation ground, which may affect the stability of the special levee. The applicable methods are the same as those of the embankment, that are shown in **Table 11.8.1** and **Table 11.8.2**.

11.9 Seismic Design

11.9.1 Basic Principles of Seismic Design

11.9.1.1 Technical Codes and Criteria for Seismic Design

In the Philippines, the seismic design methods for river structures have not been fully established. Therefore, existing Japanese design methods (only for Level 1) have been adopted for the revetment design in Phase-I to Phase-III. However, there is a strong expectation of introducing Japanese latest seismic design methods. On the other hand, "DPWH LRFD Bridge Seismic Design Specifications (after this referred to as BSDS)" was issued in the Philippines in 2013. The BSDS describes the measures against Level 2 earthquake motions. New bridges constructed after the publication of the BSDS shall be designed in consideration of Level 2 earthquake motions.

Considering the above-mentioned background, this project will introduce seismic design that takes into account the Level 2 earthquake motions.

Among the river structures to be designed in this project, river dikes have been historically designed and constructed considering only Level-1 earthquake motion. These are longitudinally continuous structures; in view of integrity of safety level along an entire river, it is not desirable to change safety level in certain river sections. Therefore, this project will put the first priority to complete the dike at a consistent safety level, and thus, they shall be designed to satisfy against the Level 1 earthquakes.

On the other hand, floodgate, sluiceway and weir which will be newly designed in this project, will be designed considering Level 2 earthquake motion, since they are independent structures.

The BSDS describes the term of Level 1 earthquake motion and Level 2 earthquake motion as follows. In comparison to the Japanese seismic methodologies, they have common objectives.

"*Level 1 Earthquake Ground Motion - The design earthquake considering seismic hazard from small to moderate earthquake with high probability of occurrence during the bridge service life (taken as 100-year return), for seismic serviceability design objective to ensure normal bridge functions."*

"Level 2 Earthquake Ground Motion - The design earthquake considering a seismic hazard corresponding to an earthquake with a return period of 1000 years (seven percent probability of exceedance in 75 years), for life safety performance objective under a large earthquake."

Source: BSDS, DPWH, P2-2

Since BSDS is a basic guideline to which the Japanese latest river structure design is applicable, the design will be conducted based on BSDS and Japanese "Performance Based Seismic Design Criteria for River Structures". Technical codes and criteria for the seismic design are as shown in the following table.

Table 11.9.1 Technical Codes and Criteria for Seismic Design

No.	Codes and Criteria	Year	Publisher
①	LRFD Bridge Seismic Design Specifications	2013	DPWH
②	Performance Based Seismic Design Criteria for River Structures I. Common	2012	MLIT (Japan)
③	Performance Based Seismic Design Criteria for River Structures II. Embankment	2012	MLIT (Japan)
④	Performance Based Seismic Design Criteria for River Structures III. Non-soil Embankment	2012	MLIT (Japan)
⑤	Performance Based Seismic Design Criteria for River Structures IV Floodgate, Sluiceway and Weir	2012	MLIT (Japan)
⑥	Guideline for Flexible Sluiceway	1998	Japan Institute of Country-ology and Engineering
⑦	Specifications for Highway Bridges I Common / IV Substructures	2012	Japan Road Association
⑧	Specifications for Highway Bridges V Seismic Design	2002	MLIT (Japan)

Source: Study Team

11.9.1.2 Seismic Design Conditions

(1) Determination of Seismic Performance

The "Performance Based Seismic Design Criteria for River Structures I. Common" states the following as a basis for the seismic performance evaluation.

"*In the seismic performance evaluation of river structures, the earthquake motions which is used to evaluate the seismic performance of river structures should be set appropriately, while a suitable evaluation method of seismic performance shall be applied*."

Source: Performance Based Seismic Design Criteria for River Structures I. Common

Hereafter, the seismic performance, the design earthquake used for seismic performance evaluations, and the method of the seismic performance evaluation are described.

The Performance Based Seismic Design Criteria for River Structures IV (MLIT, Japan) sets the seismic performance of floodgates and weirs as shown in **Table 11.9.2**. Important facilities for flood control or water use such as floodgates and weirs shall be under Seismic Performance 2, and the other of types floodgates shall be under Seismic Performance 3.

Floodgate sluiceway and weir to be designed in this project are considered to be important facilities for flood control and water use; therefore, "Seismic Performance 2" will be applied.

Table 11.9.2 Seismic Performance

Seismic Performance	Performance Required
Seismic Performance 1	Soundness as floodgate, sluiceway or weir is not impaired by an earthquake
Seismic Performance 2	Function as floodgate, sluiceway or weir is maintained even after earthquake
Seismic Performance 3	Damage caused by earthquake is limited, and function can be quickly recovered

Source: Performance Based Seismic Design Criteria for River Structures IV

(2) Seismic Force

Table 11.9.3 shows a comparison of seismic force in both standards. In Japan, standard acceleration spectra are defined for acceleration spectrum required to set seismic force, while in the Philippines, an acceleration spectrum will be individually created for each project site. The acceleration spectrum will be calculated using the occurrence probability of the target earthquake motion created by past earthquake observation data in the Philippines.

In BSDS, the spectrum is set in consideration of regional characteristics based on the historical seismic observation data. Thus, the seismic force described in BSDS (**Figure 11.9.1**) will be adopted in this project.

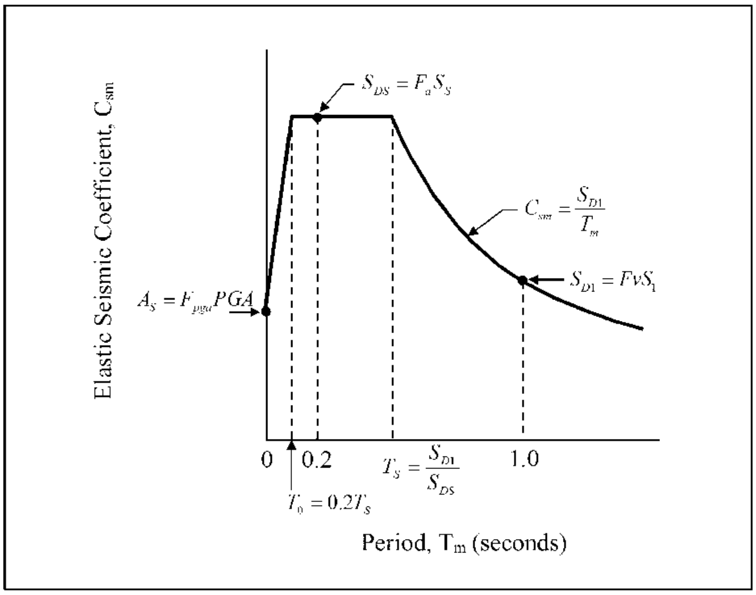
Table 11.9.3 Comparison of Seismic Force in Japanese and Philippine Standards

Performance Based Seismic Design Criteria for River Structures (Japan)	BSDS (Philippines, for Bridges)
Setting Method：Deterministic method	Setting Method：Stochastic method
Type of Earthquake Motion: Level 1 Level 2 TYPE1 (plate boundary type) Level 2 TYPE 2 (strong local earthquake) ※Common standard spectrum is applied regardless of the location	Type of Earthquake Motion: Level 1 (1/100 occurrence probability) Level 2 (1/1000 occurrence probability) ※ Spectrum is set for each target point (Ref. BSDS) ※There is no distinction between TYPE 1 and TYPE 2, but they are mixed and one spectrum is derived from the occurrence probability.
Earthquake motion for liquefaction analysis: Ground motion according to each type L1, L2 are given	Earthquake motion for liquefaction analysis: Consider in case of Level 2 and under Peak Ground Acceleration only. (In case of strong local earthquakes)

Source: Study Team

The five-percent-damped-design response spectrum shall be taken as specified in Figure 3.6.1-1. This spectrum shall be calculated using the mapped peak ground acceleration coefficients and the spectral acceleration coefficients from Figures 3.4.1-1 to 3.4.1-6, scaled by the zero-, short-, and long-period site factors, F_{pga}, F_a, and F_v, respectively.

Source: BSDS, DPWH, P3-36



Source: BSDS, DPWH, P3-36

Figure 11.9.1 Design Response Spectrum

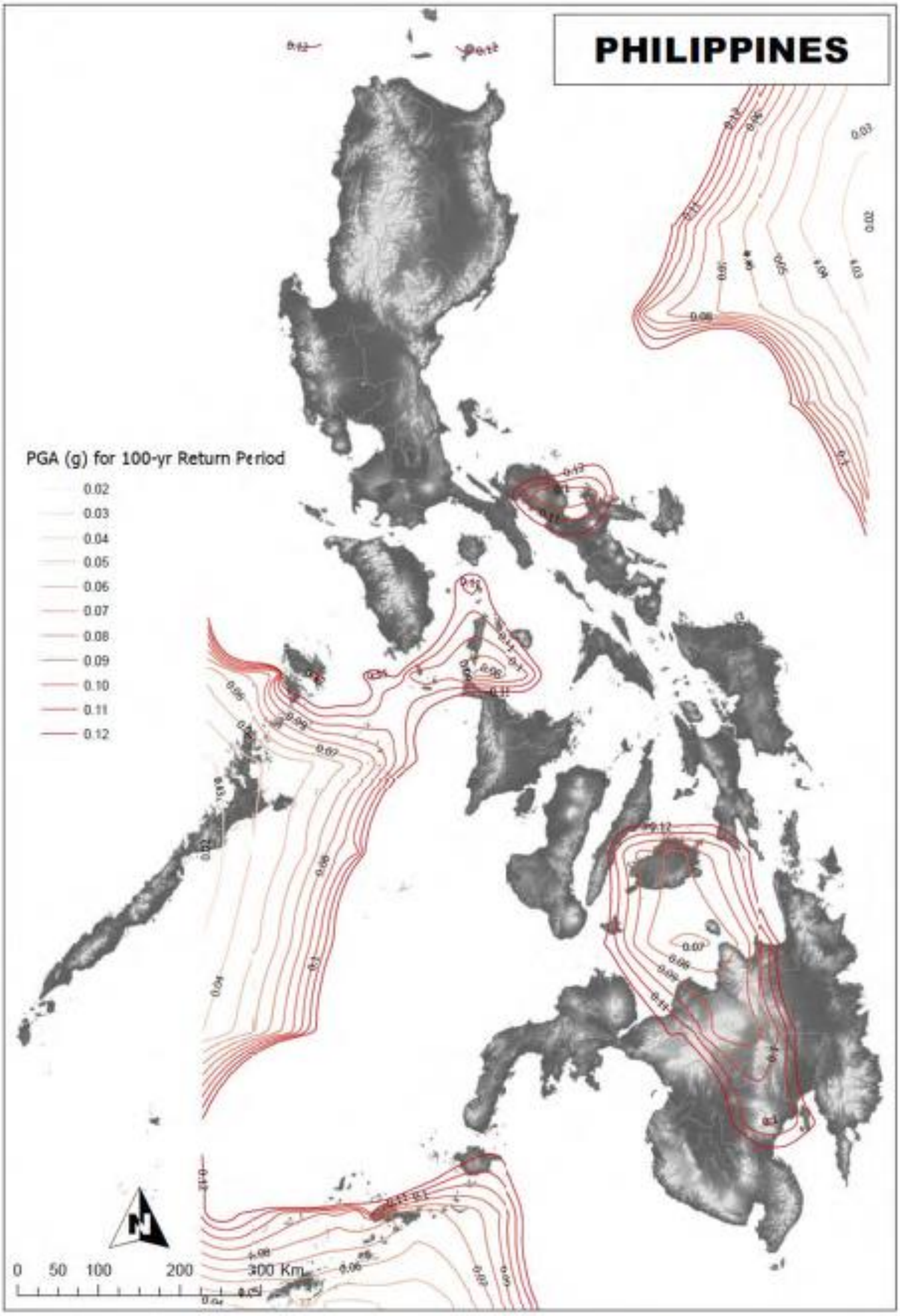


Figure 3.4.1-1 Horizontal Peak Ground Acceleration Coefficient (*PGA*) with 53% percent Probability of Exceedance in 75 Years (Approximately 100-year Return Period) for Level 1 Earthquake Ground motion

Figure 11.9.2 Horizontal Peak Ground Acceleration Coefficient (BSDS Figure 3.4.1-1)

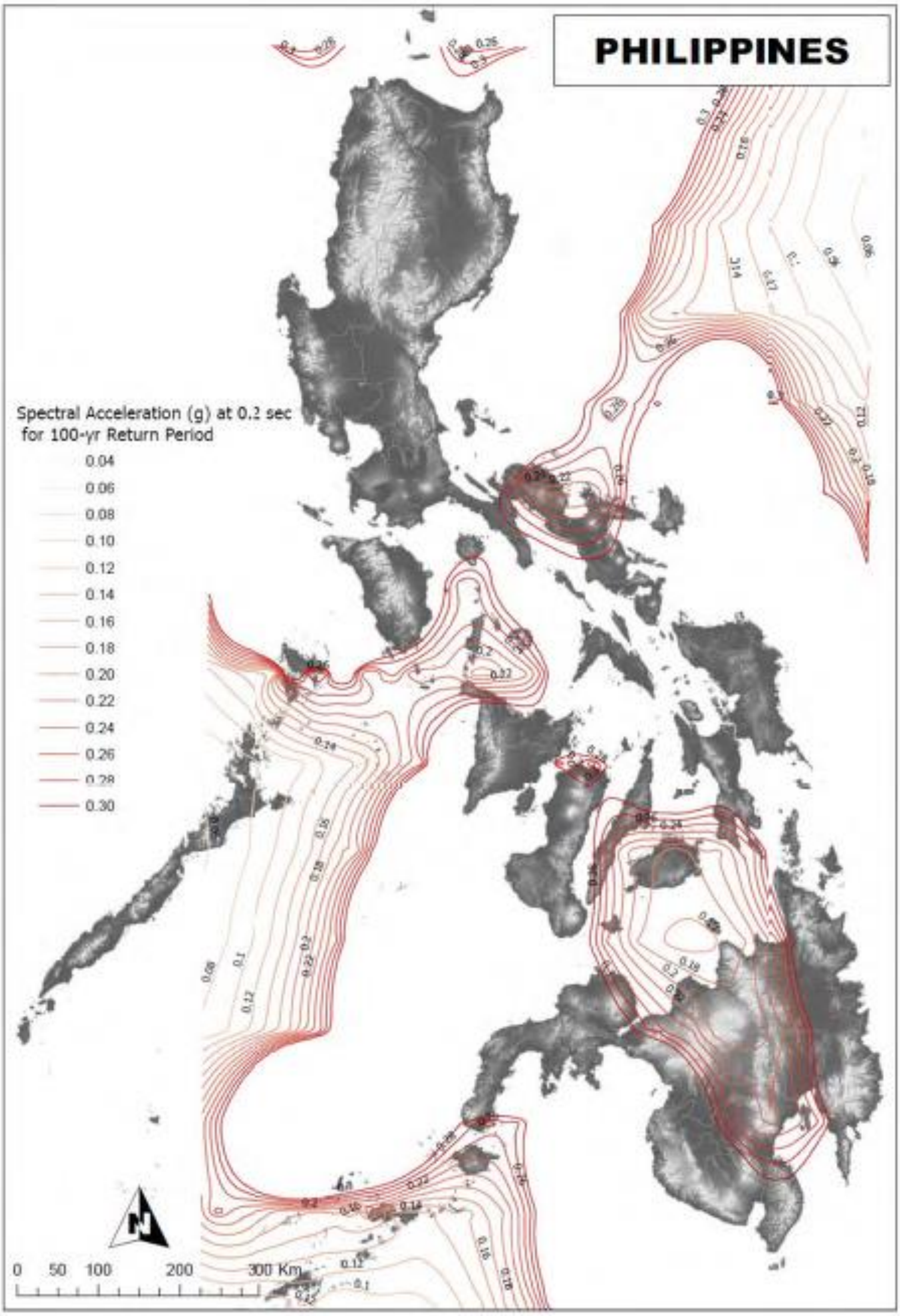


Figure 3.4.1-2 Horizontal Response Spectral Acceleration Coefficient at Period of 0.20-sec (S_s) with 53% percent Probability of Exceedance in 75 Years (Approximately 100-year Return Period) for Level 1 Earthquake Ground Motion

Figure 11.9.3 Horizontal Response Spectral Acceleration Coefficient (BSDS Figure 3.4.1--2)

