Fachhochschule Köln
Cologne University of Applied Sciences

UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

FACULTADES DE CIENCIAS QUÍMICAS,
INGENIERÍA Y MEDICINA

PROGRAMA MULTIDISCIPLINARIO DE POSGRADO
EN CIENCIAS AMBIENTALES

AND

COLOGNE UNIVERSITY OF APPLIED SCIENCES
FACHHOCHSCHULE KÖLN

INSTITUTE FOR TECHNOLOGY AND RESOURCES
MANAGEMENT IN THE TROPICS AND SUBTROPICS

Water Quality Monitoring System approach to support Guapi-Macacu River Basin Management, Rio de Janeiro, Brazil.

TO OBTAIN THE DEGREE OF
MAESTRÍA EN CIENCIAS AMBIENTALES
DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
AND

MASTER OF SCIENCE
"TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS
FOCUS AREA "ENVIRONMENTAL AND RESOURCES MANAGEMENT"
DEGREE AWARDED BY COLOGNE UNIVERSITY OF APPLIED SCIENCES

PRESENTS:

Josué Hiram Aké Hernández

CO-DIRECTOR OF THESIS - PMPCA
Dra. M. Catalina Alfaro de la Torre
CO-DIRECTOR OF THESIS - ITT:
Dr. Prof. Lars Ribbe
ADVISOR - EMBRAPA Solos:
Dra. Rachel Bardy Prado

SAN LUIS POTOSÍ, MÉXICO **AUGUST 2010**

PROYECTO FINANCIADO POR:

JOINT RESEARCH AND DEVELOPMENT PROJECT (JRDP) BR/MP2-GER/BMBF
CLIMATE CHANGE, LANDSCAPE DYNAMICS, LAND USE AND NATURAL RESOURCES IN THE ATLANTIC FOREST OF RIO DE JANEIRO (DINARIO) PROJECT

PROYECTO REALIZADO EN:

INSTITUTE FOR TECHNOLOGY AND RESOURCE MANAGEMENT IN THE TROPICS AND SUBTROPICS (ITT) IN COOPERATION WITH EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA) SOLOS RJ, BRAZIL

CON EL APOYO DE:
DEUTSCHER AKADEMISCHER AUSTAUSCH DIENST (DAAD)
CONSEJO NACIONAL DE CIENCIA Y TECNOLOGÍA (CONACYT)

LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL PROGRAMA NACIONAL DE POSGRADOS (PNP - CONACYT)

Erklärung / *Declaración*

Name / *Nombre*: Josuè Hiram Akè H.

Matri.-Nr. / *N° de matricula*: 11069547 (CUAS), 08 - 0169626 (UASLP)

Ich versichere wahrheitsgemäß, dass ich die vorliegende Masterarbeit selbstständig verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Schriften entnommen sind, sind als solche kenntlich gemacht.

Aseguro que yo redacté la presente tesis de maestría independientemente y no use referencias ni medios auxiliares a parte de los indicados. Todas las partes, que están referidas a escritos o a textos publicados o no publicados son reconocidas como tales.

Die Arbeit ist in gleicher oder ähnlicher Form noch nicht als Prüfungsarbeit eingereicht worden.

Hasta la fecha, un trabajo como éste o similar no ha sido entregado como trabajo de tesis.

San Luis Potosí, den /*el* ________________

Unterschrift / *Firma*: ______________

Ich erkläre mich mit einer späteren Veröffentlichung meiner Masterarbeit sowohl auszugsweise, als auch Gesamtwerk in der Institutsreihe oder zu Darstellungszwecken im Rahmen der Öffentlichkeitsarbeit des Institutes einverstanden.

Estoy de acuerdo con una publicación posterior de mi tesis de maestría en forma completa o parcial por las instituciones con la intención de exponerlos en el contexto del trabajo investigatición de las mismas.

Unterschrift / *Firma*: __________________

Dedicated to Jaden and Vivian

I like would to express my sincere gratitude and love to my family, for their unconditional support and love. Especially to my parents, the strength and courage of my dear mother, Barbara; and the patience and respect of my father, Jaime Sr. To my sister and brother, Cristina and Jaime Jr., for always being there for me and helping me in any way possible. I Love you ALL.

Acknowledgement

I would like to express my gratitude to professors, Dra. Ma. Catalina Alfaro de la Torre, from the Facultad de Ciencias Químicas, UASLP, México and Dr. Lars Ribbe, from ITT, Fachhoschule Köln, Germany for being an integral part of my thesis committee; I express my appreciation for their guidance and constant support on completing the requirements for the ENREM International Master's degree.

My heartfelt gratitude to Dr. Rachel Bardy Prado, researcher in Geotechnologies and Environmental Monitoring at the Brazilian Agricultural Research Corporation in Soils (EMBRAPA Solos), Rio de Janeiro, Brazil for her technical assistance and guidance during the fieldwork phase and revision of the final thesis document. I also extend a warm thanks to Santiago Penedo, Ph.D Student, for his guidance and revision of the final thesis document.

I also extend my appreciation and gratitude to the Staff of the State Institute of Environment (Instituto Estadual do Meio Amiente) in Rio de Janeiro, Brazil; especially to Fátima Soares and André Leoni for their time and the provision of information during the field work phase of this endeavor in Rio de Janeiro. Thanks to Mr. Antoni Alberto da Motta Menezes, of the Municipal Authority Water and Sewage of Cachoeiras de Macacu, for contributing information during the fieldwork phase of this undertaking.

To the CONACYT and DAAD I extend my appreciation for their financial assistance which allowed me to further my academic education. Thanks to the DINARIO Project, for the technical and logistic assistance during fieldwork. Furthermore, to the staff and faculty of the PMPCA and ITT, who in some way assisted and endure the completion of the first ENREM Program, especially to Gaby and Simone.

I also extend my thanks to my ENREM 2008 colleagues for making this educational venture a once-in-a-life-time experience: Ana Julia, Jonathan, Mara, Libi, Ivan, Anita, Toa, Enma, Irene, Anja, Leslie, Jan, Nyzar, Caro, Isaac, Christine, Christian and Swen.

Lastly, to my friends: Lugie, Eden, Julie, Rolando, Aisha, Ariany, Shareen and Nelson.

Abstract

Scarcity of surface water and groundwater has initiated actions in water quality management to prevent and reduce the negative impacts on water sources for human consumption and ecological performance. Decentralized Water policy establishes the framework to have maximum use with a proper management of the resource with public participation at the river basin. Water quality monitoring is an essential component of water resource management, providing water quality and quantity information to organizations for decision making. In 1997, Brazil approved such water policy, National Water Resource Policy (NWRP), consisting with guided actions and instruments to establish integrated water resource management with federal, state and local support.

In 2001, the National Water Agency (ANA) was established to implement the water policy and prevent river water pollution. In transitional and developing countries, this type of water policy is modern and ambitious, consisting of limiting factors that hinders with providing water quality data at the river basin, hence providing limited information for decision making. For further enhancement on water monitoring, the availability and collection of adequate water quality information is needed.

The Guapi-Macacu River Basin (GMRB), located in north-eastern region of Guanabara Bay Basin in the federal state of Rio de Janeiro, consist of protected areas, good water quality and quantity in the upper reaches of the basin and in the head waters of Guapiaçu and Macacu rivers. The general objective of the master´s thesis was to analyse the current water quality monitoring system to contribute for the Guapi-Macacu river basin management plan. The methodology used was a combination of two conceptual approaches: Driving Force-Pressure-State-Impact-Response (DPSIR) Framework and Strategic Environmental Analysis (SEAN).

ANA maintains a national hydro-meteorological network for water quantity and quality coordinated with state water monitoring agencies and provides the collected information to water management departments via various websites links to the database. In Rio de Janeiro, the State Institute of Environment (INEA), does water quality monitoring within its environmental monitoring system to supervise the commitment of industries to prevent environmental pollution in the river basins. The Guanabara Bay Basin Committee (GBBC) is the public participatory body in the management, coordinating and planning of water resources with governmental bodies under the State Secretary of Environment.

It was observed that at the river basin, three entities conduct water quality monitoring, INEA, CEDAE (State Water and Sewage Company) and AMAE (Municipal Water and Sewage Authority), with the variation of parameters, frequencies and sampling sites mostly based on three national Norms, Resolutions CONAMA # 247/2000, CONAMA # 357/2005 and Ordinance #518/2004.

Recently, GMRB, with land use changes, mainly to farming activities, along with increase number of industrial establishments and untreated domestic sewage production, the current sampling sites of both monitoring entities are irrelevant in collecting representative water quality data to comply with control of environmental pollution. Based on the results of this research, recommendations were given for the newly established management plan of the environmental protected area of the basin of Macacu river in GMRB.

Key words: *water quality management, DPSIR framework, Strategic Environmental Analysis (SEAN), river basin.*

Resumen

La escasez de agua superficial y subterránea ha propiciado acciones en la gestión de la calidad del agua para prevenir y reducir los impactos negativos sobre las fuentes de agua para consumo humano y rendimiento ecológico. La política descentralizada del agua establece un esquema para el uso máximo y la gestión adecuada de los recursos junto con la participación pública en la cuenca. El monitoreo de calidad de agua es un componente importante en la gestión de los recursos hídricos, proporcionando información sobre la calidad y cantidad de agua a las organizaciones que realizan la toma de decisiones. En 1997, Brasil aprobó una política del agua, la Política Nacional de Recursos Hídricos (NWRP), que consiste en acciones e instrumentos para establecer una gestión integrada de los recursos hídricos con el apoyo federal, estatal y local.

En 2001, se creó la Agencia Nacional de Agua (ANA) para implementar la política del agua y prevenir la contaminación de los ríos. En los países considerados en transición y en desarrollo, este tipo de política del agua es moderna y ambiciosa, que contiene factores limitantes que dificultan la comunicación de datos de calidad del agua en la cuenca, por lo que se limita la información disponible para tomar decisiones. Para continuar con la mejora del monitoreo de agua, son necesarias la obtención y la disponibilidad de información adecuada de calidad del agua.

La Cuenca Guapi-Macacu (GMRB), ubicada en la región noreste de la Cuenca de Bahía de Guanabara en el Estado Federal de Río de Janeiro, está formada por áreas protegidas, así como por agua en óptimas cantidades y calidad en la parte alta de la cuenca y en la cabecera el río Guapiaçu y Macacu. El objetivo general de la tesis de maestría fue analizar el sistema vigente de calidad de agua para contribuir al plan de gestión de la cuenca Guapi-Macacu. La metodología utilizada fue una combinación de dos enfoques conceptuales: el Marco Driving Force-Pressure-State-Impact-Response (DPSIR) y el Análisis Estratégico Ambiental (AEA).

ANA mantiene una red nacional hidro-meteorológica sobre la cantidad y calidad de agua, en coordinación con organismos estatales de monitoreo de agua y proporciona la información recogida a los departamentos de gestión de agua a través de enlaces a diversas páginas web desde la base de datos. En Río de Janeiro, el Instituto Estatal de Medio Ambiente (INEA) hace el monitoreo de agua dentro del sistema de monitoreo ambiental para supervisar el compromiso de las industrias para prevenir la contaminación ambiental en las cuencas. El Comité de Cuenca de Bahía de Guanabara (GBBC), es el organismo de participación pública para el manejo, coordinación y planeación del recurso agua junto con organismos gubernamentales bajo la Secretaría Estatal del Ambiente.

Se observó que en la cuenca Guapi-Macacu, tres entidades llevan a cabo monitoreo de calidad de agua, el INEA, CEDAE (Compañía Estatal de Agua y Alcantarillado) y AMAE (Autoridad Municipal de Agua y Alcantarillado) con la variación de parámetros, frecuencias y sitios de muestreo basado en tres normas nacionales, Resoluciones CONAMA # 247/2000, CONAMA #357/2005 y Ordenanza # 518/2004

Debido a cambios en el uso de suelo, principalmente por actividades agropecuarias, y con el incremento del número de establecimientos industriales y producción de aguas residuales domésticas sin tratamiento, recientemente los sitios de muestreo de la cuenca de Guapi-Macacu de las dos entidades de monitoreo, resultan irrelevantes en la colección de datos representativos de calidad de agua que cumplan con el control de la contaminación ambiental. Basado en los resultados de esta investigación, se dieron recomendaciones para el de gestión del área protegida de la cuenca del rio Macacu en GMRB.

Palabras claves: *Gestión de Calidad de Agua, Marco DPSIR, Análisis Estratégico Ambiental (AEA), cuenca*

Zusammenfassung

Die Knappheit von Oberflächen- und Grundwasser hat Maßnahmen zum Wasserqualitätsmanagement in Gang gebracht, um negative Auswirkungen auf Wasserquellen für den menschlichen Gebrauch und ökologische Dienstleistungen zu vermeiden bzw. zu reduzieren. Die dezentrale Wasserwirtschaftspolitik bereitet den Rahmen für eine optimale Nutzung und ordnungsgemäße Bewirtschaftung der Wasseressourcen unter Beteiligung der Bürger auf Einzugsgebietsebene. Wasserqualitätsmonitoring ist ein wesentlicher Bestandteil der Bewirtschaftung der Wasserressourcen, in Form einer Bereitstellung von Informationen zu Wasserqualität und -quantität für die Entscheidungsträger. Im Jahr 1997 genehmigte Brasilien eine solche Wasserpolitik, die „National Water Resource Policy", bestehend aus geführten Maßnahmen und Instrumenten, um eine integrierte Bewirtschaftung der Wasserressourcen mit Bundes-, Landes- und lokaler Unterstützung zu etablieren. Im Jahr 2001 wurde die Nationale Wasserbehörde (National Water Agency - ANA) gegründet, um die politischen Vorgaben umzusetzen und die Verschmutzung von Flüssen zu verhindern. In Schwellen-und Entwicklungsländern ist diese Art der Wasserpolitik modern und ambitioniert, bestehend aus limitierenden Faktoren, die mit der Bereitstellung von Daten über die Wasserqualität im Einzugsgebiet, also die begrenzte Informationen zur Entscheidungsfindung behindert. Für die weitere Verbesserung des Wassermonitorings sind die Verfügbarkeit und Sammlung adäquater Informationen zur Wasserqualität Voraussetzung.

Die Guapi-Macacu Flussbecken, in nordöstlichen Region der Guanabara Bay becken des Bundesstaat Rio de Janeiro gelegen, besteht aus Schutzgebiete, gute Wasserqualität und-quantität im Oberlauf des Beckens und in den Gewässern des Kopfes Guapiaçu und Macacu Fussen. Das Einzugsgebiet verfügt über gute Wasserqualität und -quantität im oberen Teil des Einzugsgebietes und in den Oberläufen des Guapiaçu- sowie des Macacu-Flusses. Das Hauptziel der Masterarbeit war es, das Wasserqualitäts-Monitoring-System zu analysieren, um einen Beitrag für den Entwurf des Guapi-Macacu Bewirtschaftungsplans zu leisten. Die verwendete Methodik war eine Kombination von zwei Konzepten: Driving Force-Pressure-State-Impact-Response (DPSIR) Framework und Strategic Environmental Analysis (SEAN).

Die ANA unterhält ein nationales hydro-meteorologisches Netzwerk für Wasserqualität und-quantität, koordiniert mit staatlichen Wassermonitoring-Institutionen, und stellt die gesammelten Informationen diversen Wasserwirtschaftabteilungen über verschiedene Weblinks zu ihrer Datenbank bereit. In Rio de Janeiro ist die Landesanstalt für Umweltschutz (INEA) für die Überwachung des Wassers in den Einzugsgebieten des Staates verantwortlich.

Die Guanabara Bay Basin Committee (GBBC) ist die öffentliche Stelle in der partizipative Management, Koordinierung und Planung der Wasserressourcen mit staatlichen Stellen unter der Staatssekretär des Umweltministeriums. Es wurde beobachtet, dass im Einzugsgebiet drei Behörden das Wasserqualitätsmonitoring durchführen: INEA, CEDEA (Bundestaatliche Wasserbehörde) und AMAE (municipality Bundestaatliche Wasserbehörde). Die Variation von Parametern, Frequenzen und Messtellen basiert dabei meist auf drei nationalen Normen Resolution CONAMA # 247/2000, CONAMA # 375/2005 und Portaria # 518. ,

Kürzlich GMRB, mit Änderungen der Landnutzung, vor allem mit landwirtschaftlichen Tätigkeiten, zusammen mit Erhöhung der Anzahl der gewerblichen Betriebe und häusliche Abwässer unbehandelt Produktion, sind die aktuellen Messstellen, Überwachung der beiden Organisationen bei der Erhebung repräsentativer Daten über die Wasserqualität zu erfüllen irrelevant Kontrolle der Umweltverschmutzung. Basierend auf den Ergebnisse werden Empfehlungen für die neu gegründete Management-Plan des Environmental Schutzgebiete des Basins von Macacu River in der GMRB gegeben.

Schlüsselwörter: *Wasser Qualitätsmanagement, DPSIR Rahmen, Strategic Environmental Analysis (Sean), Einzugsgebiete.*

Table of Content

List of Figures

List of Table

Chapter One

Introduction

Recently, the “Water Crisis” has caused many initiatives of water quality management to reduce and prevent the negative impacts of anthropogenic activities and climatic changes on the water sources for human consumption and maintain the *status quo* of water bodies (UNEP, 2003; UN Water, 2006; IPCC, 2007). Therefore, water quality monitoring has taken the ‘spotlight’ of Environmental Management at national and local levels, that is, River Basins in different scales; with the integration of research and advanced technology (Ribbe, 2008; Ward et al., 2003).

Decentralized water policy is a policy that has the maximum use with a proper management of the resource with public participation at the local level, at a river basin. (Iza, 2009) Latin American countries, like Brazil and Mexico are leading in implementing the decentralized water policies. River Basin Committees are the management body composed of government officials and water users as representatives of a determined number of water bodies, rivers and sub basins.

The brazilian Atlantic Forest (Mata Atlântica) classified as a biodiversity hotspot, located between the coordinates 3°S to 31°S and 35°W to 60°W, along the brazilian coast, having a vegetation cover of 148,194,638 ha. The remaining vegetation cover ranges from 11% to 16%, existing in small fragments (less than 100 ha each) that are isolated from each other. Amongst the largest fragments, the Serra do Mar is the largest fragment (Costa, 2006; Ribeiro et al., 2009).

Rio de Janeiro State, with the second largest city in Brazil and the third largest metropolitan area, is a federal state with rich diversity of natural resources, sharing the Atlantic Forest and water abundance. However, urbanization and deforestation have relatively damaged the Guanabara Bay’s water quality due to an increase of production of domestic and industrial sewage (Ribeiro et al., 2002). Therefore, adequate water quality management is necessary for water resources management in a river basin, specifically having a sound water quality monitoring system to indicate the status of the water bodies.

The Guapi-Macacu river basin (GMRB) is located on the eastern region of the Guanabara Bay Basin, contributing to the supply of water to nearly 2.5 million inhabitants living in six municipalities (Itaboraí, Cachoeiras de Macacu, Niterói, São Gonçalo, Tanguá and Rio Bonito) in the Federal State of Rio de Janeiro. This water is also used for agricultural irrigation and fish farming (Costa, 2008; Pedreira et al., 2009)

Recently, the construction of the Rio de Janeiro’s Petrochemical Complex (COMPERJ) in the municipality of Itaboraí, south of the Guapi-Macacu river basin; is the largest petrochemical industrial undertaken in the history of Brazil and with a total investment of around US$ 8.5 billion (Torrico, 2008). The complex will need a large amount of water supply and manpower, this will possibly cause impacts to land use dynamics and to the Guapi-Macacu river basin management.

Therefore, the Guapi-Macacu river basin needs a good water quality monitoring system to provide adequate information to the decision making to maintain good water quantity and quality. In Rio de Janeiro, efforts are being met to implement water quality monitoring systems and measures as stated by national and state laws through river basin management plan. As a contribution to the efforts, this thesis work will analyze the current water quality monitoring systems in the GMRB.

This thesis was supported and related to the DINARIO (Climate change, landscape dynamics, land use and natural resources in the Atlantic Forest of Rio de Janeiro) Project, it’s a Brazilian-German cooperation program, launched by the Brazilian Agricultural Research Corporation (EMBRAPA, Brazil) and the German Federal Ministry of Education and Research (BMBF, Germany) that started in 2010. The main implementing German institutions are the Institute for Technology and Resources Management in the Tropics and Subtropics (ITT) from the Cologne University of Applied Sciences and the Leipzig University. The project addresses the objectives of methodological advancement and applicability of results in decision-making at the interface of environmental management and economic progress in the Brazilian Atlantic Forest region[1].

[1] Source: http://dinario.fh-koeln.de/

Chapter Two

Objectives

2.1 GENERAL OBJECTIVE

To analyse the water quality monitoring system to contribute to the Guapi-Macacu river basin management plan.

2.2 Specific objectives

2.2.1 To understand the current implementation of the water monitoring framework in this river basin.

2.2.2 To identify the major causes and impacts that at the short and long term has defined the water monitoring activities in the state.

2.2.3 To identify the effectiveness of the water monitoring activities in this basin.

Chapter Three

Background

Since the ancient civilizations, three main focuses of water governance policies have remained constant through time; 1) controlling water contamination, 2) water policies must abide with other social and economic policies and 3) establishing institutional mechanisms (Nanni, 2007; Iza, 2009). Country´s water governance is directly related to its national political system. Nowadays, most transitional and developing countries have decentralized-communitarian water policies, containing the three main focuses mentioned before (Global Water Partnership, 2007).

3.1 INTEGRATED WATER RESOURCE MANAGEMENT

3.1.1 General approach

Nowadays, there is no universally agreed definition of Integrated Water Resource Management (IWRM) amongst the environmental and economical organizations (Davis, 2007). However, most countries are slowly complying with the fundamentals of IWRM at watershed or River Basin level.

According to the Global Water Partnership Report (2009), the road to follow is the direct signing and implementation of the IWRM Plans at the river basin level to improve the institutional and legal framework for sustainable water management (Global Water Partnership and International Network of Basin Organizations, 2009). For developing countries and transitional countries, it remains a great challenge.

3.1.2 Brazilian approach

Brazil has approved the national policy and implemented the institutions for integrated water resource management in a river basin level. The Brazilian National Water Resource Policy (Law # 9.433/97, NWRP) also known as the “National Water Law”, inspired by the French Water Policy, was approved and implemented in 1998. Issues like integrated water resources management, river basins as management units, provisions for public participation and provisions for water pricing were similar as in already existing state water laws (Porto et al., 1999), and hence this national water law commits in every federal state the sustainable use of water resources.

Various federal states, for example, São Paulo (1991), Ceará (1992), and Santa Catarina (1993); Minas Gerais and Rio Grande do Sul (1994); Bahia (1995), Paraíba and Rio Grande do Norte (1996); and Pernambuco and Sergipe (1997) had already implemented water laws for water resources management before the approval of the National Water Law (1998) (Tortajada, 2002; Porto, 2008).

3.1.2.1 Brazilian National Water Resources Policy

The third article of the National Water Law consists of six (6) actions as guidelines (see Annex A) for implementing the policy and establishing the National System of Water Resource Management. These guidelines are: 1. Estuaries and coastal management system, 2. Association from the aspects of quantity and quality, 3. Environmental Management, 4. Description of the physical, biotic, demographical, economical, social and cultural diversity among the different regions, 5. Plans (national, state, and regional) and 6. Land use management. Porto (2008) encourages the improvement of knowledge of water availability (water quality and quantity) and demand (multiple uses) in each hydrographic region, as part of the decision making system evaluation for institutional reform at the federal level for river basin management. Moreover, the author emphasizes a clear definition of the protection and use of groundwater in the legislation system (Porto, 2008).

In Brazil, to manage the sustainable use of the water resources, the Resolution CNRH # 32, of May 15, 2003, under the National Plan of Water Resources divided the territorial area into twelve (12) hydrographic regions (Figure 1). The Southeastern Atlantic Hydrographic Region is shared by Espirito Santo, Minas Gerais, São Paulo and Rio de Janeiro.

Southeastern Hydrogrphic Region

Figure 1: Hydrographic Regions in Brazil[2]

[2] Source: (Agência Nacional de Águas, 2005)

3.1.2.2 National water resource management system

The objectives of the management system as stated in the NWRP are: to be a system to support integrated water management, to solve conflicts about water resources at the administrative level; to plan, to regulate and to control the use, preservation and recovery of water resources; besides it encourage the charging of fees for the use of water resources[3]. Figure 2 presents the Brazilian institutional structure related to water resource management to help understand these objectives. The main parts of the structure were described in the sequence.

