2 EXISTING CONDITIONS

2.1 Natural and Physical Conditions

The Philippine Archipelago comprises of approximately 7,100 islands which border the Pacific Ocean to the east and the South China Sea to the west. The country is divided into three island groups namely Luzon, Visayas and Mindanao. They are further subdivided into 17 regions (see **Figure 2.1.1**) with a total of 1,631 cities and municipalities. The Manila Bay basin covers three regions in Luzon i.e. Region III (Central Luzon), Region IV (Southern Tagalog) and the National Capital Region (NCR).

Figure 2.1.1: Regional map of the Philippines

2.1.1 Physical Characteristics

The greater Survey Area comprises the entire watershed of the two main bodies of water in southern Luzon, namely the Manila Bay and the Laguna de Bay (or Laguna Lake). This area extends as far north as the boundary of the Sierra Madre-Caraballo Mountains in the province of Nueva Ecija, and as far south as the volcanic terrain in the provinces of Cavite and Laguna. This combined watershed covers the Provinces of Pampanga, Bulacan, Tarlac, Rizal and NCR. **Figure 2.1.2** shows the location of the greater Survey Area in relation to the combined watersheds of the Manila Bay and Laguna de Bay.

(a) Topography

There are four geomorphic features characterize the topography of the region around the Manila Bay and Laguna de Bay, namely the Zambales Mountain Range, the Central Valley Basin, the Macolod Corridor, and the southern extension of the Sierra Madre Mountain Range (see **Figure 2.1.3**).

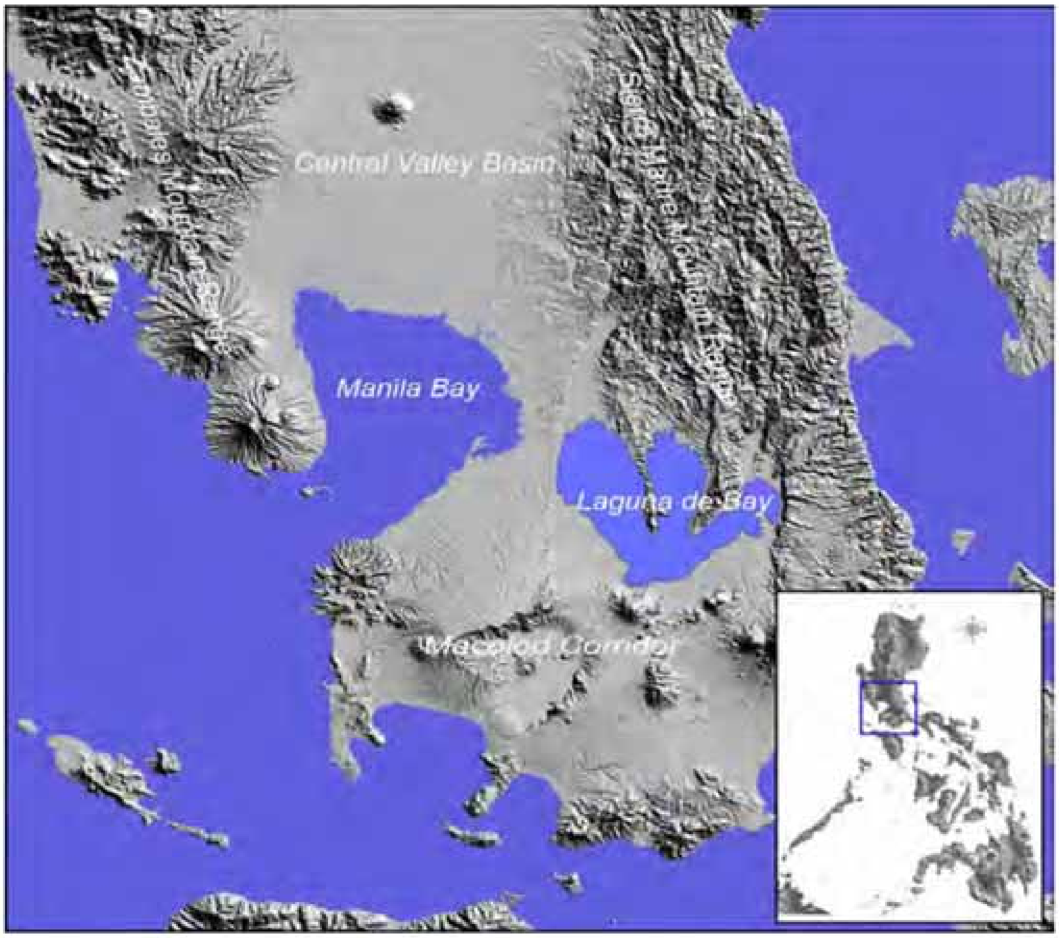


Figure 2.1.3: Geomorphic features surrounding the Manila Bay and Laguna de Bay

The Zambales Mountain Range (also known as the West Luzon Volcanic Arc) is a north-northwest trending string of active and inactive volcanic centers that serve as the western boundary of the Central Valley Basin. It includes Mt. Natib, Mt. Mariveles and Mt. Pinatubo. Its protrusion into the Manila Bay is known as the Bataan Peninsula.

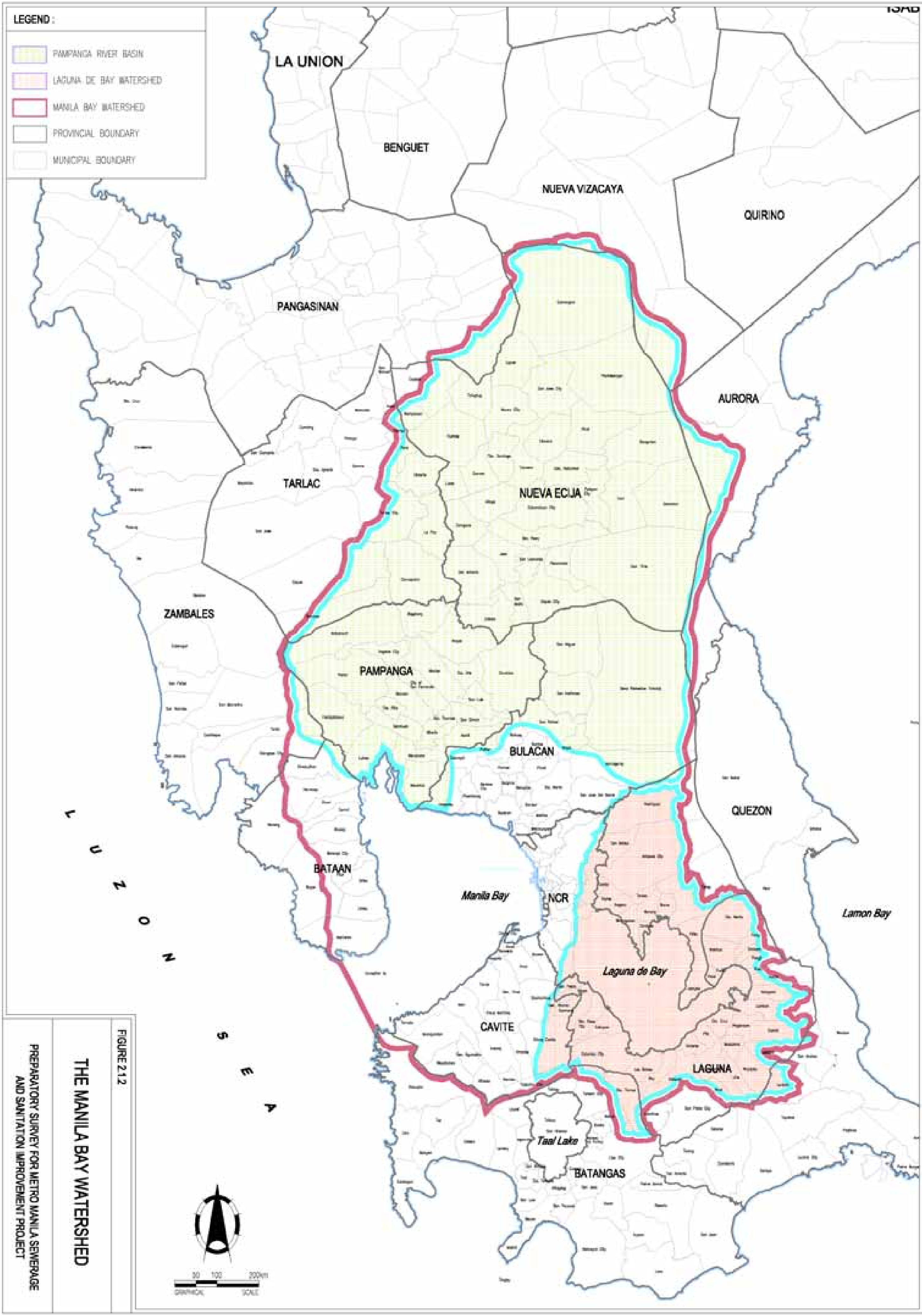


FIGURE 2.1.2

THE MANILA BAY WATERSHED

PREPARATORY SURVEY FOR METRO MANILA SEWERAGE AND SANITATION IMPROVEMENT PROJECT

The Central Valley Basin is a large flat-lying area in between the Zambales and Sierra Madre Mountain Ranges and which opens to the Manila Bay to the south. This fertile land is also known as the rice bowl of the Philippines because of the extent of rice farming in the valley covering the Provinces of Bulacan, Pampanga and Nueva Ecija. The main river that drains the Central Valley Basin is the Pampanga River, which originates from north of the Manila Bay watershed and exits into the Manila Bay as a complex system of meandering streams through the Pampanga wetlands. The delta consists mainly of the delta plain, the low alluvial terraces and the low-lying area of the Candaba Swamp.

