CHAPTER 9 SUPPLEMENTAL INVESTIGATION ON WATER USE AND LOSS IN RIMAC RIVER BASIN

9.1 Introduction

(1) Purpose of Supplemental Investigation

The Study Team commenced the Supplemental Investigation on August 7, 2001 based on the implementation procedure of PHASE II described in item 2 of the Minutes of Meeting signed on March 1, 2000.

The purpose of the Supplemental Investigation is:

1) To obtain necessary data and information of the water use and water quality in the main stream of the Rímac River, and the main stream of the tributaries, the Santa Eulalia River and the San Mateo River.

2) To identify and to confirm problems in water use, water quality, and water demand.

3) To assess if the water losses in the main stream of the Rímac River in the dry season are larger than or equal to that estimated in the SEDAPAL's Water Supply Master Plan for Lima Metropolitan Area (December 1998).

4) To clarify the implementation of the feasibility study for Phase II.

The Scope of the Study for the Supplemental Investigation on Water Use and Loss in the Rímac River Basin is stipulated in the attachment of the Minutes of Meeting signed on August 27, 2001.

(2) Study Area

The Study area is the Rímac River basin, one of the most important rivers of Peru, where, the capital city, Lima occupies its coastal and middle stretch. It provides the basic needs of water resources to support its natural environment and the greatest socio-economic activity of the country, where more than 30 % of the national population, about 7.5 million in 2001, and more than 60 % of the industries are concentrated.

9.2 Existing Condition of the Rimac River Basin

9.2.1 Topography and Geology

The catchment area of the Rímac River is about 3,583 km^2, of which altitude varies from sea level to 4,850 m.a.s.l. The length of the main stream is 143 km and its average river gradient is 1/29.5 (0.0339). The main river divides upstream of Chosica into two tributaries, the Santa Eulalia River and the Rímac River. (The stretch higher than elevation 2,500 m.a.s.l. yields water resources.)

In general, the basin is covered by elastic sedimentary and volcanic formations of the age from Jurassic to Tertiary, intrusive rocks of the age from Cretaceous to Tertiary and also Quaternary deposits. Jurassic formations are exposed in the northern part of Lima and extend to NW-SE direction along the Pacific Coast. The formations consist predominantly of andesitic extrusives associated with chert, shale, and etc.

Various facies of intrusive rocks are found in the western area of the Western Cordillera. These intrusives consist of granite, granodiorite, and tonalite, etc. of Cretaceous and Tertiary ages and andesite of Cretaceous. Small intrusive bodies such as andesite, rhyodacite, and trachyandesite are found in the Tertiary area.

There are many metal mines in the investigated area. Principal mineralization has been associated with igneous activity in Miocene deformation stage during Andean geotectonic process. The minings excavate various types of minerals which consist of galena, spherlite, chalcopyrite, barite with pyrite, etc.

Quaternary deposits, divided into Pleistocene and Helocene, consist of terrace with various levels, glacial, recent river and talus deposits. The deposits forming the ground of Lima is largest among them in scale. Thick piles of sand and gravel with clay are found. Major part of the deposits are presumably Pleistocence in age and covered by fan deposits of the Rímac river.

The basin is situated in the arid or semi-arid climate area with less vegetation. Furthermore, the mountains in the basin (the Andes mountains) upheaved during the Tertiary are accompanied with various faults and fractures. As such, the basin is severely exposed to weathering, making the basin vulnerable to the various disasters.

River terraces formed at Pleistocene are found in several places along the Rímac and Santa Eulalia river. There is a distribution of two or three-layered terrace deposits having its height ranging from 10 to 50 m in the vicinity of Chosica. There is also terrace deposits in the upstream of Chosica. These deposits consist of boulder, gravel, sand, and clay having its thickness ranging from 30 to 50 m. Gravels and boulders that occupy a large part of the deposit have its size from a fist size to block more than 1 m. These are shaped roundly.

There are also old deposits which have a height of around 120 m above river bed in the upstream of Santa Eulalia river. These deposits presumed to be formed during glacial epoch are composed of various size of angular rocky materials. The similar type of deposits is also extensively distributed in many tributaries of the basin. This is the so-called “Older Huaycos” in Peru.

9.2.2 Meteorology and Hydrology

(1) Meteorology

1) General

The Rímac river basin is composed of the sub basins of the Santa Eulalia and San Mateo rivers. These two rivers merge into the Rímac river at the immediately upstream of Chosica city. The altitude of the Rímac river basin is from coast to 4,818 m.a.s.l. at Anticona in Ticlio. Oceanic climate system generates two distinct seasons, i.e. the wet season from November to April and the dry season from May to October. Less rainfall has been observed in the coastal area due to an effect of the Humboldt current, which provides cool air mass and it prevent an ascending air current.

2) Rainfall

River basins for supplying water source to Lima city consist of the river basins of the Rimac, Chillon, Lurin and most upstream area of the Mantaro. Location of the rainfall observation stations and average monthly rainfall, are shown in Figure 2.2.1 and Table 2.2.1 of Supporting report Volume IV. In the coastal area, the rainfall amount is very few throughout the year, i.e. less than 50 mm. Rainfall amount gradually increases corresponding to the altitude, e.g., about 250 mm at El. 2,000 m, 400 mm at El. 3,000 m and 600 to 900 mm at El. 4,000 m or higher.

Most of the rainfall observation stations in the Mantaro river basin are located at their altitude of 3,700 to 4,600 m. Average annual rainfall ranges between 550 mm to 900 mm. The largest annual average and maximum annual rainfall amounts were observed at Marcapomacocha (El. 4,600 m) about 1,308 mm and 2,209 mm during 27 years (1969 - 1995). In the recent three decades, the principal El Nino has occurred in 1972-73, 1982-83 and 1991-92 and 1997.

3) Meteorological Data

There are 12 climatological stations in and adjacent basins of the Rímac river basin.. as shown in Figure 2.2.3 of Supporting report Volume IV. Meteorological data observed in these stations are shown in Table 2.2.2 – 2.2.6 of Supporting report Volume IV.

(2) Hydrology

1) River System

(a) River System in and around the Rímac River Basin

There are two (2) major river basins adjacent to the Rímac river basin, namely the Chillón and Lurín river basins at the north and the south. In addition, the most upstream area in the Mantaro river basin supplies water to the Lima city. The upstream area of the Mantaro river basin lies on highly elevated mountainous area from 3,800 m to 5,000 m or higher. The catchment area of the river basins are as follows:

Catchment Areas of River Basins

River Basins	Catchment Area (km^2)	Remarks
Chillon river	2,237	
Rimac river	3,583	
Lurin river	1,642	
Mantaro basin	827.5	Marca I : 147.0 km^2 Marca II : 335.0 km^2 Marca III : 116.5 km^2 Carispacocha : 229.0 km^2

Source: Master Plan (SEDAPAL, 1998)

(b) River System in Rimac River Basin

The principal rivers in the Rimac river basin is the Rimac (San Mateo at upstream) and Santa Eulalia rivers. The Santa Eulalia river joins to the Rimac river at Chosica, 55 km from the estuary. The catchment areas of the Rimac and Santa Eulalia rivers at the confluence are 1,228 km^2 and 1,085 km^2, respectively. Longitudinal slope of the Rimac and Santa Eulalia rivers are 1:23 and 1:17 at the upstream of the confluence, and 1/65 at the lower reach after the confluence.

(c) River System in Mantaro River Basin

Upstream area of the Mantaro river basin contributes to supplying water to the Lima and surrounding area for the purposes of a potable water, hydropower generation, industrial, irrigation water supply, etc. Several lagoons located at the most upstream of the basin rink each other with small streams, and the tributaries originate from these lagoons merge into the Mantaro river.

(2) Run-off of River System

1) Hydrological Station

Location of the water level gauging stations in and around the Rímac river basin are presented in Figure 2.2.5 of Supporting report Volume IV.

2) Run-off of Rímac River Basin

Average annual discharge observed at Chosica station (SENAMHI) is estimated at approximately 25.8 m^3/sec, 814 MCM for a period of 31 years, 1965 to 1994 after the Marca I project and lagoon rehabilitation works upstream of the Santa Eulalia river have been completed in 1965. Major reservoirs and lagoons are listed in Table 2.2.7 of Supporting report Volume IV. Total effective storage volume of 125 MCM in the Rímac river basin contributes to constantly maintain river flow about 6.9 m^3/sec for the period of May to November except drought year.

3) Reservoirs and Lagoons in Mantaro River Basin

Water source development plans in the Mantaro river basin have been implemented since 1962 corresponding to an increase of the water demand in Lima and surrounding area including a hydropower generation. The main feature of these project from a view point of hydrological potential are as follows:

Description of Marca and Other Related Projects

Project Title	Reservoir and Lagoons	Diversion Capacity	Remarks
Marca I+III	Marcapomacocha : 80 MCM Antacoto : 120 MCM	7.0 m^3/sec	
Marca II	Huacracocha : 7.5 MCM Huascacocha : 9.3 MCM Huallacocha Alto : 0.74 MCM Huallacocha Bajo : 18.0 MCM Pomacocha : 70.0 MCM Total : 105.54 MCM	6.5 m^3/sec	
Huascacocha	52.5 MCM	2.5 m^3/sec	
Mantaro-Carispacocha	Carispacocha : 22.5 MCM Marcapomacocha : 100-140 MCM (*) Antacoto : 120 MCM	5.0 m^3/sec	

Notes: (*) Existing capacity is 14.8 MCM

9.2.3 Existing Water Use and Water Rights

(1) Irrigation Facility

The Rímac River Valley has a deficient irrigation facility, which is mostly primitive without control gates at the intakes and canals. The rapid reduction of the agricultural area is a main reason of these troubles, as well as the lack of cultivation and irrigation expansion plans and the inappropriate technical distribution, etc.

In the Rímac River Irrigation District, from Chosica to Callao, there are 18 intakes for irrigation and industry use, La Atarjea intake for potable water supply and diversion channel for the Huampaní Hydroelectric Power Station. The location of these facilities is shown is Figure 9.2.1.

The Chillón-Rímac-Lurín Irrigation District Technical Administration, the Rímac River Board of Users, and SEDAPAL were going to sign an agreement on the Rímac River water distribution in drought season (1999) for a better water use and management. Although it was not carried out, however the fifth clause of the agreement determined the flow rates for the different uses as follows:

Flow Rates for the Different Uses

Water Use	Flow Rates
(a) Population	80 %
(b) Agriculture (Carapongo, La Estrella, Nevería, Huachipa, Ate and Surco)	13 %
(c) Mining Industry (Cajamarquilla)	1 %
(d) Infiltration	6 %

In addition, the Rímac River minimum flow was established in 9.88 m^3/sec (1921-1997), considering a persistence of 90 %.

(2) Present Water Use Evaluation for Irrigation and Its Problems

There are several problems on the water use for irrigation, as follows: This situation does not allow the implementation of an appropriate control and measuring facility.

1) Seasonal Inconsistency in the Water Demand and the River Discharge
2) High Contamination
3) Deterioration of Intake Works and Irrigation Channels
4) Inappropriate Management of the Water Resources
5) Poor Irrigation Proficiencies
6) Poor activity of the Board of Users
7) Difficulty to collect water rates and fees from the farmers

(3) Water Rights

1) Jurisdiction and Management Authority

The Irrigation District is a geographical area upon which the Irrigation District Technical Administrator exercises authority. The Ministry of Agriculture will establish the area of each Irrigation District based on real aspects of the watershed and the needs for effective water management.

Watersheds with regulated irrigation and intensive multi-sectoral water use, like the Rímac River, are managed by the Rímac River Basin Autonomous Authority, which is responsible for formulating water resource development plans in its jurisdiction. As the main public user, SEDAPAL belongs to the Board of Directors.

The Rímac River Basin Self-Governed Authority is responsible for formulating master plans on water resource development, supervising watershed management and water-related actions, solving ultimately any appeals lodged against the directives issued by the Irrigation District Technical Administrator.

2) Board of Users

This organization represents all the water users of the Irrigation District. It is conformed by one or more representatives of each Irrigation Users Commission, one delegate of the Sanitation Service Agencies to which SEDAPAL belongs, two delegates named by the users of the Energy and Mining Sectors, respectively; and one delegate of other sectors. As the main user of the Rímac basin water resources for domestic and public purposes, SEDAPAL has preference and priority before the agricultural uses, according to the General Law of Waters.

3) Government Bodies

The Board of Users, the General Assembly, and the Board of Directors are government bodies; but the General Assembly is the most important one because all the water users constitute it.

4) SEDAPAL Administrative Proficiency

SEDAPAL, as a water user of the Rímac Irrigation District, is part of the Board of Users; and, consequently, has the monthly assignment of supplying water for public use, complying with the payment of rates.

The organization of the water use and management and its relation with SEDAPAL in the Rímac River basin are shown in Figure 9.2.2.

9.2.4 Water Quality and Environment

(1) General Description of Water Quality and Environment

It has been reported since 1960th that the water quality of the Rímac River is significantly contaminated from its origin in Ticlio to the river mouth in Callao due to toxic chemical substances (acids, pesticide, fertilizer, nitrate, sulfates, heavy metals, etc.), non degradable materials (plastic, rubber, metal, etc.) and microorganism (coliforms, viruses, general pathogen, etc.). Those are discharged from more than 107 entities (domestic, industrial, mining and agricultural-farming). The water quality of the tributary, the Santa Eulalia River is reported to be fairly good.

