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The use of economic analysis for water quality improvement investments

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Chapter 2.
The Case Study Context:
A Water Quality Improvement Program in Brazil

2.1. Introduction

The previous chapter provided an introductory overview of the global water quality challenges, the problem statement, and the main research questions that will be addressed by this dissertation. In this chapter we will provide an overview of the case study context. First, we will illustrate the reader with the country where the case study takes place: Brazil. Then we will describe the major water quality challenges in Brazil and we conclude by presenting the case study in question: a water quality improvement program in the state of São Paulo.

Figure 2.1: Locationof Brazil

Source: Editora Abril, Sao Paulo

2.2. A Glance at Brazil

Brazil, located in the northeast corner of South America, occupies a vast territory of 8.5 x 10^6 km^2 and has population of approximately 192 million inhabitants (Economist Intelligence Unit 2008), making it the largest country in Latin America and the Caribbean (see Figure 2.1). It is an industrial power with the ninth largest world GDP measured by purchasing power parity (World Bank 2008).

Since 2004, the country has achieved considerable improvements in economic, social and environmental areas, including macroeconomic stability and reductions in poverty and income inequality. Sound macroeconomic management combined with well-directed social policies has resulted in high growth rates, low inflation and improvements in social well-being (see Table 2.1). The economy has grown strongly averaging 4.8 percent between 2004 and 2008; well above average annual grow of just below 2.5 percent in recent decades (World Bank 2008).

The poverty rate (measured by a per capita income of half the minimum wage) dropped from 39.4 percent in 2003 to 30.3 percent in 2007 (World Bank 2008).

The Gini coefficient, which measures income concentration, continued to fall from 0.593 in 2003 to 0.552 in 2007, a 7% decline (UNDP 2007). Since 2005, Brazil has entered the group of countries with a high human development index (HDI) as measured by the UNDP. In 2006, Brazil had a HDI of 0.807 in a scale that goes from 0 (least developed) to 1 (most developed) (UNDP 2007).

Table 2.1. Brazil at a Glance

2007	
Population, mid-year (millions)	191.6
Average Annual Growth, 2001-07	
Population (%)	1.3
Labor Force (%)	1.8
Most Recent Estimates (latest year available, 2001-2007)	
Poverty (% of population below poverty line)	22
Urban population (% of total population)	85
Life expectancy at birth (years)	72
Infant mortality (per 1,000 live births)	19
Child malnutrition (% of children under 5)	4
Access to an improved water source (% of population)	91
Key Economic Indicators 2006	
GDP (US$ Billions)	1,067.8
Current Account Balance/GDP	1.3
Total Debt/GDP	18.2
Consumer prices (% change)	6.9

Source: World Bank fact sheet, 2009.

Despite the abovementioned significant advances, substantial challenges still remain for the country being sustained growth the major one. Growth rates have remained below the global average; activity of the private sector in different areas of the economy is limited, primarily due to various barriers to entry and weak regulatory frameworks. Inadequate infrastructure, weak business climate, rigid labor markets, high tax rates and cost of credit are major deterrents to sustained growth (World Bank 2008). Poverty and inequality also remain at high levels. Brazil also experiences extreme regional differences, especially regarding health, infant mortality, nutrition, and environmental indicators with the North facing high poverty rates and unsustainable environmental (including water) management practices.

2.3. Water Quality Issues in Brazil

Brazil is very well endowed with water resources, representing approximately 12% of the world's total (Margulis et al 2002). However, the distribution of the water resources is uneven, with 80% of the water available concentrated on the Amazon Basin[7], which is also the least-populated. The semi-arid Northeast region, including a large portion of the São Francisco river basin, has only 4% of the country's water resources by 35% of the population, the vast majority of the poor, it has a semi arid climate and it is considered the most densely populated semi arid area in the world region (Table 2.2 below depicts the water resources volumes). The humid South and Southeast regions, were 60% of the population reside, had large volumes of water resources per capita available but due to rapid urbanization and unsustainable economic growth, it has faced, in the last decade, unsustainable exploitation and misuse of surface water resources with increasing water pollution levels[8] (Margulis et al 2002). An area of approximately 900.000 km2 has a semi arid climate, with severe water scarcity, and a larger area suffers with seasonal water scarcity (3 to 5 months per year) (Clevelario Junior et al 2005).