The southern Sierra Madre Mountain Range borders the entire eastern coast of Luzon. It is characterized by rugged ridges along its main spine with peaks exceeding 600 m above sea level. Rolling hills and low-lying areas are found on its western side, which drain towards the Central Valley Basin by a series of rivers including the Angat River and the Bulacan River. A big portion of southern Sierra Madre also terminates into the Laguna de Bay and therefore a sizeable area of the mountain range also drains directly into the lake. Another structural feature, the eastern and western Marikina Valley Faults, originate in southern Sierra Madre and bind the western lobe of Laguna de Bay. The west Marikina Fault extends as far as Taal Lake in the Macolod Corridor. The low-lying Marikina valley in between the faults is drained by the Marikina River, which connects to the Manila Bay via the Pasig River and to Laguna Lake via the Manggahan Floodway.

West of the Marikina Valley Faults and north of the Pasig River is a flat but slightly elevated (30-40 meters above sea level) area, collectively known as the Diliman Plateau. This area also drains towards the Manila Bay through several rivers including the Tullahan-Tenejeros River in Valenzuela and the Marilao-Meycauayan-Obando (MMO) Rivers in Bulacan. South of the Pasig River is an extension of the coastal plains towards Paranaque City and the Province of Cavite. It is drained by several rivers including the Imus River, Julian River and the Ilang-ilang River.

The Macolod Corridor serves as the southern boundary of the Manila Bay watershed. It is a network of active and inactive volcanic centers including the Maragondon Mountains to the west, Taal Lake, Mt. Makiling and Mt. Banahaw.

(b) Water Bodies and Drainage System

Manila Bay

At its narrowest point, the Manila Bay connects to the South China Sea via a 16.7 km wide opening. The Bay gently slopes outwards at a rate of about 1m/km. Its area is approximately 1,800 km^2 with a shoreline length of about 200 km and a mean depth of 17 m (volume of 31 km^3). The Manila Bay has a total drainage area of about 17,000 km^2 distributed through 26 catchment areas, the largest of which is the Pampanga River Basin. The total freshwater inflow is estimated to be at 25 km^3/yr. Water circulation in the Manila Bay is primarily controlled by prevailing winds (northeasterly or southeasterly trade winds). This has huge implications on water movement, residence time and the flushing of poor quality waters coming from various point sources along its coast. It is judged that the water stagnates within the Bay for quite long time.

The Manila Bay has various natural habitats including a rapidly declining mangrove cover (7.94 km^2). Sea grass beds and coral reefs are found at the entrance of the Bay while the rest of the Bay consists of mudflats, sand beaches and rocky shore habitats[5]. The Manila Bay and its environs are confronted by a wide range of environmental problems that need to be addressed, e.g. land-based and sea-based sources of pollution, harmful algal blooms, subsidence and groundwater extraction, over exploitation of fishery resources, dense captured fisheries operations and habitat

[5] Partnerships in Environmental Management for Seas of East Asia (PEMSEA), 2004.

conversion and degradation.

Photo 2.1.1: Aerial view of the Manila Bay at Corregidor Island

Photo 2.1.2: Aerial view of the Manila Bay at Metro Manila

Laguna de Bay

The Laguna de Bay or Laguna Lake is the largest lake in the Philippines and the second largest body of water in Southeast Asia[6]. It is a trilobate lake that is only 2 m above sea level and covers approximately 900 km^2. The lake has a mean depth of 2.5-3.0 m and a maximum depth of 6.5 m, although this varies greatly between wet and dry seasons. The lake has a watershed area of 3,820 km^2 with a total of twenty one tributaries draining into the lake. The Pagsanjan-Lumban River and the Sta. Cruz River in the eastern lobe contribute approximately 50% of the total freshwater input into the lake. Various species of macrophytes inhabit the lake particularly in its southeastern shores. Twenty-three endemic fish species are found inhabiting the lake.

Photo 2.1.3: Panoramic view of the Laguna de Bay

Photo 2.1.4: Aerial view of the Laguna de Bay

Table 2.1.1 presents the approximate lengths of longest watercourse of the major streams draining into Laguna Lake while **Figure 2.1.4** shows the approximate boundary delineation of sub-watershed.

[6] Philippine Council for Aquatic and Marine Research and Development (PCAMRD) Zonal Center.

Table 2.1.1 : List of rivers draining into the Laguna de Bay

River system	Approximate length (km)	Location
1. Tanay River	18.1	Central Bay
2. Pililia River	19.0	Central Bay
3. Sapang Baho River	18.5	Central Bay
4. San Cristobal/Diezmo River	50.0	South Bay
5. San Juan River	33.0	South Bay
6. Bay River	32.0	South Bay
7. Morong River	17.5	South Bay
8. Siniloan River	28.5	East Bay
9. Sta. Cruz River	19.5	East Bay
10. Pagsanjan River	65.9	East Bay
11. San Pedro River	33.0	West Bay
12. Biñan River	19.7	West Bay
13. Tunasan River	8.5	West Bay
14. Mapandan (Marikina-Wawa) River	35.1	West Bay
15. Bagumbayan River	1.0	West Bay
16. Cabuyao River	19.5	West Bay
17. Sta. Rosa River	27.0	West Bay
18. Mangangate River	5.1	West Bay
19. Alabang/Muntinlupa River	4.5	West Bay
20. Sucat River	1.0	West Bay
21. Napindan River	6.0	West Bay

Source: RWSIP, 2008

Two flood control structures have been constructed to control flooding and the Pasig River backflow. These structures also affect the quality of the water in the Laguna de Bay. The first of these is the Napindan Hydraulic Control Structure (NHCS) that situated at the Napindan Channel just upstream of its confluence with the Marikina River. Its main functions are to restrict polluted saline water from entering the lake when the Pasig River reverses its flow and to protect Manila from flooding due to overbanking of the Pasig River. The second structure, the Manggahan Floodway **(Photo 2.1.5)** that links the Marikina River to the Laguna de Bay, is being used for diverting excess Marikina floodwaters into the lake to reduce the chances of overbanking of the Pasig River in Metro Manila.


Photo 2.1.5: Manggahan Floodway

In dry season, the functional minimum water level of the lake is about 10.5 m which is the mean sea level (msl). When the water level falls below the msl or below the high tide level of the Manila Bay, seawater intrusion through the Pasig River, the lake's lone outlet, causes an increase in lake water salinity[7]. This saline intrusion contributes to a temporary lake clearing due to its flocculating effect. This tidal forcing also has a huge impact in the lake hydrodynamics.

