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Abstract:	The pressure on the Urban Wastewater Systems (UWwS) increases as urbanization continues relentlessly and climate change appears to lead to more extreme rainfall events. These pressures have a negative effect on the efficiency of UWwS to reduce the urban pollution reaching water-receiving systems. One of the main causes of the problem is that the UWwSs have been traditionally designed for static/stationary loading but are operating under dynamic loading. Hence, only in the rare case of the design loading the system operates optimally. Thus, there is a lack of control in all other operational situations. The built-in capacity of the system is not used, or it is used in a way that the objectives cannot be met. In the first situation, invested capital is not productive; in the second situation, damage occurs: receiving waters are polluted or the city is flooded. Thus, the urban pollution managers are being forced to optimize the control of UWwS in order to deal with extreme variations in terms of flow and water quality and new criteria for pollution control performance. The same situation appears in the city of Cali, Colombia. EMCALI suspends the intake of raw water, due to the contamination of the water supply sources by wastewater discharges upstream form intake water, especially from South Channel and other discharges. Consequently, the drinking water plants present higher operation and treatment requirements and as a consequence an increment in the treatment costs. One of the main causes of the deficient control of the UWwS is the lack of data in each subsystem and the lack of coordination within institutions to share the information and take decisions based on it. This document presents a diagnostic report for urban wastewater monitoring systems of Cali. It includes an inventory of their components: Drainage Network, Cañaveralejo wastewater treatment plant and water receiving system (Cauca River) and identify the current status of the monitoring system. The main findings are that in the Cauca river there is a network of stations for water levels and water quality parameters but the information is not share successfully within the institutions IDEAM, CVC, DAGMA, EMCALI and hardly is used for system control purposes. The information from the sewer system is scarce and mainly at the entrance of the WwTP or in the pumping stations. The majority of information is collected in the Canaveralejo WwTP.		
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Integrated Urban Wastewater System Data Network
(Data.Net Project)

Data network system: Diagnostic Report Cali, Colombia

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UNESCO-IHE Institute for Water Education

Delft Cluster

POWER. UNESCO-IHE Partnership for Water Education and Research

Universidad del Valle

Cinara

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1 INTRODUCTION

The pressure on the Urban Wastewater Systems (UWwS) increases as urbanization continues relentlessly and climate change appears to lead to more extreme rainfall events. These pressures have a negative effect on the efficiency of UWwS to reduce the urban pollution reaching water-receiving systems.

One of the main causes of the problem is that the UWwSs have been traditionally designed for static/stationary loading but are operating under dynamic loading. Hence, only in the rare case of the design loading the system operates optimally. Thus, there is a lack of control in all other operational situations. The built-in capacity of the system is not used, or it is used in a way that the objectives cannot be met. In the first situation, invested capital is not productive; in the second situation, damage occurs: receiving waters are polluted or the city is flooded. Thus, the urban pollution managers are being forced to optimize the control of UWwS in order to deal with extreme variations in terms of flow and water quality and new criteria for pollution control performance.

The same situation appears in the city of Cali, Colombia. EMCALI suspends the intake of raw water, due to the contamination of the water supply sources by wastewater discharges upstream form intake water, especially from South Channel and other discharges. Consequently, the drinking water plants present higher operation and treatment requirements and as a consequence an increment in the treatment costs. One of the main causes of the deficient control of the UWwS is the lack of data in each subsystem and the lack of coordination within institutions to share the information and take decisions based on it.

This document presents a diagnostic report for urban wastewater monitoring systems of Cali. It includes an inventory of their components: Drainage Network, Cañaveralejo wastewater treatment plant and water receiving system (Cauca River) and identify the current status of the monitoring system.

The main findings are that in the Cauca river there is a network of stations for water levels and water quality parameters but the information is not share successfully within the institutions IDEAM, CVC, DAGMA, EMCALI and hardly is used for system control purposes. The information from the sewer system is scarce and mainly at the entrance of the WwTP or in the pumping stations. The majority of information is collected in the Canaveralejo WwTP

2 BACKGROUND OF MONITORING ACTIVITIES IN COLOMBIA

2.1 INSTITUTIONAL AND REGULATORY FRAMEWORK APPLICABLE TO MONITORING ACTIVITIES IN COLOMBIA

In Colombia the legal current framework related to the management of the water resources, has a series of norms create in order to regulate the use of water resources. Table 2.1 shows the main laws and decrees

Table 2.1 Water related laws and decrees at national level

Law	Decrees Developed
National Code of Natural Resources – CNRN (Decree –Law 2811 1974 Modified by law 99 1993.)	Developed in WRM issues via decrees 1700/1989 creation CRA 1594/1984 water use and wastewater 2858/1981 Irrigation evaluation studies 1541/1978 Water use concessions
National Sanitary Code (Law 09 1979)	Developed in water issues via decrees: 1575/2007 Protection and control of water quality system for human consumption 475/1998 Water Quality for human consumption (modified by decree 1575/2007) 1594/1984 WRM organization, water quality to diverse uses, wastewater quality
National Environmental System (Law 99 1993)	Developed in WRM issues via decrees 1200/2004 Environmental Planning Tools 155/2004 Water use fees 3100/2003 Water contamination fee 1180/2003 Environmental Licenses 1729/2002 River Basin Planning 1728/2002 Environmental Licenses 1604/2002 Commissions to administrative shared river basins 48/2001 Regional environmental management Plan 901/1997 Water contamination 1933/1994 Transfer of electric sector's revenues to environmental investment 1865/1994 Mechanism to harmonize environmental regional and municipal plans 1600/1994 SINA regulation and national system of environmental information 1277/1994 Organization of IDEAM River basin plans prioritized via resolution 104/2003 and organized by technical guides designed by IDEAM in 2004
Territorial Land Development (Law 388/1997) Modified via law 507/1990, law 810/2003 and law 902/2004	Developed via decrees 2201/2003 National projects and land use 1337/2002 Compensation for conservation land uses 932/2002Process of POT update 2015/2001 Post-disaster licenses of building 1504/1998 public space management into POT 879/1989 Regulation of POT process
National Systems of Prevention and Attention of Disasters (Decree 919/1989) Complemented via decree 1547/1984 National Disasters Fund - FNC	Developed by decrees 2378/1997 Re-organization of FNC 93/1998 National Plan of Prevention and Attention of Disasters

Source: Adapted from Guio, 2004

Also, there are different institutions at national, regional and local level that are in charge of formulating policies, regulating and controlling the management of the water resources and ensuring the appropriate delivery of public services, whose mission is to guarantee the environmental sustainability of the natural resources. Annex 1 presents a brief description of the main institutions related to the water management resources in Colombia.

With the Law 2811, 1974 National Code for Natural Resource Management (CNRN) was developed Decree 1594, 1984, together with law 9, 1979 known as the Sanitation National Code established the proceedings and measurements to carry out regulation and control of discharges and regulates the uses of water and wastewater. Regarding wastewater, Decree 1594, 1984 defines the discharge limit of hazardous substance to open body waters and sewerage systems; it establishes the permit of wastewater discharges, establishes the quality criteria for the uses of water, pollution compensation tax and environmental studies impacts.

Decree-Law 2811 of 1976, National Code for Natural Resource Management (CNRN) first created a series of government intervention mechanisms (e.g. economic incentives and grants/aids, wastewater pollution charges, environmental zoning, and the definition of environmental emergencies) such as the environmental information system to be used as a tool for developing an environmental policy. This new national code ordered arranging and keeping a current environmental information system that provided physical, economical, social, legal, and other kinds of relevant data about the environment and the renewable natural resources. The system processes and analyzes the following kinds of information: cartographic, hydrometeorological, hydrological, hydrogeological and climatic; edaphological, geological, uses of land for non-agricultural purposes, forest inventories, fauna inventories, etc.

In 1991 the Political Constitution of Colombia granted environmental protection the status of collective right, thus providing it with protection mechanisms made available to citizens, particularly in the form of community or group actions, and exceptionally in the form of writs for the protection and enforcement of constitutional rights.

In compliance with the provisions set forth in the 1991 Political Constitution of Colombia, the Ministry of the Environment was established per Law 99 of 1993. This law provided environmental management in Colombia with a systematic, decentralized, participatory, multi-ethnical and multi-cultural dimension leading to the establishment of several scientific institutes in accordance with Law 99 of 1993, Articles 16 and 17. These institutes were assigned the responsibility for deciding about studies, inventories and research works, and information management and monitoring activities that provide the basis not only for making environmental policy decisions, but also for implementing provisions, rules, and regulations for territorial planning, and management, use and usage of renewable natural resources.

As a result of Law 99, 1993 and pursuant to Law-Decree 1277 of June 21, 1994, the Institute for Hydrology, Meteorology and Environmental Studies (IDEAM) was structured and established. The main purpose of IDEAM is to generate knowledge and produce and supply environmental data and information. It also conducts studies, research projects, inventories and information management and monitoring activities that provide the basis not only for making environmental policy decisions, but also for territorial planning, management, use and usage of biophysical natural resources in this country. Its specific functions include the following (IDEAM, *et, al.,* 2002):

- Providing counseling to the regional environmental agencies (CAR's) in the implementation and operation of the Environmental Information System in accordance with the guidelines of the Ministry of the Environment, Housing and Territorial Development (MAVDT);
- Maintaining information about the use of renewable resources (especially water, soil and air) and factors that contaminate and affect or deteriorate these resources, thereby working jointly with the CARs.
- Supplying information for drafting environmental quality standards and rules; and
- Conducting studies and research projects in cooperation with other institutions aiming at establishing parameters/limits for contaminating emissions, discharges, and other conditions that are detrimental to the environment.

In addition to the above, Law 99 of 1993 entrusted IDEAM with the former duties of HIMAT (Colombian Hydrology, Meteorology and Land Refurbishment Service) with regard to hydrology, including all the information, files, laboratories and data processing centers and resources associated with its hydrological activities.

Taking into account the guidelines in Law 99 of 1993, Decree 1600 of July 27th, 1994 partly regulated the National Environmental System (SINA). This decree assigned IDEAM the responsibility for managing and coordinating the National Environmental Information System and reporting to the Ministry. In this respect, IDEAM was assigned the task of submitting protocols, methodologies, rules, and standards to the MAVDT for collecting, processing and transmitting data and analyzing and disseminating information obtained or generated by environmental research institutes, environmental agencies, and other institutes that comprise the SINA with regard to the environment and the natural resources.

The entities that form part of SINA are: the Ministry of the Environment, Housing and Territorial Development and the associated or attached institutes, the regional environmental agencies, the departments, districts or municipalities, and non-government organizations.

This decree also entrusted IDEAM with the task of keeping records of discharges, emissions and other factors that have an adverse effect on water, soil, air, climate and biodiversity, working in coordination with environmental agencies, urban environmental control agencies, and research institutions. Figure 2.1 lists the basic duties of SINA related with its member institutions

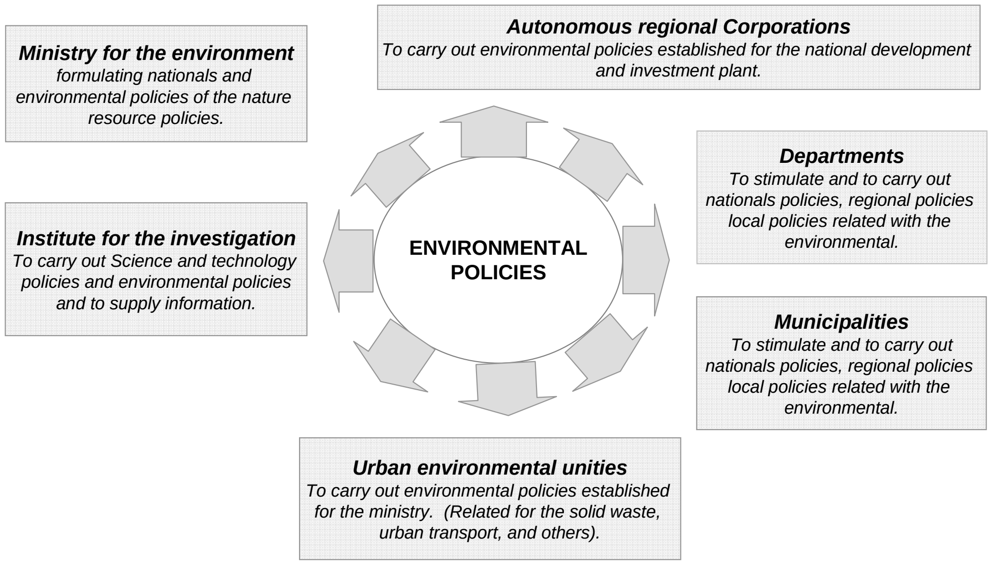


Figure 2.1Basic Duties of SINA
Source: IDEAM, et, al., 2002

At a regional level, the duties of regional environmental agencies also include implementing and operating the Environmental Information System in their respective jurisdictions (Law 99, Article 31) in coordination with territorial agencies and with the assistance of institutes associated with SINA. As the highest environmental authorities in each jurisdiction, the role of the CAR's is critical because they have to store information collected from the environmental monitoring and follow-up programs in their own regional information systems and then provide feedback to SINA.

At a local level, the Regulatory Commission for Drinking Water and Basic Sanitation (established per Law 142 of 1994 applicable to public utilities) issued Resolution 1096 of 2000 providing the technical regulations for the drinking water and basic sanitation sector (MINISTERIO DE DESARROLLO ECONÓMICO, 2000).

In accordance with RAS 2000, service providers are responsible for the operation, maintenance, control, and monitoring of rainwater or wastewater collection and evacuation systems. Therefore, the operation, control, and performance monitoring of the system, and measurements and monitoring of the drainage system must be performed in compliance with the minimum guidelines listed in Table 2.2.

Measurements must be taken to determine both water quality and quantity. The measuring methods used by the system depend on the technology available and the financial capacity of the population.

Water quality measurements are determined by the requirements in the current regulations for wastewater disposal with regard to effluents and discharges (i.e. Ministry of Health Decree 1594 of 1984). The minimum parameters to be measured in monitoring water quality based on the population size are shown in Table 2.3

Table 2.2 Wastewater and rainwater quantity & quality measurements

Complexity Level	Minimal frequency Quantity / Quality	Quantity / Quality	Periodicity of measurements
Low -Middle (<12500 inhabitants)	Biannual / Biannual	Compulsory / Recommended	Biannual. 1 or 2 control points in final emissaries
Middle-High (12501- 60000 inhabitants)	Biannual / Biannual	Compulsory / Recommended	Biannual. Strategic control points (sub-area of drainage) in main collectors and emissaries
High (>60000 inhabitants.)	Annual / Biannual	Compulsory / Compulsory	Annual. Strategic control points. (Sub-area of drainage) in main collectors and emissaries. Automatic measurement and telemetric recommended in some points

Source: MINISTERIO DE DESARROLLO ECONÓMICO, 2000 (RAS 2000)

Table 2.3 Parameters to be measured according to the complexity of the system

Complexity level	Parameters
Low (<2500 inhabitants)	Total and dissolved BOD, suspended, dissolved and settleable solids, total and soluble COD, Total Kjeldahl Nitrogen, Phosphorus (particulate and soluble)
Middle (2501–12500 inhab.)	Total and dissolved BOD, suspended, dissolved and settleable solids, total and soluble COD, Total Kjeldahl nitrogen, Phosphorus (particulate and soluble).
Middle - High (12501-60000 inhab.)	Total and dissolved BOD, suspended, dissolved and settleable solids, total and soluble COD, Phosphorus (particulate and soluble), grease and oil, , detergents, and total Kjeldahl Nitrogen
High (>60000 inhab.)	Total and dissolved BOD, suspended, dissolved and settleable solids, total and soluble COD, Total Kjeldahl nitrogen, Phosphorus (particulate and soluble), grease and oil, detergents, chloride, heavy metals: Cd, Pb, Cr, Ni, Zn, Hg, Cu, Ag, and volatile organic compound.

Source: MINISTERIO DE DESARROLLO ECONÓMICO, 2000 (RAS 2000)

With regard to the control of commercial and industrial effluents, the service provider responsible for the collection and evacuation of wastewater is also responsible for granting the appropriate permits for industrial water effluents and implementing measures to control and monitor effluents in accordance with applicable rules and regulations.

Monitoring the drainage systems is generally part of the responsibilities of service providers to the local and regional environmental authorities with regard to water resource management. It is also a result of local and regional rules, plans and strategies.

At regional level there are different strategies aimed to plan and guarantee the environmental sustainability of the Valle del Cauca department. However, it is important to highlight that the water management approach followed in Colombia is not at the river basin scale. Instead each one of the provinces works independently depending on its political jurisdiction. Decree 2811, 1976: Policy of control for users of Cauca River. It establishes the prevention and control norms to avoid contamination of the water resource and guarantee quality of water for posterior use. Following, the main strategies are summarized:

- Plan for the environmental management in the region of Valle del Cauca 2002-2012 “Participación con compromiso”. This strategy orients in a coordinated way the management and administration of the renewable natural resources.

- Plan for the development of the department of Valle del Cauca 2004-2007 “Vamos juntos por el Valle”, which establishes the strategies to reach environmental sustainability in the region.

- Plan triennial, PAT.2007-2009, which defines the actions to accomplish the targets set in the Millennium developing goals through the established national policies.

- Pact for the recovery of the Cauca River 2001: It is a pact signed among the Ministry for the environment, regional corporations-CVC the department of Valle del Cauca and the municipality of Cali. The main goal is to formulate a plan for the integrated management of the Cauca river basin. The formulation of the plan must be established based on the participatory approach from the municipalities, communities and industrial sectors involved in the uses of the river basin.

- Plan for the integrated management of the Cauca river basin-2005; It establishes the strategies and measures, to be followed by all the involved parties, to protect, recover, conserve and manage in a sustainable way the Cauca river.

At local level the local policies which sustain the urban water management in Cali are:

- Plan for the development of Cali area 2004-2007. Its main goals are: 1) Social equity, 2) economical recovery, development and competitiveness, 3) Urban culture, livelihoods, security and peace, 4) Environmental recovery and development of the territory, 5) Institutional enforcement and defense of the public sector.

- Master plan for Cali 2000-2020. It coordinates the use and destination of the public areas to ensure the social-economical development considering the needs and interest of the involved population. Regarding the environment it defines land uses, protected areas, risk areas, urban growth. Likewise it defined the uses of the natural resources in the city.

- Sanitation and management of waste-discharges plan PSMV-EMCALI 2007. It includes programs, projects and measures for the management of wastewater in the city following quality standards and policies defined by the environmental authority in the region (DAGMA). The plan encompasses recollection, transport, treatment and final disposition.

- Environmental management Plan for the city of Cali. DAGMA 2005-2019. It includes all the decisions and strategies to de developed by the different stakeholders in the city (at institutional, social and economical level). Such strategies are aimed to improve the quality of life of the community as well as to improve the economical productivity.

- Plan for the solid waste management in Cali-PGIRS 2002. This plan was developed to be mainly responsibility of the municipalities. Its mission is to establish an integral management of the solid waste taking into account all aspects from the production of the waste until its final disposition and considering strategic aspects like recycling and reuse.

- Resolution 376-2006 and 019-2007. Set by DAGMA, these resolutions define goals for the reduction of emissions and waste discharge to water bodies in Cali. Specifications for the uses of the different rivers in Cali are also set. It also set deadlines (to be accomplished by the public agencies) in reducing the waste discharge to the rivers.

- Environmental municipal management system (SIGAM): Implemented by the municipality, it establishes environmental profiles and identifies responsibilities and responsible for control, management and control of the environment in Cali.

- Environmental agendas. The latest agenda was established in 1998. The agendas are developed at local level to show the current state of the environmental resources inside the city. They also formulate approaches to follow up the development of environmental strategies.

2.2 MONITORING EXPERIENCES IN COLOMBIA

There is not enough information available in Colombia about the implementation of networks to monitor urban drainage systems and water quality in rivers. Additionally, in most cases recorded information is not complete or up-to-date (URL-3).

IDEAM now has a monitoring network that consists of 2,883 hydrometeorological stations, including both automated and conventional stations.

- 1,463 stations that collect rainfall data on a daily, monthly, annual and decadal basis. The most comprehensive information about monthly rainfall data has been available at the National Astronomical Observatory in Bogota uninterruptedly since 1901.
- 529 stations of different climatological categories provide information about other parameters such as temperature, relative humidity, wind, cloudiness, sunshine, etc.
- 891 hydrological stations supply information about water levels, flow rates, sedimentation, measurements of liquids and solids, etc. in streams and bodies of water across the country.
- "*Arrancaplumas*", which is located in the mid region of the Magdalena River, is the oldest station where monthly data records have been available since 1934

IDEAM monitors hydrological behavior of the main rivers in this country based on the real-time hourly data it receives from the automated stations, which are supplemented by more than 40 hydrological stations that transfer data in the first morning hours all year round. The network is basically designed to cover the area of the largest rivers in the country, but especially those located in the Magdalena-Cauca River basin. The purpose of the stations is to provide technical information that would allow warning the population living along the riverside about potential floods. (URL-3)

IDEAM also has 834 hydrological stations (i.e. 389 limnimetric and 445 limnigraph stations) in the five hydrographical basins in the Colombian territory. These stations supply data about the hydrological system of the main riverbeds and bodies of water and enable monitoring the run-off process in the water cycle and associated extreme events. Certain parameters, such as river water levels and sediment concentrations, are observed twice a day.

IDEAM has divided the country into zones and assigned 10 work teams in the department capitals or operating areas. Each zone is responsible for operating and maintaining the hydrometeorological and environmental network, taking hydrometeorological and environmental measurements, collecting data from the observers at the stations and transferring data to the technical files at the IDEAM after conducting a data quality check (URL-3)

Table 2.4 Operational areas in IDEAM's hydrological, meteorological and environmental network

Operational areas	City headquarters	Department coverage
1	Medellín	Antioquia and Chocó
2	Barranquilla	Atlántico, Bolívar, Córdoba and Sucre
3	Villavicencio	Meta, Guainía, Guaviare, Vaupés and Vichada
4	Neiva	Huila and Caquetá
5	Santa Marta	Magdalena, Cesar and La Guajira
6	Duitama	Boyacá and Casanare
7	Pasto	Sur del Cauca, Nariño. Putumayo and Amazonas
8	Bucaramanga	Santander, Arauca and Norte de Santander
9	Cali	Valle, Caldas, Cauca, Chocó, Quindío and Risaralda
10	Ibagué	Tolima
11	Bogotá	Cundinamarca, Amazonas, San Andrés and Providencia and Santa Catalina

Source: URL-3

IDEAM's Hydrometeorological and Environmental Network Program operates and maintains the network in operation. It processes data from environmental stations to generate information that feeds the Information Service and the National Environmental System (SINA). It also supplies information to the Hydrometeorological and Environmental Alert Program which issues warnings and alerts to the population about potential natural environmental and hydrometeorological disasters.

Since the Regional Environmental Agencies are responsible for monitoring and keeping track of water resources in their respective jurisdictions, there are different monitoring programs in place which depend on the specific characteristics of the water resources.

The Hydroclimatological Network of Cundinamarca's Regional Environmental Agency is the second largest network in Colombia after IDEAM's network. The network consists of 365 hydrological and climatological stations located at different locations within the jurisdiction of the CAR. The stations are used for either monitoring or measuring parameters such as temperature, rainfall, sunshine, and relative humidity, which allows identifying and characterizing the behavior of the weather in the areas where the stations are located (URL-4)

Most of these stations are conventional. CAR has been gradually upgrading these stations. There are currently 7 automated and 23 telemetric stations. There are also 30 stations, including automated and satellite stations, operating under an agreement with IDEAM. 65% of the stations are located in the Bogota river basin. That is the reason that CAR is now installing 22 new stations running on automated (15) and satellite (7) systems. 296 local observers collect data from the stations on a daily basis. The data are then stored and forwarded to CAR every 6 months.

The results delivered by the Hydroclimatological Network provide the basis for the design of infrastructure projects such as roads, bridges, and water supply and sewerage systems. They are also useful for the operation of Dams and Irrigation Districts (URL-4)

The Water Quality Monitoring Network run by the Regional Environmental Agency for the Preservation of the Bucaramanga Plateau performs an evaluation of the water quality index on 16 rivers (i.e. Suratá, de Oro, Frío, Manco, Negro, Salamaga, Playonero, Lebrija, Jordán, Tona, Cáchira, Umpalá, Charta, Vetas, Lato, and Silgará) and 8 creaks (Arenales, Aranzoque, La Angula, Zapamanga, Grande, Chimitá, La Iglesia, and Saratoque). The collected information contains data from 1998, 1999, and 2000 (URL – 5).

According to CORANTIOQUIA's 2004 Performance and Achievement/Project Report, the monitoring network activities include a characterization of the quality, quantity and continuous flow of superficial streams, potential alternatives for use, and sustainability levels. These activities were carried out in the following 17 basins: La Ardita and La Combia (Fredonia), La Purco (La Causala (Anzá)), San Mateo (Betulia), Rodas (Copacabana and Bello), La García (Bello and San Pedro de los Milagros), La Mata de los Ortega and El Chocho (Girardota), Sinifaná River (Fredonia, Venecia, Titiribí, Amagá, and Caldas), Piedras Blancas (Copacabana), La Gabriela and El Hato (Bello), La Magallo and Comiá (Concordia), Poblanco River (Fredonia, Santa Bárbara, and La Pintada), La Cianurada (Remedios and Segovia), and La Juan Vara (Zaragoza).

For each of the above mentioned water streams a monitoring network were implemented. Each network consisted of a set of sampling points located along the main stream and its most relevant tributaries, thus representing the profile of the system in the hydrographic basins and guaranteeing proper spatial understanding of the drainage area. (Corantioquia, 2005).

Also worth of note is the water quality monitoring program on La Vieja River, the hydrographic basin of which is located within the jurisdiction of 3 regional environmental agencies, i.e. CRQ, CARDER, and CVC. As reported in the "Project for the Planning and Preservation of La Vieja River Basin, Diagnostic Report from July 2005", the implementation of this water monitoring network on La Vieja river emerged in response to the high degree of contamination and sedimentation in the river all along its path to the Cauca River.

The analysis of the physicochemical and bacteriological quality of the water sources and the estimation of contaminant loads (including domestic, industrial and agricultural) and contributions of tributaries to La Vieja River entail conducting sampling at 14 different stations on a periodical basis.

The water samples are tested for the following parameters: pH, alkalinity, turbidity, conductivity, color, dissolved oxygen, COD, BOD, total dissolved solids, total suspended solids, total coliforms, fecal coliforms, ammonia, nitrates, phosphates, ambient temperature, and water temperature.

Table 2.5 Monitoring Stations on La Vieja River

N°	Monitoring station	Municipalities, Department
1	Consota river, La Curva	
2	Consota river, Puente de Madera	
3	Quindío river, Bocatoma EPA	Vereda Boquía, Salento, Quindío
4	Quindío river, Puente La María	Calarcá, Quindío
5	Quindío river, después de curtiembre	Calarcá, Quindío
6	Quindío river, Club de tiro y caza	Armenia, Quindío
7	Quindío river, Calle Larga	
8	Quindío river, Tarapacá	Armenia, Quindío
9	Verde river, Experimental Center of Guadua	Córdoba, Quindío
10	Barragán river, Arenera	
11	La Vieja river, Piedras de Moler	Alcalá, Valle
12	La Vieja river, Bocatoma Cartago	Cartago, Valle
13	La Vieja river, Aeropuerto Cartago	Cartago, Valle
14	Barbas river	Risaralda, Quindío

Based on the results obtained from the physicochemical characterization, the different possible uses of water were defined taking into account the guidelines in Decree 1594 of 1984. The IFSN index was also established to determine the water quality requirements at the various sampling points.

Since 1996, CARDER (Regional Environmental Agency of Risaralda) has been conducting a water quality monitoring program on the main rivers in this department. The purpose of the program is to determine the sanitary quality of the main surface water sources at specific locations and, overall, in the Department of Risaralda.

The program originally started with 6 streams, but then the basins of the San Juan and Cestillal Rivers were included. In order to gather funds from wastewater pollution charges, additional sampling locations at other water sources have been incorporated. Today 10 hydrographic areas are being monitored. These water sources are monitored 3 times a year.

Table 2.6 lists the surface water sources monitored by CARDER, the number of stations at each source, and the date from which information is available.

CARDER's monitoring program is intended to: i) generate management strategies aimed at the preservation and/or sanitation of water sources; ii) ensure compliance with the water quality requirements for domestic use; iii) check the results of actions to control effluents; iv) identify water quality changes associated with the introduction of new contaminants; and v) determine the impact of changes in seasonal, hydrological, and climatic factors on the condition of water resources.

Table 2.6 Water sources included in CARDER's monitoring program

No.	Record since	River Name	Station quantity
1	1996	Cestillal Gully	5
2	1993	Río Consota River	9
3	1988	Desquebradas Gully	6
4	1995	Quebradagrande Gully	3
5	1987	Otún River	10
6	1998	Quincia – Opiramá River	5
7	1989	Risaralda river	10
8	1989	San Eugenio river – Campoalegre	10
9	1998	San Francisco river – La Nona	5
10	1998	San Juan river - Tatamá	4

The Regional Environmental Agency of Tolima developed a project called "Prevention and Control of Environmental Deterioration Factors in the Department of Tolima", which has an environmental testing laboratory engaged in monitoring activities at 118 locations, out of which 74 are tested for the purpose of invoicing wastewater pollution charges, 26 are used for characterizing the hydrographic basins that are now under a territorial rearrangement process, and the remaining 18 locations are used for control and monitoring activities. These hydrographic basins were characterized based on information about rivers Prado, Guali, Opia, and Chipalo, and creek Cay (URL–7).

