Chapter 5

WATER QUALITY IN THE LAKE BILLINGS AND RIO GRANDE ARM

5. WATER QUALITY IN THE LAKE BILLINGS AND RIO GRANDE ARM

5.1 Situation of Water Quality Based on the Previous Studies

5.1.1 Study by CETESB

(1) Study by CETESB during 1997 to 1998

As for the water quality and bottom sediment (**Figure 1.5.1**, **Table 1.5.1**) of the Billings Lake, the research study had been conducted in parallel with water quality monitoring by CETESB from the viewpoint of its importance since 1970.

After the reverse transmission was forbidden in 1992, CETESB investigated water quality, bottom sediment quality, and fishes on great scale at many points of the Tiete River. (1997 April – 1998 March). These results of investigation are indicated as summary in the Billings Lake project-TOME II. The major findings were as follows.

- Water quality has been deteriorating close to the Pedreira pumping station,
- Generally, lake water is in the state of eutrophication or poly-trophication.
- Heavy metal pollution is seen in the Rio-Pequeno river and the upstream channel of the Henry Borden.
- With the Borore arm and the Taquacetuba arm, high concentration of fecal coliform bacteria is detected and it showed that the domestic sewage is involved. It is the same with Cocaia arm and the Rio Grande arm similarly.
- In the Taquacetuba arm, the potential poisonous algae had occurred frequently. It is the cause of the unpleasant taste and smell.
- Remarkable concentration of cadmium, nickel, and zinc are confirmed in the bottom sediment of the Taquacetuba arm.
- According to the chronic toxicity test of Taquacetuba arm, the mutagenesis effect was seen, although it was low level. It would be a restriction factor for drinking water use.
- Plankton colonies are seen in the Rio Grande arm.

(2) Water Quality Monitoring by CETESB

In the Lake Billings and Rio Grande Arm, the CETESB and SABESP have conducted regular water quality monitoring at the locations as shown in **Figure 5.1.1**.

Figure 5.1.2 and **Table 5.1.1** show the average water quality in both lakes during the period of 1994 to 2003 and for the year of 2004.

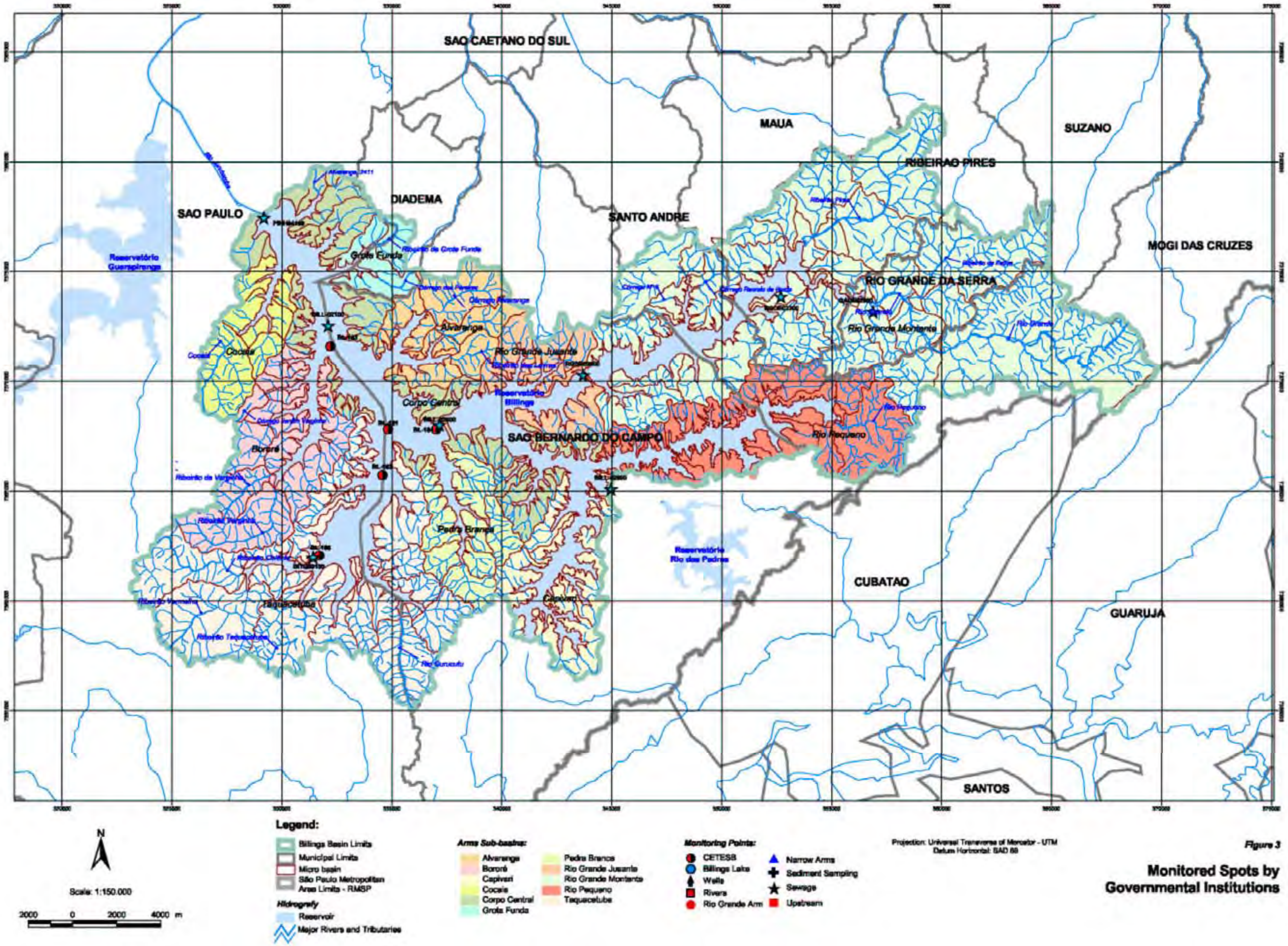


Figure 5.1.1 CETESB and SABESP have conducted regular water quality monitoring at the locations

It is supposed that the biggest pollutant source to the present Billings Lake is the elution reaction from the sludge which is supposed to have accumulated about 50,000,000m^3 on the bottom of the lake by polluted water inflow. Depending on the condition, the load by the elution would exceed several times compared with the load inflowing from outside

One of the important pollution sources from the outside is polluted water of the Pinheiros River by reverse water transmission carried out at Pedreira dam. Since this river water has been polluted very much, the influence on the water quality to the Billings Lake was significant. The reverse water transmission was about 10m3/s (864,000m^3/day) during 10 years, although its annual average inflow had decreased sharply compared with the years before 1992.

On the other hand, nitrogen and phosphorus by the domestic sewage would be the problem from the land area.

Although the water quality of the Billings Lake varies by locations under the influence of pollution loads from outside, the strong eutrophication is generally seen and damage by the eutrophication is extending to tap water use.

The biggest pollutant source in the Rio Grande Arm is domestic wastewater from Ribeirao Pires that are treated substantially at a wastewater treatment plant by a up flow anaerobic sludge blanket process (UASB). This process removes BOD5 by 65%, but are not effective for phosphorous and nitrogen removal. Domestic wastewater in Rio Grande da Serra, that has a wastewater treatment plant by a stabilization pond process with a limited treatment capacity, also enters into the lake. For these reasons, the Rio Grande Arm has been eutrophied.

Table 5.1.1 Current status of water pollution of the Billings Lake

(unit: mg/L)

Point	Year	Pinheiros	Billing	Billing	Billing	Billing	Rio Grande	Rio Grande	Rio Grande	Rio Grande
		PINH04100	BILL02100	BITQ00100	BILL02500	BILL02900	RGDE02900	RGOE02200	GADE02900	PIRE02900
Conductivity	1994-2003	286	205	192	194	172	255	300	502	469
	2004	289	210	201	190	155	241	269	366	251
Turbidity	1994-2003	22	25	17	8	7	3	14	9	17
	2004	22	5	13	6	6	2	5	5	13
COD	1994-2003			8.17			6.35			
	2004			5.65			4.47			
THMFP	1994-2003			336			240			
	2004			548			293			
NH_3-N	1994-2003	1.5	0.88	0.35	0.68	0.4	0.51	0.52	0.45	0.2
	2004	0.5	1.49	0.43	0.77	1.46	0.73	2.59	0.9	0.87
NH_4-N	1994-2003	4.70	0.29	0.13	0.11	0.08	0.26	0.71	0.58	10.74
	2004	8.97	0.13	0.05	0.1	0.07	0.11	0.62	0.79	7.59
OD	1994-2003	1.4	7.4	10.1	7.4	8	7.2	8	4	2.5
	2004	0.8	7.9	22.5	8.7	8.7	7.6	9.2	4.8	1.9
BOD	1994-2003	15	6	7	5	4	3	5	4	21
	2004	15	5	5	5	4	4	5	3	13
T-P	1994-2003	0.682	0.174	0.096	0.054	0.068	0.069	0.104	0.095	1.31
	2004	1.232	0.087	0.088	0.063	0.048	0.07	0.082	0.095	0.678
Coliform Termot.	1994-2003	127.758	32	2	9	8	18	77	7.542	174.356
	2004	18.418	52	1	4	3	18	37	596	23.565
Chlorophyl-a	1994-2003		89.35	58.09	42.18	20.33	13.01			
	2004		54.93	48.22	41.93		10			

2) Secular changes in water quality

The results of the periodical water quality monitoring surveys conduced by CETESB from 1985 to 2003 and the periodical water quality monitoring surveys conducted by SABESP were summarized. The results are as shown below.

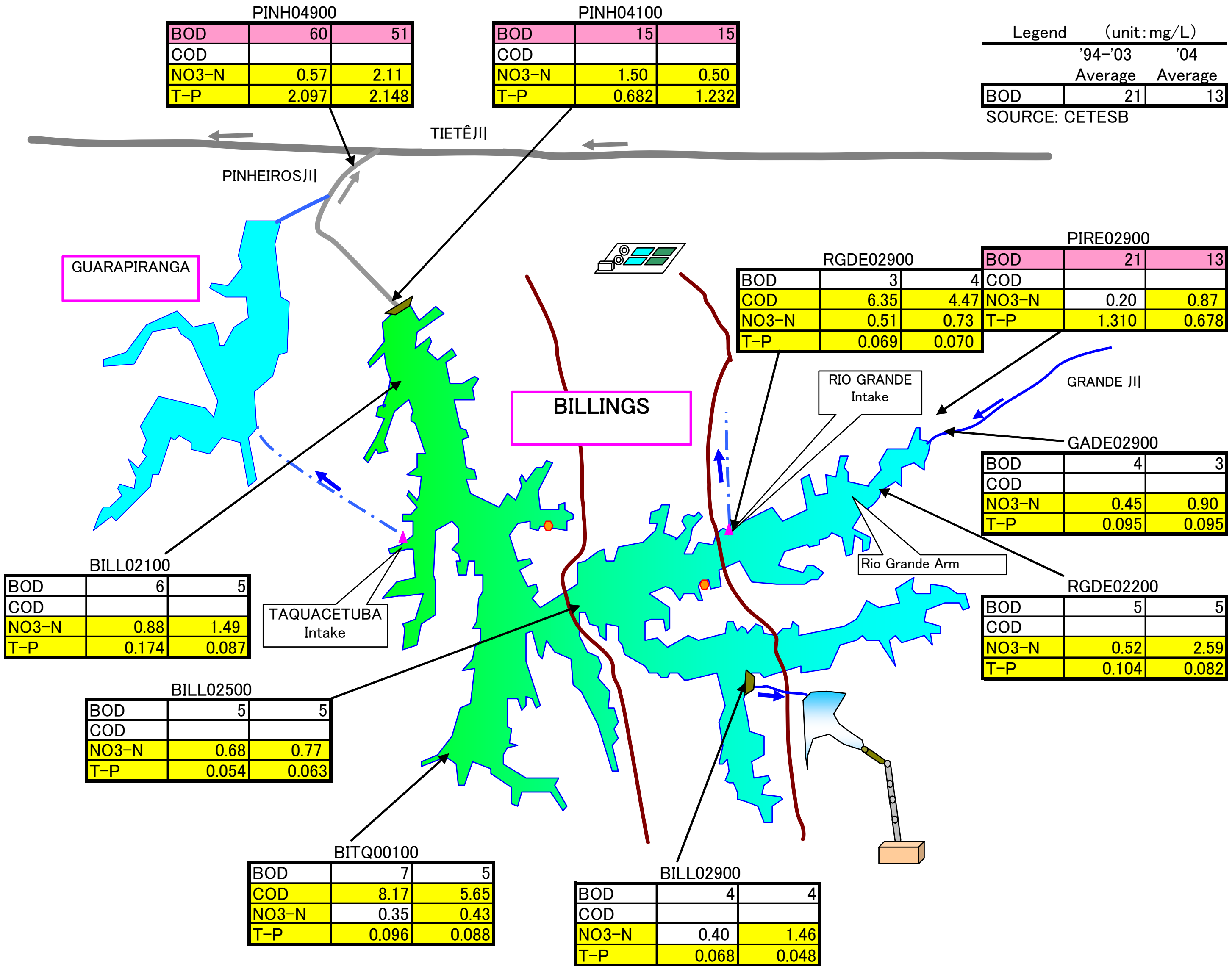


Figure 5.1.2 Current status of water pollution of the Billings Lake

(a) Water quality of Lake Billings

Figures 5.1.3 to **5.1.5** show the relationship between secular changes in the water quality of Lake Billings and the pumping discharges from Pedreira for each of the water quality items (BOD, TP and Hg). As far as these figures are concerned, BOD and TP show a tendency toward gradual improvement with time, reflecting a decrease in the pumping discharges from Pedreira.

However, heavy metals such as Hg, Mn and Fe, after showing a tendency toward improvement, are deteriorating. This is considered to be the result of elution from bottom sludge accumulated in the lake.

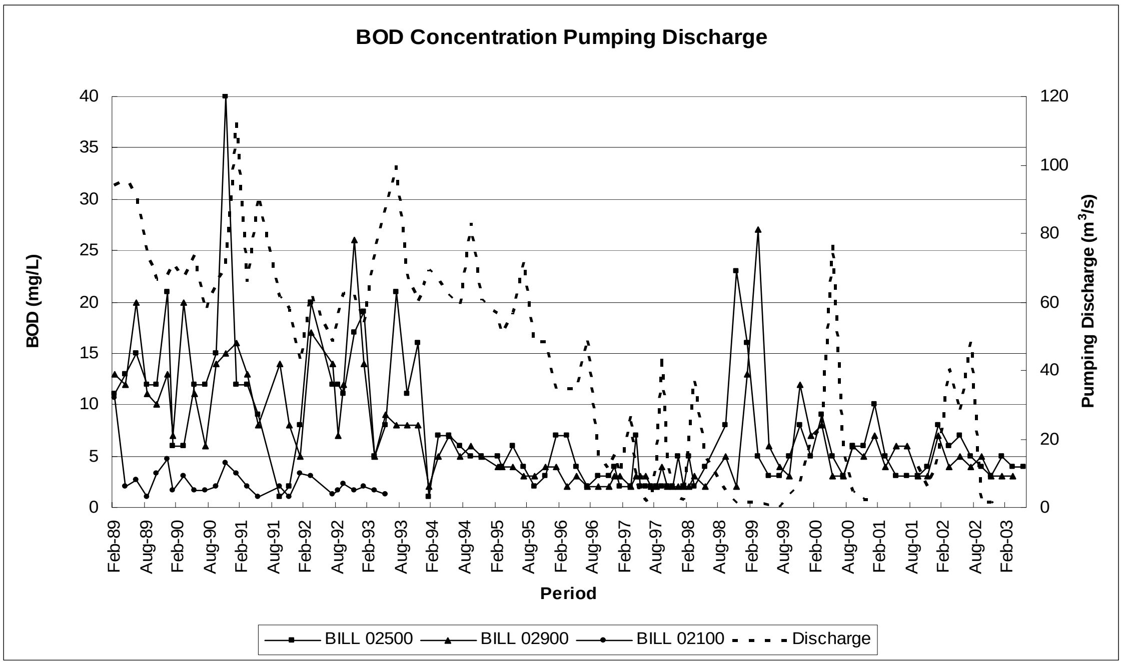


Figure 5.1.3 Secular Changes in Water Quality (BOD) of the Lake Billings
(Relationship between Lake Water and Pumping Discharge from Pedreira)

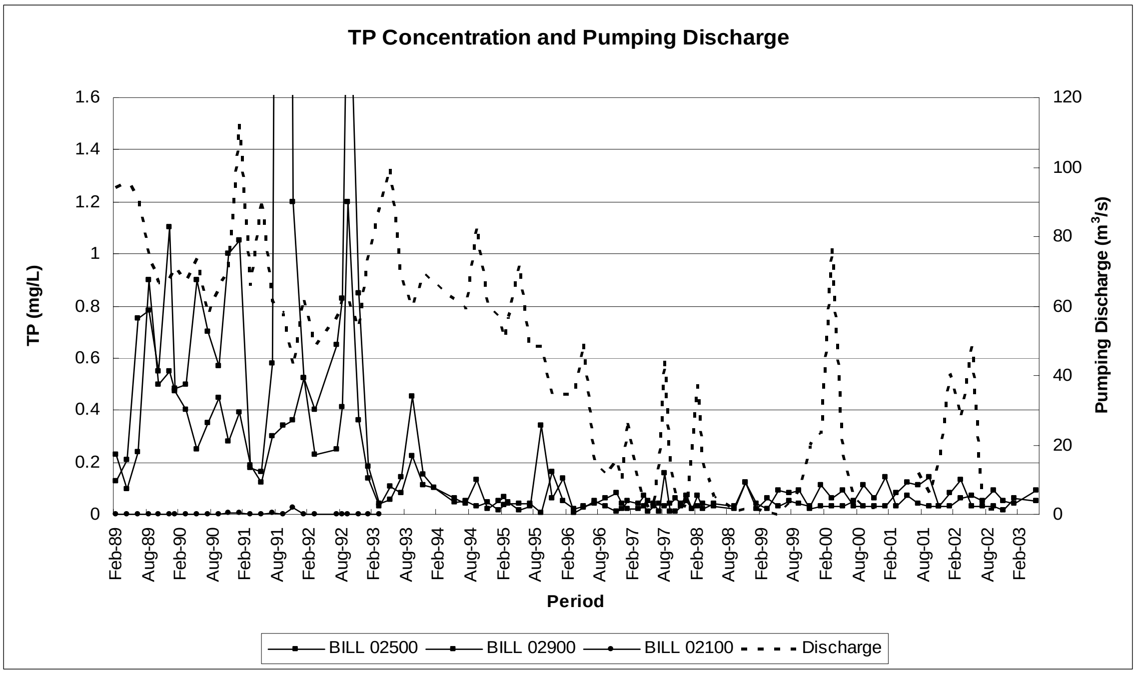


Figure 5.1.4 Secular Changes in Water Quality (TP) of Lake Billings (Relationship between Lake Water and Pumping Discharge from Pedreira)

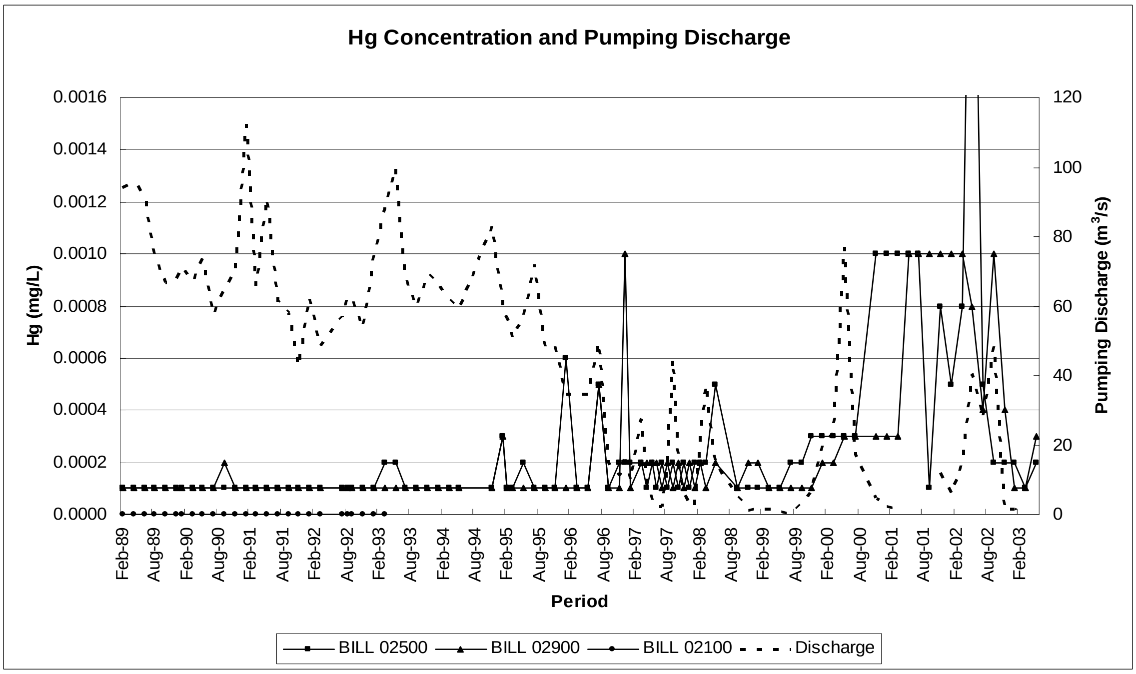


Figure 5.1.5 Secular Changes in Water Quality (Hg) of Lake Billings (Relationship between Lake Water and Pump Discharge from Pedreira)

(b) Water quality of Lake Rio Grande Arm

Figures 5.1.6 to **5.1.8** show the secular changes in water quality of Lake Rio Grande Arm for each of the water quality items (BOD, NH_4 and Chlorophyll-a). As far as these figures are concerned, TN, TP and Chlorophyll-a have an upward trend, showing the gradual advance of eutrophication.

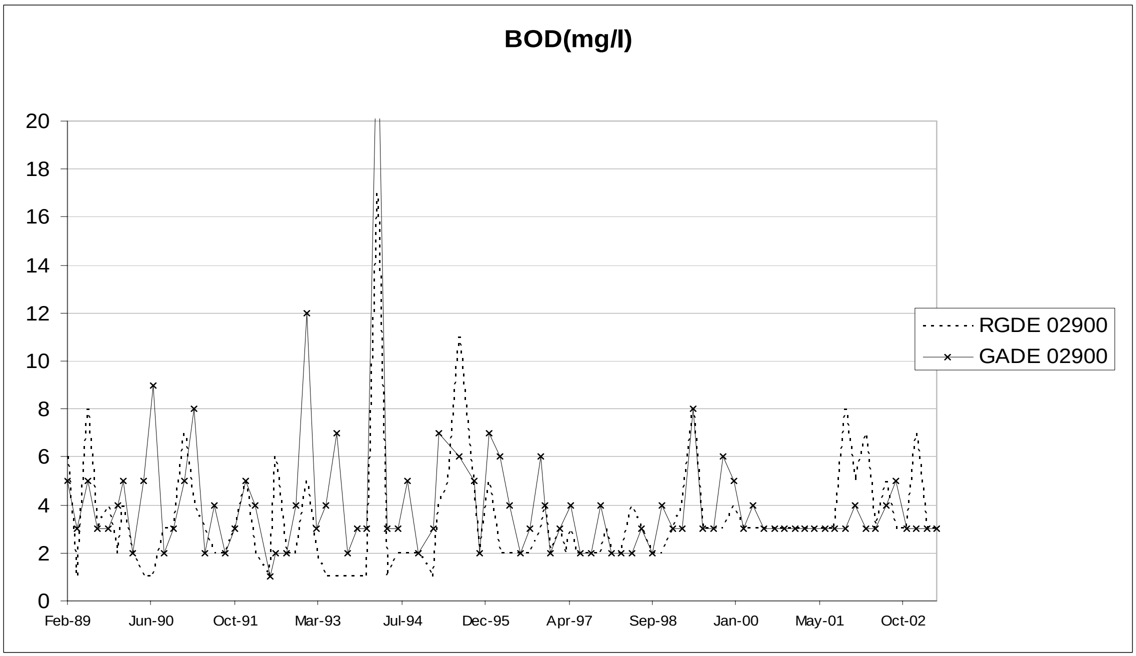


Figure 5.1.6 Secular Changes in Water Quality (BOD) of Lake Rio Grande Arm

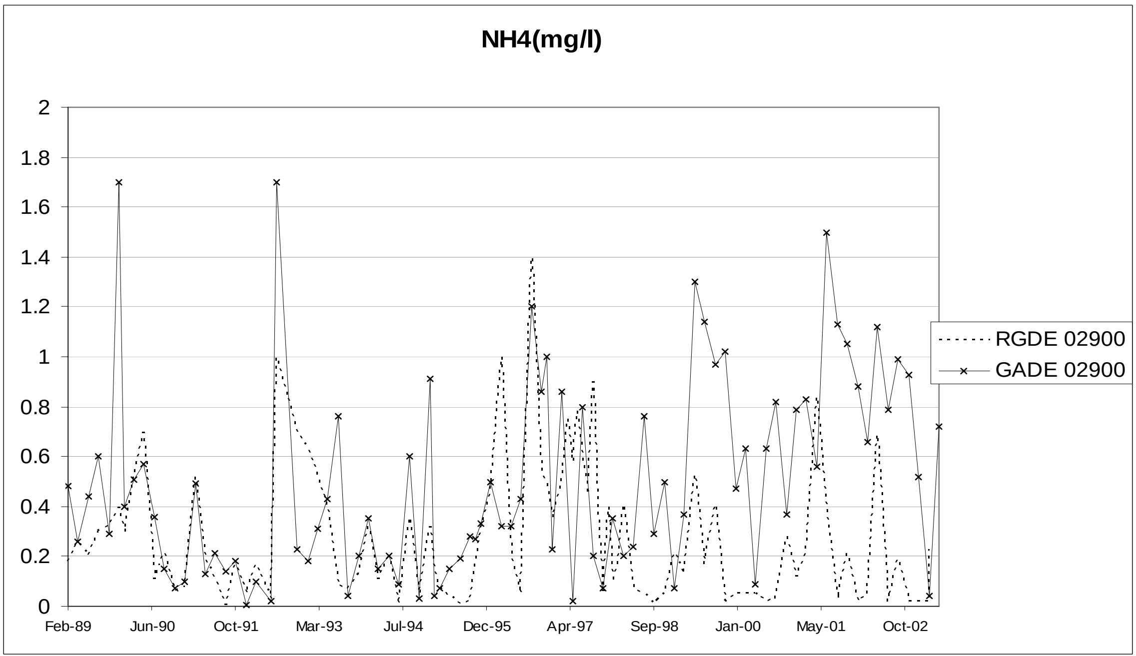


Figure 5.1.7 Secular Changes in Water Quality (NH_4) of Lake Rio Grande Arm

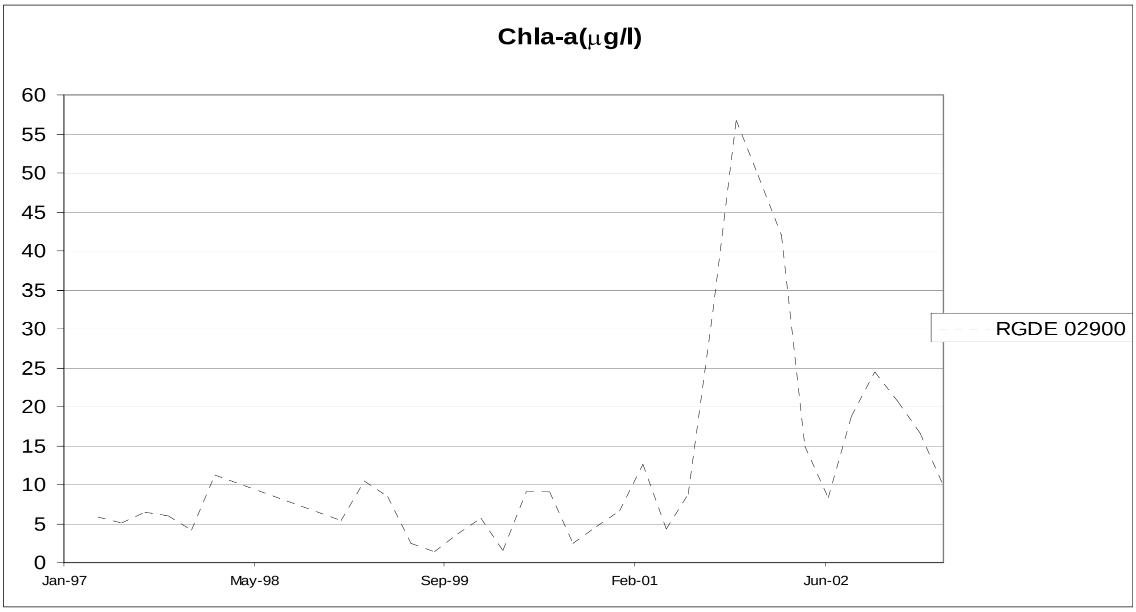


Figure 5.1.8 Secular Changes in Water Quality (Chlorophyll-a) of Lake Rio Grande Arm

5.1.2 Water Quality of Rio Grande Arm

(1) Existing Water Quality Data

According to the report on Sao Paulo State by CETESB, the following No. of parameters are tested.

Physico-chemica	l37 parameters
Microbiological	5 parameters
Hydrobiological	2 parameters
Ecotoxicological	5 parameters

The results of water quality test on physico-chemical and micro-organism are evaluated based on the standard of National Environmental Council (CONAMA). The water quality in 2000 of the intake point (RGDE 2900) in the Arm is described below.

1) Physico-chemical Test

Table 5.1.2 shows result of physico-chemical test.

The parameters which are higher than the standard of CONAMA were T-P, Lead, Copper, Manganese and Phenol as follows.

Table 5.1.2 Water Quality of Intake Point (RGDE 02900) in 2000 (1)

DADOS DE QUALIDADE	PADRÃO DE QUALIDADE CONAMA 20/86	JAN	MAR	MAI	JUL	SET	NOV
PARÂMETROS FÍSICO-QUÍMICOS							
TEMPERATURA DO AR (^oC)		26	24	27	20	31	23
TEMPERATURA DA ÁGUA (^oC)		27	24	25	19	25	23
pH	6,0 a 9,0	6.9	7.4	7.2	7.6	8.5	7.9
OXIGÊNIO DISSOLVIDO (mgO_2/L)	5.0	6.6	6.5	6.1	7.4	8.5	7.4
$DBO_{5,20}$ (mgO_2/L)	5	4	<3	<3	<3	3	3
DQO (mgO_2/L)		<17	<25	<25	<25	<25	<25
CARBONO ORGÂNICO DISSOLVIDO (mg/L)		7.00	6.55	6.55	5.70	5.64	8.32
ABSORBÂNCIA NO ULTRAVIOLETA		0.056	0.092	0.073	0.070	0.025	0.060
NITRATO (mgN/L)	10.00	0.70	0.60	0.60	0.53	0.66	0.63
NITRITO (mgN/L)	1.000	0.050	0.010	0.010	0.007	0.050	0.060
AMÔNIA (mgN/L)	# 0,50	0.05	0.05	0.05	<0,02	0.03	0.28
KJELDAHL (mgN/L)		0.54	0.09	0.09	0.76	0.76	0.87
NITROGÊNIO TOTAL (mgN/L)		1.29	0.70	0.70	1.30	1.47	1.56
ORTOFOSFATO SOLÚVEL (mgP/L)		<0,007	0.009	0.009	0.009	<0,007	<0,007
FÓSFORO TOTAL (mgP/L)	0.025	<0,030	<0,030	<0,030	0.160	0.110	0.050
RESÍDUO FIXO (mg/L)		139	116	116	28	144	163
RESÍDUO VOLÁTIL (mg/L)		26	28	28	42	36	27
RESÍDUO FILTRÁVEL (mg/L)	500	164	134	134	164	175	190
RESÍDUO NÃO FILTRÁVEL (mg/L)		1	10	10	6	5	0.0
RESÍDUO TOTAL (mg/L)		165	144	144	170	180	190
TURBIDEZ (UNT)	100	0.82	1.00	1.00	4.34	2	2
CLORETO (mg/L)	250.0	71.9	57.4	57.9	63.3	93.9	85.3
SURFACTANTES (mg/L)	0.50	<0,08	<0,08	<0,08	<0,08	<0,08	<0,08
COND. ESPECÍFICA ($\mu S/cm$)		321	288	288	295	351	353
ALUMÍNIO (mg/L)	0.10	<0,10	0.14	0.14	<0,10	0.17	0.24
BÁRIO (mg/L)	1.00	<0,08	<0,08	<0,08	<0,08	<0,08	<0,08
CÁDMIO (mg/L)	0.001	<0,001	<0,009	<0,001	<0,001	<0,001	<0,001
CHUMBO (mg/L)	0.03	<0,02	<0,02	<0,02	<0,02	0.42	<0,02
COBRE (mg/L)	0.02	0.02	0.06	0.06	0.170	0.02	<0,004
CROMO TOTAL (mg/L)	# 0,05	<0,05	<0,06	<0,05	<0,05	<0,05	<0,05
NÍQUEL (mg/L)	0.025	<0,010	0.040	0.010	<0,010	<0,010	<0,010
MERCÚRIO (mg/L)	0.0002	<0,0003	<0,0003	<0,0003	<0,0003		<0,0010
ZINCO (mg/L)	0.18	<0,01	0.01	0.01	<0,01	<0,01	0.01
FERRO (mg/L)		0.07	0.21	0.21	0.16		0.14
MANGANÊS (mg/L)	0.10	0.01	0.09	0.09	0.15	0.03	0.01
FENÓIS (mg/L)	0.001	<0,003	0.007	0.007	<0,003	0.005	<0,003
POTENCIAL DE FORMAÇÃO DE THM ($\mu g/L$)		162.0	244.0	189.0	163.0	231.0	187.0

2) Microbiological Test

The existing parameters tested on microbiology are Fecal colifom, Clostridium, Cryptosporidium and Giardia. The contamination level by microorganisms is low. For example cryptosporidium and Giardia which are in the news in Japan were not detectable.