It was reported that biological resources, wild life, plant life, and land ecosystems were completely transformed since 1960th, in particular the ecosystems induced in the agricultural fields, the river forests, and the urban parks. Those transformed include high diversity of birds, rodents, insects and reptiles. The hydro-biological resources are also practically extinct. The river shrimp and an endemic fish, pejerrey were extinct since 1960th. However, many of natural springs in the valley between Chosica and La Atarjea still sustain very small and ornamental fish.

The legislation decree No. 613, Environmental and Natural Resources Code was enacted on September 8, 1990. The general water law, D.L. No. 17752 was enacted on July 24, 1969. Under the general water law and its norms, the environmental sanitation office of the Ministry of Health is the institution in charge of enforcing compliance to these established norms. The legislation decree No. 613, Environmental and Natural Resources Code was enacted on September 8, 1990.

(2) Water Quality Monitoring Method and Result

SEDAPAL has established its monitoring water quality program including establishment of sampling stations in order to evaluate and determine the water quality of the entire Rímac River basin. Physical and chemical analyses of water samples for the program started from 1993 in the SEDAPAL's laboratory for the following parameters:

Physiochemical pH, temperature, muddiness, specific conductivity, dissolved oxygen, total solids, dissolved oxygen, total solids, dissolved solids, suspended

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Source: *Law for Boards of Users and Irrigation Commissions*
Edited by the National Board of Users of the Irrigation District of Perú
March 2001

solids, cyanide, total carbon, inorganic carbon, organic carbon, trihalomethanes, iron, manganese, lead, cadmium, chrome, copper, zinc, aluminum, barium, arsenic.

Metals iron, manganese, lead, cadmium, chrome, copper, zinc, aluminum, barium, arsenic.

These parameters are mainly total metals and dissolved in water. All the metals in the list are considered toxic. These parameters are required to evaluate the level of contamination. Some parameters are also used to evaluate the environmental impact or the toxicity level of the water, whether for human health reasons, aquatic resources, agriculture or irrigation.

SEDAPAL's laboratory adopts the physical-chemical analysis, metal analysis, cyanide analysis, organic carbon analysis, trihalomethane analysis. The analytical method for respective parameters is shown in Table 2.4.1 of Supporting report Volume IV. The annual average results of the water quality analysis in the period 1993-1996 are summarized in Table 9.2.1. The conditions of 1999-2000 period was reported to be more ore less same. The location and condition of the sampling station is shown in Figure 9.2.3. These values are compared to the permissible limits for watercourses, Classes I of the general water law, D. L. No. 17752 and the level of the WHO guidelines. The condition of the water quality is summarized below.

Parameters	**Limits of General Water Law**	**WHO Guidelines**	**Quality Level**
Physical-chemical analysis			
pH	5 – 9	< 8	Within the permissible limit for Classes I & III
Suspended solids (turbidity)	0 mg/l	5	Fairly high value (34.5mg/l) at La Atarjea, increasing from Graton tunnel to Tamboreque intake, Lower in Huanpani-La Atarjea stretch than the mountain reach (21-61mg/l)
Dissolved Oxygen (DO)	> 3.0 mg/l		Within the permissible limits for all the classes
Metal Analysis			
Aluminum, Al	-	0.2 mg/l	High concentrations identified in the complex in Tamboreque (0.5-6.0 mg/l) and the Aruri river (0.9-1.5 mg/l), La Atarjea intake (0.6-2.1 mg/l), the rest below 2.0 mg/l)
Arsenic, As	0.1 mg/l	0.01 mg/l	Identified above the permissible limit for Class I and III (0.2 mg/l), The complex in Tamboreque (0.04-2.1 mg/l), Ruri river (0.31-0.63), La Atarjea intake (0.02-0.07), the rest below the permissible limit
Barium, Ba	0.1 mg/l	0.7 mg/l	Identified above the permissible limit for Class I at all stations, La Atarjea intake (max.0.14 mg/l)
Cadmium, Cd	0.01 mg/l	0.003 mg/l	Identified above the permissible limit for Class I at several stations (0.01-0.03 mg/l), La Atarjea intake (0.004-005 mg/l)
Zinc	5.0 mg/l	3.0 mg/l	Mostly below permissible limit for human consumption for Class I (5.0 mg/l) and Class III (25.0 mg/l), Maximum identified at Tamboreque (6.3 mg/l) and Arui river (5.1 mg/l)
Copper, C	1.0 mg/l	2.0 mg/l	Below permissible limit for Class I (1.0 mg/l) at all stations, The complex in Tamboreque (1.1-0.29 mg/l), La Atarjea intake (0.006-0.09 mg/l)
Chrome, Cr	0.05 mg/l	0.05 mg/l	Below permissible limit for Class I (0.05 mg/l) at all stations, The complex in Tamboreque (0.0007-0.01 mg/l), La Atarjea intake (max. 0.013 mg/l)
Iron, Fe	1.5 mg/l	0.3 mg/l	Identified above the permissible limit for Class I at all stations, La Atarjea intake (2.7-5.3 mg/l), Santa Eulalia river (0.58-1.55 mg/l), Tamboreque II bridge (max 9.36 mg/)
Manganese	0.1 mg/l	0.5 mg/l	Above permissible limit for Class I at most stations except Santa Eulalia river (0.04-0.12 mg/l), La Atarjea intake (max. 0.13-0.22 mg/l)
Lead, Pb	0.05 mg/l	0.01 mg/l	Above permissible limit for Class I at all stations, lowest in Santa Eulalia river, La Atarjea intake (max. 0.17-0.26 mg/l)
Cyanide	0.2 mg/l	0.07 mg/l	Below permissible limit for Class I at all stations, The complex in Tamboreque (0.005-0.01 mg/l), La Atarjea intake (max. 0.0011 mg/l)
Trihalomethane analysis	-	-	1.88-13.93μg/l (from other data 1993-1996)

Concentration of most of the toxic substances are identified significantly higher than the permissible maximum limits, in particular lead and arsenic at Station No. 6 downstream of the Tamboreque mine complex.

Domestic wastewater contains fecal liquid and solids. Bacteriologic contamination is caused mainly by this source. This problem was confirmed through an invertebrate macro study by FAO (1993). High concentration of fecal coliforms were reported downstream of Chosica all the year, in particular in the area between Ricardo Palma and Chaclacayo (30,00-160,000 NMP/100ml in 1993-2000). It varied from 1,000 to 240,000 NMP/100ml at the La Atarjea Intake in 1993-2000. Main sources of organic contamination result from the industries located along the river, mainly between Ricardo Plama and Ñaña with small contribution from agricultural and domestic sources (CEPIS 1992). BOD was recorded in a range 1.2-7.3 mg/l in 1993-2000.

Assessment of these values is presented in Section 9.3.3

9.2.5 Hydrogeology and Groundwater

The aquifer of Lima is made of complex fluvial-alluvial formations, intercrossed with bedding levels and its thickness varies from 100 m in Vitarte (Huachipa Bridge) to 400-600 m in the coastal area, according to geophysical studies. There are isolated outcrops in the valley like hills arising at several points of the fluvial-alluvial plain and the plain continues to the Western Andean Mountain foothills, among which the Rímac and Chillón Rivers run, crossing the valley.

It has been possible to check lithological profiles and geophysical conditions of the upper part of the alluvial plain of the lower reach of the Rímac river basin. The plain is composed of granular sediments, and these tend to accumulate a greater quantity of fine sediments in deeper portion, becoming less usable as an aquifer. In the valley, the rock foundation is at depths varying from 100 m in Vitarte to 400-600 m toward the Coastal area.

The aquifer of the Rímac River Valley is recharged basically by ground water flows of the upper part of the valley (7.20 m^3/sec); filtration flows from irrigation channels and leaks of the sewerage network in the urban area (1.60 m^3/sec); the interchange between Chillón River, Rímac River and the aquifer (3.90 m^3/sec); and from the interchange between the aquifer and the sea (seawater inflow or fresh water outflow) (1.30 m^3/sec). The Amsa-Antea Association made these calculations in 1998.

The valley ground water has suffered an unbalance in the last 30 years due to the overexploitation of ground water through tubular wells. This unbalance, interpreted as permanent decreases in ground water, has caused a decline of ground water levels at a rate of 1.5 m/year, and there are many borderlines of aquifer with decreases of up to 4.0 m per year. These decreases have caused the inflow of seawater into the aquifer, contaminating it. The damaged areas are the districts located in the coastal zone.

In 1997, the aquifer exploited 12 m^3/sec using 1,100 tubular wells (from which 400 were for population use, with discharges of 8.3 m^3/sec, and 700 were for the industrial use with discharges of 2.45 m^3/sec), and 50 wells for private agricultural use with discharges of 1 m^3/sec.

To date, the ground water exploitation at the valley is of 12 m^3/sec (6 m^3/sec by SEDAPAL and 6 m^3/sec by private sector), including the aquifers of Rímac and Chillón rivers. In order to maintain the balance of inflow and outflow water in the aquifer of Lima, ground water exploitation should not exceed 8.0 m^3/sec, expressed in a constant discharge or its equivalent to 240 MCM (Amsa-Antea, 1999), in the other hand SEDAPAL as conservationist policy is limiting ground water exploitation to 5 m^3/sec.

The evolution of values for electric conductivity that measures the global concentration of dissolved salts in water has shown variations. The electric conductivity data for 1971, obtained from the hydrogeological map of Lima was between 0.6 and 3.0 mmhos/cm at +25°C, while the conductivity data recorded for 1994 are between 0.4 and 6.0 mmhos/cm at + 25 °C.

This increase in conductivity denotes the chemical damage that the Rímac River Valley aquifer suffers, due to an overexploitation of ground water, without considering the ground water salinity due to seawater inflow. The valley waters are classified chemically in bicarbonate-calcium waters and sulfate-calcium waters.

The induced recharge pilot project operates along 6 km of the middle Rímac river valley, upstream from La Atarjea treatment plant, by drilling 30 wells located near the Rímac riverbanks: 18 on the right riverbank and 12 on the left riverbank, with a production capacity of 1.5 m^3/sec. Based on the results of the induced recharge pilot project, consideration is being given to carry on and expand the project until reaching 22 km, to the town of Chaclacayo. From the 400 m^3/sec surface water that currently discharge to the sea during flood seasons, it is expected to divert 5 m^3/sec surface water.

9.3 Assessment of Water Quantity and Quality

9.3.1 Discharge

The SENAMHI, EDEGEL and SEDAPAL are responsible for the data collection and processing in most of the stations. The discharge data have been practicably analyzed in monthly and annual basis.

The annual run-off in the Rímac river basin (1965-1994) is estimated at about 21.3 m^3/sec (672 MCM) in average referring to the discharge balance observed at the Chosica station (EDEGEL, 25.8 m^3/sec, 814 MCM) and at the Milloc station (4.5 m^3/sec, 142 MCM) which has been diverted from the Mantaro river basin. Duration curve of the Rímac river observed at the Chosica station is shown in Figure 9.3.1. The discharge of 50 % and 90 % reliability, which include diversion flow from the Mantaro river basin and also regulated flow from the Yuracmayo reservoir, are 22.1 m^3/sec and 14.7 m^3/sec, respectively.

The historical discharge records well indicate the water resources development in both river basins for four decades. However the hydropower plants have depleted and varied the stream flows so as to meet daily and seasonal power demand. Furthermore the reservoirs as well as natural and artificial lagoons regulate the stream flow during the dry season. Consequently complex operation of reservoirs and power plants does not allow accurate run-off calculation.

Run-off coefficient is an important indicator to estimate actual run-off amount. Run-off coefficient of 0.56 was observed at the Yauli river basin (Pomacocha) of Marca II project in the Mantaro river basin. While run-off coefficient in the Rímac river basin is roughly estimated at 42 % based on the mean annual run-off and rainfall data. It is assumed that higher run-off coefficient in the Mantaro river basin is due to the low permeability of the surface layer and less vegetation cover.

Other than the monthly discharge records, hourly discharge data observed at the Chosica station (SENAMHI) and La Atarjea intake (SEDAPAL) have been collected to estimate a stream flow loss in lower reach of the Rímac river basin in 30 km long, where a wide and deep river deposit causes infiltration loss. Furthermore monthly discharge data at Sheque and Tamboraque stations under the EDEGEL operation have been collected for a loss calculation in the middle and upper reach. Other discharge data observed at the hydropower stations located upstream the Chosica station are unlikely to be used for estimating loss because their flow measurements are limited to the hydropower generation, and discharge is controlled by regulating ponds in response to the power demand from time to time.

9.3.2 Surface Water Quantity and Loss

(1) Discharge Measurement

1) Finding at Discharge Measurement

It is notified that the discharge records used for several study reports have notable discrepancy in quantity, in particular the loss calculation of the river flow of the 1998 SEDAPAL Master Plan, this loss was assumed to be 5 % in the dry season mean discharge which amounts 0.67 m^3/sec. In this regard, a discharge measurement has been conducted to examine the physical water loss in the river channel, confirming also accuracy of the discharge records measured at several gauging stations.

