DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE REPUBLIC OF THE PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

DATA COLLECTION SURVEY ON DRAINAGE SYSTEM IN METRO MANILA IN THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

DECEMBER 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI ENGINEERING INTERNATIONAL CO., LTD.
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(October 1st, 2015)

Acknowledgement

In response to a request from the Government of the Republic of the Philippines, the Japan International Cooperation Agency (JICA) decided to conduct "Data Collection Survey on Drainage System in Metro Manila".

We are pleased to submit herewith the Final Report on the Survey for your kind consideration.

On this occasion the Survey Team would like to express its sincere appreciation to JICA, the Advisory Committee which examined the Survey from specialist and technical point of view, and also to the Department of Public Works and Highways, particularly UPMO-Flood Control Management Cluster Director Patrick B. Gatan, Ms. Angelina C. Forcadilla, Ms. Leonie R. Mercado and Ms. Lydia C. Aguilar for the cooperation extended to the Team during the Survey.

We sincerely hope that the results of the Survey will contribute to the solution and/or mitigation of flooding problems in Metro Manila and that the amicable relationship between our countries will further continue in the future.

Very truly yours,

December 2015

Hajime TANAKA

Team Leader

Data Collection Survey on Drainage System in Metro Manila

LOCATION MAP

EXECUTIVE SUMMARY

1. Background

This Survey was carried out in response to the request of the Government of the Republic of the Philippines and in accordance with the Terms of Reference (TOR) for the Data Collection Survey on Drainage System in Metro Manila (herein after referred as "the Survey"), which was agreed upon between the Department of Public Works and Highways (hereinafter referred to as "DPWH") and the Japan International Cooperation Agency (hereinafter referred to as "JICA") on July 30, 2015.

According to the current situation, the DPWH has set a new target of 25-year return period (RP) and 50-year RP for flood and drainage projects, and since it is necessary for Metro Manila to improve and strengthen the drainage capacity of the drainage system, the DPWH has been conducting the DPWH Survey[1] under local funds.

However, DPWH is facing many difficulties on the implementation of new drainage facilities which require an extensive construction period resulting in strong social impact caused by prolonged traffic congestion, presence of underground utilities which might be affected by construction, disruption of social and economic activities, among others. The DPWH is considering the suitability of utilising Japanese deep tunnel technology to solve the drainage situation in Metro Manila and had sent an official letter to the Embassy of Japan requesting JICA to conduct a survey for a possible short construction period project utilizing Japanese underground tunnel technologies to the drainage system in Metro Manila.

2. The Purpose of the Survey

The Survey is to collect information on the Drainage System in Metro Manila including the examination of possible short construction period projects to utilize Japanese underground tunnel technologies (shield tunnel, micro tunnel, etc.) as the solution to drainage improvement problems in Metro Manila, as well as the effective assistance approaches of JICA in the sector.

3. Outline of the Survey

The Survey selected España-UST area and Buendia-Maricaban area in Metro Manila as target areas to examine the possibility of the drainage improvement project by using Japanese Tunnel technology.

3.1 Planning Concept

Drainage improvement plan is developed under following concepts.

- Target safety level will achieve 25 to 50-yr return period for Metro Manila Drainage System.
- Expandability toward 50-yr return period and climate change should be considered.
- Underground tunnel is the final approach for the area.

Proposed Project Specification (Early Drainage Plan)

	Espana-UST	Buendia-Maricaban
Drainage Area (km^2)	7.42	15.00
Tunnel Length (km)	3.5	7.2
Tunnel Volume (m^3)	446,000	844,000
Pump Capacity (m^3/sec)	4.0	7.6

[1] Consulting Service for the Review and Detailed Engineering Design of Comprehensive River Management for San Juan River and Review and Updating of Feasibility Studies and Detailed Engineering Design of Various Urgent Flood control Projects in Metro Manila, Woodfiels Engineering Company, 2015(On-going)

3.2 Preliminary Cost Estimation

Construction cost (excluding non-construction cost such as Consultancy Service Cost and Compensation cost and Contingency) and O&M cost are as follows.

Construction Cost and O&M Cost (Approximate Estimate)

	Espana-UST	Buendia-Maricaban
Construction Cost（million Php）	15,389	24,881
Annual O&M Cost (Normal Period) (Php)	63,445	126,890
O&M Cost during Flood (Annual Average) (Php)	478,224	956,448

3.3 Preliminary Project Evaluation

The EIRRs for Espana-UST and Buendia-Maricaban is 12% and 14% respectively.

However, possibility of project cost reduction was indicated with a combination of the pump and the storage pipe. If the construction cost decreases EIRR will be improved.

3.4 Environmental and Social Consideration

España-UST Area is located in the north area of Manila City. Land owners of the proposed project sites (on the ground) are government (one site) and private (four sites). ISFs are not identified in the proposed sites but one of the proposed sites is residential area and therefore land acquisition and displacement of PAPs will be needed.

Buendia-Maricaban Area is located in the cities of Pasay, Makati and Taguig. Land owners of the proposed project sites (on the ground) are government (four sites) and private (two sites). Proposed site of intake No.4 is occupied by ISFs and displacement of them will be needed accordingly.

The possibility of environmental and social impacts by the implementation of the project area as follows.

- Pre-Construction Stage: There will be such impacts as conflicts between the proponent and land owners during negotiation for land acquisition, possibility of expropriation, displacement of formal settlers and ISFs (informal settler families), impacts on their livelihood and economic activities, etc.
- Construction Stage: There will be such impacts as air pollution by emission gas, noise and vibration due to construction works on the ground, generation of low frequency sound, ground movements and drawdown of groundwater level and impact on groundwater use due to tunnelling works, impacts on road traffic due to transportation of construction materials and excavated materials, impacts due to disposal of the excavated materials, etc.
- Operation Stage: There will be such impacts as noise (impulsive sound of water falling at intake facility), noise and offensive odor from pumping station.

4. Activities to the Next Stage and Recommendation

4.1 Activities to the Next Stage

Activities to the next stage are summarized below.

Activities to the Next Stage

Further Study for the Proposed Projects	Activities for Drainage Improvement in Metro Manila
Required Basic Surveys such as Geological Survey along the Alignment for Designing and Planning	Promotion of Recovery and Improvement of Drainage Capacity of Existing Drainage Systems
Determination of Layout considering Expandability	Strengthening of Cooperation between DPWH and MMDA on the Drainage Sector
Confirmation of Effective and Assured Diversion of Floodwater	Improvement of Dumping of Solid Wastes and of Water Quality in Drainage Channels
Estimate of Frequency of Facility Usage and Confirmation of Disappearance of Inundation Areas through Flood Inundation Analysis	Promotion of Land Use Management and River Basin Management considering Flood Disaster Risk Reduction (DRR)
Necessity under the Drainage Improvement Plan to Conduct Necessary Procedures for the Environmental Impact Statement (EIS)	
Implementation of Basin Management to the Maricaban River	
Necessary Preparation of Laws for Deep Underground Development and Public Use of Deep Underground Facilities	
Introduction of Operation and Management System for Drainage Facilities using Rainfall and Meteorological Observation and Forecast System	

4.2 Recommendation

The drainage improvement works proposed by the DICAMM 2005 and DPWH Survey have just been commenced and the results of the works should be assessed and necessary remedial measures to attain the target of 25-year RP and 50-year RP should be identified.

It is necessary for DPWH to conduct a further study on the effects of the works before finalizing the proposed deep underground tunnelling drainage facilities as the final measures to sustain the future development of Metro Manila.

DPWH has set the target safety level of as high as 25-year return period (RP) and 50-year RP for the safety level of flood and drainage projects and require new basis for project evaluation.

In order to realize the proposed deep underground drainage projects it is recommended that DPWH should conduct further studies as follows:

Further Study:

- Consistent implementation and the evaluation of the items mentioned in Section 4.1 should be assessed.
- For evaluation and assessment purposes, the on-going and planned drainage improvement works in the core area are to be assessed as to their effects in the disaster risk reduction, and their functions in the short term are to be identified for attaining the target safety levels of 25-year RP and 50-year RP in the Core Area.
- Formulation of necessary drainage improvement measures including their O&M measures to attain the target safety levels of 25-year RP and 50-year RP in the Core Area.
- Study on the bases of project evaluation for challenging drainage improvement works including adaptation measures against inevitable climate change.

DATA COLLECTION SURVEY ON DRAINAGE SYSTEM IN METRO MANILA
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ABBREVIATIONS AND ACRONYMS

AASHTO:	American Association of State Highway and Transportation Official
ADB:	Asian Development Bank
AO:	Administrative Order
BOD:	Biochemical Oxygen Demand
CCEP:	Construction Contractor's Environmental Program
CCP:	Cultural Center of the Philippines
CNC:	Certificate of Non-Coverage
CMP:	Community Mortgage Program
C/S:	Construction Supervision
DAO:	DENR Administrative Order
DENR:	Department of Environment and Natural Resources
DILG:	Department of the Interior and Local Government
DO:	Dissolved Oxygen
DPWH:	Department of Public Works and Highways
DOF:	Department of Finance
DOH:	Department of Health:
DOT:	Department of Tourism
DOTC:	Department of Transportation and Communications
DSWD:	Department of Social Welfare and Development
DWO:	Drainage and Waterways Operation, MMDA
ECC:	Environmental Compliance Certificate
EFCOS:	Effective Flood Control Operation and Warning System
ECA:	Environmentally Critical Area
ECC:	Environmental Compliance Certificate
ECP:	Environmentally Critical Project
EDSA:	Epifanio de Los Santos Avenue
EIA:	Environmental Impact Assessment
EIS:	Environmental Impact Statement
EMB:	Environmental Management Bureau
FCSM:	Flood Control and Sewerage Management Office, MMDA
FCSEC:	Flood Control and Sabo Engineering Center
GDP:	Gross Domestic Product
GIS:	Geographic Information System
GOJ:	Government of Japan
GOP:	Government of Republic of the Philippines
GNP:	Gross National Product
GPS:	Global Positioning System
GRDP:	Gross Regional Domestic Product

GSIS: Government Service Insurance System
IBRD: International Bank for Reconstruction and Development (World Bank)
IEE: Initial Environmental Examination
IFS Informal Settle Families
JICA: Japan International Cooperation Agency
LARRIPP: Land Acquisition, Resettlement, Rehabilitation and Indigenous Peoples Policy
LGC: Local Government Code
LGU: Local Government Unit
LGU-Makati: Local Government Unit Makati City
LGU-Manila: Local Government Unit City of Manila
LGU-Pasay: Local Government Unit Pasay City
LiDAR Data: Light Detection and Ranging Data
LRT: Light Rail Transit
MC: Memorandum Circular
MLLW: Mean Lower Low Water Level
MMDA: Metropolitan Manila Development Authority
MNH: Manila North Harbor
MRT: Metro Rail Transit
MSH: Manila South Harbor
MSL: Mean Sea Level
NAIA: Ninoy Aquino International Airport
NAMRIA: National Mapping and Resources Information Authority
NCM: Normal Cubic Meter
NCR: National Capital Region, DPWH
NHA: National Housing Authority
NCSO: National Census and Statistics Office
NDRRMC: National Disaster Risk Reduction Management Council
NEDA: National Economic and Development Authority
NGO: Non-Government Organization
NHA: National Housing Authority
NAMRIA: National Mapping & Resources Information Authority
North Manila: North or right bank of the Pasig River
NSO: National Statistics Office
NWRB: National Water Resources Board
NWSS: Manila Waterworks and Sewerage System
OCD: Office of Civil Defense
PAGASA: Philippines Atmospheric, Geophysical & Astronomical Services Administration
PAP: Project Affected Person/People
PD: Presidential Decree
PD: Project Description

PEISS: Philippine Environmental Impact Statement System
PRA: Philippine Reclamation Authority
PRRC: Pasig River Rehabilitation Commission
PPA: Philippine Port Authority
PNP: Philippine National Police
PSFO: Pumping Stations and Floodgates Operation, MMDA
PNR: Philippine National Railway
RA: Republic Act
ROW: Right-Of-Way
SHFC: Social Housing Finance Corporation
South Manila: South or left bank of the Pasig River
TSP: Total Suspended Particulates
TBM: Tunnel Boring Machine
UDHA: Urban Development and Housing Act
UPMO: Unified Project Management Office
TBM: Tunnel Boring Machine
TWG: Technical Working Group
UDHA: Urban Development and Housing Act
UN-OCHA: United Nations Office for the Coordination of Humanitarian Affaires
UTM: Universal Transverse Mercator Projection
UP: University of Philippine
WB: World Bank
WHO: World Health Organization

(Study and Project)

DICAMM:	Study on Drainage Improvement in the Core Area of Metropolitan Manila (JICA), 2005
MMEIRS:	Earthquake Impact Reduction Study for Metropolitan Manila (JICA), 2004
MMUTIS:	Metro Manila Urban Transport Integration Study, 1999
PMRCIP:	Pasig-Marikina River Channel Improvement Project
PRDP:	Pasig River Environment Management and Rehabilitation Sector & Development Program
SEDLMM:	Study on the Existing Drainage Laterals in Metro Manila (JICA), 2000
MMFMP:	Metro Manila Flood Management Plan (Master Plan for Flood Management in Metro Manila and Surrounding Areas (WB), 2012)

(Unit)

ha:	Hectare
Php:	Philippine peso

CHAPTER 1. INTRODUCTION

1.1 Background

This Survey was carried out in response to the request of the Government of the Republic of the Philippines and in accordance with the Terms of Reference (TOR) for the Data Collection Survey on Drainage System in Metro Manila (herein after referred as “the Survey”), which was agreed upon between the Department of Public Works and Highways (hereinafter referred to as “DPWH”) and the Japan International Cooperation Agency (hereinafter referred to as “JICA”) on July 30, 2015 as per Annex-1.

The Republic of the Philippines (hereinafter referred to as “the Philippines”) is one of the most disaster-prone countries in Southeast Asia, and Metropolitan Manila is the center of political, economic and cultural activities which are seriously affected by flood and storm-water and hence the Government of the Philippines (hereinafter referred to as “GOP”) has been working continuously on flood management planning and project implementation regarding flood management for more than 50 years. Moreover, Metropolitan Manila (Metro Manila), which includes the City of Manila, has yet to establish resiliency against flood and storm-water and has to work on having an effective flood disaster risk management capable of handling climate changes.

The GOP identifies river basin preservation as well as efficient and effective infrastructure development for flood disaster risk reduction as one of its main policies in the National Development Plan (2011-2016). This is further reflected in the Philippines Climate Change Adaptation Strategies (2010-2022), where risk and vulnerability reduction through appropriate infrastructure development is one of the strategies for climate change adaptation. The GOP is serious in promoting the main streaming of flood disaster risk management.

In the National Development Plan, the DPWH implements flood mitigation measures against storms caused by typhoons and tropical cyclones. Based on the current situation, the DPWH has set a new target of 25-year return period (RP) and 50-year RP for flood and drainage projects, and since it is necessary for Metro Manila to improve and strengthen the drainage capacity of the drainage system the DPWH has been conducting DPWH Surveys[1] with local funds.

Under the DPWH Surveys, and based on the Master Plan (M/P) formulated by JICA in 2005, the “Study on Drainage Improvement in the Core Area of Metro Manila” (hereinafter referred to as “2005 JICA M/P” or “DICAMM 2005”) and the “Master Plan for Flood Management in Metro Manila and Surrounding Area” (World Bank in 2012) (hereinafter referred to as “2012 WB M/P”) had has formulated river improvement and urgent works for Metro Manila and Surrounding Area which signified the start of the implementation of the urgent works (ex. Bluementritt Interceptor).

However, DPWH is facing many difficulties on the implementation of new drainage facilities which require an extensive construction period resulting in strong social impact caused by prolonged traffic congestion, presence of underground utilities which might be affected by construction, disruption of social and economic activities, among others. The DPWH is considering the suitability of utilizing Japanese deep tunnel technologies to solve the drainage situation in Metro Manila and had sent an official letter to the Embassy of Japan, dated 6 April 2015, requesting JICA to conduct a survey for a possible short construction period project utilizing Japanese underground tunnel technologies to the drainage system in Metro Manila.

The Survey aims to collect information on the drainage system in Metro Manila and to examine the applicability of the Japanese underground tunnel technologies in improving the drainage system in Metro Manila.

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[1] Consulting Service for the Review and Detailed Engineering Design of Comprehensive River Management for San Juan River and Review and Updating of Feasibility Studies and Detailed Engineering Design of Various Urgent Flood control Projects in Metro Manila, Woodfiels Engineering Company, 2015(On-going)

JICA dispatched a contact mission to the Philippines from June 22 to 26, 2015 and the TOR mission from July 27 to 31, 2015.

1.2 The Purpose of the Survey

The Survey was to collect information on the Drainage System in Metro Manila including the examination of possible short construction period projects to utilize Japanese underground tunnel technologies (shield tunnel, micro tunnel, etc.) as the solution to drainage improvement problems in Metro Manila, as well as the effective assistance approaches of JICA in the sector.

1.3 The Survey Area

The Survey Area is the same as that of the DPWH Survey that covered Metro Manila (Zapote-Las Piñas, Buendia-Maricaban-NAIA-Parañaque, España-UST, Tullahan and San Juan) as shown in the Location Map.

1.4 Counterpart Agency

The Counterpart Agency is the Department of Public Works and Highways (DPWH) and the DPWH office in charge is the Unified Project Management Office-Flood Control Management Cluster.

1.5 Scope of the Survey

The Survey was conducted in accordance with the TOR agreed upon between DPWH and JICA on July 30, 2015. The JICA Survey Team conducted the survey to attain the purpose of the Survey and to prepare the reports for submission to JICA as listed in Section 2.3.

1.6 The Work Program

The Work Program is as shown in Table 1.6.1.

Table 1.6.1 Work Program of the Survey

No.	Work Item	Period 2015 September	October	November	December
(1)	In-country work I				
	- Review the result of past surveys and existing materials and formulate the Inception Report				
	- Examination of survey approach and methodology and work plan				
	- Arrangement of survey items and formulation of field survey plan				
	- Formulation of the Inception Report and submission it to JICA				
(2)	Explanation of the Inception Report	IC/R			
(3)	Organize current situations and issues of existing drainage channels and pumping stations				
(4)	Collectinformation and data including the basis of the results of DPWH survey, and verification of their reliability				
(5)	Classification of candidate areas for Janpanese underground tunneling technologies (shield method, pipe jacking etc.,) that may be applicable among the survey areas.				
(6)	Among the areas mentioned in (5) classification of points to be considered and issues of detailed technologies, suitability, superiority of Japanese technologies about applicable Japanese technologies				
	- Examination of actual construction methods of Japanese underground tunneling technology				
	- arrangement of adequacy of the construction methods for the selected areas, also superiority compared with other countries.				
	- Arrangement of pints to note and issues for application of each of construction methods				
(7)	Arrangement of criteria to select priority areas among candidates.				
	- Selection of the highest priority				
	- Arragement of candidate areas based on the criteria				
	- Propose draft drainage improvement plans and conduct project evaluation for priority areas				
(8)	Report to the committee at JICA Headquarters the interim results of the survey ※Interim progress report		TV Conference		
(9)	Presentation of drainage improvement plans at multiple candidate areas in (7).				
	- Setting target design scale				
	- Alignment plan for water collection and/or drainage channels.				
	- Extention, diameter and lying depth of the water collection and/or drainage channels for each candidate area				
	- Draft construction plan for each candidate area.				
(10)	Evaluation of effect of the projects in (8) above.				
	- Preliminary project cost estimation				
	- Caluculation of preliminary EIRR.				
(11)	Consideration of the possible options of financing/funding plan for the candidate.				
(12)	Confirmation of the current situation of environmental and social impacts at the candidate areas.				
(13)	report of any issues and points to be considered when conducting further study and implementing projects found in the Survey.				
(14)	Consultation with and related authorities regarding the Draft Final Report			DF/R	
(15)	Report to JICA Headquarters ※Final Report				
(16)	Formulating Final Report				F/R
(17)	Others				

【Legend】 Local work — In-country work — Meeting ○ Explanation RP △

1.7 Survey Team Members and Staffing Schedule

1.7.1 Survey Team Members

The Survey Team is composed of eight (8) members as shown in Table 1.7.1.

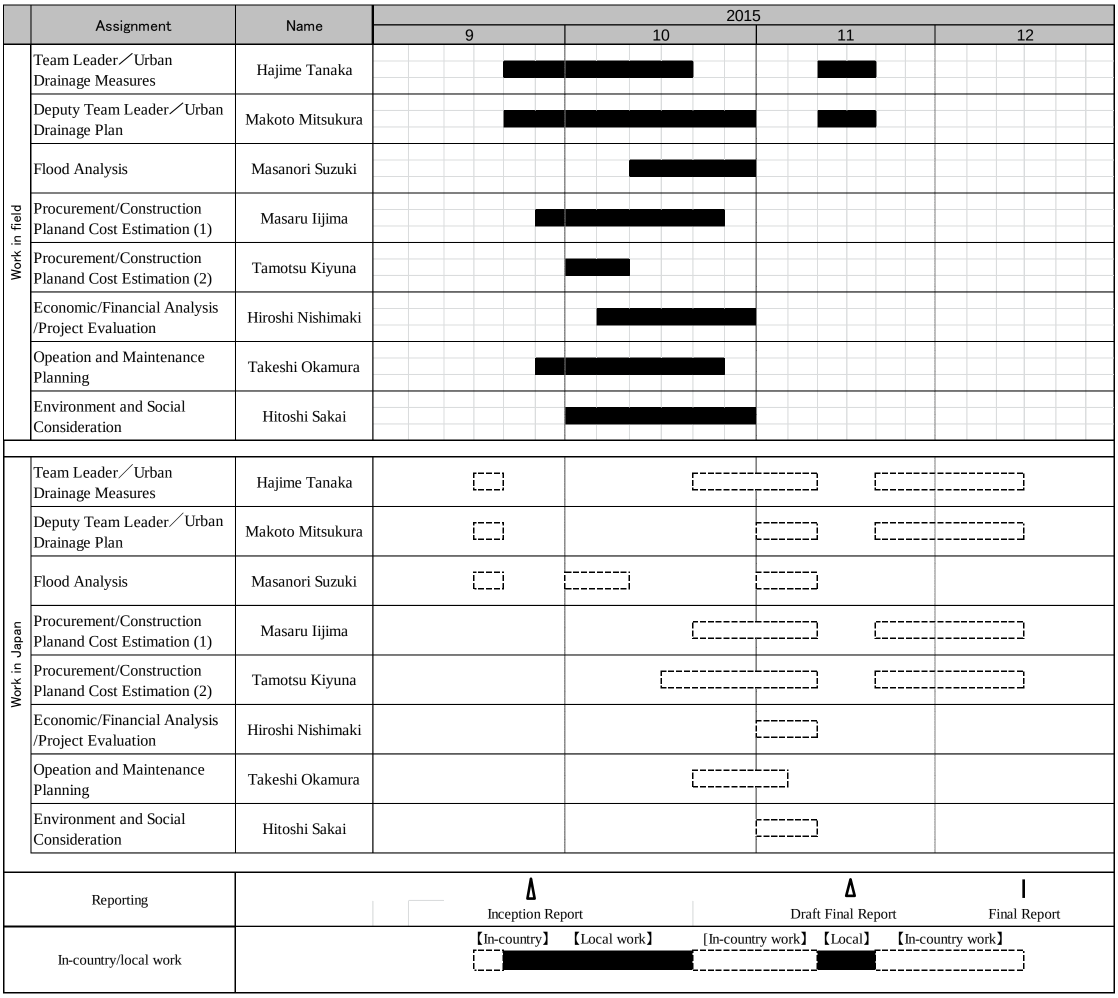
Table 1.7.1 Survey Team Members

Name	Assignment
Hajime TANAKA	Team Leader/Urban Drainage Measures
Makoto MITSUKURA	Deputy Team Leader/Urban Drainage Plan
Masanori SUZUKI	Flood Analysis
Masaru IIJIMA	Procurement/Construction Plan and Cost Estimation (1)
Tamotsu KIYUNA	Procurement/Construction plan and Cost Estimation (2)
Hiroshi NISHIMAKI	Economic/Financial Analysis and Project Evaluation
Takeshi OKAMURA	Operation and Maintenance Planning
Hitoshi SAKAI	Environment and Social Consideration

1.7.2 Staffing Schedule

The staffing schedule is as shown in Table 1.7.2.

Table 1.7.2 Staffing Schedule



CHAPTER 2. SURVEY AREA

2.1 Basic Information

2.1.1 The Survey Area of the DPWH Survey

The survey areas; namely Zapote–Las Piñas, Buendia–Maricaban–NAIA–Parañaque, España–UST, Tullahan and San Juan, are divided into two areas. The first is the core area of Metro Manila which include Buendia–Maricaban-NAIA, España–UST and the second is the surrounding river areas which involeve five rivers; namely, the Zapote–Las Piñas, Parañaque, Tullahan and San Juan. DPWH set a new target for flood and drainage projects to attain a safety level of 25-year return period (RP) and 50-year RP.

In the core area of Metro Manila, drainage improvement works have been on-going for a long time; however, the drainage capacity has decreased because of the heavy deposits of sand and dumped solid wastes and the houses of numerous informal settlers along the creeks/esteros. The 2005 JICA M/P Study has proposed improvement of the drainage capacity to attain the 10-year RP of a 2-day rainfall, the MMDA has likewise been conducting the dredging of channels and rehabilitation of drainage pumping stations, and DPWH has commenced improvement works such as new interceptors and drainage channels.

In the surrounding river areas in Metro Manila, only the Pasig River is now under improvement and the other river systems are yet to be improved, but the river systems may expect improvement under the 2012 World Bank M/P. The DPWH Survey had included the preparation of river improvement works (2015-2020) and urgent works (2015-2018) for the five rivers, and the urgent works commenced in 2015.

2.1.2 Flood Situation in the Core Area of Metro Manila

The 2005 M/P divided the core area of Metro Manila into two areas: the left bank of the Pasig River or “North Manila” (28.78 km²) and the right bank of the Pasig River or ”South Manila” (43.80 km²). The flooding conditions in these areas are as follows:

In the North Manila are, the flood prone areas are Aviles and Sampaloc under the drainage block of Quiapo–Aviles pumping stations and also include the major trunk road of España which is affected by floods yearly. In the 1999 flood the floodwater depths varied from 0.5~1.0 m and the flood receding time was more than 24 hours. During Ondoy in 2009 the flood depths were 1.0 m to 1.5 m and the flood receding time were for one to three days[2].

In the South Manila area, the flood-prone areas are the drainage areas of Zobel Roxas, PNR Canal and Calatagan Creek-1, and San Isidro, San Antonio and Pio del Pilar located at the east side of PNR, which are located in the drainage block of Libertad–Tripa de Gallina Pumping Stations. The major trunk road of Osmeña HWY is affected yearly by floods. During the 1999 flood, the flood depths were reported to be over 0.5 to 1.0 m, and the flood durations were less than 12 hours. During Typhoon Ondoy in 2009 the flood water depths were about 0.5 to 1.0 m and the flood receding time was three days to one week longer than the others.[3]

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[2] The Preparatory Study for Sector Loan on Disaster Risk Management in the Republic of the Philippines Final Report –Needs Assessment Study on Flood Disasters Caused by Typhoons No.16 (ONDOY) amd No.17 (PEPENG), JICA, 2010

[3] ditto

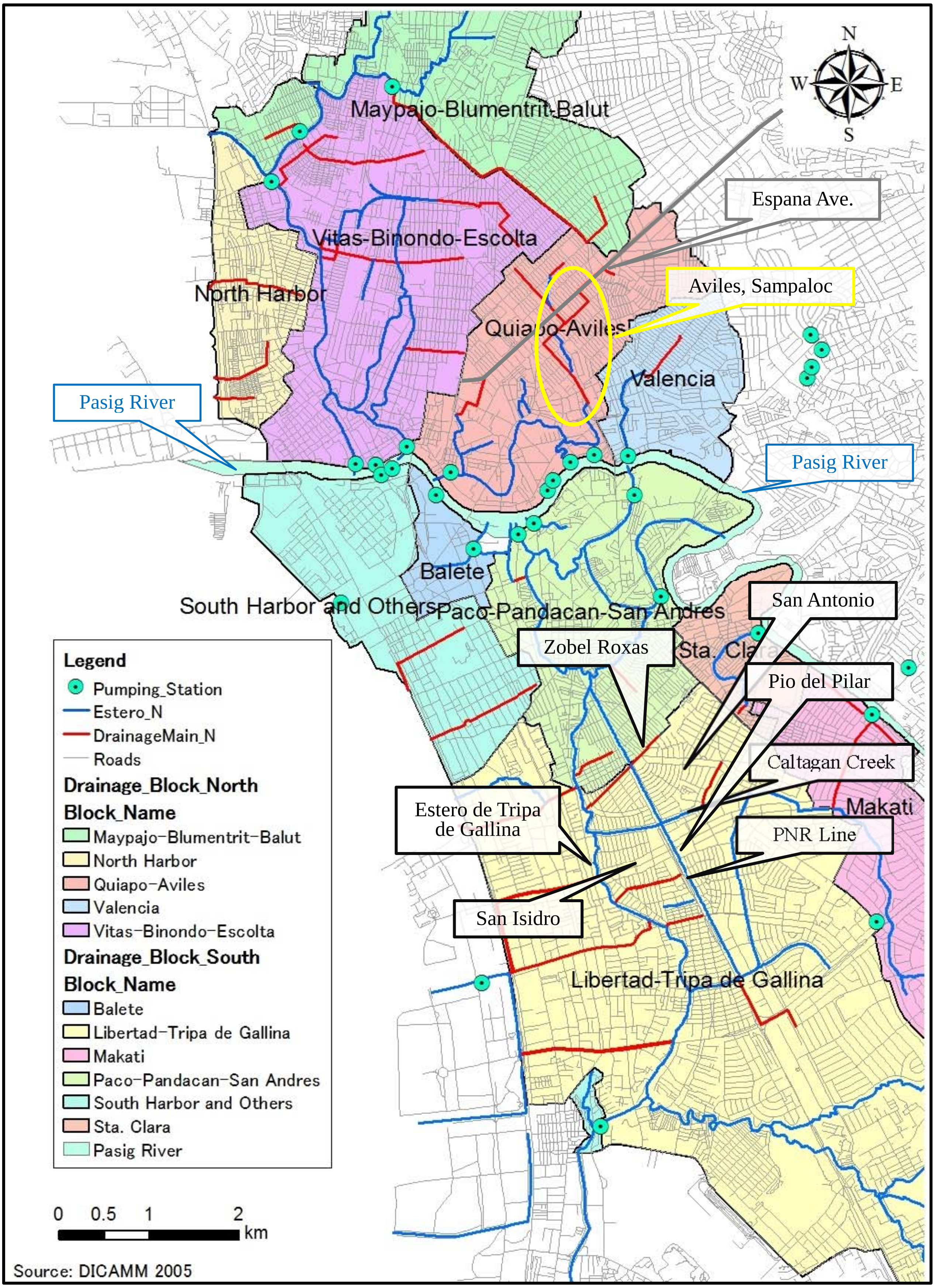


Figure 2.1.1 Drainage Block in Metro Manila

2.2 Drainage Management in Metro Manila

The core area of Metro Manila is low-lying and about 70% (52 km^2) of the area depends on the pumped drainage system. The drainage facilities of the core area are:

- Major pumping stations: 15 sites
- Small scale pumping stations: 8 sites
- Open channels (esteros/creeks): 74 km
- Box culverts: 35 km
- Pipe culverts: 400 km.

The O&M of drainage facilities were handed over from DPWH to MMDA in 2002 in accordance with Republic Act (RA) 7924 (July 9, 2002) Responsibilities for the O&M of drainage facilities however belong to MMDA, and the responsibilities for construction of new drainage facilities (major drainage channels and drainage pumping stations) belong to DPWH. O&M works such as dredging of esteros/creeks, cleaning of wastes, relocation of Informal ISF and rehabilitation of pumping stations are conducted by MMDA. New drainage improvement works proposed by the DPWH Survey are to be conducted by DPWH.

2.3 Situation of Drainage Facilities in the Core Area of Metro Manila

The drainage facilities in the core area of Metro Manila are composed of drainage channels (trunk channels, secondary channels and tertiary channels) and drainage pumping stations.

The premise of the 2005 JICA M/P is that the existing open channels are assumed to have conveyance capacities of more than 10 year return period, but they had lost their discharge capacities because of the heavy deposits of sand/gravel, dumped solid wastes (estimated amount: 920,000 m^3), and the presence of ISF (estimated: 6,000 families) in the open channels. The discharge capacity of the drainage system is estimated to have been reduced to less than 60% of the original capacity and assessed at the level of 2 to 3-year return period.

As for the drainage pumping stations, the 15 major drainage pumping stations established from 1970s to 1980s, have been in operation for more than 30 years and are superannuated. The 2005 JICA M/P has proposed to attain the drainage capacity of 10–year return period by recovering the original discharge capacity through new additional structures and the rehabilitation of 12 pumping stations installed from the 1970s to 1980s.

In Metro Manila the authority for the management of drainage facilities is divided into two: the authority to plan and implement drainage facilities belong to the DPWH and that of O&M belong to the MMDA. However, in order to carry out planning, implementation and their O&M effectively and improve the O&M activities, it is necessary for the DPWH and the MMDA to promote information sharing and to establish a better cooperation between them. As for big scale drainage facilities such as deep underground tunnel storages their planning/implementation/O&M should require a seamless management and the establishment of a new organization for the implementation is required.

2.4 Progress of the 2005 M/P

The implementation of new facilities under the 2005 JICA M/P has been delayed but recently restarted. O&M works are being conducted by the MMDA. The National Development Plan (2011–2016) emphasizes the importance of infrastructure support for the conservation of river basins and reduction of flood disaster risks as an important policy. There is a strong basis for MMDA to start working on the recovery of drainage capacities of drainage channels by dredging/cleaning of channels and by relocating Informal Settler Families (ISF) along channels and rehabilitating major pumping stations.

As for the relocation of ISF the ISF Fund of Php 50 billion where Php 10 billion per year is to be used from 2011 to 2016 has been established and LGUs are conducting relocation of ISFs residing along esteros/creeks.

In North Manila, the priority activities are:

1) Implementation of priority projects: Blumentritt Interceptor
2) Dredging and clean-up of esteros and creeks

In South Manila, the priority activities are:

1) Implementation of priority projects: Makati Diversion Channel
2) Dredging and clean- up of esteros and creeks

2.4.1 Status of Cleaning up and De-silting of Estero/Creek

(1) Status of Rehabilitation of Drainage Facilities

The location of projects conducted by MMDA from 2014 to August 2015 is shown in Figure 2.4.1.

The projects are composed of 1) Improvement of channels, 2) Dredging of channels, 3) Clean-up of drainage channels and 4) Remedial works for revetments.

Table 2.4.1 shows the budget of MMDA allocated for the maintenance of drainage channels (excluding personnel expenses) It also shows an increase in the budget for the last 3-4 years for the implementation of activities that brought positive drainage improvement.

Table 2.4.1 MMDA Budget for Maintenance

Unit: thousand Php

Year	Amount	Year	Amount
2016	260,848	2011	204,464
2015	255,547	2010	199,225
2014	250,134	2009	214,300
2013	247,658	2008	214,300
2012	209,371	2007	203,236

Source: Approved Budget for Maintenance and Other Operation Expenses, Flood Control and Sewerage Management, MMDA

(2) Situation of Rehabilitation of Drainage Pumping Stations

According to MMDA, rehabilitation of the 12 pumping stations, as shown in Table 2.4.2, has already been done except for those pumping stations whose current diesel pumps are waiting to be replaced by pumps run by electricity.

Table 2.4.2 Drainage Pumping Stations under Rehabilitation by MMDA

PUMP STATION	NO. OF ENGINES/ HP/ KVA	TYPE OF PUMPS	CAPACITY/ PUMP (cms)	TOTAL CAPACITY (cms)	NO. OF ENGINES/ HP/ KVA	TYPE OF PUMPS	CAPACITY/ PUMP (cms)	TOTAL CAPACITY (cms)
SOUTH CLUSTER	BEFORE				NOW			
1. Trip de Gallina	8 M.E. x 450 hp	Model 1650HSGE	7	56	8 electric drive	EBARA Model 1650HSGE	8.75	70
2. Libertad	4 M.E. x 390 hp 2 M.E x 390 hp	Model 1650HSGE Model 1650HZGE	7.0 7.0	42	6	EBARA Model 1650HSGE EBARA Model 1650HZGE	7.0 7.0	42
3. Makati	2	EBARA Model 1200VSGE	3.5	7	2	EBARA Model 1200VSGE	3.5	7
4. Sta. Clara	2	EBARA Model 1000VSGE	2.65	5.3	2	EBARA Model 1000VSGE	2.65	5.3
NORTH CLUSTER	BEFORE				NOW			
5. Aviles	4 M.E. x 230 hp	Model 1200VSGE	3.625	14.5	4	FLYGT (submersible pump)	4.5	18
6. Valencia	4 M.E. x 180 hp	Model 1000VSGE	2.625	10.5	4	FLYGT (submersible pump)	3.5	14
WEST CLUSTER	BEFORE				NOW			
7. Quiapo	4 M.E. x 130 hp	Model 1000VSGE	2.375	9.5	4	GRUNDFOS (submersible pump)	3.63	14.52
8. Binondo	4	GRUNDFOS (submersible pump)	3.63	14.52	4	GRUNDFOS (submersible pump)	3.63	14.52
EAST CLUSTER	BEFORE				NOW			
9. Paco	3	EBARA Model 1000VSGE	2.53	7.59	3	EBARA Model 1000VSGE	2.53	7.59
10. Pandacan	2	FLOW SERVE Vertical Axial Flow Pump	2.75	5.5	2	FLOW SERVE Vertical Axial Flow Pump	2.75	5.5
11. Balete	5	EBARRA Model type 500DSZ FLYGT	3 x 1 cms 1 x 0.8 cms 1 x 1.0 cms	4.8	5	EBARRA Model type 500DSZ FLYGT	3 x 1 cms 1 x 0.8 cms 1 x 1.0 cms	4.8
12. Arroceros	4	EIM Submersible Pump EBARRA Submersible Pump	1 x 0.30 cms 1 x 0.50 cms 1x 0.80 cms 1 x 1 cms	2.6	4	EIM Submersible Pump EBARRA Submersible Pump	1 x 0.30 cms 1 x 0.50 cms 1 x 0.80 cms 1 x 1 cms	2.6

Source: MMDA

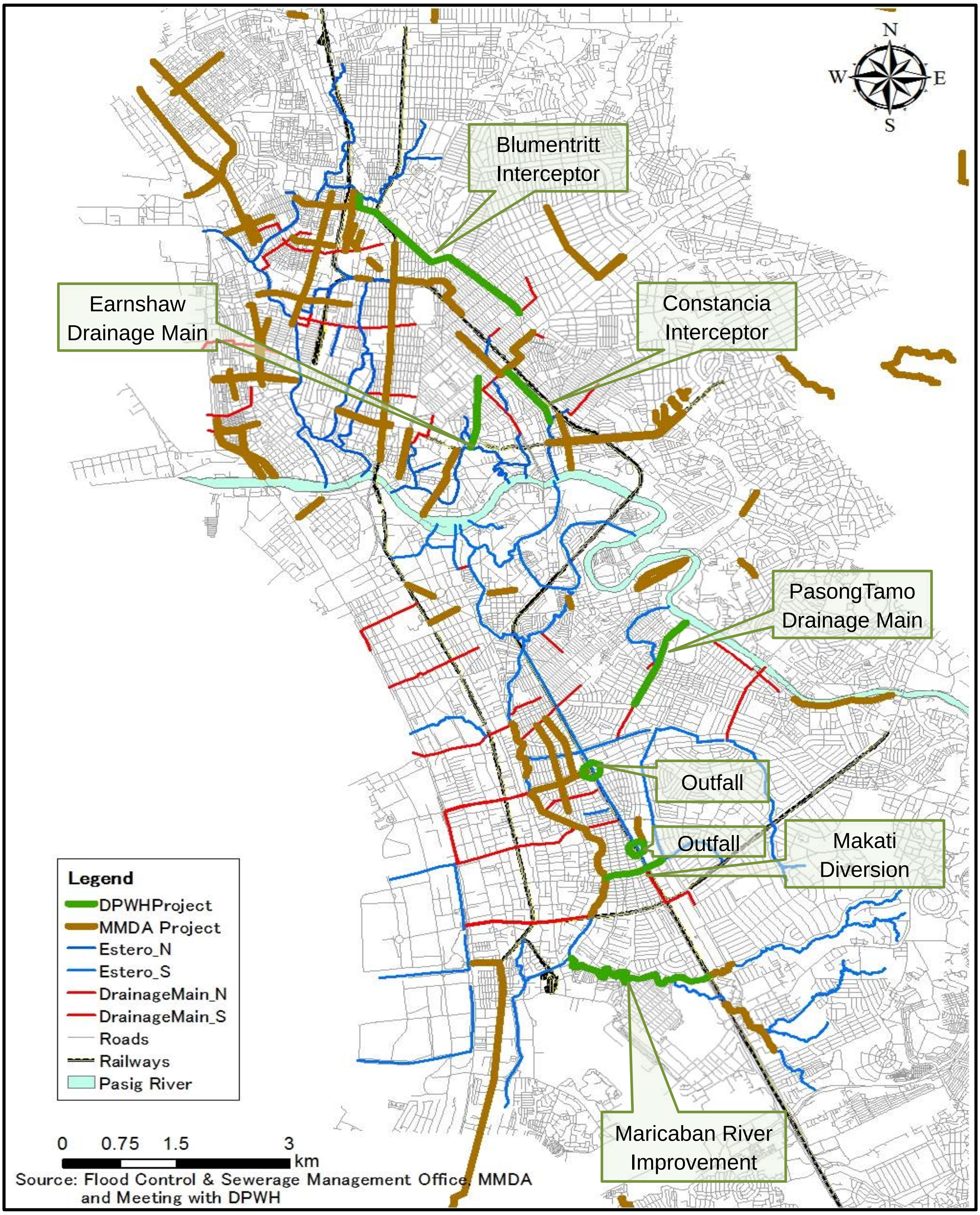


Figure 2.4.1 Location Map of MMDA Projects

2.5 DPWH Survey

The DPWH Survey took into consideration the flood control plan composed of the river improvement works (2015~2020) and the urgent works (2015~2018) of the 2005 JICA M/P and the 2012 World Bank M/P. It validated the status of implemented projects. The total cost of each plan is Php 86 billion and for Urgent Works Php 22 billion respectively.

For España-UST, the urgent works of Constancia Interceptor and Earnshaw Drainage Main are planned to commence in 2015.

River improvement works are formulated for the rivers in Metro Manila, and involves dredging embankment/revetment, and replacement of bridges.

