CHAPTER 5

SEWAGE QUANTITY AND QUALITY

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5.1 General

For confirmation of the availability of sewage to be taken and determination of present sewage discharge amount, sewage flow measurements on the Surco Outfall and three planned intake points were conducted several times in this Study.

When the flow measurement on the Surco Outfall was taken the second time, water intake from the Rimac River to the Surco River was stopped to discount any possible influence of such operation on the sewage flow.

Based on the results of the flow measurements, and data on present and projected population, an estimate was made of the sewage discharge amount in year 2000.

Simultaneous with the flow measurements, sewage water quality analyses were conducted to determine the required capacity of sewage treatment plant for a given design sewage quantity. Analyses on Heavy Metals were performed during this period taking into consideration the possibility of irrigation use.

5.2 Present Sewage Quantity

5.2.1 Surco Outfall

(1) Sewage Flow Measurement

Sewage flow measurements were conducted two times at the same points as shown in FIGURE 5-1 (refer to APPENDIX 7 for details).

Sewage flow of the Surco Outfall was taken as the summation of measured sewage quantities of three main sewers, namely the Colector Surco, the Colector Circunvalacion and the Colector Balnearios del Sur. The measurement was conducted for periods of 24 hours from May 31 to June 1, and from October 19 to 20, 1989. On the second measurement, the intake gates of the