One of the projects executed by the Chivor Regional Environmental Agency (CORPOCHIVOR) involved the implementation of a hydroclimatic monitoring network from 2001 to 2006. The objective of this network was to become acquainted with the environmental conditions of water, air, and soil components. One of the plans that are part of this project is the implementation and operation of a water monitoring network which will allow evaluating the quality, quantity and continuous flow of water resources. However, the results or methodology for carrying out this activity have not yet been specified (URL-8).

The Medellin Public Utility Company has a hydrometeorological network consisting of more than 200 stations which are 95% automated (URL-9). The network collected data is used for: sizing dams, power plants, hydroelectric generation plants, drinking water supply systems; designing hydraulic structures and sewerage networks (weirs, deviation conduits, and canals); operating hydrothermal systems; forecasting water availability; and conducting environmental studies. The primary components of the hydrometeorological network of the Medellin Public Utility Company are shown in Figure 2.2

The telemetric equipment are located at the remote stations transfers data to the Regional Dispatch Center via the GOES satellite. Information is stored in the Hydron database that feeds the HBV-IHMS forecasting model (URL-10)

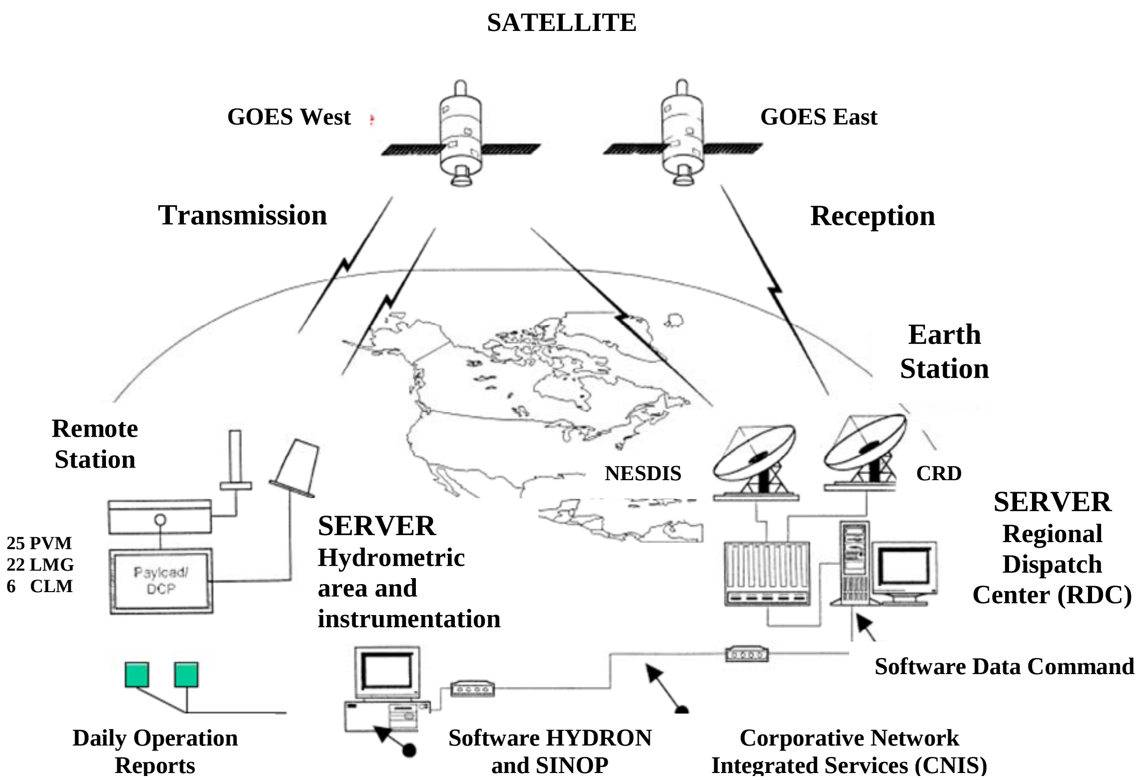


Figure 2.2Primary components of the hydrometeorological network of the Medellin
Source: URL-10

The location of the various hydroclimatological and water quality monitoring stations owned by entities such as IDEAM, CVC, EMCALI, and DAGMA is selected taking into account the area of influence of Cali and the different components of the urban water management system, i.e. the drainage system, the receiving body of water (Cauca River), and the Cañaveralejo wastewater treatment plant (detailed information about these components is provided below in Chapter 4.

3 WASTEWATER MANAGEMENT SYSTEM IN CALI CITY

3.1 GENERAL CHARACTERISTICS OF CALI CITY

3.1.1 Geographic location

The city of Cali is the capital of the Valle del Cauca department. It is located to the south-west part of Colombia between the central mountain range and the Pacific Ocean; it is located near to the Port of Buenaventura which is the main commercial port in the country. Its coordinates of location are: North 92.000N and 116.000N and East 6.000E and 18.000E. Cali is the third city most important of the country, with 560,3 Km^2 of a municipal area. Figure 3.1 shows the location of the Valle del Cauca department and the urban area of Cali.

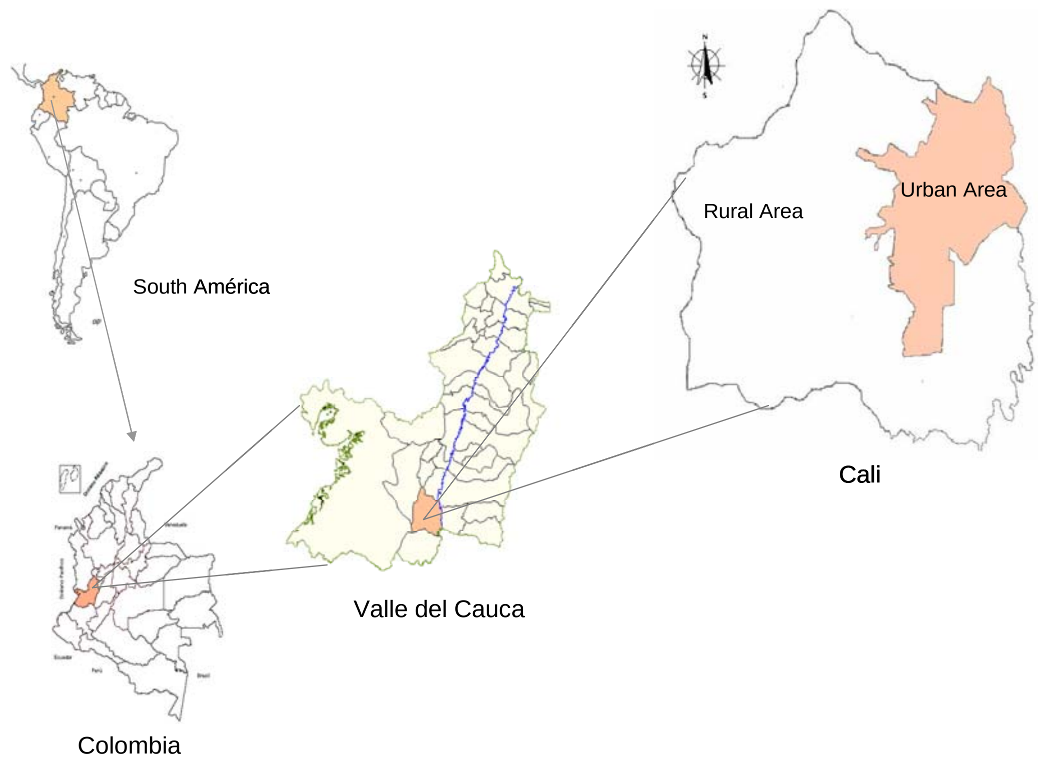


Figure 3.1Geographic location City of Cali

Since Cali is located in a tropical zone, there are not seasons affecting climate. The climate is mostly defined by the mountainous topography and by the elevation above sea level so the weather changes between middle cold and hot temperature (DAPM, 2000). There are identified four climates based on the air temperature and the spatial distribution of precipitations. Figure 3.2 shows the climates, temperature and precipitation distribution along the transversal section of the municipality of Cali.

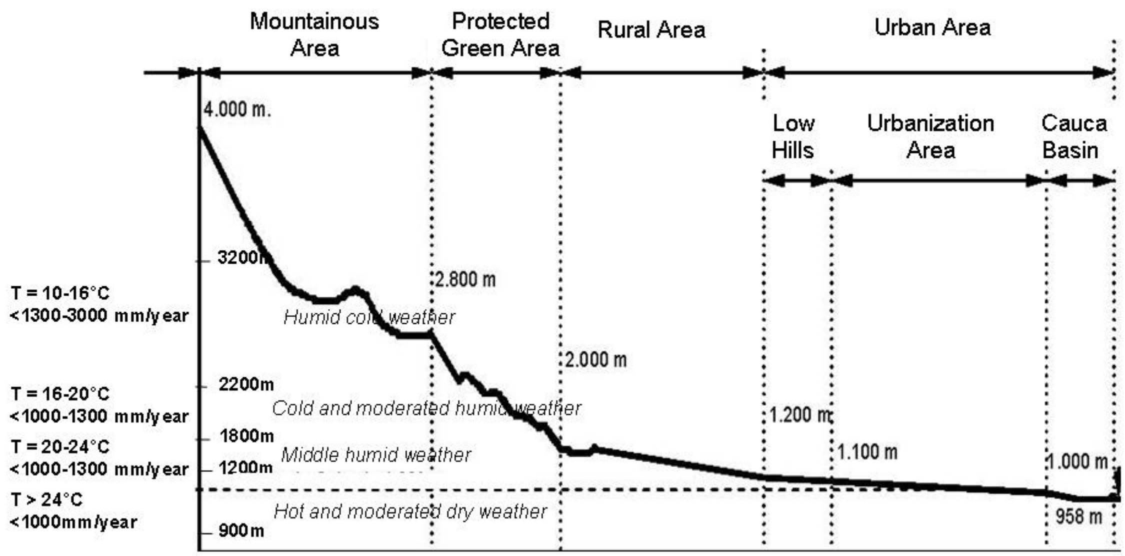


Figure 3.2 Transversal section of the Municipality of Cali and the respective climates, temperatures and precipitations regimes
Source: DAPM, 2002

Precipitations in the city vary between 1300 mm/year in the south and 1000 mm/year in the north increasing in the south-west direction. In the mountain areas, precipitations vary between 1300 and 3000 mm/year. Rainy periods occur mainly in the months of March, April, May, October and November. Dry periods correspond to the months of January, February, august and September. December and June are the transition periods (URL-2).

The urban part of the municipality of Cali is composed by two areas: 1) consolidated area which is the existing urban area until year 2007 and consists of 22 "comunas" or districts, and 2) the future development area that is located to the south-east of the city and consists of two areas: Navarro and Cali-Jamundí sectors (EMCALI, 2007).

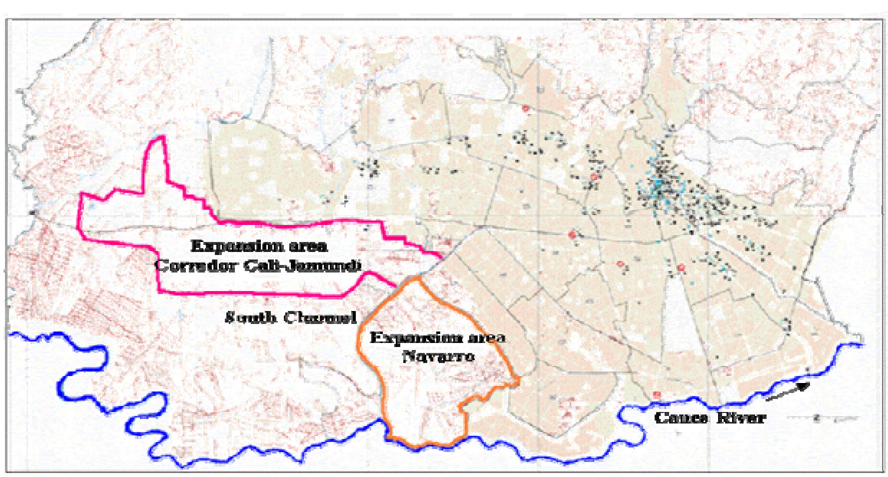


Figure 3.3 Location of existing and future urban areas in the Municipality of Cali
Source: EMCALI 2007.

According to the National statistics department (DANE, 2005a), Cali has a total population of 2´075.380 inhabitants, from which 979.530 are male and 1'095.850 are female.

Furthermore, according to DAPM (2006), in year 2005, 85% of Cali citizens were located in "estratos" 1, 2 and 3". "Estratos" is a way of economically classifying the sectors in the city; Hence "estratos 1 and 2" correspond to the most economical stressed groups and "estratos 3, 4, 5 and 6" correspond to the economical middle class to the upper class economic groups.

Population in the city has increased mainly by immigration from the rural areas, from the south-west part of the country and from other regions in the country. This increase has produced an additional pressure in the demand of land and public services such as water and sanitation.

3.1.2 Public Services

Water supply system

EMCALI is the company responsible for the delivery of water supply, sewerage and energy services in Cali. The current drinking water coverage in Cali is 97% (Emcali, 2007). The drinking water distribution system in the city is supplied by: Puerto Mallarino, Río Cauca, Río Cali, La Reforma and La Ribera plant. Table 3.1 shows a summary of the design parameters and characteristics of the five plants that supply the drinking water demand in Cali.

Table 3.1 Drinking water plants characteristics

Plant	Río Cali	Río Cauca	Puerto Mallarino	La Reforma	La Ribera
Initial operation year	1930	1958	1978	1993	1991
Technology	Conventional	Compact	Complete cycle	Conventional	Multiple stage filtration
Source	Cali River	Cauca River	Cauca River	Melendez River	Pance River
Installed capacity (m^3/s)	1,80	2,50	6,60	1,00	0,012
Average production (m^3/s)[1]	1,23	1,77	4,11	0,41	0,012
Plant shutdowns (hours/year)[2]	11,3	37	35	19,6	-
Sludge production (ton/month)[3]	17,9	30,7	67,8	2,3	0,0
Cost treated m^3 ($\$/m^3$)[4]	39,6	97,14	51,8	31,2	-

Source: 1.Production information, December 2006, EMCALI. La Ribera Plant, production information, January 2008.
2. Production year 2005, EMCALI.
3. Sludge production year 2003, EMCALI
4. Production costs year 2006, EMCALI. Río Cauca and Río Cali plant, production costs – September 2007. Costs without expenses of personnel.
(-) Without date

According to the report from the Technical Planning Department from EMCALI, in September 2007, the maximum available flow for the rivers Cali and Meléndez are below the installed capacity of the drinking plants they supply. This situation has caused that the drinking water production from Río Cauca and Puerto Mallarino plants, supplied by Cauca river, increase so that they can cope with the water demand in the city.

Due to the contamination of the water supply sources, the drinking water plants present higher operation and treatment requirements and as a consequence an increment in the treatment costs. When there are pollution peaks, EMCALI suspends the intake of raw water. As it can be seen in Figure 3.4 the drinking water plants that present higher operation-time stops are Rio Cauca and Puerto Mallarino which are supplied by Cauca river.

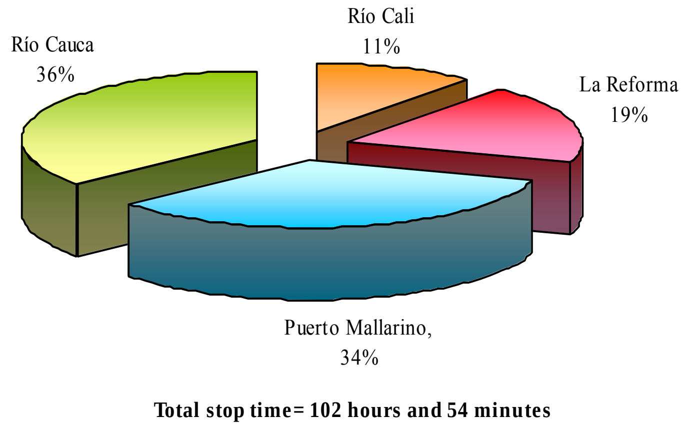


Figure 3.4 Percentage of time that the drinking water plants were shutdown due to high pollution concentration in the water sources in year 2005.
Source: Vasco, 2006

The city of Cali depends 77% on the Cauca river for the drinking water provision. The deterioration of the quality of this source is threatening the safe provision of water to the population, when the risk is increased as much as the acute and chronic point beyond the capacity of treatment of the Río Cauca and Puerto Mallarino plants.

The two most important sources of contamination upstream the water intake of Puerto Mallarino Plant are the South Channel and the Navarro disposal site which discharge wastewater and pollution around 5 km upstream the Puerto Mallarino water intake.

Figure 3.5 shows the number of times that the Puerto Mallarino and Rio Cauca plants were stopped due to high contaminating levels in Cauca river since the year 2000 to 2006. The number of time that the plant was left out operation has increased during the years.

The distribution network is divided depending on the type of service: High network (pumped system), low network (gravity system) and “La Reforma”. Additionally, there is the Ribera water supply system which covers the communities located in the Pance area. Figure 3.6 shows the low and high network distribution systems.

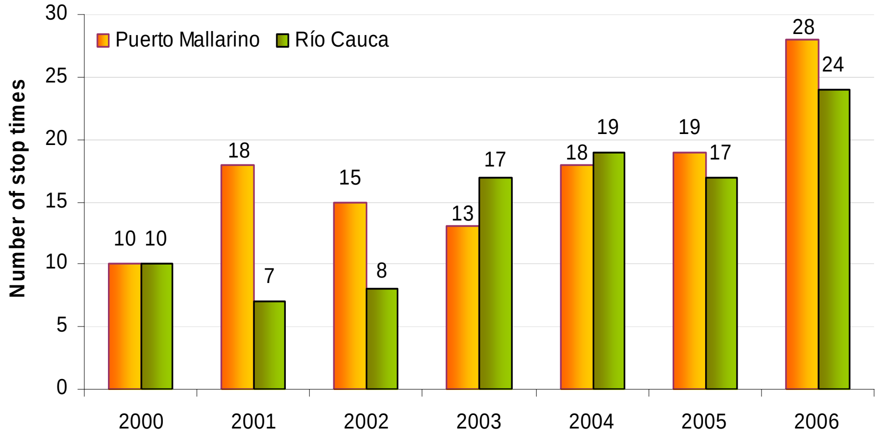


Figure 3.5Times Puerto Mallarino and Rio Cauca plants were put out of operation, 2000 to 2006

Source: Data reports given directly by Rio Cauca plant years 2000-2006 and EMCALI-Universidad del Valle, 2007

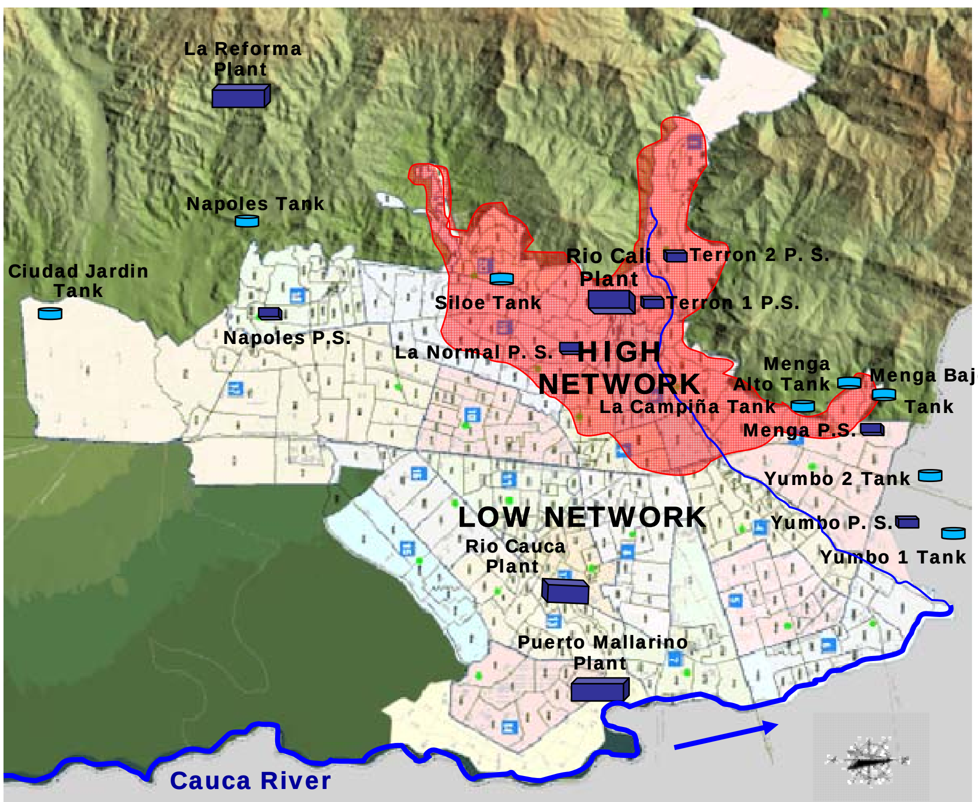


Figure 3.6 High and low distribution networks in Cali.

Table 3.2 briefly describes the distribution network in the city, considering the water source and the population covered.

Table 3.2 General description of the water distribution network in Cali

Source	Drinking water plant	Network	Percentage covered population
Cauca river	Puerto Mallarino	Low	77% of the population located in the flat area of Cali and a sector located in the flat area of the municipality of Yumbo
	Rio Cauca		
Cali river	Rio Cali	High	17,1% of the population located in the slope hill (north-west and center of Cali)
Meléndez river	La Reforma	Reforma	5,7% of the population located in the slope hill (south-west of Cali)

Source: Adapted from EMCALI-Universidad del Valle, 2007

In 2003 the total volume of produced water was 219.475.452 (m^3/year), where 86'161822 m^3 of this total was not charged. According to EMCALI, for the year 2007 until July the unaccounted for water index has reached an average of 39,98%. This percentage indicates presence of illegal connections mainly in slum areas. Such amount of water lost (not charged) represents great economic losses for the drinking water company in charged, in this case EMCALI.

Regarding contamination of drinking networks, after a study carried out by EMCALI-Universidad del Valle (2007), it was found that the high network presents problems associated to presence of particulate material which influences the turbidity, total solids and real color in the water. Such problem may be related to the age of pipes which are older than 36 years.

There are also chlorine concentrations above 1 mg/l recorded in the monitoring control stations in the distribution network which can influence formation of by-products in the network and increase the risk of chemical contamination in the water (EMCALI-Universidad del Valle, 2007).

Sewerage system

According to EMCALI, the coverage of the sewerage system to September, 2007 is 94,8%. The sewage system in Cali is divided in three drainage systems: the South Drainage System (SDS), North-West Drainage system (SDN) and East Drainage System (SDO).

Through these three drainage systems, Cali directly drains its wastewaters and storm waters to Cauca river. The only way of control of wastewater contamination in the city of Cali is made through the use of the wastewater treatment plant of Cañaveralejo (C-WwTP) which receives around 56% of the total wastewater produced in the city. Chapters 3.2 explain in detail the sewerage system of the city and the characteristics of the C-WwTP.

Electric energy

EMCALI is the responsible for providing the electric energy service to the municipalities of Cali and Yumbo. The company is the owner of the distribution infrastructure and together with EPSA (Energy company of the Pacific) own the energy sub-stations which are connected to the electric energy national network (URL-6).

Solid waste collection and disposal

EMSIRVA has been the company in charge of the collection, transport and final disposition of the solid waste produced by the city of Cali since 1966. The coverage of the service is 100% in the urban area and around 90% in the rural area of Cali (EMSIRVA, 2007).

The approximate 1800 ton/day of waste produced in the city are collected and transported to the solid waste deposit Navarro, located to the district of Navarro, in the south-east of Cali to the left margin of Cauca river and nearby of the south channel (see Figure 3.7). The area is characterized by a flat topography, with low slopes to the natural drainage of Cauca river, by the presence of phreatic levels at a depth of 4,5 meters respect to the ground level and a high degree of flooding.

Figure 3.7 Location Solid waste deposit of Navarro.

The main environment impact caused by the disposal site of Navarro is the leachate contamination in surface and underground waters. CVC (2004) has recognized the ground water contamination by leachate, which reaches about two kilometers along the

"Madrevieja"[1] with a depth of 10 meters. Leachate contamination is also reflected in the presence of hazardous substances such as arsenic, cadmium, cyanide, copper, phenol compounds, chromium, mercury, silver, lead and selenium.

Furthermore, regarding surface water around Navarro site which is mainly composed by Cauca river, "Madrevieja" and South channel (which receives the Cañaveralejo channel - Cañaveralejo River once it has been channeled, Ferrocarril channel and Líli and Melendez Rivers), such systems are in imminent danger of contamination through percolation of leachate or clandestine direct discharge to them. The discharge point of south channel to Cauca River is located approx. 5 km upstream the water intake point of the drinking plants of Puerto Mallarino and Río Cauca, causing an increase in the risk of use of the source for the water supply of the city (Agudelo et al., 2005).

Navarro is not considered as a proper land fill so currently the environmental authority CVC has stated that the disposal site needs to be closed and new alternatives of solid waste disposal need to be found. Therefore, after the evaluations of different alternatives to locate a final solid waste disposal site, the conclusion was that the most likely place to establish the technical landfill for the city of Cali is the Municipality of Yotoco.

3.2 DESCRIPTION BY COMPONENTS OF THE URBAN WASTEWATER MANAGEMNET SYSTEM, OF THE CITY OF CALI

3.2.1 Sewage System

General Overview

According to EMCALI, the coverage of the sewage system to September, 2007 is 94,8%. Cali's sewage system is a complex system since issues such as illegal connections and wastewater discharges to storm water channels have caused throughout the years that the majority of the sewage system has become mostly combined.

The sewage system in Cali is composed of:

i) Storm and combined water sewers
ii) Regulation systems such as the dam of Cañaveralejo and the lagoons of the Pondaje
iii) Pumping stations
iv) The Cañaveralejo wastewater treatment plant C-WwTP

The sewage system in Cali is divided in three drainage systems: the South Drainage System (SDS), North-West Drainage System (SDN) and East Drainage System (SDO).
Figure 3.8 shows the areas of drainage of each one of these systems (EMCALI-Universidad del Valle, 2006b).

[1] "Madrevieja", is an abandoned natural water stream that is located along the solid waste disposal site of Navarro.

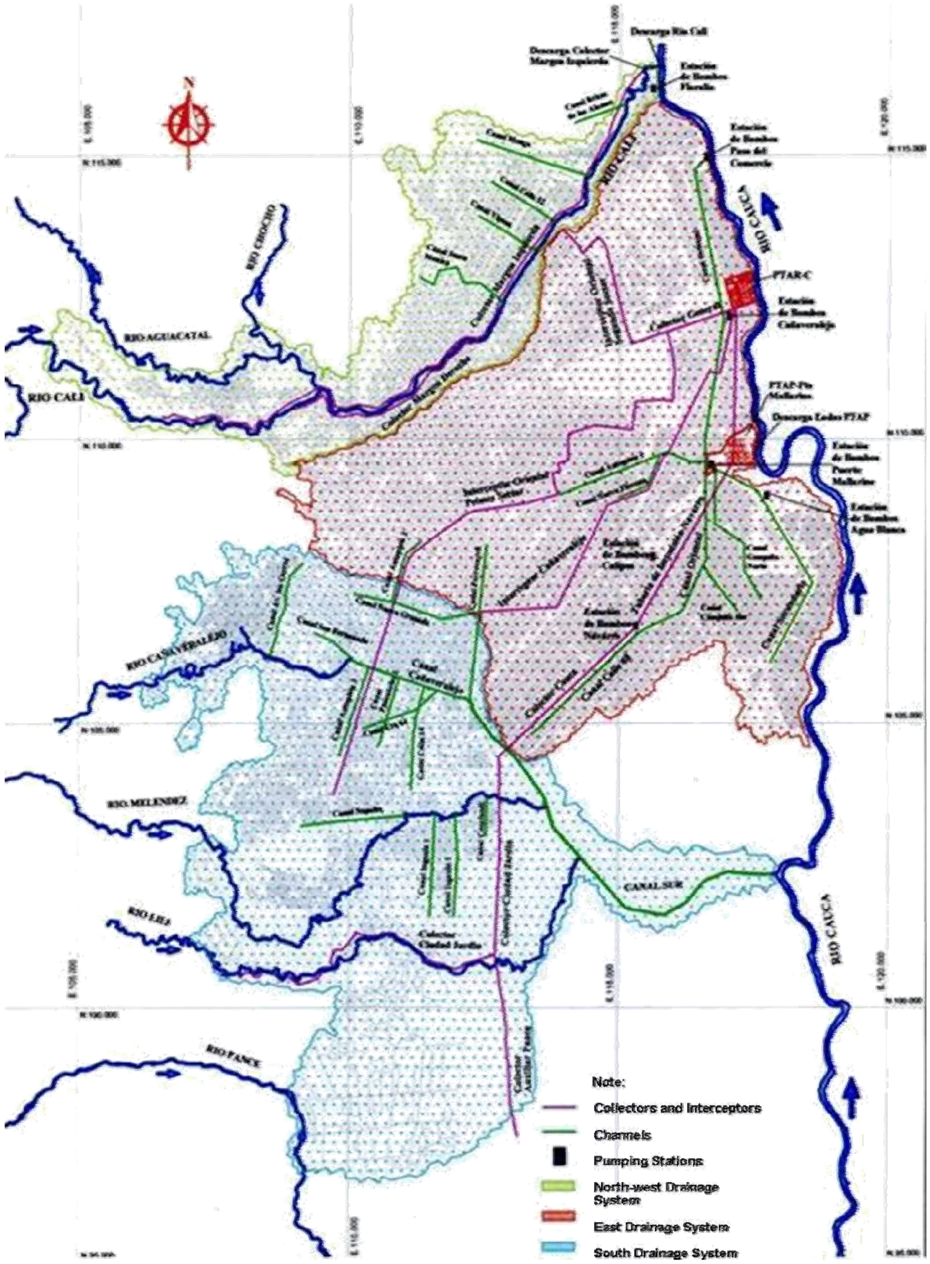


Figure 3.8 Drainage systems in City of Cali.
Source: EMCALI-Universidad del Valle, 2006b

Through these three drainage systems, Cali directly drains its wastewaters and storm waters through the left margin of the Cauca river using four discharge points: 1) South Channel "Canal Sur", 2) Pumping station Puerto Mallarino- "Estación de Bombeo Puerto Mallarino", 3) sludge from drinking water Plant Puerto Mallarino-"Descarga Lodos PTAP, 4) effluent from Wastewater treatment plant Cañaveralejo (C-WwTP), and 5) Paso del Comercio pumping station - "Estacion de Bombeo Paso del Comercio".