Field investigation and discharge data analysis have identified the following conditions:

(a) Five (5) hydropower stations control stream flow by the regulating ponds from time to time to meet power demand in Lima and surroundings. Variation of the power plant flow interrupts loss estimation.

(b) As described in (a) above, river discharge fluctuates in a short period due to the hydropower plant operation. SEDAPAL therefore estimates the intake discharge at the La Atarjea intake site subtracting about 6.0 m^3/sec from the total discharge observed at the upstream gauging stations of the Huinco and the Matucana hydropower stations in the Santa Eulalia and the Rímac rivers, respectively. This 6.0 m^3/sec is equivalent to the discharge loss.

(c) There exist several diversion weirs along the Rímac river for the use of the industrial and irrigation purposes. The loss mentioned above includes those water use.

(d) The channel training works of the Rímac river, widening the channel width from about 20 m to 180 - 200 m for improving groundwater recharge through the permeable river deposits in the stretch of 6.0 km long immediately upstream of the La Atarjea intake site.

(e) The discharge records at the Chosica SENAMHI station are assessed as most reliable for the run-off analysis because there is no bypass or overflow at the station.

(f) Diversion discharge through the existing irrigation intakes varies from time to time depending on the water level of the Rímac river.

After review of the foregoing findings, several sites have been selected for the Study Team's direct discharge measurement as indicated in Figure 9.3.2. Measurement at the sections 1B to 5B aims at infiltration rate measurement in the 6.0 km stretch where groundwater recharge project is under operation at present. Sections 1A to 4A aim at counterchecking accuracy of the existing discharge records of SENAMHI and EDEGEL.

(2) Amount of Water Loss

1) Loss in the Lower Reach of the Rímac river

With regard to the water loss in the main stream of the Rímac river basin, the findings are as follows:

(a) Majority of the water loss in the main stream of the Rímac river basin occurs in the lower reach of the Rímac river, in particular in the stretch between Chosica and La Atarjea.

(b) The total mean water loss in the 30 km stretch between Chosica and La Atarjea will be in a range of 6.0 - 10.0 m^3/sec, at least 6.0 m^3/sec during the dry season. This is due to the fact that the minimum discharge balance between Chosica and La Atarjea intake is about 6.0 m^3/sec as shown in Figure 9.3.3. The loss is composed of the riparian water use (irrigation and industry) and infiltration loss including evaporation. The component of irrigation and industrial water use seems to be predominant. No clear infiltration area or spot has been identified. It is assumed that the irrigation and industrial water use and the infiltration loss is 4.0 m^3/sec (70 %) and 2.0 m^3/sec (30 %).

(c) The total discharge of 17 irrigation intakes located upstream of the La Atarjea intake, 6.8 m^3/sec measured by the Study Team seems to be the maximum amount. (refer to Figure 9.2.1) The daily average withdrawal for irrigation and industrial use is assumed to be 4.0 m^3/sec with consideration of the existing irrigation area of about 4,750 ha.

(d) It is assumed that infiltration loss in the 7 km stretch between Huachipa bridge (3B, 5B) and the La Atarjea intake (1B) including the 6 km river training works is about 2.0 m^3/sec.

Flow Balance of the Rímac is shown in Table 9.3.1. In Table 9.3.1, infiltration discharge of 2.0 m^3/sec is quantitatively reasonable comparing with the total water loss of 3.5 - 3.6 m^3/sec between Chosica and La Atarjea intake during the drought years, 1991 - 1992. Discharge records at Sheque and Tamboraque intakes of EDEGEL have been also obtained to calculate stream flow losses in the upper reach of the Rímac river with comparison to that at the Chosica station. It is difficult to estimate the water losses accurately because discharge and subsurface flow from the residual catchment area of 1,180 km^2 is included in the flow record at Chosica.

2) Accuracy of Discharge Records and Measurement

The error range of the discharge records of SENAMHI, EDEGEL and SEDAPAL seems 10 - 20 %. The flow measurement done directly by the Study Team seems to include an error of 10 - 20 %. The details are as follows:

Discharge Measurement Errors

No.	Location	Measurement Errors (Comparison with JICA Study Team)
1A	Chosica (SENAMHI)	Measurement by SENAMHI is about 6 % larger. (*1)
2A, 3A	Sheque (EDEGEL)	Measurements by EDEGEL and JICA Study Team are almost same.
4A	Tamboraque (EDEGEL)	Measurement by EDEGEL is about 13 % smaller. (*2)
1B-5B	River discharge between Chosica and La Atarjea intake	Measurement error in several observations ranges 10 - 20 %.

(*1) Error in measurement. Measurement error of 6 % is not applicable to long period discharge data by SENAMHI because discharge measurement by the JICA Study Team was carried out in quite short period.

(*2) EDEGEL converts water level in the tunnel section into discharge. Water level is measured by sensor, and calibration of sensor is necessary. Measurement error of 13 % is not applicable to long period data by EDEGEL for the same reason as (*1) above.

In addition, Figure 3.2.3 of Supporting report Volume IV shows discharge data observed at Chosica by SENAMHI and EDEGEL (Huampaní intake for hydropower plant), both observation stations are closely located. Discharge records at respective two stations are almost same during low water periods (the dry season), while discharge record during high water periods (the wet season) are inaccurate in several years because of its higher run-off coefficient and unstable flow condition due to high velocity. These are found at both stations especially January to March. Considering this fact, water balance calculation by monthly basis or shorter period is recommended to minimize an effect of discharge measurement error during high water periods.

9.3.3 Water Quality

(1) Preliminary Assessment of Water Quality

The water quality of the Rímac River has been contaminated significantly since 1960^{th} due to toxic chemical substances, non-degradable materials and microorganism. Though some improvement has been reported, the condition is basically kept unchanged at present in spite of greatest effort of the agencies concerned, such as environmental sanitation office of the Ministry of Health, SEDAPAL, etc.

Present raw water quality standard, the permissible limits for watercourses, Classes I to IV of the general water law, D. L. No. 17752 (refer to Table 2.4.3 of Supporting Report Volume IV). Class I and II basically stands on the same concept of the WHO Guideline for drinking water, bacteriological quality of drinking-water, chemicals of health significance in drinking-water (a. inorganic constituents, b. organic constituents, c. pesticides, d. disinfectants and disinfectant by-product), chemical not of health significant at concentrations normally found in drinking-water, radioactive constituents of drinking-water, etc. The environmental quality standard for general watercourses in Japan and the environmental quality standard for river water concerning conservation of the living environment in Japan are shown in Table 2.4.4 and Table 2.4.5 of Supporting Report Volume IV respectively. Combination of Table 2.4.4 and Table 2.4.5 corresponds to Class I and II of Peru.

Presently high concentration of fecal coliforms and heavy metals (chromium, lead, arsenic etc.) are subject of public dispute in the Rímac River basin. The water quality test results listed in Section 9.2.4 is assessed with comparison of Japanese standard as follows:

1) Atarjea, is accepta If any of lead, cadmium, chromium, arsenal and cyanide is identified in the raw water of a proposed water source, it is not accepted as a water source for drinking in Japan.
2) Under the Japanese environmental water quality standard for river concerning the conservation of the living environment, the raw water which contains the suspended solid of more than 30 or 60 mg/l is not suitable for raw water for domestic water supply.
3) Any king of toxic substances in raw water can be technically and theoretically removed by using iron-exchange method. However, the iron-exchange method is developed for producing highly purified industrial water, such as IC industry, and thus it is not economically feasible for drinking water. On the other hand, the raw water containing toxic heavy metals or chemicals is involved in high risk that such polluted water might be supplied to household unexpectedly when the water purification facilities are malfunctioning.
4) It is recommended to conduct a water quality investigation that aims to trace variation of the content of toxic materials in the process of water treatment including sedimentation process (SS).
5) Mercury is recommended to be included in the monitoring items of water quality.
6) Trivalent chromium in raw water can be removed by the conventional coagulation-sedimentation process. On the other hand, the former process can not

remove hexavalent chromium, but it can be technically removed by a special method with a reduction process. However it requires a complex pH control process (raising/ lowering) during the reduction process. Therefore pH control is not recommendable from the standpoint of safety control.

7) Removal of cyanide also can be technically possible by a special method with oxidation process including pH control, but it is also dangerous and not recommendable.
8) BOD (Biological Oxygen Demand), generally less than 5 mg/l upstream of La Atarjea, is acceptable range in spite of industrial and domestic sewerage.

Heavy chlorination has been applied for disinfection of water supply with extra cost of chlorine. Heavy metals, that might cause degradation of public health in long term, will not be able to be eliminated by normal water treatment plant with reasonable cost. Excessive dosage of chlorination yields by-product such as trihalomethane, and it might also cause degradation of public health.

(2) Study for Alternative Measures

The water loss identified in Section 9.3.2 will not be resolved by construction of new water source facilities only. For maintaining the balance of demand and supply of potable water to Lima, it would be required to adopt either or adequate combination of structural and non-structural measures, such as reducing the water loss, managing the demand and developing new water sources.

In view of the identified water loss and quality issues the Study Team suggests SEDAPAL to study the following measures as a hint to resolve present problems:

a. Monitoring Water Quality and Aquatic Ecology
- To make inventory of aquatic species and fish population
- To assess the fish fauna and fish population dynamics
- To introduce artificial reproduction of endemic fish with ecological and/ or economic interest
- To assess the aquatic environment through the use of bio indicators: integrated monitoring approach using benthic organisms, zooplakton toxicity tests, and fish liver tissues to evaluate pollution effects, and correlate with chemical and metal analysis at specified areas,
- To conduct water quality test for selected pesticide and toxic chemicals
- To conduct water quality test for mercury (not included in SEDAPAL’s list)

b. Institutional and Legal Arrangement
- Institutional and legal arrangement to regulate point source control of industrial waste water discharge in particular mining industry
- Enhancement of cleaner production among the industries: it aims to enhance technology to reduce the content of toxic chemical materials contained in sewage and solid waste in the production process, and to reduce the use of the toxic chemical materials in quantity including recycle and reuse technology
- Enactment of polluter’s pay principle

c. Alternative Structural Measures
- Installation of specific treatment plants for toxic chemicals and metals (costly)

- Relocation of the existing SEDAPAL intake facilities from La Atarjea to appropriate upstream site including bypass pipeline

(3) Integrated Management of Surface Water and Groundwater

Comprehensive and quantitative river basin management under the concept of hydrological cycle management will be required for the Rímac River basin in the future. The management will aim to establish sustainable development and environment of the basin by improving:

1) the national or regional institutional framework for water resources development and management;

2) the organizational and financial framework for basin management;

3) the regional water quality management regulatory institutions and implementation;

4) irrigation management policy, institutions and regulations;

An example is shown below.

Legal and Institutional Arrangement: Legal and institutional framework that enables the anticipated management framework,

Monitoring System: Integrated monitoring and management of surface water and ground water, and water quantity and quality, and

Public Involvement: Establishment of autonomous (public-private) organization to monitor and improve the river environment by participatory approach.

9.3.4 Water Loss Due to Hydrogeological Condition

(1) Infiltration Calculated by SEDAPAL

Based on the information on maximum and minimum water levels recorded in 19 observation wells (piezometers) and 30 extraction-recharge wells of the pilot project, SEDAPAL obtained the answer for the water level recovering produced between October 1998 and March 1999, due to the induced recharge effect.

The obtained data determined that the water volume filtered into the pilot project service area, between Huachipa Bridge and La Atarjea, was 4.12 MCM during that period, equivalent to 0.317 m^3/sec during the 5 observation months or 0.130 m^3/sec for one year.

(2) Theoretical Infiltration Calculated by Morits Equation

To quantify the infiltration theoretically, considering the constant permeability conditions in the covered area, the Moritz equation has been used. (see Annex III)

As a result of this equation, an average infiltration of 1.49 m^3/sec for the 6-km area between Huachipa Bridge and La Atarjea is obtained. The average velocity (1.11

m/sec) and the average flow (26.93 m^3/sec) are obtained from the measurements carried out by the JICA Study Team at the 1B point, 200 m upstream of La Atarjea intake.

(3) Other Infiltration Values Obtained from Investigation

According to investigations developed by several consultants in the Rímac river Valley aquifer, the infiltration values do not show the same magnitude rate.

(4) Direct Measurement by JICA

The infiltration between 1B and 3B sites was approximately estimated to be 2.0 m^3/sec by the JICA Study Team based on the water flow measurement by use of current meters during August 27 to September 19, 2001.

(5) Binnie & Partners (1980)

A balance performed by B & P considers that the infiltrations between Chosica and Callao are 4.72 m^3/sec. The infiltrations downstream La Atarjea are 1/3 of the total infiltration between Chosica and Callao; and La Atarjea flows have been calculated from the Chosica flow minus the 2/3 of infiltration losses produced between Chosica and Callao.

The infiltrations considered in the different studies on the Rímac River are shown in the following table:

Infiltration Rates in Different Studies

	Date	Distances (km aprox.).	Infiltration (m^3/sec)	Infiltration (m^3/s/km)	Scope
SEDAPAL	1999	6	0.13	0.02	Huachipa -La Atarjea
Morits Equation	2001	6	1.49	0.25	Huachipa- La Atarjea
JICA	1981	6	2.0	0.33	Vitarte – La Atarjea
B&P	1980	22	3.15	0.14	Chosica –La Atarjea

(6) Conclusions:

1) According to the obtained information, it was not possible to get a definitive conclusion about the infiltration produced between Huachipa Bridge and La Atarjea. In addition, the flow measurements carried out by the JICA Study Team between August and September, 2001, in the above-mentioned area, do not show the existence of significant point infiltrations in the area.

