D. MATHEMATICAL MODEL AND SIMULATION

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D.1 OBJECTIVE OF MODEL DEVELOPMENT

The study area comprises a complex network of interconnected esteros, drainage mains, laterals, and connecting pipes. In addition, hydraulic facilities like thrash screens, gates, reservoirs and especially pump stations connected by esteros and drainage mains make the flow condition highly unpredictable during inundation. To analyze the highly dynamic behavior of the interconnected drainage system of the study area, comprehensive hydrodynamic models for north and south drainage systems have been developed. The main objectives of the model development are:

- to evaluate the existing capacity of the drainage system;
- to evaluate the performance of the drainage system under design condition (different alternatives/scenarios such as with and without project condition) and
- to prepare inundation maps for different scenarios and return periods.

D.2 SELECTION OF SOFTWARE

There are two sets of software widely used for hydrodynamic simulation of unsteady one-dimensional flow, namely:

- For one-dimensional unsteady river flow simulation of non-urbanized area: MIKE 11 (requires license) developed by Danish Hydraulic Institute (DHI) of Denmark and HEC-RAS (free) developed by Hydraulic Engineering Center (HEC) of U.S. Army Corps of Engineers.
- For one-dimensional unsteady sewer flow simulation of urbanized area: MOUSE (requires license) developed by DHI and SWMM (free) developed by Environmental Protection Agency (EPA) of U.S.A.

HEC-RAS and MIKE 11 are mainly for simulation of free surface flow and are not so suitable for simulation of pressurized pipe flow. SWMM still lack a user-friendly graphical user interface. Both HEC-RAS and SWMM have only the hydrodynamic part and for hydrologic (runoff) part, some other software like HEC-HMS (free) developed by HEC of U.S. Army Corps of Engineers has to be used. Also, MIKE 11, HEC-RAS and SWMM lack automatic inclusion of different hydraulic functions such as pumps and regulators. All these make difficult to apply these software for hydrodynamic simulation of the complex drainage system of the study area. Finally, MOUSE of DHI has been selected as the hydrodynamic modeling software for this study due to the following advantages/characteristics of MOUSE:

- Simulates fully dynamic one-dimensional unsteady free surface and pressurized pipe flow.
- Have automatic functions for various hydraulic facilities like pump, gate, valve etc.
- Integrates runoff and hydrodynamic model in one unit.
- Simulates sewer and open channel network of any complexity as well as flow over road.
- Have user-friendly graphical user interface (GUI) to develop and run the model and view model results.

D.3 GENERAL STEPS OF SIMULATION BY MOUSE

Schematic diagram of simulation by MOUSE is shown in *Figure D.3.1*. MOSUE applies implicit finite difference method to solve St. Venant's fully dynamic wave equation using Double-Sweep algorithm. Please refer to MOUSE Pipe Flow Reference Manual for details.

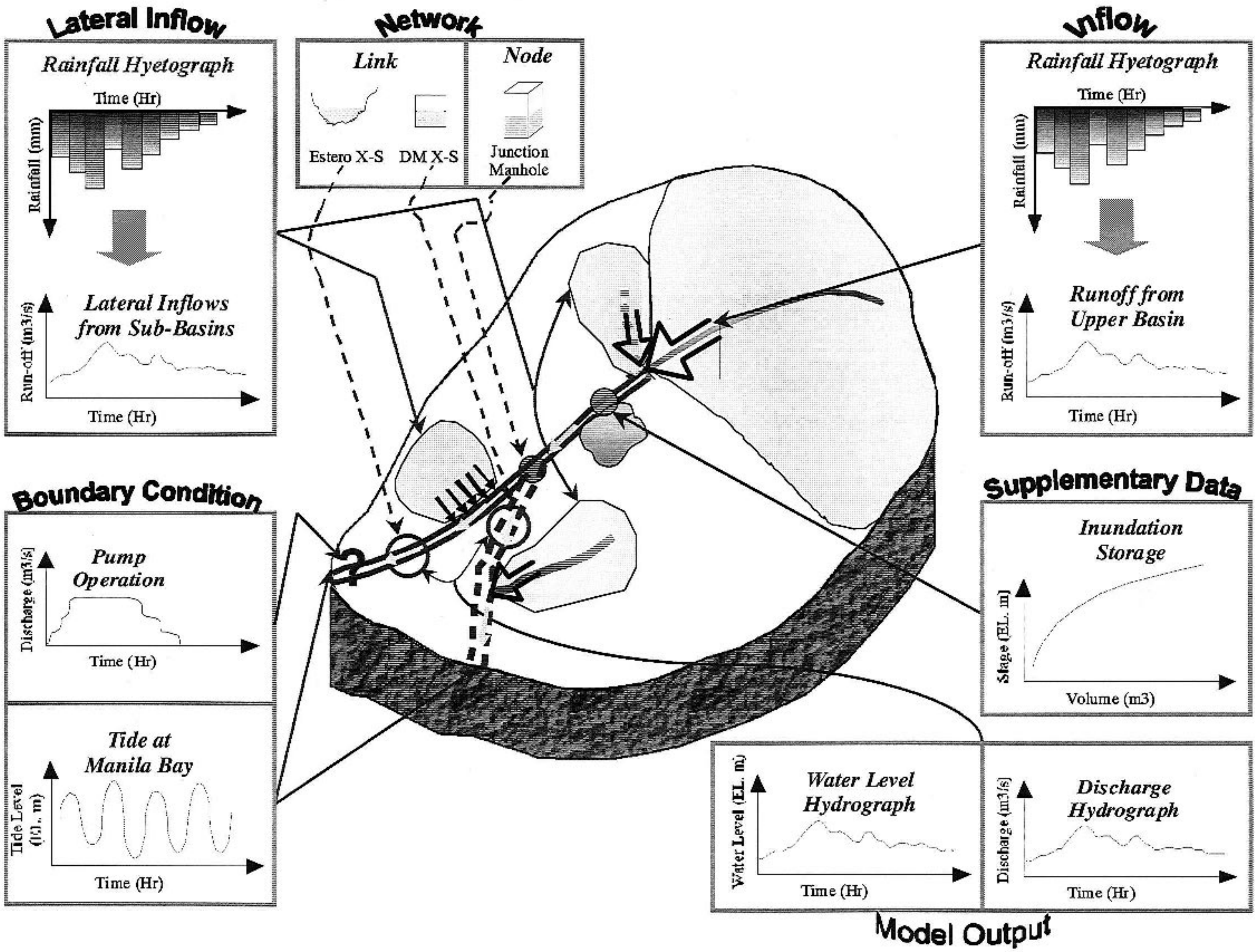


Figure D.3.1 Schematic Diagram of Simulation by MOUSE

The general steps to carry out simulation by MOUSE are:

- Construction of model network consisting of nodes (manholes, estero junctions etc.) and links connecting two nodes (esteros, drainage mains, roads etc.).
- Setting up boundary conditions (tide level at Manila Bay, water level along Pasig River, pump and gate operation rule etc.).
- Specifying inflow from upstream sub-basins and lateral inflow from intermediate sub-basins.
- Adding supplementary data (elevation-storage relation etc.).
- Specifying hydraulic parameters (roughness, time steps).
- Carrying out simulation (water level, discharge, flood depth etc. are the model output).
- Viewing and interpretation of simulation results by MIKE View.

D.4 CASES OF SIMULATION BY MOUSE

The Study went through the following five stages (or cases) while carrying out simulation by MOUSE:

- *Model Calibration*: Simulation network without project condition has been developed during this stage. Existing esteros, drainage mains, hydraulic facilities / structures etc. have been used to set up the model. In addition, main roads have been added to incorporate flow connectivity and storage effect. Runoff analysis and hydrodynamic simulation under existing condition has been carried out during this stage. Runoff analysis has been carried out using divisions of reach-basins delineated based on existing drainage network, time of concentration computed based on existing drainage condition and runoff coefficient estimated under existing landuse condition. The developed model has been calibrated against August 1999 inundation. For calibration, inundation maps for both depth and duration have been used. The calibrated parameters were roughness of road which acts as flood plain, time of concentration and inundation storage from the uppermost catchments.
- *Sensitivity Analysis*: After calibrating the model, simulations under existing condition as well as for dredged condition, with and without channel improvement works and also with and without pump stations have been carried out to understand the effect of tide, dredging, channel improvements, pump operation etc.
- *Alternative Study*: Simulation network has been reconstructed during this stage with project condition based on proposed drainage system and facilities improvement plans for different alternatives. Divisions of sub-basins based on alternative plans, time of concentration based on improved drainage condition and runoff coefficient under future landuse condition has been taken into account for runoff analysis.
- *Scenario Simulation*: Simulation has been carried out with and without project condition under different design rainfall events. As for rainfall events, 2, 3, 5, 10, 20 and 30 years return period have been used. For with project condition, proposed alternative plan has been applied.

Table D.4.1 lists all the simulation cases. In total, 57 cases have been simulated: 26 for North Manila (Case E-4 = Case D-1 and Case S-4 = Case A-1) and 31 for South Manila (Case E-4 = Case D-1 and Case S-4 = Case A-2).

Table D.4.1 Hydrodynamic Simulation Cases

North Manila

Model Cases				Model Network					Boundary Condition			Comment
Simulation				Estero & Drainage Main	Other Improvement Works	Reach Basin	Pump	Sampaloc Interceptor	Rainfall	Tide or Water Level	Landuse	
Main Case	Sub-Case	ID	Run									
Calibration	Calibration	C	C-1	Existing	-	Existing	Existing	-	August-99	August-99	Existing (2003)	Model Calibration
Sensitivity Analyses	Pump Effect	P	P-1	Existing	No	Existing	No operation	No	Design 10-yr	Design	Future	Effect of pump
			P-2	Fully dredged								
	Channel Improvement Effect	D	D-1	Existing	No	Existing	Existing	No	Design 10-yr	Design	Future	Effect of improvement works
			D-2	Fully dredged								
			D-3		Fully implemented	Proposed						
Alternative Study	Alternative-1	A	A-1	Fully dredged	Fully implemented	Proposed	Aviles increased, UriUri pump added	No	Design 10-yr	Design	Future	Alternative selection
	Alternative-2		A-2				Existing	Yes				
Scenario Simulation	Existing	E	E-1	Existing	No	Existing	Existing	No	Design 2-yr	Design	Future	For damage analysis without project condition
			E-2						Design 3-yr			
			E-3						Design 5-yr			
			E-4						Design 10-yr			
			E-5						Design 20-yr			
			E-6						Design 30-yr			
	Selected Alternative	M	M-1	Fully dredged	Fully implemented	Proposed	Aviles increased, UriUri pump added (Same as Alternative A-1)	No	Design 2-yr	Design	Future	For damage analysis with full project implementation (as of M/P menu)
			M-2						Design 3-yr			
			M-3						Design 5-yr			
			M-4						Design 10-yr			
			M-5						Design 20-yr			
			M-6						Design 30-yr			
	Selected Alternative	F	F-1	Partially dredged	Partially implemented	Proposed	Aviles increased	No	Design 2-yr	Design	Future	For damage analysis with partial project implementation (as of F/S menu)
			F-2						Design 3-yr			
			F-3						Design 5-yr			
			F-4						Design 10-yr			
			F-5						Design 20-yr			
			F-6						Design 30-yr			