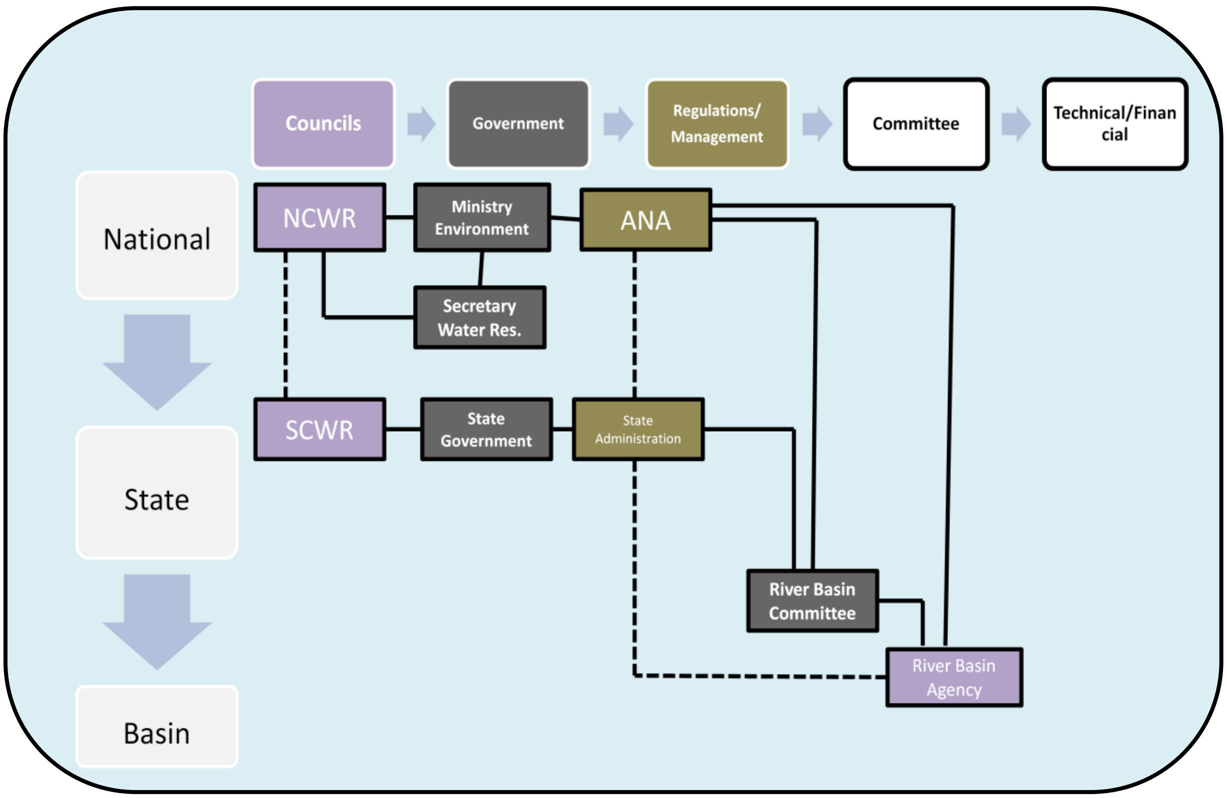


Figure 2: Institutional structure of national water resource management system in Brazil[4].

[3] Brazilian National Water Resource Policy (Política Nacional de Recursos Hídricos) Lei Nº 9.433, LEI Nº 9.433, DE 8 DE JANEIRO DE 1997
[4] (Agência Nacional de Águas, 2005)

a) **The National Water Resources Council[5] (NCWR)** – It is the highest authority and is responsible for the supervision and creation of rules to manage and plan the water resources at the national, regional and state levels. It is also responsible to approve the guidelines for the license for water use and withdrawals. It is also the final arbitration stage for inter-stage conflicts (Garrido, 2001). The Council consist of representatives of:

- Federal Government ministries and departments concerned with the management of water resources;
- Appointed representatives of the State Water Resources Councils;
- Water resources users; and
- Civil water resources organizations.

There is an exception to the overall management of the national water resources; federal government participation is always 50% plus one vote, which means that the Federal Government has a majority in decisions at the top of the system (Garrido, 2001). The chairman of this council is the Minister of the Environment, while the Executive Secretary is the head of the department housed within the Ministry of the Environment responsible of the management of the water resources. The council consist of twenty-nine[6] (29) representatives; fifteen (15) of the Federal Government, 5 nominated from the state council of water resources, 6 from water resource users and 3 from water resource organization.

b) **Water Resources Secretary** – It formulates the National Water Resource Policy and acts as the Executive Secretary of the National Council of Water Resources (ANA, 2004).

c) **National Water Agency (ANA)** [7] – it was created with the Law # 9,984, of July 17, 2000, had the mandate to implement the provision of the National Water

[5] Source: ANA. Website: http://www.ana.gov.br/ingles/waterPolicy.asp
[6] Source: (Agência Nacional de Água , 2002). Downloaded Document at: http://www.ana.gov.br/ingles/docs/24%20PG%20MADRID.pdf
[7] Brazilian National Water Resource Policy (Política Nacional de Recursos Hídricos) Lei Nº 9.433, LEI Nº 9.433, DE 8 DE JANEIRO DE 1997

Resource Policy and the National Plan; it includes the guideline of actions and instruments to the river basin level with the coordination of the national and state councils, to support the installation and operation of river basin committee and agencies and state systems for the management of water resources. At the same time, ANA is responsible for the National Water Resources Management System, established in the 1988 Federal Constitution, which regulates the water use for the development of Brazil, to guarantee good water quality and sufficient water quantities for current and future generations and allow multiple uses (ANA, 2004). ANA is the national autonomous (financially and administratively) executive branch from the Ministry of Environment. In providing technical support to implement the policy, ANA must contribute to solve two major national problems[8]:

- Prolonged drought, especially in the north-east region
- River pollution

ANA consists of a board of five (5) directors[9]; one director of the 5 is appointed president of the agency by the president of the country. Under the board of directors, there are ten administrative, technical and financial departments.

d) **State Water Resource Council (SCWR) –** it is the regulatory and deliberative agency for the State Water Resources Management System responsible for creating principles and guidelines for state water resource policy (ANA, Management Report, 2003, 2004).

e) **River Basin Committee –** it is in charge for the entire river basin, including sub-basin and micro-basin. As a political association, it is responsible for the following:

- Encourage debates about issues related to the use, recovery and preservation of water resources.
- Arbitrating conflicts as the first administrative level, related to water resources.
- Approval of the watershed plan and monitoring its implementation.

[8] Source: ANA. Website - http://www.ana.gov.br/ingles/theagency.asp
[9] Source: ANA. Website - http://www2.ana.gov.br/Paginas/institucional/SobreaAna/organograma_inst.aspx

- Establishing the fee-charging mechanisms for the use of water resources and suggest the amounts to be charged;
- Establishing criteria and undertaking the share-out of costs of works for multiple uses, in the community interest.

The river basin committee consists of representative of:

- The federal government;
- The states and the federal district whose territories are located partially within their respective areas of operation;
- The municipal districts;
- Water users;
- Civil water resources entities with proven activities within the basin.

The number of representatives of the executive authorities of federal government, state, federal district and municipal district is limited to one half of the total number of members[10]. The committee is headed by a chairman and a secretary, elected by the members.

f) **River Basin Agency –** Executive secretary of committees responsible for the update water balance of the available water resources, operation of water use collection (Garrido, 2001)

3.1.3 Guapi-Macacu river basin approach (Guanabara Bay basin plan)

As mentioned, the water resource management plan is an instrument used by the river basin committees to strategically and sustainably to use the resource at a long term.

[10] Source: ANA website - http://www.ana.gov.br/ingles/waterPolicy.asp

According to the direct plan done for the Guanabara Bay basin by Ecologus-Agrar Consórcio (2005), Guapi-Macacu river basin is located in north east of Guanabara Bay basin, therefore water resource management of that river basin is done in the Guanabara bay basin level.

The law # 3.539/99 established the state policy of water resources which is similar to the National Water Law in its principles, management tools, organizations, policy and institutional framework. Generally, the institutions responsible to implement the state policy are:

a) State Council of Water Resources: political body responsible for oversight, standardization and regulation of the state system of water resources management.
b) State Water Resources Fund (FUNDRHI): financial system to support water resource management.
c) Basin Committees (CBHs): political committee to decision-making regarding the use, protection and recovery of water, involving government, users and civil society;
d) Water Agencies: executive arm of the Basin Committees.
e) Bodies of government, federal, state and municipal governments, involved in the management of water resources.
f) Basin Agency: it is the base of the state management system being the promoter and executor of the Committee both in technical and management, having the role of secretary of the Executive Committee.

Actually, the basin agency is nonfunctional; hence the State Institute of Environment (INEA) has the responsibilities of the basin agency. INEA was established with the INEA Act (Law # 5.101/2007) in January 2009, under the State Secretary of Environment (SEA). It was established by merging three former state agencies: the State Superintendent of Rivers and Lakes (SERLA), responsible of water resource management; the State Foundation of Engineering and Environment (FEEMA), responsible of environmental control, permits, and environmental impact assessment; and the State Institute of

Forestry (IEF), responsible of biodiversity conservation, forest, wildlife and state parks. INEA is a decentralized watershed-based organization made up of engineers, biologist, scientists, technicians, policy analysts and other dedicated professionals[11].

3.2 WATER QUALITY MANAGEMENT

Water quality management consists of policy, technical, institutional and financial components that maintain or improve the approved objectives of quality with regulatory instruments (effluent regulations and national water quality guidelines) for water supply and prevents water pollution (Ongley, 2000). For a water quality management plan, Ongley (2000) strongly recommends a plan with a mechanism to identify national and local priority (goals and objectives) for water quality management that will guide domestic and donor investment, including donor support, partnerships and self-support initiatives; and a cost-effective data program for water quality related to the water uses. While in India, the Central Pollution Control Board has a guideline for water quality management plan with twelve steps (Central Pollution Control Board, 2008). According to Garrido (2002), in Brazil, after years of discussion on institutional reform for water quality management responsibility, the National Water Agency and the state water agencies have been responsible for this task.

3.2.1 In Brazilian water resource management

The importance of water quality to maintain or increase the water quality is well stated in the NWRP in its objectives “secure for the present and future generations the necessary water supply, in parameters of quality adequate for the respective uses” (Art.2, Cap. II, Tit. I, Law # 9.433/97) and the proper management with the integration of environmental management as stated in Article 3, Cap. III, Tit. I (Agência Nacional de Águas, 2005). There are six (6) management instruments (See Annex A) that are used to implement the national water policy within river basins. They are the following: 1. Water resources plan; 2. Classification of water bodies in classes, according to the prevailing water uses; 3. Rights

[11]Source: INEA Website: http://www.inea.rj.gov.br

of water resource use; 4. Water resources use charge; 5. Information system on water resources and 6. Compensation to municipalities.

The water resources plan and the classification of water bodies in classes, accordingly to the prevailing water uses are the main instruments to maintain or increase water quality in a river basin.

- Water resource plan contains the long term goals of water resource management, including a diagnosed of the current situation of water resources and use, measures to be taken into action for a sustainable use in the future (charges and water rights). It also includes targets and programs to maintain or increase the quality and quantity of the water of the river basin[12]
- The classification of water bodies in classes, accordingly to the prevailing water uses is a planning and management instrument that is linked to the other instruments in Water Resource Management (grants, charging plans, Basin Plans) and environmental management tools (licensing and monitoring). This instrument established the quality levels (classes) of the water bodies that should be reached or maintained at a long term. Table 1 shows the established classes (13) of freshwater quality as mentioned in the Resolution CONAMA # 357 of march 2005 (Costa et al., 2007)

[12] Source: the Brazilian National Water Resource Policy (Política Nacional de Recursos Hídricos) Lei Nº 9.433, LEI Nº 9.433, DE 8 DE JANEIRO DE 1997

Table 1: Classification of water bodies in classes[13].

Classes[1]		Uses
Freshwater	**Special**	Supply for human consumption, disinfected
		Preservation of the natural equilibrium of aquatic communities
		Preservation of aquatic environments in conservation units of integral protection
	1[1]	Supply for human consumption, after simplified treatment
		Protection of aquatic communities
		Primary contact recreation such as swimming, water skiing and diving, as stated in CONAMA No. 274, 2000.
		Irrigation of vegetables that are consumed raw and fruits that are full developed within the soil and are eaten raw without the peel removal.
		Protection of aquatic communities in indigenous lands.
	2[1]	Supply for human consumption, after conventional treatment
		Protection of aquatic communities
		Primary contact recreation such as swimming, water skiing and diving, as stated in CONAMA No. 274, 2000.
		Irrigation of vegetables, fruit trees and from parks, gardens, fields of sports and leisure, that the general public has direct contact.
		Aquiculture and fishing activities
	3[1]	Supply for human consumption, after conventional and advanced treatment
		Irrigation of tree crops, cereal and forage
		Secondary contact recreation
		Watering animals
		Recreational fishing
	4[1]	Navigational
		landscaping
Sea Water	**Special**	Preservation of aquatic environments in conservation units of integral protection
		Preservation of the natural equilibrium of aquatic communities
	1	Primary contact recreation, as stated in CONAMA No. 247, 2000
		Protection of aquatic communities
		Aquiculture and fishing activities
	2	Recreational fishing
		Secondary contact recreation
	3	Navigational
		Landscaping
Brackish Water	**Special**	Primary contact recreation, as stated in CONAMA No. 247, 2000
		Preservation of the natural equilibrium of aquatic communities
	1	Primary contact recreation, as stated in CONAMA No. 247, 2000
		Protection of aquatic communities
		Aquiculture and fishing activities
		Supply for human consumption, after conventional and advanced treatment
		Irrigation of vegetables that are consumed raw and fruits that are full developed within the soil and are eaten raw without the peel removal and
		Irrigation of parks, gardens, fields of sports and leisure, that the general public has direct contact.
	2	Recreational fishing
		Secondary contact recreation
	3	Navigational
		landscaping

1 – Water quality parameters with conditions and limits (standards) for freshwater classes in Annex B.

[13] Source: (Costa et al., 2007)

3.2.2 Water quality monitoring system

Water quality monitoring is the fundamental component in water quality management. Countless literature exists of water monitoring structural process. These three words are often used to describe the structure of the process: system, program and framework. In this thesis, 'system' will be use to indicate the structural process of water monitoring. Water monitoring system consists of activities, indicators, limits and agencies to achieve the main objective of a set goal. For example, to achieve good water quality for drinking to a community, indicators are chosen and measured to achieve and sustain a good water quality.

Therefore, water monitoring system consists of seven components: developing monitoring objectives (information needs), evaluation program (assessment strategies), design monitoring program (monitoring program), collect field and laboratory data (data collection), compliment and manage data (data handling), assessment and interpretation data (data analysis), and convey findings (reporting) (Figure 3) (Ward et al., 2003).

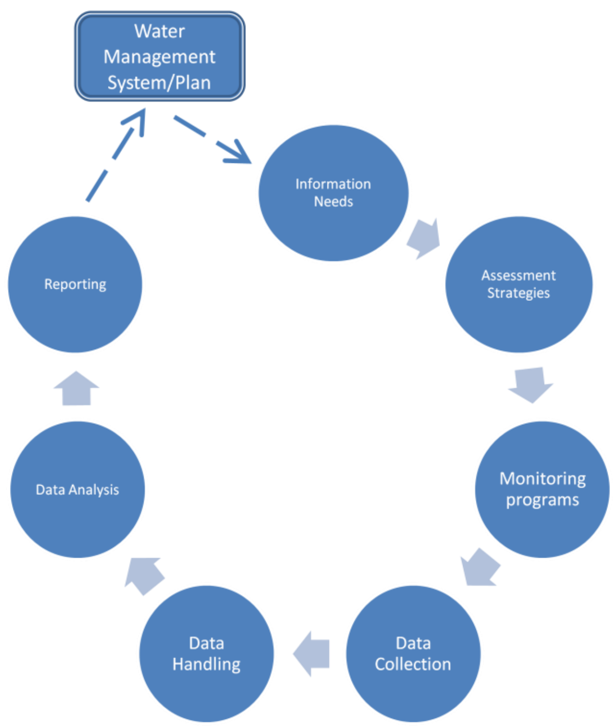


Figure 3: Water Quality Monitoring System in WQM[14].

[14] Source: (Ribbe, 2008)

There has been great progress in western nations in developing more cost-effective monitoring, analytical protocols, and assessment methods (Ongley, 2000). At the same time, Ongley (2000) agrees with the statement of Ward et al. (1986), that many water quality monitoring systems can be classified as *data rich but information poor*, referring to the fact that often large data sets of water quality are available but they were gathered without clearly defined objectives derived from actual water management issues. This leads to a large amount of "useless" data and most countries are still at the beginning of the process to harmonize data collection strategies with real information requirements (Ward et al., 1986). This thesis focuses mainly on the collecting water data and information needs component of the water quality monitoring system.

This thesis will focus on the water quality management in the water resource management at the Guapi-Macacu River Basin. A brief description will be done, focusing on the set goals, water quality monitoring system, instruments, actions and set objectives for water quality.

3.2.2.1 Definitions and Types

Monitoring is described by the International Organization for Standardization (ISO) as:
"The programmed process of sampling, measurement and subsequent recording or signaling, or both, of various water characteristics, often with the aim of assessing compliance to specified objectives" (Bartram et al., 1996).

There are three types of monitoring activities that distinguish between long-term, short-term and continuous monitoring programs as follows:

- *Monitoring* is the long-term, standardized measurement and observation of the aquatic environment in order to define status and trends.
- *Surveys* are finite duration, intensive programs to measure and observe the quality of the aquatic environment for a specific purpose.
- *Surveillance* is continuous, specific measurement and observation for the purpose of water quality management and operational activities.

Water quality monitoring can be classified based on the water body where data is being collected. There are two types of water bodies: natural and technical. The natural water bodies are related to saline and freshwater ecosystem, while the technical relates to drinking water, wastewater or industrial water. Natural water quality monitoring in freshwater ecosystems can be subdivided into streams, lakes and groundwater.

Monitoring of water quality can also be classified based on the parameters being monitored (Ribbe, 2008). This monitoring is related to mitigating or preventing water pollution. In this case the main types of monitoring are:

- Physo-chemical analysis of water, suspended matter, and sediments. This monitoring is done on drinking water, wastewater and industrial waste
- Eco-toxicological monitoring. It is done when the objective of monitoring is to find toxical pollutants using plants or small animals like indicators that aren't resistant to these toxical pollutants that can cause human health problems.
- Biological monitoring. This monitoring is done on the biological community or individual organisms (biological indicator) to indicate effects on the ecosystem. The changes in the organisms' characteristics, physiological and morphological, in relation to co-existence and abundance are observed on site.

Biological and eco-toxicological monitoring are typically performed at low frequencies, usually every few years to several times per year because they are difficult to analysis and has a high cost.

3.2.3 Water quality monitoring in decision making process

There have been many formulations of management framework to better the decision making process at a regional and national level (Ward et al., 1986). However, in recent years the focus has shifted to the local level with a more integrated point of view along advancement in technology and research (Ward et al., 2003). As it can be shown in Figure 3, the water quality monitoring system is a major component for the water resource management.

The water quality data helps the decision makers identify problems, document improvements, and demonstrate overall trends in water resource management. Further enhancement on water monitoring system is accomplished with the availability and the use of adequate water quality information. However, in transitional and developing countries, financial and technical resources are a major limiting factor to carry out frequent water monitoring. Therefore, to ensure effectiveness, an evaluation adopted for a water quality monitoring system should cover all relevant technical design features, including selection of sampling sites, sampling frequencies, variables to be monitored, synergy, and sampling duration (UNEP, 2003).

Chapter Four

Study Area

4.1 LOCATION

The GMRB consists of a catchment area of about 1.260 km² (EMBRAPA Solos, 2009), with a population estimate of 106,341,000 habitants; is located on the eastern part of the Guanabara Bay in Rio de Janeiro State, between coordinates: from 22°20'00" S to 22°40'00" S and from 43°05'00" W to 42°30'00" W, (Pedreira et al., 2009)

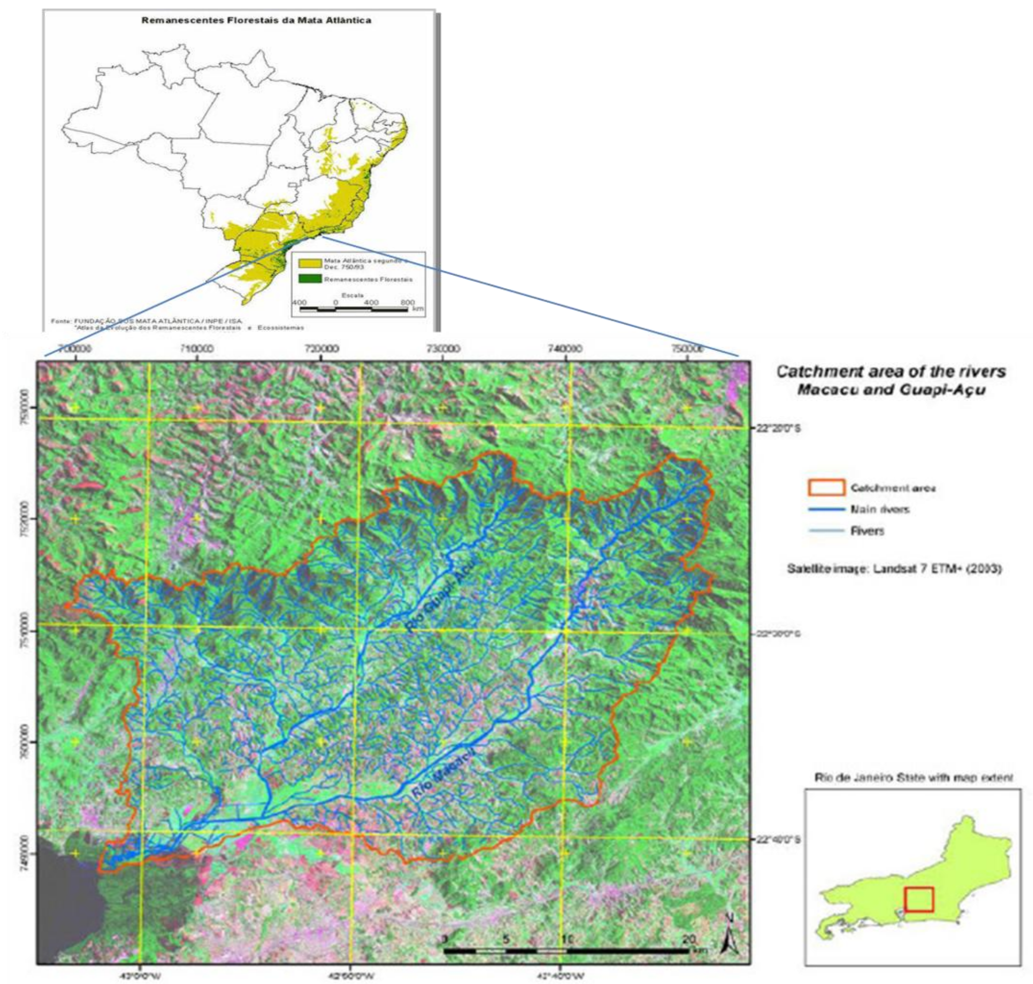


Figure 4: Guapi-Macacu river basin in the Guanabara Bay Hydrographic Region, RJ.[15]

[15] Source: (Torrico, 2008)

The basin contains the municipalities of Cachoeiras de Macacu and Guapimirim, with a small portion of Itaboraí (Costa, 2008). GMRB is located within the “Serra do Mar” Corridor and its springs are born in the “Parque Estadual do Três Picos (PETP)” and in the “PARNA Serra dos Órgãos” and “ESEC Paraíso”. 24,352.6 ha of the total area of PETP are within the Guapi-Macacu river basin. (Torrico, 2008).

4.2 CLIMATE AND SOIL

The mean annual precipitation varies from 2,500 mm, in the steep slopes of the mountain range; to 1,500 mm, in the lowest areas, with 140 rainy days in the year and the relative air moisture is around 83%. The annual mean temperature ranges from 18°C to 23°C.
The steepness in the river basin is mostly high from the mountain range (State Park Tres Picos) and moderate towards the catchment area, while the relief is similar to that of the steepness high to moderate. (Torrico, 2008).