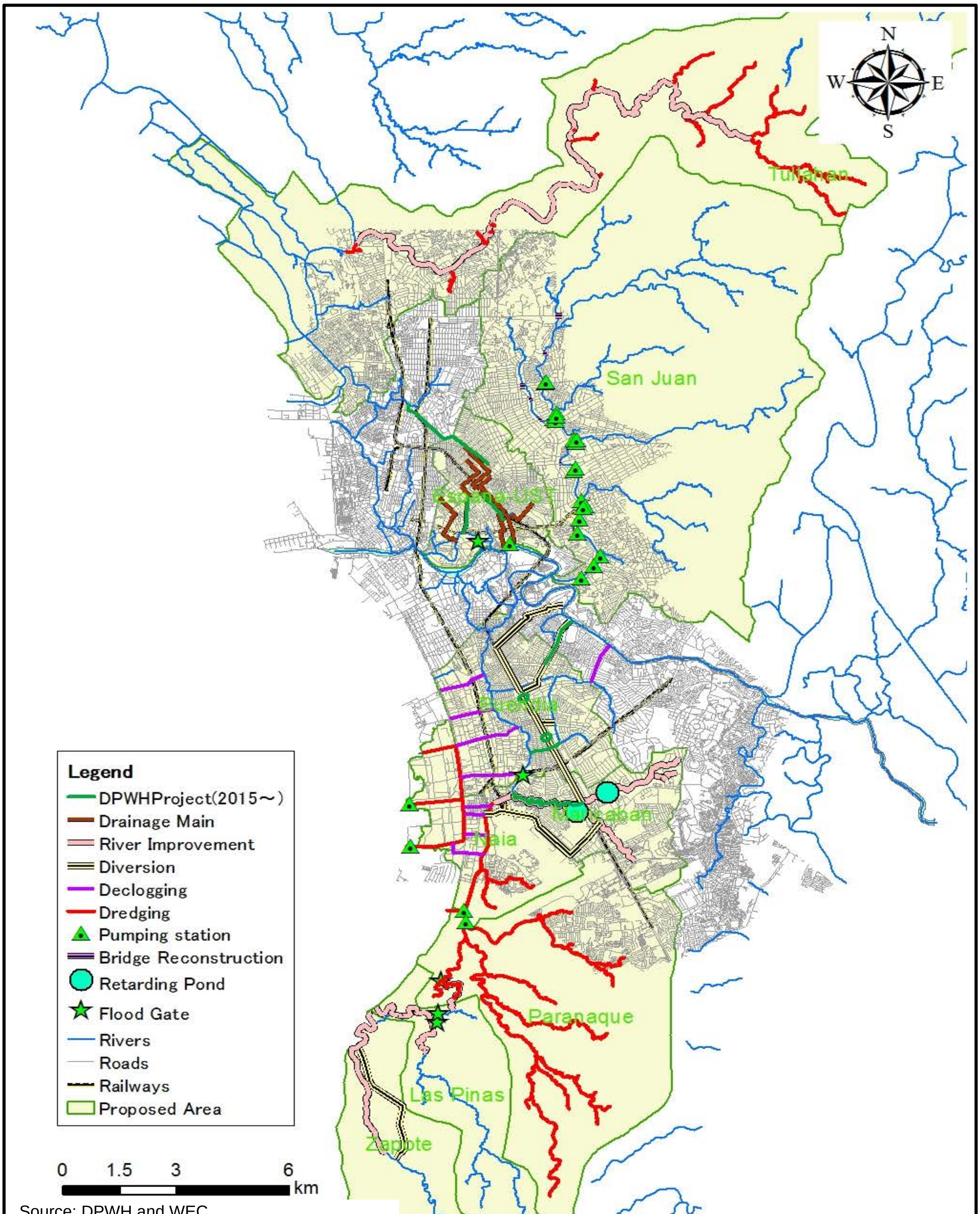
Table 2.5.1 Project Cost and Evaluation for the DPWH Survey

Unit: Million Php

No.	River and Drainage Block	Master Plan (2015~2020)	Urgent or Priority Project (2015~2018)	Outline of Evaluation
1	Tullahan River	18,712	4,804	Design cross-section, ROW, Relocation of people are tasks
2	San Juan River	25,260	10,728	ROW, relocation of people, Raising river bed, relation with the Pasig River are major tasks.
3	España-US T	6,840	3,802	Width of road, width of proposed culvert, pumping station, slope, etc. There are many tasks and seem difficult for implementation
4	Buendia	6,757	29	Draining to Pasig River, slope, etc. There are many tasks and difficulty for implementation.
5	Maricaban	2,031	206	River improvement and construction of flood ways, There are many tasks and difficulty for implementation.
6	NAIA	6,540	395	Small task and possible river improvement
7	Parañaque River	2,246	363	Small task and possible river improvement
8	Las Piñas	4.997	1,689	ROW is task
9	Zapote River	12,373	-	ROW is task
TOTAL		85,756	22,016	

Source: Presentation of DPWH Survey "Consulting Services for the Review and Detailed Engineering Design of Comprehensive River Management for San Juan River and Review and Updating of Feasibility Studies and Detailed Engineering Design of various Urgent Flood Control Projects in Metro Manila" DPWH 2015

Table 2.5.1 is culled from the presentation material of Woodfields Engineers Company (WEC) that was submitted to the DPWH. The design discharges and standard cross sections (reference material 2-2) were provided upon request during the survey. Specific discharges, the specific discharge of the river basins are 8~20 m^3/sec/km^2, which are within a range, but those of drainage basins showing large values such as 40 or 50 m^3/sec/km^2. The same rainfall data were used on both studies and are calculated by Rational Formula. The Survey Team used limited data and information provided by WEC on the proposed projects in the DPWH Survey. The outline of the proposed projects is as follows:



Source: DPWH and WEC

Figure 2.5.1 Projects Proposed by DPWH Survey

2.5.1 Tullahan River

(1) Outline of the DPWH Survey Results

Catchment Area: 68.89km^2

Measure Menu: River channel dredging, revetments and replacement of bridges

As shown in the following figure, the river reach is divided into 4 reaches; the Urgent project is Reach 1.

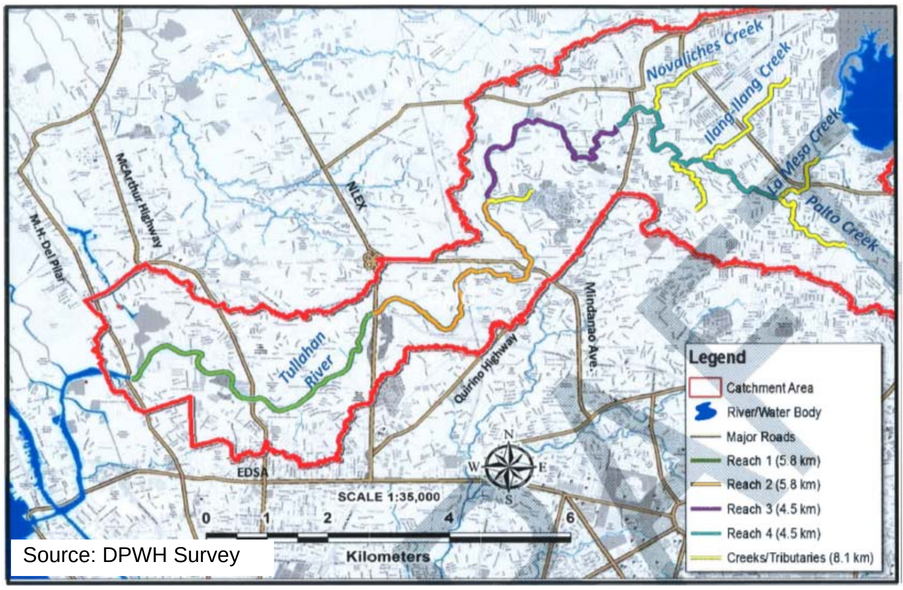


Figure 2.5.2 The Tullahan River Improvement Plan

The design peak discharges are shown in Table 2.5.2. Only the data of the most downstream (Reach 1) was obtained.

Table 2.5.2 Design Discharge of the Tullahan River(100-yr)

Project Site	Rainfall Station	Duration	Catchment Area (km^2)	Peak Discharge (m^3/s)
1. Tenejeros Bridge	Science Garden	24-hrs	70.00	588.40
2. PNR	Science Garden	24-hrs	68.44	582.00
3. McArthur highway	Science Garden	24-hrs	62.12	564.40
4. NLEX	Science Garden	24-hrs	52.50	553.20

Sources: DPWH-UPMO-FCMC and WEC

The project cost is Php18 billion.

Table 2.5.3 Project Cost for the Tullahan River

Tullahan Area	Reach 1	Reach 2	Reach 3	Reach 4	Tributaries
LENGTH (km)	6.3	5.4	4.5	4.5	8.1
RIVER IMPROVEMENT COST					
A. Drainage and Excavation	336	288	240	240	433
B. Revetment Works	3,764	3,222	2,686	2,686	1,660
C. Bridge Reconstruction	153	-	103	220	160
Compensation/Land Acquisitions Cost	551	529	443	415	583
PROJECT COST (Mil. Php)	4,804	4,039	3,472	3,561	2,836
GRAND TOTAL					18,712

(2) Evaluation of the Plan Outline

No detailed data was available, but based on the data obtained through satellite image of Google Earth and site inspection, the following are the results of the evaluation.

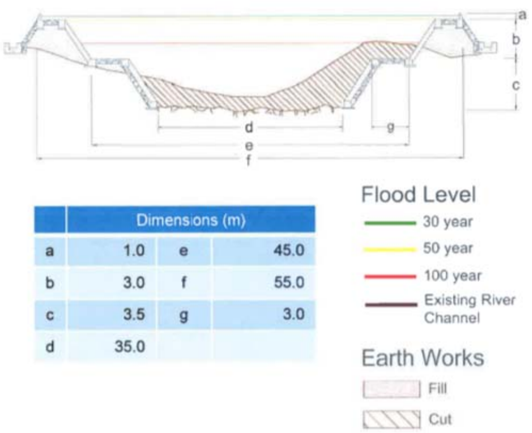
Table 2.5.4 Evaluation of the Plan Outline

No.	Reach	Outline	Remark
1	Reach 1 (6.3km)	Width of river at downstream is 40 ~ 50m, at 2nd bridge site the width is 30m, width at upper reach is 15~30m, futher upper reach is urban area and the width is 30m. The proposed river width is 55m, and the project requires ROW and in the upper reach relocation of people will be required.	Identified by standard cross-section and google Earth Data
2	Reach 2 (5.4km)	The width of river is 10~30m. Based on the cross section provided, ROW and relocation of people will be required.	Identified by standard cross-section and google Earth Data
3	Reach 3 (4.5km)	The width of river is 10m. Based on the compensation cost, ROW proposed improvement plan is not clear.	No specificatiob data, river width identified by Google Earth.
4	Reach 4 (4.5km)	The width of river is about 10m. Based on the compensation cost, proposed improvement plan is not clear.	No specificatiob data, river width identified by Google Earth.

Furthermore based on the existing data, Reach 1 is the urgent plan for improvement based on the standard cross section (shown in Figure 2.5.2). Figure 2.5.3 which is newly provided from WEC shows the river width of 50 m(1: 0.5 slope) and low water width of 40 m.

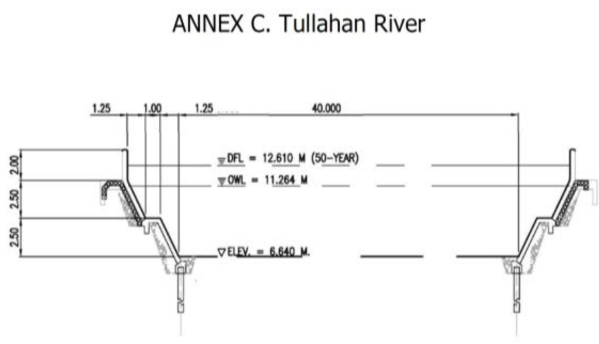
Based on Figure 2.5.2 cross section is about 270 m², design discharge is 590 m³/sec and velocity is estimated as 2.2 m/s, the values are considered to be reasonable. However, these cross sections have the following problems from the designing aspects.

- Berm is normally more than 3 m in Japan, but 1 m in Figure 2.5.3 (the reason is based on land acquisition or other reason)
- About stability of 2 m parapet during floods
- Slope (1 : 0.5) seems to have a high possibility of sliding during earthquake (it is necessary to check the slope stability by circular slip)



Source: DPWH Survey

Figure 2.5.3 Standard Cross Section of Tullahan River



Source: DPWH-UPMO-FCMC and WEC

Figure 2.5.4 Cross Section obtained by Field Survey

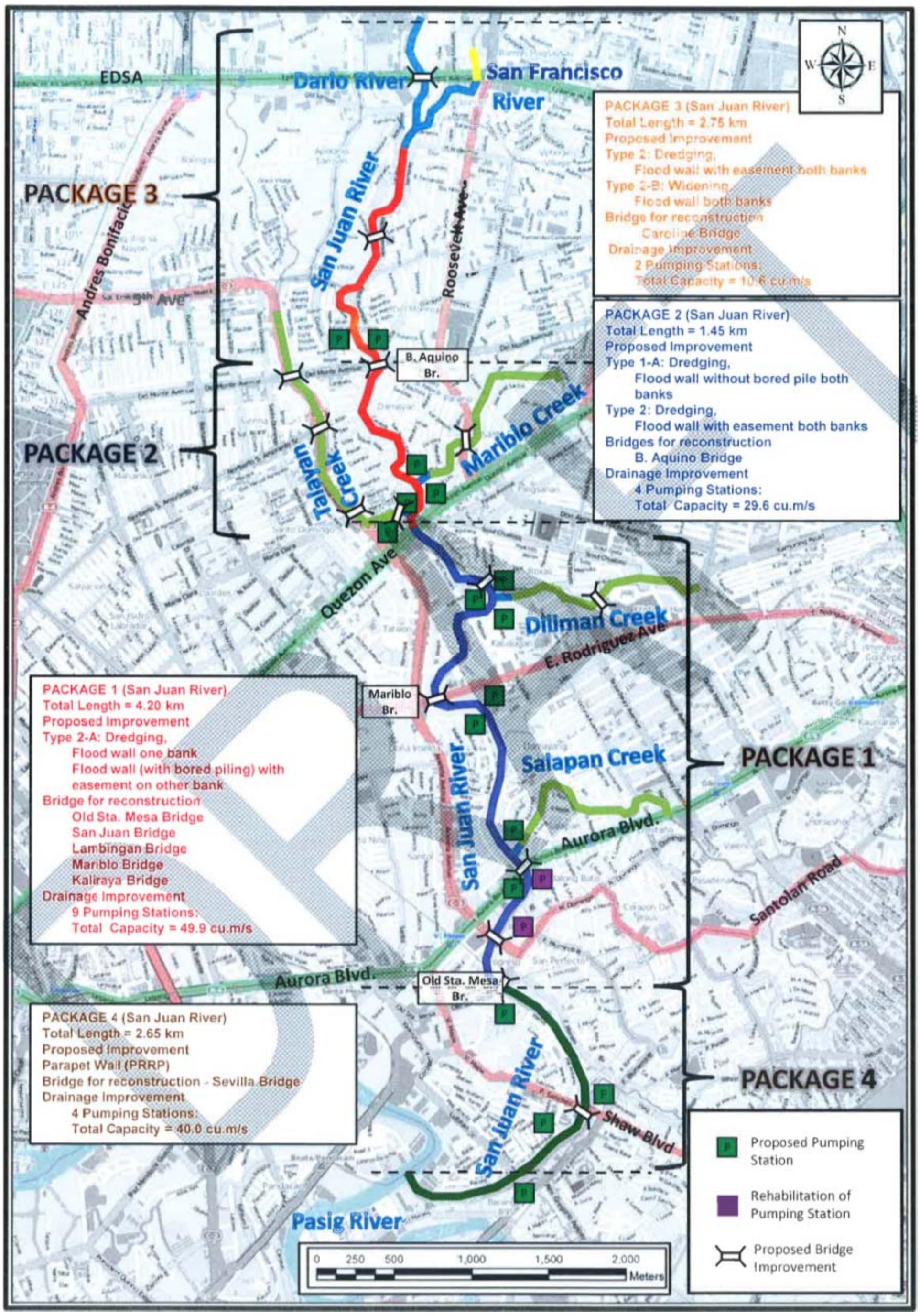
2.5.2 San Juan River

(1) Outline of DPWH Survey

Catchment Area: 91.65 km2

Measure Menu: River channel dredging, bank and revetment, replacement of bridges, drainage pump stations and improvement of tributaries

The river improvement plan is composed of 4 packages as shown in the Figure, and Package 1 is selected as the urgent project.



Source: DPWH Survey

Figure 2.5.5 San Juan River Improvement Plan

Design discharges are in Table 2.5.5.

Table 2.5.5 Design Discharge for San Juan River(50-yr)

Project Site	Rainfall Station	Duration	Catchment Area (km^2)	Peak Discharge (m^3/s)
1. STA 1+100	Science Garden	24-hrs	91.60	822.50
2. STA 3+350	Science Garden	24-hrs	82.58	728.46
3. STA 7+250	Science Garden	24-hrs	51.49	436.95
4. STA 11+100	Science Garden	24-hrs	14.40	283.60

Source：DPWH-UPMO-FCMC and Woodfields Consultants Inc.

The project cost is estimated at Php 25 billion as shown in the following Table.

Table 2.5.6 Project Cost for San Juan River

Work Item	Package1	Package2	Package3	Package4	Total
Compensation Cost		1,919	1,378		3,297
Dredging and Excavation	268	77	146	140	631
Revetment Works	4,968	992	1,878	875	8,713
Bridge Reconstrunction	579	104	57	103	843
Pumped System for Local Drainage	3,495	1,766	633	2,802	8,696
Tributary Improvement	1,418	1,336	327		3,081
Total (Mil. Php)	10,728	6,194	4,419	3,920	25,261

Source: DPWH Survey

(2) Evaluation of Plan Outline

No detailed data was available, but based on the data obtained through satellite image by Google Earth and site inspection, the results of the evaluation are as shown in Table 2.5.7.

Since no information on depth in the standard cross section was available, examination of cross section was not possible The plan is based on the assumption that there is high water level and theoretically set 2~4 meter parapet walls on the existing ground. Since the walls will be higher than the neighboring ground and will retard flood water from draining naturally, flood risks will be higher. With regard to the implementation order, the plan will concentrate flood to the downstream and hence the implementation order should be changed.

However, the San Juan River is one of the tributaries of the Pasig River so that the flood discharge of the tributary should be decided duly considering the flood discharge of the Pasig River. According to the Pasig-Marikina River M/P, the design discharge of the San Juan River is700 m^3/sec, but design discharge of the San Juan River is 823 m^3/sec (50-year) (Table 2.5.5). The Pasig River downstream and the confluence of the San Juan River has already been improved. The river improvement works for the San Juan in relation to the Pasig River is thus necessary to be studied as part of the Pasig River Basin Management.

Table 2.5.7 Evaluation of the Plan Outline

N0.	Reach	Outline	Remark
1	Package 1	The river improvement works are marginal, but possible because the width of river channel is 40~50 m the design width of river channel dredging is 40 m. As for 9 pumping stations 2 sites are improvement of the existing pumping station, 5 sites are open space and 2 sites have structures. compensation cost will be required for the pumping stations.	Assumed by standard design cross section and Google Earth Data
2	Package 2	For the channel width less than 20 m the river channel improvement works of 21 m width with floodwalls is proposed. The works may require ROW and relocation of people. As for 4 pumping stations 3 sites are open spaces and 1 site has structure. For Talayan Creek rectangle channel of 9.1 m width is proposed. the existing 6 m channel is to be dredged and improved. However, no information of design discharges and difficult to evaluate the conveyance capacity.	Assumed by standard design cross section and Google Earth Data
3	Package 3	The existing river channel (about 21 m) is proposed to be improved to 21 m width. The improvement works may require ROW and relocation of people. The proposed two pumping station have open spaces.	Assumed by standard design cross section and Google Earth Data
4	Package 4	The river improvement works are possible. The existing river channel of 50~60 m width is proposed to be improved by channel improvement works with parapet walls.	Assumed by standard design cross section and Google Earth Data

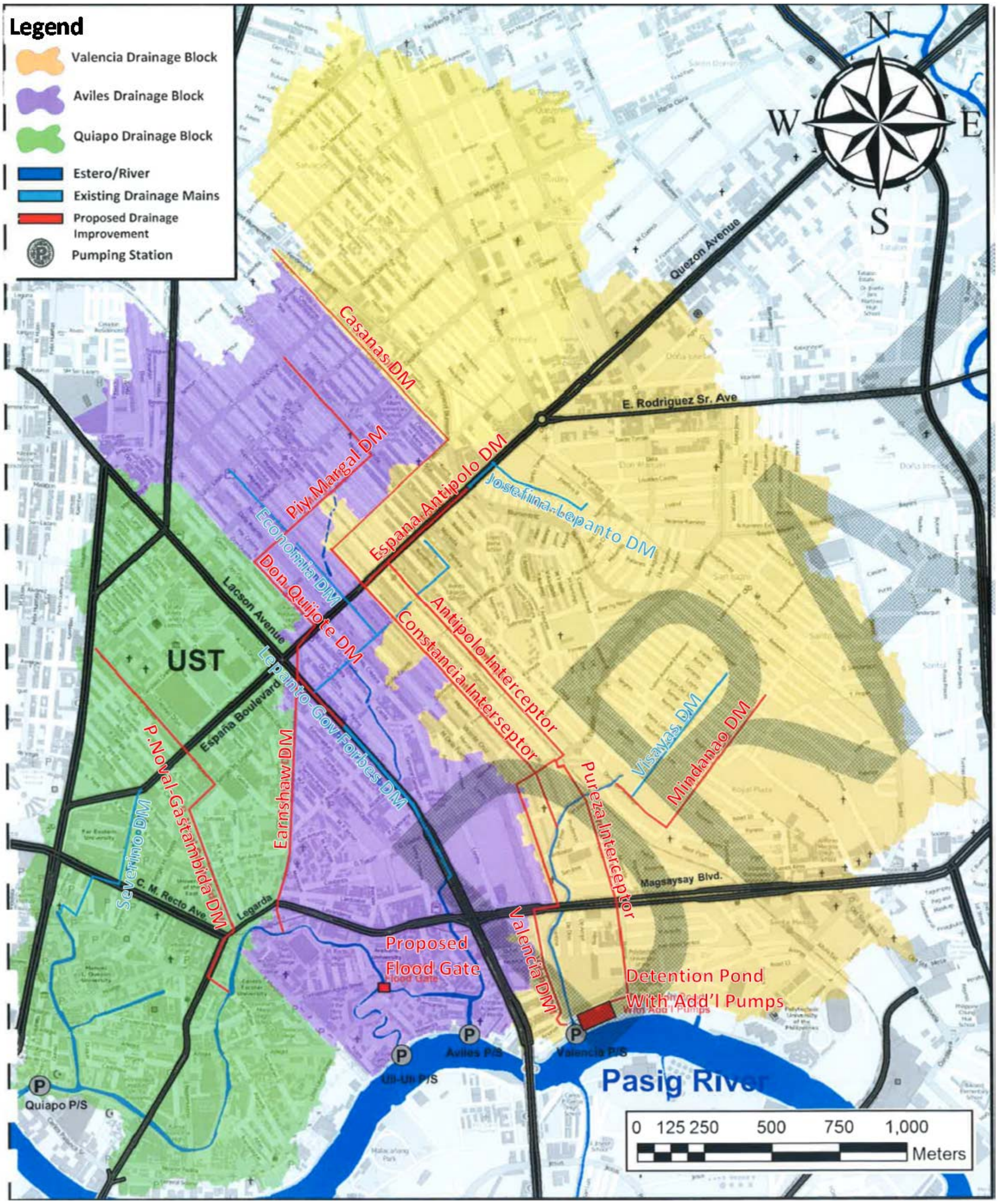
2.5.3 España- UST

(1) Outline of the DPWH Survey Results

Catchment Area: 7.96km2

Measure Menu: Additional culverts, improvement of existing culverts, river channel dredging, retarding basins and additional pump stations

In this area the following projects are proposed.



Source: DPWH Survey

Figure 2.5.6 Improvement Plan for España-UST Area

The design discharge volumes calculated by the rational formula are as shown in the following table:

Table 2.5.8 Design Discharges for the España-UST Area(25-yr)

Project Site	Rainfall Station	Duration	Catchment Area (km^2)	Peak Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)
1. Constancia Interceptor	Port Area	1 hr	1.55	17.25	11.12
2. Antipolo Interceptor	Port Area	1 hr	1.50	21.92	14.59
3. Pureza Interceptor	Port Area	1 hr	3.25	51.55	15.84
4. Casanas-Margal-Quijote DM	Port Area	1 hr	1.98	19.68	9.94
5.Earnshaw DM	Port Area	1 hr	0.23	5.81	24.99
6.Lepanto-Forbes DM (Existing)	Port Area	1 hr	2.43	20.10	8.29
7. Estero de Valencia	Port Area	1 hr	1.84	29.08	15.80
8.Estero de Sampaloc I	Port Area	1 hr	2.73	20.17	7.38
9. Estero de San Miguel- Uli-Uli	Port Area	1 hr	0.47	7.09	14.98

Source：DPWH-UPMO-FCMC and WEC

The project cost is estimated at Php 6.5 billion and as shown in the following table.

Table 2.5.9 Project Cost for the España-UST Area

ESPAÑA-UST		VALENCIA DRAINAGE BLOCK	AVILES DRAINAGE BLOCK	QUIAPO DRAINAGE BLOCK
Work items				
A. ADD'L DRAINAGE MAINS				
1	Mindanao DM	219.40		
2	España-Antipolo DM	189.04		
3	Antipolo Interceptor	540.03		
4	Constancia Interceptor	541.48		
5	Pureza Interceptor	542.30		
6	Valencia DM	278.45		
7	Casanas	39.90		
8	Piy Margal Extension DM		170.64	
9	Don Quijote DM		187.94	
10	Lacson DM		30.81	
11	Earnshaw DM		240.16	
12	P. Noval-Gastambide DM			393.11
B. DECLOGGING				
1	Visayas DM	4.34		
2	Josefina-Lepanto DM	3.54		
3	Economia DM		2.72	
4	Piy Margal DM		0.72	
5	Lepanto-Gov. Forbes DM		7.06	
6	Severino DM			3.35
C. DREDGING				
1	Estero de Valencia with widening	15.27		
2	Estero de Calubcob		0.91	
3	Estero de Sampaloc I		5.86	
4	Estero de San Miguel		38.53	
5	Estero de Quiapo			22.10
D. DETENTION AREA		225.94		
1				
E. ADDITIONAL PUMPS		2502.47		
F. BRIDGE RECONSTRUCTION		77.75		
1	Lepanto-Gov. Forbes DM		180.41	
G. FLOOD GATE			17.60	
ESTIMATED COST (Million Php)		5,179.91	883.36	418.56

Source：DPWH-UPMO-FCMC and WEC

(2) Evaluation of the Plan Outline

Although no detailed data was obtained, the plan was evaluated based on the obtained data and satellite image of Google Earth reality/site and summarized in the following Table.

Table 2.5.10 The Plan Outline and the Evaluation Results

No.	Reach	Outline	Remarks
1	Constancia Interceptor	Three (3) lanes of box culvert (3 m x 2 m) are proposed under the road of 8 m width. The relocation of people and ROW along the road will be required.	Assumed by additional data provided.
2	Antipolo Interceptor	Two (2) lanes of box culvert with a discharge capacity of 22 m^3 /sec is proposed under the road of 6~7 m width. The space for construction works seems marginal.	Assumed by additional data provided and Google Earth Data.
3	Pureza Interceptor	Two (2) lanes of box culvert (3.2 m x 4 m) with a discharge capacity of 52 m^3/sec is proposed under the road of 8 m width. The space for construction works seems marginal.	Assumed by additional data provided and Google Earth Dat.
4	Casanas-Margal-Quijote DM	Two (2) lanes of box culvert (3.5 m x 2.4 m) with a discharge capacity of 19.7 m^3/sec is proposed under Casanas Street of 8~9 m width, Ply Margal Street of 8~9 m width and Don Quijote Street of 12 m wideth. The rout seems different from the existing rout map.	Assumed by additional data provided and Google Earth Data.
5	Earnshaw DM	Two (2) lanes of box culvert (2.4 m x 2.4 m) with a discharge capacity of 5.9 m^3/sec is proposed under the road of 12 ~ 14 m width which is wide enough. Open cut constructon method may be possible depend on trafic conditions.	Assumed by additional data provided and Google Earth Data.
6	Lepanto-forbes DM	Design discharge of 20.1 m^3/sec is proposed under Lacson Street, but there is an existing culvert under Lacson Street. Detailed information is unclear.	Detailed information is unclear.
7	Estero de Valencia	Esteo improvement works of 7.1 m width and 3.5 m depth with a design discharge of 29.1 m^3/sec is proposed. The estero is to discharge to Valencia drainage pumping station of which the draiage capacity is 14 m^3/sec.	No information of design channel bed slope.
8	Estero de Sampaloc 1	Esteo improvement works of 8.426 m width and 3.5 m depth with a design discharge of 20.2 m^3/sec is proposed.	No information of design channel bed slope.
9	Estero de San Miguel-UliULi	Esteo improvement work of 6.32 m width and 3.5 m depth with a design discharge of 7.1 m^3/sec is proposed. The estero is to discharge to Uli-Uli drainage pumping station of which drainage capaciy is 6.0 m^3/sec.	No information of design channel bed slope.

Among the projects, the Constancia Interceptor (No.1 in the table above) and Earnshaw (No.5 in the table above) are proposed as urgent projects. However, the Constancia Interceptor has the following problems:

(a) Size of Box culvert and the Width of Road

The actual road width is 8 m, but the larger size of 3 box culverts proposed, will need additional space beyond the road width. This will entail additional land acquisition.

(b) Elevation of the Outlet of the Culvert

The ground elevation is about EL. 1.0 m at the upper end of the culvert. Total length is 1,130 m and the bet elevation of the estero is EL. 0.2 m at the outlet of the culvert, so that the box culvert (B.C) will need a drainage pump facility.

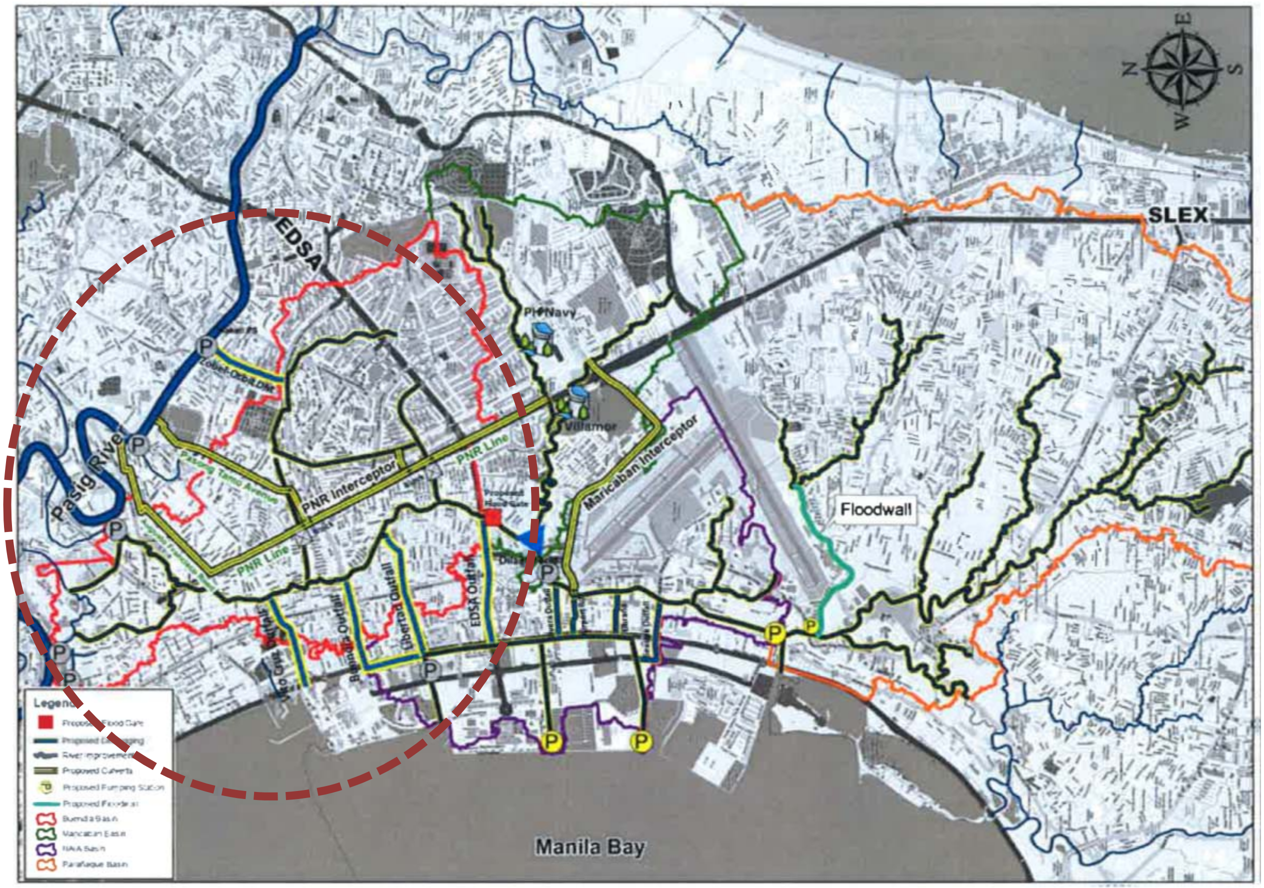
2.5.4 Buendia Area

(1) Outline of the DPWH Survey Plan

Catchment Area: 16.44 km^2 (Estimated by JICA Survey)

Measure Menu: River Clean-up, river dredging, new interceptor, gate

As shown in the map below, an interceptor which divides the catchment and gate, and cleaning up /river dredging are proposed.



Source: DPWH Survey

Figure 2.5.7 River Improvement Plan for the Parañaque River

The design discharges calculated by rational formula based on rainfall intensity at Port Area are as shown in the following table.

As to the proposed design discharges of the PNR Interceptor, refer table 2.5.17.

Table 2.5.11 Design Discharges for the Buendia Area(25-yr)

Project Site	Rainfall Station	Duration	Catchment Area (km^2)	Peak Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)
BUENDIA					
Tripa de Gallina	Port Area	60 mins	0.83	14.49	17.39
Calatagan Creek I	Port Area	60 mins	1.17	44.04	37.57
Calatagan Creek II	Port Area	60 mins	2.46	79.02	32.18
Zobel DM	Port Area	60 mins	2.26	49.36	21.86
Makati Diversion I	Port Area	60 mins	3.63	59.08	16.29
Makati Diversion II	Port Area	60 mins	1.17	48.81	41.74
Makati Div-Tripa	Port Area	60 mins	0.32	5.04	15.63
Calatagan Creek	Port Area	60 mins	0.65	14.69	22.72
Paco	Port Area	60 mins	1.42	14.04	9.88
Pandacan	Port Area	60 mins	1.91	15.49	8.11
Provisor	Port Area	60 mins	2.30	18.49	8.04
Libertad pumping Station	Port Area	60 mins	6.51	58.99	9.06
Edsa Outfall	Port Area	60 mins	1.27	55.68	43.99
Libertad Outfall	Port Area	60 mins	0.99	10.06	10.14
Buendia Outfall	Port Area	60 mins	2.27	22.14	9.76
Vito Cruz Outfall	Port Area	60 mins	0.42	6.01	14.35

Source：DPWH-UPMO-FCMC and WEC

Project cost is estimated as Php6.5 billion in total.

Table 2.5.12 Construction Cost for the Buendia Area

Buendia Basin		Priority 1. Declogging (m^3/m)	Priority 2. Dredging (m^3/m)	Priority 3. PNR Interceptor (m^3/m)	Priority 4. Flood Gate (m^3/m)	Tributaries Cost (M Php)
	Work items					
1	Libertad	1,847				6
2	EDSA	2,450				6
3	Zobel-Orbit	264				5
4	Priority 4. Flood Gate	2,654				5
5	Buendia	2,886				7
	GRAND TOTAL					29
1	Calatagan Creek I		1,710			15
2	Calatagan Creek II		1,000			9
3	Calatagan Creek III		2,560			23
4	Makati Diversion Channel I		1,083			12
5	Makati Diversion Channel II		1,990			22
6	Estero de Pandacan		3,123			60
7	Estero de Provisor		1,020			31
8	Estero de Paco		887			15
9	Estero de Tripa de Gallina		4,378			69
	GRAND TOTAL					257
1	1 barrel of 3.5x4.0			1,850		581
2	1 barrel of 4.5x4.5			658		280
3	2 barrels of 4.5x4.5			1,500		1,248
4	1 barrel of 5.0x4.5			560		259
5	1 barrel of 4.0x4.4			115		44
6	2 barrels of 3.7x4.5			2,100		1,398
7	2 barrels of 3.5x4.5			730		459
8	2 barrels of 4.0x4.5			3,070		2,186
	GRAND TOTAL					6,455
1	Flood Gate				10x3.0	16
	GRAND TOTAL					16

Source: DPWH Survey

(2) Evaluation of the Plan Outline

Although no detailed data was not obtained, the plan was evaluated based on the data obtained from the satellite image of Google Earth and site inspection. The evaluation results are in the following Table.

Table 2.5.13 The Plan Outline and Evaluation

No.	Reach	Outline	Remarks
1	PNR Interceptor	Box culvert (3.5 m x 4.0 m) and two (2) lanes of culvert (4.5 m x 4.5 m) to No.1, Box culvert (4.0 m x 4.5 m) and two lanes of culvert (3.5 m x 4.5 m) to No.2 are proposed at the open space along PNR and the road. The culverts may be possible to be constructed by open cut construction methods.	Assumed by additional data provided and Google Earth Data.
2	Augusto Francisco Road	Two (2) lanes of box culvert (4.0 m x 4.5 m) is proposed under the road of 10 m width. The culvert of which the design discharge is 91.2 m^3/sec and requires a drainage pumping station to discharge it to the Pasig River but difficult to find a proper site for the pumping station.	Assumed by additional data provided and Google Earth Data.
3	Pasong Tamo Ave.	Two (2) lanes of box culvert (3.7 m x 4.5 m) is proposed under the road of 10 m width. The culvert of which the design discharge is 79.1 m^3/sec, requires a drainage pumping station to discharge it to the Pasig River but difficult to find a proper site for the pumping station.	Assumed by additional data provided and Google Earth Data.
4	Maricaban Interceptor	Culvert (4.5 m x 4.5 m) is proposed under the road which is wide enough.	Assumed by additional data provided and Google Earth Data.

Other than the projects proposed, no river dredging and river cleaning and no difficulty ware identified. However, there are problems as follows:

(a) Discharge to the Pasig River

The original drainage area is within the drainage blocks of Tripa de Gallina and Libertad, and not within the Pasig River Basin. It is not proper to change the drainage basin and any negative impact to the Pasig River which flows through the capital area must be avoided.

(b) Difficulties of Open Cut Construction Methods

It is possible to conduct open cut construction methods for the above No.1, 2, and 3, considering the current traffic conditions, although some impacts to the traffic congestion are anticipated.

(c) Status of the PNR Interceptor

As for the PNR Interceptor, the ground elevation at the right tributary of Maricaban River which is the starting point of the interceptor is EL. 5.54 m and the elevation of the discharge point at the Pasig River is EL. 2.3 m. The total length of the Interceptor is 7,923 m; accordingly, the average channel slope is 1/2445.

Table 2.5.14 Evaluation of the PNR Interceptor

n=	0.015						
uniform flow							
RCBC size	3.5*4	4.5*4.5	2*4.5*4.5	4.0*4.5	2*3.5*4.5	2*4.0*4.5	Total
DPWH-Design Discharge	28.0	54.6	109.3	45.8	71.5	91.2	
Q (I=2445)	21.5	35.8	71.6	30.1	49.6	60.2	
I to cope with DPWH-Q	1,400	1,050	1,050	1,050	1,150	1,850	
Length	1,850	658	1,500	115	730	3,070	7,923
d	1.32	0.63	1.43	0.11	0.63	1.66	5.78

Source: JICA Survey Team

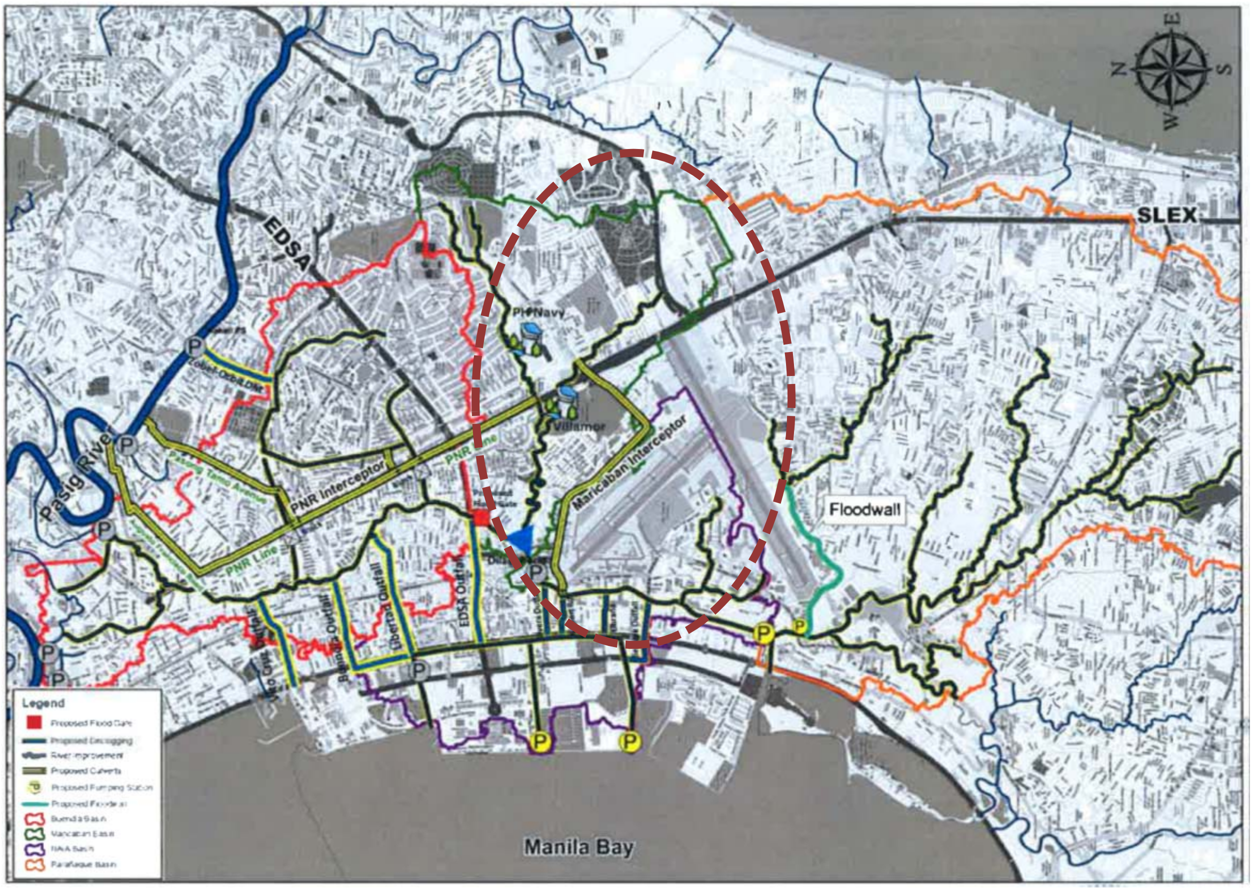
As shown in Table 2.5.14, the results of the calculation are a little lower than the design discharges. In order to get the ideal design discharge values, it is necessary to set a steeper slope of 1/1050~1850 for the interceptor. The difference of elevation will, however, become 5.78 m and the elevation of the outlet becomes -0.38 m, and which will require a pumping station for proper discharge. A pumping station is not proposed.

(3) Outline of the DPWH Survey Results

Catchment Area: 11.64 km^2(Estimated by JICA Survey Team)

Measure Menu: River channel dredging, retarding basin, floodway

As shown in the following figure, for each of the right and left tributaries a retarding basin and a diversion channel are proposed in order to reduce flood risks.



Source: JICA Survey Team

Figure 2.5.8 Improvement Plan for the Maricaban Creek

For Maricaban Creek, the flooding area is identified at around the confluence of the right and left tributaries, and dense populated areas are located in the flood prone areas. The idea to distribute flood waters from the right and left tributaries is realistic.

Design discharges are shown in the following table:

Table 2.5.15 Design Discharges for Maricaban Area(25-yr)

Project Site	Rainfall Station	Duration	Catchment Area (km^2)	Peak Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)
MARICABAN					
Maricaban Creek I	NAIA	60 mins	6.45	217.36	33.69
Maricaban Creek II	NAIA	60 mins	1.56	77.56	49.74
Maricaban Creek III	NAIA	60 mins	3.34	164.21	49.21

Source：DPWH-UPMO-FCMC and WEC

The project cost is estimated as Php 2.0 billion.

Table 2.5.16 Project Cost for the Maricaban Area

Work Item	Total
Dredging	206
Retarig Pond	119
Maricaban Interceptor	1,706
Total	2,031

Source: DPWH Survey

(4) Evaluation of the Plan Outline

Although no detailed data was not obtained, the plan was evaluated based on the data obtained from satellite image of Google Earth and site inspection. The evaluation results are in the following table.

Table 2.5.17 The Plan Outline and Evaluation

No.	Reach	Outline	Remarks
1	Maricaban I	River improvement works of 25 m width and 5 m depth are proposed. A wide ROW and numerous relocation of people may be required along the channel because the creek is 15~20 m width at most, but few meters at narrow sections.	Assumed by additional data provided and Google Earth Data.
2	Maricaban II	River improvement works of 25 m width and 5 m depth are proposed. A wide ROW and numerous relocation of people may be required along the channel because the creek is 15~20 m width at most, but few meters at narrow sections.	Assumed by additional data provided and Google Earth Data.
3	Maricaban III	River improvement works of 15 m width and 3 m depth are proposed. A wide ROW and numerous relocation of people may be required along the channel because the creek is around 7 m width.	Assumed by additional data provided and Google Earth Data.
4	Retarding Basin (2 sites)	At present the two sites seem difficult to be used as retarding basins.	Detailed information is unclear.
5	Maricaban Interceptor	the flood way of 55 m^3/sec diveted from the left tributary of Maricaban is proposed. The flood way of box culvert of 4.5 m x 4.5 m is planned to be constructed under the road by open cut metod. The construction may be difficult because of the heavy trafic.	Assumed by existing data

2.5.5 NAIA Area

(1) Outline of the DPWH Survey Results

Catchment Area: 11.64 km^2(Estimated by JICA Survey Team)

Measure Menu: River channel dredging, river clean-up, new pumping station and retarding basin

As shown in the map below, measures are proposed to improve drainage by new pumping station and river channel dredging works.