Table 5.1.3 Water Quality of Intake Point (RGDE 02900) in 2000

PARÂMETROS MICROBIOLÓGICOS

DADOS DE QUALIDADE	PADRÃO DE QUALIDADE CONAMA 20/86	JAN	MAR	MAI	JUL	SET	NOV
COLIFORME FECAL (NMP/100mL)	1.0E+03	9.0E+01	Ausente	4.0E+00	Ausente	<2,0E+00	4.0E+00
ESTREPTOCOCOS FECAIS (NMP/100mL)		Ausente	Ausente		Ausente	<2,0E+00	
CLOSTRIDIUM PERFRINGENS (NMP/100mL)		1.7E+01	2.2E+01		1.4E+01	1.3E+01	
CRYPTOSPORIDIUM sp (oocistos/L)		Ausente	Ausente		Ausente	Ausente	
GIARDIA sp (cistos/L)		Ausente	Ausente		Ausente	Ausente	

3) Biology Test

Two parameters of Chlorophyll-a and Feofitin-a are measured. The concentration of Chlorophyll-a ranging from 1.53 to 9.15 μg/L was low level.

Table 5.1.4 Water Quality of Intake Point (RGDE 02900) in 2000

PARÂMETROS HIDROBIOLÓGICOS

DADOS DE QUALIDADE	PADRÃO DE QUALIDADE CONAMA 20/86	JAN	MAR	MAI	JUL	SET	NOV
CLOROFILA-a (μg/L)		5.75	1.53	9.08	9.15	2.45	4.54
FEOFITINA-a (μg/L)		2.30	4.35	5.32	4.74	6.44	11.26

4) Ecotoxicological Test

The bioassay (AMES test) using S9 is done as ecotoxicological test to check the mutagenicity of the cells by chemical substances. The results of test were not detectable through a year.

Table 5.1.5 Water Quality of Intake Point (RGDE 02900) in 2000

PARÂMETROS ECOTOXICOLÓGICOS

DADOS DE QUALIDADE	PADRÃO DE QUALIDADE CONAMA 20/86	JAN	MAR	MAI	JUL	SET	NOV
TESTE DE AMES							
TA98-S9 (revertentes/L)		ND	ND	ND	ND	ND	ND
TA98+S9 (revertentes/L)		ND	ND	ND	ND	ND	ND
TA100-S9 (revertentes/L)		ND	ND	ND	ND	ND	ND
TA100+S9 (revertentes/L)		ND	ND	ND	ND	ND	ND
TESTE DE TOXICIDADE CRÔNICA							

5) Water Quality in 1993-2004

The water quality in 2003 and average water quality in 1993-2002 are shown in **Table 5.1.6.** In consequent, the water quality in 2004 and average water quality in 1994-2003 are shown in **Table 5.1.7**.

The sampling point of RGDE2200 is almost center of Rio Grande Arm and RGDE2900 is intake point for the Rio Grande WTP aforementioned. The parameters tested in 2003 and 2004 are as follows:

2003: Conductivity, Turbidity, Nitrite, Nitrate, Ammonium-Nitrogen, DO, TDS, Anionic Surfactant, and Coliform.

2004: Conductivity, Turbidity, COD, THM-PF, Nitrate, Ammonium-Nitrogen, DO, TP, Chlorophyll-a, and Coliform.

Table 5.1.6 Water Quality in 2003 and Average of 1993- 2002 in Rio Grande Arm

	PARAMETROS																					
	Conductiv.		Turbidez		NO2		NO3		NH3-N		OD		$DBO_{5.20}$		Res.Filtravel		Surfact.		Fosforo Total		Coliforme Termot.	
	µS/cm		NTU		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		MPN	
Codigo do Ponto	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002	Media 2003	Media 1993-2002
RGDE02200	327	299	8.9	13	0.235	0.067	0.55	0.48	0.91	0.68	8.6	7.8	6.2	5	178	502		0.07	0.200	0.093	1.20E+02	7.40E+01
RGDE02900	271	252	1.9	3	0.048	0.047	0.42	0.49	0.08	0.28	7.3	7.3	4	3	147	135		0.05	0.062	0.068	4.50E+00	1.90E+01

Table 5.1.7 Water Quality in 2004 and average 1994- 2003 in Rio Grande Arm

	PARAMETROS																					
	Conductiv.		Turbidez		COD		PFTHM		NO3		NH3-N		OD		$DBO_{5.20}$		Fosforo Total		Coliforme Termot.		Clorofila a	
	µS/cm		NTU		mg/L		µg/L		mg/L		mg/L		mg/L		mg/L		mg/L		MPN		µg/L	
Codigo do Ponto	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004	Media 1994-2003	Media 2004
RGDE02200	300	269	14	5					0.52	2.59	0.71	0.62	8.0	9.2	5	5	0.104	0.082	77	37		
RGDE02900	250	241	3	2	6.35	4.47	240	293	0.51	0.73	0.26	0.11	7.2	7.6	3	4	0.069	0.070	18	18	13.01	10.00

(2) Water Quality Monitoring in Rio Grande Arm

SABESP monitors the conditions of algae generation in Rio Grande Arm regularly because the algae sometimes causes odor problems. SABESP is taking much effort to control algae-generation because algae-generation fluctuates very much by year. Rio Grande Arm is divided into four areas for monitoring and water sampling is done at RG101, RG102, RG103 and RG104 as presented in **Figure 5.1.9**.

Besides, SABESP scatters on the Arm with copper sulfate ($CuSO_4$) and hydrogen peroxide (H_2O_2) to reduce algae-generation. This activity is done using the algicide scattering map presented in **Figure 5.1.10**.

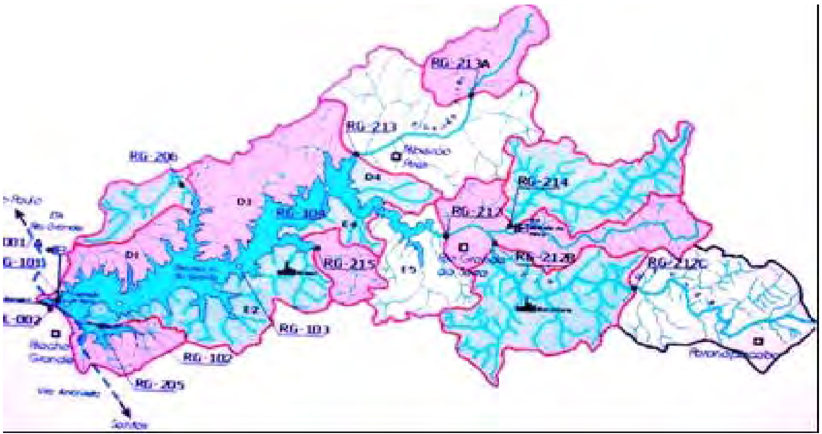


Figure 5.1.9 Sampling Point by SABESP in Rio Grande Arm

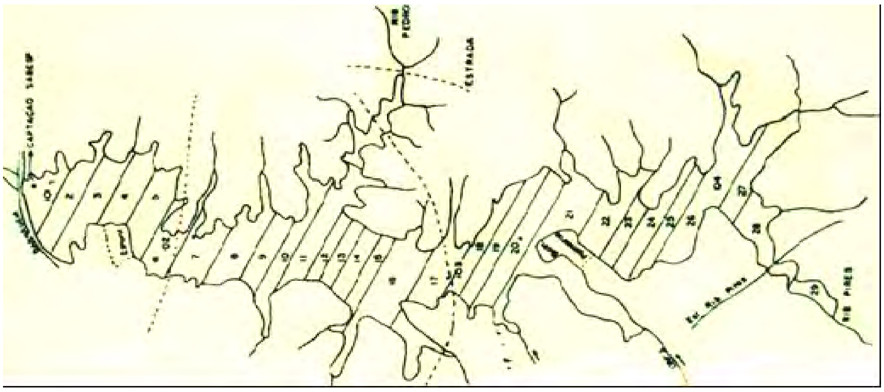


Figure 5.1.10 Algicide Scattering Map in the Rio Grande Arm

(3) Algae-generation Season

Summer season from December to March is the time of algae-generation every year. In addition, algae-generation depends on the water level of the Arm. Therefore, when algae-generation is anticipated, algaecide is scattered on the Arm in advance.

When the water level became down to 50 % of ordinal year in 2001-2002, water bloom increased explosively at the intake point. In that time the fence was installed to stop entering of water bloom. The water level in 2005 is 85% of ordinal year.

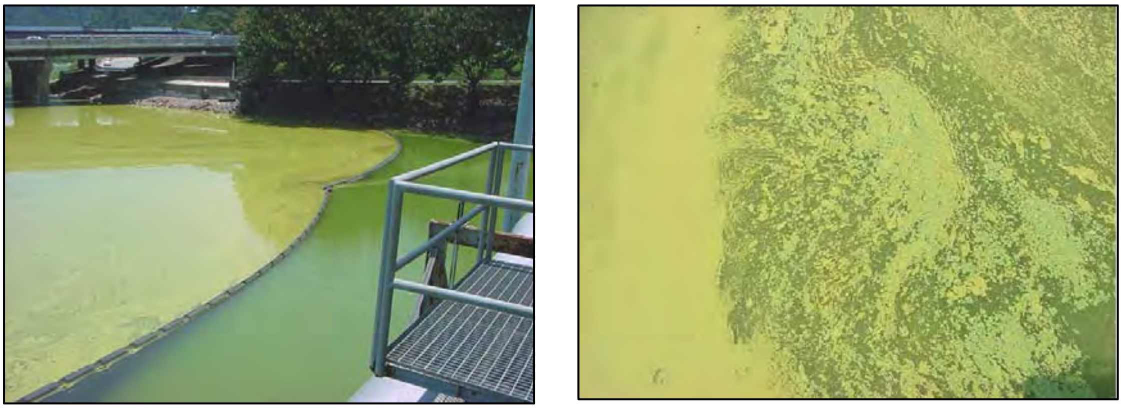


Photo 5.1.1 Water Bloom near Intake Point in 2001

(4) Type of Water bloom

Water bloom is one of phenomena such as heavy algae-generation, especially it is called water bloom that water looks green due to accumulation of algae on water surface.

As cyanobacterium forming water bloom, Anabaena, Microcystes, and Oscillatoria are known. Among these species, water bloom by Microcystes is seen very often in general. The dominant species of water bloom in Lake Billings is also Microcystes. Anabaena and Oscillatoria known as generating bad smell are also found in Lake Billings. Hence, odor and outlook should be paid attention carefully.

(5) Planktons in Lake Billings and Rio Grande Arm

In this study, plankton survey in main part of Lake Billings and Rio Grande Arm was conducted. Sampling dates are as follows:

September 1st –main of part of Lake Billings

September 2nd --Rio Grande Arm

The sampling points of are shown in **Figure 5.1.11**. No.1 – No.4 are sampling points for main part of Lake Billings and RG101 - RG104 are sampling points for Rio Grande Arm.

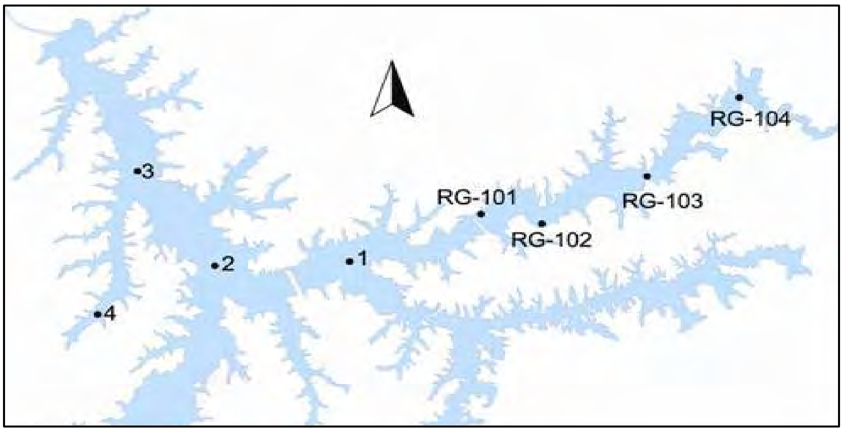


Figure 5.1.11 Sampling Points for Plankton Survey

a) Main Part of Lake Billings

Phytoplankton examined with a microscope are shown in **Table 5.1.8**

Table 5.1.8 Plankton in Main Part of Lake Billings

Sampling Point	Sampling Method	Phytoplanktons				
		1	2	3	4	5
No.1	Superficial	Cylindrospermopsis sp	Mycrocystes sp.	Oscillatoriales	Oscillatoria sp.	Chroococcales
	Horizontal	Mycrocystes sp.	Oscillatoria sp.	Melosira sp.	Mougeotia sp.	Coelastrum sp.
	Vertical	Mycrocystes sp.	Melosira sp.	Mougeotia sp.	Oscillatoria sp.	-
No.2	Horizontal	Mycrocystes sp.	Oscillatoria sp.	Melosira sp.	Mougeotia sp.	-
	Vertical	Mycrocystes sp.	Oscillatoria sp.	Melosira sp.	-	-
No.3	Superficial	Mycrocystes sp.	Cylindrospermop sis sp	-	-	-
	Horizontal	Mycrocystes sp.	Oscillatoria sp.	Melosira sp.	-	-
	Vertical	Mycrocystes sp.	Oscillatoria sp.	Melosira sp.	-	-
No.4	Horizontal	Mycrocystes sp.	Anabaena sp.	Oscillatoria sp.	Melosira sp.	Mougeotia sp.

Judging from appearance, algae-generation in sampling point No.1 locating at East side of Imigrantes Avenue is a little, while in West side of Imigrantes Avenue, thin algae-film was recognized on the surface.

The most dominant species in the surface of sampling point No.1 was Cylindrospemopsis, and 2nd and 3rd dominant species are Microcystis and Oscillatoria, respectively. In the horizontal layer of 20-30 cm below, Microcystis is the most dominant, and Oscillatoria and Melosila are next dominant species.

In sampling point No.2 and No.3, many planktons were found. But dominant species are Microcystis and Oscillatoria which are same as sampling point of No.1. In contrast, the 2nd dominant species of sampling point of No.4 was Anabaena which generates bad smell like fust. This result is corresponding that smell of fust was recognized in the sampling site.

b) Rio Grande Arm

Phytoplanktons examined with a microscope are shown in **Table 5.1.9**.

Table 5.1.9 Plankton in Rio Grande Arm

Sampling Point	Sampling Method	Phytoplanktons				
		1		3	4	5
RG-101	Horizontal	Mougeotia sp.	Anabaena sp.	Euglena sp.	Diatomaceas	-
	Vertical	Mougeotia sp.	Anabaena sp.	Dinoflagelados	-	-
RG-102	Horizontal	Mougeotia sp.	Anabaena sp.	Dinoflagelados	-	-
	Vertical	Mougeotia sp.	Anabaena sp.	Dinoflagelados	-	-
RG-103	Horizontal	Mougeotia sp.	Anabaena sp.	Euglena sp.	Trachelomonas sp.	Ankistrodesmus sp.
	Vertical	Mougeotia sp.	Anabaena sp.	Melosira sp.	Asterionela sp.	-
RG-104	Horizontal	Anabaena sp.	Mougeotia sp.	Oscillatoriales	Diatomaceas	-
	Vertical	Anabaena sp.	Mougeotia sp.	Diatomaceas	-	-

The dominant species is Microcystis that is typical species of waterbloom in main part of Lake Billings, while the dominant species in Rio Grande Arm is Mougeotia that is a kind of green algae. However Mougeotia has not irrupted in Rio Grande Arm in the past.

(6) Measures against Waterbloom

The dominant species of waterbloom in Lake Billings is Microcystis aforementioned. A group of cells of Microcystis is covered with film like vegetable gelatin. This gelatin-film is broken by pre-chlorination then a group of cells is disrupted to many cells. Some part of these decomposed cells passes filters. This cells' passing results in filtered water with high turbidity and color. Moreover Microcystis contains mycrocystin which is one of toxins. Hence conventional treatment is not enough to remove mycrocystin. To remove mycrocystin, a process using granular activated carbon (GAC) or ozone treatment is appropriate.

The existing process of Rio Grand WTP is not suitable for remove mycrocystin, because the treatment process is settlement using ferric sulfate, sand filter and chlorination not GAC or ozone treatment. Fortunately waterbloom in Rio Grande Arm is not severe at present. However in case of progressing eutrophication, countermeasure might be needed in future.

Table 5.1.10 shows mycrocystin removal performance by treatment process.

Table 5.1.10 Mycrocystin Removal Performance by Treatment Process

No.	Treatment Process	Concentration of GAC	Coagulant	Toxin Type	Removal Rate (%)
1	Coagulated Clarification+ Sand filtration + Chlorination	-	$Al_2(SO)_3 \cdot H_2O$	M1	11
				M2	11
2	Coagulated Clarification+ Sand filtration + Chlorination	-	$FeCl_3$	M1	0
				M2	16
3	GAC+ Coagulated Clarification+ Sand filtration + Chlorination	5 mg/L	$Al_2(SO)_3 \cdot 8H_2O$	M1	20
				M2	34
4	Coagulated Clarification+ Sand filtration + GAC + Chlorination	-	$Al_2(SO)_3 \cdot 8H_2O$	M1	100
				M2	100
5	Ozone + Coagulated Clarification+ Sand filtration + Chlorination	1 mg/L	$Al_2(SO)_3 \cdot 8H_2O$	M1	100
				M2	100

Note: GAC-Granular Activated Carbon Source: Humberg et al

(7) Aquatic Plant-Generation and Countermeasure

Not only algae but also aquatic plant has irrupted in Lake Billings in the past. Aquatic plant irrupted in 1982 and May-October in 2005 in Rio Grand Arm.

Plant-Generation in the Arm is not correlative with water and atmospheric temperature but the water level. The lower water level become, the more aquatic plant generates. This correlation may result from high nutrient concentration of the Arm in low water level. Aquatic plant in Arm is called Macrofitas as generic name. The dominant aquatic species are Salvinia and Pistia. Water Hyacinth is also seen partly.


Photo 5.1.2 Removal Macrofitas

Aquatic plants generated within Arm are moved by wind from upstream of Ribeirao Pirres and Rio Grande da Serra to the intake point. Finally the aquatic plant accumulates at the space nearby the siphons which are located at westmost of the Arm. The maximum covered area by aquatic plant in 2005 was 50,000m^2. The covered area by aquatic plants in 2005 was 150,000m^2 which is three times as large as area in 2005.

Macrofitas was removed manually by 20-30 workers in the past. At present 2-3 workers removed Macrofitas because belt conveyers were installed shown in above photo. Removed Macrofitas is carried to a solid waste disposal site or is used for fertilizer.

The following pictures taken in September 2005 show aquatic plants near the intake point and the belt conveyor. Amount of aquatic plants looks not so much. According to the interview to the staff of SABESP, aquatic plants decrease from September then disappear in October because of water level raise due to starting rainy season.

Photo 5.1.3 Aquatic Plant around Intake P/S

Photo 5.1.4 Belt Conveyor for Removal of Aquatic Plant

5.1.3 Water Quality of the Taquacetuba Arm

(1) Water quality monitoring results by the SABESP

The SABESP has commenced to take a water of 4.0 m^3/sec from the Taquacetuba Arm in 2000 to supplement through pumping to the Lake Guarapiranga which is a water source for Sao Paulo. According to the Guarapiranga 2005 Report prepared by the SABESP, the water pumped from the Taquacetuba Arm shares 29% in the total water resource of the Lake Guarapiranga and the Lake Billings is regarded as an important supplemental reservoir for the Lake Guarapiranga.

For this reason, The SABESP has conducted water quality monitoring since water pollution in the Lake Billings brings water pollution of the Lake Guarapiranga. Watching cyanobacteria in **Figure 5.1.13**, the water from the Lake Billings becomes one of pollutant sources of the Lake Guarapiranga.

From the SABESP's report on "Qualidade da Agua do Sistema Billings - Guarapiranga, Relatorio 28, Janeiro e Julho/05" and "Relatorio 29, Ago e Dezembro/05", the following are pointed out in terms of the water of the Taquacetuba Arm (see **Figure 5.1.13**) for which the environmental standards Class Special of CONAMA No.357 is apllied to.

(a) Nutrient

TP concentrations at BL105 are lower during January to December in comparison with an environmental standard of 0.020 mg/L, while TN is almost same as an environmental standard during January to June, but lower during August to December.

(b) Algae - Cyanobacteria

Cyanobacteria at BL 102 and BL103 is in Alert 2 during May to early-July and high as 300,000 Cel/mL in mid-July, while that at BL105 is high in Aleta 3 during January to July and 100,000 Cel/mL during August to December.

"Aleta" in Portuguese means "alert" in English. The categolization of Aleta in the Lake Billings is Alerta 1: below 20,000 Cel/mL, Alerta 2: 20,000～100,000 Cel/mL and Alerta 3: over 100,000 Cel/mL

But Aleta for the Lake Guarapiranga is different from that for the Lake Billings and more stringent. The categolization of Aleta in Lake Guarapiranga is Alerta 1: 100,000-300,000 Cel/mL, Alerta 2: 300,000-600,000 Cel/mL and Alerta 3: over 600,000 Cel/mL

(c) Microcystis

Microcystis was 1.0 μg/L at all monitoring points in the Lake Billings, but recorded a high concentration at the surface layer of BL102 and BL103 only one day on July 11. A high value of 4.0

μg/L was recorded at BL105 on May 26 and a high concentration lasted at the surface layer of BL102, BL103 and BL105 since October 25. The middle layer of BL105 was 2.0 μg/L.

(d) Toxicity

Toxicity concentration were low at all monitoring points in the Lake Billings, but recorded middle levelvalue at the surface layer of BL105 on February 3, July 19 and September 20.

(e) Heavy Metal

In comparison with CONAMA357environmental standards, values of As is in a high level at the surface layer of all monitoring points. High values are observed at the surface layer in Cd and Hg, and lower layer in Cd and Pb. Hg has the maximum value of 0.0012 mg/L at the surface layer of BL103 on January 18. PB recorded a high value of 0.045mg/L at the lower layer of BL102 on January 18.

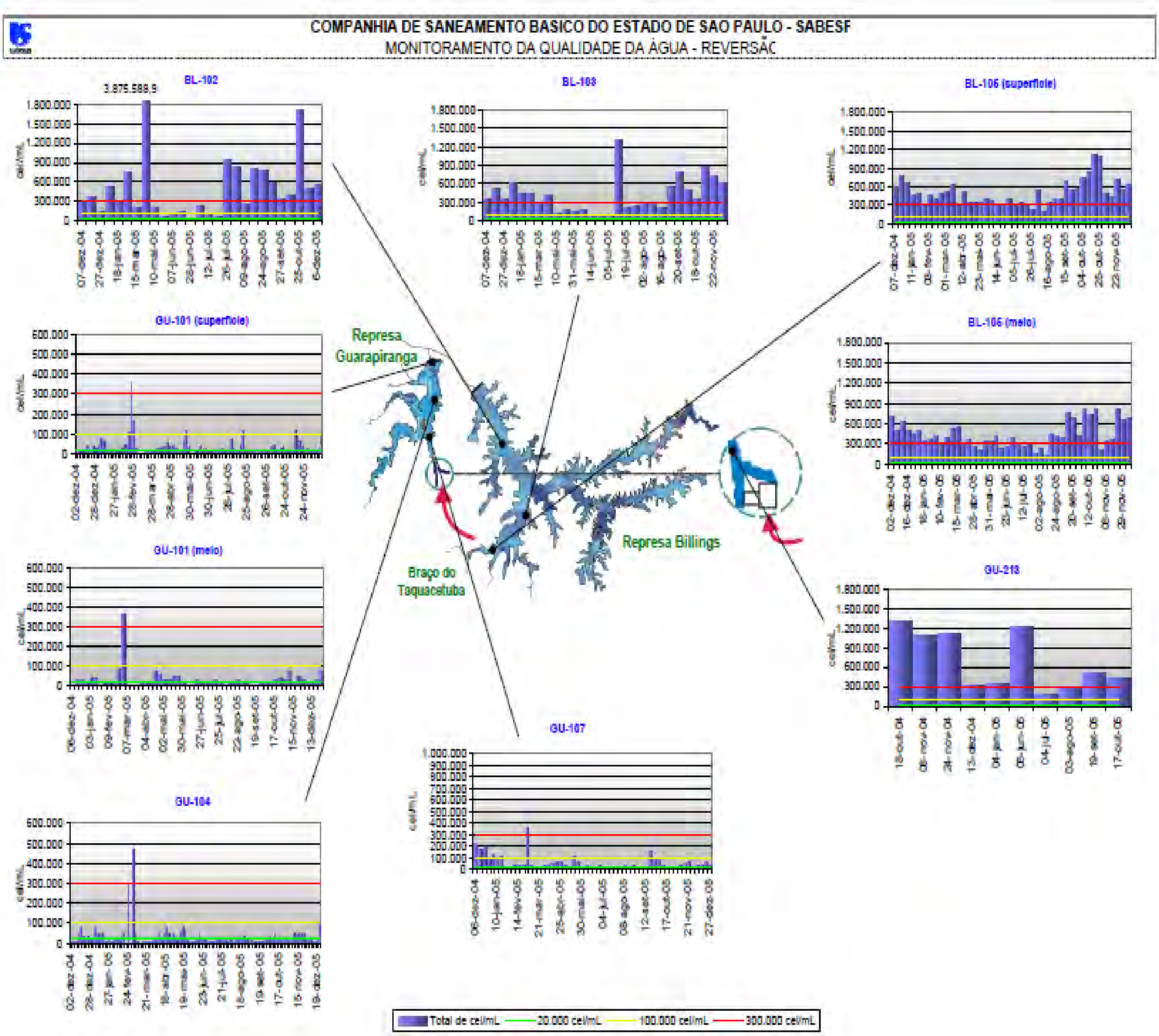


Figure 5.1.12 Yearly Change of Cyanobacteria (Dec. 2004 to Dec. 2005)

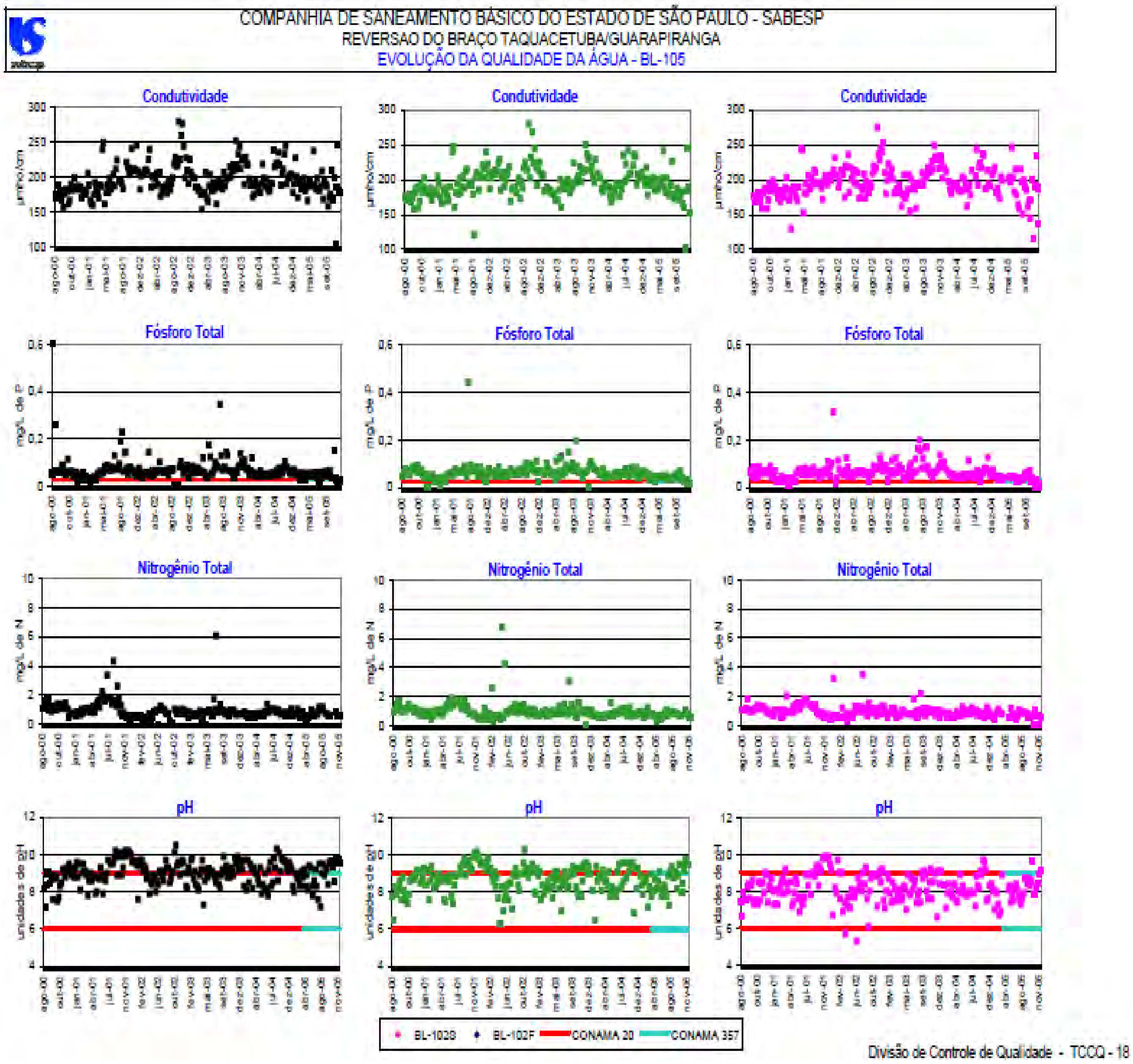


Figure 5.1.13 Change of water quality (conductivity, TN, TP, pH) at BL105 of the Taquacetuba Arm (Dec. 2004 to Dec. 2005)

The monitoring point of the SABESP at BL105 is the same as that of the CETESB at BITQ00100 for reference.

The pumping operation in 2005 from the Taquacetuba Arm to the Lake Guarapiranga was suspended during January18 to May 5 due to pump trouble and resume pumping of 2.0 m^3/s from May 6 with an increase to 4.0 m^3/s from June 4, but stopped again from November 6 as shown in **Figure 5.1.14**.

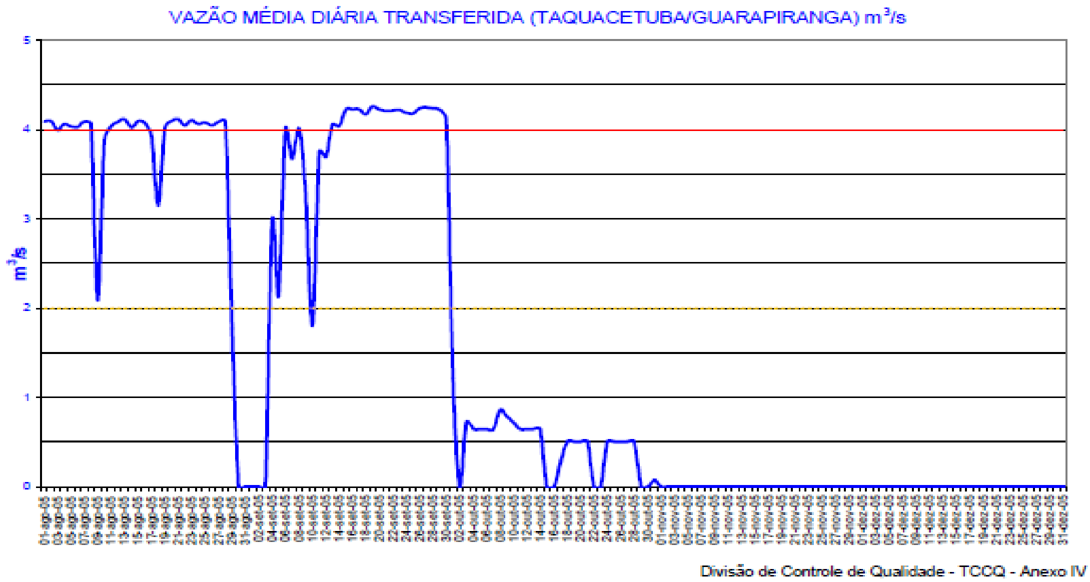


Figure 5.1.14 Pumping operation from the Taquacetuba Arm to the Lake Guarapiranga in 2005

(2) Water quality monitoring results of the CETESB and JICA Study in 2005

Water quality monitoring results of the JICA Study is shown in **Table 5.1.11** which is modified as shown in **Table 5.1.12** and **Figure 5.1.15** by additng the CETESB's results. Among four monitoring of the JICA Study, one was done in September during a rainfall and different in hydrological conditions with other monitorings. Accordingly, the results are evaluated except for those in September.

According to the JICA Study, BOD is in the range of 5 to 14 mg/L or 3mg/L higher than environmental standards, while COD 26 to 45 mg/L , TN 0.90 to 1.87 mg/L and TP 0.042 to 0.215 mg/L that is rather higher than an environmental standard. Faecal coliform is zero to 1 MPN/100mL below of an environmental standard of 200 MPN/100mg/L.

The concentrations were 0.103 to 0.152 mg/L in Fe, 0.018 to 0.022 mg/L in Mn and not detective (below 0.0001 mg/L) in Hg.

High values of TN and TP, especially Fe and Mn were found to the lower layer, which reflected the influence by eluted loads.

Table 5.1.11 Water Quality Monitoring Results in the Taquacetuba Arm (From August 2005 to January 2006)

Date (dd/mm/yy)	Hour**	Weather**	Depth** (m)	Water temp.** (°C)	DO (mg /L)	BOD (mg /L)	COD (mg /L)	DOC (mg /L)	TP (mg /L)	TN (mg/L)	F-coli (NMP/100ml)	Chlorophyl-a (μg/L)	Fe (mg /L)	Mn (mg /L)	Hg (mg /L)
18/08/05	2:20 PM	cloudy	0	22.3	10	6	26	7.3	0.215	1.87	0	3.21 -feo 45.44	0.139	0.016	n.d.
			2	19.8	7	5	20	6.8	0.192	1.2	20	9.62 -feo 26.68	0.187	0.019	n.d.
			4	19	5.8	6	24	7	0.158	0.9	1	2.14 - feo 15.82	0.124	0.024	n.d.
			6	19.5	2.8	5	22	6.8	0.238	1.31	0	nd - feo 8.55	0.302	0.071	n.d.
06/09/05	10:40 AM	rainy	0	19	8.8	1	19	6	< 0.045*	0.71	1	1.60 - feo 54.53	0.187	0.032	n.d.
			2	19	8.4	1	18	5	< 0.045*	1.16	2	nd - feo 25.98	0.22	0.037	n.d.
			4	19	8.2	2	16	6.6	< 0.045*	1.3	1	nd - feo 14.38	0.217	0.035	n.d.
			6	19	6	1	12	6.8	< 0.045*	1.18	4	nd - feo 12.72	0.454	0.077	n.d.
23/11/05	3:40 PM	cloudy	0	25	10	14	45	9.2	0.082	1.601	1	48.6	0.152	0.022	n.d.
			2	24	10.2	12	43	9.5	0.119	2.285	0	43.3	0.197	0.023	n.d.
			4	24	9.4	14	52	9	0.083	2.511	20	63.1	0.223	0.028	n.d.
			6	21	8.6	7	61	9.5	1.84	1.866	2	1.1	0.629	0.333	n.d.
11/01/06	2:00 PM	fine	0	28	11	5	29	6.5	0.042	0.904	0	72.7	0.103	0.021	n.d.
			2	28	11	6	38	7.5	0.057	0.97	0	39	0.141	0.023	n.d.
			5	27	8.2	6	26	5.5	0.051	0.95	0	78	0.21	0.042	n.d.
			7	25	1.8	5	34	5.5	0.013	1.715	1	25.7	0.415	0.248	n.d.