According to Torrico 2008, Guapi-Macacu river basin is located within Serra do Mar Corridor, the basin consist of mainly small forest fragments. The soil in the basin is a result from the combination of the granite of the highly dissected relief and dense forest cover. Based on the classification of the FOA, there are five types of soils in the basin (Torrico, 2008):

- **Cambisols:** Brown soils typically under forests in mountains, relatively young, often nutrients from basement (rock, saprolite), and stabilizing slopes by roots systems.
- **Ferralsols:** Deep, strongly weathered tropical and subtropical soils with chemically poor but physically stable subsoil (B-Horizon). Strong reddish or yellowish, usually old, poor in nutrients, low base saturation and very acidic.
- **Acrisols:** Similar, but with a clay rich B-Horizon.
- **Fluvisols:** Young soils in alluvial deposits. Worldwide occurrence on river floodplains, deltaic areas, and coastal marine lowlands. Properties vary with age, parent material, etc.
- **Gleysols** Soils with permanent or temporary wetness near the surface. Its characteristic is the oxidation and reduction horizons.

4.3 LAND USE AND COVER

The forest covered by Atlantic Forest in Rio de Janeiro includes dense rain forest and semi-deciduous forest. In separate projects done by Pedreira et al. (2007) and Fidalgo et al. (2008) in land use and cover mapping for the GMRB both used the established legislation of CONAMA (CONAMA, # 6, 1994 and CONAMA, 2006) to categorize the different types of land use and natural vegetation cover (based on ecological succession). Table 2 illustrates the types of land use and cover found in this river basin.

Table 2: Types of land use and cover in GMRB[16].

Exposed soil	**Pasture**	**Urban area**	**Flooded field**	**Natural Vegetation**		
Mangrove	**Rocky outcrop**	**Field elevation**	**Conservation Units**	*Initial Forest*	*Middle Forest*	*Dense Forest*
				initial regeneration stage	intermediate regeneration stage	advanced regeneration stage

4.4 PROTECTED AREAS (CONSERVATION UNITS)

Apart from representing approximately a quarter of the entire drainage area contributing to the Guanabara Bay, the Guapiaçu and Macacu rivers provides the most important source of water quality and quantity in the region. Therefore, GMRB consists of nine Terrestrial Protected Areas (Conservation Units) managed by federal, state and municipal government agencies and non-governmental organizations. According to the National System of Conservation Units there are two types; Conservation units of integral protection and Conservation units of sustainable use (Pedreira et al., 2007; Fidalgo et al., 2008). As a Conservation Unit of Sustainable Use, the Environmental Protected Area of Macacu River Basin (EPA) was established in 2002 with an estimated area of 19.497 ha; with the main objective to protect important water sources that supply the municipality of Cachoeiras de Macacu, Niterói, São Gonçalo, Itaboraí and Tanguá. This state CU consists of a range (buffer zone) of 150 meters on both sides of the Macacu River along its entire length. (Benavides et al., 2009).

[16] (Pedreira et al., 2007; Fidalgo et al., 2008)

Figure 5 shows the Conservation Units located in Guapi-Macacu River Basin, including EPA Macacu river and COMPERJ area.

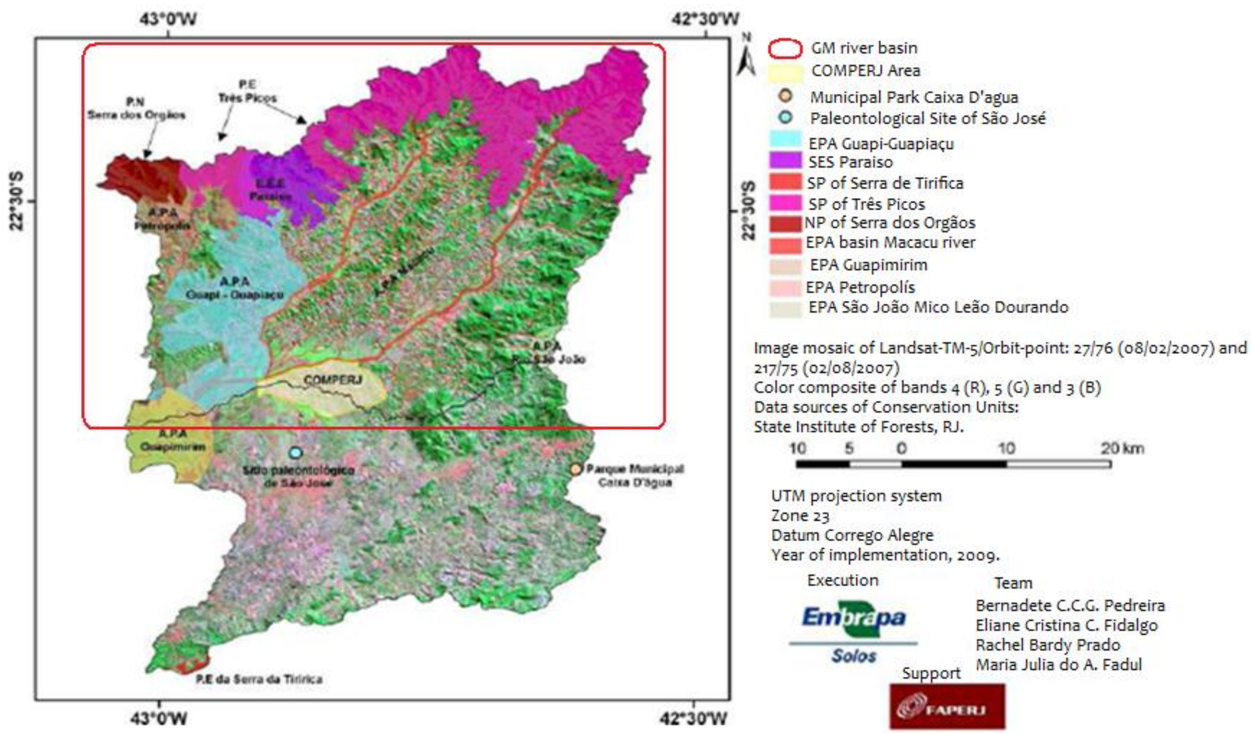


Figure 5: Conservation Units (CU) and surrounding area of COMPERJ[17].

[17] Source: (EMBRAPA Solos, 2009). The map of Figure 5 is the river basins of Macacu Guapi and Caceribu -on Landsat-5 TM images of 02.08.2007, with the delimitation of the protected area and COMPERJ. Source: Project "Spatial-temporal dynamics of land use in catchment areas of rivers Guapi-Macacu and Caceribu, RJ: subsidies to environmental planning

Chapter Five

Methodology

The methodology is focused towards the qualitative and quantitative methods which will provide the tools to obtain the three specific objectives along with the general objective of the thesis. It is a combination of two conceptual approaches, Driving Force-Pressure-State-Impact-Response (DPSIR) and Strategic Environmental Analysis (SEAN), to obtain the rapid analysis of the current water quality monitoring system carried out at the river basin within the existing water resource management framework (Organization for Economic Cooperation and Development (OECD), 1994; European Environmental Agency , 1999 Kessler, 2003; Neves, 2007). This methodology has five steps to analyze the current water quality monitoring system in this basin (Figure 6).

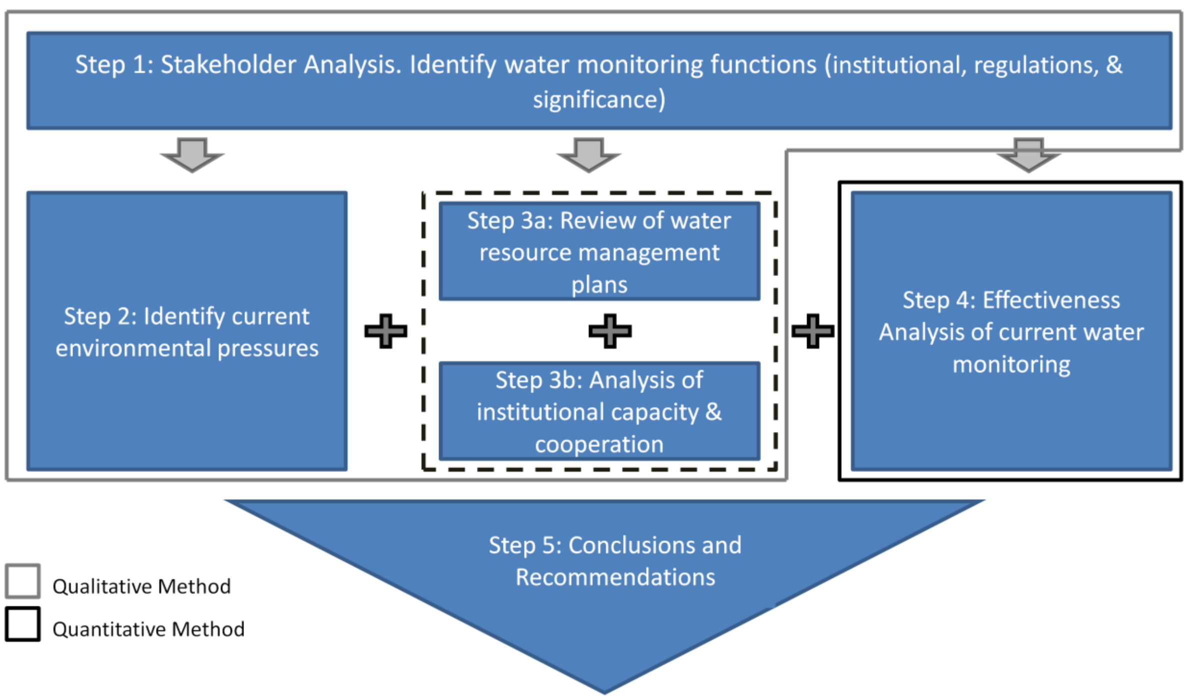


Figure 6: Mixed framework for the thesis research methodology[18]

[18] Source: Prepared by author.

Secondary source information reflects data that is collected by individuals or agencies for purposes other than a particular research study[19]. For this thesis, firstly, it was collected from six (6) sources (Table 3). Moreover, secondary source information was a priority for step one (1) to step three (3); hence to accomplish the first and second specific objective.

Table 3: Institutions and source of secondary information.

Institutions	***Type of data and source***
State Institute of Environment (INEA)	Spreadsheet of water quality data, Maps (pdf)
Brazilian National Centre for Soil Research (EMPRAPA Solos)	Management Plans, Articles, Reports
Federal Fluminense University (UFF)	Final Report, Software
Websites	
Brazilian Institute of Geography and Statistics (IBGE)	http://www.ibge.gov.br/home
INEA	http://www.inea.rj.gov.br
State Water and Sewage (CEDAE)	http://www.cedae.com.br
National Water Agency (ANA)	http://www.ana.gov.br

These data were organized in a data base to contribute to the others steps (2 and 3b) in this thesis. Afterwards, the primary data were collected, with on-site fieldtrips along the GMRB and with key informant interviews. The following will explain the phases and five (5) steps of the methodology, within the qualitative and quantitative methods spheres being considered.

5.1QUALITATIVE EMPIRICAL METHODS

Qualitative methods can be defined according to Berg et al. (2006) in the own words of Filstead in his argument differentiating between qualitative and quantitative methodology as: “those strategies, such as participant observation, in-depth interviewing, total participation… which allows the researcher to obtain first-hand knowledge about the empirical social world in question. Qualitative methodology allows the researcher to ‘get close to the data’, thereby developing the analytical, conceptual and categorical components of explanation from the data itself – rather than from the preconceived, rigidly structured, and highly quantitative techniques that pigeonhole the empirical social world…”. The following steps contain the explanations and tools used in this thesis.

[19] Source :http://www.fao.org/docrep/w3241e/w3241e03.htm

5.1.1 Step 1: Stakeholder Analysis

According to the World Wildlife Fund, a Stakeholder is defined as (Golder, 2005):

"Any individual, group, or institution who has a vested interest in the natural resources of the project area and/or who potentially will be affected by project activities and have something to gain or lose if conditions change or stay the same."

There has been further classification of types of stakeholders; primary and secondary (US Overseas Development Administration, 1995; Schmeer, 2004). Stakeholder Analysis (SA) is a tool that identifies stakeholders, assessment of their interests, participation and ways in which these interests affect projects (US Overseas Development Administration, 1995). The reasons to do a stakeholder analysis lie mainly on selecting stakeholders with whom to work jointly towards a common goal (Golder, 2005). Therefore, a stakeholder analysis was done on the current water resource management of the Guapi-Macacu River basin, including for the water quality monitoring system in the river basin.

5.1.2 Step 2: Identification of Current Environmental Pressures

This step consisted in:

A. A description of current environmental pressures in the studied river basin was done based on the collected secondary source information from the sources indicated at Table 3.

B. A simple observation, during a fieldtrip, was done in three sub–basins of GMRB; namely: Batatal, Regua and São José da Boa Morte. Digital pictures and waypoints were taken from each visited site that was considered an environmental pressure.

5.1.3 Step 3: Review of Management Plan and Analysis of Institutional Capacity and Cooperation.

This step was divided into two (2) sections (3a and 3b) to accomplish specific objective one and two.

Step 3a: Review of management plan

Review and description of the river basin management plans for the studied river basin was done based on the collected secondary source information from the sources indicated at Table 3.

Step 3b: Analysis of Institutional capacity and cooperation

Interviews can be differentiated into quantitative or structured, which are conducted through surveys and a standardize schedule, in depth or ethnographic, and semi-structured, which consist of open-ended questions or discussion points. The latter was planned used since it encourages two-way interaction, including exchange of information (Bunce, 2000). The semi-structure interview questions (see Annex C) were used for step 3b of this thesis. It consisted of identifying key-informants to interview for institutional capacity and cooperation (step 3b in Figure 6). Appoints were made to do the semi-structured interviews. In this step it was possible to evaluate the main difficulties there are in the monitoring system in the basin studied.

Table 4: List of key informants

Function	Institution	Place	Level of monitoring
Coordinator of water quality monitoring	INEA –Office Lagoa	Lagoa – Rio de Janeiro	State monitoring
Environmental technician responsible to water sampling	INEA –Office Lagoa	On the field –Cachoeiras de Macacu	State monitoring
Laboratory Technicial	AMAE	Cacheoiras de Macacu	Municipality monitoring
Government official	Cachoeiras de Macacu municipality council	Cacheoiras de Macacu	Decision maker

5.2 QUANTITATIVE METHOD

5.2.1 Step 4: Effectiveness Analysis

It is defined by the World Bank as a tool that assesses the costs of an activity that can be justified by the outcomes and impacts. However, the input is assessed by monetary means, while the outcomes are assessed by non-monetary measure (World Bank, 2004).

It has been shown that there are two ways to do a Cost-Effectiveness Analysis (CEA), the bottom-up and the top-down approaches. The first approach deals with focus on technical specifications of measures at a single water body. While the other one, deals with instruments or group of measurements at the sub-basin (Schrank, 2006). For step 4 of the thesis (Figure 6), it is proposed to do only an Effective Analysis (EA) with the first mentioned approach of the current water monitoring in a specified area of the river basin, because it was not possible have access to the real cost of monitoring in this basin.

The water quality data was collected, including list of parameters, waypoints and the frequency of monitoring. The effectiveness of doing water quality monitoring was shown, based on a selected measurement (s) on a water body or river.

ARGIS is Geographical Information System (GIS) that has tools providing standard based platform for spatial analysis, data management and mapping. Then, in this step the ARCGIS (version 9.3) from ESRI [20] was used to presents maps from GMRB like:

- To show current water monitoring sites and drainage net in Guapi-Macacu river basin;
- To propose effectiveness water monitoring network for Guapi-Macacu river basin.

The final step (step 5), of this thesis consists to present the main steps to solve difficulties and improve water quality monitoring in Guapi-Macacu river basin. It will be available to the governmental and nongovernmental organizations responsible in water quality monitoring in the River Basin, Guanabara Bay Committee and INEA. Simultaneously, it will be provided to the database of the DINARIO Project to contribute to the general objective of the project.

[20] Source:http://www.esri.com/software/arcgis/index.html

Chapter Six

Results and Discussion

6.1 BRAZILIAN WATER QUALITY MONITORING SYSTEM

The National Water Agency (ANA), as previously mentioned, is responsible for the implementation of guideline actions and instruments of the National Water Resource Policy which consists of integrated river basin water management and strategic planning and coordination amongst national, state and municipal governmental representatives; including supporting the establishment of River Basin Committees and Agencies. Apart from these ambitious and long term responsibilities, ANA is responsible for the prevention of water pollution in all Brazilian rivers. In water quality monitoring, ANA sets forth the provision for collecting water data including water quality data from the water monitoring done by state governmental or non-governmental agencies or organizations. ANA provides:

- Information systems that act as the link to collecting water monitoring entities and water decision making entities.
- Technical and financial assistance.
- Guidance to implement river basin programs or projects to improve water quality.
- Guidance to sustainable water resource management to state and river basin committees.

6.1.1 National hydro-meteorological network

Since the late 19th century, hydro-meteorological monitoring started in Brazil. Now days, ANA conducts the National Hydro-Meteorological Network along with other partners in the twelve established Hydrological Regions to collect information, produces studies, define policies and assess water availability. Moreover, ANA with the water data collected like the elevation data, the stream flow, the precipitation, the evaporation, the river profile, the sediment and water quality data, provides information to implement programs and projects related to consumptive and non-consumptive use, including irrigation and urban water supply projects. The information is available through the website of ANA or the National Information System on Water Resources[21].

In 2009, ANA started to operate and maintain a basic hydro meteorological network composed by 4,633 gauged stations where six parameters are monitored (Dissolved Oxygen [DO; % of saturation], conductivity [µmhos/cm], pH, air temperature [°C], water temperature [°C] and turbidity [turbidity units]) (ANA, 2002-2010). This kind of information can be access through the database website[22]that also includes the collection of water quality data.

6.1.1.2 Monitoring of water quality

Water quality monitoring in a country as big as Brazil is hindered by the heterogeneity of existing monitoring networks, mostly operated by federal states that have adopted different approaches (number of parameters, sampling frequency and others) in the implementation of their monitoring system.

The annual report of the Panorama of the Quality of Superficial Water (2004) stated that seventeen out of the twenty-seven Federal States operate and maintain water quality monitoring networks, with a total of 2,259 sites, with a variation of parameters and frequency.

In 2002, the Brazilian Environmental Ministry concluded that information about water quality in the country was insufficient or inexistence in many basins since nine Federal States had water quality monitoring systems considered as “Great” or “Very Good”, while five had “Good” or “Regular” systems, and thirteen had “Weak” or “Incipient” systems (Figure 7).

The criterion for the grouping of states was based on four aspects: Percentage of hydrographical basin monitored, types of parameters analyzed, frequency of sampling and form of information availability within the states (Agência Nacional de Águas, 2005).

[21] Source: National Hydro-Meteorological Network in Brazil website - http://www2.ana.gov.br/Paginas/servicos/informacoeshidrologicas/redehidro.aspx
[22] Source: Data base website - http://www.ana.gov.br/portalsnirh/Esta%C3%A7%C3%B5esdaANA/tabid/359/default.aspx

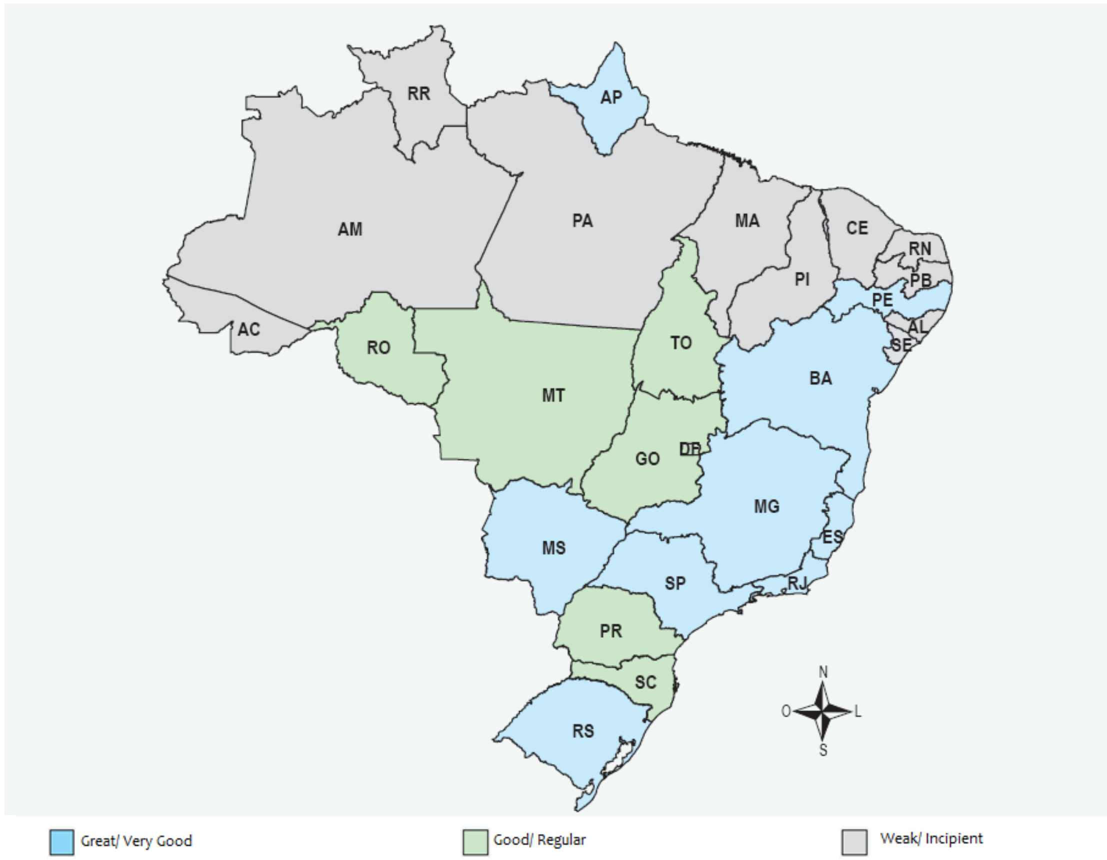


Figure 7: National water quality status[23]

In 2002 and 2006, ANA conducted National Water Quality Monitoring (NWQM) campaigns to determine the water quality status of surface freshwater, one of the three indexes used in the two campaigns is: Water Quality Index; the other indexes are the Trophic State Index (TSI) and Estimation of the assimilative capacity of the sewage charges. Water data were collected from fourteen Federal States. These two campaigns were done in federal states that were at risk of water contamination from disposal of untreated sewage in water bodies.

This Water Quality Index (WQI) known as WQI of the National Sanitation Foundation (WQI_{NSF}) was elaborated by Brown et al (1970) by the summation of sub indexes into one equation for the National Sanitation Foundation (NSF), in the United States. In Brazil, the Companhia de Tecnologia de Saneamento Ambiental (CETESB) of São Paulo, in 1975, used the WQI_{NSF} with a few replacements of parameters, total nitrogen

[23] Source: (Agência Nacional de Águas, 2005)

and total phosphorus, to determine the water quality of water bodies. Since then, other federal states used the adapted version of WQI_{NSF} and ANA use this WQI for their two NWQM campaigns.

The WQI composed of nine (9) Parameters, including three parameters that are in the set of parameters of the 2009 basic hydro meteorological network. They are: DO (% of saturation), fecal coliform (#/100ml), pH, biochemical oxygen demand (BOD, mg/L), temperature (°C), total nitrogen (Total-N, mg/L), total phosphorus (Total-PO_4, mg/L), turbidity (turbidity units) and total residue (mg/L).

Table 5 shows the classification of the quality of water bodies based on the numerical results of the WQI and these related to conditions and colors.

Table 5: Classification Table[24]

Classes	Conditions	Color
80 – 100	Great	
52 – 79	Good	
37 – 51	Regular	
20 – 36	Bad	
0 – 19	Very bad	

From those campaigns, it was observed that for 2002, the water quality was mostly Good (green) with 71%, basically similar as in 2006, with 70%. While the percentage of Bad status decrease in 2006 from 2002, from 8% to 5%.

From the campaigns (2002 and 2006), it was observed that for 2002, the water quality was mostly Good (green) with 71%, basically similar as in 2006, with 70%. While the percentage of Bad status decrease in 2006 from 2002, from 8% to 5%.

In 2010, ANA launched a website called Water Quality Portal (Portal da Qualidade das Águas[25]), that links the institutions responsible for the monitoring program and management with the users of this information (State Council of Water, the water industries, etc).

