3.5 DATABASE AND DECISION SUPPORT SYSTEM

3.5.1 INTRODUCTION

In order to formulate effective plans for improvement of natural environment, it is necessary to process and analyze a large amount of data with a wide range of information rationally. In general, the information is not unified, not managed properly and not ready for use for decision making. Since, Guanabara Bay Basin covers several municipalities and engages a lot of organizations related to the environmental management, the information for formulating the environmental management plan are scattered. To improve this situation, a database with a system of decision support has been established by the Study to unify the scattered data/information.

3.5.2 DATABASE SYSTEM

(1) Basic Concept of Database

1) Concept for Database Design

Since the database is a part of decision support system of Guanabara Bay improvement, the roles of the database are as follows:

- To create an input data for water quality simulation of the Bay
- To show the pollution load in various conditions.

In order to achieve the roles mentioned above, it is necessary to integrate the data/information scattered in various organizations and to arrange it for use for estimating the pollution load and decision-making.

On the other hand, the value of database would be increased by accumulation of more data/information, by continuous periodical update and by increased utilization of the database. The following were taken into account for easy accumulation of the data/information and the database maintenance:

- Simplified database/layer structures are applied in order to maintain the database with less knowledge of the database operation.
- Sources of the data/information are clearly referenced in the database to reach them easily.
- The areas of data/information, which are currently not available but required in the future, are reserved in the database to avoid further construction work.

Since the database acts as a part of the decision support system, it is better to have capabilities of processing and analyzing special (graphic) data/information. In this context, it tis proposed to construct the database as a Geographic Information System (GIS) based database.

In addition, construction of the database with clarified strategy and structure would decrease the degree of dependency on database software and would make it easier to transfer the database to other software. It makes easier to obtain sustainable use of the database.

2) Database and GIS

Relation between Database and GIS is shown in *Figure 3.20*.

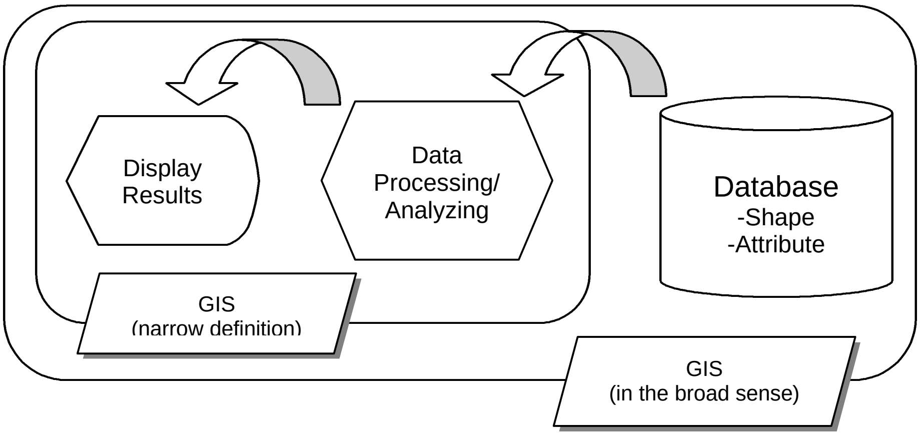


Figure 3.20 Relations between Database and GIS

As shown in *Figure 3.20*, GIS and database are strictly speaking different; however, in most cases, the GIS software has the function of a database. The database is to be constructed by using the database function of GIS software of ArcView with following considerations:

- Amount of data handling in the database
- Popularization of Software
- Ease of operation for data processing/analyzing
- Ease of conversion of the database file to other database format.

(2) Base Map for GIS

1) Topographic Map

A base topographic map for the database was prepared mainly based on digital topographic map with a scale of 1/50,000 prepared by CIDE as a part of PDBG project (for the index map, refer to *Figure 3.21*). Digital topographic maps with a scale of 1/400,000 prepared by CIDE were utilized for some small parts in the fringe areas of the Study Area, which are not covered by the PDBG maps. The projection and other information of geographic features for the system are as follows:

- Projection: Cônica Conforme de Lambert
- Datum: Córrego Alegre
- Unit: Meters
- Standard Parallel 1: -20° 40’
- Standard Parallel 2: -23° 20’
- Central Meridian: -45° 00’
- Reference Latitude: -19° 30’
- False Northing: 0.0
- False Easting: 0.0

2) Administration Boundary

Latest spatial information prepared by CIDE and IBGE has been imported to the database as administration boundaries.

3) Basin Boundary

Basis of the basin boundary and the boundary of the Study Area, which is equal to the Guanabara Bay Basin, is from the latest information of CIDE. The information was examined in detail and modified and determined through the Study.

4) Landuse

Landuse map prepared by CIDE in 1998 with a scale of 1/100,000 using 1996 SPOT satellite image is the latest landuse map available for the Study area and is stored in the GIS database. While landuse map with a scale of 1/50,000 was also available from CIDE the map was divided into too many parts. Considering integrity of data, 1/100,000 scale landuse map was finally used in this Study.

5) Population

Population data by sector for year 2000 is from IBGE with a scale of 1/10,000. The data comprise population of the municipalities intersected by the Guanabara Bay basin. Some missing data was updated by this Study using landuse map overlayed with sector map to make the population data complete and ready for analyzing using GIS. Based on the sector population data, population by municipalities and by river basin have been generated using geo-processing utility of ArcView GIS.

(3) Information for Database

There are two kinds of data/information stored in the database: one is the data/information prepared based on existing information and the other is created by this Study. Examples are shown in *Table 3.12* below:

Table 3.12 Information for Database

Based on Existing Information	Established by this Study
Natural Conditions (Topography, Geology, River, etc.) Geographical Information (Road, Railway, Building, etc.) Socio-Economic Condition (Population, Landuse, etc.) Monitoring Information (Meteo-Hydrology, Water Quality, etc.)	Wastewater Planning Information (Sewer District, Wastewater Treatment Plant, Pumping Station, Sewer Pipe, etc.)

(4) Layer Structure of Database

1) General

Since the database is constructed as a GIS based one, the database is organized in layer structure. Each layer consists of three pieces of information: namely, feature, location and attribute. Please refer to *Supporting 15* on “Database and Decision Support System” for detailed tables on layer structure.

2) Composition of Files

There are two types of data in GIS. One is the spatial map data and the other is the text base attribute. The spatial map data holds information on location of features such as line, polygon, point and grid with their XY coordinates. Spatial maps have only information on location, area or length. These spatial data are saved in shape file format in ArcView 3. Each shape files has a single feature.

Another type of data is the text base attribute such as name of river, observation data of monitoring station and statistical figures, etc. Any kind of text data that explains the spatial data can be added to the attribute table. The attribute data is saved as dbf (dBASE) file format (attribute table) in ArcView 3. Each shape file is dynamically linked with its attribute table. A shape file corresponds to an attribute table one by one.

3.5.3 DECISION SUPPORT SYSTEM (DSS)

(1) Background

The GIS based database for the environmental management of Guanabara Bay was built during the Study. On the other hand, water quality of the bay was simulated by MIKE 21, a package software for water quality simulation developed by Danish Hydraulic Institute (DHI). Input data, such as pollution load for MIKE 21 simulation was calculated using information stored in the database and input to MIKE 21 manually, because the GIS database itself does not have a function to generate the data.

Operation of GIS database, data preparation and operation of MIKE 21, and analysis of simulation results are currently carried out separately and special skills for each program is required. Such a complicated process hinders the efficient use of these systems for decision-making process of environmental management, and it is, therefore, necessary to link between the systems and provide seamless environment of system operation.

(2) Objective of System Development

The objectives of the system development are:

- To develop a Graphical User Interface (GUI) for easy operation of GIS database and MIKE 21
- To develop interface and data exchange tools between GIS database and MIKE 21
- To create a seamless environment of system operation.

(3) DSS Functions

1) General

Based on decision-making process considerations, the following functions are required for this system:

- GUI for viewing and editing the GIS database (Stage 0)
- Calculation of pollution load and preparation of input data file for water quality simulation by MIKE 21 (Stage I)
- Simulation of Guanabara Bay water quality by MIKE 21 (Stage II)
- Display and evaluation of the results of water quality simulation based on pre-set criteria (StageIII).

The GUI for the system was developed as an interactive one using ESRI’s MapObjects LT 2.0 software. MapObjects is a collection of mapping components for application developers that works under Visual Basic programming language environment. Using MapOjects LT 2.0 and Visual Basic 6, DSS was developed as stand-alone executable software such that no other software is needed to run DSS. However, to make pollution load calculation and to run water quality simulation, Microsoft Excel and MIKE 21 software are pre-requisite. DSS comes with a setup file that has to be installed in the user’s computer.

2) GUI for Viewing and Editing the GIS Database (Stage 0)

An interactive GUI into which the users can view and edit the database easily, is provided in this system development. Same shape and dbf (dBASE) files developed in the GIS database are shared by DSS. Maps can be viewed and data (attribute tables) can be edited in DSS. Even though, geometry or shape of the map objects can't be directly modified from DSS but any modification or updating of the shape files using GIS software like ArcInfo or AutoCAD Map will be reflected in DSS since the system uses the same file system stored in the GIS database. This makes DSS a powerful tool for GIS data visualization and editing.

3) Calculation of Pollution Load to the Bay (Stage I)

A process diagram of this stage is shown in *Figure 3.22* at the end of this chapter. In this process, pollution load to the bay is calculated using data stored in the GIS database and some coefficients to be input manually. The calculation result is exported to MIKE 21 time series data using a visual basic macro program from within DSS. Same pollution load calculation methodology that has been applied in this Study has been used in DSS. There are three interfaces for data input:

- Basin Data: where the user has to input population and sewage treatment ratio by river basin (under GIS environment)
- Load Parameters: where the user views and edits general load parameters applicable for all river basins
- WWTP Data: where the user has to input population and sewered ratio for each waste water treatment plant (under GIS environment).

As a pre-set condition, population for year 2000 and sewage treatment ratio used by this Study have been set up. Based on the input data and parameters, DSS automatically calculates pollution load by river basin and by WWTP.

4) Water Quality Simulation (Stage II)

Water quality of the Guanabara Bay is simulated by the Eutrophication Module of MIKE 21 in this process. MIKE 21 is stand-alone software that works by itself. However, to ease the simulation process, pre-set files have been included in DSS. The users have to open MIKE 21 setup file, then view and modify the pre-set data according to their needs and run the simulation. As a pre-set condition, in the hydrodynamic model, basin runoff for average year and in the eutrophication model, pollution load corresponding to basin population for year 2000 have been set up. Since, export of the MIKE 21 2D time series result files require some sort of post-processing within MIKE 21, therefore, the users of DSS have to view the 2D result files from within MIKE 21. However, users can view results at the bay water quality monitoring points which are zero-dimension time series files, from within DSS as explained in Stage III below. Process diagram of this stage is shown in *Figure 3.23*.

5) Display of Simulation Result (Stage III)

In this process, simulation results at the bay water quality monitoring points can be viewed and evaluated against pre-set criteria. The process involves importing MIKE 21 time series simulation results to DSS by using a visual basic macro program integrated with DSS. Process diagram of this stage is shown in *Figure 3.24*.

This completes the decision making process: starting from viewing and updating of the GIS database using the DSS, pollution load calculation within the DSS, exporting updated pollution load data from DSS to MIKE 21, simulation of water quality by MIKE 21, importing simulation results from MIKE 21 to the DSS and finally evaluation of bay water quality using DSS and decision making.