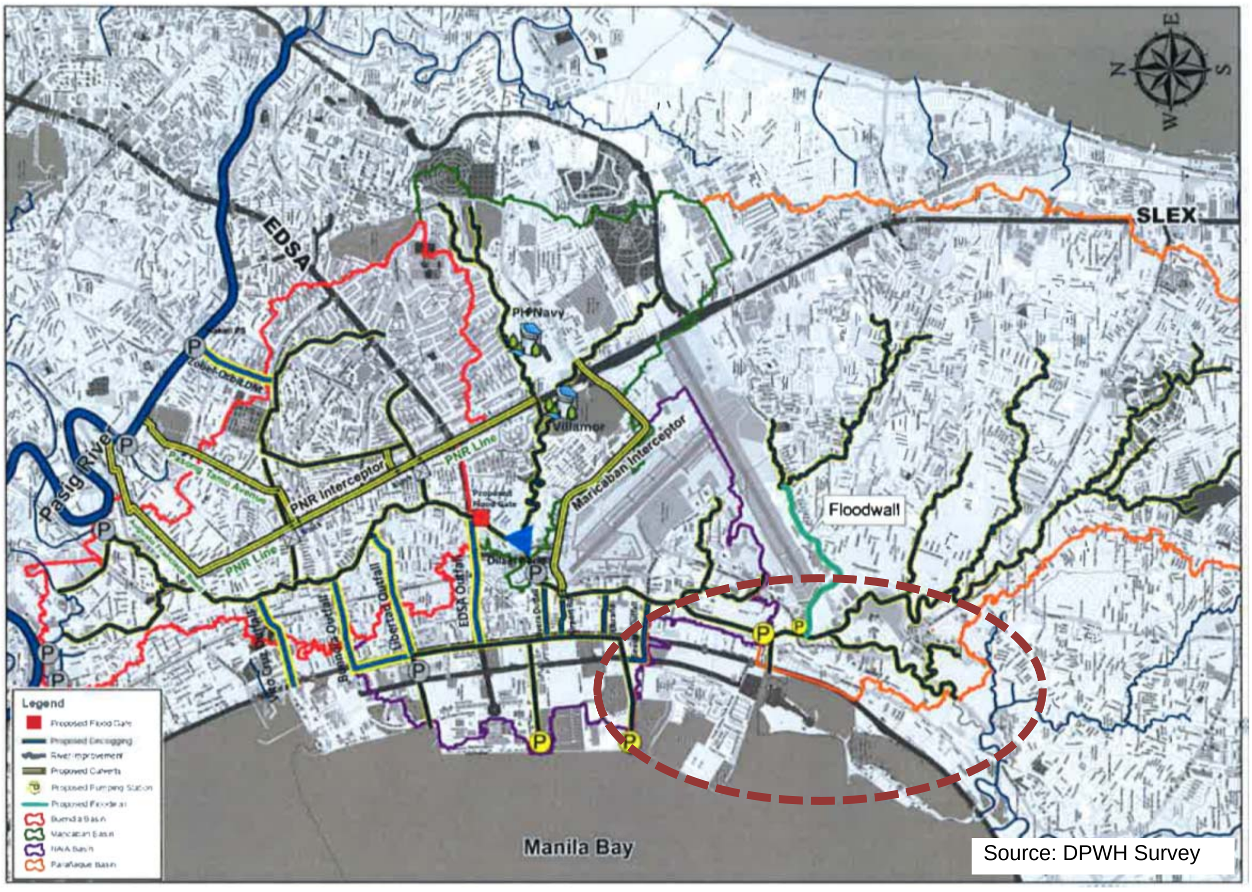


Figure 2.5.9 River Improvement Plan for the Parañaque River

The design discharges are as shown in the following table:

Table 2.5.18 Design Discharges for the NAIA Area(25-yr)

Project Site	Rainfall Station	Duration	Catchment Area (km^2)	Peak Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)
NAIA					
Parañaque Channel 1	NAIA	60 mins	11.02	266.26	24.16
Rivera	NAIA	60 mins	0.44	23.07	52.34
Parañaque Channel 2	NAIA	60 mins	10.58	171.97	16.26
Airport Road	NAIA	60 mins	1.06	49.92	47.19
Parañaque Channel 3	NAIA	60 mins	12.08	186.57	15.45
Librada	NAIA	60 mins	1.21	20.24	16.76
Parañaque Channel 4	NAIA	60 mins	12.88	160.76	12.48
Seaside	NAIA	60 mins	1.49	10.30	6.93
Parañaque Channel 5	NAIA	60 mins	15.74	192.21	12.21
Inland Channel	NAIA	60 mins	1.74	101.35	58.36
Redemptorist Channel	NAIA	60 mins	2.68	105.00	39.12
Seaside Channel	NAIA	60 mins	4.73	126.99	26.87
Banana Island Creek	NAIA	60 mins	1.47	31.97	21.77
Ibayo Creek	NAIA	60 mins	0.27	13.46	50.20
Cut-cut Creek	NAIA	60 mins	1.94	48.38	24.93

Source: DPWH-UPMO-FCMC and WEC

Project cost is estimated at Php 6.5 Billion

Table 2.5.19 Project Cost for the NAIA Area

Work Item	Total
Dredging	395
Declogging	9
Pumping Station	5,005
Detention Basin	1,131
Total	6,540

Source: DPWH Survey

(2) Evaluation of the Plan outline

As shown in the table above, the basic measure proposed is river dredging which is very possible to implement. There is enough open space for the three pumping stations and there seems no difficulty for its implementation.

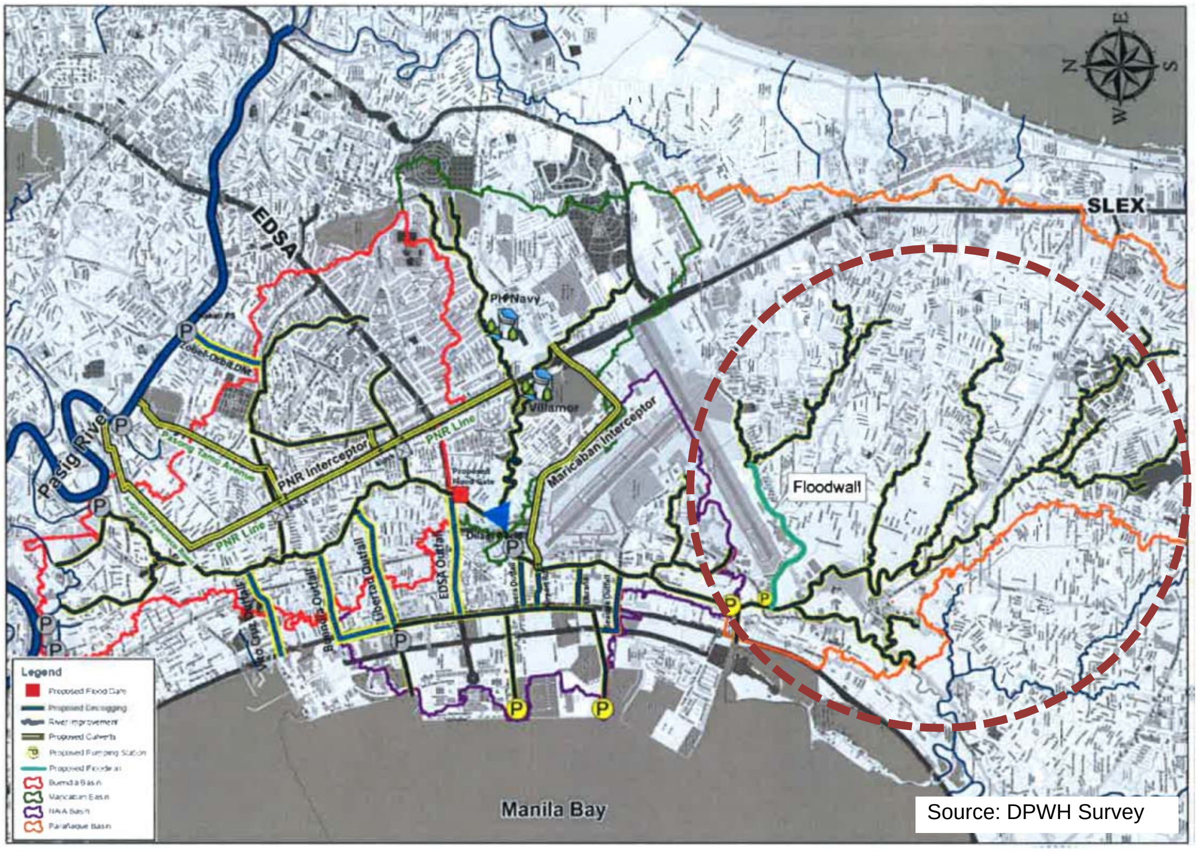
2.5.6 Parañaque

(1) Outline of the DPWH Survey Results

Catchment Area: 41.36 km2 (estimated by the JICA Survey Team)

Measure Menu: River channel dredging, construction of parapet walls, emergency pumping stations

As shown in the following figure, except flood walls and pumping stations, river channel dredging for the main stream and tributaries is proposed as the urgent project.



Source: DPWH Survey

Figure 2.5.10 River Improvement Plan for the Parañaque River

The design discharges are calculated by rational formula based on the rainfall intensity at the Port Area Station and are shown in the following table.

Table 2.5.20 Design Discharges for the Parañaque River(50-yr)

Project Site	Rainfall Station	Duration	Catchment Area (km^2)	Peak Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)
PARAÑAQUE					
Baliwag River	NAIA	60 mins	9.09	276.31	30.41
Don Galo River	NAIA	60 mins	15.39	510.57	33.17
San Dionisio River	NAIA	60 mins	10.22	90.62	8.86
San Isidro River	NAIA	60 mins	13.54	521.25	38.49
Las Piñas River	NAIA	60 mins	12.38	122.85	9.92
South Parañaque River	NAIA	60 mins	42.36	863.92	20.39
Parañaque River (Manila Bay)	NAIA	60 mins	57.23	1024.68	17.91

Source：DPWH-UPMO-FCMC and WEC

The project cost is estimated at Php 2.2 billion and as shown in the following table:

Table 2.5.21 Project Cost for the Parañaque River

Work Item	Priority1	Priority2	Priority3	Total
Dredging	363			363
Parapet Wall		1,823		1,823
Relief Pumping Station			60	60
Total	363	1,823	60	2,246

Source: DPWH Survey

Contents of the projects are as follows:

Priority 1: Dredging
- Baliwag: 5,000 m
- South Parañaque: 793 m
- San Dionisio: 2,831 m
- San Isidro: 6,809 m
- Don Bosco: 2,468 m

Priority 2: Parapet Wall
- Don Galo: 5,238m

Priority 3: Relief Pumping Station
- NAIA Pumping Station 1 m^3/sec

(2) Evaluation of the Plan Outline

Proposed measure for river improvement is dredging of existing river channel which is not difficult to implement. Also construction of addition pumping stations is feasible with the available open spaces.

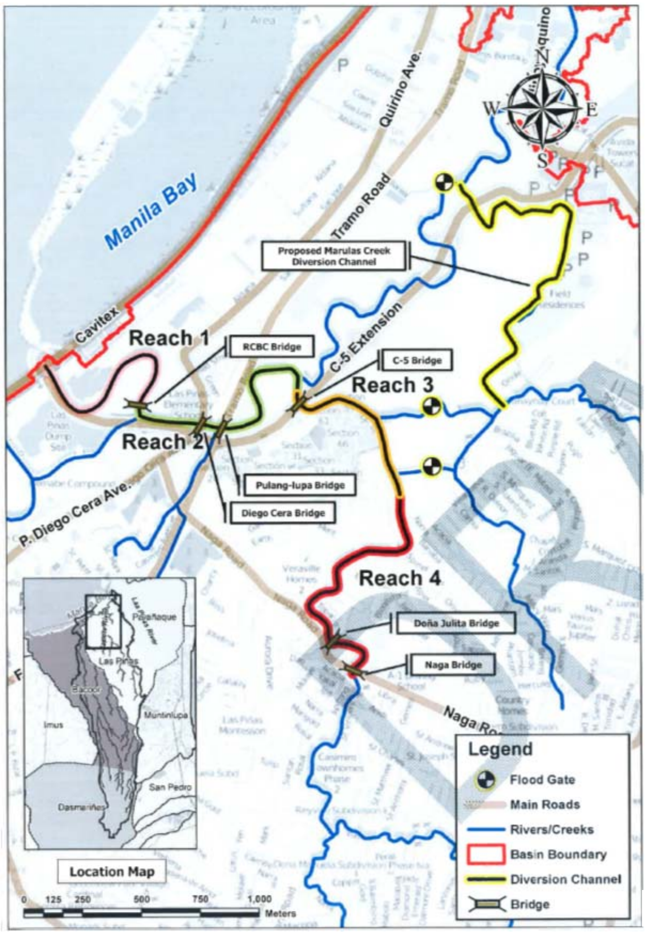
2.5.7 Las Piñas River

(1) Outline of the DPWH Survey Results

Catchment area: 16.58 km^2 (Estimated by the JICA Survey Team)

Measure menu: River channel dredging, arrangement of revetment, replacement of bridges, development of flood way

As shown in the following figure, there are 4 reaches of river improvement works of and the floodway. Reach 2-2 and replacement of bridges are proposed as the urgent projects.



Source: DPWH Survey

Figure 2.5.11 River Improvement Plan for the Las Piñas River

The design discharge of the Las Piñas is 197 m³/sec.

The project cost is estimated at Php 4.0 billion as shown in the following table:

Table 2.5.22 Project Cost for the Las Piñas River

Item	Main Civil Works	2015	2016	2017	2018	2019	2020	Total Cost
Reach 2-2	Dredging/Excavation		60					60
	Revetment Work		160					160
Pulang Lupa Br.	Bridge Reconstruction		85					85
Reach 1 RCBC			85					85
Sandbar	Dredging		315					315
Marula Creek	Diversion channel			387	157			544
Reach 3	Dredging/Excavation			46	23			69
	Revetment Work			123	61			184
C-5 Br.	Bridge Reconstruction			43	43			86
Reach 4	Dredging/Excavation				88	28		116
	Revetment Work				232	74		306
Doña Julita Br.	Bridge Reconstruction				43	43		86
Naga Br.					43	43		86
Reach 1	Dredging/Excavation					85		85
	Revetment Work					225		225
Cavitex Bridge	Bridge Reconstruction					200		200
Reach 2-1	Dredging/Excavation						36	36
	Revetment Work						94	94
Diego Cera Br.	Bridge Reconstruction						85	85
Compensation/Land Acquisitions Cost		220	220	220	220	220		1,100
Total Cost								4,007

Source: DPWH Survey

(2) Evaluation of the Plan outline

Although no detailed data was obtained, the plan was evaluated based on the data obtained from satellite image of Google Earth and site inspection. The evaluation results are in the following Table.

Table 2.5.23 The Plan Outline and Evaluation

No.	Reach	Outline	Remarks
1	Reach 2-2	The river improvement works of 30 m width and 4 m depth is proposed. The width of the existing river channel is about 14~15 m. The left bank is open space and relocation of people may not be required, but ROW is required.	Additionally provided data and Google Earth Data
2	Reach 3	The river improvement works of 24 m width and 4.5 m depth is proposed. The existing river channel width is about 12~13 m. In the left bank the residential area and road are located, but the right bank is open space. Relocation of people may not be reuired but ROW will be reqiered.	Additionally provided data and Google Earth Data
3	Reach 4	The river improvement works of 21 m width and 5 m depth is proposed. The existing river channel is 12 m width utmost and ROW will be required. At a part of the right bank upstream embankments like walls are observed.	Additionally provided data and Google Earth Data
4	Reach 1	The river improvement works of 36 m width and 3.5 m depth is proposed. The river mouth is wide enough, but at the upper part of the reach relocation of people may be required. At bents the river channel become narrow and ISFs are observed.	Additionally provided data and Google Earth Data
5	Reach 2-1	The river improvement works of 30 m width and 4 m depth is proposed. The existing river channel is about 20 m width and at the both banks structures like parapet walls are observed. Both relocation of people and ROW will be required.	Additionally provided data and Google Earth Data

2.5.8 Zapote River

(1) Outline of the DPWH Survey Results

Catchment Area: 50.34 km^2 (Estimated by JICA Survey Team)

Measure Menu: River channel dredging, arrangement of revetments, replacement of bridge.

The projects are composed of five river reaches and flood.

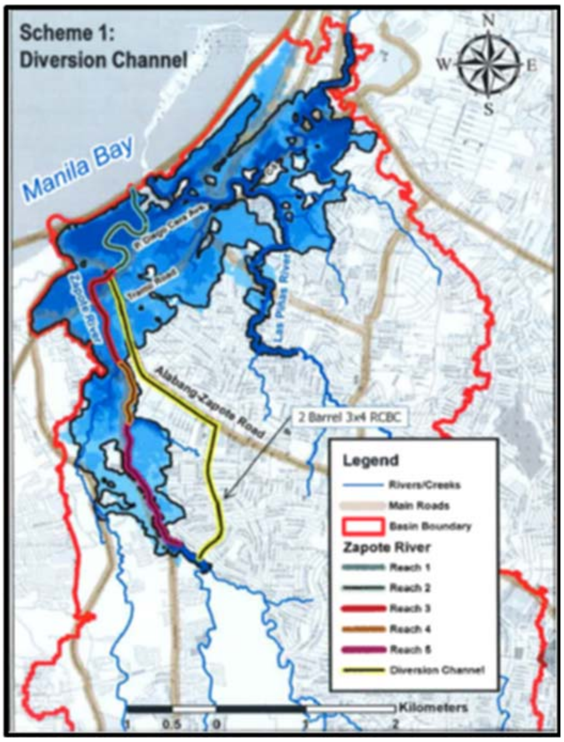
The design discharge is estimated at 70.3 m^3/sec (25-yr) at the downstream.

The project cost is estimated at Php 8.0 billion as shown in the following table.

Table 2.5.24 Project Cost forthe Zapote River

Zapote Area	Scheme 1
RIVER IMPROVEMENT COST	
A. Drainage and Excavation	908
B. Revetment Works	1,331
C. Bridge Reconstruction	685
Compensation/Land Acquisitions Cost	2,850
Diversion Channel	2,178
PROJECT COST (Mil. Php)	7,952

Source: DPWH Survey



Source: DPWH Survey

Figure 2.5.12 River Improvement Plan for the Zapote River

(2) Plan Outline and Evaluation

Although no detailed data was obtained, the plan was evaluated based on the data obtained from satellite image of Google Earth and site inspection. The evaluation results are in the following Table.

Table 2.5.25 The Plan Outline and Evaluation

No.	Reach	Outline	Remarks
1	Reach 1	The river improvement works of 99 m width is proposed. The width of the existing river channel is about 40~50 m. The right bank is not developed yet and relocation of people may not be required, but ROW is required.	Assumed by standard design cross section and Google Earth Data
2	Reach 2	The river improvement works for the reach require ROW.	Assumed by standard design cross section and Google Earth Data
3	Reach 3	The river improvement works are proposed to widen the existing channel more than double. The left bank is not developed yet and relocation of people may be not required, but ROW will be required.	Assumed by standard design cross section and Google Earth Data
4	Reach 4	The river improvement works are proposed to widen the existing channel more than double. Both the right and left banks are not developed yet and relocation of people are not required, but ROW will be required.	Assumed by standard design cross section and Google Earth Data
5	Reach 5	The river improvement works of 16 m width are proposed, but the existing channel is 13 m at most. Relocation of people along the channel may be required.	Assumed by standard design cross section and Google Earth Data
6	Diversion channel 1	No cross section is not available and neither is discharge data.	Assumed by standard design cross section and Google Earth Data

2.6 Technical Assistance and Surveys by the World Bank

2.6.1 Master Plan for Flood Management in Metro Manila and Surrounding Area(June 2012)

The Survey Area is as follows:

(1) Laguna Lake Basin

(2) Pasig‐Marikina River Basin (641 km^2)

(3) Malabon‐Tullahan River Basin (70 km^2)

(4) Meycauayan River Basin (171 km^2)

(5) South‐Paranaque‐Las Piñas River Basin (101 km^2)

(6) Inflow rivers to Laguna Lake (3,281 km^2)

(7) Drainage Basins such as the Manila Core Area, Malabon‐Navotas, Parañaque‐Las Piñas and others (108 km^2)

As for the core area of Metro Manila, drainage facilities and rehabilitation and improvement of drainage pumping stations proposed by the 2005 JICA M/P are proposed.

As one of the alternatives, the measures proposed by the 2005 JICA M/P plus underground storage in the North Manila Core Drainage System is proposed. The case with underground storage is also feasible, but it has a higher cost and also needs high and sophisticated technology for construction as well as operation and maintenance.

2.6.2 Metro Manila Flood Management Project, ‐ Phase I

DPWH/MMDA and the World Bank are currently finalizing the details of the “Metro Manila Flood Management Project, Phase I”. The project is composed of the following four (4) components:

Component I: Modernization of Drainage Area (2016 – 2021)

Component II: Minimizing Solid Wastes in Waterways (2016 ‐ 2021)

Component III: Participatory Housing and Resettlement (2016 ‐ 2018)

Component IV: Project Management, Support, and Coordination (2016 ‐ 2021)

Target Areas: Practically all of Metro Manila LGUs

Cost Sharing: 60% foreign financing, 40% NG share

The target of the rehabilitation in the first year is 10 major drainage pumping stations. The project aims to rehabilitate and construct a total of 90 stations in Metro Manila.

2.7 Usage of Public Land

The Survey plans to use the underground of the public lands as much as possible for the project.

2.7.1 Survey Results of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

The MLIT Survey has conducted hearing survey of DPWH and MMDA. The results of the survey show that there is no law and regulation for deep underground development and usage of deep underground of private land.

2.7.2 JICA Subway Survey

The Data Collection Survey on Subway System in Metro Manila shows the following views:

- Presently there is no law and regulation impeding the use of underground space.
- With regard to the underground space under a private land, the land owner has rights to get compensation for actual value.
- Under the current legal structure the user of underground space should pay compensation to the surface landowner.

CHAPTER 3. DRAINAGE PLAN

3.1 Hydrological Analysis

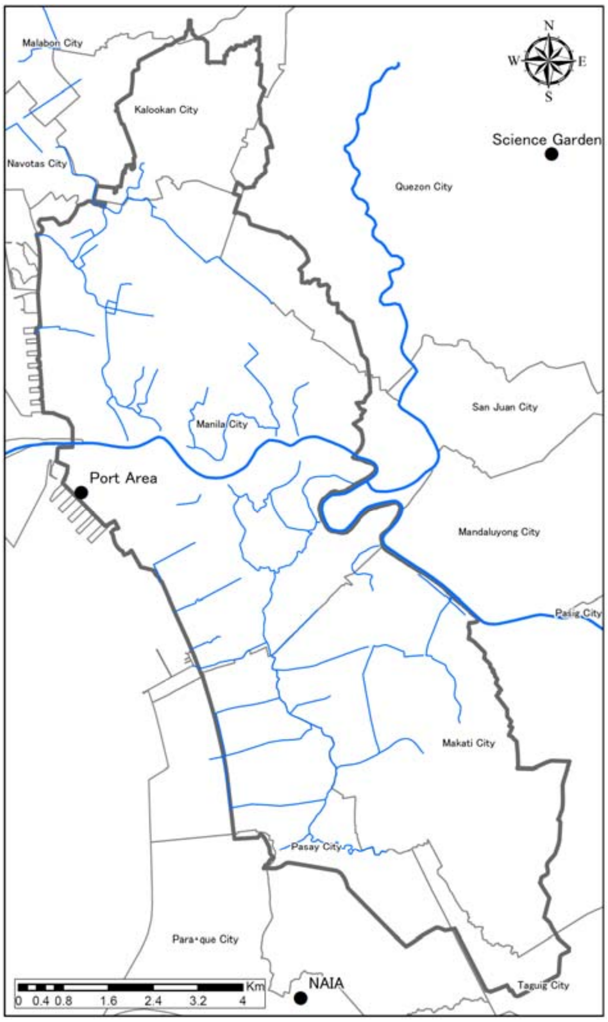
3.1.1 Collection of Rainfall Data

Daily rainfall data covering the river basin within the Study Area and the surrounding area were collected from PAGASA. The following table and figure show the specification and location of observation stations where the data were collected.

Table 3.1.1 Specification of Rainfall Observation Stations

No	Name	Code	Administrator	Location		Note
				latitude	longitude	
1	Port Area	425	PAGASA	14.589	120.966	Daily
2	NAIA	429	PAGASA	14.507	121.004	Daily
3	Science Garden	430	PAGASA	14.646	121.043	Daily

Source: JICA Survey Team



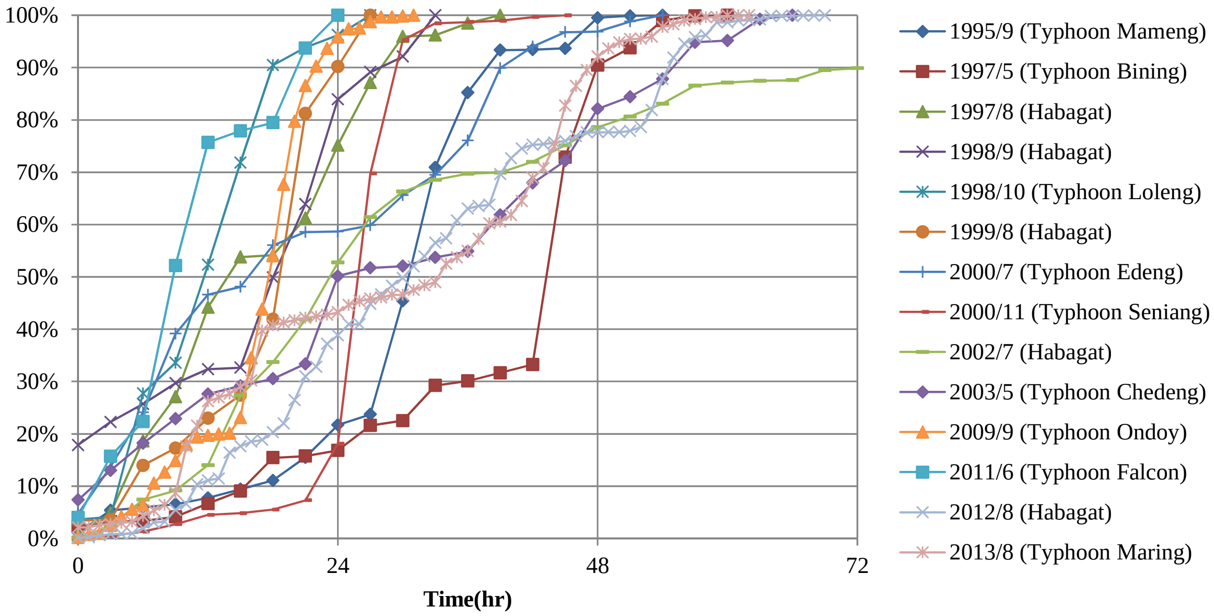
Source: JICA Survey Team

Figure 3.1.1 Location Map of Rainfall Gauging Station

3.1.2 Rainfall Analysis

(1) Rainfall Duration

The study on rainfall duration has been conducted to set the target rainfall. A cumulative rainfall curve was developed for the 14 major flood events around Metro Manila by utilizing the 6-hour rainfall data collected at the Port Area Observation Station of PAGASA. As for the 4 flood events, including those of October 1998, August 1999, June 2011, and September 2009 (Typhoon Ondoy), the rainfall events were converged within 24 hours. On the other hand, other flood events, except those of July 2002, May 2003, August 2012 (Monsoon rainfall or Habagat), August 2012 (Typhoon Maring), the rainfall events converged within 48 hours. Therefore, the target rainfall duration was set at 48 hours for the target study basin (Core Manila Basin).



Source: JICA Survey Team

Figure 3.1.2 Accumulative Rainfall Curve at Port Area Station

(2) Basin Mean Rainfall

For the rainfall data observed at three observation stations located in the target study area from 1961 to 2014 and the surrounding area, the annual maximum basin average one-day rainfall and two-day rainfall were calculated by applying the Thiessen Method. It should be noted herein that the Thiessen coefficient was calculated for each year by generating the different Thiessen patterns for 4 cases according to the data availability (missing data) at the stations. The following Figure and Table show the Thiessen segmentation and the calculated maximum basin average for a two-day rainfall, respectively.

Thiessen (1)

Thiessen (2)

Thiessen (3)

Thiessen (4)

Source: JICA Survey Team

Figure 3.1.3 Thiessen Polygons

Table 3.1.2 Annual Maximum Basin Average Rainfall

No	1-Day		2-days		Thiessen
	Date	Rainfall (mm)	Date	Rainfall (mm)	No
1	1961/6/27	224.1	1961/6/27	315.4	1
2	1962/7/23	177.8	1962/9/5	285.9	1
3	1963/9/8	149.9	1963/9/9	239.8	1
4	1964/6/29	227.0	1964/6/30	252.0	1
5	1965/7/26	100.1	1965/7/27	154.0	1
6	1966/9/5	139.1	1966/9/5	261.0	1
7	1967/6/7	161.8	1967/6/8	201.4	1
8	1968/8/28	99.2	1968/8/29	126.9	1
9	1969/7/26	84.5	1969/7/27	127.5	1
10	1970/9/1	325.0	1970/9/1	424.9	1
11	1971/11/14	88.3	1971/10/12	101.2	2
12	1972/7/20	300.0	1972/7/20	537.4	1
13	1973/10/15	105.2	1973/10/16	120.4	1
14	1974/8/17	172.0	1974/8/17	267.1	1
15	1975/10/18	161.1	1975/10/19	165.0	1
16	1976/8/10	256.0	1976/8/10	299.7	1
17	1977/8/19	189.5	1977/8/20	277.7	1
18	1978/10/9	217.4	1978/8/13	349.6	1
19	1979/6/21	108.8	1979/5/17	143.7	4
20	1980/5/24	67.4	1980/5/25	125.3	4
21	1981/6/24	233.7	1981/6/24	341.1	4
22	1982/7/22	88.7	1982/7/2	103.5	1
23	1983/7/15	83.0	1983/8/15	105.2	1
24	1984/8/7	80.9	1984/6/22	127.1	1
25	1985/6/27	264.0	1985/6/27	373.1	1
26	1986/10/5	240.9	1986/10/6	394.2	1
27	1987/8/18	92.5	1987/8/19	93.2	1
28	1988/10/13	109.5	1988/6/3	171.3	1
29	1989/8/13	97.7	1989/8/20	131.6	1
30	1990/8/24	222.8	1990/8/24	279.3	1
31	1991/7/26	145.8	1991/8/17	174.8	1
32	1992/10/25	143.2	1992/7/20	154.5	1
33	1993/8/27	83.1	1993/7/29	120.6	3
34	1994/8/2	118.2	1994/8/2	184.1	3
35	1995/8/29	134.0	1995/8/30	185.6	3
36	1996/9/17	101.3	1996/9/17	177.0	3
37	1997/8/18	234.4	1997/8/19	390.3	3
38	1998/10/23	128.7	1998/9/18	202.5	3
39	1999/10/16	187.6	1999/8/2	301.0	3
40	2000/10/28	176.3	2000/7/8	250.8	3
41	2001/7/19	172.8	2001/7/19	188.3	3
42	2002/7/20	244.0	2002/7/6	391.4	3
43	2003/9/2	123.4	2003/5/28	224.0	3
44	2004/11/29	112.5	2004/8/25	193.7	3
45	2005/10/27	92.0	2005/9/15	102.2	3
46	2006/7/23	95.6	2006/7/24	171.3	3
47	2007/8/17	153.5	2007/8/18	203.9	3

No	1-Day		2-days		Thiessen No
	Date	Rainfall (mm)	Date	Rainfall (mm)	
48	2008/6/22	121.2	2008/6/22	171.2	3
49	2009/9/26	272.9	2009/9/26	341.6	3
50	2010/7/13	127.2	2010/7/13	131.6	3
51	2011/6/24	205.5	2011/6/24	385.5	1
52	2012/8/7	360.4	2012/8/7	664.0	3
53	2013/8/19	288.4	2013/8/19	550.1	1
54	2014/9/19	107.2	2014/9/19	207.5	1

Source: JICA Survey Team

(3) Probable Rainfall

Rainfall analysis has been conducted based on the annual maximum basin average rainfall as discussed in a previous section. For the analysis, a program named as "Hydrological Statistics Utility" developed by the Japan Institute of Country-ology and Engineering was used. First, the probability hydrological amount was calculated by the probability distribution model as shown in Table 3.1.3, then a fitness evaluation was done by SLSC, and finally the distribution model was selected by considering the results of the stability evaluation of estimation which gives the minimum estimation error. Table 3.1.4 to Table 3.1.6 show the calculation results while Figure 3.1.4 and Figure 3.1.5 show the probability distribution.

Table 3.1.3 Probable Distribution Model

Name	Abbr	Name	Abbr
Exponential Distribution	Exp	Ishihara/Takase Method	Ishihara
Gumbel Distribution	Gumbel	Log-normal Distribution (Quantile Method)	LN3Q
Extreme Value Distribution	Gev	Log-normal Distribution 3 (Slade II)	LN3PN
Square-root Exponential Type Maximum Distribution	Sqrt-Et	Log-normal Distribution 2 (Slade I L-moment Method)	LN2LM
Peason Type III Distribution (Real Space)	LP3Rs	Log-normal Distribution 2 (Slade I, Product moment method)	LN2PM
Peason Type III Distribution (Logarithmic Space)	LogP3	Log-normal Distribution 4 (Slade I, Product moment method)	LN4PM
Iwai Method	Iwai		

Source: Japan Institute of Country-ology and Engineering

Table 3.1.4 Probable Rainfall

Probability	1-Day	2-Days
2	150.7	209.7
3	181.8	259.1
5	216.3	318.8
10	259.8	401.1
20	301.5	488.1
25	314.7	517.4
30	325.4	541.8
50	355.4	612.9
80	382.8	681.7
100	395.8	715.7
150	419.4	779.4
200	436.1	826.2
400	476.3	944.6
Distribution Model	Gumbel	Gev

Source: JICA Study Team

Table 3.1.5 Probable Rainfall

Item	Return Period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Probable Rainfall	2	138.3	150.7	144.7	147.9	153.7	146.4	145.9	－	146.0	－	148.7	148.7	－
	3	170.8	181.8	173.7	178.3	185.9	176.5	176.2	－	176.1	－	179.8	178.9	－
	5	211.8	216.3	208.8	213.4	219.9	212.1	212.3	－	211.6	－	215.4	213.3	－
	10	267.5	259.8	256.8	259.5	259.3	259.8	260.5	－	258.9	－	261.4	257.5	－
	20	323.1	301.5	307.1	305.9	294.0	308.7	309.5	－	306.8	－	306.6	300.8	－
	25	341.0	314.7	323.9	321.1	304.4	324.8	325.7	－	322.5	－	321.2	314.8	－
	30	355.6	325.4	337.8	333.6	312.6	338.2	339.0	－	335.5	－	333.2	326.2	－
	50	396.6	355.4	378.1	369.4	334.7	376.7	377.1	－	372.6	－	367.1	358.4	－
	80	434.4	382.8	416.8	403.2	353.9	413.5	413.3	－	407.7	－	398.6	388.4	－
	100	452.3	395.8	435.7	419.6	362.6	431.6	430.9	－	424.8	－	413.8	402.8	－
	150	484.8	419.4	471.0	450.0	378.0	465.2	463.5	－	456.4	－	441.7	429.2	－
	200	507.9	436.1	496.7	472.1	388.5	489.8	487.3	－	479.4	－	461.8	448.2	－
	400	563.5	476.3	561.4	526.9	412.6	551.8	546.5	－	536.6	－	511.2	494.8	－
JackKnife Estimate Value	2	138.3	150.7	144.4	147.8	152.0	146.3	144.8	－	149.1	－	148.5	148.5	－
	3	170.8	181.8	173.7	178.3	184.4	176.4	175.4	－	179.2	－	179.4	178.6	－
	5	211.8	216.3	209.1	213.7	219.3	212.1	212.1	－	213.1	－	214.9	213.0	－
	10	267.5	259.8	257.6	260.2	261.0	259.6	261.5	－	255.5	－	260.6	257.1	－
	20	323.1	301.5	308.3	306.6	298.5	308.0	312.0	－	295.6	－	305.5	300.3	－
	25	341.0	314.7	325.2	321.8	309.9	324.0	328.7	－	308.1	－	320.0	314.2	－
	30	355.6	325.4	339.3	334.2	319.0	337.1	342.4	－	318.3	－	331.9	325.6	－
	50	396.6	355.4	380.0	369.3	343.6	374.8	381.8	－	346.4	－	365.4	357.6	－
	80	434.4	382.8	419.0	402.2	365.2	410.6	419.3	－	371.8	－	396.6	387.5	－
	100	452.3	395.8	438.1	418.0	375.1	428.0	437.5	－	383.7	－	411.7	401.8	－
	150	484.8	419.4	473.8	446.9	392.6	460.3	471.3	－	405.0	－	439.2	428.0	－
	200	507.9	436.1	499.8	467.6	404.7	483.8	495.9	－	420.0	－	459.1	446.9	－
	400	563.5	476.3	565.1	518.1	432.6	542.5	557.3	－	455.3	－	507.9	493.2	－
JackKnife Estimate Error	2	8.2	8.9	8.8	11.7	11.0	10.4	10.3	－	10.1	－	8.7	8.7	－
	3	10.3	11.2	11.8	14.3	13.3	12.8	12.6	－	12.3	－	11.3	11.1	－
	5	13.6	14.0	15.8	16.3	15.4	15.2	15.1	－	14.8	－	14.9	14.4	－
	10	18.5	17.8	21.6	18.1	17.4	18.4	18.8	－	20.2	－	20.2	19.3	－
	20	23.5	21.5	27.9	20.9	19.5	22.5	23.9	－	29.8	－	26.1	24.7	－
	25	25.2	22.8	30.1	22.4	20.3	24.2	25.9	－	33.8	－	28.1	26.5	－
	30	26.6	23.7	31.9	24.0	21.1	25.7	27.7	－	37.5	－	29.8	28.1	－
	50	30.4	26.5	37.2	30.0	23.7	31.1	33.5	－	49.3	－	34.8	32.6	－
	80	33.9	29.1	42.4	37.9	26.7	37.3	39.7	－	62.3	－	39.5	36.9	－
	100	35.6	30.3	45.0	42.4	28.3	40.8	43.0	－	69.1	－	41.9	39.1	－
	150	38.7	32.5	49.8	52.1	31.7	48.0	49.5	－	82.8	－	46.4	43.1	－
	200	40.9	34.1	53.3	60.0	34.3	53.9	54.6	－	93.3	－	49.7	46.1	－
	400	46.2	37.9	62.3	82.7	41.4	70.5	68.3	－	122.0	－	58.0	53.7	－
X-COR		0.976	0.988	0.979	0.985	0.989	0.983	0.983	－	0.984	－	0.987	0.988	－
P-COR		0.992	0.990	0.992	0.992	0.989	0.993	0.993	－	0.993	－	0.992	0.992	－
SLSC		0.046	0.031	0.037	0.034	0.051	0.034	0.034	－	0.034	－	0.036	0.037	－
Select			✓											

Source: JICA Survey Team

Table 3.1.6   Probable Rainfall

Item	Return Priod	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Probable Rainfall	2	198.8	219.6	208.2	210.0	216.9	208.1	211.4	213.5	202.8	−	213.2	213.2	−
	3	253.3	271.6	255.4	259.0	270.3	257.3	261.0	263.9	253.0	−	263.9	262.7	−
	5	321.9	329.5	312.8	318.2	330.3	317.9	320.0	322.6	317.2	−	323.6	320.7	−
	10	415.1	402.2	392.1	399.8	405.3	402.4	398.8	399.5	409.7	−	402.5	397.1	−
	20	508.2	472.0	475.6	486.5	476.2	492.6	479.0	476.3	510.7	−	481.9	473.7	−
	25	538.2	494.1	503.5	515.8	498.5	523.1	505.4	501.3	545.3	−	507.9	498.6	−
	30	562.6	512.1	526.8	540.4	516.5	548.7	527.1	521.8	574.3	−	529.3	519.2	−
	50	631.3	562.3	594.2	612.4	566.4	623.6	589.4	580.2	659.6	−	590.3	577.7	−
	80	694.4	608.2	659.1	682.9	611.6	697.0	648.5	635.1	743.6	−	647.8	632.7	−
	100	724.4	629.9	690.8	718.0	632.8	733.4	677.3	661.6	785.4	−	675.7	659.4	−
	150	778.9	669.4	750.3	784.5	671.2	802.5	730.6	710.6	864.6	−	727.3	708.6	−
	200	817.5	697.3	793.7	833.9	698.2	853.8	769.3	745.9	923.4	−	764.7	744.3	−
	400	910.6	764.6	902.9	961.4	762.7	985.9	866.1	833.6	1074.7	−	857.6	832.7	−
JackKnife Estimate Value	2	198.8	219.6	207.7	209.7	213.8	207.7	213.3	213.9	202.5	−	212.7	212.7	−
	3	253.3	271.6	255.2	259.1	266.8	257.2	263.0	266.1	253.1	−	263.2	262.2	−
	5	321.9	329.5	313.1	318.8	327.9	317.8	320.6	326.3	317.6	−	322.5	320.1	−
	10	415.1	402.2	393.0	401.1	406.5	402.0	395.4	404.2	409.9	−	400.7	396.2	−
	20	508.2	472.0	477.1	488.1	483.1	491.0	469.4	480.7	509.7	−	479.3	472.4	−
	25	538.2	494.1	505.3	517.4	507.5	520.9	493.3	505.3	543.6	−	504.9	497.2	−
	30	562.6	512.1	528.8	541.8	527.5	545.9	512.8	525.5	572.1	−	526.1	517.7	−
	50	631.3	562.3	596.7	612.9	583.2	618.6	568.0	582.3	655.2	−	586.2	575.7	−
	80	694.4	608.2	662.1	681.7	634.4	689.1	619.4	635.1	736.4	−	642.8	630.4	−
	100	724.4	629.9	694.2	715.7	658.7	723.9	644.1	660.4	776.6	−	670.2	656.8	−
	150	778.9	669.4	754.1	779.4	702.8	789.3	689.4	706.7	852.5	−	720.9	705.5	−
	200	817.5	697.3	797.9	826.2	734.1	837.4	721.9	739.9	908.6	−	757.6	740.8	−
	400	910.6	764.6	908.1	944.6	809.6	959.7	801.5	821.3	1051.7	−	848.7	828.2	−
JackKnife Estimate Error	2	13.3	15.1	14.3	17.2	16.5	16.0	15.5	17.3	13.3	−	14.1	14.1	−
	3	18.3	20.3	19.4	21.9	21.4	20.5	19.9	22.2	18.0	−	19.1	18.8	−
	5	25.9	26.8	26.2	27.0	27.6	26.3	25.9	27.6	26.2	−	26.2	25.5	−
	10	36.9	35.4	36.3	35.2	36.7	36.0	36.4	35.8	42.4	−	37.4	35.9	−
	20	48.3	43.9	47.3	47.9	47.4	49.8	50.5	46.8	65.0	−	49.9	47.7	−
	25	52.0	46.6	51.1	53.4	51.4	55.3	55.8	51.1	73.7	−	54.3	51.7	−
	30	55.0	48.8	54.3	58.5	54.8	60.4	60.5	54.9	81.3	−	58.0	55.1	−
	50	63.6	55.0	63.6	76.1	65.3	76.8	75.0	66.7	105.3	−	68.8	65.2	−
	80	71.4	60.7	72.6	96.9	76.3	95.4	90.2	79.5	130.8	−	79.6	75.1	−
	100	75.2	63.4	77.1	108.4	81.9	105.5	98.1	86.1	144.1	−	84.9	80.1	−
	150	82.0	68.3	85.6	132.5	92.9	126.0	113.5	99.1	170.4	−	95.0	89.4	−
	200	86.8	71.8	91.8	152.0	101.3	142.5	125.2	109.1	190.7	−	102.6	96.3	−
	400	98.5	80.2	107.6	208.6	123.4	188.9	156.4	135.8	245.8	−	121.8	114.1	−
X-COR		0.976	0.992	0.989	0.993	0.992	0.992	0.992	0.994	0.994	0.988	−	0.994	0.994
P-COR		0.992	0.994	0.992	0.995	0.995	0.994	0.996	0.995	0.995	0.996	−	0.995	0.995
SLSC		0.046	0.026	0.032	0.027	0.025	0.041	0.026	0.029	0.032	0.025	−	0.031	0.031
Select					✓									

Source: JICA Survey Team

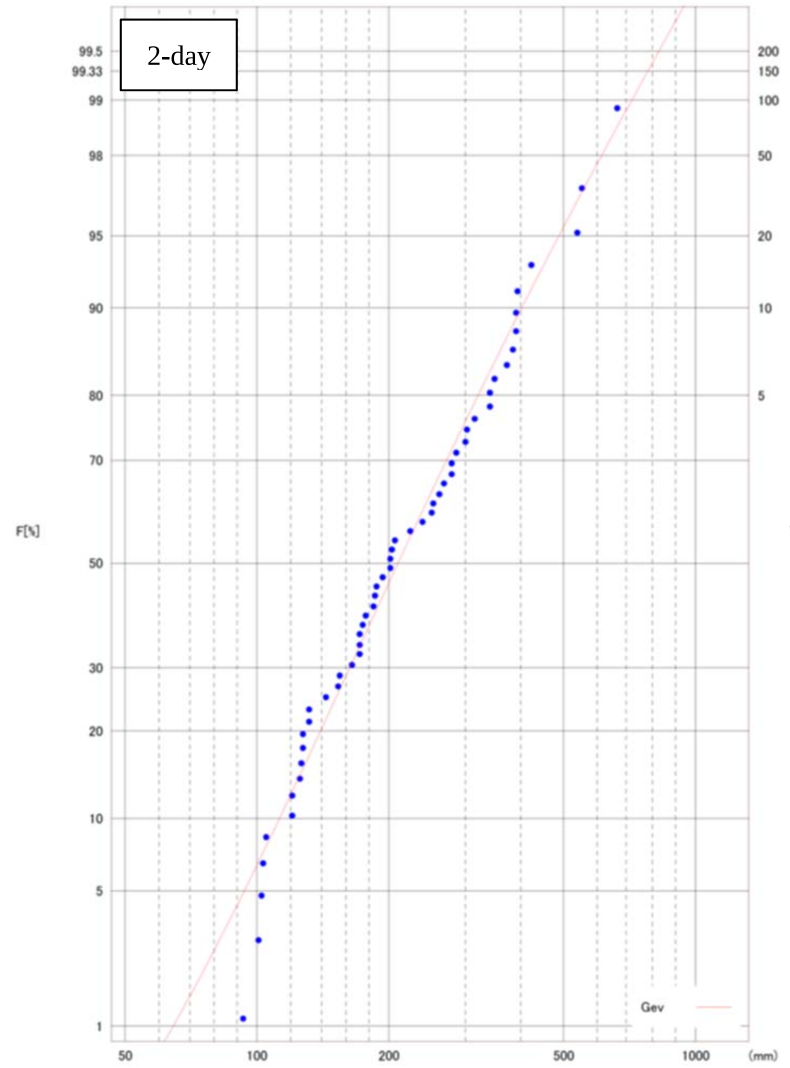


Figure 3.1.5 The Calculation Results of the Probability Rainfall (Two-Day Rainfall)

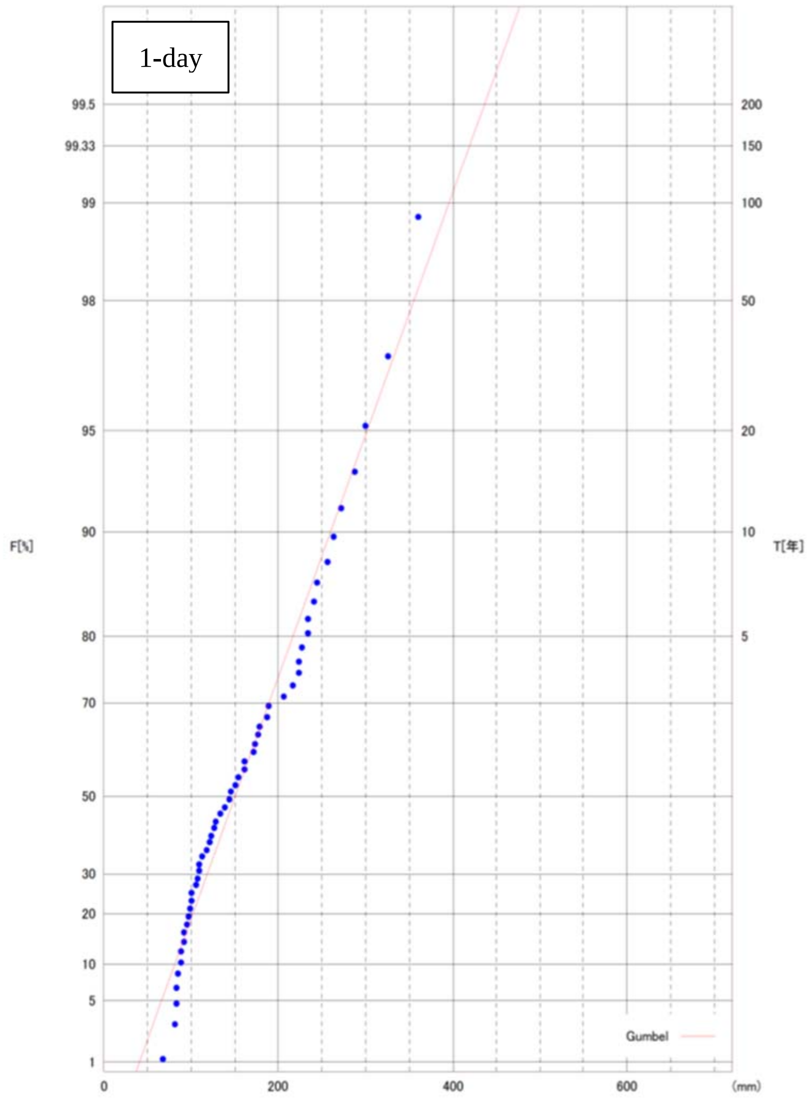


Figure 3.1.4 The Calculation Results of the Probability Rainfall (One-Day Rainfall)

Source: JICA Survey Team

(4) Wave Profile of Rainfall

(a) The Selection of Target Rainfall

Subject to the wave profile of rainfall, three rainfall events were selected from past records as shown below. These three rainfalls represent the recent rainfall events which caused serious damage to Metro Mania. In addition to these three, a hyetograph of centralized model was generated/

- Typhoon Ondoy, 2009
- Monsoon Rainfall Habagat, 2012
- Typhoon Maring, 2013

(b) Equation of Rainfall Intensity

To generate the hyetograph of centralized model, the data on rainfall intensity is needed in order to apply the formula of short-term rainfall. Among the rainfall stations located within the target study basin area and the surrounding area, the short-term rainfall is observed at the Port Area Station and Science Garden Station. Therefore, the rainfall intensity formula at the Port Area Station which is the closest station to the target basin was selected.