2) The discrepancies between SEDAPAL and the mentioned consultants require a future investigation.

9.4 Review of 1998 Water Supply Master Plan

9.4.1 Water Demand

(1) Domestic and Non-Domestic Water Demand

1) Projection of Future Population of Metropolitan Lima

Metropolitan Lima is constituted by 43 districts of Lima Province and 6 districts of Callao Province. Figure 4.1.1 of Supporting report Volume IV shows all districts as well as SEDAPAL water supply areas. Total population in Metropolitan Lima as 1993 census was 6,434,323 which is 28.4% of the total population of Perú. Table 4.1.1 of Supporting report Volume IV shows the future population of Metropolitan Lima as estimated by SEDAPAL M/P, BLASA and INEI. For the planning horizon of 2030 such population projected ranges between 11.5 to 11.75 millions. A summary is given below

Metropolitan Lima Population

	1993	1998	2000	2005	2010	2020	2030
MASTER PLAN	6,434,323	7,130,008	7,505,802	8,233,031	8,934,224	10,266,351	11,751,197
Annual Growth Rate (%)		2.07	2.60	1.87	1.65	1.40	1.36
BLASA			7,400,352	8,083,627	8,768,901	10,133,451	11,500,000
Annual Growth Rate (%)				1.78	1.64	1.46	1.27
INEI			7,500,542	8,187,398	8,881,228	10,267,751	11,713,832
Annual Growth Rate (%)				1.77	1.64	1.46	1.33

2) Water Demand

Domestic and non-domestic water demand for Lima Metropolitan Area which includes 49 districts has been calculated by four (4) methods, they are:

* SEDAPAL Master Plan (1998)
* BLASA (Revised water demand, 2001)
* BLASA/Master Plan (It is BLASA approach applying to it population given by SEDAPAL Master Plan)
* BLASA/INEI (It is BLASA approach applying to it population forecasted by National Institute of Statistics)

BLASA in April 2001 under contract with SEDAPAL revised water demand calculated by SEDAPAL Master Plan in 1998 because unbilled potable water(*) instead to decrease was increasing from 35% in 1997 to 44% in year 2000 notwithstanding that unit water consumption for same period decreased from 319

(*) Unbilled potable water (UPW) means the sum of physical and no physical water loss plus no identified water loss.

l/p/d to 290 l/p/d, thus basically targeted water demand forecasted by SEDAPAL Master Plan did not accomplish.

Main differences between Master Plan and BLASA are as follows:

* BLASA forecasted population is less than that one of SEDAPAL Master Plan
* BLASA present metered water consumption is larger than that one of SEDAPAL Master Plan
* BLASA considered some little unit water consumption for those non-connected population and SEDAPAL Master Plan did not consider any
* BLASA coverage is a little less than that of SEDAPAL Master Plan
* Water supply efficiency (1-loss ratio) were settled as follows:

Water Supply Efficiency

Year	SEDAPAL Master Plan	BLASA
2000	65 %	70 %
2005	70 %	75 %
2010 - 2030	75 %	75 %

For the four (4) methods above mentioned total water demand was calculated as shown in Table 9.4.1 as well as in Figure 9.4.1. For year 2000, 2005, 2010, 2020 and 2030 total water demand is shown as follows.

Methods	2000	2005	2010	2020	2030
Water Demand Master Plan (m^3/sec)	27.80	29.67	30.64	35.54	40.68
Water Demand BLASA (m^3/sec)	32.09	26.34	29.13	35.17	40.17
Water Demand BLASA/PM (m^3/sec)	32.46	26.72	29.56	35.54	40.87
Water Demand BLASA/INEI (m^3/sec)	32.45	26.61	29.42	35.54	40.77

For year 2030 differences among each method are only 2% and this difference is due to the population natural increment.

For the purpose of this supplementary study and in order to carry out water balance BLASA approach was selected.

(2) Water for Agricultural Uses

There sums to be difference between SEDAPAL'S report and actual amount of the riparian irrigation water use. In order to capture a potential range of the irrigation water use, the present irrigation water demand is estimated based on the prevailing irrigation activity and land area. Among four possible cases the study team evaluates the alternative 2A being the most realistic case that represent the actual agricultural activities in the area, because this area shows the greatest agricultural development of the Rímac river valley. The total irrigation demand would be in an order of 2 m^3/s (63 MCM/year).

Present Irrigation Water Demand

Alternative	Area (has)	Irrigation Efficiency by		Irrigation Efficiency (%)	Irrigation Water Loss (%)	Total Demand (MCM)	Scope
		Conveyance (%)	Distribution (%)				
1A	5,683	75	67	50	50	74.47	All the Irrigation District (San Mateo-Callao)
1B	5,683	70	60	42	58	89.42	All the Rímac Irrigation District (San Mateo-Callao)
2A	4,751	75	67	50	50	62.42	From Ricardo Palma to Callao
2B	4,751	70	60	42	58	74.42	From Ricardo Palma to Callao

(Refer to the monthly irrigation water demand in Table 4.1.3 of Supporting Report IV.)

9.4.2 Progress of Water Saving Measures

(1) Unbilled Water and Water Losses

In accordance with SEDAPAL yearbook 2000, water consumption per capita (Produced water/Served inhabitant) has decreased during the period 1997-2000 from 319.4 l/day to 288.9 l/day.

As of April 2001 unbilled water is 43% of which breaking down is 30% for water supply system losses and 13% for unrecorded losses (Refer to Table 4.2.1 of Supporting report Volume IV). System losses are taken into account for the purpose of calculating water production requirements and the balance would be the efficiency of the whole system for the intake, production and distribution of potable water. It can be said that the efficiency of the system managed by SEDAPAL is about 70%, which is quite close to values being handled in the large capital cities of South America.

(2) Micrometering

The house connections and number of installed meters has evolved favorably in the period 1997-2000, as shown below:

Year	1997	1998	1999	2000
Installed connections	839,337	871,723	940,325	971,130
Metered connections	308,544	352,485	488,011	631,263

In reviewing these figures it is observed that as of year 2000, despite a significant effort by SEDAPAL, there still is 35% of installed house connections without meter.

(3) Current Network and Rehabilitation of Potable Water Network

The evolution of the potable water network as well as its rehabilitation are shown below:

Year	1997	1998	1999	2000	2001
Potable water network (km)	8,158	8,464	8,652	8,751	
Cumulative rehabilitated Network (km)	156.13	198.99	337.67	435.93	440.29

(4) Saved Water due to Micrometering and Network Rehabilitation

According to data furnished by SEDAPAL's Micrometering and Records Team, water savings due to the combined effects of the increase in micrometering, network rehabilitation and leakage control, amounted to an average of 5.6 m^3/sec as of August 2001.

This potable water savings has been reflected in an improvement of service to the supplied population, i.e. bigger amount of water, higher pressures and better service continuity; however, it has not been reflected in achieving the target service coverage due to the lack of new distribution networks that enter in operation as the population increases.

9.4.3 Review of SEDAPAL's Expansion Plan

SEDAPAL Master Plan had considered following project be under operation in order to supply raw water during dry season in average as follows:

Marca III (Surface water) in year 1999: Q= 3.0m^3/sec

Chillón Project (surface and ground water) in year 2001: Q= 0.71 m^3/sec

Marca II (Surface water) in year 2003: Q= 6.5 m^3/sec

Huascacocha (Surface water) in year 2015: 2.5 m^3/sec

Cañete or Mantaro (Surface water) in year 2020: 5.0 m^3/sec (or 2.5 m^3/sec each in years 2021 and 2025)

SEDAPAL's Master Plan took into account 5% (0.67 m^3/sec) of the average dry season discharge as infiltration in the Rímac river upstream of La Atarjea water intake.

In case counting the Rímac water loss (Irrigation water intake, infiltration and others) be 6.0 m^3/sec, then situation is completely different from that forecasted by SEDAPAL Master Plan because total water sources available (surface and ground water) has to be reduced in the same amount of loss.

Based on what has been stated above Figure 9.4.2 was prepared in order to show how loss in 6 m^3/sec affects the SEDAPAL expansion plan but still keeping that Marca II has to be under operation in year 2003 as it was planed by Master Plan. Main conclusions are:

- Huascacocha project in the amount of 2.5 m^3/sec has to get early into operation in year 2007 instead 2015
- Mantaro-Carispacha project in the amount of 5 m^3/sec has to get early into operation in year 2012 instead 2020, and
- A new source of surface water in the amount of 5.4 m^3/sec has to get into operation in year 2020

Regarding actual situation of SEDAPAL implementation are as follows:

- Marca III (3m^3/sec): under operation since 1999 as scheduled
- Chillón ground water project in the amount of 0.8 m^3/sec went into operation in June 2001
- Marca II is delayed. Construction has been scheduled to start in 2004 and operation in 2007.

Taking into consideration those above facts then Huascacocha project and Marca II have to be under operation in year 2007 in the total amount of 9.0 m^3/sec as shown in Figure 4.3.5 of Supporting report Volume IV. The location of these projects in the Mantaro River basin is shown in Figure 9.4.3.

9.4.4 Water Demand and Supply Balance

(1) Annual Water Balance by SEDAPAL's Method

Water balance carried out by SEDAPAL Master Plan in 1998 following procedure was applied:

* Projection of active water demand (D/I, commercial, state use and park and gardens) from 1998-2030. Active water demand means the water demand which occurs in future if MIO program is implemented (institutional and operational improvement program)
* Assessment of surface and groundwater source present and future
* Water production required taking in consideration total water loss (physical and no-physical). Loss were assessed as 35% in period 1998-2000, 30% in 2005 and 25% from 2010 to 2030.
* Loss in Rímac river upstream La Atarjea during dry season (May-November) was assessed as 5% of the average discharge in same period
* Irrigation water demand in Rímac and Lurín valley
* Reuse of sewerage treated water in gardening and agriculture

Water balance was carried annually and monthly for four (4) alternatives (1, 1a, 2 and 3). Alternatives 1a and 2 include to bring 5m^3/sec either from Cañete or Mantaro River Basin. Alternative 2 was finally selected by SEDAPAL Master Plan.

Based upon average daily water demand, the proposed expansion system of SEDAPAL Master Plan is presented in Figure 9.4.4.

It was assumed that all domestic and non-domestic water demand of Lima Metropolitan area is taken at La Atarjea where intakes and potable water treatment plant are located. Water balance was calculated as water offer (surface and groundwater) minus water demand. The details are presented in Section 4.3.1 of Supporting Report Volume IV.

(2) Water Demand and Supply Balance Analysis

1) Balance Model by Monthly Discharge

The water balance point is set at SEDAPAL's intake site at La Atarjea. The available surface water flow at La Atarjea intake is assumed to be the discharge at Chosica minus the aggregate water loss between La Atarjea and Chosica. The aggregate water loss between La Atarjea and Chosica is assumed to be the sum of the irrigation demand and other water losses consisting of riparian water uses, infiltration and evaporation in the stretch.

It is assumed that all domestic and industrial water demand of the Lima Metropolitan area is withdrawn at La Atarjea. The net D/I water supply demand is balance of the total D/I water supply demand minus the total groundwater supply.

In short the water balance is calculated by:

$$Q_{BL,t} = Q_{C,t} - (D_{IR,t} + L_{AC,t}) - (D_{WS,t} - Q_{G,t}) + Q_{Ri,t}$$

$$= Q_{C,t} - D_{IR,t} - L_{AC,t} - D_{WS,t} + Q_{G,t} + Q_{Ri,t}$$

Where,

$Q_{BL,t}$: Demand and supply balance at year t (m^3/sec)

$Q_{C,t}$: Surface flow discharge at Chosica (SENAMHI Station) at year t (m^3/sec)

$D_{IR,t}$: Irrigation water demand between La Atarjea and Chosica at year t (m^3/sec)

$L_{AC,t}$: Water loss in the stretch between Atarjea and Chosica at year t (m^3/sec)

$D_{WS,t}$: D/I Water supply demand of Lima Metropolitan area at year t (m^3/sec)

$Q_{G,t}$: Groundwater Supply for Lima Metropolitan area at year t (m^3/sec)

$Q_{Ri,t}$: Regulated flow from reservoirs and diversion at year t (m^3/sec)

2) Flow Condition

The monthly mean discharge record of 20 years at Chosica from 1979 to 1998 is used as the surface discharge at Chosica.

The discharge during the period was modified by the regulated flow by the Marca I Project facilities commissioned in 1962 and the Yuracmayo Project commissioned in 1996, but it is treated as the existing natural flow, i.e., without project.

3) Calculation Case and Result

The water demand and supply balance is done for the following category, where Marca I and Yuracmayo Projects are treated as the existing condition:

Cases for Water Balance Calculation

Category	Dam & Water Transfer	D/I Water Demand	Water Loss
A	Without Project	2000, 2005, 2010, 2020, 2030	6.0 m^3/sec
B	With Project Marca III, Marca II	2005 ~ 2030	0.67 m^3/sec
C	With Project Marca III, Marca II, Huascacocha, Mantaro-Carispacha (or Cañete) Max. 16.5 m^3/sec	2005 ~ 2030	6.0 m^3/sec (Irrigation, Factory, Infiltration, Evaporation, etc.)