Table 2.2: Mean Water Flows per Hydrographic Region

Hydrographic Region	Area (Km^2)	Mean Flow (m^3/s)
Amazon	3.869.953	131.947
Tocantins-Araguaia	921.921	13.624
Northeast Atlantic (East)	274.301	2.683
Parnaiba	333.056	763
Northeast Atlantic (West)	286.802	779
São Francisco	638.576	2.850
East Atlantic	388.160	1.492
Southeast Atlantic	214.629	3.179
South Atlantic	187.522	4.174
Uruguay	174.533	4.121
Parana	897.873	11.453
Paraguay	363.446	2.368
Brazil	8.532.772	179.433

Source: Ministerio de Meio Ambiente 2006.

7 In the National Water Resources Plan, the water resources have been divided into twelve hydrographic regions: Amazon, Tocantins-Araguaia, Northeast Atlantic (East), Parnaiba, Northeast Atlantic (West), Sao Francisco, East Atlantic, Southeast Atlantic, South Atlantic, Uruguai, Parana, and Paraguai.

8 An increase in the pollution levels decrease the availability of water hence the volume per capita decreases.

The importance of water quality in Brazil is clearly addressed in the National Water Resources Policy which defines, among its objectives to ensure to the present and future generations the required supply of water with adequate quality for its respective uses (Ministerio de Meio Ambiente 2006).

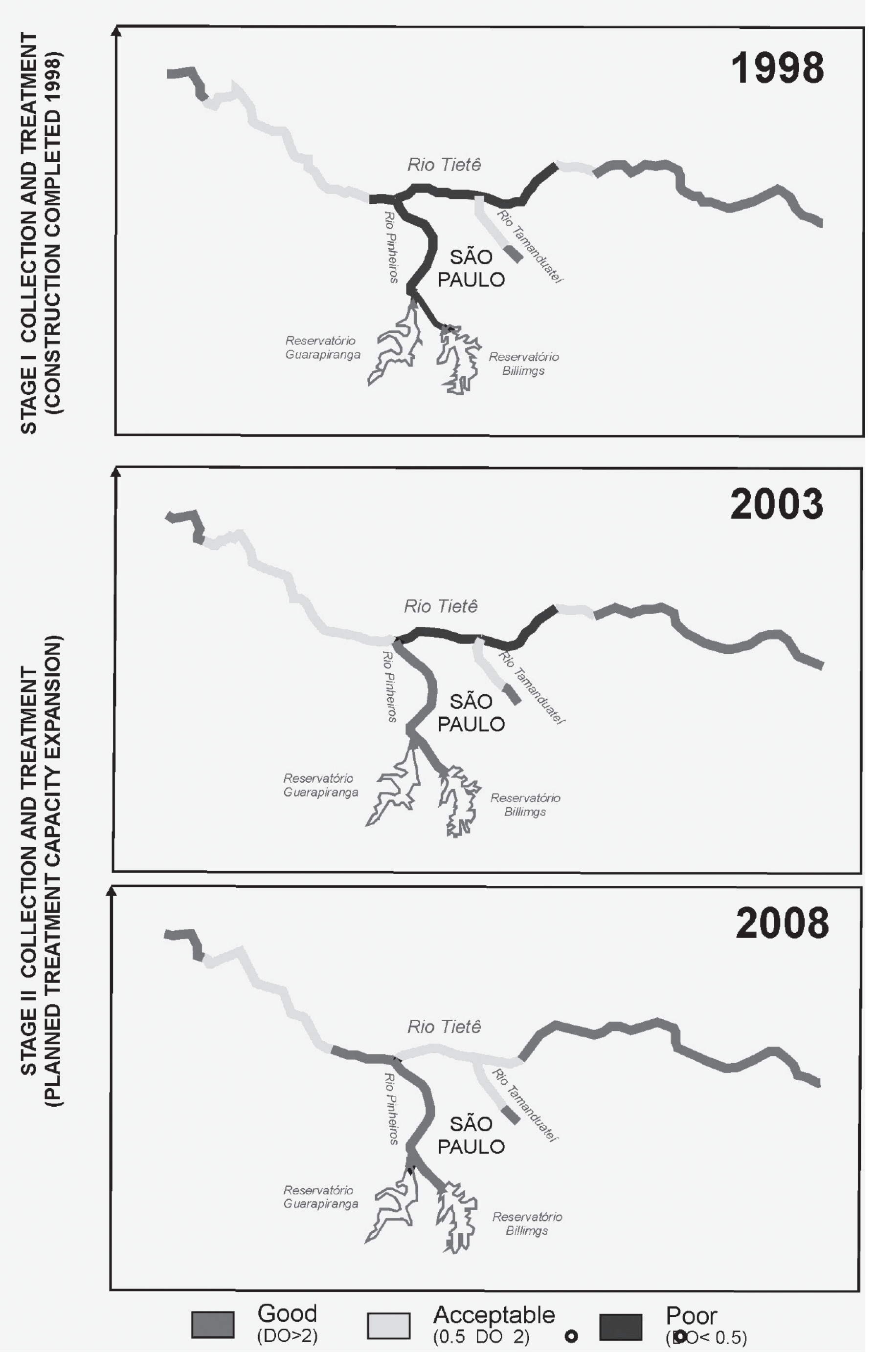
In 2002, the Brazilian Institute of Geography and Statistics (IBGE in Portuguese) conducted a survey among municipalities to identify the main environmental problems facing them. Fifty-three (53%) percent of the municipalities identified the sedimentation of the rivers as the main environmental issue and 38% depicted water pollution as the most critical problem (IBGE 2002). Pollution from domestic waste was cited as the most critical. This was particularly identified for municipalities located in the Southeast and Northeast of the country; the most populated regions. In the South region, non point agricultural sources were identified as the most critical issue; the South is where most of the agriculture is produced (IBGE 2002).