As for the hyetograph of centralized model, the 24-hour rainfall of one hour pitch and 48-hour model hyetograph were generated based on the rainfall intensity formula as below:

$I = a / (T^n + b)$

I：rainfall intensity (mm/hr), T： rainfall duration (min), a, b, n： constant

Table 3.1.7 Constant Values for Rainfall Intensity Formula (Port Area Station)

Return Period	constant		
(年)	N	a	b
2	0.73	1,428	6.42
5	0.71	1,767	6.35
10	0.69	1,841	5.56
20	0.69	2,130	5.92
25	0.68	2,075	5.39
30	0.68	2,143	5.46
50	0.68	2,337	5.64
100	0.67	2,425	5.23

Source: JICA Survey Team

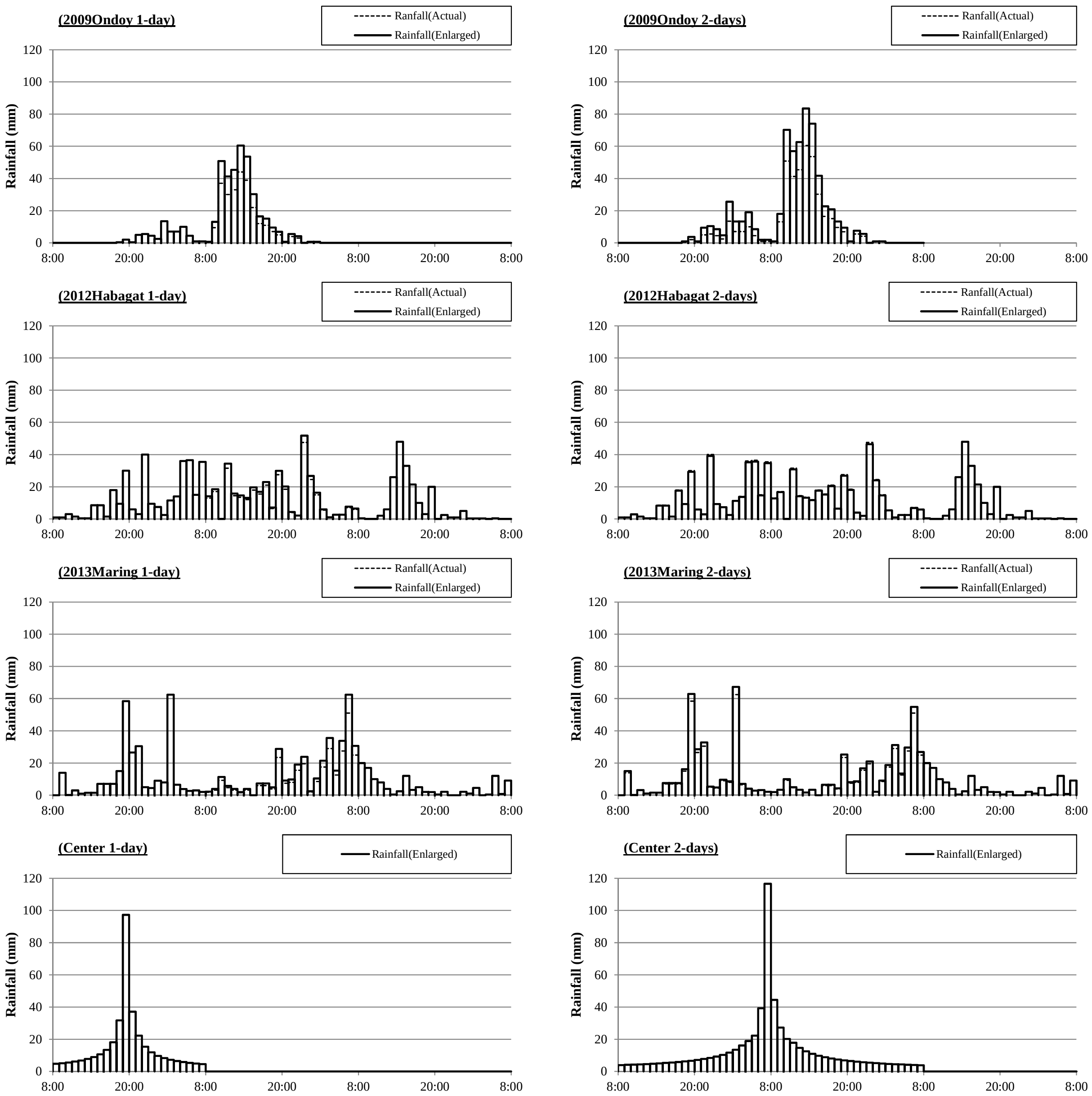
Table 3.1.8 Probability Rainfall Intensity of Hourly Rainfall Duration (Port Area Station)

Return Period	The Probability Rainfall Intensity of Hourly Rainfall Duration					
(year)	1-hour	3-hour	6-hour	12-hour	24-hour	48-hour
2	54.3	28.2	17.9	11.1	6.8	4.2
5	71.7	38.2	24.7	15.6	9.8	6.0
10	82.1	44.3	28.9	18.6	11.8	7.4
20	93.5	50.8	33.3	21.4	13.6	8.5
25	96.2	52.5	34.5	22.3	14.2	9.0
30	99.0	54.1	35.6	23.0	14.7	9.3
50	107.1	58.7	38.7	25.0	16.0	10.1
100	116.8	64.4	42.7	27.8	17.8	11.4

Source: JICA Survey Team

(c) Target Rainfall Wave Profile

The wave profile of the target rainfall was prepared by enlarging or shortening the selected wave profile of the rainfall in order to match the rainfall amount of target rainfall duration time with the rainfall amount at various probability scale. The created hyetograph is shown below.



Source: JICA Survey Team

Figure 3.1.6 Target Rainfall Wave Profile

3.2 Present Condition of Drainage and Pumping Station

It is important to recognize flow capacity of existing drainages and capacity of pumping stations and to develop flood simulation model accurately in order to evaluate the effect of the project properly. Therefore, simple evaluation of drainages and pumping stations are carried out as shown below.

3.2.1 Condition in DICAMM 2005

Under the DICAMM 2005, the following condition and issues were pointed out.

- The discharge capacity of existing drainage channels was assessed to be performing less than the peak discharge of a 2-year return period, though they were designed to have the capacity of a 10-year return period.
- The capacity of existing drainage channels are in need of rehabilitation.
- There is a need to improve and recover through dredging/de-clogging, related works and additional facilities.

3.2.2 Existing Drainages or Estero

(1) Maintenance Work of Drainage System by MMDA

MMDA is carrying out drainage system maintenance works such as 1) Drainage Improvement, 2) Dredging, 3) De-clogging and 4) Revetment as a flood control project in Metro Manila described in Chapter 2.

(2) Verification of Cross Section of Estero by LiDAR Data

The cross section data gathered by the JICA Survey Team were the ones obtained or surveyed in DICAMM 2005 and may not correspond to current condition. Hence the cross sections shown in Figure 3.2.1 were verified using LiDAR data of 1m grid size (AusAID, 2011).

The comparison result is shown in Figure 3.2.2. It shows that LiDAR data was not able to delineate cross section of drainage, however, some cross sections were not so different and some showed increase of sedimentation.

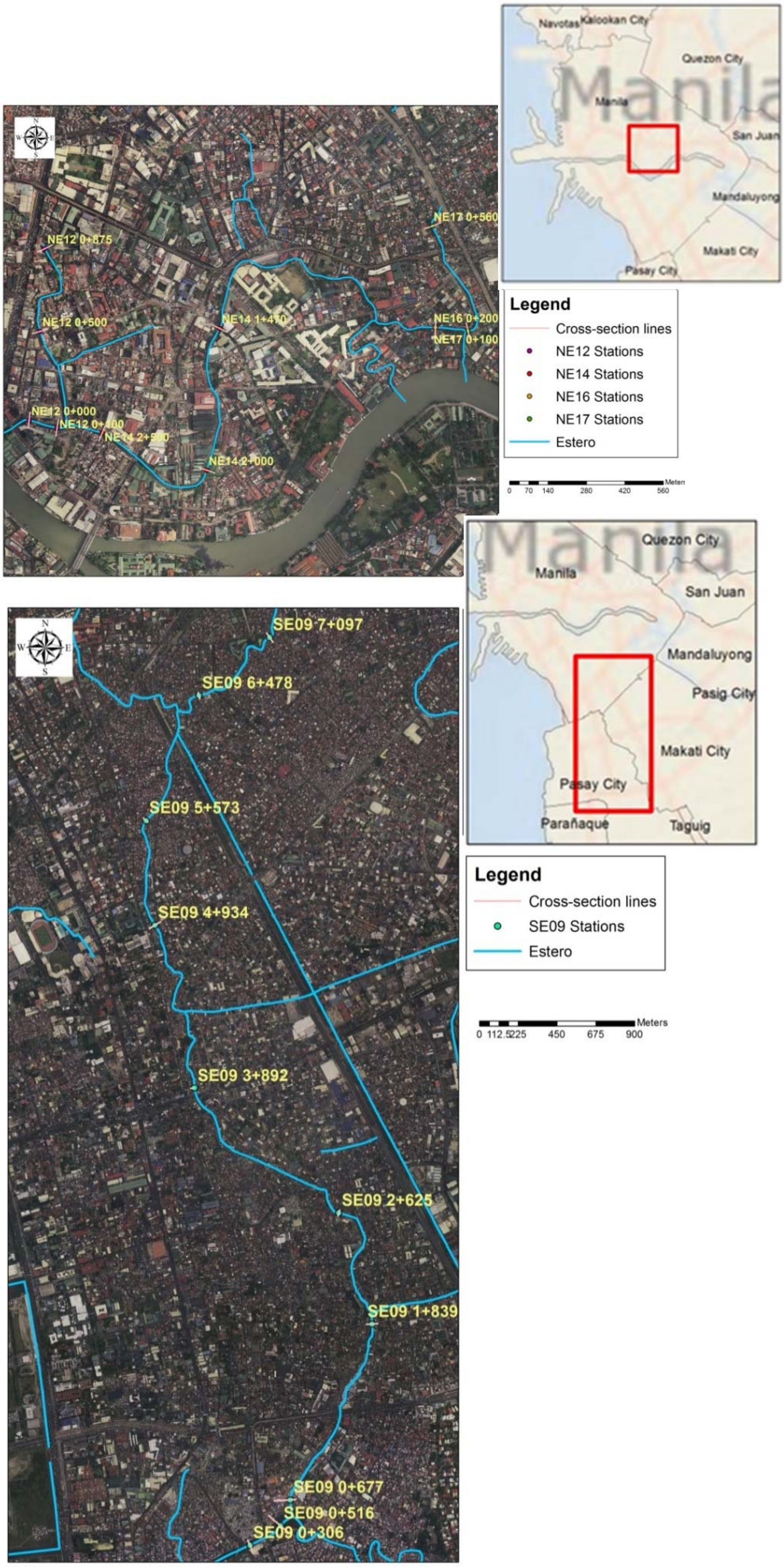


Figure 3.2.1 Location Map of Verified Cross Sections by LiDAR Data

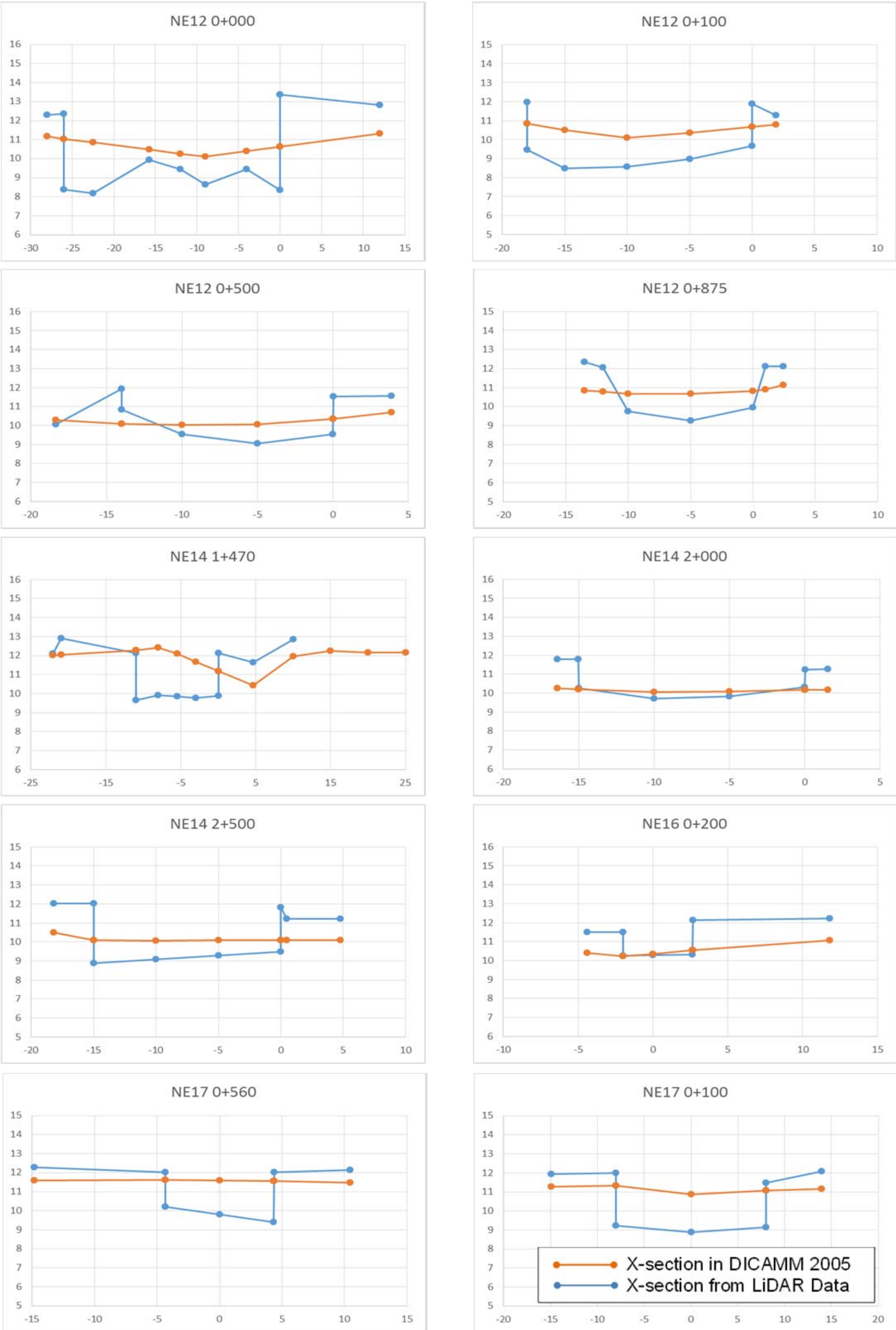


Figure 3.2.2 Comparison of Cross Section (North)

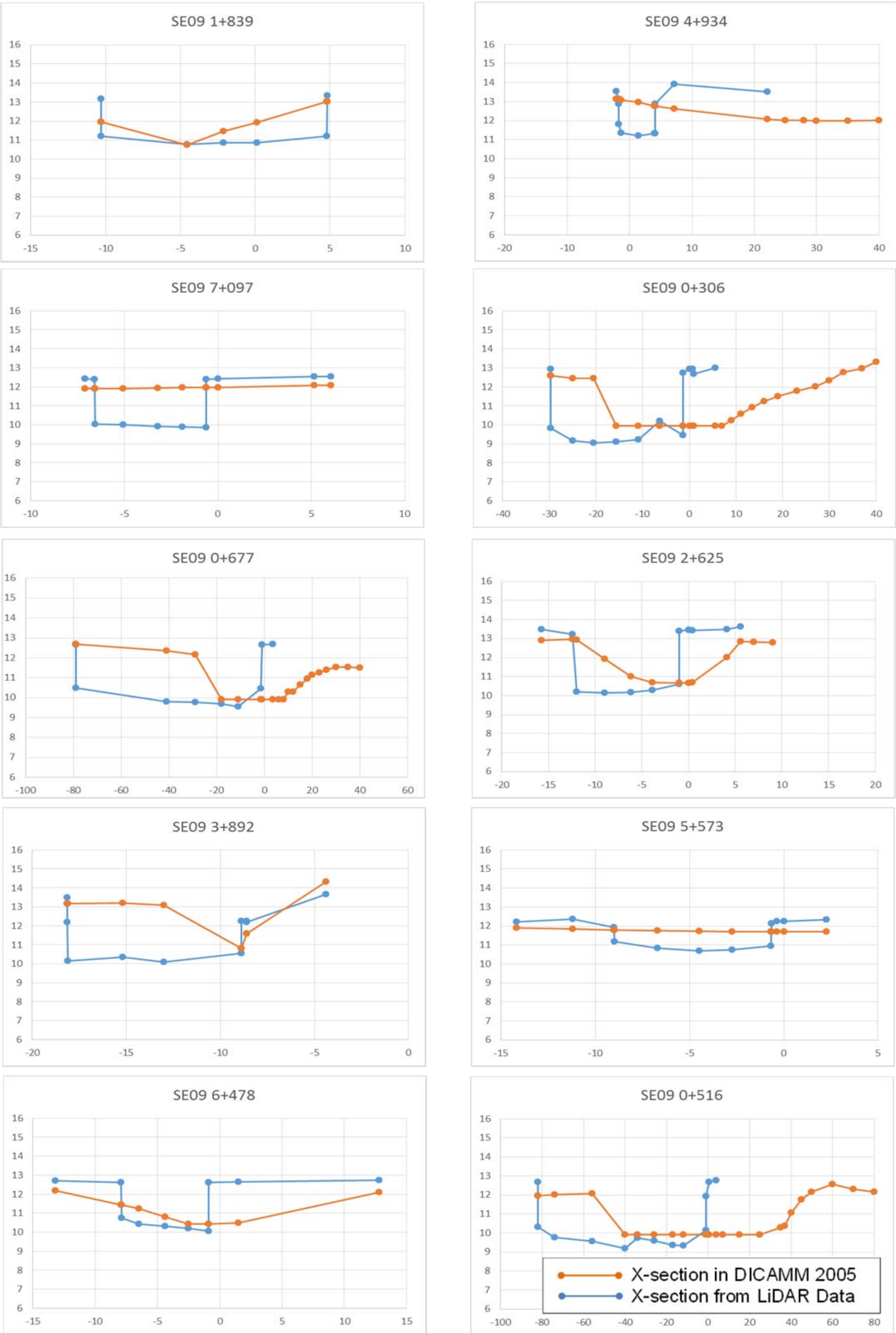
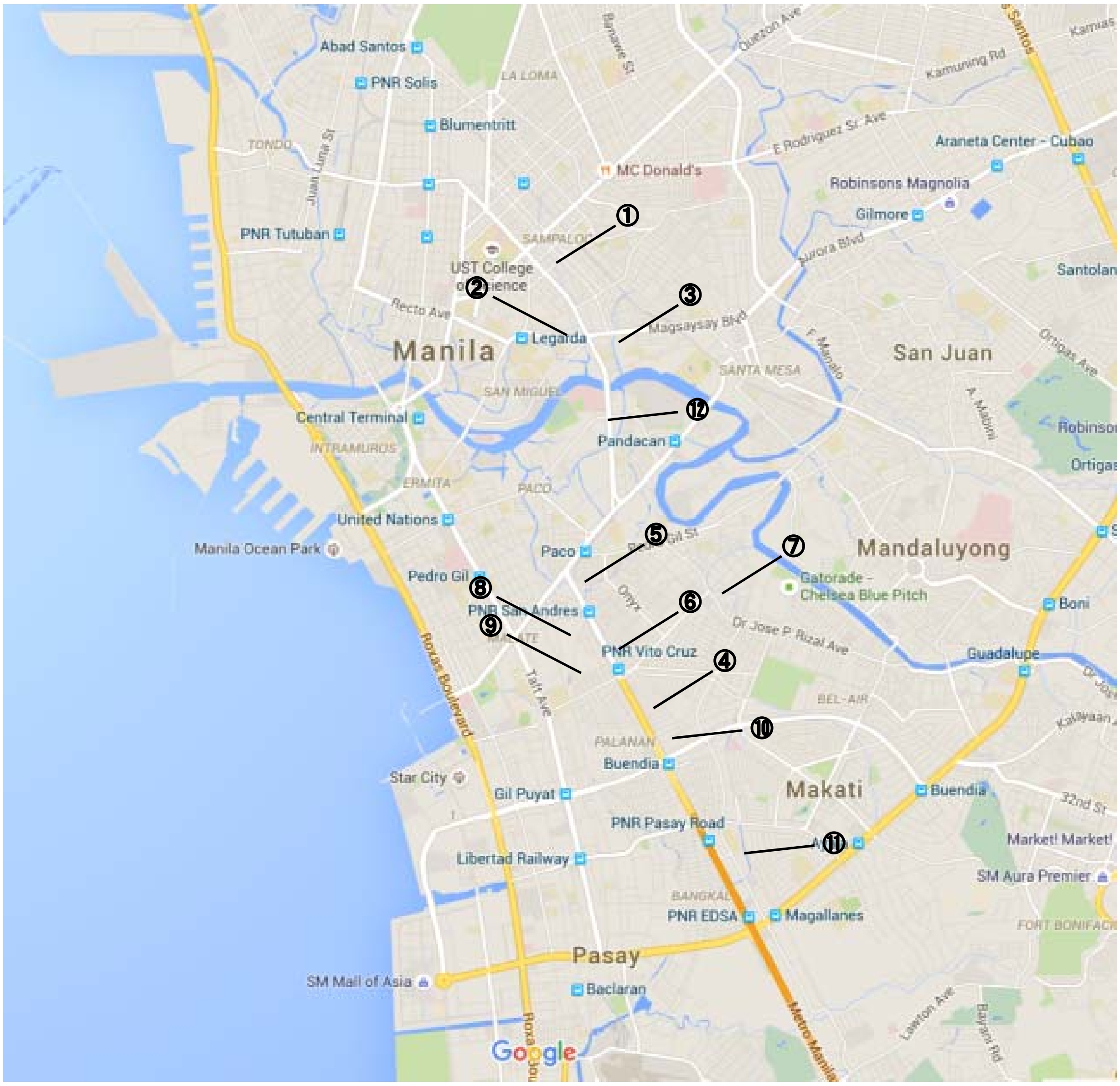


Figure 3.2.3 Comparison of Cross Section (South)

(3) Site Inspection

Site visits were conducted to verify the present condition of the drainage system. Some drainage channels are not properly maintained based on the presence of significant amount of sediment and garbage contributing to the obnoxious smell (see pictures below). Flow capacity of drainage system in Metro Manila is quite limited because some parts of the drainage showed 1) no difference between water level of drainage channel and ground elevation, 2) clearance of Box Culvert is less than 0.2m and 3) no water flow due to clogged channel.



Source: JICA Survey Team

Figure 3.2.4 Location Map of Pictures of Drainages

	
① Estero de Sampaloc I Outlet of DM under Lacson Ave. Wide but water level is high. Flow capacity is limited.	②Estero de San Miguel Facing north from Jose Laurel St. Sediment deposition and garbage accumulation is seen.
	
③Estero de Valencia Upstream of Valencia Pumping Station Sediment deposit is seen but there is bigger allowance of drainage than South Manila.	④PNR Creek Sedimentation in the channel. Waterway intersects the cross. The width of the entire drainage are of the same size.
	
⑤Estero passing under PNR to the west Plants and flowers are growing thickly. The vegetation will retard the natural draining of flood. This is the project of the Pasig River Rehabilitation Commission (PRRC).	⑥PNR Creek Box culvert seems to be clogged. The channel cannot drain even small rainfall.

Figure 3.2.5 Condition of Drainage (1)

	
⑦Santa Clara Creek Facing downstream from H. Santos Street. Flow capacity is quite small due to soil sedimentation.	⑧Estero de Tripa de Gallina Dredging operations were stopped. Substantial volume of soil is deposited.
	
⑨Estero de Tripa de Gallina Facing north from Ocampo St. Sediment deposition and garbage accumulation is present. Right side of the picture is ISF’s house.	⑩PNR Creek Corrugated pipe under road. Flood cannot be drained in this situation.
	
⑪Makati Diversion Facing downstream from Chino Roces Ave. (Pasong Tamo Ave.) (seeing west direction)	⑫Pandacan Creek Northeast direction from President Quirino Ave. Substantial volume of soil is deposited.

Figure 3.2.6 Condition of Drainage (2)

3.2.3 Condition of Pumping Stations

(1) Existing Pumping Stations

There are 54 pumping stations including relief stations with small capacity in Metro Manila as shown in Figure 3.2.7 and Table 3.2.1.

Table 3.2.1 Pumping Stations in Metro Manila

Name of Pumping Station		Pump Capacity (m^3/sec)	Drainage Area (ha)	REMARKS	
I. FOREIGN/LOCAL ASSITED PUMPING STATIONS:					
I-1	Tripa de Gallina P. S.	70.00	1,769	rehabilitated on 2015	*
I-2	Libertad P.S.	42.00	779	rehabilitated on 2015	*
I-3	Vitas P.S.	32.00	578		*
I-4	San Andres P.S.	19.00	356		
I-5	Avilles P.S.	18.12	356	rehabilitated on 2015	
I-6	Binondo P.S.	18.12	279	rehabilitated on 2015	
I-7	Valencia P.S.	14.00	246	rehabilitated on 2015	
I-8	Quiapo P. S.	14.52	225	rehabilitated on 2015	
I-9	Paco P.S.	7.59	182	rehabilitated on 2015	*
I-10	Makati P.S.	7.00	1541	rehabilitated on 2015	*
I-11	Sta. Clara P.S.	5.30	133	rehabilitated on 2015	*
I-12	Pandacan P.S.	5.50	180	rehabilitated on 2015	
I-13	Balete P.S.	4.80	52	rehabilitated on 2015	*
I-14	Balut P.S.	2.00	49		*
I-15	Escolta P.S.	1.50	with Binondo P.S.		*
I-16	Abucav P.S.	1.60	312		
I-17	Uli-Uli P.S.	6.00	with Aviles P.S.		
I-18	Balong-Bato P.S.	2.00	18.72		
I-19	Salapan P.S.	2.00	18		
II. WEST OF MANGGAHAN:					
II-1	Tapayan P. S.	15.00	526		
II-2	Labasan P.S.	9.00	601		*
II-3	Taguig P.S.	12.00	1,423		
II-4	Hagonoy P.S.	6.00	528		
III. LOCALLY FUNDED SMALL PUMPING STATIONS PROJECT:					
III-1	Arroceros P. S.	2.40	6	rehabilitated on 2015	
III-2	Luneta Park P. S.	0.37	15		
III-3	Central Post Office P.S.	0.07	3.5		
III-4	Jones Bridge Underpass P.S. (North side)	0.10	1		
III-5	Jones Bridge Underpass P.S. (North side)	0.07	1		
III-6	Ste. Bañez P.S.	0.34	10		
III-7	San Francisco P.S.	1.80	17		
III-8	Ayala Tunnel P.S.	3.00	0.5		
III-9	San Agustin P.S.	592	3		
III-10	Ilugin P.S.	1.00	75		
III-11	Aurora P.S.	592	1		
III-12	Tuazon P.S.	592	1		
III-13	Aurora P.S.	0.60	2.8		
III-14	Libis P.S.	0.08	2		
IV. RELIEF PUMPING STATIONS DIRECTLY UNDER THE FCSMO-MMDA					
IV-1	Lopez R.P.S.		N.A.		
IV-2	N.Vicencio R.P.S.		N.A.		
IV-3	Rivera R.P.S.		N.A.		
IV-4	Magsaysay R.P.S.		N.A.		
IV-5	Niugan R.P.S.		N.A.		
IV-6	Herrera R.P.S.		N.A.		
IV-7	Concepcion R.P.S.		N.A.		
IV-8	Muzon R.P.S.		N.A.		
IV-9	Roque R.P.S.	2.75	N.A.		
IV-10	Sanciangco R.P.S.		N.A.		
IV-11	Acacia R.P.S.		N.A.		
IV-12	Santolan R.P.S.		N.A.		
IV-13	Artex R.P.S.		N.A.		
IV-14	Merville Dampalit R.P.S.		N.A.		
IV-15	Balot R.P.S.		N.A.		
IV-16	Hulong Duhat R.P.S.		N.A.		
IV-17	Tanza R.P.S.		N.A.		

Source: MMDA

*: MMDA recommended to WB as high priority pumping stations to be rehabilitated

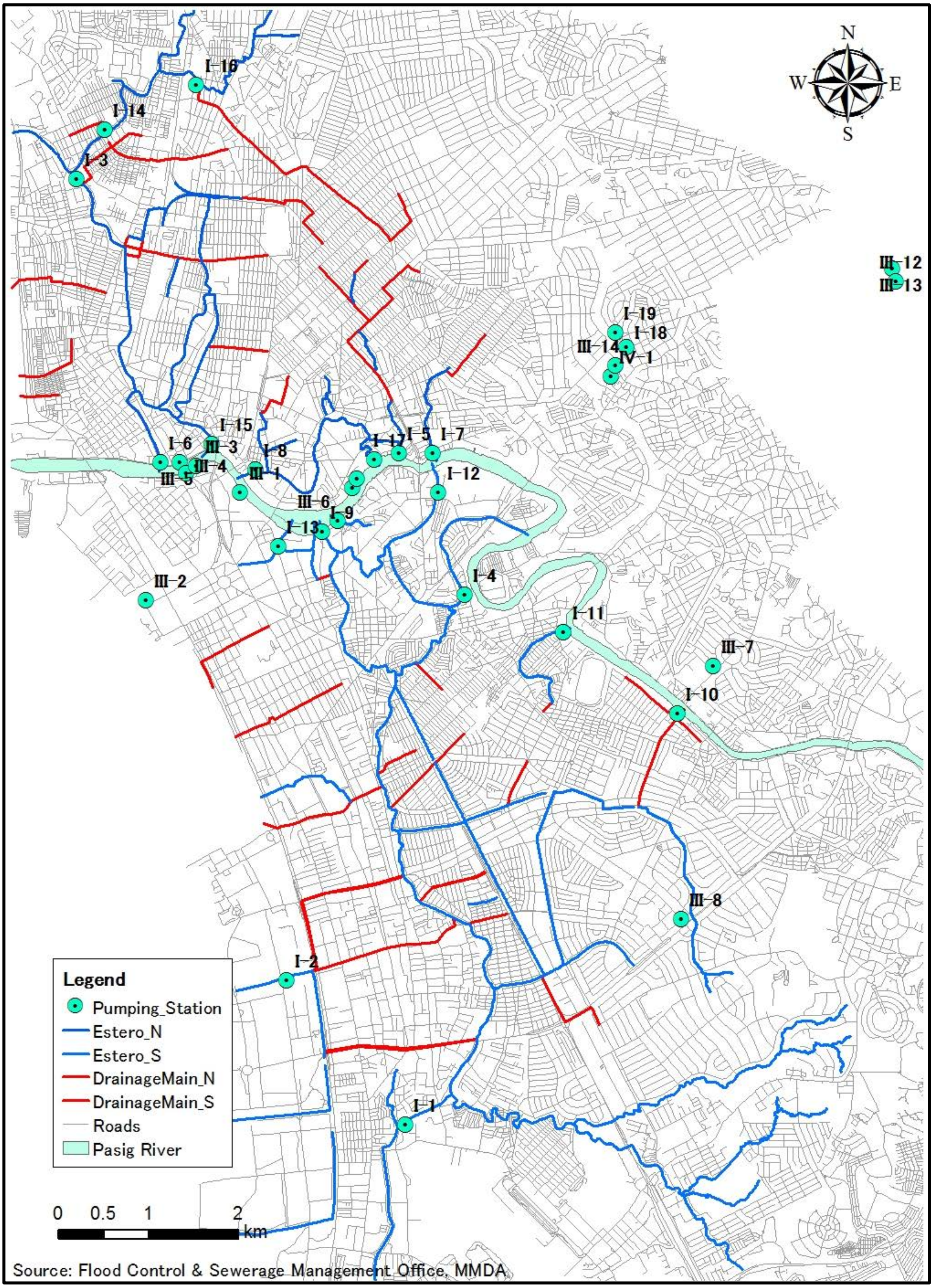


Figure 3.2.7 Location Map of Pumping Stations in Metro Manila

(2) Rehabilitation of Pumping Stations

MMDA is currently undertaking repairs and rehabilitation of 12 pumping stations as mentioned in Chapter 2. In addition, MMDA and the World Bank are holding discussing regarding the "Metro Manila Flood Management Project". MMDA has already recommended 10 pumping stations as priority for rehabilitation as indicated in asterisk * in Table 3.2.1. In addition, 90 pumping station will be rehabilitated and newly constructed after the 2nd year of the project. With the drainage improvement in Metro Manila, a target that is higher than the level proposed in the DICAMM 2005 is going to be achieved.

(3) Operation Record of Pumping Stations

The Operation Records of 10 pumping stations were studied in order to confirm the flow capacity of the existing drainage channels. The target floods are those from the Habagat in August 2012, Typhoon Maring in August 2013 and Typhoon Ondoy in September 2009 which has inundation interview survey results. All events caused severe flooding.

Regarding the flow capacity of drainage channels, they can convey flood waters to the respective pumping stations. The pumping stations were working well in general as shown in Table 3.2.2 – 4.

During the 2012 typhoon Habagat, the drained ratio of the pumping station was 73% at the Libertad Drainage Area. This was due to the gate operation that was opened during heavy rains so that there was no need to operate the pumps.

As for the 2013 Typhoon Maring, the drained ratio was generally high and it shows that rain water gathered into each pumping station. However, as to Makati and Sta. Clara pumping stations there is the possibility that the catchment areas cannot gather water completely.

With regard to for the 2009 Typhoon Ondoy, Tripa de Gallina and Libertad pumping stations opened the gates to drain water to the sea in accordance with the sea water level. Regarding Quiapo pumping station, there is a missing record for September 27, but available records show that drained ratio is low. There was no operation from around 4pm on 26 September in the Makati, Paco, Pandacan and Sta. Clara pumping stations. This is due to the fact that pumps were submerged and they were not operated for fear of electric shock due to the rapid rise of water level.

Except for these special cases, pumping volume is much larger than runoff volume in many stations and the given reasons of flooding is follows:

- Pump was not in full operation (Amount of pumping volume is computed as a full operation when turned on in the record.)
- Actual pump capacity is smaller than that of the table (Running time is longer because pump capacity is smaller than expected)

The first reason is not possible because it was confirmed from MMDA that the pump capacity was not able to control the output power.

In the latter situation, since the pumping capacity will be improved by the MMDA rehabilitation mentioned in Chapter 2 and the World Bank Project, it can be said that there is no effect on the planning in this Survey.