South Manila

Model Cases				Model Network						Boundary Condition			Comment
Simulation				Estero & Drainage Main	Other Improvement Works	Reach Basin	Pump	Libertad Pond	Maricaban Diversion	Rainfall	Tide or Water Level	Landuse	
Main Case	Sub-Case	ID	Run										
Calibration	Calibration	C	C-1	Existing	No	Existing	Existing	No	No	August-99	August-99	Existing (2003)	Model Calibration
Sensitivity Analyses	Tide Effect	T	T-1	Existing	No	Existing	Existing	No	No	Design 10-yr	0-hr Lag	Existing (2003)	Determine Lag time between design rainfall and tide peak
			T-2								1-hr Lag		
			T-3								2-hr Lag		
			T-4								3-hr Lag		
	Pump Effect	P	P-1	Existing	No	Existing	No operation	No	No	Design 10-yr	Design	Future	Effect of pump
			P-2	Fully dredged									
	Channel Improvement Effect	D	D-1	Existing	No	Existing	Existing	No	No	Design 10-yr	Design	Future	Effect of improvement works
			D-2	Fully dredged	No			No					
			D-3		No			Yes					
			D-4		Fully implemented	Proposed		Yes					
Alternative Study	Alternative-1	A	A-1	Fully dredged	Fully implemented	Proposed	Gallina increased	Yes	No	Design 10-yr	Design	Future	Alternative selection
	Alternative-2		A-2				Existing	Yes	Yes				
Scenario Simulation	Existing	E	E-1	Existing	No	Existing	Existing	No	No	Design 2-yr	Design	Future	For damage analysis without project condition
			E-2							Design 3-yr			
			E-3							Design 5-yr			
			E-4							Design 10-yr			
			E-5							Design 20-yr			
			E-6							Design 30-yr			
	Selected Alternative	M	M-1	Fully dredged	Fully implemented	Proposed	Existing	Yes	Yes (Same as Alternative A-2)	Design 2-yr	Design	Future	For damage analysis with full project implementation (as of M/P menu)
			M-2							Design 3-yr			
			M-3							Design 5-yr			
			M-4							Design 10-yr			
			M-5							Design 20-yr			
			M-6							Design 30-yr			
	Selected Alternative	F	F-1	Partially dredged	Partially implemented	Proposed	Existing	No	No	Design 2-yr	Design	Future	For damage analysis with partial project implementation (as of F/S menu)
			F-2							Design 3-yr			
			F-3							Design 5-yr			
			F-4							Design 10-yr			
			F-5							Design 20-yr			
			F-6							Design 30-yr			

D.5 MODEL DEVELOPMENT FOR EXISTING CONDITION

Schematic diagrams of model networks under existing condition for south and north drainage areas (Case C-1 and other cases with existing estero and drainage mains) are shown in *Figure D.5.1* and *Figure D.5.2,* respectively. There are slight differences in model networks for different cases as listed in *Table D.4.1*. Summary of features of simulation setup for south and north drainage areas is presented in *Table D.5.1*. Simulation model has been set up for total areas of 28.39 and 40.76 km^2 covering 98% and 93% for North and South Manila, respectively. Total area covered by hydrodynamic simulation is 69.15 km^2, which is about 95% of the total Study area. Total length of simulation network for north and south drainage areas includes 24.12 and 35.05 km of estero and 17.15 and 20.79 km of drainage main, respectively, and roads with connections. Total number of cross-sections for north and south drainage areas are 181 (49 from JICA Study Team (2004) and 132 from SEDLMM (2000)) and 217 (132 from JICA Study Team (2004) and 85 from SEDLMM (2000)), respectively. Total number of nodes for north and south drainage areas is 389 and 360, respectively. Total number of pumps for north and south drainage areas is 8 and 9, respectively (with equal numbers of gates).

Table D.5.1 Summary of Features of Model Development

Feature	Attribute	Drainage Area		
		North	South	Total
Nodes (maximum) (varies by case)	Manholes along drainage mains, junctions of estero and drainage mains, nodes on roads (number of nodes)	389	360	749
Links (maximum) (varies by case)	Esteros, drainage mains and roads (number of links)	616	469	1,085
Estero and Drainage Mains (maximum) (varies by case)	Estero (length in m)	24,117	35,054	59,171
	Estero (number of reaches)	18	17	35
	Drainage main (length in m)	17,154	20,788	37,942
	Drainage main (number)	18	18	36
Roads (maximum) (varies by case)	9 m wide (length in m)	13,835	8,768	22,603
	16 m wide (length in m)	12,399	10,594	22,993
	20 m wide (length in m)	14,378	26,401	40,779
Cross-Sections (maximum) (varies by case)	JICA Study Team (2004) survey (number)	49	132	181
	SEDLMM (2000) survey (number)	132	85	217
Hydraulic Facilities (maximum) (varies by case)	Pumping stations (number)	8	9	17
	Gates (number)	8	9	17
Reach-Basins (maximum) (varies by case)	Area (ha)	2,839	4,076	6,915
	Catchment (number)	51	55	106