[24] Source: (Agência Nacional de Águas, 2005; Agencia Nacional de Água, 2009)

[25] Source: ANA website - http://pnqa.ana.gov.br/default.aspx

On June 2010, the National Program of Water Quality Assessment (Programa Nacional de Avaliação da Qualidade das Águas, PNQA) was launched by ANA to once again to assess the water quality of the country. PNQA is an initiative started in 2006 to achieve a standardize system of water quality monitoring in the hydrographical regions and federal states for the 2015. The criteria are the same as mentioned; Percentage of hydrographical basin monitored, types of parameters analyzed, frequency of sampling and form of information availability within the states (Mazzola, 2009). As Mazzola (2009) indicates, the PNQA is a good strategic program that will include adequate information system, number of monitoring sites and frequency depending on the identified critical areas.

6.2 WATER QUALITY MONITORING IN RIO DE JANEIRO STATE

To analyze the current water quality monitoring system at GMRB, it is necessary first to briefly describe the water quality monitoring system at the level of the state of Rio de Janeiro. It will be observed that the water quality monitoring is part of the environmental monitoring program in the state carried out by INEA. The INEA technician explained that the complete system of water monitoring consist of decision making departments as the State Council of Water Resources (CERH), the State Council of Environment (CONEMA), and the Guanabara Bay Sub-Basin Committees (CBBG); jointly determine the goal of the monitoring and the users of the results. To do that, the user than can be a water committee from a basin. Thus, they need to present a monitoring written Plan that includes the rivers and other water bodies, the parameters to be determined, the sites and the sampling frequency. Public consultation is done with the water users in the area to be studied asking them to agree with the Monitoring Plan. INEA does the monitoring, including the collection of water samples, the analysis of water and the report which is given to the water quality assessment planning department within INEA (the Environmental Monitoring and Information branch).

6.2.1 Water resource management institutions

Coordination occurs between INEA and other state water and environmental departments under the State Secretary of Environment (SEA), including CERH, CONEMA and the CBBG for water data for integrated water management or also known as "Basin Water Management".

In Rio de Janeiro, the CERH has the authority to regulate and elaborate the principles and guidelines of the system of water resource management.

Another identified state government department under SEA was the State Committee for Environmental Control (CECA); it works closely with INEA for water pollution control, with responsibilities including:

- Approve and propose to the Secretary of State for Public Works and Services the necessary measures to control pollution and environmental protection recommended by INEA;
- Exercise police power inherent in pollution control and environmental protection;
- Authorize the operation of facilities or potentially polluting activities.

Since 2008, the CERH has divided the hydrographic regions for administration reasons (see Figure 8). These hydrographic regions are: Baía da Ilha Grande – RHI, Guandu – RHII, Médio Paraíba do Sul – RHIII, Piabanha – RHIV, Baía de Guanabara - RHV, Lagos São João – RHVI, Rio Dois Rios – RHVII, Macaé e das Ostras – RHVIII, Baixo Paraíba do Sul – RHIX, Itabapoana – RHX, Figure 8 (Fundação CIDE & SERLA, 2008).

Figure 8: Hydrographic regions of the Rio de Janeiro state[26].

The Guanabara Bay Basin has twelve (12) river basins with the following sub-basins: Guaxindiba-Alcântara, Caceribu, Guapi-Macacu, Roncador ou Santo Aleixo, Iriri, Suruí, Estrela, Inhomirim, Saracuruna, Contribuintes à Praia de Mauá, Iguaçu, Pavuna-Meriti, Ilha do Governador, Irajá, Faria-Timbó, Drenantes da Vertente Norte da Serra da Carioca, Drenantes da Vertente Sul da Serra da Carioca. Each basin is divided in sub-basins and Guapi-Macacu river basin below is a sub-basin on the eastern region of Guanabara Bay Basin.

Rio de Janeiro State has ten hydrographical region and eight committees formally established for the following basins: Baía de Guanabara, Piabanha, Guandu, Lago São João, Macaé, Rio Dois Rios, Médio Paraíba do Sul, Baixo Paraíba do Sul.

Guanabara Bay Basin Committee (Baía de Guanabara)

The state law #3.239, 1999; created the Guanabara Bay Committee (GBC) a collective entity, of decentralized and participative management with attributions, advisories and norms at the river watershed level connected to the State Council of Water Resources and integrate the state System of Water Resource Management. Therefore, it is an ongoing

[26]Source: INEA Website - http://www.inea.rj.gov.br

forum for discussions on the situations in this geographic and makes decisions on actions relevant to the basin.

Main objectives of the Basin Committee:

The organizational structure of the Guanabara Bay Committee consists of:

a) Plenary: It is composed of sixty (60) members from three public sectors entitled to vote:

- Water Users - 20 (twenty) representatives and their alternates;
- Civil Society Organizations - 20 (twenty) representatives and their substitutes;
- Public Power - 20 (twenty) representatives and their alternates.

b) Board of Directors: It is composed of six (6) members (councilors) from the Plenary: 2 from the water resource users group, 2 from the civil society organizations group and 2 from the municipality government. They can only be reelected one consecutive time amongst them there is a General Director, a Deputy Director, and a Secretary Director. The General Director is responsible in directing work in the GBC, including be present in the meeting of the Board of Director and plenary. The Secretary Director is responsible in coordinating activities with the Executive Secretary

c) Executive Secretary: It is a member of the Board of Directors elected by the Plenary; responsible to provide technical advice to the GBC and General Director and coordinate with the Secretary Director, while organizing administrative activities of the Technical Councils;

d) Technical Council (TC): The GBC can create TC for a temporarily or permanent period depending on the decision of the Plenary. The TC is made up of 6 members. The Technical Councils are committees to examine and report Plenary on matters of their competence.

The Committee of the Guanabara Bay River Basin and the Lagoon Systems of Maricá and Jacarepaguá was instituted with the State Decree #38.260 of September 16, 2005, approved by the Guanabara Bay River Basin Committee in April 2007 and implemented this current year. This State Decree consists of two new additions:

a. Water Agencies – it is an executive body with proper legal identity, financial and administrative autonomy, instituted and controlled by the GBC. As a non-profit agency, it can collaborate with research institutes and universities to provide technical advice to the Committee. Moreover, it will assist the committee financially with assisting in establishing water use charge fees.

b. Management Group will be created and established by the GBC and plenary, respectfully, for each of the 6 different sub-regions or sub-basins that make the Guanabara Bay Basin. Each of these management group will be responsible to adopt planning and management, specifically and autonomous of its resource characteristics, promoting environmental assessment, identification and description, of the social, economic and environmental characters of the sub-basins.

The management of the GMRB is within the management of the sub-basin region draining into the Bay of Guanabara-East section, hence under the jurisdiction of the sub-committee of the Eastern section of Guanabara Bay Basin (GBB East).

According to the Management plan of EPA Macacu River, the sub-committee BBG-East, as part of the State Council of Water Resources is under re-structuring. Before 2009, for the water users' representatives in the plenary were composed mainly of industrial representatives and for the civil society organization, the majority came from sub-basin region draining into the Bay of Guanabara-West section.

In 2010, a 'new commitment' began for the water resource management in the Guanabara Bay Basin when a new reform basin committee was established (JusBrasil, 2010). As the inter General Director, from INEA explained, the major priority for the new Committee is to recuperate the water quality of the rivers to get prepared for two major World Events, The World Cup (2014) and The Olympics Games (2016).

6.2.2 Water quality monitoring Institutions

6.2.2.1 INEA

Before the amalgamation of the three governmental agencies (SERLA, IFE and FEEMA) to establish INEA, that is, before 2009, FEEMA (State Foundation of Environmental Engineering) was established with the article 15 in chapter 3, in decree # 39, 1975 (Grael, 2007). FEEMA was the technical body (comprising four divisions) that acts as executor of the CECA, responsible for:

- Research, environmental control, establishment of norms and standards, personnel training and provision of services aimed at the rational use of the environment;
- Provide technical support to the CECA to the exercise of its functions;
- Suggest the necessary measures to control pollution and environmental protection, specifically of drinking water distribution, municipal and industrial waste, public pools and insects;
- Exercise, on behalf of the CECA, the enforcement of rules on control of environmental pollution in the state, including federal regulations, by agreement.

One main program that was created for environmental protection and control pollution was the Licensing System of Polluting Activities (SLAP) established by Decree # 1.633/77, which regulates the Decree #134/75 providing the Prevention and Control of Pollution of the Environment in Rio de Janeiro. In 1981, the Federal Law #6938/81 placed the licensing system as one instruments of the National Policy on the Environment, determining its mandatory nationwide. On 1997, the CONAMA Resolution # 237/97 was the act that dealt with environmental license or permit, consisting with the process and the list of businesses, including water use businesses/industries that must apply for the environmental license to be installed, requiring a resume report of the EIA.

Therefore, FEEMA was responsible for water monitoring system, within the environmental monitoring programs of rivers, lagoons and beaches; for the metropolitan area of Rio de Janeiro to contribute to the Licensing System of Pollution Activities for the process during and after of environmental licensing of required industries and businesses.

INEA's technical sector is organized in a different way, but has the same objectives for pollution control, environmental licensing and protected areas. It consists of six branches interconnected to achieve their objectives. The Branch of Information and Environmental Monitoring has five sub-branches including all the components of a water quality monitoring system, except information needs and assessment strategies; even though the water monitoring system is done as part of the environmental monitoring (see Annex D). Under this branch, INEA technicians do water quality monitoring, including collection of water samples, water analysis in laboratories, and reporting the results, doing water quality assessment and doing reports for the other branches in INEA and other departments in SEA. For example, CECA need the information to charge industries when water pollution occurs.

Presently, INEA does systematic traditional and automatic water quality monitoring. The first monitors the trend of water quality conditions over time, providing data from a list of parameters and pre-established frequency. The latter gathers data from limited number of parameters at many short intervals as frequency.

6.2.2.2 ANA

In Rio de Janeiro, ANA receives water monitoring data from INEA of a total of 327 sites of 5 different sets of water data, 54 sites are for water quality data, Table 6. Figure 9 shows the monitoring sites from Table 6.

Table 6: Number of monitoring sites of various water data sets in Rio de Janeiro State.

Stations with Rainfall data	125	
Stations for Pluviogram data	9	
Stations for Elevation data	67	
Stations for Flow data	63	
Stations for Sediment data	9	
Stations for Water Quality data	*54*	

Figure 9: Map of the water monitoring sites administrated by ANA in Rio de Janeiro State

6.2.3 National Water Quality Legislation

The following resolutions consist of water quality conditions and limits (standards) to classify the water bodies for their multiply uses. The conditions and standards of water quality are based for human consumption and maintaining ecological status quo. Table 7 consists of the description of the resolutions used by ANA and INEA for water quality monitoring of water bodies.

Table 7: National water quality resolutions used as a guide for the use of waters.

Name		Description
Resolution CONAMA #274/2000		Contains the standards of water quality levels for the water use known as primary contact recreation, in class one (1) of freshwater, brackish and saline water bodies, such as for swimming, water skiing and snorkeling and diving.
Excellent	80% or more than one set of samples obtained in each one of the five previous weeks, harvested in the same place, have no more than 250 fecal coliforms (thermotolerant), 200 *Escherichia coli* or 25 *Enterococci* per 100 mL.	
Very Good	80% or more than one set of samples obtained in each of the five previous weeks, harvested in the same place, have no more than 500 fecal coliforms (thermotolerant), 400 *Escherichia coli* or 50 *Enterococci* per 100 mL.	
Satisfactory	80% or more than one set of samples obtained in each of the five previous weeks, harvested in the same place, have no more than 1,000 fecal coliforms (thermotolerant) 800 *Escherichia coli* or 100 *Enterococci* per 100 mL.	
Resolution CONAMA # 357/2005		Provides water quality conditions and parameters limits (standards) for the classification of water bodies based on multiply uses as shown in table 1. Since the information about the water quality conditions and standards is in tables, Table 8 has the general description of the composition of the conditions and standards.
Resolution CONAMA # 344/2004		Establishes the general guidelines and the procedures for the assessment of the minimum material to be dredged in order to manage its disposal in Brazilian waters. It consist of chemical limits of sediments, including the frequency of sampling, amount of disposal.
Ordinance #518/2004		This is an ordinance passes by the Ministry of Health in 2004 for the important assistance to effective surveillance and control of water quality for human consumption, in order to ensure the prevention of various diseases and promoting good health. Table 9 consists of the units and limits of microbiological parameters for potability of drinking water for human consumption. Table 10 consists of the number of monitoring sites of physo-chemical parameters related to density of human population. Table 11 consists of the frequency of physo-chemical parameters.

Table 8: Parameters for the water quality conditions and standards.

Water body type	Classes	Conditions[1]	Classes	Water quality standards[1]
		Type of Parameters		**Type of Parameters**
Freshwater	1[1],2[1],3[1],4[1]	**Pysho-Chemical**: Solid waste, floating materials, oils and grease, , color, DO, $BOD_{5.20°C}$, turbidity, pH, phosphorus,	1[1],2[1],3[1]	Organic & Inorganic
		Biological: total and fecal coliform, E.Coli, Chlorophyll A		
Brackish wáter	1,2,3	**Pysho-Chemical**: Solid waste, floating materials, oils and grease, DO, turbidity, pH, phosphorus, total organic carbon	1,2	Organic & Inorganic
		Biological: Total and fecal coliform, E.Coli, DO, turbidity, pH, total organic carbon		
Saltwater	1,2,3,	**Pysho-Chemical**: Solid waste, floating materials, oils and grease,	1,2,3	Organic & Inorganic
		Biological: total and fecal coliform, E.Coli,		
Sewage discharge		vegetable oils and animal fats, floating materials, mineral oil, material, temperature, pH		Organic & Inorganic

Note: DO – Dissolved Oxygen, $BOD_{5.20°C}$ – Biochemical Oxygen Demand,
1 – Annex B contains the limits and measurement units for the conditions and standards for the freshwater classes.

Table 9: Microbiological standard for potability of drinking water for human consumption.

Parameters	VMP (Maximum allowed value)
Water for human Consumption – including individual source, like wells, mines, springs	
Escherichia coli or coliforms termotolerants	Absence in 100ml
Water exiting the treatment plant	
Total Coliform	Absent in 100ml
Treated water in the distribution system (reservoirs and network)	
E.coli or Coliform thermotolerants	Absent in 100ml
Total Coliform	Systems that do 40 or more sampling per month – absent in 100ml in 95% of the analysed samples Systems that do less than 40 sampling per month - only one sample can result positive in 100ml.

VMP is the limit of each parameter. Total Coliforms and E. Coli - #/100ml.

Table 10: Parameters of the water quality considered by the Ordinance 518/2004.

Parameters	Source Type	treatment output (number of samples per unit of treatment)	Distribution system (Reservoirs and network)		
			Population supplied (# hab.)		
			<50,000	50,000 to 250,000	>250,000
Color (uH), Turbidity (UT)and pH	Surface	1	10	1 for every 5,000	40 + (1 for every 25,000
	Groundwater	1	5	1 for every 10,000	20 + (1 for every 50,000
CRL (mg/L)	Surface	1			
	Groundwater	1			
Fluorine (mg/L)	Surface and groundwater	1	5	1 for every 10,000	20+ (1 for every 50,000
Cyanotoxins (mg/L)	Surface and groundwater	1	-	-	-
Trihalomethanes (mg/L)	Surface	1	1	4	4
	Groundwater	-	1	1	1
Other parameters	Surface or groundwater	1	1	1	

CRL – Free residue chlorine

Table 11: Frequency of sampling for water quality control of water supply system

Parameters	Source Type	treatment output (Frequency per unit of treatment)	Distribution system (Reservoirs and network)		
			Population supplied (# hab.)		
			<50,000 hab.	**50,000 to 250,000**	**>250,000 hab.**
Color (uH), Turbidity (UT), pH and fluorine (mg/L)	Surface	Every 2 hours	Monthly	Monthly	Monthly
	Groundwater	Daily			
CRL (mg/L)	Surface	Every 2 hours			
	Groundwater	Daily			
Cyanotoxins (mg/L)	Surface	Weekly	-	-	-
Trihalomethanes (mg/L)	Surface	Quarterly	Quarterly	Quarterly	Quarterly
	Groundwater	-	Annual	Semiannual	semiannual
Other parameters	Surface or groundwater	Semiannual	Semiannual	Semiannual	Semiannual

Parameters	Distribution system (Reservoirs and network)			
	Population supplied (# hab.)			
	<5000 hab.	**<5000 to 20,000**	**20,000 to 250,000**	**>250,000**
Total Coliforms	10	1 for every 500	30+ (1 for every 2,000)	105 + (1 for every 5,000) max. 1000

CRL – Free residue chlorine

6.3 WATER QUALITY MONITORING IN GMRB

ANA has one monitoring site out of the 54 water quality data monitoring sites located in GMRB in the urban area of Papucaia in the municipality of Cachoeiras de Macacu.

It can be observed that there are two (2) governmental agencies and a public-private water company that conduct water quality monitoring in the Guapi-Macacu River Basin.

A. The Information and Environmental Monitoring Branch of INEA is the State Water Quality Monitoring Agency. They do the water quality monitoring: 1. To monitor the industries in a compliance with the regulation of environmental licensing. 2. To report to the CECA.
B. AMAE of Cachoeiras de Macacu is the Municipal Authority of Water and Sewage. They do the water quality monitoring: 1. To maintain the water quality of water supply sources for human consumption.
C. CEDAE is the State Company of Water and Sewage. They do the water quality monitoring: 1. To maintain the water quality of water supply sources for human consumption. 2. To treat wastewater.

CEDAE has only water supply capture area in the river basin, hence it is responsible to monitor the water being collected from the Imunana Canal. Figure 10 shows the current water quality monitoring systems in GMRB. However, the results show two observation of a complete water quality monitoring system:

- They participate in the complete monitoring system by doing the monitoring program, data collection, and data handling.
- There are three water monitoring systems conducted by three different institutes. CEDAE and AMAE-CM have the same reasons to participate in the monitoring system. While INEA has different reasons because the water quality monitoring is part of environmental monitoring in the river basins of Rio de Janeiro.

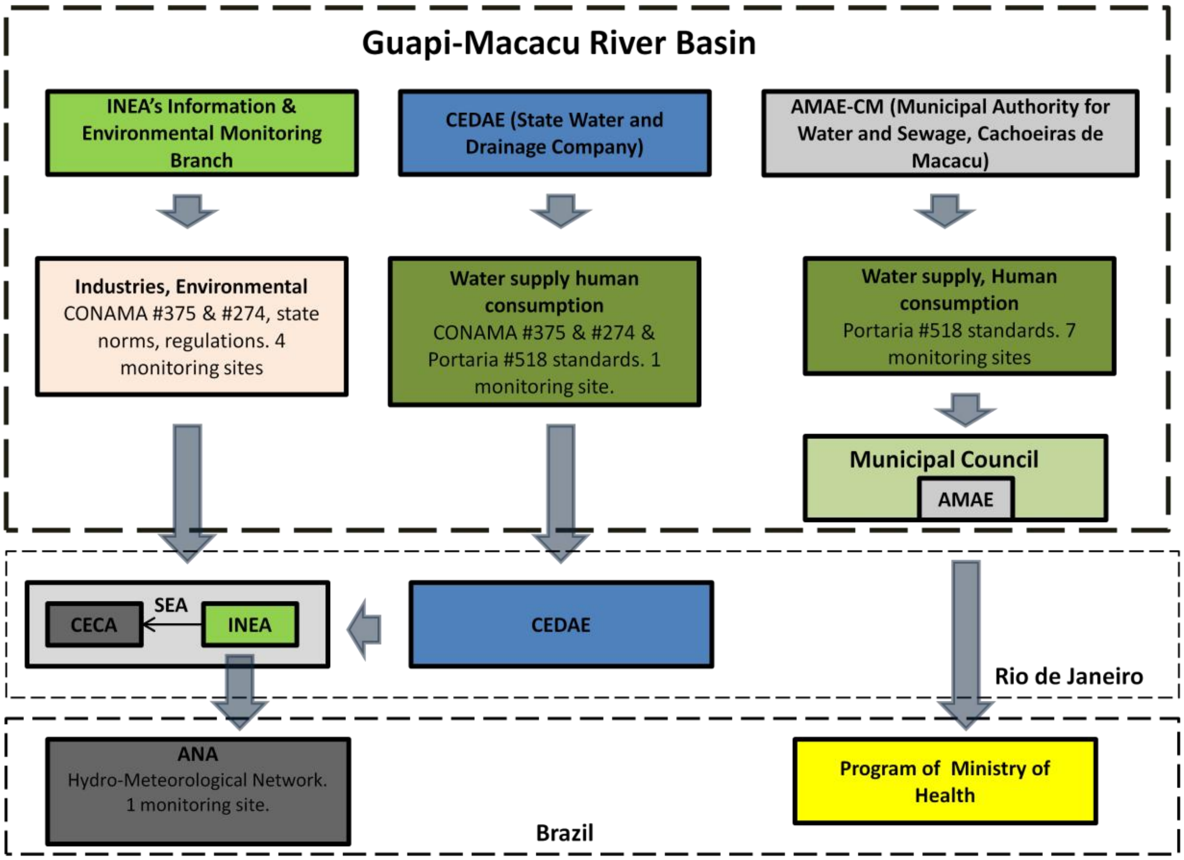


Figure 10: Institutions doing water quality monitoring at GMRB

The description of Figure 10 will be done in the following sequence of the water monitoring institutes in GMRB.

6.3.1 INEA

6.3.1.1 Resolutions, Methods and Standards

The website of INEA (http://www.inea.rj.gov.br/leis/leis.asp) has the list of the federal and state Laws, Decrees, Resolution and Ordinances establishing and regulating functions and agencies of water resource management, like in water use regulation, water use charge, water body protection and licensing process. The initial and important state law is # 134/75 that states the prevention and control of environmental pollution in Rio de Janeiro and other measures. Table 12 has other decrees and ordinances dealing with water pollution control.

Table 12: State decrees and ordinances that concern the management and protection of the aquatic resources.

Name	Area
DECRETO N° 2.330, 1979	Protection
LEI N° 650, 1983	Water bodies' protection
PORTARIA SERLA N° 308, 2003	Water use regulation
PORTARIA SERLA N° 385, 2003	Water use regulation
PORTARIA SERLA N° 462, 2006	Water use regulations
PORTARIA SERLA N° 564, 2007	Water use charge
PORTARIA SERLA N° 565, 2007	Water use charge
PORTARIA CONJUNTA SEA/FEEMA/SERLA/IEF N. 001/2007	Environmental Licensing process

While the website of INEA (http://www.inea.rj.gov.br/fma/legislacao.asp) is a database of State Manual, Methods, Technical Standards, Background Standards apart from the Decrees, Laws, and Resolutions. The Technical and Background Standards, and Methods are standards and methods of water and air quality. The objectives of these are to comply with the SLAP, according to the interview of INEA Technician; one main reason to do water quality monitoring is to observe if these standards are being followed by industries, therefore doing a comparison with the results submitted by the industries to abide to the environmental licensing regulations. Annex E has the methods used in water quality monitoring and the legal instruments for water use regulations and charges.

As mentioned, water quality monitoring is done within environmental monitoring mainly for monitoring industrial liquid sewage (effluents) and their toxicity. Those residues need to meet the standards mentioned in Technical Standards NT-202.R-10 (criteria and standards for launch of liquid effluent) and NT 213.R-NT-4 (Criteria and standards for control of toxicity in industrial liquid effluents).

6.3.1.2 Parameters and Frequency

The choice of sampling points and parameters to be analyzed is made according to the water body, the beneficial use of its waters, the location of activities that may influence its quality and nature of the pollutant, such as evictions industrial sewage and agricultural drainage water or urban.

The set of parameters vary on the water bodies being monitored, coming from resolution CONAMA #274 and #357. In the Guapi-Macacu River Basin, parameters are also from NT-202.R-10 and NT 213.R-NT-4; since the river basin consist of industries. Table 13 show the general list of parameters and frequency considered for the water bodies of the Guanabara Bay Basin.