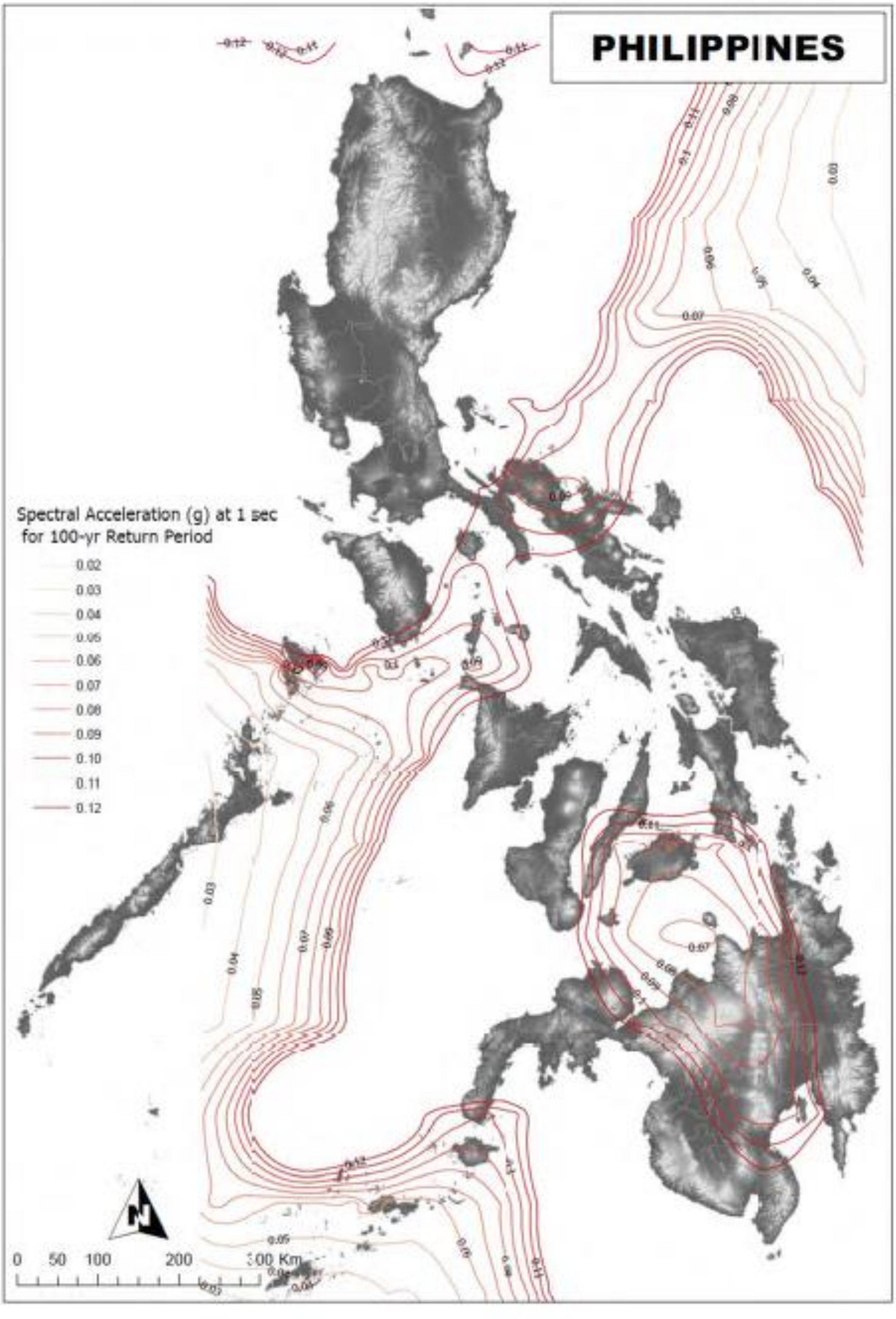


Figure 3.4.1-3 Horizontal Response Spectral Acceleration Coefficient at Period of 1.0-sec (S_1) with 53% percent Probability of Exceedance in 75 Years (Approximately 100-year Return Period) for Level 1 Earthquake Ground motion

Figure 11.9.4 Horizontal Response Spectral Acceleration Coefficient (BSDS Figure 3.4.1-3)

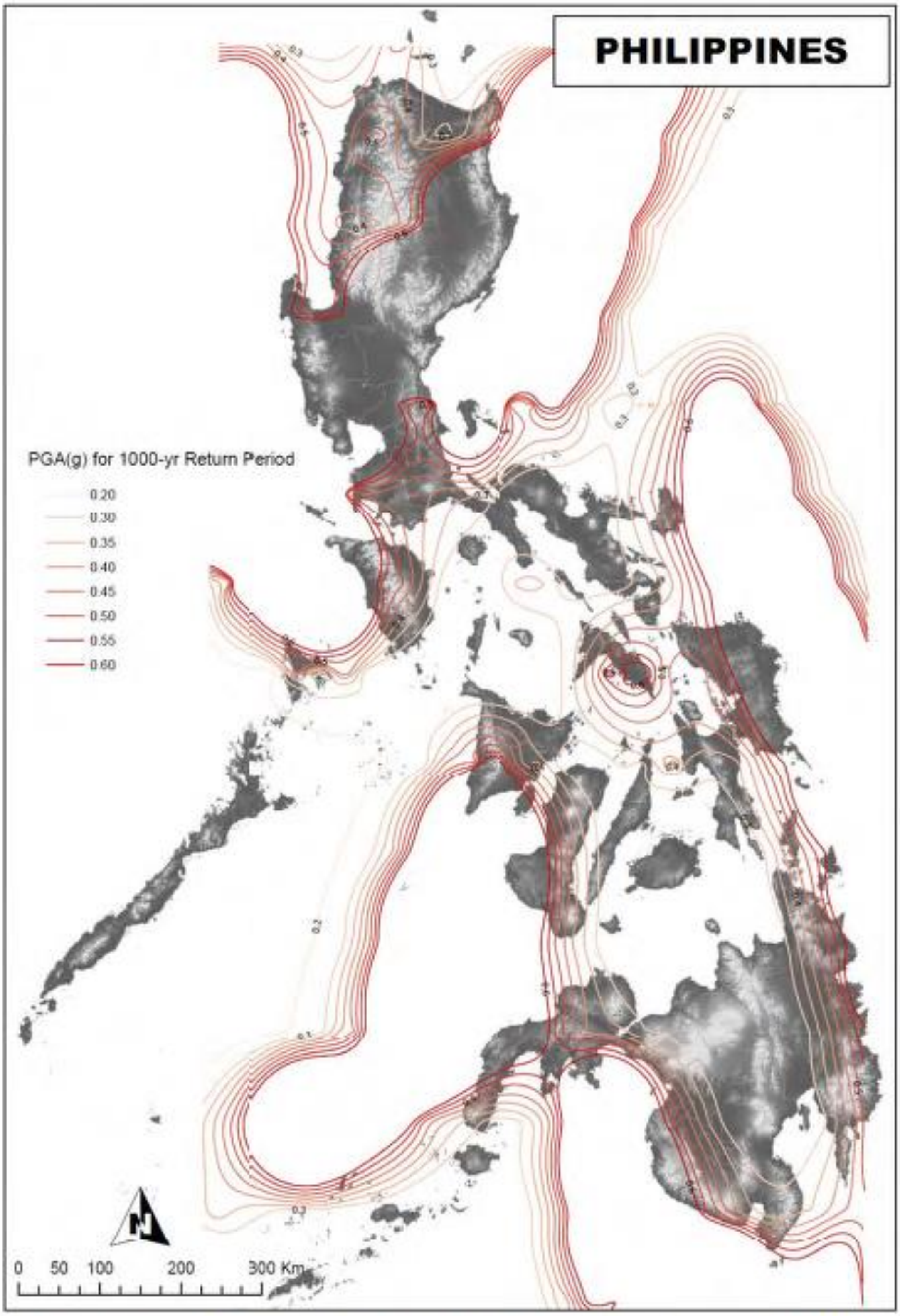


Figure 3.4.1-4 Horizontal Peak Ground Acceleration Coefficient (*PGA*) with Seven percent Probability of Exceedance in 75 Years (Approximately 1,000-year Return Period) for Level 2 Earthquake Ground motion

Figure 11.9.5 Horizontal Peak Ground Acceleration Coefficient (BSDS Figure 3.4.1-4)

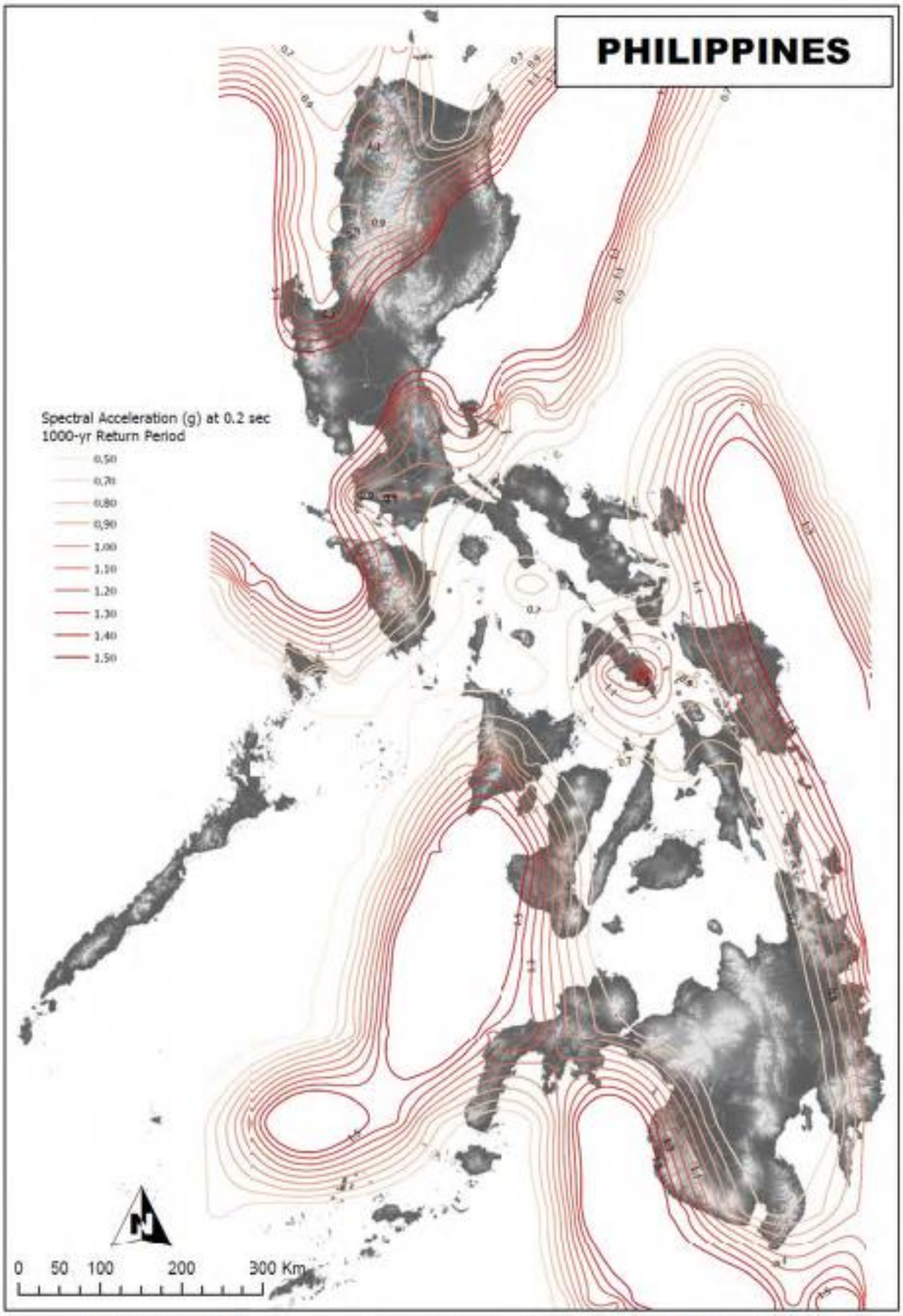


Figure 3.4.1-5 Horizontal Response Spectral Acceleration Coefficient at Period of 0.20-sec (S_s) with Seven percent Probability of Exceedance in 75 Years (Approximately 1,000-year Return Period) for Level 2 Earthquake Ground Motion

Figure 11.9.6 Horizontal Response Spectral Acceleration Coefficient (BSDS Figure 3.4.1-5)

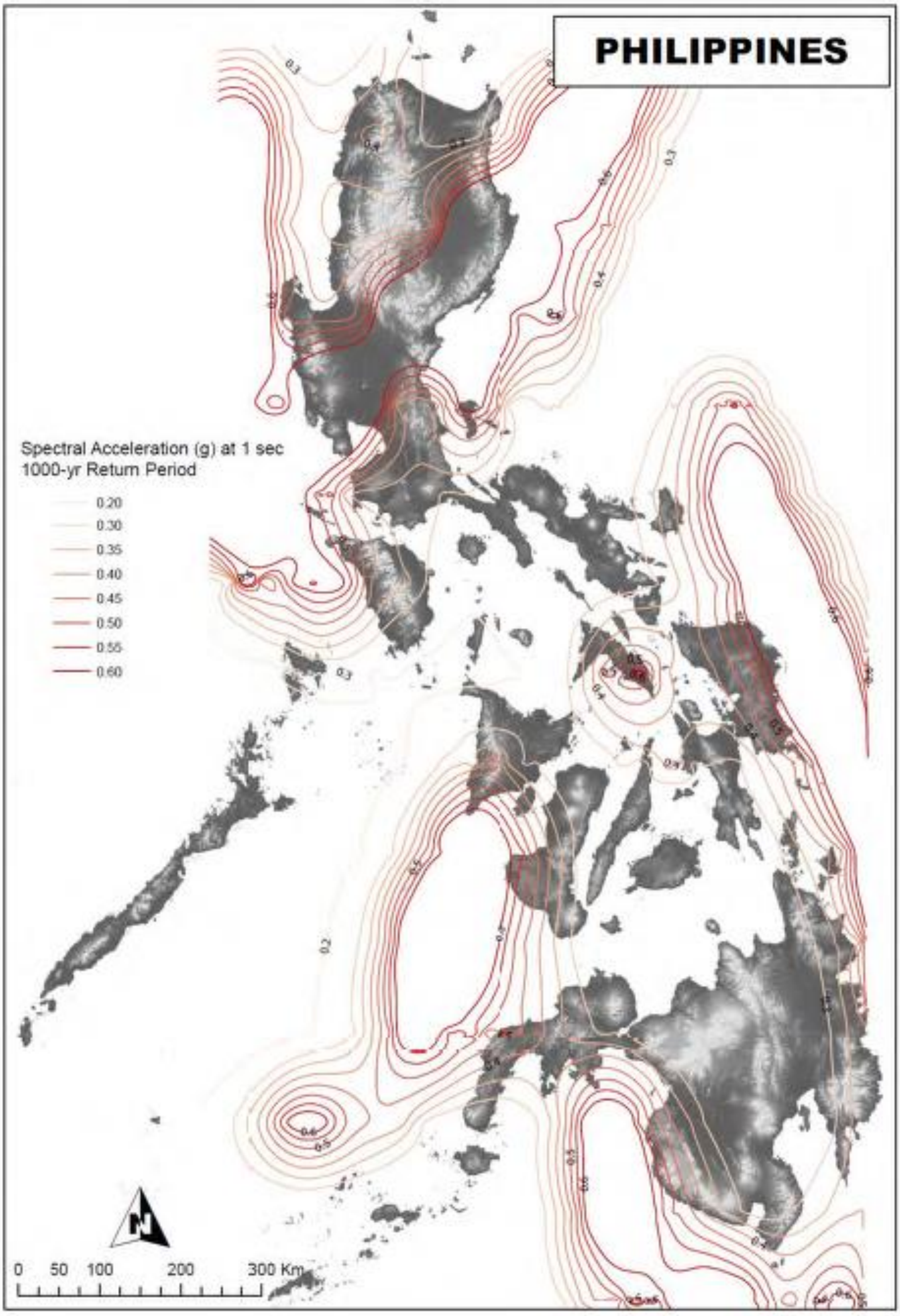


Figure 3.4.1-6 Horizontal Response Spectral Acceleration Coefficient at Period of 1.0-sec (S_1) with Seven percent Probability of Exceedance in 75 Years (Approximately 1,000-year Return Period) for Level 2 Earthquake Ground Motion

Figure 11.9.7 Horizontal Response Spectral Acceleration Coefficient (BSDS Figure 3.4.1-6)

(3) Limit State

In the seismic performance evaluation of the floodgate and weirs, it is necessary to select the members and parts to be considered for plasticization, and to properly set the limit conditions of individual members based on the limit conditions of the floodgates and weirs

The limit conditions for each seismic performance are shown in **Table 9.8.4**. The floodgate and weirs in this project are facilities in which Seismic Performance 2 is required. Therefore, the Limit State Design (LSD) will be carried out in such a manner that plastic deformation is considered only for members considering plasticization, and the plastic deformation does not hinder the opening and closing of the gate.

In addition, the seismic performance evaluation of the floodgate and weir is carried out by checking that the condition that occurs in each member of the structures does not exceed the limit state of the member when the earthquake motion of seismic evaluation acts. The limit states for each member are shown in **Table 9.8.5**.

Table 11.9.4 Seismic Performances and Limit States

Seismic Performance	Limit State	Performance to be Secured
The soundness as a floodgate, a sluiceway or a weir by an earthquake does not impaired (Seismic Performance 1)	The state that the mechanical property of each member does not exceed the elastic range	Usability, Repairability (or no repair necessary)
The function as a floodgate, sluiceway or weir will be maintained even after an earthquake (Seismic Performance 2)	The state that the plastic deformation does not hinder the opening and closing of the gate. (Plastic deformation is considered only for members that the plasticization shall be considered)	Usability, Repairability
The damage caused by an earthquake is limited, and that function can be quickly recovered (Seismic Performance 3)	The state that the plastic deformation does not hinder the quick repair of the member. (Plastic deformation is considered only for members that the plasticization shall be considered)	Repairability

Source: Performance Based Seismic Design Criteria for River Structures IV

Table 11.9.5 Limit State for Each Members of Floodgate or Weir

<table>
<tr><th>Members</th><th>Seismic Performance 1</th><th>Seismic Performance 2</th><th>Seismic Performance 3</th></tr>
<tr><td>Columns/ Piers</td><td rowspan="4">The state that does not exceed the elastic range</td><td>The state in which plastic deformation occurs only in members considering the plasticization and the deformation does not hinder the opening and closing of the gate.</td><td>The state in which plastic deformation occurs only in members considering the plasticization and the deformation does not hinder the quick repair of the gate.</td></tr>
<tr><td>Foundation</td><td colspan="2">The state, in principle, the members remains in secondary plasticity.</td></tr>
<tr><td>Floor Slab of Piers</td><td colspan="2">The state that does not exceed the elastic range</td></tr>
<tr><td>Gate</td><td>The state that the opening and closing of the gate is possible</td><td>The state that residual displacement, which is difficult to repair, does not occur.</td></tr>
</table>

- The members to be considered for plasticization should be selected appropriately, and only these members should be plasticized.
- Since damage of foundations is usually difficult to find and repair, plasticization on the foundation should not be accepted. In general, it is reasonable to consider plasticity of the columns and piers.

Source: Performance Based Seismic Design Criteria for River Structures IV

11.9.2 Seismic Analysis

11.9.2.1 Seismic Analysis Method

Table 11.9.6 shows the method of level 2 seismic performance evaluation in each standard. Both Japanese and Philippine standards are based on LSD, but there is a difference in analysis method, handling of plasticized members in frame analysis. Similarly, the failure mode is not considered in the Philippine standard.