[7] Francisco, 1985

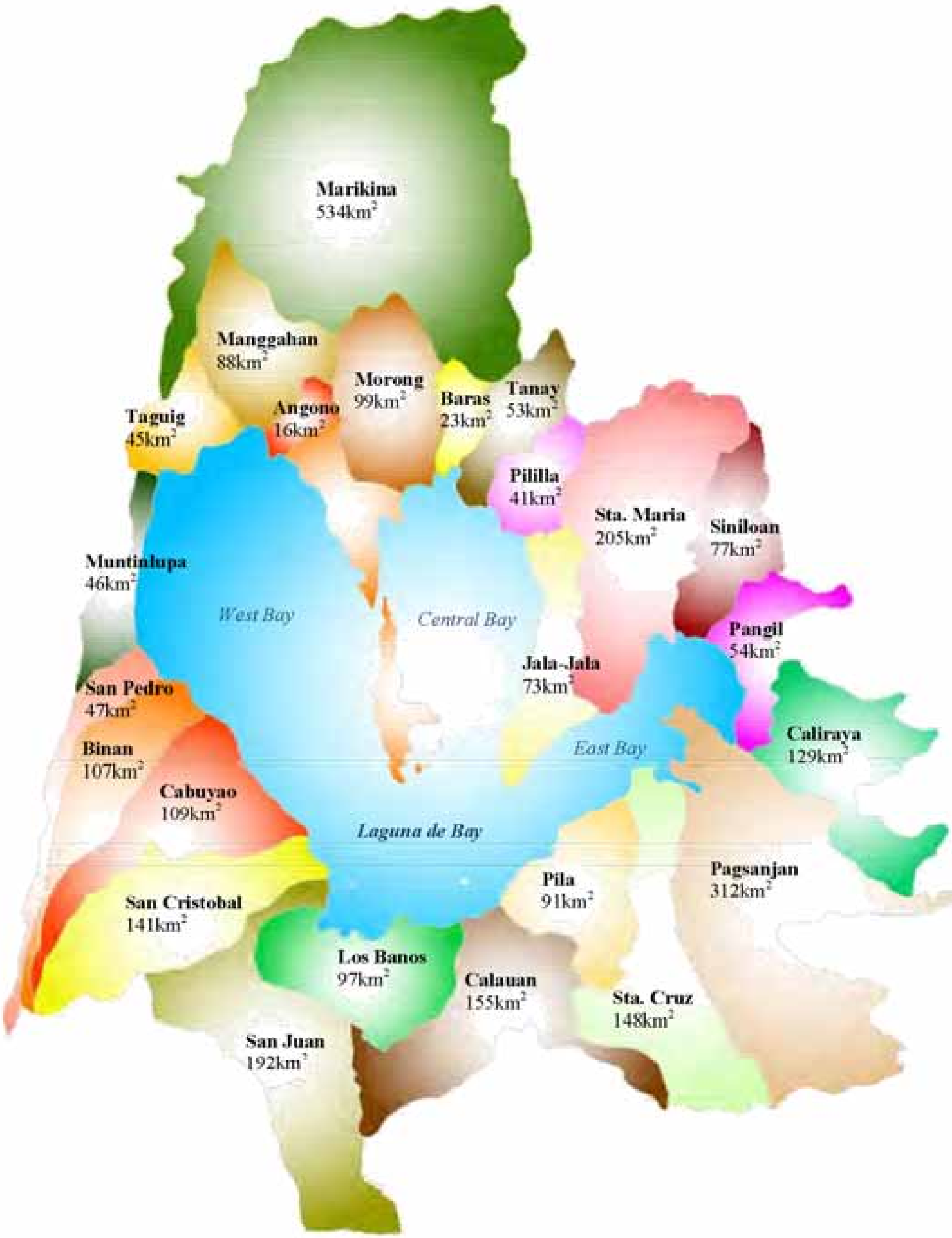


Figure 2.1.4: Sub-catchments of the Laguna de Bay

Pampanga River

The Pampanga River is the third largest river in the Philippines with a course length of about 260 kilometers and an approximate aggregate basin area of approximately 10,540 km^2 (including the allied basin of the Guagua River) (see **Figure 2.1.5**).

Photo 2.1.6: Pampanga River System (aerial view from the central valley basin)

Located in the Central Luzon region, its headwaters originates from the western slopes of the Sierra Madre Mountains and runs a south and southwesterly course traversing the provinces of Quezon, Nueva Ecija, Tarlac, Pampanga, and Bulacan. The river has a relatively low-gradient channel particularly at the middle and lower sections. At the lower sections of the Pampanga River Basin, where the Pampanga delta lies, the Pampanga River system divide into relatively small branches, crisscrossed with fishponds to form a network of sluggish, tidal flats and canals, which eventually find their way to the Manila Bay.

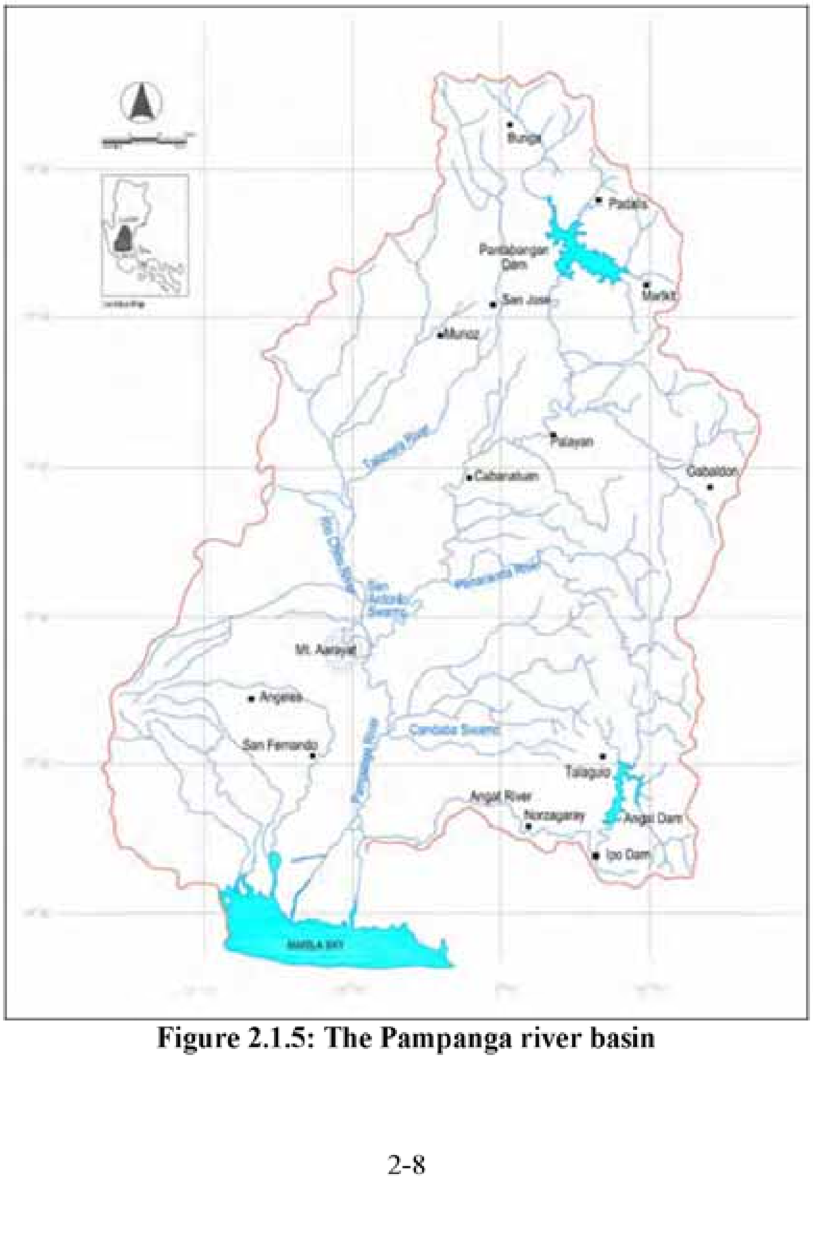


Figure 2.1.5: The Pampanga river basin

The major waterway that drains the northern east portion of the MWSS service area is the **Marikina River**. It winds generally south-westward for some 50.57 km from its headwaters in Antipolo City and Rodriguez cutting through the Marikina Valley and eventually to its confluence with the Pasig River and the Napindan Channel. The river starts out from the waters of Tayabasan and Boso-Boso Creeks in Antipolo City to the southeast, while to the north are the rivers of Tanog, Puroy, and Montalban. Four major lowland tributaries feeds the Marikina river with additional flows, these are the Burgos River, Ampid River, and the Nangka River in the east bank and the Payatas Creek coming from the west bank.

The 27 km **Pasig River** is considered as an estuarine river that serves as the sole connecting waterway of the Laguna de Bay and the Manila Bay (via the Napindan Channel). It has around 47 tributaries including the Marikina River, San Juan River, Pateros-Taguig River and the numerous *esteros* (canals) that serve as flood and sewerage canals for Metro Manila.

The **San Juan River**, which connects to the Pasig River at the boundary of the cities of San Juan and Manila, drains most of the built-up areas of Quezon City among others. According to the historical water quality monitoring results, the river is found to be the most polluted river amongst the Pasig River tributaries.

Northwest of the MWSS service area is the **Malabon-Navotas-Tullahan-Tenejeros** (MNTT) River system. Its headwater starts from the northern portions of Quezon City running southwestward draining the densely built-up and industrialized areas of Caloocan, Valenzuela, Malabon, and Navotas before finally discharging into the Manila Bay.

South of the service area are the Paranaque, Zapote, Imus and Tunasan Rivers, the first four of which discharge into the Manila Bay and the last into the Laguna de Bay. **Figure 2.1.6** shows the alignments of the abovementioned rivers.

2.1.2 Meteorology

The Philippines has four (4) climatic settings, of which, the Survey Area belongs to Type I and partly to Type III according to the revised Corona Classification (see **Figure 2.1.7**).

Type I climate has two pronounced seasons; dry from November to April and wet during the rest of the year. Type III climate has seasons that are not very pronounced; relatively dry from November to April and wet during the rest of the year. This climate type covers the western slopes of the Sierra Madre Mountain Range including the low-lying hills that transition to the Central Valley Basin.

These climate patterns are in part controlled by the prevailing monsoon winds. From June to August, the southwest monsoon, combined with the South Pacific trade winds, bring heavy precipitation augmented by the typhoon season which normally spans from May to October. The northeast monsoon (September to May) causes heavy rainfall only on the eastern coast of Luzon Island which may partially affect even the western side of the Sierra Madre. The dry period in the Survey Area extends from December to April.