Table 13: Water quality parameters and frequency of measurement considered by INEA

Parameters	Units	Guanabara Bay Basin	
		Stations	Frequency
DO (Dissolved Oxygen)	% of saturation	All	Monthly
$BOD_{5.20°C}$ (Biological Oxygen Demand)	mg/L	All	Monthly
COD (Chemical Oxygen Demand)	mg/L	All	Monthly
pH	#	All	Bimonthly
Conductivity	-	All	Bimonthly
Alkalinity	-	All	Bimonthly
Total Non-Filtered Waste	-	All	Bimonthly
Total Waste	-	All	Bimonthly
Turbidity	turbidity units	All	Bimonthly
Ammonia	mg/L	All	Bimonthly
Nitrogen Dioxide (Nitrite, NO_2^-)	mg/L	All	Bimonthly
Nitrate (NO_3^-)	mg/L	All	Bimonthly
Phosphates (PO_4)	mg/L	All	Bimonthly
Total Phosphate	mg/L	All	Bimonthly
Cyanide	mg/L	All	Bimonthly
Iron	mg/L	All	Bimonthly
Heavy Metals	mg/L	All	Trimonthly
PCB's	mg/L	Nil	Nil
Total HAP's	mg/L	IA260, IA261, IA262	Bimonthly
Phytoplankton	-	All	Bimonthly
Bio Assays	-	Nil	Nil

INEA has fifty-three (53) monitoring sites in Guanabara Bay Basin, including beaches, lagoons and rivers; four (4) of these 53 sites are located in the Guapi-Macacu River Basin.

Table 14 has the description of the 4 monitoring sites of INEA in Guapi-Macacu River Basin:

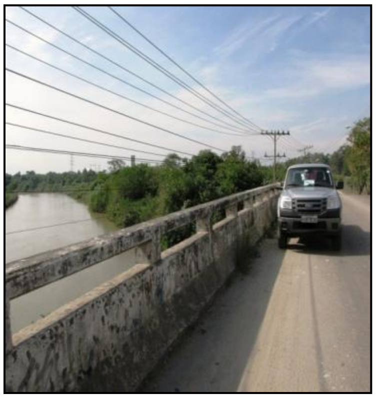
Table 14: Monitoring sites considered by INEA

INEA Code	Description	Latitude	Longitude
00RJ10GP0600	Guapimirim River (Highway River – Mage after crossing the railroad in Itambi, 6km)	22° 40‘ 33.84“	42° 58‘ 25.49“
00RJ10GP0601	Guapimirim River (Bridge where water is taken at the Imunana Canal for the ETA Laranjal)	22° 41‘ 02.79“	42° 57‘ 02.16“
00RJ10MC0965	Macacu River (Bridge situated in Cachoeiras de Macacu)	22° 25‘ 07.37“	42° 37‘ 13.38“
00RJ10MC0967	Macacu River (Bridge in Japuiba)	22° 33‘ 38.86“	42° 41‘ 38.09“

6.3.1.3 Sampling

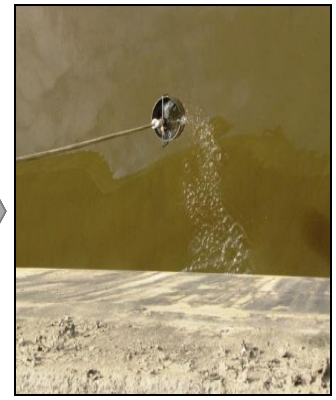
To observe the daily water sample collection activities, a fieldtrip was taken with the technician of INEA to collect samples of water monitoring sites. Figure 11 shows the different activities involved in the field collection of water quality sampling. Firstly, as the technician reached the river on the bridge, the assistant filled a metal container approximately 5 liter in volume with river water (picture b to d). On site, the water temperature was taken and the dissolved oxygen measurement was prepared. Afterwards, a 5 liter plastic container was filled with river water. After doing these steps in four other monitoring sites, the 5 liter containers were taken to the main laboratory campus. At the laboratory campus, the remaining physical-chemical and microbiological parameters are taken.

The technician explained the weekly coordination for water sampling collection in the Guanabara Bay Basin. Since the frequency for sample collection is monthly and bimonthly, there is a team that coordinates the sampling campaign. They travel by vehicles rotating their assistance depending if the collection is done in beaches, rivers and lagoons. He mentioned that the weekly weather prediction can limit the collection of samples. During the collection of samples in beaches, tides are the main limiting factor because depending on the type of tide, then it is impossible to collect water samples.



A) Arrive at the river.

B) Getting a bucket of water.



C) & D) Filling and retrieving the container with river water.

E) Taking water temperature.

F) & G) Testing for Dissolved Oxygen.

H) Filling a 5 liter water sample container for lab testing.

I) Water Quality Laboratory.

Figure 11:On-site sampling[27]

[27] Source: Akè, 2010

6.3.2 AMAE-CM

The Municipal Authority for Water and Sewage of Cachoeiras de Macacu (AMAE-CM) is responsible in monitoring the water quality of freshwater sources for the Municipal Council of Cachoeiras de Macacu. The results are reported to the Muncipal Council and also to the Ministry of Health as part of the National Surveillance of Water Quality for Human Consumption for the rural and urban areas of the municipality.

6.3.2.1 Resolutions, Methods and Standards

AMAE uses the water quality conditions and standards from the Ordinance #518/2004 to monitor the water quality in the treatment units for water supply. The methods to measure the physical-chemical and microbiological parameters are stated in the Ordinance #518.

6.3.2.2 Parameters and Frequency

Parameters based on Ordinance #518/2004, are the following: color (uH), turbidity (turbidity units), pH, residual chlorine (mg/L), coliform (Total and Fecal) (#/100ml), heterogical bacteria ((#/100ml) and heavy metals (mg/L).

Table 15: Parameters and sampling frequency followed at the monitoring sites at the GMRB[28]

Name	Urban Area	Water Source	Frequency				
			4 time/day	2 times a month			
			pH, Color, Turbidity, Chlorine	Total Coliform	Fecal Coliform	Heter. Bacteria	Metal
Tocas Tuim	Tuim	Stream Tocas	√	√	√		
Boa Vista	Boa Vista	Stream Afonso	√	√	√		
França	Cidade Alta	Stream Tocas & José da Hora	√	√	√		
Fazenda	Ganguri de Baixo	Stream Acir	√	√	√		
Zacarias	Ganguri de Cima	Stream Cachorra & Cirilo	√	√	√		
Lota	Cidade Alta	Stream Lota	√	√	√		
Bela Vista	Cidade Alta	Stream Tocas	√	√	√	√	
Maraporá	Cidade Alta	Artesian Well	√	√	√	√	√
Bonanza	Bonanza	Artesian Well	√	√	√	√	√

[28] Source: Obtained from AMAE-CM Laboratory Technician.

6.3.2.3 Sampling

The process of collecting and analyzing the water samples was explained in an interview with the AMAE-CM Laboratory Technician. The collection of the water samples is done four times a day (8-17h) with an interval of two hours. Two laboratory assistances do the collection with motorcycles due to the distance, rough terrain and the large number of water samples to transport. The water sample for each treatment unit is placed in a three liter plastic container. It is transported to the water laboratory of AMAE-CM located in the city of Cachoeiras de Macacu.

The analysis of the water samples is done on a weekly basis by the head laboratory technician. There is a minimum help by the assistants in the analysis. Majority of the analysis is done on Wednesdays of every week, while the water samples are stored in a refrigerator.

Based on the collected information, the water quality monitoring of these treatment units started in 2008 with the implementation of the national surveillance of water by the Ministry of Health.

6.3.3 CEDAE

The Federal Decree # 5.440/2005, form the State Company of Water and Drainage (CEDAE) (Companhia Estadual de Agua e Esgoto (CEDAE), 2006). CEDEA has signed agreements to plan, construct and operate water supply systems and drainage sanitation in sixty-three (63) municipalities, approximately 9.7 million people in Rio de Janeiro state.

In Guapi-Macacu River Basin, CEDAE has a water intake downstream of the Guapimirim River at the Imunana Channel. The channel starts at the junction of the Guapiaçu and Macacu rivers leading to the Guapimirim river. The canal made the natural flow of Macacu River shift and was joined with Guapimirim river. It captures 7 m^3/second of water and flows through a 3,250 m long pipeline, reaching a pumping station, where it is pump to the Water Treatment Plants (WTP), Laranjal, located in São Gonçalo, is the second largest WTP in Rio de Janeiro. Water is treated here and distributed by CEDAE and its subsidiary Águas de Niterói to the municipalities of Itaboraí, Niteroí, São Gonçalo, Guapimirim and Cachoeiras de Macacu. (Costa, 2008; BioAtlântica, 2009). Therefore, CEDAE do water quality monitoring at the source (raw water) of superficial water at the caption area, canal Imunana, and at the WTP, Larangal; before distribution of water supply to verify the water quality to be adequate for human consumption.

6.3.3.1 Resolutions, Methods and Standards

The water quality conditions and Standards from the Resolution CONAMA #357/2005 are used to monitoring the water quality of the raw water of headwaters, springs at the caption area, Imunana Canal. Since it is for human use and consumption, the conditions and standards of the water quality is of the second class freshwater, Table 16.

The water quality conditions and standards from the Ordinance #518/2004 are used to monitor the water quality at the WTP, Larangal before the distribution. The methods to measure the parameters are stated in the Ordinance #518.

6.3.3.2 Parameters and Frequency

Imunana Canal

The frequency for the monitoring is Bimonthly, except for Biological Oxygen Demand and Dissolve Oxygen, which is monthly.

Table 16: Water conditions and standards

Water body type	Classes	Conditions[1]	Classes	Water quality standards[1]
		Type of Parameters		Type of Parameters[1]
Freshwater	2[1]	**Pysho-Chemical**: Solid waste, floating materials, oils and grease, , color, DO, $BOD_{5.20°C}$, turbidity, pH, ,	2[1]	Organic & Inorganic. Agricultural
		Biological: Total Fecal Coliform, E.Coli, Chlorophyll Cynobacteria, Algea		

DO- Dissolved oxygen (% of saturation) , $BOD_{5.20°C}$ – Biochemical oxygen demand (mg/L)

1 – See Annex B for the units and limits of these parameters.

Larangal WTP

Parameters based on Ordinance #518/2004, are the following: color, turbidity, pH, residual chlorine (RCL), coliform (Total and Fecal) and fluoride.

The frequency of monitoring as stated for Color, Turbidity, pH, RCL, and Fluorine is every two hours daily. While for Coliform 248 time a month, since the population to be supplied with water is more than 250,000 inhabitants. In the first month of 2010, CEDAE made 249 tests of Coliforms. In a 2006 monthly water quality report, the required frequency for the physio-chemeical parameters was of 120 a month.

6.3.3.3 Sampling

Technically, CEDAE has one sampling site in the Guapi-Macacu, which is the capture area at the Imunana Canal. However, at the WTP Larangal, there is the department of water quality control with laboratories that do monitoring of the water before treatment. In doing this monitoring, if the microbiological parameters, Coliforms, don't comply with the limits, samples are collected and actions are taken until the limits are satisfying.

An important observation was made about where or to who the collected and analyzed water quality data is to be reported. As Figure 10 shows, AMAE-CM submits its reports of analyzed water quality data to the municipality council for decision making. Simultaneously, it submits the data to the National Environmental Health Monitoring related to Water Quality for Human Consumption coordinated by the Secretary of Health Monitoring of the Ministry of Health through the General Coordination for Environmental Heath Monitoring. Information collected for the research, including from interviews, there is no indication that AMAE-CM submits a report of the analyzed water quality data to INEA or to the State Secretary of Environment.

Due to limited time this research was only able to acquire general information about the National Program of Environmental Health Monitoring related to Water Quality for Human Consumption. It is a federal program with state and municipal health authority. Its overall goal is the development of actions for Environmental Health Monitoring related to Water Quality for human consumption, in order to guarantee the population water access in sufficient quantity and quality compatible with the standards established for drinking by the existing legislation of the National Ordinance # 518/2004 for health promotion.

On the other hand, CEDAE, being a water industry, do submit reports of analyzed water quality data to INEA. At the national level, INEA supply water quality data to ANA's national hydro-meteorological network. There is no collected information that ANA is supplied with water quality data from the ministry of health at the national level.

6.4 EFFECTIVENESS ANALYSIS

This section will consist of an Effectiveness Analysis based on the identified environmental pressures, the relevance of the selection of monitoring site, the sampling frequency and parameters, and the water quality data sharing to identify improvements in the current water quality monitoring system for the management plan of GMRB.

6.4.1 Environmental pressures related to land use.

Based on the secondary information collected, the main indirect environmental pressures of water quality are related to land use changes in the river basin.

According to Pedreira et al (2009), the main environmental pressures are the inappropriate land-use activities, specifically, removal of majority of the original vegetation cover, removal of riparian forest, unplanned urban sprawl, lack of sewage treatment and improper supervision of industrial activities; causing steep erosion and river siltation (Pedreira et al., 2009).

The removal of the vegetation cover and the riparian forest are directly linked to the increase in pasture and agricultural lands over the last three decades, as evidently has been shown by Fidalgo et al (2008) in the classification of land use and cover for the river basin, see Annex F.

Pedreira et al (2009) estimated that the most dominant type of land use and cover in the river basin are pasture (43.6%) and dense forest (42.4%) respectfully. However, the natural vegetation is concentrated on the highest parts of the relief, on large and continuos fragments and in lowlands, covering hills in forms of small fragments; while pastures occupy the hill edges (Pedreira et al., 2009). When natural vegetation was compared to the areas of Conservation Units (CU), there is an almost similar occupation area in the river basin; 26% of CU and 23% of natural vegetation in the river basin (Fidalgo et al., 2009)

The water quality in the Southeastern Hydrographic Region presents diverse situations, placing the pollution source into three types (Agência Nacional de Águas, 2005).

6.4.1.1 Diffuse pollution – in rural areas by pesticides, organic or chemicals fertilizers.

Historically, in this river basin, agricultural products were grown in fertile soils in the vicinity of what are today Japiuba and Papucaia; like cassava (mandioca), maize, sugar cane, coffee, rice and beans. In 2004, according to Tribunal de Contas do Estado do Rio de Janeiro (TCE-RJ), the fastest growing activity was farming with 14.54% (BioAtlântica, 2009).

Irrigation is a major activity that requires water quantity for agriculture lands. As found in the literature review, is a nearly 50% dramatic increase of this activity in a very short period of time. In 1996, the agriculture census recorded a total of 1,231 Ha irrigated and in 1999, Costa obtained data for the municipalities of Cachoeiras de Macacu, Gaupimirim and Itaboraí a total of 2,013 ha irrigated. Three sites were visited, two in the Guapiaçu river sub-basin and one in the Macacu river sub-basin. Figure 12 below shows the location and name of the visited sites.

<u>Batatal</u>

Batatal site is a tributary called Batatal de Baixo river connected to the Macacu river. Downstream, it passes through the communities of Farao de Cima, Farao de Baixo and Bom Jardim do Farao. It was observed that before and after the rapid at this tributary there is initial forest cover (picture A and B) with a section of erosion of the river bank, along with coconut and cassava plantation; and pasture (picture D and E) at the short distance (see Figure 13).

REGUA (Guapiaçu Reserve) Area

There are small streams at this site that connects to Guapiaçu river. The Guapiaçu river passes through the communities of Estreito and Matumbo. This site is located in front and beside the forest reserve with pasture lands being the dominant land cover and use (picture A) and a small portion of agricultural land (picture B). Pictures C to E in Figure 14, were taken in Matumbo, there is harvesting at the plantain plantation immediately along the river bank of Guapiaçu River, while a water supply PVC pipe crosses the river attached to a wooden stem.

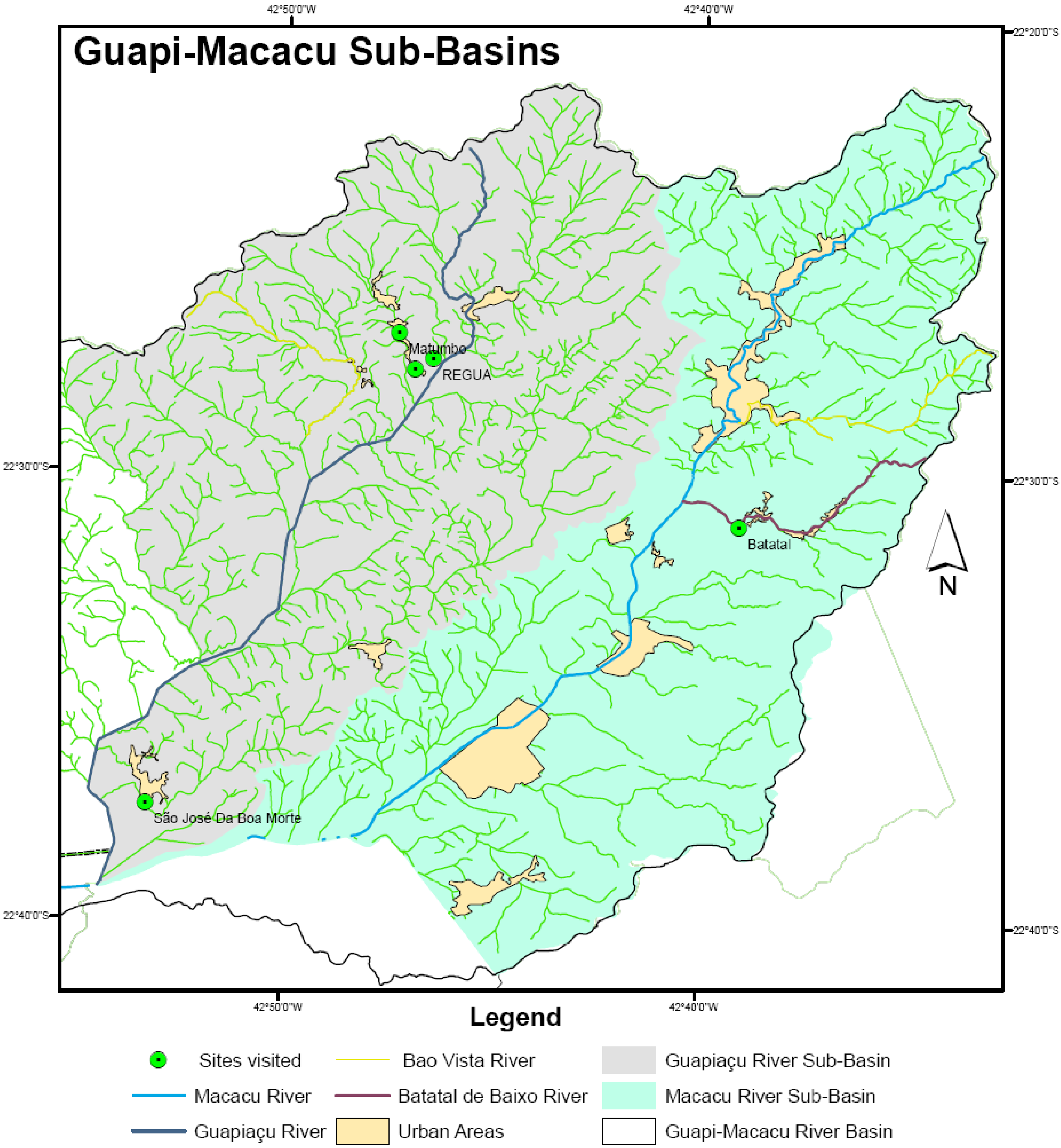


Figure 12: Sites visited in the GMRB[29]

[29] Source: (Aké; 2010)

A) River stretch

B) Start of a Meander

C) A rapid

A), B) & C): Batatal de Baixo Tributary

D) Cassava (*Manihot esculenta*) plantation

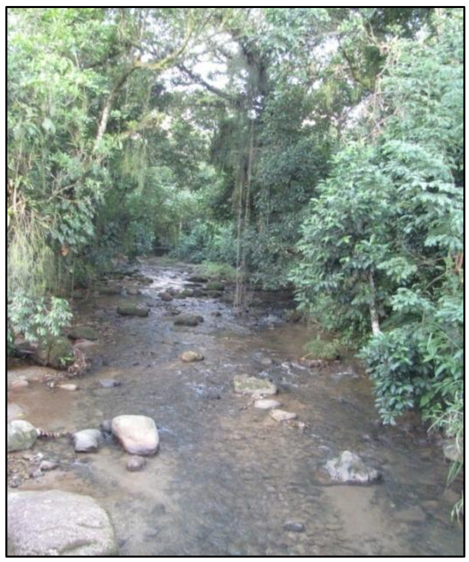
E) Coconut (*Cocos nucifera*) plantation

Figure 13: At Batatal de Baixo tributary of Macacu river sub-basin.

Source: (Aké, 2010)

A) Cattle Raising Pasture

B) Corn (*Zea mays*) Plantation



C) Stream

D) River stretch

E) Plantain plantation along the river bank

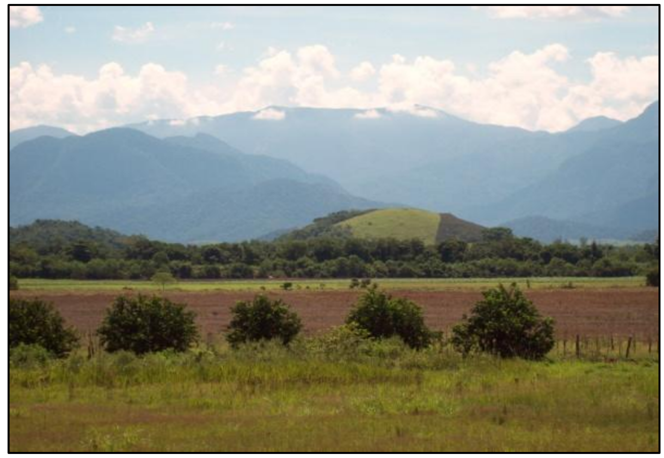
Figure 14: REGUA area in the Guapiaçu river sub-basin

São José da Boa Morte

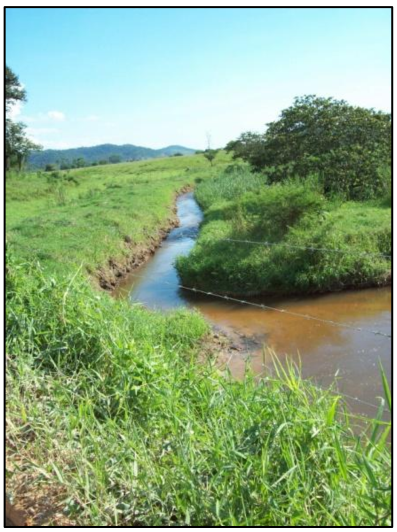
At this site, it is evident that there is intensive agricultural land (pictures A and B) producing orange, guava and cassava. This is a low lying area with natural channels and streams within the community of Bonanza. As picture E and F demonstrates a stream in the middle of land used for sugar cane plantation. It can be said that it can be a potential source of diffuse pollution by fertilizers runoff (See Figure 15). In this site, it was described by farmers, the flooding of this area when the Guapiaçu river overflows as it rains.

These three sites are evidence on the finding of Pedreira et al (2009) that agricultural lands and pasture lands are the direct cause of riparian forest lost along the river banks and initial and medium forest cover, respectfully. Also, it is noted that the tributary in the Batatal site and the Guapiaçu river beside the forest reserve (REGUA) pass through urban settlement, meaning that water supply is gotten directly from these water bodies for irrigation and livestock. While at the site of São José da Boa Morte, apart from water supply source for the intensive agriculture; the runoffs are delivered in the streams connecting to the Guapiaçu river. Moreover, there is an urgent need of attention at this site to control or prevent the flooding.

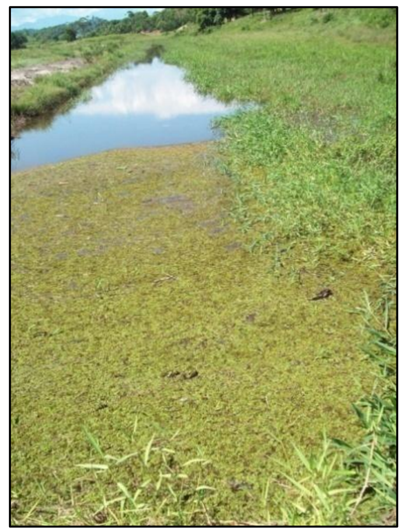
A) Variation of plantation



B) Agriculture land



C) natural channel



D) Stream

E) Agricultural land

F) Stream in the middle of agriculture land

Figure 15: São José da Boa Morte tributary in the Guapiaçu river sub-basin.

Castro, et al (1997) conducted a survey on the use of pesticides in the municipality of Cachoeiras de Macacu. His findings from the visits and interviews were that the farmer in 40 rural properties, apply mainly pesticides as the insecticide Decis 25 CE (highly toxic) and the herbicide Gramoxone (extremely toxic) from a list of 25 other agrochemical products. Moreover, another alarming result is that 27.5 % of the empty agrochemical containers are simply thrown into rivers or bushes. (Castro et al., 1999). This author did the interviews in the area of San José da Boa Morte and observed that the majority of the farmers have limited training on the handling of the agrochemical products and are aware of the danger in the use but continue to use it.