The main issue, in terms of water quality in Brazil, is the discharge of domestic waste. Only 47% of the municipalities in Brazil have sewerage systems for collection and only 18% receive any kind of treatment. The total load of domestic wastes has been estimated to be 6.389 t/day (ANA 2005). The city of São Paulo has better treatment levels currently estimated at 58% but given its size, the situation is still alarming and the Tietê River is still one of the most polluted in the entire country.

2.4. The Tietê River Pollution Problem

The poor water quality of the River system was already addressed in a 1953 master plan that recommended the construction of six wastewater treatment plants at secondary level for the city of São Paulo. However, the construction for the first facility begun in the late 1980s. In this same period, public outcry against the problems caused by the poor ambient water quality of the water bodies reached a climax (Hermann and Braga 1997). The population of the State, with support from the media, demanded action to curtail the increasing degradation of the river. In September 1991, and in response to the outcry, the State Government launched the Tietê Program with the objective to clean up the rivers and reservoirs of the São Paulo area (Hermann and Braga 1997). The first stage of this Program included the formulation of a new master plan for sewage collection and disposal which was completed in 1987. Under this plan, five wastewater treatment facilities were considered. A later revision to the plan concluded that the treatment capacity had to be increased, resulting in a revised plan including three new treatment plants and expansion of an existing one.

Figure 2.2: Water Quality in the Tietê River



The Tietê River originates just 95 km east of the city, picks up its pollution load upon passing through it, and flows for another 1095 km before joining the Parana River. The majority of the municipalities in the area are located in the watershed of the Tietê River (upper Tietê) and its main tributaries: the Pinheiros, Tamanduatei, and Juqueri. The industrial center of Cubatao, which generates the highest atmospheric and water pollution in Brazil, is located in São Paulo State.

The state of São Paulo in Brazil occupies approximately 250,000 km^2 (2.9% of Brazil's area) and has a population of around 40 million (21% of the population of Brazil). It is the most populated state in the country with the largest industrial park, generating almost 34% of Brazil's Gross Domestic Product (Emplasa 2008). This makes the state the biggest economy of South America. It is the richest state in the country with the second highest per-capita income (lower only that the Federal District) and it has one of the highest standards of living Brazil. At the same time, it contains high poverty rates, particularly in the peripherals parts of the cities.

The state's capital city, São Paulo, is the largest city in South America (estimated population of 11 million residents within an area of 1,500 km^2); is the 19th richest city in the world (per capita income was approximately $10,331 USD in 2005), and is among the four largest metropolitan regions of the world (Emplasa 2008). Even though its richness, social inequality is very visible. In 2007, the city of São Paulo run a survey to determine the quality of life of its population. The Human Development Index (HDI), developed by the United Nations, was the main indicator used to qualify the quality of life. The results proved the vast difference in quality of life of its population: there are areas in the city with HDIs equal to or greater than the indexes of some Scandinavian countries. At the same time, other areas in the lower range had HDIs in line with, for example, the Magreb.