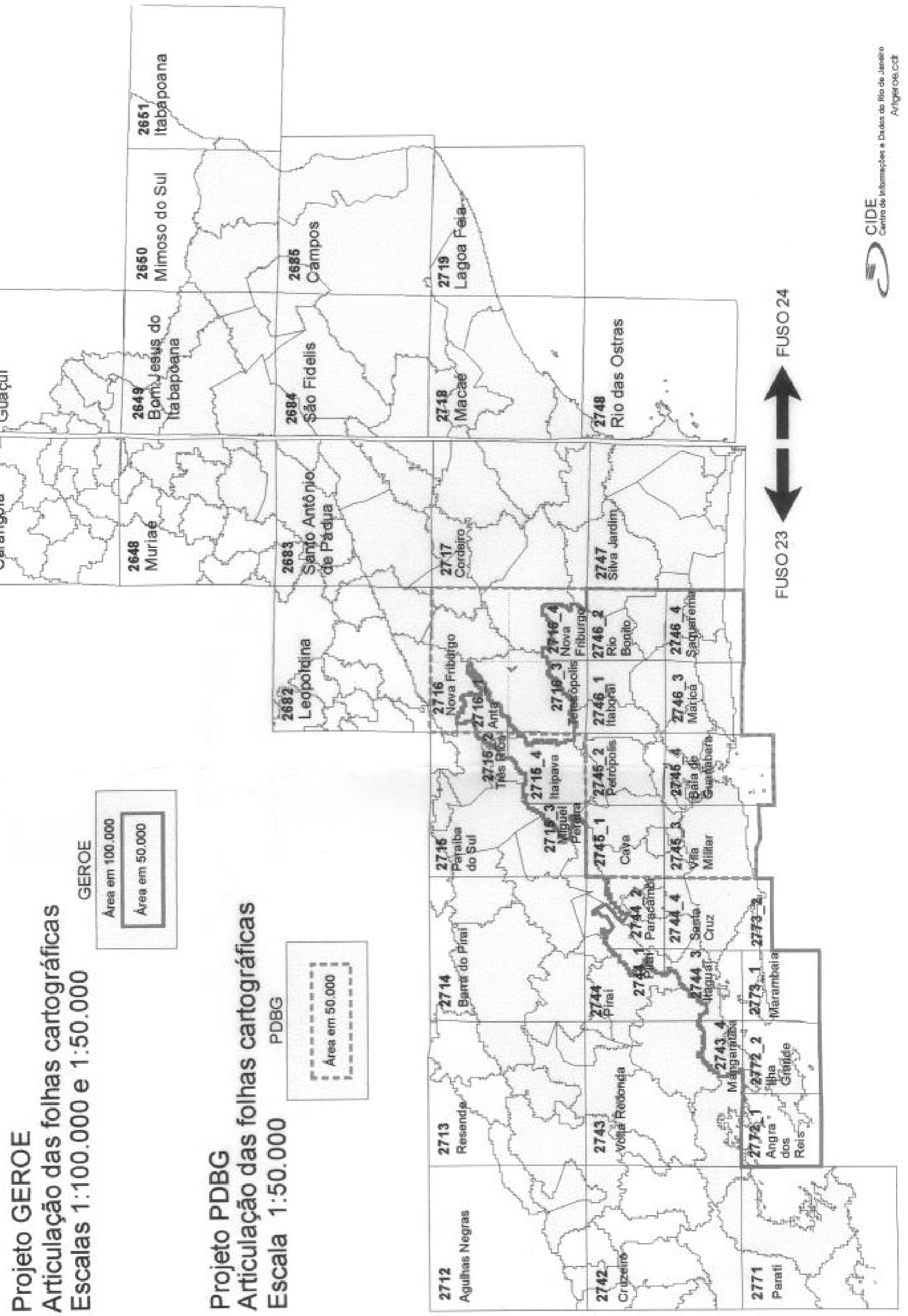


Figure 3.21 Index Map for Base Map

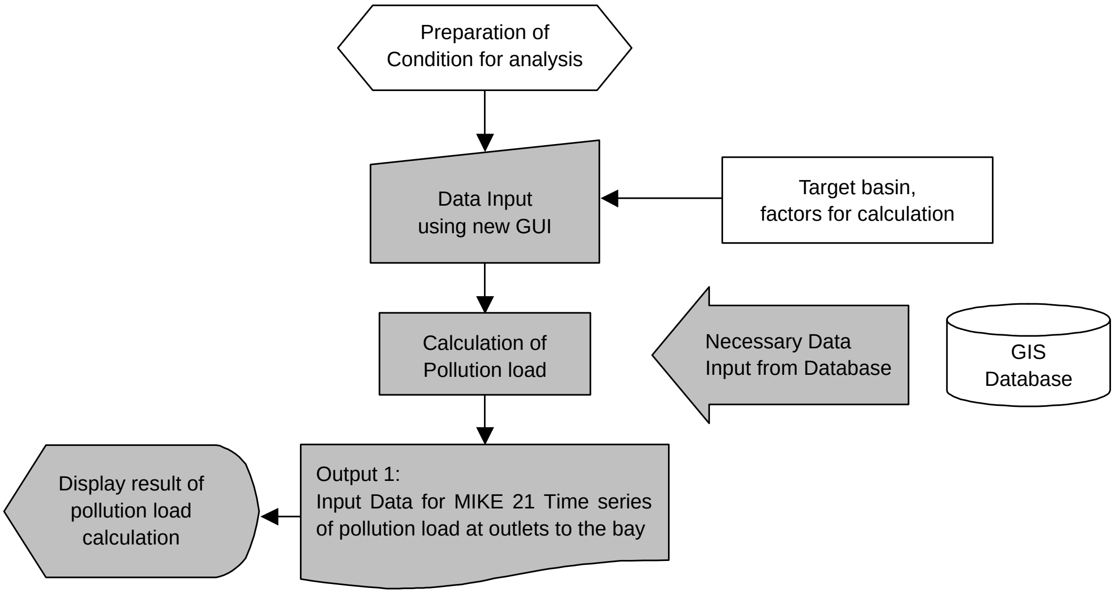


Figure 3.22 Process Diagram for Calculation of Pollution Load to the Bay (Stage I)

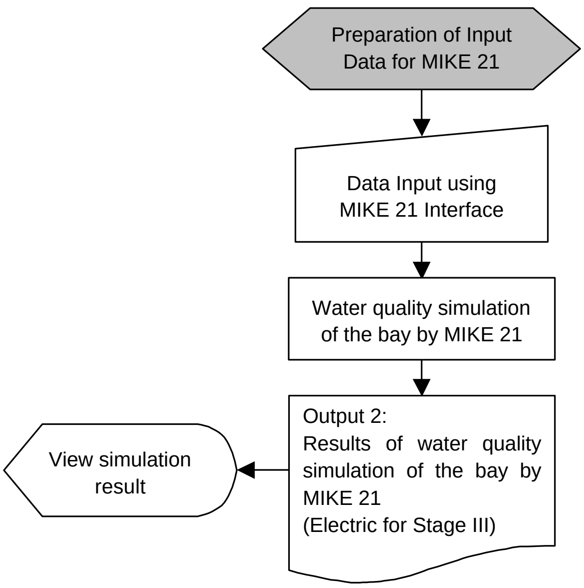


Figure 3.23 Process Diagram for Water Quality Simulation (Stage II)

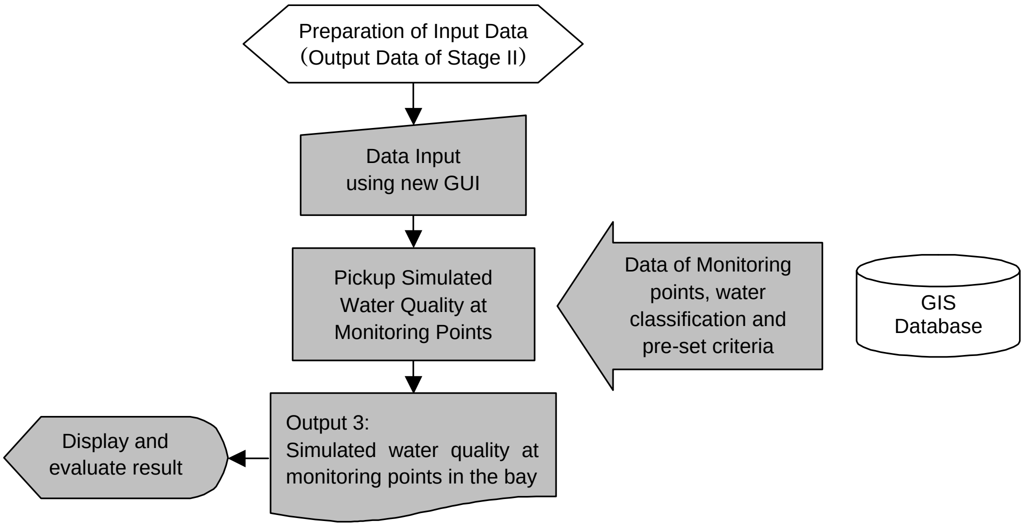


Figure 3.24 Process Diagram for Display of Simulation Result (Stage III)

CHAPTER 4

REVIEW OF JICA MASTER PLAN

CHAPTER 4 REVIEW OF JICA MASTER PLAN

4.1 INTRODUCTION

"The Study on Recuperation of the Guanabara Bay Ecosystem" conducted by JICA in 1994 proposed a comprehensive water quality control plan (referred to "JICA M/P" in this report). JICA M/P set up the target water quality of the Bay, identified necessary pollutant loads reduction and proposed countermeasures to attain the water quality target. The proposed countermeasures covered the following components:

- Sewerage system development
- Stabilization pond construction
- Ocean outfall
- Enhancement of industrial wastewater discharge control
- Improvement of solid waste disposal
- Preservation of forests
- Landuse control
- Improvement of channel areas

Among the proposed countermeasures, sewerage system development was a dominant measure and only one measure of which water quality improvement effects were quantitatively evaluated. Sewerage system development was realized as one of project components of "Guanabara Bay Pollution Abatement Program (PDBG)", which commenced in 1996 as a state project with co-financing of IDB and JBIC. Scope of PDBG was not necessarily determined based on the JICA M/P, but it was more that JICA M/P adopted the sewerage system developing components of PDBG, which were being prepared in parallel with the study on JICA M/P, as the scope of the sewerage system development of the JICA M/P.

Sewerage system development of PDBG commenced in 1996 and is to be completed in July 2003. The State intends to continue further sewerage system development as PDBG Phase II by positioning the present PDBG as PDBG Phase I. JICA M/P was reviewed to evaluate the effects of sewerage system development and to make the plan more effective by adjusting it to the present conditions that significantly differ from the ones predicted in JICA M/P.

The review includes:

- To update socio-economic conditions
- To clarify the scenario proposed in JICA M/P and to evaluate its realization

and based on the above:

- To propose the strategy of the improvement of Guanabara Bay environment with emphasis on the realization.

4.2 REVIEW OF SOCIO-ECONOMIC CONDITIONS

Socio-economic conditions, such as population and economic activities, are essential factors of master planning of the water quality improvement because they are a major cause of pollutant loads and dominant factors for designing of countermeasures. JICA M/P estimated the population and economic growth for years 2000 and 2010 based on Census 1991 data that was the latest available data at that time. The estimation is verified by the present conditions identified in the Study.

4.2.1 POPULATION

Table 4.1 shows comparison of the population in the Guanabara Bay basin projected in JICA M/P and in the Study (for details, refer to *Supporting 2*).

Table 4.1 Population in the Guanabara Bay Basin

	1991	2000	2010	2020
JICA M/P 1)	7,594,031 2)	8,636,030	9,564,783	NA
The Study	NA	8,290,300 3)	9,013,026	9,619,561
Ratio (JICA MP/The Study)	NA	1.042	1.061	NA

Note: 1) Based on Scenario 2 of the estimation of socioeconomic conditions. For details of the Scenario, refer to Chapter 12 of Main Report of "The Study on Recuperation of the Guanabara Bay Ecosystem", 1994, JICA
2) Actual value based on Census 1991
3) Actual value based on Census 2000

The JICA M/P gives larger population in 2000 and 2010 than 2000 census and the Study's projection, respectively. The population growth rates in Brazil are decreasing and share of Rio de Janeiro in the Federal region is decreasing, too, from two decades before. JICA M/P forecast the future population considering these trends. However, results of Census 2000 showed that the trends have accelerated more than expected about 10 years before.

As a result, the present population (year 2000) is lower by about 4 % and accordingly, population in 2010 is lower by 6 %.

4.2.2 ECONOMIC ACTIVITIES

(1) Economic Growth Rates of JICA Master Plan

JICA M/P estimated the economic growth rates by industrial classification as shown in *Table 4.2*.

Table 4.2 Economic Growth Rates by Industrial Classification Estimated by JICA M/P

Industrial Classification	Period			Remarks
	1980-1985 (Actual)	1986-2000 (Estimated)	2001-2010 (Estimated)	
Primary Sector	0.56	0.2	0.2	Based on increase of cultivated land area.
Secondary Sector	-2.29	2.27	1.83	Based on numbers of employees in the selected 12 industries.
Tertiary Sector	2.03	2.04	1.09	Based on numbers of employees in the lodging and food services.

(Unit: %)

Note: Estimation is based on Scenario 2. For details of the Scenario, refer to Chapter 12 of Main Report of "The Study on Recuperation of the Guanabara Bay Ecosystem", 1994, JICA
Source: JICA M/P

Except the primary sector, the annual growth rates from 1986 to 2000 are approximately 2%. Although the actual annual growth rate of GRDP of the Rio State from1994 to 2000 was 4.09 % as mentioned below, the estimation of JICA M/P is considered to be approximately consistent with the actual growth because the economic growth rates of Rio de Janeiro State is very much pulled up by oil production.

(2) Update of Economic Growth Rates

Economy in RJ State experienced higher development than the national average. The average annual growth rate of RJ State was 4.09% from 1994 to 2000. But an economic projection by Secretaria de Estad de Fazenda (SEF) is not optimistic it can be met.

SEF is preparing a projection of public finance until 2017. In the projection, the average annual growth rate of GRDP is forecast based on the following assumptions:

- Average annual growth rate until 2010 is 2.5 percent.
- It will decrease to 1.5 percent from 2011 to 2017.

As described in Section 2.2.3, high and stable economic development of the RJ economy came from a rapid production increase in the petroleum industry. The economic projection until 2010 is almost the same level as the national average annual growth rate from 1994 to 2000. This means that the rapid increase of the petroleum industry will stop in 10 years, and the economy of RJ State will perform as same as the national average.

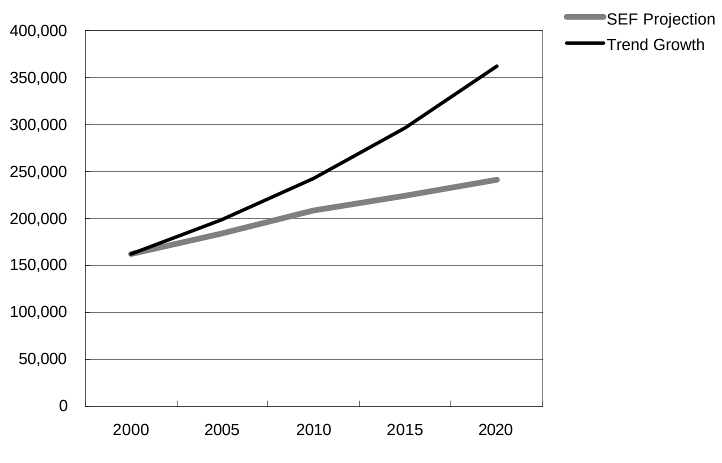
Table 4.3 and *Figure 4.1* show the projection of GRDP in RJ State until 2020. The “Trend growth” in them means that the economic development path will have an average growth rate of 4.09%. In this case the volume of GRDP in 2020 will be R$363 billion, 2.2 times GRDP in 2000. But in case of SEF’s projection, the volume of GRDP will be limited to R$242 billion, only 1.5 times the level in 2000.

The adoption of the SEF’s projection in estimating future economic conditions of the Study Area is more realistic, because SEF has set a projection on the public finance under this projection, and public investment plans will follow such projection.

Table 4.3 Projection of GRDP in RJ State

	2000	2005	2010	2015	2017	2020
Projection of GRDP by SEF	162,600	**183,967**	**208,142**	**224,228**	**231,006**	**241,558**
Trend growth (AAGR: 4.09%)	162,600	**198,702**	**242,819**	**296,731**	**321,510**	**362,612**

Note: Projection of GRDP is calculated by the Study Team based on the assumption of SEF.
Source: Secretaria de Estado de Fazenda
Anuario Estatístico do Estado do Rio de Janeiro 2001. CIDE



Source: JICA Study Team

Figure 4.1 Projection of GRDP

4.3 OUTLINES OF JICA MASTER PLAN

4.3.1 TARGET YEARS

JICA M/P set target years for the improvement as follows:

Short term target: 2000
Medium term target: 2010
Long term target: Not specified

The target years 2000 and 2010 were determined to correspond to PDBG then under preparation. While project components of PDBG actually implemented have far differed from those supposed at the time, as explained in the later section of this report, they are shown *Table 4.4*. The target years seem to have been determined based on a possible time schedule of the implementation of improvement measures rather than requirements derived from necessity of environmental improvement.

Table 4.4 Outlines of PDBG Project Assumed in JICA M/P

Stage of PDBG	Proposed Completion Year	Major project components
Stage 1	2000	Development of several sewerage systems with primary treatment.
Stage 2	2010	Up-grading of the treatment level of the above systems to secondary treatment.

Note: PDBG was referred as IDB/OECF Program in JICA M/P.