Table 3.2.2 Pump Operation Result (2012 Typhoon Habagat)

Pumping Station	Pump	Capacity	Operation	Drained Volume		Area	Rainfall	Runoff	Drained Ratio
	No.	m3/s	hr	m3		km2	mm	m3	%
Tripa de Gallina	1	7	56.5	1,423,800					
	2	7	37.75	951,300					
	3	7	1	25,200					
	4	7	44	1,108,800					
	5	7	35.25	888,300					
	6	7	41	1,033,200					
	7	7	40.75	1,026,900	Total				
	8	7	40	1,008,000	7,465,500	17.05	603	7,710,863	97
Libertad	1	7	27.5	693,000					
	2	7	10	252,000					
	3	7	5.75	144,900					
	4	7	20.75	522,900					
	5	7	17.75	447,300	Total				
	6	7	16.25	409,500	2,469,600	7.48	603	3,382,830	73
Aviles	1	3.625	55.5	724,275					
	2	3.625	54.75	714,488					
	3	3.625	62.25	812,363	Total				
	4	3.625	64	835,200	3,086,325	3.28	816	2,141,184	144
Valencia	1	2.625	72	680,400					
	2	2.625	65.75	621,338					
	3	2.625	69.25	654,413	Total				
	4	2.625	61.25	578,813	2,534,963	2.37	816	1,547,136	164
Quiapo	1	2.375	76.75	656,213					
	2	2.375	67	572,850					
	3	2.375	75.25	643,388	Total				
	4	2.375	67.75	579,263	2,451,713	2.29	816	1,494,912	164
Binondo	1	3.63	25.75	336,501					
	2	3.63	32.25	421,443					
	3	3.63	33.5	437,778	Total				
	4	3.63	35.25	460,647	1,656,369	2.69	816	1,756,032	94
Makati	1	3.5	35	441,000	Total				
	2	3.5	38.75	488,250	929,250	1.65	816	1,009,800	92
Paco	1	2.53	68.5	623,898					
	2	2.53	69	628,452	Total				
	3	2.53	66.5	605,682	1,858,032	1.74	816	1,064,880	174
Pandacan	1	2.75	38.75	383,625	Total				
	2	2.75	37.25	368,775	752,400	1.15	816	703,800	107
Sta. Clara	1	2.65	60	572,400	Total				
	2	2.65	47.75	455,535	1,027,935	1.57	816	960,840	107

Operattion: from MMDA

Rainfall: NAIA for Trip de Gallina and Libertad, and Port Area for others

Runoff: Northern Area of Pasig River is 0.8, and Southern Area is 0.75

Table 3.2.3 Pump Operation Result (2013 Typhoon Maring)

Pumping Station	Pump No.	Capacity	Operation	Drained Volume		Area	Rainfall	Runoff	Drained Ratio
		m3/s	hr	m3		km2	mm	m3	%
Tripa de Gallina	1	7	61.25	1,543,500					
	2	7	64.75	1,631,700					
	3	7	54.25	1,367,100					
	4	7	51.75	1,304,100					
	5	7	52.5	1,323,000					
	6	7	62	1,562,400					
	7	7	28	705,600	Total				
	8	7	52.5	1,323,000	10,760,400	17.05	574.5	7,346,419	146
Libertad	1	7	64	1,612,800					
	2	7	48.5	1,222,200					
	3	7	51	1,285,200					
	4	7	60	1,512,000					
	5	7	41.5	1,045,800	Total				
	6	7	37	932,400	7,610,400	7.48	574.5	3,222,945	236
Aviles	1	3.625	42.5	554,625					
	2	3.625	37.75	492,638					
	3	3.625	36.75	479,588	Total				
	4	3.625	33.75	440,438	1,967,288	3.28	688.7	1,807,149	109
Valencia	1	2.625	42.26	399,357					
	2	2.625	65.5	618,975					
	3	2.625	57.25	541,013	Total				
	4	2.625	31.35	296,258	1,855,602	2.37	688.7	1,305,775	142
Quiapo	1	2.375	54.75	468,113					
	2	2.375	59.5	508,725					
	3	2.375	55.5	474,525	Total				
	4	2.375	36.25	309,938	1,761,300	2.29	688.7	1,261,698	140
Binondo	1	3.63	60	784,080					
	2	3.63	59.75	780,813					
	3	3.63	66.75	872,289	Total				
	4	3.63	64	836,352	3,273,534	2.69	688.7	1,482,082	221
Makati	1	3.5	20.25	255,150	Total				
	2	3.5	28.75	362,250	617,400	1.65	688.7	852,266	72
Paco	1	2.53	39	355,212					
	2	2.53	52	473,616	Total				
	3	2.53	53.5	487,278	1,316,106	1.74	688.7	898,754	146
Pandacan	1	2.75	49	485,100	Total				
	2	2.75	31	306,900	792,000	1.15	688.7	594,004	133
Sta. Clara	1	2.65	15.25	145,485	Total				
	2	2.65	41.75	398,295	543,780	1.57	688.7	810,944	67

Operattion: from MMDA

Rainfall: NAIA for Trip de Gallina and Libertad, and Port Area for others

Runoff: Northern Area of Pasig River is 0.8, and Southern Area is 0.75

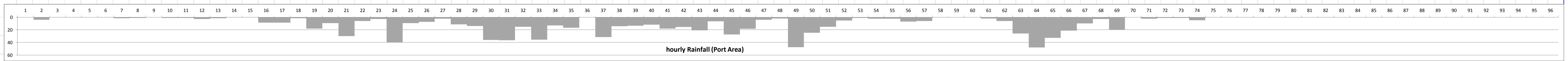
Table 3.2.4 Pump Operation Result (2009 Typhoon Ondoy)

Pumping	Pump	Capacity	Operation	Drained Volume		Area	Rainfall	Runoff	Drained Ratio
Station	No.	m3/s	hr	m3		km2	mm	m3	%
Tripa de Gallina	1	7	33.25	837,900					
	2	7	15.25	384,300					
	3	7	41	1,033,200					
	4	7	23.75	598,500					
	5	7	31	781,200					
	6	7	32.5	819,000					
	7	7	0	0	Total				
	8	7	15.5	390,600	4,844,700	17.05	331.7	4,241,614	114
Libertad	1	7	0	0					
	2	7	0	0					
	3	7	20.75	522,900					
	4	7	38.25	963,900					
	5	7	32	806,400	Total				
	6	7	20.75	522,900	2,816,100	7.48	331.7	1,860,837	151
Aviles	1	3.625	43.5	567,675					
	2	3.625	40.25	525,263					
	3	3.625	45.25	590,513	Total				
	4	3.625	41	535,050	2,218,500	3.28	331.7	870,381	255
Valencia	1	2.625	33.5	316,575					
	2	2.625	43	406,350					
	3	2.625	40.75	385,088	Total				
	4	2.625	48.25	455,963	1,563,975	2.37	331.7	628,903	249
Quiapo	1	2.375	7.5	64,125					
	2	2.375	16.75	143,213					
	3	2.375	22.01	188,186	Total				
	4	2.375	17	145,350	540,873	2.29	331.7	607,674	89
Binondo	1	3.63	34	444,312					
	2	3.63	39.5	516,186					
	3	3.63	44.75	584,793	Total				
	4	3.63	43	561,924	2,107,215	2.69	331.7	713,818	295
Makati	1	3.5	11	138,600	Total				
	2	3.5	4	50,400	189,000	1.65	331.7	410,479	46
Paco	1	2.53	4.75	43,263					
	2	2.53	6.5	59,202	Total				
	3	2.53	9.75	88,803	191,268	1.74	331.7	432,869	44
Pandacan	1	2.75	8.75	86,625	Total				
	2	2.75	5	49,500	136,125	1.15	331.7	286,091	48
Sta. Clara	1	2.65	9.75	93,015	Total				
	2	2.65	11.5	109,710	202,725	1.57	331.7	390,577	52

Operattion: from MMDA
Rainfall: Port Area
Runoff: Northern Area of Pasig River is 0.8, and Southern Area is 0.75

Table 3.2.5 Pump Operation Record (2012 and 2013)

(1) 2012.8 Typhoon Habagat



6-Aug

PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Tripa de Gallina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1														0	1	1	1	1
	3																								
	4	1	1	1	1	1	1	1	1										1	1	1	1	1	1	1
	5	1	1	1	1	0																1	1	1	1
	6	1	1	1	1											1	1	1	1	1	1	1	1	1	1
	7	1	1	1	1	1	1													1	1	1	1	1	1
	8	1	1	1	1	1													1	1	1	1	1	1	1
Estero WL		1025	1000	1010	990	980	970	965	960	980	995	995	995	1000	1010	985	980	1015	1020	1010	1010	1030	1080	1100	1130
Manila Bay		1180	1170	1175	1170	1150	1130	1120	115	1110	1120	1130	1135	1145	1145	1150	1150	1100	1160	1165	1170	1190	1210	1210	1220
Gate												← CLOSE →													
Libertad	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1															0	1	1	1	
	3																			1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1						1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1									1	1	1	1	1	1	1
	6	1	1	1	1	1	1	1											1	1	1	1	1	1	1
Estero WL		1090	1090	1080	1060	1000	980	980	970	975	980	990	995	1105	1010	1005	990	990	995	1000	1000	1150	1080	1080	1115
Manila Bay		1125	1120	1115	1110	1090	1090	1090	1105	1110	1115	1130	1135	1140	1140	1135	1130	1120	1090	1095	1095	1105	1090	1090	1110
Gate												← CLOSE →													
Aviles	1						0	1	1	1								1	1	1	1	1	1	1	1
	2		1	1	1												1	1	0	1	1	1	1	1	1
	3	1	1	0												1	1		1	1	1	1	1	1	1
	4	1										1	1	1	1				1	1	1	1	1	1	1
Valencia	1	1	1	1	1	1	0			1	0								1	1	1	1	1	1	1
	2						0	1	0		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1															0	1	1	1	1	1	1
	4																1	1	1	1	1	1	1	1	1
Quiapo	1	0	1	0			0	1				0	1	1		0	1	1	1	1	1	1	1	1	1
	2																				1	1	1	1	1
	3	0	1	0			0	0				0	1			0	1	1	1	1	1	1	1	1	1
	4	0	1	0			0	0											1	1	1	1	1	1	1
Binondo	1						1	1	1										1	1	1	1	1	1	1
	2						1	1	1								1	1	1	1	1	1	1	1	1
	3	1	1	0								1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1						1	1	1	1						1	1	1	1	1	1	1
Makati	1		1									1	0			0	1		1	1	1	1	1	1	1
	2	0	1	0		0	1												1	0	1	1		1	1
Paco	1				1	1						1	1	1					1	1	0	1	1	0	1
	2				1	1		1	1							1	1		1	1	1	1	1	0	1
	3	1	1													1	1		1	1	1	1	1	0	1
Pandacan	1				1	1	0				1	1		1	1	0	1	1	0	1	1	1	1	1	1
	2	1	1																1	1	1	1		0	1
Sta. Clara	1	0	0	1		0	0				0	0					0		1	1	1	1	1	1	1
	2	1	1		0			0						1		0	0	1	1	1	1	1	0	0	1

7-Aug

PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Tripa de Gallina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3																								
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Estero WL		1190	1210	1230	1245	1245	1245	1240	1230	1220	1195	1185	1160	1130	1130	1150	1195	1215	1230	1240	1240	1230	1230	1220	1200
Manila Bay		1230	1235	1240	1245	1245	1245	1240	1230	1225	1215	1215	1210	1200	1210	1220	1225	1230	1240	1240	1240	1230	1230	1220	1200
Gate													← CLOSE →												
Libertad	1											0	1	1	1	0									
	2											1	1	1	1	0									
	3																								
	4											1	1	1	1	0									
	5											1	1	1	1	0									
	6											1	1	1	1	0									
Estero WL		1125	1130	1130	1120	1115	1110	1115	1110	1105	1110	1125	1120	1105	1105	1120	1120	1120	1115	1110	1195	1090	1010	1100	1110
Manila Bay													1140	1140	1135										
Gate							← OPEN →							←→											
Aviles	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Valencia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Quiapo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Binondo	1	1	1	1	1	1	1	0					1	1	0										
	2	1	1	1	1	1	1	0					1	1	0										
	3	1	1	1	1	1	1	0					1	1	0										
	4	1	1	1	1	1	1	0					1	1	0										
Makati	1	1			1	1	0		1	1	1	0	1	,75	1	1	0	1	1	0		1	1		
	2	1	1	1			1	1		1	1	1		1	1	0	1	1	1	1	1	1	1	1	
Paco	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1			0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pandacan	1	1			0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0			0
	2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sta. Clara	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	0	1	0	0		1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1

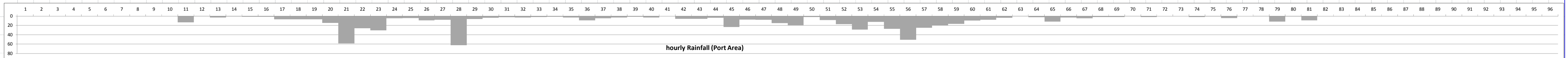
8-Aug

PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Tripa de Gallina	1	1	1	1	1	1																			
	2	1	1	1	1	1																			
	3																								
	4	1	1	1	1	1																			
	5	1	1	1	1	1																			
	6	1	1	1	1	1																			
	7	1	1	1	1	1	1																		
	8	1	1	1	1	1	1																		
Estero WL		1180	1210	1210	1230	1225	1215	1215	1215	1205	1200	1190	1170	1160	1150	1180	1210	1240	1250	1250	1245	1230	1215	1200	1185
Manila Bay		1180	1220	1220	1230	1225	1215	1215	1215	1205	1200	1190	1170	1160	1150	1180	1210	1240	1250	1250	1245	1230	1215	1200	1185
Gate				← CLOSE →											← OPEN →										
Libertad	1																0	1							
	2																								
	3																								
	4																0	1							
	5																								
	6																								
Estero WL		1120	1120	1125	1130	1125	1120	1110	1110	1110	1110	1105	1110	1115	1130	1120	1120	1115	1110	1105	1105	1105	1105	1110	1115
Manila Bay																									
Gate																				← OPEN →					
Aviles	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1					
	2	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1					
	3	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	0	1	1	1	1
	4	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	0	1	1	1	1
Valencia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Quiapo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0			
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0			
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
Binondo	1										0	1	1	1	1	1	1								
	2										0	1	1	1	1	1	1								
	3										0	1	1	1	1	1	1								
	4										0	1	1	1	1	1	1								
Makati	1	1	1	1	1	1	1	0			0	1		1	1	1	1	1	1	1	1				
	2	1	1	1	1		1	1	1	1						1	1	1	1	1	1	1	1	1	
Paco	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Pandacan	1	1	1	1	1	1	1	1	1	0															
	2	1	1	1	1	1	1	1	1	0															
Sta. Clara	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1		0	1	1	1	1	1	1	1	1	1	1

9-Aug

PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Tripa de Gallina	1																		0	1	1	1	1	1	
	2																								
	3																			1	1				
	4																			1	1				
	5																								
	6																								
	7																			1					
	8																								
Estero WL		1160	1155	1150	1145	1140	1135	1130	1125	1120	1120	1115	1115	1110	1110	1110	1110	1110	1110	1040	990	980	980	980	1000
Manila Bay		1160	1155	1150	1145	1140	1135	1130	1125	1120	1120	1115	1115	1110	1110	1110	1110	1110	1110	1120	1120	1100	1090	1090	1100
Gate										← OPEN →												← CLOSE →			
Libertad	1																								
	2																								
	3																								
	4																								
	5																								
	6																								
Estero WL		1125	1130	1135	1140	1135	1130	1125	1120	1110	1100	1095	1095	1100	1105	1105	1105	1105	1105	1100	1095	1095	1095	1105	1110
Manila Bay																									
Gate																									
Aviles	1							0	1	1	1	1	1	0			1	0						1	1
	2							0	1	1	1	1	1	0			1	0							1
	3	1	1	1	1	1	1	1								0	1	1	1	1					1
	4	1	1	1	1	1	1	1								0	1	1	1	1	1	0			
Valencia	1	1	1	1	1	1	1	1	1	1	1	1	1	0											1
	2	1	1	1	1	0								1											1
	3	1	1	1	1	1	1	1	1	1	1	0				1	1	1	0						1
	4	1	1	1	1	1	0													1	0				1
Quiapo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0			0	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			0	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0							1
Binondo	1											1	1	1	1									0	1
	2											1	1	1	1	1	1	1					1	1	
	3															1	1	1	1	1	0				
	4											1	1	1	1	1	1	1	1	0			1	1	1
Makati	1									1	1		0							1					
	2	1	0			1	0																		
Paco	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0							0	1
	2	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1						0	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0							0	1
Pandacan	1																		1				1	1	1
	2																		0					0	1
Sta. Clara	1	0	0		0	0	1	0		0	0					0	0		0	0		1	0	1	1
	2												0	0							1		1	1	1

(2) 2013.8 Typhoon Maring



18-Aug

PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Trip de Gallina	1																		1	1	1	1	1	1	1
	2											1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3																					0	1	1	1
	4											1	1	0						1	1	1	1	1	1
	5																			1	1	1	1	1	1
	6											0	1	1			1	1	1	1	1	1	1	1	1
	7																						0	1	1
	8																				1	1	1	1	1
Estero WL		1050	1060	1070	1080	1090	1100	1110	1115	1120	1120	1100	1100	980	970	980	975	970	990	1020	1000	1020	1100	1160	1180
Manila Bay		1105	1110	1120	1140	1160	1170	1175	1180	1175	1170	1170	1170	1150	1120	1100	1100	1100	1110	1150	1150	1165	1200	1220	1225
Gate													← CLOSE →												
Libertad	1						1	1			1	1	1	1	1		1	1	1	1	1	1	1	1	1
	2										1											1	1	1	1
	3																				1	1	1	1	1
	4						1	1			1								1	1	0	1	1	1	1
	5										1	0						0	1	1	1	1	1	1	1
	6										1	0						0	1	1	1	1	1	1	1
Estero WL		1050	1060	1070	1080	1085	1080	1145	1000	1020	1030	980	975	980	975	970	995	980	1120	1010	1000	1030	1080	1095	1100
Manila Bay		1105	1115	1130	1145	1160	1170	1180	1180	1175	1165	1140	1110	1000	1065	1050	1045	1045	1055	1065	1075	1085	1095	1100	1110
Gate													← CLOSE →												
Aviles	1					1												1	1	1	1	1	1	1	1
	2														0	1	1			1	1	1	1	1	1
	3										1							1	0		1	1	1	1	1
	4										1	1	1	1					0	1	1	1	1	1	1
Valencia	1																			1	1	1	1	1	1
	2				0	,75				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1						1			0	1						1	1	1	1	1	1	1	1
	4																			1	1	1	1	1	1
Quiapo	1					0	1				0	1	1	0			0	1	1	1	1	1	1	1	1
	2					0	1				1	1				1	0	1	0	1	1	1	1	1	1
	3					0	1				1	1				1	0			0	1	1	1	1	1
	4																				1	1	1	1	1
Binondo	1										1	1						1	1	0	1	1	1	1	1
	2									0	1	1					1	1		1	1	1	1	1	1
	3					1	1	1	0		0	1	1	0				1	1	1	1	1	1	1	1
	4					1	1	1	0					1	1	0			1	1	1	1	1	1	1
Makati	1																				0	1	1	1	1
	2									0	0							0			0	1	1	1	
Paco	1	0	1	1						1	1			0	0			0	1		1	1	1	1	1
	2	0	1	1						1	1			0	1			0	1		1	1	1	1	1
	3	0	1	1						1	1	0		0	1			0	1		1	1	1	1	1
Pandacan	1	1				1	0				1					1	0	1	1	1	1	1	1	1	1
	2										1	0								1	1	1	1	1	1
Sta. Clara	1					0	0		0									1	0		0	1	1	1	1
	2									1	1							1		1	1	1	1	1	1

19-Aug

PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Trip de Gallina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1
	7															1	1	1	1	1			1	1	1
	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1
Estero WL		1200	1195	1170	1210	1245	1245	1245	1245	1240	1220	1200	1160	1120	1050	1020	1020	1015	990	990	1000	1040	1120	1160	1170
Manila Bay		1225	1215	1225	1240	1245	1245	1245	1245	1240	1240	1230	1220	1205	1180	1165	1150	1140	1130	1110	1130	1190	1220	1250	1240
Gate														← CLOSE →											
Libertad	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	0					1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	0	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1										0	1	1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1														
Estero WL		1100	1105	1110	1120	1130	1140	1140	1135	1140	1100	1010	1150	1120	1090	1080	1010	1050	1030	1030	150	1070	1090	1110	1105
Manila Bay		1120	1120	1125	1135	1145	1160	1170	1185	1190	1190	1170	1150	1120					1050	1060	1080	1090	1110	1165	1110
Gate													← CLOSE →												
Aviles	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						1	1	1	
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1							1	1		1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1		1	1
	4	1	1	1	1	1	1	1	1	1	1	1			1	1	0							1	1
Valencia	1	1	1	1	1	1	1	1	1	1	1	1	1	1											0
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1					0	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1																1	1
Quiapo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0		0	1	1	1		0	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1	1			1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	0										
Binondo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1
Makati	1		1	1	0						1														
	2	1	1	1	1						1		1	1								1	1	1	1
Paco	1	1	1	1	1	1	1	1	1	0															1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	0	1
Pandacan	1	1	1	1	1	1	1	1	1	0	1	1	1					0	0	1	1	1	1	1	1
	2	0	1	1	1	1	1	1							1	1									
Sta. Clara	1	1	1	1	1	1	1	1	1	0	0	1		0						0					
	2	1	1	1	1	1	1	1	1	1	1		1		0		0				1	1	1	1	1

20-Aug

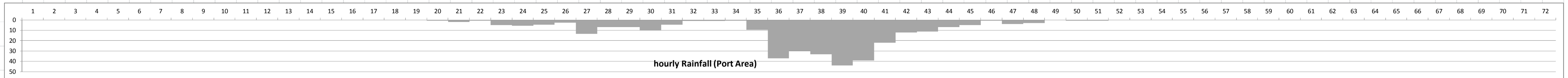
PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Trip de Gallina	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	7	1	1	1	1	1	1	1							1	1	0	1	1	1	1	1	1	1	1
	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Estero WL		1200	1195	1170	1145	1195	1240	1250	1290	1300	1300	1300	1300	1300	1300	1280	1275	1260	1260	1255	1250	1240	1230	1215	1195
Manila Bay		1230	1225	1220	1220	1245	1250	1250	1290	1300	1300	1300	1300	1300	1300	1280	1275	1260	1260	1255	1250	1240	1230	1215	1220
Gate													← CLOSE →												
Libertad	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1				1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	0		1	1	1	1	1						1	1
	6													1	1	1	1	1		1	1	1	1	0	1
Estero WL		1105	1105	1105	1110	1175	1140	1160	1170	1180	1190	1185	1175	1150	1130	1110	1095	1095	1075	1010	1080	1090	1100	1105	1110
Manila Bay		1105	1105	1110	1120	1135	1150	1170	1180	1185	1190	1185	1175	1150	1130	1110	1095	1095	1075	1010	1080	1090	1100	1105	1110
Gate												← CLOSE →													
Aviles	1		1	1	1	1	1	1	1	0												1	1	1	1
	2	1		1	1	1	1	1	1	1	1													0	1
	3	1	1	1				1	1	1	1														
	4	1	1			1	1	1	1	1															
Valencia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0				
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0						
Quiapo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
Binondo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Makati	1	0	1	1	1	1	1	1	1	1	1	1	1	0					0	1					
	2				1	1	1	1	1	1	1	1	1	1	1		1	1	1		1	0	1	0	
Paco	1	1		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	
	2	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Pandacan	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	2			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0				
Sta. Clara	1																								
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	

21-Aug

PUMP STATION	No.	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Trip de Gallina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	0										
	3	1	1	1	1	1	0			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	0						1	1	1	1	1	1	1	1							
	5	1	1	1	1	1	1	1				1	1	1	1	1	1	1							
	6	1	1	1	1	0				1	1	1	1	1	1	1	1	1							
	7	1	1	1	0									1	1	1	0								
	8	1	1	1	1	0																			
Estero WL		1150	1100	1030	1000	985	990	990	1000	1060	1110	1123	1150	1135	1100	1040	1010	1000	1015	1005	1000	995	985	975	980
Manila Bay		1200	1200	1175	1150	1140	1130	1130	1140	1185	1220	1225	1220	1220	1205	1180	1155	1130	1115	1110	1100	1100	1105	1110	1110
Gate														← CLOSE →											
Libertad	1	1	1	1	1	0		1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
	2					0	1	1	1	1	1	1	1	1											
	3	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1				0	1	
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1									
	5	1								1	1	1	1	1	1	1	1	1	1	1					
	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1		1
Estero WL		1110	1105	1100	1085	1075	1010	1160	1055	1070	1100	1105	1110	1110	1100	1090	1060	1050	1030	1070	1030	1010	1005	1015	1000
Manila Bay		1110	1110	1120	1125	1130	1130	1140	1160	1180	1190	1195	1195	1195	1170	1120	1100	1070	1065	1070	1080	1095	1100	1115	1115
Gate													← CLOSE →												
Aviles	1				1	1	1	1	1	1	1	1	1	1	1					1	1				
	2	1								1	1	1	1	1	1	1		1	1				0	1	1
	3				1	0			1	1	1					1	1					1		0	
	4	1	1					1	1	1				1						1	1	1	0		
Valencia	1							1	1	1	1	1	1	1	0							1	0		
	2	1	1	1	1	1		1	1	1	0		0	1	1	1	1	1	1	1	1	1	1		
	3					0	0	1	1	1	1									1	1	1	1	1	1
	4																								
Quiapo	1	1											0	1	1	1	1	1							
	2			0	1	1	0	1	1	1	1	0		1						1	1	1	1	1	1
	3	1	1	1	1			1	1	1	1	1	1	0					0	1	0				
	4																								
Binondo	1	1	1	1	0				0	1	1	0													
	2	1	1	0							1	1	1	1	1	0									0
	3	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1
	4	1	1	1	1	1	0	1	1	1	1	1	1	1					1	1	1	1	1	1	1
Makati	1	0								1	1														
	2			1				1	1	0			1	0	0	0			1	1					
Paco	1							1	0	1	0		0	1				1		1	1	1	1	1	0
	2	1	1	1			0	1		1	1		0	1				1		1					
	3	1	1	1			0	1	0	1			0	1	1			1		0					
Pandacan	1							1	1	1	1	1	0					1	1		0				0
	2		1					0	0	0			0	1								1			
Sta. Clara	1																								
	2			0			0	0	1	1	1	1	1	1	0					1					

Table 3.2.6 Pump Operation Record (2009)

(3) 2009.9 Typhoon Ondoy



PUMP STATION	No.	25-Sep																							
		12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Trip de Gallina	1	0	0	0.25	1	0.5	0	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0.25	1	0.25	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	1	1	0.75	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0	0	1	1	1	1
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estero WL		960	1000	1015	985	970	995	1015	965	975	1010	990	970	980	1000	1015	990	970	970	1000	1020	990	965	970	990
Manila Bay		1155	1160	1165	1160	1145	1125	1110	1105	1085	1010	1015	1070	1060	1050	1065	1080	1085	1080	1085	1015	1105	1115	1130	1160
Gate		← CLOSE →																							
Libertad	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0.5	0.25	0	0	0.25	0.75	0	0	0.5	1	0.25	0	0	0.5	0.25	0	0	0	0	0	0.75	1	1
	5	0	0.75	0.25	0	0	0.25	0.75	0	0	0	0	0	0	0	0.75	0	0	0.25	1	0.5	0	0.25	1	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estero WL		1015	895	1010	995	1015	1000	970	990	1010	1005	980	975	1000	1015	980	985	1100	1015	975	980	1005	1100	970	980
Manila Bay		1145	1140	1140	1140	1130	1120	1100	1180	1000	1060	1030	1055	1060	1065	1070	1080	1080	1090	1095	1095	1105	1120	1135	1145
Gate		← CLOSE →																							
Aviles	1	0.75	0.5	0	0	0	0	0	0	0.75	0.5	0	0	0	0	0	0	0	0	0	0.75	0.5	0	0	0
	2	0	0	0	0	0.25	1	0.75	0	0	0	0	0	0	0	0	0	0	0.75	0.25	0	0	0	0.25	1
	3	0.25	1	0.25	0	0	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	0.25	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.75	0	0	0	0	0	0.25	1	0.5
Valencia	1	0	0	0	0	0.25	0.25	0.25	0	0	0	0	0	0.25	0.25	0	0	0	0	0	0	0	0	0.75	1
	2	0	0	0	0	0	0	0.5	0.5	0	0	0.5	0	0	0.25	0.25	0	0.25	0.25	0	0	0	0.5	1	1
	3	0	0	0	0	0	0	0	0	0	0.5	0	0.75	0.25	0	0.25	0.25	0	0.25	0.75	0	0	0	0	0
	4	1	1	1	0.75	0	0	0	0.25	0.75	0	0	0	0	0	0	0.25	0.25	0	0.25	1	1	1	0	0
Quiapo	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0.25	0	0	0	0	0.5	0.25	0	0	0	0	0	0.5	0.25	0	0	0	0	0	0	0	0	0	0.25
	3	1	0.25	0	0	0	0.75	0.26	0	0	0	0	0	0.75	0.75	0	0	0	0	0.25	1	0.75	0.5	1	1
	4	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.5	0	0	0	0
Binondo	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	1	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0.75	0	0	0	0
	3	1	0.75	0	0	0.75	0.75	0	0	0	0	0	0	0	0.5	0.75	0	0	0	0.75	0.25	0	0	0	0.5
	4	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0.5	0.75	0	0	0	0	0	0.5	0.5	1	0.75
Makati	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0	0.5	0.25	0.5
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paco	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
	2	0	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0	0	0	0	0	0	0.25	1	0.25	0
	3	0	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0	0	0	0	0	0	0.25	1	0.25	0.5
Pandacan	1	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0	0.75
Sta. Clara	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0
	2	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0	0.25	0.25	0.25

PUMP STATION	No.	26-Sep																							
		12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Trip de Gallina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
	2	0	1	1	0.5	1	0.5	0	0.25	0.75	0	0.25	1	1	1	1	1	1	0	0	0	0	0	0	0
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
	4	0	0	0	0.75	1	1	1	1	1	0.25	0.25	1	1	1	1	1	1	0	0	0	0	0	0	0
	5	0.75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0.25	1	1	1	0.25	0	0	0.75	1	1	1	1	1	0.25	0	0	0	0	0	0
Estero WL		970	990	1010	1030	1035	1035	1035	1010	985	975	1070	1190	1270	1300	1300	1300	1300	1300	1300	1300	1300	1290	1270	1260
Manila Bay		1170	1180	1190	1195	1195	1195	1190	1180	1135	1150	1170	1240	1280	1300	1300	1300	1300	1300	1300	1300	1300	1290	1270	1260
Gate		← CLOSE →																	← OPEN →						
Libertad	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0.75	1	1	1	1	1	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	1	1	1	1	1	1	1	0.75	0	0	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0
	5	0.25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0
	6	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0
Estero WL		980	980	985	970	975	975	975	970	970	975	1090	1100	1100	1105	1105	1115	1130	1135	1140	1140	1135	1140	1150	1170
Manila Bay		1160	1165	1155	1140	1120	1125	1110	1100	1090	1090	1090	1100	1100	1105	1105	1115	1130	1135	1140	1140	1135	1140	1150	1170
Gate		← CLOSE →																← OPEN →							
Aviles	1	0.5	1	1	1	1	1	1	0	0	0.75	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	0.25	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	0	0.5	1	1	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	0	0	0.25	0.25	0.75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Valencia	1	1	1	1	1	1	1	0	0	0	0.75	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	0.25	0.75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	0.25	1	1	1	0.25	0	0	0	0	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	0	0	0	0	0.75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Quiapo	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0.5	0	0	0	0	0	0
	2	1	1	1	1	1	1	0.75	0	0	0.5	1	1	1	1	1	1	1	0.5	0	0	0	0	0	0
	3	1	1	1	1	1	0.75	0	0	0	0.75	1	1	1	1	1	1	1	0.25	0	0	0	0	0	0
	4	0	0	0	0.75	1	1	1	1	1	1	1	1	1	1	1	1	1	0.25	0	0	0	0	0	0
Binondo	1	0	0	0	0	0	0	0	0	0.25	1	1	1	1	1	1	0.75	0	0	0	0	0.75	1	1	0.75
	2	0.5	1	1	1	1	1	0.75	0	0	0.25	1	1	1	1	1	0.75	0	0	0	0	0.75	1	1	0.75
	3	1	1	1	1	1	0.75	0	0	0	0	0.75	1	1	1	1	0.75	0	0	0	0	0.75	1	1	0.75
	4	0	0	0	0.75	1	1	1	1	1	0.5	0.5	1	1	1	1	0.75	0	0	0	0	0.75	1	1	0.75
Makati	1	0.25	1	1	1	0.5	0.5	0.25	0.25	0.25	0.75	1	1	1	0.25	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0.75	1	1	1	0.25	0	0	0	0	0	0	0	0	0	0
Paco	1	0	0	0	0.25	1	1	0.5	0	0	0.25	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
	2	0.25	1	1	0	0	0	0	0	0	0.75	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
	3	0.25	1	1	0.25	1	1	0.5	0	0	0.75	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
Pandacan	1	0	0.25	1	1	1	1	0.25	0	0	0.25	1	1	1	0.25	0	0	0	0	0	0	0	0	0	0
	2	0.25	1	0.25	0	0	0	0	0	,25	1	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
Sta. Clara	1	0.25	0.5	0	0.75	0.25	0.5	0.25	0	0.25	0.75	1	1	1	1	1	0.5	0	0	0	0	0	0	0	0
	2	0.25	0.25	0.75	0.25	0.75	0.5	0.25	0.5	0.25	0.75	1	1	1	1	1	0.5	0	0	0	0	0	0	0	0

PUMP STATION	No.	27-Sep																							
		12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Trip de Gallina	1	0	0.5	1	1	1	1	1	1	1	1	1	1	1	1	0.25	0	0	0	0	0	0	0	0	0
	2	0	0	0.75	1	1	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	0	0.5	1	1	1	1	1	1	1	0.5	0	0	0	0	0	0.25	0.25	0	0	0	0	0	0	0
	5	0	0	0.5	1	1	1	1	1	0.5	0	0	0	0	0	0	0.25	1	1	1	1	1	1	1	1
	6	0	0.5	1	1	1	1	1	1	0.5	0	0	0	0	0	0	0.25	0.75	1	1	1	0.25	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0.5	1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estero WL		1250	1235	1200	1160	1120	1050	1035	1000	1000	1015	1005	995	990	980	990	1020	1020	1010	990	985	985	995	965	965
Manila Bay		1250	1250	1200	1210	1210	1185	1170	1160	1140	1120	1120	1105	1100	1100	1090	1100	1100	1100	1105	1105	1100	1110	1125	1130
Gate		OPEN →	← CLOSE →																						
Libertad	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0.25	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	0
	4	0	0	0	0	0	0.25	1	1	1	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	1
	5	0	0	0	0	0	0.25	1	1	1	1	1	1	1	0.5	1	1	1	0.5	0	0	0	0	0	0
	6	0	0	0	0	0	0	1	1	1	1	1	1	0.75	1	0.75	0	0	0	0	0	0	0	0	0
Estero WL		1175	1180	1180	1180	1175	1160	1130	1110	1090	1135	1000	990	990	980	970	975	970	980	975	970	970	970	975	975
Manila Bay		1175	1180	1180	1180	1175	1150	1130	1110	1090	1075	1165	1060	1060	1060	1060	1070	1080	1085	1090	1095	1105	1115	1125	1135
Gate		← OPEN →						← CLOSE →																	
Aviles	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	0	0	0.25	1	1	0.75	0	0
	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0.5
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.25	0	0	0	0
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.75	0	0	0	0	0	0
Valencia	1	1	1	1	1	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	1	1	1	1	1	1	1	1	1	1	0.5	0	0	0	0	0.25	1	1	1	1	0.25	0	0	0
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.75	0	0	0	0
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.75	0	0	0	0.25	1	1	1	1
Quiapo	1	missing data																							
	2																								
	3																								
	4																								
Binondo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5
	2	1	1	1	1	1	1	1	1	1	1	1	0.75	1	1	1	1	1	1	1	0.5	1	0.25	0	0
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	0
Makati	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paco	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pandacan	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sta. Clara	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The interview survey results for the case of 2009 Typhoon Ondoy are shown in Figure 3.2.8.

The figure shows that the drainage channel was flooded even if Libertad and Tripa de Gallina pumping stations accelerated the draining by opening their gates. This means that drainage channel and pumping drain cannot cope with the amount of rainfall.

Some pump stations were flooded by rapid rise of water. The pumping station drainage cannot accommodate the amount of rainfall like Ondoy which poured 40mm/hour in a few hours.

The 6-hour rainfall of 2009 Typhoon Ondoy was 205mm, and the amount is evaluated to be that of a 10-20 year return period by rainfall analysis.

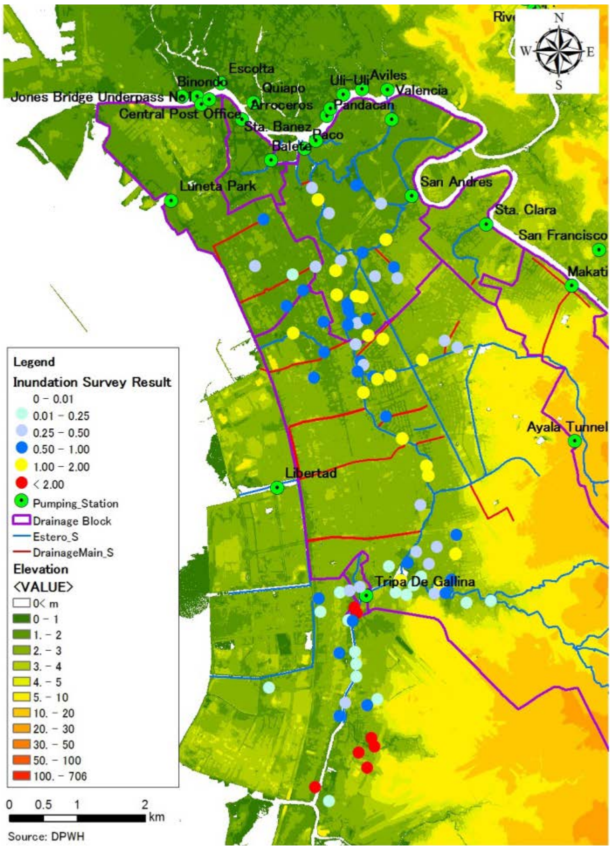


Figure 3.2.8 Inundation Depth of Typhoon Ondoy

3.2.4 Issues and Challenges on Drainage Improvement in Metro Manila

Taking into consideration the current situation described in Chapter 2, abovementioned condition of drainage channels/esteros and pumping stations and general issues facing a mega city such as Metro Manila, issues and challenges related to drainage improvement in Metro Manila are as summarized below.

(1) Constraints on the construction period brought about by urban character of the project sits

- Issue 1: Difficulties on Land Acquisition
- Issue 2: Tedious coordination with different and various private and semi-government agencies handling underground utilities
- Issue 3: Limited area that can be used during project construction (narrow road, etc.)

(2) Difficulties of open-cut-method from point of view of road traffic condition

- Issue 4: Difficulties due to heavy traffic and traffic jam aggravated by construction work

(3) Constraint for drainage improvement in the low-lying area

- Issue 5: Solution is additional pumping station, but land acquisition is limited.

(4) Limitation of handling floods by pumping stations

- Issue 6: Need for additional pumping stations as well as Storage Facilities

(1) Issue 1: Difficulties on Land Acquisition

A lot of houses along drainage channel makes widening very difficult and will require funding for land acquisition as shown below left. The picture below right shows that the presence of residential structures and encroachment by ISFs houses makes it difficult for channel improvement. These situations are typical case in Metro Manila.

Figure 3.2.9 Situation along drainage channel in Metro Manila

The example of difficulties of ROW is shown in Figure 3.2.10. Road width is only 6m which is not enough for the proposed box culvert to install. It is assumed that ROW and resettlement along this road will be required and it is very difficult.

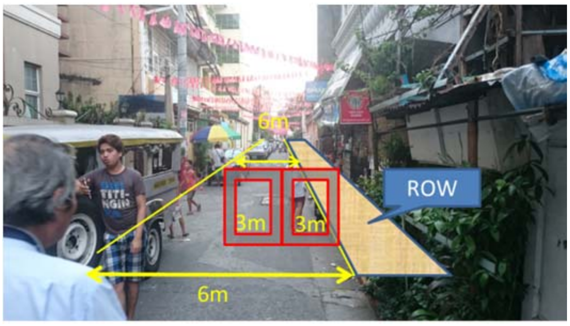


Figure 3.2.10 ROW and Resettlement

(2) Issue 2: Tedious coordination with different and various private and semi-government agencies handling underground utilities

Below is a photo (left) of the excavation work to install a drainage pipe under the road. Coordination with water supply administrator and re-construction of water pipe along this road will be required.

Picture below (right) shows the utility pole standing in the drainage channel and this utility blocks flood water flow. This pole may have been constructed without any coordination. There is a need for the administrator and the utility agency to coordinate for its correction.

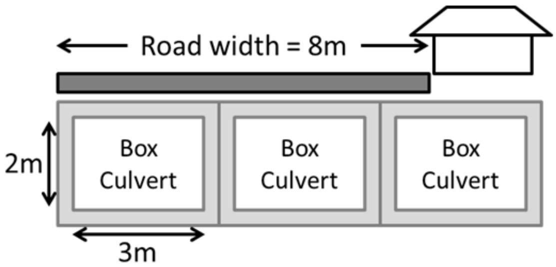
Figure 3.2.11 Example of coordination with utility agency

(3) Issue 3: Limited area that can be used during project construction

As seen in the right picture, in this case, work space is in the drainage channel for the maintenance dredging. In this manner, in Metro Manila the space for project construction is often limited.

Figure 3.2.12 Dredging in Channel Space

Moreover, box culvert is proposed in narrow road as shown below. In this case it may be difficult to implement the project.



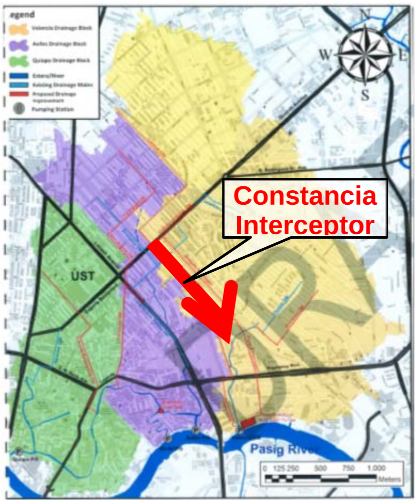


Figure 3.2.13 Proposal under Narrow Road

(4) Issue 4: Difficulties due to heavy traffic and traffic jam aggravated by construction work

Construction work for long distance road – occupies space are causing heavy traffic due to the reduction of road space for vehicle transit. The left picture shows construction works for elevated bridge with road occupation same as box culver project.

Box culvert is proposed under the road shown in the right picture. To occupy even one lane is fatal in this heavy traffic condition.

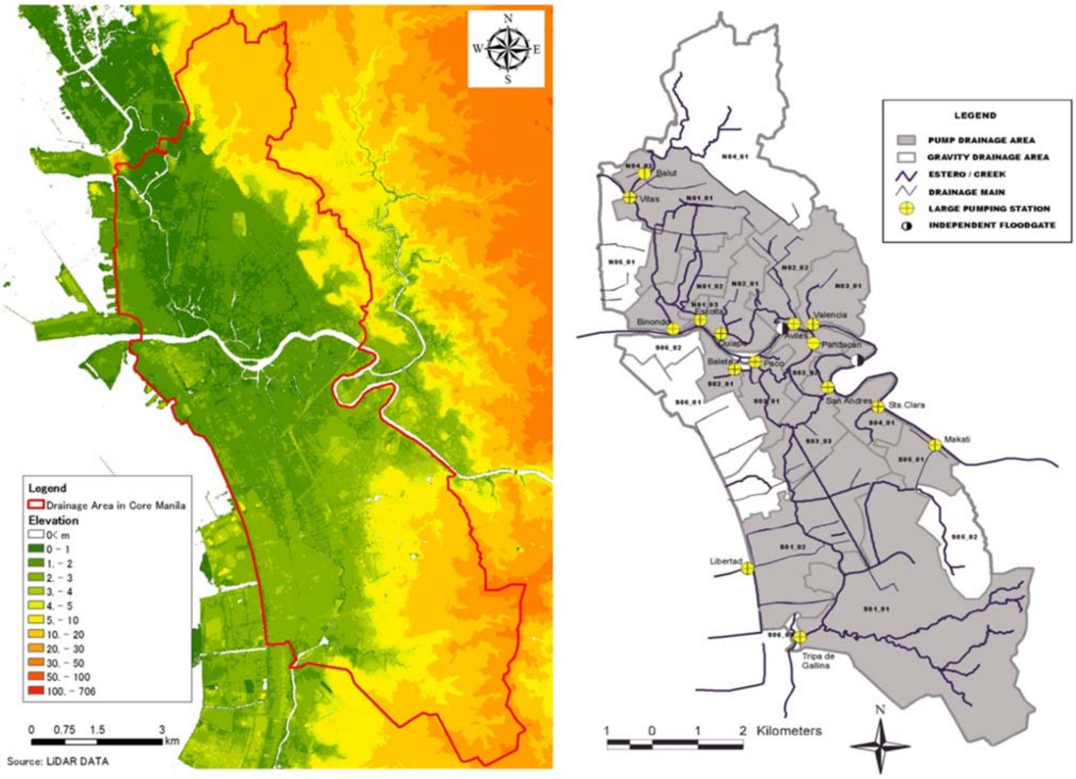
Figure 3.2.14 Road Occupation and Traffic Condition

(5) Issue 5: Solution is additional pumping station, but limited land for acquisition.

Although gravity drain is available in coastal area and hilly area, 70% of drainage area in Metro Manila requires pumping station as shown below. Especially in low-lying area, even if box culvert was installed as drainages, the outlet is lower than the drainage main or estero river bed, so that pumping station to drain water effectively is still needed.

According to simulation result described later, flood water flow down to low-lying area which cannot be drained by gravity.

Thus, drainage improvement in Metro Manila requires new or enhancement of pumping station. However, it is very difficult to acquire the land as mentioned in Issue 1.



Source: JICA Survey Team made from LiDAR Source: DICAMM 2005

Figure 3.2.15 Topographic Map and Drainage in Metro Manila

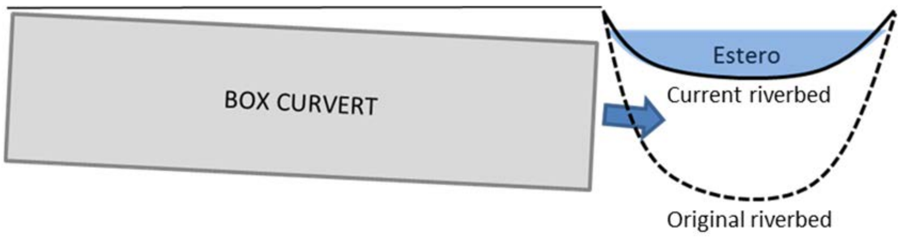


Figure 3.2.16 Box Culvert Installation in Low-lying Area

(6) Issue 6: Need for additional pumping stations as well as storage facilities

Some pumping stations were flooded by rapid rise of water. The pumping station drainage cannot accommodate the amount of heavy rainfall in a few hours as described in Subsection 3.2.3(4). Therefore, storage facilities to store the excess water are required in Metro Manila. However, it is very difficult to acquire the land as mentioned in Issue 1.

3.3 Selection of Priority Project Areas in Metro Manila

3.3.1 Preparation of Criteria to Select Priority Area

The following criteria were formulated to give emphasis on the importance of each area. These criteria serves as a simple ‘checklist’ of what is found in each nominated area and must be considered in ‘equal’ values during its evaluation.

1 Properties to be protected from floods

- 1-1 Population Density: Large investments/properties and human life to be protected from flood.
- 1-2 Inundated Vital Facilities: Airport, Hospitals, City Hall, Government headquarters such as National Police are expected.
- 1-3 Inundated Major Road Network: Roads considered as core network of Metro Manila that need to be protected.

2 Flood Risk

- 2-1 Inundation Area: The extent of inundation in the area that will be considered as flood risk
- 2-2 Population in the inundation area: The number of people exposed to the flood risk
- 2-3 Geographical Aspect: Determine where the drainage improvement is not easy due to its topography such as 1) pumping station is required in addition to drainages in low-lying area and 2) drainage construction along the terrain cannot accommodate rain water in basin-like terrain.
- 2-4 Damages of Past Flood: Area that has the most damages recorded

3.3.2 Classification of Area Based on the Criteria

Evaluation of each area using the above-mentioned criteria is shown in Table 3.3.1. As a result, san Juan, España-UST and Buendia with many “○” are the top prioritized area.

Table 3.3.1 Selection of Priority Area based on the Criteria

	Tullahan	San Juan	Espana-UST	Buendia	Maricaban	NAIA	Pranaque	Las Pinas	Zapote
1-1		○	○	○					
1-2						○			
1-3	○	○	○	○		○	○	○	○
2-1	○	○	○	◎		○		○	
2-2	○	◎	◎	○					
2-3			○	○	○	○			
2-4	○	○					○		

*: ○ One indicator satisfied, ◎ Two indicators satisfied

Evaluation based on each criterion is as follows.

Evaluation by Criteria 1-1 is described in Table 3.3.4.

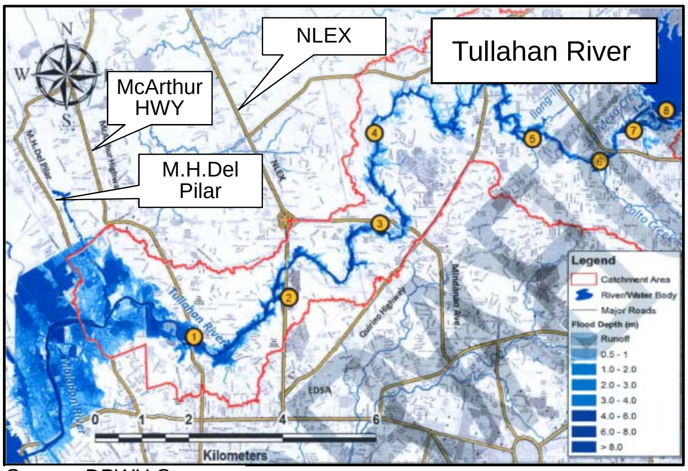
For Criteria 1-2, only NAIA area was selected because the international airport was partially inundated. Other facilities such as City hall in other area were not flooded.

Evaluation by Criteria 1-3, except for the Maricaban Area, main road were flooded thus removing access to the area as shown in the table below.