Therefore, it is evident that farming is one of the main activity consider to be an environmental pressure in the river basin, especially in the area of San José da Boa Morte.

6.4.1.2 Point source pollution - Domestic sewage and other urban effluent

The lack of sewage and industrial waste treatment has been identified as the present and future direct environmental pressure to water quality in the municipalities and urban settlements in the Guapi-Macacu river basin. (Pedreira et al., 2009).

In 2002, Ribeiro and Kjerve strongly recommended that in order to improve the water quality of the Guanabara Bay, it is necessary the political will and economic investment to treat 80%-90% of all domestic and industrial wastes appropriately. Specifically, it is highly convenient to introduce secondary sewage treatment (Ribeiro et al., 2002). Eventhough, programs and initiatives were undertaken by the State Water and Sewage Company (CEDAE) of Rio de Janeiro to construct treatment plants in the metropolitan area , for the growing urban population of the river basin, especially in the municipality of Cachoeiras de Macacu where the population size is 57,300 (2009); sewage treatment plants or networks has not been constructed.

Collected information shows that the municipality of Cachoeiras de Macacu has a key role to play in the negative impact of water quality for water supply to Nitero and Sáo Gonçalo. Firstly, this municipality has 47% of households connected to the treatment network, 7% throw their sewage in open ditches and 7% launch straight into rivers; while

17% of the treated sewage is by septic tanks and 20% is connected to a pit. Secondly, the headwaters of the Macacu river passes through the municipality of Cachoeiras de Macacu, Japuba and Papucaia before reaching the treatment plant for water supply, Imunana-Laranjal, to other municipalities. Strangely, in Cachoeiras de Macacu the demand of water supply and sewage treatment are of the same fate since in general rural areas of the municipalities in the river basin get water supply from wells and springs (Pedreira et al., 2009).

A short exercise was done to show the negative impact of the increasing human population in a rural or urban area through their domestic sewage because those residues are rejected to the water bodies and tributaries contributing to the eutrophication. According to Arceivala (1981) each inhabitant eliminates, on average, 0.002 kg of phosphorus (P) and 0.008 kg of nitrogen (N) per day, through the sanitary sewage. This exercise involves the annual load of these elements released by the population of Cachoeiras de Macacu, Guapimirim and Itaboraí.

Figure 16 show the results of nitrogen (N) and phosphorus (P) level from the population estimates of 2009. 12% of Itaborai area is in Guapi-Macacu river basin, but it produces majority of N and P, followed by Cachoeiras de Macacu and Guapimirim

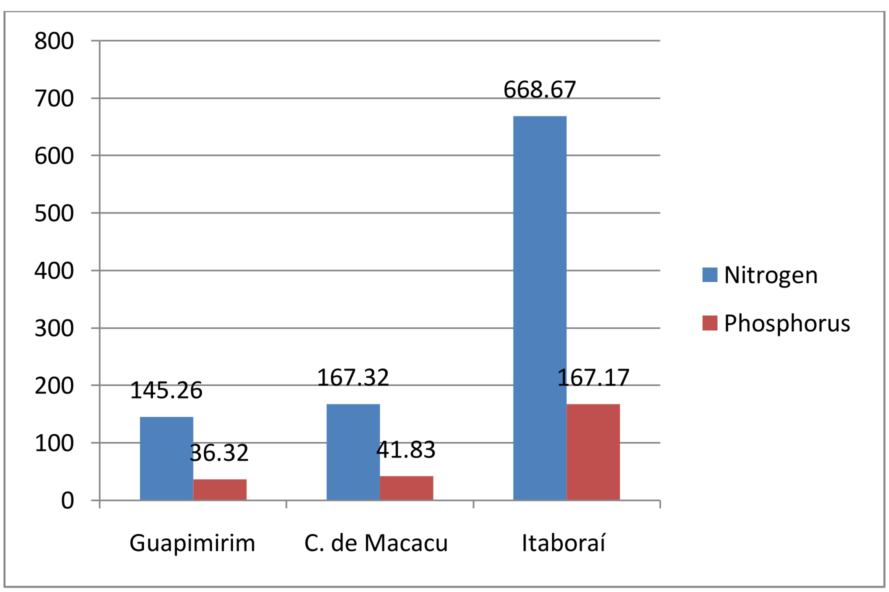


Figure 16: Nitrogen and phosphorus levels (mg/L.y) wasted at the GMRB.

6.4.1.3 Point source pollution - Industrial waste and effluents

The number of Industrial establishment in the river basin is increasing. Table 17 shows the list of industries from the registration system from INEA for 2009.

Table 17: List of Industries in Guapi-Macacu River Basin[30]

Identification	Location	Description	Latitude	Longitude
Companhia de Bebidas do Rio de Janeiro (Schincariol)	Cachoeiras de Macacu	Beverage	22°31'18.88	42°42'1.94"
Cooperativa Cia. do Leite	Cachoeiras de Macacu	Dairy products	22°33'39.07	42°47'27.20
W.T. de Sá Laticínios ME	Cachoeiras de Macacu	Dairy products	22°27'50.86	42°39'09.90
Maraporã Cooperativa Agropecuária Industrial Ltda	Maraporã - Cachoeiras de Macacu	Processing	22°33'59.45	42°49'29.99
Banana & Cia.	Cachoeiras de Macacu	Fruit Processing	22°32'37.08	42°41'13.00
Fumel Indústria e Comércio Ltda	São José da Boa Morte - Cachoeiras de Macacu	Fruit Processing	22°34'00.54	42°49'30.02
Água Mineral Cascataí Ltda	Guapiaçu - Cachoeiras de Macacu	Mineral Water	22°25'01.03	42°43'56.20
Riograss Gramas e Gramados	Cachoeiras de Macacu	Grass	22°32'48.03	42°41'09.05
Faresa Indústria e Comércio Ltda	Valério - Cachoeiras de Macacu	Mineral Water	22°26'31.30	42°37'21.00
Salsicharia Guapiense Ltda ME	Limoeiro - Guapimirim	Meat Products	22°30'25.23	42°58'35.36
Souza Neto e Chavão Ind. e Com. de Gen. Alim. Ltda ME	Vila Olímpia - Guapimirim	Food	22°31'56.86	42°59'24.44
Serra Azul Água Mineral Ltda	Vale das Pedrinhas - Guapimirim	Mineral Water	22°38'24.10	43°00'09.60

The increase number of industries in the river basin will have great impact, apart from the economic impact in providing jobs; it will also impact the water demand, consumption and the generation of industrial wastes and effluents. According to Costa (1999) the lacteous industry Cooperativa Cia. do Leite stopped their production but in its place, another industry was settled, the Schincariol beer industry and all that near to the headwaters of the Macacu River.

Another primary activity that has become popular is the extraction of sand, stone and water resources for the sale of mineral water and supply industries (BioAtlântica, 2009). However, the since the establishment of the Environmental Protected Area Macacu River, sand extraction has been banned.

[30] Source: (Andrade et al., 2010)

In 2006, the Guapi-Macacu River basin was classified as an urban Industrial because of three ongoing constructions:

- COMPERJ is the Petrochemical Complex being constructed in the municipality if Itaborí.
- GasDuc3 ‘Gas passage’ from PETROBRAS connecting the fluminence municipality of Macaè to the refinery in Duque de Caxias.
- Arco Metropolitano do Rio de Janeiro. A highway leading to the port of Sepetiba.

According to the Environmental Impact Report (EIA), the COMPERJ have a demand of around 1.5 m3 / s of water, to increase production of petrochemicals, with the processing of about 150,000 barrels/day of domestic heavy oil and will be developed for production of thermoplastic resins and fuels (PETROBRAS, 2008). However, for the members of Watershed Committee of the Guanabara Bay this demand is underestimated and is not yet clear whether the basins in question have the capacity to meet additional demand generated by the installation of the complex (Pedreira et al., 2009).

The Report Proyecto Macacu recommends the construction of small dams in the Macacu river south of the river basin as an alternative to meet the water demand of COMPERJ (Hora et al., 2010). Based on a discussion with the technical group that made the Proyecto Macacu, there are continuos initiatives to find other alternative for water demand of the petrochemical complex. The results from the water quality survey done by Proyecto Macacu demonstrate that the headwaters of Macacu river are of good water quality, the water quality conditions and standards of resolution CONAMA #375/2005 and Ordinance #518/2004 were used.

6.4.2 Relevance of water monitoring sites selection

Figure 17 shows the current monitoring sites for CEDAE, AMAE-CM, INEA and ANA.

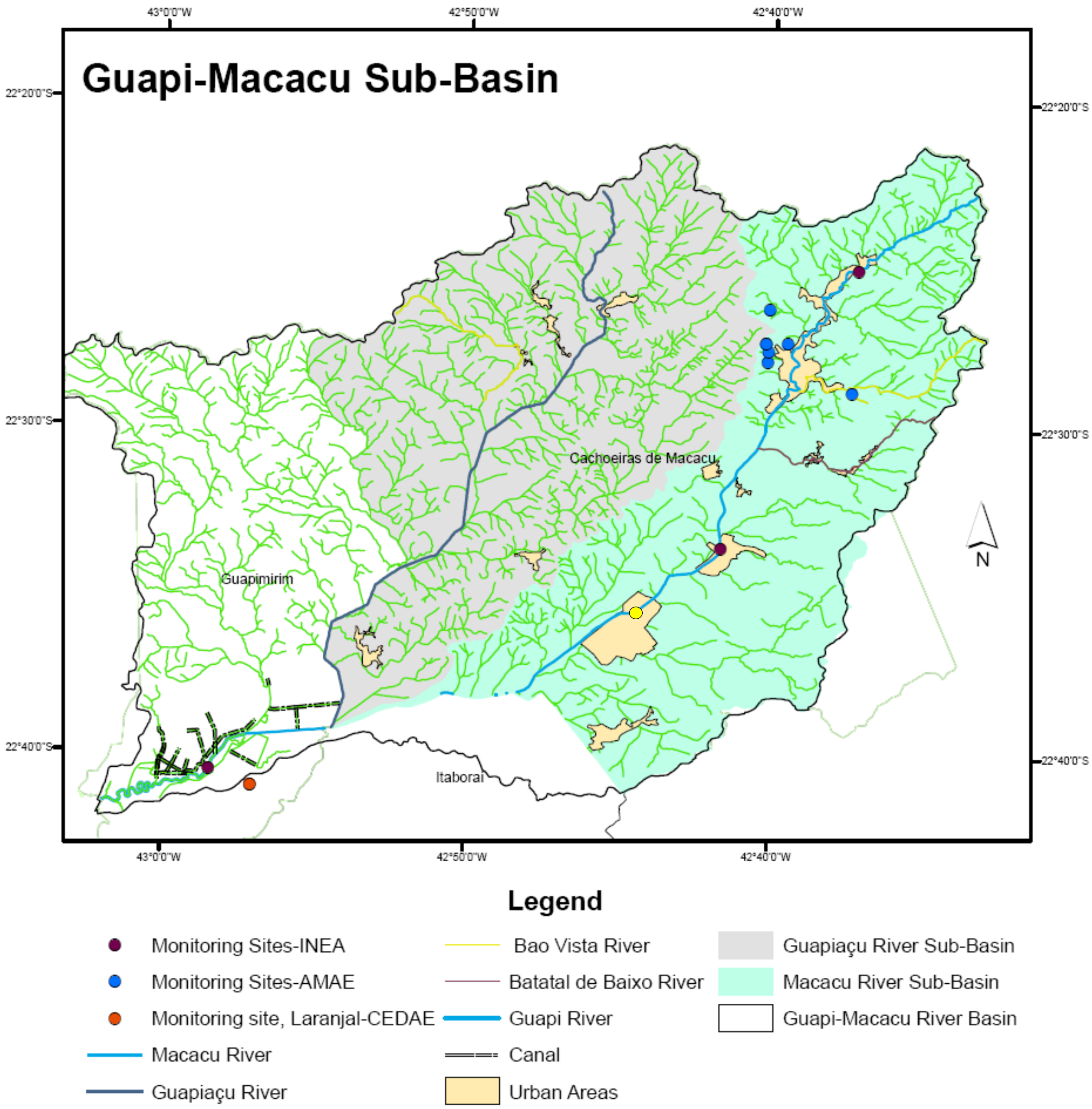


Figure 17: Water quality monitoring sites in GMRB

This map geographically show that in the Macacu river sub-basin, ANA obtains its water quality data from one monitoring site located at Ribeira park, Papucaia (yellow point).INEA has two monitoring sites, in the Macacu river, in Cachoeiro de Macacu city and Japuiba. Either of the mentioned governmental agencies does not have sampling sites in Guapiaçu river sub-basin. However, AMAE-CM, being the local authority has monitoring sites in the two river sub-basins, seven in Macacu river sub-basin and two in Guapiaçu river sub-basin. In contrast, CEDAE has no monitoring sites in the two sub-basins. The seven sites of AMAE-CM in the Macacu river sub-basin are distributed closely to Cachoeiras de Macacu City, the commercial and residential urban area in the municipality. These sites are the sources of water supply for human consumption. Two sites of the seven are in different tributary of the Macacu river, Boa Vista and Tocas Tuim.

According to the Interviewee, these to water sources have good water quality and abundant water. The two sites that are located in Guapiaça river sub-basin are both wells, and are in two urban areas, Bonanza and Maraporâ. Bonanza is the community located in the intensive farming area of São José da Boa Morte.

Evidently, the land use changes, establishments of industries and untreated domestic sewage have rapidly occurred in the studied river basin, having an impact on the quality of water, specifically:

1. Intensive farming contributing to the diffuse sources of water pollution. Thus, the river basin will receive urban effluents with extremely toxic agrochemicals. This agricultural activity has occurred in areas, like São José da Boa Morte, a low population density community, where neither INEA nor AMAE have sampling sites. Even though, AMAE has identified a monitoring site in Bonanza but there are not reports of samples taken at this site. Another farming area is Batatal, where farming occurs alongside the river bank.
2. Potential Industrial effluent. The increase numbers of industries establishment are widely distributed in the sub-basins. Apart from the construction of COMPERJ, there is also water purifying industries.

3. Domestic sewage. This type of water pollution is considered very serious in the city of Cachoeiras de Macacu because AMAE presently only conducts water quality monitoring at water sources for human consumption. Moreover, the water of the Macacu river that passes through Chacoeira de Macacu city, also passes through other two community downstream and finally reaches the Imunana Canal, capture area by CEDAE for human consumption to metropolitan cities.

The INEA and AMAE-CM are the only institutions conducting water quality monitoring in the Guapi-Macacu river basin, since CEDAE has its monitoring site in its pumping station which is not located in the sub-basins of Guapiaça and Macacu rivers. Therefore, with just two monitoring sites by INEA and closely located monitoring sites by AMAE-CM it is evident that both sets of monitoring sites are irrelevant because their spatial location do not supply representative information to monitor the present and potential water quality impacts caused by the identified environmental pressures.

The general objective for conducting water monitoring programs is reflected on the economic and social activities in a basin. Ongley (2000) and Ward et al (1986) classified a water quality monitoring systems as *data rich but information poor*, because of unclear defined objective of the monitoring system. However, the two water quality monitoring in the studied river sub-basins can be classified as such but specifically because of limited sample sites by INEA and closely located monitoring sites by AMAE-CM.

The key to understand and solve water quality challenges is the part done by the water monitoring institutes. This part consists of collecting, storing, analyzing, and sharing water quality data to protect human and ecosystem health.

6.4.3 Water quality data sharing

In GMRB, the sharing of water quality data is not as effective as at the national level, where ANA has played a major role in establishing information sharing system for water monitoring and water resource management. The National Water Agency (ANA) has established systems of information (data bases, center of discussions, and information linkage about water quality/quantity, a Monitoring Networks and Management) hence committing to the general objective of National Systems of Information about Water Resource Management in Brazil (ANA, 2008; ANA, 2009; ANA, 2002-2010). Table 18 shows the programs and internet links of water resource information sharing.

Table 18: National information sources of water resource management in Brazil

Name	Description	Websites
	Water Resource Management information Source	
Proágua Nacional	Its mission is to structure the water resource management, with emphasis on institutional strengthening of all stakeholders involved in water resources management in Brazil, implementation of water infrastructure and promoting the rational use of water resources.	http://proagua.ana.gov.br/proagua/
Conjuntura dos Recursos Hídricos	This is a recently constructed information website that contains the current situation of water resources in Brazil.	http://conjuntura.ana.gov.br/
Atlas of urban Water Supply	Consist of a diagnosis of current conditions of water supply from municipal, identifies the main alternative techniques (for springs and water production systems) and management actions to ensure meeting the demand for human supply for 2015 and 2025. Studies also include sewage treatment actions necessary for the protection or restoration of water quality of adapted springs.	http://atlas.ana.gov.br/Atlas/forms/home.
	Water Quality Information Sources	
HidroWeb	Database with all information collected by the hydrometeorological network.	http://hidroweb.ana.gov.br/
Programa Produtor de Água	This program focus on the reduction of erosion and siltation of water sources in rural areas, providing improved water quality and increasing the flow of media streams in a watershed of strategic importance for the country	http://www.ana.gov.br/produagua/

This research has found a lack of water quality data management of information lacking share mechanism of diffusion of the information between the two water monitoring governmental institutions, AMAE-CM and INEA. As stated, the Environmental Monitoring Branch of INEA monitors all the state rivers in Rio de Janeiro to comply with its responsibilities. While AMAE-CM monitors the water sources in the municipality of Cachoeiras de Macacu. It seemed obvious that AMAE-CM should provide collected and analyzed water quality data to INEA as an information provider from the local level to the state level, to have a better panorama of the water quality of the river basin with the seven monitoring sites.

Therefore, a database of collected analyzed water quality data should be established at the state level. ANA and INEA should take the initiative to establish the database and accessibility of information by water resource management institutions. As ANA is achieving the objective of the national system of information, INEA should work to achieve the state and river basin system of information.

Link to this observed gap in water quality data sharing is the type and number of parameters and frequency being use to collect to analyze the water quality. It is not a lack of data, but rather a variation of unnecessary data to assess the impacts of industrial facilities and agriculture activities, like intensive farming along the river banks.

6.4.4 Parameters and frequency

The question is for what the water quality data is needed and be collected? It is essential to propose strategies that improve the water quality monitoring system. In the case of GMRB, Table 19 consists of the set of parameters and sampling frequency that the three monitoring institution do in the river basin.

Table 19: Comparison of parameters and frequency in GMRB.

Parameters	INEA		AMAE		CEDAE	
	4 Sites	Frequency	9 Sites	Frequency	1 Sites	Frequency
Physo-chemical						
DO	All	Monthly	Nil	Nil	Canal	Monthly
BOD	All	Monthly	Nil	Nil	Canal	Monthly
COD	All	Monthly	Nil	Nil	Nil	Nil
pH	All	Bimonthly	All	Four times a day	All	Monthly
Color	Nil	Nil	All	Four times a day	All	Monthly
Chlorine	Nil	Nil	All	Four times a day	Nil	Nil
Conductivity	All	Bimonthly	Nil	Nil	Nil	Nil
Alkalinity	All	Bimonthly	Nil	Nil	Nil	Nil
Total Non-Filtered Waste	All	Bimonthly	Nil	Nil	Canal	Monthly
Total Waste	All	Bimonthly	Nil	Nil	Canal	Monthly
Turbidity	All	Bimonthly	All	Four times a day	All	Monthly
Ammonia	All	Bimonthly	Nil	Nil	Nil	Nil
Nitrogen Dioxide (Nitrite, NO_2-)	All	Bimonthly	Nil	Nil	Nil	Nil
Nitrate (NO_3-)	All	Bimonthly	Nil	Nil	Nil	Nil
Phosphates (PO_4)	All	Bimonthly	Nil	Nil	Nil	Nil
Total Phosphate	All	Bimonthly	Nil	Nil	Nil	Nil
Manganese	Nil	Nil	2 sites (wells)	Bimonthly	Nil	Nil
Cyanide	All	Bimonthly	Nil	Nil	Nil	Nil
Iron	All	Bimonthly	2 sites (wells)	Bimonthly	Nil	Nil
Free Chlorine Residue	Nil	Nil	7 sites	Monthly	WTP	Monthly

(CRL)						
Microbiological						
Total Coliform	All	Monthly	All	Bimonthly	All	Monthly
Fecal Coliform	All	Monthly	All	Bimonthly	All	Monthly
Heterotrophic Bacteria	Nil	Nil	Bonanza	Bimonthly	All	Monthly
Floating material	All	Monthly	Nil	Nil	All	Monthly
oil and grease	All	Monthly	Nil	Nil	All	Monthly
Organic parameters	All	Monthly	Nil	Nil	All	Monthly
Inorganic Parameters	All	Monthly	Nil	Nil	All	Monthly

Table 19 shows the types of parameters measured by INEA, AMAE and CEDAE. These parameters are from the type (1) physical-chemical, (2) microbiological, (3) organic and (4) inorganic. The parameters in italics and bold (6) are measured by the three mentioned institutions. While the parameters in italics (7) along with the organic and inorganic parameters are measured by INEA and CEDAE.

The frequency of sampling varies between the provisions of resolution CONAMA # 357/2005 and Ordinance # 518/2004. For the ordinance # 518/2004, the frequency of sampling in a monitoring site for physical-chemical parameters are taken four-times a day, the microbiological parameters are taken twice a month. AMAE and CEDAE use the parameters in ordinance # 518/2004 and INEA uses the parameters of resolution CONAMA # 357/2005.

The European Union (EU) Water Framework Directive passed in 2000, placed water quality at the center, including the types of parameters, methods for analysis and the frequency of sampling; having the target of achieving a "good" ecological status of the water bodies by 2015 (United Nations Environmental Program, 2010).

Brazil has similar provision in its national water law as of the EU Water Framework Directive; it only differs in establishing parameters and frequency of sampling to achieve a "good" ecological status of the water bodies. However, ANA has started a national water quality monitoring program (PNQA) to achieve a standardized monitoring program with the focus areas of monitoring sites selection, parameter and frequency, and water data sharing mechanisms by hydrographical regions and based on economic activities in the regions. Rio de Janeiro monitoring institute (INEA) needs to collaborate in the implementation of the PNQA in the river basins in the federal state. Since the WQI is being use as a reference in determining the number of parameters for the PNQA, INEA has the opportunity to start a local standard monitoring program in GMRB with the collaboration of AMAE, GBB East and NGOs of conservation units in the river basin.

6.4.5 Contribution to the Management Plan

The Management Plan of the Environmental Protected Area (EPA) of the Macacu River (2009) has classified the entire Guapi-Macacu River Basin in various use zones (See Annex F). The following zones are important for improving water quality monitoring in the river basin:

- Agriculture Use Area 1: very intensive and extensive agriculture production.
- Agriculture Use Area 2: more extensive agriculture production and livestock.

The Direct Plan of Guanabara Bay Basin has classified the rivers as appropriate to use in the Guapi-Macacu River Basin area (BioAtlântica, 2009) as follows.

Class 1 – Boa Vista River and Batatal de Baixo River (tributaries)

Class 2 – Macacu River and Guapiaçu River (headwaters)

The goal of the Management Plan EPA of Macacu River is the conservation and protection of Macacu and Guapiaçu rivers and its tributaries. Hence the planned Water Monitoring Program (WMP) for the river basin is of utmost importance. Two of the objectives of the WMP is to indicate potential areas of monitoring and to define the methodologies being used, including the technical and participatory evaluation.

The direct contribution of this thesis work in the initial steps to implement the WMP is the definition of methodologies being used, mainly for the technical evaluation in the river basin. This research work has identifies essential information about the current water quality monitoring system for the state of Rio de Janeiro conducted in the sub-basins of Guapi-Macacu River Basin. Also, there is a brief description of the institutions involved in the water resource management and water quality management. The most important finding of this work was the irrelevance of the current monitoring sites of INEA and AMAE-CM since the collected sample is not representative to the identified environmental pressures in water quality in the river basin. The results of this research work identified and described the standards and methodologies used in the water monitoring. The listed programs in the Direct Plan of Guanabara Bay Basin describing the improvement of water quality can include the improvement of the water quality in the Guapi-Macacu River Basin.