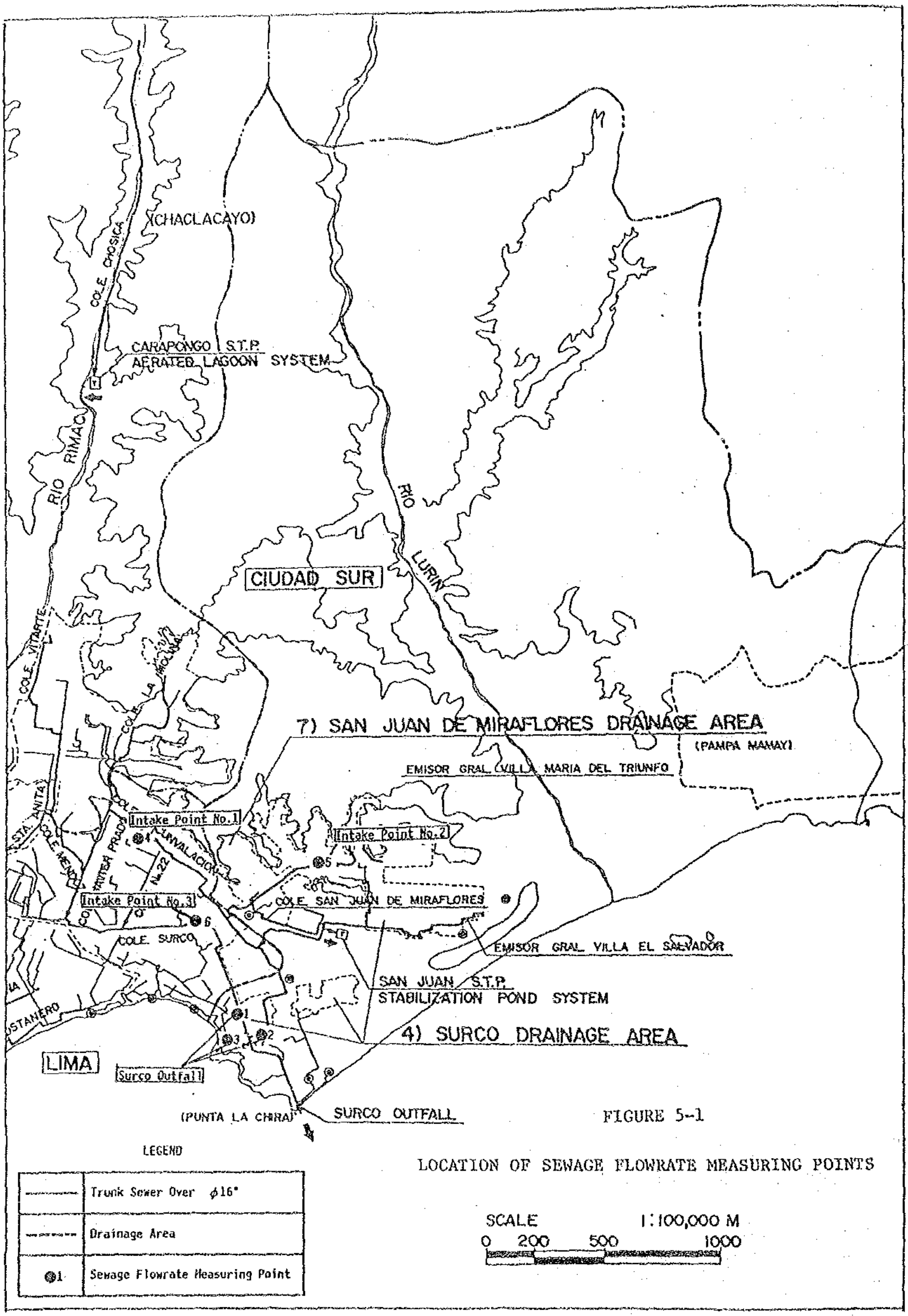


FIGURE 5-1

LOCATION OF SEWAGE FLOWRATE MEASURING POINTS

Surco River were closed for 48 hours from 12:00 noon of October 18 to 12:00 noon of October 20, to dispel the possibility of intrusion from irrigation canal known as 'acequia'. The results are summarized in TABLE 5-1 and FIGUREs 5-2 and 5-3.

TABLE 5-1 Results of Sewage Flow Measurement (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	1
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 Mejico 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

The average flows for the tow periods of measurement were 5.370 m^3/s and 4.963 m^3/s, respectively (refer to FIGURE 5-4). This difference of 0.407 m^3/s which is equivalent to around 8 % of the total sewage flow, may be attributed to one or both of the following reasons:

- decrease of sewage discharge caused by decrease in water consumption
- decrease of intrusion flow from the Surco River

The amount of water supplied by Atarjea Treatment Plant during the time of measurement is shown in TABLE 5-2 and FIGURE 5-5. This table shows a decrease of 1.43 m^3/s in the daily average water supply amount. The effect of this decrease in water supply to the reduction in sewage quantity is calculated as follows (refer to APPENDIX 8 regarding the ratios):