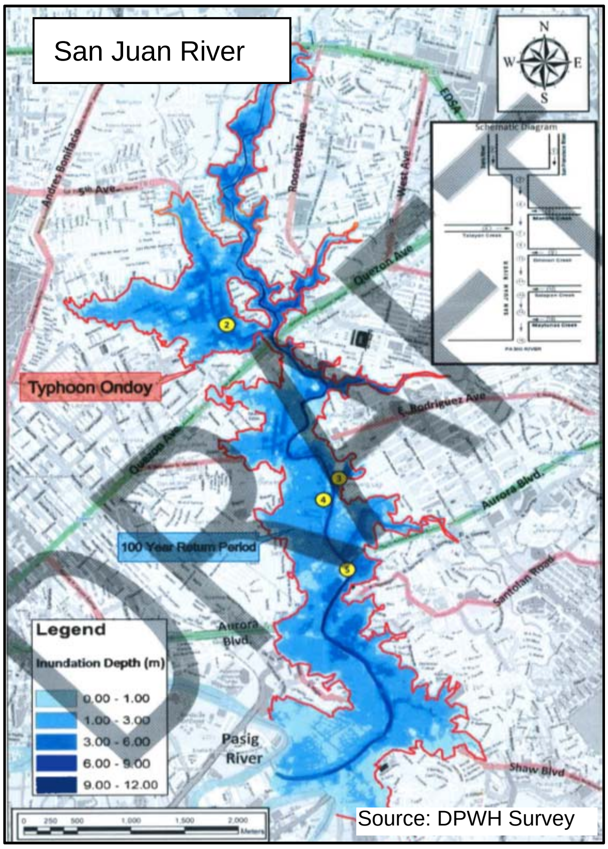
Table 3.3.2 Flooding Condition along Main Roads in Metro Manila

Area	Main Road	Inundation	Remarks
Tullahan	M. H. Del Pilar	x	Map of DPWH Survey
	McArthur Highway	x	Map of DPWH Survey
	NLEX	-	Map of DPWH Survey
San Juan	Quezon Ave.	-	Road wider than 20m
	E. Rodriguez Ave.	x	Road wider than 20m
	Aurora Blvd.	x	Road wider than 20m
	P. Sanchez St. (Shaw Blvd.)	x	Road wider than 20m
Espana-UST	Espana Ave./ Quezon Ave.	x	Road wider than 20m
	A. H. Lacson Ave.	x	Road wider than 20m
	Magsaysay Blvd.	x	Road wider than 20m
	Recto Ave.	x	Road wider than 20m
	Alfonso Mendoza St.	x	Road wider than 20m
Buendia	Quirino Ave.	x	Road wider than 20m
	Taft Ave.	-	Road wider than 20m
	Osmenia Highway	-	Road wider than 20m
	Gil Puyat Ave. (Buendia)	x	Road wider than 20m
	Makati Ave.	-	Road wider than 20m
	Paseo de Roxas	-	Road wider than 20m
	Ayala Ave.	-	Road wider than 20m
	EDSA	-	Road wider than 20m
Maricaban	Oemenia Highway	-	Road wider than 20m
NAIA	Roxas Blvd.	x	Road wider than 20m
	Quirino Ave.	x	Road wider than 20m
	Ninoy Aquino Avenue	x	Road wider than 20m
Pranaque	Quirino Ave.	x	Map of DPWH Survey
	Ninoy Aquino Avenue	x	Map of DPWH Survey
Las Pinas	Carlos P. Garcia Ave. Ext.	x	Map of DPWH Survey
	Diego Cere Ave.	x	Map of DPWH Survey
Zapote	Alabang Zapote Rd.	x	Map of DPWH Survey
	Morino Blvd.	x	Map of DPWH Survey

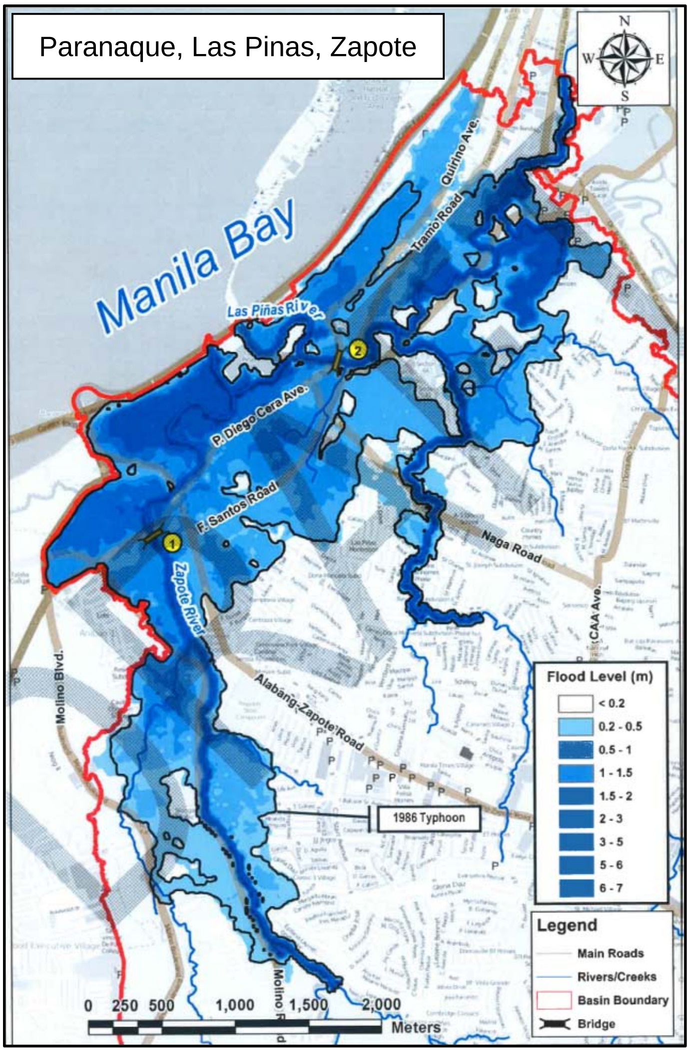
Source: JICA Survey Team



Source: DPWH Survey



Source: DPWH Survey



Source: DPWH Survey

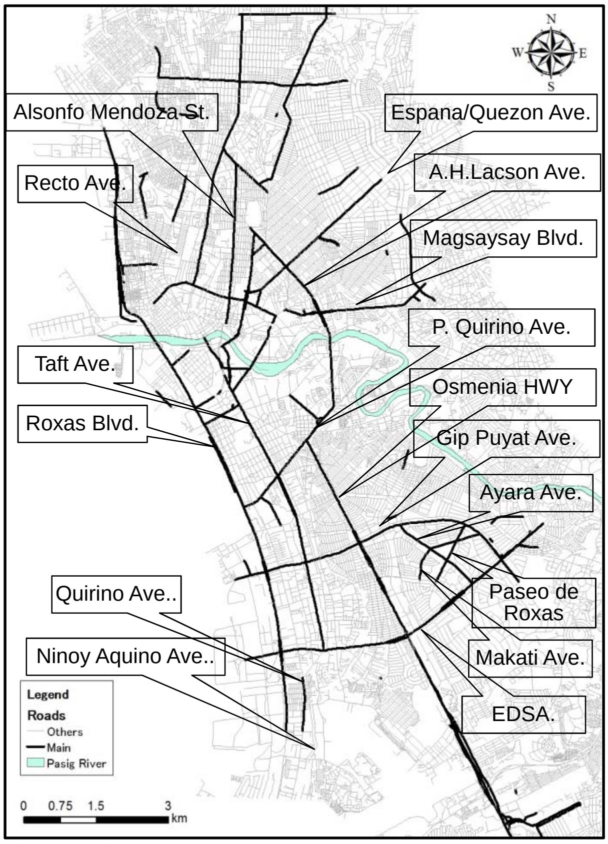


Figure 3.3.1 Main Road in each Area

Evaluation by Criteria 2-1 and 2-2 is described in Table 3.3.4.

For the following four (4) areas, it was not easy to develop a drainage improvement plan using Criteria 2-3.

(1) España-UST

There is a low-lying area (near UST) in the basin-shape of this site and the drainage for this area is not feasible as shown in Figure 3.3.2.

(2) Buendia

Although the elevation of the northern part is low, the drainage from this site relies on the drainage from the central part of the area and due to the poor capacity of existing drainage channel the area along this drainage channel suffers from floods.

(3) Maricaban

Upstream of this area is on high elevation and rain water flows down to the low-lying area rapidly. However the low-lying area relies on pumping drainage.

(4) NAIA

Almost all area is low-lying and water run-offs from Buendia and Maricaban areas were intercepted in this area.

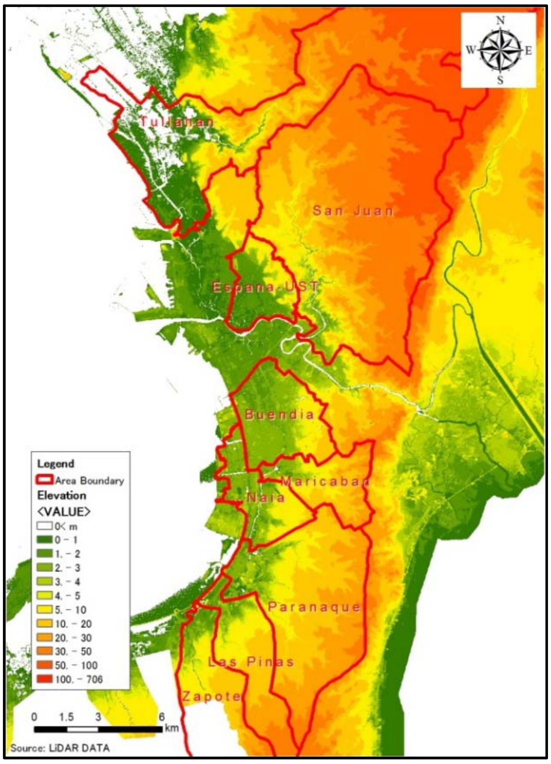


Figure 3.3.2 Topomap of each basin

Infrastructure damage and agricultural damage of the 2009 Typhoon Ondoy are summarized in the Situation Report (Sitrep) of OCD. Damage of each area based on the Sitrep is used as basis for Criteria 2-4 (see Appendix 3-1). The damage of each city in Metro Manila is calculated. However Bacoor City and Dasmarinas City in the Zapote Area were considered within the area of Cavite Province. Thus the damages of Bacoor and Dasmarinas are estimated by ratio of the area to Cavite.

Table 3.3.3 Damage in Sitrep of 2009 Typhoon Ondoy

Unit: thousand Php

Tullahan	San Juan	España-UST	Buendia	Maricaban	NAIA	Paranaque	Las Pinas	Zapote
29,435	43,622	3,450	2,060	1,195	5,354	24,444	5,728	6,140

Source: Situation Report of OCD

Evaluation by other criteria is shown in Table 3.3.4.

Table 3.3.4 Evaluation by Other Criteria for Selection of Priority Area

Area Name	Area (km)^2	Criteria 1-1		Criteria 2-1		Criteria 2-2	
		Population	Population Density (Person/sqKM)	Inundation Area (km)^2	Inundation Ratio (%)	Population in Inundation Area	Population density in inundation area
Tullahan	90.03	1,609,062	17,873	14.68	16.3	333,970	22,750
San Juan	88.64	1,880,360	21,213	11.43	12.9	327,784	28,678
Espana-UST	10.13	383,280	37,818	4.18	41.2	187,813	44,931
Buendia	16.44	478,371	29,095	5.03	30.6	167,349	33,270
Maricaban	11.64	173,202	14,883	3.13	26.9	87,201	27,860
NAIA	11.46	108,586	9,474	3.58	31.2	50,585	14,130
Paranaque	41.36	582,003	14,073	0.96	2.3	15,988	16,654
Las Pinas	16.58	299,960	18,092	1.97	11.9	47,006	23,861
Zapote	50.34	432,740	8,596	3.61	7.2	66,226	18,345

*: Top (3) three are hatching

Source: JICA Survey Team

3.3.3 Proposed Project in each Area

The drainage improvement project including the urgent projects proposed in the DPWH Survey has some problems but will be implemented in general. However, the proposed project in España-UST and Buendia-Maricaban area has many issues and challenges and will be difficult. It is recommended that for these two areas the underground tunnelling technology shall be utilized. The basis for the recommendation is discussed in Section 3.4.

(1) Tullahan

River improvement is proposed as described in Subsection 2.5.1.

(2) San Juan

River improvement and pumping station are proposed as described in Subsection 2.5.2.

(3) España-UST

Combination of new drainage main and drainage channel improvement as described in Subsection 2.5.3 and underground storage pipe explained in Section 3.4 are proposed.

(4) Buendia

Combination of dredging and de-clogging of drainage channel as described in Subsection 2.5.4 and underground storage pipe explained in Section 3.4 are proposed.

(5) Maricaban

Combination of river improvement as described in Section 2.5.5 and underground storage pipe explained in Section 3.4 are proposed.

(6) NAIA

Dredging of drainage channel and pumping station are proposed as described in Subsection 2.5.6.

(7) Paranaque

Dredging of drainage channel and parapet flood wall is proposed as described in Subsection 2.5.7.

(8) Las Pinas

River improvement, bridge reconstruction and flood gate are proposed as described in Subsection 2.5.8.

(9) Zapote Area

River improvement and diversion Box Calvert are proposed as described in Subsection 2.5.9.

3.4 Selection of Candidate Areas for Japanese Underground Tunnel Technologies

3.4.1 Basic Policy on Underground Tunnel River in Japan

Based on the “Technical Criteria for River Works – Practical Guide for Planning”, a tunnel river should not be installed unless it is unavoidable in the light of topographic features or for other special reasons in view of the following aspects;

- Negative effects against flow debris during flood
- Difficulties in increasing the flow capacity
- Difficulties in channel maintenance such as cross-section occlusion caused by falling objects during floods

Moreover, according to the “Guide for urban river planning - three-dimensional river facilities”, the planning policy is that the “Tunnel River shall be planned only if there are other particularly compelling reason” because tunnel river should be avoided as much as possible.

3.4.2 Preparation Criteria on Selection of Candidate Areas for Japanese Underground Tunnel Technologies

In the above mentioned policy, underground tunnel is not an alternative but a final approach. Therefore, it is necessary to select the area where underground tunnel is the only solution. The selection criteria were developed with the DPWH are:

1. Great improvement effect is expected (Core Manila): The project site should be in the Core Manila, where a great impact is expected because underground tunnel requires huge amount of project cost. Therefore, this criterion is the highest.
2. Necessity of emergency onset of the measures

   2-1. Project area will consider a lot of ROWs for an open-cut/excavation construction method translating to prolonged project implementation due to the intricacies involved in the procurement of the ROW. Therefore, underground tunnel method which requires limited ROW has advantage.

   2-2. High urbanized land use and high level of economic activities (or expected in near future): Highly urbanized area attracts (or expects) investments. Thus the area could increase the rate of urbanization and economic activities with the installation of the underground tunnel.
3. Minimal to None Effect on Traffic condition

   3-1 Heavy Traffic: Underground tunnel technology will remove the impact on traffic unlike in the case of open-cut method that aggravates traffic condition.

   3-2 No detour route: Underground tunnel method requires land acquisition only for the vertical shaft, while open-cut method needs a land acquisition along the road. Tunnel method alignment can be located under government-owned land removing requirement of private lands for ROW.
4. Land Development

   4-1 Difficulties on road-widening works for the planned drainage channel: Box culvert for drainage main or diversion channel is proposed under roads to avoid land acquisition as much as possible. However road is narrow in populated area and in some case the road width is not enough for box culverts. In this case only tunnel is the solution.

   4-2 No space for the additional pumping station to be enhanced: Rain water drainage in Metro Manila relies on pumping station. Drainage improvement project requires new pumping station or enhancement of the capacity as well as the water way improvement. If there is not enough land acquired or is not available then drastic countermeasure is required (in this study the countermeasure is underground tunnel).

For these criteria, the 1) España-UST area, 2) Buendia area and 3) Maricaban area were selected as shown below.

Table 3.4.1 Selection by Criteria for Japanese Underground Technology

	Tullahan	San Juan	Espana-UST	Buendia	Maricaban	NAIA	Pranaque	Las Pinas	Zapote
1	-	-	○	○	○	○	-	-	-
2-1	○	○	-	○	○	-	-	○	○
2-2	○	○	○	○	○	-	-	○	-
3-1	-	-	○	○	○	-	-	○	○
3-2	-	-	○	-	○	-	-	-	○
4-1	-	-	○	○	-	-	-	-	○
4-2	-	-	-	○	○	-	-	-	-

*: ○ Criterion Satisfied

Source: JICA Survey Team

Evaluation by each criterion is as follows.

(1) Criteria 1: Great improvement effect is expected (Core Manila)

The target area of DICAMM 2005 is called Core Manila, and España-UST, Buendia, Maricaban and NAIA is within the area.

(2) Criteria 2-1: A lot of ROWs under open-cut/excavation construction method

As evaluated by the DPWH Survey, the Tullahan, San Juan, Buendia, Maricaban, Las Piñas and Zapote area require a lot of ROWs and/or house relocation.

(3) Criteria 2-2: Highly urbanized land use (or expected in near future)

The area has a population density that is higher than that of Tokyo (14,849 people/km2, as of September 1, 2015) where has same rainfall characteristic due to monsoon and has underground tunnel are selected.

(4) Criteria 3-1: Heavy Traffic

Heavy traffic is assumed to be terrible by interpretation of Google Earth, field survey and interview survey.

(5) Criteria 3-2: No detour route

Map information such as google map etc. is used for the evaluation taking into consideration one-way and U-turn.

(6) Criteria 4-1: Difficulties of road-widening works for planned drainage channel

Road width from Google Earth and field survey and box culvert size in the DPWH Survey result are used for the evaluation.

(7) Criteria 4-2: No space for the additional and/or enhancement of the pumping station

The pumping stations that are proposed in the DPWH Survey are confirmed by field survey.

3.5 Preliminary Drainage Improvement Plan in the Selected Area

3.5.1 Conditions for Planning

(1) Surrounding Circumstances

Based on the DICAMM 2005, Core Manila can be protected against a 10-yr flood period mainly through dredging, de-clogging, new drainage main and pump rehabilitation.

As mentioned in Subsection 3.4.1, application of underground tunnel should be the final approach. The underground tunnel can convey the excess water of over a 10-yr return flood if used as the basis of the DICAMM 2005. This scenario is achievable since 1) DPWH just started drainage improvement as flood control project in 2015, 2) MMDA has carried out maintenance works actively in recent years and 3) WB and MMDA are presently discussing the pumping rehabilitation project.

(2) Design Scale

DPWH started the drainage improvement project in 2015 which is supposed to meet a 10 to 25-yr return flood. The project cost is a huge amount based on the size of the proposed tunnel. Moreover, the existing drainage/estero should be improved to convey rainwater to the tunnel to cope with 50-yr return period flood, thus, requiring a longer implementation period and additional cost.

Therefore, the design scale of this project is 25-yr return period with expandable plan to consider a 50-yr flood and climate change adaptation.

3.5.2 España-UST

(1) Planning policy

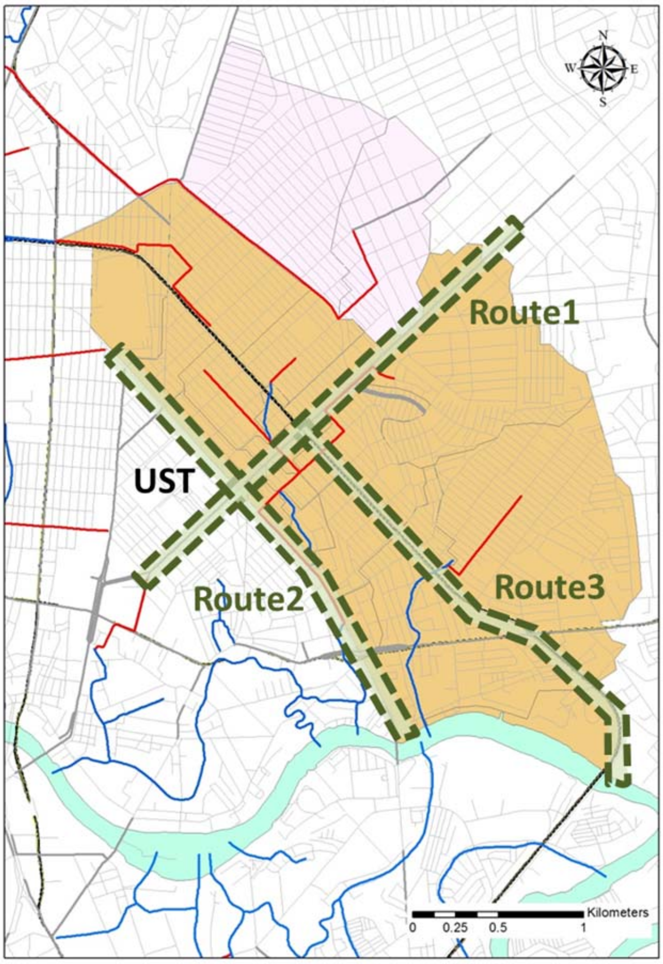
1) ROW Acquisition

The three routes shown below are major roads or railway that has wider carriage width, something that was considered for the size of the tunnel. Hence, the alignment of the tunnel can be easily adjusted depending on the location of the vertical shaft since land acquisition is needed and will depend on the location of the acquired land.

Route 1 (España Avenue): Under the wide road, and expandability for diversion channel from San Juan River can be considered in the future

Route 2 (Lacson Avenue): Under the wide road, near existing pumping station, wider area can be covered.

Route 3 (Philippine National Railway (PNR)): Under the railway



Source: JICA Survey Team

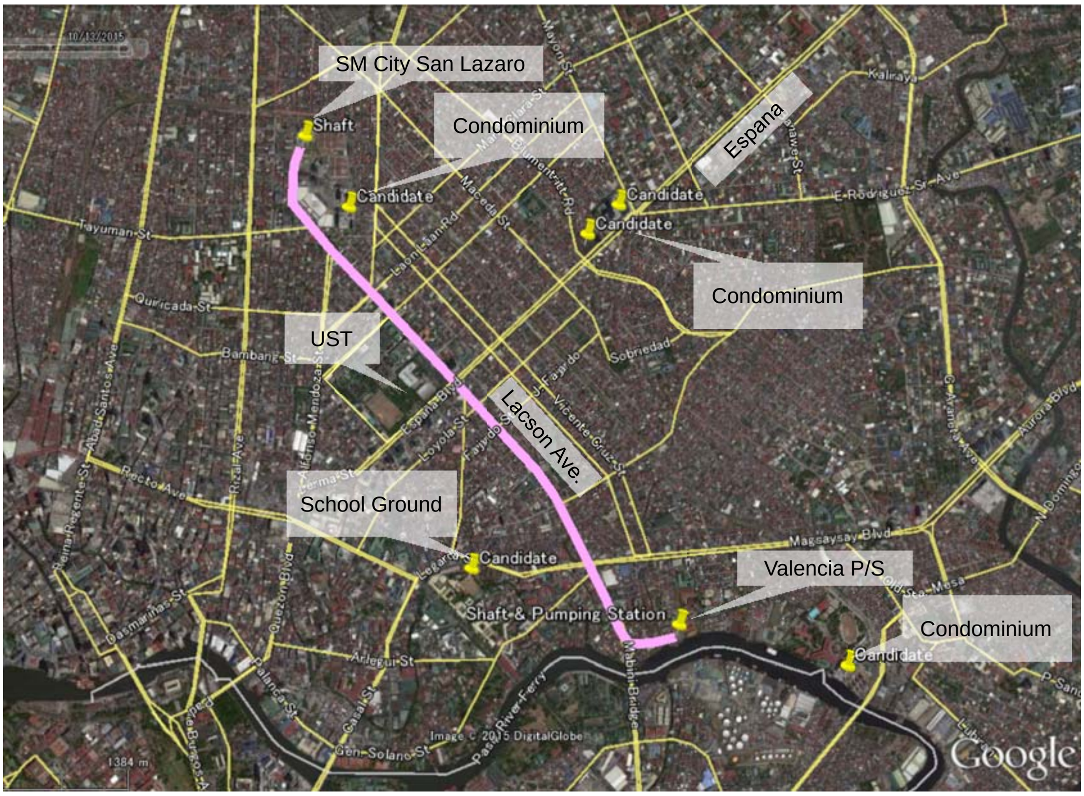
Figure 3.5.1 Candidate Routes for Tunnel in España-UST

2) Basic Concept of Operation of the Underground Tunnel

The basic concept of operation of the underground tunnel is first, to store all excess water and then pump it out after the flood. If the tunnel volume is not enough to store all water, it will divert water immediately to the pumping station. The advantage of the tunnel as a storage pipe is in its expandability for future diversion channel in case of larger design scale but this will necessitate that the volume should be large.

(2) Tunnel Route

The points with yellow pin are selected as candidate areas for vertical shaft using Google Earth interpretation. Site inspection is carried out to validate if these points are still available and to look for other available sites. As shown in Figure 3.5.1, the vacant lots on the north side of SM City San Lazaro and on the west side of Valencia Pumping Station are selected as vertical shaft. The pink line is the tunnel alignment of 3.5km in length.



Source: JICA Survey Team

Figure 3.5.2 Location Map Proposed Tunnel Route in España-UST

(3) Drainage Area and Tunnel Volume

As shown in Figure 3.5.2, northeast area from the Lacson Avenue is the drainage area.

The drainage area is divided into two areas: Area (1) and Area (2). Area (1) is the original drainage area. Blumentritt Interceptor is proposed in Area (2) to drain 10-yr flood water, any excess water will come down to the tunnel.

Tunnel volume is computed at 446,000 m3 as described below.

1) Store excess run-off water then pump up after flood

Tunnel volume is calculated as follows.

- Total drainage area: 7.42km2 (Area (1) 5.86km2 and Area (2) 1.56km2)
- Tunnel Length: 3.5km
- Runoff coefficient: 0.8
- Rainfall (difference between 10-yr and 25-yr rainfall): 116.3mm
- Total runoff (Tunnel Volume): 690,357m3
- 48 hours pumping capacity: 4.0m3/sec

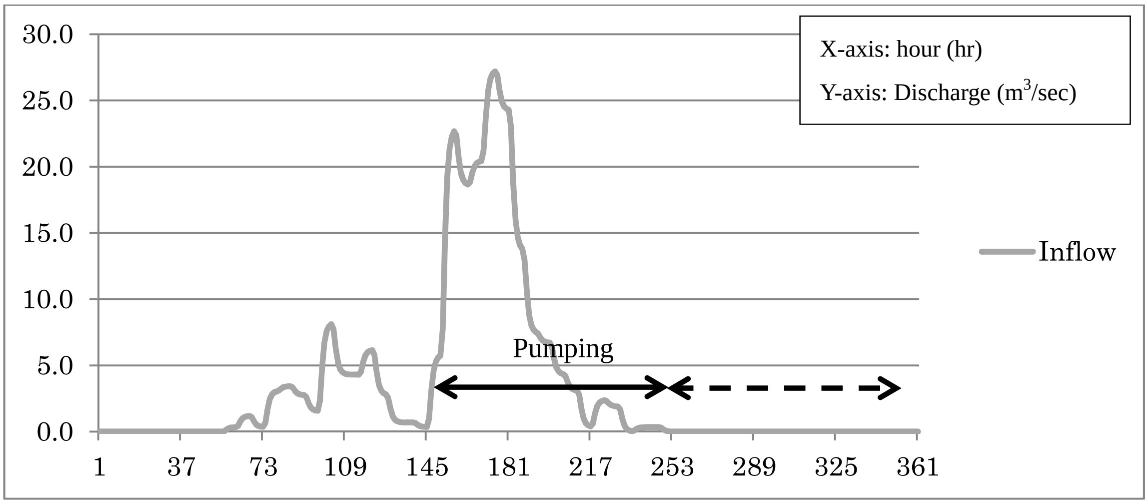
2) Pumping start during flood

The tunnel volume reduction was examined by starting running the pump earlier because large volume and huge cost are required if the storage pipe impound all runoff.

The inflow to the tunnel is computed by runoff simulation model (unit hydrograph method) developed by the DICAMM 2005. The inflow hydrograph is calculated by the difference between 25-yr hydrograph and 10-yr hydrograph.

The period from the start of pumping until the end of flood is 17 hours as shown in Figure 3.5.3, and the total pumping volume is $4.0m^3/sec \times 17hours \times 60minutes \times 60seconds = 244,800m^3$.

Thus, the tunnel volume is 690,357 – 244,800 = 445,557m3.

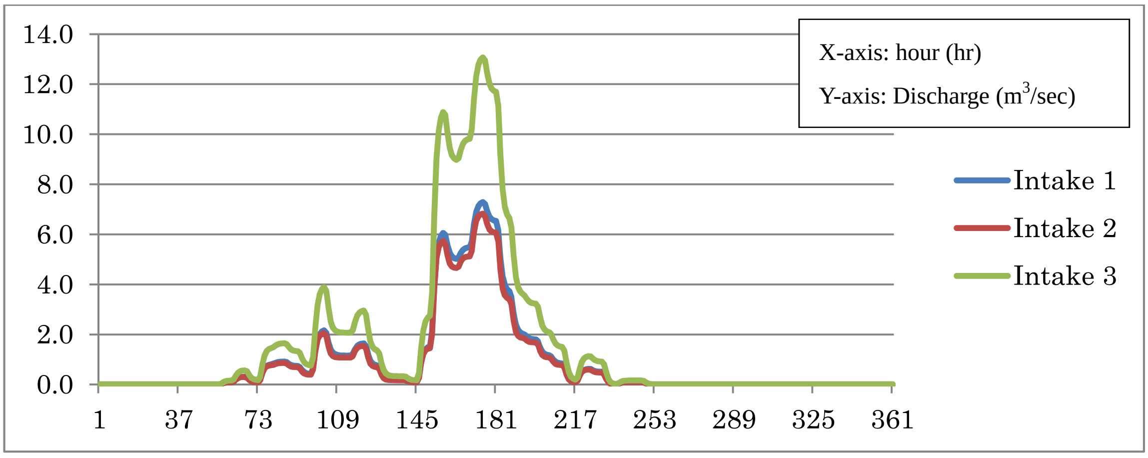


Source: JICA Survey Team

Figure 3.5.3 Tunnel Inflow in España-UST

(4) Intake discharge into the Tunnel

The inflow from each intake was computed as that of the runoff simulation. The hydrograph of each intake and peak-cut volume are shown below.



Source: JICA Survey Team

Figure 3.5.4 Inflow at each Intake in España-UST

Table 3.5.1 Inflow and Peak-cut Discharge at each Intake in España-UST Area

Unit: m3/sec

Espana-UST	Intake 1	Intake 2	Intake 3
Catchment Area (km^2)	2.07	1.59	3.74
Q50-yr	38.3	35.8	68.6
Q25-yr	32.3	30.3	57.9
Q10-yr	25.0	23.4	44.9
Cut(25yr-10yr)	7.3	6.9	13.0
Cut(50yr-10yr)	13.3	12.4	23.7

Source: JICA Survey Team

(5) Expandability toward 50-yr flood

The expandability toward 50-yr flood, peak-cut discharge increase as shown in Table 3.5.1 and increment of pumping capacity is required. The appropriateness of the measures was confirmed by a simple calculation of the inflow from the intake and outflow of the pumping station. The detail of simple calculation is attached in Appendix 3-2.

As a result, an increment of pumping capacity (4.0 → 32.6m3/sec) is needed to cope with a 50-yr flood.

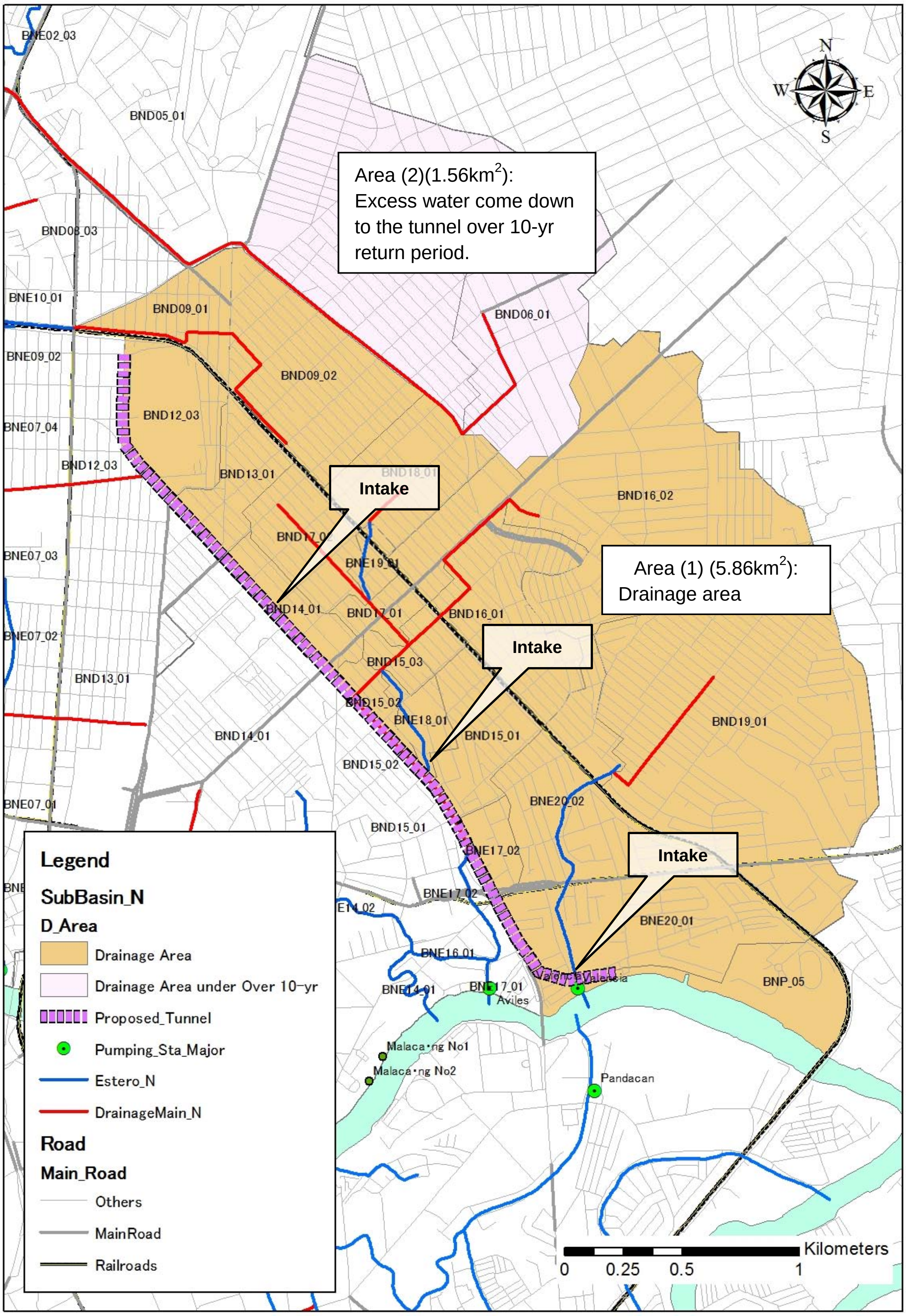
(6) Consideration on Climate Change

Taking climate change into consideration countermeasure against 30-yr flood was examined. To increase pumping capacity from 4.0 to 6.0 m3/sec with the construction cost of 400 million Php is the countermeasure.

(7) Possibility of Cost Reduction with the Balance between Pump Capacity and Volume of Storage Pipe

Cost increase of pump capacity enhancement and cost down due to reduction of storage pipe volume, the latter effect is larger for the total cost, therefore, there is the possibility of further reducing construction cost. For example, when the pumping capacity increase from 4.0 to 6.0 m3/sec, the storage pipe volume decrease 4,460000 to 310,000 m3.

However, hydraulic analysis is necessary to examine how much the pump capacity includes, how is the flow condition among free-surface flow, pressure flow and the mixed flow.



Source: JICA Survey Team

Figure 3.5.5 Drainage Area in España-UST

3.5.3 Buendia-Maricaban

(1) Planning Policy

1) Buendia and Maricaban as a Unit

As mentioned before the proposed tunnel will cross the Maricaban River. Using this alignment will entail social acceptability challenges since there are ISFs remaining and flooding is frequent in the area.

These areas were treated as a unit in DICAMM 2005 within the drainage area of Libertad and Tripa de Gallina.

2) Basic Concept of Operation of the Underground Tunnel

The location of the PNR Interceptor proposed in the DPWH Survey is appropriate because 1) the alignment is along a road dividing the basin and 2) the location is a flood prone area where rainwater gathers naturally.

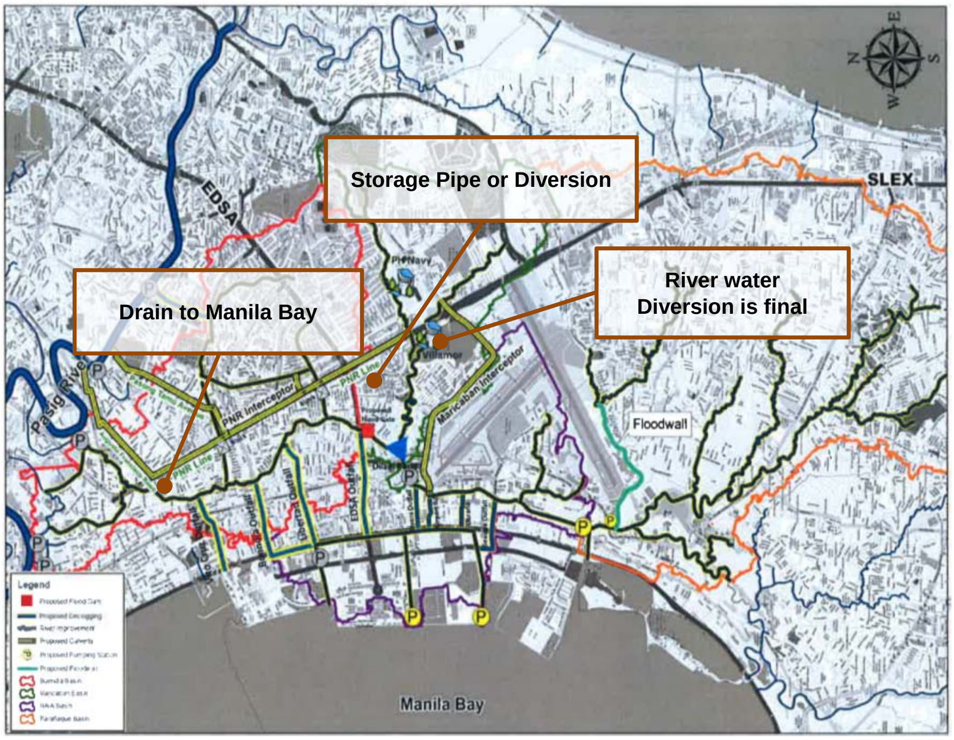
The basic concept of operation of the tunnel is first, to store all excess run-off water and then pump it out after flood. If the tunnel volume is not enough to store all water, it will immediately divert the excess by pumping it out without storing it first. The advantage of a storage pipe is the expandability for future diversion channel in case of larger design scale but this will translate to a larger volume.

3) Drain to Manila Bay is the principle

Although the PNR Interceptor is proposed to discharge into the Pasig River in the DPWH Survey, Buendia and Maricaban drainage areas are not within the Pasig River Basin. This means that the outlet of the PNR Interceptor is the Manila Bay preferentially in this JICA Survey.

4) River water diversion as a final approach

In the DPWH Survey, diversion from both tributaries with retarding basin is proposed. Possibility of river improvement should be examined again.



Background drawings: DPWH Survey

Figure 3.5.6 Planning Policy for Buendia-Maricaban Area

(2) Tunnel Route

One site for the shaft was selected in Nichols Interchange in Pasay City because it is the only site with enough space for the shaft.

Three (3) candidate routes were selected as shown in Figure 3.5.7 and Route 3 was selected as proposed tunnel alignment after site inspection because Route 3 requires the smallest land acquisition.

Route 1: Osmeña Highway - Mataas na Lupa St. - Quirino Ave.:8.2km

Route 2: Osmeña Highway - Ocampo St. - Pedro Bukaneg St.:7.7km

Route 3: Osmeña Highway – Senator Gil Puyat Ave. (Buendia Ave.): 7.2km

Source: JICA Survey Team

Figure 3.5.7 Candidate Route for Tunnel in Buendia-Maricaban

Each route has the following feature based on the site survey.

1) Route 1

The width of Mataas na Lupa St. is only 6.5m and San Andres St. has only 10m width. Taking into consideration the diameter of the tunnel, the tunnel has to pass under private lot. Moreover available open space for pumping station could not be found, so that pumping station have to be constructed in Manila Bay by caisson method.

2) Route 2

The 9 to 10m width of Ocampo St. is not enough for the tunnel. Regarding open space for vertical shaft and pumping station, several large parking lots along Pedro Bukaneg St. are available.

3) Route 3

Gil Puyat Ave. (Buendia Ave.) has enough width for underground tunnel. However it will be a challenge for the shield machine to turn at the corner of Gil Puyat and Osmeña Highway within the area of the intersection. It is assumed that the machine can turn without passing under private lot in this planning stage. As for the vertical shaft and pumping station, there is an open space in the seacoast area as shown in Figure 3.5.7.

(3) Drainage Area and Tunnel Volume

The drainage area of the proposed tunnel is along Osmeña Highway from Nichols Station until Quirino Ave. as shown in Figure 3.3.6.

Tunnel volume is computed to be 844,000 m3 as described below.

1) Store excess run-off water then pump up after flood

Tunnel volume is calculated as follows.

- Drainage Area 15.00km2
- Tunnel Length: 7.2km
- Runoff Coefficient: 0.75
- Rainfall (difference between 10-yr and 25-yr rainfall): 116.3mm
- Total Runoff (Tunnel Volume): 1,308,375m3
- 48 hours pumping capacity: 7.6m3/sec

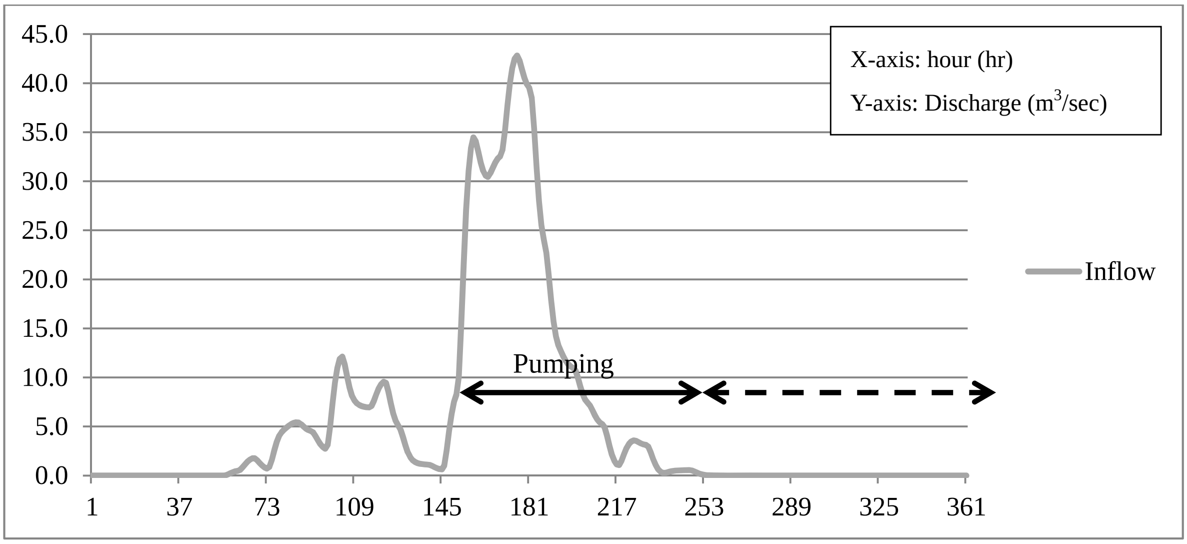
2) Pumping start during flood

The Tunnel volume reduction was examined by starting and running the pump earlier because large volume and huge cost are required if the storage pipe impound all runoff.

The inflow to the tunnel was computed by runoff simulation model (unit hydrograph method) developed by the DICAMM 2005. The inflow hydrograph was prepared by the difference between 25-yr hydrograph and 10-yr hydrograph.

The period from the start of pumping until the end of flood is 17 hours as shown in Figure 3.5.3, and the total pumping volume is $7.6m^3/sec \times 17hours \times 60minutes \times 60seconds = 464,530m^3$.

Thus, the tunnel volume becomes 1,308,375 – 464,530 = 843,845m3.



Source: JICA Survey Team

Figure 3.5.8 Tunnel Inflow in Buendia-Maricaban Area

(4) Intake discharge into the Tunnel

The inflow from each intake was computed as that of the runoff simulation. The hydrograph of each intake and peak-cut volume are shown in the following figure.