4.3.2 TARGET WATER QUALITY

JICA M/P set target water quality for each target year. For target water quality of the long term plan, the Plan mentioned “a level where the ecosystem in Guanabara Bay will be recuperated.” Although this is supposed to correspond to the conditions prior to mid 1960’s, the Plan did not specify tangible targets.

For the medium and short term targets, the Bay area was categorized by four classes by considering current and future expected water uses. Water quality indices representing each class were determined based on CONAMA Resolution No. 020/86 (Refer *to Table 2.20* of this Report). The classification of Guanabara Bay for the middle term and short term targets are shown in *Figure 4.2* and the water quality indices for each class is shown in *Table 4.5*.

Table 4.5 Classification of Bay Area of JICA M/P and It's Water Quality Indices

Class	Objective of Water use	Water Quality Indices							
		pH	Biological Oxygen Demand (BOD)	Dissolved Oxygen (DO)	Total Nitrogen (T-N)	Total Phosphorus (T-P)	Number of Coliform Groups (Fecal)	Suspended Solids (SS)	N-Hexane Extracts
A	Fishery (Class 1) Recreation (Primary Contact) Uses listed in Class 5 - 6	7.8 | 8.3	3 mg/l or less	7.0 mg/l (4.5 mg/l) or more	0.3 mg/l or less	0.03 mg/l or less	1,000 MPN/100ml or less	10 mg/l or less	Not Detectable
B	Fishery (Class 2) Recreation (Secondary Contact) Conservation of Natural Environment Uses listed in Class 6	7.0 | 8.5	5 mg/l or less	6.0 mg/l (3.5 mg/l) or more	0.6 mg/l or less	0.05 mg/l or less	1,000 MPN/100ml or less	25 mg/l or less	Not Detectable
C	Commercial Navigation Industrial Water Conservation of Environment	6.5 | 8.5	8 mg/l or less	4.0 mg/l (2.5 mg/l) or more	1.0 mg/l or less	0.09 mg/l or less	4,000 MPN/100ml or less	50 mg/l or less	
D	Waste Dilution and Circulation	6.5 | 8.5	10 mg/l or less	2.0 mg/l (1.5 mg/l) or more	1.5 mg/l or less	0.13 mg/l or less		50 mg/l or less	

Note: 1) Values given in parentheses for DO are target water qualities in the bottom layers.
2) With regard to the number of coliform groups for recreation (primary contact), fecal coliform shall be less than 250 MPN/100 ml.
3) With regard to the number of coliform groups for recreation (secondary contact), fecal coliform shall be less than 500 MPN/100 ml.
4) Supplementary indices are omitted.

Source: Modified from JICA M/P

4.3.3 TARGET POLLUTANT LOAD REDUCTIONS

JICA M/P estimated allowable pollution load conditions to achieve the target water quality by trial and error calculation of the water quality simulation model developed in the study. The Plan also identified contribution to pollution conditions of the bay by pollutant sources, such as external loads (pollution loads generated in the basin and flowing into the Bay) and internal loads (internal production by photosynthesis and release form sediments). Contribution of the internal loads was estimated as high as 65%. Therefore, it was concluded that the nutrient load reduction was essential to achieve the target water quality.

While the plan did not directly indicate the required pollution load reduction, it is summarized based on the estimated data in the plan as shown in *Table 4.6*.

Table 4.6 Target Pollutant Load Reduction Estimated in JICA M/P

Basin		Estimated Allowable 1) External Pollution Load to Achieve the Medium Term Target Water Quality (ton/year)	Esimated Pollution 2) Loads from each basin (ton/year)		Target Pollution Load 3) Reduction (ton/year)	
			2000	2010	2000	2010
Eastern	BOD	24	26.12	29.18	2.12	5.18
	T-P	0.8	1.67	1.89	0.87	1.09
Northeastern	BOD	44	55.58	64.47	11.58	20.47
	T-P	2.5	3.20	3.73	0.7	1.23
Northwestern	BOD	59	110.68	128.69	51.68	69.69
	T-P	3.3	6.56	7.66	3.26	4.36
Western	BOD	98	174.72	184.30	76.72	86.3
	T-P	6.2	11.29	11.85	5.09	5.65
Islands	BOD	7	8.29	8.69	1.29	1.69
	T-P	0.4	0.53	0.56	0.13	0.16
Total	BOD	232	375.39	415.33	143.39	183.33
	T-P	13.2	23.25	25.69	10.05	12.49

Note: 1) and 2) are data estimated in JICA M/P. 3) is calculated in this study (= 2) – 1))

4.3.4 COUNTERMEASURES TO ACHIEVE TARGET

To achieve the improvement target, JICA M/P proposed "Optimum Combination of Measures by Basin" (referred to as the countermeasures in this chapter), and it is summarized in *Table 4.7*.

The countermeasures made stage 1 of PDBG (referred as IDB/OECF Program in JICA M/P) their components but did not adopt the stage 2 since it had not been committed at the time. Among the countermeasures listed in *Table 4.7*, pollutant reduction by the stage of PDBG and ocean outfall of the effluent from Alegria WWPT, which is located in the Western basin, were estimated quantitatively. The pollutants load reduction quantitatively estimated by JICA M/P can be presumed as shown in *Table 4.8*.

Table 4.7 Optimum Combination of Countermeasures to Achieve the Water Quality Targets in 2010 proposed in JICA M/P

Basin	Measures	
	Physical Measures	Non-physical Measures
Eastern	➢ Sewage treatment (Primary) ➢ Sewage treatment (Tertiary) ➢ Treatment of fish processsing industires	
Northeastern	➢ Stablization ponds	➢ Landuse control
Northwestern	➢ Sewage treatment (Primary) ➢ Stablization ponds ➢ Treatment of fish processsing industires	➢ Landuse control
Western	➢ Sewage treatment (Primary) ➢ Ocean outfall	➢ Improvement of sanitation service in Favelas
Islands	➢ Sewage treatment (Tertiary)	
All Basin		➢ Strengthening industrial wastewater control

Source: JICA M/P

Table 4.8 Estimated Pollutant Load Reduction by Countermeasures of JICA M/P

Basin		Quantitatively estimable countermeasures proposed in JICA M/P	Pollution Load Reduction (ton/year)	
			By Countermeasures*	Required to achieve the targets
Eastern	BOD	Construction of Icarai, Toque and S-II system with primary treatment	4.5	5.18
Northeastern	BOD	Non	0	20.47
Northwestern	BOD	Sarapuí	3.0	69.69
Western	BOD	Construction of Alegria and Pavuna systems with primary treatment, and ocean outfall of the effluent of Alegria system	52.7	86.3
Islands	BOD	Non	0	1.69
Total	BOD		60.0	183.33

Note: *Expected pollution reduction was not calculated in JICA M/P and was calculated by this Study.

The required pollution load reduction is added at the far right column of the table for comparison. The qualitatively estimated pollution load reduction is about a third of the required reduction. Expecting the remaining required reduction amount can be achieved by the proposed additional and supplemental measures, such as tertiary treatment, treatment of industrial wastewater, improvement of sanitation service in Favelas, installation of stabilization pond and landuse control, JICA M/P concluded the "Optimum Combination of Measures by Basin".

4.4 EVALUATION OF REALIZATION OF JICA MASTER PLAN

4.4.1 PROPOSED COUNTERMEASURES

(1) General

In general, no countermeasures proposed in JICA Master Plan have been realized, except sewerage system development and industrial wastewater treatment.

Industrial wastewater control was not necessarily implemented as proposed. It is only supposable from a fact that pollutant load from industries estimated in JICA M/P, BOD 64.5 ton/year, has deduced to 9.64 ton/year estimated in this Study based on information reported to FEEMA from each industry.

(2) Sewerage System

Sewerage system development has been realized as project components of PDBG. When JICA M/P made the PDBG as countermeasures, PDBG itself was in the preparation stage and the scope of PDBG repeatedly changed during the preparation. Moreover, there were further changes of the scope during the implementation stage. Therefore the final scope of PDBG has very much differed from the countermeasures proposed in JICA M/P. *Table 4.9* shows the comparison of the proposed countermeasures and scope of PDBG implemented.

Table 4.9 Comparison of Sewerage System Development proposed by JICA M/P and implemented by PDBG

Sub-Basin	Scope proposed in JICA Master Plan [1)]	Scope implemented by PDBG [2)]	Remarks
Eastern	Icarai, Toque Toque and S-II systems with primary process	Icarai: Treatment cap.; 0.952 m^3/sec Treatment Level; Primary Service Pop.; 234,000	Completed
		São Gonçalo: Treatment cap.; 0.765 m^3/sec Treatment Level; Secondary Service Pop.; 235,000	Completed
Northeastern	-	-	
Northwestern	Sarapuí system with primary process	Sarapuí: Treatment cap.; 1.5 m^3/sec Treatment Level; Secondary Service Pop.; 431,000	Up-grading to secondary process and pipe installation are ongoing as of October 2002.
Western	Alegria and Pavuna systems with primary process	Alegria: Treatment cap.; 5.0 m^3/sec Treatment Level; Secondary Service Pop.; 1,500,000	Up-grading to secondary process and pipe installation are ongoing as of October 2002.
		Pavuna Treatment cap.; 1.5 m^3/sec Treatment Level; Secondary Service Pop.; 410,500	Up-grading to secondary process and pipe installation are ongoing as of October 2002.
		Marina Gloria: Intercepting and ocean outfall	Completed
Islands		Ilha do Governador: Treatment cap.; 0.525 m^3/sec Treatment Level; Secondary Service Pop.; 240,000	Completed
		Paquetá: Treatment cap.; 0.027 m^3/sec Treatment Level; Secondary Service Pop.; 15,000	Completed

Note: 1) No technical information was available.
2) Based on the final project scheme of PDBG provided by CEDAE

The most significant change is the level of sewage treatment. JICA M/P assumed that while sewerage system development with primary process was to be implemented (it was referred as "IDB/OECF program stage 1"), the possibility of upgrading of the treatment by adding the secondary process (it was referred as "IDB/OECF program stage 2) was omitted. The treatment level in the PDBG scope at the beginning of the implementation was primary level, too. However, in the course of the implementation, scope was changed to upgrade the treatment process to the secondary level. Four WWTPs have been completed with the secondary process and three WWTPs are under construction to complete them with the secondary process.

Systems developed by PDBG also differed from those proposed by JICA M/P. Toque Toque and S-II WWTPs were not implemented but São Gonçalo, Ilha do Governador and Paquetá WWPTs, which had not been included in the countermeasures, were implemented.

In conclusion, actual progress of the sewerage system development has proceeded further than those proposed in JICA M/P. However, it does not necessarily mean that sewage collected and treated have increased according to the design capacity of completed collection system; there are several operational reasons for this.

4.4.2 TARGET POLLUTION LOAD REDUCTION

JICA M/P estimated the pollutant load reduction which is the responsibility of the sewerage system as shown *Table 4.8*. Target pollution load reduction in 2000 is compared to the present conditions below.

(1) Present Conditions

As explained in section 4.4.1, sewerage system development has made considerable progress. Pollutants load reduction could be calculated by the actual operation conditions. However it was found difficult through this Study for the following reasons:

- In Alegria, Sarapuí and Pavuna systems, construction work is still going on and sewage collected is much smaller than the design sewage amount.
- Some of WWTPs are not operated.
- Even in the sewered areas, rates of connection to sewer are still low and thus the sewage collected is low compared to the design sewage amount.
- Operational records are not available to estimate the actual condition amount.

(2) After PDBG I

Pollution load reduction is calculated assuming the condition where all the PDBG1 projects are completed and all the facilities are operated as designed.

Table 4.10 shows the expected pollutant load reduction after completion of PDBG, comparing them to the target pollution load reduction of JICA M/P. Since the actual PDBG adopted the secondary process, pollution load reduction of BOD by PDBG is about 2.5 times the one estimated in JICA M/P, almost achieving the target pollution reduction. However, the estimated reduction of T-P remains 30% of the target. This suggests the need of tertiary treatment.

Table 4.10 Estimated Pollutant Load Reduction by PDBG

Parameter	Estimated Pollutant Load Reduction by PDBG	Estimated pollutant Load Reduction by JICA M/P	Target Pollution Reduction of JICA M/P
BOD	148.96	60	183.33
T-P	3.3	-	10.05

Note: Pollutant loads are calculated for the load conditions 2000. (ton/year)

4.4.3 TARGET WATER QUALITY

(1) Present Conditions

Table 4.11 shows the comparison of the present water quality conditions and the short-term target of JICA M/P. While the short-term target of JICA M/P was given as a spatial drawing (refer to *Figure 4.2*), in the table, they are presented by water quality of the monitoring points that represent the water quality classification. Since the sewerage system development by PDBG1 has not worked out enough, it is natural that improvement effect is not observed.

Table 4.11 Comparison of the Present Water Quality and the Short-Term Target

Monitoring Points [1)]	Present Water Quality [2)] (BOD mg/l)	Short-Team Target [3)] (BOD mg/l)
GN-064	4.3	3
GN-022	5.6	5
GN-043	**12.7**	**10**
GN-040	**22.8**	**10**
GN-020	**19.3**	**8**
GN-042	**13.7**	**8**
GN-000	**7.6**	**5**
GN-026	5.9	5

Note: 1) For the location of each monitoring point, refer to *Figure 4.3*.
2) Average of water quality monitoring by FEEMA, 2000
3) Read out from *Figure 4.2*.

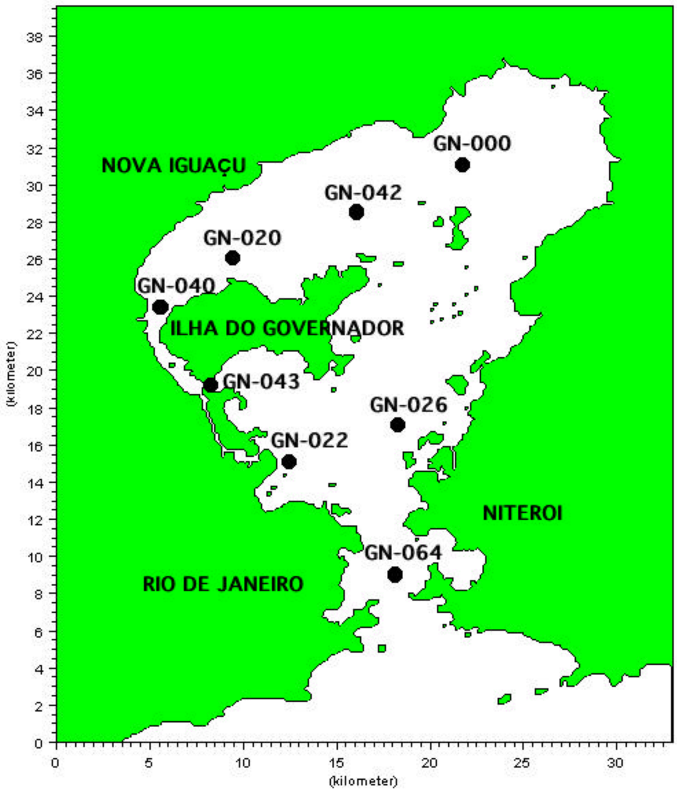


Figure 4.3 Location of the Monitoring Points

(2) After PDBG I

Figure 4.4 shows the estimated water quality for the pollutant load conditions where all the PDBG Phase 1 project components are assumed to have completed and been in full operation. *Table 4.12* shows the comparison of the estimated water quality at the monitoring points and the short-term target of JICA M/P. Compared to the present conditions shown in *Table 4.11*, considerable improvement effect was expected. However, severely polluted area remains in the deep western part of the Bay.

