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REPUBLIC OF PERU

SERVICIO DE AGUA POTABLE Y ALCANTARILLADO DE LIMA

(SEDAPAL)

THE FEASIBILITY STUDY
ON
THE IMPROVEMENT OF SEWERAGE SYSTEM
IN
SOUTHERN PART OF LIMA

FINAL REPORT

VOLUME I
SUMMARY

MARCH, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of Peru, the Japanese Government decided to conduct a Feasibility Study on the Improvement of the Sewerage System in the Southern Part of Lima and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Peru a survey team headed by Mr. Hiroshi Irie, Nippon Jogesuido Sekkei Co., Ltd., from April to June, 1989, and from October to November, 1989.

The team held discussions with concerned officials of the Government of Peru, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

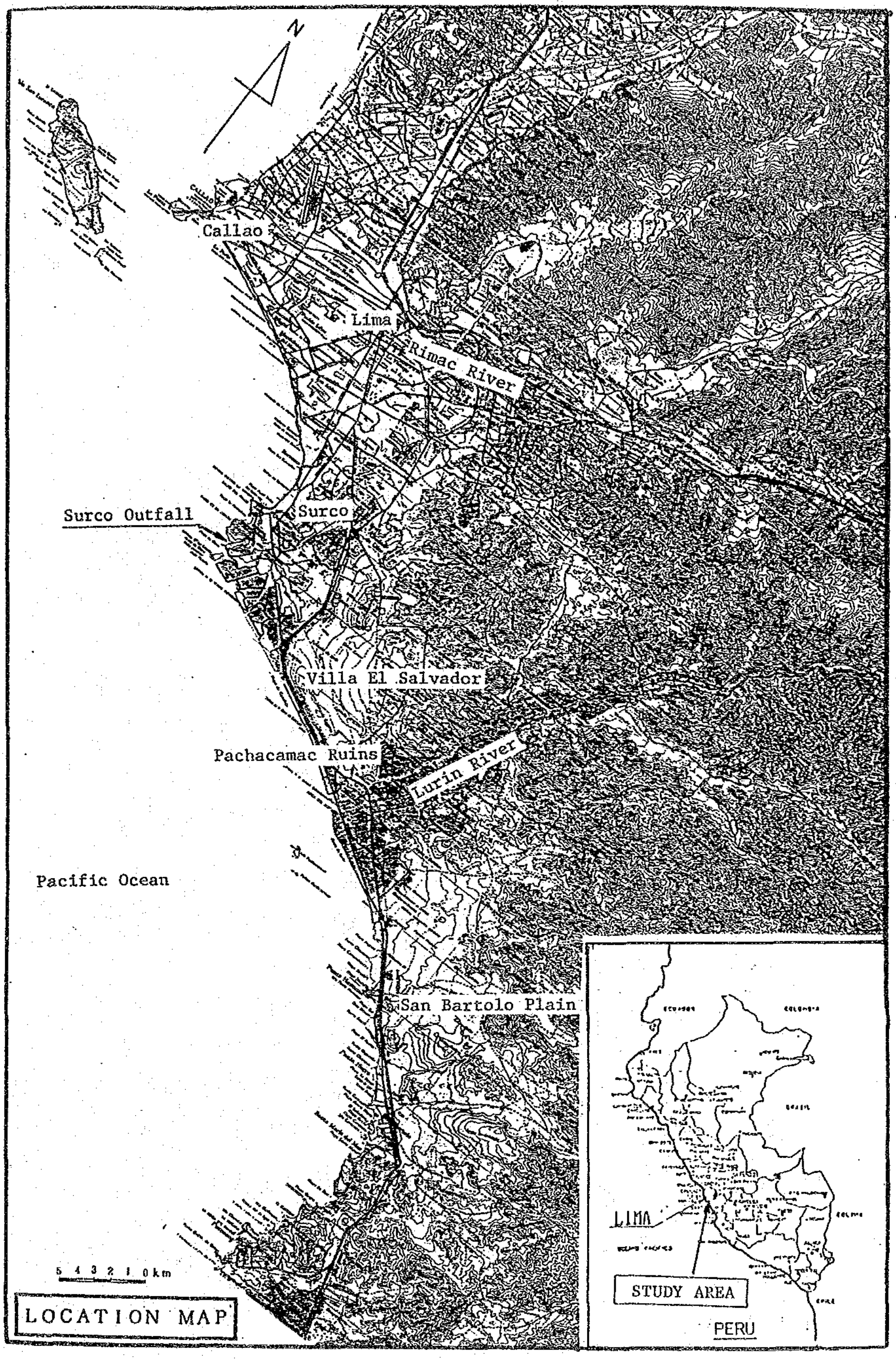
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Peru for their close cooperation extended to the team.

March, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency



N
Callao
Lima
Rimac River
Surco Outfall
Surco
Villa El Salvador
Pachacamac Ruins
Lurin River
Pacific Ocean
San Bartolo Plain
5 4 3 2 1 0 km
LOCATION MAP
LIMA
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PERU

FEASIBILITY STUDY
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ABBREVIATIONS AND ACRONYMS

UNIT

CFU: colony formed unit
cu.m/s: cubic meter per second
ha: hectare
I/.: Peruvian intis
kg/cm^2: kilogram per square centimeter
kW: kilowatt
kWH: kilowatt-hour
l/capita/day: liter per capita per day
lpcd: liter per capita per day
m: meter
m^2: square meter
m^3: cubic meter
$m^3/m^2/day$: cubic meter per square meter per day
m^3/min: cubic meter per minute
m^3/s: cubic meter per second
m^3/sec: cubic meter per second
$m^3/year$: cubic meter per year
μg/kg: microgram per kilogram
mg/kg: miligram per kilogram
μg/l: microgram per liter
mg/l: miligram per liter
mm: milimeter
MPN/100ml: most probable number per 100 mililiter
m/s: meter per second
μS/cm: micro-siemens per centimeter
MW: megawatt
%: percentage
ppb: parts per bilion
ppm: parts per milion
sec.: second
ton/m^2: ton (metric) per square meter
ton/m^3: ton (metric) per cubic meter
US$: United States dollar
Yen: Japanese yen

ORGANIZATION

CEPIS: Centro Panamericano de Ingenieria Sanitaria y Ciencias del Ambiente
(Pan American Center for Sanitary Engineering and Environmnental Sciences)

DITESA: Direccion Tecnica de Salud Ambienta, Ministerio de Salud
(Environmental Health Technical Ofiice, Ministry of Health)

GOJ: Government of Japan

GOP: Government of Peru

IMARPE: Instituto del Mar del Peru
(Peruvian Institute of the Sea)

INE: Instituto Nacional de Estadistica
(National Institute of Statistics)

JICA: Japan International Cooperation Agency

SEDAPAL: Servicio de Agua Potable y Alcantarillado de Lima
(Lima Water Supply and Sewerage Service)

SEDTACNA: Servicio de Agua Potable y Alcantarillado de Tacna
(Tacna Water Supply and Sewerage Service)

SENAPA: Servicio Nacional de Abastecimiento de Agua Potable y Alcantarillado
(National Water Supply and Sewerage Service)

UNI: Universidad Nacional de Ingeneiria
(National University of Engineering)

OTHERS

AL: Aerated Lagoon System

ASP: Activated Sludge Processing System

BOD: Biological Oxigen Demand

BOD_5: Biological Oxigen Demand in 5 days

COD: Chemical Oxigen Demand

D/S.H: Direct Water Supply High Consumption

D/S.L: Direct Water Supply Low Consumption

EAP: Exrended Aeration Processing System

EIRR: Economic Internal Rate of Return

FIRR: Financial Internal Rate of Return

FIRR: Financial Internal Rate of Return

GDP: Gross Domestic Product

G.F.: Grabity Flow

GL: Ground Level

GNP: Gross National Product

HWL: High Water Level

I.D: Indirect Water Supply

IRR: Internal Rate of Return

I.S.: Inverted Siphon

LWL: Low Water Level

MUC: Mercado Unico de Cambios (Sole Market Exchange Rate)

OD: Oxidation Ditch System

SS: Suspended Solid

STP or S.T.P.: Sewage Treatment Plant

TF: Trickling Filter System

WSP: Waste Stabilization Pond System

SUMMARY

CHAPTER 1

INTRODUCTION

SUMMARY

CHAPTER S.1 INTRODUCTION

S.1.1 Background of the Study

The existing sewerage system of Metropolitan Lima consists principally of 6,000 kilometers sanitary sewers, around 30 sewage relay pumping stations, and two major treatment plants with a combined capacity of 0.4 m^3/sec. However, a study conducted in 1985 indicated that the city generated the amount of domestic sewage and industrial wastewater equivalent to 16 m^3/sec, thus the bulk of the remaining sewage is discharged without any form of treatment directly to the sea. As a result, the coastal area and beaches of Lima have become severely contaminated, creating a serious social problem which the Peruvian government decided must be addressed urgently.

Treated water is utilized for agricultural and silviculture irrigation, and has been considered in a recent experiment for use in aquiculture. Although prohibited, the reuse of raw sewage for food crop cultivation is practiced in some areas. In parks in the urbanized area of Lima, watering of lawns and trees are sometimes done by plugging the sewers. The contribution of the park greenery to the environment is a positive aspect and is a strong argument for the reuse of sewage for irrigation. As raw sewage constitutes a potential health hazard to farmers as well as to people who consume agricultural crops irrigated with it, prior treatment to a desired level is required before sewage is used for irrigation.

Taking into account the current situation then, the Government of Peru in August 1986, conducted initial inquiries on the possibility of implementing a sewerage system improvement project with the assistance of the Japanese Government. In September 1988, the Government of Peru presented an official request together with a Terms of Reference for the improvement of the sewerage system of southern Lima with the end view of upgrading environmental conditions.

In response to the request, the Japanese Government decided to carry out a feasibility study of the proposal and dispatched a preliminary Survey Team through the Japan International Cooperation Agency (JICA) between the end of November and the beginning of December 1988. Investigation on the problem of the existing sewerage system was made in coordination with the Servicio de Agua Potable y Alcantarillado de Lima (SEDAPAL) which is the counterpart agency for the Study. The Scope of Work for this Study was agreed between the JICA Survey Team and SEDAPAL in Lima on December 7, 1988.

S.1.2 Objectives of the Study

Based on the contents of the request of the Government of Peru, the objectives of the Study are: i) to carry out a feasibility study relative to the improvement of the existing sewerage system in the southern part of Lima and, subsequently, to carry out the feasibility study relative to the plan for construction of a Treatment Plant, and ii) to transfer relevant technology applied in the Study to Peru through activities of the Study Team.

S.1.3 Scope of the Study

The Study Area covers the southern part of Lima, specifically extending from an intake point to be constructed at the middle point of the Colector Surco and/or the main sewers on the north, to the Quebrada Pucara northern boundary of the San Bartolo plain on the south. Target year for the Project in this Study is year 2000.

The Study which consisted of field work in Peru and home office work in Japan, covered several tasks items in pursuit of the objectives and in accordance with the Agreement and the Minutes of Meeting prepared by the JICA Study Team on December 7, 1988. These tasks are: data collection and review; field survey work consisting of measurement of sewage quantity and quality, and topographic survey and soil investigation; preparation of alternatives; identification of the optimum plan which includes facilities planning, implementation planning, and organization, operation and management planning; and evaluation of the proposed system.

CHAPTER 2

DESCRIPTION OF THE STUDY AREA

CHAPTER S.2 DESCRIPTION OF THE STUDY AREA

S.2.1 Brief History of Metropolitan Lima

Metropolitan Lima, which now comprise the Province of Lima and the Constitutional Province of Callao, started in 1535 as a principal part of Lima province and expanded with the annexation of the neighboring constitutional province of Callao during the Second World War. From its population of 64,000 inhabitants as Lima province in 1820, the population of Metropolitan Lima has grown to more than 6 million in 1989. The city is experiencing rapid development in recent years especially in the southern part where migrants have built new settlements called "Pueblos Jóvenes" in wide area.

S.2.2 Natural Condition

The Study Area encompasses 16 of the 41 districts which make up the province of Lima. It occupies 122 square kilometers of the 2,800 square kilometers area of the province of Lima and includes 1.8 million of its 6 million inhabitants. The Study especially covers the "Pueblos Jóvenes" because they are in immediate need of water supply and sewerage services.

Lima is situated in the coast of a fan-shaped valley formed by the Rimac, Chillon and Lurin rivers, and lies at an altitude of 40 to 200 meters above sea level. The Study Area falls between the Rimac and Lurin rivers. Except for low-lying river valleys, the area was desert previously with cliffs rising abruptly from the sea shore. Ground surface gradient in river valleys is less than 5 percent while it is around 5 percent sloping towards the sea in the deserts.

A formation consisting of Tertiary strata base and overlying sands from the Quarternary era characterizes the geology of the Study Area. These sands originated from river depositions, fluvial terraces, and dunes formed by aeolian deposits.

Metropolitan Lima is traversed by three rivers: the Chillon river which runs in the northern part, the Rimac river which cuts through the heart of the city, and the Lurin river which traverses the Study Area. Chillon river is mainly used for irrigation and is being eyed as a possible source of domestic supply in the year 2000. Rimac river is the principal source of water supply for Metropolitan Lima and is also used for irrigation. Sole use of the Lurin river at present is for irrigation.

The sea fronting Peru is subject to ocean currents called the Humboldt, South Equatorial and Equatorial Counter currents, which combined action either creates rare heavy rainfalls along the coasts or spawn great volumes of plankton. Thus, the marine area of Peru has a strong and varied influence on the fishing and on the coastal agro-industry.

Earthquake is the only probable natural disaster of significant proportion that could occur in Peru. The Andes area is considered to be most earthquake-prone but this is far from Lima. Except in the San Bartolo plain where many traces of debris flow are found, the Study Area does not experience landslide or debris flow.

Lima falls under a desert type climate. Because of the influence of the cold Humboldt ocean current, humidity is high and temperature is lower than in an area in Brazil of the same latitude. Annual average relative humidity is more than 80 percent while the average monthly minimum and maximum relative humidity ranges from 60 to 95 percent. Monthly average temperature ranges from 12.7 to 28.9 degrees Centigrade with an average annual value of 18 degrees Centigrade.

In Metropolitan Lima, precipitation is very minimal to practically nil, storms and seasonal winds do not occur, and atmospheric pressures and winds are stable at any time of the year. Average annual evaporation is in the order of 1,470 mm with monthly averages ranging from 70 to 170 mm.

Solar exposure is greatest during the month of April at 58-60 percent and is least during the month of August at 14-16 percent.

S.2.3 Economy

The Gross Domestic Product (GDP) of Peru, which registered increases of 9.5 and 7.8 percent in 1986 and 1987, respectively, ended up in 1988 with a decrease of 8.4 percent. The economic growth in 1986 and 1987 adversely resulted to the reduction of foreign currency reserves and to the economic plunge in 1988. Because of the increased money supply, the inflation rate went up to 62.9, 114.5 and 1,722.3 percent in 1986, 1987, 1988, respectively. In 1988, only the agriculture and fishing sectors gained in GDP, the latter owing to the favorable ocean currents which increased the fish catch.

Peru's main products are derived from agriculture and mining. The agriculture - forestry, fishery and mining industries accounted for 10.9, 0.8 and 10.1 percent, respectively, of the GDP in 1987. Except for a slight increase in the manufacturing sector, no major change had taken place in the industrial structure of Peru since 1985.

Tourism is a principal foreign currency earning industry in Peru. In 1987, about 1,890,000 tourists consisting of 250,000 foreigners and 1,640,000 Peruvian nationals visited Metropolitan Lima, earning for the tourism industry the amount of US$ 393 million. Major tourist spots in Lima include several beach resorts along the Pacific coast. Another beach resort in the coast of Chira is being planned for the promotion of tourism but a raw sewage outfall locally known as Colector Surco has polluted the sea water in the area and is causing major environmental problems.