3.2.2 Wastewater collection and transport

- ***South Drainage System***

This system drains by gravity the South-west part of the city through the main channels which are called South Channel, Cañaveralejo channel (which is the Cañaveralejo River once it has been channeled) and Ferrocarril channel. The drainage system intercepts the rivers Meléndez and Líli. The South Drainage System is the only system that does not count with pumping stations. It completely works by gravity.

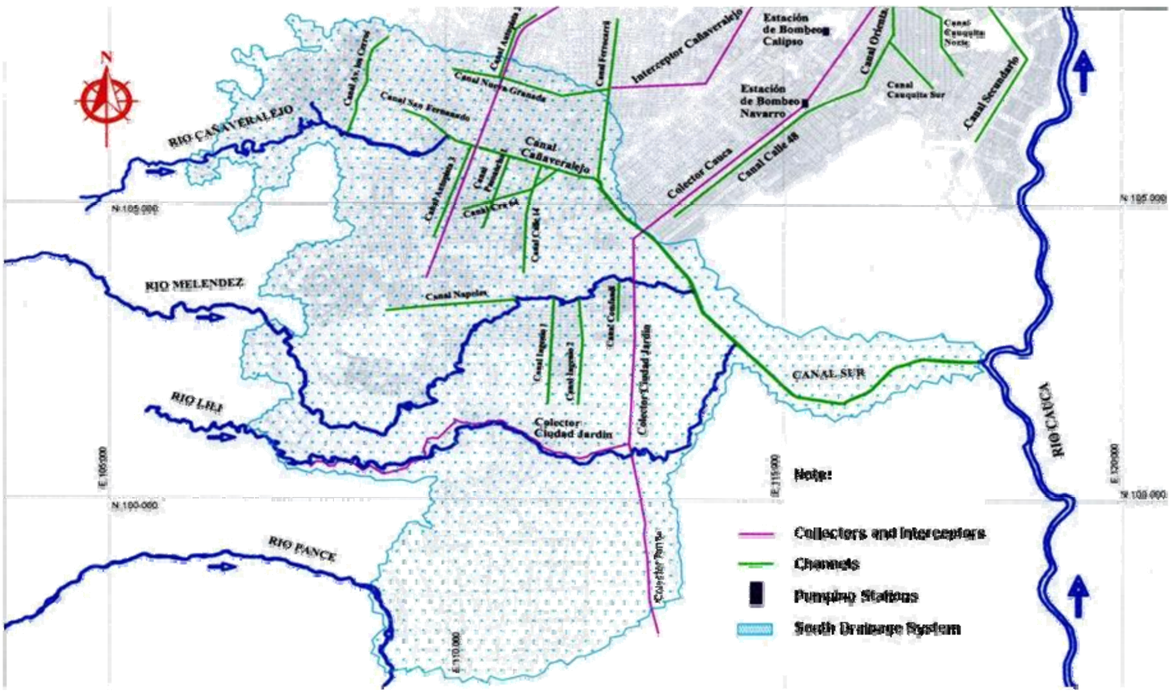


Figure 3.9 South drainage system and its main components
Source: EMCALI-Universidad del Valle, 2006b

The final wastewater discharge of this system is the Cauca River. The discharge point is located approx. 5 km upstream the water intake point of the drinking plants of Puerto Mallarino and Cauca river. The main transport channel of the system is the South Channel whose length is 7730 m and it is coated in its two first sections (3500 m). Its average depth is of 6 m (EMCALI, 2007a).

Wastewater discharge: The South Channel conveys all wastewater collected in the South Drainage System to finally discharge it to Cauca river. Figure 3.10 shows the South Channel discharge point to Cauca river.

Figure 3.10 South Channel discharge point to Cauca river

- ***North-West Drainage System***

The system is composed mainly by the sanitary and storm water collectors Margen Izquierda and Margen derecha, and Guaduales and Floralia pumping stations. The approximated total length of channels in the system is 15170 m. There are no regulation systems in this drainage system (see Figure 3.11).

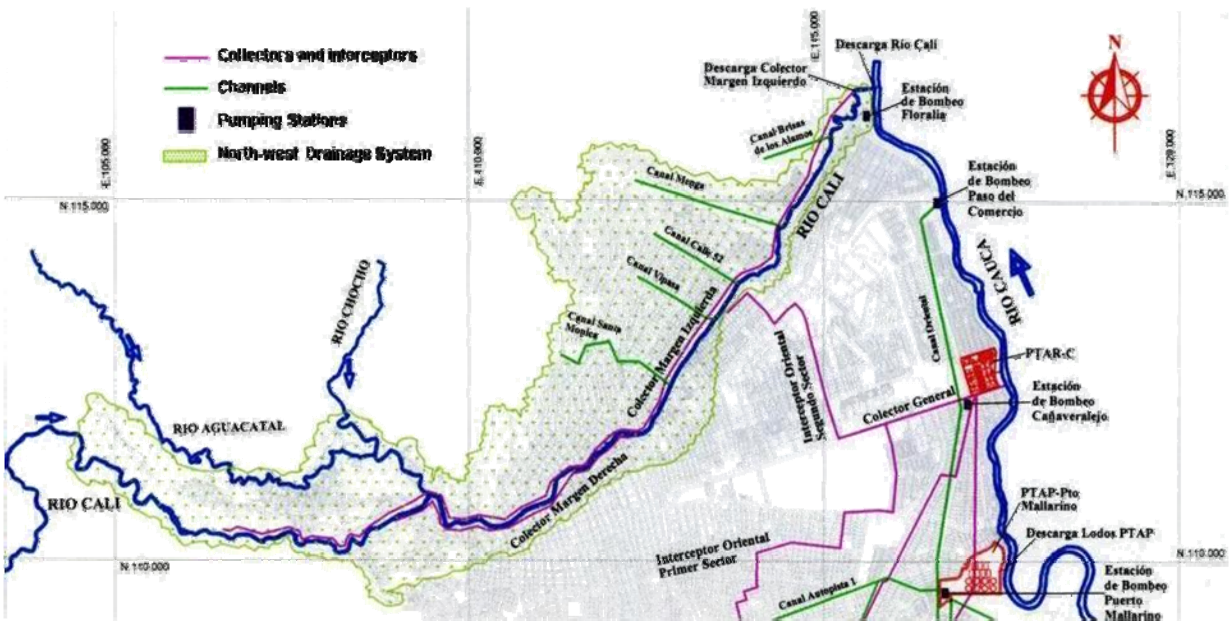


Figure 3.11 North-west Drainage System and its main components
Source: EMCALI-Universidad del Valle, 2006b

The main collector of the system is the Margen Izquierda collector which is located parallel to Cali river. Its total length is 12 km. During its course, it receives the wastewater from the north-east part of the city and from Margen Derecho collector. Margen Izquierda collector finally discharge to Cali River approximately 800 m before Cali river discharges to Cauca River (EMCALI-Universidad del Valle, 2006b). However, on 2003 this collector collapsed and the discharge point moved approximately 1000 m upstream the original discharge point (see Figures 3.12 and 3.13).

Figure 3.12 Collector Margen Izquierda discharge point, before collapsing in 2003.

Figure 3.13 Margen Izquierda Collector discharge point, after collapsing in 2003.

The Margen Izquierda collector conveys and transport wastewater directly to Cauca river. This collector transports around 10% of the total wastewater produced by the city of Cali. The other discharge point is the Floralia pumping station which pumps around 2% of the total wastewater produced in the city to Cauca river (EMCALI, 2007a).

Since December 16th, 2007 are operating the works of construction made for convey and transport the wastewater from the Marginales collectors up to the wastewater treatment plant of Cañaveralejo (C-WwTP), with the main purpose of reduce the polluting discharges made directly to the Cauca river from Floralia pumping station and take advantage of the capacity of the plant and increasing the flow to treat in approximately 850 l/s.

The work of construction has two stretches, the first one with a diameter of 36" and 380 m of length, which go from the Margen Izquierda collector up to the Floralia pumping station; the second one is the impulsion line of 33" of diameter and 4300 m, which initiates at the Floralia pumping station up to the wastewater treatment plant of Cañaveralejo (C-WwTP).

- ***East Drainage System***

The main components of the East System are the General and Cauca collectors, Oriental and Cañaveralejo interceptors, Cañaveralejo, Navarro and Aguablanca pumping stations and the wastewater treatment plant of Cañaveralejo (C-WwTP). The channel system is mainly composed by Oriental and Cauquita Norte channels and the Paso del Comercio and Puerto Mallarino pumping stations. The lagoons of Pondaje and Charco Azul make part of the regulating system of this system as well.

The General or Central collector is the principal collector of the system. It works by gravity and receives the wastewater coming from Oriental interceptor, other secondary interceptors and Cañaveralejo interceptor through Cañaveralejo pumping station. The general collector is connected to the line influent of the C-WwTP and counts with a by-pass system to the Cauca river, which is used in season of rains.

The East Drainage System has the following final discharge points: i) Paso del Comercio pumping station which pumps around 2% (169 l/s) of the total wastewater to Cauca river, ii) Puerto Mallarino pumping station which pumps around 5% (322 l/s) of the total wastewater and iii) the effluent from the C-WwTP which discharges around 56% (3810 l/s) of the total wastewater produced in the city (EMCALI, 2007a).

3.2.3 Systems of regulation

Cañaveralejo Dam - South Drainage System In the South System is located the dam of Cañaveralejo. The Cañaveralejo dam is an artificial system of regulation whose aim is to buffer the flow peaks that appear during winter season in the Cañaveralejo River and hence avoid flood events in nearby zones. It covers an area of 78492 m^2.

Lagoons El Pondaje and Charco Azul - East Drainage System It consists of an artificial wetland constructed in the 60`s for the regulation of the storm water in the city and for the regulation of the frequent flood events presented in this area of the city. It is composed by two lagoons, one denominated the Pondaje (South) and the other Charco azul (North). The ponds finally discharge to the Oriental Medio channel. Due to presence of illegal slums in the area, the lagoons have lost their initial hydraulic capacity (EMCALI, 2007a). Table 3.3 shows a comparison between the Pondaje lagoons design operation parameters and the design capacity in year 2000.

Table 3.3 Comparison between design and characteristics in year 2000 Pondaje lagoons.

Characteristics	Design (1959)	At year 2000
Área (ha)	31	25 (80% of the original area)
Storage capacity (m^3)	620000	265000 (42% of the original)
Inhabitants living nearby the lagoons	250 (year 1969)	61000 (comuna 13) and 4889 people living in the lagoon protected area.

Source: Quantum, 2000

These regulation lagoons were designed to serve as dams lowering hygrograms peaks so that the maximum pumping flows could be decreased and a reduction in the costs of operation of the pumping stations could be reached as well.

Figure 3.14 Pondaje lagoons in 1982.
Source : Quatum (2000)

Figure 3.15 Lagoons El Pondaje and Charco Azul in 2004
Source: Contraloría de Cali, (2005).

3.2.4 Pumping stations

North-West Drainage System

Pumping station Floralia: It is located on the north-east side of the city near the confluence of the Cauca and Cali rivers. It drains an important part of the right margin of the Cali River, including part of wastewaters of the nearby districts. It was designed to evacuate storm water from the low zones of the sector.

This station has four pumps in parallel (see Figure 3.16), each one with a volume of 250 l/s. In addition the station counts with a system of four auxiliary pumps with a capacity of 2500 l/s, available for storm water events (EMCALI-Universidad del Valle 2006b).

Figure 3.16 Floralia pumping station

Currently, this pumping station receives the wastewaters coming from the Marginales collectors from the Cali river; through impulsion line this pumping station impels waste water to the C-WwTP.

Pumping station Guaduales: It is located in the right margin of the Cali river, in the Guaduales sector. It is a storm water station and counts with and installed capacity of $8m^3/s$. It operates only one month per year.

East Drainage System

Navarro pumping station: It receives waste waters from the Cauca Collector and it impels them until the C-WwTP. It has an installed capacity of 8 m^3/s.

Aguablanca pumping station: It receives waste waters of an ample sector of Aguablanca and it impels them until the C-WwTP. It has an installed capacity of 2,8 m^3/s.

Cañaveralejo Pumping station: It receives waste waters of the Cañaveralejo interceptor and it transports them to the C-WwTP. It has a capacity of 6,5 m^3/s. (EMCALI, 2007a)

Paso del Comercio: It was initially designed for the evacuation of storm water coming from Oriental Channel. However, as it was mentioned before, due to illegal connections from the sanitary collectors in the city, at the moment a combined water volume is pumped from the Comunas or districts 13, 16, 15 and 6 (see Figure 3.17).

Figure 3.17 Exit channel from Paso del Comercio pumping station

Figure 3.18 Discharge point Puerto Mallarino Pumping station

Pumping station Puerto Mallarino: It was originally designed to evacuate storm water; however it pumps wastewater as well as consequence of illegal connections (see Figure 3.18). It receives water coming from Cauquita Norte and Secundario Channel. The system is composed by 5 pumps. Each one has a capacity of 3,6 m^3/s. The total pumping capacity is 18 m^3/s.

Pumping station Calipso: It drains directly some neighborhoods located in the North-west part of the city. It is located in the South and it pumps wastewater to Navarro pumping station, which pumps wastewater to C-WwTP and the Pondaje Lagoons. It has an installed wastewater pumping capacity of capacity 0,7 m^3/s and a storm water pumping capacity of 3,5 m^3/s (EMCALI, 2007a).

3.2.5 Wastewater characteristics of drainage system.

Final wastewater discharge points from the city of Cali to Cauca river

Cali’s current situation, based on year 2005, shows a BOD discharge load from the city to Cauca River estimated around 38% from the total discharge load in the Valle del Cauca department (CVC, 2006 cited by EMCALI , 2007a). The only way of control of wastewater pollution in the city of Cali is made through the use of the wastewater treatment plant of Cañaveralejo (C-WwTP) which treats over 56% of the total wastewater flow produced in the city (EMCALI, 2007a).

Untreated wastewater is directly discharged into the Cauca River at the following locations: i) South Channel; ii) Puerto Mallarino pumping station; and iii) Paso del Comercio pumping station. In the past the collector on the left side of the river and the Floralia pumping stations used to be points of final discharges of wastewater generated by the city of Cali, but since December 2007 this wastewater has been carried to the C-WwTP where it undergoes treatment.

As shows Figure 3.19, the effluent from the C-WwTP represents the biggest BOD load discharged to the river, its discharge impact to Cauca river is the highest since the dilution capacity of the river in that point is affected by this critical single load.

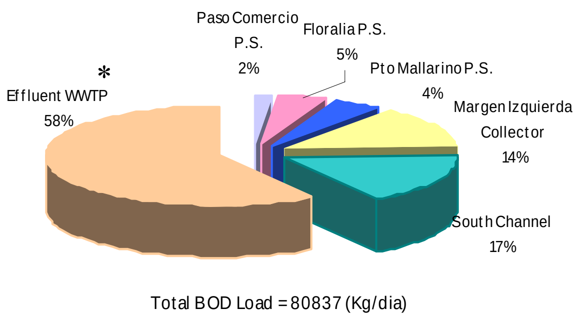


Figure 3.19 Total BOD Load discharged to the river

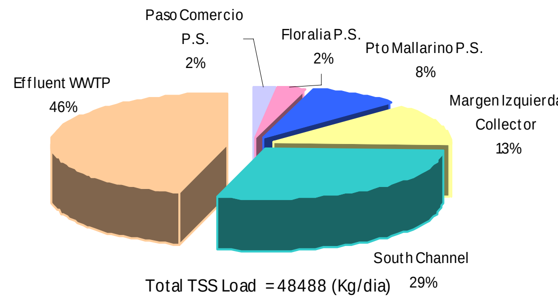


Figure 3.20 TSS Load discharged to the river

Notes: *Average year 2006
Sampling made by EMCALI in August 2006
Source: EMCALI, 2007. PSMV

A similar situation occurs with the load of TSS where the discharges from the C-WwTP (followed by the South Channel) represent the largest load of TSS dumped into the Cauca River (see Figure 3.20).

In addition, there is also presence of hazardous substances in the wastewater discharges specially from the South channel. Such substances are phenol compounds, lead and mercury. Presence of these substances is critical since they all finally arrive to Cauca river which is also the water source for drinking water for the city of Cali.

Industrial wastewater in the wastewater of the City

The industries in the urban area of Cali discharge directly their wastewater in the sewage system of the city. According to DAGMA in the period from 1998 to 1999 the total BOD and TSS load discharged by the industrial and commercial sectors in the city was approximately 24% to 26% from the total wastewater load generated in the city. The main impact to the domestic wastewater is the contribution of hazardous substances present in the wastes from the industries such as the metal, dental, and mechanic industry.

The C-WWTP is now receiving more than 56% of the wastewater generated in the city of Cali. Characterizing the affluent to the C-WWTP, including the new locations (i.e. the collector on the left side and the Floralia pumping station) recently incorporated to the treatment, allows identifying, to a large extent, the amount of contaminant load from both domestic and industrial wastewater generated in the city of Cali.

The following is a characterization of these locations as a function of the BOD and TSS loads from the domestic and industrial sectors.

The physicochemical characteristics of the affluent from the C-WwTP match the typical characteristics of domestic wastewater. Figure 3.21 shows the contaminant load in terms of BOD and TSS from the industrial sector and domestic wastewater

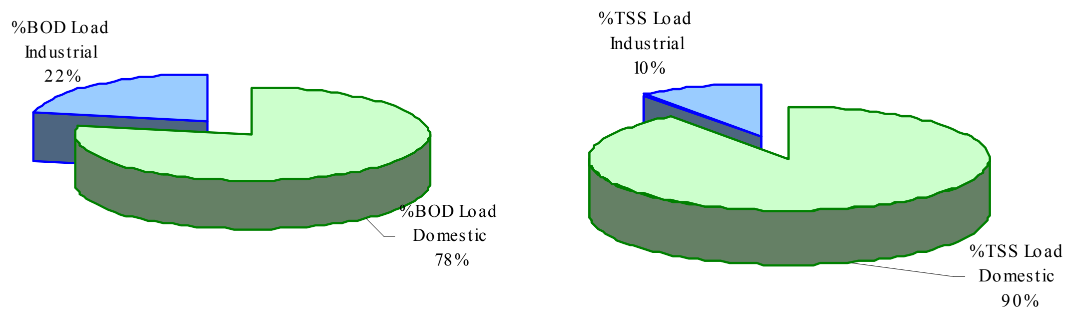


Figure 3.21 Loads of domestics and Industrial Wastewater that arrives to C-WwTP
Source: EMCALI-UNIVALLE, 2006

Domestic discharges account for 78% of the BOD load while industrial discharges represent the remaining 22%, the largest portion of which comes from the central collector that gathers wastewater from the foods and beverages industries. The largest contribution of these manufacturing activities is associated with high BOD and TSS loads and low pH values Domestic discharges generate the largest load of TSS accounting for 90% of the total load, while industries generate the remaining 10%.

Other activities that generate a minor amount of contaminant load to the affluent at the C-WwTP are listed in Table 3.4. Some of these activities generate inorganic substances, heavy metals or other hazardous contaminants which not only have an adverse effect on biological treatment processes, but also deteriorate the quality of the receiving bodies of water.

Table 3.4 Industrial discharges that generate a minor amount of contaminant load to the affluent at the C-WwTP

Activity	Number of companies	Contaminats
*Chemists and pharmaceutica*l -Cosmetics and pharmaceutical Laboratories	9	Vegetal and animal organic material, metals, phenols, cyanides and acids
Textiles- cotton, wool	4	High alkalinity, pH, high total solids, BOD y COD, cyanides, phenols, phosphates, chlorine, manganese, nitrogen, sulphides and greases.
Health - Hospitals and clinics	12	Pathogens microorganisms, virus, micro-pollutants.
Printers - Lithography and publishing house	5	Phenols, cyanides, metals, pH, Cr, Cu.
Metallurgy	7	pH, heavy metals, phenols, cyanides, Ni, Pb
Services - Restaurants, commercial centres, terminal transport, airports	8	Organic matter, grease and oil, phosphates.
Paper	3	Na, Sulphides, pH, metals (mercury)

Source: Adopted from EMCALI-UNIVALLE, 2006

Figure 3.22 shows the percentage of the contribution of industrial and domestic contaminant load from the collector on the left side. It is worth noting that the largest load comes from domestic wastewater because there isn't a significant presence of industries in the area of influence of the collector, but rather a predominant number of service facilities such as shopping malls and hospitals

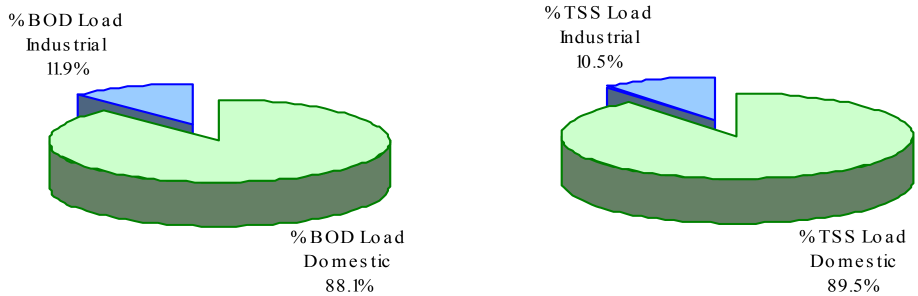


Figure 3.22 Loads of domestics and Industrial Wastewater in the Margen Izquierda Collector
Source: EMCALI-UNIVALLE, 2006

The largest impact of industrial wastewater on this collector is due to service facilities. However, the BOD and TSS loads generated by healthcare institutions account for 21% and 31% of the industrial effluent, respectively. This shows that these discharges have a large content of organic matter and biological contaminants

Compared to other locations, the Floralia pumping station registers the highest concentrations of BOD. This characteristic may be the result of the large contribution of organic load generated by Cadbury Adams, which is a foods and beverages manufacturing company that generates 94% of the industrial load discharged into its area of influence. Figure 3.23 shows the percentages of both domestic and industrial contaminant loads

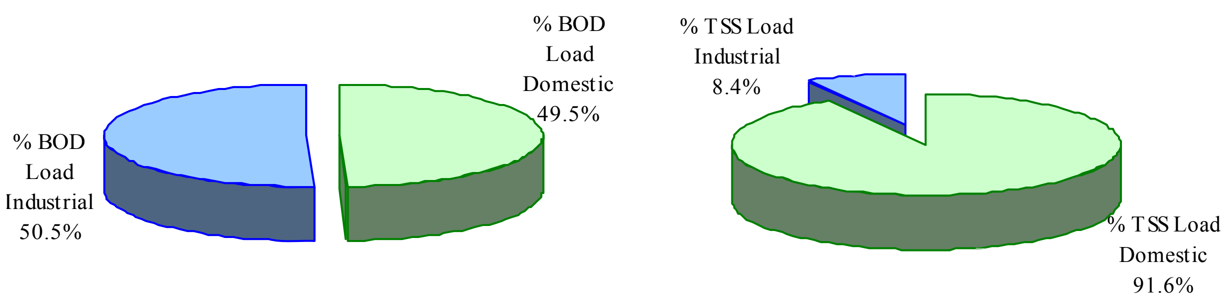


Figure 3.23 Loads of domestics and Industrial Wastewater in the Floralia Pumping Station
Source: EMCALI-UNIVALLE, 2006

3.3 WASTEWATER TREATMENT PLANT - CAÑAVERALEJO DESCRIPTION

3.3.1 General overview

From the decade of the 80's, EMCALI formulated the plan for wastewater decontamination, based on the studies of feasibility for the treatment of wastewaters of Cali. It was defined that the service of sewage system would be complemented with three wastewater treatment plants: the WwTP- Cañaveralejo, that would convey the main collectors and interceptors, with a coverage of approximately 85% of waste waters of the city, the WwTP - Rio Cali, that would receive the wastewater generated in the north-western zone of the city transported by the marginal collectors to the Cali river, with a coverage of approximately 15% and the WwTP - South (WwTP-S) that would receive the waste water generated by future zones of urban expansion of Cali. At the moment, C-WwTPanaveralejo (C-WwTP) is the only one constructed and in operation.

The C-WwTP is located in a lot of 22 Hectares; it is located between communes 6 and 7 of the city of Cali (Llanos, 2000). The wastewater influent to the plant comes from: the General collector (by gravity) and the pumping stations of Cañaveralejo, Navarro and Aguablanca. In addition, since December 2007, the C-WwTP receives wastewater coming from Floralia Pumping Station. Figure XX shows the location of the C-WwTP.

The only way of control of wastewater pollution in the city of Cali is made through the use of the wastewater treatment plant of Cañaveralejo (C-WwTP) which treats around 56% of the total wastewater flow produced in the city (EMCALI, 2007a). Following a description of the plant, its operation and treatment efficiencies is made.

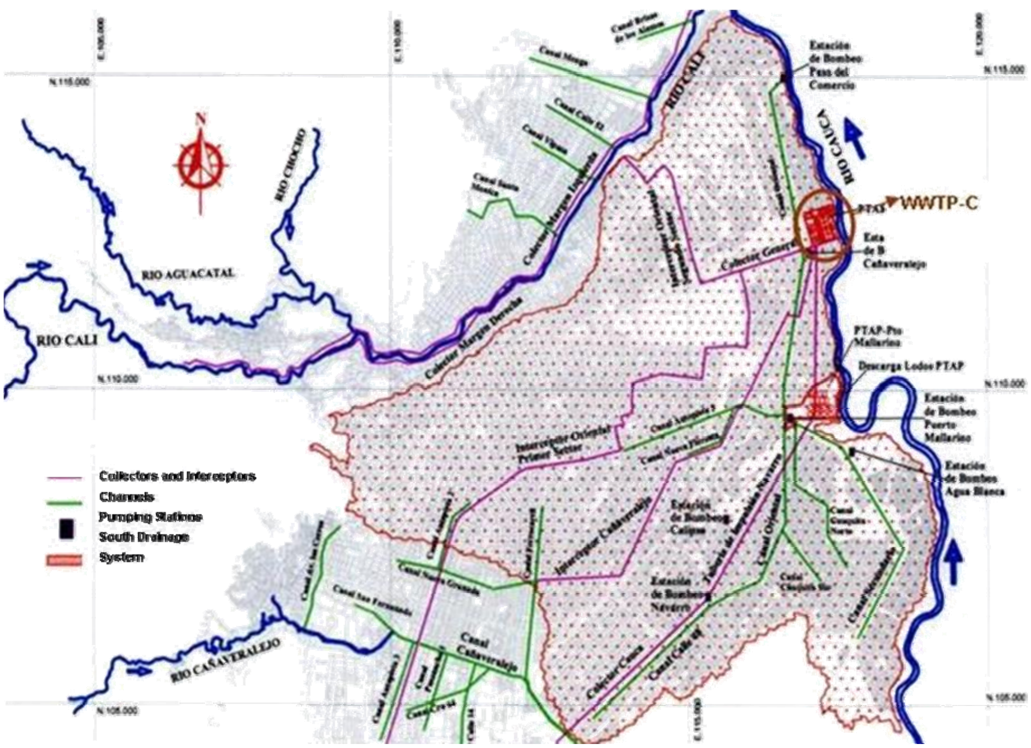


Figure 3.24 Location C-WwTP with its influents from Cañaveralejo, Navarro and Aguablanca pumping stations and General collector (East drainage system)

The plant began operating in December of year 2001 (EMCALI, 2007a). It can operate in two ways: through conventional primary treatment or through advanced primary treatment (TPA). The conventional treatment consists on a simple sedimentation whereas the TPA consists on the addition of ferric chloride ($FeCl_3$) as coagulant and organic polymer to enhance flocculation and improve the removal of solids. The general scheme of the plant is shown in Figure 3.25.