The areas around the centre of the city São Paulo have experienced very large urbanization rates: from a population of merely 1.8 million in 1940 to 11 million today). This rapid increase in its population has caused several problems: a) unplanned growth, b) overcrowded public transport, c) poor quality of transport infrastructure (due to heavy usage and poor maintenance), d) high crime rates, e) air pollution, and f) the two major rivers crossing the city, the Tietê and the Pinheiros are highly polluted due to lack of proper sewerage and wastewater treatment. São Paulo lies in the center of the São Paulo Metropolitan Area (SPMA), which occupies 8,000 km2 and has a population of 16 million (11.2% of the country's total) (IBGE 2008).

The parts of the Tietê River and its tributaries flowing through the SPMA are the most polluted bodies of water in the State and in Brazil. A study conducted by the Brazilian Institute of Geography and Statistics (IBGE in Portuguese) in 2004 to assess the water quality of the country's river concluded that the Tietê and the Iguaçu rivers are the most polluted[9] (IBGE 2004).

The Tietê enters the metropolitan area with acceptable water quality characteristics but in Guarulhos, at the confluence of the Jacu River, it becomes anaerobic (see Figure 2.2). From the Jacu downstream the large volume of untreated domestic and industrial waste dumped into the relatively small volume of river flow has made the river an open sewer that supports no aquatic life, smells most of the year, and is used only as a sewer canal for more than 80 kilometers.

The city of São Paulo has developed around the Tietê in a way that adjusts for the river's extreme pollution. On either side of the river, the state has built large expressways, which impede access. Land adjacent to the expressways is used predominantly for industry or commercial storage and wholesale activities. Land use has adjusted, but the problem remains. Surveys indicate that people who drive the expressways and work in the areas are aware of the stench of the river. Sections of the expressways frequently flood in rainy season exposing people to health risks. The water is too contaminated even for industrial use.

The Edgard de Souza dam, located about 20 kilometers downstream from the confluence of the Tietê and the Pinheiros rivers, permits the diversion of the Tietê into the Pinheiros. Between 1930 and 1991 the elevating plants of Traição and Pedreira pumped Tietê/Pinheiros water to the Billings Reservoir where it was used by the 887 MW Henry Borden hydroelectric plant. Because of the increasing deterioration of the quality of the Tietê, the 1989 Constitution of the State of São Paulo required state and municipal authorities "to take effective measures" to stop the pumping of waste waters, and other polluting substances to Billings reservoir. The pollution is costing the power generating company, EMAE, about US$66 million in foregone revenue.

The tributaries of the Tietê in the metropolitan area and the Tiête itself receive waste well beyond the river's natural processing capacity. At present the organic load is predominantly from households (360 tons per day, 80% of the total). Surface runoff accounts for 62 tons per day and industry contributes 30 tons per day. The problem is severe all year long and becomes critical in the dry season.

9 For this analysis, IBGE utilized the Indice de Qualidade de Agua (IQA); a water quality index developed by the Companhia de Tecnologia de Saneamiento Ambiental de Sao Paulo (CETESB in portuguese) in 1975. The IQA is obtained from a mathematical formula which uses as variables the temperature, pH, dissolved oxygen, the biochemical oxygen demand, the amount of fecal matter, nitrogen, phosphorous and total residues dissolved and water turbidity. The highest the IQA the better the quality of the water. Rivers scoring more than 80 points are considered of acceptable quality for potable water. The score for Tiête was 30.

2.4.1. Domestic Contamination

The Tietê River and its principal tributaries are fed by a number of smaller tributaries in the SPMA. These tributaries lie in the service areas of four sanitation companies. Three of these companies (Saneamento Basico do São Paulo--SABESP, the municipality of Guarulhos, and ABC are upstream from the critical areas of the river affected by the project), the fourth, the municipality of Osasco, is downstream.

Table 2.3 presents the data on the percentage of houses in each of these four areas with water and sewerage services supplied by public sanitation companies. Table 2.3 shows that SABESP treats more of the sewage it collects (61%) than any of the other three companies operating in the SPMA. ABC has higher coverage with sewerage services (85% vs. 79%) but a much lower percentage treated 48%. Guarulhos has the worst indicators with 70% sewerage coverage and no treatment at all. Thus it is hardly surprising that the Tietê becomes anaerobic when it flows through Guarulhos.