Note: A detection limit of Hg is 0.0001 mg/L

Table 5.1.12 Water quality monitoring results by the CETEB and the JICA Study (2005)

Samppling	BOD (mg/L)	COD (mg/L)	TN (mg/L)	TP (mg/L)	Chl-a (g/L)
05/01/05	5	<50	1.60	0.05	63.4
09/03/05	4	<50	2.36	0.06	32.4
04/05/05	5	<50	1.80	0.07	67.3
06/07/05	3	<50	1.75	0.03	28.3
18/08/05	6	26	1.87	0.22	45.4
06/09/05	1	19	0.71	0.05	54.5
20/09/05	4	<50	1.29	0.05	52.1
23/11/05	5	<50	2.09	0.06	71.5
23/11/05	14	45	1.60	0.08	48.6
11/01/06	5	29	0.90	0.04	72.7

(shaded rows) :JICA Study

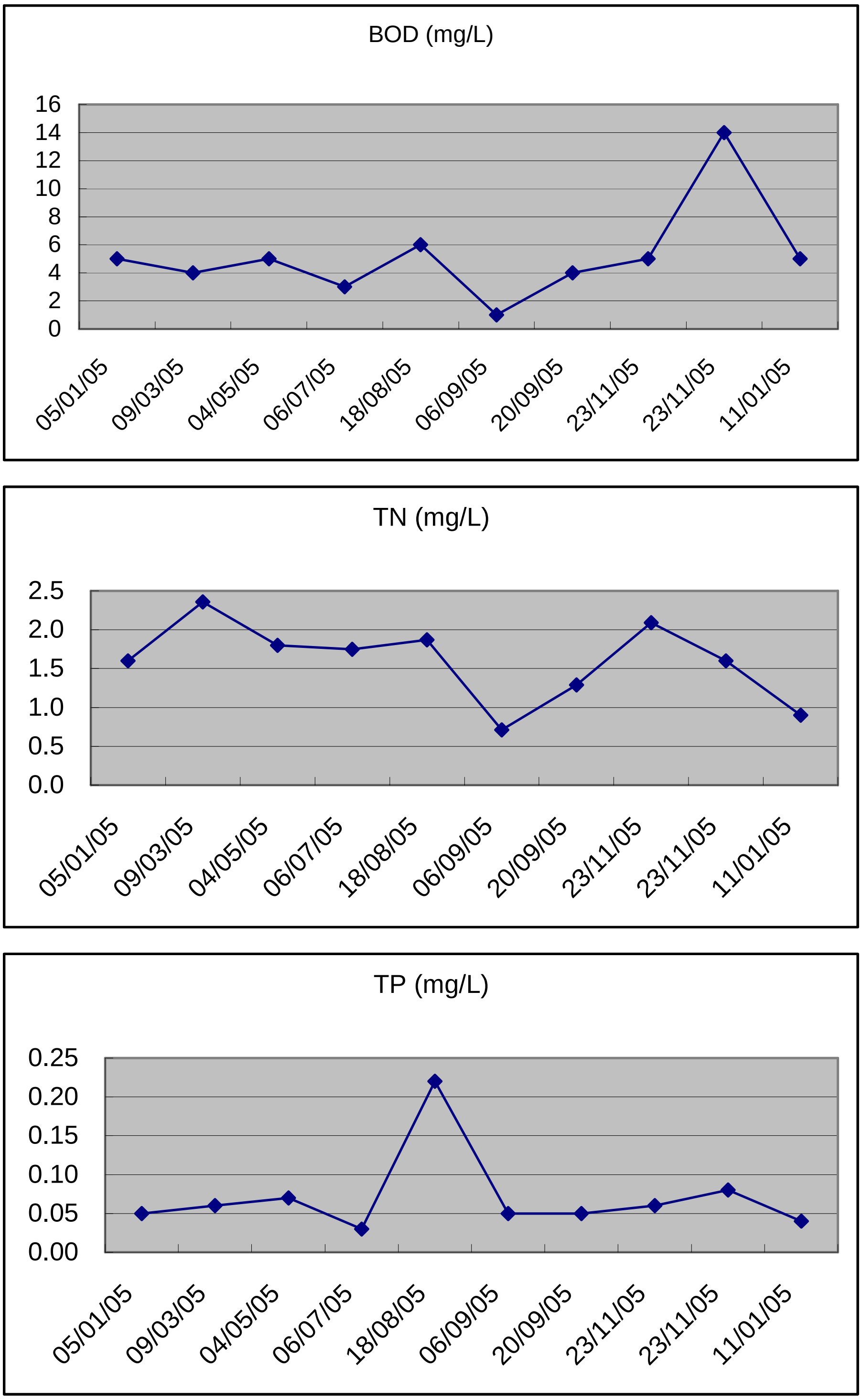


Figure 5.1.15 Water quality monitoring results by the CETEB and the JICA Study (2005)

5.2 Water Quality Evaluation based on the Previous Studies

CETESB classifies the state of Sao Paulo into the 22 districts, and the Billings Lake area corresponds to the 6th area. Water quality is generally evaluated as drinking water source on the basis of the influence against people's health and index of the environmental preservation such as possibility of swimming.

In addition to the water quality evaluation by CETESB, specifically it is evaluated from a viewpoint of the influence on the water treatment system and influence of potable water for the health. Current status of water quality in the both lake as a source of drinking water is studied in terms of degree of eutrophication and generation status of algae.

Report on water quality in the past by CETESB (Relatorio de Qualidade das Aguas InteRiores do Estado de Sao Paulo) and results of the water quality survey conducted in this project were referred for water quality evaluation.

5.2.1 Current status of eutrophication

The cause and its influence against lake/ reservoir water pollution and contamination are classified as shown in the following table.

Table 5.2.1 Cause and its influence to water pollution or contamination

Cause	Influence
Suspended solids, such as soil and sand	Turbidity
Organic matter	Anaerobic condition by consumption of a dissolved oxygen (Generation of bad smell, death of fishes by oxygen deficiency, etc.)
Nutrient salt (nitrogen, phosphorus, etc.)	Eutrophication
Chemical substances (agricultural chemicals etc.)	Influence on health and ecosystem
Pathogenic microbe	Influence on health

(Source; 2004 Chiba Environmental Research Center, water quality/ environmental quality, Hirama)

(1) Circulation of mass in a lake

The Billings Lake is important for the residents as an electric power source, source of tap water, agriculture use, industry use and recreational fields. In the Billings Lake, problems such as generation of algal bloom by eutrophication and aquatic plants such as macrophitas and emission of the musty odor by algae have been occurring recent years. The status of eutrophication of the Billings Lake is examined as follows;

Material circulation in a lake can be expressed by inflow, internal production, sedimentation, elution, and discharge as shown in the following figure.

As pollutant sources of organic matter contamination for the Billings Lake, there are "point source contamination" like factories/ households and "non-point-source contamination" like farmland or a city area. Internal production which is the organic matter production by phytoplankton must be taken up as another contamination. It is reported by the latest research that there are some type of water body in which the organic matter by internal production reaches 50 % of all the organic matters generated in the water during a summer.

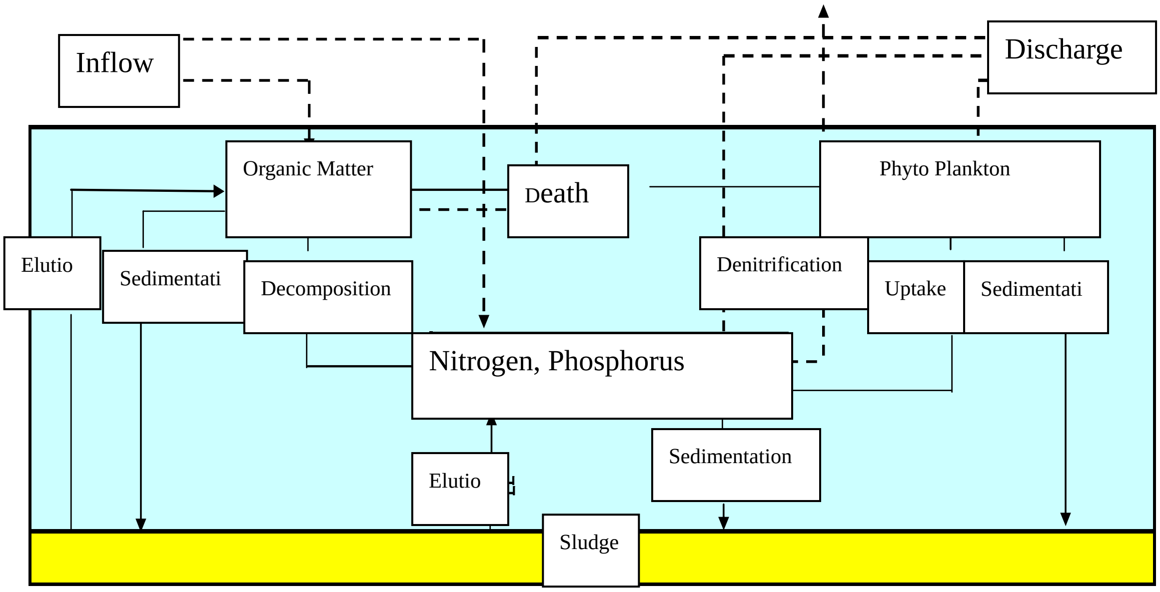


Figure 5.2.1 Mass circulation by inflow, internal production, sedimentation, elution and discharge in a lake

When COD is used as an index of the amount of organic matters for mass circulation, COD in a lake is the sum of COD which flows in from the outside and COD produced in the lake by growth of phytoplankton. The growth of phytoplankton is determined by nutrient salt concentration, such as the nitrogen and phosphorus, etc. in a water body, an amount of insolation, water temperature, and the detention time.

According to the COD data in the Billings Lake by CETESB, they are 8.17 mg/L (average value in 1994 - 2003), and 5.85 mg/L (2004) respectively at BITQ00100, southwest of the Billings Lake. Since the present generation of algae of this point is comparable with the whole west side region of the Imigrantes highway, the value can be considered a representative value of the COD in the whole Billings Lake.

The internal production by growth of phytoplankton can be cited as a reason that comparatively high COD in the Billings Lake.

(2) The eutrophication status of the Billings Lake and the Rio Grande arm

Generally, nitrogen and phosphorus which are nutritive salts required for growth of phytoplankton etc. are used as indices by which the status of eutrophication of a lake is evaluated.

The data of nitrogen and phosphorus in the Billings Lake and the Rio Grande arm are furnished fairy well. Average concentration of nitrogen and phosphorus in 1992 – 2002 and the concentration of nitric nitrogen, ammonia nitrogen and total phosphorus for 2003 and 2004 in each measuring spot are shown below.

Table 5.2.2 Concentration of nitrogen and phosphorus in the Billings Lake and Rio Grande Arm

	Data Year	NKT mg/L	NH_4-N mg/L	NO_2-N mg/L	NO_3-N mg/L	T-N mg/L	T-P mg/L	T-N/T-P
BILL02100	2004	1.14	0.13	0.06	1.49	2.69	0.087	31
	2005							
BILL02500	2004	0.92	0.10	0.04	0.77	1.73	0.063	27
	2005							
BILL02900	2004	0.95	0.07	0.14	1.48	2.57	0.048	54
	2005							
BITQ00100	2004	1.58	0.05	0.02	0.43	2.03	0.088	23
	2005							
RGDE02200	2004	1.69	0.62	0.17	2.59	4.45	0.082	54
	2005							
RGDE02900	2004	0.83	0.11	0.05	0.73	1.61	0.070	23
	2005							

In the lake, 3 ranks according to the degree of biological production are determined to describe the type of eutrophication of water body of Polytrophic, Mesotrophic, and Oligotrophic. The classification of the type of water body in Japan is conducted according to the range of concentration being shown in the **Table 5.2.3**.

Table 5.2.3 Type of water body of lakes by nitrogen and phosphorus concentration

Type of water body	Nitrogen (N)	Phosphorus (P)
Oligotrophic	0.02～0.2 mg/L	0.002～0.02 mg/L
Mesotrophic	0.1～0.7 mg/L	0.01～0.03 mg/L
Polytrophic	0.3～1.3 mg/L	0.01～0.09 mg/L

The type of the state of eutrophication of each study point of the Billings Lake and the Rio Grande arm is classified according to the type of water body and past data (average value in 1993 - 2002) as follows. In the Billings Lake, concentration of nitrogen and phosphorus at the point of BILL02500 and BILL02100 are in the strong eutrophication state. And in BILL 02900 and BITQ00100, phosphorus concentration shows the state of strong eutrophication and nitrogen in the state of medium eutrophication. In the Rio Grande arm, both nitrogen and phosphorus are in the state of strong eutrophication. In light of the concentration of nitrogen and phosphorus they are both already eutrophicated.

Table 5.2.4 State of eutrophication in the Billings Lake and Rio Grande arm

Location	Nitrogen (N)	Phosphorus (P)
BILL02100	Polytrophic	Polytrophic
BILL02500	Polytrophic	Polytrophic
BILL02900	Polytrophic	Polytrophic
BITQ00100	Polytrophic	Polytrophic
RGDE02200	Polytrophic	Polytrophic
RGDE02900	Polytrophic	Polytrophic

The north-west part of the Billings Lake is adjacent to Sao-Paulo city. In this area of the Lake, eutrophication has been advancing extensively and the generation of algal bloom was acknowledged. In some arms of the same area, bad smell by the decomposition and the generation of methane gas was found.

In the Guarapiranga reservoir, a report described that the deterioration of water quality and algal bloom had been occurring since seven years ago. Since the algae had been growing from past at the location, copper sulfate ($CuSO_4$) was sprinkled to control generation of algae in the area every time the sign of bloom was observed. However, since sprinkling copper sulfate in the reservoir was prohibited by regulation, bad influences were thought to be remarkable to the water treatment.

Moreover, phosphoric acid in detergent is considered to be the source of phosphorus concentration with a degree of mesotrophic state in all the location in the Billings Lake and the Rio Grande arm all point. At all above-mentioned location, approximately 0.1 mg/L of the anionic surface active agent (MBAS) has been detected, which is the main substance of detergent.

In the Sao-Paulo state, reduction of discharge nitrogen and phosphorus into the Billings Lake is aimed at making the regulation of discharge control or setting up environmental standards, however, such regulations do not seem effective due to social and economical reason.

Growth of the phytoplankton by the elution of the nutritive salts from bottom sediment (one of the processes of material recycling in the lake) would be raised as one of the big problem. Decomposition of the organic matter in the bottom sediment will be promoted by the rise of water temperature in the summer and, the bottom will be in the condition of reduction by the fall of dissolved oxygen concentration. Phosphorus and nitrogen may carry out an elution to the water from the bottom sediment under such condition, and rapid multiplication of phytoplankton may be promoted. After the decomposition, nitrogen and phosphorus in organic matter will be a form of nitric acid and phosphoric acid, and they will serve as nutritive substance for phytoplankton. These nitrogen and phosphorus in the lake or the closed water body will be circulated to make excrescence of the algae leading to algal bloom or a musty odor continuously.

When eutrophication states for every location are expressed by the chlorophyll-a concentration which is the water quality standard proposed by Vollenweider (1986) of WHO as an index of eutrophication, the result is as follows; Chlorophyll-a is the pigment contained in an algae, and it is known that correlation with the amount of an algae and its concentration is very high. For this reason, Chlorophyll-a is used as an index by which the total amount of an algae is evaluated. In the point of BILL02100, BILL02500, and BITQ00100, they are all in strong eutrophication states-polytrophic, and BILL02900 and RGDE02900 is Mesotrophic by the average value in 1994 - 2003. Such evaluation becomes a little bit severer than that of by nitrogen and phosphorus. However, according to the data of chlorophyll-a, the value has been always in the range of 40-80microg/L in the Billings Lake, it has been about 1/4 to 1/8, that is approximately 10micro-g /L in the Rio Grande arm.

Table 5.2.5 Eutrophication criteria of Vollenweider

Eutrophication state	Chlorophyll-a concentration (μg/L)	
	Average	Maximum
Mesotrophic state	8.0～25.0 8.0-25.0	25.0～75.0 25.0-75.0
Polytrophic state	>25.0 25.0	>75.0 75.0

Table 5.2.6 Chlorophyll-a in the Billings Lake

Location	Clorofila a (μg/L)	
	Average of 1994-2003	Average 2004
BILL02100	89.35	54.93
BILL02500	42.18	41.93
BILL02900	20.33	
BILL00100	58.09	48.22
RGDE02200		
RGDE02900	13.01	10.00

Microcystis, one of the representative cyanobacterium, is not dominating species in the Rio Grande arm, but Mougeotia which is one of the green algae is the dominant instead. In the Billings Lake, thin layer of Microcystis is always seen on the surface of the lake.

5.2.2 Water quality evaluation from the view of environmental preservation

The designation of water quality class in the environmental standards is Class 2 for the Centarl Channel from Pedreira Dam to summit Dam and the Rio Grande Arm and Class special for the Arms of Borore, Taquacetuba, Pedra Blanka and Capivari upstream of power transmission line crossing the respective arams, and Rio Pequeno Arm upstream of the Anschieta Highway crossing the arm.

The water quality monitoring points are set at four points in the Lake Billings and two points in the Rio Grande Arm. The environmental standards consist of 103 parameters, but the CETESB doesn't necessarily cover all parameters in the monitoring every one month. The monitoring is focused on organic pollution parameters and inorganic parameters which is composed of rainfall, color, water temperature, air temperature, transparency, 27 physico-chemical parameters, 3 microorganism and biological parameters and one ecological toxicity. Unattainment situation of environmental standards in the past three years (2003 to 2005) is shown in **Table 5.2.7**, which shows that parameters of BOD_5, Al, Phenol, Mn, and TP sometimes does not meet the standards both in the Lake Billings and the Rio Grande Arm.

Table 5.2.7 Unattainment of environmental standards in the Lake billings and the Rio grande Arm

(unit: times/6-times)

Environmental standards	Lake Billings												Rio Grande Arm					
	BILL02100 Near Pedreira Dam			BILL02500 Confluence with the Taquacetuba Arm			BILL02900 Intake to Summit Dam			BITQ00100 Taquacetuba Arm			RGDE02900 Near Rio Grande Intake Works			RGDE02200 Intermediate point		
Class	2			2			2			Special			2			2		
year	03	04	05	03	04	05	03	04	05	03	04	05	03	04	05	03	04	05
Al	4	2	4	2	3	5	2	3	3	5	4	5	1	2	3	5	4	5
Chlorides													1					
Pb												1						
Cu													3	5			2	
BOD_5	3	1	1	3	1		2			6	5	5	1	1		3	1	3
Fenol		2				1		2	1		1			2				
TP	5	6	6	5	6	5	5	5	4	5	6	6	5	3		4	5	5
Mn															3	1		2
Hg							2									2		
Ni															1			
NH_4-N	1															4	3	1
NO_3-N			1														1	
NO_2-N																1		
DO	1		2	1						1			1					
Turbidity	1																	

Note 1: Due to the revision of CONAMA environmental standards in 2004, a standard in 2005 may be different from the previous one depending on parameter.

Note2: By the revision of CONAMA environmental standards in 2004, a standard of total Al (0.1mg/L) is changed to that of soluble Al (0.1mg/L). The values in 2005 were evaluated based on the previous standard, since the 2005 analysis was done for total Al

Note 3: Cu in the Rio Grande Arm do not meet an environmental standard, but Cu in the Ribeirao Pires River and the Rio Grande River, that are the pollutant sources of the lake, are below an environmental standard. The Cu concentration is attributed to the internal source probably spreading of copper sulphate that is used as algaecide in the lake for operation of the Rio Grande WTP.

There are a lot of parks and clubhouses which are built waterside of the Billings Lake, the Rio Grande arm and the Guarapiranga Lake as they are shown in the figure. Thus, while the Billings Lake and the Rio Grande arm are the important water sources of tap water for the Sao Paulo area, the lakeside serves as water front which is important for citizens' relaxation.

Figure 5.2.2 Clubs and Parks around the Lake Billings and Rio Grande Arm

CETESB evaluates the water quality of the Billings Lake and the Rio Grande arm from a viewpoint of safety for swimming every year.

The evaluation of the safety of swimming in the water is made to classify the water quality into four divisions shown below by the numbers of fecal coliform bacteria group or infectious microbes. All the location of measurement of the east side of center in the Billings Lake were evaluated that the water is safety for swimming. The trend of water quality improvement is shown in the transition of evaluation of the data in the Billings Lakes and the Rio Grande arm from 1995 to 2004.

Table 5.2.8 Eligibility for Swimming in the Lake billings and Rio grande arm

	‘95	‘96	‘97	‘98	‘99	‘00	‘01	‘02	‘03	‘04
Clube Prainha Taiti	D	C	C	B	B	C	B	C	C	C
Clube de Campo do Sind. Metal. Do ABC				A	B	B	A	C	A	A
Próximo ao Zoológico do Parque Municipal	C	C	C	C	C	B	A	A	C	C
Prainha do Parque Municipal	D	C	C	C	C	C	C	A	A	A
Prainha da ETE	D	D	D	D	D	D	C	C	C	C
Parque Imigrantes							C	C	C	C
Próximo a Entrada de DERSA					C	C	C	C	C	C
Praia do Jardim Los Angeles				C	C	B	C	C	C	C

Index A Good throughout a year
B Almost good throughout a year
C Not proper for less than half year
D Not proper for more than half year

Note: The screened portion show the Lake Billings and others the Rio Grande Arm.

5.2.3 Water quality evaluation from the view point of drinking water source

In the Billings lake, water flowrate of 4.0m^3/s is supplied to the reservoir of Guarapiranga from the Taquacetuba arm and from the Guarapiranga, after the water intake of about 14~15 m^3/s water treatment is made to supply the water to the Sao-Paulo city. In the Rio Grande arm, as a source of tap water, the 4.5m^3/s of water intake is carried out, and the water is processed in the Rio Grande water treatment plant to be supplied to the ABS urban area.

It is thought that the problem as water quality of both the Billings Lake and the Rio Grande arm is as follows.

< The Billings lake>

- Extensive generation of cyanobacterium
- Generation of a musty odor (2-MIB)
- Generation of bad odor and methane gas in some arms.
- High chromaticity.

< Rio Grande arm>

- Generation of a musty odor (2-MIB)
- Generation of green algae (Moogeotia)
- Generation of aquatic plant such as macrophitas
- The elution of the iron and manganese from a bottom sediment
- High chromaticity
- Low alkalinity

(1) The algae generation status

The clear difference arising from the difference in eutrophication level is seen in the generation status of the algae of the Billings Lake and the Rio Grande arm.

The kind and the amount of outbreaking algal bloom have a close relation to eutrophication state of the water body. Generally, diatoms, golden algae, etc. appear in dominance with few amounts in an oligotrophic type lake. In the progressed eutrophication status, green algae, cyanobacterium, euglena algae, etc. serve as dominant species, and the numbers of kinds also increase. Further, if eutrophication progresses remarkably, although the number of kinds decreases, biomass will tend to increase extremely.

(2) The Billings Lake

In this study, algal bloom was observed almost throughout the surface of the lake water except for the east side of the Imigrantes highway. The dominant species of algal bloom of the Billings Lake is Microcystis. And Anabaena is detected in some areas and it causes a musty odor (2-MIB). Moreover, Cylindrospermopsis other than Microcystis is detected.

(3) The Rio Grande arm

In this study, the generation of algal bloom was not found in the Rio Grande arm.

The dominant species of the algae detected in the Rio Grande arm was Mougeotia of green algae, in addition there were many green algae of Euglena, Staurastrum, etc., and it seemed that the level of eutrophication is not stronger compared with the Billings Lake since most Microcystis which are the dominant species of algal bloom were not detected. .

(4) Influence on the health by an algae (toxicity of a cyanobacterium)

Algal bloom is seen very ordinarily in pond and lake closely, and is considered to be harmless. It not only worsens tastes and smell of potable water, but there is some reports that pastured live stocks die with drinking the water contains algal bloom or human sometimes impairs liver function at the time of algal bloom breeding in the area where uses lake water for drinking water. Appearance of harmful cyanobacterium attracts attention due to its toxicity.

It has been confirmed that many species of cyanobacterium have toxin. The toxin is classified according to the target organs, such as liver poison, neurotoxin, and cytotoxin. As liver poison, there are micro cystines which Microcystis aeruginosa, M.viridis, Anabaena flos-aquae, Oscillatoria agardhii, etc. produce. As neurotoxin, anatoxin-a from Anabaena flos-aquae, and anatoxin-a(s) are identified. Moreover, it turns out that a neo saxitoxin, a saxitoxin, etc. are produced from Aphanizomenon flos-aquae. Further, it is known that Scytonema pseudohofmanni produces Scytophicin and that Hapalindol A is produced from Hapalosiphon fontinalis.

(5) Damage caused by poisonous cyanobacterium

The area where livestock and animal damage caused by harmful cyanobacterium were seen, and the country to which the appearance of harmful cyanobacterium was reported are shown below.

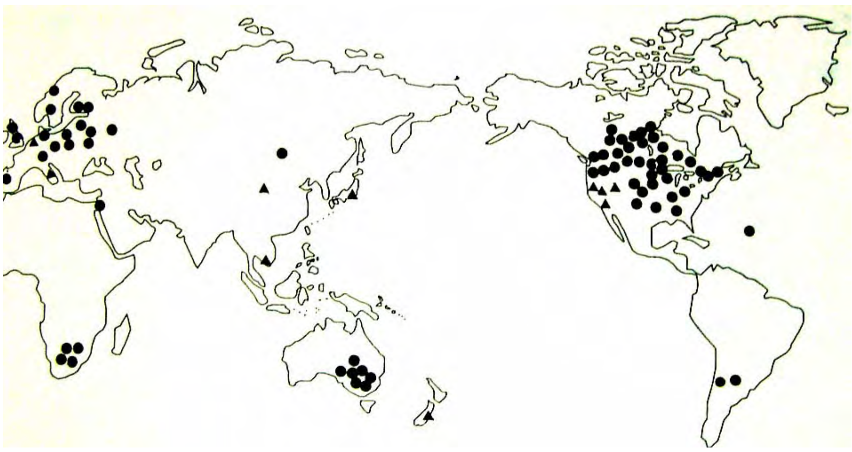


Figure 5.2.3 Area where damages for cattle were caused by harmful cyanobacterium

Also in Brazil, the damage caused by microcystine had occurred in the hemodialysis pin center, of the Caruaru city in the northeast part in February, 1996.

In this hospital, the symptoms were found in 117 of 136 patients (86%). 100 persons started acute hepatitis after that, and 50 persons died among those. This incident is called "Caruaru Syndrome". Since this incident is of water service origin, it needs management strengthening of the water resource and treated water quality in the water supply which uses water source with possibility of algal blooms.

(6) The generation of bad smell

As kinds of bad smell of tap water, there are musty odor, algae smell, smell of soil, chemical smell and iron smell. In using a reservoir for the water resource, bad smell resulting from algae poses a problem. Also in the Billings Lake and the Rio Grande arm, the musty odor by Anabaena and Oscillatoria of cyanobacterium is observed.

The algae which generate musty odor and the kind of musty odor are shown in the following table.

Table 5.2.9 Cyanobacterium by which musty odor production was confirmed

Cyanobacterium	Odor Substances
Anabaena macrospora	Geosmin
Anabaena spiroides	Geosmin
Aphanizomenon flos-aquae	Geosmin
Oscillatoria agardhil	Geosmin
Oscillatoria amoena	Geosmin
Oscillatoria splendida	Geosmin
Phormidium autumnale	Geosmin
Schizothrix muellerii	Geosmin
Oscillatoria cortiana	2-metyl-iso-boruneol
Oscillatoria geminata	2-metyl-iso-boruneol
Oscillatoria limnetica	2-metyl-iso-boruneol
Oscillatoria tenuis	2-metyl-iso-boruneol
Phormidium favosum	2-metyl-iso-boruneol
Phormidium tenue	2-metyl-iso-boruneol

(7) Disinfection by-product

As disinfection by-products, there are trihalomethane, dichloroacetic acid, trichloroacetic acid, formaldehyde and bromate ion, etc. The item measured in the Rio Grande water treatment plant is only trihalomethane. About formaldehyde or bromate ion, it seems satisfactory from a viewpoint of a water-purifying art and water-resource classification. About haloacetic acid, especially dichloroacetic acid, it is strongly recommended to measure for monitoring.

According to the study of CETESB, PFTHM (trihalomethane generative capacity) at the water-intake of the Rio Grande arm were 240 micro-g/L by the average value from 1994 to 2003 and 293micro-g/L in 2004. This is beyond 100micro-g/L which is a water quality standard value.

Moreover, in the Rio Grande water treatment plant, the average trihalomethane of the clean water is 64micro-g/L from 1997 to 2002 and the maximum value is 158microg/L. The number of times which exceeded the water quality standard value is 3 times.

(8) Chemical substance

Several kinds of agricultural chemicals were detected from treated water of the Rio Grande water treatment plant in the past.

A large-scale chemicals factory (Solvay) of Santo Andre is located on the south of the Rio Grande arm, and its waste water may have become a pollutant source. Regarding this waste water, it is scheduled to be sent to the ABC sewage treatment plant of SABESP from December, 2005. Even though improvement may be counted on, monitoring of agricultural chemicals and heavy metal may need to be performed continuously, since it had passively deposited on the bottom as sediment.

5.3 Water Quality, Pollutant Load and Bottom Sediment of the Lake Billings and Rio Grande Arm and Their Incoming Rivers.

The outline of water quality monitoring is described in **Annex A5.3.1**.

5.3.1 General Trend of Water Quality at the Principal Monitoring Points

The outline of the scheme for monitoring lakes and rivers in this study is as shown in **Table 5.3.1.** The points of monitoring are as illustrated in **Figure 5.3.1** for lakes **and Figure 5.3.2** for incoming rivers.

Table 5.3.1 Outline of the Scheme for Water Quality Monitoring

		No. of monitoring points	Monitoring frequency	Note
Lakes	Billings	6 points at monitoring points of CETESB	4 times	Vertical distribution (Bottom sediment: 3 points)
	Rio Grande Arm	3 points at monitoring points of CETESB plus 11 points for arms.	4 times. 2 times for arms	Vertical distribution. Surface only for arms (Bottom sediment: 2 points) Depth sounding
Rivers	Incoming Rivers	20 points including 2 WWTP	4 times with 6 times for 11 points on principal rivers	Surface only, including flow rate

5.3.2 Trend of water quality of lakes

(1) Water quality of Lake Billings

1) Horizontal variation along the river drifts

Based on the 4 times of water quality monitoring, the horizontal variations along the river drifts (from Pedreira Dam down to Summit Dam) are illustrated in **Figure 5.3.3**. Observations are made on principal indices of water quality as follows:

At most of the monitoring points, the water quality standard in terms of BOD, which should be lower than 5 mg/L, was not met, and the tendency showed, except for August when the influence of the pollutant load of Cocaia River influx (due to rainwater) was the least significant during the dry season, a gradually ascending and descending dome-shaped curve, falling gradually to reach the minimum value at the monitoring point BL-4 in Taquacetuba. Other indices of water quality, including TN, TP, Chlorophyll-a, F-coliform, etc., also showed similar tendencies.