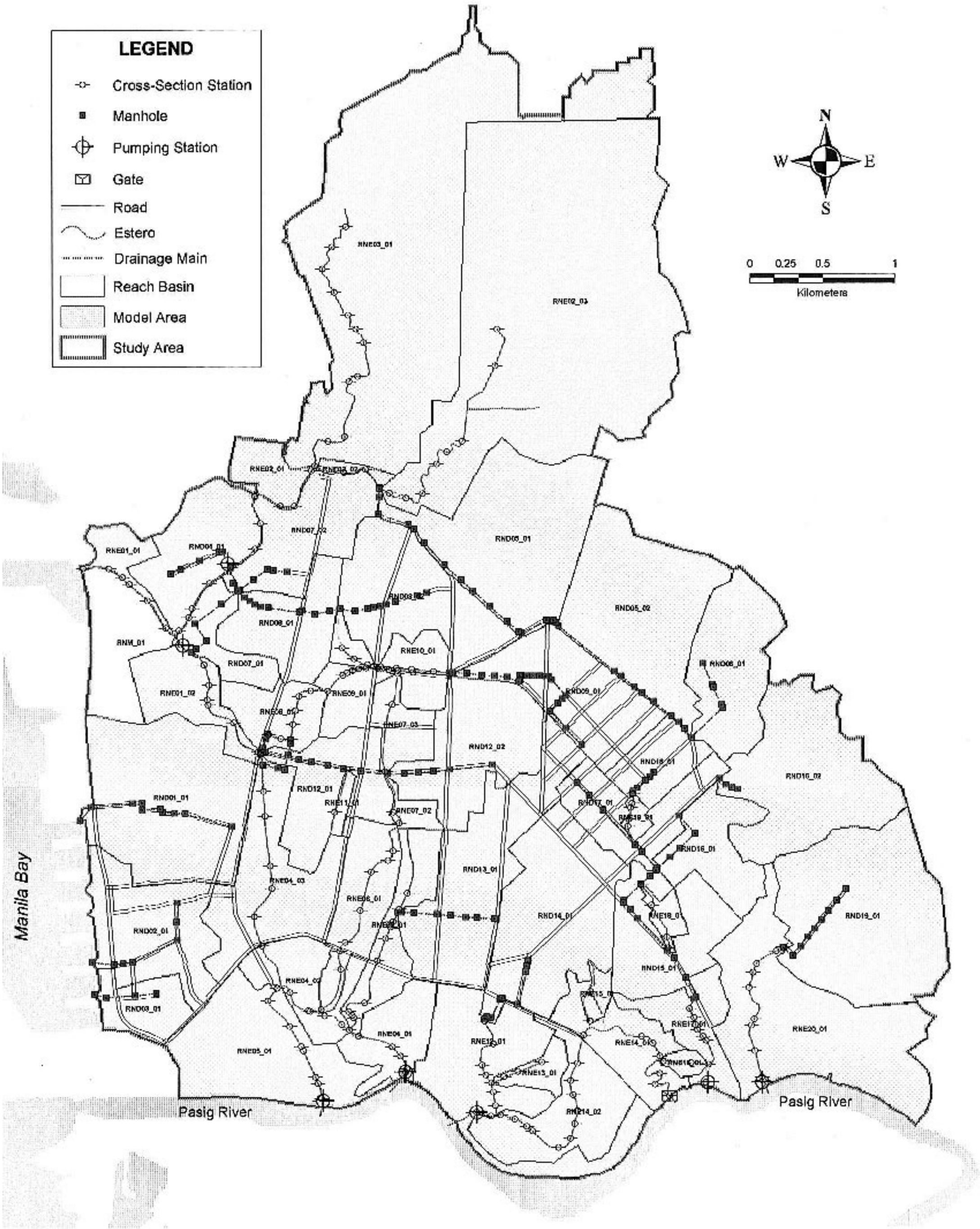


Figure D.5.1 Hydrodynamic Simulation Network for North Manila

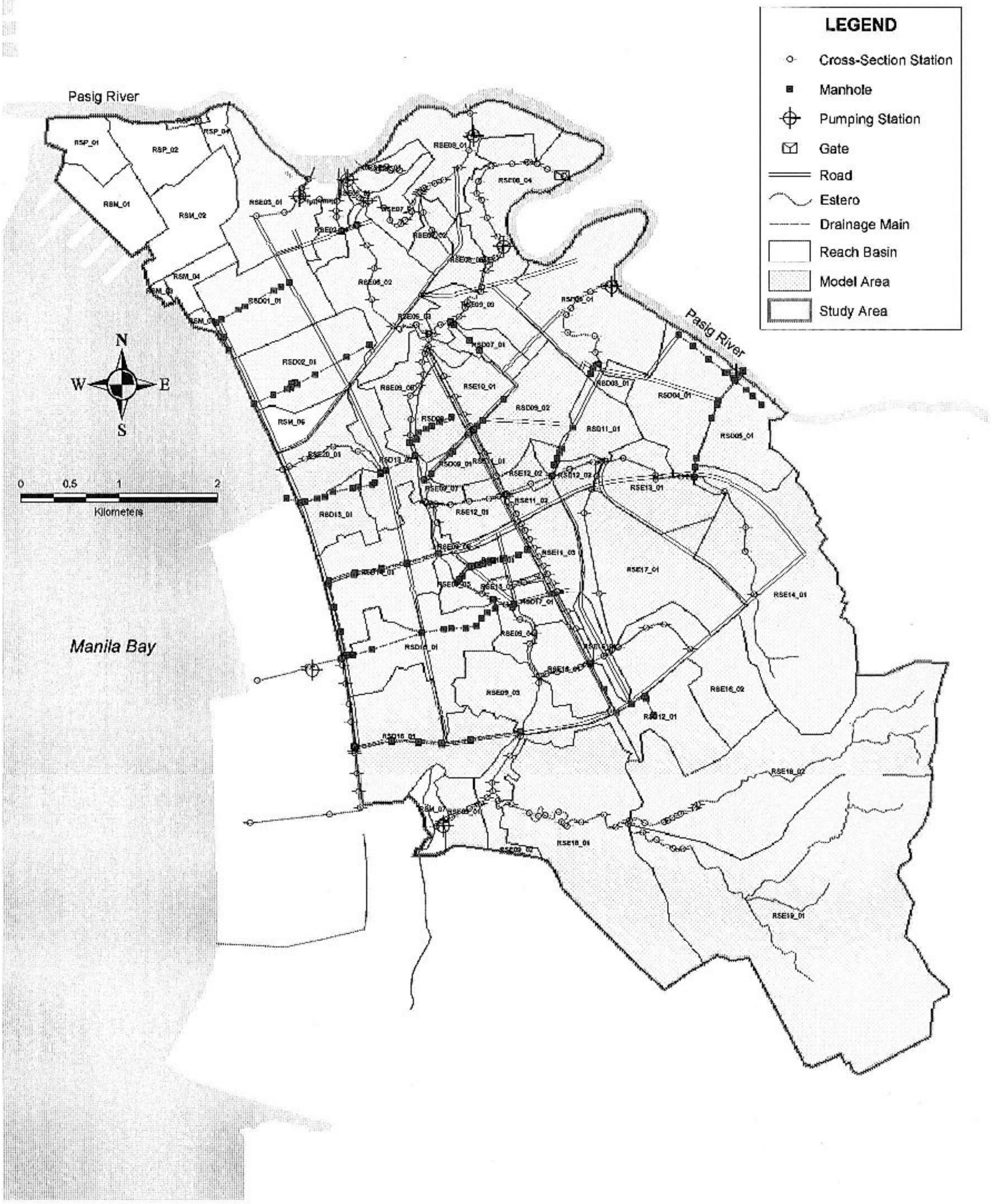


Figure D.5.2 Hydrodynamic Simulation Network for South Manila

D.6 MODEL CALIBRATION

The developed simulation models for both North and South Manila have been calibrated against 1999 inundation depth and duration surveyed by SEDLMM (2000). The 1999 inundation has a return period of 10 years or less. After developing model networks for North and South Manila under existing condition, model calibration has been carried out through the process of runoff analysis and hydrodynamic simulation. The main model parameters were time of concentration of the catchments' contributing flow and storage in the flood plain or reach basins. However, to keep the calibration process simple, time of concentration has been estimated separately instead of calibrating it inside the MOUSE model. During the estimation of time of concentration by reach basin, runoff analysis has been carried out repeatedly with different flow velocity and the peak runoff by each reach basin has been checked so that the runoff analysis produces reasonable specific runoff for all the reach basins. The estimated time of concentration (called lag time in MOUSE runoff model) by reach basins as well as other basin parameters like runoff coefficient, areal reduction factor etc. were inputted directly in the runoff model of MOUSE. It should be noted that flow velocity in channels was estimated based on the existing condition, which reflects the effects of deposition of garbage and sediment, for calibration case. As for the storage in the reach basins, road network, as detailed as possible, has been carefully integrated into the model through repeated simulation of the hydrodynamic model. In a similar manner, after several runs of the hydrodynamic model of MOUSE, roughness coefficient of road has been selected as 0.10, which produces good agreement with 1999 observed inundation maps. This means that roads in the present simulation model act as virtual floodplain channels that reflect the effects of buildings surrounding those on inundation flow. For catchments in the uppermost reaches of the esteros (2 in North Manila with reach basin ID RNE 02_03 and RNE 03_01 and 2 in South Manila with reach basin ID RSE 18_02 and RSE 19_01) for which no road network has been set up, storages of those catchments have been included in the basin nodes of uppermost estero of those catchments as elevation-area data. Stage-storage relation of the above mentioned reach basins have been extracted using GIS database of contour and basin boundary.

(1) Runoff Model

Runoff model in MOUSE consists of loss model that defines loss due to infiltration and storages, and hydrograph model that defines the shape of runoff hydrograph. For the present study, Proportional Loss, or in other words Rational Method, has been applied as the loss model. Rational Method is almost standard for runoff analysis of urban area. Rational method has been applied extensively by previous studies due to less parameter and easiness in application with acceptable degree of accuracy. As for the shape of hydrograph, triangular unit hydrograph of the Unit Hydrograph Model (UHM) has been selected, which produces runoff hydrograph with peak runoff very close to peak runoff calculated by Rational method (a little bit less due to non-symmetric nature of triangular unit hydrograph applied by MOUSE UHM model).

For ease of modeling, small sub-basins have been grouped into reach-basins, where a reach basin is defined as the catchment contributing flow to a reach or branch between two junctions of estero-drainage mains. In total, 106 reach basins or catchments have been inputted in the runoff model with 51 and 55 for North and South Manila, respectively. In the MOUSE runoff model, the runoff parameters were area (in ha), aerial reduction factor, runoff coefficient and lag time (in hour). *Table D.6.1* and *D.6.2* show the runoff parameters for both the existing and the proposed drainage schemes.

As for rainfall, hourly rainfall data at Port Area from August 1-6, 1999 (5 days) has been used. Due to absence of hourly (chart) rainfall data at Science Garden and no data at NAIA and Napindan, only Port Area rainfall has been used for runoff analysis. To include the effect of spatial distribution of rainfall, aerial reduction factor for each reach basin has been applied.

(2) Boundary Condition

Hourly tide level at Manila Bay and observed water level along the Pasig River during 1999 inundation has been applied as dynamic boundary condition at the downstream mouths of esteros and drainage mains. *Figure D.6.1* shows the observed water levels at different pump stations along the Pasig River. Rainfall at Port Area and tide at Manila Bay during 1999 inundation are presented in the meteo-hydrology part. No return flow from the Pasig River through small outlets of drainage was taken into account in the simulation model, because of difficulty to estimate it and its uncertainty.

(3) Pump and Gate

There exist 7 large pumps in the North and 8 large pumps in the South Manila. Start and stop levels of each pump station along with design capacity is listed in *Table D.6.2*. Differential type pumps have been set up in the MOUSE model along with non-return valves at gate of each pump station. Capacity curve (dH-Q data) of each pump station has been calculated based on only available experimental data at Vitas pump station assuming that all the pump stations behave in a similar way. The capacity curve tables of the pump stations are presented in *Table D.6.3*.

(4) Hydrodynamic Simulation

Fully dynamic wave model has been applied for hydrodynamic simulation. Variable time step of 30 to 600 seconds with an increasing factor of 1.5 has been used since MOUSE automatically adjusts the time step to get the maximum optimum time step that produces stable simulation.

MOUSE automatically calculates an initial water surface based on boundary condition applying non-uniform flow equation. Even though, at the onset of simulation, the initial water level might deviate from real or design condition, within a few time steps, the water levels at every point of the simulation network come close to real or design condition and no problem could be encountered with automatic adjustment of initial water level of MOUSE model.

Manning's roughness coefficient for esteros and drainage mains have been selected based on information of estero and drainage mains' bed and side materials (from survey result), field visit, previous studies and FCSEC guidelines.

Type of Channel	Manning's Roughness Coefficient (n value)	
	Existing Condition	Improved Condition
Estero	0.030	0.025
Drainage Main	0.018	0.015
Road (Floodplain)	0.10	0.10

Inflow points of runoff from the catchments to the simulation network (at nodes) have been specified based on topography, laterals, catchment shape, flow path etc.

Table D.6.1 Runoff Calculation Parameters for North Manila (1/2) (Existing Drainage Scheme)

Block ID	Basin ID	Reach ID	Reach Basin Area (km^2)	Reach Basin Area (ha)	Areal Reduction Factor	Runoff Coefficient Existing C	Runoff Coefficient Future C	Flow Length (m)	Existing Flow Vel. (m/s)	Existing Flow Time (s)	Dredged Flow Vel. (m/s)	Dredged Flow Time (s)	Inlet Time (s)	Time of Con. (Lag Time) Existing (hr)	Time of Con. (Lag Time) Dredged (hr)
N05	N05_01	RND01_01	1.13	112.66	0.99	0.83	0.83	1157	1.00	1157	1.00	1157	997	0.60	0.60
N05	N05_01	RND02_01	0.62	61.83	1.00	0.81	0.85	873	0.78	1117	1.75	499	629	0.48	0.31
N05	N05_01	RND03_01	0.23	22.90	1.00	0.79	0.85	429	0.10	4291	1.19	360	720	1.39	0.30
N04	N04_02	RND04_01	0.49	49.39	1.00	0.79	0.79	511	1.14	448	1.65	309	800	0.35	0.31
N04	N04_01	RND05_01	1.06	105.70	0.99	0.47	0.47	1752	0.75	2327	1.27	1382	1206	0.98	0.72
N04	N04_01	RND05_02	0.98	98.35	1.00	0.70	0.70	1219	0.39	3093	1.20	1014	1614	1.31	0.73
N04	N04_01	RND06_01	0.58	57.92	1.00	0.66	0.66	630	1.23	513	1.72	366	1437	0.54	0.50
N01	N01_01	RND07_01	0.22	21.52	1.00	0.69	0.76	654	1.34	486	1.66	394	658	0.32	0.29
N01	N01_01	RND07_02	0.49	49.39	1.00	0.79	0.79	386	1.06	364	1.65	234	1984	0.65	0.62
N01	N01_01	RND08_01	0.44	43.53	1.00	0.73	0.73	719	0.91	790	1.36	527	1118	0.53	0.46
N01	N01_01	RND08_02	0.71	70.55	1.00	0.74	0.74	645	0.84	771	1.30	497	1496	0.63	0.55
N01	N01_01	RND09_01	0.59	59.20	1.00	0.74	0.74	1368	0.10	13684	0.76	1800	1250	4.15	0.85
N01	N01_01	RND12_01	0.47	46.85	1.00	0.67	0.75	859	0.35	2455	1.67	515	1092	0.99	0.45
N01	N01_01	RND12_02	0.65	64.72	1.00	0.64	0.64	736	0.89	822	2.16	341	1108	0.54	0.40
N01	N01_02	RND13_01	0.86	86.29	1.00	0.74	0.77	669	1.65	405	2.28	293	3071	0.97	0.93
N02	N02_01	RND14_01	0.93	92.64	1.00	0.72	0.74	640	1.31	490	1.64	390	2531	0.84	0.81
N02	N02_02	RND15_01	0.51	51.34	1.00	0.61	0.72	1146	0.67	1713	0.92	1251	896	0.72	0.60
N02	N02_02	RND16_01	0.37	36.88	1.00	0.69	0.69	905	0.94	964	1.22	743	816	0.49	0.43
N02	N02_02	RND16_02	0.94	94.30	1.00	0.69	0.69	158	1.30	121	1.64	97	2437	0.71	0.70
N02	N02_02	RND17_01	0.38	37.70	1.00	0.74	0.74	824	1.24	666	1.64	503	403	0.30	0.25
N02	N02_02	RND18_01	0.24	23.84	1.00	0.74	0.74	212	0.62	340	1.00	212	705	0.29	0.25
N03	N03_01	RND19_01	1.21	120.80	0.99	0.65	0.65	674	1.46	463	1.94	348	1458	0.53	0.50
N04	N04_01	RNE01_01	0.14	13.61	1.00	0.52	0.60	835	1.01	822	0.99	847	1191	0.56	0.57
N01	N01_01	RNE01_02	0.32	32.21	1.00	0.82	0.82	1117	0.99	1131	1.32	847	576	0.47	0.40
N04	N04_01	RNE02_01	0.16	16.50	1.00	0.98	0.85	1832	1.07	1707	1.20	1521	1278	0.83	0.78
N04	N04_01	RNE02_02	0.04	3.93	1.00	0.82	0.82	535	0.69	769	2.99	179	148	0.25	0.09
N04	N04_01	RNE02_03	3.44	344.45	0.98	0.68	0.68	1913	1.97	969	2.23	858	3985	1.38	1.35
N04	N04_01	RNE03_01	3.02	301.90	0.98	0.75	0.75	2202	1.68	1314	1.94	1135	4067	1.49	1.44
N01	N01_03	RNE04_01	0.30	29.61	1.00	0.79	0.79	520	1.12	464	1.57	330	1140	0.45	0.41
N01	N01_02	RNE04_02	0.18	17.70	1.00	0.78	0.78	618	1.29	480	1.68	368	572	0.29	0.26
N01	N01_01	RNE04_03	0.83	82.99	1.00	0.79	0.79	1300	0.65	1985	0.90	1445	980	0.82	0.67
N01	N01_02	RNE05_01	0.80	79.62	1.00	0.80	0.80	938	1.00	938	1.23	760	1698	0.73	0.68
N01	N01_02	RNE06_01	0.39	39.22	1.00	0.74	0.74	1300	0.77	1689	1.37	950	518	0.61	0.41
N01	N01_02	RNE07_01	0.33	33.40	1.00	0.76	0.76	1023	1.03	997	0.70	1451	392	0.39	0.51
N01	N01_01	RNE07_02	0.07	6.87	1.00	0.70	0.70	429	0.88	489	0.68	628	320	0.22	0.26
N01	N01_01	RNE07_03	0.19	18.87	1.00	0.74	0.74	340	0.81	420	0.55	618	534	0.26	0.32
N01	N01_01	RNE08_01	0.27	26.76	1.00	0.74	0.74	689	0.94	731	1.56	442	776	0.42	0.34
N01	N01_01	RNE09_01	0.25	24.61	1.00	0.75	0.75	365	0.73	497	0.94	388	666	0.32	0.29
N01	N01_01	RNE10_01	0.18	17.61	1.00	0.73	0.78	525	0.43	1213	1.00	524	450	0.46	0.27
N01	N01_01	RNE11_01	0.04	3.67	1.00	0.70	0.70	0	0.50	0	0.50	0	918	0.26	0.26
N02	N02_01	RNE12_01	0.76	76.08	1.00	0.75	0.75	897	1.65	544	1.36	662	1696	0.62	0.66
N02	N02_01	RNE13_01	0.10	10.03	1.00	0.71	0.71	382	0.36	1070	0.84	456	474	0.43	0.26
N02	N02_02	RNE14_01	0.35	35.40	1.00	0.74	0.74	722	0.71	1024	0.94	767	542	0.43	0.36
N02	N02_01	RNE14_02	0.51	50.53	1.00	0.72	0.72	900	1.37	656	1.45	619	758	0.39	0.38
N02	N02_02	RNE15_01	0.06	5.57	1.00	0.66	0.74	486	0.50	972	0.50	972	946	0.53	0.53
N02	N02_02	RNE16_01	0.04	4.18	1.00	0.76	0.76	340	2.47	138	0.91	376	246	0.11	0.17
N02	N02_02	RNE17_01	0.28	28.26	1.00	0.73	0.73	680	0.97	697	1.47	462	832	0.42	0.36
N02	N02_02	RNE18_01	0.07	6.94	1.00	0.74	0.74	360	0.38	954	0.68	532	268	0.34	0.22
N02	N02_02	RNE19_01	0.04	3.99	1.00	0.71	0.71	328	1.54	213	1.30	252	244	0.13	0.14
N03	N03_01	RNE20_01	1.16	116.19	0.99	0.71	0.71	1167	1.29	903	2.02	578	1990	0.80	0.71