Table 4.12 Comparison of the Estimated Water Quality after PDBG Completion and the Short-Term Target

Monitoring Points 1)	Estimated Water Quality 2) (BOD mg/l)	Short-Team Target 3) (BOD mg/l)
GN-064	3	3
GN-022	5	5
GN-043	9	10
GN-040	**13**	**10**
GN-020	**10**	**8**
GN-042	6	8
GN-000	6	5
GN-026	5	5

Note: 1) For the location of each monitoring point, refer to *Figure 4.3*.
2) Estimated by the water quality simulation model assuming PDBG full operation for load condition 2000.
3) Read out from *Figure 4.2*.

4.5 STRATEGY OF IMPROVEMENT OF GUANABARA BAY ENVIRONMENT

4.5.1 GENERAL

As described above, it has become clear that the sewerage system development, which is one of the major components of PDBG, is the only countermeasure that realizes JICA M/P, and that no indication of increased improvement has been observed. In addition to the fact that the actual conditions around the Guanabara Bay environment have deviated from the conditions that JICA M/P predicted, because of reasons listed below, the improvement of Guanabara Bay environment should reflect the actual conditions and should be pursued in more realistic or easier to be materialized ways.

- Water Quality Target in JICA M/P was set based on the expected water use of the Bay. There was not enough consideration of the technical possibility of the achievement.
- JICA M/P proposed to reduce two third of required pollutant load to achieve the target by countermeasures other than sewerage system and ocean outfall of the effluent of the sewage treatment. However, these countermeasures were not and have not been an established technology. Although there are examples of the application in many places, they should be considered at a research and development stage.
- A master plan should make a clear pass to the target by proposing countermeasures supported by currently available technology.

Therefore, to realize the improvement, JICA M/P shall be modified so that the target and the countermeasures are consistent with each other and are viable. The Study adopts following strategy to make the JICA M/P more viable:

- To position the sewerage system development as the main focus of the improvement measures.
- To reestablish the water quality target so it can be achieved by viable countermeasures.

More details are discussed in following sections.

4.5.2 MAIN FOCUS OF IMPROVEMENT COUNTERMEASURES

(1) Reliable Countermeasures

Sewerage system is a well-established technology adopted for the reduction of the pollution load to the environment. It was one of the only two countermeasures for which effect was quantified in JICA M/P. However, while it is the reliable method for the pollutant reduction, it has following limitations:

- Practically, it is not possible to fully cover the basin. Remaining un-treated wastewater will flow into the bay.
- Sewerage system can reduce the pollutant loads only from point sources, but can not reduce pollutant loads from non-point sources, such as surface flash out from urban areas and runoff from agriculture land, forest, pasture, and so on. Pollutant load from the non-point-source is not small; it is particularly significant for nutrient loads that cause eutrophication.

Therefore, the improvement of water quality of closed water bodies requires more comprehensive countermeasures to reduce the pollutant load from the non-point sources. Along this line, JICA M/P proposed several countermeasures.

It is a matter of fact that every proposed countermeasure reduces the pollutant load to some extent, however, none can block 100% of it. Therefore, the Study adopts the sewerage system as a main focus of the countermeasures to achieve water quality target. Although this concept doesn’t exclude measures other than sewerage system, their expected effect would be counted just as supplemental but not indispensable to achieve the target.

(2) CEDAE Master Plan

“Plano Director de Esgomento Sanitário da Região Metropolitana de Rio de Janeiro” (referred to as CEDAE M/P in this report) covers the whole metropolitan area of the State of Rio de Janeiro, including the entire basin of Guanabara Bay. CEDAE M/P covers the Guanabara Bay basin with 16 sewerage systems. Sewerage systems of some of the 16 systems have been implemented as parts of PDBG. They did not necessarily follow CEDAE M/P, but they can be practically considered as parts of CEDAE Mater Plan.

Consecutive implementation of CEDAE M/P could work out as the improvement measures of the Guanabara Bay environment. However, nearly 10 years has past since CEDAE M/P was formulated, and conditions around the sewerage system, such as population and economic activities, have deviated from those predicted in CEDAE M/P. Moreover, since CEDAE M/P does not take enough consideration of the relation between the sewerage system and the Guanabara Bay environment, it will not produce the effective improvementrequired.

Therefore, CEDAE M/P is reviewed in Chapter 5 to update it to meet the actual conditions and it is proposed in Chapter 6 as a strategy plan to achieve the water quality target by evolving it around the water quality improvement of Guanabara Bay.

4.5.3 Supplemental Improvement Measures

While the strategy to be proposed does not adopt countermeasures other than sewerage to achieve the water quality target, it is still worth to consider those countermeasures to supplement the environmental improvement by the sewerage development.

Characteristics of major supplemental improvement countermeasures are discussed as follows:

(1) Dredging of Bottom Sediment

Bottom sediments have two adverse effects to the bay environment.

One adverse effect is sensuous unpleasant condition in terms of visual and smelly effects caused by the bottom sediment. The bottom sediment is rich with organic materials that consume oxygen in water resulting in anaerobic conditions. Under anaerobic conditions, organic materials rot, generating black color materials and the smell of sulfide.

Another adverse effect is acceleration of eutrophication. Bottom sediment is rich with nutrients, such as phosphate and nitrogen. It releases nutrients to water. As long as there exists bottom sediment, reduction of the nutrient inflow from the basin has its limitations for control of the eutrophication.

It would not be easy to estimate the quantitative effect to eutrophication control by the sediment removal. However, the sediment removal could have a significant effect to reduce visual or smelly unpleasant conditions.

There are several studies on sediment dredging focusing the Fundao channel. However, mainly due to difficulty in treatment and disposal of dredged sediment, any plans have not been judged to be feasible. To develop an acceptable waterfront, it is essential to dredge the sediment, as well as to improve water quality. Therefore, it is required to continue studies Sfocusing on sediment disposal.

(2) Removal of Garbage

Garbage in water causes visual problems, too. There two types of garbage in water.

One is the garbage that has an origin of natural materials that are supplied by river runoff, such as trees, branches and leaves. Another is the garbage that is thrown into river carelessly or intentionally. The latter depends on people’s behavior. Low concern about the environment allows garbage disposal to the rivers. In this regard, environmental education could have a significant effect on people’s behavior.

(3) Mangrove Preservation and Reforestation

Mangrove is important to the natural environment. It must be preserved at least as it is. In addition, it has a purification function by settling down the suspended materials in the water by its intricate root system. Moreover, it is believed that it decomposes settled materials by its metabolism. Unfortunately, however, there is no quantitative evaluation of these functions. Mangrove preservation and reforestation is recommended as a measure for the restoration of the natural environment.

(4) Conservation of Wetlands

Wetlands act as a sedimentation pond. Some amount of the pollutant materials in the river water can be settled by wetlands. Therefore, the existence of the wetlands could reduce the pollutant load from the river. The wetlands should be conserved; however, the reconstruction of the wetlands would be practically difficult because most of former wetlands has been already occupied with human activities, such as farming, residential area, roads and so on.

4.5.4 RE-ESTABLISHMENT OF WATER QUALITY TARGET

JICA M/P depicted the ideal condition of Guanabara Bay as “a level approximately equal to that prior to the mid 1960’s”. However, the earlier conditions of the Bay environment comprising physical, chemical and biological features has significantly been affected by human activities. This is the ultimate nonbinding target from the viewpoint that untouched nature is the target of the environmental improvement. However, in reality, aside from the preservation of untouched nature, improvement of the environment deteriorated by human activities is equivalent to the mitigation of the effect of human activities by another human activity. Therefore, in the improvement plan subject to being implemented, the target should be determined as a balance between the utility value of the environment and viability of the countermeasures.

The water quality classification of Guanabara Bay by DZ105 (refer to section 2.4 and *Figure 2.8* of this report) is considered to be the only one authorized target, which is related to the utility value of Guanabara Bay. Therefore, the Study considers it as a target required for water use of the Bay and the possibility of achievement is discussed from viewpoint of viability.

On the other hand, there could be another target, which aims to eliminate or mitigate intolerable conditions, for a highly polluted environment. In case of Guanabara Bay, it is well known that the western part of the bay always reeks of foul smell, particularly around the channels near Governador and Fundao Islands. Removal of this obnoxious unpleasant condition should have higher priority than the restoration of the utility value.

The improvement target is studied by evaluating the viability and is reestablished on the balance between the target required from the present bay conditions and viability by the sewerage system development.

(1) Preliminary Study on Achievable Target

To identify the pollutant load conditions that achieve the two improvement targets mentioned in the above section (the two achievement targets are represented by conditions shown *Table 4.13* for easy comparison.), water quality simulation calculations are carried out.

Table 4.13 Numerical Expression of the Two Improvement Targets

mprovement Targets	Description	Numerical Expression for Comparison 2)	Remarks
A	To remove the obnoxious unpleasant condition around the chanells near Governador and Fundao Islands.	BOD is less than 10 mg/l all the water quality monitoring points in the Bay.	Assuming the maximum BOD consentration that does not genrate the septic condition is 10 mg/l
B	Improvement Target Water Quality Classification by DZ105 1)	BOD is less than 5 mg/l all the water quality monitoring points in the Bay, except GN-022 and GN-043.	The classification assign Class 5, of which BOD criteria is less than 5 mg/l all the bay area, except port areas in Rio de Janeiro and Niteroi sides.

Note: 1) For schematic location, refer to *Figure 2.8* of this report.
2) For the location of the monitoring points, refer to *Figure 4.3*

1) Improvement Target A

As can be seen from *Tables 4.11* and *4.12*, to improve the western part of the Bay is required. Effects of four pollutant load conditions shown in *Table 4.14* are simulated.

Considering the high internal production of organic material (BOD) derived from photosynthesis, 50 % of T-P removal rate is adopted to load conditions. Although tertiary treatment to remove nutrient is not supposed to be practicable, as explained in another section, it is adopted as an enhanced sedimentation treatment, which has been already applied to some of WWTPs of PDBG.

Results of the simulation are shown in *Figure 4.5*. Since the most polluted area is the west part, only case of pollutant load reduction in the western zone has a significant effect. In *Figure 4.5*, although there remain small parts where BOD exceeds 10 mg/l, it is confirmed that improvement target A would be possible by a realistic pollutant load reduction.

Table 4.14 Pollutant Load Conditions Applied to Trial Calculations

Case	Pollutant Load Conditions	Zone where Pollutant Load is Reduced *
1	Generated Pollutant Load in 2000	Eaes (E)
2	BOD Rudction rate: 90%	Northeast (NE)
3	T-N Rudction rate: 30%	Northwest (NW)
4	T-P Reduction Rate: 50%	West (W)

Note: (*) For Division of the Bay basin, refer to *Figure 4.5*.

2) Improvement Target B

Figure 4.6 shows the best result of the improvement simulation in this Study. Against the improvement target to keep BOD of the bay water quality less than 5 mg/l almost everywhere in the Bay, there still exist areas where BOD exceeds 5 mg/l.

This simulation was made for pollutant load 2000 with the reduction rate; 90% for BOD, 80% for T-N and 80% for T-P. Such reduction rates are possible as removal ratios of tertiary treatment. However, the reduction rates used in the simulation are not removal ratios in WWTPs but ratios to be applied to the whole pollutant load in the basin to reach to the Bay. It includes pollutant load from people who are not connected to sewer system and pollutant load from non-point sources.

This means that even if the whole tertiary treatment development is completed, such high reduction rates cannot be accomplished. There is no effective and reliable measure to remove pollutant load from non-point sources.

Therefore, it is hardly possible to achieve this target by presently available technology from engineering viewpoint and it should be left as a nonbinding target.

(2) New Water Quality Target and Target Year

Based on the above results, three targets (short-term target, long-term target and middle-term target) are discussed as follows and new water quality target and target years are established as shown in *Table 4.15* and water quality target represented by water quality of the monitoring points is shown in *Table 16*:

1) Short-Term Target

Since the improvement target A is considered to be achievable by concentrating the sewerage system development to the western basin where the present situation requires urgent improvement, it is adopted as a short-term water quality target. As it is required to be improved in the earliest timing, the target year is set at 2010, considering required time for the preparation and construction. The treatment may require having a coagulant dosing process to remove some of T-P in wastewater, which has been adopted in some WWTPs of PDBG.

2) Long-Term Target

There are no currently available countermeasures to improve the Bay water quality to satisfy Water Quality Classification of Guanabara Bay by DZ105 (referred as the

Improvement Target B in the above discussion.). Therefore, Water Quality Classification of Guanabara Bay by DZ105 is improper as a target for plans to be realized.

The strategy plan will adopt the short-term target that aims to keep the bay water quality less than BOD 10 mg/l everywhere in the Bay to eliminate obnoxious conditions. According to the preliminary estimation, the pollution reduction to achieve the short-term target, in other words, the pollution reduction to improve the water quality of the western part of the Bay, also affects the water quality of whole bay area, expanding areas with BOD less than 5 mg/l (target water quality of Water Quality Classification of Guanabara Bay by DZ105) toward the northern part of the Bay.

Intermediate-range of the short-term target and Water Quality Classification of Guanabara Bay by DZ105 could be a more realistic target, which can be achieved by realistic countermeasures. Therefore, the Study proposes to make Water Quality Classification of Guanabara Bay by DZ105 the long-term target as an ultimate and nonbinding target without specific target year and to set a middle-term target that allows areas with BOD above 5 mg/l in limited area of the Bay.

2) Middle-Term Target

The middle-term target is a target to be achieved by the strategic plan to be proposed in a later section. The strategic plan was formulated based on a sewerage system development plan, as discussed in the preceding section. The sewerage system development plan is formulated based on foreseeable future conditions.