The failure mode is a type classification of whether the structure is destroyed by bending or by shear when a level 2 earthquake motion is applied as an external force.

It is desirable to design the structure to become a bending failure type in seismic design since shear failure causes brittle fracture and can lead to fatal damage to the structure.

In the seismic performance evaluation of river structures, it is necessary to be able to maintain the required functions according to the seismic performance needed after the earthquake (for example, to maintain the states that the opening and closing of the gate is possible, etc.). Therefore, it is essential to consider deformation in the whole structure system after the plastic deformation of members without causing brittle failure at the time of earthquake. **The seismic analysis method shall thus follow the Japanese method: "Performance Based Seismic Design Criteria for River Structures."**

The seismic design in this detailed design is carried out based on the static analysis, which is generally applied to the seismic design of floodgates and weirs.

However, if the result of the eigenvalue analysis (after determination of the structure type of the floodgate or weir) shows that the primary vibration mode is not dominant, or the point where the major plasticization occurs is not clear, the dynamic analysis will be required.

In such a case, measures should be discussed between JICA and DPWH.

Table 11.9.6 Comparison of Seismic Performance Evaluation Methods

Performance Based Seismic Design Criteria for River Structures (Japan)	BSDS (Philippines, for Bridges)
Analysis method：static analysis (Pushover Analysis)	Analysis method：dynamic analysis (Response Spectrum Method) -For single span bridge and retaining walls, etc., static analysis (seismic intensity method) using PGA (peak ground acceleration) is applied
Examination：Lateral Load Carrying Capacity Analysis (LSD)	Examination：Load Factor Design (LSD)
Plasticization of members：Considered Consider nonlinear members in frame analysis	Plasticization of members：Considered Consider only linear members in frame analysis -The response value becomes excessive. -Although some correction methods (SRSS method etc.) are proposed, the error tends to be large
Failure mode：Considered	Failure mode：Not Considered

Source: Study Team

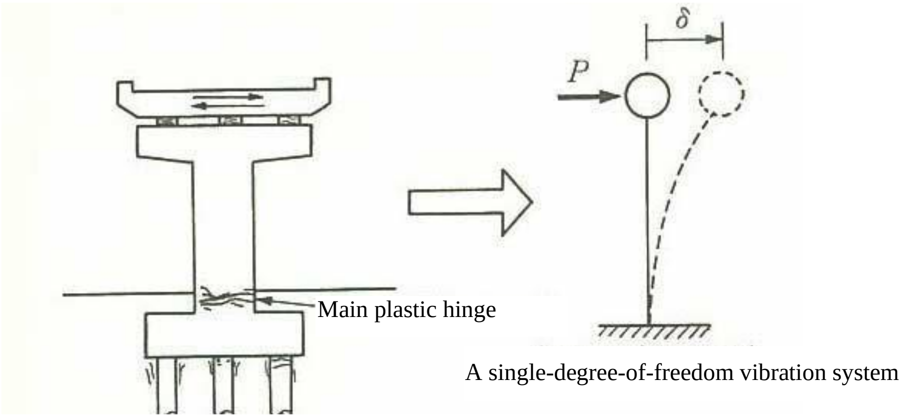
The Performance Based Seismic Design Criteria for River Structures IV describes the following method of seismic performance evaluation.

> *"3.2 Method of Seismic Performance Evaluation"*
>
> *"The check of the seismic performance of the floodgates, sluiceway, and weir shall be conducted based on the appropriate method according to the earthquake motion used for the seismic performance evaluation and the limit state of the floodgate, sluiceway, and weir."*
>
> *"However, in general, if the seismic performance evaluation is conducted according to the static analysis specified in 4., it may be considered that this requirement is satisfied."*

Methods of seismic performance evaluation are broadly classified into two types: dynamic analysis that assesses the seismic behavior of structures dynamically, and static analysis that analyzes the effects of earthquakes statically.

The columns and piers of the floodgates and weirs designed in this project are relatively simple structures similar to a bridge pier. When an earthquake occurs, the primary vibration mode is predominant (See **Figure 11.9.8**) for these structures, and the points can be identified where the main plasticization occur.

Therefore, for the seismic performance evaluation in this design, the static method is applied.



Source: Key Points of Civil Engineering Design. Seismic Design Method / Limit State Design Method (Japan 1993)

Figure 11.9.8 A Single-Degree-of-Freedom Vibration System (Example of a Pier)

In addition, the guidelines describe the method of seismic performance evaluation by the static analysis as follows:

> *"As a rule, the seismic performance of floodgates, sluiceways and weirs shall be checked based on the seismic coefficient method. Besides, the seismic performance evaluation by the static analysis for Level 2 earthquake motions shall be based on the lateral load carrying capacity analysis."*
>
> *"Source: Performance Based Seismic Design Criteria for River Structures IV P8"*

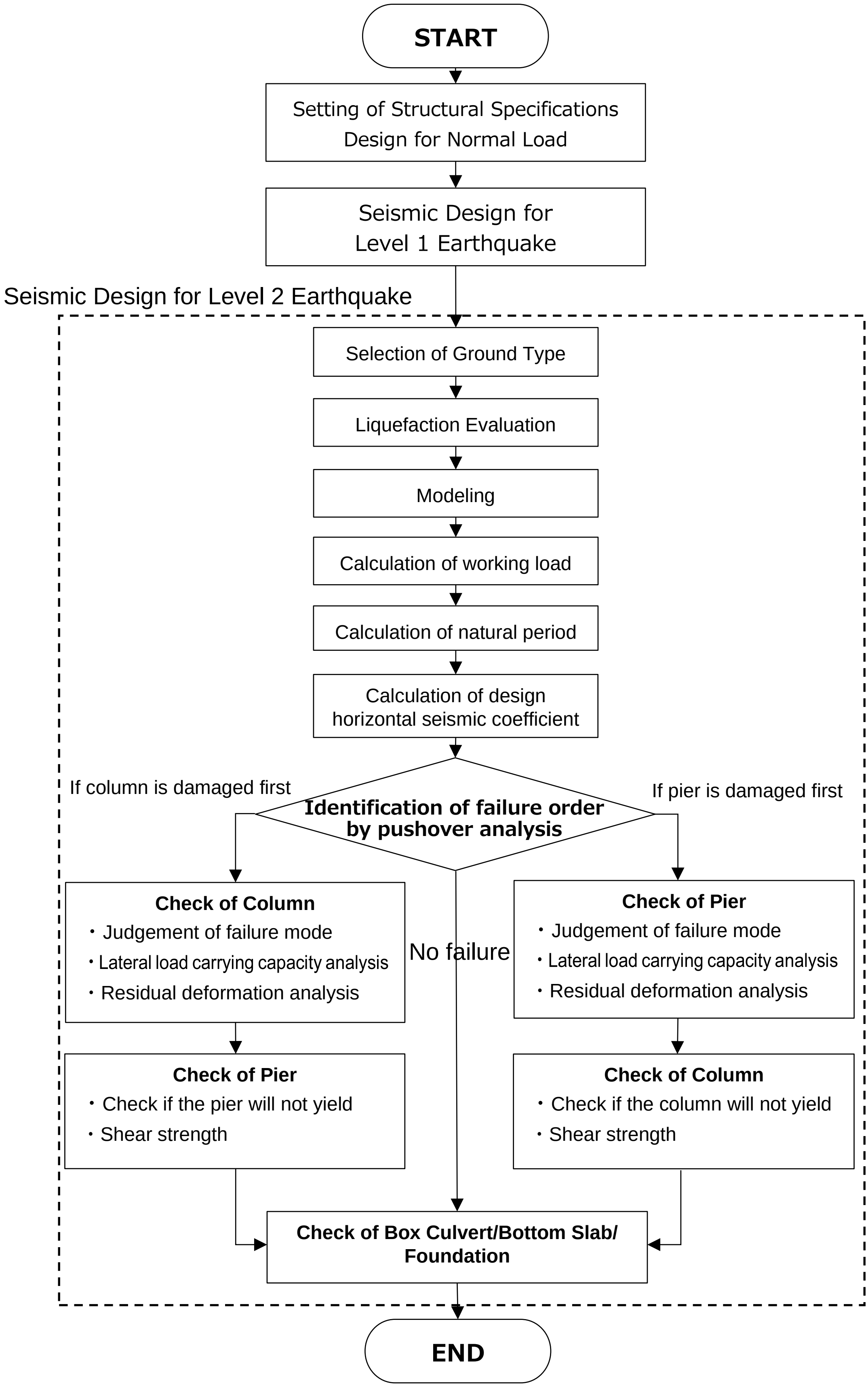
The seismic performance evaluation of the floodgate and weir in this project will be implemented according to the guidelines, as follows:

- Level 1 earthquake motion : Seismic Coefficient Method
- Level 2 earthquake motion : Lateral Load Carrying Capacity Analysis

Lateral Load Carrying Capacity Analysis is a method of checking the seismic performance by replacing the influence of the earthquake with a static load, considering the lateral load carrying capacity, deformability, and energy absorption at the time of earthquake in the plastic region of the structure.

- By allowing damage to members as well as taking into account the effect of energy absorption by the damaged points (plastic hinges), it is possible to make reasonable evaluation against Level 2 earthquake motions.
- The members to be plasticized and not to be plasticized during an earthquake (= control damage) shall be carefully chosen.

11.9.2.2 Analysis Flow



Source: Study Team

Figure 11.9.9 Flow of Seismic Analysis

(1) Selection of Ground Type

The ground type is determined by the Ground Characteristic Value TG. The methods and ground types shown below are the same in both Japanese and the Philippines standards.

$$T_G = 4\sum_{i=1}^{n}\frac{H_i}{V_{si}}$$

Where,

V_{si} : Primary Shear-Wave Velocity (sandy soil $V_s=80N^{1/3}$, clayey soil $V_s=100N^{1/3}$)
N : N Value of each soil layer
i : i th soil layer number

Table 11.9.7 Ground Type

Ground Type	Ground Characteristic Value T_G (s)
Type I	$T_G \leqq 0.2$
Type II	$0.2 < T_G \leqq 0.6$
Type III	$0.6 < T_G$

Source: BSDS (DPWH) / Performance Based Seismic Design Criteria for River Structures

(2) Liquefaction Evaluation

The liquefaction which occurs in the saturated sandy soil layer significantly affects the behavior of the structure during an earthquake. Thus, liquefaction evaluation will be carried out to identify the risk of liquefaction of the soil layer under (around) the planned structure. The assessment will be conducted using FL (= specific resistance against liquefaction), which is calculated by using the information about grain size test from boring data and cyclic triaxial test.

The determination of liquefaction risk will be based on the BSDS and the "Performance Based Seismic Design Criteria for River Structures." If the FL is less than 1.0, it is regarded that liquefaction may occur during the earthquake. The evaluation formula and the judgment criteria are the same in both guidelines. Concerning the external force, however, BSDS considers the case at PGA only. In this study, the external force is set following BSDS.

The liquefaction evaluation is conducted, satisfying all the following conditions.

1) Saturated soil layer with depth less than 20 m below the ground surface and having ground water level higher than 10 m below the ground surface.
2) Soil layer containing a fine content (FC) of 35% or less, or soil layer having plasticity index, I_P, less than 15, even if FC is larger than 35%.
3) Soil layer having a mean particle size (D_{50}) of less than 10 mm and a particle size at 10% passing (D_{10}) (on the grading curve) is less than 1 mm.

Source: BSDS, DPWH, P6-3

(3) Seismic Analysis of Columns and Piers

1) Seismic Analysis Method

Columns and piers are relatively simple structures similar to bridge piers; during earthquakes the primary vibration mode is predominant, and the areas where major plasticization occurs are usually clearly identified. Therefore, it is possible to evaluate the seismic performance by the static analysis, using the lateral load carrying capacity analysis.

2) Cross-Section for Seismic Analysis of Columns and Piers

The seismic analysis shall be conducted for the dimension of both flow direction and the cross-sectional direction of flow. For the floor slab of a pier, it is necessary to check that the stress generated in the floor slab is less than the yield stress.

3) Calculation of Working Load

The horizontal seismic coefficient will be calculated for both the flow direction and the cross-sectional direction of flow depending on the loading direction. The inertial force of the frame is defined as the horizontal force, that is, its own weight multiplied by the horizontal seismic coefficient.

4) Calculation of Natural Period

Since plastic hinges generated at columns and piers are the main non-linear factors, the effect of the plastic hinges will be taken as yield rigidness[156].

Natural period will be calculated by the following formulae.

$$T = 2.01\sqrt{\delta}$$

Where,

T : Natural Period (s)

δ : Horizontal displacement at the point of inertial force application in upper structure when force equivalent to 80% of the weight of the pier or pier is applied in the direction of inertial force (m)

5) Calculation of Allowable Value

It is required to evaluate if the following conditions are satisfied: The horizontal load capacity of the piers and piers during the earthquake is not less than the inertial force acting on the piers and piers, and the residual displacement of the piers and piers is smaller than the allowable residual displacement determined from the gate opening and closing abilities.

The allowable residual displacement of the columns and piers shall be determined for each structure based on the deformation angle, which does not hinder the opening and closing of the gate. The deformation angle is determined by the compositions of the gate and the gate stop, the roller type, the side roller, etc.

6) Formulae for evaluation

(a) Formula for calculating shear strength

Shear strength Ps will be calculated by the following formula shown in the Specifications for Highway Bridges V Seismic Design[157].

$$P_s = S_C + S_S$$

$$S_C = C_C C_e C_{pt} \tau_C bd$$

$$S_S = \frac{A_w \sigma_{sy} d(sin\theta + cos\theta)}{1.15a}$$

Where,

S_c : Shear capacity that concrete bears (kN)
τ_c : Average shear stress that concrete can bear (N/mm^2)
C_c : Correction factor for the effect of reversed cyclic loading
C_e : Correction factor for effective height d of bridge cross section
C_{pt} : Correction factor for axial tensile bar ratio P_t
b : Width of the bridge cross section perpendicular to the direction of the shear capacity calculation (mm)
d : Effective height of bridge cross section parallel to the direction of the shear capacity calculation (mm)

156 Specifications for Highway Bridges V Seismic Design P56
157 Specifications for Highway Bridges V Seismic Design P186

P_t : The axial tensile rebar ratio, the value obtained by dividing the sum of the cross-sectional areas of the main reinforcement on the tensile side from the neutral axis by *bd* (%)
S_s : Shear capacity that the band reinforcement bears (kN)
Aw : Cross-sectional area of band reinforcements arranged at spacing *a* and angle θ (mm^2)
σ_{sy} : Yielding point of band reinforcement (N/mm^2)
θ : Angle between the band reinforcement and the vertical axis (°)
a : Spacing between band reinforcements (mm)

(b) Judgement of Failure Mode

In the seismic performance analysis for columns and piers of floodgates and weirs, it is necessary to identify the characteristics of failure that the columns and piers may suffer and to take appropriate reinforcements and measures to satisfy the seismic performance according to the form of the failure. Therefore, the failure mode is determined from the following formulae.

$P_u \leqq P_s$: Bending failure type
$P_s < P_u \leqq P_{s0}$: Transition type from bending failure to shear failure
$P_{s0} < P_u$: Shear failure type

Where,

P_u : Ultimate horizontal strength (kN)
P_s : Shear strength (kN)
P_{s0} : Shear strength calculated with a correction factor of 1.0 for the effect of reversed cyclic loading

(c) Lateral Load Carrying Capacity Analysis

$k_h W \leqq P_a$

Where,

k_h : Horizontal Seismic Coefficient
W : Equivalent Mass Of A Structure
P_a : Lateral Load Carrying Capacity

The lateral load carrying capacity P_a will be calculated as follows according to the failure mode.

$P_a = P_u$: Bending failure type ($P_c < P_u$)
$P_a = P_u$: Transition type from bending failure to shear failure
$P_a = P_{s0}$: Shear failure type

Where,

P_c : Horizontal resistance against cracking (kN)

Regardless of failure mode, if $P_a \geqq k_{hc} W$ is satisfied, it is judged that the lateral load carrying capacity at the time of earthquake is adequate (OK). The constants required to check the lateral load carrying capacity are calculated as shown below.

(i) Final lateral load carrying capacity P_u

The final lateral load carrying capacity P_u is calculated by the following equation in consideration of the plastic hinge which occurs at the damaged cross section.

$$P_u = \frac{M_u}{h}$$

Where,

M_u : Final bending moment (N・mm)

h : The height from the lower end to the upper structure to which inertia force works (mm)

(ii) Design horizontal seismic coefficient K_{hc}

Design horizontal seismic coefficient for Level 2 earthquake motion will be calculated by the following formulae.

$$k_{hc} = C_s C_z k_{hc0}$$

Where,

C_s : Correction factor of structure characteristics
$C_z\,k_{hc0}$: Horizontal seismic coefficient calculated from natural period and design response spectrum

Correction factor of structure characteristics C_s is obtained as follows.

$$C_S = \frac{1}{\sqrt{2\mu_a - 1}}$$

Where,

μ_a : Allowable plasticity rate of reinforced concrete columns

μ_a is calculated as follows according to failure mode.