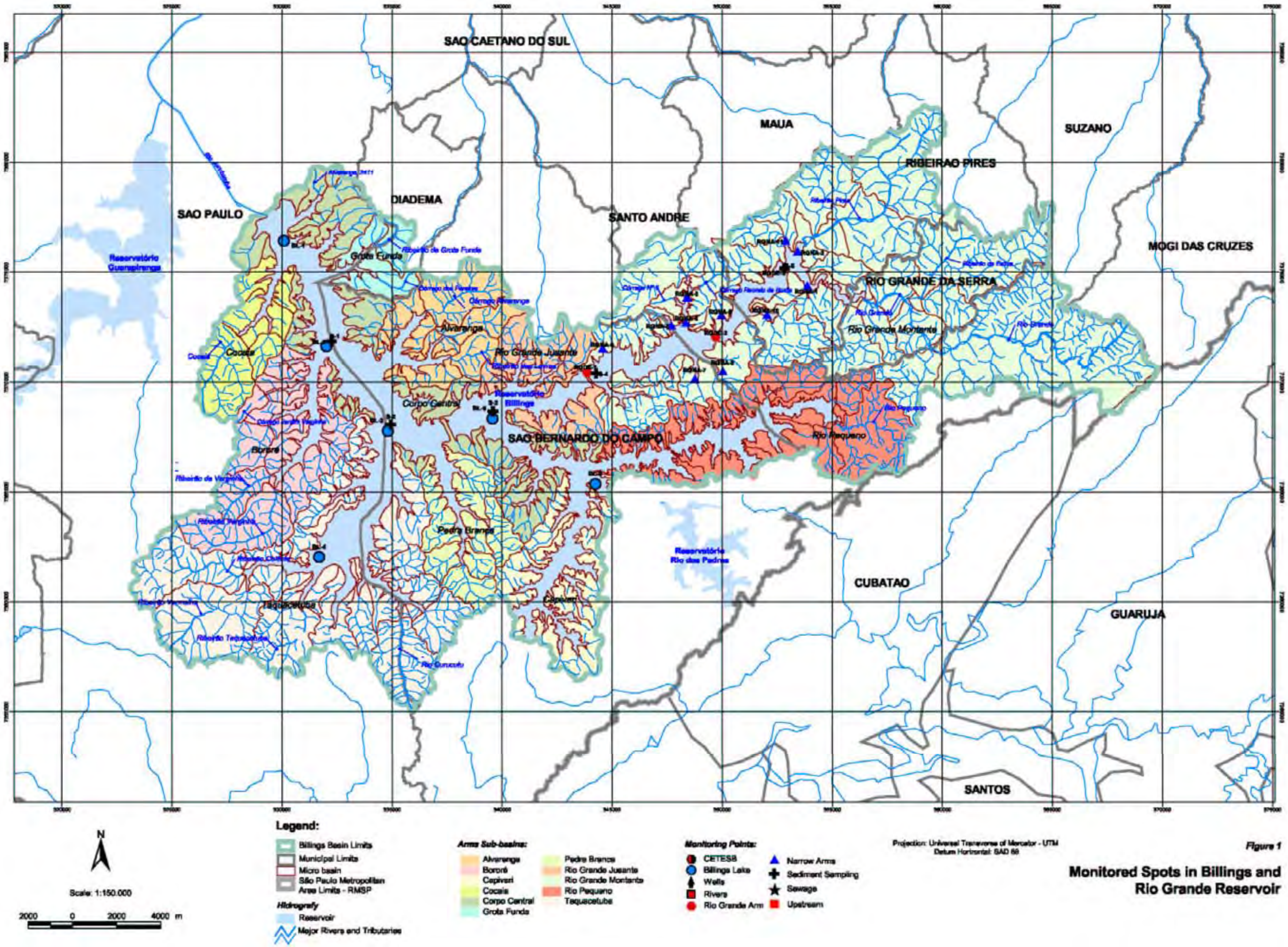


Figure 5.3.1 The points of monitoring for lakes

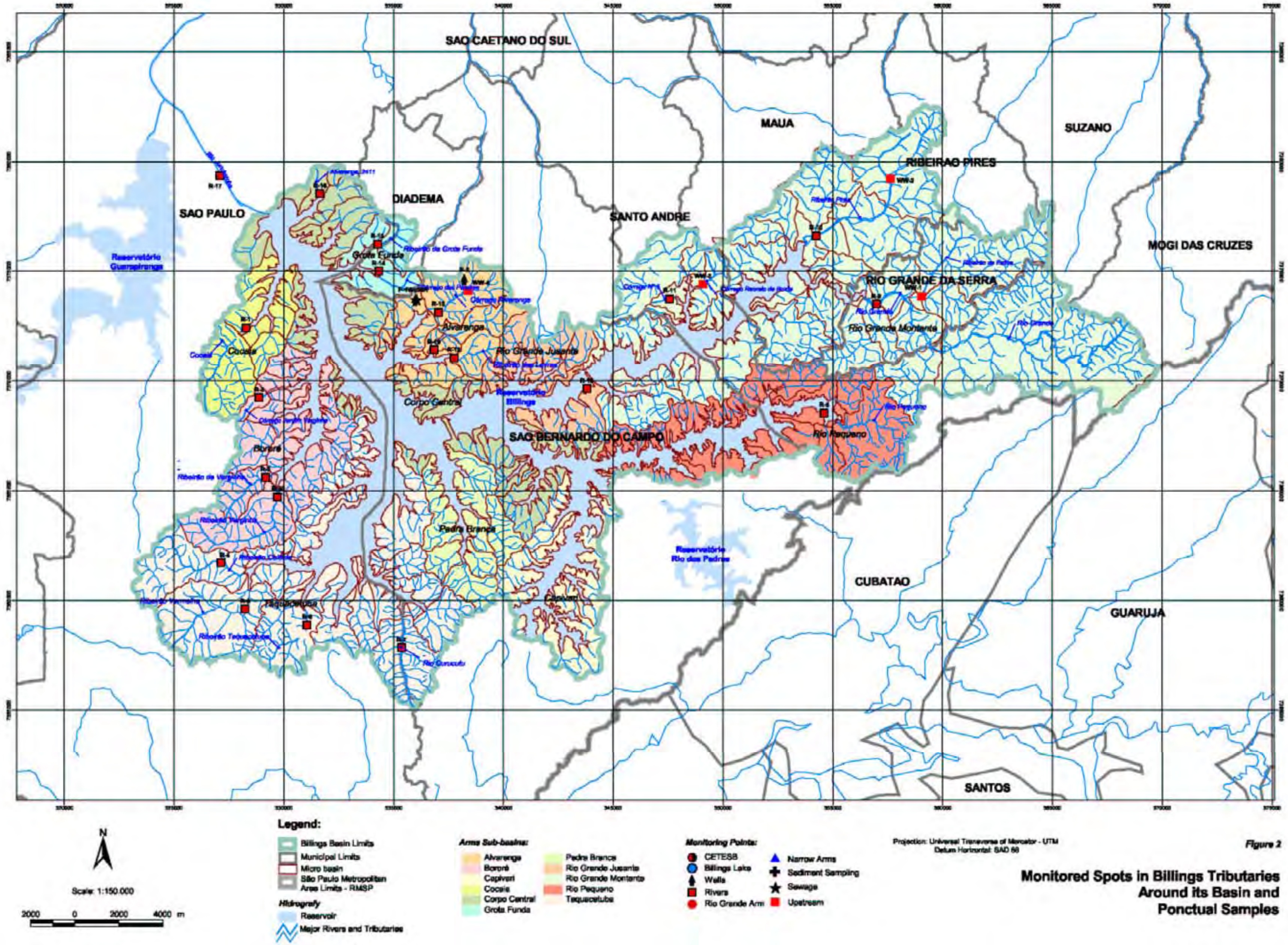
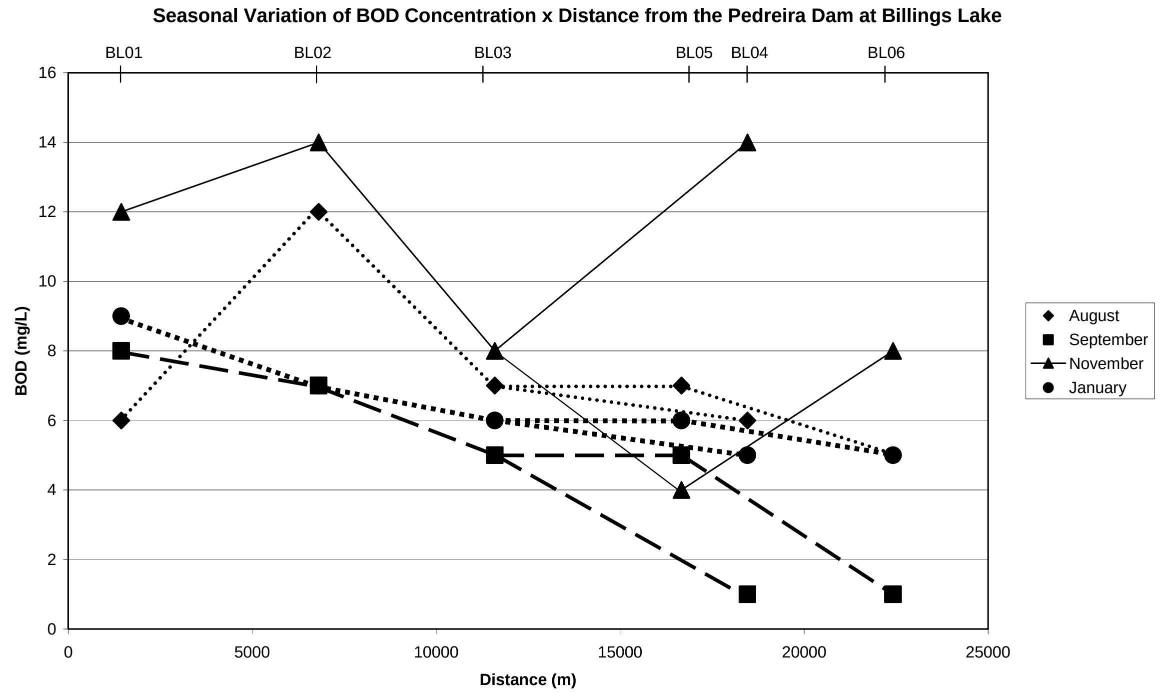


Figure 5.3.2 The points of monitoring for incoming rivers



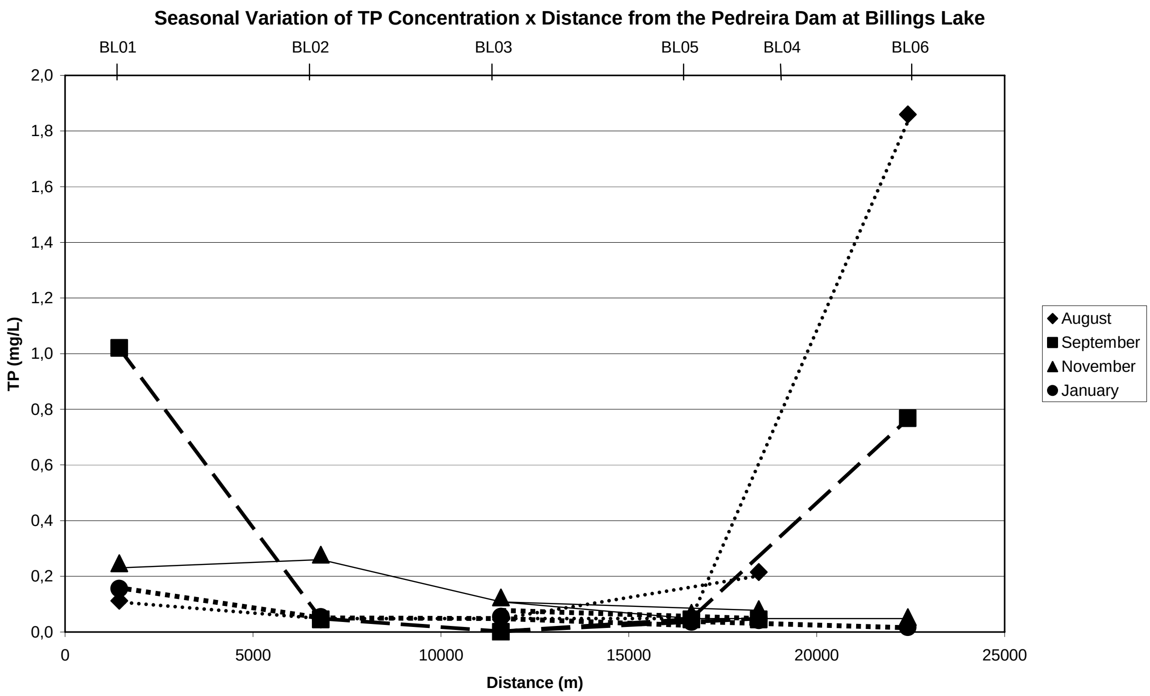
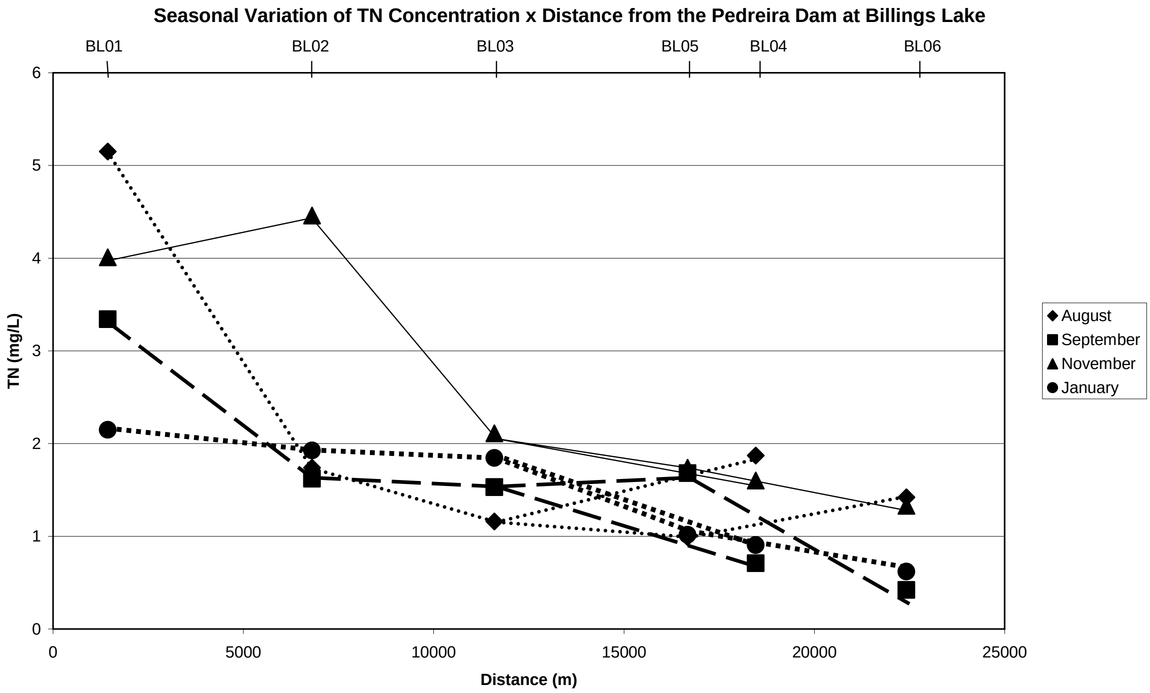


Figure 5.3.3 (1) Horizontal variation of water quality (BOD,TP) along the river drifts at the Lake Billings



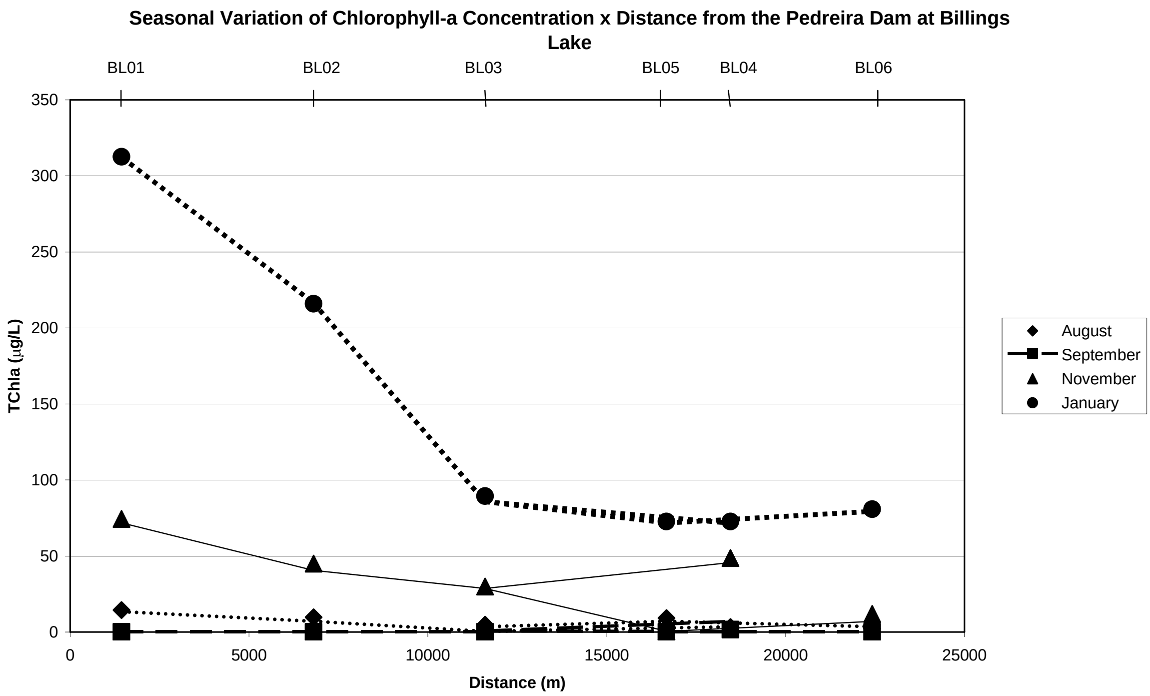


Figure 5.3.3 (2) Horizontal variation of water quality (TN,Chlo-a) along the river drifts at the Billings Lake

2) Vertical variation at monitoring points

The vertical distribution of water temperature and that of the water quality index of DO at the point BL-01 are shown in **Figure 5.3.4**.

Notably the monitoring during August, when a zero-precipitation spell in the dry season lasted long, revealed a distinct pattern of stratification (at other monitoring points, no stratification was observed). The monitoring subsequent to it at the location BL-01 revealed that the pattern of stratification was disturbed and mixed layers were formed, due to the influences of influx of rainwater, collection of drinking water, and wind.

At the time of monitoring in August, at the points including BL-1, observed values of DO at the levels deeper than 4 m, were less than 2 mg/L, indicating a low oxygen status, and an induced environment where nutrient salts of TN & TP, and such heavy metals as Mn, Fe, Hg, etc., were liable to be dissolved in water. In this manner, although the similar pattern did not necessarily appear at all the points, at the monitoring points near Pedrera, the seasonal formation of two-tier stratification was observed.

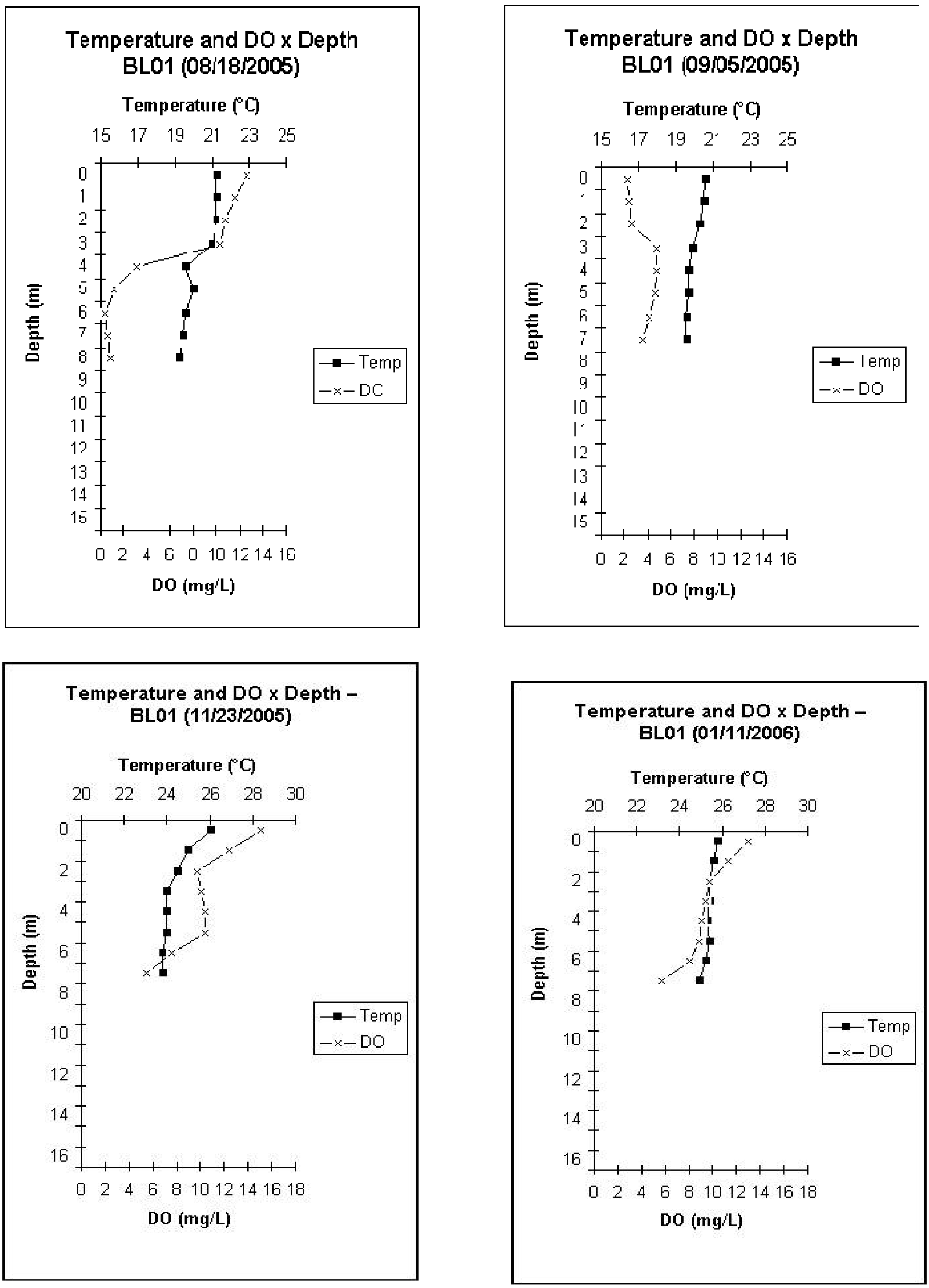


Figure 5.3.4 Vertical variation of water quality at BL-01of the Lake Billings

3) Seasonal variations

Seasonal variations are shown in **Figure 5.3.5**. The tendency of more pollution in the rainy season than in the dry season was observed. Particularly, Chlorophyll-a was observed to indicate high values during the rainy season.

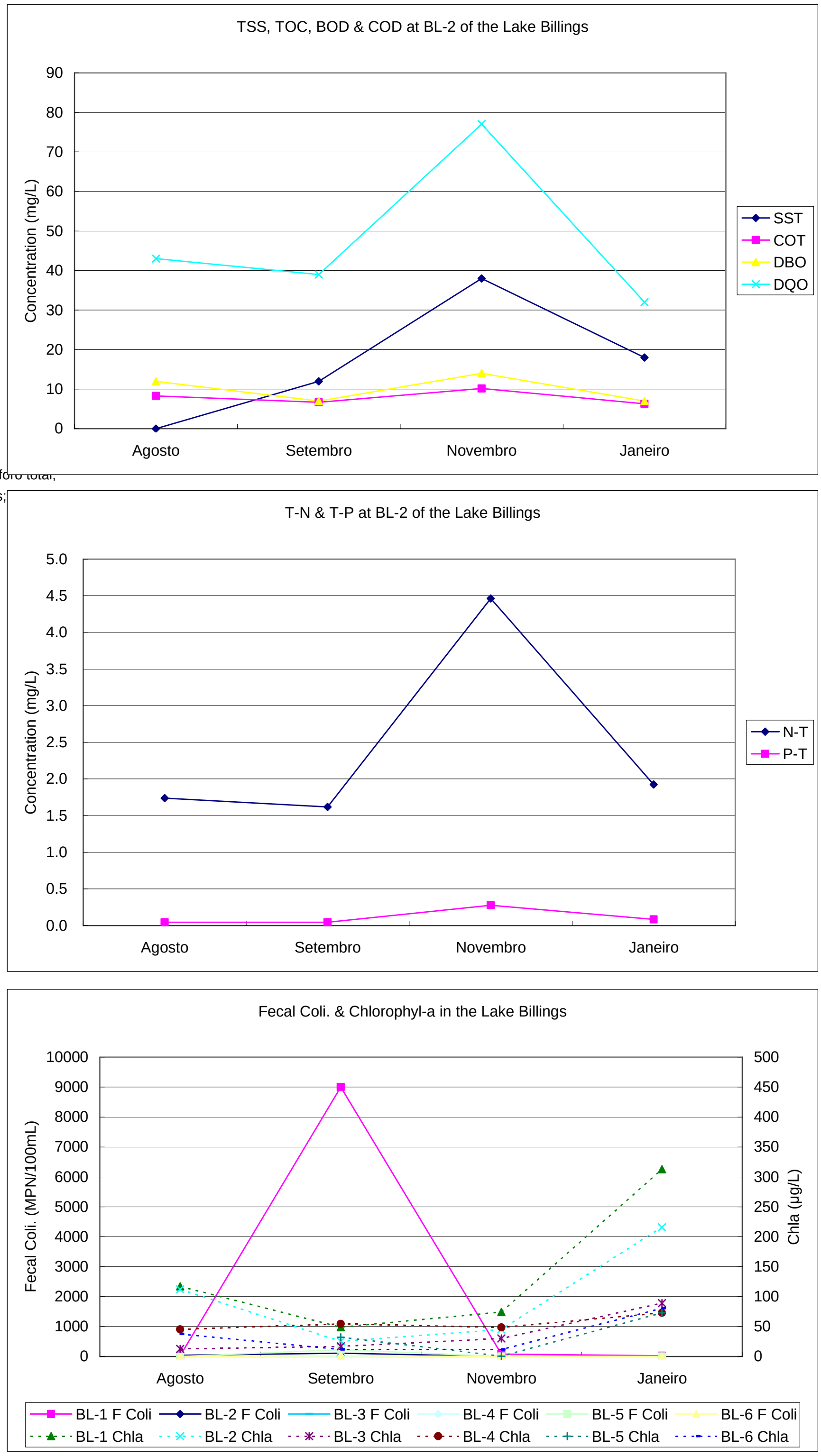
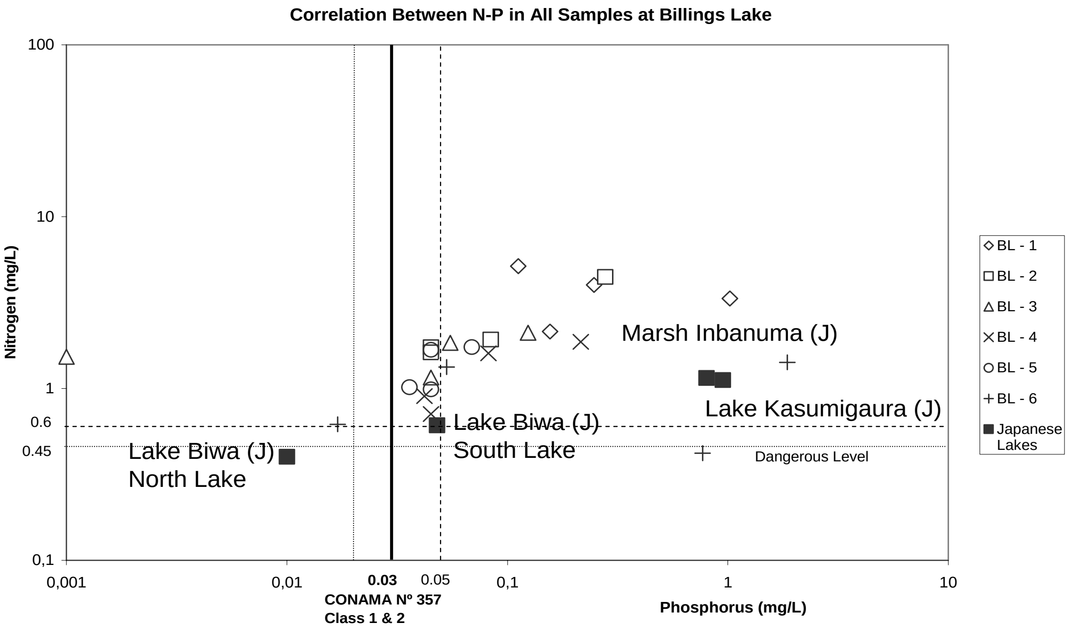


Figure 5.3.5 Seasonal variations of water quality in the Lake Billings

4) Degree of eutrophication

In order to perceive the degree of eutrophication, the relationship between TN-TP is shown in **Figure 5.3.6** (for reference, the data of water quality collected from principal lakes in Japan are also included). In Japan, the values higher than TN(0.45mg/L), TP(0.025mg/L) are considered to be in the danger zone of excessive eutrophication, compared with which the water quality at the monitoring points on Lake Billings surpassed those levels, indicating an environment conducive to the occurrences of Algal bloom. For reference, regarding the degree of pollution due to organic matters, the relationship between BOD-F-Coli is also shown in **Figure 5.3.6**.



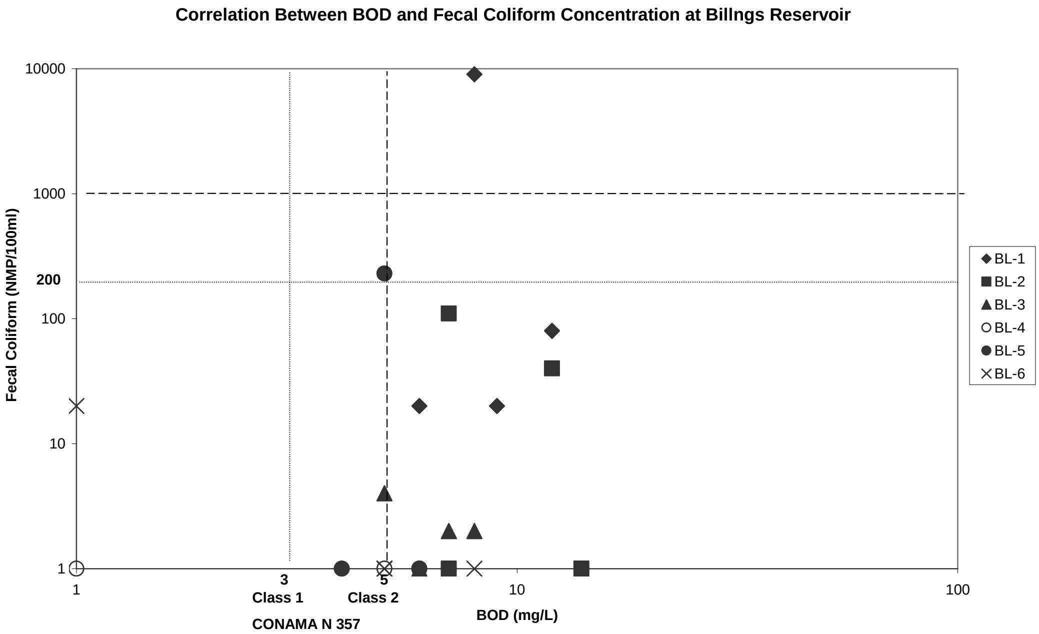
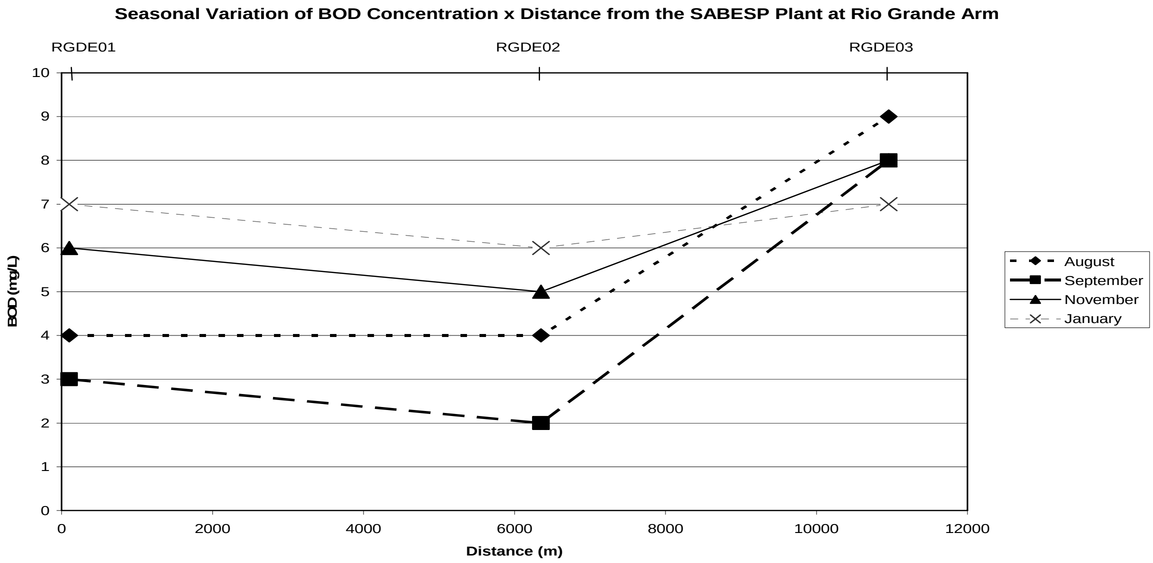


Figure 5.3.6 Relationship between parameters (T-N vs. T-P and F-Coli vs. BOD) at the Lake Billings

(2) Water quality of Rio Grande Arm

1) Horizontal variation along the river drifts

Horizontal variation of water quality along the river drift (from Rio Grande drinking water treatment plant to the discharge point of the river) is shown in **Figure 5.3.7**. BOD values satisfy the standard requirement, values lower than 5mg/L, at almost every location, and the tendency showed gradual linear rise to reach the highest value at the monitoring point (RGDE-3), immediately downstream of the outlet of Rio Grande. Other indices of water quality, including TN, TP, Chlorophyll-a, and F-Coliforms, also showed similar tendencies, albeit with slight differences among indices.