Table D.6.1 Runoff Calculation Parameters for North Manila (2/2) (Proposed Drainage Scheme)

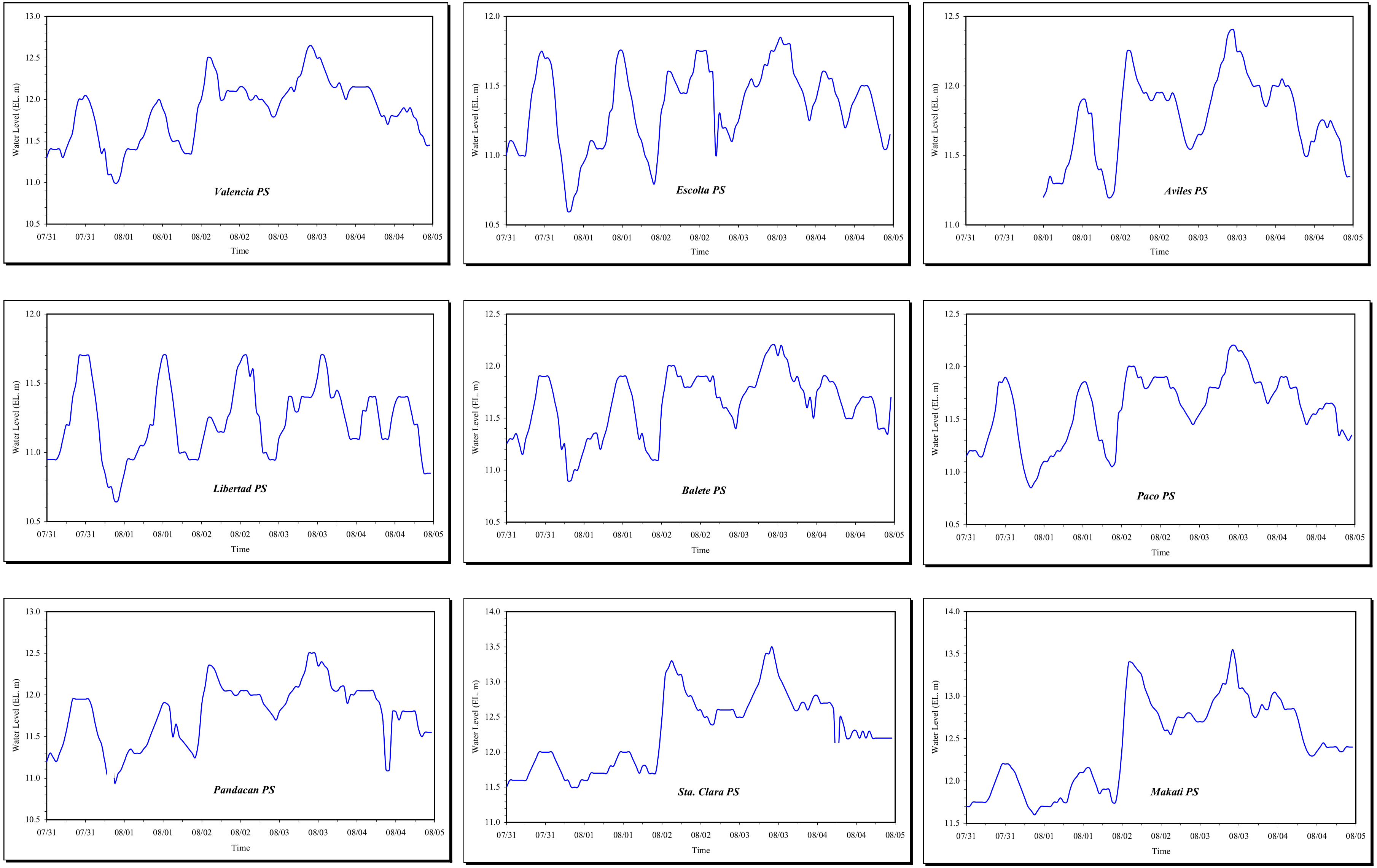
Block ID	Basin ID	Reach ID	Reach Basin Area		Areal Reduction Factor	Runoff Coefficient		Flow Length	Existing		Dredged		Inlet Time	Time of Con. (Lag Time)	
						Existing C	Future C		Flow Vel.	Flow Time	Flow Vel.	Flow Time		Existing	Dredged
			(km^2)	(ha)				(m)	(m/s)	(s)	(m/s)	(s)	(s)	(hr)	(hr)
N05	N05_01	RND01_01	1.13	112.66	0.99	0.83	0.83	1157	1.00	1157	1.00	1157	997	0.60	0.60
N05	N05_01	RND02_01	0.62	61.83	1.00	0.81	0.85	873	0.78	1117	1.75	499	629	0.48	0.31
N05	N05_01	RND03_01	0.23	22.90	1.00	0.79	0.85	429	0.10	4291	1.19	360	720	1.39	0.30
N04	N04_02	RND04_01	0.49	49.39	1.00	0.79	0.79	511	1.14	448	1.65	309	800	0.35	0.31
N04	N04_01	RND05_01	1.05	105.12	0.99	0.47	0.47	1752	0.75	2327	1.27	1382	1206	0.98	0.72
N04	N04_01	RND05_02	0.95	94.59	1.00	0.70	0.70	400	0.39	1015	1.20	333	2200	0.89	0.70
N02	N04_01	RND06_01	0.62	61.68	1.00	0.66	0.66	630	1.23	513	1.72	366	1437	0.54	0.50
N01	N01_01	RND07_01	0.22	21.52	1.00	0.69	0.76	654	1.34	486	1.66	394	658	0.32	0.29
N01	N01_01	RND07_02	0.20	20.30	1.00	0.79	0.79	386	1.06	364	1.65	234	1000	0.38	0.34
N01	N01_01	RND08_01	0.44	43.53	1.00	0.73	0.73	719	0.91	790	1.36	527	1118	0.53	0.46
N01	N01_01	RND08_02	0.71	70.55	1.00	0.74	0.74	645	0.84	771	1.30	497	1496	0.63	0.55
N01	N01_01	RND09_01	0.59	59.20	1.00	0.74	0.74	1368	0.10	13684	0.76	1800	1250	4.15	0.85
N01	N01_01	RND12_01	0.47	46.85	1.00	0.67	0.75	859	0.35	2455	1.67	515	1092	0.99	0.45
N01	N01_01	RND12_02	0.65	64.72	1.00	0.64	0.64	736	0.89	822	2.16	341	1108	0.54	0.40
N01	N01_02	RND13_01	0.86	86.29	1.00	0.74	0.77	669	1.65	405	2.28	293	3071	0.97	0.93
N02	N02_01	RND14_01	0.93	92.64	1.00	0.72	0.74	640	1.31	490	1.64	390	2531	0.84	0.81
N02	N02_02	RND15_01	0.51	51.34	1.00	0.61	0.72	1146	0.67	1713	0.92	1251	896	0.72	0.60
N02	N02_02	RND16_01	0.37	36.88	1.00	0.69	0.69	905	0.94	964	1.22	743	816	0.49	0.43
N02	N02_02	RND16_02	0.94	94.30	1.00	0.69	0.69	158	1.30	121	1.64	97	2437	0.71	0.70
N02	N02_02	RND17_01	0.38	37.70	1.00	0.74	0.74	824	1.24	666	1.64	503	403	0.30	0.25
N02	N02_02	RND18_01	0.24	23.84	1.00	0.74	0.74	560	0.62	899	1.00	560	400	0.36	0.27
N03	N03_01	RND19_01	1.21	120.80	0.99	0.65	0.65	674	1.46	463	1.94	348	1458	0.53	0.50
N04	N04_01	RNE01_01	0.14	13.61	1.00	0.52	0.60	835	1.01	822	0.99	847	1191	0.56	0.57
N01	N01_01	RNE01_02	0.32	32.21	1.00	0.82	0.82	1117	0.99	1131	1.32	847	576	0.47	0.40
N04	N04_01	RNE02_01	0.16	16.50	1.00	0.98	0.85	1832	1.07	1707	1.20	1521	1278	0.83	0.78
N04	N04_01	RNE02_02	0.19	19.00	1.00	0.82	0.82	535	0.69	769	2.99	179	148	0.25	0.09
N04	N04_01	RNE02_03	3.44	344.45	0.98	0.68	0.68	1913	1.97	969	2.23	858	3985	1.38	1.35
N04	N04_01	RNE03_01	3.02	301.90	0.98	0.75	0.75	2202	1.68	1314	1.94	1135	4067	1.49	1.44
N01	N01_03	RNE04_01	0.30	29.61	1.00	0.79	0.79	520	1.12	464	1.57	330	1140	0.45	0.41
N01	N01_02	RNE04_02	0.18	17.70	1.00	0.78	0.78	618	1.29	480	1.68	368	572	0.29	0.26
N01	N01_01	RNE04_03	0.83	82.99	1.00	0.79	0.79	1300	0.65	1985	0.90	1445	980	0.82	0.67
N01	N01_02	RNE05_01	0.80	79.62	1.00	0.80	0.80	938	1.00	938	1.23	760	1698	0.73	0.68
N01	N01_02	RNE06_01	0.39	39.22	1.00	0.74	0.74	1300	0.77	1689	1.37	950	518	0.61	0.41
N01	N01_02	RNE07_01	0.33	33.40	1.00	0.76	0.76	1023	1.03	997	0.70	1451	392	0.39	0.51
N01	N01_01	RNE07_02	0.07	6.87	1.00	0.70	0.70	429	0.88	489	0.68	628	320	0.22	0.26
N01	N01_01	RNE07_03	0.19	18.87	1.00	0.74	0.74	340	0.81	420	0.55	618	534	0.26	0.32
N01	N01_01	RNE08_01	0.27	26.76	1.00	0.74	0.74	689	0.94	731	1.56	442	776	0.42	0.34
N01	N01_01	RNE09_01	0.25	24.61	1.00	0.75	0.75	365	0.73	497	0.94	388	666	0.32	0.29
N01	N01_01	RNE10_01	0.18	17.61	1.00	0.73	0.78	525	0.43	1213	1.00	524	450	0.46	0.27
N01	N01_01	RNE11_01	0.04	3.67	1.00	0.70	0.70	0	0.50	0	0.50	0	918	0.26	0.26
N02	N02_01	RNE12_01	0.76	76.08	1.00	0.75	0.75	897	1.65	544	1.36	662	1696	0.62	0.66
N02	N02_01	RNE13_01	0.10	10.03	1.00	0.71	0.71	382	0.36	1070	0.84	456	474	0.43	0.26
N02	N02_02	RNE14_01	0.35	35.40	1.00	0.74	0.74	722	0.71	1024	0.94	767	542	0.43	0.36
N02	N02_01	RNE14_02	0.51	50.53	1.00	0.72	0.72	900	1.37	656	1.45	619	758	0.39	0.38
N02	N02_02	RNE15_01	0.06	5.57	1.00	0.66	0.74	486	0.50	972	0.50	972	946	0.53	0.53
N02	N02_02	RNE16_01	0.04	4.18	1.00	0.76	0.76	340	2.47	138	0.91	376	246	0.11	0.17
N02	N02_02	RNE17_01	0.28	28.26	1.00	0.73	0.73	680	0.97	697	1.47	462	832	0.42	0.36
N02	N02_02	RNE18_01	0.07	6.94	1.00	0.74	0.74	360	0.38	954	0.68	532	268	0.34	0.22
N02	N02_02	RNE19_01	0.04	3.99	1.00	0.71	0.71	328	1.54	213	1.30	252	244	0.13	0.14
N03	N03_01	RNE20_01	1.16	116.19	0.99	0.71	0.71	1167	1.29	903	2.02	578	1990	0.80	0.71
N04	N04_01	RND05N_01	0.15	14.60	1.00	0.79	0.79	580	1.00	580	1.00	580	510	0.30	0.30