Table 2.3. Percentage of Households in the SPMA Served by Publicly Supplied Water and Sewerage Service in 1998

Company	Water Service Coverage	Sewer Service Coverage	Sewage Treated
SABESP	98%	79%	61%
Guarulhos	95%	70%	0 %
ABC	100%	85%	48%
Osasco	98%	70%	24%

The SPMA still has 89 collectors serving sewer networks that discharge untreated sewerage directly into the tributaries of the Tietê. In addition, there are a large --but unknown-- number of households with sewers connected to the storm sewer system also discharging raw sewerage in the Tietê River and its tributaries.

2.4.2. Surface Runoff

A second source of contamination comes from material washed by rainfall from the streets and land into the storm sewer system or directly into the streams and rivers. Much of this contamination comes from households that are not connected to the sanitary sewer system. Contamination also comes from solid wastes that have been thrown in streets, gullies, or streams and from organic matter (such as fallen leaves) that is washed to the storm sewers or local streams.

The households not connected to the sewer system have a separate and important problem of contamination of the local environment. These conditions lead to localized health problems.

2.4.3. Industrial Contamination

During the first stage of the Tietê project (see below) completed in 1998 the Companhia de Tecnologia de Saneamento Ambiental (CETESB) focused on controlling the discharges of the 1,250 most important polluters. It succeeded in reducing the organic discharges of industry by 59% and the inorganic discharges by 74%. Many of these industries now pre-treat their effluents before they are discharged to the Tietê, but these pre-treated effluents still go into the river system. In addition, there are an additional 3,486 industries with significant pollution potential that are discharging untreated wastes into the river. Thus, each day roughly 150 tons of biochemical oxygen demand (BOD) and 1.5 tons of inorganic load per day are still being discharged by industry into the Tietê.

2.5. Description of the Project Program

The program for cleaning up the Tietê River involved extension of sewers to currently unsewered households (and businesses) and the provision of wastewater treatment plants at the discharge ends of those sewers. The major objective is the removal of oxygen-demanding organic materials (measured as BOD) and safe disposal of sewage sludge.

The problem of contamination of the Tietê is enormous. The solution is expensive and will take many years to achieve. Given this, the State divided the project in three stages, taking the technical and financial resources into consideration although financial issues were the main factors. The preference, of course, would be to avoid the staging of the project, at least from the perspective of economic analysis. The investment program should have been analyzed as a whole, taking a strategic and tactical approach. The stages are not independent; all are needed to attain any benefits.

Stage I (1993-1998)

The main objectives of the first stage, were to: (i) enhance the quality of life for the population of the SPMA; (ii) improve health and environmental conditions in the area; (iii) reduce the pollution of the Tietê River and its main tributaries; (iv) study the use of the water resources and formulate subsequent stages of the project; (v) strengthen the legal and institutional structure of the state of São Paulo for control of industrial waste; and (vi) train technical and administrative staff to operate and maintain the wastewater treatment plants.

In addition to the wastewater treatment plants of direct concern here, the project also provided for sewer construction. The treatment component involved the construction of two new wastewater treatment plants and the expansion of an existing plant; increasing the proportion of wastewater treated from 19% in 1992 to 45% by 1998. Specifically, the works were:

1. São Miguel Plant: construction of the first module using the activated sludge treatment process with digestion by anaerobic bacteria. This plant will treat 40% of the flow from industries located in the area and serve a population of approximately 720,000.
2. Parque Novo Mundo Plant: construction of an initial module using activated sludge treatment. The sludge produced will be chemically stabilized and primary sedimentation omitted. The plant will serve a population of 1.2 million and it will treat 14% of the flow from industries located in the area.
3. Barueri Plant: expansion of the number of secondary sedimentation units. The plant will serve an additional 1.2 million persons and 14% of the total flow will be from industries located in the area.