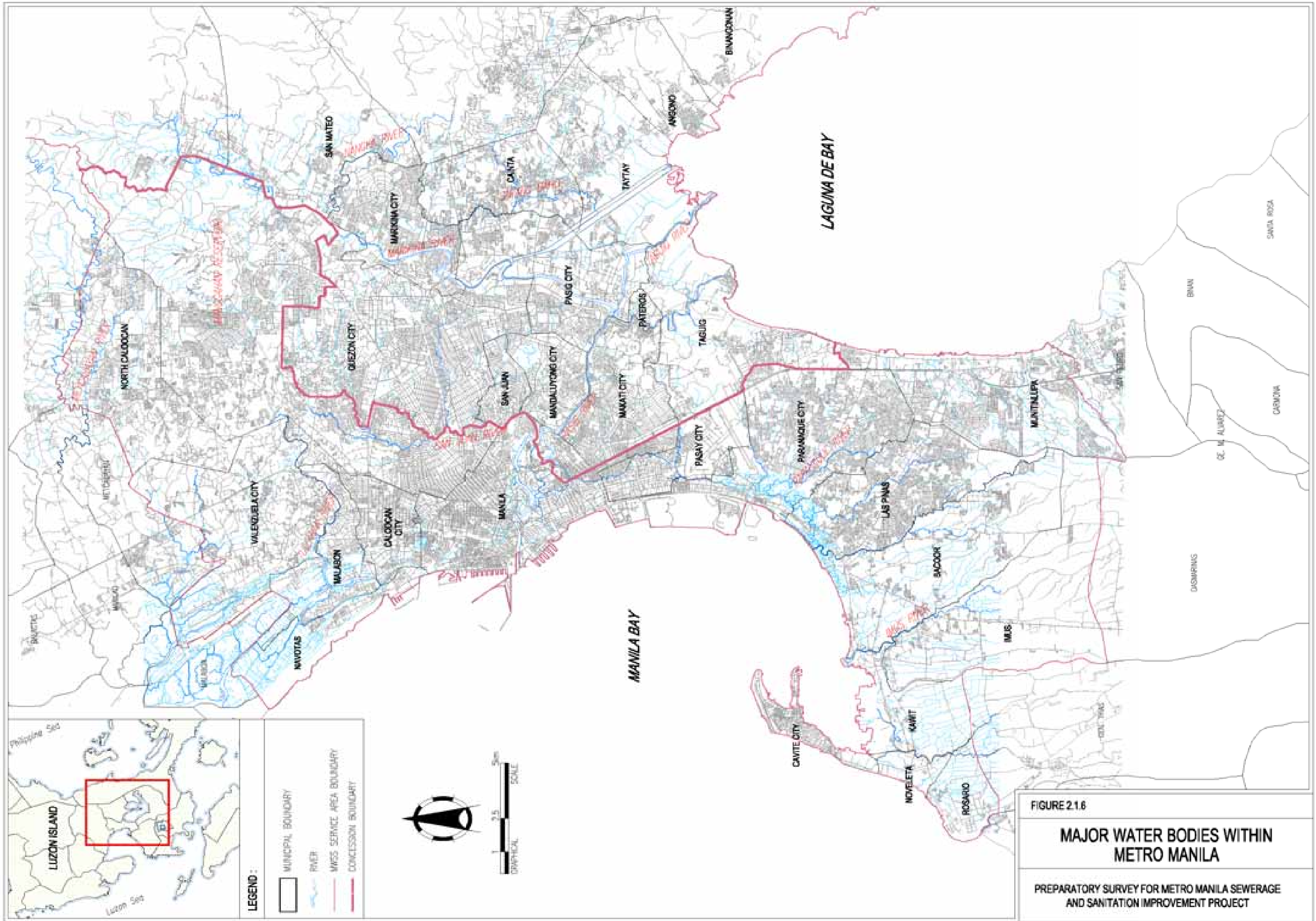


FIGURE 2.1.6

MAJOR WATER BODIES WITHIN METRO MANILA

PREPARATORY SURVEY FOR METRO MANILA SEWERAGE AND SANITATION IMPROVEMENT PROJECT

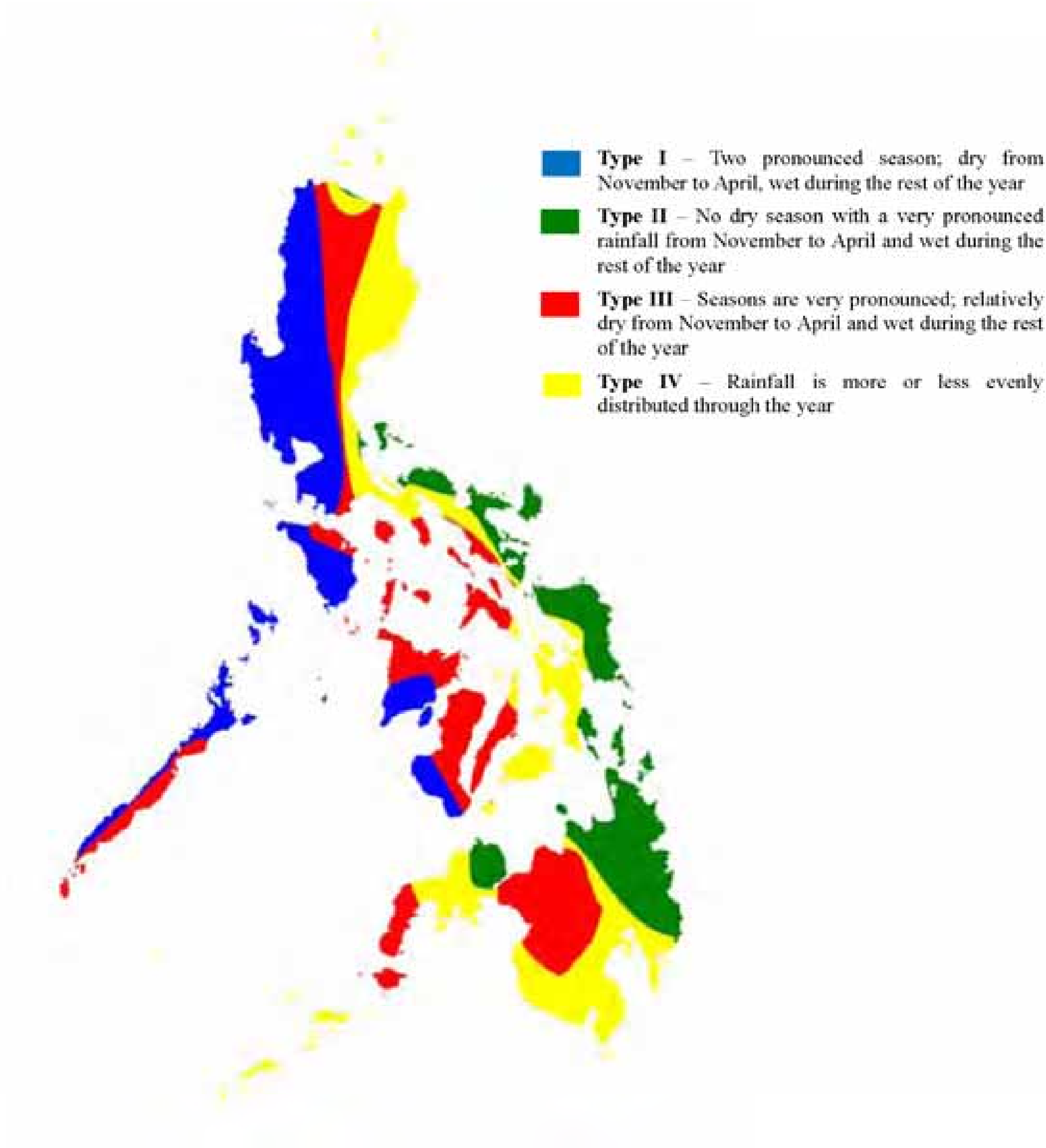


Figure 2.1.7: Revised Corona climate classification

In Metro Manila the annual average rainfall is about 2,160 mm, with an average number of rainy days of 133 per year. In Central Valley Basin, the average precipitation ranges from 1,800 to 2,300 mm/year. About 75% of the annual precipitation occurs during June to October, while during the dry months of December to April only about 10% of the annual precipitation occurs. The remaining 15 percent occurs between the two transition months of May and November.

The overall monthly temperature is about 27.7ºC. Warmest days occur during the summer months of April and May with an average high temperature of 29.6ºC while the coolest month is January with low average temperature of 25.9ºC.

2.1.3 MWSS Drainage Basins

Under the MWSS Master Plan (2005), the service area was divided into nine (9) major drainage basins to aide in planning as well as pollution load assessment i.e. Meycauayan, Tullahan, North Manila, San Juan, Marikina/Antipolo, South Manila, Taguig, Paranaque and Pasong Diablo/Magdaong/Sucat (see **Figure 2.1.8**).

The Meycauayan catchment is drained by the Meycauayan River, which joins the Marilao River to the north and exits towards the Manila Bay through the Obando River. The Tullahan catchment is at the south of Meycauayan and is primarily drained by the Tullahan River. The North Manila and San Juan catchments connect to the Pasig River via the San Juan River and a network of *esteros*. The Marikina-Antipolo catchment likewise drains into the Pasig River, however, the Manggahan Floodway permits water from the Marikina River to flow to the Laguna de Bay during wet season. South Manila and Taguig form the southern catchment boundary of the Pasig River. Lastly, the Pasong Diablo-Magdaong-Sucat catchment composes of small streams directly draining into the Manila Bay or connects to the tributaries in South Manila.

These Basins were further subdivided into 31 sewerage sub-catchments as shown in **Table 2.1.2**.