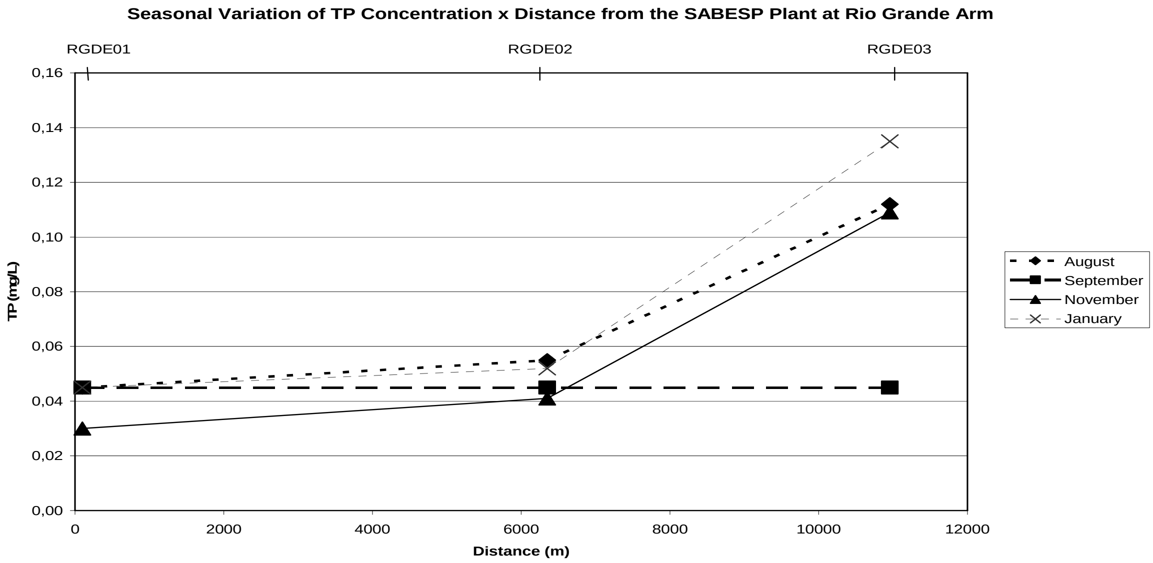
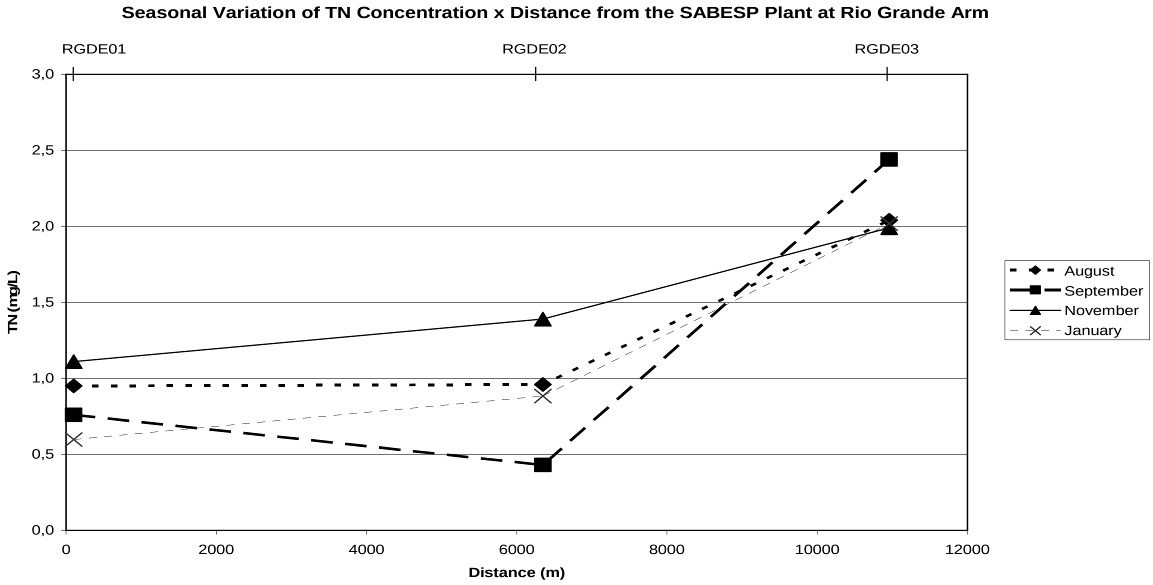


Figure 5.3.7(1) Horizontal variation of water quality (BOD, T-P) along the river drifts at Rio Grande Arm



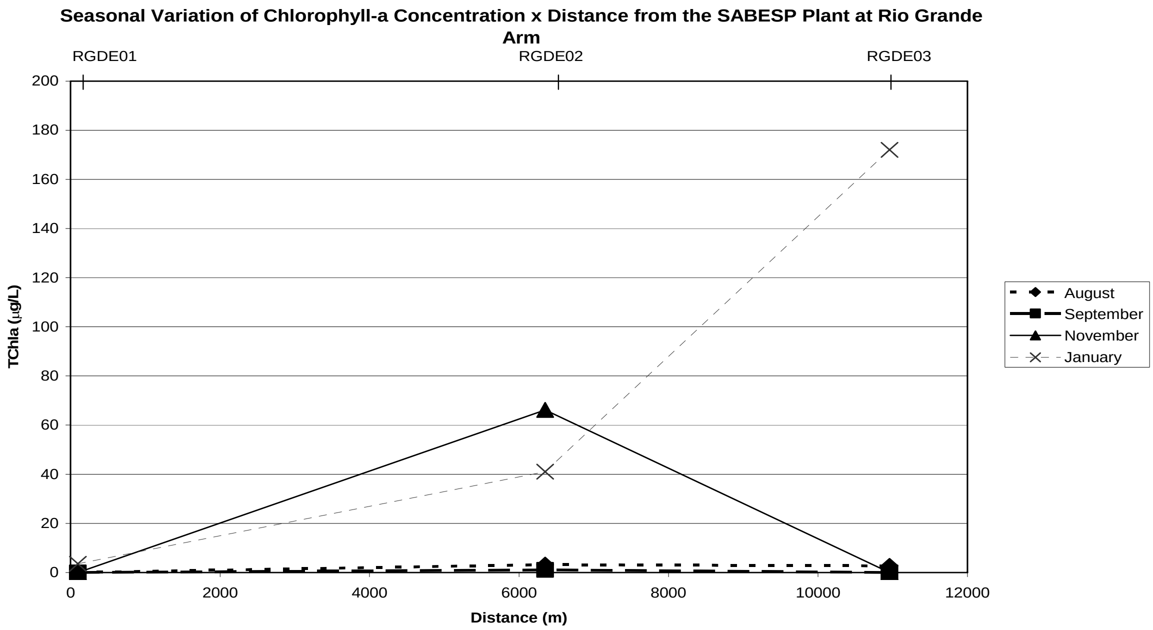


Figure 5.3.7(2) Horizontal variation of water quality (T-N, Chlo-a) along the river drifts at Rio Grande Arm

2) Vertical variation at monitoring points

The vertical distribution of water temperature and DO value at the monitoring point RGDE01 is shown in **Figure 5.3.8**. At any points, the distinct pattern of stratification was not observed at all. Due to the influences of influx of rainwater, the collection of drinking water, and wind, the stratification was not formed, and mixed layers were formed instead.

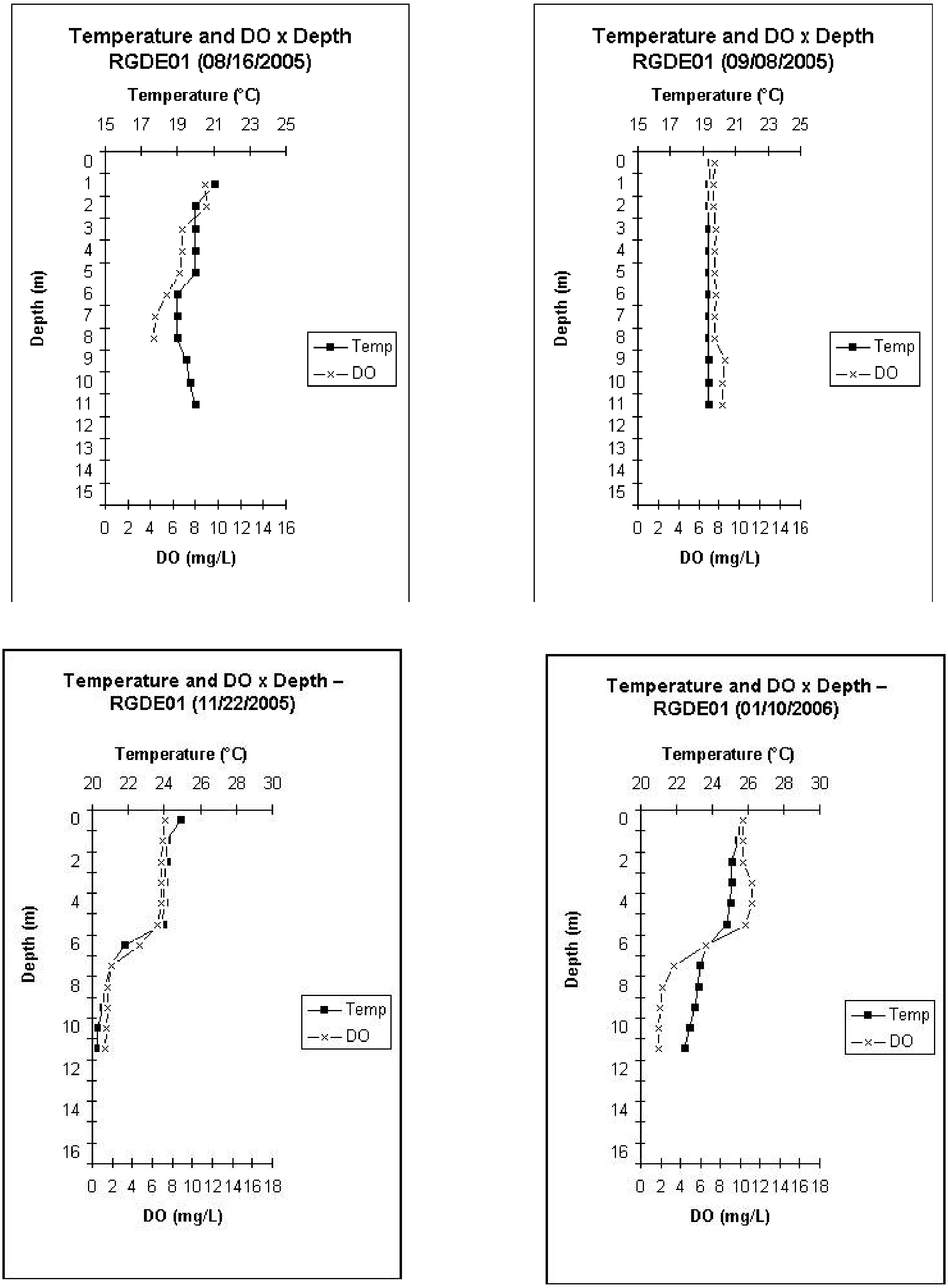
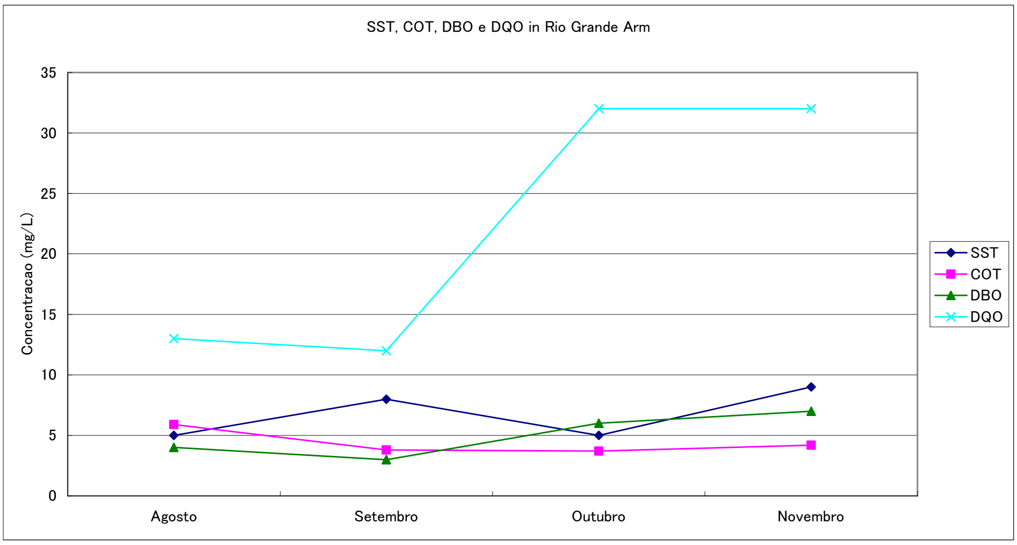
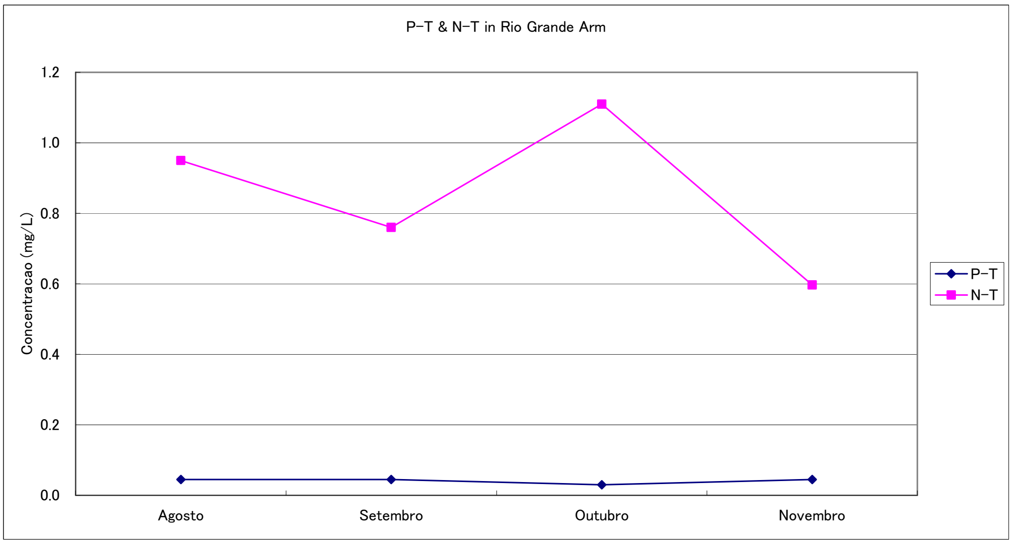


Figure 5.3.8 Vertical variation of Water Quality at Rio Grande Arm (RGDE01)

3) Seasonal variation

Seasonal variations are shown in **Figure 5.3.9**. The tendency of more pollution in the rainy season than in the dry season was observed. Particularly, Chlorophyll-a was observed to indicate high values during the rainy season.





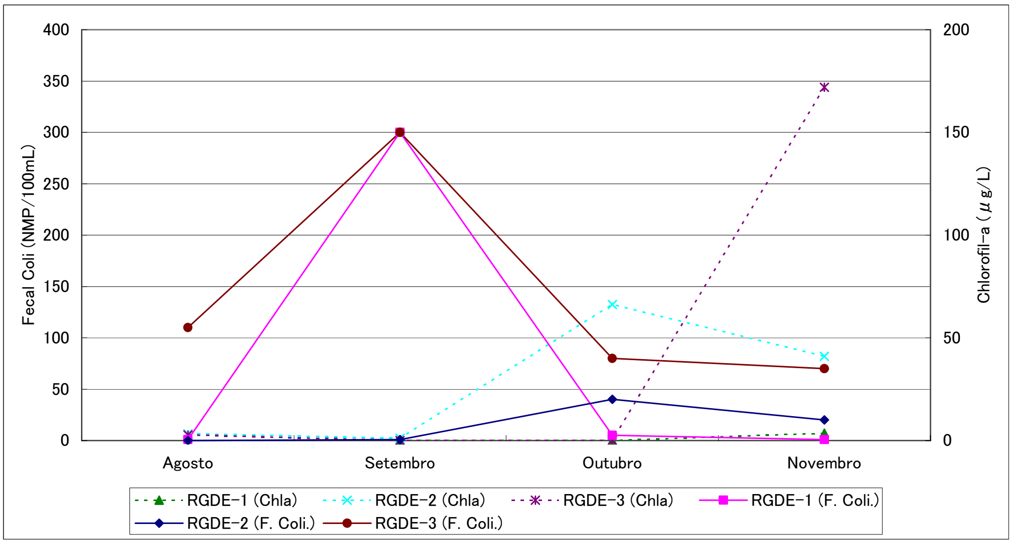


Figure 5.3.9 Seasonal Variations of water quality at RGDE01 of Rio Grande Arm

4) Degree of eutrophication

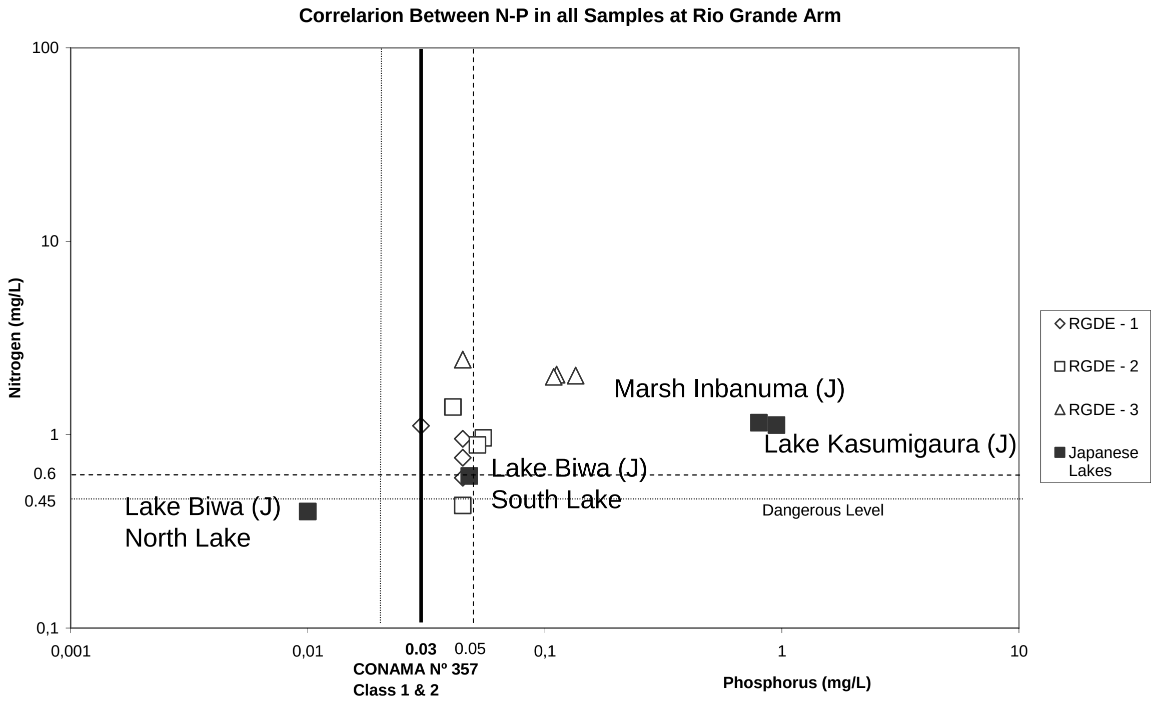
In order to identify the degree of eutrophication in Lake Rio Grande Arm, the relationship between TN-TP is shown in **Figure 5.3.10** (for reference, the data of water quality collected from principal lakes in Japan are also included). Compared to Lake Billings, in Lake Rio Grande Arm the process of eutrophication is apparently less advanced. However, at the monitoring point RGDE-3, downstream of the outlet of Rio Grande, the water quality in terms of indices is in such a condition as to cause the occurrences of Algal bloom with a high probability. As a matter of fact, at the time of the water depth measurement on 14th January, 2006, the occurrence of a large quantity of Algal bloom was confirmed at the outlet of Rio Grande.

(January 14, 2006, at the monitoring point RGDE-3)

Mechanism of occurrence of Algae Bloom

In the lake with water of a high level of eutrophication, when the water temperature rises under sunny weather, the population of phytoplankton is activated to multiply abnormally, taking up nitrogen and phosphor as nutrients. While the plankton population remains small, the lake surface looks as if green watercolor paint has been mixed, which will turn foul and emit offensive odors when the population becomes large. This phenomenon is called Algae Bloom. As the species constituting Algae Bloom, those of the genus of blue-green algae Myrostis are indicated in the narrow sense. Generally speaking, however, they include other blue-green alga belonging to genera Anabaena and Aphanizomenon as well.

For reference, regarding the degree of pollution due to organic matters, the BOD-F-Coli relationship is shown in **Figure 5.3.10**.



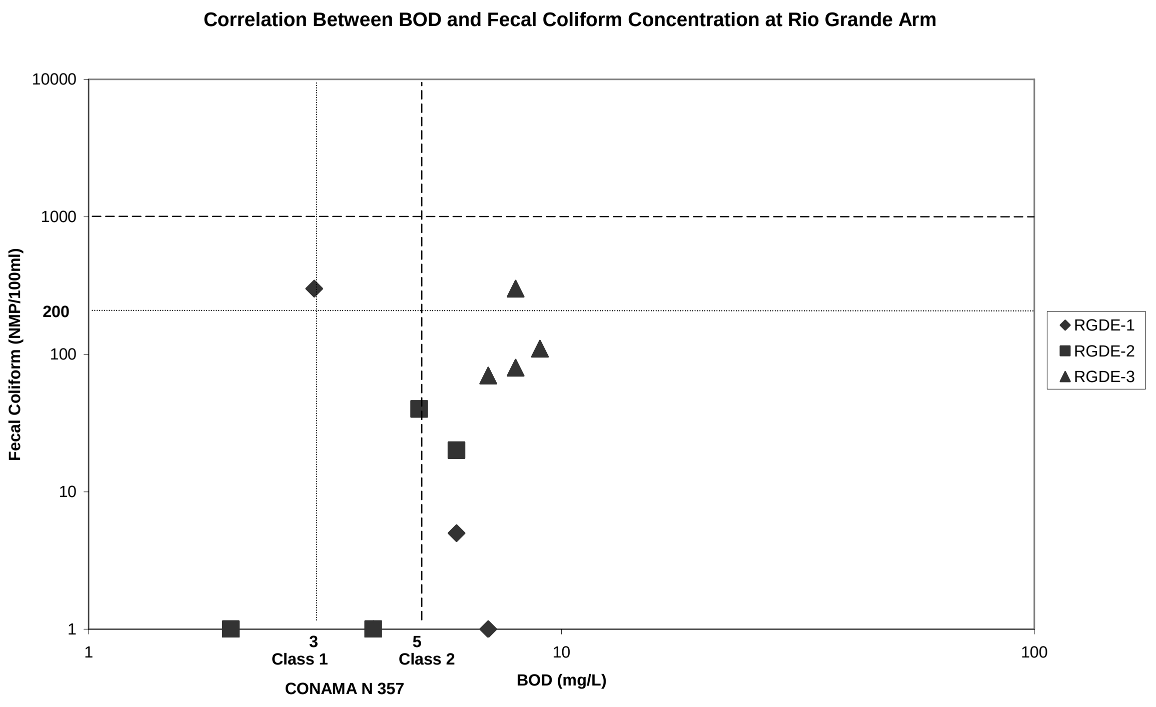


Figure 5.3.10 Relationship between parameters (T-N vs. T-P and F-Coli vs. BOD) at Rio Grande Arm

(3) Water quality and pollutant load of incoming rivers to the lakes

1) Water quality

The water quality of 20 principal rivers (including discharges out of sewage treatment plants) flowing into the two lakes was as represented in **Figure 5.3.11**. Except for Pinheiros River flowing outside the same watershed, the observations on principal indices of water quality of rivers flowing into the lakes are described as follows:

- The rivers which were highly polluted with BOD values exceeding 100mg/L were R-1 Cocaia, R-12 Das Lavras, R-13 Alvarenga, R-14 Pereira, R-15 Grota Funda, and R-16 2411/Alvarenga road, all of which were under a high degree of influence of domestic wastewater. On the contrary, those rivers which were unpolluted with BOD values lower than 5 mg/L were R-3 Jardim Varginia, R-6 Taquacetuba, R-7 Cucurutu, R-8 Rio Pequeno, and R-20 Varginha.
- The highly polluted rivers with TN values exceeding 30mg/L were R-1 Cocaia, R-11 number 6, R-12 Das Lavras, R-13 Alvarenga, R-14 Pereira, R-15 Grota Funda, and R-16 2411/Alvarenga road, the same group of rivers under a high degree of influence of domestic wastewater. On the contrary, those rivers which were unpolluted with TN values lower than 3 mg/L were R-6 Taquacetuba, R-7 Cucurutu, R-8 Rio Pequeno, and R-9 Rio Grande.
- Those polluted rivers with TN values exceeding 3 mg/L were almost the same group of rivers with high TN values.
- The rivers with a large number of coliform bacteria were the above-mentioned ones with high BOD values.
- Furthermore, the entire monitoring operation included the examination of the water discharged from two sewage treatment plants. The quality of water from Jardim Pinheiros treatment plant was inferior with 144-184 mg/L of BOD, 85-146 mg/L of TN, and 11-13mg/L of TP, indicating the state of failure of treatment.
- In addition, the seasonal variations of water quality of principal rivers are as illustrated in **Figure 5.3.12.**

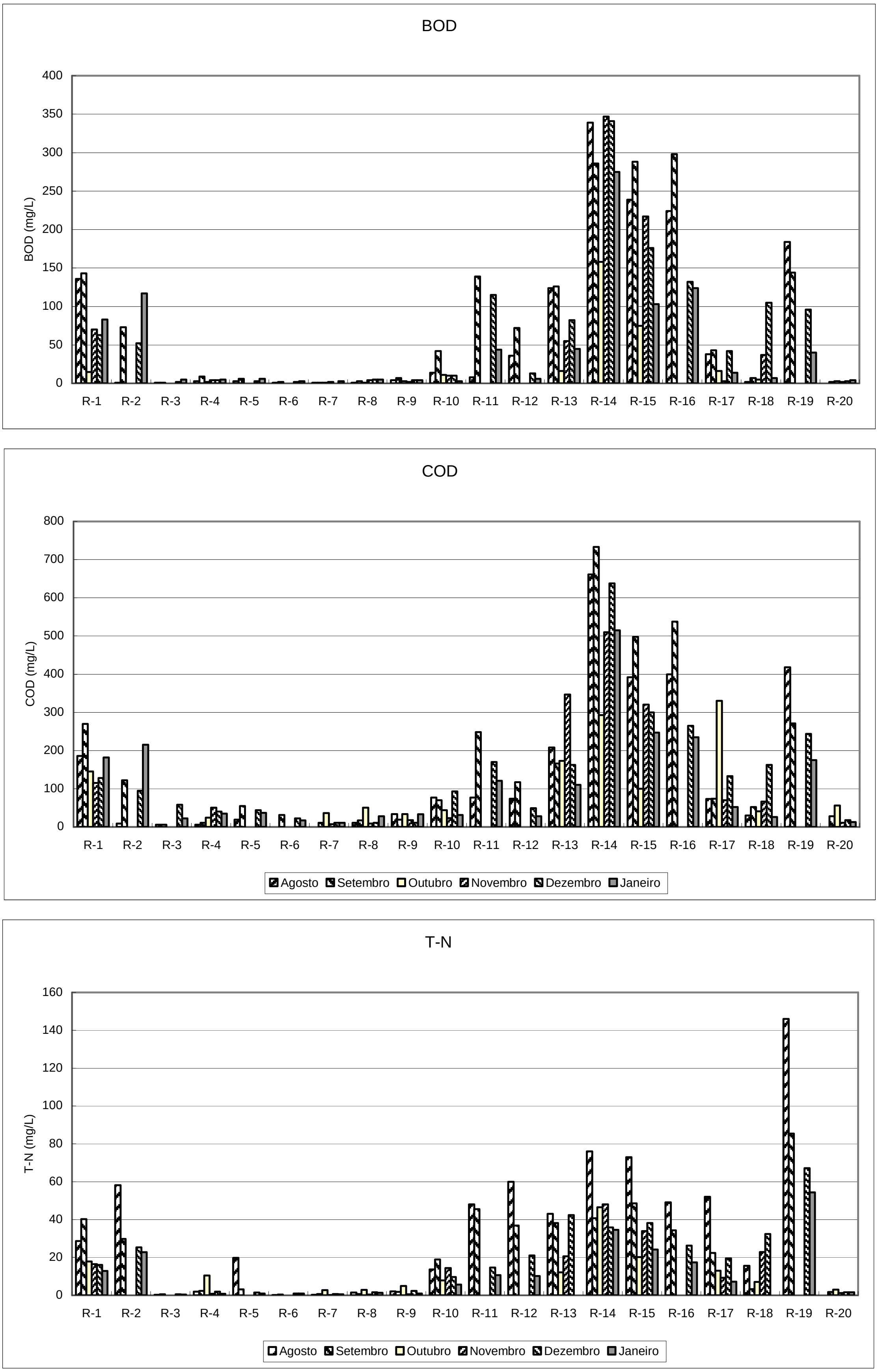


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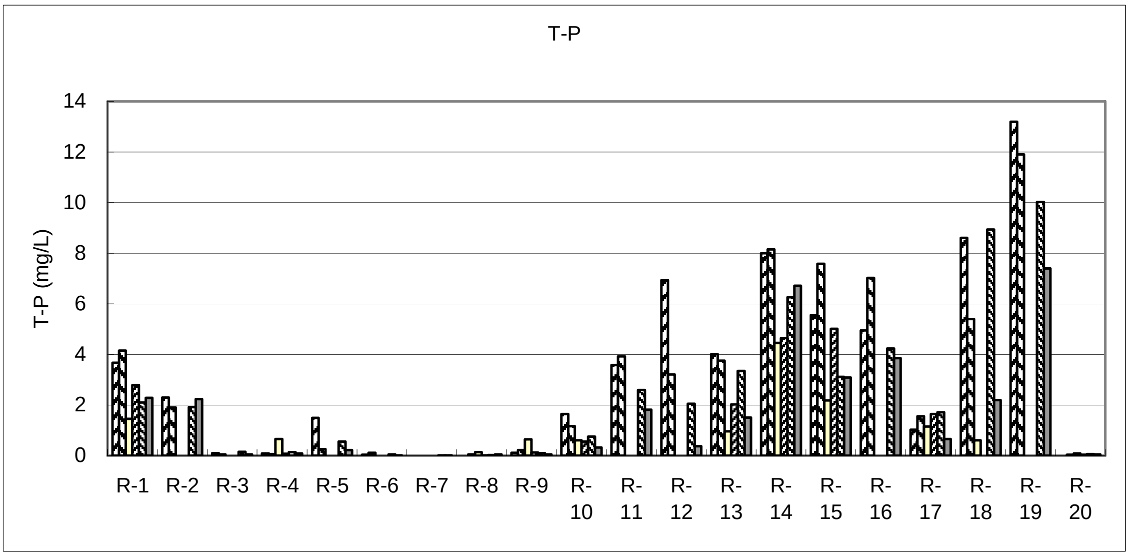
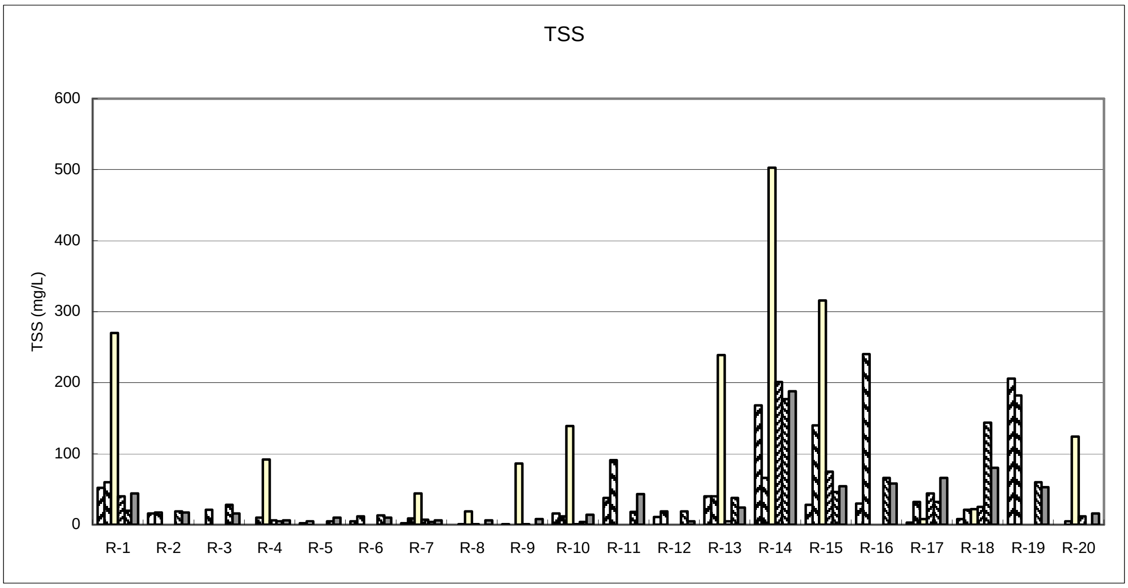
Figure 5.3.11(1) Water quality of incoming rivers (BOD/COD/T-N)





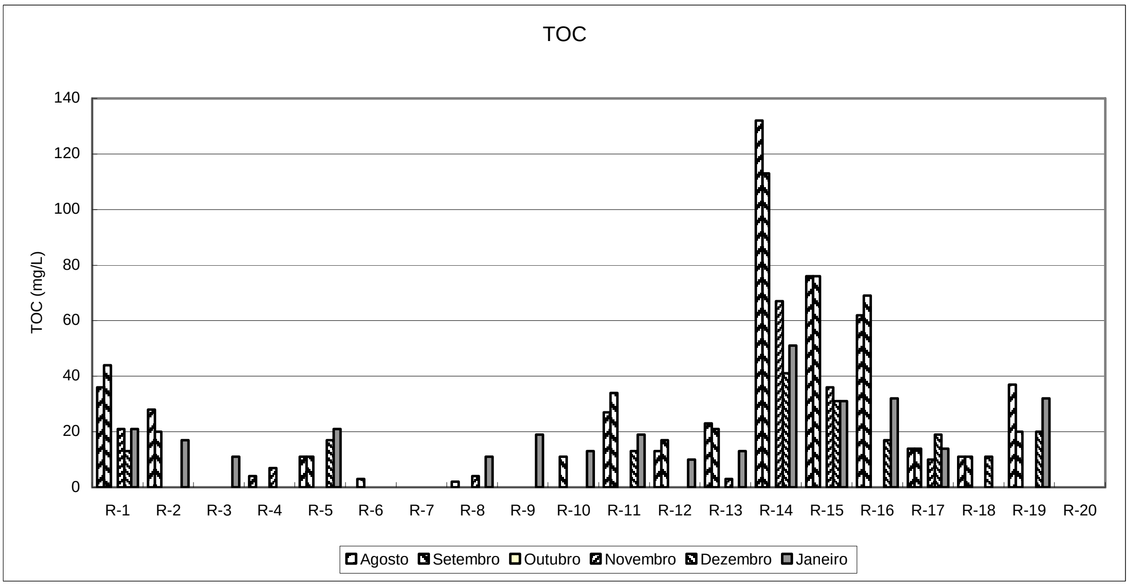


Figure 5.3.11(2) Water quality of incoming rivers (T-P/TSS/TOC)

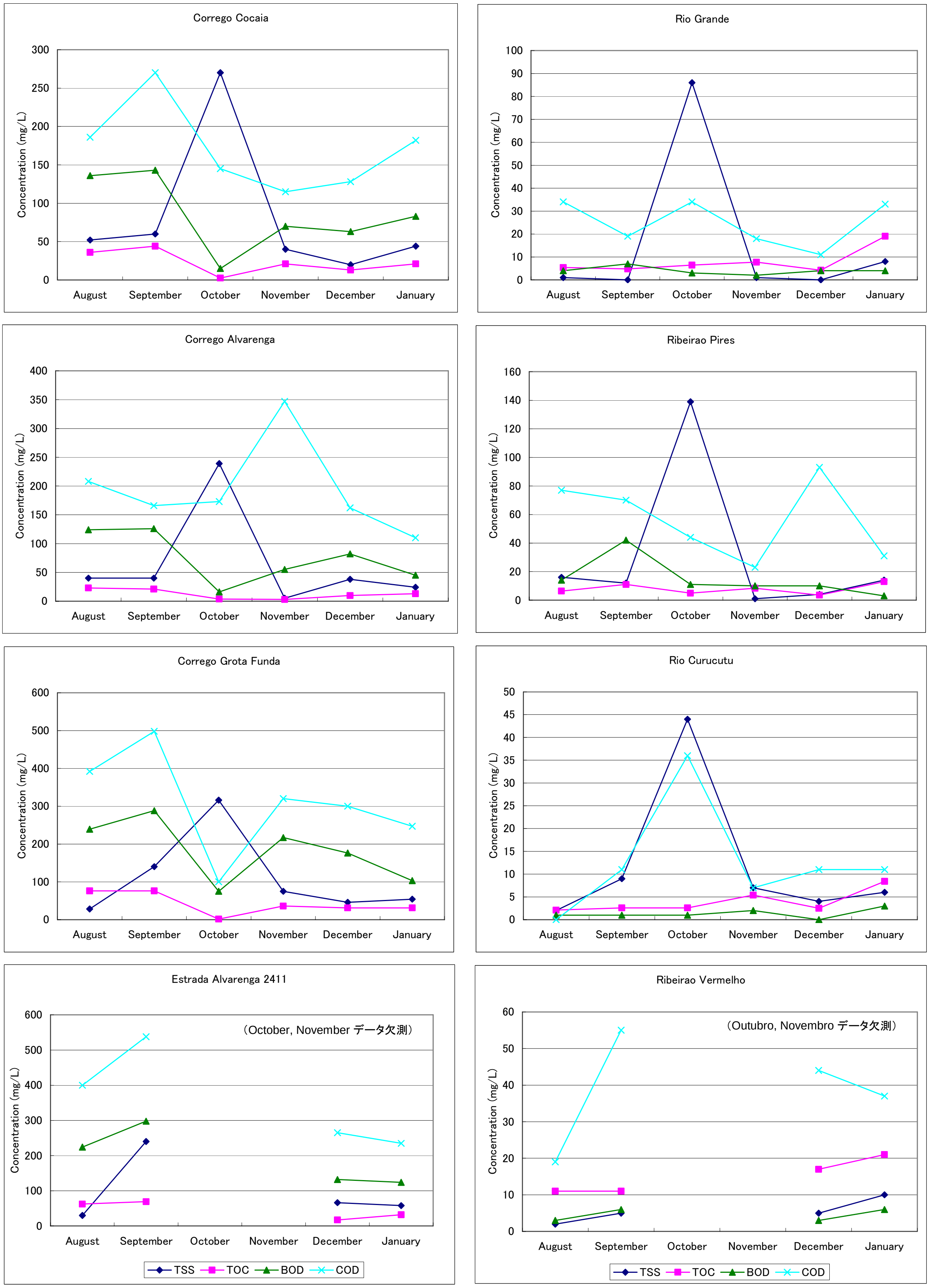


Figure 5.3.12 Seasonal variation of water quality of incoming rivers to the lakes

2) Runoff load (including discharge)

- The total discharge and runoff load of 20 rivers (including two sewage treatment plants) were as shown in **Annex 5.3.2** and **Table 5.3.2.** During the dry season, they were as follows: discharge stood at 2.67 m^3/s; BOD load at 14.9 t/day; TN load at 4.24 t/day; and TP load at 0.45 t/day. In the rainy season, they were: discharge at 9.15 m^3/s; BOD load at 12.01 t/day; TN load at 3.41 t/day; and TP load at 0.34 t/day. The discharge and pollutant load during the rainy season, in comparison with those for the dry season, were: greater by 3.4 times in discharge; lower by 0.8 times in BOD load; by 0.8 times in TN load; and by 0.76 times in TP load. The reason for the smaller ratios observed for the indices in the rainy season, except for the discharge, could be ascribed to the circumstances that the measurement was taken on the days of no rainfall even during the rainy season.
- The discharges of respective rivers are as illustrated in **Table 5.3.2.** The rivers with large discharges are R-1 Cocaia and R-13 Alvarenga, both characterized by their function to drain urban areas, and R-8 Rio Pequeno, R-9 Rio Grande, and R-10 Ribeirao Pires, all with characteristics of natural waterways.
- Regarding the pollutant load discharged by respective rivers, those with large BOD load were R-1 Cocaia, R-13 Alvarenga, R-15 Grota Funda, and R-16 2411/Est. Alvarenga. With respect to the pollutant load for TN and TP, the situation was similar to that of BOD.