Therefore, year 2020, which is considered a year foreseeable with determinate accuracy, is proposed as the target year of the middle-term target. Water quality target is proposed to allow areas with BOD more than 5 mg/l in the western and eastern parts of the bay, while achieving BOD less than 5 mg/l in other areas.

Table 4.15 New Water Quality Target and Target Year

Terget	Descriotion	Target Year
Short-term	Removal of obnoxious conditions BOD is less than 10 mg/l at all the water quality monitoring points in the Bay.	2010
Middle-term	BOD less than 5 mg/l in all areas except western and eastern areas.	2020
Long Term	Water Quality Classification by DZ105.	Not specified

Table 4.16 New Water Quality Target Represented by Water Quality of the Monitoring Points

Monitoring Points[1)]	Short-Term Target (BOD less than mg/l)	Middle-Term Target (BOD less than mg/l)	Long-Term Target (BOD less than mg/l)
GN-064	10	5	5
GN-022	10	5	5
GN-043	10	10	5
GN-040	10	10	5
GN-020	10	10	5
GN-042	10	5	5
GN-000	10	5	5
GN-026	10	5	5

Note: 1) For the location of each monitoring point, refer to *Figure 4.3*.

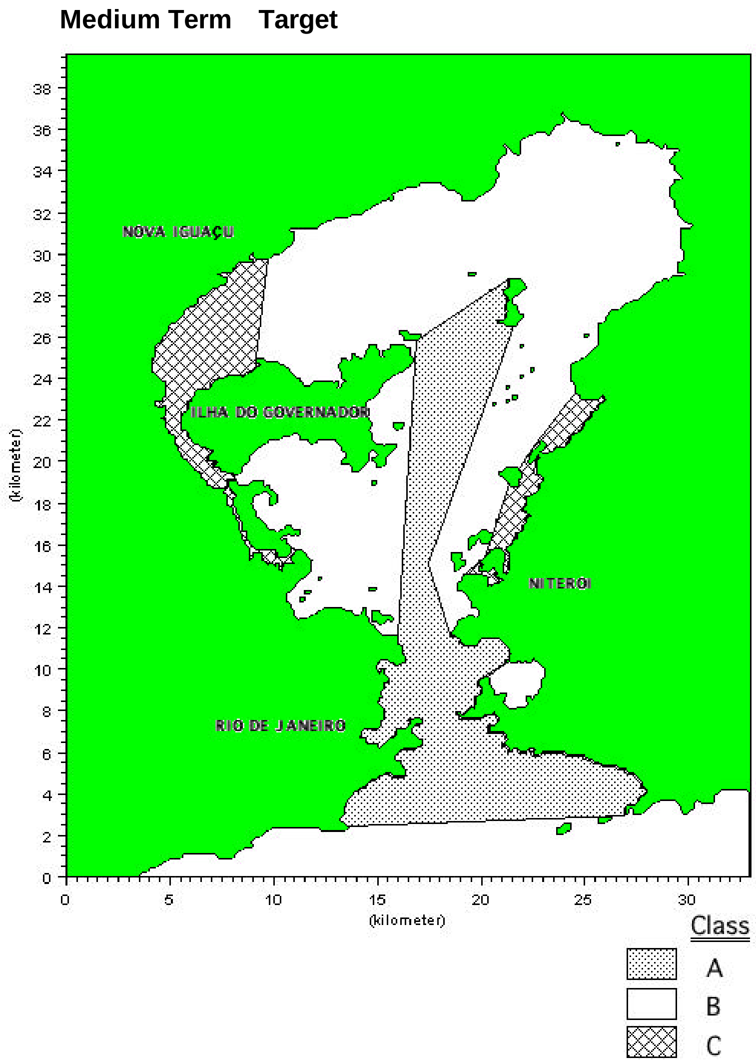
4.6 CONCLUSION

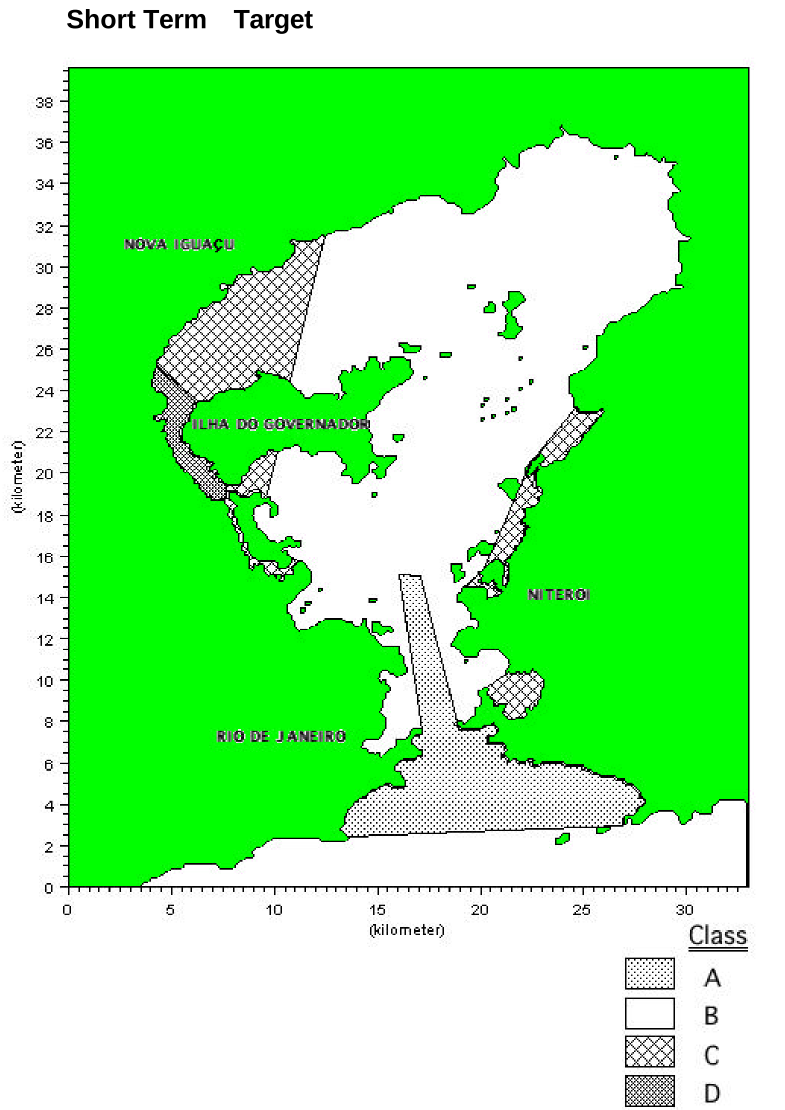
By reviewing JICA M/P, status of the realization of the Master Plan is as follows:

- JICA M/P proposed to improve the Guanabara Bay environment by the Combination of Countermeasures, which comprises sewerage system development and other supplemental improvement measures.
- It planned to reduce a third of the pollutant load reduction required to achieve the target by the sewerage system development and to reduce the remaining two third by the supplemental measures.
- Among the combination, only sewerage system development has been realized by one of project components of PDBG since JICA M/P. Scope of the sewerage system development of PDBG has already exceeded the one proposed by JICA M/P.
- However, no improvement effect has been recognized yet because the PDBG project was not completed. Moreover, it is predicted that on-going sewerage system development would not achieve an improvement target proposed in JICA M/P as "short term target".

Based on the above observation, the Study concludes a strategy for Guanabara Bay environment improvement as follows:

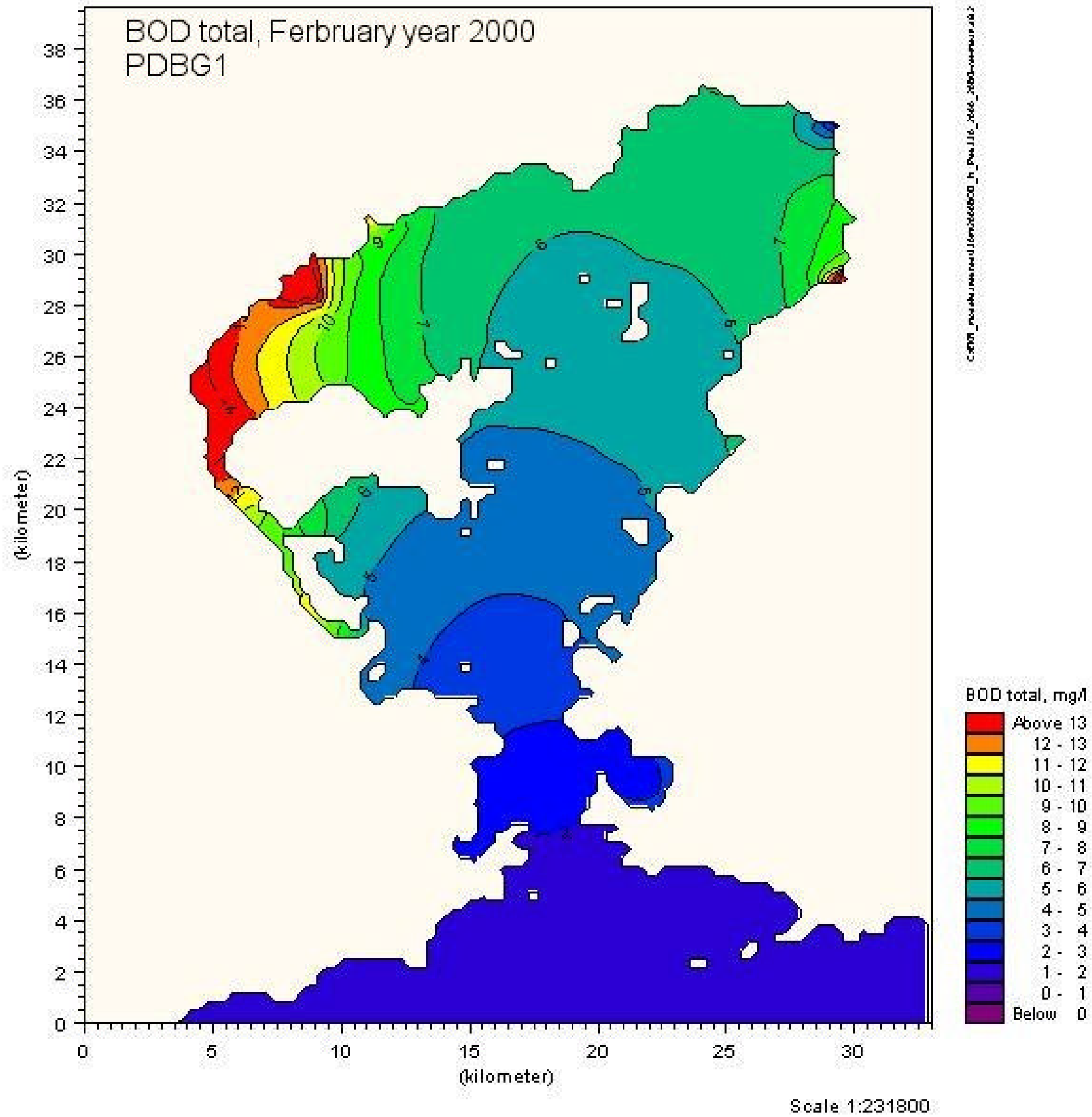
- Since supplemental countermeasures proposed in JCA Master Plan are not quantitatively appraisable in terms of improvement effect, thus can not be components of a plan to be realize, the Study adopts further sewerage system development as the major means of the improvement.
- Since there exists a CEDAE Sewerage Master Plan and some parts of it have been implemented by PDBG, the Study reviews CEDAE M/P and consequently proposes a strategy plan for the sewerage system development to improve the Guanabara Bay environment based on it.
- On condition that the principal improvement countermeasure adopted is sewerage system development, water quality target is reestablished as technical viabile.
- As result, Water Quality Classification of Guanabara Bay by DZ 105 has been adopted as a long-term non-binding target without specific target year and removal of obnoxious conditions (represented by "BOD less than 10 mg/l any place in the Bay) has been adopted as a short term target with target year 2010. Middle-term target has been established to further improve the Bay environment after the short-term target with a target year of 2020.





Note: For water quality indices, refer to Table 4.9
Source: Redrawing of JICA Master Plan

Figure 4.2 Classification of Guanabara Bay for Water Quality Target Proposed by JICA M/P



Assuming Completion of PDBG1 and Full Operation
Load Condition: 2000

Figure 4.4 Result of Water Quality Simulation (Case:PDBG1, 2000)