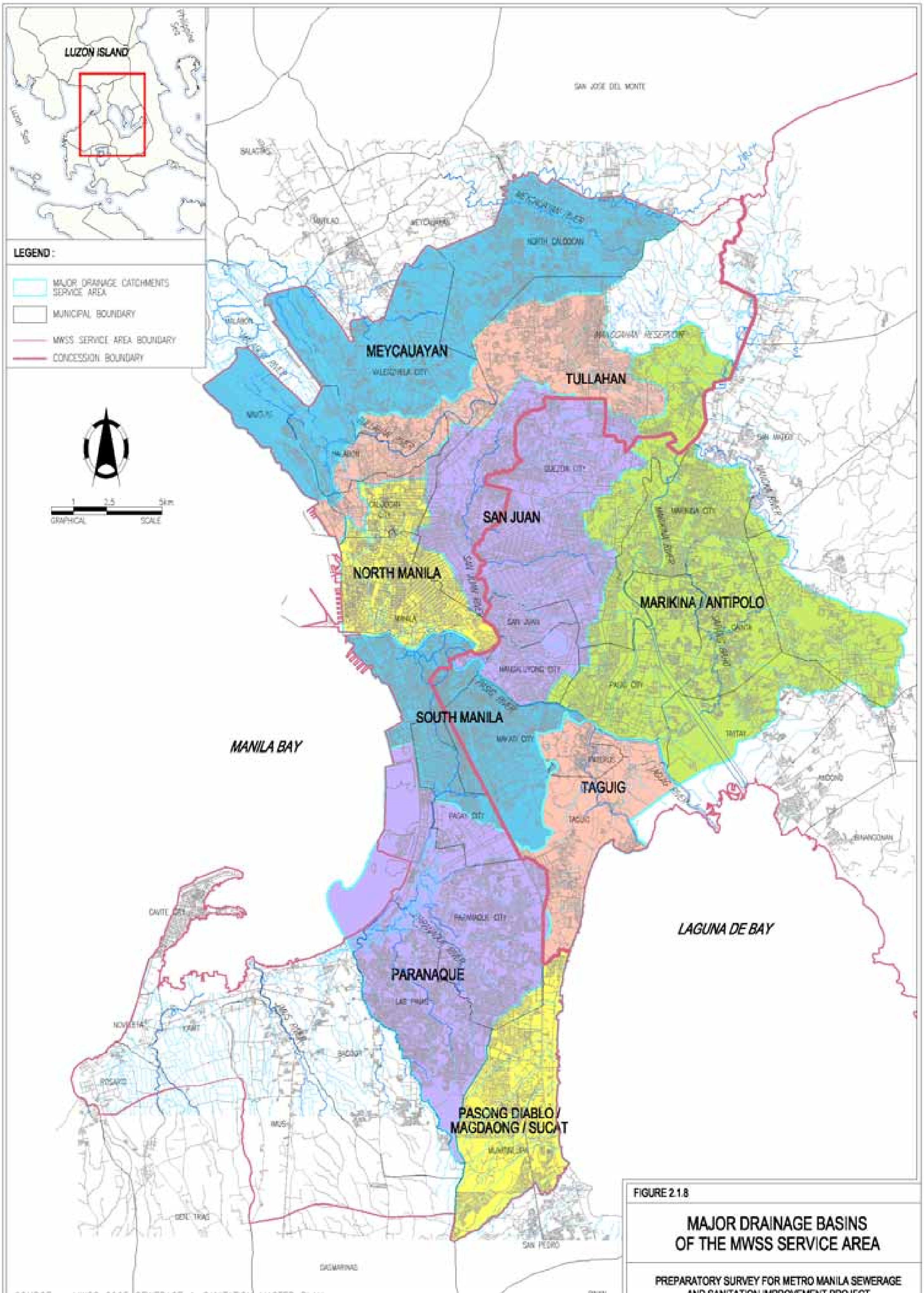


FIGURE 2.1.8

MAJOR DRAINAGE BASINS OF THE MWSS SERVICE AREA

PREPARATORY SURVEY FOR METRO MANILA SEWERAGE AND SANITATION IMPROVEMENT PROJECT

Table 2.1.2: The nine major drainage basins of MWSS service area

Drainage Basin / Sewerage sub-catchment		Area (km^2)	City/Municipality	Major rivers	Concessi-onaire
1	**Pasong Diablo/Magdaong/ Sucat**	**39.5**	Muntinlupa	Zapote River	MWSI
1.1	Muntinlupa (W-1)	39.5			
2	**Paranaque Basin**	**92.4**	Las Pinas, Paranaque, Pasay	Paranaque River, Canutes River	MWSI
2.1	Las Pinas (W-2)	39.3			
2.2	Paranaque (W-3)	36.5			
2.3	Pasay-NAIA (W-4)	16.6			
3	**South Manila Basin**	**47**	Pasay, Makati, Manila	Pasig River	MWSI / MWCI
3.1	South Manila (W-5)	11.7			
3.2	Pandacan (W-6)	5.0			
3.3	Central Manila (W-7)	7.1			
3.4	Part of Makati (E-2)	23.2			
4	**North Manila Basin**	**32.3**	Manila, Quezon City, Caloocan	Pasig River	MWSI
41	Central North (W-8)	17.2			
4.2	Sampaloc (W-9)	6.5			
4.3	Balut (W-10)	1.4			
4.4	Caloocan A (W-12)	7.2			
5	**Tullahan Basin**	**50.3**	Caloocan, Navotas, Malabon, Valenzuela, Quezon City	Malabon-Navotas-Tullajan-Tenejeros River System	MWSI
5.1	Dagat-Dagatan (W-11)	5.2			
5.2	Malabon-Tullahan (W-13)	9.9			
5.3	QC-Novaliches (W-14)	20.3			
5.4	Malabon (W-19)	14.9			
6	**Meycauyan Basin**	**100.5**	Caloocan, Navotas, Malabon, Valenzuela, Quezon City	Meycauayan River, Veinte Reales River, Polo River, Obando River	MWSI
6.1	Navotas (W16)	31.3			
6.2	Valenzuela (W-17)	28.4			
6.3	Caloocan B (W-18)	40.8			
7	**San Juan Basin**	**90.2**	Quezon City, San Juan, Mandalauyong, Manila	San Juan River, Pasig River	MWSI / MWCI
7.1	Quezon Central (EW-1)	15.0			
7.2	Quezon North (EW-2)	33.3			
7.3	Quezon West (W-15)	10.8			
7.4	Mandaluyong-San Juan (E-6)	10.4			
7.5	Quezon South (E-8)	20.7			
8	**Marikina-Antipolo Basin**	**143.8**	Quezon City, Marikina, Antipolo, Pasig, Cainta, Taytay	Marikina River, Napindan Channel, Manggahan Floodway	MWSI & MWCI
8.1	Quezon East (EW-3)	24.3			
8.2	Pasig (E-5)	32.9			
8.3	Taytay (E-7)	28.4			
9	**Taguig Basin**	**36.19**	Taguig, Pateros, Makati	Taguig River, Tipas-Ibayo River	MWCI
9.1	Taguig (E-1)	18.8			
9.2	Pateros (E-3)	14.95			
9.3	Bonifacio (E-4)	2.49			

2.1.4 Water Quality

The DENR Administrative Order (DAO) No. 1990-34 classifies surface water in the Philippines according to its intended use. Each classification has a set water quality criteria for various parameters from which monitoring data can be compared to. As of 2005, 525 lakes, rivers and coastal areas have been classified, representing 62.5% of the inventoried bodies of water in the country. **Table 2.1.3** summarizes the DAO 90-34 classification (see **Annex 10**). The Revised Effluent Regulations and the Drinking Water Standard are attached under **Annex 11** and **Annex 12**.

Table 2.1.3: DENR DAO 90-34 classification of surface waters

Classification	Intended use	Selected water quality criteria*		
		BOD (mg/l)	DO (mg/l)	Total coliform (MPN/100ml)
Freshwater				
Class AA	Waters intended as sources of public water supply requiring only disinfection to meet the PNSDW[8]	1	5	50
Class A	Waters suitable as public water supply requiring conventional treatment to meet the PNSDW	5	5	1,000
Class B	Waters intended for primary contact recreation	5	5	1,000
Class C	Waters for fishery, recreation/boating and supply for manufacturing processes after treatment	7	5	5,000
Class D	Waters intended for agriculture, irrigation, livestock, etc.	10	3	-
Coastal/Marine				
Class SA	Waters suitable for fishery production, tourism, marine parks, and reserves.	3	5	70
Class SB	Waters intended for recreation such as bathing, swimming, etc. and as spawning areas for Bangus and similar species	5	5	1,000
Class SC	Waters intended for recreation/boating, fishery and as mangrove areas for fish and wildlife sanctuary	7	5	5,000
Class SD	Waters used for industrial purposes such as cooling	-	2	-

**Yearly average*

(a) Manila Bay and Tributaries

At present, pollution loads from domestic, commercial, industrial and also agricultural sources significantly affect the water quality of the Manila Bay with domestic wastewater discharge being the highest contributor to the Bay's organic pollution[9]. The eastern shore of the Bay adjacent to Metro Manila shows the most significant signs of water quality degradation, more particularly within the vicinity of mouths of rivers and outfalls of major storm drains. However, water quality improves significantly in relation to the distance between the sampling and identified major discharge points.