Table D.6.2 Runoff Calculation Parameters for South Manila (1/2) (Existing Drainage Scheme)

Block ID	Basin ID	Reach ID	Reach Basin Area		Areal Reduction Factor	Runoff Coefficient		Flow Length	Existing		Proposed		Inlet Time	Time of Con. (Lag Time)	
						Existing C	Future C		Flow Vel.	Flow Time	Flow Vel.	Flow Time		Existing	Proposed
			(km^2)	(ha)				(m)	(m/s)	(s)	(m/s)	(s)	(s)	(hr)	(hr)
S06	S06_01	RSD01_01	0.93	93.24	1.00	0.76	0.81	1160	1.06	1095	1.36	853	843	0.54	0.47
S06	S06_01	RSD02_01	0.92	92.44	1.00	0.74	0.79	1347	0.82	1639	1.19	1132	725	0.66	0.52
S04	S04_01	RSD03_01	0.09	8.80	1.00	0.70	0.70	133	1.00	133	1.00	133	899	0.29	0.29
S05	S05_01	RSD04_01	1.00	100.15	0.99	0.66	0.66	626	1.11	565	1.61	388	2122	0.75	0.70
S05	S05_01	RSD05_01	0.65	64.90	1.00	0.71	0.71	393	2.03	193	2.67	147	1785	0.55	0.54
S03	S03_03	RSD07_01	0.23	22.61	1.00	0.73	0.73	414	0.47	889	0.63	654	1300	0.61	0.54
S03	S03_03	RSD08_01	0.32	32.34	1.00	0.71	0.71	518	0.67	778	1.12	462	1600	0.66	0.57
S01	S01_02	RSD09_01	0.22	22.07	1.00	0.71	0.71	701	0.92	763	1.32	532	630	0.39	0.32
S01	S01_02	RSD09_02	0.79	78.61	1.00	0.73	0.73	160	0.65	245	0.86	185	2600	0.79	0.77
S01	S01_02	RSD10_01	0.32	31.98	1.00	0.72	0.72	821	0.93	880	1.15	716	778	0.46	0.41
S01	S01_02	RSD11_01	0.49	48.83	1.00	0.68	0.68	543	0.50	1087	0.50	1087	1524	0.73	0.73
S01	S01_01	RSD12_01	0.72	71.51	1.00	0.73	0.73	1108	3.17	350	3.87	287	1841	0.61	0.59
S01	S01_03	RSD13_01	0.36	35.68	1.00	0.75	0.75	1047	0.94	1111	1.28	820	682	0.50	0.42
S01	S01_03	RSD13_02	0.53	52.78	1.00	0.71	0.71	150	0.94	159	1.28	118	2622	0.77	0.76
S01	S01_02	RSD14_01	1.14	113.96	0.99	0.76	0.76	1992	1.15	1738	1.49	1338	1144	0.80	0.69
S01	S01_02	RSD15_01	1.01	100.59	0.99	0.77	0.77	1796	1.08	1670	1.40	1288	1120	0.77	0.67
S01	S01_02	RSD16_01	1.38	138.06	0.99	0.76	0.76	1731	0.93	1868	1.36	1272	1596	0.96	0.80
S01	S01_02	RSD17_01	0.16	15.85	1.00	0.79	0.79	434	1.00	434	1.00	434	730	0.32	0.32
S03	S03_01	RSE02_01	0.21	21.33	1.00	0.69	0.68	0	0.50	0	0.50	0	0	0.00	0.00
S02	S02_01	RSE03_01	0.94	93.90	1.00	0.64	0.67	1095	0.77	1417	0.60	1811	1899	0.92	1.03
S03	S03_01	RSE04_01	0.19	18.58	1.00	0.52	0.58	0	0.50	0	0.50	0	1743	0.48	0.48
S04	S04_01	RSE05_01	1.48	148.14	0.99	0.63	0.63	1450	0.79	1839	1.61	901	2132	1.10	0.84
S03	S03_01	RSE06_01	0.04	3.68	1.00	0.73	0.73	307	2.17	141	2.70	114	240	0.11	0.10
S03	S03_01	RSE06_02	1.00	100.48	0.99	0.75	0.78	1499	0.85	1768	1.33	1125	1340	0.86	0.68
S03	S03_03	RSE06_03	0.08	8.45	1.00	0.76	0.83	487	0.81	597	0.81	597	348	0.26	0.26
S03	S03_01	RSE07_01	0.30	29.91	1.00	0.69	0.72	1081	1.35	798	1.51	717	554	0.38	0.35
S03	S03_02	RSE08_01	0.91	91.43	1.00	0.60	0.60	854	0.93	917	1.84	465	2140	0.85	0.72
S03	S03_02	RSE08_02	0.23	23.28	1.00	0.74	0.74	719	0.88	818	1.84	390	648	0.41	0.29
S03	S03_03	RSE08_03	0.24	23.95	1.00	0.75	0.75	354	0.85	415	0.83	426	1354	0.49	0.49
S03	S03_03	RSE08_04	0.87	86.84	1.00	0.70	0.70	290	0.64	451	0.84	345	880	0.37	0.34
S01	S01_01	RSE09_01	0.28	28.27	1.00	0.62	0.68	412	0.48	861	0.96	429	1372	0.62	0.50
S01	S01_01	RSE09_02	0.44	43.93	1.00	0.72	0.72	932	0.42	2211	0.84	1106	944	0.88	0.57
S01	S01_01	RSE09_03	0.66	66.00	1.00	0.77	0.77	612	0.35	1737	0.85	724	2156	1.08	0.80
S01	S01_02	RSE09_04	0.19	19.22	1.00	0.78	0.78	1101	0.36	3066	0.97	1133	350	0.95	0.41
S01	S01_02	RSE09_05	0.19	18.62	1.00	0.77	0.77	365	0.39	941	0.79	464	484	0.40	0.26
S01	S01_02	RSE09_06	0.11	11.38	1.00	0.69	0.69	538	0.32	1688	0.73	732	424	0.59	0.32
S01	S01_02	RSE09_07	0.11	11.34	1.00	0.71	0.71	625	0.25	2492	0.63	993	362	0.79	0.38
S03	S03_03	RSE09_08	0.47	47.03	1.00	0.75	0.75	1339	0.37	3642	0.61	2191	702	1.21	0.80
S03	S03_03	RSE09_09	0.67	66.79	1.00	0.71	0.71	1246	0.73	1706	1.04	1200	1800	0.97	0.83
S03	S03_03	RSE10_01	0.35	35.20	1.00	0.70	0.70	922	0.19	4873	0.71	1295	1260	1.70	0.71
S01	S01_02	RSE11_01	0.04	4.21	1.00	0.75	0.85	736	0.50	1483	0.55	1335	114	0.44	0.40
S01	S01_02	RSE11_02	0.14	13.58	1.00	0.80	0.80	310	0.94	329	1.08	288	878	0.34	0.32
S01	S01_02	RSE11_03	0.50	49.88	1.00	0.80	0.80	1610	0.51	3135	1.22	1320	620	1.04	0.54
S01	S01_02	RSE12_01	0.32	32.26	1.00	0.70	0.70	761	1.12	679	1.50	508	848	0.42	0.38
S01	S01_02	RSE12_02	0.28	28.36	1.00	0.74	0.74	510	0.41	1254	0.41	1254	176	0.40	0.40
S01	S01_01	RSE13_01	0.72	72.37	1.00	0.73	0.73	995	1.53	651	1.53	651	601	0.35	0.35
S05	S05_02	RSE14_01	2.66	265.71	0.98	0.60	0.60	2773	2.58	1076	2.58	1076	1800	0.80	0.80
S01	S01_02	RSE15_01	0.09	8.95	1.00	0.76	0.76	0	0.50	0	0.50	0	1500	0.42	0.42
S01	S01_01	RSE16_01	0.64	64.08	1.00	0.79	0.79	751	1.85	406	2.83	266	1706	0.59	0.55
S01	S01_01	RSE16_02	1.21	120.69	0.99	0.69	0.69	1008	2.78	363	2.78	363	2161	0.70	0.70
S01	S01_01	RSE17_01	1.54	154.23	0.99	0.75	0.75	1733	0.74	2336	1.13	1538	4000	1.76	1.54
S01	S01_01	RSE18_01	2.50	250.31	0.98	0.63	0.68	2157	0.91	2374	2.14	1008	2322	1.30	0.93
S01	S01_01	RSE18_02	2.94	293.50	0.98	0.56	0.65	4034	1.75	2309	1.75	2309	734	0.85	0.85
S01	S01_01	RSE19_01	5.40	540.12	0.96	0.53	0.56	4249	1.50	2842	1.50	2842	122	0.82	0.82
S01	S01_03	RSE20_01	0.55	54.95	1.00	0.64	0.64	1196	1.04	1152	1.04	1152	918	0.58	0.58

Table D.6.2 Runoff Calculation Parameters for South Manila (2/2)
(Proposed Drainage Scheme)