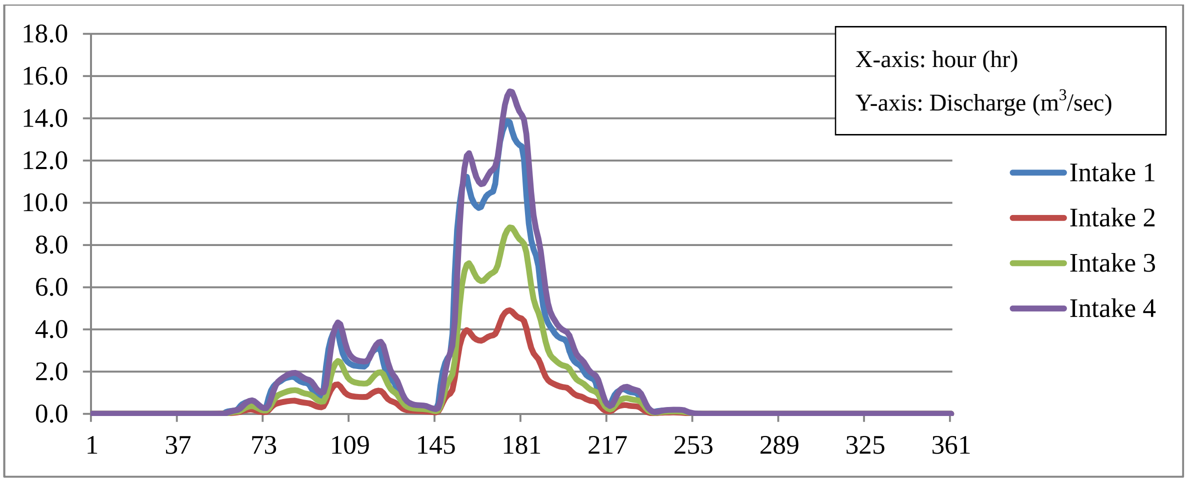


Figure 3.5.9 Inflow at Each Intake in Buendia-Maricaban Area

Table 3.5.2 Inflow and Peak-Cut Discharge at each Intake in Buendia-Maricaban Area

Unit: m3/sec

Buendia	Intake 1	Intake 2	Intake 3	Intake 4
Catchment Area (km^2)	5.77	1.80	2.72	4.71
Q50-yr	79.7	25.8	46.4	80.2
Q25-yr	68.4	21.8	39.1	67.7
Q10-yr	54.8	16.9	30.3	52.5
Cut(25yr-10yr)	13.6	4.9	8.8	15.2
Cut(50yr-10yr)	24.9	8.9	16.1	27.7

Source: JICA Survey Team

(5) Expandability toward 50-yr flood

Regarding the expandability toward 50-yr flood, peak-cut discharge increase as shown in Table 3.5.1 and the increment of pumping capacity is required. The appropriateness of the measures was confirmed by a simple calculation of inflow from intake and outflow of the pumping station. The detail of the simple calculation is attached in Appendix 3-3.

As a result, an increment of pumping capacity (7.6 → 44.7m3/sec) can be accommodated to cope with a 50-yr flood.

(6) Consideration on Climate Change

Taking climate change into consideration countermeasure against 30-yr flood was examined. To increase pumping capacity from 7.6 to 15.7 m3/sec with the construction cost of 1,200 million Php is the countermeasure.

(7) Possibility of Cost Reduction with the Balance between Pump Capacity and Volume of Storage Pipe

Cost increase of pump capacity enhancement and cost down due to reduction of storage pipe volume, the latter effect is larger for the total cost, therefore, there is the possibility of further reducing construction cost. For example, when the pumping capacity increase from 7.6 to 11.4 m3/sec, the storage pipe volume decrease 844,000 to 740,000 m3 and the total construction cost may reduce.

However, hydraulic analysis is necessary to examine how much the pump capacity includes, how is the flow condition among free-surface flow, pressure flow and the mixed flow.

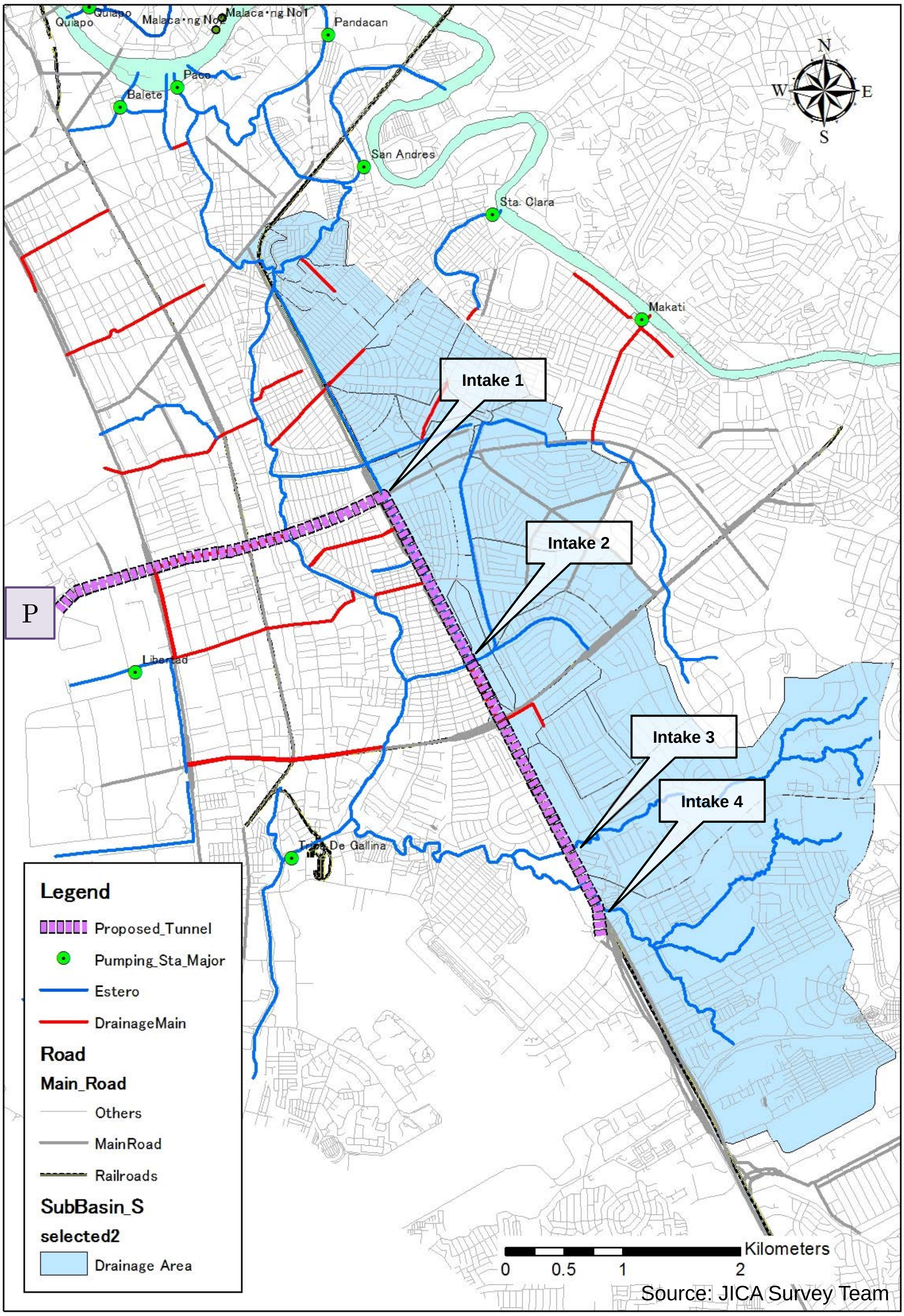


Figure 3.5.10 Drainage Area in Buendia-Maricaban Area

3.6 Inundation Analysis

3.6.1 Inundation Model

(1) Model Description

In this Study, since inland inundation of the city channel system is the main target, it is deemed to conduct an analysis of inland inundation by applying the rainfall value directly to the mesh of inundation analysis model. However, in order to properly reproduce the arrival time of flood or travel time of flood flow, the inundation analysis model used in the WB Master Plan Study (hereinafter referred to as the existing model) was modified and utilized for the inundation analysis.

For the existing model, rainfall data was set as the external force condition, the discharge obtained from the rainfall runoff analysis was applied to the river channel, and the simulation was conducted by the combination of the one-dimensional unsteady flow model for modeling the river routing and the two-dimensional unsteady model for modelling the protected inland area. MIKE-FLOOD developed by DHI was applied.

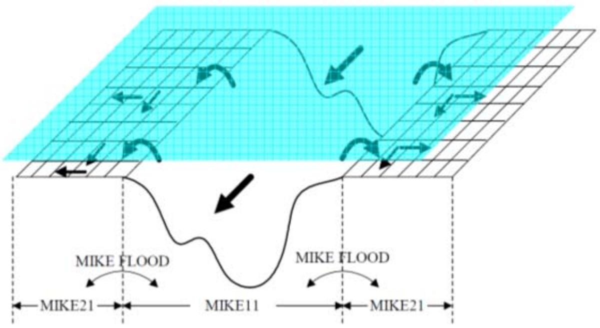


Figure 3.6.1 Model Configuration

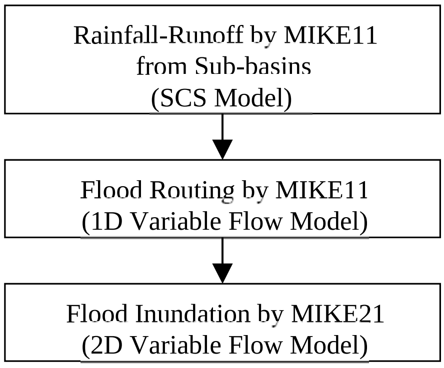


Figure 3.6.2 Flowchart of Inundation Analysis

(2) Rainfall Runoff Analysis Model

SCS method of the existing model was used for the rainfall runoff analysis. The coefficients of rainfall loss of the SCS model were set as C=0.8 for North Manila and C=0.75 South Manila which values were referred from the existing study (WEC study). The time lag was set based on the existing model which value is shown in Table 3.6.2. Figure 3.6.3 and Figure 3.6.4 show the basin segmentation for North and South Manila, respectively.

(3) Channel Networks and Pumps

The channel network was developed based on the existing model, and the cross-sectional channel data were the present cross-section used in DICAMM Study and the designed cross-section applied in the Master Plan. Table 3.6.3 shows the list of channels and covered conduits modeled in this Study. Based on the trial of the reproduction of Typhoon Ondoy, the roughness coefficient of the present channel was determined by modifying values in the existing model and set as shown in Table 3.6.1. The roughness coefficient of the planned channel was set as same as the one used in the Master Plan.

This Study included 16 pump stations, which were the same as the ones set in the existing model. The specification of the pump stations is discussed in Chapter 2. Figure 3.6.5 shows the location map of river channel networks and pump stations.

Table 3.6.1 Roughness Coefficient n of Channel and Covered Conduit

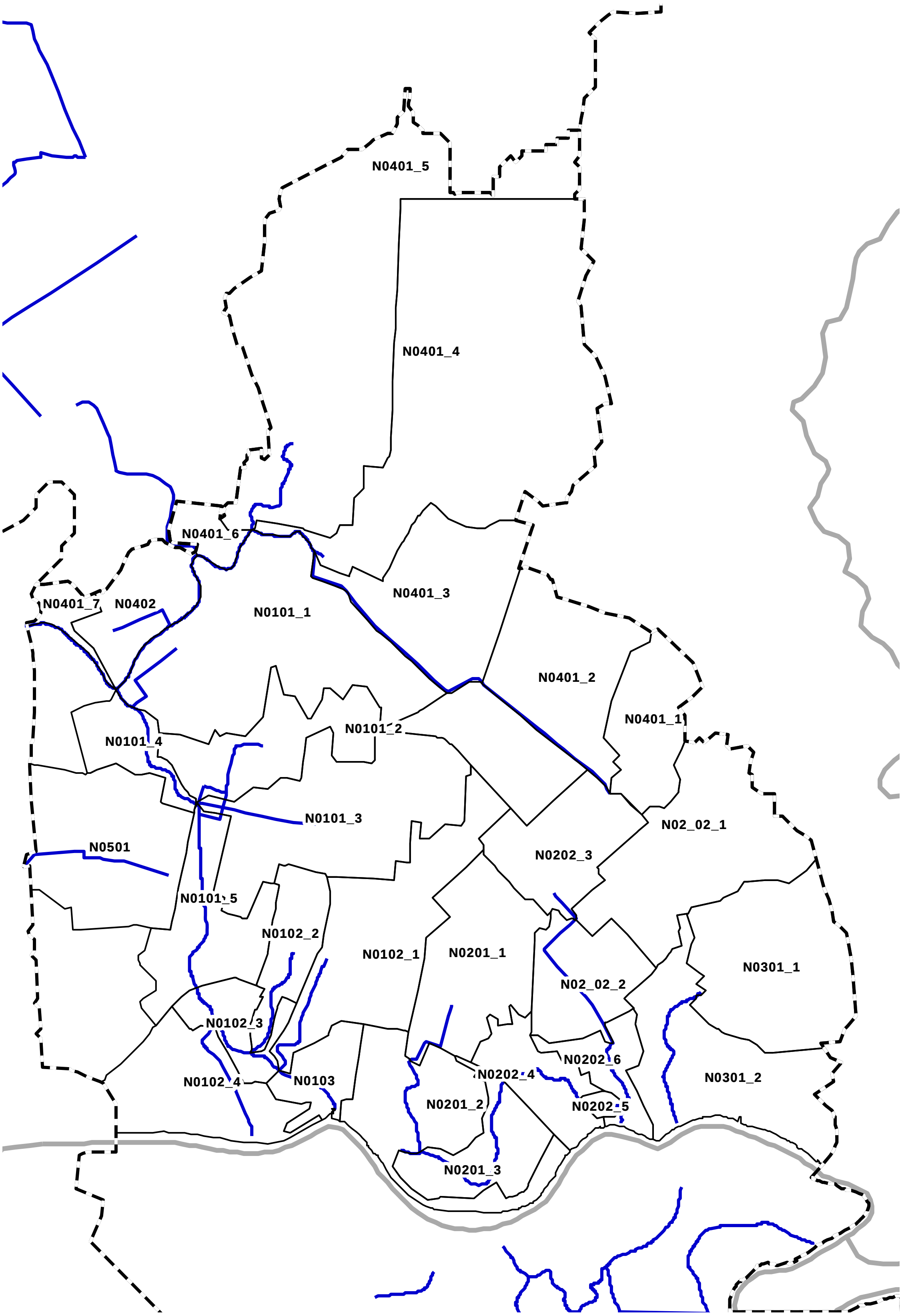
Item	Existing Model in 2005		This Study	
	Existing	Planning	Existing	Planning
Estero	n = 0.030	n = 0.030	n = 0.050	n = 0.025
Drainage	n = 0.018	n = 0.015	n = 0.050	n = 0.015

Source: JICA Survey Team

Table 3.6.2 Lag Time of Every Basin (Lag Time)

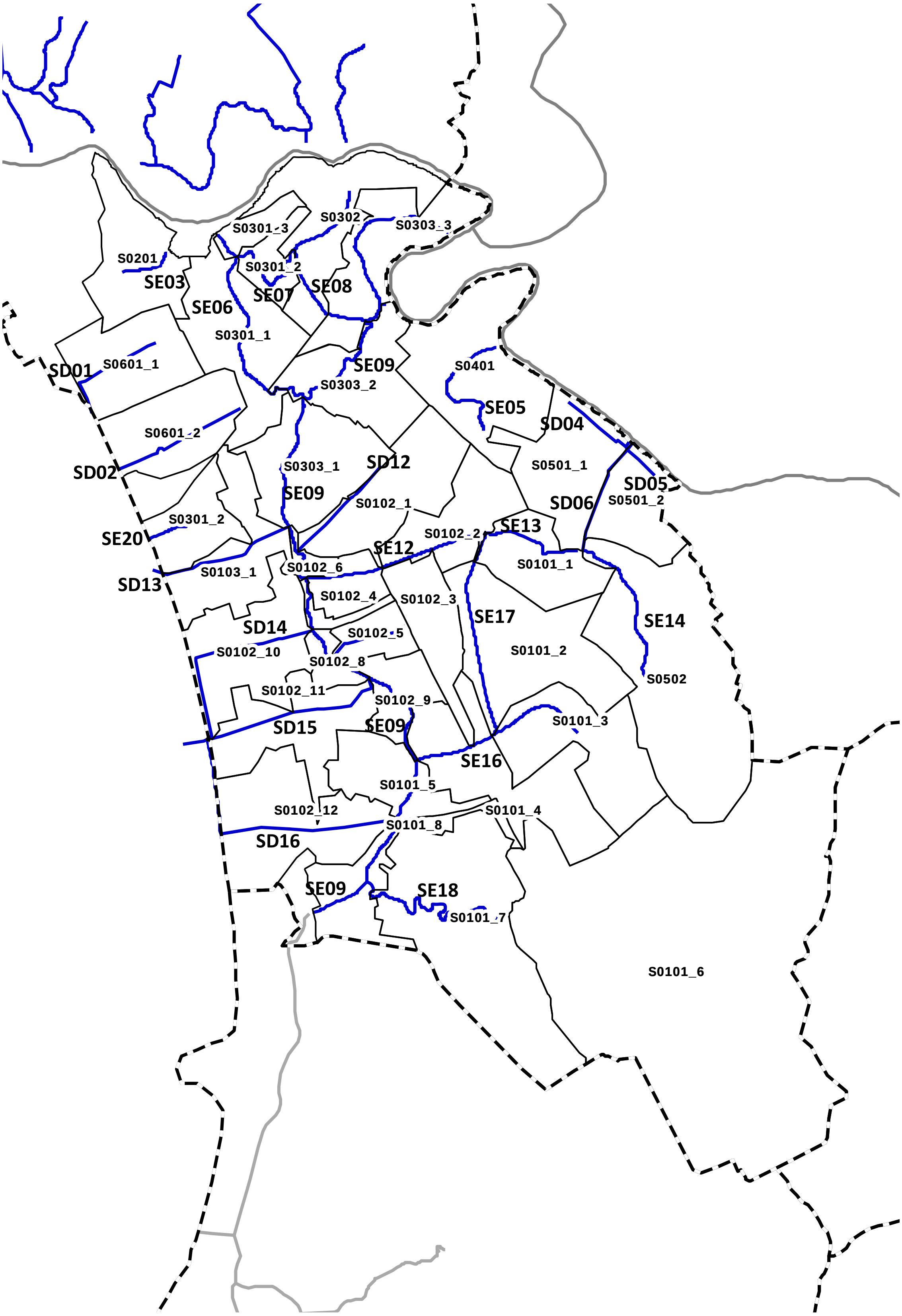
No	Area (km2)	Tf (s)	Tin (s)	Tc (s)	Lag Time (hr)	No	Area (km2)	Tf (s)	Tin (s)	Tc (s)	Lag Time (hr)
N0101_1	1.8	1,024	1,702	2,725	0.45	S0101_1	0.7	0	1,144	1,144	0.19
N0101_2	1.3	2,712	1,489	4,201	0.70	S0101_2	1.5	0	2,134	2,134	0.36
N0101_3	1.4	341	1,626	1,967	0.33	S0101_3	1.2	0	1,485	1,485	0.25
N0101_4	0.3	0	995	995	0.17	S0101_4	1.4	350	1,377	1,727	0.29
N0101_5	0.7	0	1,419	1,419	0.24	S0101_5	0.7	0	1,960	1,960	0.33
N0102_1	1.2	293	2,747	3,040	0.51	S0101_6	8.3	2,842	333	3,175	0.53
N0102_2	0.4	0	1,161	1,161	0.19	S0101_7	2.5	0	1,613	1,613	0.27
N0102_3	0.3	0	1,055	1,055	0.18	S0101_8	0.7	0	1,475	1,475	0.25
N0102_4	0.8	0	1,532	1,532	0.26	S0102_1	1.1	0	2,739	2,739	0.46
N0103_1	0.3	0	1,455	1,455	0.24	S0102_2	0.8	1,087	2,752	3,839	0.64
N0201_1	0.9	390	2,666	3,056	0.51	S0102_3	0.6	3,135	1,164	4,299	0.72
N0201_2	0.7	0	1,459	1,459	0.24	S0102_4	0.3	0	1,501	1,501	0.25
N0201_3	0.5	0	1,381	1,381	0.23	S0102_5	0.3	0	1,230	1,230	0.21
N0202_1	1.3	840	1,545	2,384	0.40	S0102_6	0.1	0	1,005	1,005	0.17
N0202_2	0.6	0	1,500	1,500	0.25	S0102_7	0.1	0	1,016	1,016	0.17
N0202_3	0.7	464	1,370	1,834	0.31	S0102_8	0.2	0	842	842	0.14
N0202_4	0.4	0	1,357	1,357	0.23	S0102_9	0.4	434	1,299	1,733	0.29
N0202_5	0.0	0	682	682	0.11	S0102_10	1.1	0	1,602	1,602	0.27
N0202_6	0.3	0	1,210	1,210	0.20	S0102_11	1.0	0	1,790	1,790	0.30
N0301_1	1.2	348	1,143	1,491	0.25	S0102_12	1.4	0	1,915	1,915	0.32
N0301_2	1.2	0	1,541	1,541	0.26	S0103_1	0.9	0	2,455	2,455	0.41
N0401_1	0.6	0	1,022	1,022	0.17	S0103_2	0.5	0	1,593	1,593	0.27
N0401_2	1.0	0	1,312	1,312	0.22	S0201	0.7	1,417	1,993	3,411	0.57
N0401_3	1.1	0	1,097	1,097	0.18	S0301_1	1.2	0	1,524	1,524	0.25
N0401_4	3.5	858	2,061	2,919	0.49	S0301_2	0.3	0	942	942	0.16
N0401_5	3.0	0	1,923	1,923	0.32	S0301_3	0.0	0	555	555	0.09
N0401_6	0.2	0	1,362	1,362	0.23	S0302	1.1	0	1,795	1,795	0.30
N0401_7	0.1	0	1,055	1,055	0.18	S0303_1	1.1	4,873	1,718	6,591	1.10
N0402	0.5	0	1,179	1,179	0.20	S0303_2	1.0	889	1,837	2,726	0.45
N0501	1.1	0	2,122	2,122	0.35	S0303_3	1.1	0	1,372	1,372	0.23
						S0401	1.6	0	1,859	1,859	0.31
						S0501_1	1.0	0	2,049	2,049	0.34
						S0501_2	0.7	0	1,163	1,163	0.19
						S0502	2.7	0	1,326	1,326	0.22
						S0601_1	0.9	0	1,238	1,238	0.21
						S0601_2	0.9	0	1,220	1,220	0.20

Source: WB Study in 2011
Note: Tf = Travel time of flood flow in a channel, Tin= Inlet time, Tc = Time of concentration



Source: 2011 WB Study

Figure 3.6.3 Basin Segmentations (North Manila)



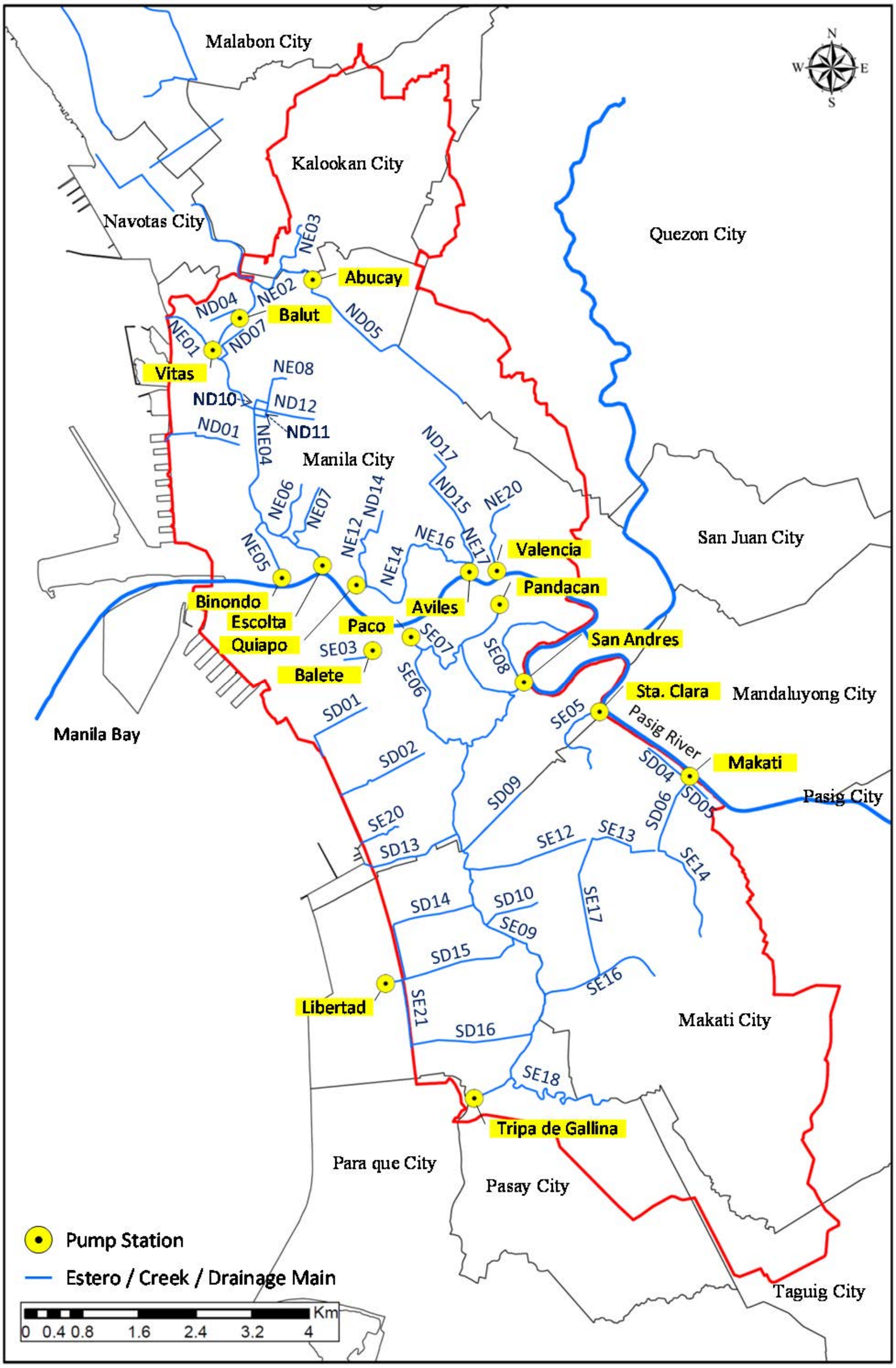
Source: 2011 WB Study

Figure 3.6.4 Basin Segmentations (South Manila)

Table 3.6.3 List of Channels Included in the Inundation Model

Area	No	Name of Channel		Type	Length (km)	Cross Section	Link with 2D Model
Core Area (North)	1	NE01	Estero de Vitas	E	1.99	13 secs.	yes
	2	NE02	Estero de Sunog Apog/Maypajo	E	2.44	13 secs.	yes
	3	NE03	Casili Creek	E	0.90	5 secs.	yes
	4	NE04	Estero de la Reina	E	2.84	16 secs.	yes
	5	NE05	Estero de Binondo	E	0.92	7 secs.	yes
	6	NE06	Estero de Magdalene	E	0.85	4 secs.	yes
	7	NE07	Estero de San Lazaro	E	1.01	8 secs.	yes
	8	NE08	Estero de Kabulusan	E	0.69	8 secs.	yes
	9	NE12	Estero de Quiapo	E	0.90	8 secs.	yes
	10	NE14	Estero de San Miguel/Uli Uli	E	2.04	15 secs.	yes
	11	NE16	Estero de Aviles	E	0.35	2 secs.	yes
	12	NE17	Estero de Sampaloc I	E	0.66	7 secs.	yes
	13	NE20	Estero de Valencia	E	1.13	9 secs.	yes
	14	ND01	Pacheco	D	1.16	9 secs.	yes
	15	ND04	Buendia	D	0.51	5 secs.	yes
	16	ND05	Blumentritt Interceptor	D	2.98	18 secs.	yes
	17	ND07	Pampanga-Earnshaw Sub	D	0.65	4 secs.	yes
	18	ND10	Kabulusan Sub	D	0.14	2 secs.	yes
	19	ND11	Kabulusan	D	0.37	4 secs.	yes
	20	ND12	Tayuman	D	0.86	7 secs.	yes
	21	ND14	Severino Reyes	D	0.65	7 secs.	yes
	22	ND15	Lepanto-Gov. Forbes	D	1.16	7 secs.	yes
	23	ND17	Economia	D	0.26	3 secs.	yes
Core Area (South)	1	SE03	Estero de Balete	E	0.50	3 secs.	yes
	2	SE05	Santa Clara Creek	E	1.39	10 secs.	yes
	3	SE06	Estero de Paco	E	2.27	10 secs.	yes
	4	SE07	Estero de Concordia	E	1.07	8 secs.	yes
	5	SE08	Estero de Pandacan	E	3.86	23 secs.	yes
	6	SE08add		E	0.05	estimated	yes
	7	SE09	Estero Tripa de Gallina	E	7.54	45 secs.	yes
	8	SE12	Calatagan Creek I	E	1.71	11 secs.	yes
	9	SE13	Calatagan Creek II	E	1.00	5 secs.	yes
	10	SE14	Calatagan Creek III	E	1.54	5 secs.	yes
	11	SE16	Makati Diversion Channel I	E	1.79	10 secs.	yes
	12	SE17	Makati Diversion Channel II	E	1.99	6 secs.	yes
	13	SE18	Dilain Creek/Maricanban Creek I	E	2.27	12 secs.	yes
	14	SE20	Estero de San Antonio Abad	E	0.61	5 secs.	yes
	15	SE21	Libertad Channel	E	1.21	4 secs.	yes
	16	SD01	Padre Faura	D	1.16	7 secs.	yes
	17	SD02	Remedios	D	1.35	6 secs.	yes
	18	SD04	Makati Headrace-I	D	0.71	4 secs.	yes
	19	SD05	Makati Headrace-II	D	0.45	3 secs.	yes
	20	SD06	Zobel Orbit	D	1.17	5 secs.	yes
	21	SD09	Zobel Roxas	D	1.16	8 secs.	yes
	22	SD10	Faraday	D	0.82	9 secs.	yes
	23	SD13	Vito Cruz	D	1.45	6 secs.	yes
	24	SD14	Buendia Outfall	D	1.99	4 secs.	yes
	25	SD15	Libertad Outfall	D	1.80	4 secs.	yes
	26	SD16	EDSA Outfall	D	1.72	3 secs.	yes

Source: 2011 WB Study
Note: E- estero/creek, D- drainage main (box culvert)

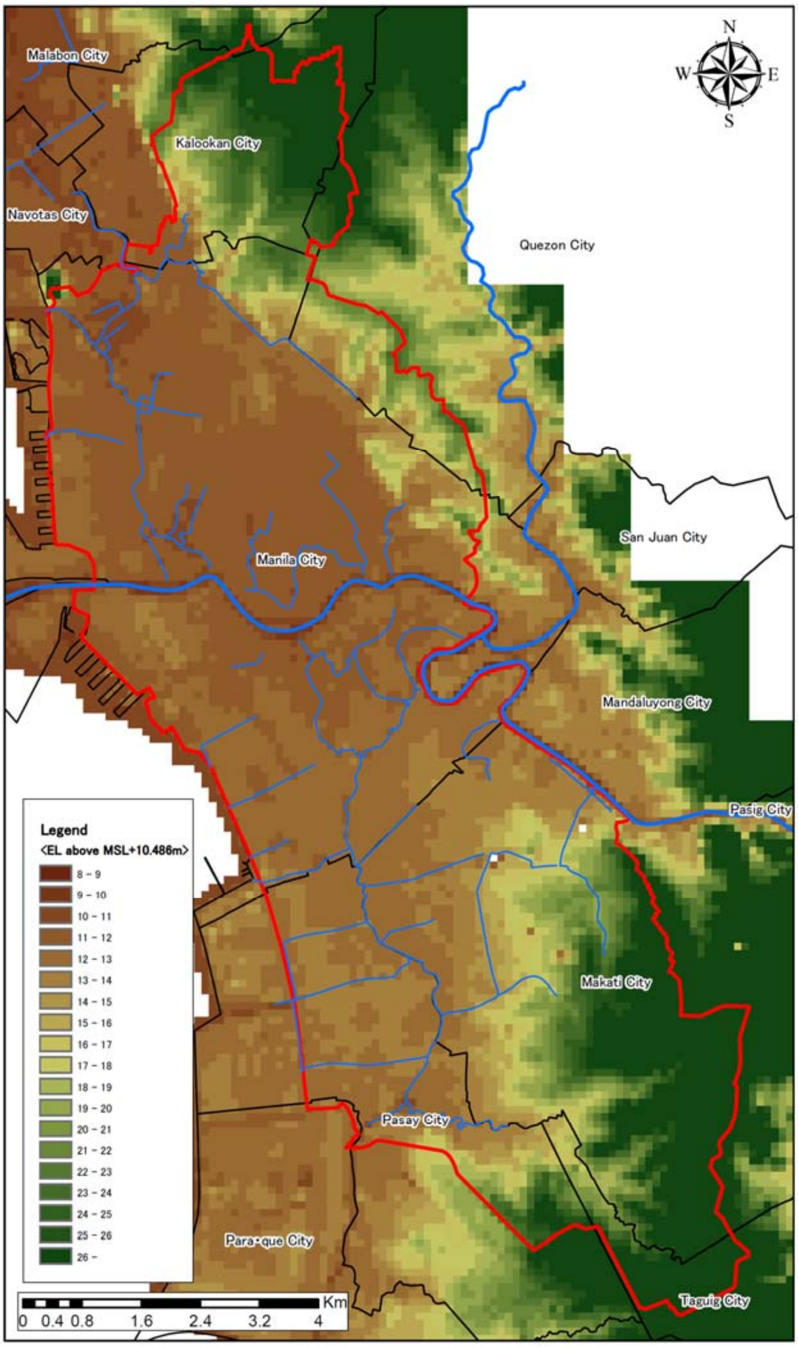


Source: 2011 WB Study

Figure 3.6.5 Location Map of Channels and Pump Stations Included in the Inundation Model

(4) Floodplain Elevation (DEM) and Floodplain Roughness Coefficient

The LiDAR data collected around Metro Manila by DOST-ASTI in 2011 was utilized to develop the Digital Elevation Model (DEM) for the inundation analysis model. The arithmetic mean value of LiDAR data at every 1 m within 100 m grid was used to determine the elevation at every 100m grid. The following figure shows the elevation distribution map which was generated based on the created DEM. The roughness coefficient of floodplain was set as same as the WB model and applied n=0.100 uniformly.



Source: JICA Survey Team

Figure 3.6.6 Distribution Map of 100m Mesh Elevation

3.6.2 The Results of Inundation Analysis

(1) Existing Condition

The calculation case of Inundation Analysis is shown in Table 3.6.4.

Table 3.6.4 List of Calculation Case

Branch Condition	Rainfall					
	Tyhoon Ondoy Reproduction	5-yr	10-yr	25-yr	50-yr	100yr
Present Condition	O	O	O	O	O	O
Present Condition with TUNNEL	―	O	O	O	O	O
With TUNNEL + DICAMM 2005	―	―	―	O	―	―

Souse: JICA Survey Team

(2) Inundation Map

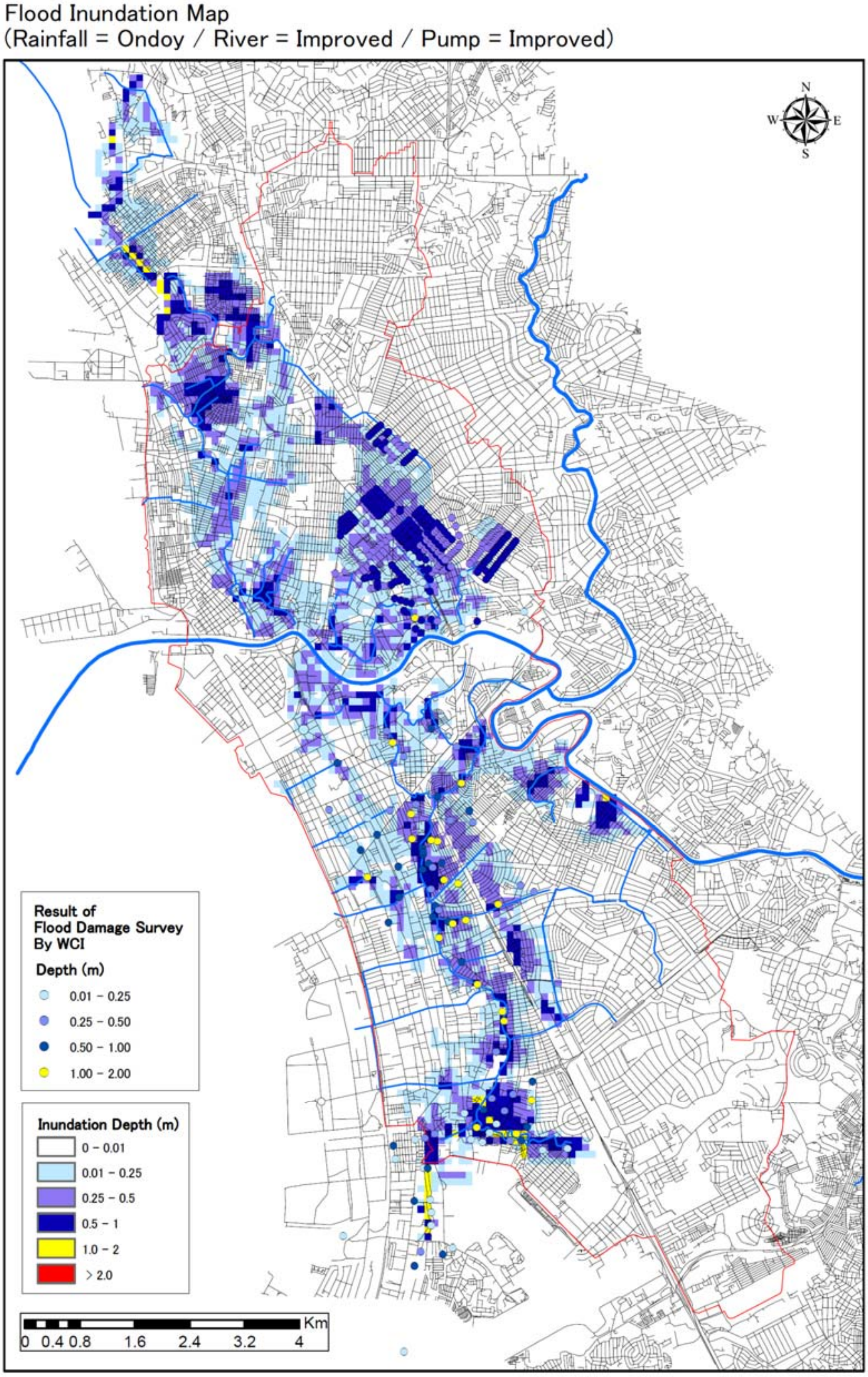
(a) Pattern of Typhoon Ondoy, 2009

The reproduction calculation of Typhoon Ondoy (September 2009) was conducted. Figure 3.6.7 shows the results of the reproduction calculation with overlaying the damage survey conducted by Woodfield Consultants Inc. However, the damage survey of the Woodfield Consultants Inc. does not cover the entire Manila, so that the figure cannot show the overall comparison. In the comparison of inundation depth, although the results of flood damage survey were slightly larger than the results of the reproduction calculation at some area, it is generally agreed.

(b) 25-yr Return Period

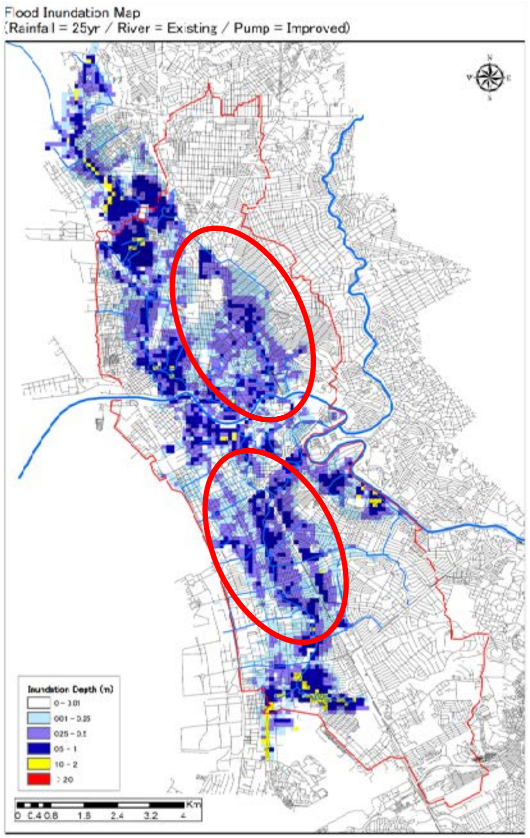
The result of inundation analysis was compared. The compared cases are “Present Condition”, “Present Condition with Tunnel”, and “With Tunnel and DICAMM Project”.

A Comparison of ”Present Condition” and ”Present Condition with Tunnel” show that both inundation area and depth have greatly reduced. In particular, inundation depth has been reduced in the range indicated by the red circle in Figure 3.6.8, so that the effect of the tunnel can be confirmed visually.