Conclusions and Recommendations

The significance of the water monitoring system, as an important component for water resource management at the river basin, is stated in the Brazilian National Policy of Water Resources. The National Policy implement the national and state water resource management system, the River Basin Management Plan and the water body classification based on their multiple uses for water use charges. At the national level, ANA is responsible in maintaining a national monitoring network in every hydrographical region. Assisting river basin committee and state government department in their water monitoring system to collect and make available the information to state and national water and environmental departments. In Rio de Janeiro, as described with the case study of the Guapi-Macacu river basin, the State Institute of the Environment conducts water quality monitoring within their environmental monitoring system. This thesis has mainly focused on the water quality monitoring system components: monitoring program, data collection and data handling..

The establishment of INEA has a new approach about the natural resource management based on the interdisciplinary and the integration of the public participation from the hydrographical regions of Rio de Janeiro. At a glance, this new approach can be seen as an ambitious and complex approach because with less than two years old, there are still limitations and adjustments to be made. An interviewee specified the limitation of infrastructure for storage and working space. In the other hand, uncertainty has the advantage since it is an innovating approach in integrated resource management, it can be seen as a simple approach to accomplish the mission statement with the assistance of many sectors especially the academic and the public sector putting major emphasis in public participation via the basin committee.

The effectiveness of the monitoring system in the sub-basins of Guapi-Macacu was identified within the component of Data Collection and Reporting of data. In the Data Collection component it was concluded that the current sampling sites are irrelevant because their spatial location do not supply representative information to monitor the present and potential water quality impacts caused by the identified environmental pressures. Another observation was that the two water quality monitoring agencies have no data sharing in supplying collected data amongst themselves, although each have well established objectives, water quality conditions and standards, collection schemes and data analysis.

Overall, the water quality of the rivers and tributaries in the Guapi-Macacu River Basin can be kept within the parameters limits set for freshwater class one and two, with the active participation of the sub-committee at the East section of the Guanabara Bay, and therefore be a prime example on the timely and spatial use of the water resource in a sub-basin.

The research found limited financial information on the cost of conducting water quality monitoring; hence a cost-effectiveness analysis was unable to be done. Semi-structured interviews with two key informants resulted in general cost for doing water quality monitoring. It was decided in this research paper to briefly describe the source of funding from where water monitoring system receives financial funding.

According to the Direct Plan of the Guanabara Bay Basin (2005), the State Water Resources Fund (FUNDRHI) is the financial system to support water resource management. From this Fund, water quality monitor programs are financed. The Fund is financed and refinanced with the legal instrument of charging the water users a minimal percentage for the use of water. As the Direct Plan dictates, the charging fee from 2005 to 2009 is of R$0.02/m3 from, R$0.03/m3 from 2010 to 2015, R$0.04/m3 from 2015 to 2019 and R$0.05/m3 from 2020 onward. The main water user in the Basin is CEDAE. (Ecologus-Agrar, 2005).

The following are recommendations to strategically improve water quality monitoring for the Guapi-Macacu River Basin Management Plan.

- Do a Cost-Benefit Analysis of the two current water quality monitoring in GMRB. Thereafter, propose an alternative water quality monitoring system (Monitoring objectives, Plan, monitoring programming, data collection and data handling) for the GMRB, the sub-committee of the eastern section of the Guanabara Bay Basin (GBB East) and INEA must take the initiative.

- Elaborate a Survey of potential monitoring sites in GMRB, considering the identified environmental pressures to the water quality. As a recommendation from the results of this work is to establish one monitoring site along the Guapiaçu river in the Agricultural Use Area one, and one monitoring site in the Agricultural Use Area 2. One monitoring site industrial effluent production areas.

- Elaborate a list of accepted number of parameters, frequency and format by the GBB East, AMAE and INEA. This list is essential to avoid duplication of water quality parameter measurement in the selected monitoring sites.

- Systematic scheme between INEA and AMAE to do water quality sampling collection to avoid double collection.

- Establish an information exchange mechanism between AMAE and INEA. At the same time, establish a database of the collected and analyzed water quality data to be accessed by water resource management institutions.

- Continuation of public participation and awareness with industries and conservation organizations in the river basin about maintaining and reaching the good water quality of the river basin for continuous and future use. Since COMPERJ is being constructed in the south of the rive basin, allow the participation of PETROBRAS in maintaining the good water quality of the GMRB by proposing programs and project to PETROBRAS for funding.

Bibliography

United Nations Environmental Program. (2010). *Clearing the Water: A Focus on Water Quality Solutions.* Nairobi, Kenya: UNEP and Pacific Institute.

Agência Nacional de Água . (2002). *The evolution of the Organization and Implementation of Water Basin Management in Brazil.* Brasilia: ANA.

Agencia Nacional de Água. (2009). *Conjuntura dos Recursos Hidricos no Brasil 2009.* Brasilia: ANA.

Agência Nacional de Àgua. (2008). *Relatório de Atividades.* Brasilia: ANA.

Agência Nacional de Águas. (2005). *Panorama da Qualidade das Águas Superficiais no Brasil - Cadernos De Recursos Hídricos 1.* Brasília -, DF: Ministério do Meio Ambiente.

ANA. (2008, June). *Agência Nacional de Àgua* . Retrieved June 28, 2010, from Gestão da Rede Hidrometeorológica: http:/www2.ana.gov.br/Paginas/imprensa/noticoa.aspx?id_noticia=8747

ANA. (2009). *ATLAS - Abastecimento Urbano de Agua*. Retrieved July 7, 2010, from ATLAS - Abastecimento Urbano de Agua website: http://atlas.ana.gov.br/atlas/forms/analise/RegiaoMetropolitana.aspx?rme=107

ANA. (2009). *Comitês de Bacias Hidrograficas*. Acesso em 07 de July de 2010, disponível em Comitês de Bacias Hidrograficas website: http://www.cbh.gov.br

ANA. (2009). *Comitês de Bacias Hidrograficas*. Retrieved July 07, 2010, from Comitês de Bacias Hidrograficas website: http://www.cbh.gov.br

ANA. (2009). *Conjuntura de Recursos Hidrico do Brasil*. Retrieved July 7, 2010, from Conjuntura de Recursos Hidricos do Brasil Website: http//conjuntura.ana.gov.br/

ANA. (2002-2010). *Estaões ANA - Pesquisa Avançada*. Retrieved July 7, 2010, from SGI/ANA. DotNetNuke Coporation: http://www.ana.gov.br/portalsnirh/Esta%C3%A7%C3%B5esdaANA/tabid/359/default.aspx

ANA. (2004). *Management Report, 2003.* Brasilia: Ministry of Environment, Brazil.

Andrade, E., Silva, I., & Dias Gonçalves, L. (2010). Coordenadoria de Usos e Potencialidades Agrícolas. In *Proyecto Macacu.* Rio de Janeiro.

Bartram, J., & Ballance, R. (Eds.). (1996). *Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies ands Monitoring Programmes.* Washington, D.C: UNEP & WHO.

Benavides, Z., Pezza Cintrão, R., Cardoso Fidalgo, E. C., Bardy Prado, R., & Gomez Pedreira, B. d. (2009). *Consumo e Abastecimento de Água nas Bacias Hidrograficas dos Rios Guapi;Macacu e Caceribu.* EMBRAPA Solos. Rio de Janeiro: EMBRAPA Solos.

Berg, M., & Willinder, M. (2006). *Fear in everyday life- A Qualitative Study on the Everyday Routines of Burundian and Conglese Women Residing in Tanzanian Refugee Camps.* Malmö: Malmö University.

BioAtlântica. (2009). *Projecto entre Serras e Águas: Pano de Manejo APA da Bacia do Rio Macacu.* Rio de Janeiro: BioAtlântica.

Bunce, L. (2000). *Socioeconomic manual for coral reef management.* (Vols. ISBN 0-642-32205-8). Townville, Australia : Institute of Marine Science .

Cachoeiras de Macacu . (n.d.). Retrieved July 3, 2010, from http://www.macacu.com/macacu/index.php?option=com_content&task=view&id=13&Itemid=33

Castro, J. S., & Confalonieri, U. (1999). Pesticides use in Cachoeiras de Macacu, Rio de Janeiro, Brazil. *Ciência & Saúde Colective , 10* (2).

Central Pollution Control Board. (2008). *Guidelines for Water Quality Management, Parivesh Bhawan, East Arjun Nagar.* Delhi.

Collins, S. (2010, April 22). Water quality monitoring in Guapi-Macacu River Basin. *DINARIO Project.* Josué Aké. Rio de Janeiro.

Companhia Estadual de Agua e Esgoto (CEDAE). (2006, January 1). *Rio de janeiro Relactorio.* Retrieved April 21, 2010, from Nova CEDAE Website: http://www.cedae.com.br/

Costa, J. P. (2006). Roteiro para o entendimento de seus objetivos e seu Sistema de gestao. In J. L. Albuquerque, *Série Cadernos da Reserva da Biosfera da Mata Atlantica* (Vol. II). Sao Pualo: Consórcio da Mata Atlantica, Conselho Nacional da Reserva da Biosfera da Mata Atlantica, UNESCO, Fundacao MacArthur.

Costa, J. R. (2008). Impactos Ambientais na bacia hidrográfica de Guapi-Macacu e suas conseguências para o abastecimento de água nos municípios do leste da Baía de

Guanabara. In *Série Gestão e Planejamento Ambiental* (p. 26p). Rio de Janeiro: CETEM-MCT.

Costa, M., & Gomez Zoby, J. L. (2007). *Panorama do enquadramento dos corpos d água do Brasil e Panorama da qualidade das águas subterrâneas no Brasil* (Vol. Caderno de Recursos Hídrcos 5). (J. G. Lotufo Conejo, Ed.) Brasilia, DF, Brazil : Agencia Nacional da Água (ANA).

Davis, M. D. (2007). Integrated Water Resource Management and Water Sharing. *Journal of Water Resources Planning and Management* , 427-445.

Dworak, T. P. (2008). *Selecting cost effectiveness measures under the EU Water framerk.*

Ecologus-Agrar, C. (2005). *Plano Director de Recursos Hidricos da Bacia de Guanabara, Rio de Janeiro. Relatorio Final -Sintese.* Rio de Janerio.

EMBRAPA Solos. (2009). *Consumo e Abastecimento de Água nas Bacias Hidrográficas dos Rios Guapi-Macacu - RJ.* Empresa Brasileira de Pequisa Agropecuária , Centro nacional de Pesquisa de Solos. Rio de Janeiro : Ministerio da Agricultura, Pecuria e Abastecimento.

European Environmental Agency . (1999). *Environmental Indicators: typology and overview.* Technical Report # 25.

Feas Vasquez, J. (2003). *A methodology for policy analysis in water resources management.* Venice, italy : Fondazione Eni Enrico Mattei.

Fidalgo, E. C., Bueno de Abreu, M., Barroso de Moura, L., Pinto Godoy, M. D., & Gomez Pedreira, B. d. (2008). *Uso e Cobertura da Terra na Bacia Hidrográfica do Rio Guapi;Macacu.* EMBRAPA Solos. Rio de Janeiro: EMBRAPA Solos.

Fidalgo, E. C., De Carvalho Junior, W., G. Pedreira, B. d., & Da Silva Chagas, C. (n d). Adequação de uso da Terra e detecção de conflictos na bacia hidrográfica do rio Guapi-Macacu, RJ. *XXXII Congresso Brasileiro de Ciência do Solo: "O Solo e a Produção de Bioenergia: Perspectivas e Desafios".* Rio de Janeiro.

Fundação CIDE & SERLA. (2008, January). Map: Regiões Hidrográficas do Rio de Janeiro.

Garrido, R. (n.d). Institutional Aspects of Water Quality Management in Brazil. *Abstract*.

Garrido, R. (2001). *Water Resources National Policy in Brazil: Contributing Paper.* Brazil: Ministry of Environment.

Global Water Partnership and International Network of Basin Organizations. (2009). *A Handbook for Integrated Water Resources Management in Basin.* Sweden: Scriptoria and Elanders.

Global Water Partnership. (2007). *Effective Water Governance: Learning from the Diagues.*

Global Water Partnership. (2007). *Effective Water Governance: Learning from the Diagues.*

Golder, B. a. (2005). *WWF Standards of Conservation Project and Programme Management. Cross-Cutting Tool Stakeholder Analysis .* Foundations of Success, WWF-US and ARTEMIS Services.

Grael, A. (2007). FEEMA Activitade. Rio de Janeiro.

Hora, M., & Costa Gonçalves, P. H. (2010). *Proyeto Macacu .* Rio de Janeiro .

IPCC. (2007). *Climate Change 2007: Synthesis Report.* Geneva, Switzerland.

Iza, A. a. (2009). *RULE - Reforming Water Governance.* Gland, Switzerland: IUCN.

Kessler, J. J. (2003). *Strategic Environmental Analysis (SEAN): Short Version.* Amsterdam: AIDenvironment.

Maia Castro, J. S., & Confalonieri, U. (2005). Pesticide use in Cacheiras de Macacu, Rio de Janeiro, Brazil. *Ciência e Saúde Coletiva* (volume 10 no. 2).

Mazzola, M. (2009, April). SITUAÇÃO DO MONITORAMENTO DE QUALIDADE DE ÀGUA NO BRASIL. PROGRAMA NACIONAL DE AVALIAÇÃO DA QUALIDADE DAS ÁGUA - PNQA. *ANA PowerPoint Presentation* .

Ministerio da Saude. (2005). *Portaria MS No.518/2004.* Retrieved April 2010, from www.saude.gov.br/svs

Nanni, M. (2007). *Principles of Water Law and Administration: National and International. 2nd Edition .* London : Taylor and Francis Gruop .

Netto, O. C. (2005). *Water Resource Management in Brazil at the National Level.* National Water Agency, Brazil.

Neves, R. (2007). *Human-ecosystem interactions. Modelling DPSIR for all sites. Deliverable 2.16 MARETEC.* Portugal : Marine & Environment Technology Center. Instituto Superior Tecnico.

Ongley, E. D. (2000). Water quality management: Design, financing and sustainability considerations. *World Bank's Water Week Conference: Towards A Strategy For Managing Water Quality Management*, *II.* Washington, D.C.

Organization for Economic Cooperation and Development (OECD). (1994). *Environmental Indicators.* Paris .

Pedreira, B. C., Brady Prado, R., Cardoso Fidalgo, E. C., Pezza Cintrão, R., & Cáceres Benavides, Z. (2009). *Demanda e Oferta de Água nas Bacias Hidrograficas Guapi-Macacu e Caceribu em Área de Mata Atlântica - RJ.* Rio de Janeiro: EMBRAPA Solos & CPDA/UFRRJ.

Pedreira, B. C., Cardoso Fidalgo, E. C., & Bueno de Abreu, M. (2009). Mapeamento do Uso e Cobertura da terra da bacia hidrográfica do rio Guapi-Macacu, RJ. *XIV Simpósio Brasileiro de Sensoriamento Remoto.* Rio de Janeiro.

Pedreira, B. C., Cardoso Fidalgo, E. C., & Bueno de Abreu, M. (2007). *Proposta de Legenda para o Mapeamento do Uso e Cobertura de Terra na Bacia Hidrográfica do Rio Macacu.* Rio de Janeiro: EMBRAPA Solos.

PETROBRAS. (2008). *Relatório de Impacto Ambiental - RIMA Complexo Petroquímico do Rio de Janeiro .* Rio de Janeiro .

Porto, M. (2008). *Gestão de bacias hidrográficas. estudos avançados.* São Paulo.

Porto, M. (2008). The Brazilian Water law: A New Level of Participation and Decision Making. 175 - 182.

Ribbe, L. A. (2008). *Monitoring to support water quality management in North-Central Chile.* Chile.

Ribeiro, C. H., & Kjerfve, B. (2002). *Anthropogenic influence on the water Quality in Guanabara Bay, Rio de Janeiro, Brazil.* Rio de Janeiro, Brazil: Departamento de Geoquimica, Universidade Federal Fluminense.

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. (2009). The Brazilian Atlantic Forest> How much is left and how is the remaining forest distributed_ Implications for conservations.

Schmeer, K. (2004). *Policy Toolkit for Strengthening health Sector Reform: Section 2. Stakeholder Analysis Guidelines.*

Schrank, A. (2006). *The Case Study and Casual Influence. E.Perecman and S.Curran. A handbook for social field research. Essays & bibliographic sources on research design and methods.*

Soares Martins, J. P. (2009). *A Implementação da Cobrança pelo uso de recursos hídricos e Agência de água das bacias dos Rios Piracicaba, Capivari e Jundiaí - The Implementation of water use charges and water Agency in the Piracicaba, Capivari and Jundiaí river basins.* Agência Nacional de Águas. Brasilia: ANA, SAG.

Torrico, J. N. (2008). Study Area.

Tortajada, D. C. (2002). *Institutions for Integrated River Basin Management in Latin America.* Retrieved March 2010, from Third World Centre: www.thirdworldcentre.org

UN Water. (2006). *Mapping Existing Global Systems & Initiatives.* Stockholm: FAO on behalf of the UN-Water Task Force on Monitoring.

UNEP. (2003). *Global Environment Outlook (GEO) Project. In Latin America and Caribbean.* Costa Rica.

US Overseas Development Administration. (July de 1995). *Guidance Note on How to do Stakeholder Analysis of AID Projects and Programmes*. Acesso em 14 de May de 2010

Ward, R. C., & Peters, C. A. (2003). *Water Resources Impact: Seeking a common framework for water quality monitoring.* American Water Resource Association.

Ward, R. C., Loftis, J. C., & Mcbride, G. B. (1986). *The data-Rich but Information-Poor Syndrome in Water Quality Monitoring.*

Ward, R. L. (1990). *Design of water quality systems.* New York: Wiley.

Wirkus, L. (2006). *Water Governance. Bonn International Center for Convention.* Bonn: GTZ.

Wood, M. B.

World Bank. (2004). *Monitoring and Evaluation: Some tools, methods, & Approaches.* Washington.

Annex

Annex A: This section consist of the action guidelines of the National Water Law[31]

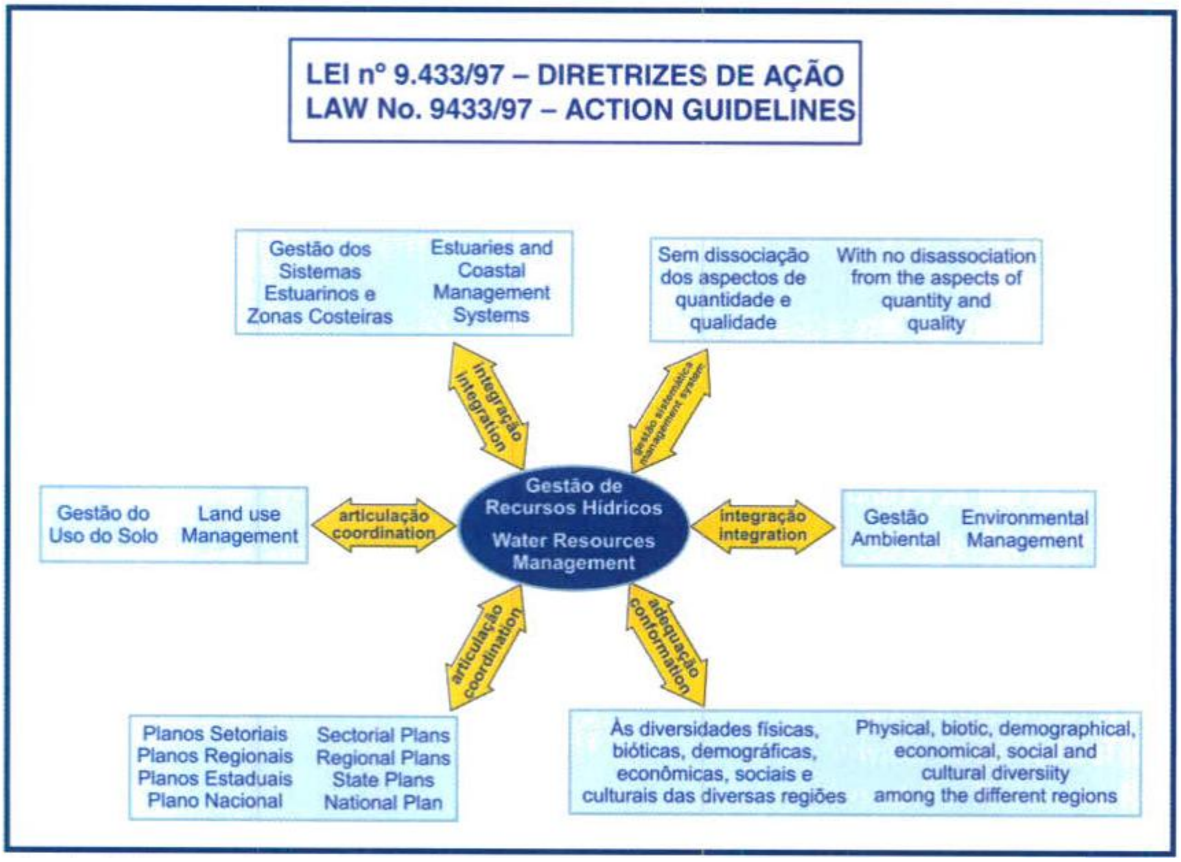
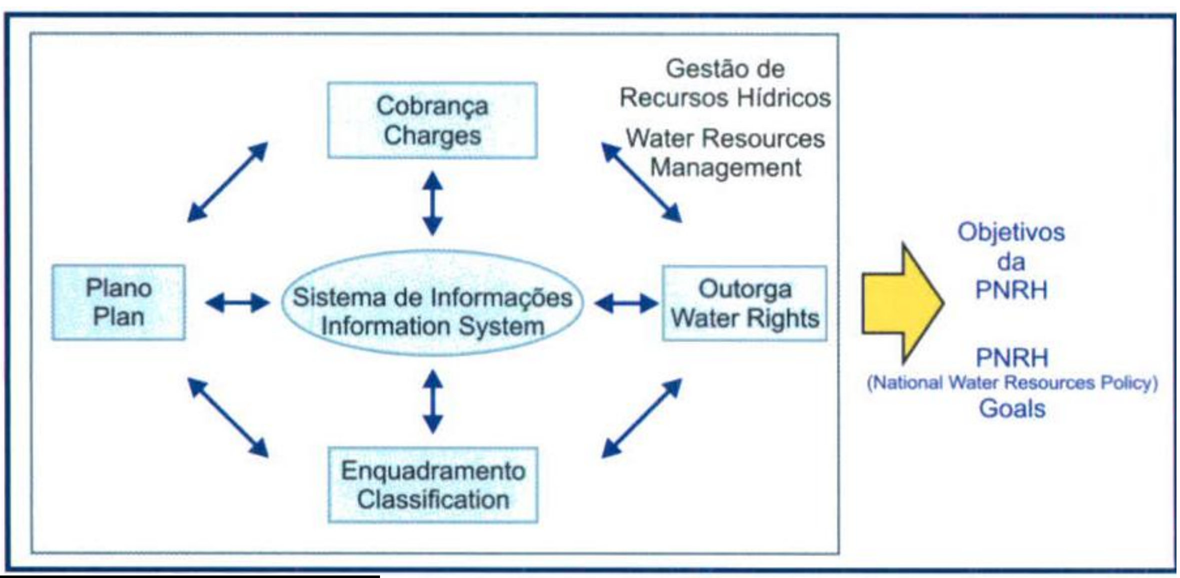


Diagram below is the water resources management instruments and their inter-relationships.



[31] Source: (Soares Martins, 2009)

Annex B: This section consist of tables with limits (standards) & units of water quality conditions for freshwater classes 1 to 4[32].