As for the trade balance of Peru, there was a surplus of US$ 1,172 million in 1985 and but has since then incurred deficits, the biggest being US$ 463 million in 1987.

S.2.4 Public Health Condition

Sanitary and health conditions in Peru are generally still considered unsatisfactory as infectious diseases continue to affect and claim lives of many Peruvians every year. Although a number of water-borne diseases have been kept almost at the same level through the 9-year period from 1980 to 1988, incidence rates of other infectious diseases had been on the steady rise since 1982. Infectious water-borne diseases in Peru are definitely serious problems caused by insanitary water and inadequate sewage treatment. Infantile mortality is very much higher compared to other age groups at a ratio of more than 9:1. High infantile mortality, as expected, occurs in departments where there are few hospitals, beds, doctors and nurses. Medical condition in Peru which is presently insufficient, will be worsen due to lack of medicine caused by current economic regression of Peru.

Although infantile mortality is lower in Lima than in other departments and nourishment conditions are quite better in comparison to other areas, incidence rates of infectious diseases including water-borne diseases during the last 4 years from 1985 to 1988 are high, some even higher than the nationwide figure. Typhoid and Paratyphoid, Virus-Hepatitis, and Gastroenteritis had the highest rates of incidence among the water-borne and infectious diseases. These diseases particularly occur in high number of cases in children younger than 4 years old.

Results of separate questionnaire surveys conducted recently by the SEDAPAL and the Villareal University epidemiology class indicated an interrelation between the incidence of skin rash and allied diseases in bathers of the coasts near the Surco Outfall, to the pollution of seawater in the marine recreational areas.

Residents of Lima obtain their supply of water from various sources like the systems of the SEDAPAL groundwater from wells, communal faucets, water vendors, etc. Of these, water bought from tank trucks which are stored in cisterns for several days and water taken from some private wells are most likely subject to contamination by causative agents of infectious diseases. As before mentioned, some of the raw sewage is reused for irrigation including vegetable cultivation, a practice which results to the transmittal of infectious water-borne diseases.

S.2.5 Energy Supply Condition

ELECTROPERU is the national agency responsible for policy decisions on plans for the development of sources, generation and supply of power. It distributes power to local agencies, among them ELECTROLIMA, which supplies electricity to the Study Area.

As of 1986, only 41 percent of the country was electrified. Completion of a power supply network that would cover practically the entire country is expected by the year 2000.

Due to the reduction of the equipment capacity caused by various factors, the effective output of power generating facilities is now only about three-fourths of the installed capacity. Occasional planned power cuts occur in the Study Area but there had been no instance when power supply totally stopped over the whole area.

Based on 1987 and 1988 statistics, the SEDAPAL consumed electricity equivalent to approximately 1.5 percent of the total maximum demand on the North-Central grid, the largest in Peru. A sewage treatment plant employing aerated lagoon system with 1.0 m^3/sec capacity would roughly contribute an additional 8 percent to the total consumption of SEDAPAL. Expenditure on electric charges represents 1.6 percent of the total expenses of SEDAPAL, if reserve costs like depreciation is included; otherwise the proportion would be 3.5 percent.

With the apparent power supply shortage in Metropolitan Lima, any planning for pumping stations and treatment facilities must be made in consultation with ELECTROLIMA and that provisions must be made for power outages.

S.2.6 Water Supply System in Metropolitan Lima

The sources of potable water supply for Metropolitan Lima are the Rimac river and wells. Water from the Rimac river is treated at the Atarjea Treatment Plant while groundwater from wells is treated by chlorination in accordance with SEDAPAL standards. Based on records of the SEDAPAL, the combined production of the sources between January 1988 and February 1989 averaged about 20.5 m^3/sec/day.

The SEDAPAL system currently supplies water to about 5 million of the 6.5 million inhabitants of Metropolitan Lima, indicating a service coverage of 77 percent. Average per capita consumption based on the total population and water actually consumed is 244 l/day. Unaccounted for water is approximately 13.5 percent of the total volume supplied.

In particular, the water supply to the Surco drainage area which also comprises the Study Area is under the responsibility of SEDAPAL. Amount of water supplied to the drainage area in 1989 was 5.1 m^3/sec.

S.2.7 Other Infrastructures

Networks of air, overland and maritime transportation centered around Lima link the major Peruvian cities. Air transport routes radiate from the Jorge Chavez International Airport in Lima. A railroad line used mainly for cargo transport passes through a central station in Lima. The construction is underway for an urban railway, principally for the carriage of passengers connecting the southern part of Lima to the central area. Most important highway networks in the country are the Pan-americana along the coast and the Central Highway which crosses the Andes from Lima and branches inland. In maritime transportation, the largest terminal for domestic and overseas maritime transport in Peru is the port of Callao in Lima.

The around 2,200 km Peruvian coastline has numerous fishing harbors and ports, 15 of which are classified as principal ports. Port of Callao, being the principal port of entry, handles the bulk of the import and export cargoes. Establishments dependent on the fishing industry also abounds in the said port. Chorillos, a port near the Study Area unloads tons of fresh fish mainly for the consumption of Lima. The largest petroleum refinery in Peru, which supplies the fuel requirements of the port of Callao and the Jorge Chavez International Airport, is located in Ventanilla which is located north of Callao.

In the Study Area, patches of the surrounding desert are being developed through conversion to agricultural lands or green areas. Works are in progress by a relevant government agency to provide several large public parks with ample green areas.

CHAPTER 3

EXISTING SEWERAGE SYSTEM

CHAPTER S.3 EXISTING SEWERAGE SYSTEM

S.3.1 Master Plan of Sewerage System

The master plan for the sewerage system of Lima, first developed in 1945, had undergone changes on many occasions. Most recent of these revisions is the total restructuring of the master plan for the water supply and sewerage system of Lima done in 1981 through the financial assistance of the International Bank for Reconstruction and Development (IBRD). A related project, the feasibility study for recycling sewage to irrigate part of the arid zone south of Lima, was carried out in 1985. Results of these currently in force master plan and feasibility study formed the bases for studies under this Project.

The 1981 water supply and sewerage system master plan study including an investigation into the recycling of treated waste water, which was prepared by the Engineering Science Inc., covers 580 square kilometers of Metropolitan Lima. Planning period extends 30 years from 1981 to 2010, within which span of time the population in the planning area was projected to grow from 5.0 million in 1980 to 15.2 million in 2010. Average sewage quantity was estimated to increase from 13.8 m^3/sec in 1980 to 31.3 m^3/sec (if special control is adopted) or 36.8 m^3/sec (if there is no special control). Maximum daily sewage flow was taken as 110 percent of the average. Important features of the master plan are: i) the flow direction of the Surco sewer system is maintained but all sewage discharge to rivers and sea will be intercepted, ii) by the year 2000, 11.2 m^3/sec of sewage will be recycled as groundwater recharge, and for agriculture and parks irrigation, iii) remaining unrecycled sewage will be discharged to the sea through submerged pipes after primary treatment, iv) sewage not connected to the public sewerage system, which is estimated to reach 1.8 m^3/sec in the year 2000, will be treated in an oxidation lagoon and emptied into nearby canals, v) considerable length of pipes with diameter greater than 350 mm are planned to be installed, and vi) the construction of a 4 m^3/sec or 5 m^3/sec capacity treatment plant together with a conveyance system for the transport of sewage for irrigation.

The feasibility study for recycling sewage for irrigation purposes was undertaken by the TAHAL Consulting Engineers Inc. with financial assistance from the Inter American Development Bank. the project involves treatment and conveyance of sewage from the Surco main sewer for the irrigation of around 5,000 hectares of desert in the San Bartolo plain. After a study of several alternatives. The scheme found to be most attractive is a system with, i) a capacity of 2.4 m^3/sec, ii) combined gravity and pumped transmission line from the intake point at San Juan primary treatment facility to San Bartolo plain consisting of buried steel pipe and open channel, and iii) primary treatment through sedimentation in nearby open lands and park, and secondary treatment by aeration lagoon in San Bartolo. Except for the intake amount and transmission route, this present Study and that of the TAHAL study are fundamentally the same.

S.3.2 Sewer Systems

The existing sewerage system of Metropolitan Lima is able to serve the entire urban areas of Lima and Callao but the sewer network in other parts is insufficient. In old sections of the city, particularly, sewer lines are so deteriorated by antiquity that breaks often occur. Frequent street flooding also occurs due to the insufficiency of the drainage capacity of sewers caused by the increase in sewage discharge. Parts of the sewer network, notably that on the northern and southern outskirts of the city, are currently being expanded.

The public sewerage system which is shown in FIGURE S-1, consists of 7 drainage areas, namely: Comas, Callao, Costanero, Surco, Area No.6, San Martin/Rio Bamba, and San Juan Miraflores. In areas where such public facility is not available, large establishments like factories and commercial centers have their own sewerage system. Operation of the system is mostly by gravity except in some low-lying areas where pumps are employed. Pertinent data on the drainage areas are outlined in TABLE S-1. Surco drainage area, which is the largest in the system and subject of the Study, has about 30 sewer lines flowing into the Colector Surco, the drainage area's trunk sewer. Colector Surco empties to the sea in the vicinity of "Punta la Chira".

TABLE S-1 Pertinent Data on Drainage Area

NAME	DRAIN.AREA (ha)	MAIN SEWER	DIA. (mm)	LENGTH (m)	CAPACITY (m^3/sec)	DISCHARGE (1988) daily avg.(m^3/sec)	REMARKS
Comas	4,000	Colector Comas	1,200 - 350	64,452	4.00	1.700 (1.70)	
Callao	5,100	Colector Centenario	1,300 - 350	61,050	6.27	3.016 (3.70)	
Costanero	4,000	Colector Costanero	1,300 - 350	63,350	4.34	3.038 (3.30)	
Surco	11,900	Colector Surco	2,100 - 350	144,091	10.77	4.770 (5.70)	Disc. 5.359 (1989)
No.6	2,300	Colector No.6	1,500 - 350	34,221	4.60	1.530	
San Martin Rio Bamba	700	Colector Conde Villa Zarumilla	900 - 350	11,106	0.32	0.280 0.210	2 outfalls
San Juan	800	Colector San Juan	700 - 350	5,730	0.38	-	Disc. 0.275 (1989)
TOTAL	28,800	-	-	384,000	-	-	

Source: SEDAPAL Measuring Date: 9/23/1988, June/1989

* Values in parenthesis are estimated.

It is estimated that half of the water produced from the private wells are discharged into the public sewerage system. Based on the results of the latest investigation conducted by the SEDAPAL, the Surco drainage area absorbs 0.32 m^3/sec of industrial wastewater from 249 factories.

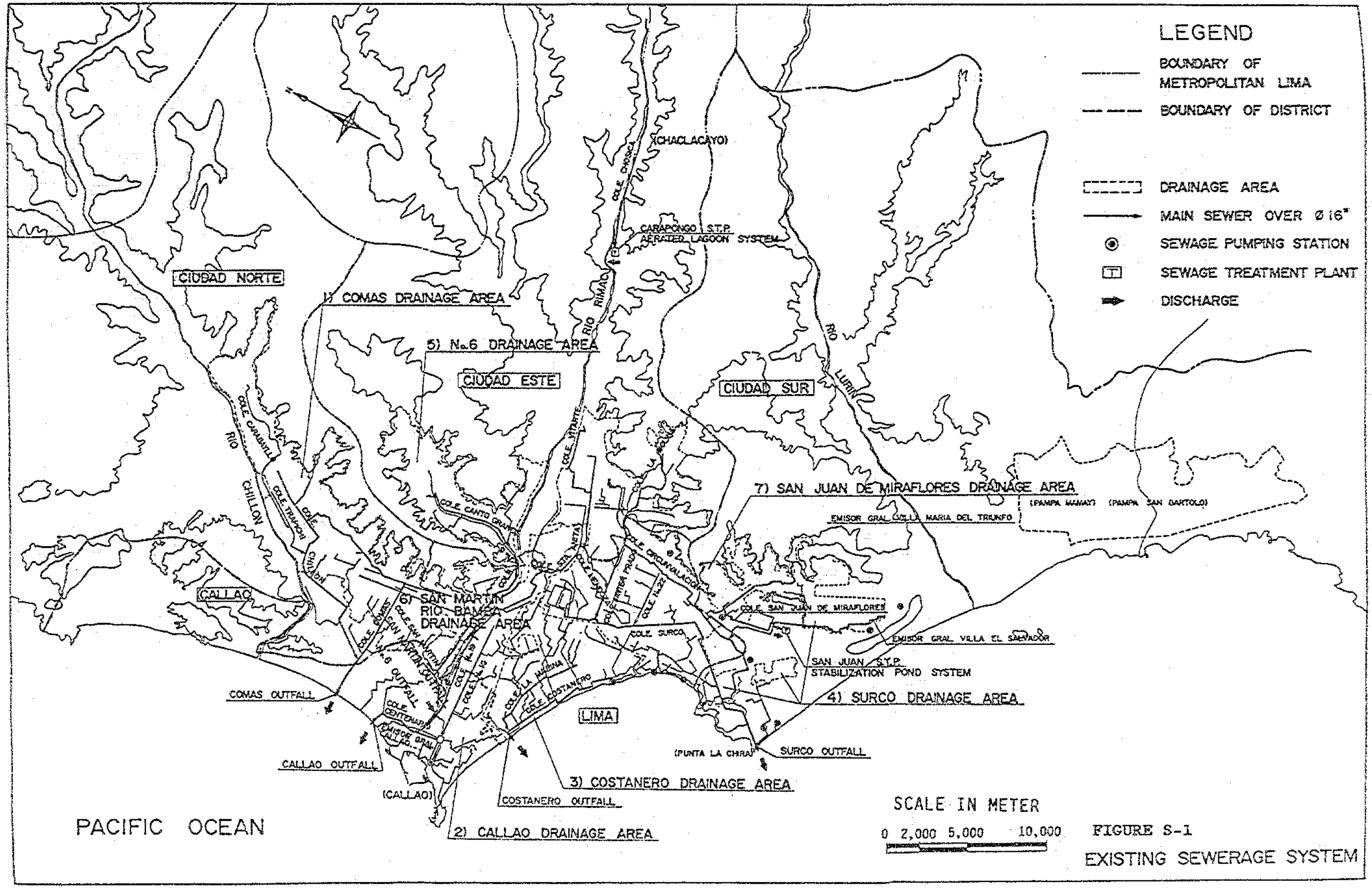


FIGURE S-1
EXISTING SEWERAGE SYSTEM

S.3.3 Sewage Pumping Stations

There are around 30 sewage pumping stations installed at some low-lying branch sewer lines where sewage cannot be conveyed to the mains by gravity flow. Pertinent data on these pumping stations are outlined in TABLE S-2. Several other sewage pumping facilities are under construction. Submersible sewage pumps are normally used for smaller facilities while vertical shaft centrifugal pumps are used for medium and large facilities. In principle, automatic operation is adopted but due to breakdowns, pumps are often operated manually. There are no facilities for measurement of flow, hence discharge is calculated from the duration of pump operation. All pumping stations are operated using commercial power supply, although a few of them are equipped with emergency units for use during periods of outages. Most of the stations using vertical pumps are provided with manual rakes for screens but none of them have grit chambers.