【Bending failure type】

$$\mu_a = 1 + \frac{\delta_u - \delta_y}{\alpha\delta_y}$$

Where,

δ_u : Final displacement (mm)
δ_y : Yield displacement (mm)
α : Safety factor (**Table 11.9.8**)

Table 11.9.8 Safety Factor to Calculate Allowable Plasticity of Reinforced Concrete Piers (for Bending Failure Type)

Seismic performance	Safety factor α used to calculate allowable plasticity rate for the type I earthquake motion	Safety factor α used to calculate allowable plasticity rate for the type II earthquake motion
Seismic Performance 2	3.0	1.5
Seismic Performance 3	2.4	1.2

Source : Specifications for Highway Bridges V Seismic Design

[Transition type from bending failure to shear failure]

$$\mu_a = 1.0$$

(iii) Equivalent Weight W

Equivalent weight W will be calculated as follows.

$$W = W_u + C_p W_p$$

Where,

C_p : Coefficient of equivalent weight
W_u : Weight of superstructure supported by the column concerned (N)
W_p : Weight of column or pier (N)

Table 11.9.9 Coefficient of Equivalent Weight C_p

Transition type from bending failure to shear failure	Shear failure type
0.5	1.0

Source：Specifications for Highway Bridges V Seismic Design

(d) Residual Displacement Analysis

$$\delta_R \leqq \delta_{Ra}$$

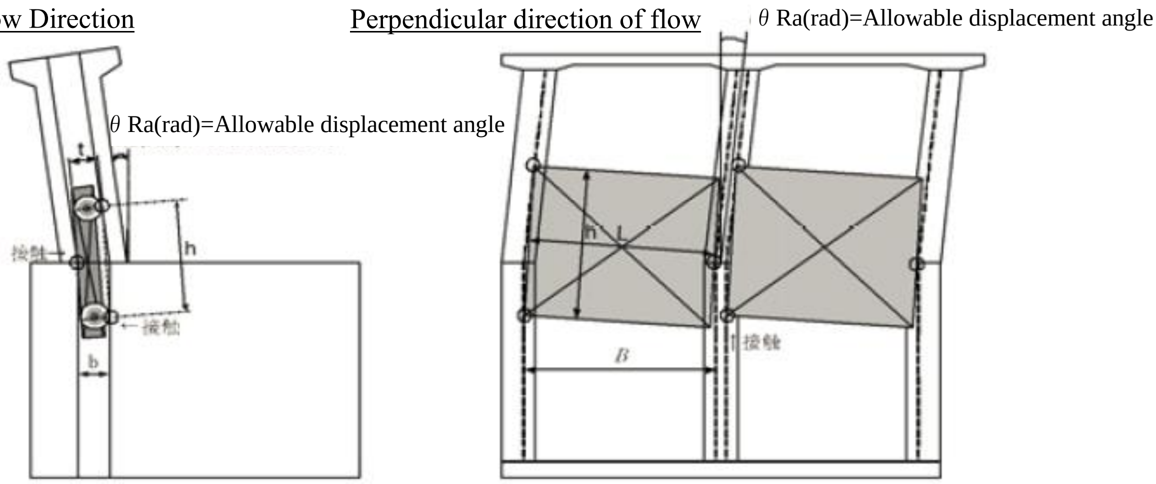
Where,

δ_R : Residual Displacement

δ_{Ra} : Allowable Residual Displacement (δ_{Ra1} or δ_{Ra2})

δ_{Ra1} : Allowable residual displacement (mm) of columns and piers, in principle, residual displacement that does not prevent the opening and closing of the gate (**Figure 11.9.10**).

δ_{Ra2} :Allowable residual displacement (mm) of columns and piers：It shall be 1/100 of the height from the bottom of the pier or pier to the position of the inertia force of the upper structure.



$$\theta_{Ra} = 2\cos^{-1}\left(\frac{h^2-4b^2}{-4bt+h\sqrt{h^2+4t^2-4b^2}}\right)$$

h : Distance between rollers (or gate height)
L : Diameter of Roller(or gate thickness)
B : width between gate guide

$$\theta_{Ra} = 2\cos^{-1}\left(\frac{h^2-4B^2}{-4BL+h\sqrt{h^2+4L^2-4B^2}}\right)$$

h : Gate height
L : Gate width
B : width between gate guide

Source: Performance Based Seismic Design Criteria for River Structures IV

Figure 11.9.10 Calculation Method of Deformation Angle (Allowable Residual Deformation angle) that Does Not Hinder Opening and Closing of the Gate

(4) Check of Box Culvert[158]

In the check of box culvert for the Seismic Performance 2, the deformation in the longitudinal direction of the box is calculated statically. It will be checked that the bending moment and the shear force generated in the box are less than the final bending moment and the shear strength.

158 Performance Based Seismic Design Criteria for River Structures IV 4.5.4 Check of Box Culvert

In addition, it will be checked that the displacement of joints remains within the allowable value.

(5) Check of Bottom Slab

For a bottom slab of floodgate and weir piers, it shall be checked that it has the necessary thickness for bending moment, shear force and punching shear force.

(6) Check of Foundation[159]

The check of the foundations of piers and piers shall be conducted according to the foundation type specified in the "Specifications for Highway Bridges V Seismic Design".

The yielding of the foundation may be determined as the point when the horizontal displacement at the location of the inertia force of the upper structure starts to rapidly increase due to the plasticity of the foundation member or the ground resistance, or the lifting of the foundation.

[159] Performance Based Seismic Design Criteria for River Structures IV 4.5.4 Check of Foundation

11.10 Building Works

11.10.1 Building Structures in This Project

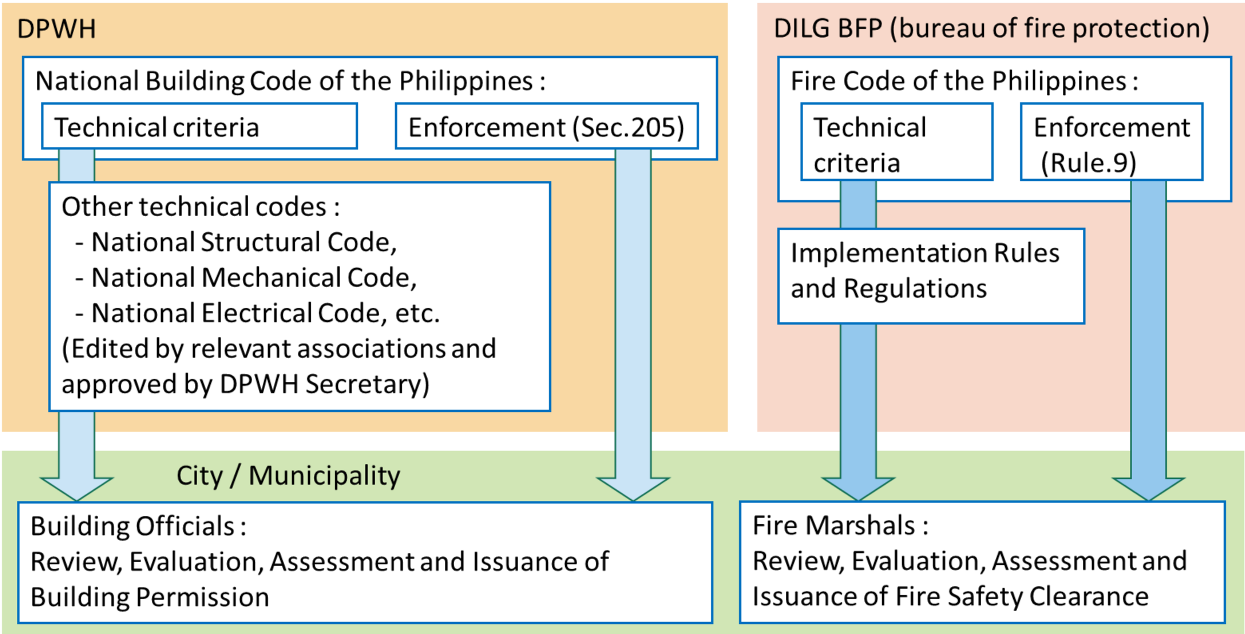
In this project, local control house and generator house of MCGS, Cainta flood gate and Taytay sluiceway are should be designed as building structure. The design of building structures shall conform to the relevant codes and standards used in the Philippines.

11.10.2 Overview of Building Codes and Other Relevant Standards in the Philippines

An overview of building codes and other relevant standards in the Philippines is shown in **Figure 11.10.1**. "National Building Code of the Philippines" (hereafter NBCP), which was authorized by Presidential Decree (Presidential Decree No. 1096), takes an essential role for standard system for building design. DPWH is the ministry responsible for administration and enforcement of NBCP. In addition to NBCP, several technical standards have been established as reference standards (Referral Codes) for NBCPs by relevant professional and authorized under name of DPWH secretary. Some of major ones are;

- ✓ National Structural Code of the Philippines (NSCP),
- ✓ Philippines Electrical Code and
- ✓ Philippine Mechanical Engineering Code.

Besides standard system under NBCP, regulations and technical standards for fire protection are specified in the "Fire Code of the Philippines" (hereafter FC) under Bureau of Fire Protection in Department of Interior and Local Governance.



Source: Survey team

Figure 11.10.1 Outline of the system of technical standards for building structures

Besides standard system under NBCP, regulations and technical standards for fire protection are specified in the "Fire Code of the Philippines" (hereafter FC) under Bureau of Fire Protection in Department of Interior and Local Governance.

CHAPTER 12 PROJECT EVALUATION

In this Chapter, validity of project implementation is evaluated from economic, technical and environmental and social aspects.

12.1 Overall Evaluation of the Project

Economic internal rate of return (EIRR), net present value (NPV) and benefit-costs ratio (BCR) are calculated to evaluate the economic validity of Phase IV projects. Also, an economic evaluation of Marikina Dam is conducted. Conversion factors based on ICC Project Evaluation Procedures and Guidelines (See **Table 12.1.1**) are used for conversion of economic costs and benefits from project costs and benefits.

Table 12.1.1 Conversion Factor

Item	Conversion Factor	Remarks
Labor (Skilled Labor)	0.93	Shadow wages
Labor (Unskilled Labor)	0.60	Shadow wages
Construction Material (Local)	0.61	Shadow prices
Construction Equipment (Local)	0.62	Shadow prices
Imported Materials & Services	1.20	Shadow foreign exchange prices
Local Engineering	0.95	
Administration Services	0.95	
Land Acquisition & Compensation	0.60	Fair market value

Source: 2015IV&V-FS (NEDA ICC Project Evaluation Procedures and Guidelines)

In case it is not possible to clarify each unit price in the previous data, the following conversion factors are used.

Table 12.1.2 Conversion Factor (2)

Item	Conversion Factor
Foreign Currency	1.20
Local Currency	0.95

Source: Study Team

12.1.1 Calculation of Economic Cost

Cost used for economic evaluation is economic cost and transfer items such as taxes are not included. **Table 12.1.3** shows the schedule for disbursement of the economic costs of the project, including the construction of Cainta and Taytay floodgates, and **Table 12.1.4** shows the economic cost for O&M and replacement.

Table 12.1.3 Annual Disbursement of Economic Cost

Year	Annual Disbursement (Million P)	
	Financial	Economic
2021	*,***	*,***
2022	*,***	*,***
2023	*,***	*,***
2024	*,***	*,***
2025	*,***	*,***
2026	***	***
2027	0	0
Total	**,***	**,***

Source: Study Team based on Minutes of Technical Discussion on PMRCIP-IV

Table 12.1.4 Economic Cost for O&M and Replacement

Year	Financial Cost	Economic Cost	Year	Financial Cost	Economic Cost	Year	Financial Cost	Economic Cost
2026	3	3	2042	69	74	2058	42	45
2027	6	6	2043	27	29	2059	58	63
2028	6	6	2044	215	231	2060	20	21
2029	6	6	2045	75	81	2061	77	83

Year	Financial Cost	Economic Cost	Year	Financial Cost	Economic Cost	Year	Financial Cost	Economic Cost
2030	7	7	2046	49	53	2062	66	71
2031	6	6	2047	22	24	2063	226	243
2032	14	15	2048	20	21	2064	99	106
2033	22	24	2049	46	49	2065	64	69
2034	20	21	2050	34	37	2066	10	10
2035	24	26	2051	46	49	2067	8	8
2036	10	11	2052	18	19	2068	17	18
2037	27	29	2053	8	8	2069	88	94
2038	47	50	2054	88	94	2070	303	325
2039	88	94	2055	33	36	2071	358	385
2040	26	28	2056	42	45	2072	385	414
2041	64	69	2057	42	45	2073	302	325

Source: Study Team based on Minutes of Technical Discussion on PMRCIP-IV and Chapters 9 and 13 of this report

12.1.2 Estimation of the Economic Benefits

(1) Phase IV Project

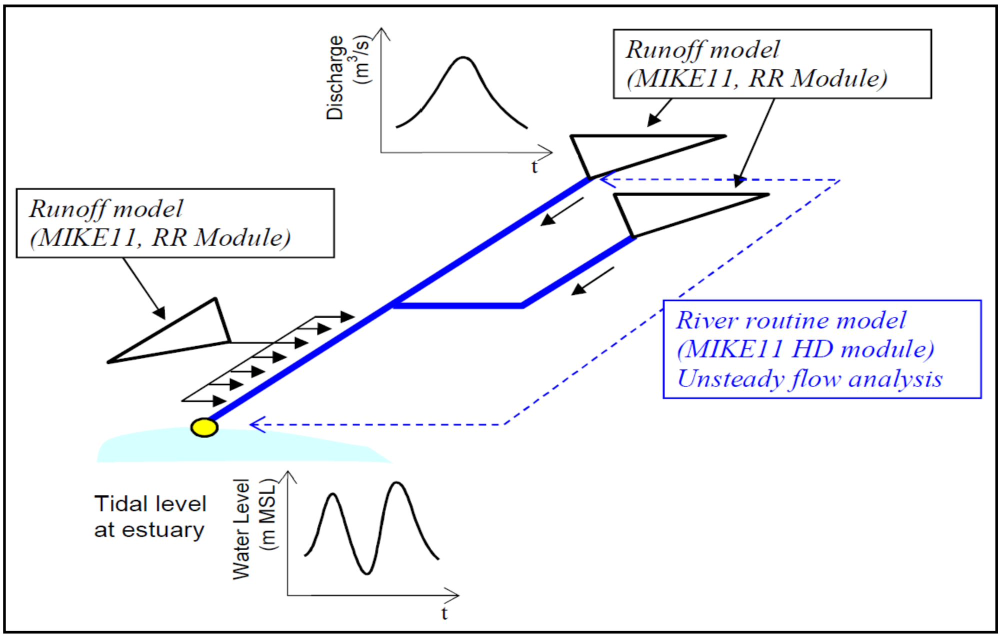
1) Flood Inundation Analysis

The same model used in the Definitive Plan is used for the analysis. The model consists of the rainfall runoff model, river network model and flood inundation model.

(a) Outline of the Runoff Analysis

(i) Structure of Runoff Model

A portion of floodwater of Marikina River is diverted to the Laguna Lake through the Manggahan Floodway. When the water level of Pasig River is low, the diverted river flow goes out of the Napindan Channel to the Pasig River and outflows into the Manila Bay. Therefore, flow condition of this river network is influenced by not only the tide level at the Manila Bay but also water level at the Laguna Lake. In order to estimate the river flow (runoff) in the Pasig-Marikina River Basin, the runoff model combined with a river routine model is applied, as shown in the following figure.



Source: 2015IV&V-FS

Figure 12.1.1 Structure of Runoff Model

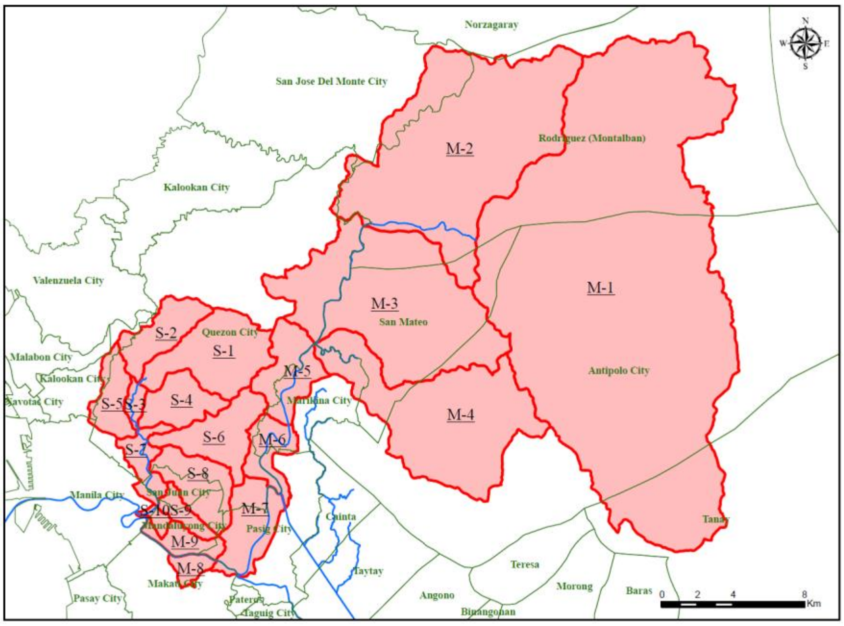
(ii) Runoff Model (MIKE 11, RR Module)

A. NAM Module

Runoff from each sub-basin is calculated by using the NAM module which is commonly utilized for short-term and long-term runoff.

B. Catchment Area

The Pasig-Marikina River Basin has a catchment area of 635km^2 consisting of two (2) major tributaries, namely; Nangka River and San Juan River. In the previous model, the river basin was divided into nineteen (19) sub-catchment areas. Basically, the same division of sub-catchment, as shown in **Figure 12.1.2,** is employed for the runoff analysis in this Study.



Source: 2015IV&V-FS

Figure 12.1.2 Sub-Catchment Area of Pasig-Marikina River

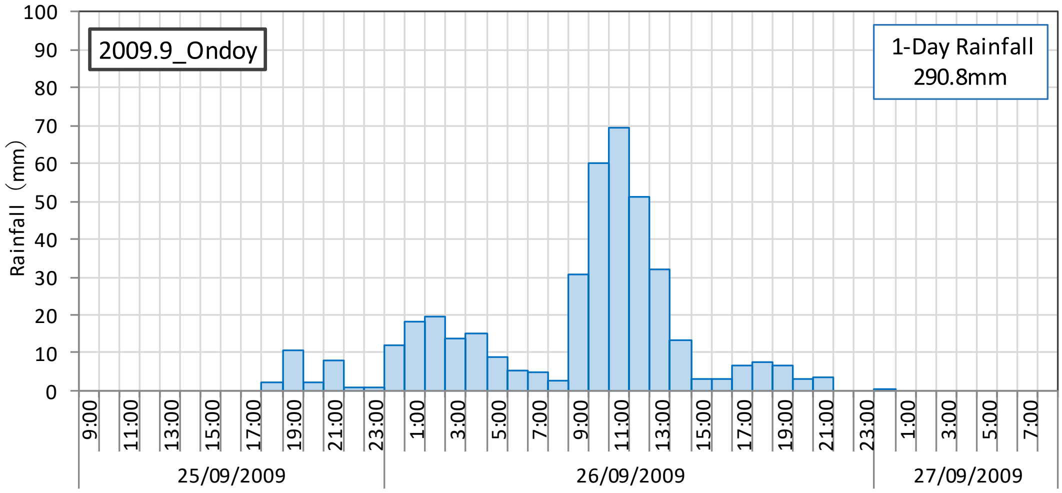
C. Rainfall Condition

Rainfall condition is the same as in the previous study. Rainfall condition and average depth of rainfall over the watershed area are as shown in **Table 12.1.5** and **Figure 12.1.3**. The probable rainfalls corresponding with each return period are the input of the model.