Table 5.3.2 Runoff Load by Sub-basin

Rivers		Dry Season average								Wet Season average							
		BOD		TP		TN		Discharge		BOD		TP		TN		Discharge	
		(ton/day)	(%)	(ton/day)	(%)	(ton/day)	(%)	(m^3/s)	(%)	(ton/day)	(%)	(ton/day)	(%)	(ton/day)	(%)	(m^3/s)	(%)
Urban Rivers	R-1 Cocaia	4.38	29.4	0.12	27.5	1.08	25.5	0.36	11.19	3.37	28.07	0.10	29.05	0.63	18.43	0.52	4.53
	R-13 Alvarenga	3.46	23.2	0.11	24.0	1.12	26.4	0.32	9.84	1.70	14.16	0.06	17.43	0.85	24.87	0.31	2.70
	R-15 Grota Funda	2.55	17.1	0.06	14.5	0.54	12.9	0.11	3.37	1.42	11.83	0.03	8.72	0.32	9.36	0.12	1.05
	R-16 2411 Alvarenga Rd.	2.61	17.5	0.06	13.4	0.42	9.9	0.12	3.57	1.50	12.49	0.05	14.53	0.27	7.90	0.14	1.22
	Sub-total	13.00	87.0	0.35	79.0	3.16	75.0	0.91	28.00	7.99	67.00	0.24	70.00	2.07	61.00	1.09	9.50
Mixed Rivers	R-9 Rio Grande	0.19	1.3	0.01	1.2	0.08	1.9	0.46	14.02	2.08	17.32	0.03	8.72	0.58	17.26	6.01	52.34
	R-10 Ribeirão Pires	0.40	2.7	0.02	5.2	0.25	5.9	0.18	5.68	0.20	1.67	0.02	5.81	0.26	7.61	0.43	3.75
	Sub-total	0.59	4.0	0.03	6.0	0.33	8.0	0.64	20.00	2.28	19.00	0.05	15.00	0.85	25.00	6.44	56.09
Others	R-2 Jardm Varginha	0.20	1.3	0.01	2.0	0.18	4.2	0.05	1.54	0.53	4.41	0.01	4.07	0.17	4.97	0.08	0.70
	R-3 Ribeirão da Varginha	0.00	0.0	0.00	0.0	0.00	0.0	0.01	0.43	0.02	0.12	0.00	0.12	0.00	0.05	0.05	0.41
	R-4 Ribeirão Colonia	0.03	0.2	0.00	0.1	0.01	0.3	0.07	2.12	0.07	0.56	0.00	0.42	0.02	0.59	0.17	1.45
	R-5 Ribeirão Vennelho	0.01	0.1	0.00	0.3	0.02	0.4	0.02	0.52	0.26	2.13	0.01	3.21	0.04	1.17	0.52	4.49
	R-6 Ribeirão Taquacetuba	0.00	0.0	0.00	0.0	0.00	0.0	0.02	0.62	0.04	0.31	0.00	0.09	0.01	0.33	0.15	1.33
	R-7 Rio Curucutu	0.03	0.2	0.00	0.0	0.00	0.1	0.12	3.69	0.03	25.00	0.00	0.04	0.01	0.29	0.16	1.39
	R-8 Rio Pequeno	0.11	0.8	0.00	0.2	0.12	2.9	1.15	35.42	0.11	0.88	0.00	0.15	0.03	0.97	0.24	2.13
	R-11 Córrego Numero6	0.09	0.6	0.00	1.0	0.05	1.3	0.01	0.40	0.10	0.86	0.00	0.90	0.02	0.52	0.01	0.09
	R-12 Ribeirão das Lavas	0.14	1.0	0.02	3.7	0.15	3.6	0.03	0.92	0.04	0.36	0.01	1.50	0.07	2.10	0.06	0.52
	R-14 Córrego Pereira	0.55	3.7	0.01	3.3	0.10	2.3	0.02	0.82	0.44	3.64	0.01	2.66	0.05	1.46	0.85	7.44
	R-18 ETE Riacho Grande	0.00	0.0	0.01	1.8	0.01	0.3	0.01	0.31	0.02	0.14	0.00	0.67	0.01	0.29	1.49	13.01
	R-19 ETE Pinheirinho	0.10	0.7	0.01	1.6	0.07	1.5	0.01	0.22	0.04	0.37	0.01	1.74	0.04	1.23	0.01	0.06
	R-20 Ribeirão Varginha	0.02	0.2	0.00	0.1	0.02	0.5	0.18	5.54	0.05	0.40	0.00	0.19	0.02	0.60	0.16	1.39
	Sub-total	1.31	9.0	0.06	14.0	0.74	18.0	1.70	52.00	1.74	14.00	0.05	16.00	0.50	15.00	3.95	34.41
Total		14.91	100.0	0.45	100.0	4.24	100.0	3.25	100.00	12.01	100.00	0.34	100.00	3.42	100.00	11.48	100.00

3) Proportion of contribution by individual rivers in discharge and runoff load

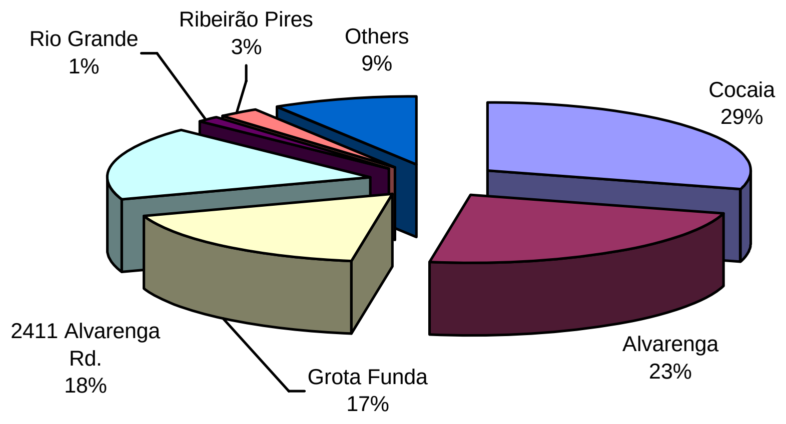
- Proportional rates of contribution by individual rivers flowing into the two lakes in discharge and runoff load during the typical dry season (August) are represented in **Figures 5.3.13** and **5.3.14**. Those rivers with particularly large proportional rates of contribution in pollutant load are R-1 Cocaia, R-13 Alvarenga, R-15 Grota Funda, and 2411 Alvarenga. These 4 rivers accounted for an 86 % share of the total BOD loading. Moreover, these 4 rivers were substantially responsible for nutrients loading with a share of 75% for TN and that of 79 % for TP.
- Furthermore, the proportional rate ascribable to 4 rivers during the rainy season was 67 % of BOD loading. Regarding the proportional rates for the load of TN and TP by 4 rivers were 61 % and 71 % respectively, representing a substantial proportion similarly as in the dry season. The proportion shared by Rio Grande and Ribeiro Rires, which contributed relatively small fractions of pollutant load during the dry season, constituted a significant part during the rainy season, by contributing 17 % of BOD loading , 25 % of TN loading, and 13 % of TP loading.

(4) General situation of water quality of the two lakes and rivers flowing into them

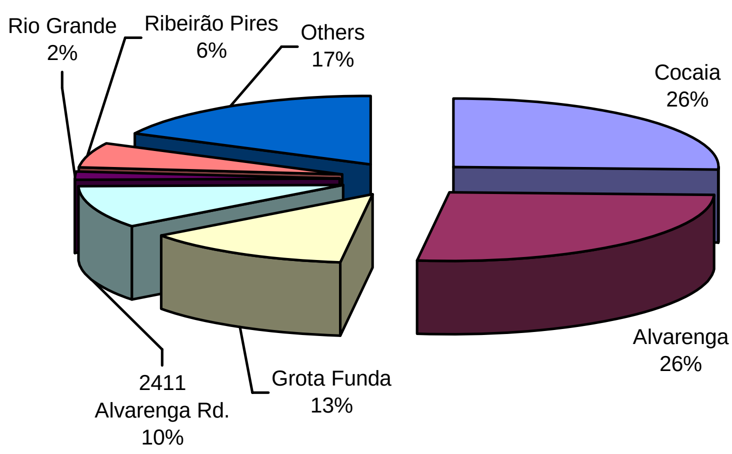
- The characteristics of the water environment of Lake Billings are recognized in its two-tier structure. As aforementioned, the water at the monitoring point BL-01 near Pedreira was found to have a two-tier structure during the dry season. Oxygen-deficient state was thus created at the depth of 4 m to 12 m (lake bottom) to form a water environment which was liable to dissolve from the sediment materials the nutrient salts constituting TN and TP or ions of Mn, Fe, Hg, etc.
- The water quality of the two lakes, as far as it was evaluated in terms of TN-TP context, indicated that a risky environment which was prone to cause the occurrences of Algal bloom was in place. Furthermore, when the level of water quality environment was considered by comparing the indices of BOD and the count of coliform bacteria with those of standards, the water situation of Lake Billings was found to be far short of satisfying the environmental requirements.
- The indices of the total pollutant load of 20 principal rivers flowing into the two lakes (including two sewage treatment plants) were as follows: during the dry season, the flow rate stood at 2.67 m^3/s; BOD load at 14.9 t/day; TN load at 4.24 t/day; and TP load at 0.45 t/day. In the rainy season, they were: flow rate at 9.15 m^3/s; BOD load at 12.01 t/day; TN load at 3.41 t/day; and TP load at 0.34 t/day. The indices of the pollutant load during the rainy season, in comparison with those for the dry season, were smaller by a factor of 0.8 times. The reason for this could be ascribed to the circumstances that the measurement was taken on the days of no rainfall.

- Among the 20 rivers flowing into the lakes, those which contributed a large share in the total influx were 4 rivers, R-1 Cocaia, R-13 Alvarenga, R-15 Grota Funda, and R-16 2411 Alvarenga which made up 86 % of the total BOD load of pollutants. Besides, the contribution rates of these rivers in the load in terms of TN and TP were 75 % and 79 %, respectively. Moreover, contribution rates of these 4 rivers in the pollutant load during the rainy season were 67 % for BOD, 61 % for TN, and 71 % for TP respectively, representing substantial proportions similar to those in the dry season. The proportion shared by 2 rivers, Rio Grande and Ribeirao Pires, which contributed relatively small fractions of the total load during the dry season, constituted a significant part during the rainy season, by contributing 17 % of BOD load, 25 % of TN load, and 13 % of TP load.

BOD



TN



TP

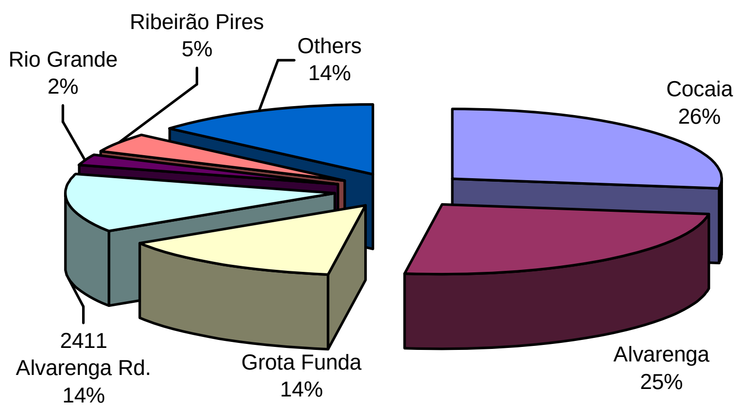


Figure 5.3.13 Proportion of contribution by river in runoff load (BOD, T-N, T-P) during dry season

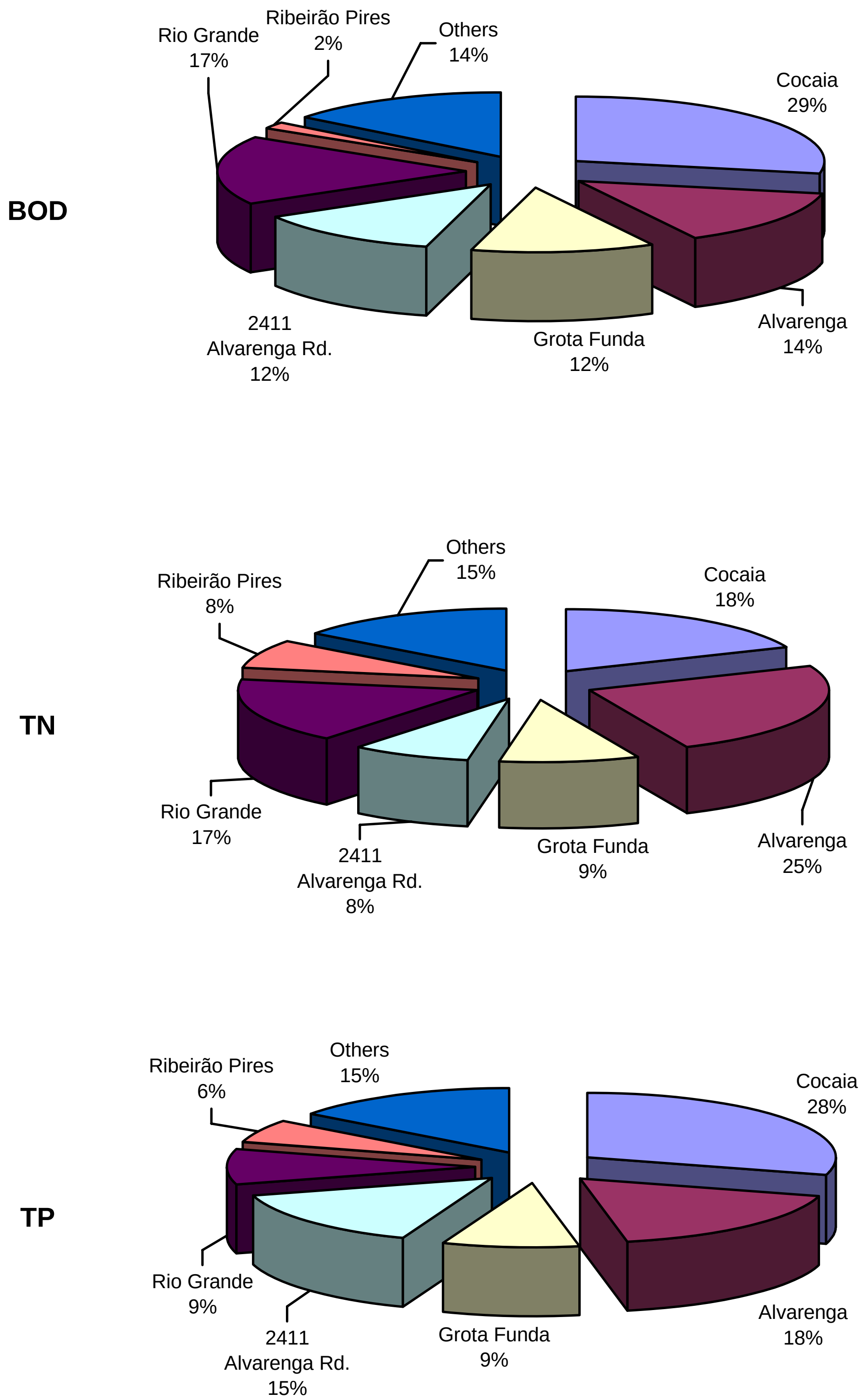


Figure 5.3.14 Proportion of contribution by river in runoff load (BOD, T-N, T-P) during wet season

5.3.3 Sludge of Lake Bottom

(1) Volume of piled sludge

1) Estimation based on H-V curve of EMAE

As regards the Lake Billing, EMAE, the administrative agency of the reservoir, prepared a chart of depth sounding in 1984-85. Furthermore, the agency recently carried out a project of sounding and compiled a new depth chart in 2004. In our study, we relied on these 2 sets of data to estimate the quantity of sediment soil by superimposing one over the other.

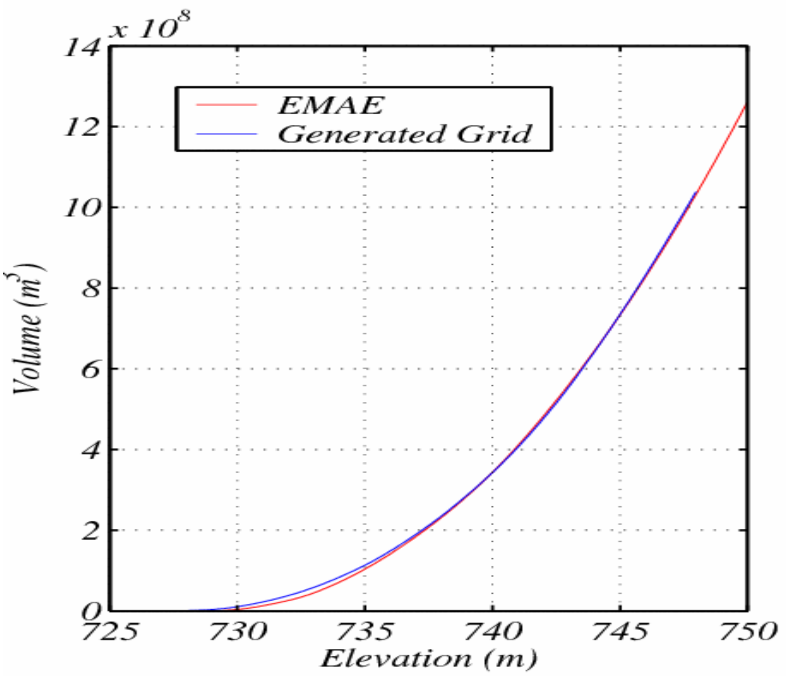


Figure 5.3.15 H-V Curve of EMAE

2) Estimation of sediment volume based on sampling from the Lake bottom

The JICA Study Team conducted the situational survey on depth and quality of sediment in cooperation with Prof. Antonio A. Mozeto of San Carlos University. Locations of sampling were in the Central Channel, downstream of the Rio Grande River, and Arms of Alvarenga, Taquacetuba, Capivari and Rio Pequeno for three days starting from November 11, 2006, using acryl columnar sludge sampler (see **Figure 5.3.16** and **Photo 5.3.1)** Volume of sediment was estimated based on the results of measurement, as shown in **Figure 5.3.17**. Accordingly, it was 47 million m^3 in the Lake Billings and 5 million m^3 in the Rio Grande Arm with average thicknesses of 51cm and 34 cm, respectively.

	
Riacho Grande (11/07/06)	Pedreira Dam (13/07/06)
	
Borore (12/07/06)	Taquacetuba (12/07/06)
	
Capivari (12/07/06)	Rio Pequeno (12/07/06)

Photo 5.3.1 Sludge Thickness Survey in the arms of the Lake Billings

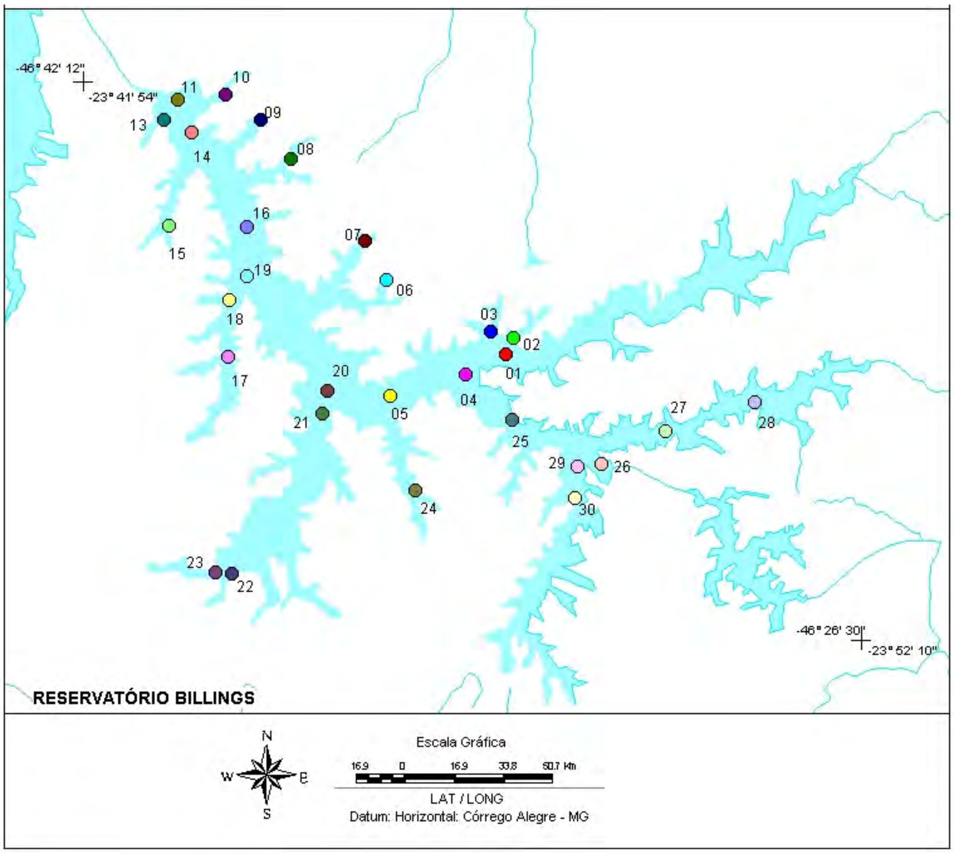


Figure 5.3.16 Monitoring Points for Water Quality and Bottom Sediment in the arms of the Lake Billings

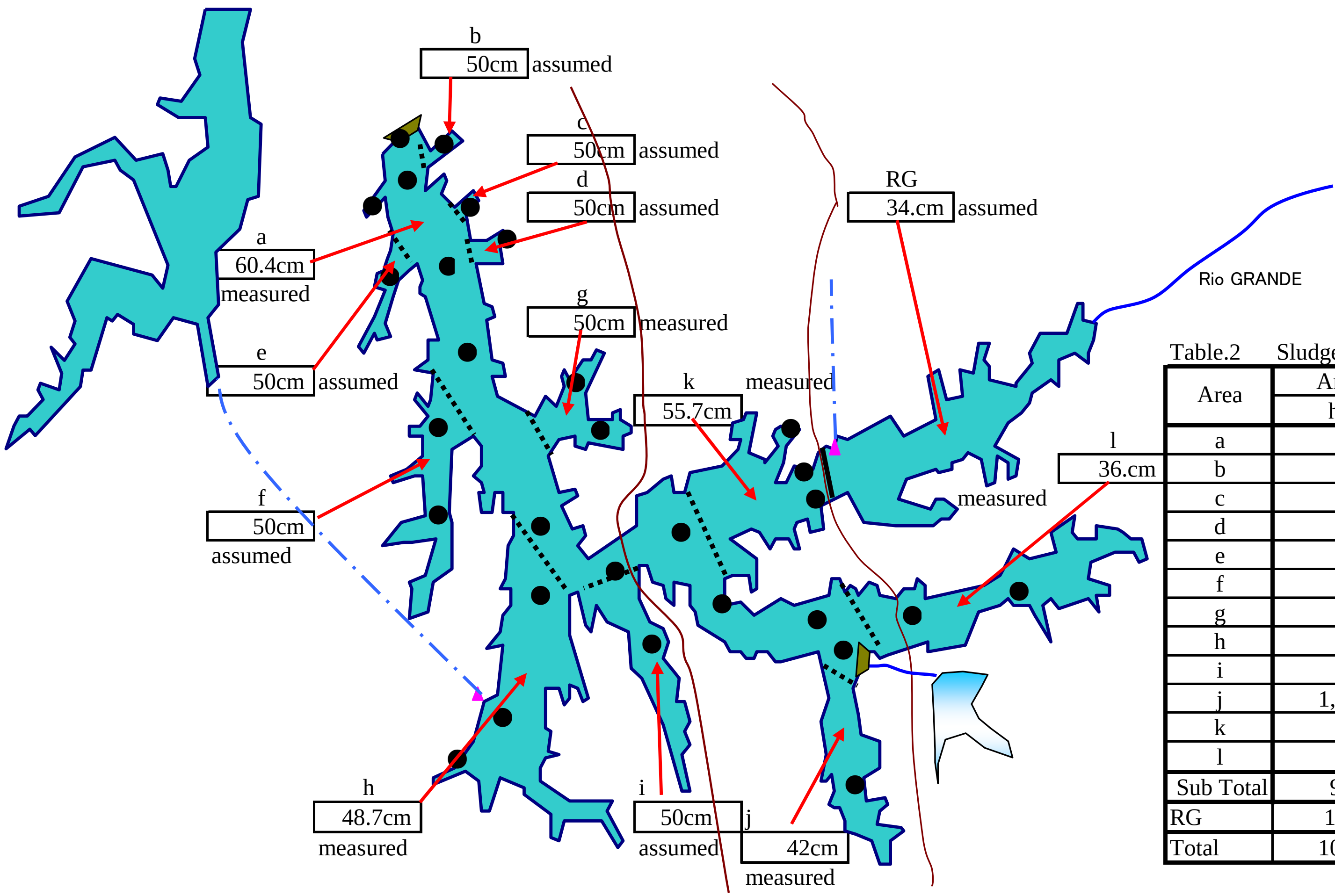


Table.2 Sludge Volume as of Aug. 2006

Area	Area	Sludge	Sludge volume
	ha	cm	m3
a	3256.9	60.4	19,671,676
b	58.5	50	292,500
c	55.9	50	279,500
d	122.9	50	614,500
e	164.3	50	821,500
f	509.2	50	2,546,000
g	300.7	50	1,503,500
h	1,732	48.7	8,434,840
i	304.4	50	1,522,000
j	1,027.50	42	4,315,500
k	578.2	55.7	3,220,574
l	1236.7	36	4,452,120
Sub Total	9,347.2		47,674,210
RG	1,467.0	34	4,987,800
Total	10,814.2		52,662,010

Average thickness in BL	0.510	m
Average thickness in RG	0.340	m
Average thickness total	0.487	m

●:Existing Monitoring points of CETESB 5Points

●:Additional Monitoring points of JICA STUDY TEAM 24 Points

Rio Grande Arm is assumed using the data of Reference 1)

Figure 5.3.17 Monitoring Points in the Lake Billings and Estimation of Piled Sludge Volume

(2) Sediment quality

1) Standards for Sediment

The guidelines for sediment quality is already prepared internationally in Australia, New Zealand, Canada, Holland, Austria, UK, Hong-Kong and Japan, in which guideline values on concentration are clearly established from the viewpoint of ecological protection. These guideline values on concentration is referred to the examples for toxicity assessment of trace materials in US, but US doesn't establish guideline values on concentration on a federal level due to difference in the regulatory manner by state. Guideline values on concentration in Australia, New Zealand and Canadaare summarized in **Table 5.3.3**, in which ISQG (interim sediment quality guideline)-low is called as threshold effect level and guidelines for low concentration side shown in n investigation level, while ISQC-high is called as possible effect level and guidelines for high concentration side shown in n investigation level

Table 5.3.3 Comparison of environmental guidelines for sediment quality

			Guidelines	unit	Hg	Cr	As	Ni	
Australia &NZ	Sediments	Ecological protection	ISQG(interim sediment quality guideline)-low	mg/kg	0.15	80	20	21	ANZECC (Australian and New Zealand) Environmental and Conservation Council) 2000)
			ISQG-high	mg/kg	1	370	70	52	ANZECC(2000)
Canada	Sediments in freshwater	Ecological protection	ISQG	mg/kg	0.17	37.3	5.9	-	-
			PEL	mg/kg	0.486	90	17	-	-
Japan	Sediments in rivers and lakes	Human health	Interim removal guidelines for sediments in rivers and lakes	ppm	25				Notice of the Environmental Agency (Oct. 28, 1975)

Source: Central research institute of electric power industry, "Collection and analysis of trace material in soil and sediments in Japan" and "Comparative study on environmental guidelines among countries", April 2003 (Japanese)

In Japan, policy is focused on the establishment of the environmental standards from the viewpoint of protection of human health, protection of organic pollution and protection of eutrophication, but not from the concept from ecological protection up to now, that is greatly different from the objective of overseas environmental regulation

The guideline values on concentration in Brazil in **Table 5.3.6** to evaluate from the viewpoint of ecological protection is applied to the results of the Lake Billings and the Rio Grande Arm in the present Study.

3) Sediment quality results of the Lake Billings and the Rio Grande Arm

Sediment quality results conducted at five points on May 15, 2005 in the Lake Billings and the Rio Grande Arm are shown in **Table 5.3.4** with a location map in **Figure 5.3.1**.

For Hg, high concentrations that exceed a SEL of 2 mg/kg are found at two points out of three, or 2.34 mg/kg at BL-3 at the confluence with the Taquacetuba Arm and 2.25 mg/kg at BL-5 downstream of the Imigrantes Bridge. They are in a possible effect level on ecology and attention be paid for them from the viewpoint of ecological protection.

For Ni, high concentrations over a SEL of 75 mg/kg are found such as 77.3 mg/kg at BL-2, 162.3 at BL-3mg/kg and137 mg/kg at BL-5 in the Lake Billings.

For reference, the Hg median of lake sediments in Japan is in the range of 0.2 to 0.25 mg/kg before 1980, but in the range of 0.1 to 0.2 mg/kg in almost years after 1980 with a tendency in a flat level.

In Japan, the Ni median of lake sediments is 55 mg/kg rather higher than that of 16 mg/kg in rivers sediment and has a tendency in a flat level

The results on water and sediments conducted for July 11-13, 2006 at the monitoring points in **Figure 5.3.16** is also shown in **Tables 5.3.5** and **5.3.6.**

The parameters to meet the environmental standards out of parameters as shown in **Table 5.3.5** are pH, DO, turbidity, chlorophyll-a (Chl-a), NH_4-N, NO_2-N, NO_3-N, TP, Cyanobacterium, E-coliform, Faecal coliform and BOD_5, but DO is below an environmental standard Class 2 at 23 points out of 29 points, similarly, chlorophyll-a at 19 points, BOD_5 at 22 points, pH at 3 points, NH_4-N at 6 points TP at 10 points and cianobacterium at 8, respectively.