TABLE S-2 Pertinent Data on Sewage Pumping Station

No.	Name	District	Design Flow Rate (l/s)	Capacity of Pump (φ)	Total Electrical Capacity (kW)	Installed Year	Remarks
1	M. de la Marina	Miraflores	300	200 x 150 l/s 2sets	113	1983	operation
				150 x 80 l/s 1set			
2	B. Baños de Barranco	Barranco	50	100 x 25 l/s 3sets	54	1983	operation
3	Domosola	Miraflores			3		
4	Malecon Armendariz	Miraflores			75		
5	Malecon Iglesias	Chorrillos	40	125 x 40 l/s 2sets	18	1985	operation
6	Matellini	Chorrillos	25	100 x 25 l/s 2sets	22		operation
7	C.C. La Laguna 1	La Molina		80 x l/s 1set	24		operation
				100 x l/s 1set			
8	Los Alamos	Surco					
9	San J. de Miraflores	Sn.J.de Miraf.			150		
10	Canto Grande	Canto Grande					
		Parque El Bosque					
11	Pro	Sn.M.de Porras					
12	Cocharcas	Chorrillos		100 x l/s 2sets	90		operation
13	Sta. Leonor	Chorrillos		80 x l/s 2sets	8		operation
14	Laguna de la Molina	La Molina		80 x l/s 2sets	3		operation
15	Jose Olaya	Surco		80 x l/s 1set	2		operation
16	Marbella	Magdalena					
	del Mar		50	100 x 25 l/s 2sets	45		operation
17	Cedros de Villa	Chorrillos	270	200 x 90 l/s 3sets	111	1986	operation
18	S.Ignacio de Loyola	Sn.J.de Miraf.		80 x l/s 2sets	4		operation
19	Camara Unica						
	del Callao	Callao	948	300 x 316 l/s 4sets	450	1954	operation
20	Camara No.2	V.El Salvador	30	100 x 15 l/s 3sets	41	1983	operation
21	Camara No.3	Lurin	15	100 x 15 l/s 1set	9		operation
22	Camara No.4,						
	Pachacamac	V.El Salvador	100	150 x 50 l/s 3sets	165	1984	operation
23	Camara No.5	Virgen de Lourdes	12	100 x 12 l/s 2sets	18		operation

Source: SEDAPAL

S.3.4 Sewage Treatment Plants

Sewage treatment facilities in Metropolitan Lima consists of the San Juan Sewage Treatment Plant, Carapongo Sewage Treatment Plant, and several waste stabilization ponds.

San Juan STP, located in the southern part of Lima within the Study Area, operates as a facultative pond with the treated water being reused for irrigation. It is the center in South America for studies and experiments conducted on subjects concerning sewage treatment. The plant consists of 2-cell facultative ponds having a total area of 22.1 ha (8.9 primary and 13.2 secondary). Numerous reports have been made on the San Juan STP by the Pan-America Center for Sanitary Engineering and Environmental Sciences (CEPIS) and useful data and information have been provided with regard to items like design methods and removal of parasites and bacteria. For example, one such report recommended an areal BOD loading of under 400 kg-BOD/ha/day on primary pond from the climate condition in Peru, as a result of long-term research done in the San Juan STP. In comparison, high areal BOD loads are experienced in its operation, resulting to the emission of strong odor from the primary ponds particularly in winter when the temperature is low. Deposited sludge in the primary ponds is removed once every 5 years and once every 7 years in secondary ponds.

Carapongo STP treats sewage from the districts of Chosica and Chaclacayo which are located 20 km from Lima upstream of the Rimac river. Design capacity of this plant is 24,000 m^3/day, of which facilities to take care of half this design capacity have been completed. Method of treatment being employed in these existing facilities is the aerated lagoon system; the use of oxidation ditch process is being considered for its future expansion. The STP is composed of a grit chamber, facultative aerated lagoon, sedimentation pond, and chlorination tank. Design influent water quality is 200 mg/l for both BOD5 and SS. Except for the abnormal generation of algae during the early days in operation, and the much accumulation of sludge especially in the upstreammost lagoon, the treatment plant is in generally good operational condition.

Apart from the San Juan STP, there are three other existing waste stabilization ponds in the southern part of Lima while treated water are all utilized for irrigation. Additionally, one other such treatment facility is under construction while another is still in the planning stage.

CHAPTER 4

POPULATION

CHAPTER S.4 POPULATION

S.4.1 Past Demographic Trends

Population of Peru and Metropolitan Lima for the years 1940, 1961, 1972 and 1981 as adjusted and interpolated from official census records of the Institute Nacional de Estadistica (INE) are shown in TABLE S-3. As indicated, the population of Peru for said years were around 7.08 million, 10.22 million, 13.95 million, and 17.75 million, compared to that of Metropolitan Lima which were about 0.65 million, 2.36 million, 3.42 million and 4.84 million, respectively.

TABLE S-3 also significantly shows a large influx of people from the rural areas to Lima from 1940 to 1961, which trend still continues to this time but at a diminished rate except in the fringe areas of the city and in "Pueblo Jóvenes".

S.4.2 Projection of the Future Population

Various entities including the SEDAPAL, INE, Engineering-Science Inc., and TAHAL Consulting Engineers Inc., have developed population projections for Metropolitan Lima. The bases of all these projections were the past census records, the latest of which was that for 1981. Although it is believed that these population studies may have been valid at the time they were prepared, such projections seem unreliable under current conditions, considering the length of time since the last census was taken and the apparent abnormal increase in population between 1981 and the present. Thus, the Survey Team attempted to calculate the future population of the Study Area based on the data of the last three census years employing different mathematical methods, namely: Logistic Curve, Exponential Curve, and Geometrical Methods.

Results of the analyses were compared with each other as well as with the projection of INE and consequently the mean values for each district obtained from the three calculation methods were adopted for the planning of this Project. However, for those districts where the calculated growth rates are absurd, values obtained from other formulas which are regarded as appropriate are adopted instead. The projected population of Metropolitan Lima based on this manner of calculation is as follows:

Year	Population
1989	5,993,400
1990	6,145,200
1995	6,899,300
2000	7,661,400

The above figure for 1990 as well as that which concerns solely the population for the 16 districts of Surco drainage area agree closely with the INE projection.

TABLE S-3 Estimated Population by District

DISTRICT	1940	1961 1/	1972	1981 2/
LIMA	276,734	262,400	366,501	390,513
ANCON	1,428	4,000	5,792	8,865
ATE	11,061	80,900	63,235	138,746
BARRANCO	19,162	43,700	50,746	48,907
BRENA	-	102,800	116,031	118,271
CARABAYLLO	12,317	43,500	28,981	55,558
CHACLACAYO	1,160	9,600	22,195	33,243
CHORRILLOS	7,244	33,300	94,088	149,294
CIENEGUILLA	-	1,300	2,628	4,783
COMAS	-	97,400	179,819	297,870
EL AGUSTINO	-	77,100	121,445	176,537
INDEPENDENCIA	-	85,100	113,827	144,918
JESUS MARIA	-	86,600	86,991	87,525
LA MOLINA	-	2,100	6,218	29,786
LA VICTORIA	56,947	201,800	274,735	284,922
LINCE	26,443	84,800	85,878	84,660
LURIGANCHO-CHOSICA	7,731	33,500	53,220	68,542
LURIN	3,817	6,400	13,259	18,104
MAGDALENA DEL MAR	16,574	57,400	58,816	58,437
PUEBLO LIBRE	6,184	70,600	80,864	88,374
MIRAFLORES	46,757	91,100	103,235	108,859
PACHACAMAC	3,711	12,100	4,705	7,134
PUCUSANA	-	1,800	2,941	4,319
PUENTE PIEDRA	2,625	8,600	19,616	35,694
PUNTA HERMOSA	-	300	940	1,063
PUNTA NEGRA	-	400	768	582
RIMAC	58,841	148,600	178,538	194,123
SAN BARTOLO	-	1,000	1,518	3,067
SAN BORJA 3/	-	53,600	68,862	59,270
SAN ISIDRO	9,082	39,000	65,513	72,706
S.J. DE LURIGANCHO	-	23,300	90,393	272,943
S.J. DE MIRAFLORES	-	64,000	110,833	174,426
SAN LUIS	-	8,600	25,072	53,306
SAN MARTIN DE PORRES	-	99,900	239,973	426,010
SAN MIGUEL	4,115	23,900	65,559	104,405
SANTA MARIA DEL MAR	-	100	46	101
SANTA ROSA	-	100	226	518
SANTIAGO DE SURCO	7,397	46,600	69,817	147,105
SURQUILLO	-	23,500	29,792	98,269
VILLA EL SALVADOR 4/	-	-	-	142,567
V.M. DEL TRIUNFO	-	94,800	188,115	187,878
Sub Total (PROV. LIMA)	579,330	2,125,600	3,091,731	4,382,200
CALLAO	72,441	124,600	205,631	270,499
BELLAVISTA	8,580	44,300	41,239	69,148
CARMEN DE LA LEGUA	-	18,300	26,977	39,498
LA PERLA	-	22,000	34,627	48,362
LA PUNTA	3,686	6,100	6,916	6,416
VENTANILLA	-	17,200	17,341	20,177
Sub Total (PROV.CALLAO)	84,707	232,500	332,731	454,100
TOTAL (METRO. LIMA)	664,037	2,358,100	3,424,462	4,836,300
PERU 2/	7,080,000	10,217,500	13,954,700	17,754,800
Proportion of Metro. Lima	9.38%	23.08%	24.54%	27.24%
Average Annual Growth Rate of Lima		6.39%	3.46%	3.95%
- do - Callao		4.93%	3.31%	3.52%
- do - M.Lima		6.22%	3.45%	3.91%
- do - Peru		1.76%	2.87%	2.71%

1/ SEDAPAL (Adjusted the influence of independence of new districts)
2/ Proyecciones de Poblacion por Años Calendarios (Boletin Especial No.10), Dec.1986, INE
3/ Summation of a part of Santiago de Surco and Surquillo in proportion to belonging area before independence
4/ Adjusted with V. M. del Triunfo

S.4.3 Projected Population Within Surco Drainage Area

The population projection for the Surco drainage area based on the correlation of the area and population of related districts and that of the area of the Surco drainage area itself is given in TABLE S-4. As indicated, the estimated population is 1,732,500 for 1989 and 2,687,100 for the year 2000, an increase of 55.1 percent in 11 years or an average annual growth rate of 4.1 percent. This growth rate is high compared to that of the rest of Metropolitan Lima, owing to the presence of the "Pueblos Jóvenes."

The projected population of the Surco drainage area is further broken down into three categories in accordance with the type of water supply and water consumption amount defined in the report for the Master plan of Lima Sewerage System as follows:

Direct Service High Consumption Group - D/S.H
Direct Service Low Consumption Group - D/S.L
Indirect Service Group - ID

The population data corresponding to each category and district for the same periods are listed in TABLE S-5.

TABLE S-4 PROJECTED POPULATION (SURCO DRAINAGE AREA)

DISTRICT	TOTAL AREA (ha)	SURCO D.(%) 1/ 1989	SURCO D.(%) 1/ 2000	POP. R. (%) 2/ 1989	POP. R. (%) 2/ 2000	1989	1990	1991	1992	1993	1994	1995
LIMA	2,121	2	2	2	2	8,100	8,200	8,200	8,200	8,300	8,300	8,300
ATE	9,822	8	39	50	70	81,000	85,400	89,900	94,600	99,400	104,200	109,100
BARRANCO	273	100	100	100	100	48,100	48,000	47,900	47,900	47,800	47,700	47,700
CHORRILLOS	3,681	25	81	90	95	159,100	161,800	164,400	166,700	168,900	171,000	172,800
EL AGUSTINO	1,836	19	21	50	60	102,600	106,100	109,600	113,100	116,600	120,000	123,400
LA MOLINA	4,169	35	60	80	90	66,400	74,900	84,200	94,300	105,300	117,300	130,100
LA VICTORIA	909	93	93	93	93	270,900	271,600	272,100	272,800	273,300	273,900	274,400
MIRAFLORES	912	45	45	45	45	50,900	51,100	51,300	51,600	51,800	52,000	52,200
SAN BORJA	1,046	100	100	100	100	56,800	56,700	56,500	56,300	56,200	56,100	56,000
SAN ISIDRO	1,007	27	27	27	27	21,000	21,100	21,200	21,400	21,500	21,700	21,800
S.J. DE MIRAFLORES	2,351	40	86	41	85	100,700	114,600	129,300	144,700	161,000	178,000	195,900
(SAN JUAN STP) 3/	(850)	(36)	(36)	(37)	(36)	(91,000)	(94,200)	(97,400)	(100,600)	(103,800)	(107,000)	(110,100)
SAN LUIS	356	100	100	100	100	64,100	65,000	65,800	66,500	67,200	67,700	68,200
SANTIAGO DE SURCO	3,493	77	91	95	100	191,000	200,900	211,200	221,700	232,600	243,700	255,100
SURQUILLO	413	100	100	100	100	101,200	101,600	101,900	102,100	102,400	102,500	102,700
VILLA EL SALVADOR	3,368	28	78	90	95	225,900	241,500	257,600	274,100	291,000	308,200	325,800
V.M. DEL TRIUNFO	7,149	18	39	90	95	275,700	292,200	309,000	326,300	343,800	361,700	379,800
TOTAL	42,906	-	-	-	-	1,823,500	1,900,700	1,980,100	2,062,300	2,147,100	2,234,000	2,323,300

DISTRICT	1996	1997	1998	1999	2000
LIMA	8,400	8,400	8,400	8,500	8,500
ATE	114,200	119,400	124,700	130,100	135,600
BARRANCO	47,600	47,600	47,500	47,500	47,400
CHORRILLOS	174,600	176,300	177,900	179,400	180,900
EL AGUSTINO	126,700	130,000	133,300	136,600	139,700
LA MOLINA	144,100	159,200	175,300	192,700	211,300
LA VICTORIA	275,000	275,600	276,100	276,600	277,100
MIRAFLORES	52,400	52,600	52,800	53,000	53,200
SAN BORJA	55,800	55,700	55,600	55,600	55,500
SAN ISIDRO	21,900	22,100	22,200	22,300	22,400
S.J. DE MIRAFLORES	214,600	234,200	254,800	276,200	298,500
(SAN JUAN STP) 3/	(113,300)	(116,500)	(119,700)	(122,900)	(126,100)
SAN LUIS	68,600	68,900	69,300	69,500	69,800
SANTIAGO DE SURCO	266,800	278,700	290,900	303,300	315,900
SURQUILLO	102,800	102,900	103,000	103,000	103,100
VILLA EL SALVADOR	343,700	362,100	380,700	399,600	419,000
V.M. DEL TRIUNFO	398,400	417,200	436,200	455,600	475,300
TOTAL	2,415,600	2,510,900	2,608,700	2,709,500	2,813,200

Note: 1/ Area collected by Surco Interceptor in each district
2/ Ratio of population collected by the Colector Surco in each district. Ratios from 1990 to 1999 are interpolated.
3/ Values for S.J. de Miraflores includes those of existing San Juan STP. Those are presented in parenthesis.

TABLE S-5 *DISTRIBUTION OF POPULATION BY DISTRICT*

NAME OF DISTRICT	1989 (A) ESTIMATED POPULATION	1989 SERVICE LEVEL DS/H	1989 SERVICE LEVEL DS/L	1989 SERVICE LEVEL ID	2000 (B) PROJECTED POPULATION	2000 SERVICE LEVEL DS/H	2000 SERVICE LEVEL DS/L	2000 SERVICE LEVEL ID	RATE OF INCREASE (B/A)
Lima	8,100	5,240	2,140	720	8,500	5,500	2,250	750	1.05
Ate	81,000	29,960	45,440	5,600	135,600	50,180	75,950	9,470	1.67
Barranco	48,100	26,960	14,450	6,690	47,400	26,560	16,150	4,690	0.99
Chorrillos	159,100	31,720	73,130	54,250	180,900	36,200	126,630	18,070	1.14
El Agustiuno	102,600	13,480	48,370	40,750	139,700	18,330	107,430	13,940	1.36
La Molina	66,400	59,760	6,640	0	211,300	190,200	21,100	0	3.18
La Victoria	270,900	197,810	46,170	26,920	277,100	202,330	47,220	27,550	1.02
Miraflores	50,900	39,640	11,260	0	53,200	41,440	11,760	0	1.05
San Borja	56,800	29,540	23,290	3,970	55,500	28,860	22,760	3,880	0.98
San Isidro	21,000	17,010	3,990	0	22,400	18,150	4,250	0	1.07
S.J.de Miraflores	100,700	15,110	77,560	8,030	298,500	44,800	229,810	23,890	2.96
(San Juan STP)	(91,000)	(13,600)	(70,120)	(7,280)	(126,100)	(18,840)	(97,170)	(10,090)	(1.39)
San Luis	64,100	34,750	21,070	8,280	69,800	37,840	25,100	6,860	1.09
Santiago de Surco	191,000	80,170	93,610	17,220	315,900	132,680	154,830	28,390	1.65
Surqillo	101,200	61,750	33,330	6,120	103,100	62,900	33,950	6,250	1.02
Villa El Salvador	225,900	2,370	169,370	54,160	419,000	8,450	335,260	75,290	1.85
V.M.del Triunfo	275,700	8,380	237,150	30,170	475,300	14,330	413,490	47,480	1.72
TOTAL	1,823,500	653,650	906,970	262,880	2,813,200	918,750	1,637,940	258,510	1.55
Ratio (%)	100	36	50	14	100	33	58	9	

CHAPTER 5

SEWAGE QUANTITY AND QUALITY

CHAPTER S.5 SEWERAGE QUANTITY AND QUALITY

Sewerage flow measurements on the Surco outfall and three planned intake points were conducted during the Study to determine the present sewage discharge amount which would serve as basis, together with the data on population projection, for estimating the amount of sewage discharge in year 2000. Measurements were made under two conditions: one is with the intake from the Rimac river to the Surco river open, and the other with the intake close.