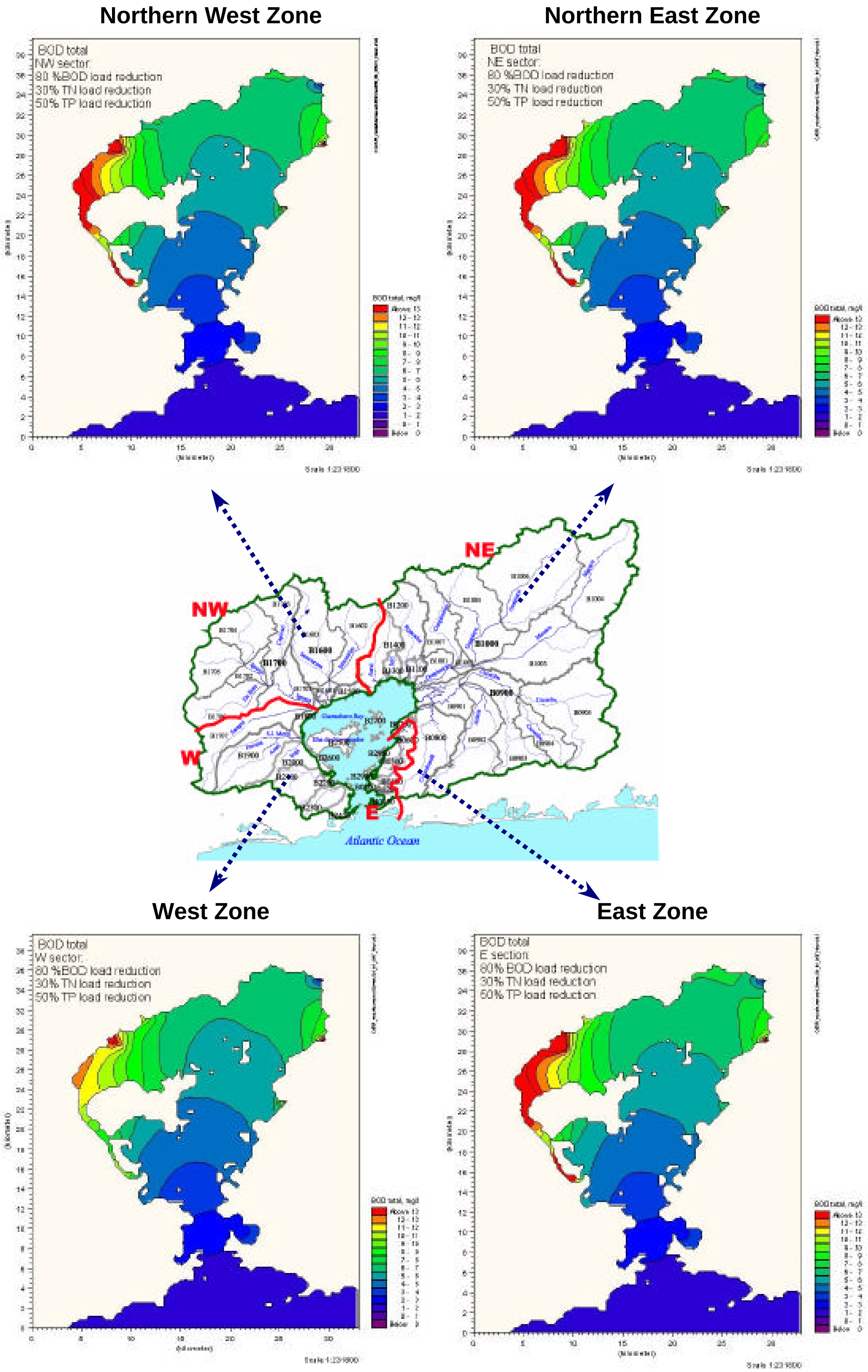
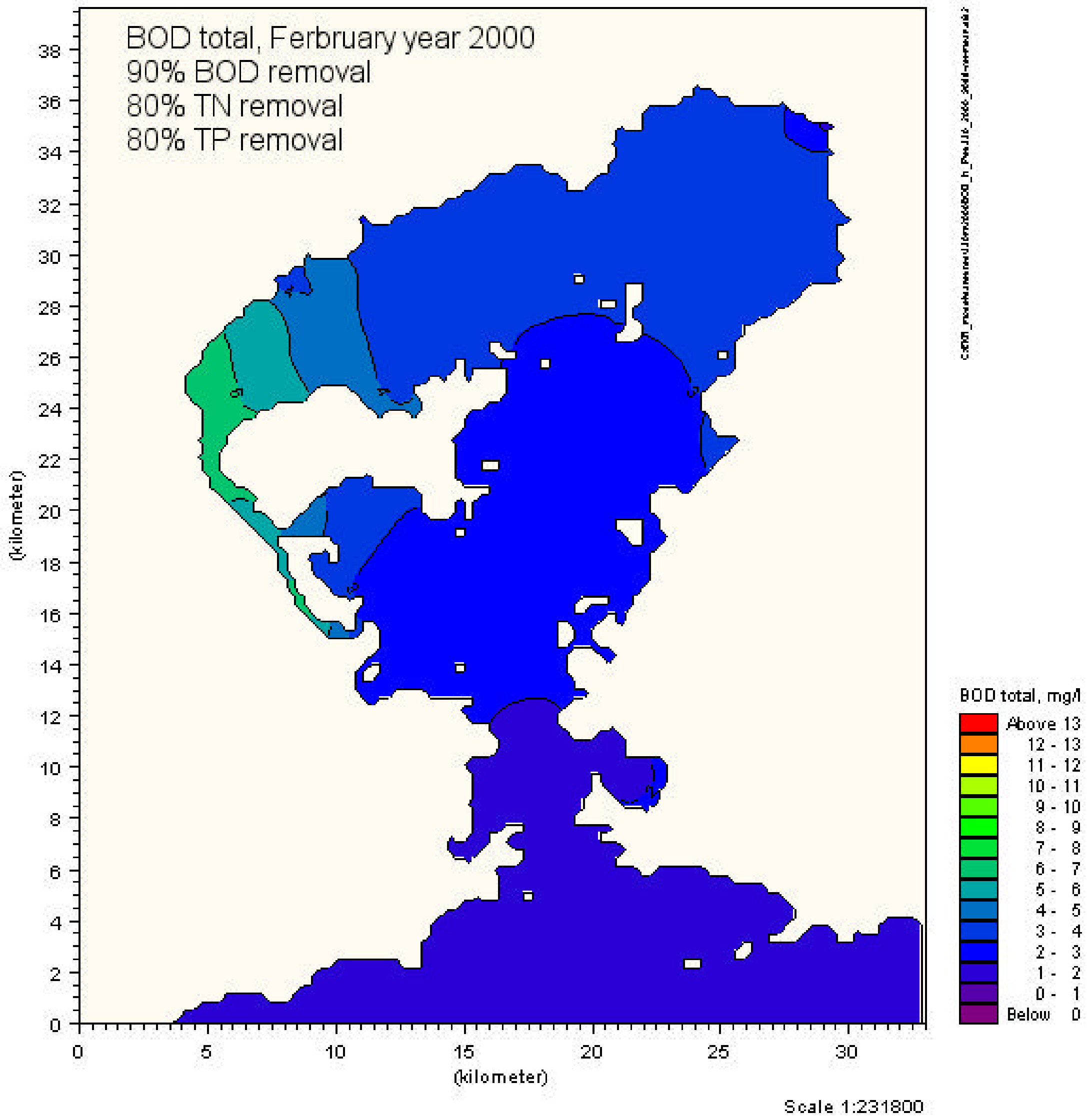


Figure 4.5 Comparison of Effects of Pollutant Load Reduction by Zone (Load Condition: 2000)



Pollution Reduction (pollutant load inflowing to the Bay), Load Conditions 2000

BOD: 90 %

T-N: 80%

T-P: 80%

Figure 4.6 Result of Water Quality Simulation
(Case: BOD90%, TN80%, TP80%, 2000)

CHAPTER 5

REVIEW OF CEDAE SEWERAGE MASTER PLAN

CHAPTER 5 REVIEW OF CEDAE SEWERAGE MASTER PLAN

5.1 PREVIOUS SEWERAGE SYSTEM MASTER PLANS

The Guanabara bay water pollution control programs conducted in the last decade have in principle followed the direction of "Plano Director de Esgotamento Sanitário da Região Metropolitana do Rio de Janeiro, 1994" (Sewerage Master Plan in Rio de Janeiro Metropolitan Region - CEDAE M/P) and "Study on Recuperation of the Guanabara Bay Ecosystem, 1994."(JICA M/P)

The existing sewerage facilities were rehabilitated and additional facilities constructed under the "Programa de Despoluição da Baía de Guanabara (PDGB)," generally in compliance with the national planning/design guidelines and criteria "ABNT- Associação Brasileira de Normas Técnicas"

5.2 REVIEW OF CEDAE MASTER PLAN 1994

5.2.1 PURPOSE OF REVIEW

The rationalization of existing sewerage systems under the CEDAE M/P intended to eliminate the current wastewater disposal problems in the State of Rio de Janeiro, and to improve the Guanabara Bay water quality that has already reached a deplorable level. CEDAE M/P elaborated the preliminary engineering design and feasibility study on sewers, pumping stations, and wastewater treatment plants (WWTPs) for the target year of 2035.

In the last decade, however, the State has experienced significant economic and social change in urban development, population growth, sewer service area, etc. which have significantly affected sewerage planning and design bases. In view of these, CEDAE M/P's original planning/design fundamentals were reviewed and updated where necessary, so that the latest developmental, social and socioeconomic conditions in the Study Area were reflected to the sewerage system planning/design in the subsequent implementation phases.

More specifically, the review includes:

(a) Sewer service population
(b) Wastewater flow rates
(c) Wastewater characteristics
(d) Hydraulic/pollutant loads to sewerage facilities
(e) Sewer Districts/Systems
(f) Sewered population
(g) Sewerage facilities
(h) Costs

The above essential issues were studied in light of the latest available data and information collected through CEDAE and other concerned agencies, and further elaborated by the results of field inspections and surveys conducted under the Study.

For the purpose of the Guanabara bay water improvement plan, the scope of CEDAE M/P review is limited to the 16 sewer systems located within the Guanabara bay basin area, and any other areas influential to the bay water improvement are also reviewed regardless whether or not they are integrated to the bay basin sewerage system.

5.2.2 POPULATION IN THE STUDY AREA

(1) Population Growth

The sewer service populations estimated in the master plan prepared by CEDAE in 1994 (CEDAE M/P) were those to be served by the sewer systems at the different implementation stages. In CEDAE M/P, the sewer service populations were estimated on the basis of the 1991 population census data, and forecast for every five-year from 1993 through 2035.

The population distribution in each sewer system was then estimated by the population density obtained from water supply bills and population census data, together with the land use patterns in the Region.

Table 5.1 summarizes the estimated sewer service populations in CEDAE M/P by sewer system and year:

Table 5.1 Estimated Population Growth

Sewer System	1993	1995	2000	2005	2010	2015	2020	2025	2030	2035
1. Alegria	1,277,291	1,283,028	1,297,693	1,312,831	1,328,461	1,344,596	1,361,256	1,378,458	1,396,219	1,414,560
2. Penha	517,019	522,473	536,609	551,494	567,167	583,672	601,050	619,349	683,618	658,907
3. Pavuna-Meriti	1,604,894	1,612,292	1,631,125	1,650,447	1,670,272	1,690,612	1,711,481	1,732,893	1,754,862	1,777,401
4. Sarapuí	714,087	747,389	837,596	856,904	856,904	856,904	856,904	856,904	856,904	856,904
5. Bangu	188,869	195,352	212,551	231,265	251,627	273,781	297,886	324,113	324,113	383,698
6. Bota	805,316	829,445	893,201	962,205	1,036,930	1,117,902	1,205,695	1,300,945	1,404,353	1,516,701
7. Iguaçu	123,893	127,548	137,275	147,910	159,534	172,244	186,138	201,329	217,935	232,489
8. Estrela	239,637	249,310	275,543	305,011	338,152	375,456	417,488	464,895	518,410	578,873
9. Roncador	95,996	98,292	104,406	111,096	118,414	126,418	13,176	144,754	155,160	166,538
10. Macacu	147,680	156,514	181,471	211,258	246,981	290,018	342,108	405,436	482,766	577,600
11. Guaxindiba	82,790	88,656	105,203	124,837	148,136	175,784	208,593	247,524	293,722	348,542
12. Alcântara	363,047	363,047	363,047	363,047	363,047	363,047	363,047	363,047	363,047	363,047
13. Imboassu	264,820	267,229	273,460	276,293	279,243	282,317	285,518	288,853	292,327	295,945
14. Norte-Niterói	171,957	171,957	171,957	171,957	171,957	171,957	171,957	171,957	171,957	171,957
15. Sul-Niterói	172,743	172,743	172,743	172,743	172,743	172,743	172,743	172,743	172,743	172,743
16. Governador	164,008	164,008	164,008	164,008	164,008	164,008	164,008	164,008	164,008	164,008
17. Paquetá	9,369	9,549	10,035	10,579	11,187	11,867	12,627	13,477	14,427	15,490
Total	6,943,416	7,058,832	7,367,923	7,623,885	7,884,763	8,173,326	8,371,675	8,850,685	9,266,571	9,695,403

Source: Plano Diretor de Esgotamento Sanitário da Região Metropolitana do Rio de Janeiro e das Bacias Contribuintes a Baía de Guanabara, Agosto/1994.

For the prediction of wastewater production rates, CEDAE M/P assumed that 10% of the residents within the public sewer service areas would have no access to the sewers even in 2035. The population to be sewered in 1993 of 7,664,500 was forecast to reach at 9,990,000 by 2035.

Since the 2000 population census data is now available by the administrative unit, the estimated populations both by CEDAE M/P and 2000 census data were compared with each other for their differences. The administrative population of 10,312,300 in 2000 is estimated to reach 11,770,900 in 2020, whereas CEDAE M/P's 7,367,900 populations in 2000 were assumed to increase to 8,371,700 by 2020. The populations estimated by the M/P and 2000 census data could not be directly compared, since CEDAE M/P estimated that 90% of the residents in the sewer districts would have access to the public sewers.

After CEDAE M/P was developed, some sewer districts were either integrated or separated due to the changes of urban development and socio-economic patterns (e.g. a part of Ipanema sewer district was integrated to Alegria district to divert the wastewater to Alegria WWTP). Accordingly, the area and service population in such districts have been modified.

The present boundaries of other sewer districts/systems have also been checked in view of the present situations of the areas, and where necessary, adjustments for demarcation were made to fit the actual conditions. The updated sewer districts/systems are shown in *Figure 5.1*.

The population distribution to each sewer district estimated by CEDAE M/P and those adjusted based on the 2000 population census data are compared in *Table 5.2*.

Table 5.2 Population and Service Area of Sewer Systems

Sewer System	Population (2000)			Estimates for future		
	(1) M/P	(2) 2000 census	(3) Ratio (2)/(1)	(4) 2035 M/P	(5) 2020 2000 census	(6) Ratio (5)/(4)
Alegria	1,297,693	1,359,500	1.05	1,414,560	1,449,300	1.02
Penha	536,609	605,300	1.13	658,907	645,300	0.98
Pavuna-Meriti	1,631,125	1,455,600	0.89	1,777,401	1,577,500	0.89
Sarapuí	837,596	854,000	1.02	856,904	993,700	1.16
Bangu	212,551	378,500	1.78	383,698	403,600	1.05
Bota	893,201	1,010,400	1.13	1,516,701	1,274,400	0.84
Iguaçu	137,275	231,300	1.68	232,489	300,400	1.29
Estrela	275,543	334,100	1.21	578,873	450,500	0.78
Rancador	104,406	137,000	1.31	166,538	202,400	1.22
Macacu	181,471	287,200	1.58	577,600	400,000	0.69
Guaxindiba	105,203	196,700	1.87	348,542	252,400	0.72
Alcâtara	363,047	401,800	1.11	363,047	499,500	1.38
Imboassu	273,460	266,900	0.98	295,945	336,700	1.14
Norte-Niterói	171,957	183,400	1.07	171,957	202,200	1.18
Sul-Niterói	172,743	183,400	1.06	172,743	202,200	1.17
Ilha do Governador	164,008	211,500	1.29	164,008	225,500	1.37
Paquetá	10,035	3,400	0.34	15,490	3,700	0.24
Total	7,367,923	8,100,000	1.10	9,695,403	9,419,300	0.97

Note: The figures under (1) and (4) are those to be served by the sewerage system (Administrative population x 0.9).

Assuming that 90% of the 2000 and 2020 census-based population would be served by the sewers, the overall sewered population in 2020 is estimated, and compared with the 2035 estimate by CEDAE M/P in *Table 5.3*.