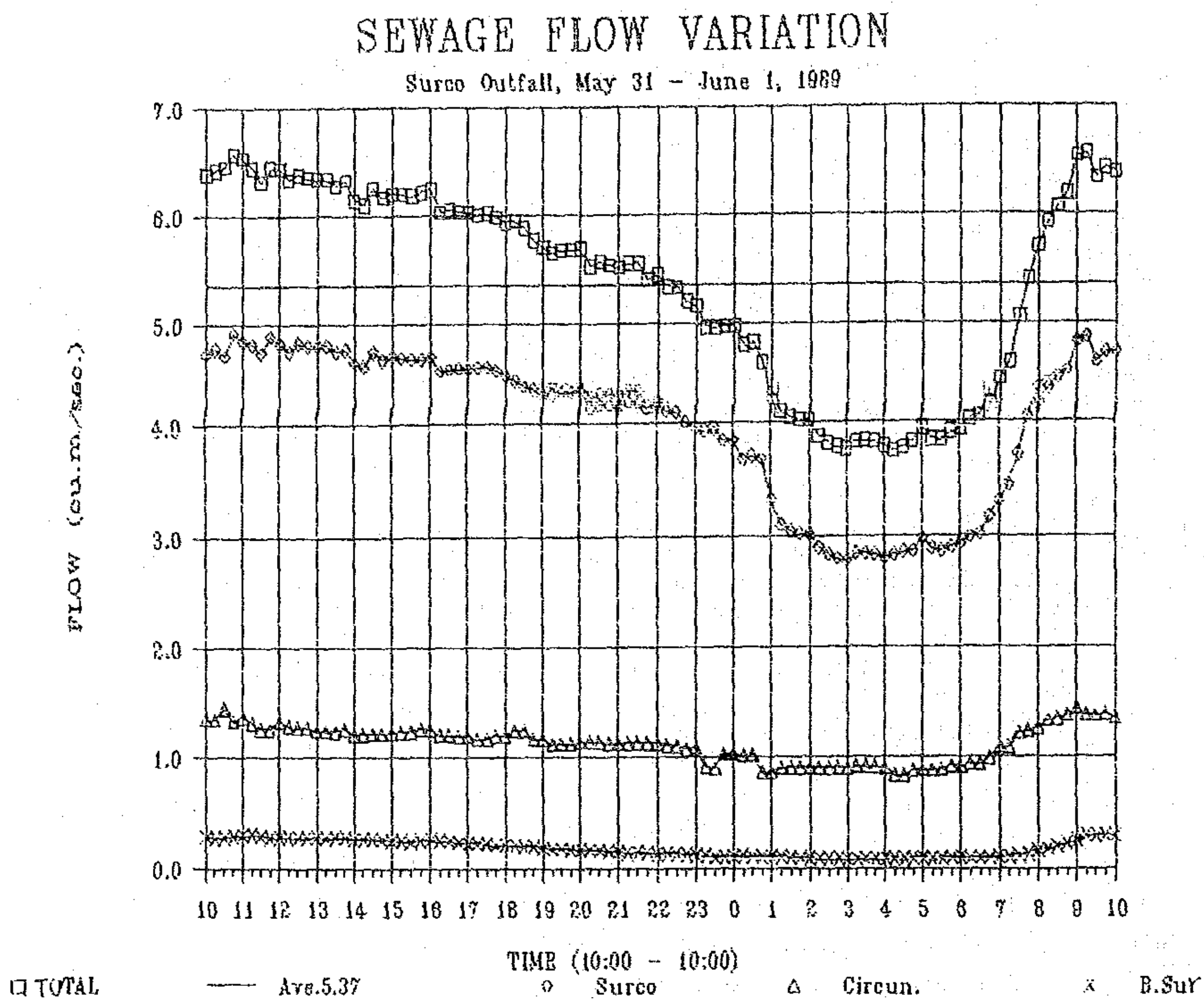


FIGURE 5-2 RESULT OF SEWAGE FLOW MEASUREMENT (SURCO OUTFALL, MAY)