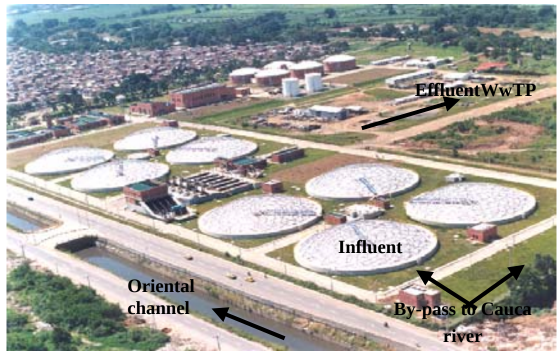


Figure 3.25 General scheme Cañaveralejo wastewater treatment plant (C-WwTP)

3.3.2 Waterline

The water line scheme and its main components is shown in Figure 3.26. Afterwards a description of the components is made.

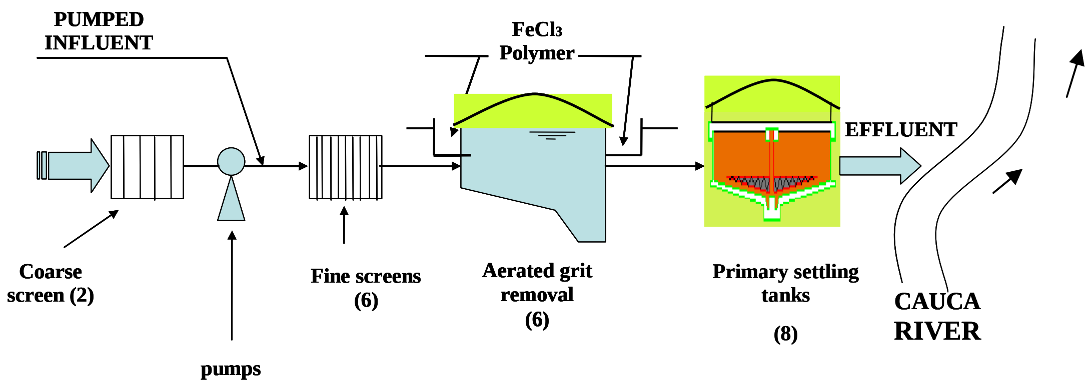


Figure 3.26 Water line scheme
Note: (#) Quantity of units

Coarse screens: There are 2 coarse screens than function mechanically to remove garbage. Their height is 2 m by 2,6 meters wide. Separation between bars is 10 cm.

Pumping station: It is composed by four screw pumps, with 2 m of diameter and a nominal capacity of 2 m^3/s each.

Flow mixing chamber: It is a chamber that mix all wastewater flows coming to the C-WwTP, from pumping stations Aguablanca – Navarro, Cañaveralejo and Floralia with wastewater coming from General collector. Before the fine screens there are a bypass systems composed by 2 bypass chambers to deviate excess waste water to Cauca river, generally under big storm water events.

Fine screens: There are 6 fine screens. The fine screens retain solids bigger than 2,5 cm.

Aerated grit removal: There are 6 aerated chambers in line with the fine screens. The process of settling and separation of sand on the bottom of the chambers is done through the addition of air by means of diffusers. The retention time of the aerated chambers is 3 minutes. The sand removal is done by means of ejection pumps that conduct the settled material to storage containers. Then the material is finally disposed in a place outside the plant premises. The volume of the each chamber is 394 m^3. Advanced primary treatment (TPA) is used to improve the removal efficiency of non-soluble BOD and TSS by the addition of ferric chloride coagulant before wastewater enters the aerated grit removal system. Similarly, an organic polymer is added to enhance flocculation in the exit channels from the grit chambers. There are 2 tanks for the storage of ferric chloride (50 m^3).


Figure 3.27 Aerated grit removal


Figure 3.28 Sand removal system

Primary sedimentation tanks: After the aerated grit removal process, wastewater is conduced to the primary sedimentation tanks. There is also a bypass connection (before primary sedimentation) to discharge excess of wastewater to Cauca river in case it is needed. There are in total 8 sedimentation tanks, distributed in two groups of four. The tanks are circular, with diameters of 47,5 meters and height of 4,20 meters (volume of 8690 m3). Wastewater is fed from the bottom of each tank and exists already treated from above. The sludge that remains on the bottom is removed from the bottom and is pumped to the thickener, prior to digestion. The floating sludge that remains on the supernatant is taken away by a mechanical sweep system and it is transported to 2 storage containers and finally to a grease trap where the wastewater is re-circulated by gravity to the beginning of the treatment process.


Figure 3.29 Primary sedimentation tanks


Figure 3.30 Mechanical sweep system

The grease is gathered and taken away from the plant. Treated effluent is conveyed to chambers which transport it to the final discharge point: Cauca river

3.3.3 Sludge Line

The sludge line scheme and its main components is shown in Figure 3.31. Afterwards a description of the components is made.

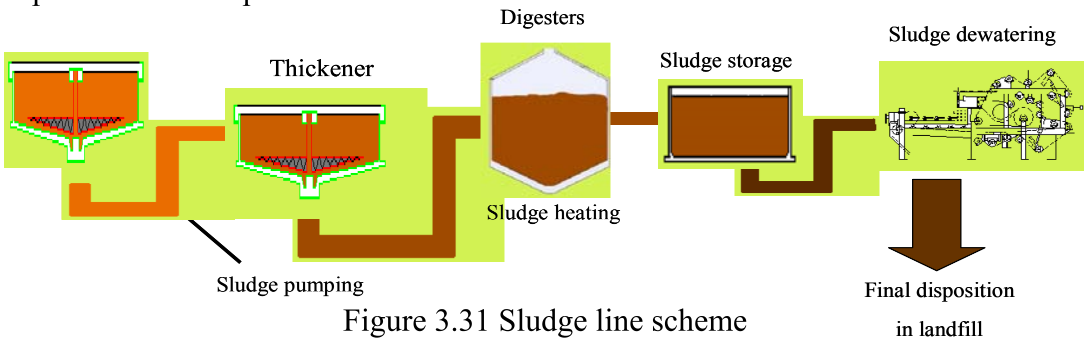


Figure 3.31 Sludge line scheme

Thickener: The sludge produced in the primary sedimentation is pumped with a DS concentration of 2% until 4 to 6% to the thickener. There is one thickener with a volume of 3322 m^3.

Anaerobic digesters: There are four digesters which receive the sludge from the thickener. The digesters function in the mesophilic range at controlled temperature of 35-38°C. The volume of each digester is 6200 m^3.

Figure 3.32 Thickener

Figure 3.33 Anaerobic digesters

Sludge dewatering: It is composed by seven dewatering units (filter press) with a daily capacity of 997 m^3/d. Lime powder is also aded to the bio-sludge to avoid odors and presence of vectors.

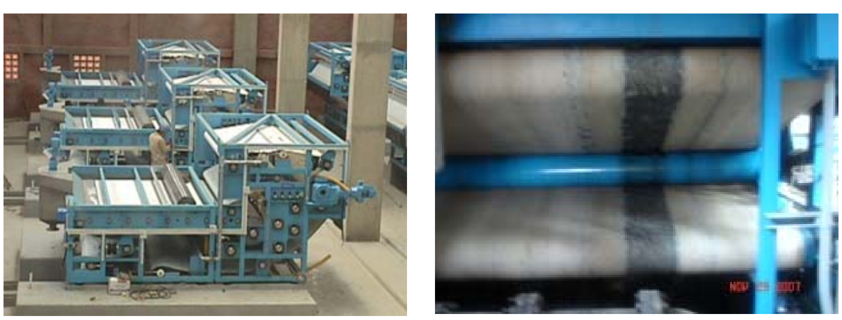


Figure 3.34 Dewatering units (filter press)

Finally, the dry sludge is disposed in a mono-fill which is located outside the plant in an area nearby drinking plant Puerto Mallarino. Figure 3.35 shows the location of the dry sludge mono-fill.

Figure 3.35 Location final disposal site for the bio-sludge coming from C-WwTP

3.3.4 Energy generation

Before generation of energy, the gas that is produced in the digesters is circulated in two gas purifiers to remove H_2S. The gas coming from the digesters is stored in two storage tanks with capacity of 1000 m^3 each. There are two generators of electric energy from the burning of biogas. Each generator has a capacity of 1000 Kw that would be used to generate energy for the internal consume of the plant that according to Llanos (2000) it requires a feed of 1600 kw/hour (for its designed demand). At present, the generators do not being used, but the biogas produced has two functions: mix and produces heat into the digestors, the excess of gas is burned using two burning units with capacity 1000 m^3 each as well.

3.3.5 Odor control

The C-WwTP counts with an odor control system called soil beds. The treatment consists on the filtration of gases through biologic filters which by means of biological reactions occurring in their interior, transform the gases that cause bad odor (sulfuric gas and others). The filters are made by organic material (humus), volcanic ashes and organic layers.

Figure 3.36 Odor control system - soil beds.

3.3.6 Wastewater characterization

The design capacity of the C-WwTP was established as 7,6 m^3/s for the year 2015. During the year 2006, the average influent flow rate ranged between 3,16 m^3/s and 4,49 m^3/s, with an annually average of 3,82m^3/s. Figure 3.37 shows the average of flows during year 2003 to 2007, it shows the increase of influent flow.

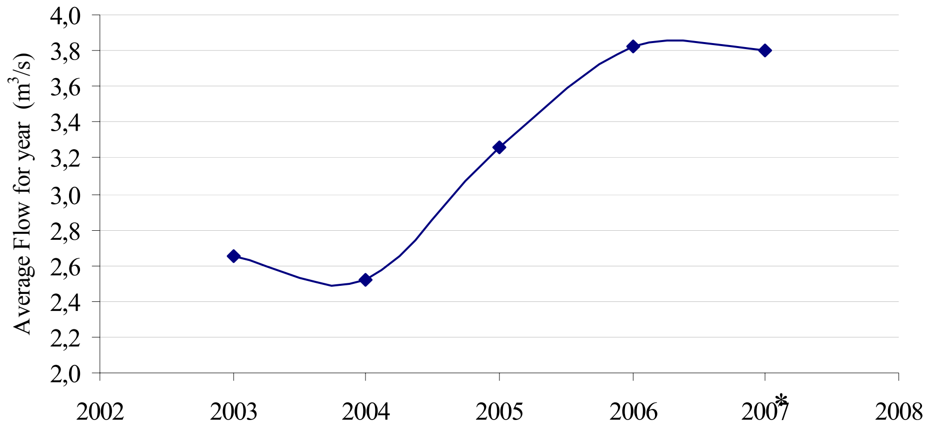


Figure 3.37 Average influent flow C-WwTP during year 2003 to 2007
Note: *Average January – September
Source: EMCALI, 2007b

In the plant, composite samples are taken during the day so that wastewater characterization is carried out daily. Table 3.5 shows the average monthly values registered for the influent and effluent in year 2006.

Table 3.5 C-WwTP influent and effluent characterization, year 2006

Month	Flow (m^3/s)	Influent				Effluent			
		TSS (mg/l)	BOD (mg/l)	COD (mg/l)	TP (mg/l)	TSS (mg/l)	BOD (mg/l)	COD (mg/l)	TP (mg/l)
January	3,78	172	208	456	4,73	78	156	322	2,8
February	3,66	175	219	474	3,81	66	136	300	2,1
March	4,08	164	198	378	-	57	125	239	-
April	3,80	167	230	415	-	59	134	240	-
May	3,64	192	226	483	6,0	55	127	281	4,0
June	3,81	174	217	438	7,2	56	136	290	5,8
July	3,16	218	271	587	8,4	65	178	364	6.4
August	3,53	189	275	566	5,7	60	177	348	4,4
September	3,72	211	235	508	6,0	62	154	328	4,9
October	3,91	238	254	548	6,9	68	156	341	4,7
November	4,49	247	191	461	4,6	90	122	301	4,1
December	4,21	202	211	472	4,7	70	132	286	4,0

Source: EMCALI, 2006.

3.3.7 Removal efficiencies

Table 3.6 shows the monthly removal efficiencies measured in 2006 for the parameters of BOD and TSS. According to the design criteria in average the plant complies with the removal efficiencies in terms of BOD and TSS with or without TPA. Additionally, it can be seen that BOD and TSS removals are slightly higher when TPA is used.

Table 3.6 C-WwTP comparison removal efficiencies with and without TPA, year 2006

Month	% removal with TPA[1]		% removal without TPA[2]	
	BOD	TSS	BOD	TSS
January	30	63	22	49
February	40	64	29	52
March	39	66	39	59
April	42	63	33	57
May	44	71	-	-
June	40	69	25	59
July	37	70	33	68
August	40	72	31	65
September	37	69	31	71
October	46	77	38	70
November	-	-	37	63
December	-	-	39	64

Source: EMCALI, 2006.

[1] *Design removal, with TPA:* BOD removal (%): 42 ± 5, TSS removal (%): 63 ± 5

[2] *Design removal, without TPA:* BOD removal (%): ≥ 25, TSS removal (%): ≥ 50

However, using TPA requires higher operation costs due to the use of chemical, to year 2006, the montly average costs was approximately $96.459.522, because of the $FeCl_3$ and organic polymer consumption, to achieve only around 15% extra removal.

During the first half of 2006 the plant operated with TPA in a continue way, stopping the treatment every 5 days in average (due to problems with valves in the plant and maintenance activities). During the second half of the year the plant operated without TPA in November and December due to failures on the monitoring system. Additionally, Table 3.7 shows the total BOD production in Cali and the respective BOD removal efficiency of the C-WwTP, in year 2005.

The C-WwTP received around 56 % of the total BOD wastewater load produced in the city of Cali. However, after treatment only 18,6% to 24,8% BOD removal (from the total BOD produced in the city) was achieved. In addition, the influence of primary advanced treatment in the whole treatment represents an additional 15% BOD removed which compared to the total load discharge to Cauca river still represents the highest contribution in terms of BOD load to Cauca river.

Table 3.7 Total BOD load production in Cali and BOD removal efficiency of the C-WwTP, in year 2005

Parameter	Value
Total BOD load produced in Cali (ton/day)	113
BOD load discharged to Cauca river without treatment*	
BOD load arriving to C-WwTP (ton/day)	70
BOD load effluent from C-WwTP with TPA (ton/day)	42
BOD load effluent from C-WwTP without TPA (ton/day)	49
BOD load removal C-WwTP with TPA (ton/day)	28
BOD load removal C-WwTP without TPA (ton/day)	21
BOD removal from the total BOD produced in the city (%)	24,8
BOD removal from the total BOD produced in the city (%)	18,6

Source: adapted from EMCALI, 2007a

* From the other sewage discharge points to Cauca river: South channel, Margen izquierdo collector, pumping stations of Floralia, Puerto Mallarino and Paso del Comercio, and sludge from Puerto Mallarino.

3.3.8 Bio-solid production

Bio-solid is the digested sludge that has been also dried and that is ready for final disposal. Based on the production reports carried out in the plant during January to May 2007, the average production of bio-solid was 75 ton/d. This production depends also from the way of operation (TPA or not). During year 2006, around 38673 tons of bio-solid were finally disposed on the lot “Puertas del sol” which is equivalent to 34220 m^3. In addition Figure 3.38 shows the historical production of sludge from 2003. The sludge production has increased since 2004 with a total production of 34220 m^3 in 2006. Such trend is due to the increase in wastewater treated since 2004 (see Figure 6.8). Total production of sludge until May, 2007 was 9774 m^3 .

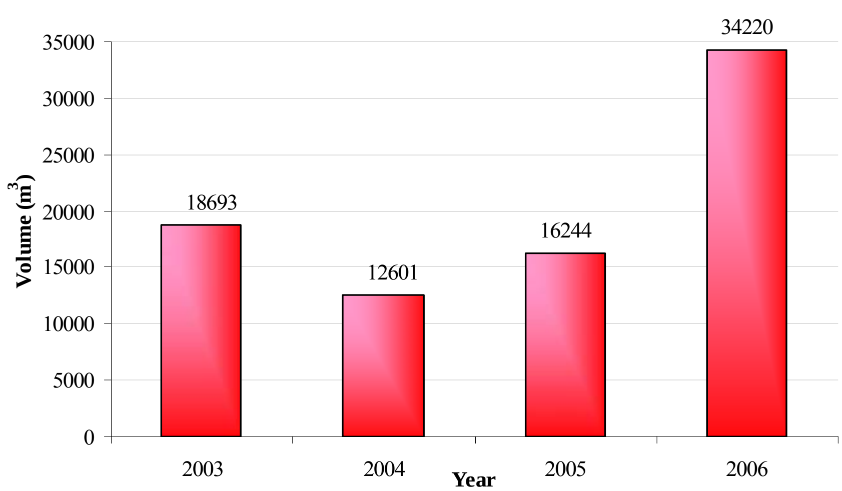


Figure 3.38 Historic production of bio-solids during the treatment of wastewater.
Source: EMCALI, 2007b

3.4 CAUCA RIVER - WATER RECEIVING SYSTEM -

The Cauca river is the second most important water source in Colombia. It is born in the Colombian mountain range (Macizo Colombiano). It surrounds the moorland of Sotará and has a length of 1350 km which crosses Colombia from the south to the north until meeting the Magdalena river (see Figure 3.39). Cauca's river basin is extended along the Central and Western Mountain ranges with an approximated area of 63300 km^2.

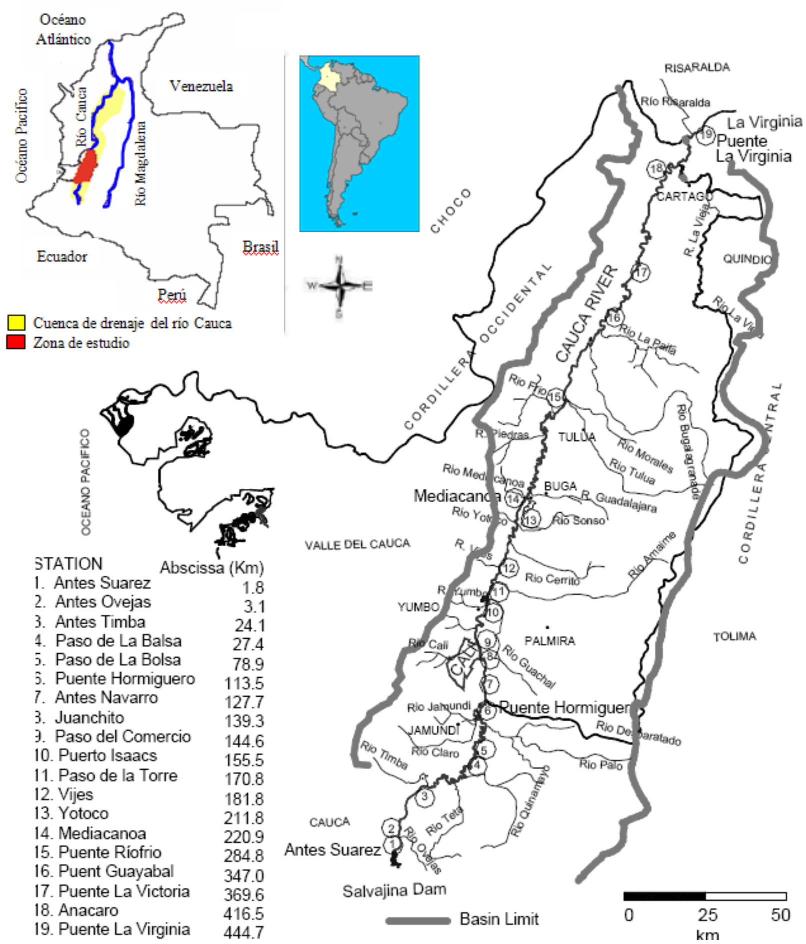


Figure 3.39 Cauca River Basin with its monitoring stations

The river crosses Colombia from south to north through the departments of the Cauca, Valle del Cauca, Quindío, Risaralda, Caldas, Antioquia, Cordoba, Sucre and the Bolivar. Along its river basin more than 10 million people live, who represent approximately 25 % of the Colombian population. Along Cauca river basin, there is located the sugar cane crops and the Colombian sugar industry, part of the coffee zone, the zones of mining and farming development of de department of Antioquia and an important sector of the manufacturing industry of the country (Velez et al., 2006).

The Cauca's river basin is divided and classified in three sections: high Cauca, medium Cauca and low Cauca (see Figure 3.40). High Cauca extents from its source through the Cauca and Valle del Cauca departments until the municipality of La Virginia (located in the department of Risaralda) with a length of 445 km. The High Cauca is called Cauca's geographical valley. Medium Cauca extents from the municipality of La Virginia until the municipality of Tarazá in the department of Antioquia with a length of 400 km. Low Cauca extents from Tarazá until it meets Magdalena river with a length of 260 km (CVC - Universidad del Valle, 2007a).

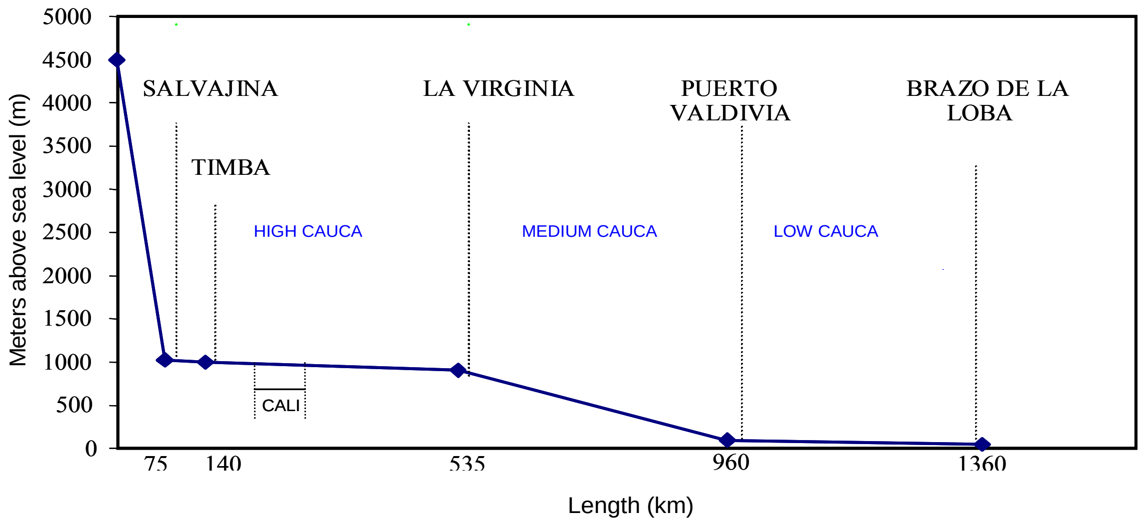


Figure 3.40 Cauca river basin general classification
Source: CVC-Universidad del Valle, 2007a

The Cauca's river geographical valley is considered as one of the most fertile areas in Colombia which is the base for an important part of the Colombian economy. Along the valley many important economic industries are located such as coffee, mining, agriculture and sugar cane production (CVC-Universidad del Valle, 2007a).

The Cauca River flows for 445 km in its geographical valley and descends from a height of 1000 meters to 900 m above sea level. The geographical valley covers an area of 317595 ha and it is located between the dam of Salvajina and the municipality of La Virginia crossing the departments of Cauca and Valle del Cauca. This stretch of the river has an average width of 105 m, which at its highest level can fluctuate between 80 m in the high part of its course (Salvajina – La Balsa) to 150 m in the lowest part (Anacaro – La Virginia). The depth at its highest level can vary between 3,5 and 8,0 m (Velez et al., 2003). There are 40 tributaries between Salvajina and la Virginia with strong slopes and considerable short-lasting spates.

Land uses The geographical valley is located mainly along the departments of Cauca and Valle del Cauca. The Cauca river basin in the Cauca department has an area of 739480 ha which represents 24,2% of the area of the department. According to the land use defined by CRC (Corporación Autónoma Regional del Cauca – environmental authority), the land uses are mainly for commercial crops of pine, coffee, plantain, flowers, cassava, and beans among others. There is also small scale fish activities, cattle breeding and agriculture exploitation by indigenous groups. The paper and sugar industries play important roles in the land use. Gold and coal exploitation is a relevant activity which has impacted natural resources (EMCALI- Universidad del Valle, 2006).

The Cauca river basin in the Valle del Cauca department is mainly used for cattle breeding in green areas which correspond to 38,6% of the land use, followed by sugar cane crops with 17% and other agriculture activities with 14%. However, sugar cane crops and its industrial process have impacted the quality and quantity of the water resource mainly by 1) groundwater depletion when it is used in irrigation and 2) river pollution by chemical products used in the process (CVC – Universidad del Valle, 2004).

Water uses: The main water uses in the department of Cauca are in the agricultural sector, industrial production, human consumption and energy generation. Cauca River has been used for fishing, recreation, energy generation, riverbed matter extraction, human consumption, irrigation and industry. It is also used as a receiving source for solid residues and dumping of industrial and domestic residual water, which has caused deterioration in water quality.

In the department of the Valle del Cauca, the Cauca river and its tributary rivers are used as water source for three important sectors in the region namely agriculture, domestic and industrial use. The sectors that more use the river as drinking water source are the domestic (7%) and agriculture (86%). The agricultural use of the Cauca River basin as irrigation is the predominant one in the Department of Valle del Cauca, being mainly used in the irrigation of the sugar cane and in the crops of the district of irrigation located in the north of the Department. The industrial sector use 3%.

Water quantity: Table 3.8 shows the resume of the flow ranges of Cauca River during the periods 1993-1997, 1998-2002 and year 2003 during summer, winter and transition season (between summer and winter); between the Suárez and La Virginia stations.

Period 1998-2002 and 1993-1997 present the biggest flows during winter-transition season and summer season respectively. Also, an increasing flow trend is seen in this sector.

Table 3.8 Flow ranges measured in the Cauca river. Periods 1993-2003

Period	Winter (m^3/s)	Transition (m^3/s)	Summer (m^3/s)
1993-1997	158-548	129-334	103-251
1998-2002	204-670	140-341	97-234
2003		81-360	80-251

Source: CVC-Universidad del Valle, 2004

Water quality: During the project of modeling of the Cauca river (PMC), and adaptation of a water quality index for the potential use of water bodies as sources for human consumption was carried out (ICAUCA) to evaluate Cauca river. This adaptation was made based on the most widely used national and international standards according to the environment conditions present in the Cauca river basin. The ICAUCA index showed that neither of the monitored stations along Cauca river presents an optimum water quality. In the section Salvajina – Puente Hormiguero (before Cali), the river reports the highest ICAUCA values, classifying the water between good and acceptable (see Figure 3.41)

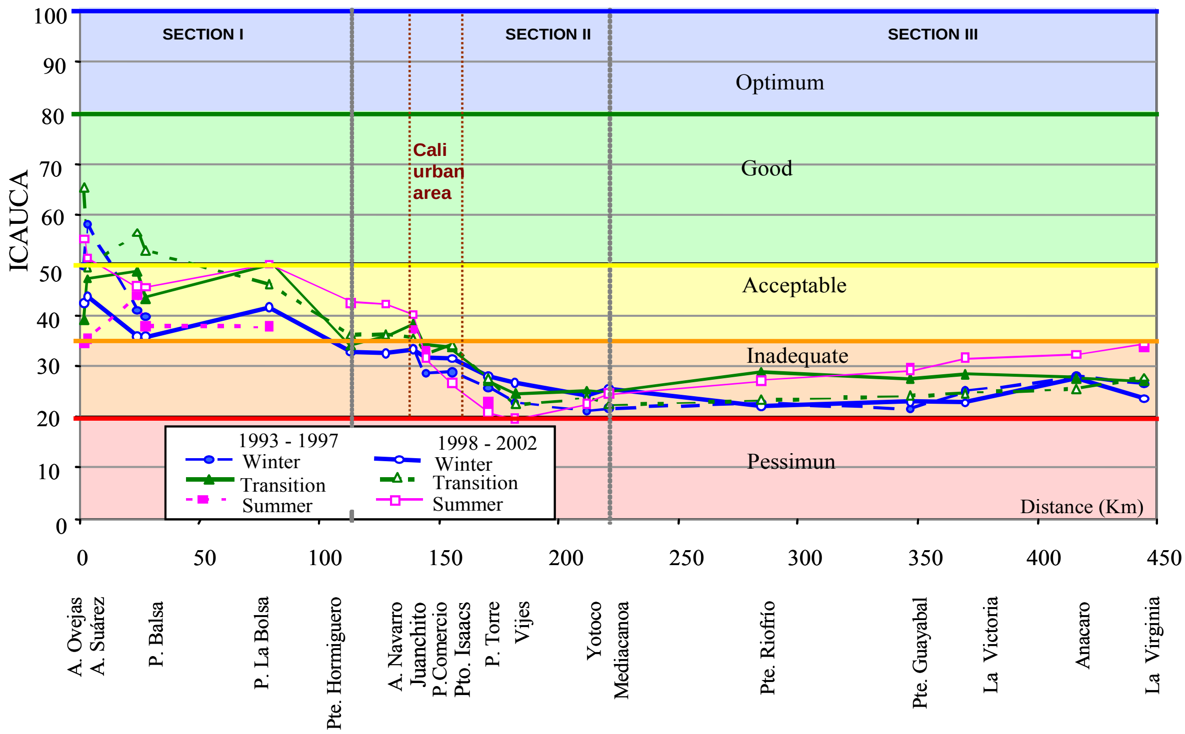


Figure 3.41 Water quality in Cauca River according to ICAUCA index. Period 1993 – 1997 and 1998 – 2002. Winter, transition and summer season.
Source: Patiño et al., 2005

However, at the end of this section the quality decreases to an inadequate water quality in both winter and summer season. This progressive decrease in the water quality is associated to the impacts generated by the tributary rivers when finally discharging to Cauca River. The water quality in the section Puente Hormiguero – Mediacanoa (including Cali's discharges) decreases from acceptable to inadequate in the beginning to inadequate and bad at the end of the section, being the worst index at the Paso de la Torre and Vijes stations.