Block ID	Basin ID	Reach ID	Reach Basin Area		Areal Reduction	Runoff Coefficient		Flow Length	Existing		Proposed		Inlet Time	Time of Con. (Lag Time)	
						Existing	Future		Flow Vel.	Flow Time	Flow Vel.	Flow Time		Existing	Proposed
			(km^2)	(ha)	Factor	C	C	(m)	(m/s)	(s)	(m/s)	(s)	(s)	(hr)	(hr)
S06	S06_01	RSD01_01	0.93	93.24	1.00	0.76	0.81	1160	1.06	1095	1.36	853	843	0.54	0.47
S06	S06_01	RSD02_01	0.92	92.44	1.00	0.74	0.79	1347	0.82	1639	1.19	1132	725	0.66	0.52
S04	S04_01	RSD03_01	0.09	8.80	1.00	0.70	0.70	133	1.00	133	1.00	133	899	0.29	0.29
S05	S05_01	RSD04_01	1.00	100.15	0.99	0.66	0.66	626	1.11	565	1.61	388	2122	0.75	0.70
S05	S05_01	RSD05_01	0.65	64.90	1.00	0.71	0.71	393	2.03	193	2.67	147	1785	0.55	0.54
S03	S03_03	RSD07_01	0.23	22.61	1.00	0.73	0.73	414	0.47	889	0.63	654	1300	0.61	0.54
S03	S03_03	RSD08_01	0.32	32.34	1.00	0.71	0.71	518	0.67	778	1.12	462	1600	0.66	0.57
S01	S01_02	RSD09_01	0.22	22.07	1.00	0.71	0.71	701	0.92	763	1.32	532	630	0.39	0.32
S01	S01_02	RSD09_02	0.79	78.61	1.00	0.73	0.73	160	0.65	245	0.86	185	2600	0.79	0.77
S01	S01_02	RSD10_01	0.35	35.05	1.00	0.72	0.72	821	0.93	880	1.15	716	778	0.46	0.41
S01	S01_02	RSD11_01	0.49	48.83	1.00	0.68	0.68	543	0.50	1087	0.50	1087	1524	0.73	0.73
S01	S01_01	RSD12_01	0.72	71.51	1.00	0.73	0.73	1108	3.17	350	3.87	287	1841	0.61	0.59
S01	S01_03	RSD13_01	0.36	35.68	1.00	0.75	0.75	1047	0.94	1111	1.28	820	682	0.50	0.42
S01	S01_03	RSD13_02	0.53	52.78	1.00	0.71	0.71	150	0.94	159	1.28	118	2622	0.77	0.76
S01	S01_02	RSD14_01	1.14	113.96	0.99	0.76	0.76	1992	1.15	1738	1.49	1338	1144	0.80	0.69
S01	S01_02	RSD15_01	1.01	100.59	0.99	0.77	0.77	1796	1.08	1670	1.40	1288	1120	0.77	0.67
S01	S01_02	RSD16_01	1.38	138.06	0.99	0.76	0.76	1731	0.93	1868	1.36	1272	1596	0.96	0.80
S01	S01_02	RSD17_01	0.16	15.85	1.00	0.79	0.79	434	1.00	434	1.00	434	730	0.32	0.32
S03	S03_01	RSE02_01	0.21	21.33	1.00	0.69	0.68	0	0.50	0	0.50	0	0	0.00	0.00
S02	S02_01	RSE03_01	0.94	93.90	1.00	0.64	0.67	1095	0.77	1417	0.60	1811	1899	0.92	1.03
S03	S03_01	RSE04_01	0.19	18.58	1.00	0.52	0.58	0	0.50	0	0.50	0	1743	0.48	0.48
S04	S04_01	RSE05_01	1.48	148.14	0.99	0.63	0.63	1450	0.79	1839	1.61	901	2132	1.10	0.84
S03	S03_01	RSE06_01	0.04	3.68	1.00	0.73	0.73	307	2.17	141	2.70	114	240	0.11	0.10
S03	S03_01	RSE06_02	1.00	100.48	0.99	0.75	0.78	1499	0.85	1768	1.33	1125	1340	0.86	0.68
S03	S03_03	RSE06_03	0.08	8.45	1.00	0.76	0.83	487	0.81	597	0.81	597	348	0.26	0.26
S03	S03_01	RSE07_01	0.30	29.91	1.00	0.69	0.72	1081	1.35	798	1.51	717	554	0.38	0.35
S03	S03_02	RSE08_01	0.91	91.43	1.00	0.60	0.60	854	0.93	917	1.84	465	2140	0.85	0.72
S03	S03_02	RSE08_02	0.23	23.28	1.00	0.74	0.74	719	0.88	818	1.84	390	648	0.41	0.29
S03	S03_03	RSE08_03	0.24	23.95	1.00	0.75	0.75	354	0.85	415	0.83	426	1354	0.49	0.49
S03	S03_03	RSE08_04	0.87	86.84	1.00	0.70	0.70	290	0.64	451	0.84	345	880	0.37	0.34
S01	S01_01	RSE09_01	0.28	28.27	1.00	0.62	0.68	412	0.48	861	0.96	429	1372	0.62	0.50
S01	S01_01	RSE09_02	0.44	43.93	1.00	0.72	0.72	932	0.42	2211	0.84	1106	944	0.88	0.57
S01	S01_01	RSE09_03	0.66	66.00	1.00	0.77	0.77	612	0.35	1737	0.85	724	2156	1.08	0.80
S01	S01_02	RSE09_04	0.19	19.22	1.00	0.78	0.78	1101	0.36	3066	0.97	1133	350	0.95	0.41
S01	S01_02	RSE09_05	0.16	15.56	1.00	0.77	0.77	365	0.39	941	0.79	464	484	0.40	0.26
S01	S01_02	RSE09_06	0.11	11.38	1.00	0.69	0.69	538	0.32	1688	0.73	732	424	0.59	0.32
S01	S01_02	RSE09_07	0.11	11.34	1.00	0.71	0.71	625	0.25	2492	0.63	993	362	0.79	0.38
S03	S03_03	RSE09_08	0.47	47.03	1.00	0.75	0.75	1339	0.37	3642	0.61	2191	702	1.21	0.80
S03	S03_03	RSE09_09	0.67	66.79	1.00	0.71	0.71	1246	0.73	1706	1.04	1200	1800	0.97	0.83
S03	S03_03	RSE10_01	0.35	35.20	1.00	0.70	0.70	922	0.19	4873	0.71	1295	1260	1.70	0.71
S01	S01_02	RSE11_01	0.04	4.21	1.00	0.75	0.85	736	0.50	1483	0.55	1335	114	0.44	0.40
S01	S01_02	RSE11_02	0.14	13.58	1.00	0.80	0.80	310	0.94	329	1.08	288	878	0.34	0.32
S01	S01_02	RSE11_03	0.50	49.88	1.00	0.80	0.80	1610	0.51	3135	1.22	1320	620	1.04	0.54
S01	S01_02	RSE12_01	0.32	32.26	1.00	0.70	0.70	761	1.12	679	1.50	508	848	0.42	0.38
S01	S01_02	RSE12_02	0.28	28.36	1.00	0.74	0.74	510	0.41	1254	0.41	1254	176	0.40	0.40
S01	S01_01	RSE13_01	0.72	72.37	1.00	0.73	0.73	995	1.53	651	1.53	651	601	0.35	0.35
S05	S05_02	RSE14_01	2.66	265.71	0.98	0.60	0.60	2773	2.58	1076	2.58	1076	1800	0.80	0.80
S01	S01_02	RSE15_01	0.09	8.95	1.00	0.76	0.76	0	0.50	0	0.50	0	1500	0.42	0.42
S01	S01_01	RSE16_01	0.64	64.08	1.00	0.79	0.79	751	1.85	406	2.83	266	1706	0.59	0.55
S01	S01_01	RSE16_02	1.21	120.69	0.99	0.69	0.69	1008	2.78	363	2.78	363	2161	0.70	0.70
S01	S01_01	RSE17_01	1.54	154.23	0.99	0.75	0.75	1733	0.74	2336	1.13	1538	4000	1.76	1.54
S01	S01_01	RSE18_01	2.50	250.31	0.98	0.63	0.68	2157	0.91	2374	2.14	1008	2322	1.30	0.93
S01	S01_01	RSE18_02	2.94	293.50	0.98	0.56	0.65	4034	1.75	2309	1.75	2309	734	0.85	0.85
S01	S01_01	RSE19_01	5.40	540.12	0.96	0.53	0.56	4249	1.50	2842	1.50	2842	122	0.82	0.82
S01	S01_03	RSE20_01	0.55	54.95	1.00	0.64	0.64	1196	1.04	1152	1.04	1152	918	0.58	0.58



Source: Compiled data using raw data from pump stations offices

Figure D.6.1 Water Levels during 1999 Inundation at Pump Stations along Pasig River

Table D.6.3 Start and Stop Levels and Capacities of Pump Stations

North Manila / *South Manila*

Pump Station	Start level (EL. m)	Stop level (EL. m)	Capacity (m^3/s)	Pump Station	Start level (EL. m)	Stop level (EL. m)	Capacity (m^3/s)
Valencia	10.5	10.3	10.5	Tripa de Gallina	9.9	9.6	56.0
Aviles	10.5	10.3	14.1	Libertad	9.9	9.6	42.0
Quiapo	10.5	10.2	9.5	Balete	10.6	10.5	1.2
Escolta	10.0	9.8	1.5	Paco	10.5	10.2	7.6
Binondo	10.0	9.8	11.6	Pandacan	10.5	10.2	4.4
Vitas	10.1	9.8	32.0	San Andres	10.5	10.2	19.0
Balut	9.1	8.9	2.0	Sta. Clara	11.2	11.0	5.3
				Makati	11.3	10.9	7.0

Source: Investigated by this Study

Table D.6.4 Pump Capacity Curves

North Manila

Valencia		Aviles		Quiapo		Esclota		Binondo		Vitas		Balut	
dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)
3.86	8.26	3.62	10.92	2.92	7.56	4.09	1.05	3.39	8.12	3.74	22.40	4.21	1.40
3.48	9.44	3.27	12.48	2.64	8.64	3.70	1.20	3.06	9.28	3.38	25.60	3.80	1.60
2.89	10.62	2.72	14.04	2.19	9.72	3.07	1.35	2.54	10.44	2.80	28.80	3.16	1.80
2.15	11.80	2.02	15.60	1.63	10.80	2.28	1.50	1.89	11.60	2.08	32.00	2.34	2.00
1.24	12.98	1.17	17.16	0.94	11.88	1.32	1.65	1.09	12.76	1.20	35.20	1.36	2.20
0.05	14.16	0.05	18.72	0.04	12.96	0.06	1.80	0.05	13.92	0.05	38.40	0.06	2.40
-1.36	15.34	-1.28	20.28	-1.03	14.04	-1.44	1.95	-1.19	15.08	-1.32	41.60	-1.48	2.60

South Manila

Tripa		Libertad		Balete		Paco		Pandacan		San Andres		Sta.Clara		Makati	
dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)	dh (m)	Q (m^3/s)
3.74	39.90	3.27	29.40	4.09	2.10	3.27	5.32	3.62	3.08	22.20	3.01	4.09	3.71	4.21	4.90
3.38	45.60	2.96	33.60	3.70	2.40	2.96	6.08	3.27	3.52	20.06	3.44	3.70	4.24	3.80	5.60
2.80	51.30	2.45	37.80	3.07	2.70	2.45	6.84	2.72	3.96	16.65	3.87	3.07	4.77	3.16	6.30
2.08	57.00	1.82	42.00	2.28	3.00	1.82	7.60	2.02	4.40	12.35	4.30	2.28	5.30	2.34	7.00
1.20	62.70	1.05	46.20	1.32	3.30	1.05	8.36	1.17	4.84	7.15	4.73	1.32	5.83	1.36	7.70
0.05	68.40	0.04	50.40	0.06	3.60	0.04	9.12	0.05	5.28	0.30	5.16	0.06	6.36	0.06	8.40
-1.32	74.10	-1.15	54.60	-1.44	3.90	-1.15	9.88	-1.28	5.72	-7.82	5.59	-1.44	6.89	-1.48	9.10

Source : Calculated by this Study based on only available experimental data at Vitas pump station

D.7 SIMULATION RESULTS

The results of simulation for all the cases have been compiled using GIS in the form of inundation area by depth and duration as well as inundation maps. *Table D.7.1* and *Table D.7.2* show the simulated inundation areas by depth and duration for North and South Manila, respectively. Inundation maps for depth and duration are presented in *Figure D.7.1*. Except for Case C-1, all other simulation cases have been run with design rain, tide and water levels. Inundation depths have been calculated at junctions of esteros and drainage mains and on roads after careful checking of the ground elevations at calculation points and the inundation maps have been prepared based on the calculated depths and durations where durations are calculated as time for inundation depth of more than 20 cm.