Simultaneous with the flow measurements, sewage water quality analyses were carried out to determine the required capacity of sewage treatment plant. Analyses on Heavy Metals were also performed taking into consideration the possibility of irrigation use.

S.5.1 Present Sewage Quantity

S.5.1.1 Flow Measurements on the Surco Outfall

Sewage flow measurements were conducted two times each at the points shown in FIGURE S-2. It is assumed that the flow of Surco outfall is the sum of the flows of three main sewers, namely: Colector Surco, Colector Circunvalacion and Colector Balnearios del Sur. On the second measurement, the intake gates of the Surco river were closed in order to discount the possible influence of the "acequia" on the sewage flow. Results of these *measurements are summarized in TABLE S-6.*

TABLE S-6 Results of Sewage Flow Measurement at Surco Outfall

unit: m^3/s

	May 31 - June 1, 1989					October 19 - 20, 1989				
	Surco	Circun.	B.Sur	Total Q	Rate	Surco	Circun.	B.Sur	Total Q	Rate
Maximum Qmax	4.929	1.454	0.305	6.569	1.223	4.477	1.612	0.296	6.324	1.274
Average Qavg	4.058	1.134	0.178	5.370	1	3.625	1.157	0.181	4.963	I
Minimum Qmin	2.769	0.839	0.082	3.756	0.699	2.313	0.841	0.076	3.240	0.652

Location of Measuring Point, and Measuring Date and Time

1. Surco: Colector Surco, Diameter 1.54 meters
   Av. Jr Mexico 270, Surquillo
   1st: from 10:00, May 31 10:00, June 1, 1989
   2nd: from 8:45, October 19 to 8:30, October 20, 1989
2. Circun.: Colector Circunvalacion, Diameter 1.31 meters
   Av. Julio Calero 140, Surquillo
   1st: from 10:30, May 31 to 10:30, June 1, 1989
   2nd: from 8:45, October 19 to 8:30, October 20, 1989
3. B. Sur: Colector Balnearios del Sur, Diameter 0.75 meters
   Av. Daniel Portocarrero 264, Surquillo
   1st: from 10:30, May 31 to 10:30, June 1, 1989
   2nd: from 8:45, October 19 to 8:30, October 20, 1989

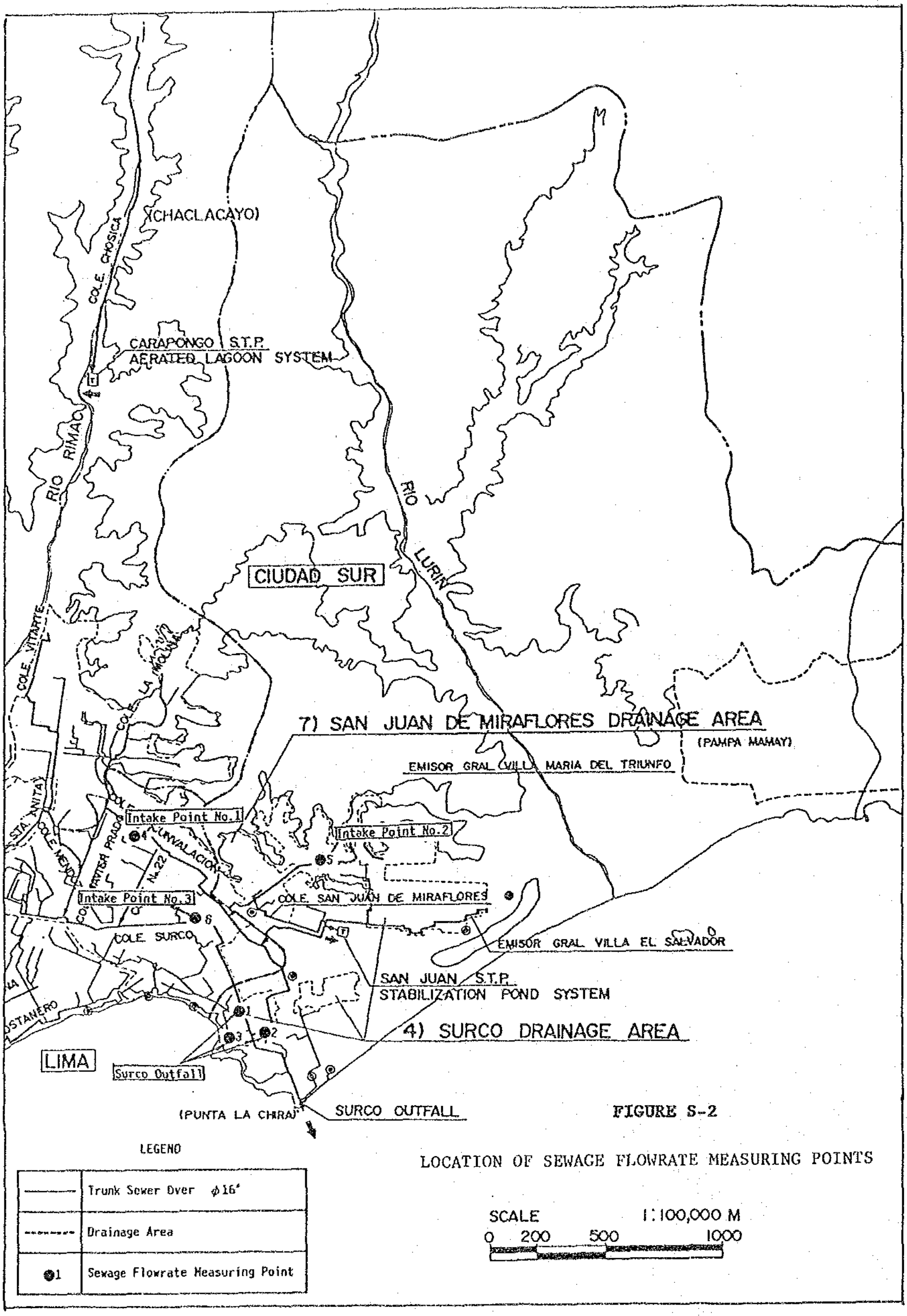


FIGURE S-2

LOCATION OF SEWAGE FLOWRATE MEASURING POINTS

As can be seen from the TABLE S-6, there was a difference of about 0.41 m^3/sec (5.370 m^3/sec in the first as against 4.963 m^3/sec in the second) between the two measured average flows. This difference is attributed to the reduction of sewage discharge due to the decrease in water consumption, and the prevention of intrusion flow from the Surco river. About 0.13 m^3/sec of this is supposed to have been due to lower water consumption as deduced from a comparison of records of amount supplied by the Atarjea Treatment Plant during same period, the balance of 0.28 m^3/sec is attributed to the stoppage of intrusion flow from the Surco river.

The present (1989) average flow was assumed at 5.0 m^3/sec, which is roughly the mean of the first measurement done in this Study (5.37 m^3/sec) and the measurement performed by the SEDAPAL in 1988 (4.77 m^3/sec). Due to obvious reasons, the result of the second measurement made in this Study was disregarded in the reckoning of the average flow.

With reference to the design standard of SEDAPAL, the estimated actual water supply amount, the results of sewage flow measurements, and the guidelines adopted in Japan, the per capita domestic sewage quantity for different service groups is projected as follows:

Service Group	Per Capita Sewage Discharge (lpcd)
Direct Service High Water Consumption	210
Direct Service Low Water Consumption	180
Indirect Service Group	110

Based on the above assumptions and on an estimate of population falling under the respective service category, the estimated domestic sewage quantity for 1989 was 3.62 m^3/sec.

TABLE S-7 Domestic Sewage Quantity (1989)

	Categories D/S.H	D/S.L	ID	TOTAL
Population	639,660	829,320	263,520	1,732,500
Sewage Discharge (lpcd)	210	180	110	
Sewage Quantity (m^3/sec)	1.555	1.728	0.336	3.619

As before mentioned, industrial wastewater and intrusion water were estimated at 0.32 and 0.28 m^3/sec, respectively. Miscellaneous wastewater comprises the 0.78 m^3/sec to complete sewage flow balance of the estimated 5.0 m^3/sec average sewage quantity.

S.5.1.2 Flow Measurements on the Intake Points

Results of flow measurements on three intake points of the Surco outfall given in TABLE S-8, show no unexplainable difference between the two measurements carried out on intake point No. 1 and intake point No. 3. The variances obtained are regarded as normal fluctuations in daily sewage discharge. On the other hand, the very large difference in measurement results for intake point No. 2 can be explained by a sudden decrease in sewage flow due to the shifting of the distribution of water supply to another drainage area.

TABLE S-8 Results of Sewage Flow Measurement

unit: m^3/s

	Intake Point No.1 Circunvalacion				Intake Point No.2 Villa Maria				Intake Point No.3 Surco			
	6/06-07		10/24-25		6/06-07		10/24-25		6/06-07		10/24-25	
	Flow	Rate	Flow	Rate	Flow	Rate	Flow	Rate	Flow	Rate	Flow	Rate
Maximum Qmax	0.6071	1.67	0.6693	1.57	0.2222	1.83	0.0827	1.70	3.3469	1.21	3.1344	1.21
Avarage Qavg	0.3632	1	0.4243	1	0.1209	1	0.0486	1	2.7611	1	2.5751	1
Minimum Qmin	0.1501	0.41	0.2006	0.47	0.0936	0.77	0.0222	0.45	1.5189	0.55	1.5138	0.58

Location of Measuring Point, and Measuring Date and Time

1. Intake Pt. No.1: Colector Circunvalacion, Diameter 1.3 meters
   Parque Fundadores, Av. J. de Aliaga, Santiago de Surco
   1st: from 10:45, June 6 to 10:30, June 7, 1989
   2nd: from 9:45, October 24 to 9:30, October 25, 1989
2. Intake Pt. No.2: Emisor General Villa Maria del Triunfo
   1st: Av. Pachacutec 828, Diameter 1.2 meters
   from 11:15, June 6 to 11:00, June 7, 1989
   2nd: Av. Pachacutec/Jose Carlos Mariategui, Dia. 0.632 meters
   from 9:30, October 24 to 9:15, October 25, 1989
3. Intake Pt. No.3: Colector Surco, Diameter 1.25 meters
   Av. Nueva Tomas Marsano/Jorge Chavez CDA 38
   1st: from 11:00, June 6 to 10:45, June 7, 1989
   (Data at 9:30, 9:45 and 10:15 are interpolated.)
   2nd: from 9:15, October 24 to 9:00, October 25, 1989

S.5.2 Future Sewage Quantity

S.5.2.1 Surco Outfall

Based on the same per capita sewage discharge according to service group adopted for 1989, the sewage quantity in year 2000 is estimated to reach 5.68 m^3/sec.

TABLE S-9 Domestic Sewage Quantity (2000)

	Categories D/S.H	D/S.L	ID	TOTAL
Population	899,290	1,507,860	279,950	2,687,100
Sewage Discharge (lpcd)	210	180	110	
Sewage Quantity (m^3/s)	2.186	3.141	0.356	5.683

Industrial wastewater is expected to increase by 10 percent from the 1989 figure to 0.36 m^3/sec. Intrusion flow which was suspected to have come from the Surco river is eliminated. Quantity of miscellaneous wastewater is projected to decrease to 60 percent of its present level or to 0.47 m^3/sec. The predicted total sewage flow in the year 2000 is therefore 6.51 m^3/sec.

S.5.2.2 Intake Points

Projected available sewage flows at the intake points in the year 2000 are summarized by category in TABLE S-10. Sewage flows are 0.74 m^3/sec at intake point No. 1, 0.92 m^3/sec at intake point No. 2, 2.39 m^3/sec at intake point No. 3, and 2.46 m^3/sec at remaining main sewers.

TABLE S-10 Available Sewage Quantity at Each Intake Point

INTAKE POINT, NAME OF MAIN SEWER	SEWAGE QUANTITY BY CLASSIFICATION (m^3/s)			
	DOMESTIC	INDUSTRIAL	OTHERS	TOTAL
No.1, Colector Circunvalacion	0.651	0.036	0.053	0.740
No.2, Emisor General Villa Maria del Triunfo	0.857	0.000	0.066	0.923
No.3, Colector Surco	1.932	0.264	0.172	2.388
Remaining	2.244	0.035	0.176	2.455
Total Sewage Quantity	5.684	0.355	0.467	6.506

The sewage quantities planned to be taken at the intake point as called for in the selected optimum alternative are 1.0 m^3/sec each at intake point No. 1 and intake point No. 2 in Phase I, and 2.0 m^3/sec at intake point No. 3 in Phase II. This shows that, i) there will be enough sewage flow at intake point No. 3 in the year 2000, ii) available sewage flow at intake point No. 2 will be almost the same as the planned intake amount, and iii) intake point No. 1 will have insufficient flow. It may be possible to secure additional sewage flow for intake point No. 1 through interception of flows from other areas, and if the efficiency of the water supply system is improved. However, due to many unpredictable factors, it is advisable to consider these measures after assessment of actual conditions when the Project is completed. Additionally, if the planned intake quantity cannot be obtained by any of the above measures, pumping sewage from the Colector Surco would be another possible alternative solution.

S.5.3 Present Sewage Quality

S.5.3.1 Biochemical Oxigen Demand (BOD_5) and Suspended Solid (SS)

Summary of past records of the SEDAPAL and results obtained in this Study with regard to the water quality analyses at existing sewage facilities, namely: the main sewers, San Juan STP and Carapongo STP, are as follows:

TABLE S-11 Present Sewage Quality

(unit: mg/l)

Facility	BOD_5		Suspended Solid (SS)	
	Range	Average	Range	Average
Main Sewers	146-333	227	152-289	239
San Juan STP	214-300	252	88-306	221
Carapongo STP	130-280	187	171-590	298

BOD_5 concentration in the Carapongo STP is lower than in other facilities possibly because of the influence of water intrusion from the "acequia".

Colector Surco and Colector Circunvalacion, which raw sewage will be diverted for irrigation reuse in this Project, have the following water quality values:

TABLE S-12 Present Sewage Quality in Main Sewers

(unit: mg/l)

Name of Main Sewer	BOD_5 (mg/l)		SS (mg/l)	
	Range	Average	Range	Average
Colector Surco	231-333	269	241-300	270
Colector Circunvalacion	146-233	185	152-278	228

S.5.3.2 Heavy Metals

Since it is highly possible that treated sewage will be reused for irrigation under this Project, it is important to consider the presence and concentration of heavy metals in sewage. In this regard, Class III of Water Quality Standards is applied for irrigation based on the General Law of Water in Peru.