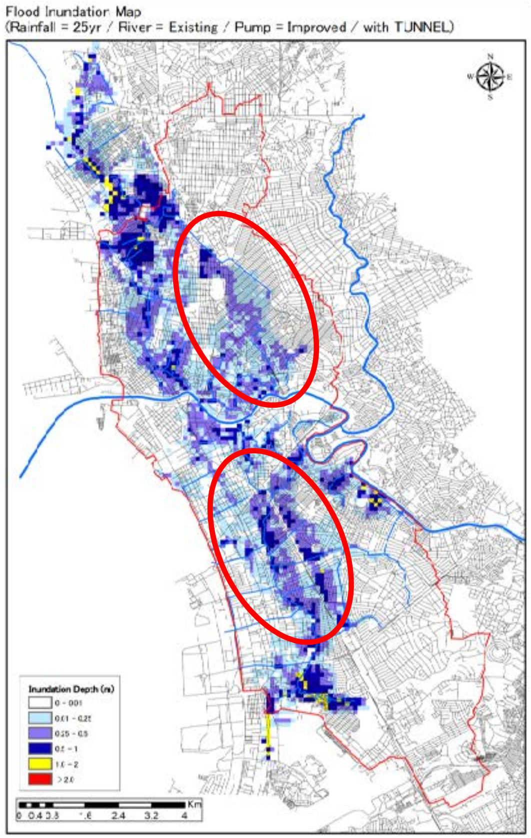


Source: JICA Survey Team

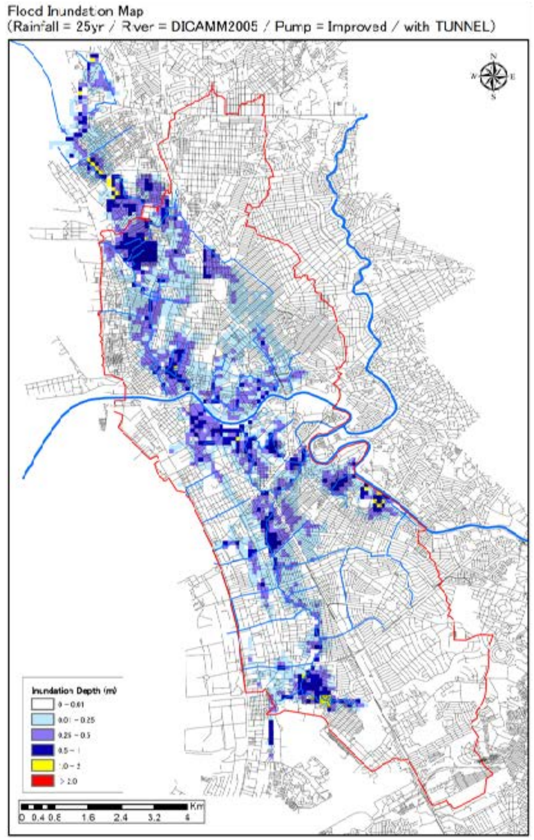
Figure 3.6.7 Results of Inundation Analysis (Reproduction of Typhoon Ondoy, 2009)



Rainfall: 25-yr / River: Present Condition/ Pump: Improved



Rainfall: 25-yr / River: Present Condition/ Pump: Improved/ with Tunnel



Rainfall: 25-yr / River: DICAMM 2005/ Pump: Improved/ with Tunnel

Figure 3.6.8 Inundation Map

JICA Survey Team

ESPAÑA-UST

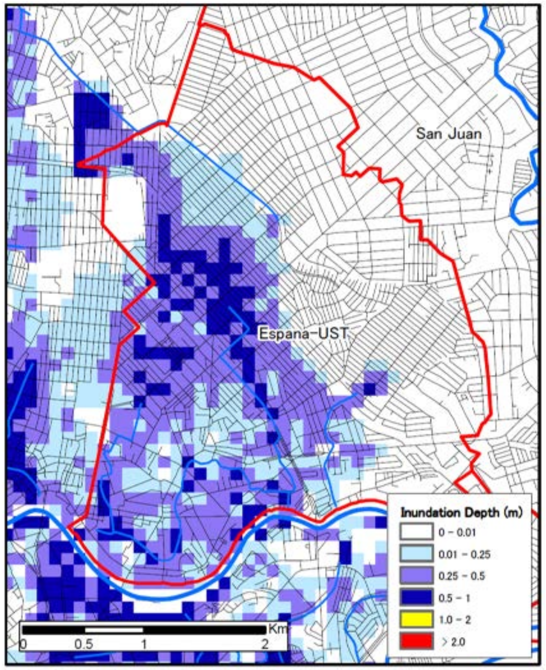
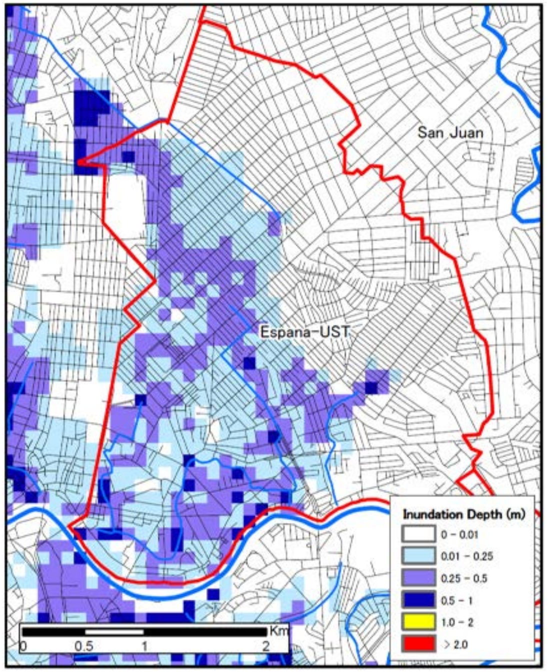
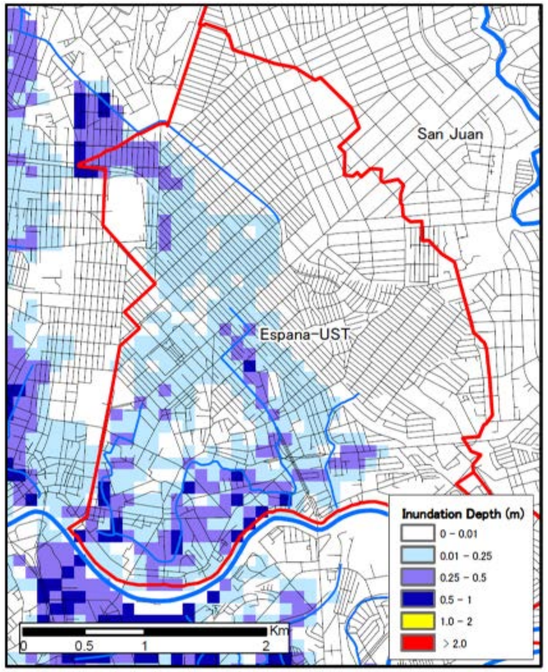
Present Condition	Present Condition with Tunnel	With Tunnel + DICAMM2005
		

Figure 3.6.9 Inundation Map (Larger Version)

BUENDIA-MARICABAN

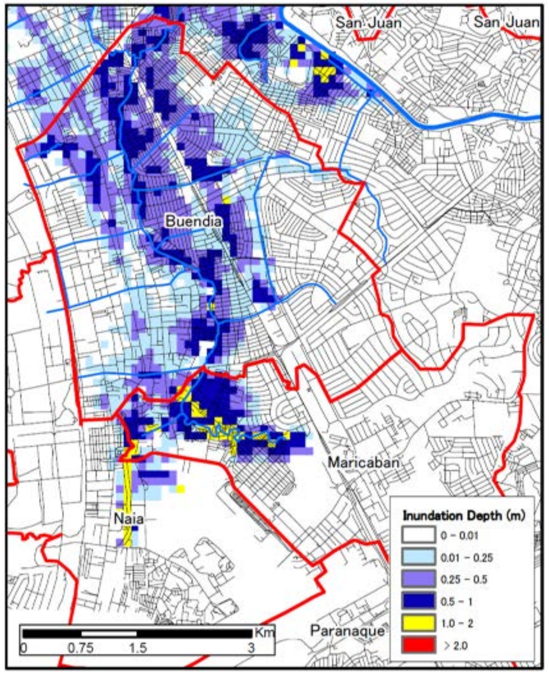
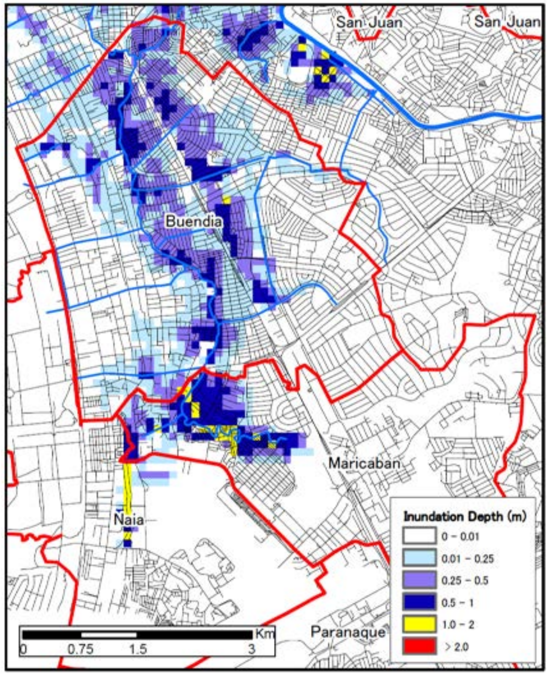
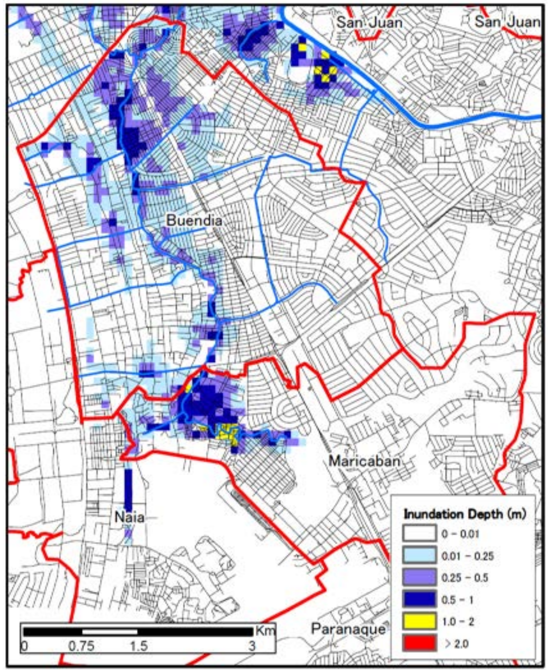
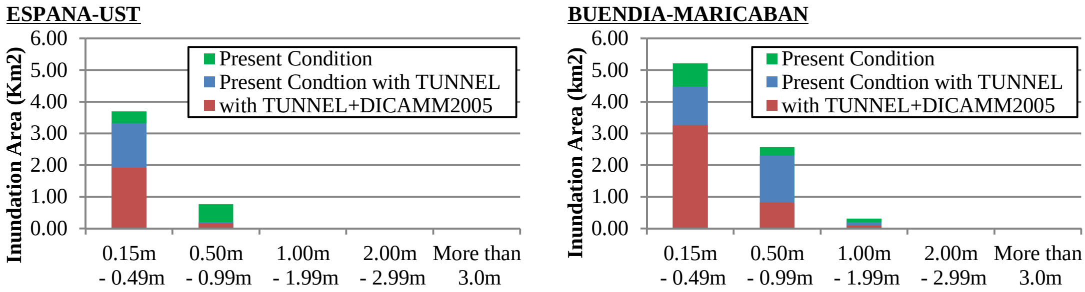
Present Condition	Present Condition with Tunnel	With Tunnel + DICAMM2005
		

Figure 3.6.10 Inundation Map (Larger Version)

(3) Estimated Flood Inundation Area

In the calculation of the flood damage in the economic evaluation, the occurrence of such house and building damage was assumed in the case of more than inundation depth of 0.15m. If this project is implemented, the estimated flood inundation area, which is more inundation depth of 0.15m in return period 25-yr, is reduced from 4.47km^2 to 3.52km^2 in España-UST, and from 8.09km2 to 6.97km^2 in Buendia - Marikaban.



Source: JICA Survey Team

Figure 3.6.11 Estimated Reduction Flood Inundation Areas (Return Period 25-yr)

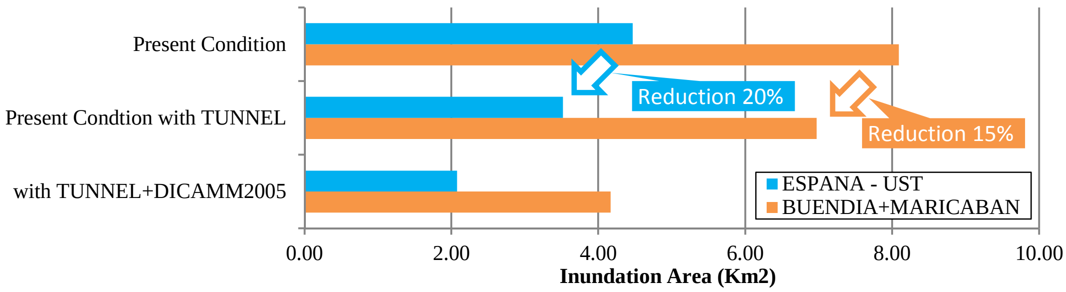


Figure 3.6.12 Estimated Reduction Flood Inundation Areas (Return Period 25-yr)

Table 3.6.5 Estimated Flood Inundation Area

Inundation Depth (m)	Inundation Area (km2) (25-yr)					
	ESPAÑA - UST			BUENDIA+MARICABAN		
	Present Condition	Present with Tunnel	w Tunnel and DICAMM2005	Present Condition	Present with Tunnel	w Tunnel and DICAMM2005
0.15m - 0.49m	3.70	3.32	1.92	5.22	4.48	3.26
0.50m - 0.99m	0.76	0.20	0.16	2.56	2.30	0.82
1.00m - 1.99m	0.01	0.00	0.00	0.31	0.20	0.09
2.00m - 2.99m	0.00	0.00	0.00	0.00	0.00	0.00
More than 3.0m	0.00	0.00	0.00	0.00	0.00	0.00
Total	4.47	3.52	2.08	8.09	6.97	4.17

Source: JICA Survey Team

Table 3.6.6 Estimated Number of Houses and Building in Inundation Area

Inundation Depth (m)	Number of Houses and Buildings (25-yr)					
	ESPAÑA - UST			BUENDIA+MARICABAN		
	Present Condition	Present with Tunnel	w Tunnel and DICAMM2005	Present Condition	Present with Tunnel	w Tunnel and DICAMM2005
0.15m - 0.49m	37,764	34,235	17,819	51,821	47,519	36,614
0.50m - 0.99m	7,474	1,563	1,081	33,000	28,954	13,490
1.00m - 1.99m	49	0	0	5,036	3,393	1,725
2.00m - 2.99m	0	0	0	0	0	0
More than 3.0m	0	0	0	0	0	0
Total	45,287	35,798	18,899	89,857	79,866	51,828

Source: JICA Survey Team

Table 3.6.7 Estimated Population in Inundation Area

Inundation Depth (m)	Population (25-yr)					
	ESPAÑA - UST			BUENDIA+MARICABAN		
	Present Condition	Present with Tunnel	w Tunnel and DICAMM2005	Present Condition	Present with Tunnel	w Tunnel and DICAMM2005
0.15m - 0.49m	152,804	138,522	72,098	204,173	185,891	145,548
0.50m - 0.99m	30,242	6,325	4,373	131,353	115,040	54,555
1.00m - 1.99m	197	0	0	20,343	13,641	6,996
2.00m - 2.99m	0	0	0	0	0	0
More than 3.0m	0	0	0	0	0	0
Total	183,243	144,846	76,471	355,869	314,572	207,100

Source: JICA Survey Team

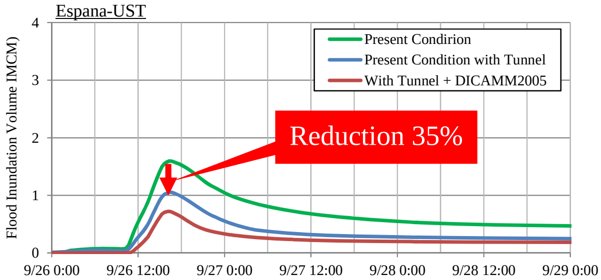
(4) Estimated Inundation Volume (25-yr Return Period)

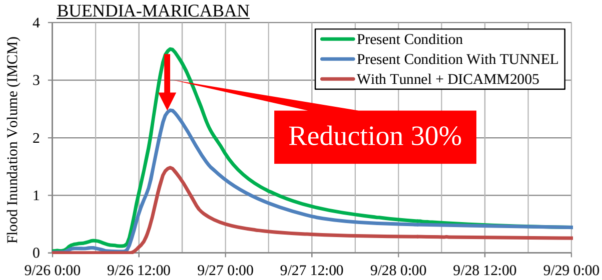
The inundation volume is estimated 1.60 MCM in España-UST and 3.54 MCM in Buendia-Maricaban at the maximum inundation depth. If the project is implemented, the estimated flood inundation volume is reduced to 1.05 MCM (Reduction 35%) in España-UST and to 2.48 MCM (Reduction 30%) in Buendia-Maricaban. As the result of computation the average inundation depth each basin, the average inundation depth is reduced 0.36m to 0.16m in España-UST and 0.44m to 0.18m in Buendia-Maricaban.

Table 3.6.8 Estimated Population in Inundation Area

Area	Maximum Inundation Area (25-yr) (km2)	Present Condition		With Tunnel		With Tunnel + DICAMM2005	
		Maximum Volume (MCM)	Average Depth (m)	Maximum Volume (MCM)	Average Depth (m)	Maximum Volume (MCM)	Average Depth (m)
España-UST	4.47	1.60	0.36	1.05 (-35%)	0.24	0.72	0.16
Buendia-Maricaban	8.09	3.54	0.44	2.48 (-30%)	0.31	1.48	0.18

Source: JICA Survey Team





Source: JICA Survey Team

Figure 3.6.13 Transition of Inundation volume in the each Basin

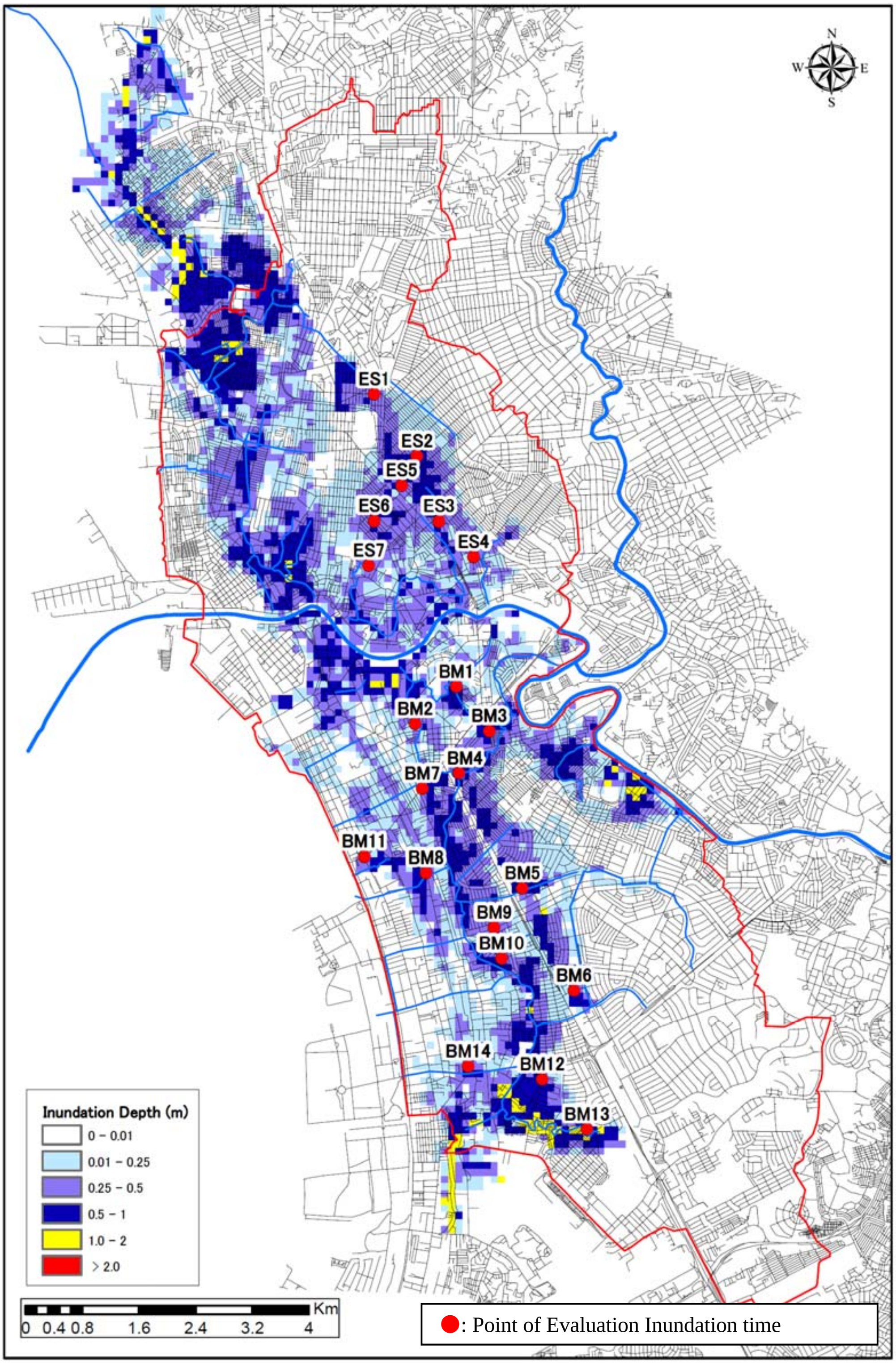
(5) Inundation Time

The inundation time was computed at 21 typical points in estimated inundation area. These points are 7 points in España-UST, and 14 points in Buendia-Maricaban. Distribution map of Inundation Time above 1cm and above 25cm is shown in Figure 3.6.16 to Figure 3.6.19. The area of more than 2 days and above 25cm is reduced in España-UST. Similar trend was also seen in Buendia - Maricaban

Table 3.6.9 Effect on Flood duration of more than 25cm by the Tunnel

No.	Name	Vicinity of the facility	Present Condition (hr)	With Tunnel (hr)	With Tunnel + DICAMM2005 (hr)
1	ES1	Vicinity of “Antipolo St”	6	5	2
2	ES2	Vicinity of “PNR Laong-Laan”	Over 2-days	4	0
3	ES3	Vicinity of “A H Lacson Ave”	Over 2-days	Over 2-days	Over 2-days
4	ES4	Vicinity of “Magsaysay Blvd and A. Lacson-Mabini Flyover”	5	2	0
5	ES5	Vicinity of “UST College of Science”	Over 2-days	4	0
6	ES6	Vicinity of “UST College of Science”	Over 2-days	12	0
7	ES7	Vicinity of “Recto Ave”	17	10	6
8	BM1	Vicinity of “Estero de Pandacan”	Over 2-days	Over 2-days	Over 2-days
9	BM2	Vicinity of “Apacible St”	0	0	0
10	BM3	Vicinity of “Quirino Ave”	Over 2-days	Over 2-days	Over 2-days
11	BM4	Vicinity of “Quirino Ave and South Supre High Way”	25	24	11
12	BM5	Vicinity of “Buendia Station”	26	18	10
13	BM6	Vicinity of “South Supre High Way and Don Bosco”	7	8	0
14	BM7	Vicinity of “Quirino Ave”	25	15	6
15	BM8	Vicinity of “Vito Cruz Station and Taft Ave”	11	0	0
16	BM9	Vicinity of “Sen. Gil J Puyat Ave”	10	6	0
17	BM10	Vicinity of “A. Armaiz Ave”	16	13	7
18	BM11	Vicinity of “Manila Zoo”	23	20	5
19	BM12	Vicinity of “Pasay Road and Taft Ave”	6	5	2
20	BM13	Vicinity of “Villamor Golf Course”	8	7	1
21	BM14	Vicinity of “Pasay Road and Aurora Blvd”	2	0	0

Source: JICA Survey Team



Note：Inundation Depth is case of 25-yr return period without Project
Note：ES=España-UST, BM=Buendia-Maricaban
Source: JICA Survey Team

Figure 3.6.14 Location Map of Evaluation point of Inundation Time

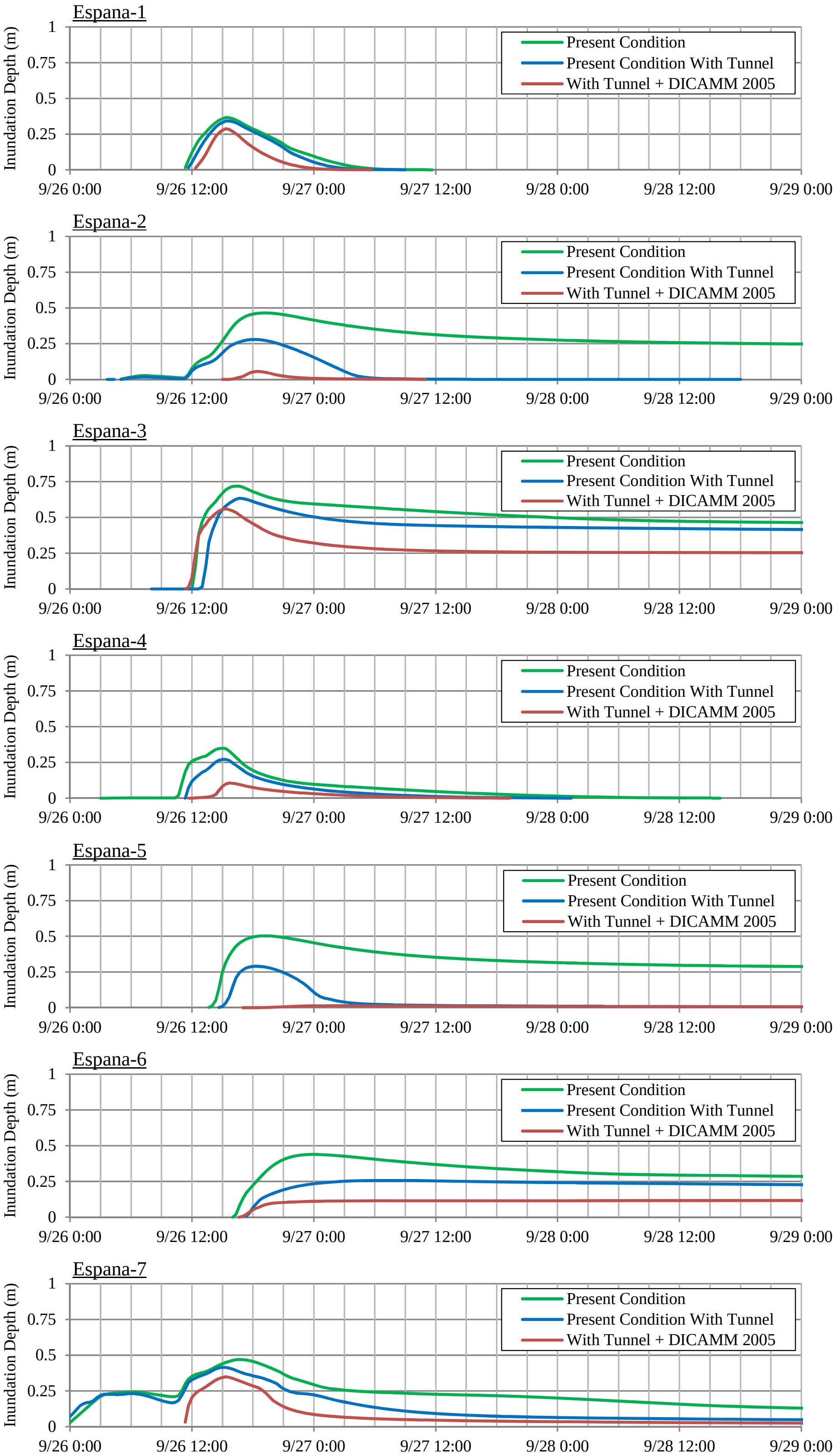


Figure 3.6.15 (1) Variation of Inundation Depth

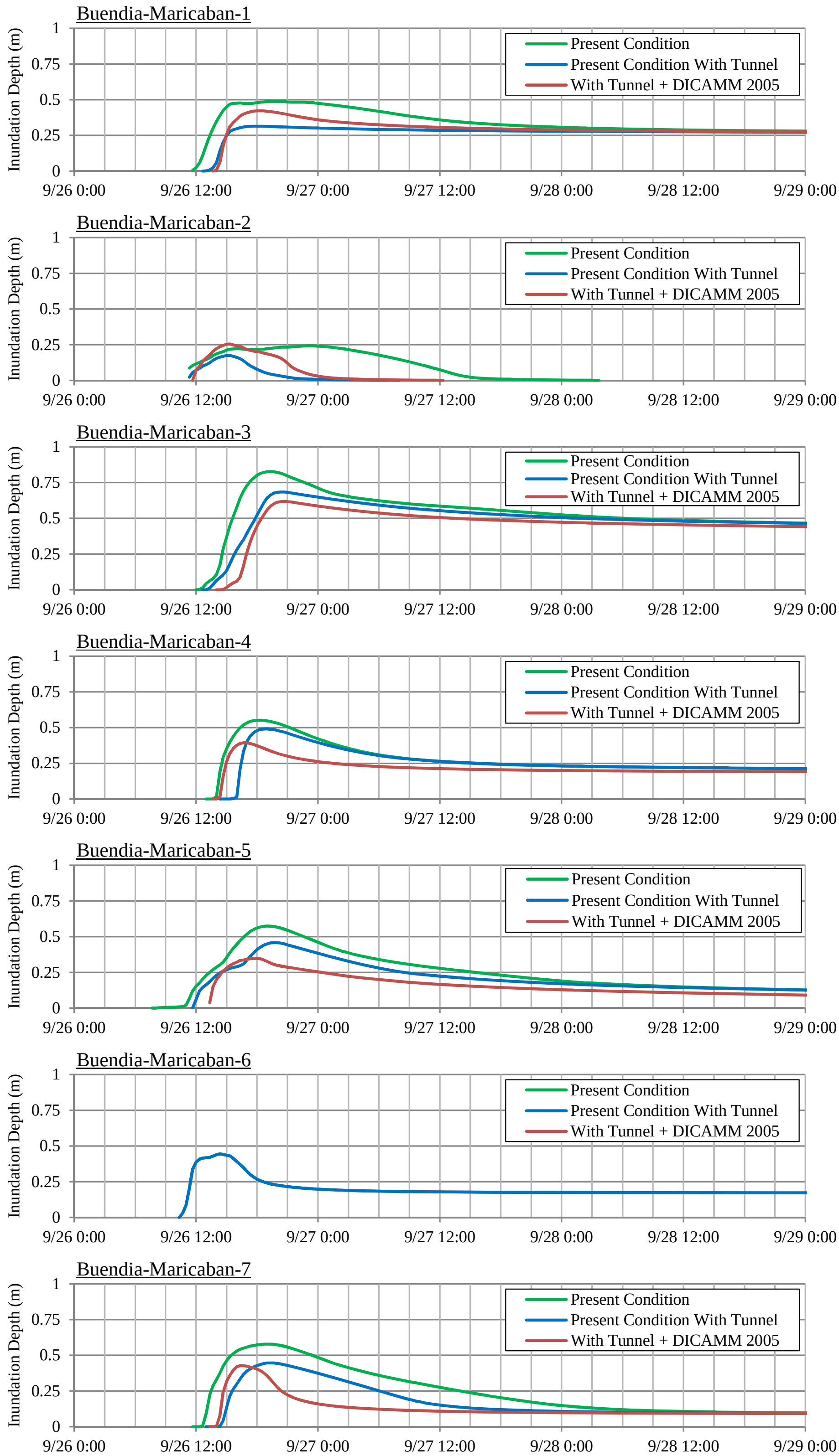


Figure 3.6.15(2) Variation of Inundation Depth

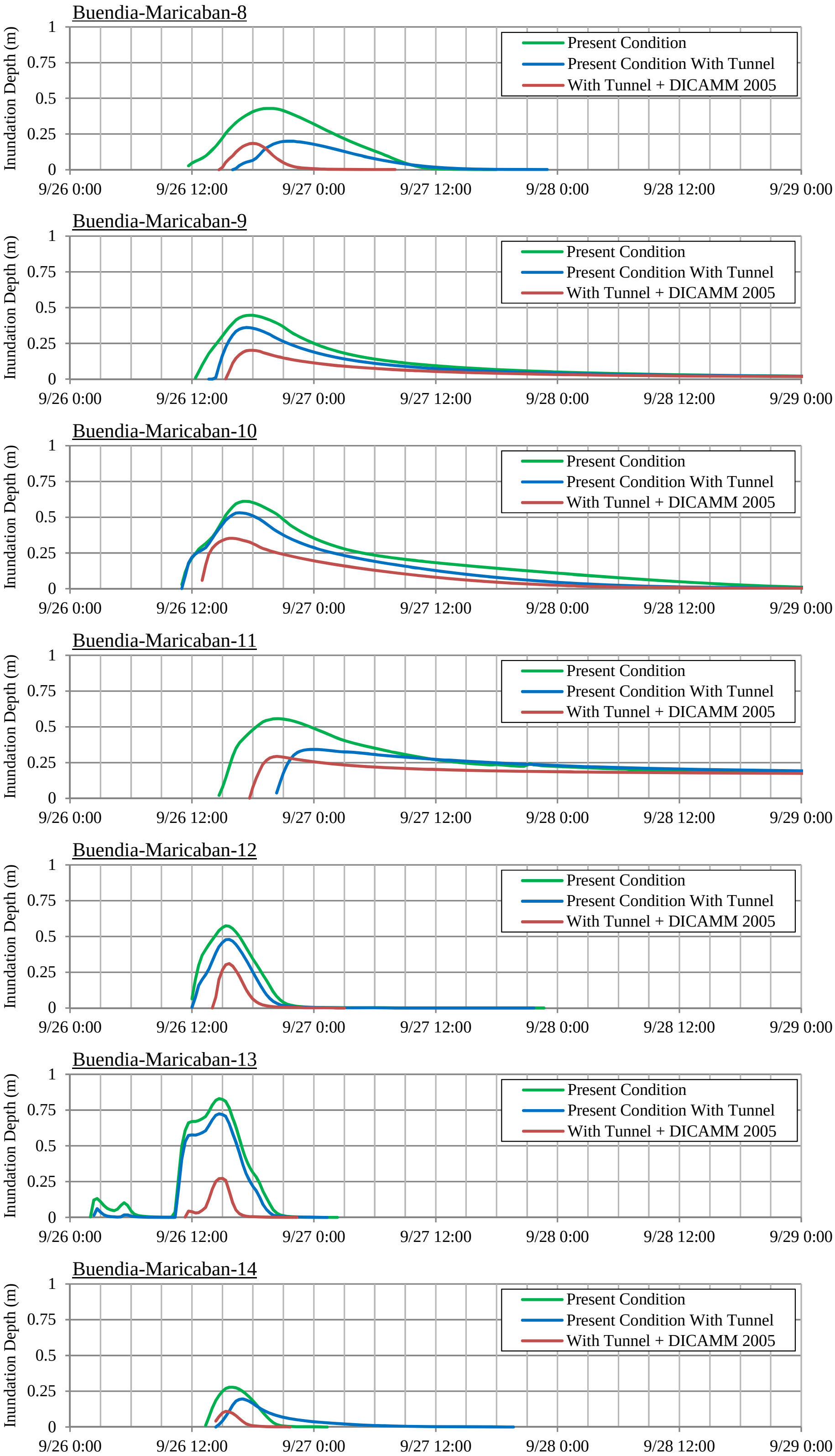


Figure 3.6.15(3) Variation of Inundation Depth

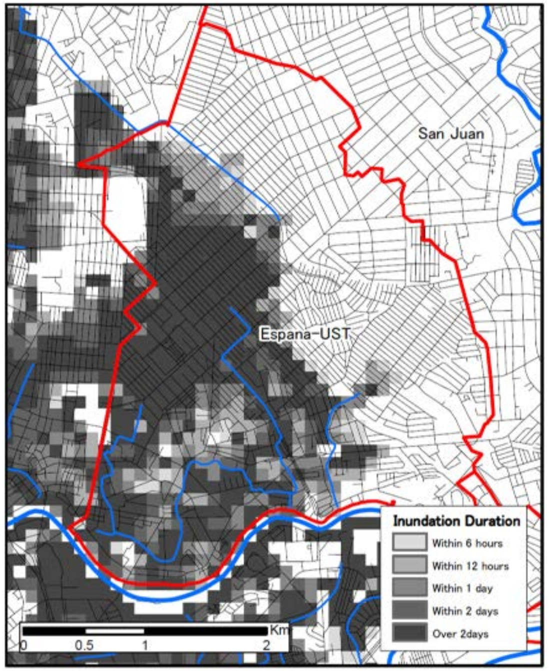
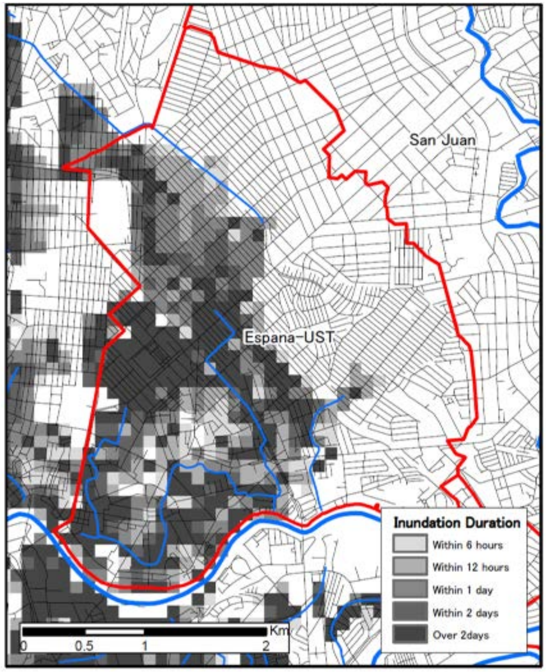
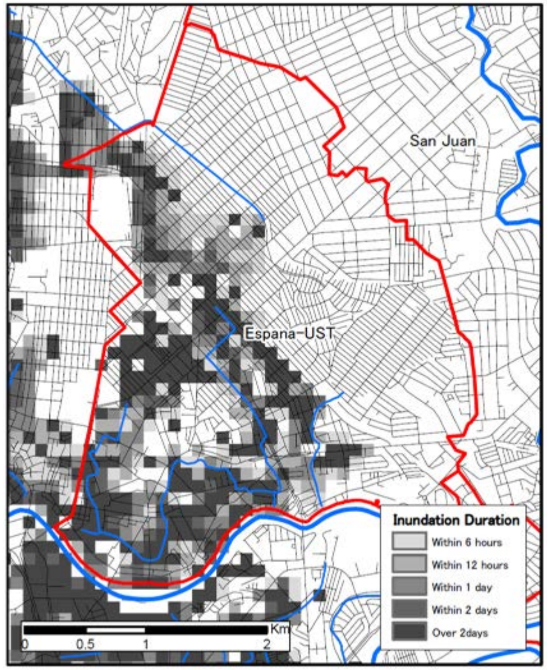
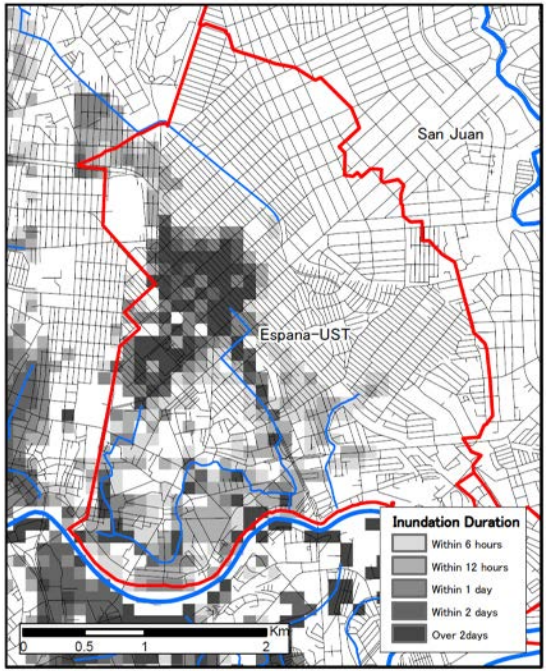
ESPAÑA-UST		
Present Condition	**Present Condition with Tunnel**	**With Tunnel + DICAMM2005**
		

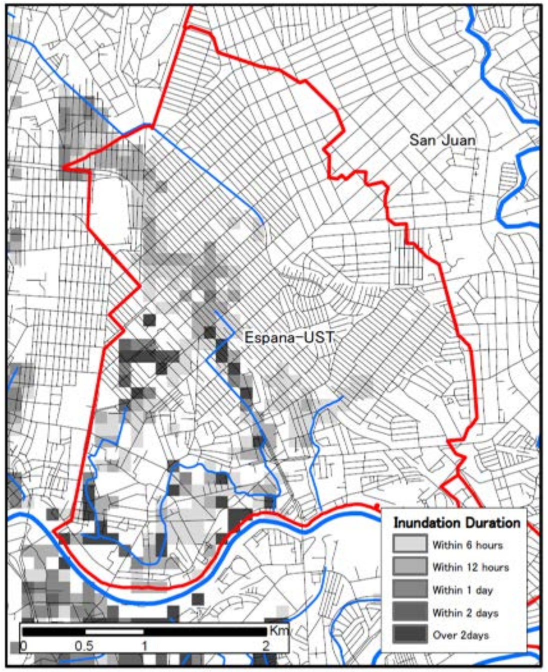
Figure 3.6.16 Distribution Map of Inundation Duration (Inundaton Depth is above 1cm)

ESPAÑA-UST

Present Condition



Present Condition with Tunnel



With Tunnel + DICAMM2005

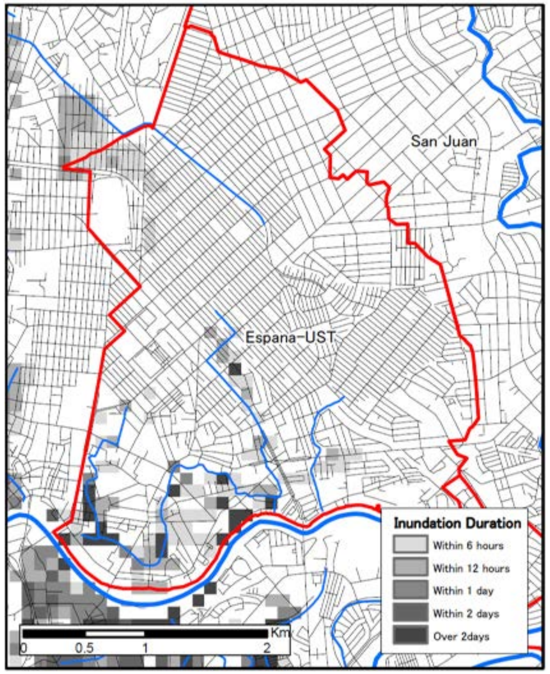


Figure 3.6.17 Distribution Map of Inundation Duration (Inundaton Depth is above 25cm)

BUENDIA-MARICABAN

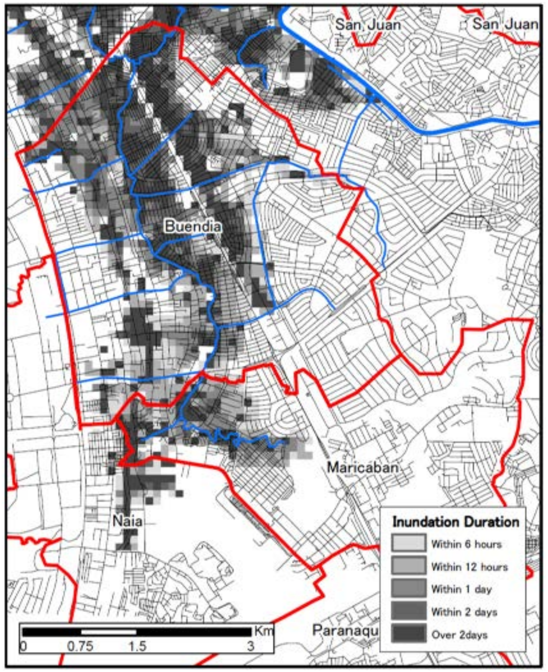
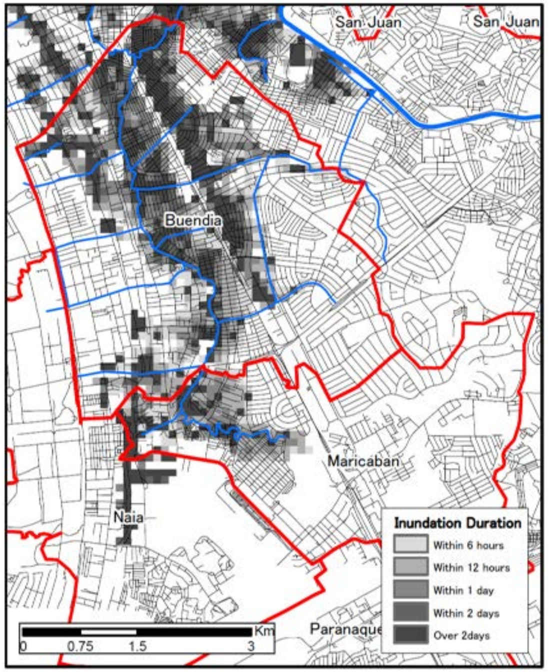
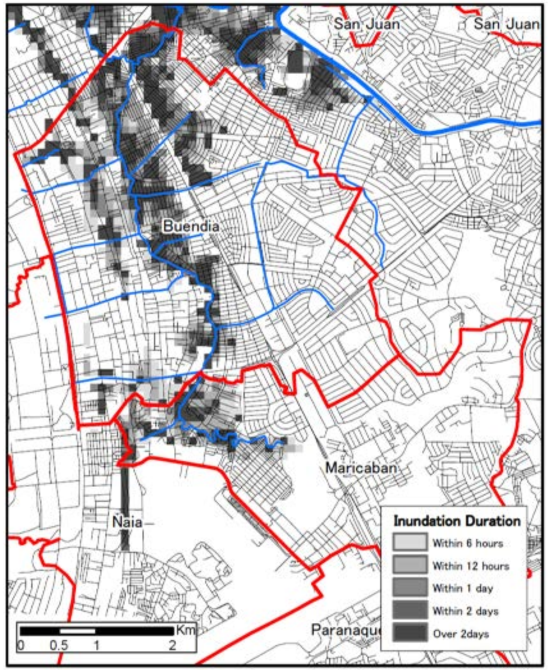
Present Condition	Present Condition with Tunnel	With Tunnel + DICAMM2005
		

Figure 3.6.18 Distribution Map of Inundation Duration (Inundaton Depth is above 1cm)

BUENDIA-MARICABAN

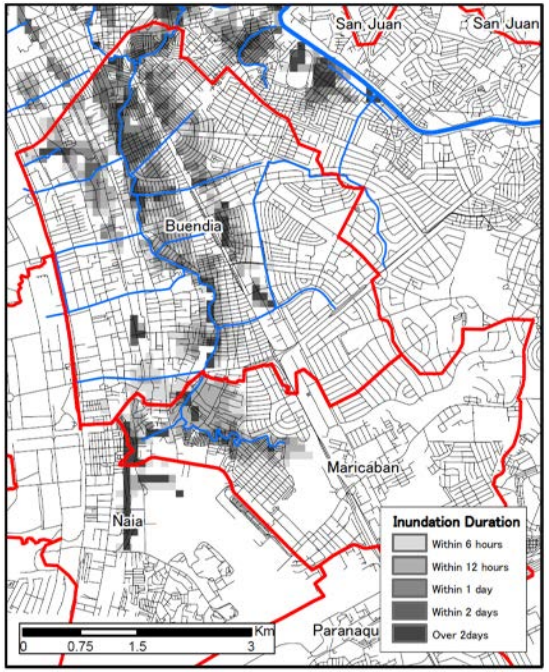
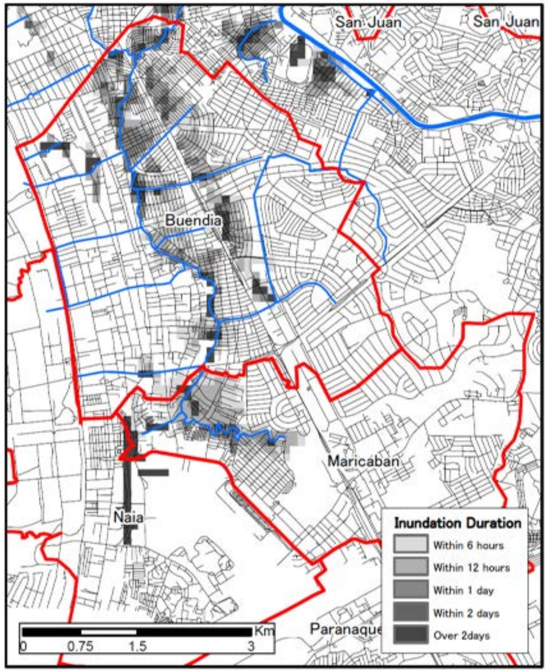
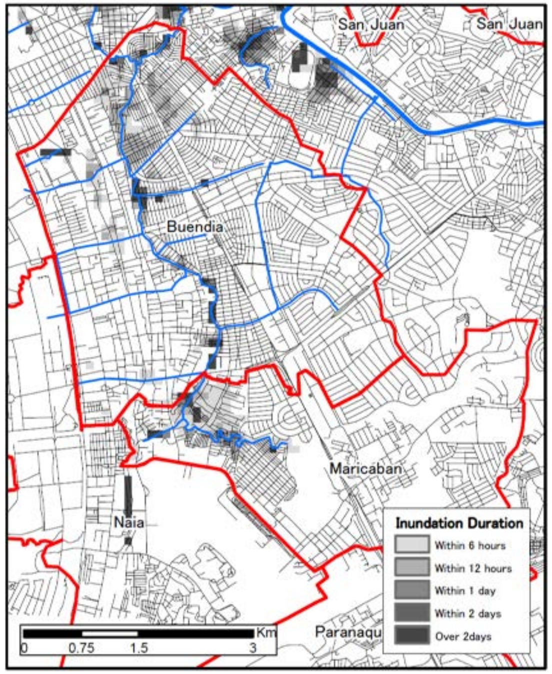
Present Condition	Present Condition with Tunnel	With Tunnel + DICAMM2005
		

Figure 3.6.19 Distribution Map of Inundation Duration (Inundaton Depth is above 25cm)