(1) Model Calibration

After comparing simulated inundation maps for depth and duration (Case C-1) for both North and South Manila with the observed inundation maps, it can be said that the developed hydrodynamic model could replicate the 1999 inundation condition well, especially for severely inundated area. Therefore, the calibrated simulation model can be applied for planning purposes and various simulation cases have been run with the calibrated simulation model.

(2) Sensitivity Analyses

Sensitivity analyses have been carried out on three effects: tide effect, pump effect and channel improvement effect.

Effect of Tide: Since different catchments have different time of concentrations, it is unknown which combination of design rainfall and tide peak will cause the most severe inundation. In order to estimate the lag time (defined as the time difference between maximum tide and rainfall peak) that would produce most severe inundation, 4 cases (Case T-1 to T-4) have been simulated for South Manila. Since there is almost no possibility that the most severe inundation condition would occur during the ebb tide, therefore, all the cases on tide effect were carried out considering rainfall peak occurs before maximum tide. The cases are: Case T-1, T-2, T-3 and T-4 with lag time of 0-hr, 1-hr, 2-hr and 3-hr, respectively. Simulation results show that Case T-3 with 2-hr lag time is the most critical in terms of inundation. Therefore, all the simulation cases for North and South Manila under design rainfall and tide have been carried out with a 2-hr lag time.

Effect of Pump: Two cases for both North and South Manila (Case P-1 under existing condition and Case P-2 with dredged condition) have been simulated to see what could be the inundation condition of the Study area under 10-year rainfall without any pumping stations (no pumps and floodgates). Simulation results reveal that the study area would have been severely inundated if there were no pumps and floodgates, which simply justifies the necessity of pump drainage of the study area.

Effect of Channel Improvement: Three cases for North Manila (Case D-1 under existing condition and Cases D-2 and D-3 under dredged condition with and without channel improvements) and four cases for South Manila (Case D-1 under existing condition and Cases D-2 to D-4 under dredged condition with and without channel) and with Libertad pond improvements where Libertad pond has been set up with 1978 M/P dimension of 1700m x 100m) have been simulated. Simulation results show that dredging the channels along with recovering the original sizes of the channels would drastically improve the inundation condition of the study area. However, there will remain severe inundation at some locations that could be considerably improved with other improvement works as the simulation results suggest (Please refer to *Supporting Report E* for details of other improvement works.).

(3) Alternative Studies

Hydrodynamic simulation has been carried out for two alternative cases for both North and South Manila (Please refer to *Supporting Report E* for details of Alternative cases.). As for Alternative-2 (Case A-2) of South Manila, catchment RSE 19_01 has been replaced by direct runoff hydrograph after subtracting diverted discharge through the proposed Maricaban Diversion Channel. Simulation results show that inundation condition could be highly improved with the proposed alternative measures (Alternative A-1 for North Manila and Alternative A-2 for South manila) although there will be still remained local inundation problems of short duration at some locations.

(4) Scenario Simulations

Hydrodynamic simulation has been carried out under existing and proposed conditions for 2-yr, 3-yr, 5-yr, 10-yr, 20-yr and 30-yr return periods (Cases E-1 to E-6, F-1 to F-6, M-1 to M-6). The results clearly show severer inundation condition with increasing return period.

(5) Inundation Characteristics of the Study Area

From simulations results, inundation characteristics of the study area have been interpreted as shown in *Figure D.7.2*. It can be seen that the proposed drainage improvement works are highly effective in reducing inundation depth. *Figure D.7.2* also shows the trend in increase of inundation areas by return periods.

Longitudinal profiles of maximum water levels for 10-year return period at existing (Case E-4), after F/S implementation (Case F-4) and after M/P implementation (Case M-4) conditions along Blumentritt Interceptor in North Manila and Estero de Tripa de Gallina in South Manila are shown in *Figure D.7.3* and *D.7.4,* respectively. The figures provide an image of the effectiveness of the proposed implementations.

Table D.7.1 Simulated Inundated Areas by Depth and Duration for North Manila

Simualtion Case C-1				Simualtion Case P-1				Simualtion Case P-2			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	3,512,037	3 ~ 12	4,089,946	0.20 ~ 0.50	2,204,307	3 ~ 12	7,722,032	0.20 ~ 0.50	4,699,070	3 ~ 12	6,162,279
0.50 ~ 1.00	4,246,099	12 ~ 24	2,147,757	0.50 ~ 1.00	9,698,077	12 ~ 24	3,247,215	0.50 ~ 1.00	10,016,268	12 ~ 24	1,469,223
> 1.00	956,913	> 24	1,794,726	> 1.00	4,133,484	> 24	1,351,080	> 1.00	373,152	> 24	277,745

Simualtion Case D-1 (also E-4)				Simualtion Case D-2				Simualtion Case D-3			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	4,801,524	3 ~ 12	6,497,560	0.20 ~ 0.50	2,960,205	3 ~ 12	1,431,838	0.20 ~ 0.50	2,998,835	3 ~ 12	624,088
0.50 ~ 1.00	4,005,622	12 ~ 24	1,163,635	0.50 ~ 1.00	1,725,803	12 ~ 24	231,606	0.50 ~ 1.00	213,080	12 ~ 24	154,169
> 1.00	3,376,475	> 24	1,045,006	> 1.00	192,859	> 24	46,162	> 1.00	0	> 24	42,988

Simualtion Case A-1 (also Case M-4)				Simualtion Case A-2				Simualtion Case E-1			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	779,422	3 ~ 12	620,184	0.20 ~ 0.50	738,777	3 ~ 12	621,114	0.20 ~ 0.50	4,738,344	3 ~ 12	3,323,742
0.50 ~ 1.00	214,359	12 ~ 24	157,057	0.50 ~ 1.00	229,156	12 ~ 24	156,300	0.50 ~ 1.00	2,583,821	12 ~ 24	841,112
> 1.00	0	> 24	44,313	> 1.00	0	> 24	43,506	> 1.00	240,152	> 24	320,389

Simualtion Case E-2				Simualtion Case E-3				Simualtion Case E-5			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	3,628,203	3 ~ 12	4,103,623	0.20 ~ 0.50	3,445,158	3 ~ 12	5,196,811	0.20 ~ 0.50	4,230,931	3 ~ 12	7,542,879
0.50 ~ 1.00	3,983,560	12 ~ 24	881,518	0.50 ~ 1.00	4,320,904	12 ~ 24	935,036	0.50 ~ 1.00	5,340,335	12 ~ 24	1,626,476
> 1.00	602,003	> 24	599,662	> 1.00	1,601,298	> 24	841,110	> 1.00	4,504,025	> 24	1,181,686

Simualtion Case E-6				Simualtion Case M-1				Simualtion Case M-2			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	3,828,592	3 ~ 12	7,790,987	0.20 ~ 0.50	249,522	3 ~ 12	236,770	0.20 ~ 0.50	250,870	3 ~ 12	283,514
0.50 ~ 1.00	5,897,875	12 ~ 24	1,950,534	0.50 ~ 1.00	59,434	12 ~ 24	0	0.50 ~ 1.00	81,953	12 ~ 24	34,814
> 1.00	4,846,457	> 24	1,344,842	> 1.00	0	> 24	0	> 1.00	0	> 24	0

Simualtion Case M-3				Simualtion Case M-5				Simualtion Case M-6			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	195,750	3 ~ 12	383,907	0.20 ~ 0.50	4,442,278	3 ~ 12	776,622	0.20 ~ 0.50	5,528,173	3 ~ 12	761,372
0.50 ~ 1.00	154,522	12 ~ 24	64,937	0.50 ~ 1.00	476,176	12 ~ 24	287,686	0.50 ~ 1.00	723,052	12 ~ 24	326,918
> 1.00	0	> 24	0	> 1.00	0	> 24	174,053	> 1.00	1,618	> 24	185,540

Simualtion Case F-1				Simualtion Case F-2				Simualtion Case F-3			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	5,529,050	3 ~ 12	2,790,178	0.20 ~ 0.50	5,117,997	3 ~ 12	3,568,825	0.20 ~ 0.50	3,779,528	3 ~ 12	4,447,995
0.50 ~ 1.00	962,370	12 ~ 24	309,186	0.50 ~ 1.00	2,116,508	12 ~ 24	475,479	0.50 ~ 1.00	3,975,400	12 ~ 24	718,364
> 1.00	139,607	> 24	21,347	> 1.00	197,540	> 24	59,409	> 1.00	301,645	> 24	79,591

Simualtion Case F-4				Simualtion Case F-5				Simualtion Case F-6			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	2,998,556	3 ~ 12	5,146,495	0.20 ~ 0.50	5,231,014	3 ~ 12	6,305,825	0.20 ~ 0.50	4,605,031	3 ~ 12	6,983,767
0.50 ~ 1.00	5,279,923	12 ~ 24	1,042,199	0.50 ~ 1.00	4,934,429	12 ~ 24	1,478,159	0.50 ~ 1.00	5,447,369	12 ~ 24	1,662,562
> 1.00	607,552	> 24	194,913	> 1.00	2,032,075	> 24	331,285	> 1.00	3,007,744	> 24	471,205

Note: Inundation depth more than 20cm is considered to calculate "duration".