Table 12.1.5 Target Rainfall Condition

Item	Contents
Target Rainfall	Tropical Storm Ondoy, September 2009
Calculated Rainfall Probability	5 cases of probable rainfall (1/2, 1/5, 1/10, 1/20, 1/30)

Source: Study Team based on 2015IV&V-FS



Source: Study Team based on 2015IV&V-FS

Figure 12.1.3 Average Depth of Rainfall on the Watershed Area

(iii) River Routine Model (MIKE 11 HD Module)

To calculate the river flow (discharge) and the water level, the one-dimensional unsteady flow analysis is conducted. In this Study, the MIKE 11 HD module is applied. **Table 12.1.6** shows the method of river routine analysis.

Table 12.1.6 Outline of River Routine Analysis

Items	Contents
Hydraulic Model	One-dimensional unsteady flow (fully dynamic) DHI-MIKE11 HD module
River Network	Refer to **Figure 12.1.2**
Cross Section	The same as Definitive Plan
Structures	Rosario Weir, NHCS, MCGS, River Improvement in Phase IV section based on 2015IV&V-FS
Boundary Condition	Upstream: Calculated hydrograph with the runoff model Downstream (Manila Bay and Laguna Lake): High tide level and water level

Source: Study Team based on 2015IV&V-FS

A. River Cross Section

Table 12.1.7 shows the river cross section data of Pasig-Marikina River collected from previous studies.

Table 12.1.7 River Cross Section Data

No	Name	Length (km)	Interval	Survey Year
1	Pasig River	17.10	50m	1999
2	San Juan River	11.05	200m	1999
3	Napindan Channel	6.98	200 – 500m	1999
4	Lower Marikina River	6.70	50m (Napindan Channel to Sta.5+400)	1999/2008
5	Middle Marikina	6.60	50m (Sta.5+000 to Sto. Niño)	2014
6	Upper Marikina River	6.00	200 – 500m	1999
			50m (Sto. Niño to San Mateo Br.)	2014
7	Nangka River	4.39	8 sections (Sta.1+000 to uppermost stream)	1999
			50m (Marikina River to Sta.1+000)	2014
8	Manggahan Floodway	8.20	200m	1999

Source: 2015IV&V-FS

B. Roughness Coefficient

The same roughness coefficients as used in the previous study are applied in this study.

Table 12.1.8 Roughness Coefficients

No	River Name	Length (km)	Roughness Coefficient
1	Pasig River	0.00 km to 17.10 km	All Sections :0.028
2	San Juan River	0.00 km to 11.05 km	All Sections :0.028
3	Napindan Channel	0.00 km to 6.98 km	All Sections :0.028
4	Marikina River	km to 16.10 km (Napindan Channel to Tumana Br.)	All Sections :0.028
5		16.10 km to 19.30 km (Tumana.Br. to San Mateo Br.)	Low flow channel :0.028 High flow channel :0.060
6		19.30 km to 27.47 km (San Mateo Br. To uppermost stream)	Low flow channel :0.028 High flow channel :0.100
7	Nangka River	0.00 km to 8.20 km	All Sections :0.028
8	Manggahan Floodway	0.00 km to 2.00 km (2.00 km from Rosario Weir)	All Sections :0.021
		2.00 km to 8.20 km	All Sections :0.030

Source: 2015IV&V-FS

C. River Structures

River structures including weirs and floodgates are incorporated in the flood model to estimate water level and discharge more properly since these structures influence flow regimes during floods. **Table 12.1.9** shows the facilities built in the river routine model.

Table 12.1.9 River Facilities in River Routine Model

No.	Name	Location	Remarks
1	Rosario Weir	Marikina River: Sta. 6+650m Manggahan Floodway: Sta.0+026m Diversion point at Manggahan Floodway	Existing
2	NHCS	Marikina River: Sta. 0+000m Napindan Channel	Existing
3	MCGS	Marikina River: Sta. 6+050m	Will be constructed in Phase IV Project
4	River Improvement	Up to the completion of Phase IV	

Source: 2015IV&V-FS

In addition, the flood model is updated so that it can reproduce diversion condition between Marikina river and Manggahan Floodway which has been confirmed through hydraulic modeling test as explained in the previous Chapter 8.

D. Boundary Condition

For conducting the unsteady flow analysis, time-series data are provided for the river routine model. For the boundary condition of the downstream end, the Manila Bay's high tide (11.4, DPWH Datum) is given at the river mouth and design flood level at the mouth of Manggahan Floodway (14.0, DPWH Datum) is given at the Laguna Lake. At the upstream end, the inflow hydrographs of Nangka River and San Juan River are calculated by the MIKE11 RR module.

In low lying areas where it is difficult to identify the exact inflow sites from sub-catchment areas, it is assumed the hydrographs calculated with the MIKE11 RR module are equally distributed along rivers for modeling purposes.

(b) Outline of Inundation Analysis

The flood inundation analysis is carried out with MIKE FLOOD, which is the interface of flood analysis and combines the one-dimensional river flow model (MIKE11 HD module) and the two-dimensional inundation model (MIKE 21). By using MIKE FLOOD, inundation areas and depths, etc., are computed.

(i) Outline of Inundation Model

For the inundation analysis in flood plains, the two-dimensional unsteady flow analysis model is employed. In this Study, MIKE21 is applied for the analysis. The outline of the model is shown in **Table 12.1.10**.

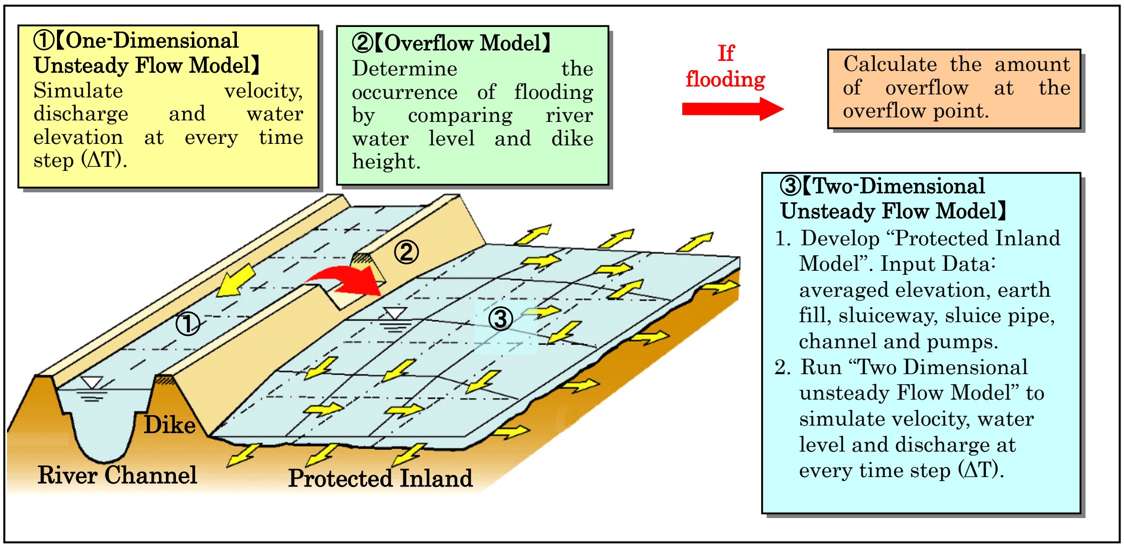
Table 12.1.10 Outline of Inundation Model (MIKE21)

No.	Items	Contents
1	Software	MIKE-FLOOD (DHI)
2	Grid Size	100m
3	Modeling Area	X: 268,747 - 304,947; Y: 1,595,112 - 1,641,912 (coordinate system: WGS84 UTM Zone 51N)
4	Elevation	Based on the result of aerial survey (LiDAR) conducted on 2011
5	Roughness Coefficient	Setup based on land use condition in 2014

Source: 2015IV&V-FS

Figure 12.1.4 is the schematic diagram of the inundation analysis model developed for this Study. Basically, a combination of three integrated hydrologic models, namely, runoff, flood routing and inundation analysis models is established. In this integrated system, outputs from one model are used as input parameter (boundary condition) of the another models.

First, a one-dimensional unsteady flow model (MIKE 11 HD module) is established for the simulation of discharge and water level along the main river channel. Second, flood routing analysis is carried out. If the calculated water level exceeds the height of dike, river water overflows into the inland area. This overflow water volume is calculated by MIKE FLOOD wherein inundated area, depth and velocity are calculated by MIKE 21.

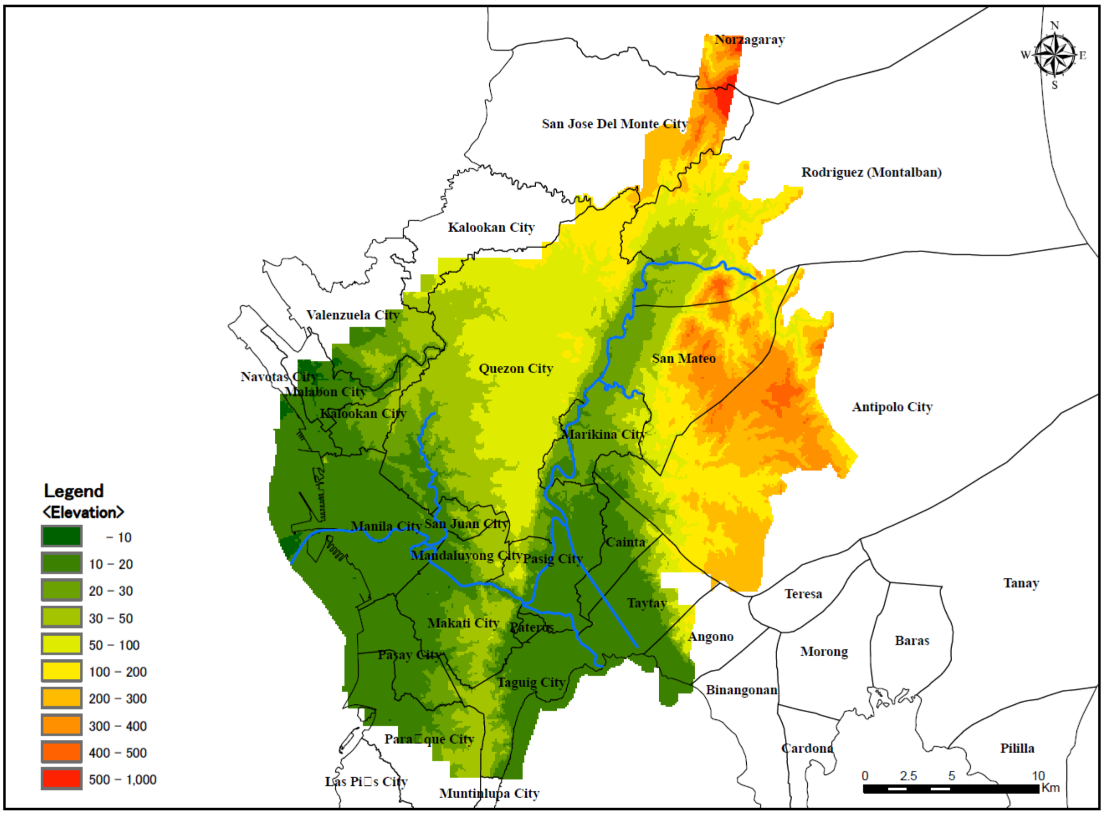


Source: 2015IV&V-FS

Figure 12.1.4 Schematic Diagram of Inundation Analysis Model

(ii) Elevation of Flood Plain

The reliability of inundation analysis depends on the accuracy of ground elevation. In this Study, the calculation grid is prepared based on the elevation data measured by aerial survey (DOST ASTI, 2011), which is the most reliable elevation data at present. The elevation map is shown in **Figure 12.1.5**.



Source: 2015IV&V-FS

Figure 12.1.5 Elevation Map

(iii) Roughness Coefficient in Flood Plain

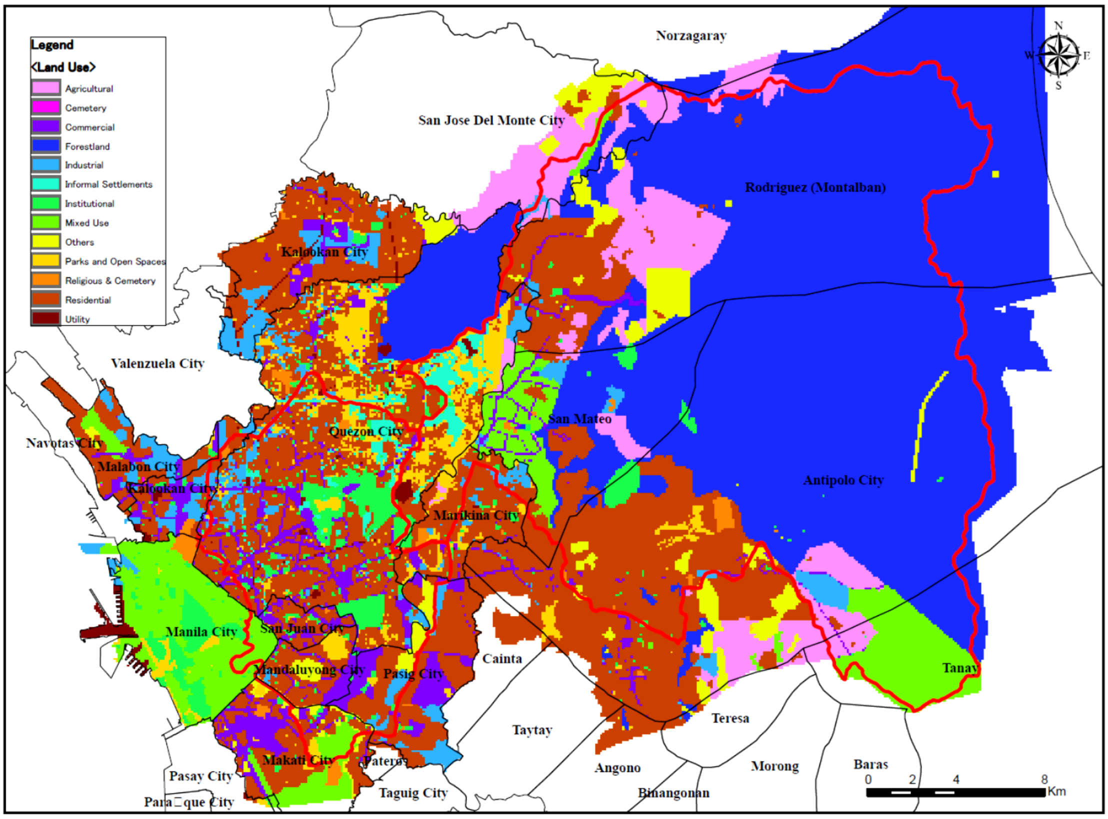
The roughness coefficient in the flood plain is assigned for each calculation grid according to the existing land use condition and vegetation cover. The standard values of roughness coefficients which have been employed for flood management studies in Japan river basins are as given in **Table 12.1.11**.

Table 12.1.11 Roughness Coefficient in Flood Plain

Land Use	Standard Value
Agriculture	0.060
Road	0.047
Others	0.050

Source: Manual on Flood Inundation Analysis, MLIT, Japan, 2005

If a calculation grid consists of more than two land uses, the roughness coefficient is calculated in proportion to the ratio of area coverage of each land use to the total model mesh area (weighted average). Based on the present land use (year and source) as shown in **Figure 12.1.6**, the roughness coefficients over the flood plain are evaluated.



Source: 2015IV&V-FS

Figure 12.1.6 Land Use Map of Pasig-Marikina River Basin

(iv) Overflow Condition

In the past JICA Study in 2014 and IV & V F/S in 2015, it was assumed that overflow occurred at the time when river water level exceeded dike height. However, in this assumption, flood damage situation might be under-estimated since flood water can flow down within clearance without overtopping even if water level exceeds DFL by clearance. In addition, basically levee structures are designed safely only for water levels within DFL and the safety is not secured for water level above DFL. Therefore, in this Study, it is assumed that flooding would occur if the river water level exceeded DFL.

(c) Case and the Result of Inundation Analysis

The inundation area by each flood probability and inundation depth is calculated using flood inundation model which is described above under the condition of cases shown in **Table 12.1.12**. The calculation result is as shown in **Table 12.1.13** and **Table 12.1.14**.