Stage I of the project removes about 25% of organic material of domestic and industrial origin discharged into the Tietê River, and similar amounts of other pollutants such as inorganic material, toxic compounds, and fecal coliforms. BOD5 concentrations in the most critical (worst) reach should fall from a "without project" level of 86 mg/l to 40 mg/l. However, despite the BOD reductions, dissolved oxygen (DO) recovery is limited, since absolute BOD levels are still too high (well over the 5 mg/l of BOD defining a "clean" river). Increases in DO between 0.5 to 1.0 mg/l would only occur just before and after the long anaerobic stretch, which Stage I shrink from 100 km to 75 km. Odor reduction is the major beneficial water quality effect of Stage I, but it still leaves DO at levels that are too low to support aquatic life.

Cost-Benefit (CB) analysis was only undertaken for the sewer connection component (including costs for sewers but not treatment plants), presumably because the benefits of Stage I alone were negligible. To choose the treatment plant capacities, locations and construction timing, a Regional Least-Cost Mixed Integer Programming model was used to minimize the sum of treatment plant investment, operation and maintenance costs, allowing construction to begin in either of two time periods subject to plant flow capacity constraints.

Stages II & III (1999-2008)

The main objectives of these subsequent stages were to continue supporting the State of São Paulo in its efforts to improve the ambient environmental quality of the Tietê Basin and use the State's water resources efficiently. The water-quality improvement component included additional collection of wastewater and extension of sewers to unsewered households and businesses, along with some treatment plant capacity expansion. Works were prioritized based on the results of a water quality model developed in Stage I. Interceptors would be built along the margins of the Rio Pinheiros. The improvement in water quality is expected to increase the use of water for hydroelectric generation at the Henry Borden power plant.

Cost Effectiveness Analysis

To select the collection networks that most effectively reduced contamination, SABESP ranked 91 networks by the ratio of investment and operating costs to load collected. The ratios ranged from R$0.12 to R$7.34 per cubic meter per year. Sixty-nine of these systems had ratios under R$1.00. Twenty-six of the 69 (29%) belong to Guarulhos and Osasco and have not been included in the second stage project investments. Twelve of these account for a significant amount of waste. This is a potential problem since Guarulhos and Osasco are not included in this project.

SABESP also analyzed 89 collection systems not connected to interceptors and ranked them by the ratio of investment and operating cost to organic load diverted. The ratios ranged from R$0.08 to R$19.83 per cubic meter per year. Fifty-six of these have ratios less than R$ 1.00 and eighteen of these are in Guarulhos and Osasco, and have been left for the third stage. Again, this is a potential problem for achieving the improvement of water quality. SABESP analyzed the impact of these works and the proposed treatment plants using a water quality simulation model.

2.6 Modeling the Impact of Contamination and Its Reduction on Water Quality

To simulate the impact of various discharges on water quality in the Tietê Basin, SABESP adapted the QUAL2E Stream Water Quality Model provided by the US Environmental Protection Agency. The model is deterministic and relatively simple. Hydrological variations are determined outside the quality model and the quality is calculated on the basis of a particular river flow and the contaminant loads that enter. The model separately accounts for contaminant loads coming in above the SPMA, point discharges of industrial and sewerage outfalls, contaminant loads from tributaries, non-point discharges from surface runoff, and river reflows from underground lenses.

The model considers the principal mechanisms of transport, advection and dispersion in the direction of the flow of the river (but not horizontally across the river). It accommodates 15 water quality indicators, the most important of which--from the point of view of the economic analysis--is dissolved oxygen. The basic technical relations that determine the level of dissolved oxygen are: atmospheric reaeration (which is calculated as a function of the velocity and depth of the river), plant evapo-transpiration, benthonic and biochemical nitrification, and temperature.

The model divides the rivers into sections. Each section is characterized in hydrological terms by volume of flow entering the section, entering or departing lateral flows, and flows exiting the section. The amount of any particular quality characteristic being traced can be described in terms of advective or dispersive transport and can be increased or decreased along subsections by external inflows or biochemical processes.

For quality calculations, SABESP uses the average flow and the "minimum" flow. SABESP has 60 years of data on daily hydrological flows[10]. The "average flow" is the mathematical average of daily flows throughout the year. The actual flow is less than the average flow 60% of the time. SABESP defines "minimum flow" as a flow that will be exceeded 90% of the time or, in more intuitive terms, the river flow will exceed this volume 329 days a year and have a flow of smaller volume 36 days a year.