In the section Mediacanoa – La Virginia, the water in the majority of the stations is classified as inadequate water quality showing a slight recovery at the end of the section, in the Anacaro and La Virginia stations (Patiño et al., 2005).

Effects of the operation of the Salvajina dam in the Cauca River

The dam of Salvajina, that began operating in the beginning of 1985, constitutes one of the most important systems of regulation of the Cauca River. This Project had as main purpose the recovery of the agricultural operation on the flat territories of the geographic valley of the Cauca River, which corresponds to 130000 ha. In the past this area was periodically affected by floods caused by the overflow of the Cauca River and its tributary rivers. As secondary purpose of the dam were considered 1) the production of hydroelectric energy with a capacity of 270 MW and 2) the decrease of the pollution of the Cauca River by the increase in its minimum volume of 70 to m^3/s to 130 m^3/s (Galvis, 1988 mentioned by CVC-Universidad del Valle, 2007b) and the discharge of 250 Mm^3 in dry periods. The dam is located in the South-west, North latitude 2º 56' and east 76º 42' and on the height 1100 m above sea level. In the Table 3.9 the main characteristics of the dam and in the Figure 3.42 a picture of Salvajina dam are shown.

Table 3.9 General characteristics of the Salvajina dam

Characteristic	Measure
Intake area (km^2)	3960
Total length (km)	32
Average width (km)	1,2
Total area (ha)	2124
Average depth (m)	36,4
Maximum depth (m)	140
Total capacity (Mm^3)	908,6
Usage volume (Mm^3)	753

Source: adapted from CVC-Universidad del Valle, 2007b

Figure 3.42 Salvajina dam

From its initial operation, the regulating effect of the dam has introduced changes in the volume regime in Cauca river that can be possibly reflected in the quality of the water of the Cauca River, added to the changes caused by the progressive deterioration of the main source of development in the Region. The modification of some of the components that define the regime of volumes (magnitude, frequency, duration, and rate of variation) has changed the space and temporary distribution of the flow, which causes alterations in the structure, the composition and the operation of the fluvial ecosystem.

The hourly volume variability originated by the operation of the dam of Salvajina causes hourly variations in the quality of water that cannot be visualized and be quantified base on the daily information. Following, the DO trend measured in years 2003 and 2005 in the stations La Balsa and Hormiguero is shown which better reflect the hourly changes in the quality of Cauca's river water caused by the operation of the Salvajina dam, considering the climatic conditions of winter and summer. In the station Balsa certain tendencies are observed that can be related to some of the following processes:

- The maximum levels of DO appear at noon (12:00 h) when the solar brightness and the temperature are maximum whereas the minimum concentrations happen at midnight (00:00 h) when the solar brightness is null and the temperature is minimum. This variation in DO can be associated with the photosynthetic activity in the sector of Balsa caused by the presence of seaweed of the dam of Salvajina.
- The dilution of the polluting load as a result of the volume increase takes place, which generates an increase in the dissolved oxygen levels. This effect is seen in the curve's changes in the hours following the release of the volumes in Salvajina.

- The fast release of the bigger water volumes from the dam can produce a reduction in the dissolved oxygen levels due to the increase in the speeds of the flow that produce the dragging of materials on the bed of the river and the settlement of sediments "phenomenon of washing of the river basin".
- The capacity of self-recovery of the river diminishes, since the concentration of DO in the water coming from Salvajina is lower than the one in Cauca River in this section until La Balsa station (CVC – Universidad de Valle, 2007b).

Wastewater discharges

There are 40 tributaries between Salvajina and La Virginia, with a strong slope and considerable short-lasting spates. From the total organic discharges to the Cauca River, 59% is discharged by means of these tributaries (145 ton/day BOD in 1999). The most critical tributary rivers in terms of BOD load discharge are: Tuluá, Guachal, La Paila, La Vieja, Palo and Cali (Velez et al., 2003).

Regarding wastewater discharges to the river, the CVC has been periodically controlling and monitoring the wastewater discharges from around 200 industries located in the geographical river basin, whose wastewaters are discharged to the Cauca River and its tributaries. Figure XX shows the BOD loads discharged to the Cauca river basin in the section Salvajina –La Virginia during 1979 to 2003. Figure 3.43 shows that sectors like the sugar cane production, paper industry and coffee production have reduced their polluting contribution to the Cauca River.

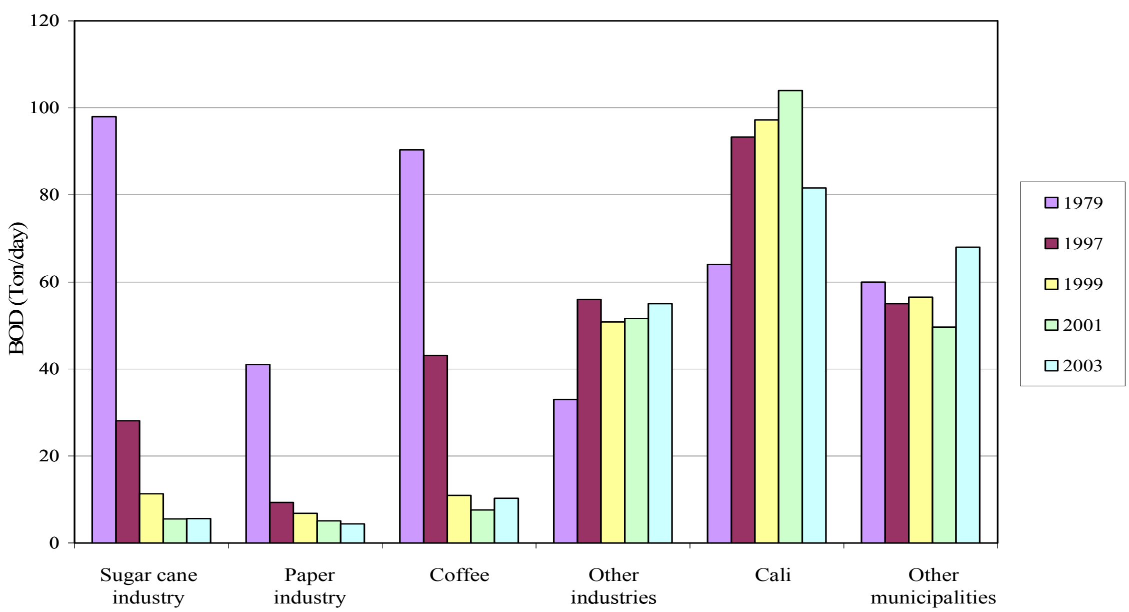


Figure 3.43 BOD load discharged to Cauca river. Section: Salvajina – La Virginia. Period: 1979 – 2003.

Source: CVC, 2003 cited by CVC-Universidad del Valle, 2004.

The sugar and paper industry and coffee sectors, are the three productive sectors of greater impact on the quality of the water of the Cauca River. However, during the years 2001 and

2003 these sectors had reduced their polluting load in near 90% (CVC-Universidad del Valle, 2004).

Although, from Figure 3.43 it can be seen a decrease in the average industrial load discharges to Cauca river, there is no monitored evidence regarding the operation of the industrial treatment systems and sporadically it had been found specific discharge points with high pollution loads.

Likewise, the municipal wastewater load discharges have increased during the years, as a result of the growth of the population, the development of the industries within the cities and the low implementation of systems of wastewater treatment. Only for the case of the municipality of Cali in year 2003, a reduction in the contribution of BOD load is observed, associated with the beginning of the Wastewater Treatment Plant of Cañaveralejo (C-WwTP) which started operation at the end of year 2002 (CVC-Universidad del Valle, 2004).

Discharges from Cauca department

Cauca river in the Cauca department from its source to the sector located near Desbaratado river (in the border with the Valle del Cauca department) receives in average a BOD load of 20,86 ton/day (see Figure 3.44) being the municipal sector the highest contributor with a 68% of the total BOD load. The river in its course through the department receives indirect or direct pollution from the nearby municipalities as well.

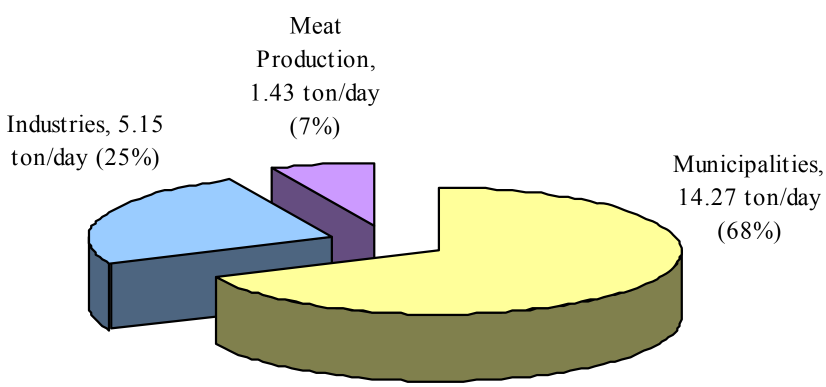


Figure 3.44 BOD load discharges in the Cauca river basin by the different commercial, industrial and domestic sectors in the Cauca department
Source: EMCALI-Universidad del Valle, 2006.

Cauca department has deficiencies regarding the management of wastewater in general. This situation is the main cause of problems related to respiratory deficiencies, water body's pollution, landscape deterioration and higher costs in the drinking water treatment (EMCALI –Universidad del Valle, 2006). Regarding the discharges from the tributary rivers to Cauca river in the Cauca department, states that 47,1% of the total load (9,8 BOD ton/day) is discharged by the rivers located after Salvajina dam namely Palo, Zanjón Oscuro, Quinamayó and Ovejas rivers (EMCALI – Universidad del Valle, 2006).

Discharges from the Valle del Cauca department

In Figure 3.45, the contribution of BOD load in 2006 by the industrial and municipal sector, (monitored by the CVC to the industries, Cali and other municipalities) is shown. In the Figure, Cali is the municipal sector that contributes the most with BOD load (38%).

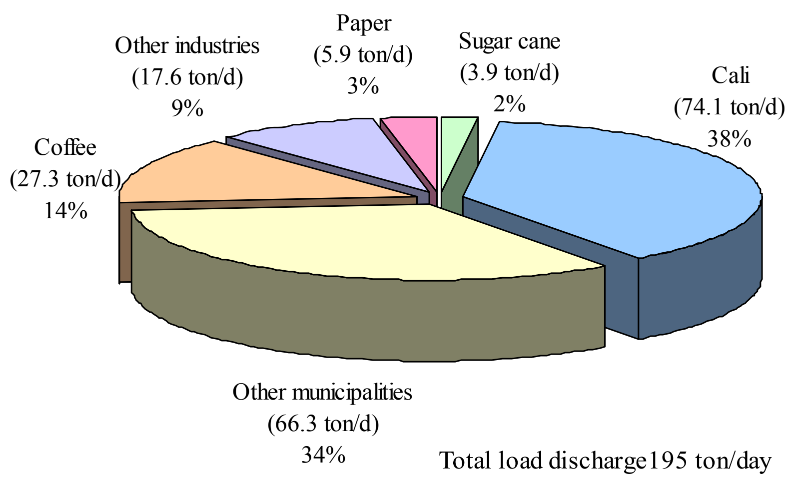


Figure 3.45 BOD load discharges to Cauca river basin in the Valle del Cauca department, year 2006

Source: EMCALI-Universidad del Valle 2006

Cauca River of the city of Cali

In Cali, Cauca river acts as the final discharge site for the wastewater produced in the city and in its rural area. From Hormiguero to Mediacanoa the progressive deterioration of the water quality is associated to the wastewater discharges from the domestic and industrial sector, mining exploitation, deforestation process and solid waste discharges from nearby municipalities.

The Cauca river enters Cali, from the mouth of the Jamundí river (South municipal limit with the municipality of Jamundí) and crosses approximately 30 km until it arrives at the mouth of the Cali river, that is the North limit of the city. In this section, it receives the discharges from Líli, Meléndez, Cañaveralejo and Cali rivers. The area of influence of Cali is located between the stations Hormiguero and Mediacanoa.

Following a description of water quality of the sub-sections of Cauca river upstream, along and downstream to Cali.

Section from Hormiguero to Before the South Channel (upstream to Cali): A slight decrease in the dissolved oxygen levels is registered. This decrease is possibly associated, among other factors, to the accumulative effect of the domestic and industrial wastewater discharges in the Desbaratado river, the stream Zanjón Oscuro and water discharges from Palo and Jamundí rivers, located upstream Hormiguero.

Section Before the South Channel – Puerto Isaacs (along Cali): There is a considerable decrease in the concentrations of the dissolved oxygen as a result of the water discharges of the station before the South Channel and the discharges before Puerto Isaacs, which correspond to wastewaters from Cali that are spilled through the systems of drainage and channels. According to the results of the monitoring campaign in 2006 (EMCALI – Universidad del Valle, 2006), the average BOD polluting load discharged by the system of drainage of the city was 116,4 ton/day when the wastewater treatment plant of Cañaveralejo (C-WwTP) was operating without addition of chemicals (Ferric chloride). The greatest contribution of BOD and COD load was the C-WwTP effluent with a percentage around 46%. In addition to the wastewater discharges of the drainage system of Cali, in this section the Cauca river receives industrial wastewaters discharges as well such as the paper industry and oil industry.

In this section, the south drainage system of the city discharges its wastewater to Cauca river which is contaminated by leachate coming from Navarro disposal site. This discharge occurs 5 kilometers upstream the water intake of drinking plants of Puerto Mallarino and Rio Cauca. The polluted discharges from the south drainage system threaten the treatment and delivery of drinking water to the city.

In the Section between Puerto Isaacs – Mediacanoa (downstream to Cali): The most critical point in the river appears in the Station Paso de la Torre, which presented anaerobic conditions, which are seen by the changes that take place in the water, such as the deterioration of the aesthetic aspect, dark coloration, floating substances and bad odors by the H_2S liberated. This condition appears as a cumulative response of the river influenced by the wastewater discharges of Cali, added to the domestic and industrial wastewater discharges of the municipalities of Palmira and Yumbo through the rivers Yumbo and Guachal. Although in this section the lowest DO concentration was recorded, after the station Paso de la Torre there was observed a recovery tendency, registering a slight increase in the DO concentrations.

The total load discharged to the Cauca river in the section Hormiguero- Mediacanoa during the four days of monitoring campaign in 2006 was 197,8 BOD ton/day; 404,2 COD ton/day and 228,4 TSS ton/day discharged by tributary rivers and the sewage system Cali. Regarding the origin of these discharges 40% arrive through the four tributary rivers and the other 60% was contributed by the city of Cali (EMCALI-Universidad del Valle, 2006).

4 MONITORING SYSTEMS IN THE AREA OF INFLUENCE OF CALI

4.1 IDEAM'S MONITORING NETWORK: OPERATIONAL AREA 9

4.1.1 Description

The city of Cali is located in the jurisdiction of IDEAM's Operational Area 9, which encompasses the following departments: Valle de Cauca, northern zone of Cauca - Tambo, Quindío, Risaralda, and southern part of Chocó. It consists of a network of 253 stations, out of which 189 are meteorological and 67 hydrometric stations. There are 221 conventional, 23 automated, and 9 combined (both conventional and automated) stations (URL-3).

Some of these stations have been installed under agreements between IDEAM, which is responsible for performing operation and maintenance of the stations, and the Regional Environmental Agencies, i.e. CVC, CRC, CRQ, CARDER, and CODECHOCÓ, and DAGMA (environmental authorities in Cali), which are responsible for purchasing or acquiring the stations.

The network operates on the technical assumption that 6 field visits are conducted to the hydrological stations; 4 to the weather stations and 2 to the pluviometric stations. To this end, commission routes are scheduled to encompass several stations of all kinds in an assigned area. The operation of the network entails performing the following activities:

- Maintenance and calibration of instruments
- Maintenance of the structures of the facilities at the stations.
- Environmental measurements (evaluations, and water and sediment quality, among others)
- Data collection and procurement
- Refresh training to observers

4.1.2 Equipment and Instruments

IDEAM has classified conventional stations into 8 different categories. Each category is assigned depending on the kinds of instruments used at each station. Table 4.1 lists the kinds of instruments used at each station. Figure 4.1 shows the equipment used at Universidad del Valle's Meteorological Station

Table 4.1 Kinds of instruments for each station category

Kinds of instruments	PM	PG	CO	SS	SP	MC	AM	MM
Pluviometer	X	X	X	X	X	X	X	
Pluviograph		X	X	X	X	X	X	
Psicrometer			X	X	X	X	X	
Anemograph				X	X	X	X	
Heliograph					X	X	X	
Thermograph					X	X	X	
Higrograph					X	X	X	
Evaporation tank						X	X	
Actinograph					X	X	X	
Anemometer						X	X	
Geothermometer							X	
Higrometer							X	
Soil							X	
Microbarograph					X	X		
Barometer					X	X		
Limnimeter								X
Maximeter								X
Limnigraph								X
Mareograph								X

Notes: Pluviometric Station (PM): Pluviograph station (PG), Main Climatological Station (MC) Common Climatological Station (CC): Main Synoptic Station (MS); Supplementary Synoptic Station (SS); Agrometeorological Station (AM) Radiosond Station (RS) Mareograph Station (MM).


Psicrometer and Thermometers

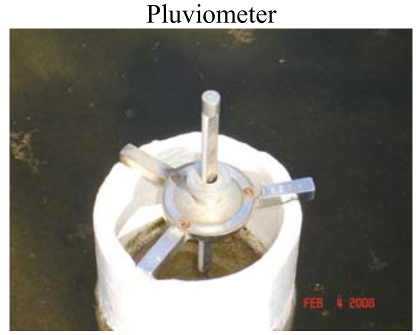

Thermograph and Higrograph

og

Pluviometer


Internal part of pluviometer


Evaporation Tank



Stabilization tank, micrometric screw and thermometers of extremes

Figure 4.1 Equipment used at Universidad del Valle's Meteorological Station


Fuess Actinograph


Heliograph


Pluviograph

Figure 4.1 Equipment used at Universidad del Valle's Meteorological Station. Cont.

IDEAM's automated meteorological stations are basically composed of: a data collection unit (a data logger), a set of sensors, a power supply unit (a solar panel, a power control unit or a battery), a data transmission component via an RS232 port (currently used), an atmospheric discharge protection device (lightning rod and grounding system). Table 4.2 shows the sensors and equipment used at IDEAM's automated stations. Figures 4.2 and 4.3 show pictures of the sensors and the equipment.

Table 4.2 Sensors and equipment used at IDEAM's automated stations

Sensors/ Equipment	Land Slide	Agro meteorological	Lagoon & lakes	Mareograph	Hydrologic	Urban	Description/Brand
Data Collection Platforms (DCP's)	X	X	X	X	X	X	OTT LOGOSENS
Satellite Transmitter	X	X	X	X	X	X	Campbell Scientific 300/1200 bps
GPS Transmitter	X	X	X	X	X	X	Campbell SAT HDR GOES transmitter
GPS Antenna	X	X	X	X	X	X	Campbell A-35 satellite transmitter
Power Control Unit - PCU	X	X	X	X	X	X	OTT PCU 12 de 12 Voltios
Battery	X	X	X	X	X	X	NEWINOX FNC121000H
DC/DC Converter	X	X	X	X	X	X	Dorsh Electronic GPH59
Yagi Antenna	X	X	X	X	X	X	GOES antenna X-Yagi
Solar Cell	X	X	X	X	X	X	Powermax Solar cell SM55 de 55W peak
Wind speed and direction	X	X	X	X		X	THIES CLIMA Anemometer Ultrasonic 2D
Global Solar Radiation	X	X	X	X		X	THIES CLIMA Pyranometer C11
Visible Radiation		X	X				THIES CLIMA BPW21
UVB Radiation							THIES CLIMA Sensor UVB E.1.c
Air temperature/humidity 2 m	X	X	X	X		X	THIES CLIMA Compact Humidity and temperature sensor
Air temperature/humidity 10 m		X					THIES CLIMA Compact Humidity and temperature sensor
Atmospheric pressure		X	X	X		X	Vaisala Barometric Pressure Transmitter PTB100
Evaporation		X	X				THIES CLIMA Ultrasound Evaporimeter
Soil temperature 10 cm.		X	X				THIES CLIMA Soil Surface Temperature transmitter
Soil temperature 30 cm.		X	X				THIES CLIMA T Soil Surface Temperature transmitter
Soil temperature 50 cm.		X	X				THIES CLIMA Soil Surface Temperature transmitter
Soil humidity 10 cm.		X	X				IMKO Micromodultechnik TRIME_EZ

Table 4.2 Sensors and equipment used at IDEAM's automated stations Cont.

Sensors/ Equipment	Land Slide	Agro meteorological	Lagoon & lakes	Mareograph	Hydrologic	Urban	Description/Brand
Soil humidity 30 cm.		X	X				IMKO Micromodultechnik TRIME_EZ
Soil humidity 50 cm.		X	X				IMKO Micromodultechnik TRIME_EZ
Soil humidity > 1 m	X						IMKO Micromodultechnik TRIME_EZ
Liquid precipitation	X	X	X	X	X	X	Mc Vann Instruments RIMCO Tipping bucket 8500-01
Solid precipitation							OTT Pluvio. Rain gauge using the weighing principle
Surface water level sensor				X			OTT Kalesto radar level sensor
Surface water level sensor					X		OTT Thalimedes Shaft Encoder Level Sensor


Carcass

Data Collection Platforms (DCP's) 16 inputs


GOES Satellite transmitter


Solar Cell and Yagi Antenna

Power Control Unit - PCU

Solar Rechargeable Battery


Earth Antenna

Figure 4.2 Components of the data collection and satellite data transmission units

Pluvio weighing precipitation sensor | Automatic precipitation gauge | Ultrasonic wind speed direction sensor

Air temperatura and humidity Sensor | Global Solar Radiation Sensor

Soil porosity sensor | Surface water level sensor | Kalesto- Radar level sensor

Figure 4.3 Sensors used at IDEAM's automated stations

4.1.3 Land station or station receiving the satellite signal

The GOES 2 land station consists of: a modulator, a converter, 100/300 bps upgrade, cables and connectors, an antenna (manual adjustment), a computer (Pentium III, Windows NT, 10 GM hard drive, 120 MB RAM), a UPS unit, a printer, Hydras III /GS software, and unlimited software licenses for nationwide use. The software allows setting the configuration of the field stations (codes, sensors, and data receiving intervals) (URL-3)

4.1.4 Information Management

Data and information transmission, control, and quality assurance

Data from the various IDEAM stations are collected in different ways: in real-time or via satellite (3%), telephone or radio (17%), via mail or collected on a monthly basis (36%), and collected by the commissioned teams (44%). Each of the operational areas is responsible for gathering, processing and sending information to IDEAM's server in Bogota on a monthly basis.

The automated meteorological stations are communicated with both the GOES satellite and a station on the ground that receives the satellite signal (DRGS). The unit on the ground is provided with state-of-the-art software (HYDRAS3) for managing and monitoring the network and the network collected data (URL-3)

Figure 4.4 shows IDEAM's plan for keeping track and ensuring quality of data at the monitoring stations.

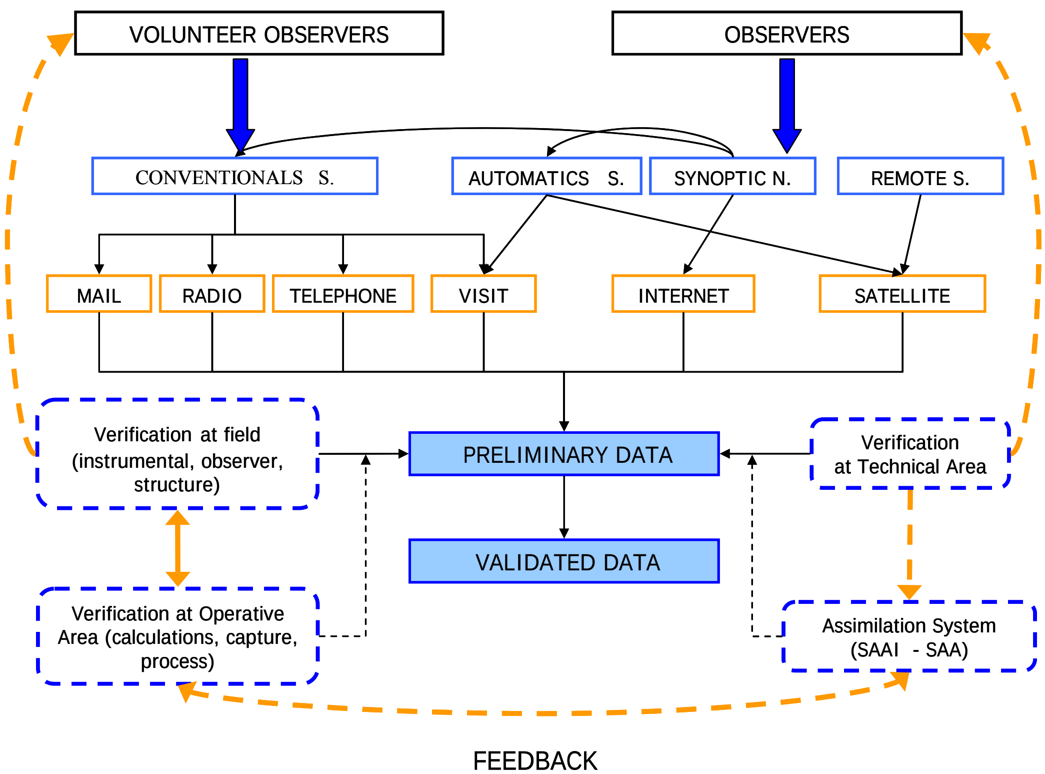


Figure 4.4 General overview of the data transmission, control and quality assurance process at IDEAM's monitoring network
Source: URL-3

Information Management Software

The Hydras 3 software is used for managing data and information from the monitoring stations. The software has a web-based application that allows coordinators of operational areas to view information from all the stations located in the country.

The OTT-developed Hydras 3 software is designed for the transmission, evaluation and management of hydrological, meteorological and environmental data. It provides an easy-to-use and practical user interface for capturing, processing, administering, managing and interpreting collected data. The configurable import and export options of the Hydras software allow integration of the software to a wide range of external applications:

- Graphical and numerical display of readings
- Multiple charts
- Graphical and numerical editing of readings
- Station management (single stations or complete networks)
- Incorporation of topographic maps
- Virtual sensors
- Correlation analysis
- Importing or exporting data
- Using alarms

The readings captured by the various sensors can be displayed both graphically and numerically. There are two different kinds of readings:

- Instant readings taken by the sensors every 10 minutes and transmitted to the PC every hour
- Hourly readings taken by virtual sensors every hour o every 3 hours (it averages instant data).

4.1.5 Uses of Information

The data from the network supplies useful specialized information that can be used as input for the design of infrastructure projects (dams, bridges, roads and water supply systems), as a tool for keeping track of weather forecasts, climatic forecasts or climatic changes on a real-time basis, and as a mechanism to forecast the generation and transportation of sediments and contaminants of bodies of water. This information is also useful for the production and supply of live stock and agricultural products and for air, maritime, fluvial and land transportation.

4.2 CVC'S MONITORING NETWORK

4.2.1 CVC's Hydroclimatological Network

Description

The CVC's hydroclimatological and water quality monitoring network encompasses the basin of the Cauca River valley from the location where the river is born in the Department of Cauca to La Virginia in the Department of Risaralda. It covers an area of approximately 22,814 km^2 and the Cauca River path, which is about 513 long. The following are some of the objectives of the CVC's monitoring network:

- Implementing and operating the environmental information system in the area within its jurisdiction in compliance with the guidelines of the Ministry of the Environment.
- Analyzing water quality of the Cauca River and its main tributaries, and analyzing air quality, monitoring levels and precipitation in high-risk areas on an on-going basis.

- Taking "real-time" readings of parameters for using a hydrological simulation model and optimizing operation of the Salvajina dam.
- Strengthening the National Disaster Prevention System
- Issuing alerts to the population at the most vulnerable locations about avalanches, floods and ground displacements.
- Reducing the costs of operating and maintaining the environmental quality and hydroclimatological networks significantly.
- Providing a database for conducting further studies and executing environmental projects in this region.

The CVC's Hydroclimatological Team is responsible for coordinating the network activities including operation and maintenance, collecting, processing and analyzing data, preparing technical reports and bulletins about the hydrological behavior and weather conditions, and disseminating real-time information about the hydroclimatological and environmental conditions, and forecasting weather either directly or on the media.