Alternative cases for the water balance and corresponding conditions are shown in Table 9.4.2. The summary of the calculation results is shown in Table 9.4.3.

These results infer the following prospect:

(a) During the last two decades the most severe drought occurred in 1989-1992 period. It continued four years, and the reservoirs and lagoons in the upstream of the Rímac River were completely emptied due to little rainfall during the rainy season.

(b) If the same event occurred, even the lowest water supply demand projected in 2005 will not be fulfilled even if Marca II is commissioned by 2005. The hydrological reliability of 'With Marca II system' is assessed to be less than 80% (4/20). That is, input of Marca II will not be sufficient even for the event of 1994-1995 draught (4/20) in 2005 even considering the optimistic water loss in the Chosica-La Atarjea stretch being only 0.67 m^3/sec instead of 6.0 m^3/sec.

(c) SEDAPAL's present planning method of water demand and supply based on the annual mean analysis is assessed to be very optimistic. Introduction of an elaborated quantitative water demand and supply balance method considering seasonal variation of discharge and water demand by use of at least monthly mean discharge records will be necessary in order to manage the reliable water supply system for the Lima metropolitan area.

9.4.5 Option for Additional Facilities

Cementos Lima (private firm in Lima) is currently proceeding a project named 'EL PLATANAL INTEGRATED PROJECT' for the development of total 270 MW power production and total 27,000 ha irrigation, with construction of a storage named Moro de Arica dam in the upstream stretch of the Cañete river. The details of the Project are presented in Chapter 5 of Supporting Report Volume IV.

Periods for the design and construction of the hydropower component and the irrigation component are assumed to be 4 years and 10 years respectively. Preparatory works including access roads are being proceeded. Social settlement in the project related area including Cañete and Yauyos provinces were started in April 2001, and commencement of construction of the dam and the power station is scheduled in 2003.

This development has dimensions (in water demand, dams, power stations, groundwater development, water conveyance and irrigation facilities) similar to those of the Scenario-2/Case 2.1 on the Table 4.2.3. It is however noted that the Case 2.1 assumes construction of Paucarcocha reservoir but the above project assumes the reservoir construction as a possibility in future.

Such being the current status of the Cañete river water development, it is necessary to implement some additional facilities to yield new water for the purpose to transfer the Cañete river water to Lima.

Option for the additional facility to yield new 5 m^3/sec water is deemed to be:

- Construction of a storage named San Jerónimo in the midstream, equivalent to the Scenario-3/Case 3.1,or,

- Construction of the Paucarcocha dam at upstream glacial lakes and 3 m^3/sec groundwater wells in the downstream coastal area, equivalent to the Scenario-3/Case 3.3.

As examined in the foregoing Section 5.2, economic comparison of the alternatives for yielding 5 m^3/sec water between the above Cañete basin facility and the Mantaro basin facility (Mantaro-Carispacha scheme) shows that the latter is preferred. Further, it would be the case that the transfer of Cañete River water to other basin, namely to Lima, induces serious objection by the people in the Cañete basin.

Table 9.2.1 Summary of Rímac River Annual Average Water Quality Test (1993 – 1996)

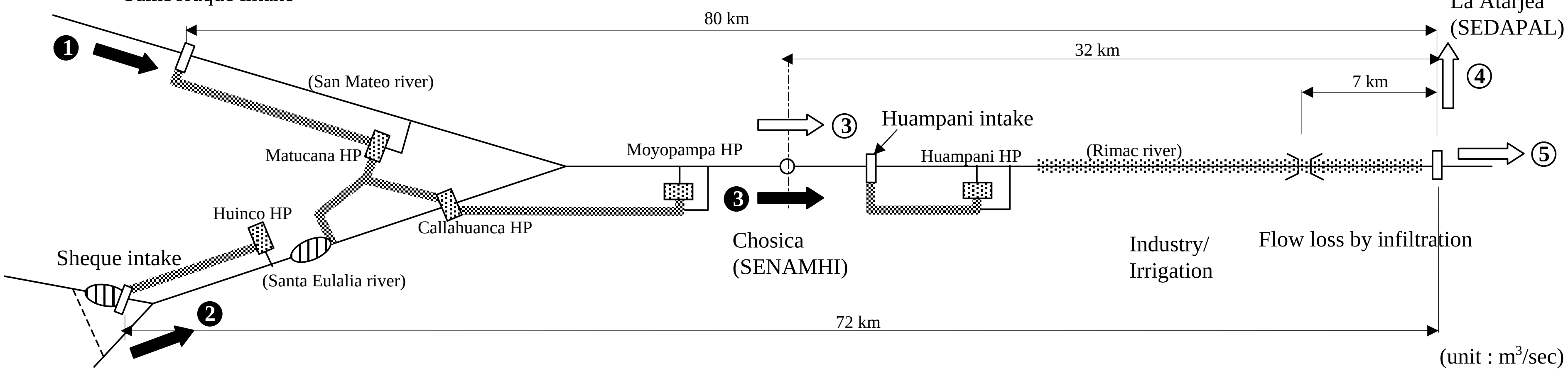
PARAMETERS	UNITS	MONITORING STATIONS													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
PH	Units	7.76	8.46	8.46	8.26	7.72	8.40	8.39	8.20	8.29	8.27	8.17	8.24	8.18	8.28
TURBIDITY	U.N.T/U.J	9.79	31.90	158.00	42.60	33.80	36.50	21.68	38.78	185.00	16.64	36.34	39.00	45.53	49.00
ELECTRIC CONDUCTIVITY	μmhos/cm	869.00	684.00	703.00	687.00	382.00	633.00	614.00	726.00	743.00	455.00	517.00	486.00	505.00	521.00
TEMPERATURE	°C	19.36	16.94	16.96	16.60	13.56	15.51	19.50	22.37	22.45	19.60	21.00	17.90	19.42	20.37
DISSOLVED OXYGEN	Mg/lt	6.64	7.69	7.78	7.79	8.32	7.81	7.73	7.64	7.69	8.68	7.99	8.21	8.32	7.88
TOTAL SOLIDS	Mg/lt	737.00	558.00	570.00	571.00	394.00	514.00	534.00	673.00	640.00	420.00	547.00	407.00	438.00	431.00
DISSOLVED SOLIDS	Mg/lt	562.00	427.00	435.00	435.00	217.00	363.00	380.00	454.00	443.00	278.00	350.00	290.00	341.00	333.00
SUSPENDED SOLIDS	Mg/lt	32.00	41.50	59.00	52.80	49.00	38.00	23.30	26.80	21.83	59.00	61.30	36.80	38.80	34.50
IRON	Mg/lt	0.891	3.250	25.087	4.826	6.709	4.572	2.296	3.203	2.420	0.949	3.154	3.857	4.235	4.176
MANGANESUM	Mg/lt	0.171	0.270	2.270	0.362	0.590	4.899	0.215	0.150	0.124	0.085	0.173	0.211	0.202	0.190
LEAD	Mg/lt	0.087	0.470	2.507	0.533	0.132	0.463	0.144	0.358	0.215	0.090	0.177	0.217	0.181	0.203
CADMIUM	Mg/lt	0.0056	0.0100	0.0230	0.0076	0.0237	0.0130	0.0074	0.0089	0.0077	0.0034	0.0055	0.0048	0.0348	0.0044
CHROMIUM	Mg/lt	0.0057	0.0100	0.0219	0.0160	0.0053	0.0124	0.0058	0.0017	0.0071	0.0064	0.0021	0.0023	0.0073	0.0078
COPPER	Mg/lt	0.065	0.210	0.634	0.249	0.313	0.246	0.090	0.096	0.052	0.046	0.441	0.117	0.072	0.071
ZINC	Mg/lt	1.381	1.520	4.615	1.906	4.290	2.205	0.956	0.887	0.372	0.333	0.481	0.700	0.588	0.530
ALUMINUM	Mg/lt	0.512	1.080	2.539	1.221	1.206	0.988	0.474	1.095	1.004	0.662	1.446	1.249	1.574	1.526
BARIUM	Mg/lt	0.160	0.140	0.145	0.144	0.114	0.140	0.129	0.314	0.195	0.113	0.176	0.123	0.125	0.134
ARSENIC	Mg/lt	0.030	0.040	0.688	0.080	0.469	0.175	0.074	0.060	0.038	0.025	0.038	0.046	0.044	0.038
CYANID	Mg/lt	<0.0025	<0.0025	0.029	0.011	<0.0025	0.015	0.002	0.002	0.015	<0.0020	0.004	<0.0025	0.001	0.001
TOTAL CARBON	Mg/lt	43.73	32.75	32.89	32.38	8.66	27.08	26.74	25.79	30.03	24.29	27.45	24.37	26.10	26.28
INORGANIC CARBON	Mg/lt	42.00	31.20	30.95	30.63	6.33	24.76	24.34	23.31	26.89	21.56	21.38	22.29	22.93	22.82
ORGANIC CARBON	Mg/lt	1.71	1.57	1.86	1.53	2.35	1.57	2.42	2.49	3.13	3.06	6.08	4.95	3.15	2.86
TRIHALOMETHANES	μg/lt	2.22	2.21	1.88	4.65	2.70	2.39	3.46	3.42	4.13	2.69	13.93	3.13	4.32	6.80

1) GRATHON TUNNEL; 2) TAMBORAQUE III BRIDGE; 3) EFFLUENTS FROM TAMBORAQUE MINING FACILITIES; 4) TAMBORAQUE II BRIDGE; 5) ARURI RIVER; 6) TAMBORAQUE INTAKE; 7) SURCO BRIDGE; 8) CORCONA; 9) RICARDO PALMA BRIDGE; 10) SANTA EULALIA RIVER; 11) LOS ANGELES BRIDGE; 12) ÑAÑA BRIDGE; 13) HUACHIPA BRIDGE; 14) LA ATARJEA INTAKE

Prepared by Marco Antonio Meza Alvarez, January 1997

Source: Physic-Chemical Laboratory. SEDAPAL Sub-Management Office for Plants

Table 9.3.1 Flow Balance in Rimac River Basin



(unit : m^3/sec)

	❶	❷	❶+❷	❸-❶-❷	❸ , ③	Industry / Irrigation	Infiltration	Others	Total	④	⑤
Monthly average (Jul.- Sep., 1991-92)	6.1 (EDEGEL)	8.4 (EDEGEL)	14.5	-0.3 -0.4	14.2 (SENAMHI) 14.1 (EDEGEL)	-1.6 -1.5	-2.0	---	-3.6 -3.5	10.6 *1 (SEDAPAL)	0.0 0.0
Monthly average (Jul.- Sep., 1993-95)	6.8 (EDEGEL)	12.1 (EDEGEL)	18.9	+0.5 -1.7	19.4 (SENAMHI) 17.2 (EDEGEL)	-4.3 -2.1	-2.0	---	-6.3 -4.1	13.1 *1 (SEDAPAL)	0.0 0.0
Monthly average (Jul.- Sep., 1996-97)	5.7 (EDEGEL)	10.0 (EDEGEL)	15.7	+5.3 +1.9	21.0 (SENAMHI) 17.6 (EDEGEL)	-7.1 -3.7	-2.0	---	-9.1 -5.7	11.9 *1 (SEDAPAL)	0.0 0.0
Daily average in Aug. 27 - Sep. 9, 2001	11.3 (JICA)	13.0 (JICA)	24.3	+2.5	26.8 (SENAMHI)	-6.8 *3	-2.0	---	-8.8	16.5 *2 (SEDAPAL)	1.5

Source: *1 Production of Plant No. 1 and 2, La Atarjea (SEDAPAL)
*2 Discharge at Sediment trap basin (Desarenadores) No. 1 and 2 (SEDAPAL)
*3 Discharge measurement in Sep. 12 - 14, 2001 by JICA
Discharge data of EDEGEL at Chosica is observed at the Huampani intake. There is no intake between Chosica SENAMHI station and Huampani intake.

Note: ⑤ Overflow discharge at La Atarjea intake was assumed to be negligible in the dry season from 1991 to 1997 because discharge observed at Chosica of 20.0 m^3/sec might diverted all for potable water production. While daily average discharge of 1.5 m^3/sec (or 6.0 m^3/sec presuming 6 hours overflow time) of overflow from flood gates was observed during Aug. 27 to Sep. 9, 2001.