Watching as a whole, in the Arms of Alvarenga (Pt.07), Grota Funda (Pt.08), Alvarenga 2411 (Pt.10), Cocaia (Pt.13), DO, EH and transparency is low, adversely turbidity, DOC, TOC, TSS, NH_4-N, TN, TP, fecal coliform, COD and BOD_5 is high suggesting that they are highly-polluted. Especially, in the Arms of Alvarenga, Grota Funda, Alvarenga 2411 and Pedreira Dam, Do is almost zero in a state of anaerobic condition. The pH values exceed at three points limitedly to the Taquacetuba Arm.

The DO concentration in **Table 5.3.6** shows that of lake water 0.5 m below the water surface at the same sampling point as for sediments.

pH values are somewhat low in several sampling points which demonstrates that anaerobic oxidation of the organic matter is taken place as it generates CO_2, a weak but important environmental acid in the sediment pore water.

Although there is a tendency of “the upper in depth the more the moisture content”, it is high as 80.1% at the lower layer (46-56cm) of Pt.20, as 78.9% at the lower layer (90-100cm) of Pt.19, while low as 53.5% at the middle layer (12-22cm) and lower layer (24-34cm) of Pt.14

For heavy metals, the Central Chanel route (Pts. 14－19－20－4－26) is in a severe effect level in terms of Cr, Cu, Ni, Pb and Zn. The concentration is highest at Pt.19 (confluence with the Cocaia Arm) followed by Pt.4 (confluence with the Rio Grande Arm) unexpectedly. Observing the variation in water depth direction at respective monitoring points, the upper layer the higher Cr, Cu, Ni and Pb at Pt.19, and Cr, Cu, Ni, Pb and Zn is highest in the middle layer at Pt.20 (confluence with the Taquacetuba Arm). At Pt.14 (Pedreira Dam) and Pt.26 (Summit Dam), a variety of concentration variation patterns are observed. Hg is in a severe effect level only at the lower layer of Pt.26 (Summit Dam).

In the Taquacetuba route from Pt.20 to Pt 22, Cu and Ni is not so high but in a effect sensitive level at the middle layer of Pt.22.

Cr and Ni in Taquacetuba, Summit Dam and Capivari, and Cu in the downstream of Rio Grande Arm are in an effect sensitive level.

Table 5.3.4 Analysis Results of Permeant Water Quality and Bottom Sediment in the Lake Billings and Rio Grande Arm (15/05/2005)

Monitoring Stations	Substrate	pH	Redox Pot. (mV)	Water Cont. (%)	TOC (mg/L)	TOC (% C)	TP (mg/L)	TP (mg/kg)	PO_4 (mg/L)	TN (µg/kg)	Fe (mg/L)	Mn (mg/L)	Hg (mg/L)	Hg (mg/kg)	Zn (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Ni (mg/kg)
Bororé	Sediment	7.21	-124	63.2		8.01		466		1.1				n.d.	497	3.4	255	77.3
(BL-2)	Per. W.	6.77	59		34		0.52		0.117		27	1.444	n.d.					
Taquacetuba	Sediment	6.4	-103	62.1		8.51		502		2.1				2.34	968.4	8.628	344.4	162.3
(BL-3)	Per. W.	6.5	70		48		0.348		< 0.050		23.1	1.897	n.d.					
Imigrantes	Sediment	6.89	-100	67.1		11.07		112		3.2				2.25	595	5.6	297.2	137
(BL-5)	Per. W.	6.65	78		31		0.368		< 0.050		38.3	4.695	n.d.					
SABESP	Sediment	7.09	-127	38.5		2.16		183		69				n.d.	51.1	n.d.	47.4	4.3
(RGDE-1)	Per. W.	6.7	59		14		1		0.062		27	1.002	n.d.					
**	Sediment	6.43	-98	68.4		6.45		109		1.1				n.d.	101	n.d.	1235	21.5
(RGDE-3)	Per. W.	7.24	93		27		0.535		< 0.050		54.6	3.956	n.d.					

Per. W.: Permeant Water

n.d.: not detected

** Confluence of Ribeirão Pires & Rio Grande

Detection limits of Hg are 0.0001 mg/L in permeant water and 0.01 mg/kn in sediment.

Table 5.3.5 Analysis Results of Water Quality in the Lake billings（11-13/07/2006）

		Air Temp.	Water Temp.	pH	DO	DO Saturation	E_H	Conductivity	Turbidity	Transparency	DOC		TOC		TSS	Chl-a	NH_4	NO_2	NO_3	TN	TP	Cyanobacteria	Coliform	Faecal coliform	COD	BOD
	Class 2			6.0-9.0	>5.0				100							30		1.0	10.0		0.030	5000				5.0
		ºC	ºC		mg/L	%	mV	mS/cm	UNT	m	mg/L		mg/L		mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cell/mL	UFC/100mL	UFC/100mL	mg/L	mg/L
1	Rio Grande	17.48	18.38	7.29	**3.49**	41.2	396	0.175	7.54	0.8	4.433	0.278	4.300	0.406	<0.02	**37.06**	0.09	0.029	4.0	1,00	<0.01	**7,318**	$3.5X10^4$	220	13	4
2	Rio Grande	16.61	18.33	8.07	**3.58**	42.2	394	0.176	8.18	0.9	3.866	0.168	4.915	1.186	<0.02	**36.59**	<0.06	0.023	2.0	0,68	0.01	4,318	$7.0X10^3$	50	36	**15**
3	Rio Grande	17.80	18.39	7.79	**3.30**	38.2	387	0.174	9.48	0.7	4.582	0.587	3.440	0.703	5.33	26.27	0.46	0.015	0.4	1,20	0.02	1,505	$2.7X10^4$	470	24	5
4	Imigrantes	18.70	18.40	7.76	**4.34**	51.0	425	0.176	7.04	1.1	4.967	0.907	7.387	0.644	7.33	**35.86**	<0.06	0.013	0.5	0,97	0.01	4,921	$1.1X10^5$	10	29	**7**
5	Imigrantes	22.11	19.26	8.03	**3.69**	44.0	405	0.187	7.93	1.0	5.118	0.817	4.380	0.795	0.33	23.91	<0.06	0.010	0.5	1,00	0.01	2,842	$4.9X10^5$	10	32	**6**
6	Alvarenga	18.72	18.41	7.23	**2.89**	33.2	407	0.208	6.50	0.8	4.470	0.623	4.310	0.456	4.33	22.18	1.50	0.035	0.8	1,70	**0.18**	1,011	$6.2X10^6$	$5,0X10^3$	29	**8**
7	Alvarenga	19.00	18.11	6.94	**0.07**	0.1	282	0.839	23.00	0.4	4.290	0.414	7.990	2.502	31.33	29.23	3.60	0.083	1.0	4,00	**0.28**	4,000	$7.1X10^5$	$2,1X10^4$	27	**6**
8	Grora Funda	21.16	19.20	7.55	**0.05**	0.0	399	0.211	11.90	0.7	4.470	0.938	5.310	0.787	8.33	23.04	1.10	0.045	1.5	1,60	**0.09**	1,675	$1.5X10^5$	$8,0X10^3$	19	5
9		20.27	19.16	7.33	**2.74**	31.6	409	0.218	16.90	0.6	4.680	0.510	4.240	0.755	6.33	15.95	**5.00**	0.051	3.0	2,60	**0.14**	2,312	$3.5X10^6$	$9,0X10^3$	32	**14**
10	Alvarenga 2411	25.50	20.56	7.20	**0.00**	0.0	91	0.263	42.10	0.2	5.630	0.663	5.003	1.199	29.33	**31.41**	**6.00**	0.005	2.0	5,70	**1.10**	1,289	$2.1X10^6$	$6,5X10^4$	44	**18**
11	Pedreira	22.98	19.23	7.06	**0.28**	1.6	22	0.267	45.30	0.1	5.980	1.124	6.460	0.287	44.33	5.59	**6.50**	0.004	0.1	5,20	**1.20**	2,656	$6.3X10^5$	$8,6X10^4$	49	**21**
13		22.70	19.32	6.93	**0.97**	10.7	76	0.250	47.10	0.2	4.310	0.497	9.350	0.577	29.33	24.19	**5.00**	0.003	12.0	5,10	**0.80**	1,763	$9.2X10^5$	$9,1X10^4$	37	**17**
14		22.87	19.23	7.16	**0.81**	7.6	323	0.232	44.20	0.3	5.410	0.898	7.530	0.628	24.33	26.47	**4.50**	0.001	0.2	4,90	**0.27**	3,534	$4.3X10^5$	$6,4X10^4$	39	**12**
15	Cocaia	22.13	20.41	7.37	6.24	75.8	313	0.237	28.60	0.5	4.780	0.451	4.350	1.761	17.33	**117.35**	**4.50**	0.082	0.6	3,20	**0.21**	1,480	$3.5X10^5$	$4,0X10^3$	40	**17**
16		20.72	19.14	7.70	5.98	69.0	409	0.202	18.30	0.6	4.824	0.207	6.340	0.530	4.33	**99.76**	0.70	0.011	1.0	1,70	**0.08**	2,682	$1.6X10^5$	$6.7X10^2$	30	**10**
17	Borore	19.00	19.40	8.75	10.06	120.0	377	0.187	18.90	0.6	5.283	0.187	6.870	0.514	5.33	**70.42**	0.20	0.015	0.2	1,00	0.02	4,683	$2.8X10^4$	30	38	**10**
18	Borore	22.32	19.38	8.89	9.77	116.6	375	0.192	19.90	0.7	4.938	0.869	6.430	0.346	7.33	**70.49**	<0.06	0.013	1.5	0,95	0.04	4,843	$2.2X10^4$	20	18	**6**
19		18.98	18.70	7.86	7.96	94.5	414	0.196	33.30	0.6	3.030	0.556	3.310	0.939	6.33	**84.29**	<0.06	0.006	2.0	1,40	0.05	**8,627**	$7.9X10^4$	$3.1X10^2$	24	**8**
20		16.38	18.44	7.47	7.87	90.5	426	0.187	11.50	0.9	3.155	0.286	8.650	2.000	4.33	**62.67**	<0.06	0.007	0.4	1,10	0.02	**5,413**	$3.3X10^4$	10	25	**7**
21	Taquacetuba	19.47	20.27	**9.38**	**4.92**	58.5	397	0.191	21.20	0.6	6.137	0.311	7.060	1.399	1.33	**64.48**	<0.06	0.011	0.4	1,50	0.03	3,859	$2.7X10^4$	30	32	**10**
22	Taquacetuba	20.46	19.41	**9.34**	**4.11**	50.1	384	0.174	21.40	0.5	5.246	0.223	7.870	1.072	7.33	**81.61**	0.12	0.009	1.5	0,94	0.02	4,992	$1.6X10^4$	$3.3X10^2$	28	**10**
23	Taquacetuba	21.29	20.46	**9.32**	**4.16**	50.8	418	0.172	29.40	0.4	6.019	0.271	7.652	0.516	15.33	**79.76**	0.04	0.008	0.2	1,10	0.02	**8,189**	$1.8X10^4$	30	41	**18**
24	Pedra Branca	23.70	19.66	8.67	**3.96**	48.3	415	0.185	9.31	0.9	3.786	0.151	3.410	0.360	3.33	**38.53**	<0.06	0.009	0.9	0,93	0.02	885	$1.3X10^5$	10	22	**6**
25		21.72	19.46	8.36	**3.85**	46.1	386	0.173	8.27	1.0	3.978	0.234	7.387	0.000	<0.02	**33.30**	0.07	0.012	0.4	1,00	0.01	4,736	$4.8X10^4$	30	30	**9**
26		24.50	18.78	8.42	**4.41**	51.9	363	0.455	9.83	0.8	2.781	0.369	6.667	0.260	<0.02	**48.73**	<0.06	0.009	0.2	1,20	0.01	4,178	$3.8X10^4$	90	14	3
27	Rio Pequeno	18.57	18.77	8.44	**3.64**	43.1	298	0.114	11.30	0.7	4.467	0.166	4.450	0.408	0.33	**38.86**	<0.06	0.005	4.5	0,97	0.01	**12,843**	$7.0X10^3$	40	17	5
28	Rio Pequeno	20.12	18.41	8.01	**3.93**	46.1	317	0.058	9.44	0.6	4.259	0.240	7.030	0.135	<0.02	24.05	<0.06	0.002	0.1	0,78	0.01	**14,025**	$9.0X10^3$	30	19	5
29	Capivari	19.08	18.42	7.03	**3.35**	39.5	389	0.157	10.10	0.6	4.833	1.401	5.559	0.405	<0.02	**45.42**	<0.06	0.007	4.0	0,74	0.01	**9,642**	$1.9X10^4$	40	25	**8**
30	Capivari	18.90	19.36	8.24	**3.74**	44.9	321	0.159	9.18	0.7	4.453	0.347	5.385	0.875	3.33	**37.51**	<0.06	0.007	0.3	0,92	0.01	**13,499**	$3.0X10^4$	10	17	5

Bold figures show that water quality clear the environmental standards for Class 2.

Table 5.3.6 Analysis Results of Bottom Sediment in the Lake billings（11-13/07/2006）

SQG's	Cd	Cr	Cu	Ni	Pb	Zn	Hg
TEL	0.596	37.3	35.7	18	35	123.1	0.17
PEL	4	90	197	36	91.3	315	0.486
SEL	10	110	110	75	250	820	2

			DO (mg/L)	pH	EH (mV)	Water content (%)	N total (%)	P total (%)	TOC (%)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)	Hg (mg/L)
1	Rio Grande		3.49	7.25	-117	83.6	0.56	1.79	6.41	0.33	91.22	823.93	65.23	53.95	154.49	0.1941
2	Rio Grande		3.58	7.97	-194	87.0	0.58	2.09	6.88	0.32	97.46	349.95	55.62	63.00	112.22	0.1531
3	Rio Grande		3.30	8.18	-294	86.4	0.62	1.37	9.80	0.08	65.49	472.34	33.74	26.79	166.71	0.1205
4	Imigrantes	0-12 cm	4.34	6.25	-158	92.6	0.58	1.39	13.17	3.34	455.74	441.89	303.35	127.07	936.32	0.3440
		29-41 cm	-	-	-	84.7	0.43	1.60	5.76	0.08	48.76	17.07	13.65	33.65	67.78	0.1252
		58-70 cm	-	-	-	62.6	0.30	1.,27	10.40	0.89	7.20	159.79	6.45	99.74	66.99	0.1913
14		0-10 cm	0.81	7.15	-176	78.4	0.53	2.00	5.49	0.90	161.09	289.26	63.84	113.21	508.70	0.5488
		12-22 cm	-	-	-	53.4	0.52	1.65	3.39	1.19	183.97	199.79	88.03	159.73	442.61	0.9379
		24-34 cm	-	-	-	53.5	0.24	1.28	3.95	1.30	186.42	226.30	95.13	141.26	480.47	0.8168
19		0-10 cm	7.96	6.68	-188	87.9	0.35	1.49	6.84	6.62	577.06	619.28	399.25	213.00	1566.97	0.1467
		45-55 cm	-	-	-	87.0	0.38	1.43	5.00	3.88	500.05	339.35	217.50	287.89	1267.11	0.1381
		90-100 cm	-	-	-	78.9	0.,42	1.48	5.82	2.59	238.52	237.03	50.79	210.64	1712.98	0.3395
20		0-10 cm	7.87	5.82	-169	90.5	0.37	1.72	8.12	1.66	229.47	213.39	104.26	114.49	540.78	0.3086
		23-33 cm	-	-	-	85.3	0.35	1.60	7.47	4.21	515.39	339.46	224.00	236.38	1184.40	0.2409
		46-56 cm	-	-	-	80.1	0.61	1.45	9.82	1.60	209.75	159.31	52.94	156.31	1108.67	2.1157
22	Taquacetuba	0-12 cm	4.11	5,91	-179	90.4	0.40	2.01	9.89	0.22	82.21	46.21	61.78	57.89	73.94	0.0681
		15-27 cm	-	-	-	84.7	0.75	1.51	9.28	0.34	163.29	48.20	80.66	60.99	141.16	0.0000
		28-40 cm	-	-	-	58.3	0.59	1.68	5.77	0.09	68.61	32.31	20.88	38.78	87.00	0.2220
23	Taquacetuba		4.16	5.67	-187	84.5	0.51	1.74	8.11	0.16	71.48	34.75	47.16	45.67	40.21	0.0596
26			4.41	6.23	-193	83.3	0.49	1.69	7.40	0.39	131.38	91.92	59.95	56.45	150.36	0.1641
28	Rio Pequeno		3.93	6.08	-139	86.5	0.55	1.52	6.75	0.15	61.85	29.93	29.43	52.87	61.35	0.1180
30	Capivari		3.74	6.73	-170	86.4	0.57	1.58	8.91	0.25	112.75	78.06	60.71	34.69	106.49	0.0819

Sediment Quality Guideline (SQG) in Brazil categorizes sediment quality into the following three levels:

TEL＝Thresghold effect level blue figures in **Table 5.3.6**

PEL=Probable effect level red figures in **Table 5.3.6**

SEL=Severe effect level red bold figures in **Table 5.3.6**

Chapter 6

STUDY ON POLLUTION SOURCES AND INFLUENCE TO THE WATER QUALITY

6. STUDY ON POLLUTION SOURCES AND INFLUENCE TO THE WATER QUALITY

6.1 Outline

The result of analysis on pollution load sources is shown below, including result of the site survey of the pollution load and documentary research stated in former chapter.

Reverse pumping up is considered to have had seriously influenced on the water quality of the Billings Lake. Major problem from now on is assumed to be sludge deposited on the bottom of the lake. Both of the reverse pumping up and untreated domestic sewage discharge are considered to be causes for the sludge deposition. Domestic sewage itself will decrease during about ten years by progress of environmental improvement due to sewerage construction and other measures. However, political control and its surveillance against expansion of population and favela are indispensable for this prediction.

The special pollutant sources were found out in the course of this study. They are discharge of water from the swamp of the Colonia crater and the old Albarenga solid waste disposal site.

The features of pollution load sources and its influence on the water quality of the Billings Lake are described in detail hereafter.

6.2 Domestic sewage

Population of 870,000 in the basin in 2000 is assumed to be approximately 1,400,000 in 2025 (**Chapter 10**). Examination of the area also showed that increase of the population could be simultaneously absorbed in the habitable zone in the basin. A political measure shall be required for restraints to this increasing tendency. Existing small residential areas which may serve as new cores of expansion of population were confirmed in the basin such as Santa Cruz, Caperinha in SBC and Vera Verde in Sao Paulo. Inside the small residential areas, population has been rapidly increasing and construction of new houses has also started on the outskirts of the areas. In such areas, problems of infrastructure were found as well. Insufficient road pavement and lack of water supply are the main issues.

It is presumed that the domestic sewage in the basin generated in 2005 was approximately 77,000m3/day, and approximately 50,000m^3/day flowed into the lake except for subterranean infiltration from septic tank. Future sewage generation in 2025 will be approximately 223,000m^3/day and discharge will be approximately 101,000m^3/day on the assumption of taking no measure for lake water pollution. Currently, generation of algal bloom is remarkable in summer, and algae smell in tap water is remarkable. Water quality in the lake as a source of water supply is in the almost limit state as drinking water.

Sewage in northeast shore area will be transmitted to the ABC sewage treatment plant and sewage of west coast area will be transmitted to the Barueri sewage treatment plant by sewerage construction, and advanced treatment plant will be constructed in the areas of Riacho Grande and Santa Cruz. As a result, most of the loads of domestic sewages will be reduced by this implementation. These improvement shall be intensively made during 2010- 2015.

Such sewerage construction may reduce discharge of raw sewage to the Billings Lake to the level of about 22,000m^3/day in 2015 and about 10,000m^3/day in 2025. 60% of sewage of 10,000m^3/day shall be treated in the advanced sewage treatment plant. (**Figure 6.2.1**).

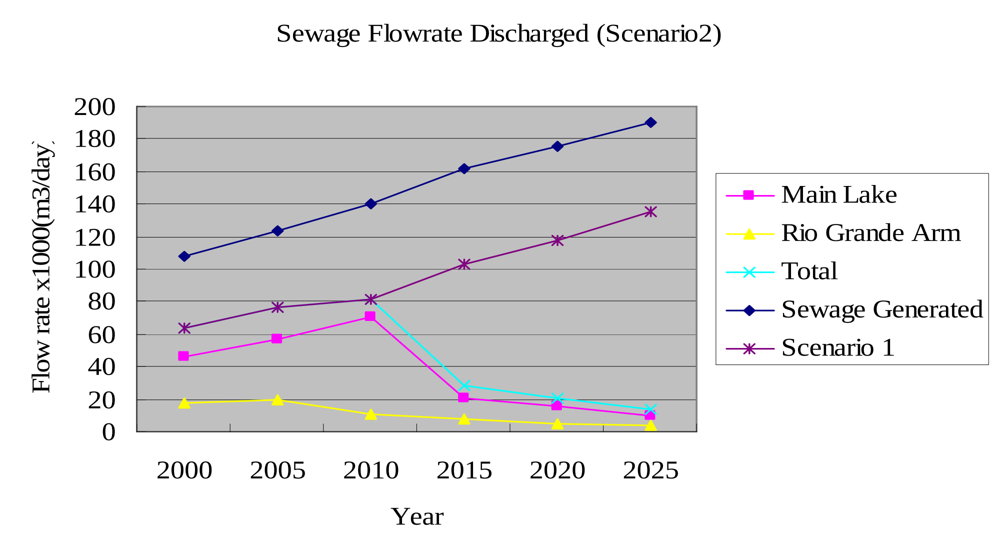


Figure 6.2.1 Comparison of amount of sewage generated and discharged (Scenario 2)

6.3 Underground infiltration from septic tank

Treatment of septic tank takes in both toilet and kitchen drainage, and liquid part is processed by underground infiltration and the solid of residue is removed by a vacuum car when storage tub become full. It largely depends on infiltration for sewage treatment and concern is pollution of underground water. Examination of the future sewage flowrate is performed by the assumption that underground infiltration from septic tank is completely effective.

In this study, future population ratio of using septic tank is considered constant from the reason below.

a) Population increases in both existing city area and newly developed area.
b) In the basin, the expected newly developed areas are scattered. And they are not suitable for dwelling in terms of road, traffic, water supply and inclination of land.
c) Population of newly developed city area will be about 400,000 on the whole in 2025. (About 1/2 of increase)
d) Introduction of sewerage service to newly developed urban areas will be fundamentally delayed because of dispersion of areas and low population density after

the development. Adoption of septic tank in such areas shall be the lawful solution.

e) Therefore, assumption of increase of sewerage service rate and decrease of usage of septic tank may result a risky estimate. For this reason, usage rate of septic tank was determined to be the same as present.

The subterranean infiltration of sewage treatment by septic tank and its load were calculated below according to this assumption. Area of infiltration is 119.17km^2 which includes existing urbanized area + farm. (96.9km^2 for the main lake and 22.7km for R.G.Arm)

Table 6.3.1 Ground infiltration and its load by septic tank

Year	Classification	Infiltration	Load infiltration	Unit load to the surface
2000	The Main Lake	42,018 m^3/day	9,454 kg/day	4.34 m^3/ha/day (0.43L/m^2/day)
	R.G.Arm	9,935 m^3/day	2,235 kg/day	4.38 m^3/ha/day (0.44L/m^2/day)
2025	The Main Lake	102,294 m^3/day	17,262 kg/day	10.56 m^3/ha/day (1.06L/m^2/day)
	R.G.Arm	21,633 m^3/day	3,656 kg/day	9.53 m^3/ha/day (0.95L/m^2/day)

According to this figure, infiltration by septic tank will increase in the future. Infiltrated sewage volume per unit area per day is not large even in the future. However, it is necessary to take into consideration that these loads may pollute ground water and flow into the Billings Lake after a long period. Oxidization may decompose carbon compounds, for example however, nitrate nitrogen may remain inside underground, may cause contamination of ground water and may attain to healthy damage, for example.

6.4 Industrial waste water

It was confirmed that industrial waste water is strictly managed by CETESB based on the MANANNCIAL law. Factories are obligated to install lawful treatment facility according to the type of industry, drainage water quality, the discharge flowrate, and conduct self-inspection periodically to report wastewater/treated water quality. The CETESB data about factories in the basin were offered. According to this data, numbers of existing factories in the basin were only 21. (Refer to **Figure 6.4.1**) The largest factory is Solvay in Santo Andre among these listed factories. According to the notification to CETESB, daily-maximum discharge of 4,080m^3/day was confirmed. Sewage is scheduled to be transmitted to the ABC treatment plant by sewer of SABESP in July, 2006. (Based on hearing.) This sewer was under construction as of March 2006 and to a Ribeirao Pires. It also became clear that nine (9) out of 21 factories did not discharge waste water nor treated water.

Confirmation of current status was made by interviewing regarding eight companies in 21 factories. Among those, though two companies (Nestle and Weg) were located inside the basin, they were out of list of CTETSB. It turned out that Nestle was not a factory but a delivery center of product. An oxidation ditch process was installed for employee's sewage. Weg was pumping up the effluent to the outside of the basin. Hereafter, the results of interviews are shown.

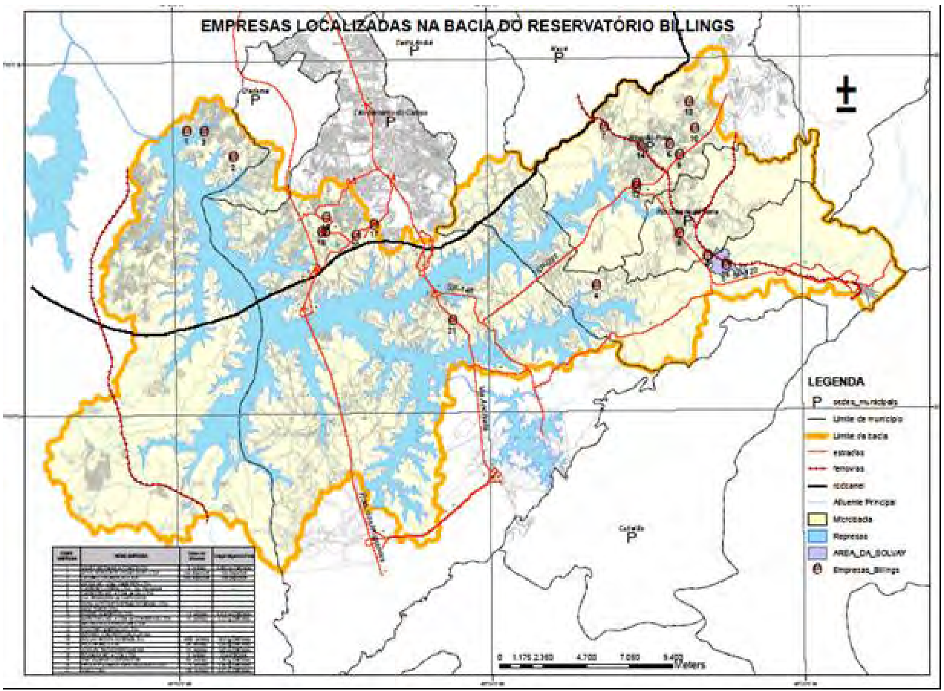


Figure 6.4.1 Factories location map in the Billings basin (source: CETESB)

Table 6.4.1 Interview result to the eight companies listed in the CETESB data

Name of Company	Rhodia Polimidia	Time	2005/08/25 10AM
Type of industry	Paint Material	Water Supply	Deep Well
Wastewater Flowrate (DA)	1.31m^3/hr	Treatment method	Trickling filter + Lagoon 3series
Influent BOD(mg/L)	3,179	Effluent BOD(mg/L)	6
Summary of Hearing	*Administration of Cetesb is very strict. *One of the targets of the company is zero wastewater emission.		
Name of Company	Acrilex Tintas Especiais	Time	2005/08/25 14PM
Type of industry	Resinate	Water Supply	Deep Well
Wastewater Flowrate (DA)	1.37m^3/hr	Treatment method	Treatment unit
Influent BOD(mg/L)	90	Effluent BOD(mg/L)	41
Summary of Hearing	*Dual treatment for sewage and wastewater *Target is perfect reuse of treated water.		
Name of Company	Akzo Nobel Ltda.	Time	2005/08/25 15PM
Type of industry	Resinate	Water Supply	Deep Well
Wastewater Flowrate (DA)	12m^3/hr	Treatment method	Lagoon 3series + Filtartion
Influent BOD(mg/L)	173	Effluent BOD(mg/L)	17
Summary of Hearing	*No discharge of treated effluent *Administration of Cetesb is very strict.		
Name of Company	The Valspar Corp.	Time	2005/08/26 10AM
Type of industry	Chemical	Water Supply	Deep Well
Wastewater Flowrate (DA)	650m^3/month	Treatment method	Chemical + Lagoon+ irrigation
Influent BOD(mg/L)	3,240	Effluent BOD(mg/L)	28
Summary of Hearing	*100% reuse for irrigation.		
Name of Company	Yakult S/A	Time	2005/08/26 11AM
Type of industry	Food industry	Water Supply	Deep Well
Wastewater Flowrate (DA)	120m^3/day	Treatment method	Oxidation Ditch + irrigation
Influent BOD(mg/L)	75	Effluent BOD(mg/L)	9
Summary of Hearing	*100% reuse for irrigation by Cetesb request.		
Name of Company	Solvay Indupa	Time	2005/11/18 11AM
Type of industry	PVC Product Manufacturer	Water Supply	River + Deep Well
Wastewater Flowrate (DA)	4,080m^3/day	Treatment method	Pretreatment+Oxidation Ditch
Influent BOD(mg/L)	Not available	Effluent BOD(mg/L)	28.5
Summary of Hearing	Sewage trunk line shall reach on July 2006 to send it to ABC STP		
Name of Company	Nestle	Time	2006/01/19 10AM
Type of industry	Distribution Center	Water Supply	Deep Well
Wastewater Flowrate (DA)	Only domestic sewage	Treatment method	Oxidation Ditch
Influent BOD(mg/L)	313	Effluent BOD(mg/L)	13
Summary of Hearing	Effluent discharged to sewer line which is connected to the Billings		
Name of Company	Weg	Time	2006/01/19 11AM
Type of industry	Motor Manufacture	Water Supply	Deep Well
Wastewater Flowrate (DA)	Only domestic sewage	Treatment method	Oxidation Ditch
Influent BOD(mg/L)	564	Effluent BOD(mg/L)	60
Summary of Hearing	Effluent discharged to sewer line which is connected to the Couros		

Waste water treatment facilities were installed to treat wastewater and the attitude to maintain the facility right was shown. Moreover, three of eight companies interviewed were not discharging effluent to outside. For example, in Yakult, spray irrigation has been carried out to neighboring woods by the automatic sprinkler. This is based on instruction of CETESB.

Photo 6.4.1 OD operation status of the Yakult factory

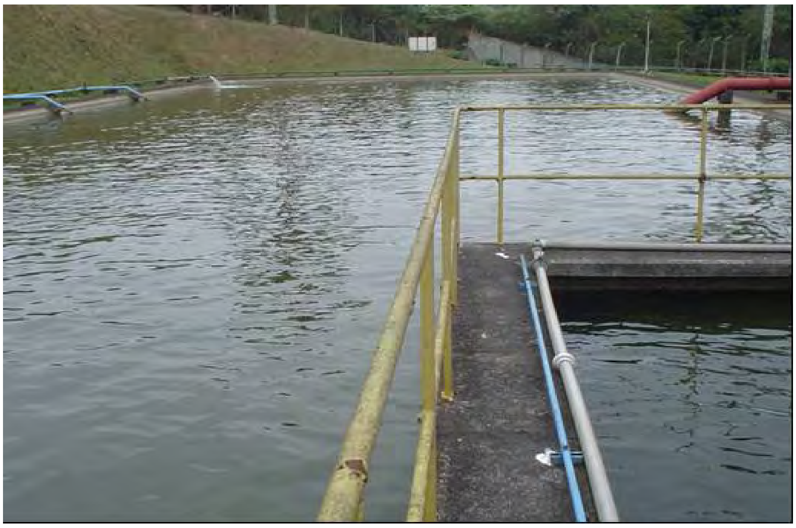


Photo 6.4.2 The Valspar com.Lagoon Operation status

Photo 6.4.3 Solvay Indupa Facility operation status

Table 6.4.2 Waste Water Data in 11 Factories (based on CETESB)

No	Name	Treatment	Flowrate (m^3/day)	BODloading (kgBOD/day)		Remarks
				Influent	Effluent	
1	Akzo Nobel Ltda.	Chemical/Biological	38.0	7.16	0.30 (7.9)	SBC
2	Acrilex Tintas Especiais	Chemical/Biological	15.0	10.60	2.60(1,733)	SBC
3	The Valspar Corp.	Chemical/Biological	60.0	141.0	1.38(23)	SBC
4	Rhodia Poliamida	Biological	118.0	―	4.48(38)	SBC
5	Yakult S/A	Biological	135.0	164.0	0.67(5)	SBC
6	VALEO SISTEMA AUTOMOTIVOS	Chemical	3.0	0.883	―	Sao Paulo
7	NOVO HORIZONTE CROMO DURO LTDA	Chemical	―	―	―	Sao Paulo
8	CROMAQ CROMEACAO LTDA	Chemical	―	―	―	Sao Paulo
9	Kassel Alimentos Ltda	Biological	1.50	4,095	0.018(12)	Ribeirao Pires
10	Marutaka Ind.	Biological	10.0	16.90	0.22(22)	Ribeirao Pires
11	Solvay Indupa	Chemical/Biological	4,080	―	28.5(7)	Santo Andre

Remarks: The inside of parenthesis of Effluent is BOD concentration (estimate).

Influence of industrial waste water on the water quality of Billings Lake is considered small after considering all the factors of the data of factories and interviews together. The reason is as follows.

- Surveillance for environmental measure, such as factory waste water administration, is severe, and the factory is performing company efforts to cope with the regulation.
- There are not much factories which are discharging in the basin and most of discharge are small-scale.
- The largest factory in the Billings Lake basin is Solvay of Santo Andre. It is scheduled to get started to transmit sewage out of the basin in July 2006.
- The factories are implementing environmental measures, such as splaying treated effluent for irrigation.
-

6.5 Agricultural pollution

(1) Land use

When predicting generation of agricultural pollution load, understanding of land use status is important. The forest occupies about 346km^2 (about 73%) among about 475km^2 of land area of the basin. Urbanized and rural area is 120km^2 (about 25%), and agricultural area is 9km^2 (1.9%).