Results of past analyses (TABLE S-13), including those obtained in this Study, on the raw sewage from Colector Surco and Circunvalacion indicated that except for Lead and Iron, concentrations of all other items were below the limit of the standards. However, it is expected that the

Lead and Iron concentrations in raw sewage will decrease to permissible levels once treated in stabilization ponds. In addition, there has been no reported harm done by heavy metals so far, even though raw sewage is being used for irrigation in many places in Lima.

TABLE S-13 Heavy Metals of Raw Sewage in Main Sewers

Items		Past Record	Analyses Result in this Study	Water Quality Standard *
		Colector Surco	Colector Surco and Circunvalacion	Class - III
Sampling Date		Nov.,1984	Oct.& Nov.,1989	-
Mercury	Hg μg/l	-	0.3 - 1.3	10
Cadmium	Cd mg/l	0.01 - 0.03	0.005 - 0.02	0.05
Lead	Pb mg/l	0.15 - 0.35	0.02 - 0.27	0.1
Chromium	Cr mg/l	-	0.00	1.0
Iron	Fe mg/l	3.2 - 6.25	1.2 - 1.44	1.0
Manganese	Mn mg/l	0.05 - 0.12	0.06 - 0.08	0.5
Copper	Cu mg/l	0.1 - 0.55	0.06 - 0.22	0.5
Zinc	Zn mg/l	0.16 - 0.34	0.32 - 0.53	25
Arsenic	As mg/l	0.02 - 0.04	-	0.2

*: Ley General de Aguas, Decreto Ley No.17752, Nov., 1983, Government of Peru. This law is based on the Standards of EPA, United States.

It may appear from the above analyses that heavy metals in irrigation is not a problem in the planned reuse of treated water for irrigation but considering their long-term effect, it is recommendable that, i) standards for receiving of industrial wastewater be consolidated, and ii) a control system for industrial wastewater quality be established.

S.5.4 Projected Sewage Quality

Projection of sewage quality for the design of sewage treatment plant was investigated and decided in consideration of the present sewage quality in existing facilities and per capita pollutant loading.

Ranges and averages of BOD5 and SS concentrations in existing facilities are given in Subsection S.5.3.1. In determining the pollutant loading per capita, references used were the World Bank Technical Paper and the actual planning values adopted in Japan. Results of calculation for BOD5 concentration of raw sewage are 225 mg/l in 1989 and 240 mg/l in year 2000.

Taking into account the above-mentioned data and considering such other factors as the ratio of flow between the two main sewers under study, the present sewage quality, and the need to provide for a slightly higher value to take care of load fluctuations, the adopted design sewage quality is 250 mg/l for both the BOD5 and SS.

CHAPTER 6

ALTERNATIVES

CHAPTER S.6 ALTERNATIVES

Five alternatives have been studied to establish an appropriate plan for the Project both for improvement of sewerage system and construction of sewage treatment plant. These are further subdivided into subalternatives in accordance with the phased implementation plan. Major differences in the alternatives involve transmission route, existence of pumping station, sewage intake points and sewage amount.

Schematic plan and layout of the different alternatives are drawn in FIGUREs S-3 and S-4.

S.6.1 Principle for Planning

The total amount of raw sewage discharged from the Surco Outfall shall be treated.

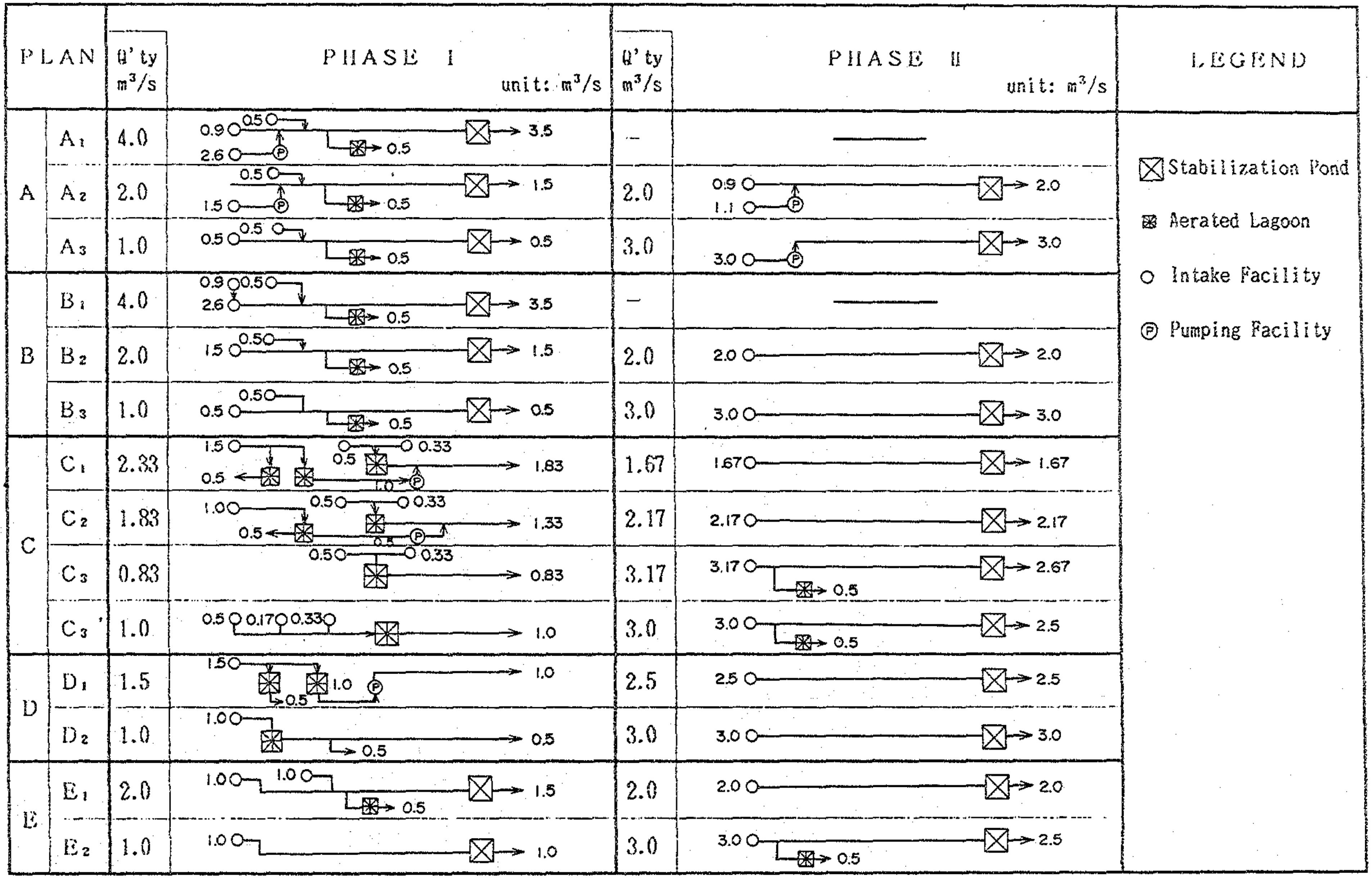
The total outflow was estimated to be 6.5 m^3/sec average in the year 2000. Of this, 4.0 m^3/sec shall be treated in San Bartolo or along the way to San Bartolo to the extent of available land area for treatment facilities (about 0.5 m^3/sec of the treated sewage shall be used to irrigate areas in Villa El Salvador) and the remaining 2.5 m^3/sec shall be treated by optimum treatment method at the Cerro La Chira site owned by SEDAPAL. Raw sewage transmission at San Bartolo shall either be at elevation 100 m or elevation 50 m.

The aerated lagoon method is adopted for the northern area of Rio Lurin (right bank) considering the difficulty of land acquisition with sufficient area, and the stabilization pond method for the southern area (left bank) where land acquisition is easy.

Screen and grit chambers shall be provided at sewage intake facilities to avoid clogging and provisions shall be made at inverted siphon section to remove sand and silt deposits.

Reinforced concrete pipe shall be used for gravity flowing sections; ductile cast iron pipe for inverted siphon sections with pressure over 4 kg/cm^2; prestressed concrete pipe for inverted siphon sections with pressure less than 4 kg/cm^2; fiberglass reinforced plastic mortar pipe for places with high salinity. Concrete lined open channels shall be used for gravity flowing sections located within sparsely populated areas.

FIGURE S-3 · Schematic Plans of Alternatives



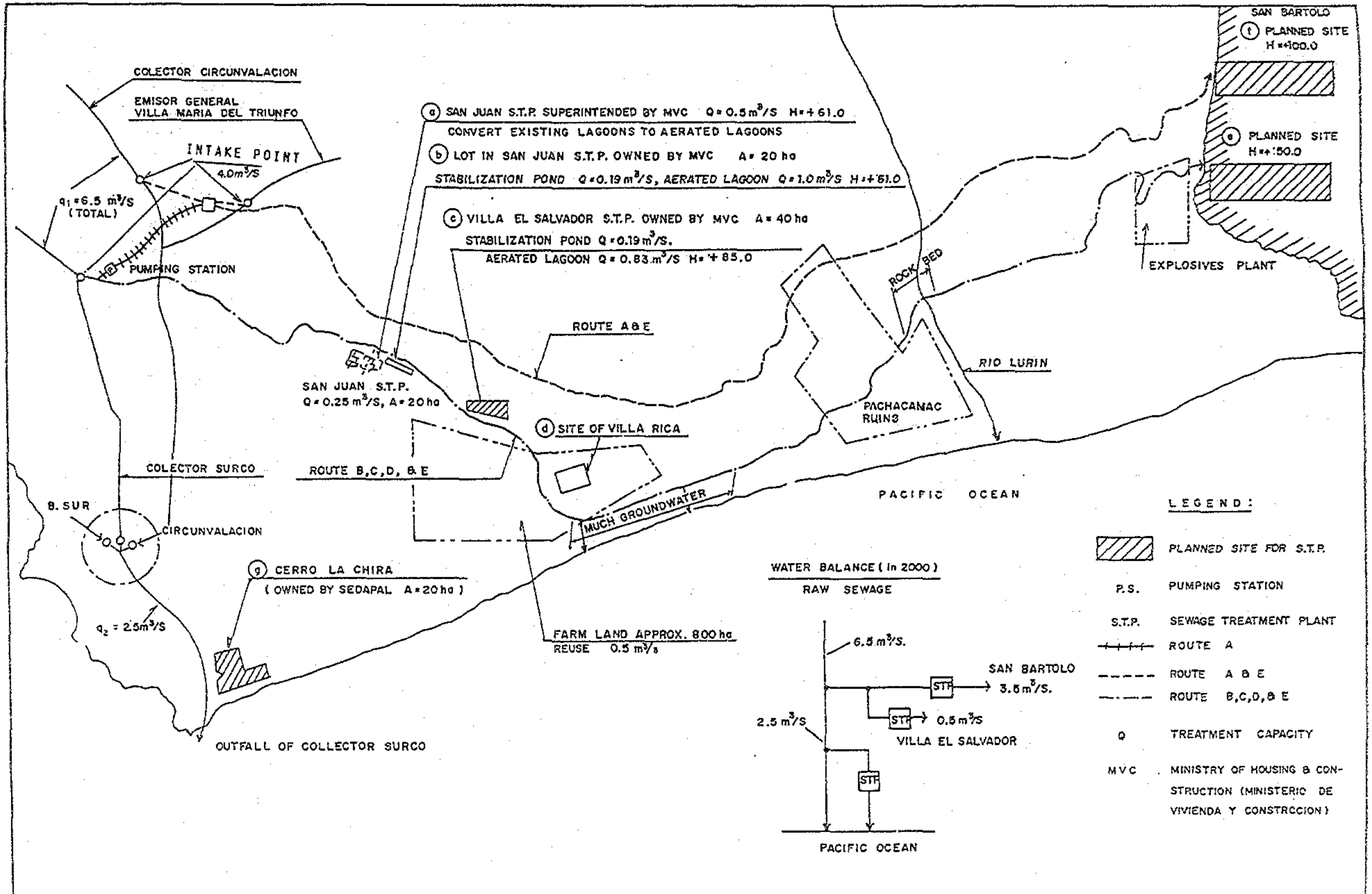


FIGURE S-4 LAYOUT PLAN OF ALTERNATIVES

Prospective sites (Refer to FIGURE S-4 for location) for the treatment plant are as follows:

LOCATION	AREA (ha)	REQUIREMENT FOR ACQUISITION
Existing San Juan STP**	10	Approval of Ministry of Housing & Construction
San Juan	35	Moving of plantation
Villa El Salvador	40	Moving of plantation and school, Existing lagoon
Villa Rica *	40	Large outlay for land acquisition
San Bartolo (Elevation 100 m)	60 x 7	Easy to acquire
San Bartolo (Elevation 50 m)	60 x 7	Easy to acquire
Cerro La Chira **	20	Planned site for future project of SEDAPAL

* Shelved in the meantime because of difficulty in raising necessary funds.

** Reserved for future project of SEDAPAL

The maximum sewage treatment capacity of each proposed site is as follows:

LOCATION	TREATMENT CAPACITY (m^3/sec) STABILIZATION POND	AERATED LAGOON
San Juan S.T.P.	----	0.5
San Juan	0.19	1.0
Villa El Salvador	0.19	1.0
San Bartolo (Elev. 100 m)	0.5 x 7	---
San Bartolo (Elev. 50 m)	0.5 x 7	---

S.6.2 Outline of Alternatives

S.6.2.1 Alternative A (Pumping and Gravity Flow)

Sewage shall be conveyed from the southern part of Lima to San Bartolo at elevation 100 m. This is accomplished by pumping from the diversion points then by gravity through inverted siphons and open channels. Treated water is supplied to the irrigation areas. FIGURE S-5 shows the schematic diagrams of three plans for this alternative.

Sewage treatment plants shall consist of aerated lagoons at Villa El Salvador and stabilization ponds at San Bartolo.

S.6.2.2 Alternative B (Gravity Flow)

Sewage shall be conveyed from the southern part of Lima to San Bartolo at elevation 50 m. Sewage is transmitted by gravity from San Juan via Villa El Salvador, Lomo de Corvina Beach and Pachacamac up to San Bartolo where it will be treated and reused for irrigation. Schematic diagram of this alternative is illustrated in FIGURE S-6. Sewage treatment plants shall be of the same methods as in Alternative A. Approval for passage through the Pachacamac Ruins and the Explosives Plant has not been obtained. However, it will be possible after settling of several problems.

S.6.2.3 Alternative C (Gravity Flow and Pumping)

Sewage from the southern part of Lima is first treated at the right bank of the Rio Lurin to the extent facilities for water treatment will allow, then conveyed to San Bartolo at elevation 50 m (Phase I). Treatment plants shall be erected in San Bartolo like in Alternate B to take care of the remaining sewage water (Phase II). FIGURE S-7 shows the schematic arrangement under several plans or subalternatives.

S.6.2.4 Alternative D (Gravity Flow and Pumping)

Alternative D is basically the same as Alternate C except the location of the treatment plant. FIGURE S-8 shows the schematic diagram of the proposed system.

S.6.2.5 Alternative E (Gravity Flow)

Sewage from the southern part of Lima is transmitted to San Bartolo, treated, and supplied for irrigation. In Phase I, the target elevation at San Bartolo is 100 m whereas in Phase II, Elevation 50 m (FIGURE S-9). This alternative was made considering the advantages of alternative A and B.

S.6.3 Summary of Planned Sewage Quantity

The sewage quantity for each alternative is summarized in TABLE S-14.