Table 5.3 Sewer Service Populations Forecast by M/P and 2000 Census Data

Estimate Bases	2000	2020	2035	Remarks
CEDAE M/P population (1994)	7,367,923	(*) 8,371,675	9,695,403	In Guanabara bay basin area
2000 census-based population	7,290,000	(*) 8,477,370	-	Administrative population x 0.9

Note: (*) See *Table 5*.1 & *2*.

In view of the above and population growths trend in the Study Area, it appears that the sewer service populations estimated in CEDAE M/P are generally in agreement with those by the 2000 census data.

Although small deviations exist between the estimated populations by CEDAE M/P and 2000 census data, in most cases these are within an acceptable range for the hydraulic capacities of the sewers. The estimated population distribution in the sewer districts/systems based on the 2000 census and the resultant wastewater flow rates are apparently applicable for the hydraulic calculations of sewerage facilities.

(2) Design Sewer Service Population

For the sewerage planning in Rio de Janeiro, the 2000 census population in each administrative sub-district is allocated to the sewer district/system. For other municipalities, the 2000 census population within each municipal boundary is also allocated to each sewer district/system, considering the size of sewer system area and extent of urbanization. Although the administrative population in each sub-district and neighborhood areas are available in the 2000 census data, some of the boundaries of related administrative districts are hardly identified in the available maps.

The actual 2000 census populations in Bota, Estrela, Macacu, Guaxindiba and Paqueta systems are smaller than those forecast in CEDAE M/P, particularly in Paquetá system that probably included tourists numbers. In other sewer systems, CEDAE M/P populations are higher than the 2000 census populations, as CEDAE M/P calculated the population growth by the geometric progression method. When the 2000 and 2035 populations are compared, the ratios are 1.7 for Bota, 2.1 for Estrela, 3.2 for Macacu, and 3.3 for Guaxindiba.

5.2.3 WASTEWATER FLOW RATES

(1) Water Consumption Rates

Table 5.4 shows the present water supply conditions in the municipalities within the Guanabara Bay Basin:

Table 5.4 Water Supply Conditions in Municipalities in Guanabara Bay Basin

Municipality	Inhabitants (A)	No. of family Members (B)	Number of service connection (C)	Served Population (D) = (B) x (C)	Service pop. ratio to inhabitants (E) = (D)/(A) x100
1. Rio de Janeiro	5,472,967	3.50	1,413,344	4,946,704	90.38
2. Duque de Caxias	661,671	3.85	115,639	445,210	67.29
3. Nilópolis	157,936	3.76	35,869	134,867	85.39
4. Nova Iguaçu(*)	1,290,289	3.93	207,323	814,779	63.15
5. São João de Meriti	424,689	3.83	97,533	373,551	87.96
6. Itaboraí	145,933	3.94	5,965	23,502	16.10
7. Niterói	435,658	3.49	104,705	365,420	83.88
8. São Gonçalo	778,820	3.75	146,786	550, 448	70.68
9. Rio Bonito	27,147	3.95	3,229	12,755	46.98
10.Magé	171,921	3.95	15.395	60.668	35.29
11.Cachoeiras de Macacu	32,016	3.89	1,429	5,559	17.36
Total	9,599,047		2, 147,181	7,733,463	80.56

Note: (*) Includes Belford Roxo, Queimados and Japeri.

Source: CEDAE, 2000 data.

Table 5.5 presents a summary of major management and physical conditions of the present water supply system in the Rio de Janeiro and part of Guanabara Bay Basin.

Table 5.5 Water Supply Management and Physical Conditions

Items	May 1999	May 2000	May 2001
1. Water service populations	9,572,493	9,530,996	9,321,605
2. House connections	1,445,923	1,423,722	1,405,851
Urban districts	1215257	1232498	1206778
Other districts	230,666	191224	199073
Residential districts	1,322,180	1,302,410	1,289,479
Commercial districts	111,639	109,318	104,682
Industrial districts	6,265	6,032	5,626
3. Metered numbers	857,987	862,697	864,473
Urban districts	711,463	726,784	719,942
Other districts	146,524	135,913	144,531
4. Distribution/transmission pipes length (m)	14,015,572	13,450,903	13,514,888
5. Water production (m^3/month)	153,539,954	150,423,763	152,825,380
6. Accounted for water (m^3/month)	69,410,466	62,324,964	61,361,678
7. Water supply to poor (m^3/month)	17,679,605	17,679,605	17,679,605
8. Per capita water production rate (lpc)	534.66	526.09	546.49

Source: ”Resumo de Informações Gerencias” Governo do Estado do Rio de Janeiro.

(2) Estimate of Domestic Wastewater Flow Rates

The wastewater flow rates estimated in CEDAE M/P included the domestic, commercial, industrial and institutional wastewaters, and infiltration/inflow for each sewer district for every five years until 2035. The domestic wastewater generation rates were estimated from the per capita water consumption rates, assuming that 80% of the consumed water would turn into the domestic wastewater.

CEDAE estimated that the present water supply system has an average leakage loss of approximately 30%, and 40% of unaccounted for water. An average daily per capita domestic wastewater may be at around 300 Lpcd.

CEDAE M/P estimated the average daily per capita wastewater flow rates for the sewer district groups in varying degrees depending on the local conditions. These were allegedly estimated by the per capita water consumption rate specific to each sewer district, which range between 200 and 400 Lpcd, as given in *Table 5.6*.

Table 5.6 Average Daily Per Capita Wastewater Flow Rate by District (Lpcd)

Flow Rates		Districts
a.	200	Districts other than those listed below.
b.	220	Do Bomba, do Guandu-Mirim, de São Pedro, de Santo Antônio, do Ouro, do Guandu 02, dos Poços, de Camboatá, de Queimados, de Ipiranga, da Madame, de Iguaçu 02, dos Fornos, do Fornos, do Felicia, do Imbariê, e do Timbó Faria.
c.	230	De Sarapuí, dos Velhos, do Canal da Banderia, do Capivari, do Pilar, do Saracuruna, do Farias, do Iguaçu 01, do Pavuna Meriti 02, e de Irajá.
d.	235	do Rio das Pedras.
e.	240	do Bota, do Centro, do Sul, de Piratininga, do Jacaré, de Camboinhas, do Mendes, de Itacoatiara, de Vigário Geral, da Penha, e Paquetá.
f.	250	do Guandu 01, e de Alegria.
g.	260	de Grumari, de Sernambeita, de Marapendi, da Ilha do Governador 01, da Ilha do Governador 02, do Fundão, do Arroio da Vavuna, de Jacarepaguá 01, de Jacarepaguá 02, de Jacarepaguá 04, do Canal do Anil, da Lagoa da Tijuca 01, da Lagoa da Tijuca 02, e da Lagoa da Tijuca 03.
h.	270	doJoiville, do Guarda, e de Sepetiba 02.
i.	300	de São Cristóvão.
j.	320	de São Conrado, da Lagoa Rodrigo de Freitas, e de Copacabana.
k.	400	de Botafogo, da Glória, do Centro, do Catumbi, e do Mangue.

Source: Plano Director de Esgotoament Sanitário da Região Metropolitana do Rio de Janeiro e das Bacias Contribuintes á Baía de Guanabara.

Lpcd: Liter per capita per day

(3) Industrial Wastewater Discharge to Publicly Owned Sewers

The principal concept on how to handle the industrial wastewater in CEDAE M/P is that the industrial enterprises are responsible to treat their own industrial wastewater. Large-scale enterprises (such as port, shipbuilding and other industries) are required to treat their wastes to meet the permissible discharge qualities to public water bodies.

The wastewater discharge from small-scale manufacturers is considered compatible with today's standards and is accepted by the publicly owned sewers. Thus, theoretically no substantial amount of industrial wastes is discharged to the sewers from small manufacturers. In CEDAE M/P, the industrial wastewaters were volumetrically included by percentage in the domestic wastewater flows, having been determined by local conditions.

(4) Wastewater flows to Sewers

From the foregoing discussions, CEDAE M/P estimated the design wastewater flow rates in the following ways:

- Average daily per capita wastewater flow rates : Per capita water consumption rate x 0.8
- Maximum daily wastewater flow rates : Average daily wastewater flow rate x 1.2
- Maximum hourly wastewater flow rates : Average daily wastewater flow rate x 1.8
- Minimum wastewater flow rates : Average daily wastewater flow rate x 0.5
- Infiltration to the sewer : 0.05~1.0 L/s km of sewer length
- Sewer service population : 90% of the total residents

In sewerage systems elsewhere, infiltration rates range between 10% and 20% of the maximum daily flow rates. Since groundwater infiltrates mainly through pipe joints and/or pipe cracks, it may be more reasonable to calculate infiltration based on the sewer length; however, as the data of existing sewer lengths are lacking, it is not possible to estimate the exact infiltration rate by the sewer pipe length, particularly of the existing sewer lines. Although it is not so clear, the design wastewater flows in CEDAE M/P have apparently included the infiltration.

(5) Wastewater Characteristics

The major parameters for the wastewater pollutant loads, in terms of BOD_5 and SS, were set in CEDAE M/P at 54 and 60 g/cpd, respectively, following the guidelines in the National Design Standards (Norma NB-570, Item 5.2). Such other pollutant parameters not defined in the Standards as COD, T-N and T-P, were set in CEDAE M/P based on the field data and experience obtained.

Although persuasive long-term data is not readily available to clearly indicate the trend of changes in per capita pollutant production rate, these values seem to be within the range of medium strengths. As compared with other wastewater systems under the similar conditions, these are to be used appropriately for sewerage planning purposes.

As previously discussed, CEDAE M/P estimated the average wastewater pollutant concentration in each sewer district, by using the per capita pollutant load and wastewater production rate specific to the sewer district.

As indicated in *Table5.7,* CEDAE M/P also set design average BOD, SS, COD, T-N and T-P, for the WWTP design and evaluation.

Table 5.7 Estimated Wastewater Pollutant Loads Concentrations

Degree of WWTP Processes	Type of WWTP Processes	SS (mg/L)	BOD (mg/L)	COD (mg/L)	T-N (mg/L)	T-P (mg/L)
Raw wastewater	-	200	220	500	40	10
Primary process	Sedimentation	100	155	350	38	9
Secondary process	Conventional activated sludge	30	25	75	30	8
Secondary process	A.S. + nitrification.	20	10	35	30	8
Secondary process	A.S. + nitrification + dentrification	20	10	30	8	8
Secondary process	A.S. + biological P removal	15	10	30	20	2
Tertiary (advanced)	A.S. + N.P. removal + Filtration	10	5	25	< 5	< 2

Note: A.S.= activated sludge process

Source: Plano Director de Esgotoament Sanitário da Região Metropolitana do Rio de Janeiro e das Bacias Contribuintes à Baía de Guanabara.

While CEDAE M/P estimated the domestic pollutant loads were based on the per capita loads, the industrial wastewater pollutant loads were allocated to each sewer district by percentages to the domestic wastewater loads following FEEMA's instructions.

5.2.4 WASTEWATER COLLECTION SYSTEM

(1) Present Sewerage Systems

The Region's sewerage system is in principle a separate system to collect the dry weather flow (DWF) only. However, a significant quantity of stormwater runoff inflows to the sanitary sewers at many locations once it rains, resulting in increased wastewater commingled with stormwater runoff that finally inflows to WWTPs.

CEDAE M/P planned to cut off the discharge of raw wastewater to the public water bodies and lead it to WWTPs. A large portion of the wastewater could flow by gravity to interceptor sewers, but on the way to WWTPs, pumping stations were planned to lift the wastewater to further continue the gravity flow.

As the existing sewer systems already cover most of the central districts of Rio de Janeiro City and its neighboring districts, it is likely that the drastic modification of the present sewer layouts and districts is not viable, except for minor modifications to either integrate or separate sub-districts due to the change of physical development and socio-economic conditions.

(2) Sewer Systems/Districts

CEDAE M/P defined an area for sewer implementation as "Sewer System" with WWTP(s), dividing the whole Rio de Janeiro State area into 32 sewer systems, out of which 16 sewer systems are located within the Guanabara Bay Basin. In some sewer systems, the area is further divided into "Sewer District(s)," which is a unit of sewered area served by a WWTP.

Although a part of Ipanema sewer system is topographically located in the bay basin area, the whole system is excluded from the Guanabara Bay Basin sewerage system, because the collected wastewater is led to the Atlantic Ocean through an ocean outfall along the Ipanema beach.

Among the municipalities within the Bay Basin, sewerage plans for Petrópolis, Chachoeiras de Macacu, and Rio Bonito were not developed in CEDAE M/P due to their low implementation priority.

(3) Design Sewer Service Populations

As previously discussed, the future population was estimated on the assumption that the population increase would follow a geometric progression, and some municipalities could have forecast higher population growth rates than the actual ones.

As a result, in certain sewer systems the population is as high as four times the base year over a 35-year period, while others might have no population increase at all. The population in Guaxindiba sewer system was estimated to increase four times higher than the Alcântara sewer system, although both systems are located side by side.

The geometric progression is in general appropriate for the short-term forecast, but may not be fitting for a long-term prediction of more than forty years or so, since it could give either too large or too small increase or decrease depending on the assumptions.

(4) Sewers and Pumping Stations

Most of the sewer systems have pumping stations that transfer the wastewater through force main pipes. Pavuna-Meriti and Sarapuí systems will have to build several pumping stations due to the prevailing topographic conditions. Pavuna WWTP may receive the wastewater through four pumping stations, and Sarapuí WWTP through three pumping stations.

The sewerage system is generally planned to collect the wastewater from the maximum possible area to minimize the number of WWTPs. In some cases, main sewers were planned along the rivers where no roads exist for laying sewers. If such is the case, it would be more economical to divide the district into two or more sub-districts following the local conditions, but these require further investigation and more data on existing facilities.

(5) Upgrade/Modification of M/P

Because of the changes that actually took place in the population distributions and urban developments, parts of the originally planned sewer district boundaries, WWTP site locations, etc. had to be modified depending upon the local situations. Thus, some sewerage systems have not been implemented exactly as CEDAE M/P originally intended. Some sewer districts have been either separated or integrated in the course of sewer planning and construction by CEDAE.

Table 5.8 summarizes certain modifications that have already been made in the sewerage systems:

Table 5.8 Change/Modification of CEDAE M/P

Sewer System	Content
1.Alegria	Centro, Portuária, Rio Comprido and Santa Teresa originally belonged to Ipanema were diverted to Alegria system. The population in these areas in 2000 was approximately 110,000.
2.Pavuna-Meriti	Part of the area to be covered by Acarí WWTP was integrated into Pavuna WWTP due to the topographic conditions.
3.Sarapuí	As the site for Edson Passos WWTP was already used for other purposes, the wastewater from this area was diverted to Sarapuí WWTP.
4.Imboassu	The names of WWTPs were changed, from Imboassu to São Gonçalo and Barro Vermelho to Bomba. Niterói City was excluded from Bomba district because it was privatized, hence Bomba district area was reduced.