[8] The Philippine National Standard for Drinking Water
[9] Philippines Environment Monitor, 2003.

The water quality of the Bay is being monitored under the Manila Bay Improvement Project under the Environmental Management Bureau (EMB) of DENR. Two of the critical parameters being monitored by EMB are BOD (to represent the amount of organic wastes introduced to the Bay) and Coliform (indicative of the relative safeness of the Bay for primary contact recreation activities considering that under the Supreme Court Decision 2008 it is targeted to improve the water quality of the Manila Bay to Class SB marine waters).

The results of total coliform counts from 1996 to 2004 in selected beach areas along the coast of the Bay are presented in **Figure 2.1.9**. The monitoring data indicate that all monitoring stations except Lido Beach exceeded the prescribed 1,000 MPN/100ml criteria for Class SB water quality. At present however, bathing in the Manila Bay more particularly along the Luneta Park station and the stretch of Roxas Blvd in the City of Manila is strictly prohibited by the local government unit due to obvious threat to public health. **Figure 2.1.10** presents the BOD monitoring results of three monitoring stations along the Manila Bay (limit for BOD is 5 mg/l for Class SB waters).

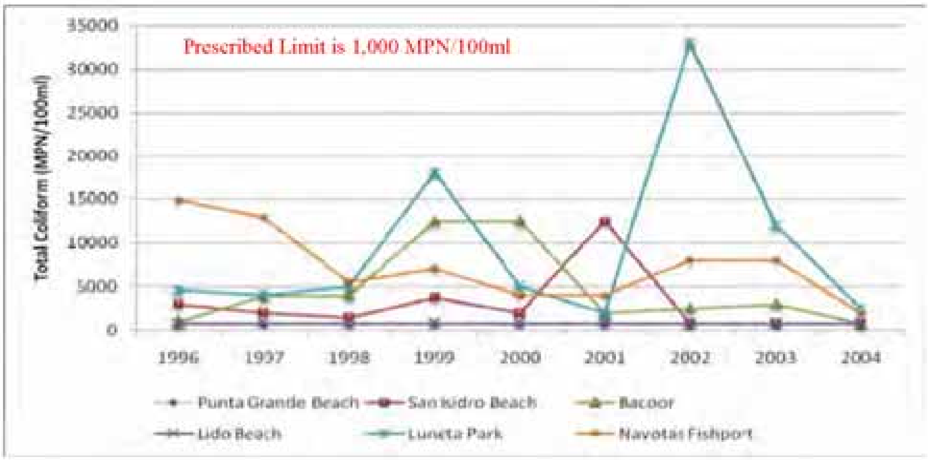


Figure 2.1.9: Total coliform count of bathing beaches in the Manila Bay, 1996-2004
(Source: DENR-EMB)

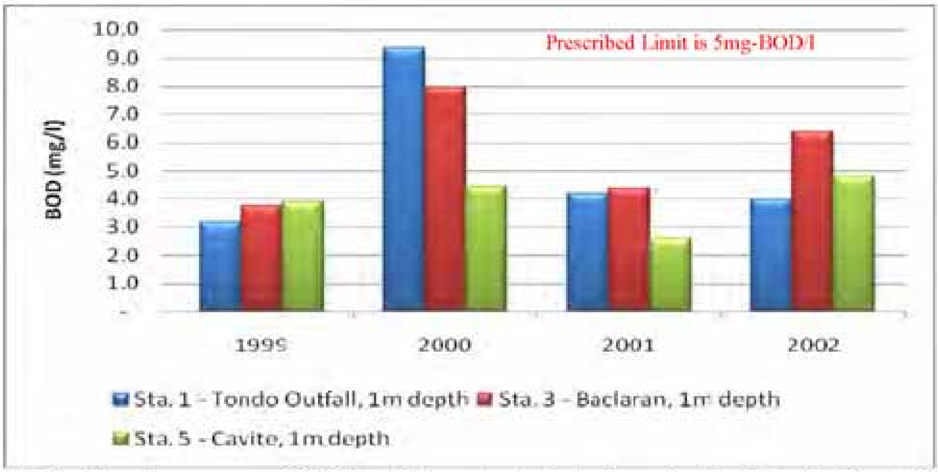


Figure 2.1.10: Yearly average BOD levels in selected stations in the Manila Bay, 1999-2002
(Source: DENR-EMB)

The Manila Bay Refined Risk Assessment Report (2004) identified four river systems as major contributors of nutrients (N and P) and organic waste (which affect biochemical oxygen demand and dissolved oxygen). The mean concentrations from the Cavite and Pampanga River systems are below the set critical values for N and P (maximum environmental concentration of 10 and 0.4

mg/l for N and P respectively). The mean environmental concentrations of these nutrients for Metro Manila and the Bulacan river systems are above these critical values. The same is also observed for BOD and dissolved oxygen (DO). The highest BOD values are recorded in the Bulacan Rivers. The water quality of Meycauayan and Marilao Rivers in Bulacan has improved in the last 3 years but still remained 3 to 5 times over the acceptable limit for BOD (<10 mg/L). DO also remained below the 5 mg/l water quality criteria with annual average of 1.0-1.2 mg/L in 2005.

Table 2.1.4: Measured Environment Concentration (MEC) mean and maximum values for 1996 to 1998 (1990-1998 for Metro Manila)

River system/Parameter	Class C criteria	MEC geomean, mg/l	MEC max, mg/l
Cavite			
NO3-Nitrogen	<10	0.29	4.83
PO4-Phosphorus	<0.4	0.24	1.26
BOD	<7	3.04	11
DO	>5	5.11	0.8
Pampanga			
NO3-Nitrogen	<10	0.13	.667
PO4-Phosphorus	<0.4	0.12	.495
BOD	<7	2.92	25
DO	>5	3.56	0.3
Bulacan			
NO3-Nitrogen	<10	0.05	2.41
PO4-Phosphorus	<0.4	1.70	9.17
BOD	<7	18.44	120
DO	>5	0.44	0.01
Metro Manila			
NO3-Nitrogen	<10	0.38	12.60
PO4-Phosphorus	<0.4	0.49	7.26
BOD	<7	11.38	190
DO	>5	2.78	0.01

Source: Manila Bay Risk Assessment Report, 2004

Other rivers in Region III that are constantly monitored include the Bocaue River in Bulacan which is classified as Class A for upstream and Class C for downstream. In all monitoring stations along the river, DO and BOD criteria are exceeded the limits in 2002-2004. The same classification is applied to the Pampanga River which recorded an annual average range of 2.5-22.8 mg-BOD/l in 2003-2005. The high readings in the midstream areas have already been identified to be due to the untreated discharge of industrial effluents (specifically an alcohol distillery plant)[10]. Upstream stations typically show lower than the 5 mg/l criteria for Class A waters except in 2005 which showed an annual average of 10 mg/l. Saltwater intrusion is also becoming a major problem as it reaches more than 10 km upstream of the Pampanga River. Other rivers in the Provinces of Bulacan, Pampanga and Bataan comply with the criteria for their water classification (EMB Region III Water Quality Status Report 2001-2005).

In Region IV, the Ilang-Ilang River in Cavite, which also drains towards the Manila Bay but outside of the MWSS concession area, is also placed under the list of priority rivers of EMB. In 2005, the measured values were 4.5 mg/L for DO and 8.4 mg/L for BOD, both showed improvements compared to 2003 data.

[10] EMB RO III Water Quality Status Report, 2005.

(b) Laguna de Bay and its Tributaries

Organic Pollutants

Since 1973, critical levels of pollution have already been detected in the Laguna de Bay (Lasco et al., 2005) which has been classified as Class C waters. Nutrient levels are high; in particular total Nitrogen that entered the lake is estimated to be 13,800 t N/yr, of which 79% come from domestic sources. Due to the high nutrient levels, lake eutrophication ensued causing algal blooms and decrease in dissolved oxygen resulting to fish kills. Turbidity and increasing organic load (BOD) are also at the uptrend. Most of the rivers at the western side of the lake are virtually dead such as San Pedro, Tunasan, San Cristobal, and the San Juan Rivers, with DO and BOD levels failing to meet Class C criteria (see **Figure 2.1.11**). This is the result of high discharge of domestic and industrial wastes from the communities and industrial establishments in the area. Within the lake itself, DO remains above Class C criteria, recording 7.6 and 7.4 mg/L (1990-1999 data) in the west and east lobes, respectively. From 1996 to 1999, BOD ranges from 1.0-4.5 mg/L, still satisfying Class C water quality criteria (see **Figure 2.1.12**). The west lobe consistently shows highest BOD levels.