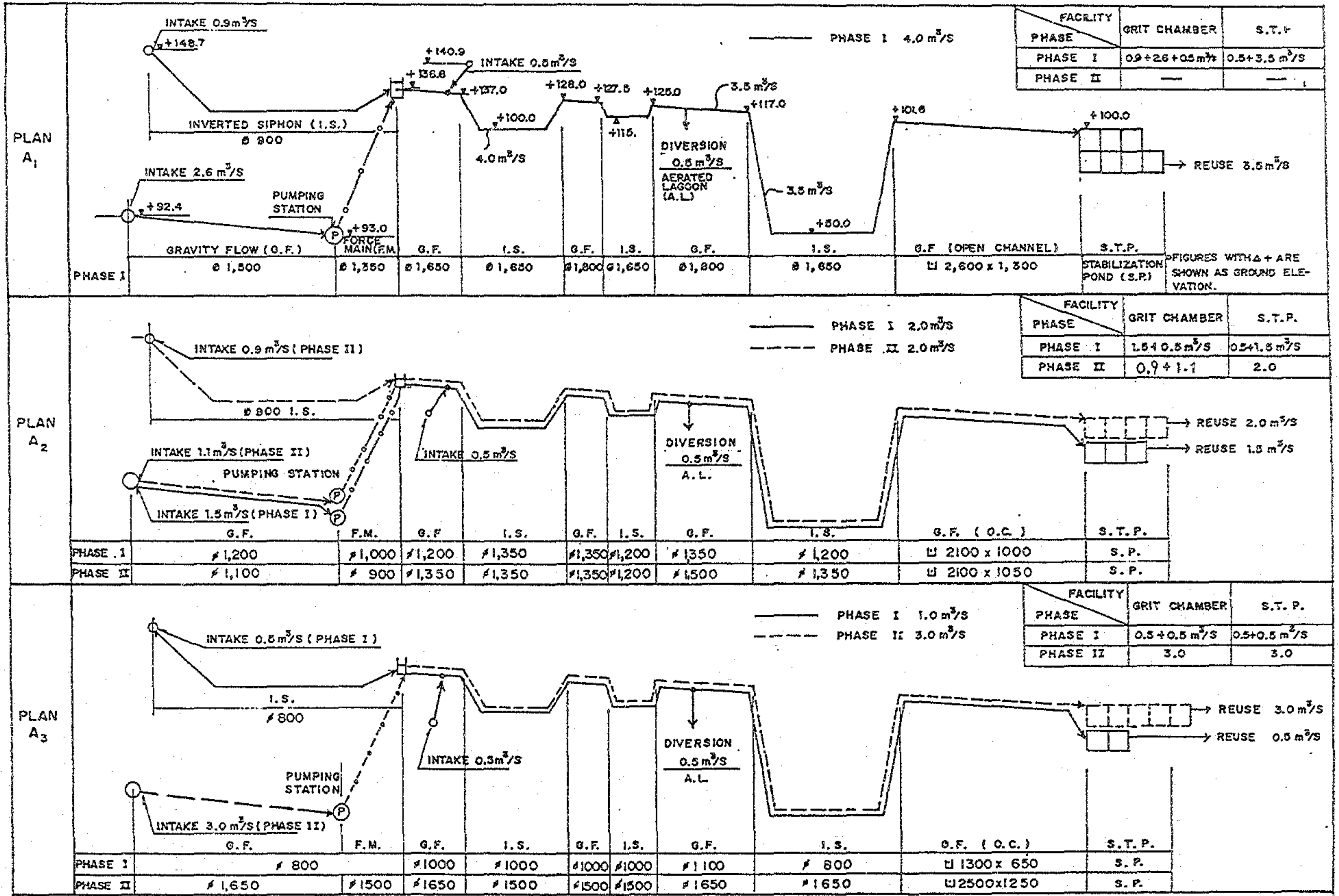


FIGURE S-5 ALTERNATIVE-A (PUMPING & GRAVITY)

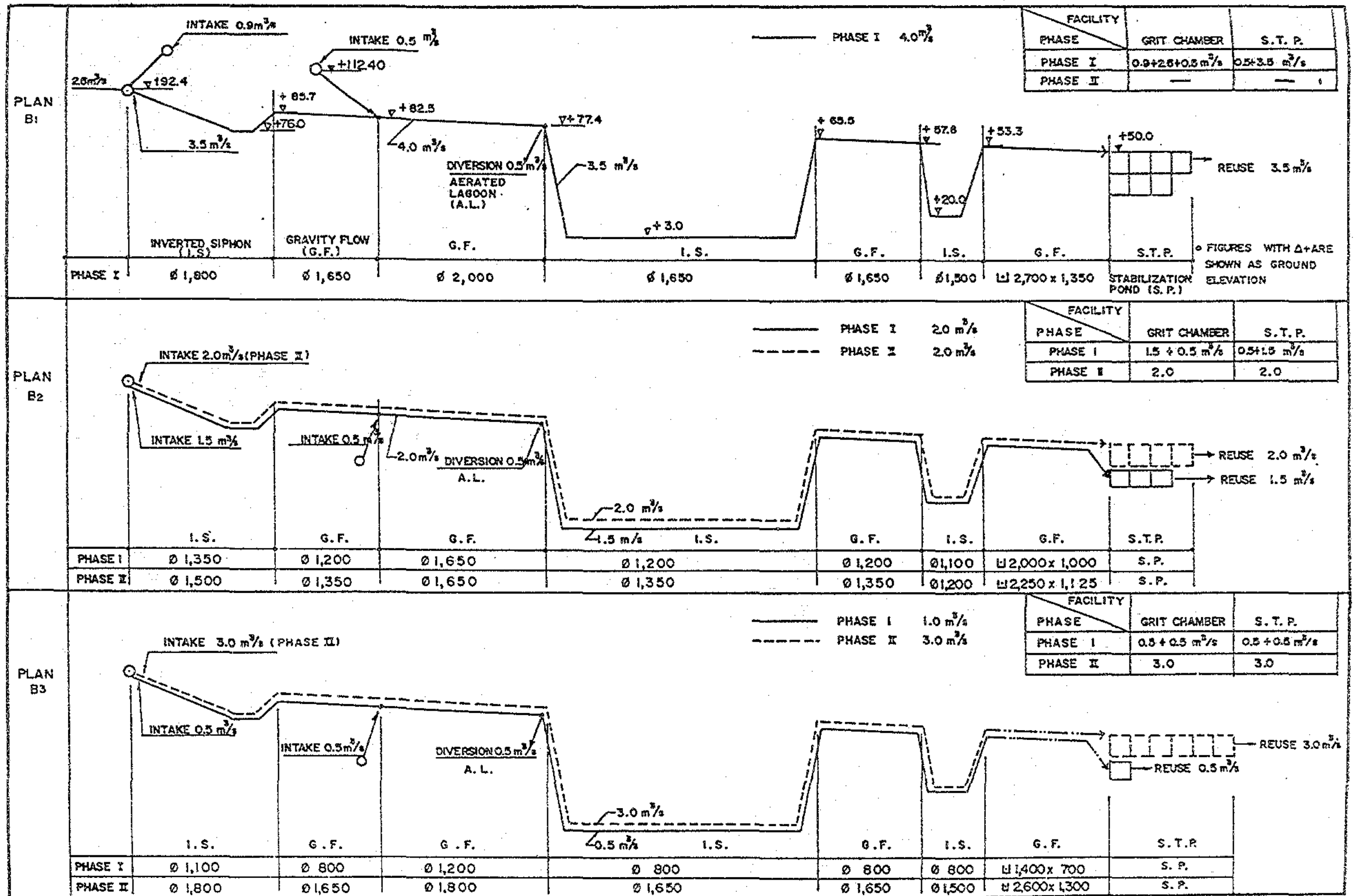
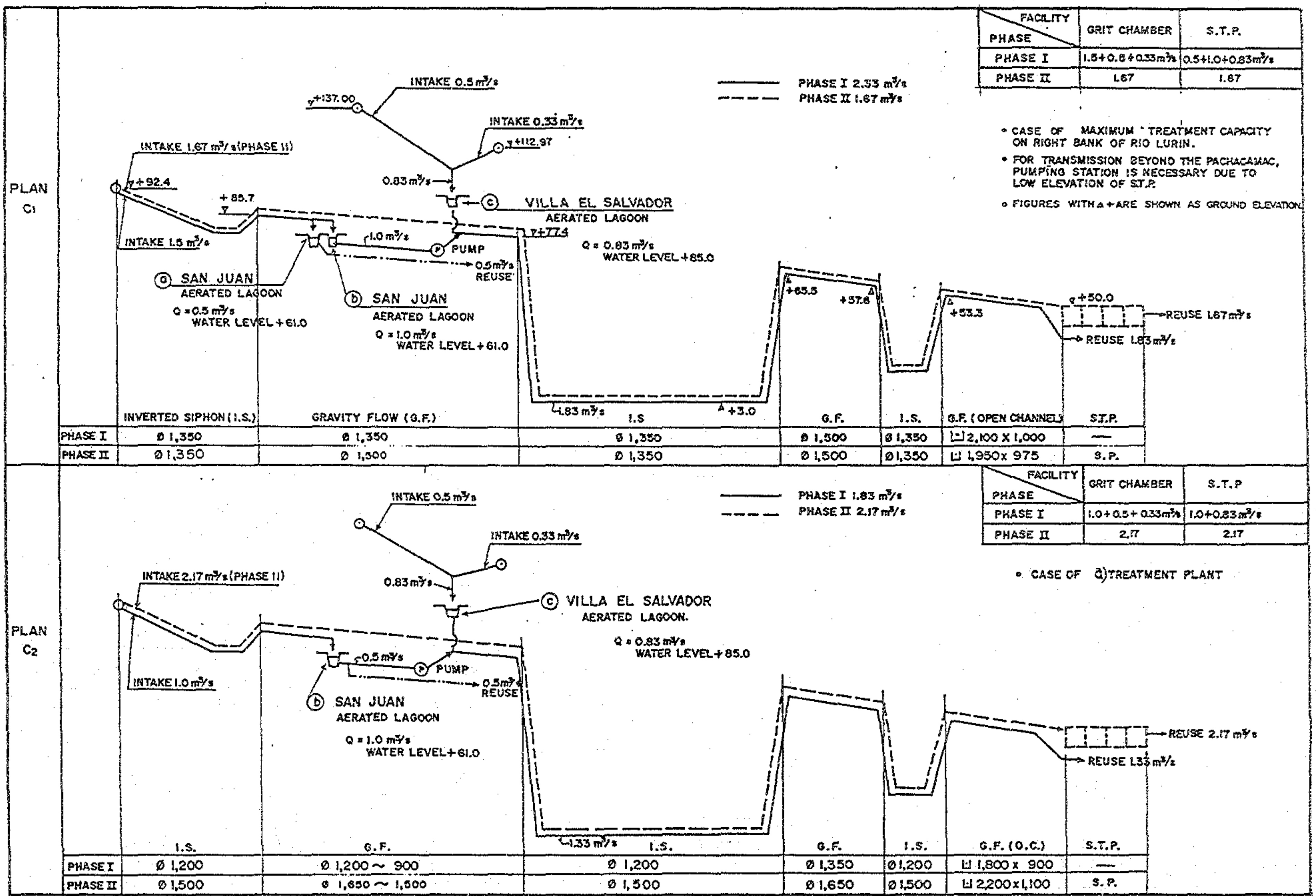


FIGURE S-6 ALTERNATIVE -B (GRAVITY)



PLAN C1

FACILITY / PHASE	GRIT CHAMBER	S.T.P.
PHASE I	1.5+0.8+0.33m³/s	0.5+1.0+0.83m³/s
PHASE II	1.67	1.67

- CASE OF MAXIMUM TREATMENT CAPACITY ON RIGHT BANK OF RIO LURIN.
- FOR TRANSMISSION BEYOND THE PACHACAMAC, PUMPING STATION IS NECESSARY DUE TO LOW ELEVATION OF S.T.P.
- FIGURES WITH Δ+ ARE SHOWN AS GROUND ELEVATION.

	INVERTED SIPHON (I.S.)	GRAVITY FLOW (G.F.)	I.S	G.F.	I.S.	G.F. (OPEN CHANNEL)	S.T.P.
PHASE I	Ø 1,350	Ø 1,350	Ø 1,350	Ø 1,500	Ø 1,350	⊔ 2,100 X 1,000	—
PHASE II	Ø 1,350	Ø 1,500	Ø 1,350	Ø 1,500	Ø 1,350	⊔ 1,950 x 975	S.P.

PLAN C2

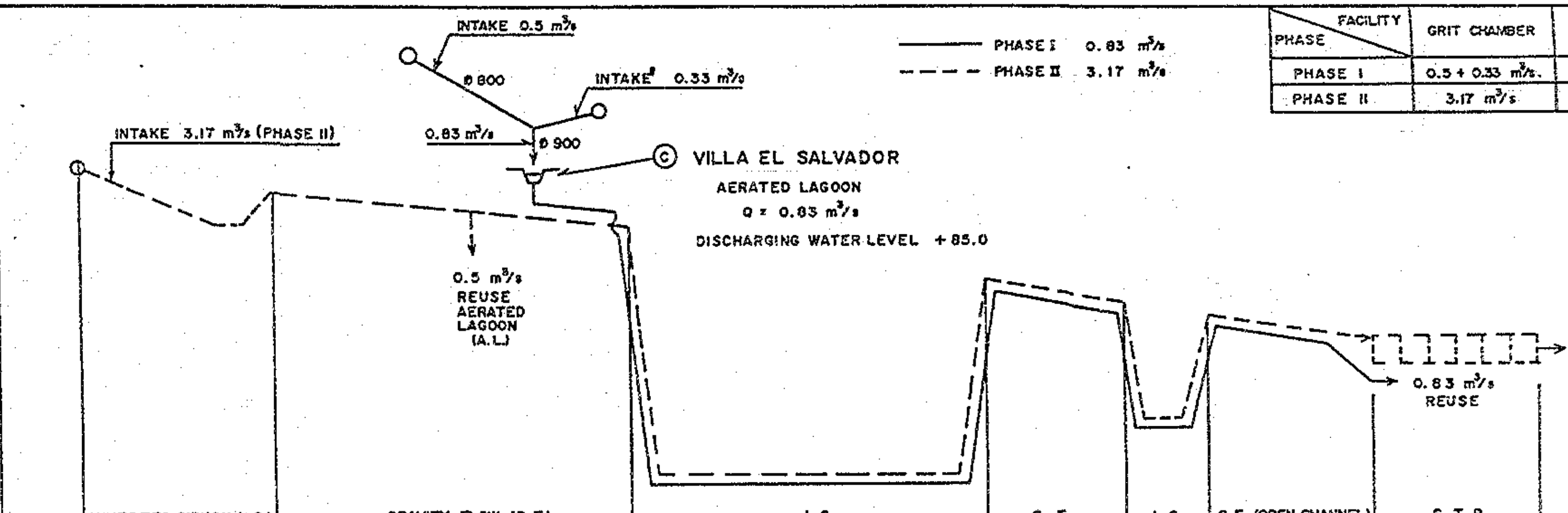
FACILITY / PHASE	GRIT CHAMBER	S.T.P
PHASE I	1.0+0.5+0.33m³/s	1.0+0.83m³/s
PHASE II	2.17	2.17

- CASE OF a) TREATMENT PLANT

	I.S.	G.F.	I.S.	G.F.	I.S.	G.F. (O.C.)	S.T.P.
PHASE I	Ø 1,200	Ø 1,200 ~ 900	Ø 1,200	Ø 1,350	Ø 1,200	⊔ 1,800 x 900	—
PHASE II	Ø 1,500	Ø 1,650 ~ 1,500	Ø 1,500	Ø 1,650	Ø 1,500	⊔ 2,200 x 1,100	S.P.