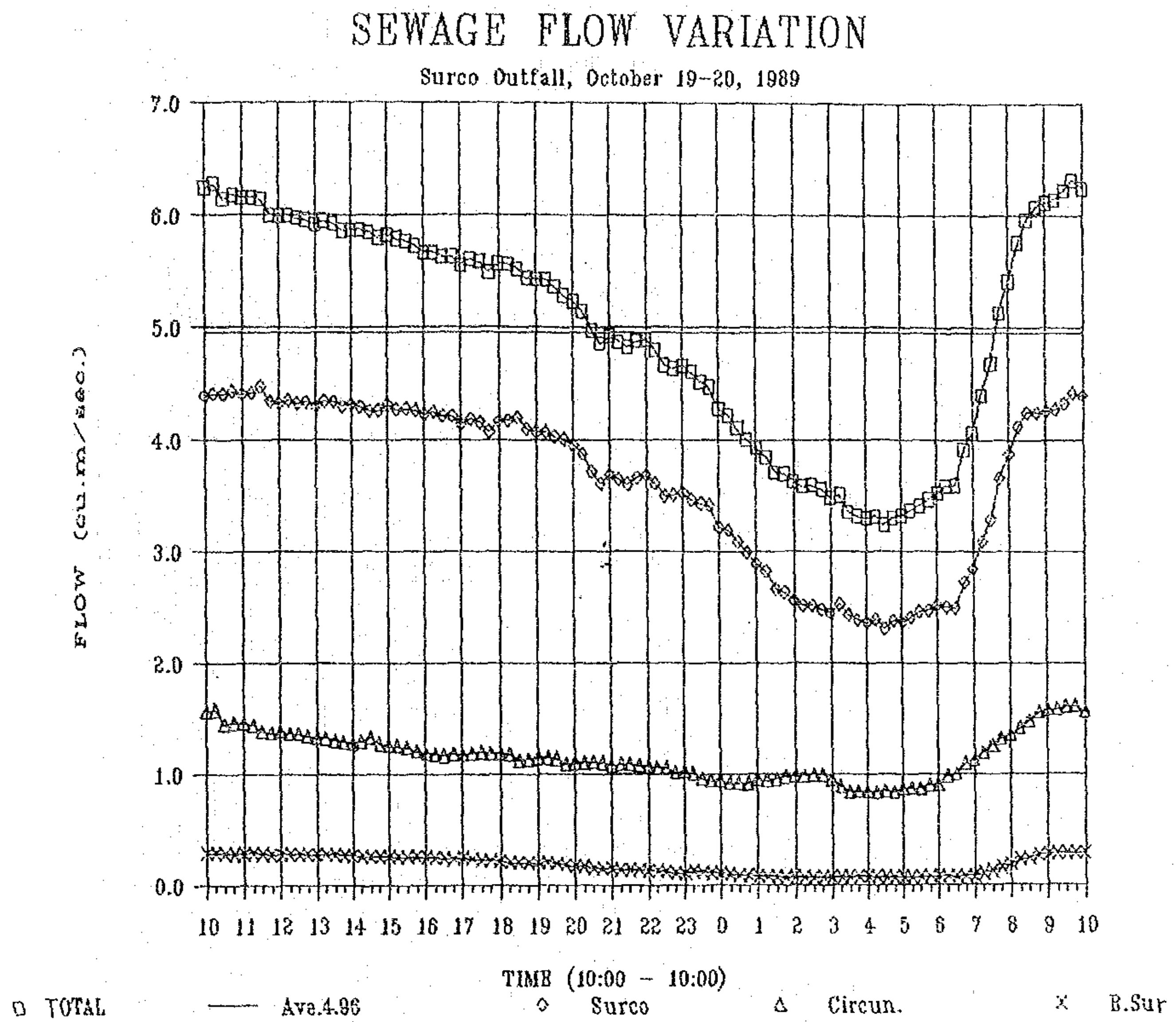


FIGURE 5-3 RESULT OF SEWAGE FLOW MEASUREMENT (SURCO OUTFALL)