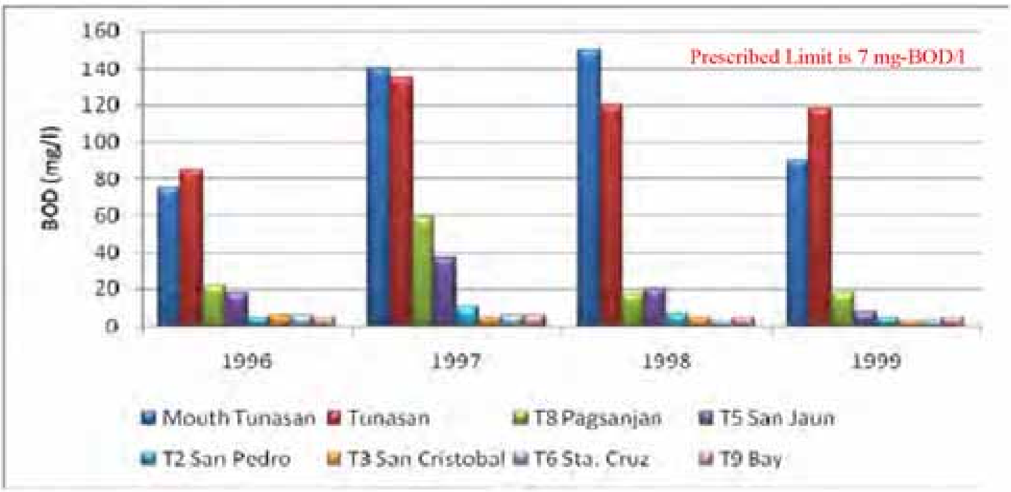


Figure 2.1.11: Annual average BOD of tributary rivers in the Laguna de Bay, 1996-1999
(Source: LLDA, 2003)

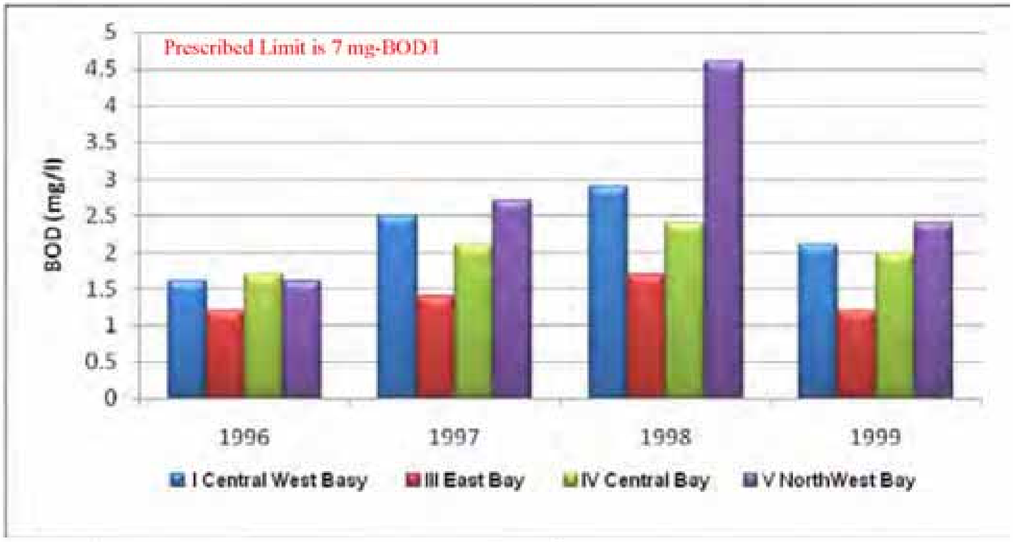


Figure 2.1.12: Annual average BOD of the Laguna de Bay, 1996-1999
(Source: LLDA, 2003)

Heavy Metal Pollutants

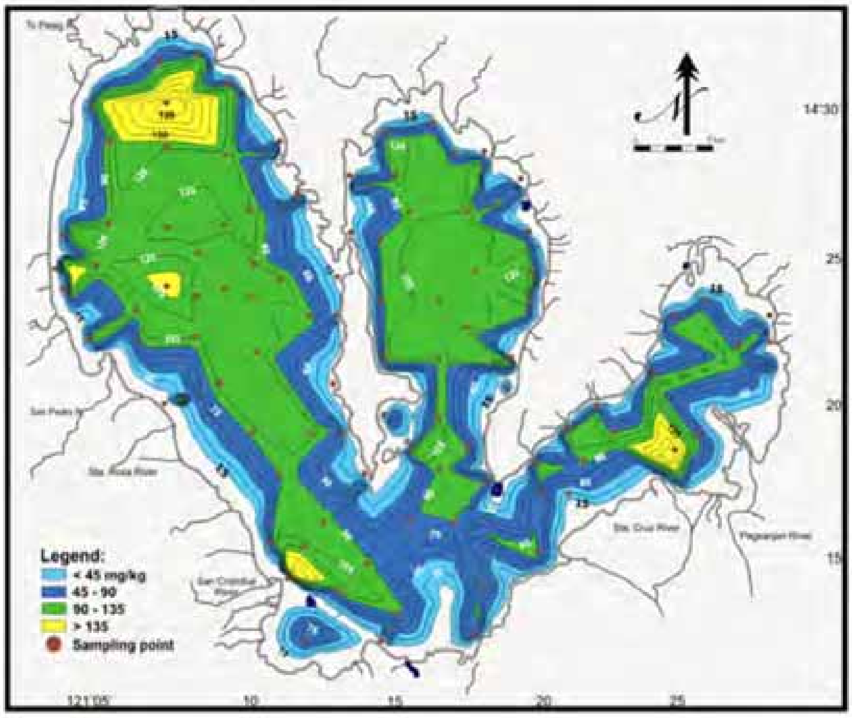
A study on historical account of heavy metal pollution in the lake using sediment cores intersected timelines as far back as 1917 (Duyanen and Siringan, 1999), or in terms of environmental evolution of the lake, as far back as 10,000 years (Jaraula, 2001). From the 1930 to 1997, historical heavy metal concentrations of Cu, Ni, Co, Cr, Pb, and Zn in the lake sediments depict general increasing trends, interpreted as imprints of a gradually industrialized watershed.

Figure 2.1.13 shows the representative distribution patterns of metal pollutants for Cu and Cd in the topmost 5 cm of the bottom sediments. As reported in the Rizal Rural Water Supply study of MWSS (RWSIP), the occurrence of high Cu concentrations in Philippine rocks is generally geogenic because of the fundamental geological nature of the Philippines. It can be expected therefore that Cu baseline in sediments is elevated compared to global standards (45 mg/kg in the average shale).

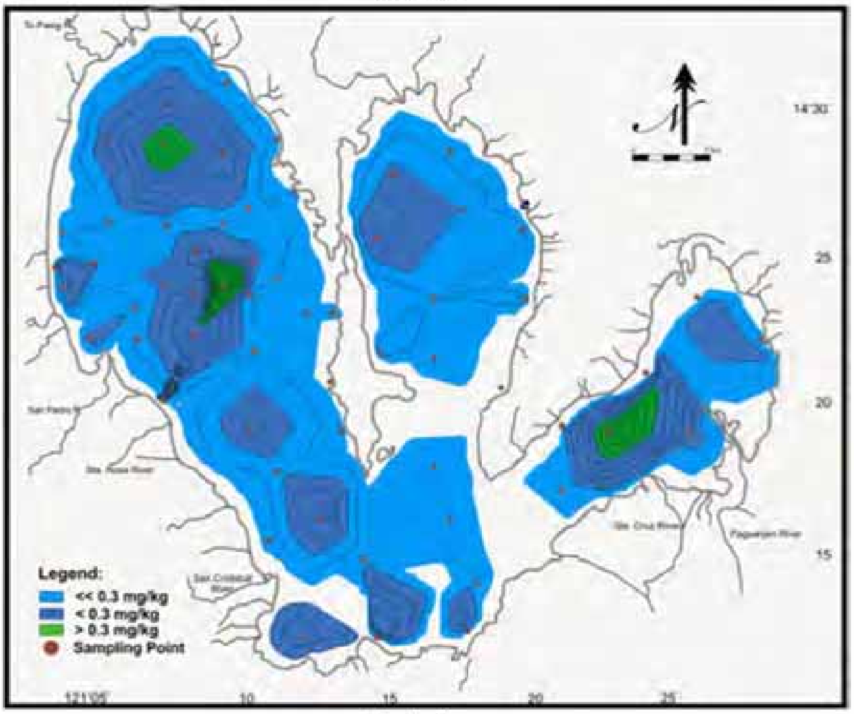
Copper (Cu) was chosen to represent the behavior of geogenic metals in the lake that are also sourced from anthropogenic origins because Cu is a well-known industrial metal. From the figure, locations of sediments with high Cu contents include the area adjacent to the Napindan channel and the Manggahan Floodway in the northern portion of the western lobe and the area adjacent to the San Cristobal River in the southern extremity of the lobe. Further, the report stated that the high concentration of Cu in these areas can be traced to the contribution of industrial loadings based on the largely industrial use of the watershed. On the other hand, Cu in the eastern lobe can be largely geogenic, possibly fed by both the Sta. Cruz and Pagsanjan Rivers.

Moreover, as reported, Cadmium was said to be geogenic, except in areas adjacent to the river mouths of the Sta. Rosa and San Pedro Rivers. These watershed areas are known to host industrial states where the high Cd contents in the lake sediments in this area of the western lobe can be traced.

Overall, sediments in the western lobe have higher metal pollutant contents than the other two lobes. The report attributed this to the inflow from the Pasig and Marikina Rivers via the Napindan and Manggahan channels. In addition, the western coast watershed which is drained by the San Pedro, Sta. Rosa, Biñan, and San Cristobal Rivers are known industrial areas. These areas are found to contribute additional loads of metal pollutants to the western lobe.