In total, the network is composed of 208 stations (including conventional and automated stations), 35 of which are automated. Figure 4.5 shows the geographical distribution of the CVC's monitoring network. Attachment 1 contains a listing of the existing stations and their main characteristics

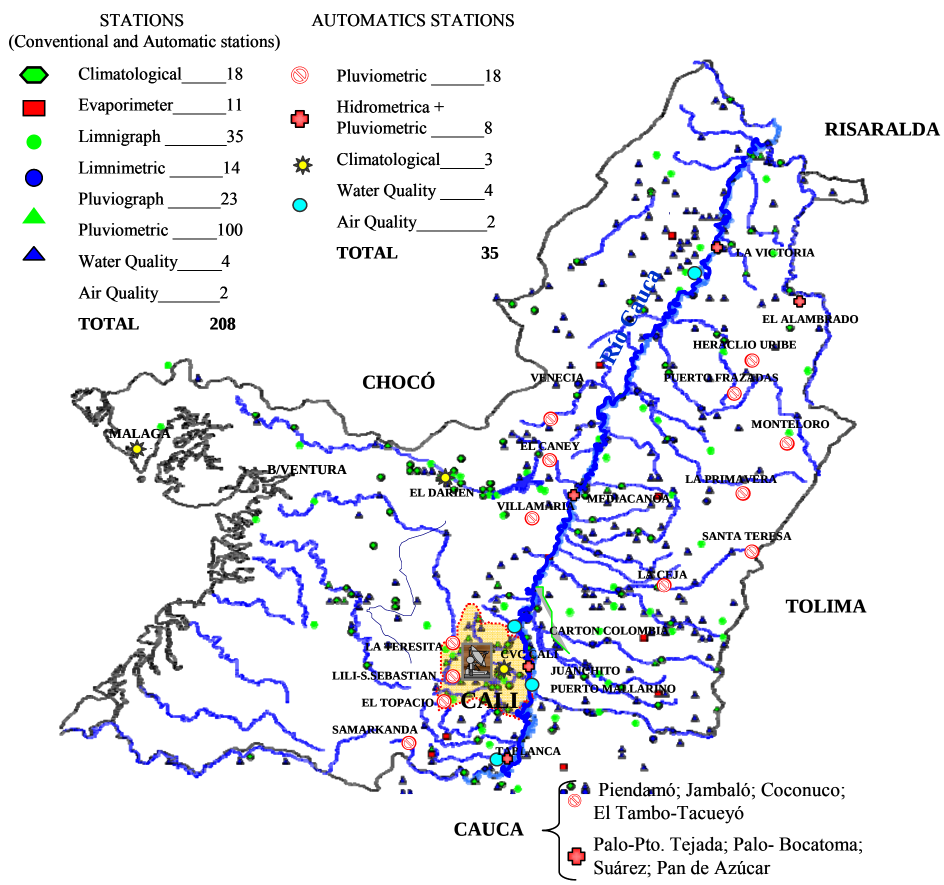


Figure 4.5 Geographical distribution of the CVC's hydroclimatological network

Equipment and Instruments

Each network has basically the following components in place: a set of instruments, a data capture and processing system, a communications system, and infrastructure facilities. As shown in Table 4.3, the conventional stations in the CVC network are classified based on the kinds of instruments available at each station.

Table 4.3 Classification of monitoring stations at the CVC network

Instruments \ Stations	PM	PG	EV	CC	LM	LG
Pluviometer	X	X	X	X		
Pluviograph		X	X	X		
Evaporation tank			X	X		
Heliograph				X		
Psicrometer				X		
Thermohygrograph				X		
Anemometer				X		
Anemograph				X		
Limnimeter					X	X
Maximeter						X
Pluviometer					X	

Notes: Pluviometric Station (PM): Pluviograph station (PG), Main Climatological Station (MC) Common Climatological Staion (CC): Limnigraph Station (LG); Limnimetric Station (LM)

Table 4.4 lists the main components of the CVC's automated stations

Table 4.4 Main components of the CVC's automated monitoring stations

Station	Components
Pluviometric– SUTRON Y SAINCO	- DCP - Data collection Platforms - GOES Transmitter - YAGI Antenna - Precipitation Sensor - Solar Cell, Battery, CPU - Protection Systems (Earth Antenna and beam antenna) - Pluviometers TB de 0.2mm (SUTRON, VAISALA, QUALIMETRIC, CASELLA)
Hydrometric - SUTRON	- DCP- Data collection Platforms - GOES Transmitter - YAGI Antenna - Shaft encoder level sensor (SUTRON) - Solar Cell, Battery, CPU - Protection Systems: Earth Antenna and Beam Antenna
Water Quality - SAINCO	- Zulling Sensors: Dissolved Oxygen, pH, conductivity, suspended solids, temperature. - Water Surface level sensor (OTT) - Pluviometers (Casella)
Air Quality - SAINCO	- Analyzers (API): nitrogen oxides and Sulfur, Ozone y Carbon monoxide - PM10 (Environmental) - VAISALA Sensors: Wind speed and direction, Solar Radiation, temperature and humidity and pressure, - Pluviometers (Casella)

Table 4.5 shows some of the technical specifications of the SUTRON DCP's or data collection platforms used at the automated stations.

Table 4.5 Data Collection Platforms (DCP's) used at the CVC's automated stations

DCP Model	Transmission rate	DCP type	Transmitter	Message format
8004	100 BPS	Selft-timed Random	Interno	Pseudo-Binary, ASCII, NESDIS Binary, SHEF
8200	100 BPS		Interno	
8210	100 BPS		Interno TGT-1	
SATLINK	100, 300 Y 1200 BPS		Satlink, TGT-2	

Figure 4.6 SUTRON Data Collection Platforms (DCP's)

Control Center

The Control Center of the automated network is located at the headquarters of the CVC (Valle del Cauca Regional Environmental Agency). It consists of:

DRGS data receiving system:

- Data receiving rate of 100 bps
- Capacity of 10 demodulators

Software for processing, managing and storing data:

- UNIX operating system
- SCADA OASYS
- SYBASE database
- ALPHASERVER 1000A redundant servers
- Sutron PCBASE2

Communication between the remote station and the Control Center takes places via the GOES satellite.

Data Transmission

The means for collecting and transmitting data vary depending on the kind of station. Data can be collected or captured in three different ways: observers, charting equipment (e.g. chart recorders), and automatic data capture. Table XXX shows the main characteristics of the stations with regard to data collection, data collection frequency, and data transmission.

Table 4.6 Data capture, collection and frequency at the CVC's monitoring stations

Station	Means of recording data	Frequency of recording data	Data transmission
Conventional Pluviometric	- Observer	- Record of precipitation every 24 hours	- The form filled is collected monthly and in some cases bimonthly - At some stations the data are transmitted daily by telephone.
Automatic Pluviometric	- Observer - Automatic	- Record of precipitation every 24 hours with the conventional pluviometer - Record of precipitation every 15 minutes with the automatic pluviometer	- The form filled is collected bimonthly. Download information from DCP every two months. - Precipitation data is transmitted from the satellite to the center of control every 4 hours
Conventional Pluviograph	- Observer - Graphic record	- Record of precipitation every 24 Hours - Graphic record of precipitation every hour.	- Both, the form filled and the graphics registered are collected weekly. In some cases is monthly
Conventional Limnimetric	- Observador	- Level record 3 times/day (6:00; 13:00 y 18:00)	- The form filled is collected monthly
Conventional Limnigraph	- Observer - Graphic record.	- Level record 3 times/day (6:00; 13:00 y 18:00) - Graphic record of levels every hour.	- The form filled is collected monthly
Automatic Limnigraph	- Observer - Graphic record - Automatic	- Level record 3 times/day (6:00; 13:00 y 18:00) - Graphic record of levels every hour. - record of levels every 15 minutes with the automatic pluviometer.	- Both, the form filled and the graphics records are collected weekly. In some cases is bimonthly. Download information from DCP bimonthly. - Level water data is transmitted from the satellite to the center of control every 4 hours
Conventional Climatological	- Observer - Graphic record	- Record of precipitation every 24 hours - Graphic record of precipitation every hour.	- Both, the form filled and the graphics registered are collected weekly. In some cases bimonthly.

At the conventional stations, data from the observer's records and charting equipment are usually collected on a monthly basis. Information from some stations is transmitted via telephone on a daily basis. Automated stations (pluviometric and limnigraphic stations) are programmed to record and store data every 15 minutes. The control center at the CVC receives only 6 records on a daily basis. These records are then transmitted via the GOES satellite every 4 hours because this mean of communication is used very intensively. Information stored in the DCP's is collected every 2 months.

4.2.2 CVC's Water Quality Monitoring Network

The CVC's water quality monitoring network has 283 stations, which are located at the main surface water sources within its jurisdiction, i.e. Cauca River and its tributaries, tributaries that flow into the Pacific Ocean, Brut and Calima dams, Sonso Lagoon, Buenaventura Bay, the beaches along the Pacific Coast in Valle del Cauca, and the rivers in the northern part of the valley of the Pacific basin (see Annex 2) (CVC, 2006).

The objectives of the monitoring network are oriented towards the generation of strategies for controlling and managing water resources (CVC-Universidad del Valle, 2003) to:

- Estimate the historical and geographical evolution of water quality in the Cauca River and its tributaries;
- Evaluate the impact of strategies to control contamination in the Cauca River and its tributary rivers;
- Obtain information for making decisions and planning policies for establishing wastewater pollution charges; and
- Propose sampling plans for calibration purposes in simulation models.

Based on the above mentioned objectives, the network operates using monitoring programs at the stations on the Cauca River, its tributary rivers, manufacturing companies, and municipalities. These monitoring programs take into account different water quality parameters depending on physical, chemical, microbiological and hydraulic properties. The CVC has the task of monitoring and controlling more than 200 manufacturing companies in the geographic valley of the Cauca Rivera.

Monitoring Frequency and parameters analyzed

The monitoring stations in the network are not linked with a specific infrastructure. The reason for that is that the stations are selected, documented and geographical referenced locations where samples are taken on a periodical basis. The sampling frequency can be monthly, quarterly or semiannually depending on the kind of water source

The sampling frequency at the manufacturing companies is typically semi-annual. In addition to this, sampling is conducted of domestic waste discharges in the municipalities in the Valle del Cauca Department within the jurisdiction of the CVC on a semi-annual basis. There is historical information available in computer systems from 1990 to 2006. Annex 2 shows detailed information on characteristics of CVC's Water Quality Sations.

CVC's Water Quality Sations Automated

CVC also has 2 automated water quality monitoring stations. Puerto Mallarino and Tablanca inlet-stations, the latter of which will be in operation in April 2008.



Sensors Data Logger Data Display

Figure 4.7 Devices at CVC's water quality monitoring station Puerto Mallarino Inlet

4.2.3 Proposal for a network to monitor quality of water in the Cauca River and its tributaries along the stretch from Salvajina to La Virginia

Several key activities were carried out which will contribute to both optimizing the quality of water in the Cauca river and its tributaries in the geographical valley and strengthening a consensus around actions for the Cauca river within the scope of the PMC project (1997-2007). These activities were aimed at proposing strategies and actions to plan and make best use of this water source, thereby seeking joint commitment of the various stakeholders involved with the quality of water of the Cauca river.

These key activities included (CVC-Univalle, 2007)

- Seminar-Workshop "Water Quality Monitoring Network on the Cauca River and its tributary rivers along the land stretch from Salvajina to La Virginia in the city of Tulua". An important number of representatives of the CVC, CRC, CARDER, CRQ DAGMA, EMCALI and Universidad del Valle participated in this workshop.

- 2 meetings with representatives from the main manufacturing companies in the Departments of Cauca (in Popayan on July 9, 2004) and Valle del Cauca (in Cali on July 21, 2004). The purpose of these meetings was to encourage involvement of the industrial sector with the monitoring network and to become acquainted with the industrial monitoring programs and strategies for controlling contamination due to wastewater discharges.

- During the execution of stage III of the PMC, the Second Seminar and the Third Meeting of the Monitoring Network Members were held on March 10 and November 28, 2006, respectively. These activities focused on setting the objectives of the Monitoring Network and discussing and defining aspects related with its incorporation, operation and sustainability.

The general objective of the network would concentrate on articulating the efforts of political institutions, productive and territorial sectors, research centers, and social groups to establish joint integrated actions that lead to the recuperation of the Cauca River.

The specific objectives are (CVC-Univalle, 2007)

- Organizing, sharing and centralizing information about the quality of water of the Cauca river and its tributary rivers.
- Scheduling activities to monitor water quality of the Cauca River on a continuous basis.
- Using available information for making decisions and planning short-term, mid-term, and long-term actions.
- Using water quality indexes
- Gather resources and funds for the operation and sustainability of the network
- Establishing knowledge networks

The next step in future activities is to communicate the proposal for the network to the members of the institutions before formally establishing the network and beginning its activities

4.3 DAGMA´S MONITORING PROGRAMME

In accordance with the provisions set forth in Decree 3100 of 2003, Article 21, the municipal sewerage service provider (EMCALI) monitors final discharges into the Cauca River in order to calculate the amount to be paid for wastewater pollution charges.

DAGMA entered into the following consulting agreements to monitor specific discharges into the affluents of the Cauca River:

- Cauca River Foundation. A pilot model to recuperate the Cauca River in the urban area along the boundaries with the township of Navarro and the outlet of the Cali River in the city of Santiago de Cali, 2006. DAGMAN-Cauca River Foundation Agreement No. 060-06

- UNIVALLE - EIDENAR. Identification of the environmental condition of the basins of the Cali and Aguacatal rivers in the urban area of the city of Santiago de Cali, 2006. DAGMA-UNIVALLE Agreement No. 192-05

- UNIVALLE – EIDENAR. Identification of specific discharges and water inlets on the riverbeds of the Meléndez and Cañaveralejo rivers and affluent creeks within the urban parameter of the municipality of Santiago de Cali. May, 2004. DAGMA – UNIVALLE Agreement No. 010 de 2003

- Physicochemical characterization of the Lili, Meléndez, and Cañaveralejo rivers and their specific discharges in the jurisdiction of the city of Santiago de Cali. ASOAMBIENTE LTDA. October 1997

- Physicochemical and hydrological characterization of the Pance, Lilí, Meléndez, Cañaveralejo, Cauca, and Cali rivers within the jurisdiction of Santiago de Cali. ASOAMBIENTE LTDA. August 1996.

The sampling parameters are listed in Law-Decree 2811 of 1974 and regulated by Decree 901 of 1997, as superseded by Decree 3100 of 2003 with regard to wastewater pollution charges.

The DAGMA has a laboratory team who performs monitoring activities to keep track of the quality of the bodies of water such as the Cali, Aguacatal, Meléndez, Cañaveralejo and Lili rivers, preferably during the summer time. The sampling locations are selected at the point of entry of the river into the urban perimeter and at the outlet of the river. The fact that the personnel who take the samples are rotated/removed on a regular basis makes it difficult to validate information.

Implementation of monitoring networks.

Under an agreement with IDEAM (MAVDT), DAGMA now has a project to implement a water quality network in the municipality of Santiago de Cali which would have both fixed and automated stations depending on the requirements for each location. The project would be funded with proceeds from the wastewater pollution charges collected in 2007. The project is registered in the project database with the Municipal Planning Department for 2008.

EMCALI is also interested in the implementation of automated water monitoring stations in the city. These entities are planning to make arrangements to prevent duplication of sampling points.

4.4 EMCALI'S MONITORING PROGRAM

4.4.1 Monitoring of the Drainage System in the city of Cali

As of today EMCALI (Cali Municipal Utility Company), which is responsible for the provision of water and sewerage services, has not yet implemented a continuous monitoring system in the municipal drainage system.

EMCALI, however, has a monitoring program in place aimed at: i) obtaining information about the physicochemical characteristics of wastewater; ii) calculating the loads of effluents produced by the city; iii) determining the payments for wastewater pollution charges as required in Decree 901 of 1996; and iv) providing supporting information for the environmental statement to be submitted to the environmental authorities at DAGMA.

Monitoring Program Description This monitoring program entails continuously monitoring of final effluents from the city of Cali into the Cauca River for 4 days during the summer. This is usually done once a year. The location of the final effluents/discharges from the city of Cali into the Cauca River is shown in Table 4.7.

Table 4.7 The location of the final effluents/discharges from the city of Cali

Punto de vertimiento final	Reference Boundary Markers	Coordinates in the MAGNA-SIRGAS WGS84 System		
		Lattitude	Longitude	Elevation
Discharge from the South Channel into the Cauca River	B442-2006	3°22'40.98966"N	76°28'21.404"W	983.560
	B443-2006	3°22'36.03994"N	76°28'20.98261"W	980.936
Puerto Mallarino Pumping Station	DES1-2006	3°26'57.17905"N	76°28'32.90469"W	979.133
	DES2-2006	3°26'55.79238"N	76°28'31.27212"W	977.714
Cañaveralejo WwTP	B438-2006	3°28'10.06538"N	76°28'44.03571"W	978.717
	B439-2006	3°28'1166644"N	76°28'37.57933"W	977.653
Paso del Comercio "Pumping Station"	B441-2006	3°29'30.3142"N	76°29'3.5326"W	973.625
Floralia Pumping Station	B057.2006	3°30'08.67402"N	76°29'35.44818"W	978.901
Margen Izquierdo Collector	B112-2006	3°30'16.34322"N	76°29'39.85769"W	977.828
	B113-2006	3°30'14.98583"N	76°29'39.49539"W	977.155

Sampling Parameters, Sampling Frequency and Sample Composition Samples are collected, preserved, transported and tested in accordance with the techniques described in the APHA, AWWA and WEF Standard Methods for Examination of Water and Wastewater (EMCALI, 2005). Tables 4.8 and 4.9 list the sampling parameters, the collection period, and the number of samples taken for monitoring final discharges from the city of Cali.

Table 4.8 Frequency of monitoring in situ parameters

in situ Parameters	Sampling period (Days)	Sampling period	
		Frequency*	Samples/Day
pH (Unit)	4	30 min	24
Temperature (°C)	4	30 min	24
Flow (m^3/s)	4	30 min	24

* All monitoring points are included except South Channel (frequency : every hour)

Table 4.9 Frequency of monitoring laboratory parameters

Parameter	Sampling Period	Measurement at the laboratory	
	(Days)	Composition/Day	Samples/Day
BOD	4	Every 6 hours	4
COD	4	Every 6 hours	4
TSS	4	Every 6 hours	4
G&O	4	Punctual	2
Phenols	4	Every 12 hours	2
Cyanides	4	Every 12 hours	2
Cd	4	Every 12 hours	2

Parameter	Sampling Period	Measurement at the laboratory	
	(Days)	Composition/Day	Samples/Day
Cr^{+6}	4	Every 12 hours	2
Pb	4	Every 12 hours	2
Ni	4	Every 12 hours	2
Cu	4	Every 12 hours	2
Ag	4	Every 12 hours	2
Zn	4	Every 12 hours	2
Hg	4	Every 12 hours	2

As part of the plan for improving control of discharges into the sewerage system, EMCALI has scheduled two monitoring campaigns to be conducted in the Melendez, Lili and Cañaveralejo rivers in 2008. These monitoring campaigns are going to allow determining the amount of contaminant loads from these rivers into the southern drainage system. The sampling points are at the location where the rivers enter the urban area of Cali and at the point of discharge into the South Channel.

EMCALI is also planning on monitoring industrial discharges into the urban drainage system for the purpose of controlling and collecting wastewater pollution charges.

Futures Expectatives - Integrated network to monitor the sewerage system of the city of cali

EMCALI is planning to install a sewerage network consisting of 8 fixed stations, 16 mobile stations, and 4 portable stations with real-time data transmission capabilities. The general and specific objectives and components are show below:

General Objective

- Developing a permanent, reliable, real-time measuring system based on monitoring quantity and quality of wastewater and rainwater in the city of Cali in order to meet the regulatory requirements;
- Optimizing the provision of sewerage and supplementary services; and
- Fine tuning the hydraulic simulation model of the sewerage system

Specific Objectives

- Characterizing water quality of discharges from the city into the Cauca River
- Characterizing water quality in the urban stretches of the Cali, Meléndez, Lili, and Aguacatal, which are incorporated to the municipal rainwater drainage system.
- Characterizing rainwater collectors and canals.
- Characterizing the main sanitary collectors and interceptors.
- Characterizing collectors that drain sectors with major industrial discharges
- Calibrating the hydraulic simulation model of the sewerage system in terms of the quality and quantity of water.

Components

- Fixed and mobile monitoring stations
- Portable monitoring stations for verification purposes
- Data transmission and reception system
- Master sewerage control center
- Network surveillance/security points

4.4.2 Water Quality Monitoring Stations run by EMCALI in the Cauca River

Monitoring station located at the inlet to the Puerto Mallarino drinking water plant.

EMCALI installed a monitoring station at the inlet to the Puerto Mallarino wastewater treatment plant. The objective of the station is to keep track of the quality of water in the Cauca River, which at times of highest contamination levels causes suspension of the wastewater treatment process at the plant.

The station is equipped with 3 probes used for taking continuous dissolved oxygen, temperature, turbidity, and pH readings.

Sensors

DCP located at the monitoring station at the water intake - Puerto Mallarino Plant

Figure 4.8 Sensors and DCP at the water quality monitoring station of Puerto Mallarino Plant

Data are first stored in a WTW datalogger and then transmitted to the SCADA system, which is used for controlling the drinking water treatment process.

Panel of data recording for the purification water process at Puerto Mallarino

Visualization of data from the stages of the treatment

Figure 4.9 System for controlling & monitoring processes at the Puerto Mallarino drinking water plant

Information is stored in an ORACLE database. EMCALI is now developing a web-based application that would allow viewing the behavior of dissolved oxygen levels at the two water quality monitoring stations on the Cauca River on a real-time basis. This information is made available to departments, agencies, and managers, as needed.

"Milán" Water Quality Monitoring Station

EMCALI recently installed a station to monitor water quality of the Cauca River. The station is located about 4 kms upstream of the inlet at the facilities of the Milan water pumping station for irrigation, which is owned by Constructora Melendez (a construction company)(see Figure 4.11)

Installation of a dissolved oxygen probe at the Milán monitoring station.

System of data storage at the Milán monitoring station.

Figure 4.10 Estación de monitoreo de calidad del Agua del río Cauca – Estación Milán

The purpose of the station is to alert about events of high contamination levels in the Cauca River.

The sensors in the Cauca River are 3 meters deep and approximately 6 meters away from the river shore. The site where the probe is located and the distribution of the water flow lines in the cross-section of the river are oriented towards the right side of the Cauca River.

The operator reports the water quality data to the Puerto Mallarino plant twice a day; usually one at 6:00 am and the other at 6:00 pm. The operator also notifies or alerts whenever there are contamination peaks in the river via radio telephone. The information obtained from the probe allows having a response time allowance of 2.5 hours.

To this date EMCALI has optimized the data transmission system and installed a telemetric system which generates data about the behavior of dissolved oxygen levels in the Cauca River every three minutes. EMCALI's personnel can view this information using a web-based application.

4.4.3 Monitoring Quality of Processes at the C-Wastewater Treatment Plant

The quality of the various treatment processes (water, sludge and odor control) is continuously monitored at the C-Wastewater Treatment Plant. The resulting residue from the treatment processes such as skim, fat and process wastewater is characterized, and raw materials used for treating wastewater are analyzed in the laboratory

Quality sampling conducted at the C-Wastewater Treatment Plant allows monitoring the processes, determining treatment efficiencies, and identifying the physicochemical and microbiological characteristics of the final effluent from the plant and the biosolids, which are finally disposed at the Puertas del Sol site.

Samples of affluent water into the plant are taken using an automatic sampling device, which is located in the flow rate integration chamber. Samples are collected every hour for 24 hours. After collecting the samples, they are transferred to the laboratory for composition analysis and testing.

Information obtained from the laboratory analyses is shared through the internal network at the plant which allows users to easily access and use this information for preparing reports.

The sampling frequency and sampling parameters at each of the quality monitoring points at the C-Wastewater Treatment Plant are provided below.

Water: Both the affluent and effluent water at the plant and in the central collector are scheduled to be monitored.

Sampling frequencies and testing parameters are listed in Table 4.10

Table 4.10 Water Quality Monitoring at the C-WwTP

Testing area	Sample contents	Parameters to analyze	Days of Sampling/Month	Samples/ Day
Flow mixing chamber and chamber of effluent A o B	Raw and treated waters	pH, Temperature, Sedimentation of solids, Conditions. COD, BOD, TSS, VSS, TS, VS	30	48
Effluent Chamber B	Treated water	Total and fecal Coliforms	4	1
Flow mixing chamber and chamber of effluent A o B	Raw and treated water	Oxidation-reduction potential	30	4
Flow mixing chamber and chamber of effluent A o B	Raw and treated water	Detergents	8	*
Flow mixing chamber and chamber of effluent A o B	Raw and treated water	Metals. Cl^-, Phosphorus, Alkalinity, Acidity, Phenols, CN, TNK	5	*
Flow mixing chamber and chamber of effluent B	Raw and treated water	Greases and oils	8	2
Central collector	Treated water	pH, COD, BOD_5,TS, VS, TSS, VSS	5	24

Source: Adapted from the November 2007 Monitoring Program at the C-WwTP

Sludge: Sludge is sampled in each of the sludge treatment stages. This allows calculating the efficiency of the process and identifying the physicochemical and microbiological characteristics of biosolids available. The sampling points and testing parameters are shown in Table 4.11

Table 4.11 Monitoring Sludge Quality at the C-Wastewater Treatment Plant

Testing area	Sample contents	Parameters to Analyze	Days of Sampling/Month	Samples/ Day
Valves of the settling tanks pumps	Primary sludge	pH, TS, TVS	30	8
Thickener valves	Thicknesses sludge	pH, TS, TVS	30	2
Valves of digesters pumps	Digested sludge	pH, TS, TVS, VAG, Total alkalinity, bicarbonate alkalinity	30	3
Storage tank	Dewatered Sludge	TS, VS	30	1
Filtres press	Biosolid	pH, Specific gravity , TS, TVS	30	1
Filtres press	Biosolid	Metals	5	
Filtres press	Biosolid	Total and Fecal coliforms, Helminths eggs, Salmonella.	1	1
Final sludge disposal site	Bio-solid with lime and sewer sludge	pH, T°, TS, VS, Total and fecal Coliforms, Helminths eggs	Every 3 months	2

Source: Adapted from the November 2007 Monitoring Program at the C-WwTP

Odor Control: In order to determine the condition of the "soil bed" filters of the odor control system, each of these filters is sampled once a month and the samples are tested for the parameters listed in Table 4.12

Table 4.12 Odor Control Monitoring

Testing area	Sample contents	Parameters to Analyze	Days of Sampling/Month	Samples/ Day
Soil Beds: A, B, C, D, E	Soil	pH, Humidity, Porosity, Density, Conductivity, Organic matter, Organic Carbon.	1	5

Source: Adapted from the November 2007 Monitoring Program at the C-WwTP

Waste: The treatment processes generate byproducts in the form of residue, which is analyzed for the purpose of identifying its physicochemical characteristics. The physicochemical testing parameters are shown in Table 4.13

Raw material: Ferric chloride ($FeCl_3$) and hydrated lime are tested for the parameters listed in Table 4.14. This testing is performed on a periodical basis depending on the shipment deliveries from the supplier.

Table 4.13 Characteristics of sampling at the locations in the plant where residue is generated

Testing area	Sample Contents	Parameters to Analyze	Days of Sampling/Month	Samples/ Day
Rubbish hopper with narrow grid	Solid waste	Humidity	4	1
Sand hopper	Sands	TS, TVS, greases and oils	30	1
Grease trap	Residual water from the treatment process	Humidity, specific gravity	4	1
Grease trap	Floating sludge	TS, TVS	4	1
Sludge and floating sludge screen of the Thickener	Wastes	pH, TSS	4	1
Thickener dump	Residual water from the treatment process	pH, TS	30	1
Pipes of the Residual water from the treatment process	Residual water from the treatment process	pH, TS, TVS	30	1
Percolated of the filter press	Residual water from the treatment process	pH, TS, TVS	30	1

Source: Adapted from the November 2007 Monitoring Program at the C-WWTP

Table 4.14 Raw material sampling

Testing area	Sample Contents	Parameters to Analyze	Frequency of Sampling	Sampling type
Storage tank $FeCl_3$	$FeCl_3$	Density of the insoluble material, ferrous ion , ferric ion , total iron, ferric chloride, free acidity	It depends on the frequency of arrivals of orders from the supplier	A sample is taken in each day
Dehydration	Lime hydrated	Humidity, % CaO, % $Ca(OH)_2$	It depends on the frequency of arrivals of orders from the supplier	At least three samples are taken from different lime bags and mixed to start the test

Source: Adapted from the November 2007 Monitoring Program at the C-WWTP

4.4.4 Meteorological Station at the Cañaveralejo WwTP

The meteorological station run by the C-WwTP is on the terrace of the administration building at the C-WwTP. The following parameters are measured at this station: temperature, wind direction, solar radiation, relative humidity, barometric pressure, and precipitation. Data recorded at this station can be viewed in the control room using the Micromet software.

The data from the station obtained in the control room are processed for reporting purposes. However, this information is not used for making decisions associated with the operation of the plant.

The measuring instruments at these stations are rusty and abandoned, and are probably not operating properly because they lack maintenance and calibration (see Figure 4.12).

Solar global radiation sensors

Pluviometer

Figure 4.11 Cañaveralejo WwTP Climatological Station

4.5 SYSTEM FOR CONTROLLING & MONITORING PROCESSES AT THE CAÑAVERALEJO WASTEWATER TREATMENT PLANT (C-WWTP)

4.5.1 General Description

The data supervision, control and acquisition (SCADA) system used at the Cañaveralejo wastewater treatment plant is based on a set of programmable computers and devices (PLC's) which are interconnected to an ethernet communications network (consisting of 2 closed-loop fiber optic networks) as shown in Figure 4.13.