Table 12.1.12 Inundation Analysis Case (Phase IV Project)

Case	Condition
W/ Project	W/ Phase II, III, and IV
W/o Project	W/ Phase II, III

Source: Study Team

Table 12.1.13 Inundation Area (W/o Project)

Inundation Depth (m)	Inundation Area (m^2) by Return Period						
	2-year	5-year	10-year	20-year	30-year	50-year	100-year
<0.15	1,380,000	2,750,000	6,220,000	8,680,000	9,860,000	10,880,000	13,990,000
0.15-0.49	1,410,000	2,530,000	8,340,000	11,820,000	15,540,000	20,080,000	24,580,000
0.50-0.99	1,320,000	2,720,000	5,470,000	9,910,000	10,790,000	13,550,000	19,410,000
1.00-1.99	1,270,000	2,830,000	4,170,000	5,560,000	6,180,000	7,350,000	9,090,000
2.00-2.99	340,000	790,000	1,440,000	2,340,000	3,640,000	3,280,000	3,980,000
≧3.00	140,000	450,000	610,000	1,060,000	1,920,000	3,540,000	4,990,000
Total	5,860,000	12,070,000	26,250,000	39,370,000	47,930,000	58,680,000	76,040,000

Source: Study Team

Table 12.1.14 Inundation Area (W/ Project)

Inundation Depth (m)	Inundation Area (m^2) by Return Period						
	2-year	5-year	10-year	20-year	30-year	50-year	100-year
<0.15	1,040,000	1,750,000	2,730,000	2,350,000	3,600,000	5,460,000	8,460,000
0.15-0.49	890,000	1,570,000	1,860,000	1,770,000	2,360,000	5,500,000	11,150,000
0.50-0.99	980,000	1,770,000	2,290,000	3,260,000	2,970,000	4,150,000	6,230,000
1.00-1.99	970,000	1,910,000	2,750,000	3,680,000	4,220,000	4,250,000	5,030,000
2.00-2.99	330,000	500,000	800,000	1,460,000	2,830,000	2,640,000	3,910,000
≧3.00	80,000	340,000	480,000	780,000	1,530,000	2,890,000	4,510,000
Total	4,290,000	7,840,000	10,910,000	13,300,000	17,510,000	24,890,000	39,290,000

Source: Study Team

2) Estimation of Assets in the Inundation Area

(a) General Assets

The general asset data in the inundation area is the same as in the 2015IV&V-FS. The number of housing units and households, the number of business establishment, and the value of assets per unit for each city and town in the study area are shown in **Table 12.1.15**, **Table 12.1.16** and **Table 12.1.17** respectively.

Table 12.1.15 Housing Units and Number of Households in the Study Area

Region	Province/ Municipality/ City	2010			2014		
		Occupied Housing Unit	Number of Households (Hh)	Ave. Hh per Unit	Occupied Housing Unit	Number of Households (Hh)	Ave. Hh per Unit
NCR	METRO MANILA						
	Quezon City	609,830	634,346	1.040	644,264	670,035	1.040
	San Juan City	27,490	28,890	1.051	28,678	30,141	1.051
	Manila City	359,892	386,835	1.075	380,974	409,547	1.075
	Mandaluyong City	75,417	79,935	1.060	79,858	84,650	1.060
	Makati City	121,211	126,457	1.043	125,957	131,373	1.043
	Pasig City	149,650	154,970	1.036	157,145	162,803	1.036
	Taguig City	147,198	150,190	1.020	153,334	156,400	1.020
	Marikina City	88,559	91,414	1.032	93,555	96,548	1.032
	Pateros	13,190	14,629	1.109	13,738	15,235	1.109
IV-A	RIZAL						
	Taytay	62,298	64,160	1.030	67,443	69,466	1.030
	Angono	22,095	22,698	1.027	23,986	24,633	1.027
	Cainta	68,922	70,891	1.029	74,598	76,761	1.029
	Rodriguez (Montalban)	64,125	65,630	1.023	69,152	70,742	1.023
	Antipolo	146,228	149,517	1.022	159,353	162,859	1.022
	San Mateo	45,063	45,926	1.019	48,459	49,379	1.019

Source: 2015IV&V-FS

Table 12.1.16 Projected Number of Business Establishment in the Study Area (2014)

Municipality/City	Projected Number of Establishments, 2014														
	Total	Industry Major division													
		A	B	C	D	E	F	G	H	I	J	K	M	N	O
NATIONAL CAPITAL REGION															
Manila	44,167	24	46	6	3,134	10	75	22,336	4,954	1,620	1,881	4,788	810	1,924	2,559
Quezon City	47,009	40	3	6	4,386	31	418	21,142	5,870	500	1,800	4,145	1,318	4,322	3,028
Mandaluyong City	8,919	-	-	10	759	3	78	4,186	1,217	162	269	1,201	131	366	536
Marikina City	6,139	3	-	-	800	-	57	3,114	592	43	218	392	182	331	407
Pasig City	16,155	16	-	25	1,397	51	140	7,299	1,975	194	580	2,312	404	889	873
San Juan City	4,196	-	-	-	338	-	36	2,112	455	49	157	475	81	220	272
Makati City	26,851	60	36	174	1,758	101	177	9,446	4,125	529	1,600	5,475	604	1,061	1,704
Pateros	1,003	-	-	-	209	-	-	390	117	8	33	71	18	77	80
Taguig City	6,590	16	10	3	843	4	22	3,091	986	59	140	485	211	286	434
Total	**161,028**	**160**	**95**	**224**	**13,624**	**201**	**1,002**	**73,115**	**20,292**	**3,166**	**6,677**	**19,345**	**3,760**	**9,474**	**9,894**
RIZAL															
Angono	1,352	3	-	-	181	8	10	660	148	7	45	84	43	91	74
Antipolo City	6,402	10	-	-	834	8	63	3,236	737	56	199	367	249	230	413
Cainta	3,130	-	-	-	353	-	51	1,481	368	36	118	205	111	160	247
Rodriguez	1,178	10	-	-	124	-	19	684	121	7	28	41	26	39	79
San Mateo	1,354	16	-	-	205	-	-	641	152	5	47	70	52	83	83
Taytay	3,402	-	-	-	759	8	22	1,706	277	7	76	169	75	139	164
Total	**16,818**	**38**	**-**	**-**	**2,456**	**24**	**165**	**8,408**	**1,802**	**118**	**513**	**936**	**554**	**742**	**1,061**

Source: 2015IV&V-FS

A - AGRICULTURE, HUNTING AND FORESTRY
B - FISHING
C - MINING AND QUARRYING
D - MANUFACTURING
E - ELECTRICITY, GAS AND WATER
F - CONSTRUCTION
G -WHOLESALE/RETAIL TRADE AND REPAIR SERVICES
H - HOTELS AND RESTAURANTS
I - TRANSPORT, STORAGE AND COMMUNICATIONS
J - FINANCIAL INTERMEDIATION
K - REAL ESTATE, RENTING AND BUSINESS ACTIVITIES
M - EDUCATION
N - HEALTH AND SOCIAL WORK
O - OTHER SERVICE ACTIVITIES

Table 12.1.17 Computed Basic Economic Unit Cost

Category		Region	Building (Pesos/ unit)	Durable Assets (Pesos/unit)	H. Effects/ Inv. Stock (Pesos/unit)	Value Added (Pesos/day)
Residence (Residential Units)			155,765		99,248	
Business Establishment	Manufacturing	NCR	1,910,265	2,459,588	22,419,920	61,497
		Calabarzon	22,706,922	27,843,018	138,752,485	529,155
	Wholesale & Retail Trade	NCR	560,054	326,313	8,782,541	17,756
		Calabarzon	332,099	110,912	2,767,175	6,264
	Hotels & Restaurants	NCR	2,252,393	471,710	163,253	11,700
		Calabarzon	701,644	179,957	176,155	6,641
	Real Estate & Business Activities	NCR	2,080,328	736,221	16,408,026	54,416
		Calabarzon	329,713	321,285	1,800,548	14,087
	Education	NCR	6,345,506	878,587	149,227	45,668
		Calabarzon	2,897,954	322,335	58,044	19,821
	Health & Social Work	NCR	2,374,027	1,422,910	903,628	25,420
		Calabarzon	1,534,475	437,896	750,119	12,058
	Electricity, Gas and Water	NCR	1,131,865,727	343,180,557	89,638,170	4,753,056
		Calabarzon	182,873,306	106,557,741	68,972,450	1,370,033
	Other Community, Social and Personal Services	NCR	4,295,673	843,818	391,871	39,671
		Calabarzon	4,602,294	450,717	1,499,034	9,459
	Construction	NCR	1,910,013	3,548,461	23,148,315	129,735
		Calabarzon	2,465,920	1,038,988	4,658,599	46,786
	Transport, etc.	NCR	7,720,985	10,204,521	2,485,306	319,141
		Calabarzon	1,746,144	2,584,187	2,280,983	23,539
	Financial Intermediation	NCR	7,063,874	1,242,379	262,409	281,983
		Calabarzon	185,920	55,601	98,240	6,649
	Fishing	NCR	1,802,474	5,949,956	6,146,798	135,412
		Calabarzon	288,348	87,599	163,268	983

Source: 2015IV&V-FS

(b) Crop Damage

The Pasig-Marikina Basin has very limited agricultural land (See **Figure 12.1.6**). In the inundation analysis for damage estimation, agricultural damage is not counted because there is no inundation in farmland.

3) Damage Estimation

(a) Method of Damage Estimation

As with the Definitive Plan, damage of each item is estimated using damage rate (**Table 12.1.18**) and the number of business suspension days (**Table 12.1.19**) based on "Manual for Economic Study on Flood Control"[1] Calculation formula for each damages are as shown in **Table 12.1.20**.

Table 12.1.18 Damage Rate

Item		Inundation Depth					
		Below Floor Level	Over Floor Level (m)				
			0.15-0.49	0.5-0.99	1.0-1.99	2.0-2.99	>3.0
1	Building	0	0.092	0.119	0.266	0.380	0.834
2	Residence (Household Effects)	0	0.145	0.326	0.508	0.928	0.991
3	Industrial Establishment						
	a. Depreciable Assets	-	0.232	0.453	0.789	0.966	0.995
	b. Inventory Stock	-	0.128	0.267	0.586	0.897	0.982
4	Crops						
	a. Lowland crop (Laguna)	-	1.0	1.0	1.0	1.0	1.0
	b. Upland crop (Laguna)	-	1.0	1.0	1.0	1.0	1.0

Note: *1 A floor level is 15 cm higher than the ground level.
Source: Economic Study Manual for River Works, 2005. Ministry of Land, Infrastructure, Transport and Tourism, Japan

[1] Manual for Economic Study on Flood Control, Ministry of Land, Infrastructure and Transport of Japan, June 1999

Table 12.1.19 The number of Business Suspension Days

<table>
<tr><th colspan="2" rowspan="3">Item</th><th colspan="6">Inundation Depth</th></tr>
<tr><th rowspan="2">Below Floor Level</th><th colspan="5">Over Floor Level (m)</th></tr>
<tr><th>0.15-0.49</th><th>0.5-0.99</th><th>1.0-1.99</th><th>2.0-2.99</th><th>>3.0</th></tr>
<tr><td>1</td><td>Suspension of Business</td><td>0</td><td>4.4</td><td>6.3</td><td>10.3</td><td>16.8</td><td>22.6</td></tr>
<tr><td>2</td><td>Stagnant Days of Business after Suspension</td><td>0</td><td>2.2</td><td>3.2</td><td>5.2</td><td>8.4</td><td>11.3</td></tr>
<tr><td colspan="2">Total</td><td>0</td><td>6.6</td><td>9.5</td><td>15.5</td><td>25.2</td><td>33.9</td></tr>
</table>

Note: Business suspension days were set with referred to general days in the Philippines.
Source: Economic Study Manual for River Works, 2005. Ministry of Land, Infrastructure, Transport and Tourism, Japan

Table 12.1.20 Calculation Formula for Damages

<table>
<tr><th colspan="3">Item</th><th>Calculation Formula</th></tr>
<tr><td rowspan="6">(1) Direct Damage</td><td rowspan="5">General Assets</td><td>Household Building</td><td>= “Number of Affected Household” x “Value of Household Building” x ”Damage Rate”</td></tr>
<tr><td>Household Assets</td><td>= “Number of Affected Household” x “Value of Household Assets” x ”Damage Rate”</td></tr>
<tr><td>Industrial and Commercial Assets (Depreciable Assets)</td><td>= “Number of Affected Industrial and Commercial Assets by Field” x “Value of Depreciable Assets” x ”Damage Rate”</td></tr>
<tr><td>Industrial and Commercial Assets (Inventory Assets)</td><td>= “Number of Affected Industrial and Commercial Assets by Field” x “Value of Inventory Assets” x ”Damage Rate”</td></tr>
<tr><td>Business Suspension</td><td>= “Number of Affected Industrial and Commercial Assets by Field” x “Business Suspension Days” x “Average Added Value per Day”</td></tr>
<tr><td colspan="2">Infrastructure Facilities</td><td>= “General Assets” x 35%</td></tr>
<tr><td colspan="3">(2) Indirect damage</td><td>= “General Assets” x 10%</td></tr>
<tr><td colspan="3">(3) Total Damage</td><td>= “(1) Direct Damage” + “(2) Indirect Damage”</td></tr>
</table>

Source: Study Team based on 2015IV&V-FS

(b) The Result of Damage Estimation

The total damage is estimated using the result of calculation of direct damage to general assets by each probability based on the above conditions. Total damage of With/Without Project are as shown in **Table 12.1.21** and **Table 12.1.22** respectively.

Table 12.1.21 Total Damage (W/o Project)

Return Period	Direct Damage (1)	Indirect Damage (2)=(1)*10%	Damage to Infrastructure (3)=(1)*35%	Total Damage (4)=(1)+(2)+(3)
2 year	7,386.24	738.62	2,585.18	**10,710.05**
5 year	15,243.36	1,524.34	5,335.17	**22,102.87**
10 year	34,886.87	3,488.69	12,210.40	**50,585.96**
20 year	56,529.53	5,652.95	19,785.33	**81,967.81**
30 year	72,815.65	7,281.57	25,485.48	**105,582.70**
50 year	89,200.07	8,920.01	31,220.02	**129,340.10**
100 year	106,857.51	10,685.75	37,400.13	**154,943.39**

Unit: Million Pesos
Source: Study Team

Table 12.1.22 Total Damage (W/ Project)

Return Period	Direct Damage (1)	Indirect Damage (2)=(1)*10%	Damage to Infrastructure (3)=(1)*35%	Total Damage (4)=(1)+(2)+(3)
2 year	6,093.86	609.39	2,132.85	**8,836.10**
5 year	10,487.60	1,048.76	3,670.66	**15,207.02**
10 year	13,156.50	1,315.65	4,604.78	**19,076.93**
20 year	15,376.36	1,537.64	5,381.73	**22,295.72**
30 year	17,346.87	1,734.69	6,071.41	**25,152.97**
50 year	25,769.57	2,576.96	9,019.35	**37,365.88**
100 year	41,425.10	4,142.51	14,498.78	**60,066.39**

Unit: Million *Pesos*
Source: Study Team

4) Estimation of Annual Average Damage Reduction

Annual average damage reduction is estimated based on total damage of With/Without project by each probability calculated above. As a result, annual average damage reduction of Phase IV project is to be 6,682.76 Million Pesos (See **Table 12.1.23**).

Table 12.1.23 Estimated Annual Average Damage Reduction (Phase IV)

Return Period	Flood Damage W/o Project	Flood Damage W/ Project	Reduction	Average (Million P)	Expectation	Benefit (Million P)
2 year	10,710.05	8,836.10	1,873.95			
				4,384.90	0.300	1,315.47
5 year	22,102.87	15,207.02	6,895.85			
				19,202.44	0.100	1,920.24
10 year	50,585.96	19,076.93	31,509.03			
				45,590.56	0.050	2,279.53
20 year	81,967.81	22,295.72	59,672.09			
				70,050.91	0.017	1,167.52
30 year	105,582.70	25,152.97	80,429.73			
					Annual Benefit:	**6,682.76**

Unit: Million *Pesos*
Source: Study Team

(2) Construction of Cainta and Taytay Floodgates

The economic benefits of the construction of the Cainta and Taytay floodgates are summarized in the Implementation Program. The outline is as shown below.

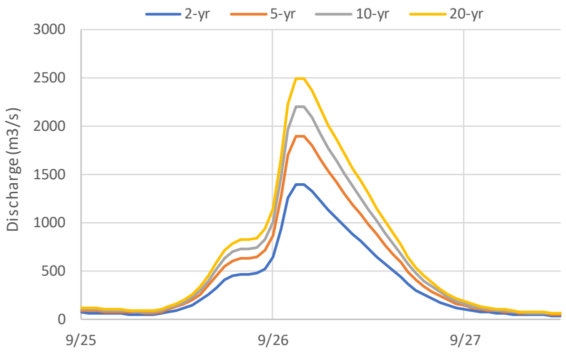
1) Flood Inundation Analysis

Assuming that the backflow from Manggahan Floodway occurs mainly at the confluence of the Cainta River (Sta.4+600), inundation area is estimated by MIKE FLOOD (two-dimensional unsteady flow) using calculation condition shown in **Table 12.1.24**. Calculated probable backflow hydrograph by MIKE FLOOD is as shown in **Figure 12.1.7** (Right) and probable inundation area by inundation depth is as shown in **Table 12.1.25**.

Table 12.1.24 Condition of Flood Analysis

Item	Contents
Target Discharge	Design Discharge in Manggahan Floodway (Ondoy Type) 4 cases of probable rainfall (1/2, 1/5, 1/10, 1/20)
Target Area	East side low-lying area of Manggahan Floodway, 100m x 100m mesh by LiDAR (2011) Lowest elevation in mesh is EL.12.5 m
Cross Section	Cainta River in 1990, Manggahan Floodway in 2002
Boundary Condition	Upstream ends of Cainta River: 1.0 m^3/s as maintenance flow to stabilize the calculation Downstream ends of Manggahan Floodway: Past Highest Water Level after Manggahan Floodway Constructed: 13.90m Upstream ends of Manggahan Floodway: Probable design discharge (See **Figure 12.1.7** Left)

Source: References on Implementation Program



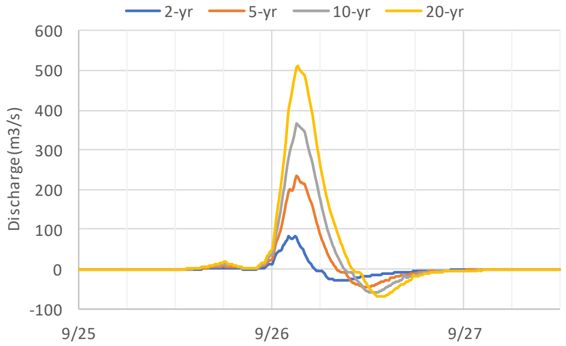


Figure 12.1.7 Hydrograph into Manggahan Floodway (Left) and Hydrograph of Backwater into Cainta River (Right)

Table 12.1.25 Inundation Area

Inundation Depth (m)	Inundation Area for Return Period (ha)			
	2-yr	5-yr	10-yr	20-yr
0.00 - 0.49	182	224	226	229
0.50 - 0.99	63	193	229	230
1.00 - 1.49	24	115	152	186
1.50 - 1.99	3	46	80	107
2.00 - 2.49	0	4	23	43
2.50 - 2.99	0	0	0	4
Total	272	582	710	799

Source: References on Implementation Program

2) Estimation of Assets in the Inundation Area

Estimation condition of assets in the inundation area and the result are as shown in **Table 12.1.26** and **Table 12.1.27**.