Table D.7.2 Simulated Inundated Areas by Depth and Duration for South Manila

Simualtion Case C-1				Simualtion Case P-1				Simualtion Case P-2			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	6,051,737	3 ~ 12	4,171,004	0.20 ~ 0.50	4,073,460	3 ~ 12	10,022,415	0.20 ~ 0.50	4,627,777	3 ~ 12	4,551,151
0.50 ~ 1.00	3,148,619	12 ~ 24	858,014	0.50 ~ 1.00	10,645,905	12 ~ 24	1,890,134	0.50 ~ 1.00	10,114,399	12 ~ 24	1,546,865
> 1.00	673,182	> 24	873,597	> 1.00	10,512,646	> 24	1,261,568	> 1.00	8,015,033	> 24	1,061,967
	9,873,538										

Simualtion Case D-1 (also E-4)				Simualtion Case D-2				Simualtion Case D-3			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	8,028,565	3 ~ 12	6,087,904	0.20 ~ 0.50	3,785,230	3 ~ 12	457,690	0.20 ~ 0.50	3,618,025	3 ~ 12	469,863
0.50 ~ 1.00	6,268,315	12 ~ 24	736,973	0.50 ~ 1.00	1,336,053	12 ~ 24	373,735	0.50 ~ 1.00	1,245,084	12 ~ 24	371,465
> 1.00	2,709,855	> 24	139,675	> 1.00	115,559	> 24	85,897	> 1.00	112,193	> 24	81,546

Simualtion Case D-4				Simualtion Case A-1				Simualtion Case A-2 (also M-4)			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	1,892,764	3 ~ 12	192,447	0.20 ~ 0.50	1,395,814	3 ~ 12	0	0.20 ~ 0.50	1,382,084	3 ~ 12	0
0.50 ~ 1.00	580,879	12 ~ 24	278,078	0.50 ~ 1.00	268,955	12 ~ 24	0	0.50 ~ 1.00	287,191	12 ~ 24	0
> 1.00	0	> 24	36,525	> 1.00	0	> 24	0	> 1.00	0	> 24	0

Simualtion Case E-1				Simualtion Case E-2				Simualtion Case E-3			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	3,072,332	3 ~ 12	2,156,673	0.20 ~ 0.50	5,055,976	3 ~ 12	3,205,467	0.20 ~ 0.50	5,857,633	3 ~ 12	4,462,822
0.50 ~ 1.00	2,141,335	12 ~ 24	381,874	0.50 ~ 1.00	2,561,683	12 ~ 24	402,318	0.50 ~ 1.00	4,207,708	12 ~ 24	430,142
> 1.00	338,605	> 24	89,190	> 1.00	538,501	> 24	108,040	> 1.00	976,305	> 24	128,806

Simualtion Case E-5				Simualtion Case E-6				Simualtion Case M-1			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	7,122,511	3 ~ 12	8,412,648	0.20 ~ 0.50	6,653,481	3 ~ 12	8,767,574	0.20 ~ 0.50	0	3 ~ 12	0
0.50 ~ 1.00	7,121,596	12 ~ 24	962,546	0.50 ~ 1.00	7,406,047	12 ~ 24	1,060,290	0.50 ~ 1.00	0	12 ~ 24	0
> 1.00	4,160,986	> 24	152,467	> 1.00	4,921,987	> 24	163,319	> 1.00	0	> 24	0

Simualtion Case M-2				Simualtion Case M-3				Simualtion Case M-5			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	9,155	3 ~ 12	0	0.20 ~ 0.50	887,679	3 ~ 12	0	0.20 ~ 0.50	2,630,437	3 ~ 12	208,852
0.50 ~ 1.00	0	12 ~ 24	0	0.50 ~ 1.00	0	12 ~ 24	0	0.50 ~ 1.00	717,047	12 ~ 24	295,002
> 1.00	0	> 24	0	> 1.00	0	> 24	0	> 1.00	28,499	> 24	0

Simualtion Case M-6				Simualtion Case F-1				Simualtion Case F-2			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	3,745,025	3 ~ 12	312,301	0.20 ~ 0.50	2,049,277	3 ~ 12	827,643	0.20 ~ 0.50	3,468,369	3 ~ 12	1,668,327
0.50 ~ 1.00	1,104,562	12 ~ 24	408,702	0.50 ~ 1.00	735,474	12 ~ 24	383,739	0.50 ~ 1.00	949,495	12 ~ 24	384,288
> 1.00	104,893	> 24	55,698	> 1.00	205,445	> 24	99,541	> 1.00	342,162	> 24	106,994

Simualtion Case F-3				Simualtion Case F-4				Simualtion Case F-5			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)	Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	5,588,840	3 ~ 12	2,276,792	0.20 ~ 0.50	9,465,503	3 ~ 12	3,059,636	0.20 ~ 0.50	8,729,698	3 ~ 12	4,347,222
0.50 ~ 1.00	1,611,457	12 ~ 24	391,469	0.50 ~ 1.00	4,478,601	12 ~ 24	592,033	0.50 ~ 1.00	7,221,875	12 ~ 24	725,658
> 1.00	499,534	> 24	124,243	> 1.00	721,830	> 24	141,066	> 1.00	1,384,225	> 24	153,488

Simualtion Case F-6			
Depth (m)	Area (m^2)	Duration (hr)	Area (m^2)
0.20 ~ 0.50	7,920,545	3 ~ 12	4,902,800
0.50 ~ 1.00	8,115,957	12 ~ 24	787,261
> 1.00	1,990,670	> 24	163,633

Note: Inundation depth more than 20cm is considered to calculate "duration".

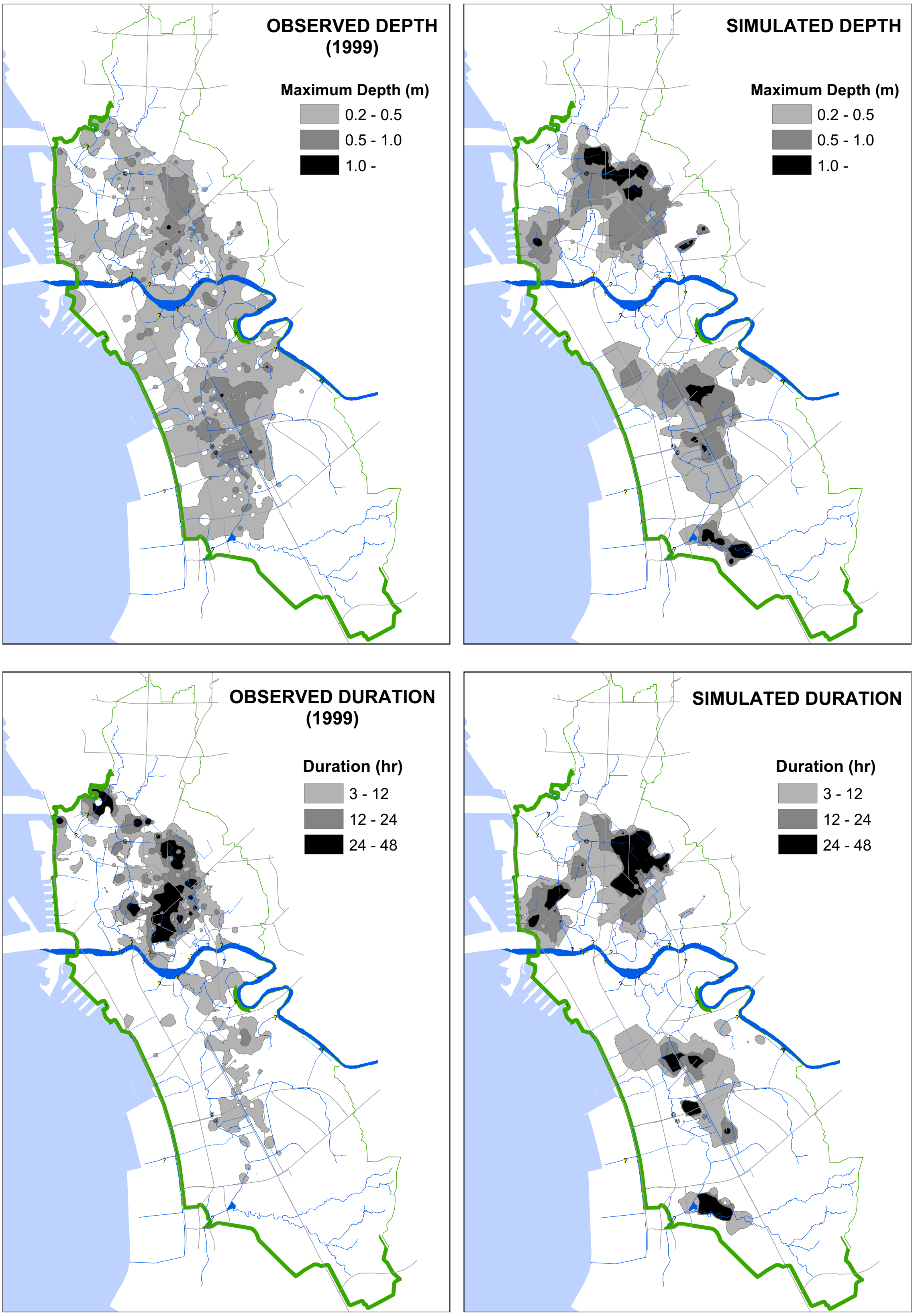


Figure D.7.1 Inundation Map of Depths and Durations for Different Cases (1/7)

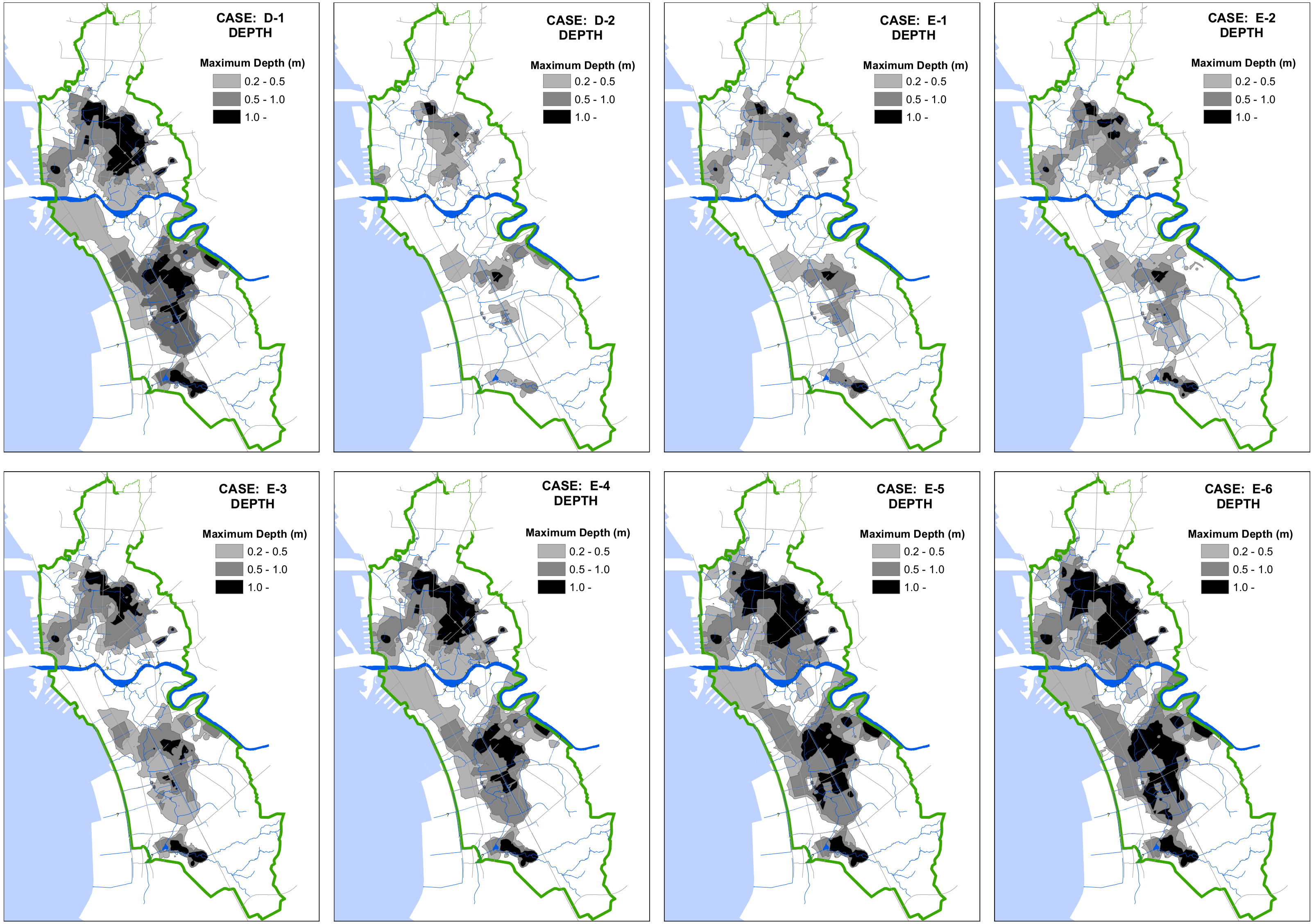


Figure D.7.1 Inundation Map of Depths and Durations for Different Cases (2/7)