Table 9.4.1 Total Water Demand (m^3/s)

Year	Water Demand Master Plan	Water Demand BLASA	Water Demand BLASA/PM	Water Demand BLASA/INEI
1998	32.29			
1999	30.05			
2000	27.80	32.09	32.46	32.45
2001	27.46	31.26	31.64	31.60
2002	28.08	30.27	30.66	30.59
2003	28.78	29.13	29.52	29.43
2004	29.48	27.82	28.21	28.10
2005	29.67	26.34	26.72	26.61
2006	29.86	26.90	27.29	27.17
2007	30.06	27.46	27.83	27.70
2008	30.25	28.01	28.42	28.29
2009	30.45	28.57	28.99	28.86
2010	30.64	29.13	29.56	29.42
2011	31.12	29.70	30.13	30.01
2012	31.60	30.29	30.70	30.61
2013	32.09	30.87	31.30	31.22
2014	32.57	31.47	31.87	31.81
2015	33.05	32.07	32.46	32.42
2016	33.55	32.69	33.07	33.05
2017	34.05	33.31	33.68	33.68
2018	34.54	33.93	34.29	34.30
2019	35.04	34.55	34.91	34.92
2020	35.54	35.17	35.54	35.54
2021	36.04	35.67	36.04	36.04
2022	36.54	36.16	36.55	36.54
2023	37.05	36.66	37.07	37.04
2024	37.55	37.16	37.59	37.56
2025	38.05	37.65	38.12	38.07
2026	38.58	38.16	38.66	38.60
2027	39.10	38.66	39.20	39.13
2028	39.63	39.16	39.75	39.67
2029	40.15	39.67	40.31	40.22
2030	40.68	40.17	40.87	40.77

Table 9.5.1 Water Resources Development Scenarios and Alternative Cases

	Scenario-1		Scenario-2		Scenario-3		
	Case 1.1	Case 1.2	Case 2.1	Case 2.2	Case 3.1	Case 3.2	Case 3.3
Water Demand:							
1)D/I Water Supply	CB+L5	CB+L10	CB	CB	CB+L5	CB+L5	CB+L5
2)Irrigation Demand	CV	CV+CLC	CV+CTP	CV+CTP5	CV+CLC+CTP	CV+CTP5	CV+CTP
3)Maintenance Flow	Mf4.3	Mf4.3	Mf4.3	Mf4.3	Mf4.3	Mf4.3	Mp1.0
4)Total Demand (MCM)	667.7	855.55	861.4	685.73	1049.28	843.41	915.05
Dam: Active Storage							
1)Morro de Arica (MCM)	205	245	245	205	245	245	245
2)Paucarcocha (MCM)	Not Applicable	55	55	Not Applicable	Not Applicable	55	55
3)Capillucas (MCM)	2.8	2.8	2.8	2.8	2.8	2.8	2.8
4)San Jeronimo (MCM)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	280	Not Applicable	Not Applicable
Power Station:							
1)Morro de Arica (MW)	46	50	50	46	50	50	50
2)El. Platanal (MW)	200	220	220	200	220	220	220
3)San Jeronimo (MW)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
New Ground Water							3m3/s(94.6MCM)
Water Conveyance	L5=5m3/s	L10=10m3/s	Not Applicable	Not Applicable	L5=5m3/s	L5=5m3/s	L5=5m3/s
Irrigation Facilities	Not Applicable	Not Applicable	CTP Full Scale	CTP Half Scale	CTP Full Scale	CTP Half Scale	CTP Full Scale

Notes

CB: D/I Water in Canete River Basin(34.22MCM), L5: Lima D/I Water Supply 5m3/s(157.68MCM), L10: Lima D/I Water Supply 10 m3/s(315.36MCM),

CV: Canete Valley Irrigation(340.20MCM), CLC: Alto Imperial Irrigation(30.17MCM), CTP: Concon-Topara Irrigation (Full Scale 351.41MCM),

CTP5: Concon-Topara Irrigation (Half Scale 175.71MCM)

Mf4.3: Maintenance Flow 4.3m3/s(135.60MCM), Mp1.0: Maintenance Flow 1.0m3/s(31.54MCM)

Table 9.6.1 Alternative Cases for Water Balance Analysis

	Without Project	With Project Without Irrigation & Loss		With Project With Loss & Irrigation
	Case A1	Case B1	Case B2	Case C1
Water Demand 1) D/I Water supply(*) 2000 ~ 2030	2000, 2005, 2010 2020, 2030	2005	2010, 2030	2005, 2010, 2020, 2030
2) Irrigation, losses & other demand, Assumed constant	6.0 m^3/s	0.67 m^3/s	0.67 m^3/s	6.0 m^3/s
3) Groundwater Supply	no	7.68 m^3/s	7.68 m^3/s	5.0 m^3/s
Dam & Water Transfer	no	Marca III (3.0 m^3/s)	Marca III + II (9.5 m^3/s)	Marca III + II, Huascacocha, Mantaro (16.5 m^3/s)

Notes,

(1) Marca I Project and Yuracmayo Project are treated as the existing condition.

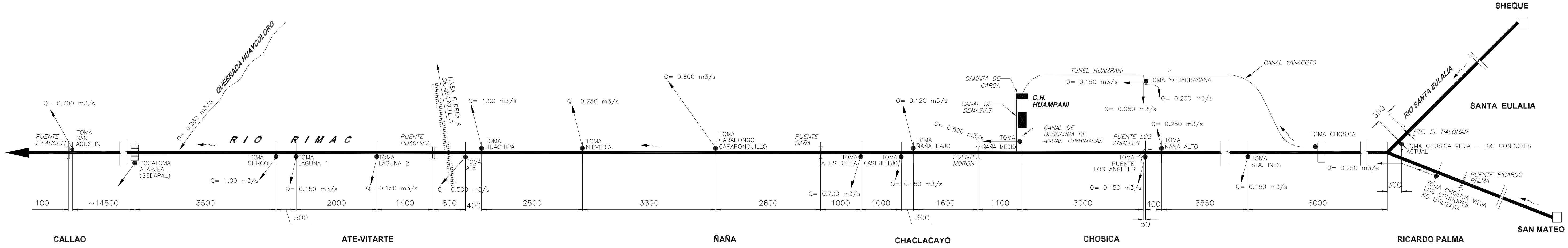
(2) Marca III (3.0 m^3/s), Marca II (6.5 m^3/s), Huascacocha (2.5 m^3/s), Mantaro - Carispacha or Cañete(5.0 m^3/s) are treated as future projects.

(*) D/I : Domestic/Industry

Table 9.6.2 Result of Water Balance Analysis

Category		Target Year	Total Demand (m^3/s)	Peak Deficit(*) (m^3/s)	Annual Deficit (MCM)			Occurence Year			Remarks
	Case				1/20	2/20	4/20	1/20	2/20	4/20	
A	A1	2000	32.09	27.69	1152.94	1151.93	714.36	1991-1992	1989-1990	1994-1995	
		2005	26.34	21.53	827.19	818.41	284.70	1991-1992	1989-1990	1979	
		2010	29.13	24.52	982.38	978.54	357.97	1991-1992	1989-1990	1979	
		2020	35.17	30.99	1338.67	1337.10	513.45	1991-1992	1989-1990	1997	
		2030	40.17	36.34	1641.39	1637.70	1134.88	1991-1992	1989-1990	1994-1995	
B	B1	2000	32.09	14.50	328.97	305.46	70.18	1991-1992	1989-1990	1979	
		2005	26.34	8.34	80.72	87.87	4.41	1991-1992	1989-1990	1980	
		2010	29.13	11.33	185.91	164.59	26.37	1991-1992	1989-1990	1979	
		2020	35.17	17.80	494.62	477.77	120.30	1991-1992	1989-1990	1979	
		2030	40.17	23.15	773.27	769.51	260.65	1991-1992	1989-1990	1997	
	B2	2000	32.09	14.50	189.06	199.01	42.38	1991-1992	1989-1990	1993	
		2005	26.34	8.34	71.77	60.30	13.28	1991-1992	1989-1990	1997	
		2010	29.13	11.33	122.91	107.61	27.85	1991-1992	1989-1990	1993	
		2020	35.17	17.80	303.79	316.17	74.14	1991-1992	1989-1990	1995	
		2030	40.17	23.15	565.19	565.99	177.64	1991-1992	1989-1990	1995	
C	C1	2000	32.09	22.69	381.29	416.69	145.39	1991-1992	1989-1990	1995	
		2005	26.34	16.53	233.09	236.68	56.22	1991-1992	1989-1990	1997	
		2010	29.13	19.52	301.40	314.25	99.48	1991-1992	1989-1990	1995	
		2020	35.17	25.99	516.82	532.45	203.86	1991-1992	1989-1990	1995	
		2030	40.17	31.34	800.11	801.59	334.89	1991-1992	1989-1990	1995	

(*) Peak Deficit : Maximum deficit in specified year.



IRRIGATION INTAKES AND DISCHARGES UPDATED 2001

N°	TOMA		MARGEN DE UBICACION EN EL RIO		COORDENADAS		ALTITUD	CAUDAL DE CAPTACION MEDIDO (m³/s)				CAUDAL SOLICITADO POR ATDR-RIMAC m3/s
								POR FLOTADOR		POR CORRENTOMETRO		
	NOMBRE	TIPO	RIMAC	STA. EULALIA	N	E	m s.n.m.	CAUDAL	FECHA	CAUDAL	FECHA	
1	SAN AGUSTIN	RUSTICA	DERECHA		8668614	0271794	70	0.700	05/09/01			
2	ATARJEA (SEDAPAL)	CONCRETO ARMADO	IZQUIERDA									
3	SURCO	RUSTICA	IZQUIERDA		8670578	0289504	346	1.00	25/08/01	0.967	12/09/01	0.52
4	LAGUNA 1	CONCRETO	IZQUIERDA					0.150	12/09/01	0.15		0.15
5	LAGUNA 2	CONCRETO	IZQUIERDA					0.150	12/09/01	0.15		0.15
6	ATE	RUSTICA	IZQUIERDA		8671620	0294059	421	0.500	28/08/01	0.320	14/09/01	0.50
7	HUACHIPA	RUSTICA	DERECHA		8671799	0294363	433	1.00	28/08/01	1.185	14/09/01	0.84
8	NIEVERIA	RUSTICA	DERECHA		8672658	0295747	464	0.750	28/08/01	0.627	14/09/01	0.51
9	CARAPONGO CARAPONGUILLO	RUSTICA	DERECHA		8673424	0299765	537	0.600	27/08/01	1.115	14/09/01	0.48
10	LA ESTRELLA	RUSTICA	IZQUIERDA		8674922	0303065	605	0.700	28/08/01	0.818	14/09/01	0.41
11	CASTRILLEJO	RUSTICA	IZQUIERDA		8675119	0304121	622	0.150	25/08/01	0.163	14/09/01	0.14
12	ÑAÑA BAJO	RUSTICA	DERECHA		8675399	0304489	637	0.120	27/08/01	0.213	14/09/01	0.21
13	ÑAÑA MEDIO	CONCRETO	DERECHA		8676048	0306870	677	0.500	27/08/01	0.595	14/09/01	0.23
14	PTE. LOS ANGELES	RUSTICA	IZQUIERDA		8676791	0310239		0.150	03/09/01	0.046	14/09/01	0.13
15	ÑAÑA ALTO	RUSTICA	IZQUIERDA		8677057	0310513	746	0.250	04/09/01	0.280	14/09/01	0.27
16	SANTA INES	RUSTICA	IZQUIERDA		8678504	0312858	804	0.160	04/09/01	0.128	14/09/01	0.21
17	CHACRASANA	CONCRETO	DERECHA		8678904	0311959	865	0.400	06/09/01	0.40		0.40
18	CHOSICA VIEJA LOS CONDORES	RUSTICA	IZQUIERDA		8681845	0318820	963	0.00	04/09/01	0.00		
19	CHOSICA VIEJA LOS CONDORES ACTUAL	CONCRETO		IZQUIERDA	8681818	0318632	959	0.250	04/09/01	0.25		0.25
								6.83		7.40		5.40

SUPPLEMENTAL INVESTIGATION
OF
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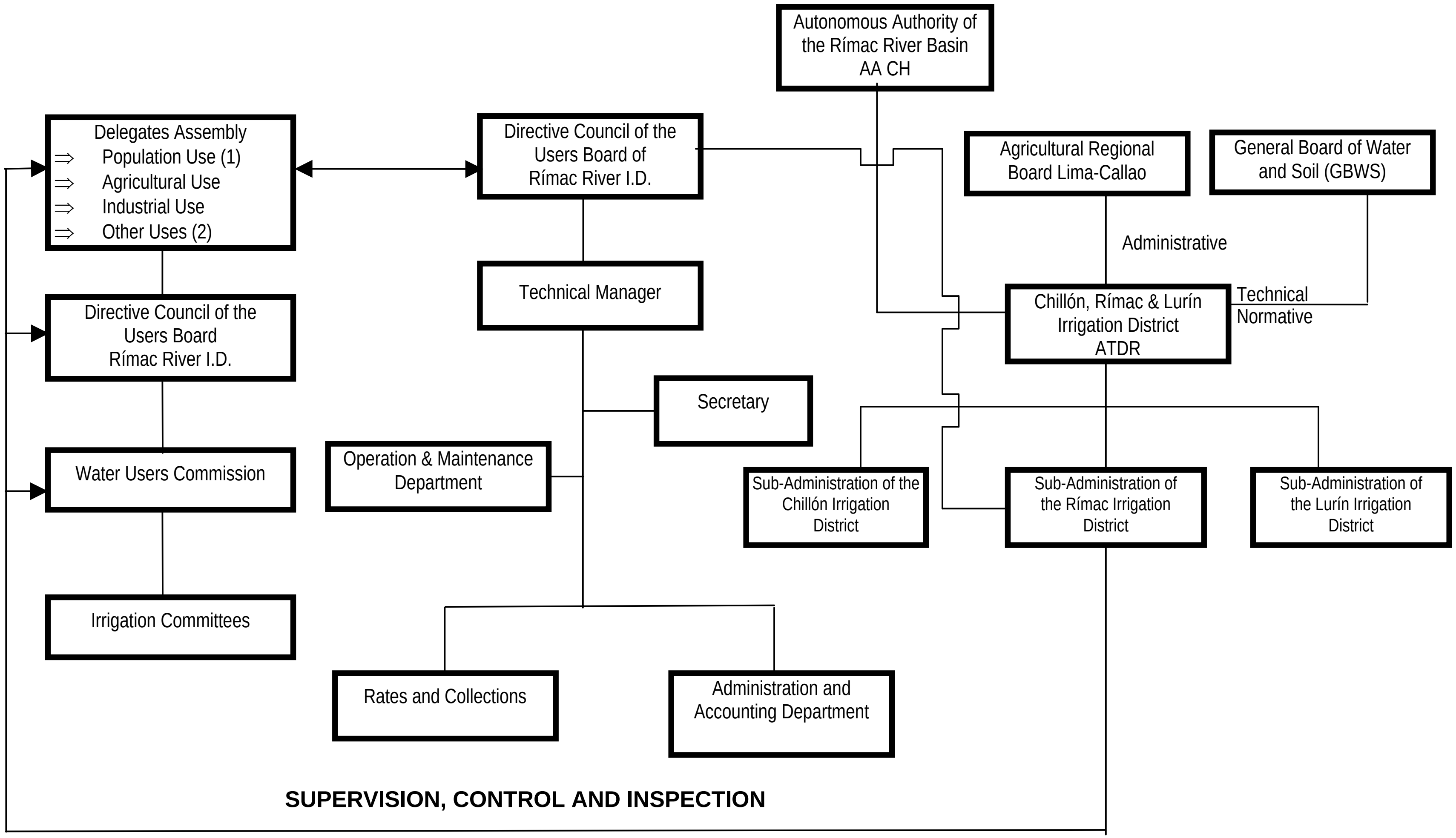
Figure 9.2.1 Irrigation Water Intakes