Table 12.1.26 Estimation Condition of Assets in the Inundation Area

Item	Contents
Assts in the Inundation Area	i. Immovable ii. Movable
Estimation of Affected Assets	Estimated based on the Number of Household Building in the Inundation Area
Unit Price	Based on Statistics for Household Building in 2000 (Surveyed in 2007); i. Immovable Asset: 200,000 Pesos / Household Building ii. Movable Asset: 100,000 Pesos / Household Building
Capitalization	By consumer price index (CPI) of Clothing, Housing & Repair in 2015 being 150 on average (2000 = 100); i. Immovable Asset: 250,000 Pesos / Household Building ii. Movable Asset: 125,000 Pesos / Household Building
Number of Household in the Inundation Area	For the population and population density in 3 cities, 14 Barangay in 2015 census, the number of household members was calculated as 4.4 persons / household. (See **Table 12.1.27**)

Source: References on Implementation Program

Table 12.1.27 Population, Population Density and the Number of Houses

City/ Municipality	Barangay	Land Area (ha)	Population (2015)	Pop'n Density (head/ha)	No. of Houses
Pasig	Rosario	414.54	50,690	122.28	11,520
	Sta. Lucia	178.31	40,553	227.43	9,217
Cainta	San Andres	322.96	95,838	296.75	21,781
	San Isidro	2,158.90	69,377	32.14	15,768
	San Juan	675.50	98,849	146.33	22,466
	San Roque	66.96	8,817	131.68	2,004
	Santa Rosa	2.77	1,627	587.36	370
	Santo Domingo	1,021.29	41,507	40.64	9,433
	Santo Nino	41.14	6,113	148.59	1,389
Taytay	Dolores	1,237.00	61,115	49.41	13,890
	Muzon	341.00	26,523	77.78	6,028
	San Isidro	442.00	36,780	83.21	8,359
	San Juan	1,490.00	103,343	69.36	23,487
	Santa Ana	800.00	91,343	114.18	20,760
Total		9,192.37	732,475	2,127.14	166,472

Source: Study Team based on References on Implementation Program

3) Damage Estimation

Table 12.1.28 shows the damage of general assets by each probability (amount of assets in the inundation area x damage rate). Total damage is estimated using the damage shown in **Table 12.1.28** with the same method as Phase IV project. The result of total damage is as shown in **Table 12.1.29**.

Table 12.1.28 Damage of General Assets

Inundation Depth (m)	No. of Affected Houses				Direct Damage (Million Pesos)			
	2-yr	5-yr	10-yr	20-yr	2-yr	5-yr	10-yr	20-yr
0.00 - 0.49	3,294.20	4,054.40	4,090.60	4,144.90	135.47	166.74	168.23	170.46
0.50 - 0.99	1,140.30	3,493.30	4,144.90	4,163.00	46.89	143.66	170.46	171.20
1.00 - 1.49	434.40	2,081.50	2,751.20	3,366.60	30.85	147.84	195.40	239.11
1.50 - 1.99	54.30	832.60	1,448.00	1,936.70	7.06	108.24	188.24	251.77
2.00 - 2.49		72.40	416.30	778.30		9.41	54.12	101.18
2.50 - 2.99				72.40				9.41
Total	4,923.20	10,534.20	12,851.00	14,461.90	220.28	575.89	776.45	943.14

Source: References on Implementation Program

Table 12.1.29 Total Damage (Without Project)

Return Period	Direct Damage (1)	Indirect Damage (2)=(1)*10%	Damage to Infrastructure (3)=(1)*35%	Total Damage (4)=(1)+(2)+(3)
1.5 year	0.00	0.00	0.00	**0.00**
2 year	220.28	22.03	77.10	**319.41**
5 year	575.89	57.59	201.56	**835.04**
10 year	776.45	77.65	271.76	**1,125.85**
20 year	943.14	94.31	330.10	**1,367.55**

Note: Since water level at the confluence is lower than 13m in 1.5-year return period and no backflow occurs, damage will be zero (0).
Source: Study Team

4) Estimation of Annual Average Damage Reduction

Annual average damage reduction is estimated based on calculated total damage as shown in **Table 12.1.29**. As a result, annual average damage reduction of Cainta and Taytay Floodgates is to be 360.16 Million Pesos (See **Table 12.1.30**).

Table 12.1.30 Annual Average Damage Reduction (Cainta and Taytay Floodgates)

Return Period	Flood Damage W/o Project	Flood Damage W/ Project	Reduction	Average (Million P)	Expectation	Benefit (Million P)
1.5 year	0.00	0.00	0.00			
				159.70	0.167	26.62
2 year	319.41	0.00	319.41			
				577.22	0.300	173.17
5 year	835.04	0.00	835.04			
				980.45	0.100	98.04
10 year	1,125.85	0.00	1,125.85			
				1,246.70	0.050	62.34
20 year	1,367.55	0.00	1,367.55			
				Annual Benefit:		**360.16**

Source: Study Team

(3) Economic Evaluation

Economic internal rate of return (EIRR), net present value (NPV) and benefit-costs ratio (BCR) are calculated using estimated annual average damage reduction of Phase IV project including Cainta and Taytay Floodgates. The result of economic evaluation is as shown in **Table 12.1.31**.

As a result, EIRR became 16.6% which exceeds NEDA's standard of 10%, and it is expected that the Phase IV project is sufficiently effective on flood management in Pasig-Marikina River Basin.

Table 12.1.31 Result of Economic Evaluation (Phase IV Project)

No.	Year	Cost (Million P)			Benefit (Million P)			Balance
		Construction	O&M and Replace	Total	Marikina	Floodgate	Total	
-	2021	*,***	0	*,***	0	0	0	-*,***
-	2022	*,***	0	*,***	0	0	0	-*,***
-	2023	*,***	0	*,***	0	0	0	-*,***
-	2024	*,***	0	*,***	0	0	0	-*,***
-	2025	*,***	0	*,***	0	0	0	-*,***
1	2026	***	3	***	6,683	360	7,043	*,***
2	2027	0	6	6	6,683	360	7,043	7,037
3	2028	0	6	6	6,683	360	7,043	7,037
4	2029	0	6	6	6,683	360	7,043	7,037
5	2030	0	7	7	6,683	360	7,043	7,036
6	2031	0	6	6	6,683	360	7,043	7,037
7	2032	0	15	15	6,683	360	7,043	7,028
8	2033	0	24	24	6,683	360	7,043	7,019
9	2034	0	21	21	6,683	360	7,043	7,022
10	2035	0	26	26	6,683	360	7,043	7,017
11	2036	0	11	11	6,683	360	7,043	7,032
12	2037	0	29	29	6,683	360	7,043	7,014
13	2038	0	50	50	6,683	360	7,043	6,993
14	2039	0	94	94	6,683	360	7,043	6,949
15	2040	0	28	28	6,683	360	7,043	7,015
16	2041	0	69	69	6,683	360	7,043	6,974
17	2042	0	74	74	6,683	360	7,043	6,969
18	2043	0	29	29	6,683	360	7,043	7,014
19	2044	0	231	231	6,683	360	7,043	6,812
20	2045	0	81	81	6,683	360	7,043	6,962
21	2046	0	53	53	6,683	360	7,043	6,990
22	2047	0	24	24	6,683	360	7,043	7,019

No.	Year	Cost (Million P)			Benefit (Million P)			Balance
		Construction	O&M and Replace	Total	Marikina	Floodgate	Total	
23	2048	0	21	21	6,683	360	7,043	7,022
24	2049	0	49	49	6,683	360	7,043	6,994
25	2050	0	37	37	6,683	360	7,043	7,006
26	2051	0	49	49	6,683	360	7,043	6,994
27	2052	0	19	19	6,683	360	7,043	7,024
28	2053	0	8	8	6,683	360	7,043	7,035
29	2054	0	94	94	6,683	360	7,043	6,949
30	2055	0	36	36	6,683	360	7,043	7,007
31	2056	0	45	45	6,683	360	7,043	6,998
32	2057	0	45	45	6,683	360	7,043	6,998
33	2058	0	45	45	6,683	360	7,043	6,998
34	2059	0	63	63	6,683	360	7,043	6,980
35	2060	0	21	21	6,683	360	7,043	7,022
36	2061	0	83	83	6,683	360	7,043	6,960
37	2062	0	71	71	6,683	360	7,043	6,972
38	2063	0	243	243	6,683	360	7,043	6,800
39	2064	0	106	106	6,683	360	7,043	6,937
40	2065	0	69	69	6,683	360	7,043	6,974
41	2066	0	10	10	6,683	360	7,043	7,033
42	2067	0	8	8	6,683	360	7,043	7,035
43	2068	0	18	18	6,683	360	7,043	7,025
44	2069	0	94	94	6,683	360	7,043	6,949
45	2070	0	325	325	6,683	360	7,043	6,718
46	2071	0	385	385	6,683	360	7,043	6,658
47	2072	0	414	414	6,683	360	7,043	6,629
48	2073	0	325	325	6,683	360	7,043	6,718
						EIRR =	**16.58%**	
						NPV =	**20,401**	
						BCR =	**1.89**	

** The time schedule of construction and completion is updated from DPWH Implementation Program (It is assumed the benefit wouldn't occurred in 2025)*

Source: Study Team

12.1.3 Economic Evaluation of Marikina Dam Project

Regarding the economic evaluation of Marikina Dam in the WB2018 UMD FS report, NEDA pointed out that the benefits overlap with the Phase IV projects. For this reason, economic evaluation of Marikina Dam is conducted separately from the Phase IV project to confirm its validity. Condition of economic evaluation is as shown in **Table 12.1.32**.

Table 12.1.32 Economic Evaluation Condition of Marikina Dam Project

Case	Condition
W/ Project	W/ Phase II, III, IV and Marikina Dam (W/o Retarding basin)
W/o Project	W/ Phase II, III, IV

Source: Study Team

(1) Flood Inundation Analysis

Flood inundation analysis is conducted using the same simulation model as the Phase IV project.

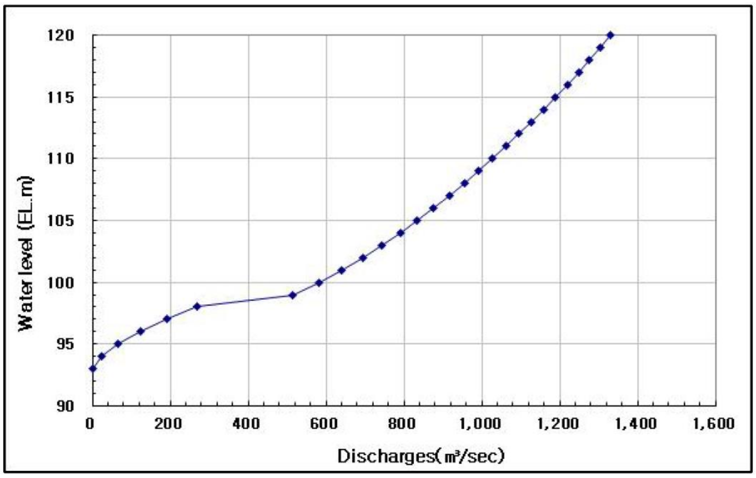
1) Estimation of Discharge from Marikina Dam

The discharge from Marikina Dam, which is the boundary condition at the upper end of the Marikina River, is estimated using limited information from the Marikina Dam FS report such as H-V curve and orifice spillway discharge curve of Marikina Dam as shown in **Table 12.1.33** and **Figure 12.1.8**.

Table 12.1.33 H-V Curve

H (EL.m)	V (Million m^3)	Remarks
60.00	0.0	Ground Level
83.00	8.1	Low Water Level (L.W.L)
93.00	17.4	Normal High Water Level (N.H.W.L)
120.00	63.3	Flood Water Level (F.W.L)
123.24	71.6	Maximum Water Level (M.W.L)

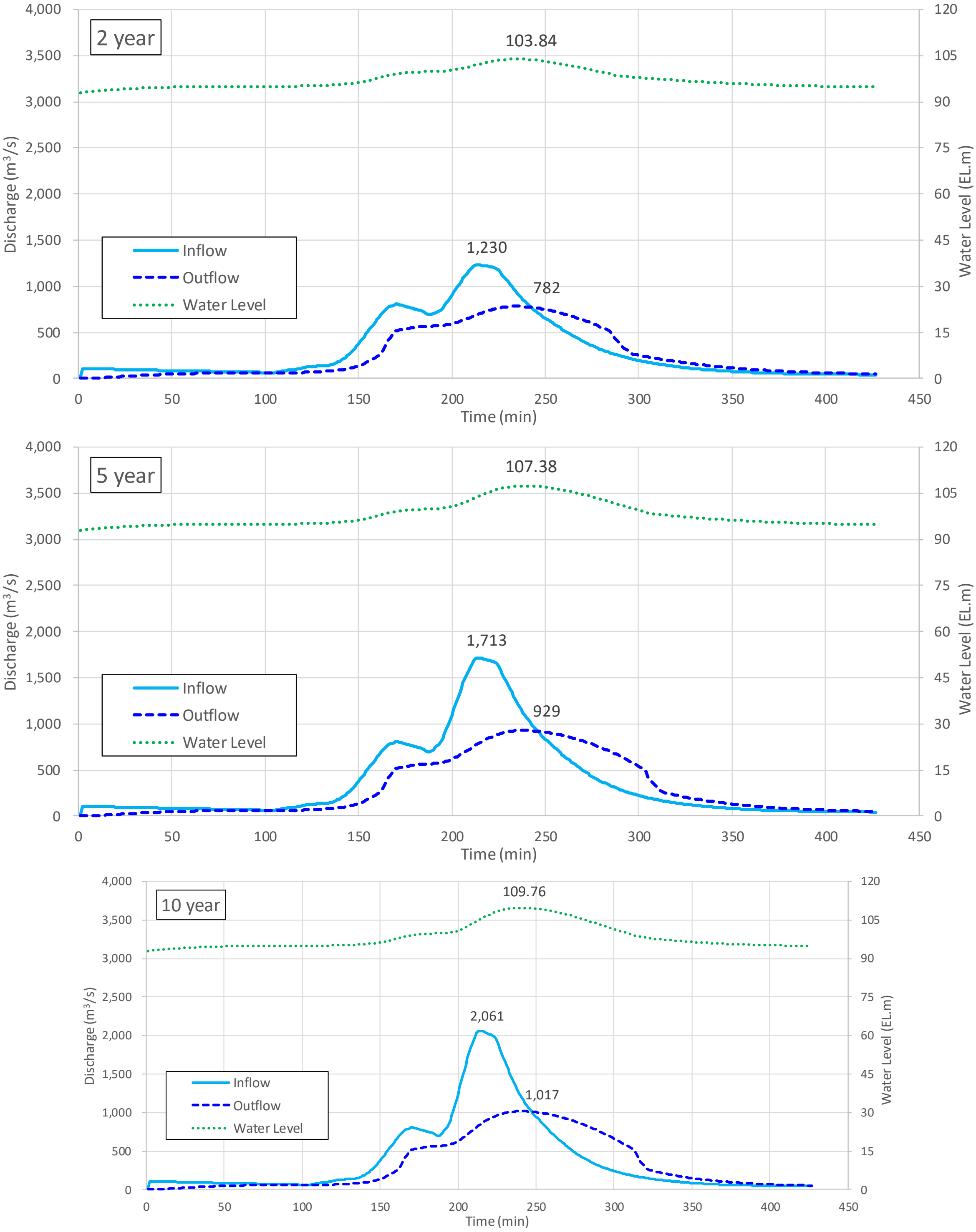
Source: WB2018 UMD FS



Source: WB2018 UMD FS

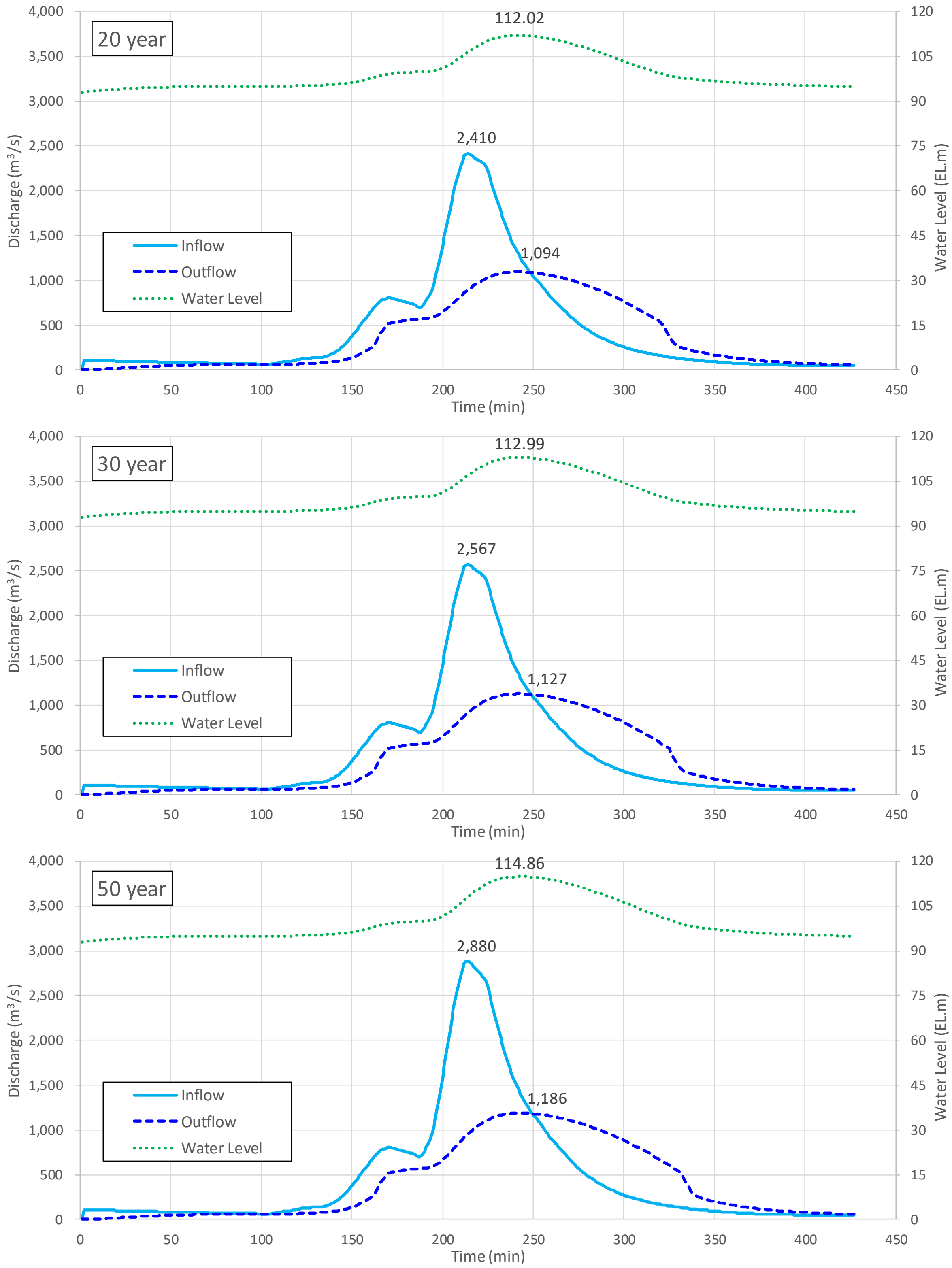
Figure 12.1.8 Orifice Spillway Discharge Curve

Estimated discharges from Marikina Dam for probable floods are as shown in **Figure 12.1.9**, **Figure 12.1.10** and **Figure 12.1.11**. It is said that the reproducibility is high comparing calculated discharge hydrograph of 100-year flood in this Study (**Figure 12.1.11**) and in WB 2018 UMD FS (**Figure 12.1.12**) which is the only one hydrograph in the report.