Table 2.4 shows the quality of water at "minimum flow" on various segments of the river system at the end of each of the "stages". Water quality will be better than the level shown 90% of the time (329 days of the year). The results indicate that, by the end of the second stage in 2003, dissolved oxygen would exceed the critical level of 0.5 mg/l from the confluence of the Pinheiros downstream (with the exception of the confluence itself, which does not quite reach 0.5 mg/l if the project is operated for hydroelectric generation). By the completion of the third stage in 2010, there will be significant levels of dissolved oxygen in all segments of the Tietê and Pinheiros whether the sys-

10 This data was collected on natural river flows between 1900 and 1960. After 1960, the river was regulated and the data series discontinued.

tem is operated exclusively for carrying wastes or for combined waste disposal and generation of electricity[11].

Table 2.4. Quality of Water in the Tietê Basin at Minimum Flow after the Conclusion of Each of the Project Stages

	Operation to Carry Away Wastes			Operation to Carry Away Wastes and Generate Electricity		
Point at Which Quality is Measured	Dissolved Oxygen mg/l	Biological Oxygen Demand mg/l	Fecal Coliforms no/100 ml	Dissolved Oxygen Mg/l	Biological Oxygen Demand mg/l	Fecal Coliforms no/100 ml
Tietê confluence Tamanduatei						
1998	0.00	33.49	850,200	0.00	33.49	850,200
2003	0.00	23.19	547,800	0.00	23.19	547,800
2010	1.46	13.64	233,300	1.46	13.64	233,300
Tietê confluence Pinheiros						
1998	0.00	15.22	150,200	0.00	28.89	777,700
2003	1.33	3.73	20,400	0.43	22.27	563,600
2010	1.14	3.70	22,000	1.98	12.55	246,900
Pinheiros Pumping Station						
1998	0.00	18.47	156,500	0.00	32.22	587,300
2003	1.99	7.21	10,500	0.55	16.66	292,800
2010	2.07	7.20	10,900	2.18	11.62	148,500
Edgar Souza						
1998	0.29	29.16	664,000	0.98	31.95	651,200
2003	1.34	22.88	505,400	2.95	26.10	460,500
2010	2.48	12.65	216,000	4.01	13.09	174,900
Pirapora						
1998	2.24	20.60	8,400	4.35	14.27	2,200
2003	2.60	17.59	10,200	4.50	13.41	2,400
2010	3.03	10.97	3,700	4.27	8.35	800

The Ponte Nova and Edgard de Souza Dams can control the flow of water in the Tietê River system. This effects volume and velocity and therefore quality. If the river is operated exclusively for carrying wastes away from the SPMA, all rivers run in their natural direction. If, however, water is to be diverted to Billings Reservoir, the gates at the Edgard de Souza Dam are partially closed to raise the level of water and cause the Pinheiros River to flow in the reverse direction. SABESP modeled two different operating regimes that are relevant

11 The results of the table stem from the hydrological analysis and are taken as given. However, we acknowledge the existence of uncertainty around each one of the estimates. Unfortunately, this uncertaintly was not derived from the hydrological model.

to the economic analysis: (1) operation exclusively to carry away wastes and (2) a joint operation in which 60% of the water goes to Billings and 40% continues downstream for other uses[12].

2.7. Concluding Remarks

Brazil's water endowment represents approximately 12% of the world's total. However, it has very unequal distribution of the water resources with the Amazon basin taking 80% of the water available and other basins, such as São Francisco River, a semi arid area, has only 4% of the available resource but 35% of the population. The rapid rates of urbanization and unsustainable growth are impacting water quality and quantity. Quantity is highly affected by decreasing quality and this is a constant problem faced by the country in large metropolitan areas such as São Paulo, the largest city in South America. The city is crossed by the River Tietê, the most polluted river in the country. The solution to clean up the River will require decades and substantial amount of financial resources. Public outcry against the problems caused by the poor ambient water quality of the river reached a climax in 1980. Finally, in September of 1991, the Government launched the Tietê program with the objective to clean up the rivers and reservoirs of the São Paulo area. The program's implementation begun in the mid 90s and the works continue. This case clearly illustrates the difficulties and the financial burden to improve ambient water quality after decades of neglect.

12 This 60-40 division of water is an arbitrary suggestion of Hidroplan, a consulting firm that developed the master plan for State water use. This division of water does not imply optimal operation and appears to reflect a judgement of what might be politically feasible. Before the Constitutional restriction, water volumes were divided 50-50 between the Tietê and Billings.

PART II

Methodological Framework