ADMINSITRATIVE AND TECHNICAL ORGANIZATION FOR THE WATER USE IN THE RIMAC RIVER BASIN

EXECUTIVE ORGANIZATION ***TECHNICAL & ADMINISTRATIVE ORGANIZATION*** ***NORMATIVE ORGANIZATION***



(1) Population Use (SEDAPAL)
(2) EDEGEL, Cajamarquilla Zinc Refinery, Mines and Others
I.D. = Irrigation District

JAPAN INTERNATIONAL COOPERATION

SUPPLEMENTAL INVESTIGATION
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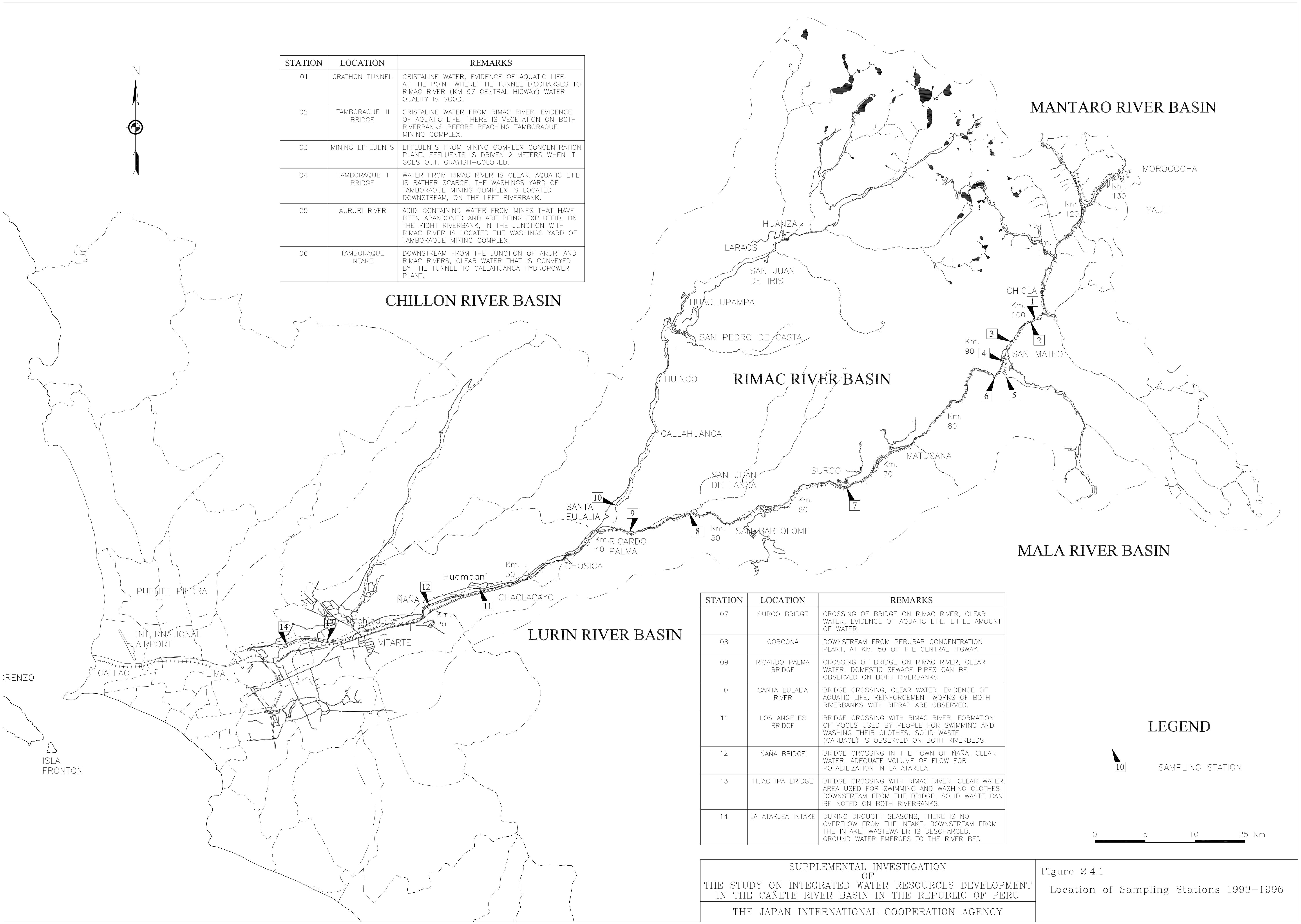
Figure 9.2.2
Administrative and Technical Organization
for the Water Use in the Rímac River Basin



STATION	LOCATION	REMARKS
01	GRATHON TUNNEL	CRISTALINE WATER, EVIDENCE OF AQUATIC LIFE. AT THE POINT WHERE THE TUNNEL DISCHARGES TO RIMAC RIVER (KM 97 CENTRAL HIGWAY) WATER QUALITY IS GOOD.
02	TAMBORAQUE III BRIDGE	CRISTALINE WATER FROM RIMAC RIVER, EVIDENCE OF AQUATIC LIFE. THERE IS VEGETATION ON BOTH RIVERBANKS BEFORE REACHING TAMBORAQUE MINING COMPLEX.
03	MINING EFFLUENTS	EFFLUENTS FROM MINING COMPLEX CONCENTRATION PLANT. EFFLUENTS IS DRIVEN 2 METERS WHEN IT GOES OUT. GRAYISH-COLORED.
04	TAMBORAQUE II BRIDGE	WATER FROM RIMAC RIVER IS CLEAR, AQUATIC LIFE IS RATHER SCARCE. THE WASHINGS YARD OF TAMBORAQUE MINING COMPLEX IS LOCATED DOWNSTREAM, ON THE LEFT RIVERBANK.
05	AURURI RIVER	ACID-CONTAINING WATER FROM MINES THAT HAVE BEEN ABANDONED AND ARE BEING EXPLOTEID. ON THE RIGHT RIVERBANK, IN THE JUNCTION WITH RIMAC RIVER IS LOCATED THE WASHINGS YARD OF TAMBORAQUE MINING COMPLEX.
06	TAMBORAQUE INTAKE	DOWNSTREAM FROM THE JUNCTION OF ARURI AND RIMAC RIVERS, CLEAR WATER THAT IS CONVEYED BY THE TUNNEL TO CALLAHUANCA HYDROPOWER PLANT.

STATION	LOCATION	REMARKS
07	SURCO BRIDGE	CROSSING OF BRIDGE ON RIMAC RIVER, CLEAR WATER, EVIDENCE OF AQUATIC LIFE. LITTLE AMOUNT OF WATER.
08	CORCONA	DOWNSTREAM FROM PERUBAR CONCENTRATION PLANT, AT KM. 50 OF THE CENTRAL HIGWAY.
09	RICARDO PALMA BRIDGE	CROSSING OF BRIDGE ON RIMAC RIVER, CLEAR WATER. DOMESTIC SEWAGE PIPES CAN BE OBSERVED ON BOTH RIVERBANKS.
10	SANTA EULALIA RIVER	BRIDGE CROSSING, CLEAR WATER, EVIDENCE OF AQUATIC LIFE. REINFORCEMENT WORKS OF BOTH RIVERBANKS WITH RIPRAP ARE OBSERVED.
11	LOS ANGELES BRIDGE	BRIDGE CROSSING WITH RIMAC RIVER, FORMATION OF POOLS USED BY PEOPLE FOR SWIMMING AND WASHING THEIR CLOTHES. SOLID WASTE (GARBAGE) IS OBSERVED ON BOTH RIVERBEDS.
12	ÑAÑA BRIDGE	BRIDGE CROSSING IN THE TOWN OF ÑAÑA, CLEAR WATER, ADEQUATE VOLUME OF FLOW FOR POTABILIZATION IN LA ATARJEA.
13	HUACHIPA BRIDGE	BRIDGE CROSSING WITH RIMAC RIVER, CLEAR WATER. AREA USED FOR SWIMMING AND WASHING CLOTHES. DOWNSTREAM FROM THE BRIDGE, SOLID WASTE CAN BE NOTED ON BOTH RIVERBANKS.
14	LA ATARJEA INTAKE	DURING DROUGTH SEASONS, THERE IS NO OVERFLOW FROM THE INTAKE. DOWNSTREAM FROM THE INTAKE, WASTEWATER IS DESCHARGED. GROUND WATER EMERGES TO THE RIVER BED.

SUPPLEMENTAL INVESTIGATION
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Figure 2.4.1
Location of Sampling Stations 1993-1996