FIGURE S-7 ALTERNATIVE-C (GRAVITY + PUMPING)

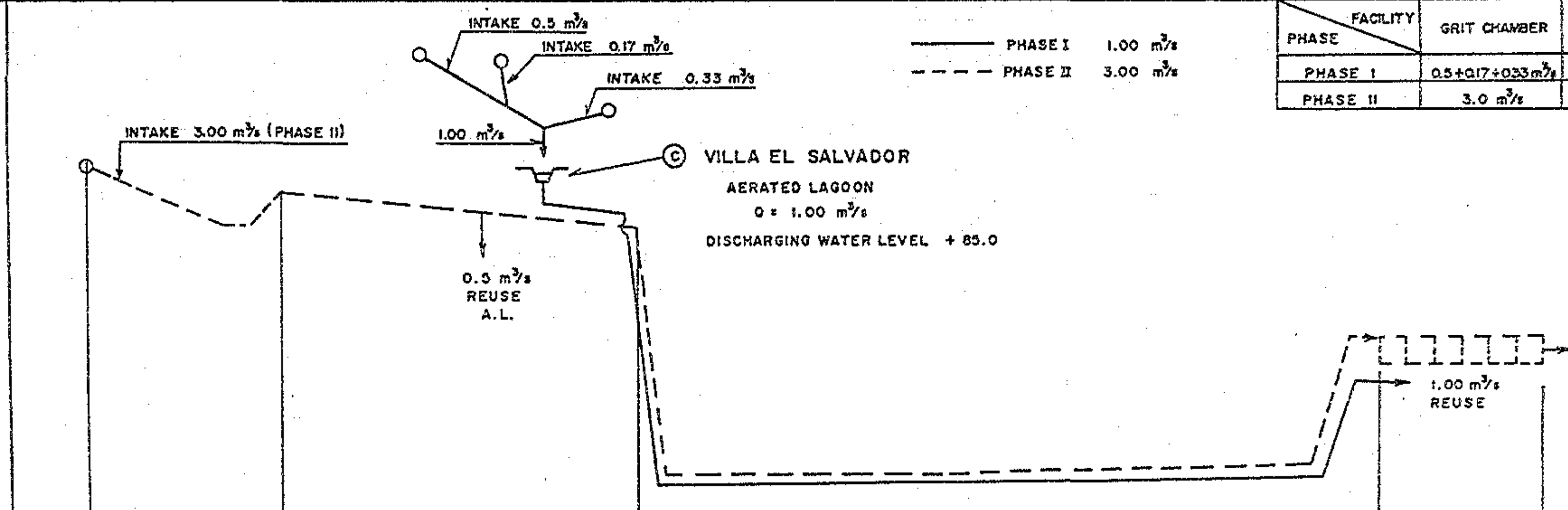
PLAN C3



PHASE \ FACILITY	GRIT CHAMBER	S.T.P.
PHASE I	0.5 + 0.33 m³/s.	0.83 m³/s
PHASE II	3.17 m³/s	0.5 + 2.57 m³/s

	INVERTED SIPHON (I.S.)	GRAVITY FLOW (G.F.)	I.S.	G.F.	I.S.	G.F. (OPEN CHANNEL)	S.T.P.
PHASE I	—	Ø 800 ~ 900	Ø 1000	Ø 1100	Ø 1000	⊔ 1600 x 800	—
PHASE II	Ø 1800	Ø 1800	Ø 1650	Ø 1800	Ø 1650	⊔ 2400 x 1200	S.P.

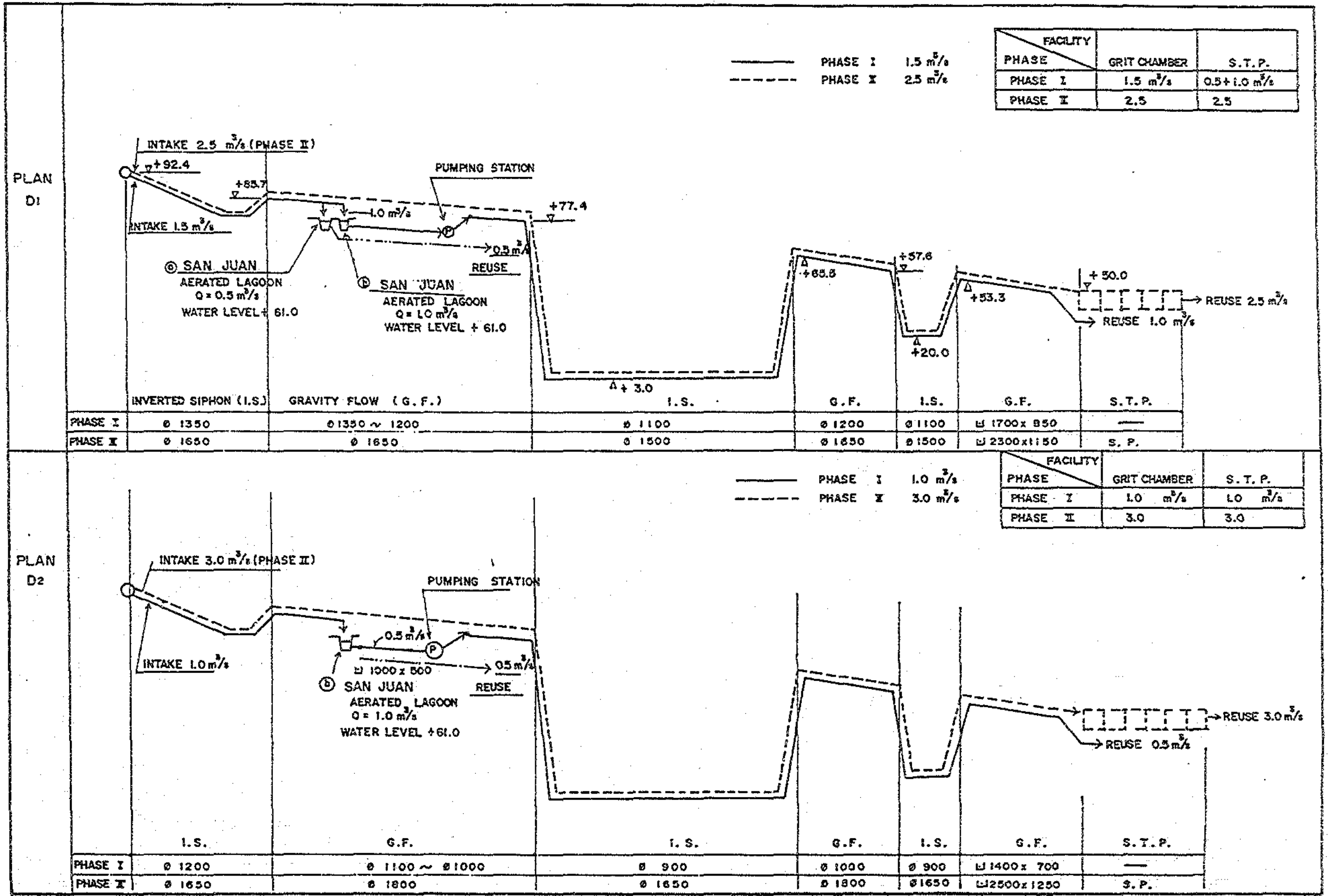
PLAN C3'



PHASE \ FACILITY	GRIT CHAMBER	S.T.P.
PHASE I	0.5+0.17+0.33 m³/s	1.0 m³/s
PHASE II	3.0 m³/s	0.5 + 2.5 m³/s

	GRAVITY FLOW (G.F.)	G.F.	INVERTED SIPHON (I.S.)	S.T.P.
PHASE I	—	Ø 800 ~ 900	Ø 1000	—
PHASE II	Ø 1800	Ø 1800	Ø 1650	S.P.

FIGURE S-7 (CONT'D)



PLAN D1

PHASE \ FACILITY	GRIT CHAMBER	S.T.P.
PHASE I	1.5 m³/s	0.5 + 1.0 m³/s
PHASE II	2.5	2.5

	INVERTED SIPHON (I.S.)	GRAVITY FLOW (G.F.)	I.S.	G.F.	I.S.	G.F.	S.T.P.
PHASE I	ø 1350	ø 1350 ~ 1200	ø 1100	ø 1200	ø 1100	⊔ 1700 x 850	—
PHASE II	ø 1650	ø 1650	ø 1500	ø 1650	ø 1500	⊔ 2300 x 1150	S. P.

PLAN D2

PHASE \ FACILITY	GRIT CHAMBER	S.T.P.
PHASE I	1.0 m³/s	1.0 m³/s
PHASE II	3.0	3.0

	I.S.	G.F.	I.S.	G.F.	I.S.	G.F.	S.T.P.
PHASE I	ø 1200	ø 1100 ~ ø 1000	ø 900	ø 1000	ø 900	⊔ 1400 x 700	—
PHASE II	ø 1650	ø 1800	ø 1650	ø 1800	ø 1650	⊔ 2500 x 1250	S. P.

FIGURE S-8 ALTERNATIVE-D (GRAVITY + PUMPING)

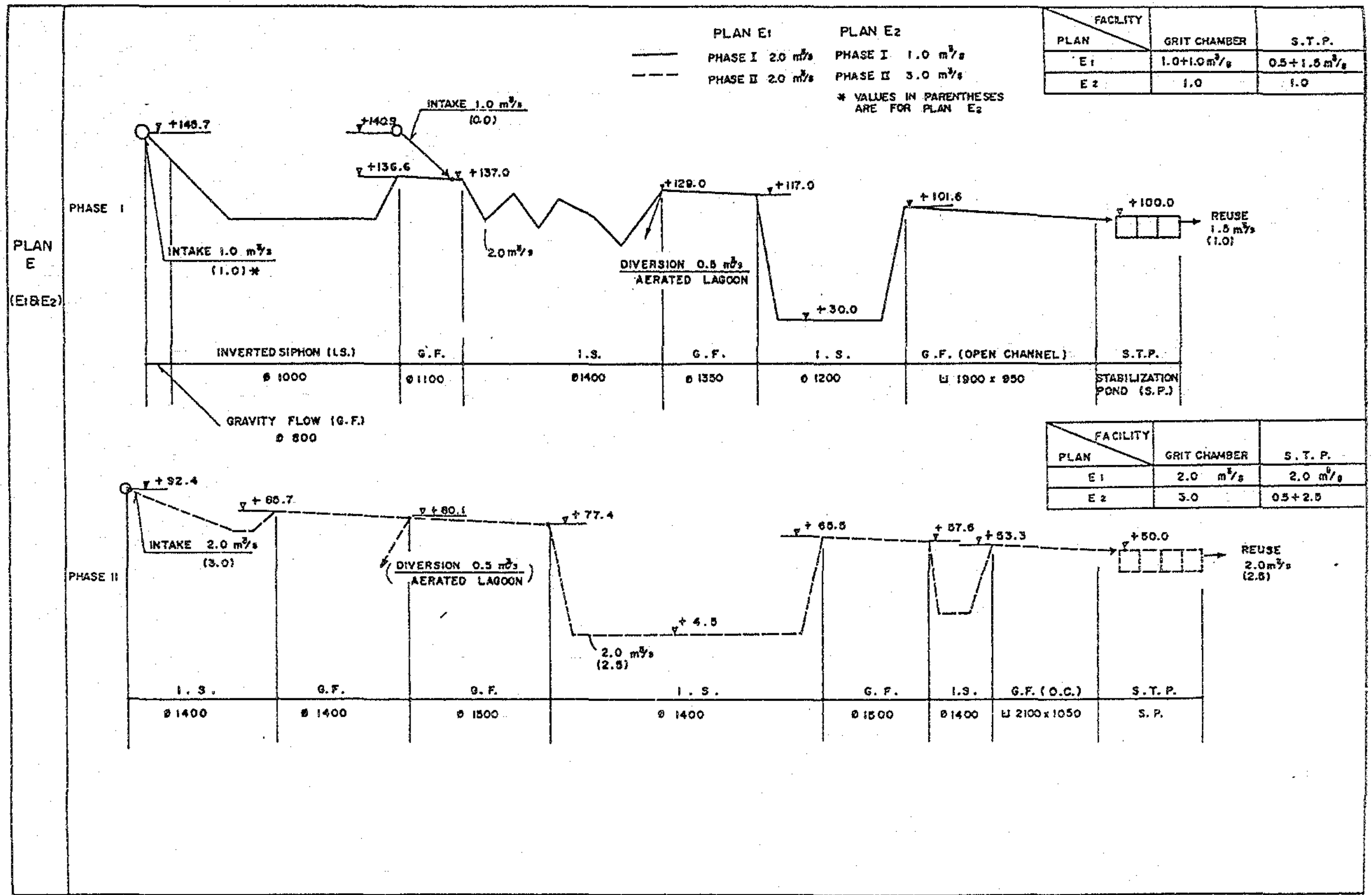


FIGURE S-9 ALTERNATIVE-E (GRAVITY)

TABLE S-14 Summary of Planned Sewage Quantity

Plan	Location of STP / Treatment Method		TOTAL PROJECT – PHASE I (a) SAN JUAN STP – Aerated Lagoon	PHASE I (b) SAN JUAN – Aerated Lagoon	PHASE I (c) VILLA EL SALVADOR – Aerated Lagoon	PHASE I (e) SAN BARTOLO – Stabilization Pond	PHASE I (f) SAN BARTOLO – Stabilization Pond	PHASE I Total	PHASE II (b) SAN JUAN – Aerated Lagoon	PHASE II (c) VILLA EL SALVADOR – Aerated Lagoon	PHASE II (e) SAN BARTOLO – Stabilization Pond	PHASE II (f) SAN BARTOLO – Stabilization Pond	PHASE II Total	REMARKS
A	Pressurized Flow Gravity Flow	A_1			0.5 m^3/s		3.5 m^3/s	4.0 m^3/s						
		A_2			0.5		1.5	2.0				2.0 m^3/s	2.0 m^3/s	
		A_3			0.5		0.5	1.0				3.0	3.0	
B	Gravity Flow	B_1		0.5 m^3/s		3.5 m^3/s		4.0 m^3/s						
		B_2		0.5		1.5		2.0			2.0 m^3/s		2.0 m^3/s	
		B_3		0.5		0.5		1.0			3.0		3.0	
C	Gravity Flow Pressurized Flow	C_1	0.5 m^3/s	1.0 m^3/s *	0.83 m^3/s			2.33 m^3/s			1.67 m^3/s		1.67 m^3/s	*A relay pumping station is necessary
		C_2		1.0 *	0.83			1.83			2.17		2.17	
		C_3			0.83			0.83	0.5 m^3/s		2.67		3.17	
		C_3'			1.00			1.00	0.5		2.50		3.00	
D		D_1	0.5 m^3/s	1.0 m^3/s *				1.5 m^3/s			2.5 m^3/s		2.5 m^3/s	*A relay pumping station is necessary
		D_2		1.0 *				1.0			3.0		3.0	
E	Gravity Flow	E_1			0.5 m^3/s	1.5 m^3/s		2.0 m^3/s			2.0 m^3/s		2.0 m^3/s	
		E_2				1.0		1.0	0.5 m^3/s		2.5		3.0	

CHAPTER S.7 PRELIMINARY ENGINEERING DESIGN OF ALTERNATIVES

Preliminary engineering design based on the concepts developed in Chapter S.6 was undertaken to provide a basic data for cost estimation. Major facilities necessary to be constructed for the project are: intake facility, transmission facility, pumping facility, and sewage treatment facility.

S.7.1 Intake Facility

Sewage intake shall be located at a point on the Colector Surco, the Colector Circunvalacion, the Colector Villa Maria del Triunfo and the Colector Villa El Salvador as shown in FIGURE S-10. TABLE S-15 shows the allocation of sewage intake corresponding to the alternatives outlined in the previous section.