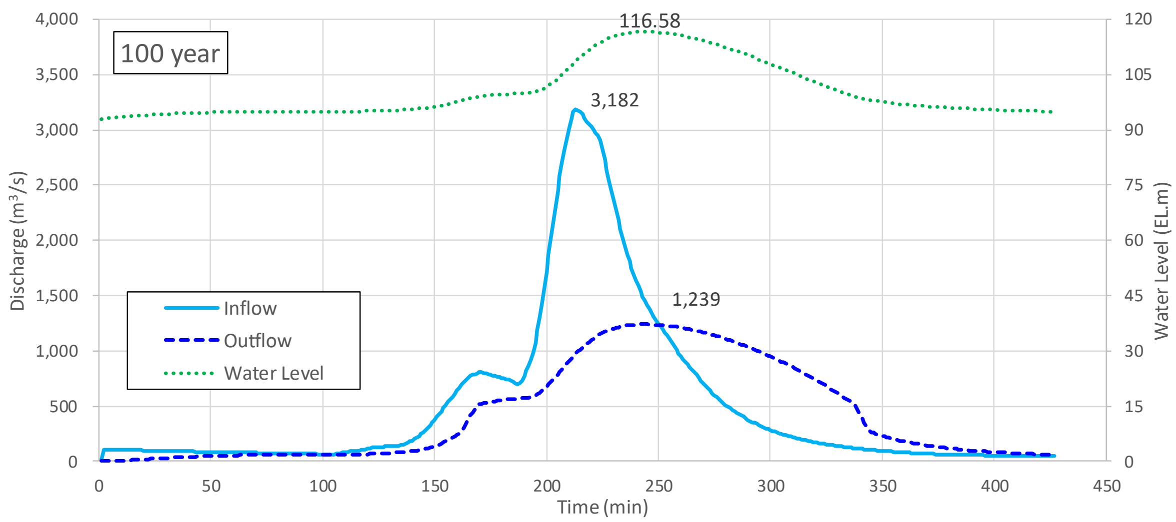
Source: Study Team

Figure 12.1.9 Estimated Discharge from Marikina Dam (2, 5, 10-Year Flood)



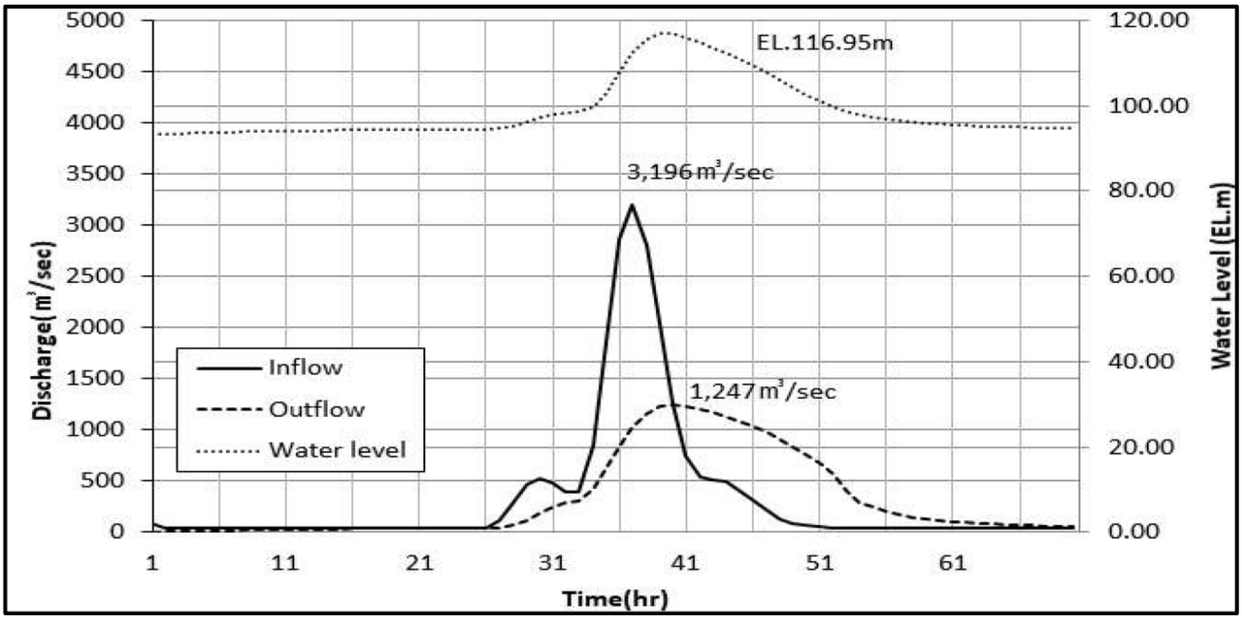
Source: Study Team

Figure 12.1.10 Estimated Discharge from Marikina Dam (20, 30, 50-Year Flood)



Source: Study Team

Figure 12.1.11 Estimated Discharge from Marikina Dam (100-Year Design Flood)

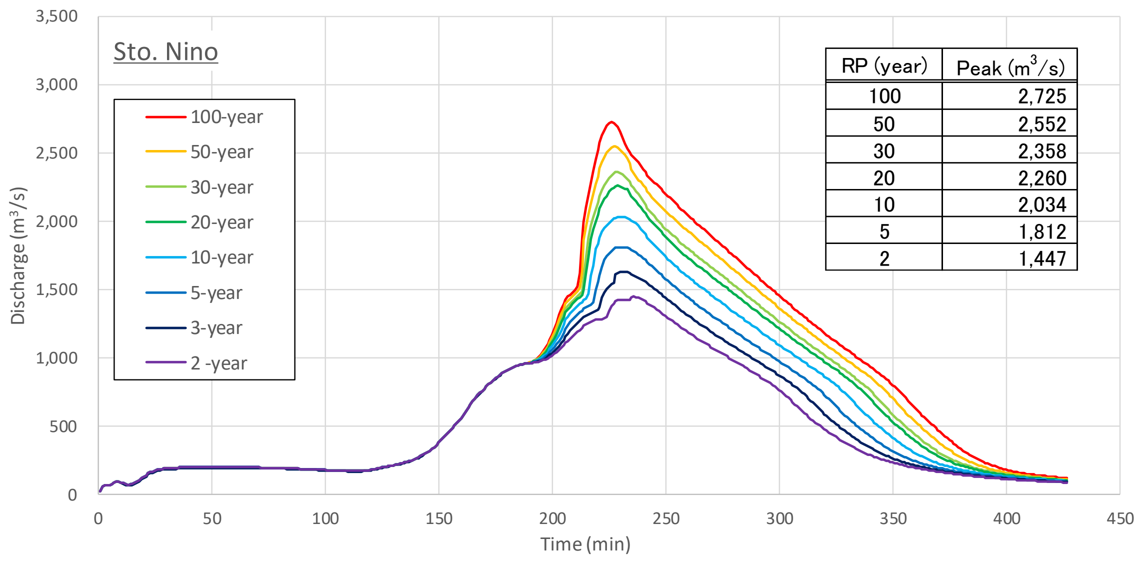


Source: WB2018 UMD FS

Figure 12.1.12 Discharge from Marikina Dam for 100-Year Design Flood (UMD FS)

2) Hydrograph at Sto. Nino

Flood inundation analysis is conducted using calculated hydrograph as boundary condition at upper ends of Marikina River. For reference, probable hydrograph at Sto. Nino is as shown in **Figure 12.1.13**. Peak discharge of 100-year design flood is 2,725m^3/s.



Source: Study Team

Figure 12.1.13 Hydrograph at Sto. Nino with Phase IV and Marikina Dam

(2) Estimation of Economic Benefits

Through the flood inundation analysis, direct damage, indirect damage and damage to infrastructure facilities are estimated with Marikina Dam. The method of project benefits estimation is the same as the Phase IV project which is described in **Section 11.2.2.1**. The result of total flood damage of With/Without Marikina Dam are as shown in **Table 12.1.34** and **Table 12.1.35**.

Table 12.1.34 Total Damage (W/o Marikina Dam)

Return Period	Direct Damage (1)	Indirect Damage (2)=(1)*10%	Damage to Infrastructure (3)=(1)*35%	Total Damage (4)=(1)+(2)+(3)
2 year	6,093.86	609.39	2,132.85	**8,836.10**
5 year	10,487.60	1,048.76	3,670.66	**15,207.02**
10 year	13,156.50	1,315.65	4,604.78	**19,076.93**
20 year	15,376.36	1,537.64	5,381.73	**22,295.72**
30 year	17,346.87	1,734.69	6,071.41	**25,152.97**
50 year	25,769.57	2,576.96	9,019.35	**37,365.88**
100 year	41,425.10	4,142.51	14,498.78	**60,066.39**

Unit: Million Pesos
Source: Study Team

Table 12.1.35 Total Damage (W/ Marikina Dam)

Return Period	Direct Damage (1)	Indirect Damage (2)=(1)*10%	Damage to Infrastructure (3)=(1)*35%	Total Damage (4)=(1)+(2)+(3)
2 year	5,878.12	587.81	2,057.34	**8,523.28**
5 year	9,366.66	936.67	3,278.33	**13,581.66**
10 year	11,493.51	1,149.35	4,022.73	**16,665.59**
20 year	13,743.22	1,374.32	4,810.13	**19,927.67**
30 year	14,433.17	1,443.32	5,051.61	**20,928.10**
50 year	15,821.09	1,582.11	5,537.38	**22,940.59**
100 year	17,911.50	1,791.15	6,269.03	**25,971.68**

Unit: Million Pesos
Source: Study Team

Annual average damage reduction of Marikina Dam is as shown in **Table 12.1.36**.

Table 12.1.36 Annual Average Damage Reduction (Marikina Dam)

Return Period	Flood Damage W/o Project	Flood Damage W/ Project	Reduction	Average (Million P)	Expectation	Benefit (Million P)
2 year	8,836.10	8,523.28	312.82			
				969.09	0.300	290.73
5 year	15,207.02	13,581.66	1,625.36			
				2,018.35	0.100	201.83
10 year	19,076.93	16,665.59	2,411.34			
				2,389.70	0.050	119.48
20 year	22,295.72	19,927.67	2,368.06			
				3,296.46	0.017	54.94
30 year	25,152.97	20,928.10	4,224.86			
				9,325.08	0.013	124.33
50 year	37,365.88	22,940.59	14,425.29			
				24,260.01	0.010	242.60
100 year	60,066.39	25,971.68	34,094.72			
					Annual Benefit:	**1,033.92**

Source: Study Team

(3) Economic Evaluation of Marikina Dam

Economic internal rate of return (EIRR), net present value (NPV) and benefit-costs ratio (BCR) are calculated using estimated annual average damage reduction of Marikina Dam. The result of economic evaluation is as shown in **Table 12.1.37**.

As a result, EIRR became 11.8% which slightly less than NEDA's standard of 10%.

Table 12.1.37 Result of Economic Evaluation (Marikina Dam)

Years	Project Costs (Million P)					Project Benefits (Million P)			Net Benefits (Million P)
	Construction	O&M	Environmental Protection Measures	Land Acquisition / Protection Measures	Total	Damage Reduction	Water Supply	Total	
2020				***.**	***.**				-***.**
2021	***.**		**.**		***.**				-***.**
2022	***.**		**.**		***.**				-***.**
2023	*,***.**		**.**		*,***.**				-*,***.**
2024	*,***.**		***.**		*,***.**				-*,***.**
2025		**.**	*.**		*.**	1,033.92	187.73	1,221.65	*,***.**
…	…	….	….	…..	….	…..	…..	….	…..
2071		**.**	*.**		*.**	1,033.92	187.73	1,221.65	*,***.**

EIRR = 11.8%
NPV = 1,137
BCR = 1.18

Source: Study Team based on WB2018 UMD FS

12.1.4 Comparison of Economic Evaluation of Phase IV and Marikina Dam

Comparison of economic evaluation of Phase IV and Marikina Dam is as shown in **Table 12.1.38**.

Table 12.1.38 Comparison of Economic Evaluation of Phase IV and Marikina Dam

Item	PMRCIP Phase IV	Marikina Dam
Project Cost (Economic Cost)	**,*** Million Pesos	*,*** Million Pesos
Annual Average Damage Reduction	7,043 Million Pesos	*,**** Million Pesos
EIRR	16.6 %	11.8 %
NPV	20,401 Million Pesos	1,137 Million Pesos
BCR	1.89	1.18

Source: Study Team

12.2 Technical Evaluation of the Project

12.2.1 River Improvement Works

The following works will be implemented in the planned river improvement:

- In the improvement of low water channel, steel sheet pile or HAT-H steel sheet pile which is the reinforced equivalent to steel sheet pile with H-steel is installed by the vibro-hammer method with water jets or the down-the-hole method, and flow area is secured by excavation and dredging in the low water channel.
- The embankment is constructed with banking + revetment or parapet wall, and height with DFL + freeboard and cross section are secured.
- Drainage outlets that flow into the main river are equipped with drains or sluice that enable appropriate wastewater treatment to meet the conditions and prevent backflow during floods.

On the other hand, although there are some points to be noted in the construction of the above structure, the steel sheet pile revetment, flood protection wall (special levee), and drainage work have already been constructed in Phases II and III with no problem. In Phase II and III, the excavated and dredged soil did not contain harmful heavy metals.

12.2.2 MCGS and Cainta and Taytay Floodgates

In the Philippines, many similar structures were built so far such as NHCS and Rosario Weir in the 1980's, locks and floodgates in KAMANAVA region in the 2000's, and there were no problems with construction.
Although there are some points to be noted in the construction of the above structure, there floodgates are structures that can be sufficiently constructed.

12.3 Environmental and Social Evaluation of the Project

The environmental and social evaluation and assessment of the project are described in detail in previous Chapter 10. The outline is as follows.

12.3.1 Environmental Category of the Project

(1) Category Classification and its Basis

The project is categorized as "A" in accordance with the JICA's Environmental and Social criteria.

This project falls under "the trait of being susceptible to influence," listed in the "JICA Guidelines for Environmental and Social Considerations" and is applied for a Category-A project. In particular, more than 10,000 indirectly-affected ISFs currently living within the Manggahan Floodway will need to be relocated, and the detailed design stage will also be required to monitor and support the activities of the DPWH, the project entity, the NHA and the related LGUs.

(2) Environmental Clearance

The Environmental Impact Statement (EIS) of the project was approved by the DENR in June 1998 (refer to Chapter 10). A Supplemental EIS was prepared by the DPWH in August 2018 and will be revised as necessary in this detailed design stage.

12.3.2 Other Assessments

(1) Pollution Control

The impacts by air quality, noise, vibration etc., during construction should be mitigated thorough water sprinkling and dust control measures, periodic maintenance of equipment, installation of temporary walls, etc.

Although muddy water caused by dredging is anticipated to give a limited impact due to flush of running water, the construction is to be considered employing methods such as installing a silt fence mandatory for the construction contractor. The embedded soils were tested and the results revealed that they had no hazardous pollutants. Therefore, they will be re-used as a material for lowland reclamation other than project sites. At present, an EIA survey has been underway to acquire an ECC for approximately 50 has of land under the jurisdiction of LLDA.

(2) Natural Environment

Since the project area does not include a susceptible area such as national parks or their surroundings, adverse impact on the natural environment is assumed to be limited.

(3) Prediction and Assessment of Impacts and Consideration of Mitigation Measures

The EMP and EMoP will be updated based on the results of surveys for riverbed sediment, dredged soil disposal site, and the logged tree inventory as well as the on-going EIA survey for the backfill site and Cainta Floodgate. Necessary items and activities will be reviewed in a timely manner into the EMP and EMoP, based on opinions from the ESSD, DENR and concerned LGUs.