Source: CEDAE's sewer planning/design.

In addition, some of the pressurized systems in Pavuna and Sarapuí sewer districts were altered to the gravity flow system.

5.2.5 WASTEWATER TREATMENT PLANTS (WWTPS)

(1) Wastewater Flows to WWTPs

In CEDAE M/P, the highest average daily wastewater flow rate of 300 Lpcd was applied in Alegria sewer system, while the lowest rate of 200 Lpcd to most other systems. Since the exact sewer lengths are not obtainable at present for CEDAE M/P review, infiltration is assumed to be 20 Lpcd. WWTP hydraulic capacities are to be calculated based on the average daily flow rates, but for conduits or other similar facilities, the maximum hourly flow rates will be applied.

The Brazilian Standard (NB-570.5) recommends the following criteria in *Table 5.9* for WWTP design.

Table 5.9 WWTP Hydraulic Loads Criteria

Flows	Flows for WWTP facility hydraulic design
Maximum hourly flow rate	Raw sewage pumping stations, channels and flow meters, inlet and outlet devices.
Average daily flow rate	All units and channels preceded by storage tanks with constant inflow rate.

(2) WWTPs' Capacities

Under CEDAE M/P a total of 42 WWTPs were planned in the 16 Guanabara Bay Basin sewer systems. *Table 5.10* presents WWTPs constructed before 1993 and under PDBG Phase I.

Table 5.10 Existing/Planned WWTPs

Construction Stages	WWTPs
WWTPs constructed before 1993	Penha, Acarí, Gramacho
WWTPs constructed under PDBG Phase I	Alegria, Pavuna, Sarapuí, São Gonçalo, Icaraí, Ilha do Governador, Ilha Paquetá,

Under the PDBG Phase I, totally ten WWTPs have either been constructed or expanded; thereby increasing the overall wastewater treatment rate from the present 13% to 51% as estimated by CEDAE.

The total WWTPs capacity will be increased to 11,669 L/s, serving about 3.9 million populations estimated for 2035, if and when all the WWTPs are completed and start their operation. The overall BOD removal efficiency will reach about 48% when the supplementary secondary treatment facilities are completed.

CEDAE M/P calculated WWTP component capacities based on the future sewered population, wastewater quantity and qualities predicted for the year 2035. The selected WWTP construction sites are located generally in the outskirt of the built-up urban districts and downstream of river/ drainage basins.

In Penha WWTP, some of the existing facilities were rehabilitated and upgraded. The sludge dewatering equipment was installed under the PDBG Phase I with no enhancement of wastewater treatment capacity.

All the newly planned WWTPs will be of the conventional activated sludge process, but in the near future it is likely that advanced treatment process might be added since more stringent water quality standards will be enforced.

Actual plans of modification, addition or expansion for the advanced treatment processes were not prepared in CEDAE M/P, while WWTP effluent nutrient contents are subject to control by the Water Quality Standards NT-202, R10 (1.0mg/L for T-P and 10 mg/L for T-N).

(3) Sludge Disposal

The treated sewage sludge from WWTPs is currently hauled mainly to the Gramacho sanitary solid disposal site for final disposal. The sewage sludge, either digested, chemicals amended or undigested, is air-dried or mechanically dewatered. The dried or dewatered sludge is hauled to the solid disposal site for final disposal, but according to the official estimate the disposal site may become full within several years.

The total 2020 average daily wastewater flow rate based on the revised population forecast is estimated to be 23,491 L/s (approximately 2,030,000 m^3/d) whose BOD and SS concentrations are 220 mg/L and 200 mg/L, respectively. If all the wastewater is treated in the activated sludge WWTPs with SS removal ratio of 90% and the dewatered sludge contains 25% solids, the sludge production is expected to be 1,460 ton/day (wet basis). It is worth recognizing that sludge production depends on the progress of sewers implementation and house connections and the WWTPs' performance.

Sludge production per capita per day is calculated as follows:

Supposing - wastewater production per capita per day of 200 L/capita/day,
- influent SS concentration of 200 mg/L, and
- SS removal ratio of 90%,
  then, SS removed = (200x200x0.9)/1000 = 36 g/capita/day (dry basis)

Supposing - moisture content of dewatered sludge of 75%,
  then, sludge production = 36/(1-0.75) = 144 g/capita/day (wet basis)

On the other hand, daily production of municipal solid waste is said to be 800 to 1000 g/capita /day (wet basis), or 5.5 to 7 times more than sewage sludge. Taking this point into account, final disposal of sludge will be investigated in close relation to municipal solid waste disposal.

Sludge reduction is another important factor to consider. Sludges withdrawn from primary and secondary clarifiers are reduced to a half by thickening and to 1/25 by dewatering. If dewatered sludge has 25% solids of which 70% is ignition loss, sludge volume can be further reduced to 1/330 by incineration process. It might be necessary in the future to investigate the effective use of sewage sludges such as their application onto green belts in addition to their disposal.

5.2.6 CONSTRUCTION COSTS

In CEDAE M/P the construction costs for branch/lateral sewers, main sewers, pumping stations, WWTPs, and outfall sewers are separately estimated in US dollars. The costs estimated in CEDAE M/P are apparently on the high side when converted into the present rate of Brazilian Real. This happened probably because the denomination took place in July 1994. The WWTP capital costs per unit flow rate were almost uniform in CEDAE M/P regardless the magnitude of plant capacity.

For the cost analysis of the sewerage system all the necessary costs were estimated based on the 2002 price level prevailing in the State of Rio de Janeiro. The capital costs consist of those for WWTPs, sewers, pumping stations, and land acquisition.

As CEDAE M/P area covers almost 4,025 km^2, and it is almost impossible to estimate all the costs in detail due to the time constraints and insufficient data. The construction costs are therefore estimated by using a cost-capacity function.

It should be noted that the costs discussed herein are order-of-magnitude, or reconnaissance level only, and that these are satisfactory for CEDAE M/P purpose, but not adequate for detailed financing plan. The currency applied is US Dollars at the following exchange rates in mid-2002:

One U.S. Dollar =R$ 2.90= ¥120

(1) WWTPs

The comparison of actual construction costs in Brazil and cost-capacity function in Japan shows the former is one-seventh to one-eighth the latter, the ratio of one-fifth being most appropriate. The cost function of a complete conventional activated sludge treatment plant is expressed in the form:

$$Cw = 260\ Q^{0.7229}$$

Where,

Cw = Capital costs of WWTP, in US$1,000

Q = Wastewater flow rate, in L/s

(2) Sewers

According to the recent contracts for sewer constructions by CEDAE, main sewer construction costs are about 70% of those described in CEDAE M/P. The costs in CEDAE M/P were estimated in US Dollars and seem to be very high as compared with the current construction costs. The ratio of the latter to the former is around 50%, but 70% is applied taking various uncertainties into account.

As for Sarapuí, Pavuna and Acarí sewer districts, unit construction cost per hectare of sewer district is applied to the areas other than those constructed under the PDBG Phase I area. The unit per hectare construction cost (Cs) of sewers is then:

Cs＝ US$ 28,000/ha

(3) Pumping Stations

70% of the construction costs estimated in CEDAE M/P is applied for the construction costs of pumping stations as in the case of sewer construction cost except for Sarapuí, Pavuna and Acarí Sewer Districts. In these districts, sewer construction costs are considered to have already included those for pumping stations. It is assumed that the land acquisition costs are included in the construction costs.

(4) Land Acquisition for WWTPs

Land acquisition cost for the conventional activated sludge WWTP is:

$$A = 1{,}855Q^{0.4864}$$

where,

A = site area required, in m^2

Q = flow rate, in L/s

Table 5.11 Land Acquisition Cost

System	WWTP	District	Cost (R$/m^2)	Cost (US$/m^2)
Pavuna-Meriti	Acarí	Rio de Janeiro	9	3
Bangu	Bangu	Rio de Janeiro	9	3
Bota	Bota	Belford Roxo	9	3
Iguacu	Campos Elíseos	Duque de Caxias	12	4
Alcantara	Trindade	S. Gonçalo	12	4
Alcântara	Alcântara	S. Gonçalo	34	12
Imboassu	Bomba	S. Gonçalo	12	4

Source: CEDAE

Though land acquisition cost per m^2 provided by CEDAE is shown in *Table 5.11*, it was estimated US$15/m^2 in Alcantara, US$10/m^2 in other WWTPs including leveling cost.

5.2.7 CONCLUSIONS

The major conclusions are enumerated below.

(a) The preceding review on the 1994 M/P and other available information/data indicate that the design fundamentals adopted for the existing sewerage facility plans/designs appear in general to be appropriate in light of the national/state design guidelines and water quality standards.

(b) The comparison of population estimates by the 1994 M/P and 2000 census data indicates that the population within sewer districts has moderately increased in the last decade, but in some built-up central urban districts the population growths are either stable or have declined.

(c) The wastewater quantities and characteristics estimated in the 1994 M/P are apparently within the medium range that may not cause severe hydraulic/pollutant overloading, provided that the facilities were designed and constructed according to the criteria as proposed in CEDAE M/P.

(d) CEDAE M/P sewer service populations estimated based on the 1991 and previous census data are generally in agreement with those estimated based on the 2000 census data, hence can be used for the forth coming sewerage planning.

(e) For the sewer systems where urban developments are intensively taking place and population is growing at high rates, such basic planning factors as population distributions, and wastewater qualities/quantities, need to be occasionally reviewed, to verify that sewer facilities are capable of handling the resultant wastewater flow changes.

(f) The proposed WWTPs with conventional or modified activated sludge process is capable of producing stable and high quality effluents if properly operated, and result in a significant reduction of the organic loads inflowing to the Bay.

(g) Flexibility to the improvement and upgrading of the WWTPs should be considered at the final design stage so that the WWTPs could meet more stringent water quality requirements, if and when such controls are strictly enforced in the future.

(h) Areas to be sewered and served by onsite sanitation systems should be clearly identified.

(i) Sewers are installed under public roads in common. CEDAE M/P proposed sewer installations along the rivers even where no roads are available. In such cases, the collection system plans have to be reinvestigated and/or sewer district boundaries have to be modified.

(j) Some of the WWTPs sites have already been urbanized and some site locations could not be identified, because these areas have been neither secured nor purchased. Alternative WWTP sites should be found and secured.

(k) CEDAE M/P review results will be fully taken into consideration in the sewerage strategy plan and the feasibility study.

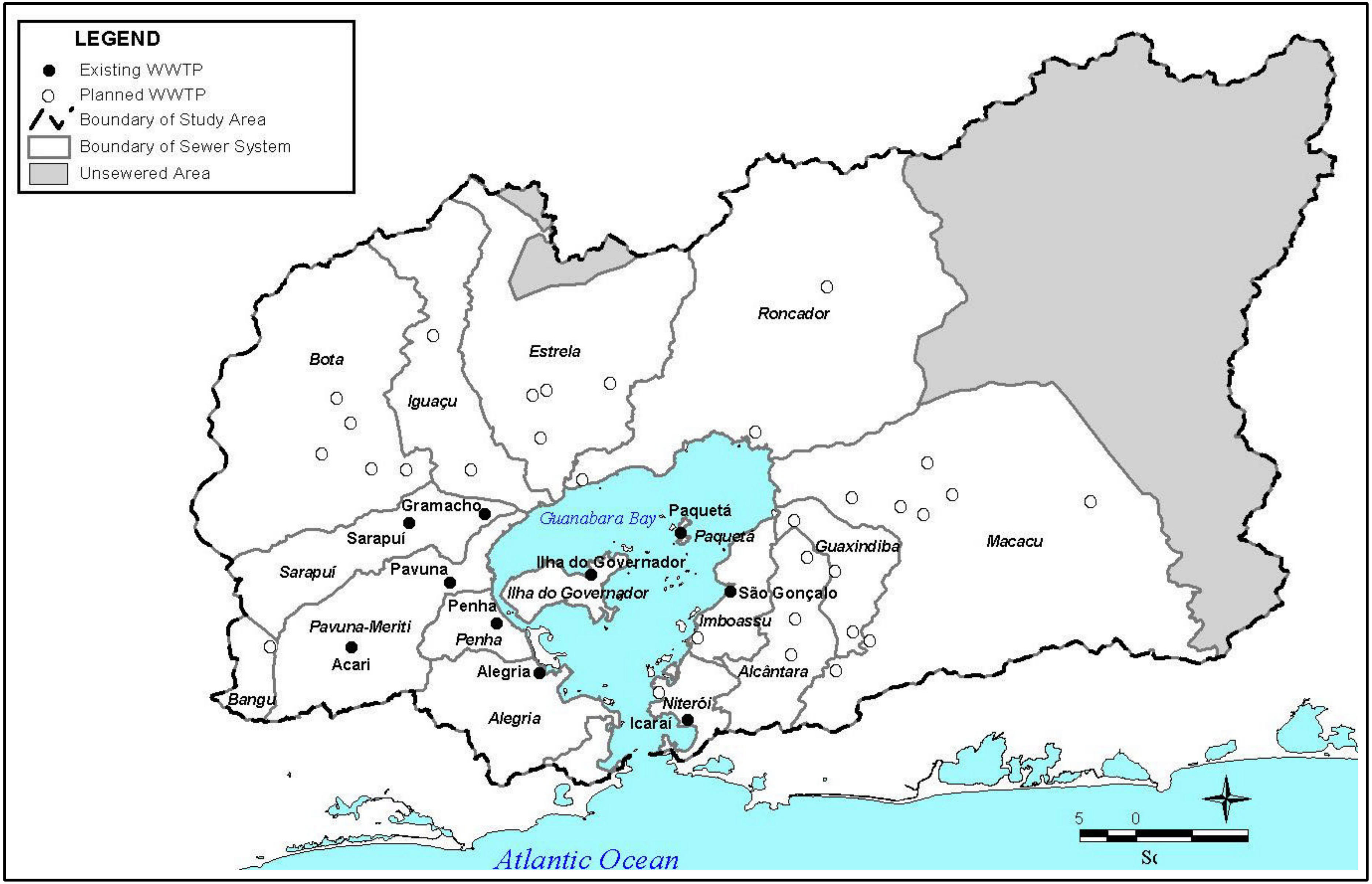


Figure 5.1 Sewer Systems and WWTPs