Freshwater: Class 1		
No chronic toxic effects on organisms based on criteria of environmental authority or national or international institutions		
Floating materials	Virtually absent	
Oils and grease	Virtually absent	
Taste or odor communicating substance	Virtually absent	
Anthropogenic-derived color	Virtually absent	
Solid waste	Virtually absent	
Total Fecal Coliform & E. Coli limits	Primary contact recreation (water for bathing) as Resolution CONAMA 274, 2000	Other uses: <200/100 ml of 80% or more of at least six samples, collected in 1 yr/bimonthly
DO	< 6 mg/L O^2	
$BOD_{5.20°C}$	≤ 3 mg/L O^2	
Turbidity	40 NTU	
True Color	Natural water body color (mg Pt)/L	
pH	6.0 – 9.0	

Freshwater: Class 2		
Not allow the presence of dyes from anthropogenic sources which are not removable by the process of coagulation, sedimentation and filtration, conventional		
Total Fecal Coliform & E. Coli limits	Primary contact recreation (water for bathing) as Resolution CONAMA 274, 2000	Other uses: <1000 /100 ml of 80% or more of at least six samples, collected in 1 yr/bimonthly
OD	< 5 mg/L O^2	
$BOD_{5.20°C}$	≤ 5 mg/L O^2	
Turbidity	100 NTU	
True Color	75 mg Pt/L	
pH	6.0 – 9.0	
Chlorophyll A	30 mg / L	
Cyano-bacterial density	up to 50 000 cells / mm 3 or 5 mL / L	
Phosphorus: with a residence time between 2:40 days	up to 0.030 mg / L, in lentic environments	
	up to 0.050 mg / L, intermediate environments	

[32] Source: Tables were made as stated in the Resolution CONAMA #357/2005

Freshwater: Class 3			
No chronic toxic effects on organisms based on criteria of environmental authority or national or international institutions			
Floating materials	Virtually absent		
Oils and grease	Virtually absent		
Taste or odor communicating substance	Virtually absent		
Anthropogenic-derived color	Virtually absent		
Solid waste	Virtually absent		
Total Fecal Coliform & E. Coli limits	Secondary contact recreation: <2500/100 ml of 80% or more of at least six samples, collected in 1 yr/bimonthly	Watering animals: <1000/100 ml of 80% or more of at least six samples, collected in 1 yr/bimonthly	Other uses: <4000/100 ml of 80% or more of at least six samples, collected in 1 yr
OD	< 4 mg/L O^2		
BOD5.20°C	≤ 10 mg/L O^2		
Turbidity	100 NTU		
True Color	75 mg Pt/L		
pH	6.0 – 9.0		
Chlorophyll A	30 mg / L		
Cyano-bacterial density for watering livestock	up to 50 000 cells / mm 3 or 5 mL / L		
Phosphorus: with a residence time between 2:40 days	up to 0.030 mg / L, in lentic environments		
	up to 0.050 mg / L, intermediate environments		

Freshwater: Class 4	
Floating materials, including foams	Virtually absent
Oils and grease	iridescence to be tolerated
Odor and appearance	Not objectionable
Easily sedimentable substances that contribute to the siltation of navigation channels	Virtually absent
DO	< 2 mg/L O^2
total phenols (substances that react with 4 - aminoantipyrine)	≤ 1.0 mg/L C_6H_5OH
pH	6.0 – 9.0

Annex B: This section consist of tables with limits and units of Inorganic and organic parameters of water quality for freshwater classes 1 and 2[33].

TABELA I - CLASSE 1 - ÁGUAS DOCES	
PADRÕES	
PARÂMETROS	**VALOR MÁXIMO**
Clorofila *a*	10 μg/L
Densidade de cianobactérias	20.000 cel/mL ou 2 mm^3/L
Sólidos dissolvidos totais	500 mg/L
PARÂMETROS INORGÂNICOS	**VALOR MÁXIMO**
Alumínio dissolvido	0,1 mg/L Al
Antimônio	0,005mg/L Sb
Arsênio total	0,01 mg/L As
Bário total	0,7 mg/L Ba
Berílio total	0,04 mg/L Be
Boro total	0,5 mg/L B
Cádmio total	0,001 mg/L Cd
Chumbo total	0,01mg/L Pb
Cianeto livre	0,005 mg/L CN
Cloreto total	250 mg/L Cl
Cloro residual total (combinado + livre)	0,01 mg/L Cl
Cobalto total	0,05 mg/L Co
Cobre dissolvido	0,009 mg/L Cu
Cromo total	0,05 mg/L Cr
Ferro dissolvido	0,3 mg/L Fe
Fluoreto total	1,4 mg/L F
Fósforo total (ambiente lêntico)	0,020 mg/L P

[33] Source: Tables were copied from the Resolution CONAMA #357/2005. Hence the language remains in Portuguese.

Fósforo total (ambiente intermediário, com tempo de residência entre 2 e 40 dias, e tributários diretos de ambiente lêntico)	0,025 mg/L P
Fósforo total (ambiente lótico e tributários de ambientes intermediários)	0,1 mg/L P
Lítio total	2,5 mg/L Li
Manganês total	0,1 mg/L Mn
Mercúrio total	0,0002 mg/L Hg
Níquel total	0,025 mg/L Ni
Nitrato	10,0 mg/L N
Nitrito	1,0 mg/L N
Nitrogênio amoniacal total	3,7mg/L N, para pH ≤ 7,5 2,0 mg/L N, para 7,5 < pH ≤ 8,0 1,0 mg/L N, para 8,0 < pH ≤ 8,5 0,5 mg/L N, para pH > 8,5
Prata total	0,01 mg/L Ag
Selênio total	0,01 mg/L Se
Sulfato total	250 mg/L SO_4
Sulfeto (H_2S não dissociado)	0,002 mg/L S
Urânio total	0,02 mg/L U
Vanádio total	0,1 mg/L V
Zinco total	0,18 mg/L Zn
PARÂMETROS ORGÂNICOS	**VALOR MÁXIMO**
Acrilamida	0,5 μg/L
Alacloro	20 μg/L
Aldrin + Dieldrin	0,005 μg/L
Atrazina	2 μg/L
Benzeno	0,005 mg/L
Benzidina	0,001 μg/L
Benzo(a)antraceno	0,05 μg/L
Benzo(a)pireno	0,05 μg/L
Benzo(b)fluoranteno	0,05 μg/L
Benzo(k)fluoranteno	0,05 μg/L
Carbaril	0,02 μg/L
Clordano (cis + trans)	0,04 μg/L
2-Clorofenol	0,1 μg/L
Criseno	0,05 μg/L
2,4–D	4,0 μg/L
Demeton (Demeton-O + Demeton-S)	0,1 μg/L
Dibenzo(a,h)antraceno	0,05 μg/L
1,2-Dicloroetano	0,01 mg/L
1,1-Dicloroeteno	0,003 mg/L
2,4-Diclorofenol	0,3 μg/L
Diclorometano	0,02 mg/L
DDT (p,p'-DDT + p,p'-DDE + p,p'-DDD)	0,002 μg/L
Dodecacloro pentaciclodecano	0,001 μg/L
Endossulfan (α + β + sulfato)	0,056 μg/L
Endrin	0,004 μg/L
Estireno	0,02 mg/L
Etilbenzeno	90,0 μg/L
Fenóis totais (substâncias que reagem com 4-aminoantipirina)	0,003 mg/L C_6H_5OH
Glifosato	65 μg/L
Gution	0,005 μg/L
Heptacloro epóxido + Heptacloro	0,01 μg/L
Hexaclorobenzeno	0,0065 μg/L
Indeno(1,2,3-cd)pireno	0,05 μg/L

Annex C: This section consist of the semi-structural questions used in the interviews of water monitoring technicians.

Name of the Interviewer	
Name of the Interviewee (*)	Technician
Agency/Department/Institution	**Instituto Estadual do Ambiente (INEA) *(State)***
Date	
Time	
Place	
Language (**)	

(*) Whether the interviewee is a public officer or not, ask for permission to use the name as a source of information. State that the answers will be used for research purposes only and they will be confidential if permission to use the name of the interviewee is denied.

(**) Interviews conducted in Portuguese

Water Quality monitoring (on the field)

1. What are the standards and norms to be complied to do water quality monitoring?
   a. Industries: Purifying water, petrochemical, chemicals
   b. Human Consumption
   c. Sanitation: Environmental and Water
2. Do you do groundwater monitoring? Why not?
3. Every when do you do reports of what you collect? And to whom?
4. In your opinion, what are the major conflict/ difficulties you have in doing your job?
5. In your opinion, what are the major needs to improve these conflicts/ difficulties?
6. What can be done to improve the collecting of water quality data and the availability of such information to the decision making process?
7. At every monitoring site do you collect the same list of parameters?
8. What equipments do you use to do the sampling and monitoring?
9. What is the cost of each equipment, fuel for the vehicle, etc?
10. If you know, what are the ongoing project in the area (Guapi-Macacu River Basin or and Rio de Janeiro State) for a long term water quality monitoring system?
11. Do you know of any other organization that does water monitoring in the river basin?

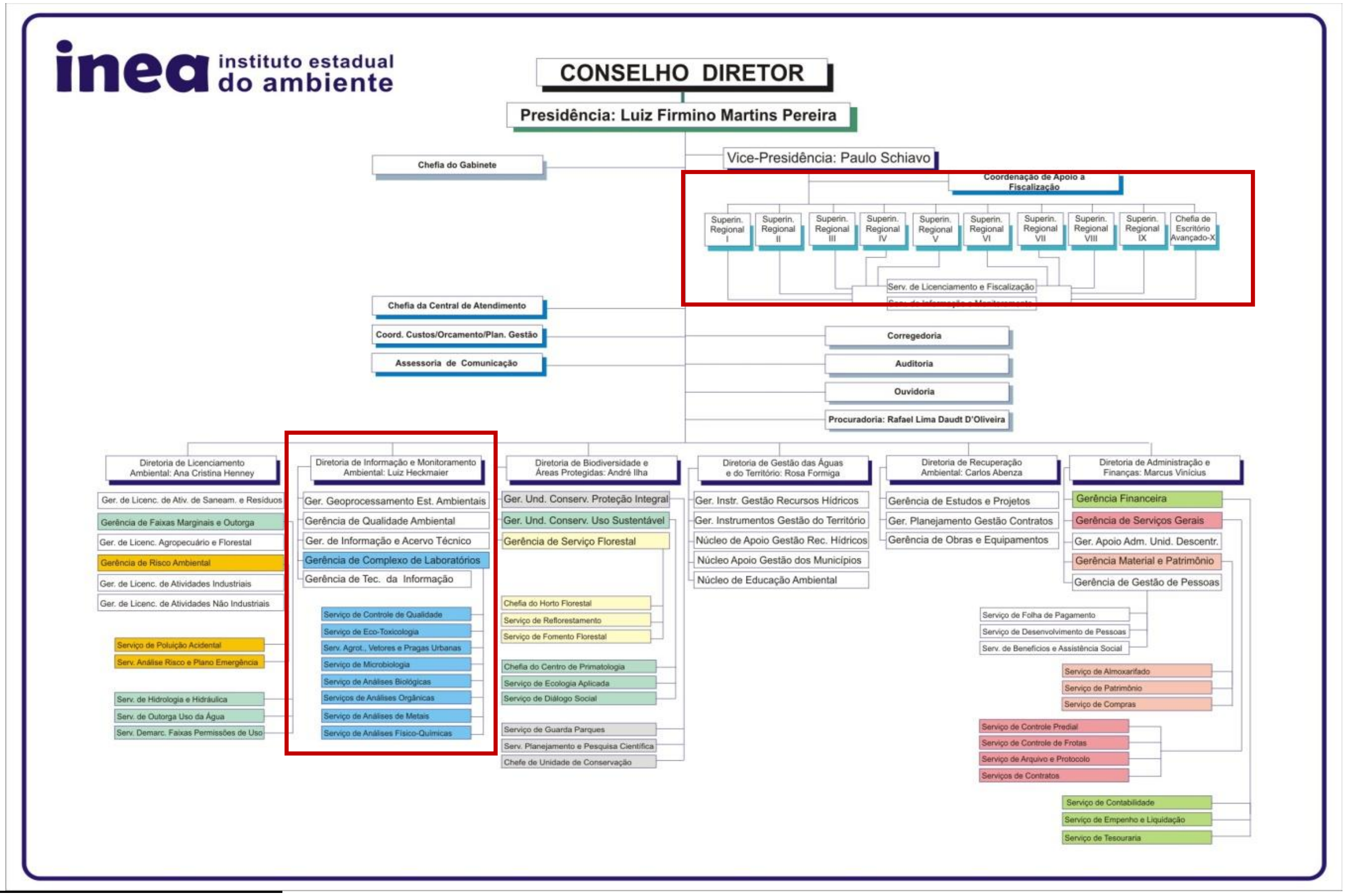
Name of the Interviewer	
Name of the Interviewee (*)	Chemist
Agency/Department/Institution	**Prefectura Cachoeiras de Macacu *(municipality)***
Date	
Time	
Place	
Language (**)	

(*) Whether the interviewee is a public officer or not, ask for permission to use the name as a source of information. State that the answers will be used for research purposes only and they will be confidential if permission to use the name of the interviewee is denied.

(**) Interviews conducted in Portuguese

1. Could you tell me what is the role or mandate of this Institute in Water Resource Management? What are the responsibilities of the institute in the decision making process and/or supplying information?
2. Do you do groundwater monitoring? Why not?
3. Every when do you do reports of what you collect? And to whom?
4. In your opinion, what are the major conflict/ difficulties you have to do your job?
5. In your opinion, what are the major needs to improve these conflicts/ difficulties?
6. What can be done to improve the collecting of water quality data and the availability of such information to the decision making process?
7. At every monitoring site do you collect the same list of parameters?
8. What equipments do you use to do the sampling and monitoring?
9. What is the cost of each equipment, fuel for the vehicle, etc?
10. If you know, what are the ongoing project in the area (Guapi-Macacu River Basin or and Rio de Janeiro State) for a long term water quality monitoring system?
11. Do you know of any other organization that does water monitoring in the river basin?

Annex D: This section shows the environmental monitoring branch and participatory sub-committees in the structural organization of INEA in Rio de Janeiro[34]



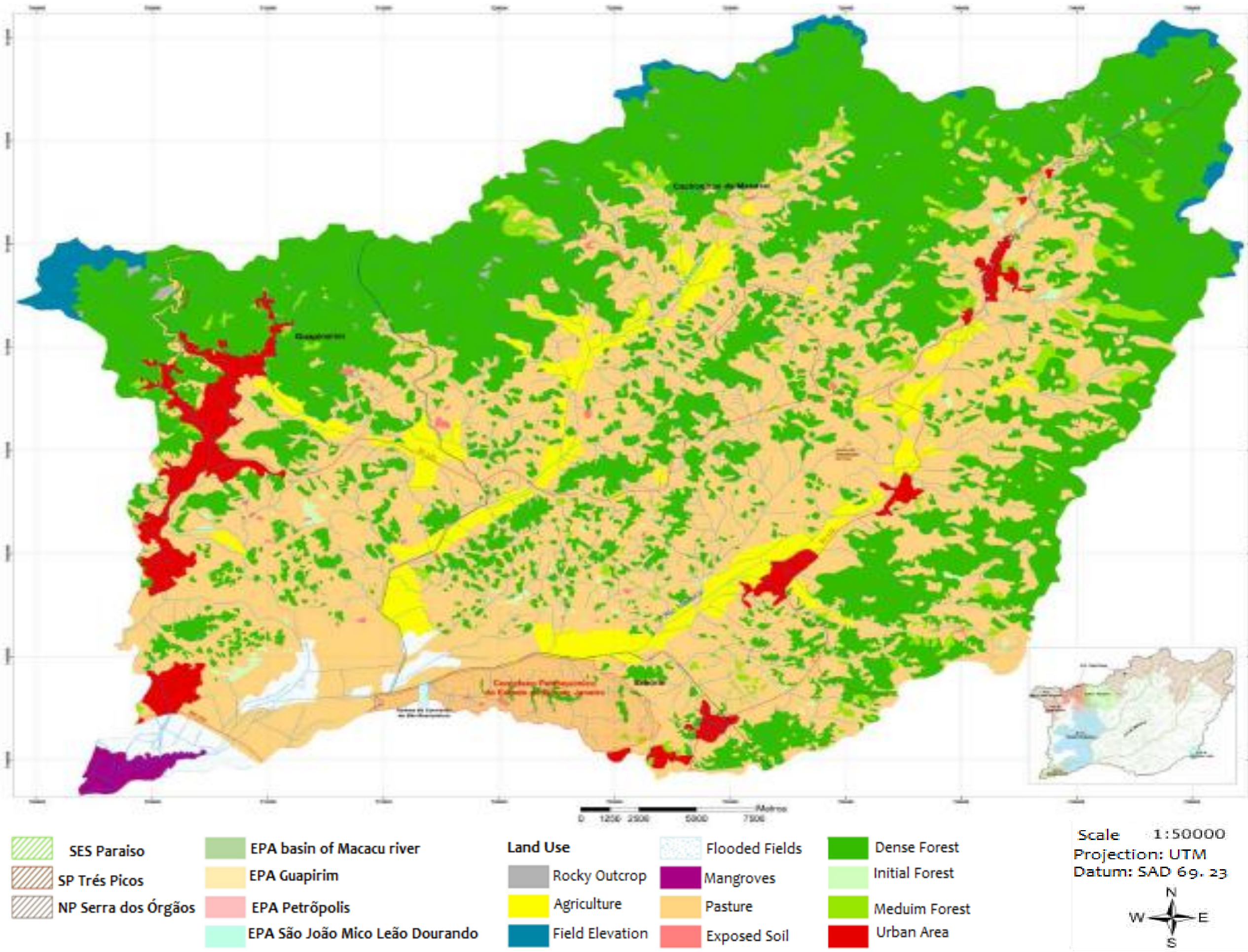
[34] Source: INEA Website - http://www.inea.rj.gov.br/imagens/organograma.jpg

Annex E: This section consists of the list of methods used in water quality monitoring to measure the parameters by INEA[35].

Number	Name	Year
MF-401. R-0	Method to determine Pentaclorophenol	2001
MF-405.R-4	Method for Determining the Most probable number (MPN) of coliform and faecal in samples of bodies of water or Effluents of SewageTreatment Stations,for the technique of Multiple Pipes	2001
MF-0406.R-3	Method to Determine heterotrophic bacterial colony forming, by "Pour Plate" technique	2001
MF-0407.R-2	Method to Determine Bacterial Colonies that precipitated Iron (Iron Bacteria) for 'POUR PLATE" Technique	2001
MF-410.R-1	Method to Determine for Flourine (Spadns)	1987
MF-411.R-4	Method to Determine Chromium by colorimetric diphenylcarbazide	1985
MF-412.R-1	Method to Determine the Oils and Greases (Extraction in Soxhlet)	1987
MF-413.R-1	Method to Determine Oils and Grease (Partion Gravimeter)	1978
MF-414.R-1	Method to Determine Mineral Oils (Soxhlet extraction and separation with Silica-Gel)	1978
MF-0415.R-1	Method to Determine Sulphates (Drag with inert gas and iodometry)	1979
MF-0416.R-0	WASTE sedimentable. (DE IMHOFF CONE).	1979
MF-0418.R-1	Titrimetric method to Determine Total Cyanide	1979
MF-0419.R-1	Colorimetric method to Determine Total Cynide	1979
MF-420.R-3	Method to Determine Ammonia (Indophenol Method)	1985
MF-421.R-2	Kjeldahl Total Nitrogen (micro Kjeldahl)	1983
MF-423.R-1	Method to Determine Nitrogen Nitrite - diazotization	1978
MF-424.R-1	Method to Determine Total Nitrogen (CÁLCULO)	1979
MF-425.R-1	Method to Determine Dissolved Oxygen (Winkler Method)	1979
MF-0426.R-1	Method to Determine pH	1979
MF-0427.R-2	Method To Determine Total Phosphorus (digestion with HNO3 + HClO4 and reaction of ammonium molybdate and ascorbic acid)	1983
MF-0428.R-1	Method to Determine Phenols (Amino antipyrine)	1979
MF-430.R-1	MOHR Method to Determine Chlorine	1980
MF-431.R-1	Turbidimeter Method to Determine Sulphate	1980
MF-0432.R-1	Method to Determine Soluble Silica (Molibdosilicato)	1980
MF-433.R-1	Method to Determine Ortho-phosphate Soluble (molybdophosphoric Method and Reduction with Ascorbic Acid)	1983
MF-434.R-1	Method to Determine Color (Visual Comparison)	1980
MF-435.R-1	Method to Determine Turbidity (nephelometric method)	1980
MF-0436.R-1	Method to Determine Total Fixed and Volatile Waste (gravimetric method).	1980
MF-437.R-1	Method to Determine Total filterable fixed and Volatile Waste (gravimetric method)	1980
MF-0438.R-1	Method to Determine Total non filterable fixed and Volatile Waste (gravimetric method)	1980
MF-439.R-1	Method to Determine the Biochemical Oxygen Demand (BOD)	1981
MF-0440.R-3	Method to Determine Chemical Oxygen Demand	1986
MF-441.R-1	Method to Determine Alkalinity (titrimetric method with indicator)	1982
MF-442.R-1	Gravimetric method to Determine Moisture	1988

[35] Source: INEA Website (2010) of database: http://www.inea.rj.gov.br/fma/legislacao.asp

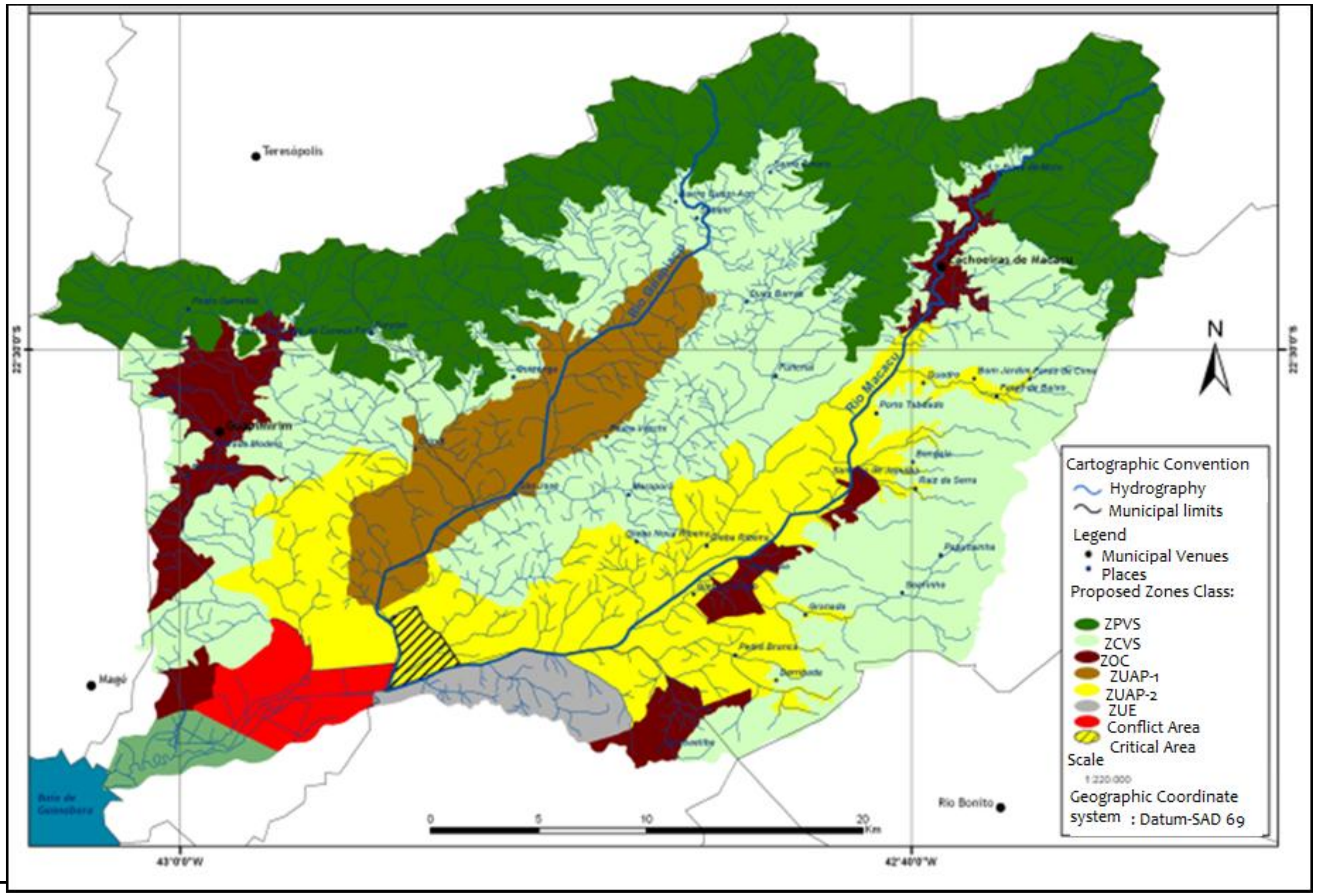
Annex F: This section consists with the Map of land use and cover for the GMRB[36] .



---

[36] Source:(Fidalgo et al., 2008)

Annex F: This section consists of the Map of planned Land Use Zones in Guapi-Macacu River basin from the management plan of environmental protected area of the basin of Macacu river[37].



[37] Source: (BioAtlântica, 2009)