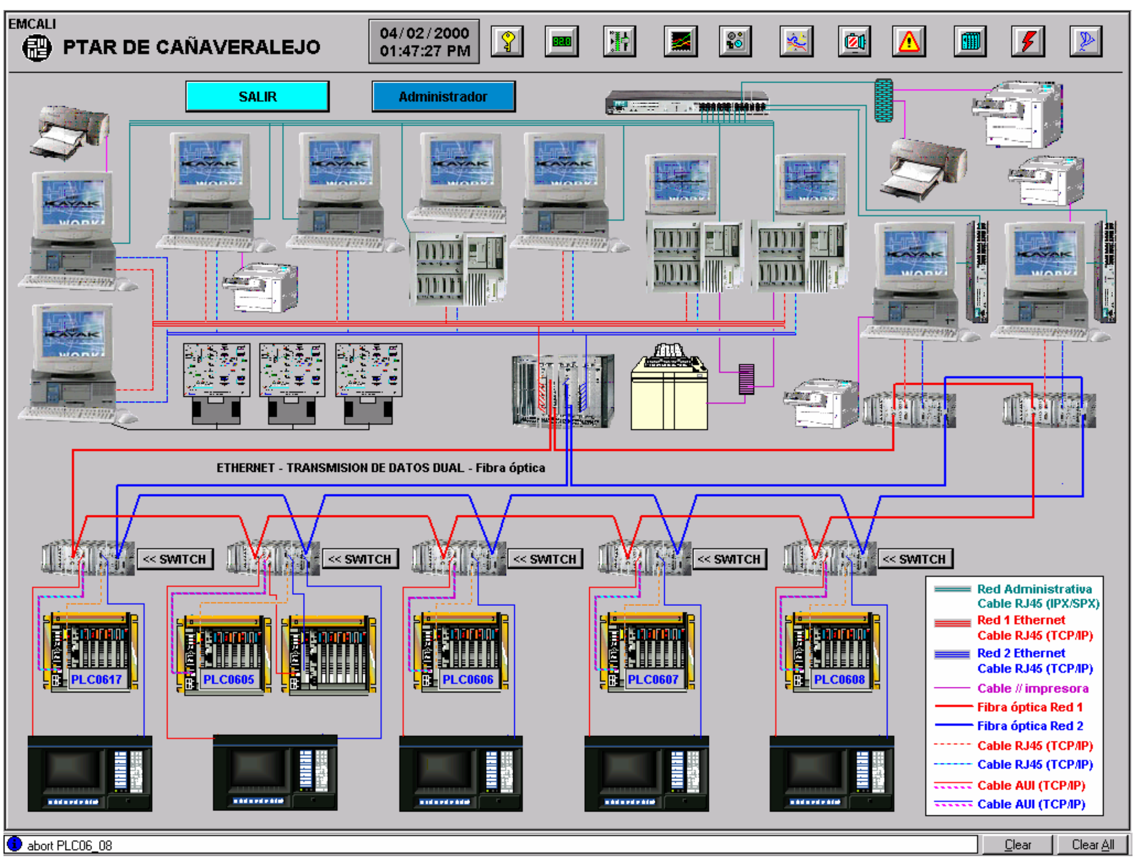


Figure 4.12 SCADA System Configuration and Communication Network

Source: EMCALI, 2001

4.5.2 Componentes

The Control System consists of:

- Computers
- Printers
- PLC's
- Sensors
- Communications equipment
- Supervision software
- Supervision application
- Electric box of the PLC's

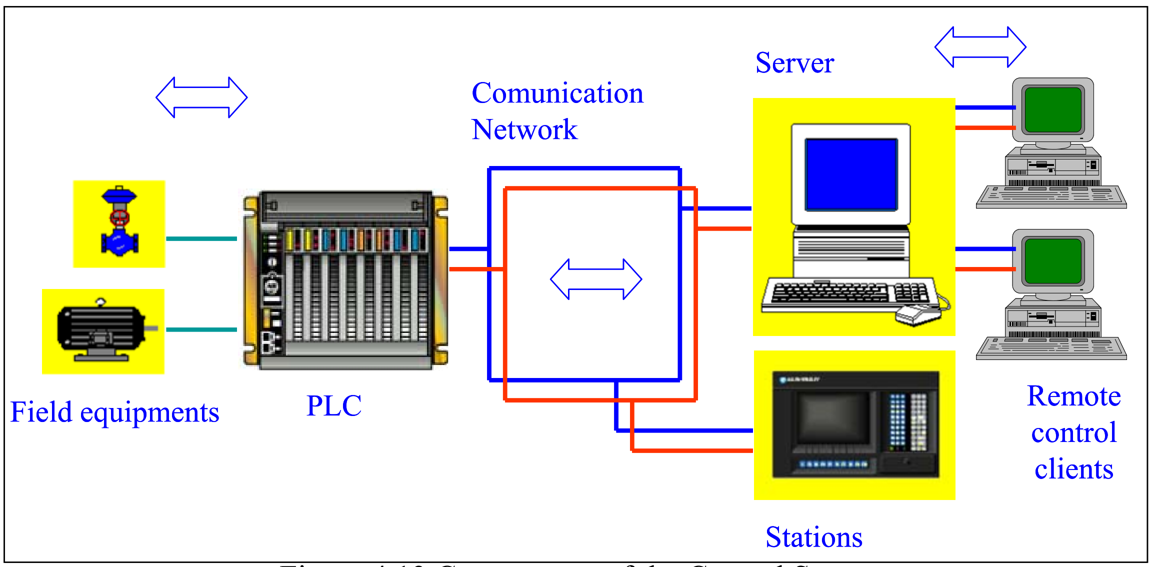


Figure 4.13 Components of the Control System.
Source: EMCALI, 2001

4.5.3 Computers

The following computer equipment is installed: 2 servers, 8 remote control clients, and 5 local control stations.

<u>*Servers:*</u> Hewlett Packard servers installed in a cabinet are used. Figure 4.15 shows pictures of the mainframe and back-up servers.

Table 4.15 shows the functions and software of the servers

Figure 4.14 Mainframe and Back-up Servers

Table 4.15 Server Features

Components	Functions	Software
Server 1 (Main server)	Runs the supervision application.	Windows NT Server
	Manages the interchanging of information with customers of the supervision.	Internet Explorer
	Supervises and manages all the operational processes within the plant.	RSView 32 Works 6.20.49
Server 2 (support server)	Manages processes which ensure printing of events and alarms.	RSView 32 Active Display Server
	Allows jobs of modification in the application.	RSLinx
	Manages the Network	

Source: Adopted from EMCALI, 2001

Remote Control Clients: The remote control clients are at different locations within the plant. Their function is to use the servers' supervision application to supervise, operate and generate database records.

These stations run on Windows NT Workstation using the RSVies, 32 Active Display Client Software. The laboratory and the server use the Oracle & Client database, and the maintenance station has the Aquamaint software installed. Annex 3, shows the distribution of remote control clients, including their respective functions.

Figure 4.15 Operator & Overhead Projection Workstations

Figure 4.16 Dataserver Workstation

Stations: The independent stations or area control panels are flat-panel type Allen-Bradley industrial computers designed to be installed cabinets. The location, functions, and software used at these stations are listed in Table 4.16

Table 4.16 Characteristics of the stations

Location	Functions	Software	
Electrical room of the pumping station Electrical room of the settling tanks Electrical room of the digesters Electrical room of the deshydration process Main electrical room of the plant	Run the application of supervision	Service Pack 5 para NT RSView 32 Runtime 6.20 RSLinx 2.10.118	 Touch screens located at the stations

Source: Adopted from EMCALI, 2001

4.5.4 Printers

The control system has different kinds of printers for printing supervision events, databases, charts and plots. The features of the printers installed are provided in Table 4.17

Table 4.17 Printers used in the Control System at the C-WwTP

Kind	Manager	Function
Printer of the process events	Server1 y Server2	Printing of events generated by applying of supervision
Printers of the network	All the computers are connected with the network (severs and customers), except for the projection workstation	Charts and curves printing Documents printing
Private printers	Reports Laboratory Maintenance Engineer	Documents printing

Source: Adopted from EMCALI, 2001

4.5.5 Controlador Lógico Programable (PLC)

A Programmable Logical Control (PLC) is a device equipped with a user-programmable memory which reads input conditions and determines the output conditions to control a machine or a process (see Figure 4.18).

The equipment installed in the field is controlled based on previously set specifications in the memory of the PLC. These controllers also store information about the operating condition of the equipment in their database. PLC's used in the control system at the C-WwTP are Allen-Bradley PLC-5 which run on the RS Logis 5 software.

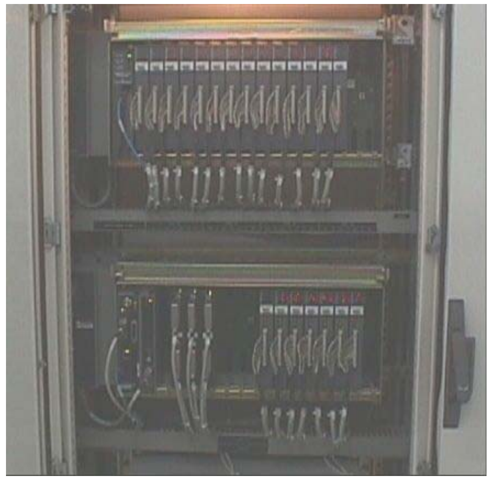


Figure 4.17 Programmable Logical Controller

6 PLC's are distributed at different locations in the plant (see Figure 4.13). The function of each PLC is to manage the following areas: elevation, pre-treatment, physicochemical treatment, digestion, dehydration, and power supply.

4.5.6 Sensors used for controlling processes at the C-WWTP

As part of the process control devices at the C-WWTP, several sensors are installed in each of the different treatment stages for measuring parameters such as flow rate, levels, pH, temperature, radix potential, and concentration of TSS and BOD. The readings of these sensors are transferred to the communication network of the SCADA system and made available to be viewed in real time from any of the control workstations. The location and the parameters measured by these sensors are listed in Table 4.18

Table 4.18 Sensors used for controlling processes at the C-WwTP

Sensor	Quantity	Location
Water line		
Flow (m^3/s)	1	Cañaveralejo Pumping Station
Flow (m^3/s)	1	Agua Blanca Pumps
Flow (m^3/s)	1	Navarro Pumps
Flow (m^3/s)	1	Total Pump
Flow (m^3/s)	1	Central collector
Flow (m^3/s)	1	Influent settling tanks
Flow (m^3/s)	1	Influent settling tanks
pH (Unit), ORP (mV) and TºC	1	Flow mixing chamber
TSS (mg/l) and BOD (mg/l)	1	Flow mixing chamber
Level (m)	4	Entrance(2) and exit (2) coarse screens
TSS (mg/l) and BOD (mg/l)	1	Chamber of effluent A
Sludges line		
Flow (m^3/s)	4	Entrance pumping chamber of primary sludge
Temperature	4	Digestes A, B, C and E
Level (m)	2	Storage tanks of digested sludges
Flow (m^3/s)	7	Digested sludges Filters 1, 2, 3, 4, 5, 6 y 7

Source: Adopted from EMCALI, 2001

Table 4.18 Sensors used in C-WwTP. Cont.

Sensor	Quantity	Location
Gas line		
Flow (m^3/h)	4	Digesters A, B, C y D
Raw material		
Velocity (%)	7	Pumps to apply organic polymer in the primary advanced treatment
Velocity (%)	7	Pumps to addition $FeCl_3$
Level (m)	2	Storage tanks of organic polymer used in dewatering
Flow (m^3/s)	7	Addition of organic polymer in the filters press 1, 2, 3, 4, 5, 6 y 7

Source: Adopted from EMCALI, 2001

In addition to the sensors shown in Table XX, certain units such as the sludge storage tank and the power generators are provided with sensors that measure sludge flow rate and gas consumption. These devices, however, are not being used because the above mentioned units are not operational.

Figure 4.19 shows the sensor that measures the flow rate of wastewater supplied to the C-WWTP. Figure 4.20 shows the sensor installed in the flow rate integration chamber for measuring pH, temperature, and redox potential.

Figure 4.18 Ultraflux Flow Sensor

Figure 4.19 WTW Sensor Net: pH, temperature and redox registered

Figure 4.21 shows the location of the monitoring points in the C-WwTP.

4.5.7 Communications Equipment

The optical interfaces allow connecting the computers and the PLC's to 2 fiber optic loops. These optical interfaces also manage circulation of information through the network when there are interruptions in the fiber optic loops. The kinds of optical interfaces used are AMC 1006 and ASGE (EMCALI, 2001).

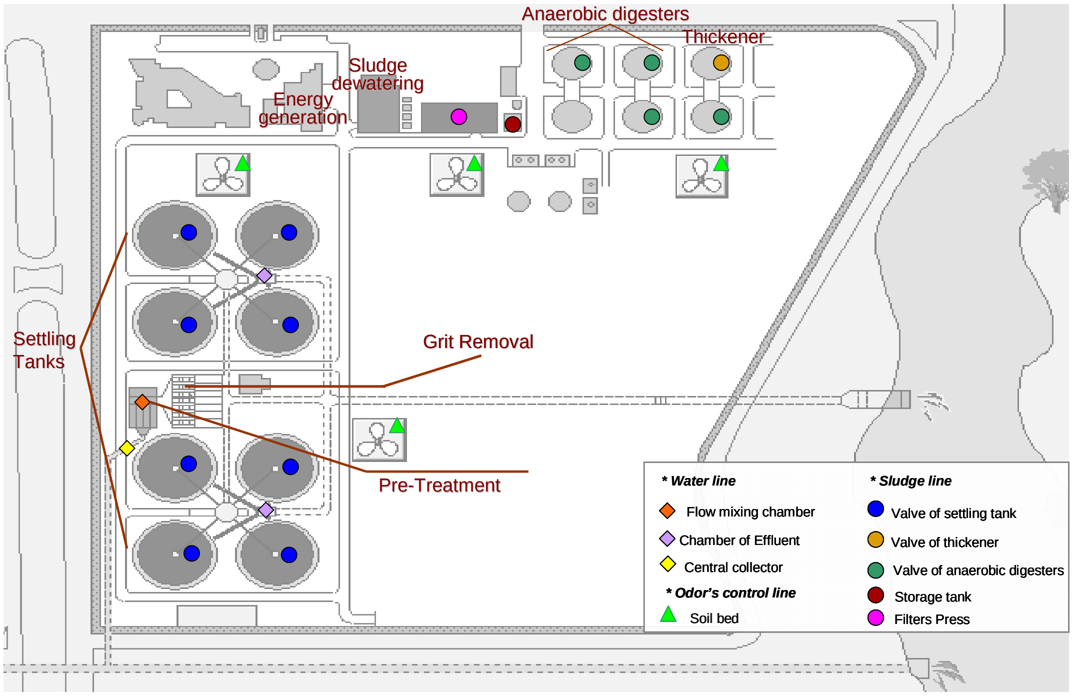


Figure 4.20 Monitoring points in the C-WwTP.

ASGE Optical Interface: This optical interface allows connecting remote computers, PLC's and industrial computers to the 2 fiber optic loops which comprise the communications network.

AMC Optical Interface: This optical interface allows connecting the computers in the control room to the 2 optic fiber loops which comprise the communications network.

The communications equipment is located in the following areas: control room, laboratory office, maintenance office, elevation electric panel, pre-treatment electric panel, digestion electric panel, dehydration electric panel, and power supply electric panel

4.5.8 Supervision Software

The supervision and control system uses the RSView 32 software. This software package supports three different kinds of configurations: i) RSView 32 Works, ii) RSView 32 Runtime, and iii) RSView 32 Active Display System. The characteristics of each of these configuration options are presented in Table 4.19

Table 4.19 Características y funciones de las configuraciones de RSView 32

RSView 32 Configuration	Characteristics	Functions
RSView 32 Works	Integrated package for developing and running monitoring and automated process control applications.	▪ Preparing and animating charts ▪ Using alarm views to display information ▪ Detecting events that can trigger actions for the supervision system to take automatic actions suitable to the issues in the process. ▪ Capturing data. This allows storing historical data of all variables associated with the application. ▪ Configuration of different security levels. This limits user's access to certain charts/applications or to make changes in the variables.
RSView 32 Runtime	This software package is used only for running monitoring and automated process control applications developed with RSView 32 Works.	This software package allows: ▪ Viewing charts ▪ Monitoring alarms. ▪ Detecting events ▪ Capturing data. ▪ Managing different security levels. ▪ Displaying historical trends ▪ Running programs in Visual Basic
Rsview 32 Active Display System	Client/Server Application	It allows users at a remote location to view and interact with the charts of a supervision application from another computer connected to the network, as if the application was installed on their own computer.

Source: Adopted from EMCALI, 2001

4.5.9 Supervision Application

The supervision system developed for the C-WwTP performs the basic functions:

- Displaying installation views
- Displaying alarms and events
- Displaying trends
- Managing remote accounts, remote commands and remote regulations

The description of its functions is shown in Annex 4.

4.5.10 Remote Accounts, Regulations and Commands

Remote accounts, regulations and commands, allow that the system shows the total running time of engines and operation of valves. Additionally, the operating conditions of certain devices can be controlled via remote regulation of: threshold values, records of levels, flow rates, temperatures and running times. The characteristics of its tools are shown in Annex 5

5 ANALYSIS OF THE MONITORING COMPONENTS OF THE DRAINAGE SYSTEM IN THE CITY OF CALI

5.1 SEWER NETWORK

31 stations (i.e. 26 meteorological and 5 hydrological stations) (see Table 5.1) have been implemented in the area of influence of the municipal drainage system in Cali. These stations are located in the urban area and in the basins of the Meléndez, Cañaveralejo Lili, Pichindé, Cali, and Cauca rivers.

Table 5.1 Meteorological and hydrological stations in the municipal drainage system of Cali

Name	Mun.	Latitude Norte	Longitude Oeste	Altitude msnm	Class	Categ.	Tiype	River	Institution
La Teresita	Cali	3°27´	76°4´	1950	MET	CO	AUT	Cali	CVC
El Topacio	Cali	3°19´	76°39´	1676	MET	CO	AUT	Pance	CVC
Bocatoma	Cali	3°27´	76°34´	997	HID	LG	CON	Cali	CVC
El Jardin	Cali	3°25´	76°34´	997	HID	LG	CON	Cañaveralejo	CVC
Pasoancho	Cali	3°22´	76°32´	1000	HID	LG	CON	Lili	CVC
Calle Quinta	Cali	3°22´	76°33´	996	HID	LG	CON	Melendez	CVC
Pichinde	Cali	3°26´	76°37´	1540	HID	LG	CON	Pichinde	CVC
Aguacatal	Cali	3°29´	76°37´	1649	MET	PG	CON	Aguacatal	CVC
Villa Aracelly	Cali	3°31´	76°37´	2040	MET	PG	CON	Aguacatal	CVC
Brasilia	Cali	3°26´	76°39´	1864	MET	PG	CON	Cali	CVC
Colegio San Luis	Cali	3°28´	76°33´	1053	MET	PG	CON	Cali	CVC
Planta Rio Cali	Cali	3°26´	77°03´	1070	MET	PG	CON	Cali	CVC
Canaveralejo	Cali	3°25´	76°35´	1056	MET	PG	CON	Canaveralejo	CVC
Colegio San Juan Bosco	Cali	3°27´	76°32´	1000	MET	PG	CON	Canaveralejo	CVC
Edificio CVC	Cali	3°24´	76°33´	985	MET	PG	CON	Canaveralejo	CVC
Planta Rio Cauca	Cali	3°27´	76°3´	956	MET	PG	CON	Cauca	CVC
Alto Iglesias	Cali	3°22´	76°38´	1705	MET	PG	CON	Melendez	CVC
La Argentina	Cali	3°2´	76°4´	1794	MET	PG	CON	Pance	CVC
Penas Blancas	Cali	3°25´	76°4´	2158	MET	PG	CON	Pichinde	CVC
Montebello	Cali	3°29´	76°33´	1260	MET	PM	CON	Aguacatal	CVC
San Pablo	Cali	3°31´	76°37´	1871	MET	PM	CON	Aguacatal	CVC
Las Brisas	Cali	3°24´	76°36´	1228	MET	PM	CON	Cañaveralejo	CVC
Los Cristales	Cali	3°26´	76°35´	1312	MET	PM	CON	Cañaveralejo	CVC
La Fonda	Cali	3°23´	76°36´	1298	MET	PM	CON	Melendez	CVC
Yanaconas	Cali	3°26´	76°36´	1730	MET	PM	CON	Pichinde	CVC
Pichinde	Cali	3°26´17,4"	76°36´5,6"	1629	MET	PM	CON	Pichinde	IDEAM
Cali Sede Ideam	Cali	3°28´0,0"	76°31´0,0"	1000	MET	PM	CON	Cali	IDEAM
Universidad del Valle	Cali	3°22´40,8"	76°32´1,6"	992	MET	CP	CON/AUT	Meléndez	IDEAM - DAGMA
El Danubio	Cali	3°24´57,7"	76°39´5,3"	2330	MET	AM	AUT	Pance	IDEAM - DAGMA
Siloe	Cali	3°25´31,0"	76°33´38,3"	1237	MET	DESL	AUT	Cali	IDEAM - DAGMA
Base Aerea M F S	Cali	3°27´0,0"	76°30´0,0"	956	MET	SS	CON/AUT	Cauca	IDEAM - DAGMA

Figure 5.1 shows the location of the existing monitoring stations in the urban and peri-urban areas of Cali.

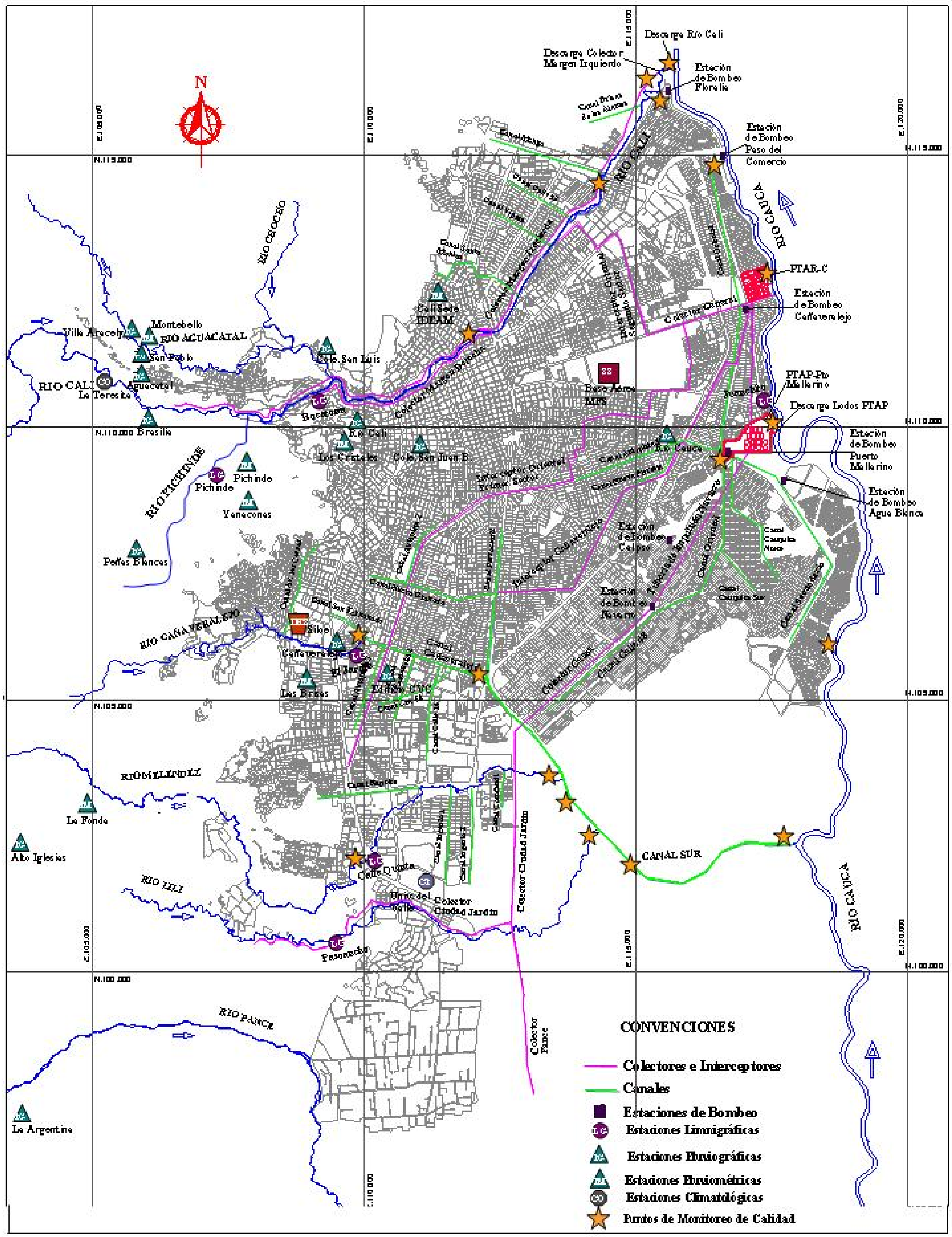


Figure 5.1Location of the existing monitoring stations in the urban and peri-urban areas of Cali.

Out of these stations, 25 (81%) are conventional, 4 (13%) are automated, and 2 (6%) have both conventional and automated units (see Table 5.2). Detailed information about these stations is provided in Annex 6

Table 5.2 Summarized inventory of hydrological and meteorological stations in the urban and peri-urban areas of Cali

Class	Category	Number of Stations			
		Total	Conventional	Automatics	Conventional/ Automatics
Hydrological	LG	5	5		
	LM	0	-		
Meteorological	PG	12	12		
	PM	8	8		
	CC	2		2	
	MC	1			1
	AM	1		1	
	SS	1			1
	SL	1		1	
TOTAL		**31**	**25**	**4**	**2**

Notes: Limnimetric Station (LM); Limnigraph Station (LG); Pluviometric Station (PM); Pluviograph station (PG), Common Climatologic Station (CC); Evaporimetric Station (EV); Main Climatologic Station (MC); Agrometeorological Station (AM) Supplementary Synoptic Station (SS); Slide Land Station (SL)

Since most of these stations are meteorological, the most important parameter measured at the stations is daily precipitation (84%). The following most relevant parameters are temperature (19%) and relative humidity (19%), and the third most important has to do with data about levels, flow rates, and sunshine (16%). (See Figure 5.2)

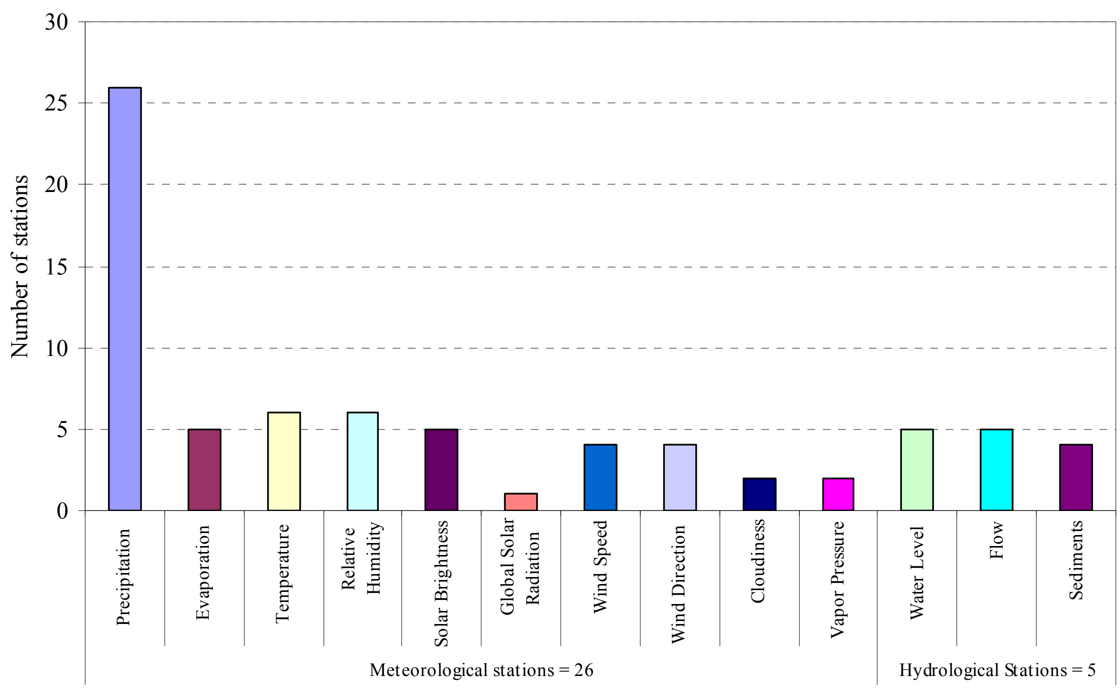


Figure 5.2 Main Meteorological and hydrological parameters measured at the stations

Information from the hydrological and meteorological stations located in the area of influence of the municipal sewerage network of Cali is usually transmitted on a monthly basis (53%), but it is also transmitted, at a lesser extent, on a daily (19%), weekly (17%), and real time (11%) basis.

Information is transmitted from the stations to the headquarters or control room of the institutions responsible for monitoring activities mostly through visits for collecting information (72%).