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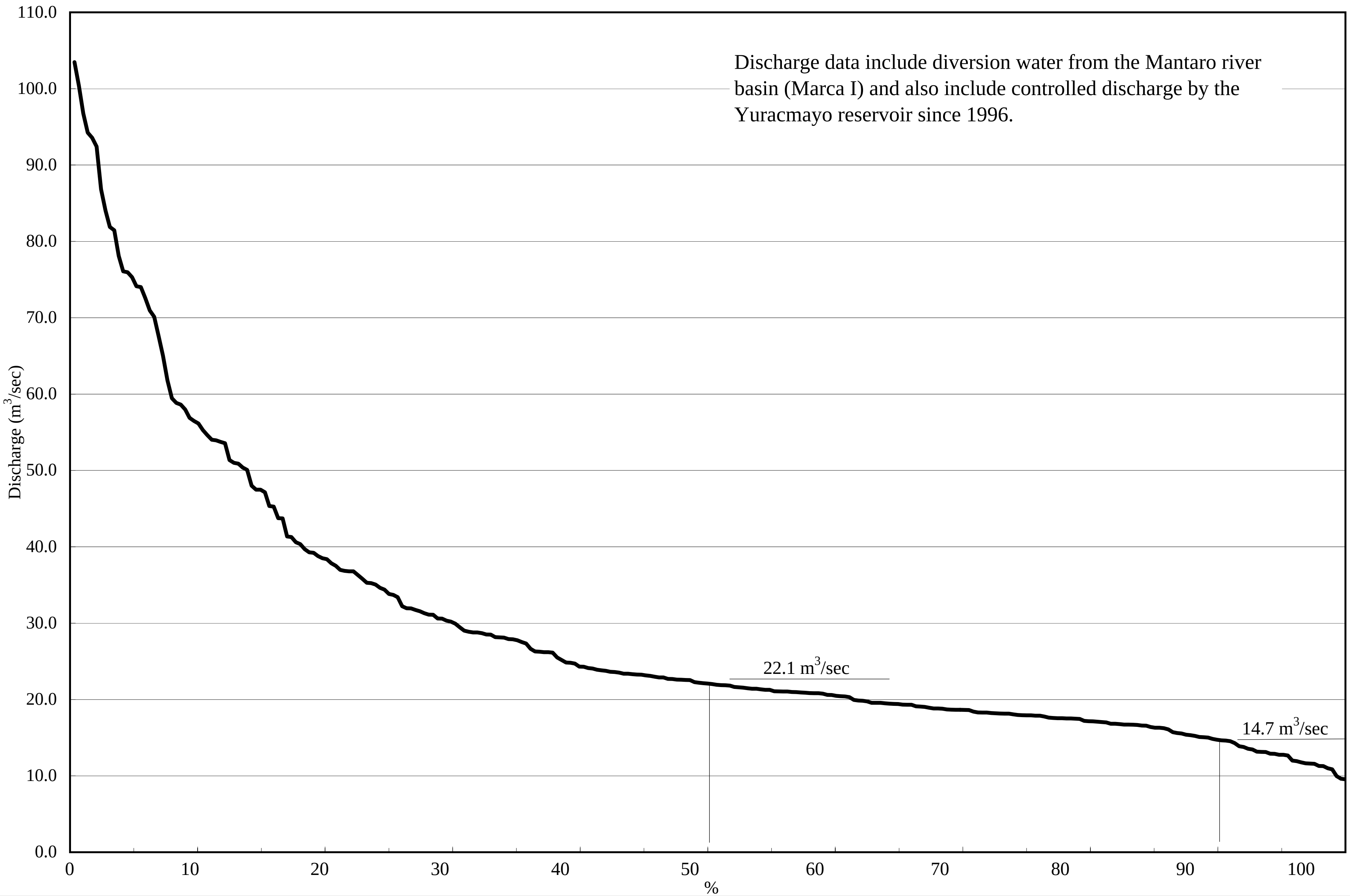
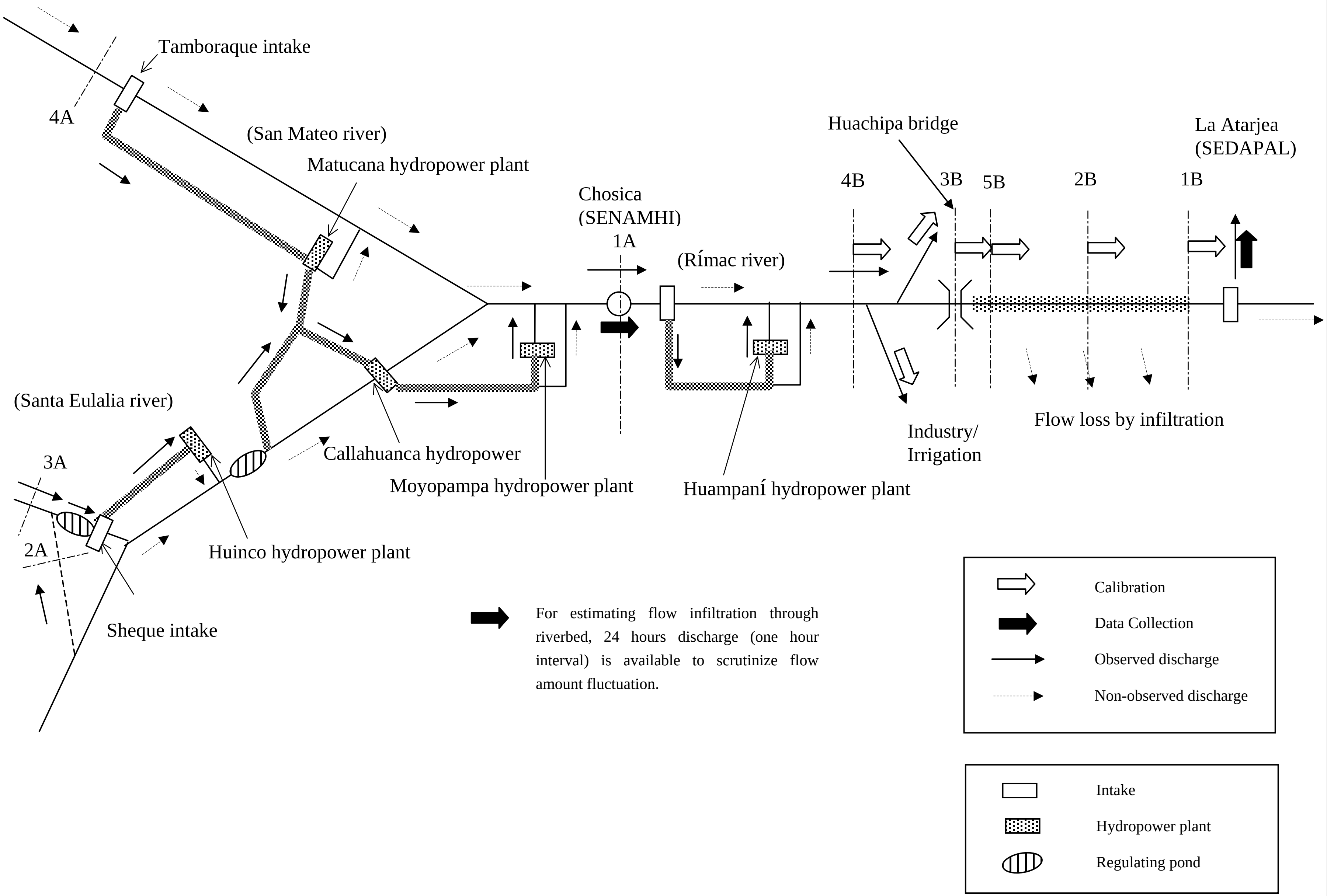


Figure 9.3.1
Duration Curve of Rimac River (Chosica, SENAMHI) Monthly average 1973-1997



STUDY ON INTEGRATED WATER RESOURCES DEVELOPMENT IN THE CAÑETE RIVER BASIN IN THE REPUBLIC OF PERU

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Figure 9.3.2 Schematic Diagram on Water Conveyance Route in Rímac River Basin

STUDY ON INTEGRATED WATER RESOURCES DEVELOPMENT
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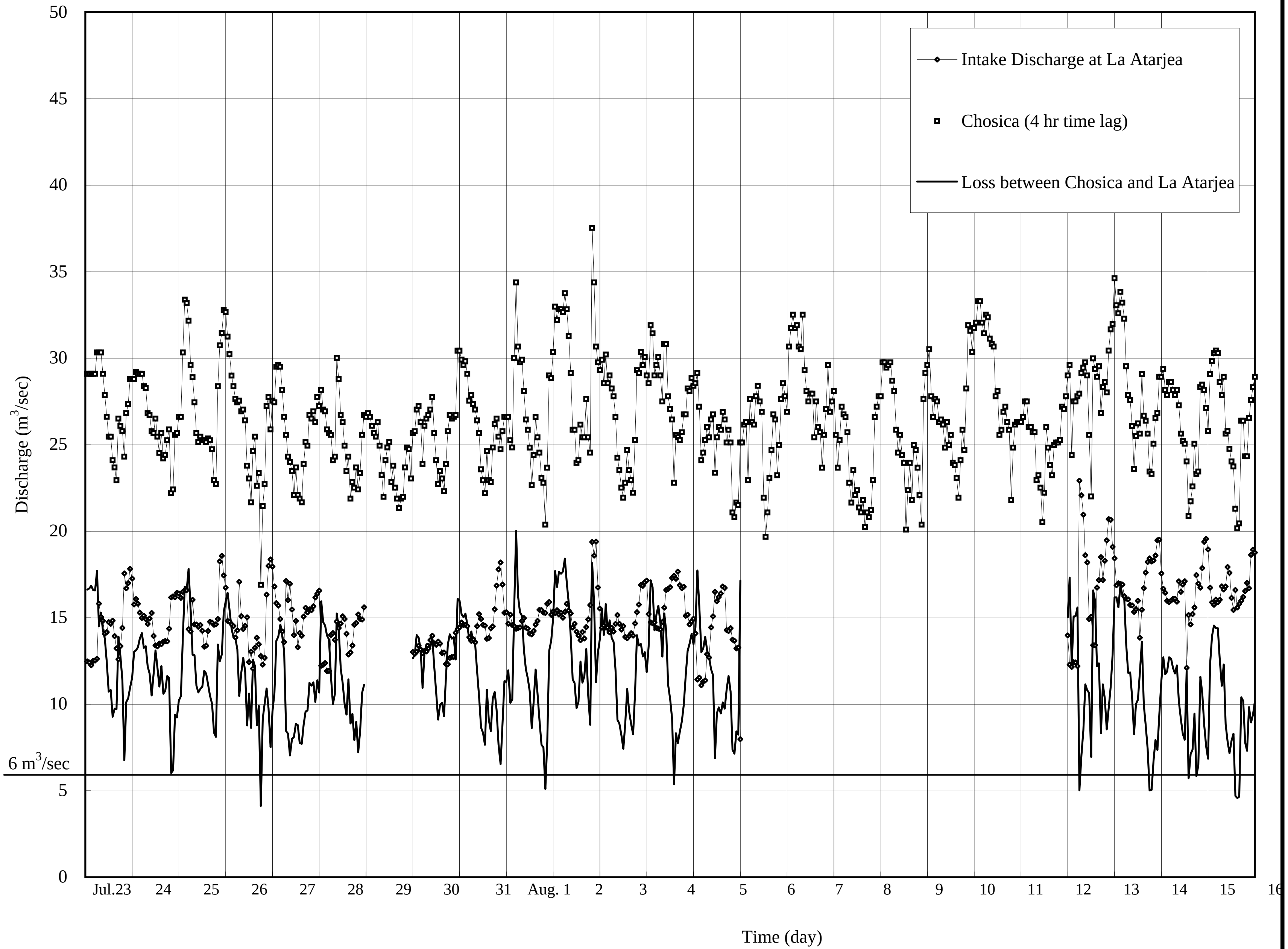

Figure 9.3.3
River Discharge at Chosica and La Atarjea (1/2)

STUDY ON INTEGRATED WATER RESOURCES DEVELOPMENT
IN
THE CAÑETE RIVER BASIN IN THE REPUBLIC OF PERU
JAPAN INTERNATIONAL COOPERATION AGENCY

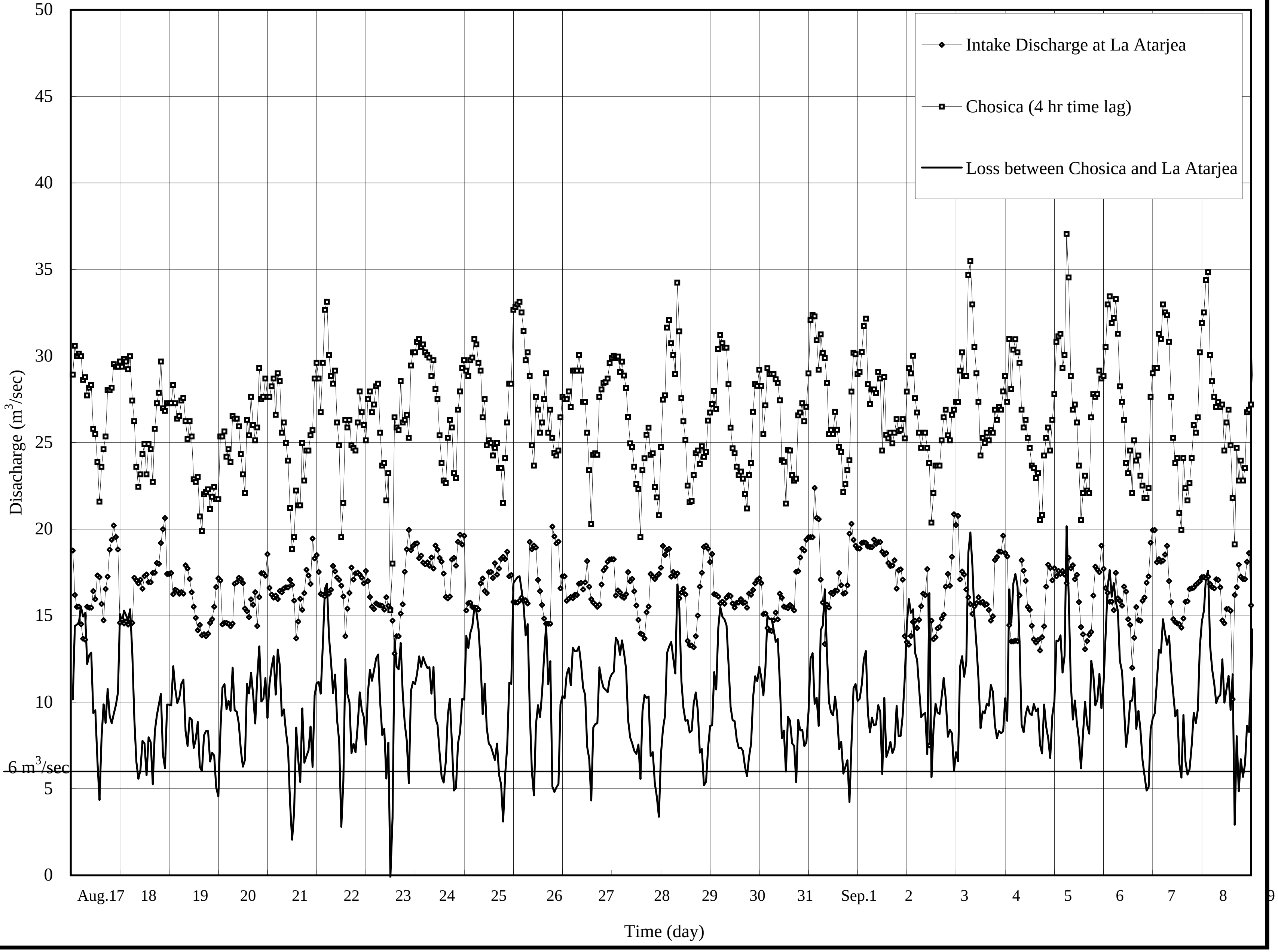

Figure 9.3.3
River Discharge at Chosica and La Atarjea (2/2)