Copper



Cadmium

Figure 2.1.13: Representative distribution patterns of metal pollutants
(Source: Duyanen and Siringan, 1999)

Overall Water Quality Status of the Laguna de Bay

The summary of overall water quality status of the Laguna de Bay based on the December 2007 LLDA Water Mondrian is presented in **Table 2.1.5**.

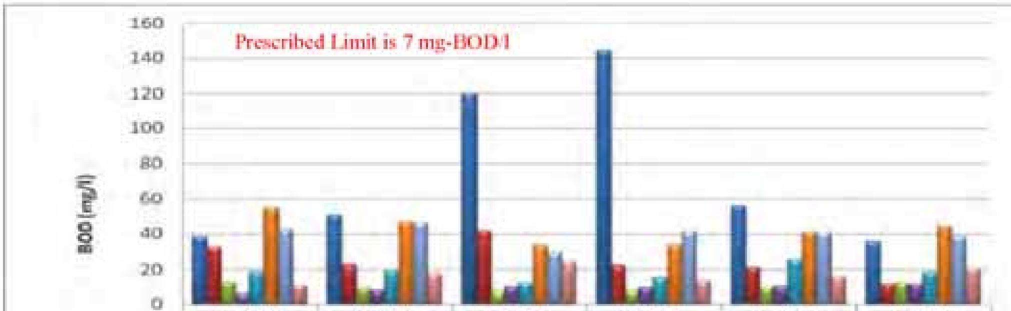
Table 2.1.5: Overall water quality status of the Laguna de Bay in December 2007

Station	Descriptions
I-Central West Bay	Class A status maintained, with BOD, %DO saturation, total and fecal coliform, phosphate, and oil and grease levels at Class A
II-East Bay	Class A status maintained, with BOD, %DO saturation, total and fecal coliform, phosphate, and oil and grease levels at Class A
IV-Central Bay	Class A status maintained, with BOD, %DO saturation, total and fecal coliform, phosphate, and oil and grease levels at Class A
V-Northwest Bay	Class C status maintained, with total and fecal coliform concentrations at Class C
VIII-South Bay	Class A status maintained, with BOD, %DO saturation, total and fecal coliform, phosphate, and oil and grease levels at Class A
E-A-Taguig	No monitoring conducted (no data)
E-B-San Pedro	No monitoring conducted (no data)
E-C-Biñan	No monitoring conducted (no data)
E-D-Sta. Rosa	No monitoring conducted (no data)
1-Marikina River	Worse than Class D status maintained, with very low % DO saturation
2-Mangangante River	Worse than Class D status maintained, with very low % DO saturation and very high BOD concentration
3-Tunasan River	Worse than Class D status maintained, with very low % DO saturation and very high BOD concentration
4-Sta. Rosa River	Worse than Class D status maintained, with very low % DO saturation and very high BOD concentration
5-Cabuyao River	Status improved to Class D from worse than Class D, with low % DO saturation, and high total coliform and phosphate concentrations
6-San Cristobal River	Class D status maintained, with high BOD, total coliform and phosphate concentrations
7-San Juan River	Status improved to Class D from worse than Class D, with high total coliform and phosphate concentrations
8-Bay River	Class D status maintained, with high total coliform concentration
9-Sta. Cruz	Class D status maintained, with high total coliform concentration
10-Pagsanjan River	Class D status maintained, with high total coliform concentration
11-Pangil River	Class D status maintained, with high total coliform concentration
12-Siniloan River	Status improved to Class D from worse than Class D, with high total coliform concentration
13-Tanay River	Class D status maintained, with low % DO saturation and high total coliform concentration
14-Morong River	Class D status maintained, with low % DO saturation, and high total coliform and phosphate concentrations
15-Sapang Baho River	Worse than Class D status maintained, with very low % DO saturation

Source: The Water Mondrian, LLDA

Water Quality in the MWSS Service Area

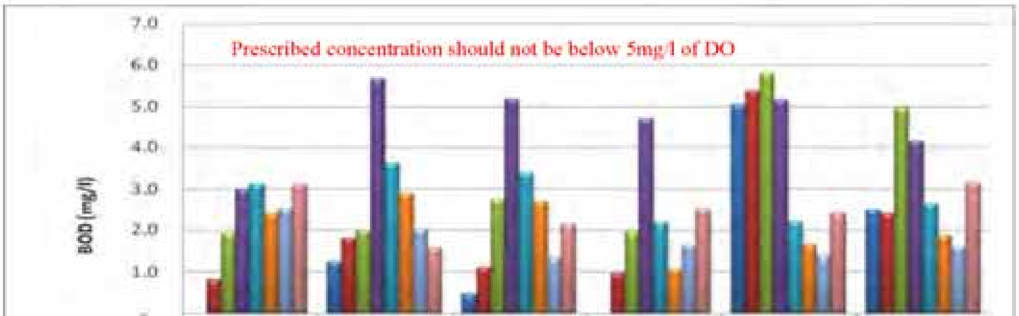
The Environment Management Bureau's National Water Quality Status Report for 2001-2005 noted that the BOD levels in most priority rivers in Metro Manila have improved since 2003-2005 but still not able to meet Class C water quality criteria (see **Figure 2.1.14**). In particular, the Marikina, San Juan and Paranaque Rivers showed annual average BOD of 12.1, 33.5 and 29.5 mg/L respectively. The Pasig River showed a decrease in water quality from 10.7 to 24.2 mg-BOD/L during the same period. The Sanchez monitoring station at the confluence of the San Juan and Pasig Rivers recorded highest BOD values along the entire stretch of the Pasig River, with BOD ranging from 20 to 34 mg/L. Dissolved oxygen in the Pasig River has likewise been below the water quality criteria with an annual average of 2.4 mg/L in 2005 (see **Figure 2.1.15**).



	Yr 2003	Yr 2004	Yr 2005	Yr 2006	Yr 2007	Yr 2008
Meycauayan	38	51	120	144	56	36
Marilao	32	23	41	22	21	11
Bocaue	12	9	6	7	9	12
Imus	6	8	9	9	10	11
Marikina	18	19	12	15	25	18
San Juan	55	47	33	33	40	44
Paranaque	42	46	29	41	40	38
Pasig	11	17	24	14	15	20

Figure 2.1.14: Yearly Average BOD Levels of EMB Priority Rivers

(Source: EMB 2009, unpublished)



	Yr 2003	Yr 2004	Yr 2005	Yr 2006	Yr 2007	Yr 2008
Meycauayan	-	1.2	0.5	-	5.1	2.5
Marilao	0.8	1.8	1.1	1.0	5.4	2.4
Bocaue	1.9	2.0	2.7	1.9	5.8	5.0
Imus	3.0	5.7	5.2	4.7	5.2	4.1
Marikina	3.1	3.6	3.4	2.2	2.2	2.6
San Juan	2.4	2.9	2.7	1.1	1.6	1.9
Paranaque	2.5	2.0	1.3	1.6	1.4	1.6
Pasig	3.1	1.6	2.1	2.5	2.4	3.2

Figure 2.1.15: Yearly Average DO Levels of EMB Priority Rivers

(Source: EMB 2009, unpublished)

Photo 2.1.7: Upstream of the Marikina River

Photo 2.1.8: Midstream of the Marikina River

Note: EMB 2003-2008 water quality monitoring data show that BOD and DO levels at the midstream of the Marikina River constantly exceeded the Class C water standard.

Photo 2.1.9: Upstream of the San Juan River (in Quezon City)

Photo 2.1.10: Downstream of the San Juan River (adjacent to the confluence with the Pasig River)

Note: 2003-2008 EMB monitoring data show that the San Juan River is the most polluted tributary of the Pasig River (highest yearly average BOD of 55 mg/l posted in 2003)

Photo 2.1.11: Downstream of the Pasig River (adjacent to river mouth)

Photo 2.1.12: Informal settlements along the Pasig River

Note: Although signs of water quality improvement were seen in 2006 to 2007, an increase in BOD levels were again posted in 2008

Photo 2.1.13: The Tullahan River adjacent to Mac Arthour's Bridge in Caloocan City

Photo 2.1.14: A scavenger is searching for recyclable items from the floating solid wastes along the Tullahan River

Note: The Tullahan River is considered as one of the most critical rivers in terms of water quality degradation in the north region of Metro Manila.

Photo 2.1.15: The Imus River

Note: Although the water quality of Imus River has exceeded Class C standard since 2008, it can still be considered as one of the least polluted rivers within the MWSS service area in terms of yearly average BOD.

Photo 2.1.16: The Paranaque River

Note: The Paranaque River is one of the major rivers at the south region of Metro Manila. Its water quality is as poor as that of the San Juan River.

Photo 2.1.17: The Meycauayan River

Note: Its headwaters can be traced in the MWSS area of Valenzuela. It is being identified as one of the most polluted rivers in the world by the Blacksmith Institute (an American environmental NGO) in 2007. Based on the EMB monitoring, BOD levels were at 120 and 144 mg/l in years 2005 and 2006 respectively. As part of the MMO River System WQMA designated in 2008, river water quality improvement initiatives are underway (thru the JICA assisted Capacity Development Project on Water Quality Management)