Because some stations have both automated and conventional equipment and instruments, one station may transmit information in four different ways, i.e. via satellite, telephone, visits or mail. See Figures 5.3 and 5.4

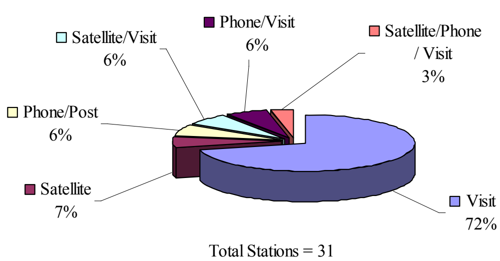


Figure 5.3 Means for data transmission from the stations to the control center

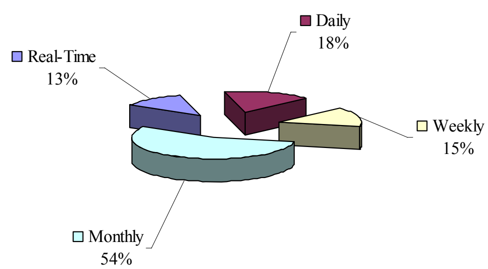


Figure 5.4 Data transmission frequency

With regard to monitoring the quality and quantity of water carried in Cali's municipal drainage system, CVC, EMCALI and DAGMA have identified a number of monitoring points at different locations in the city, particularly at the final points of discharge, canals, rainwater and wastewater collectors, and pumping stations of the sewerage system and the Cali, Meléndez, Lili, and Cañaveralejo rivers. The monitoring activities are scheduled on an annual and semi-annual basis. They are carried out for the following purposes: i) calculating the contaminant load which determines payments for wastewater pollution charges; ii) evaluating and monitoring quality of water sources; iii) characterizing effluents; and iv) estimating quality of water discharged before the inlet at Puerto Mallarino.

Table 5.3 shows a list of the quality monitoring points of the sewerage system and surface water sources in the city of Cali. Figure 5.1 identifies the location of the monitoring points in the sewerage system.

Table 5.3 Water quality monitoring points in the area of influence of the municipal sewerage system of Cali

River/ Discharge	Point of monitoring	Frequency Monitoring	Parameters	Record Since	Institution in charge
Cali River	Génesis Foundation	Half - yearly	Flow, pH, Temperature, Turbidity, Dissolved Oxygen, Total Coliforms and Faecal Coliforms, Conductivity, Solids, Total Phosphorus, Phosphate, Total Nitrogen , Ammonia Nitrogen, Nitrate and Nitrite, Colour, BOD and COD, Alkalinity, Hardness, Calcium and Magnesium, Chloride, Sulphates, Iron, Manganese, Sodium and Potassium	1996	CVC
	Before Felidia Bridge				
	Water intake of Cali Plant				
	Santa Rita Bridge				
	At head to Torre de Cali hotel				
	Calima - Floralia Bridge				
	Before final discharge to Cauca river				
Pance River	Before municipality of Pance	Half - yearly		1996	CVC
	Caserío San Francisco				
	La vorágine Bridge				
	Parque de la Salud Bridge				
	Comfandi Bridge				
	Before Final Discharge to Jamundí River				
Meléndez River	Water intake of La Reforma Plant	Hal f- yearly		1996	CVC
	Calle 5a Bridge				
	Final Discharge - Cra 80 Calle 50				
Cañaveralejo River	Vereda los Andes	Half - yearly		2004	CVC
	Limnigrafo CVC - Bridge				
	Calle 23 con Cra 50 - Bridge				
Lili River	Water intake of Alto del Rosario	Half - yearly		2004	CVC
	Parcelación La Riberita Bridge				
	Final Discharge to Channel South				
South Channel	Calle 25 Cra. 48 Bridge	Half - yearly	Flow TSS BOD COD	*2006	CVC
	Simón Bolivar Bridge				
	Las Vegas Bridge				
	Basurero Bridge				
	Chumbun Bridge				
	Bridge -Final Discharge to Cauca River				
	Final Discharge to Cauca River	Annual	pH , Temp., Flow, BOD, COD, TSS, G&O, Phenols, Cyanides, Cd, Cr^{+6}, Pb, Ni, Cu, Ag, Zn, Hg	2005	EMCALI
Final Discharge	Puerto Mallarino Pumping Station	Annual	pH , Temp., Flow, BOD, COD, TSS, G&O	1999	EMCALI
	Paso del Comercio Pumping Station	Annual			
	Floralia Pumping Station	Annual			
	Margen Izquierdo Collector	Annual			
Cañaveralejo WwTP	Final Discharge to Cauca River	Annual	pH , Temp., Flow, BOD, COD, TSS, G&O	2003	EMCALI

In total, there are 34 quality monitoring points to measure main parameters such as BOD, COD, TSS, pH, temperature, and flow rate. Considering their impact on the quality of water supply to the city of Cali, certain substances of sanitary concern such as heavy metals and precursors of trihalomethanes and carcinogenic substances have also recently been incorporated to this list of parameters. These monitoring activities are usually performed during the dry season.

EMCALI, which is the public utility company responsible for the provision of water and sewerage services, does not have a wastewater quality and quantity monitoring network that not only supplies real-time data about the sewerage system, but can also be used for operating and maintaining the drainage system.

There is also no control of the wastewater discharges from the pumping stations, especially those that directly discharge wastewater into the Cauca River, i.e. the Puerto Mallarino and Paso del Comercio pumping stations, except for wastewater processed by the system at the wastewater treatment plant. This situation is the result of the old age of the pumps and the lack of a periodical pump calibration schedule.

Based on the above mentioned situation, the following is an identification of some of the main positive and negative aspects associated with the activities to monitor the sewerage system in the city of Cali.

- There is extensive information about precipitation in the urban area, and the CVC and IDEAM have sufficient information with regard to the climatological behavior in the urban area of Cali. Despite this, to a large extent this information is not used by EMCALI when it comes to preparing forecasts of floods in vulnerable areas in the city or facilitating operation during the rainy season.

- Despite the fact that the meteorological and hydrological stations are relatively close to the control centers of IDEAM and CVC in Cali, there are deficiencies in data communication and transmission. 72% of the stations transfer information when the crews conduct their visits, which typically occur every month (54%).

- Meteorological and hydrological information obtained from the basins of the Lili, Meléndez and Cañaveralejo could be useful for issuing alerts related with extreme contamination events. During the rainy season, these rivers drag along a large amount of sediments, and their loads in terms of flow rate could be associated with re-suspension phenomena and first washout of the basin in the South Channel, thus having a negative impact on the quality of the main source of water supply to the city of Cali.

- Because monitoring activities are usually performed during the dry season, there isn't enough information available about the behavior of the quality and quantity of wastewater generated during the rainy season. This information would be useful for optimizing the drainage system, i.e. replacing the sewerage networks and collectors and designing rainwater collectors and canals in the areas where the city is now expanding.

- As mentioned in Chapter 4.4, item 4.4.1, EMCALI is planning to install a sewerage network consisting of 8 fixed stations, 16 mobile stations, and 4 portable stations with real-time data transmission capabilities.

- DAGMA fails to exercise an effective control of industrial discharges into the sewerage system. EMCALI recently started a program to identify and measure contaminant loads generated by some industries for the purpose of determining wastewater pollution charges

5.2 WASTEWATER TREATMENT PLANT

Laboratory testing is performed to monitor treatment quality at the Cañaveralejo WwTP on a regular basis. These tests are useful for determining the treatment efficiencies and controlling the processes based on the physicochemical and microbiological characteristics of water and sludge samples and other substances of sanitary concern.

In addition to this, the Cañaveralejo WwTP has a set of devices distributed in each of the different treatment stages. The data from these devices are transferred to the communication network of the Supervision and Control System (SCADA), which allows viewing data records from these sensors and operating the treatment system from the control workstations.

The Figure 5.5 below shows the monitoring locations at the C-WwTP, the location of the sensors that measure flow rate, temperature, levels, TSS, BOD, pH, and redox potential, and the location of the climatological station.

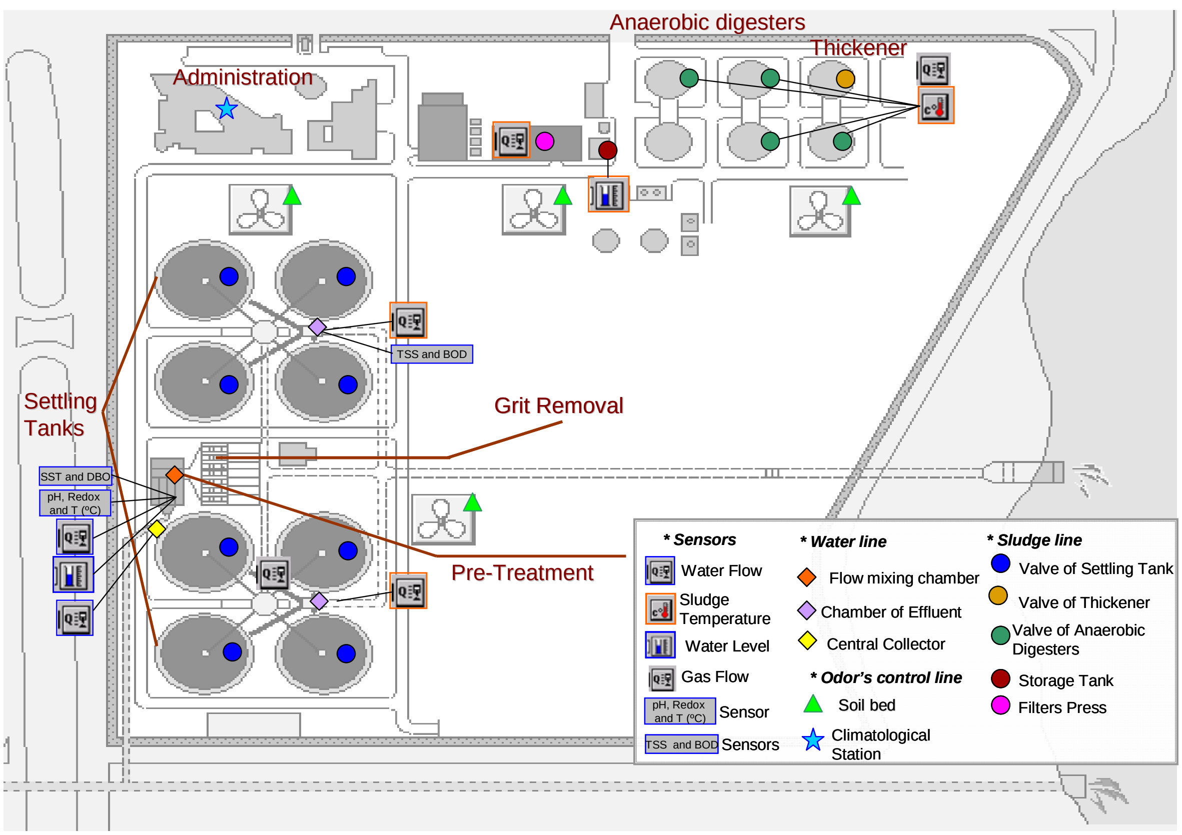


Figure 5.5 Monitoring Locations and Sensors at the C-WwTP

Based on the above, a description of some of the positive and negative aspects of the monitoring system at the C-WwTP is provided below:

- The data supervision, control and acquisition system (SCADA) has an Ethernet communications network in place which consists of 2 closed-loop optic fiber networks. When either of the networks fails, operation is switched to the other network without interrupting communication in the system.

- The supervision system developed for the C-WwTP runs on the Windows NT platform, which provides users with a practical easy-to-use interface for retrieving, processing, administering, managing and interpreting data.

- In addition to determining physicochemical parameters of the samples collected during the monitoring activities at the C-WwTP, the laboratory analysis also involves performing microbiological testing for fecal and total coliforms and other substances of sanitary concern.

- The affluent of discharges from the Cañaveralejo, Agua Blanca and Navarro pumping stations is measured by sensors located at the points of entry of these stations to the C-WwTP. The SCADA system developed for the C-WwTP does not control the flow rate or the pumping time of these stations. It only allows viewing information about these variables.

- Whenever there is a failure in the ultrasound level sensor in the ClF_3 storage tank, the consumption of coagulating agent cannot be controlled. Therefore, the advanced primary treatment plant is removed from service whenever this occurs.

- Because of the lack of a continuous monitoring system in the sewerage networks, it is impossible to anticipate and identify the characteristics of the wastewater to be treated in operating the plant. These characteristics are only known after the wastewater enters the WwTP.

- Despite the fact that the treatment plant has a climatological monitoring station, data from the station are not used for the operation of the C-WwTP. The devices at the station are abandoned and probably do not supply reliable data because of they are not calibrated or maintained properly.

- Although information from the climatological stations located in the area of influence of the pumping stations and general collector connected to the C-WwTP is of great interest for the treatment system, this information is not shared. Additionally, there isn't a communication network in place for transmitting any such information.

In general, the supervision and control system implemented at the C-WwTP performs its intended functions by capturing, storing and processing data and transmitting information efficiently. It also allows managing the treatment system from the control workstations in a practical manner.

As an in-house control mechanism, the system at the C-WwTP operates properly, but it is necessary to implement a mechanism to transmit information from the climatological stations located in the area of influence of the Cañaveralejo, Navarro, and Aguablanca pumping stations and the general collector which carry the wastewater supplied to the C-WwTP. It would allow using this information in operating the plant to anticipate rain events that have an impact on the quality and quantity of the wastewater supplied to the C-WwTP.

If a continuous sewerage monitoring system is implemented, it would be useful if this information was transmitted to the control center at the C-WwTP where it would be used, for example, for identifying specific discharges from the industrial sector. This information would be more relevant when the C-WwTP runs secondary treatment operations.

5.3 WATER RECEIVING SYSTEM (CAUCA RIVER)

53 stations (37 meteorological, 15 hydrological and 1 combined station) are located in the basin of the Cauca river along the land stretch from Salvajina to Juanchito (see Table 5.4). Figure 5.6 shows a general chart with the location of the monitoring stations at the different components of the drainage system of the city of Cali. 78% of these stations are conventional, 17% automatic, and 5% have both conventional and automated equipment. Annex 7 shows a list of the stations and the main characteristics of the stations operating in the basin of the Cauca river and its tributary rivers.

Table 5.4 Automated and conventional stations on the basin of the Cauca river and its tributary rivers. Land stretch from Salvajina to Juanchito

Class	Category	Number of Stations			
		Total	Conventional	Automatics	Conventional/Automatics
Hydrological	LG	13	7	5	1
	LM	2	2		
Meteorological	PG	2	1	1	
	PM	24	23	1	
	CC	8	1	1	1
	EV	3	2	1	
Meteorological / Hydrological	PM/ LG	1			1(PM/LG)
TOTAL		**53**	**41**	**9**	**3**

Notes: Limnimetric Station (LM); Limnigraph Station (LG); Pluviometric Station (PM): Pluviograph station (PG), Common Climatological Station (CC): Evaporimetric Station (EV)

The monitoring stations of IDEAM, CVC and EMCALI along the land stretch from Salvajina to Juanchito cover, in total, 8 tributaries to the Cauca River. 28% of these stations are hydrological, 4% limnimetric, and 24% limnigraphic (see Table 5.5).

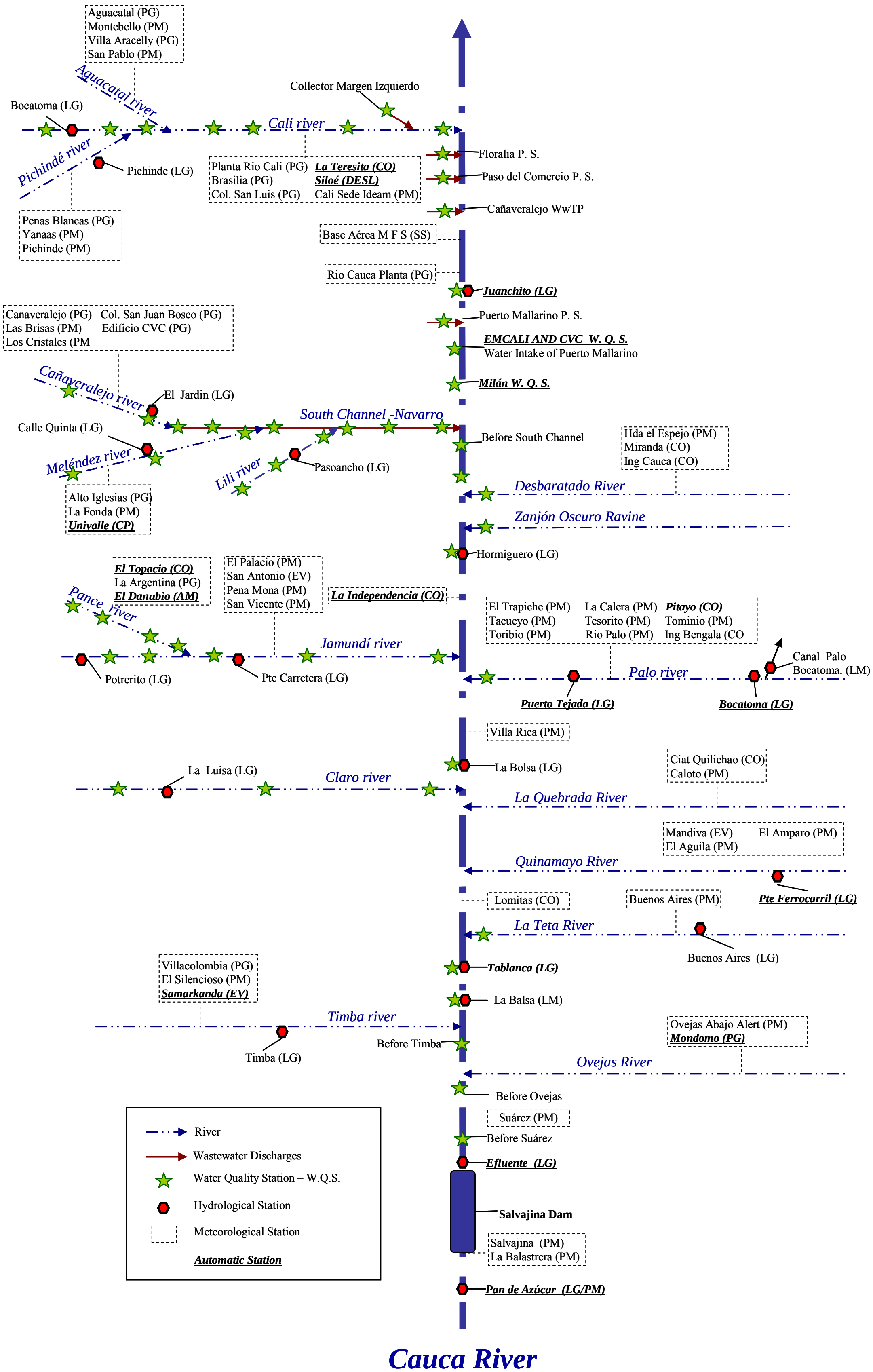


Figure 5.6 General chart with the location of the monitoring stations at the different components of the drainage system of the city of Cali

Table 5.5 Summarized inventory of hydrological and meteorological stations on the basin of the Cauca river and its tributaries. From Salvajina to Juanchito

River	MET				HYD		MET/HYD	TOTAL
	CC	EV	PM	PG	LG	LM	PM/LG	
Cauca	3		5		5	1	1	15
La Quebrada	1		1					2
Claro					1			1
Río Desbaratado	2		1					3
Río Jamundí		1	3		2			6
La Teta			2		1			3
Ovejas			2	1				3
Palo	2		7		2	1		12
Quinamayo		1	2		1			4
Timba		1	1	1	1			4
TOTAL	**8**	**3**	**23**	**2**	**13**	**2**	**1**	**53**

Notes: Limnimetric Station (LM); Limnigraph Station (LG); Pluviometric Station (PM): Pluviograph station (PG), Common Climatological Station (CC): Evaporimetric Station (EV)

Most of these stations are on the basin of the Cauca river. They consist of 8 meteorological and 7 hydrological stations (6 limnigraphic and 1 limnimetric). 4 automatic stations, i.e. Pan de Azúcar (Morales), Effluent (Suárez), Tablanca (Buenos Aires), and Juanchito (Candelaria) supply real-time information about the water levels in the Cauca river along the land stretch from Salvajina to Juanchito.

Only 2 of these automated stations on the Cauca river are part of IDEAM's alert network to control floods at Pan de Azúcar and Juanchito. Because the Pan de Azucar station is located before the Salvajina dam, it generates information to control floods and contamination that would not be useful because the Salvajina dam regulates the flow rates of water supplied to the area of influence of the inlet in the city of Cali.

The information about the levels at the Effluent station (Suarez) is controlled by EPSA. Therefore, access to this information is limited. CVC's Tablanca station has not yet been included in the alert network of the National Information System for which IDEAM is responsible.

Palo river (22%) is the second tributary river where the largest amount of hydroclimatological information is available. This is one of the tributaries with the largest impact on the quality of water in the Cauca River in terms of loads of contaminants and sediments during the rainy season. This river has 12 monitoring stations, 4 of which are automatic (2 limnigraphic and 2 pluviometric). Information obtained from these stations could be useful for strengthening the alert network to control contamination of water supply in the city of Cali.

The information generated by the hydrological stations is partly exchanged between IDEAM and CVC. The primary method of collecting information is the periodical visits conducted by team responsible for the stations.

Most information is transmitted to the control centers on a monthly basis (52%), but it is also transmitted in real time (15%) and on a daily basis (11%). The remaining information is gathered every two or three months depending on the schedule of the visits for operating and maintaining the monitoring network (see Figures 5.7 and 5.8)

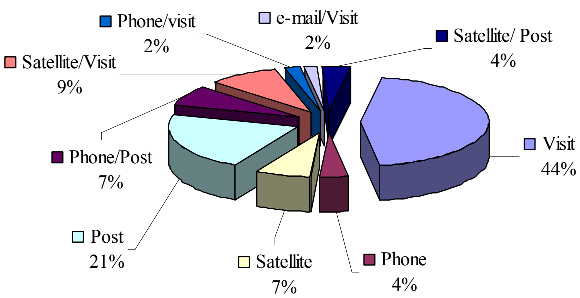


Figure 5.7 Means for transmitting data from the stations to the control center

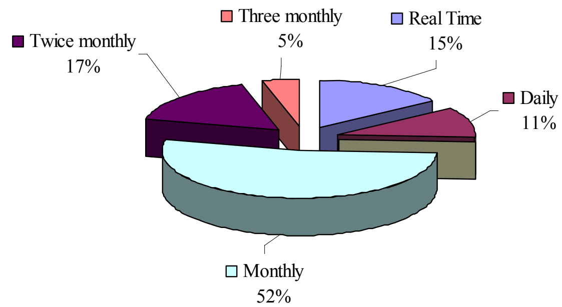


Figure 5.8 Data transmission frequency

As mentioned in the previous sections, there are 8 stations that monitor water quality on the river along the stretch from Salvajina to Juanchito. CVC is primarily responsible for this activity. In addition to this, it also monitors the outlet of 10 tributaries into the Cauca river. 8 of these tributaries are located within the jurisdiction of the CRC. Table 5.6 shows a list of quality stations on the Cauca river and its tributaries.

To this date most of the activities to monitor quality of water in the Cauca River have been carried out at specific locations, but they have failed to consider hourly fluctuations of the flow rate in the daytime and the night time because of regulation at the Salvajina dam. The exceptions to these monitoring activities have been 2 water quality monitoring campaigns on the river and its main tributaries. The campaigns were performed within the scope of the PMC project with the participation of institutions from this sector such as CVC, CRC, CARDER, CRQ, DAGMA, EMCALI, Valle del Cauca Government, Propal, Smurfit Cartón de Colombia, Lloreda Grasas, and Universidad del Valle.

The results of the campaigns conducted during the dry season (from August 19 to August 24, 2003) and rainy season (from February 21 to March 3, 2005) provided information about the fluctuations in the quality and quantity of water in the river on an hourly basis. Both studies recommended conducting a more detailed follow-up and control of future monitoring programs. Therefore, it could be said that information about the quality of water in the Cauca river is scant and does not reflect actual fluctuations over time.

Table 5.6 Water quality monitoring stations on the Cauca river and its tributaries
Land stretch from Salvajina - Juanchito

Basin/ River	Monitoring point	Monitoring Frequency	Parameters	Records Since
Cauca River	Before Suárez	Quarterly	Flow, pH, Temperature, Turbidity, Dissolved Oxygen, Total Coliforms and Faecal Coliforms, Conductivity, Solids, Total Phosphorus, Phosphate, Total Nitrogen , Ammonia Nitrogen, Nitrate and Nitrite, Colour, BOD y COD, Alkalinity, Hardness, Calcium and Magnesium, Chloride and Sulphates, Iron, Manganese, Sodium and Potassium, Cooper, Zinc, Cadmium, Chromium, Nickel and Lead	1990
	Before Ovejas			
	Before Timba			
	La Balsa			
	La Bolsa			
	Hormiguero			
	Before South Channel			
	Juanchito			
Tributaries - Final Discharge to Cauca River	Ovejas River	Quarterly		1996
	La Teta River			
	Quinamayó River			
	La Quebrada River			
	Palo River			
	Zanjón Oscuro River			
	Desbaratado River			
	Timba River			
	Jamundí River			
	Claro River			
Claro River	Before water intake of mines of Claro River	Half - yearly	pH, Temperature, Turbidity, Dissolved Oxygen, Total Coliforms and Faecal Coliforms, Conductivity, Solids, Total Phosphorus, Phosphate, Total Nitrogen , Ammonia Nitrogen, Nitrate and Nitrite, Colour, BOD y COD, Alkalinity, Hardness, Calcium y Magnesium, Chloride, Sulphates, Iron, Manganese, Sodium and Potassium	1997
	Bridge to via Suárez			
	Before Final discharge to Cauca River			
Jamundí River	Puente Las Brujas	Half - yearly		1996
	Before Jordán River			
	Later of Jordán River			
	Puente Vía Cali- Jamundí			
	Final Discharge to Cauca River			

This situation would probably improve if water quality was monitored on a continuous basis. To this end, the automatic quality monitoring stations have already been installed. CVC has installed 2 automatic stations to monitor quality of water in the Cauca river; at the inlet of Puerto Mallarino and Tablanca. Although CVC already had a water quality station at the inlet of Puerto Mallarino, EMCALI recently also installed a new automatic water quality station at the same location and another station located 4 kms upstream of the inlet along the stretch that extends from the Southern canal to Puerto Mallarino. The purpose of these new stations is to monitor and control quality of the affluent water to the drinking water treatment plant (see Figure 5.9). Table 5.7 shows some of the characteristics of the automatic stations that monitor water quality on the Cauca river.

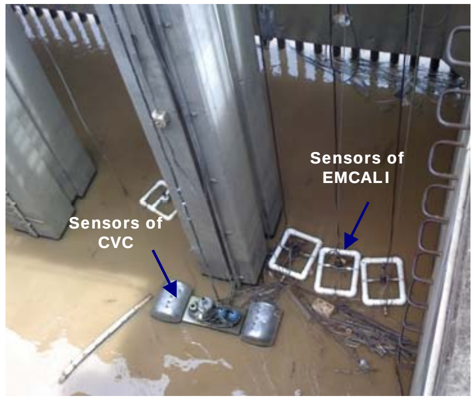


Figure 5.9 CVC's and EMCALI's automatic stations to monitor water quality

Table 5.7 Automated water quality monitoring stations on the Cauca river.

Automatic Station	Parameters	Institution in charge
Water Intake of Puerto Mallarino Plant	Dissolved Oxygen, temperature, turbidity, pH	EMCALI
Water Intake of Río Cauca River	OD, pH, Conductivity	CVC
Milán	Dissolved Oxygen	EMCALI
Tablanca	Dissolved Oxygen, temperature, turbidity, pH	CVC

This situation reflects that the activities being carried out to improve the conditions of the Cauca river are not performed in a coordinated manner, so there is duplication of efforts and deficient planning

6 FINAL CONSIDERATIONS

The implementation of a monitoring network that provides real-time information about the quantity of wastewater and rainwater in the city of Cali would contribute to resolving, to a large extent, the problems related with the drainage system and, in the long-term, to optimizing the provision of the sewerage service. These problems include localized floods, collectors of insufficient capacity, inadequate quantity and quality of information about domestic wastewater discharged into the Cauca river, lack of follow-up and control of industrial discharges, etc. It would also be part of the strategies focused on establishing the alert network of water quality on the Cauca river at the height of the Puerto Mallarino inlet.

The network needs to make best use of climatological and hydrological information from the stations available and the existing infrastructure, but particularly of the limnimetric and limnigraphic stations in the area of influence of the Cali, Meléndez, Lili and Aguacatal rivers, which are part of the rainwater drainage of the city. This activity involves coordination of the institutions responsible for running the stations, i.e. IDEAM and CVC together with DAGMA and EMCALI.

In addition to this, having knowledge of the quality of water in the drainage system would allow improving operation of the Cañaveralejo wastewater treatment plant, which has been seriously affected by the occurrence of unidentified peak load events that have an adverse impact on the efficiency of the treatment processes.

It is also necessary to optimize the system that measures the flow rate at the pumping stations that enter the C-WwTP.

In order to improve the quality of water in the Cauca river, it is essential to continue to work in the proposal and execution of strategies for the purpose of improving planning and use of this water source. Some of these strategies include achieving a holistic vision for managing water resources and facilitating synergism of activities performed by the environmental authorities, the industrial and productive sectors, the municipalities, and other institutions/agencies involved with the quality of water in the Cauca river and its tributaries.

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