TABLE S-15 Planned Intake Amount

Main Sewer		Colector Circunvalacion	Emisor General Villa Maria Del Triunfo	Colector Surco	Emisor General Villa El Salvador
A	A1	0.9	0.5	2.6	-
	A2	0.9 (II)	0.5 (I)	1.5 (I) 1.1 (II)	-
	A3	0.5 (I)	0.5 (I)	3.0 (II)	-
B	B1	0.9	0.5	2.6	-
	B2	0.9 (II)	0.5 (I)	1.5 (I) 1.1 (II)	-
	B3	0.9 (II)	0.5 (I)	0.5 (I) 2.1 (II)	-
C	C1	-	0.5 (I)	1.5 (I) 1.67(II)	0.33 (I)
	C2	-	0.5 (I)	1.0 (I) 2.17(II)	0.33 (I)
	C3	-	0.5 (I)	3.17(II)	0.33 (I)
	C3'	-	0.5 (I)	3.00(II)	0.33 (I) 0.17 (I)*
D	D1	-	-	1.5 (I) 2.5 (II)	-
	D2	-	-	1.0 (I) 3.0 (II)	-
E	E1	1.0 (I)	1.0 (I)	2.0 (II)	-
	E2	1.0 (I)	-	3.0 (II)	-

* : Branch Sewer of Emisor General Villa El Salvador.

Sluice gate type intake facility such as that shown in FIGURE S-11 shall be used.

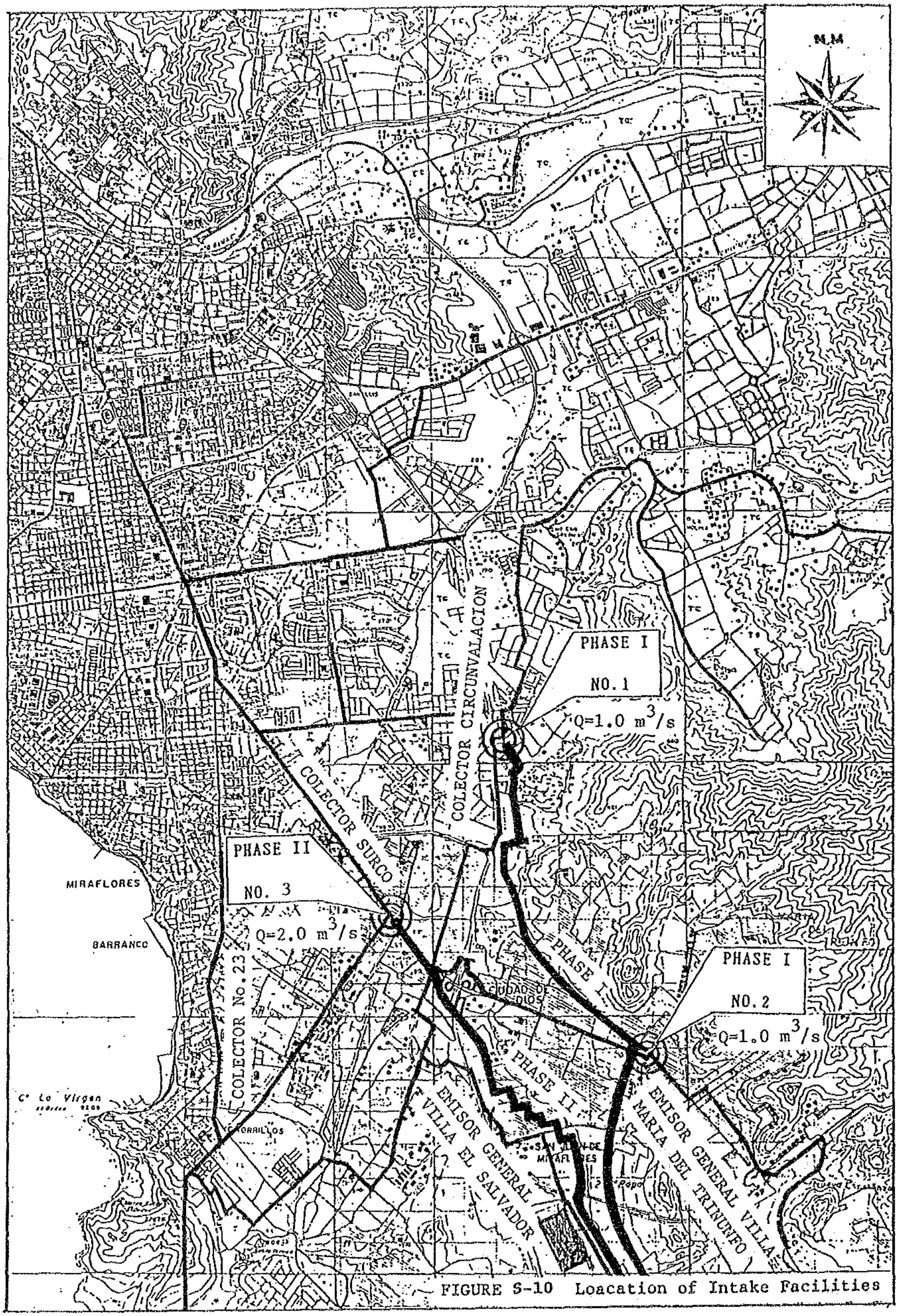
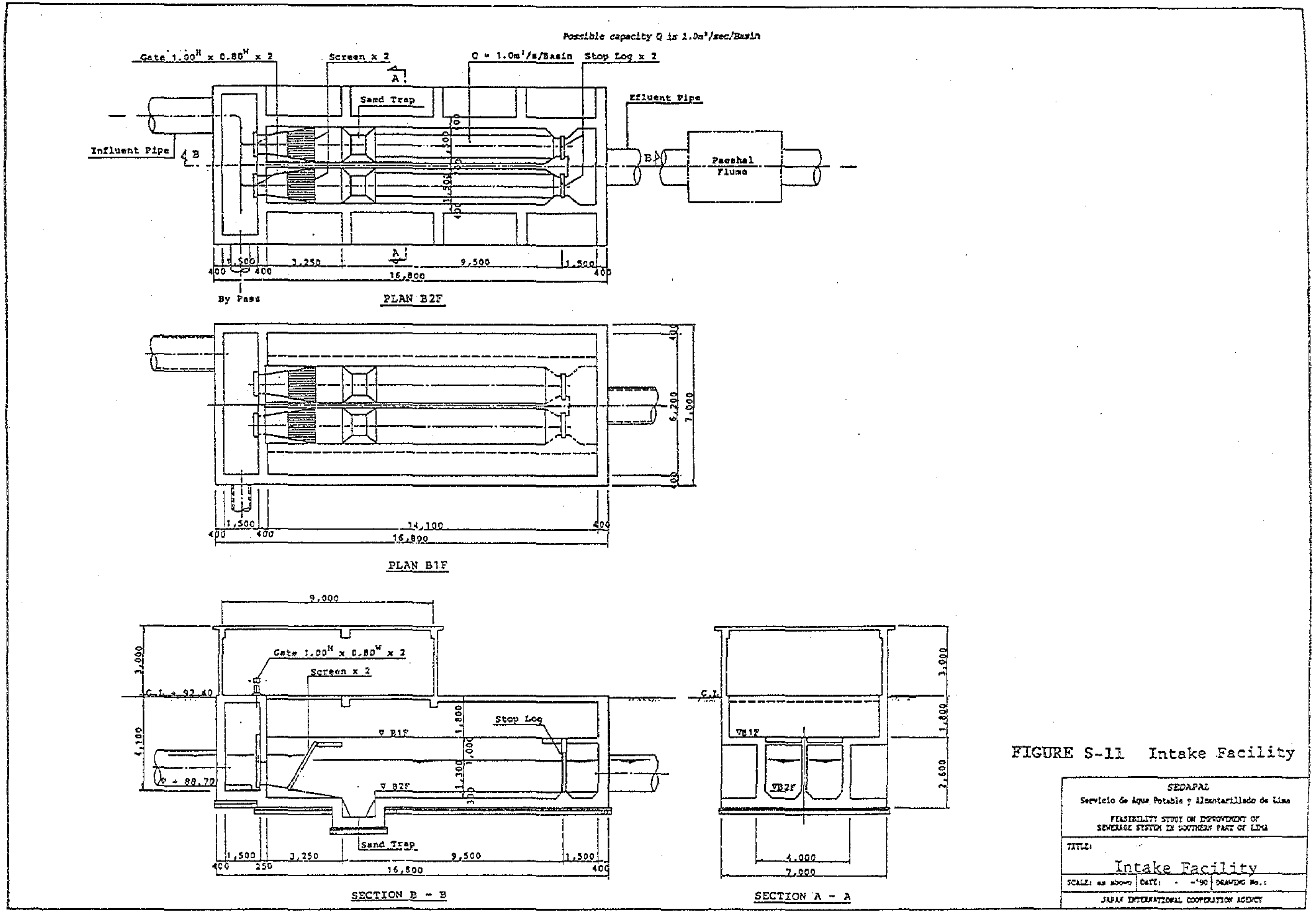


FIGURE S-10 Loacation of Intake Facilities

FIGURE S-11 Intake Facility



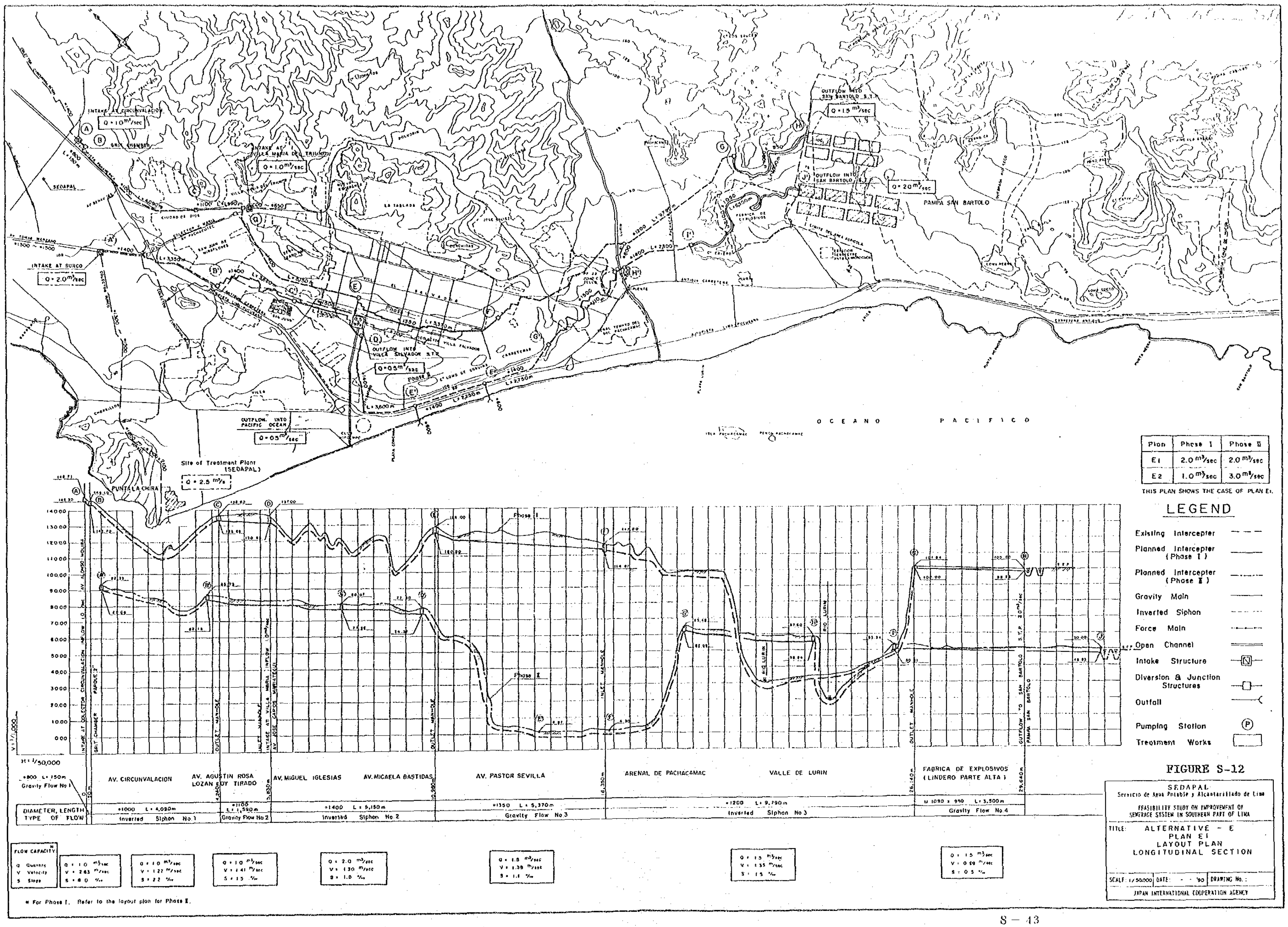
S.7.2 Transmission Facility

Conduit capacity is decided based on planned intake amount and its daily fluctuation. Manning's formula is applied for gravity flow with free water surface while the Hazen - Williams formula is adopted for sections of pressure flow.

Pipe materials planned for the alternatives are: reinforced concrete pipe for gravity flow section, ii) ductile cast iron pipe for pumping flow section, iii) prestressed concrete pipe and ductile cast iron pipe for inverted siphon, and iv) concrete lining for open channel.

The inverted siphons will be made up with inlet chamber with screen and grit chambers. Manhole will be installed in location where there are changes in pipe diameter, unevenness of invert level, pipe intersections, and where required for maintenance. Blow-off valves will be installed at appropriate intervals of inverted siphons. Drain pipes to be connected to nearest sewers except for those along the Lurin River where they shall be connected to sludge drying basins to prevent water pollution.

For illustration, layout plan and longitudinal section of transmission line for Alternative Plan E_1 are presented in FIGURE S-12.


INTAKE AT CIRCUNVALACION
Q = 1.0 m³/sec
GRIT CHAMBER
SEDAPAL
INTAKE AT VILLA MARIA DEL TRIUNFO
Q = 1.0 m³/sec
INTAKE AT SURCO
Q = 2.0 m³/sec
OUTFLOW INTO VILLA SALVADOR S.T.P.
Q = 0.5 m³/sec
OUTFLOW INTO PACIFIC OCEAN
Q = 0.5 m³/sec
Site of Treatment Plant (SEDAPAL)
Q = 2.5 m³/s
PUNTA LA CHIRA
OUTFLOW INTO SAN BARTOLO S.T.P.
Q = 1.5 m³/sec
OUTFLOW INTO SAN BARTOLO
Q = 2.0 m³/sec
PAMPA SAN BARTOLO
OCEANO PACIFICO
Plan | Phase I | Phase II
E1 | 2.0 m³/sec | 2.0 m³/sec
E2 | 1.0 m³/sec | 3.0 m³/sec
THIS PLAN SHOWS THE CASE OF PLAN E1.
LEGEND
Existing Intercepter
Planned Intercepter (Phase I)
Planned Intercepter (Phase II)
Gravity Main
Inverted Siphon
Force Main
Open Channel
Intake Structure
Diversion & Junction Structures
Outfall
Pumping Station
Treatment Works
Phase I
Phase II
H 1/50,000
V 1/1,000
AV. CIRCUNVALACION
AV. AGUSTIN ROSA LOZANO Y TIRADO
AV. MIGUEL IGLESIAS
AV. MICAELA BASTIDAS
AV. PASTOR SEVILLA
ARENAL DE PACHACAMAC
VALLE DE LURIN
FABRICA DE EXPLOSIVOS (LINDERO PARTE ALTA)
DIAMETER, LENGTH
TYPE OF FLOW
Gravity Flow No 1
Inverted Siphon No 1
Gravity Flow No 2
Inverted Siphon No 2
Gravity Flow No 3
Inverted Siphon No 3
Gravity Flow No 4
FLOW CAPACITY
Q Quantity
V Velocity
S Slope
* For Phase I. Refer to the layout plan for Phase II.
FIGURE S-12
SEDAPAL
Servicio de Agua Potable y Alcantarillado de Lima
FEASIBILITY STUDY ON IMPROVEMENT OF SEWERAGE SYSTEM IN SOUTHERN PART OF LIMA
TITLE: ALTERNATIVE - E
PLAN E1
LAYOUT PLAN
LONGITUDINAL SECTION
SCALE: 1/50,000
DATE: '90
DRAWING No.:
JAPAN INTERNATIONAL COOPERATION AGENCY