Cereals production in paddy fields and wheat fields were not seen in agricultural area, but horticulture, fruit growing and vegetables are developed instead. Feature of the agriculture in suburban areas of big cities are seen. In the swamp of water's edge, there is no cultivation of lotus roots.

As for the topsoil of the basin coast, brown forest soil dominates. The soil is evaluated having no problem, though it needs careful of management in agricultural use.

(2) Cottage with farms (Chacara)

Cottage with farms (Chacara) is one of those similar to agriculture in addition to farmland. This occupies the area of about 33km^2 in the basin, and it has about four times larger area than agricultural area. It can be classified into two kinds. One is high-class cottages which are used as party halls or banquet rooms, the other is mainly farmland. The important point of Chacara in the prime report is that it is classified as proposed sites for housing in the future expansion. It does not necessarily include farmland inside. Crops from Chacara are not for commercial but mostly consumed in private use.

(3) Agricultural products

Remarkable agricultural products in farmland are cultivation of the tree for Christmas (horticulture) and vineyard. Production of vegetables, such as lettuce, welsh onion and tomato is also seen. The method of average fertilization is as follows.

1) Vineyard

The cultivation method of grape is to build grape vine trellis to extend branches and leaves broadly for sunlight efficiently. Season of fertilization is in winter after harvest. The fertilization method is to embed cow dung in the pits prepared close to a plant. Run off of pollution load from fertilization is considered to be negligible. Spraying of pesticide is indispensable to avoid disease by noxious insects.

2) Horticulture (tree for christmas)

According to hearing, fertilization and water spraying are hardly implemented.

(4) Other Agricultural Product

Fish farming does not exist inside the Billings Lake, so there is no feed injection to the lake water for culturing the fishes. (Although some fishing ponds exist in the basin, there is distance from the water surface of the lake.) Judging from these actual conditions, it was supposed that investigation of the load and water quality by agricultural runoff is no need.

6.6 Livestock waste water

Careful attention must be paid to the bad influence of piggery wastewater from both sides of its water quality and flowrate to water body. By "Billings 2000" (NGO ISA), it has become clear that a number of piggeries had existed in Diadema and Sao Paulo. (See **Figure6.6.1**) There was no mention about the existence of pig pens in SBC in the report.

In SBC, the regulation which forbids piggery in the Billings Lake basin was enacted in 2000. Although eight piggeries were confirmed in even 2003, all piggeries were removed by force.

Only one pig pen (pig house of five heads) was found remaining in Diadema through this field survey. In case of this small pig pen, it does not have any washing device in the pig house. Because there is no channel for drainage, there is no waste water run off substantially. It was judged that there was no need for special consideration in the pollution analysis.

Pasturage of horses, cows, and hens are found outdoors or back yards in the basin, the scale of pasturing is very small with several numbers. Excrement is made in field, so it is assumed that the pollutant runoff ratio to the water body of the Billings is small. This problem is considered to be solvable by making well-known about raising method in environmental education of each municipality.

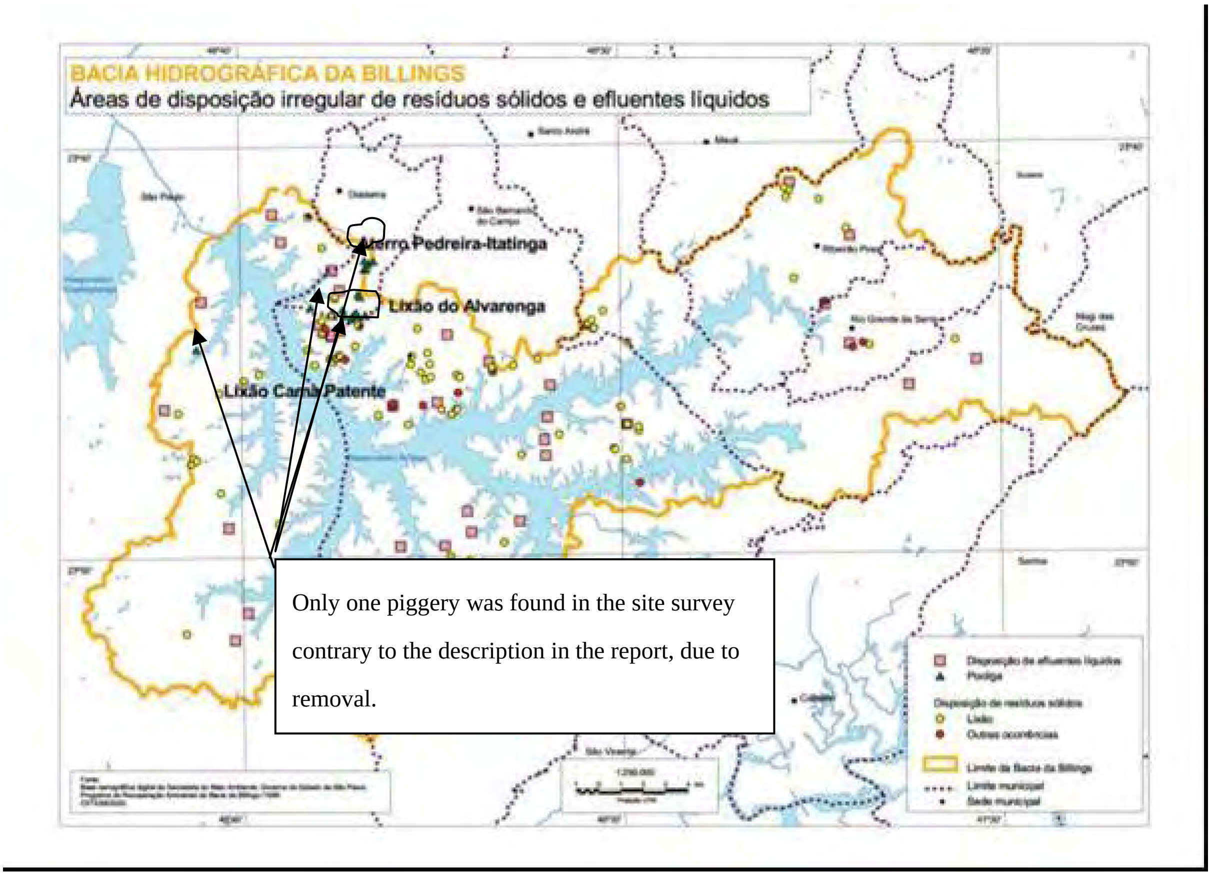


Figure6.6.1 Location of piggery and waste disposal site (source: Billings2000)

6.7 Tourism Waste Water

The following three places are considered to be the major pollution source of tourism which should be taken into consideration in the basin. (1) Paranapiacaba area (Santo-Andre city), (2) membership crab (such as Club dos Bankarios do Brasil, in SBC) and (3) a golf course (Golden Lake Golf Club, SBC).

However, they are all small-scale and the manner of tourism is mainly day trip. And two of these three, the latter haven't discharging into the lake, as they are drained by vacuum car including the kitchen foul water to dispose to the existing sewage treatment plant.

Therefore, day trip tourism in Paranapiacaba area is the pollution source which should be taken into consideration as tourism pollution. In Paranapiacaba area, ten small-scale simple hotels with no supper were confirmed. The hotels were made with conversion of interior of old household. 33 restaurants (similarly the same with hotels) were confirmed as well. There are no detailed data about the number of visitors. Most of tourists use the regular-route bus. By the operation schedule of the bus service, it is assumed that the number of visitors is approximately 200-300 persons/day. Basically weekday tourists are very few. The number of average tourists/day is assumed to be approximately 50 through a year. Day trip tourist's unit rate of sewage is considered to be about 1/7 of domestic sewage as shown in Chapter 8, therefore yearly average load becomes about seven persons (50/7≒7). From this figure, tourist's load shall be disregarded in this plan.

As resident population of existing condition, about 300 persons are presumed by taking 7 persons in an establishment including family and employees in all the 43 above-mentioned establishments. In the estimate of population, about 1700 persons was the number in 2000 for the basin of No.49 including Paranapiacaba area.

Many membership crabs were found in the basin other than above description in Sao Paulo Parelheiros area.

The result of the hearing in a golf course (Golden Lake Club) of the basin is shown as reference. Sewage volume per month is approximately $20m^3$/month, and is stored in the pit. It is taken out by vacuum cars and is processed in the existing sewage treatment plant. There is no discharge to the Billings Lake. Water is derived from deep wells including watering use.

Table6.7.1 Interview result of Golden Lake Club

Item	Description	Remarks
Hearing Date	2005.Aug.29	
Construction	1973	
Area	$677,000m^2$	
Number of Guest	Approximately 1,500 persons/week	
Employee	153	
Water Consumption	$12m^3$/day	Deep well, including watering
Sewage	Approximately $20m^3$/month	Pit tank for Toilet and drainage. No drainage (Pumping out to STP)
Fertilizer	Takenaka 25-5-20	3~3.5kg/$400m^2$/every 20days
Insecticide	Regente	1time /week

6.8 Natural pollution load

Natural pollution load is a load which flows out by rainfall in the state of no artificial contamination. This include run off of manure, humus, etc. The river-water data considered not to include artificial contamination in this study are obtained in five points. The value of natural pollution load per unit area is calculated as follows.

Table 6.8.1 Natural Pollution Load by each river in the Billings Basin

Location	Area	Flowrate	BOD /	L1	COD /	L2	T-N /	L2	T-P /	L2
	(km^2)	(m^3/s)	(mg/L)	1)	(mg/L)	1)	(mg/L)	1)	(mg/L)	1)
R-2	1.21	0.051	1	3.64	7.5	27.31	0.46	1.68	0.045	0.16
R-4	10.49	0.070	3	1.73	6	3.46	1.96	1.13	0.087	0.05
R-6	7.64	0.026	1.5	0.44	31	9.12	0.28	0.08	0.072	0.02
R-7	8.24	0.239	2.5	6.27	11	27.57	0.44	1.1	0	0
WW-1	16.35	0.098	4	2.07	22	11.39	0.69	0.36	0.045	0.02
Average			2.4	2.83	15.5	15.8	0.77	0.87	0.05	0.05
STD DV			1.2	2.23	10.7	11.0	0.68	0.64	0.033	0.064

1) : kg/km2/day

BOD load per unit area is averagely 2.83kg/km^2/day, and that of COD is 15.8kg/km^2/day. Similarly, TN is 0.87 kg/km^2/day and T-P is 0.064 kg/km^2/day. This unit load is considered to be relatively smaller than that of the forest in Japan.

One reason may be that flowrate was quite small due to dry season and the short rivers. The other may be the background of poor nutritious soil such as lathosol.

Natural pollution load itself is low level in this case. In contamination analysis, other reports and CETESB information shall also be examined.

6.9 Storm water drainage

(1) Analysis of rainfall data

Construction and maintenance of storm water drainage is under jurisdiction of each municipality. In documentary research, design criteria, such as rainfall intensity formula were not acquired. Frequency of rain, intensity of rainfall and rainfall were analyzed to produce rainfall intensity formula.

Rainfall depth and frequency was analyzed by the data for 10 years during 1995- 2004 of the meteorological observatory of the campus of the Sao Paulo university, and the following results were obtained.

There is much frequency of rain and rainfall depth compared with Japan, and there are many short-duration rainfalls. Seasonally, frequency of rainfall is higher in the rainy season as previous stated in **Chapter 1**.

Table 6.9.1 Rainfall depth and frequency in Sao Paulo (1995- 2004)

Item	Rainfall depth and frequency	Note
Annual days of rainfall	177.1 days	
Annual rainfall depth	1,493.8mm	
Annual rainfall hours	589 hours	

<Frequency distribution of rainfall>

Rainfall frequency distribution of the same data is analyzed as follows.

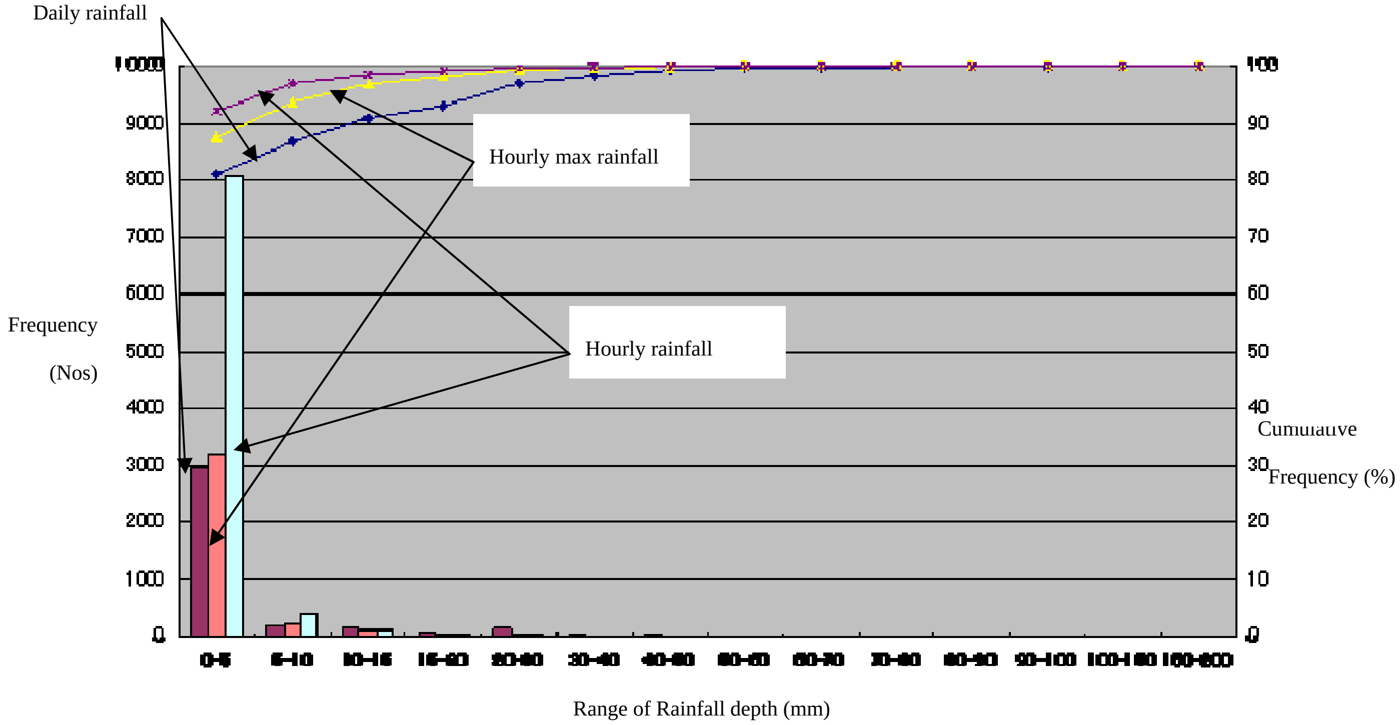


Figure 6.9.1 Rainfall frequency distribution of meteorological observatory in Sao Paulo University

1) About 81% of rainfall is 5mm/day or less. And frequency of the rainfall beyond 30mm/day or more is about 3% or about 10 times per year.

2) The rain occurrence frequency exceeding 50 mm/day is 0.3% and 2 - 3 times per year. The rainfall of 100 mm/day or more occurred 4 times in ten years.

3) About 92% of rainfall is 5 mm/hr or less. And occurrence frequency of the rainfall of 30 mm/hr or more is about 0.13% and 2 - 3 times per year.

4) 88% of rainfall is 5 mm/hr or less in terms of intensity. The occurrence frequency of the rainfall of 30 mm/hr or more is 0.3%, 2 - 3 times / yr. The rainfall of 50 mm/hr will appear once in about 5 years.

<Rainfall Intensity Formula>

Rainfall intensity formula is required in the planning of storm water drainage facility. Based on the data above mentioned, the formula was presumed as follows. The Talbot type was adopted as basic formula type.

Table 6.9.3 Intensity-of-rainfall type calculation result

	Formula	Duration of rainfall (min)					
		10	20	30	60	90	120
SAO PAULO	I3 = 9,840÷(t+152)	60.7	46.9	39.2	30.6	76.9	82.0
	I5 = 13,649÷(t+190)	68.2	65.0	62.0	54.6	48.7	44.0
	I7 = 16,817÷(t+221)	72.8	69.8	67.0	59.8	54.1	49.3
	I10 = 21,068÷(t+262)	77.5	74.7	72.2	65.4	59.9	55.2
	I5 = 5,200÷(t+38)	108.3	89.7	76.5	53.1	40.6	32.9

(2) Change of manner of land use

Population in the basin will increase rapidly. It is assumed that land use manner changes in connection with this population increase. Expansion of population will be absorbed by the next change. a) Increase of population density in existing urban area, b) Urbanizing of Chacara(34.54km^2) around the existing urban area. (Increase of population density from around 70 persons /ha to approximately 100 persons / ha according to the change of a) and b)). c) Urbanization of capoeira (65.73km^2) will be followed with the average population density of about 60 persons / ha. Distribution of such area for the expansion is shown in **Chapter 8**.

By expansion of this newly urbanized area, non permeable area will increase sharply as well. Result is shown in **Table 6.9.3** about this projection. This road area was predicted by result of analysis that road ratio is being 32% of city area in the existing urbanized area and average road width being w= 12.54m. Although the infiltration area of in the basin is about 39,000 ha now (about 82% of the basin), it will decrease to 30,000ha (about 63% of the basin) in the future. Therefore, there is a possibility of increase of run off at rainfall (= run off of the pollutants by flash and flooding damage). It is also concerned about reduction of infiltration to the underground. For this reason, installation of permeable pavement, infiltration pit might be necessary.

Table 6.9.4 Increase of non-permeable area by expansion of urbanized area

	2000			2025		
	Urbanized Area	Road Area	Road Length	Urbanized Area	Road Area	Road Length
	(ha)	(ha)	(m)	(ha)	(ha)	(m)
Existing Urban Area	8,463	2,708	2,159,729	8,463	2,708	2,159,617
Chacara/Capoeira				3,454	1,105	881,404
Chacara/Capoeira				5,630	1,802	1,436,683
	8,463	2,708	2,159,729	17,547	5,615	4,477,704
Total Land Area	47,463			47,463		
Permeable Area	39,000			29,916		

(3) Current status of storm water drainage

Generally, the basin has enough vegetation as a whole. As shown in the foregoing paragraph, the level of natural pollution is considered to be relatively low. The load by run off of the humus from the Colonia crater is a representative natural pollution load by rain water. However, humus is COD of refractory organic substances and it does not lead to contamination directly. Sometimes it has good influence adversely to the aquatic ecosystem.

However, when the flash of the contamination deposited at fine weather is washed away to flow into the lake in the area such as Cocaia Alvarenga with little vegetation and high population density, it will result cause of contamination. Flood occurs frequently at the same time. As shown in the example of the Jardin Laura area, these areas do not almost have vegetation and its rate of a non-permeated area is very high. For this reason, safety and sanitary problem has been occurring to the households around channels. The analytical data about the storm runoff in the Jardin Laura area are shown below.

Table 6.9.5 Fundamentals for the storm runoff in the Jardin Laura area

Item	Unit	Fundamentals	Note
Area	ha	7.9ha	
Residential area	ha	4.95ha	Flow coefficient 0.9
Road area	ha	2.33ha	Flow coefficient 0.9
Bare ground	ha	0.62ha	Flow coefficient 0.5
Flow coefficient	－	0.87	overall
Gutter capacity	m^3/s	0.15	U300、i=10‰、Manning
Rain runoff 1	m^3/s	0.096	5mm/hr, Rational Formula
Rain runoff 2	m^3/s	0.192	10mm/hr, Rational Formula

According to this result, it turns out that capacity of gutter is not big enough to flood with the rain of 10 mm/hr. It is necessary to improve by taking the measures against run off of both of road surface and roof. Water permeable pavement and run-off regulation tank with vegetation recovery shall be also needed.

6.10 Influence of pumping up of Pinheiros river water

(1) The outline of pump facility in the Pedreira dam

The Pedreira dam has the structure of an earth fill type. The reinforced concrete building was built at the boundary of the Pinheiros River to install pump facility for pumping up the water in the Pinheiros to the Billings Lake. The pump facility was installed aiming at mainly power generation in the Henry Borden power plant from 1939 to 1992, until when regulation banned pumping up except for the emergency. The power generated period is for 35 years during 1957~1992. After 1993 pump operation has been made only when an emergency for the flood control of the Tiete River.

The average pump up flowrate in 1939~1997 : 50.9m^3/sec (source: Termo de Referencia para o Programa de Recuperacao Ambiental da Bacia Billings, SMA July, 1999)

Water level between the Billings Lake and the Pinheiros River is about 20～25m. The result of hearing about the pump equipment of the Pedreira dam is shown below.

Type of Pump: Mixed flow vortex pump
Number of pumps: 8 sets
Pump capacity: 395m^3/sec (at full operation) Capacity per set approx. 50m^3/sec
Pump head: 25m

(2) Rate of pump up

According to the data of the Pinheiros river pump up at the Pedreira pumping station, the status of pumping up to the Billings Lake became clear. The figure of pumping up is shown in **Figure6.10.1**. The rate of flow was large during 1986 – 1992. The yearly average flowrate of 70m^3/sec (approx. 2,200 million-m^3/yr) was pumped up. It is equivalent to continuous operation of approx. 1.5 sets of pumps having always worked on in this period. As the inflow of annual daily average influent waters in natural state to the Billings Lake is about 15m^3/day, it meant that the amount of river water pump up was about 5 times bigger than natural state. The water of the Pinheiros River was already polluted then. The nominal volume of the Billings Lake is about 1,150 million m^3, and detention time of the water during 1986- 1992 was assumed to be about five months when pumped up water and natural influent water is added up. It is assumed that the whole lake water had been decomposed and anaerobic during this period due to influence of the Pinheiros River water.

The rate of flow decreased sharply by regulation from 1993, and from year 2000 flowrate became approx. 5m^3/sec (approx.160 millions m^3/yr). It was operated once in 2005 to avoid flooding in the Tiete River basin in May.

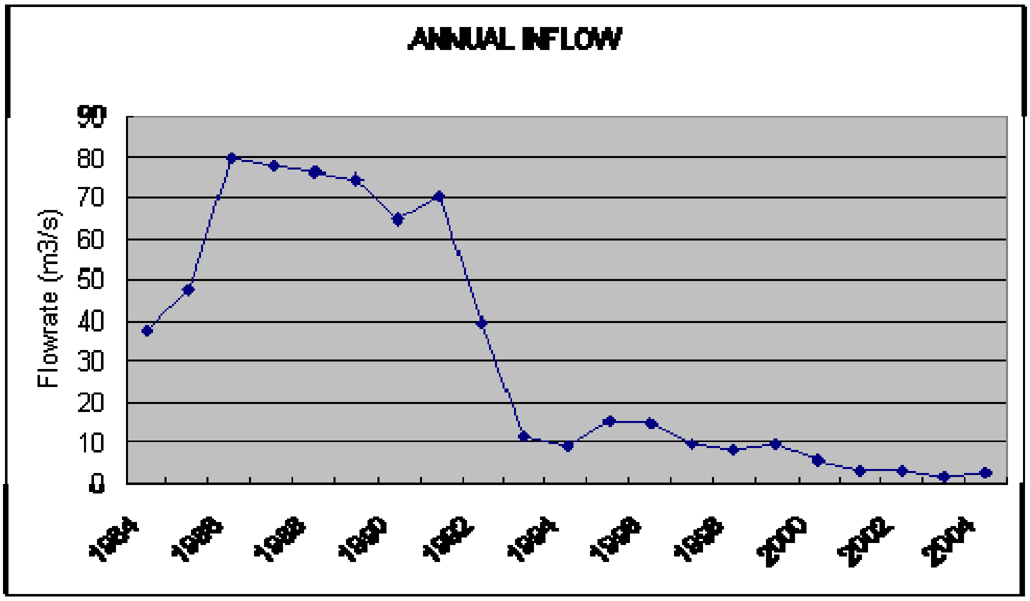


Figure 6.10.1 Current status of pumping up from the Pinheiros river

3) Pollution of the Billings Lake by Pinheiros river water pumping up

The river water of the Pinheiros River has been polluted by decomposition of organic matters, and the blackish suspended solid is floating in the water considerably. Moreover, the bad odor of hydrogen sulfide has been full on the outskirts. The cause is considered to be contamination according to the untreated sewage discharged to the Tiete River basin and the Pinheiros River. Although it was able to swim in the Tiete River till the 1960's, around 1970's recreation use became impossible by contamination.

The water flow is stagnant at the front of the dam in the Pinheiros River and it is foul and digested now. Sewage from the Tiete River was pumped up then for water power generation.

The pollution load inflow to the Billings Lake by this pumping is calculated and shown in T**able 6.10.1**. The load inflow was obtained that BOD concentration in the Tiete River is about 60 mg/L referring the latest water quality data in the Tiete River. In 1986, the total yearly inflow amount is assumed to be 150,000t BOD/ year which comes the worst for the past. (Amount of 415 t/day) Although about 500,000 populations were resided in the basin at the same period, this amount of BOD loads is 25 t/day (50g-BOD/person/day x 500,000 population). Seriousness of the bad influence of the pumping up is obvious from this fact.

Table 6.10.1 Examination of BOD load inflow to the Billings Lake by pump-up

Year	Yearly pump up flow rate	Annual pump up amount of water	Inflow of BOD load (60mg/L)	
	(m^3/sec)	(1000m^3/year)	(ton/year)	t/day
1984	37.5	1,184,561	71,074	195
1985	47.5	1,492,733	89,563	245
1986	80	2,521,394	151,284	415
1987	78	2,459,972	147,598	404
1988	76.5	2,407,191	144,431	396
1989	74.6	2,348,064	140,883	386
1990	64.8	2,046,254	122,775	336
1991	70.5	2,221,528	133,292	365
1992	39.3	1,235,847	74,150	203
1993	11.6	363,231	21,794	60
1994	9.4	292,343	17,541	48
1995	15.8	403,229	24,194	66
1996	14.9	390,387	23,423	64
1997	9.8	309,252	18,555	51
1998	8.4	261,403	15,684	43
1999	9.8	304,266	18,256	50
2000	5.6	174,161	10,450	29
2001	3.4	107,352	6,441	18
2002	3.3	103,956	6,237	17
2003	1.9	59,754	3,585	10
2004	3.1	97,174	5,830	16
	Total	20,784,053,000m^3	1,247,043 ton	

4) Presumption of deposition sludge in the Billings Lake

Presumption of deposition sludge on the bottom of the Billings Lake was conducted from the amount of inflow SS in 1970 to 2004 and the result is as follows. It was assumed that contamination started in 1970 and the digestion reaction of organic matter under the low temperature had occurred in the bottom of the lake. The ratio of organic matter in SS was assumed to be 70% and the organic matter decrease by digestion to be 50%. Sludge loss by water flow and the underwater elution were assumed to be 30 to 50% inclusively. Moreover, sludge is assumed to be diffusing uniformly all over the bottom of a lake.

Table 6.10.2 Examination of sludge deposition in the Billings Lake

Item	Description	Remarks
SS Inflow During 1970~2004	1970~1983 1,348,353ton	50.9m³/sx60mg/lx14yrsx365x86400
	1984~2004 1,247,043ton	Table6.10.1
	Total 2,595,396ton	
Concentration of SS Inflow	60mg/L	1994~2003 PINH04900
Ratio of Organic matter	Organic：Inorganic=70:30	Same with domestic sewage
Reduction rate of organic matters	Assumed to be 50 %	Anaerobic digestion under low temperature
Assumed sludge deposition	843,503 ~ 1,180,905 ton	2,595,396 x 0.5~0.7 x (0.7X0.5 + 0.3) Loss of sludge 0.3 to 0.5
Assumed sludge thickness	(843~1181/108/1,000=0.008~0.011) 0.8 ~ 1.1 cm	Water surface Area ＝ 108km² 、Specific Gravity＝1.0

The amount of deposition sludge will be set to about 1 million ton as shown in **Table 6.10.2**., when based on the Pedreira dam flowrate data and these assumptions above. This is equivalent to sludge having accumulated on the bottom of the Billings Lake by the thickness of approx. 1cm. In fact, due to sedimentation after pumping, it is assumed that topographical concentration is considered to be carried out near the Pedreira dam.

According to CETESB, it is reported that the sludge of 50,000,000m³ had been accumulated in the phase of late 1970's. (Source: Convenio HIBRACE (1968)) Although sludge should have deposited by about 50cm thickness all over the bottom of a lake from this figure, it was not able to confirm the sludge thickness of 50cm in the Lake. This value from the report of CETESB differs greatly from examination result shown in **Table 6.10.2**.

From the result of field site survey shown in ANNEX, it was confirmed that approximately sludge of 52,000,000m³ is deposited on the bottom of the lake. One of the reason is considered to be the reproduction due to the strong eutrophication in the lakes.

5) Contamination by the sewage from population in the basin

The trend of the basin population in the past was about 400,000 populations in the Billings Lake basin in 1985. In 2000, it became about 850,000 persons in track record.

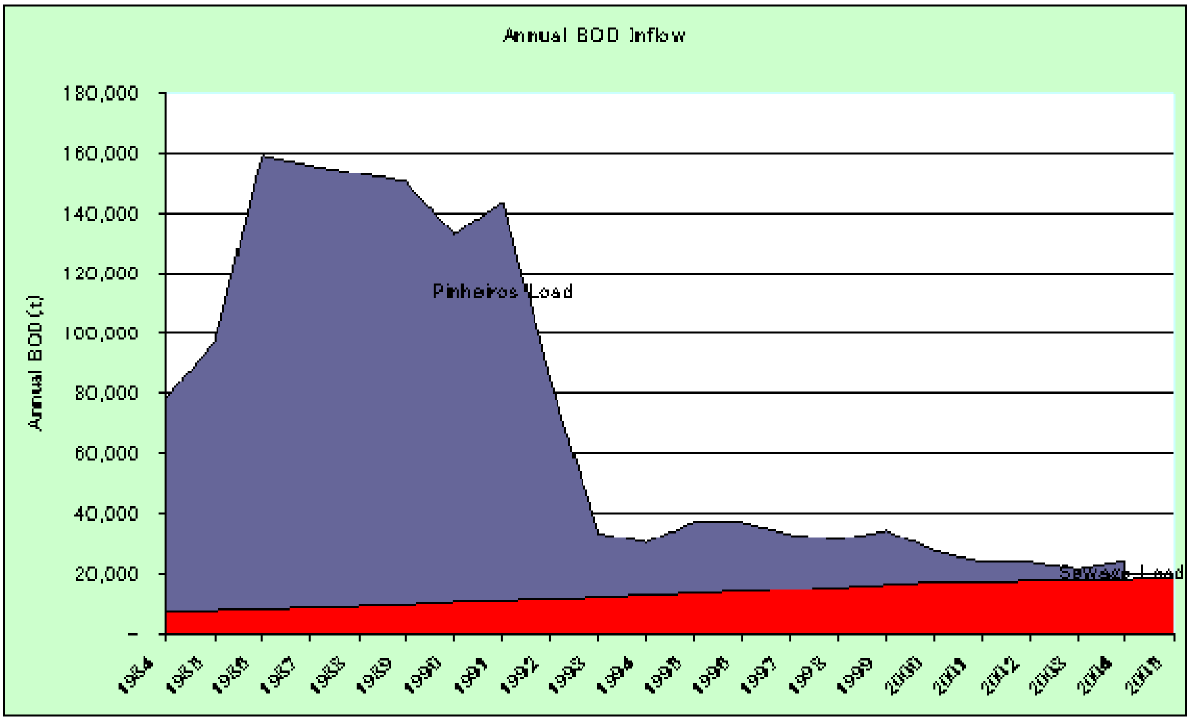


Figure6.10.3 Presumption of amount of SS inflow to the Billings Lake

6.11 Specific Pollution Source

As specific pollution sources, the discharge from the Colonia crater and the leachate from old Alvarenga waste dumping site were found out. Those locations are shown in **Figure 6.11.1**.

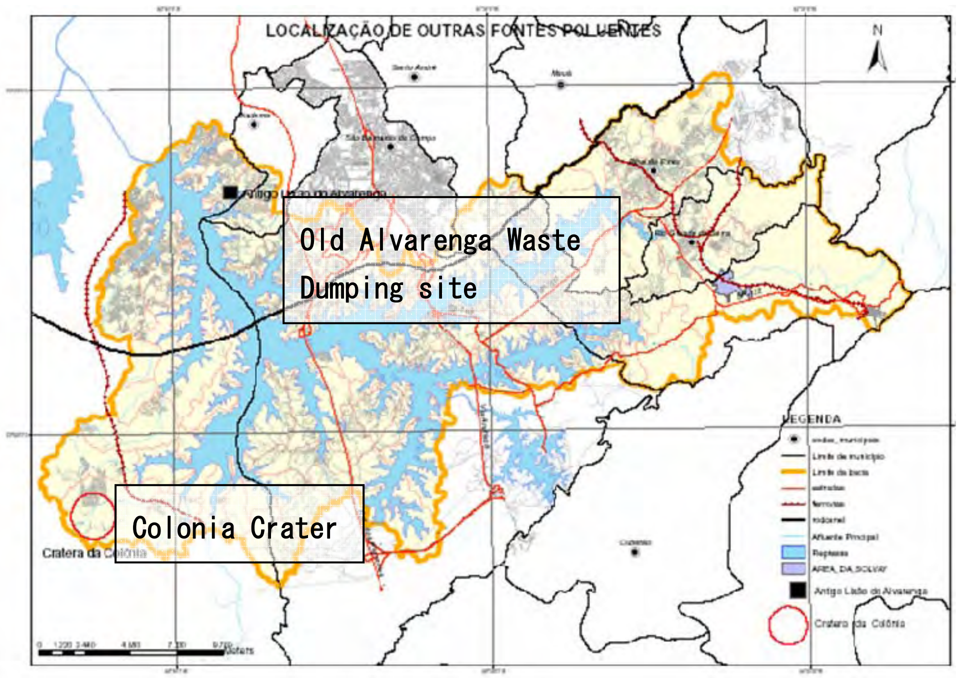


Figure 6.11.1 Locations of specific Pollution Source