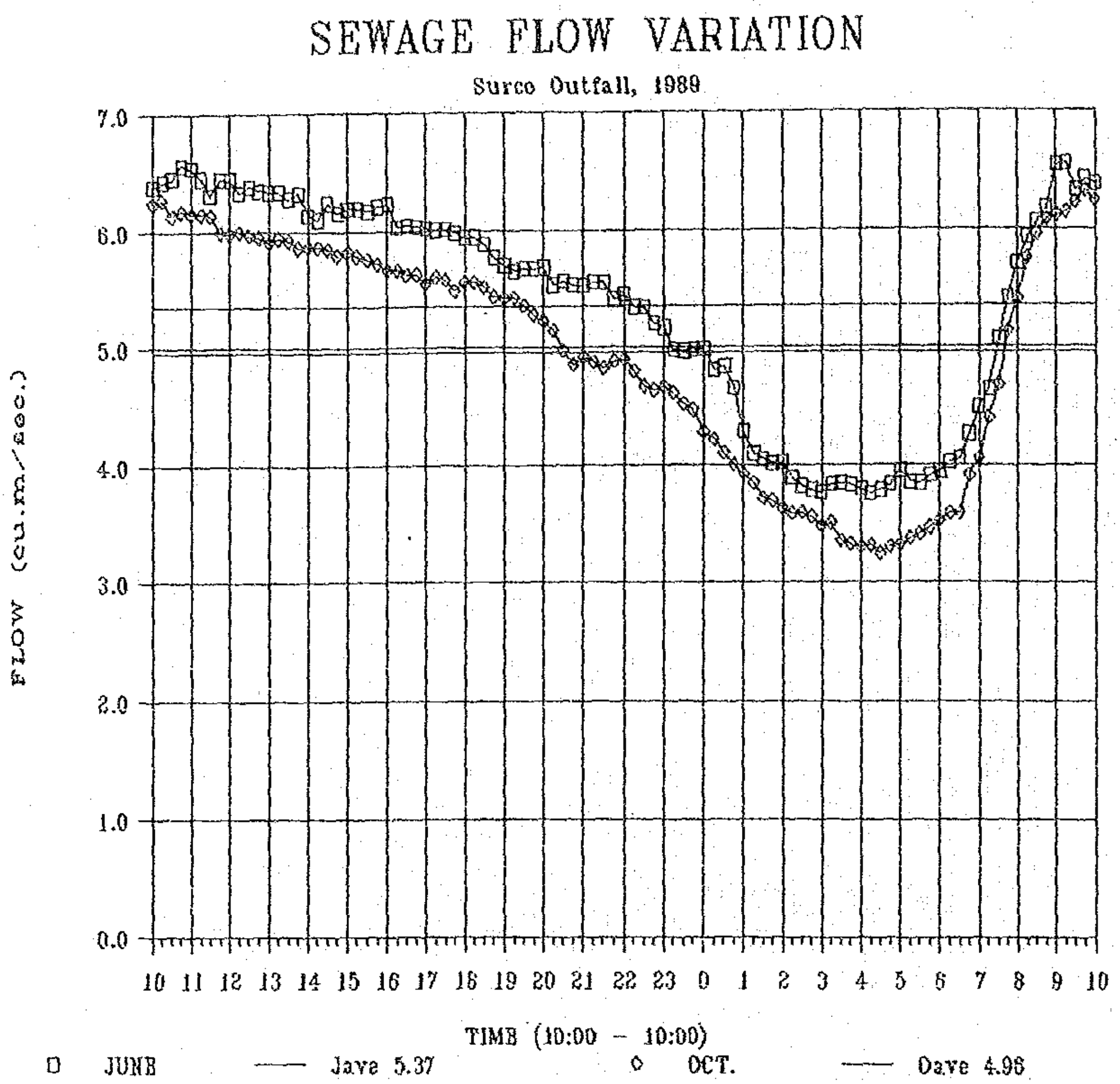


FIGURE 5-4 SEWAGE FLOW OF SURCO OUTFALL (JUNE AND OCTOBER)

TABLE 5-2 WATER SUPPLY AMOUNT FROM ATARJEA TREATMENT PLANT

hh : mm	May 31 - June 1 FLOW m3/h.	m3/s.	RATIO	October 19 - 20 FLOW m3/h.	m3/s.	RATIO
10 : 00	55,296	15.36	1.10	53,390	14.83	1.18
11 : 00	62,396	17.33	1.24	52,590	14.61	1.16
12 : 00	57,046	15.85	1.13	46,790	13.00	1.04
13 : 00	57,745	16.04	1.15	47,190	13.11	1.04
14 : 00	54,445	15.12	1.08	48,740	13.54	1.08
15 : 00	58,295	16.19	1.16	50,390	14.00	1.12
16 : 00	55,095	15.30	1.10	50,390	14.00	1.12
17 : 00	46,946	13.04	0.93	48,690	13.53	1.08
18 : 00	51,346	14.26	1.02	49,590	13.78	1.10
19 : 00	52,296	14.53	1.04	47,590	13.22	1.05
20 : 00	48,996	13.61	0.97	43,190	12.00	0.96
21 : 00	47,895	13.30	0.95	43,090	11.97	0.95
22 : 00	47,895	13.30	0.95	42,190	11.72	0.93
23 : 00	48,595	13.50	0.97	41,540	11.54	0.92
0 : 00	46,795	13.00	0.93	43,790	12.16	0.97
1 : 00	42,896	11.92	0.85	37,890	10.53	0.84
2 : 00	43,996	12.22	0.88	38,740	10.76	0.86
3 : 00	43,196	12.00	0.86	33,790	9.39	0.75
4 : 00	42,896	11.92	0.85	37,040	10.29	0.82
5 : 00	42,045	11.68	0.84	39,390	10.94	0.87
6 : 00	42,045	11.68	0.84	40,990	11.39	0.91
7 : 00	47,595	13.22	0.95	45,190	12.55	1.00
8 : 00	49,495	13.75	0.98	47,390	13.16	1.05
9 : 00	61,096	16.97	1.22	54,390	15.11	1.20
MAXIMUM Qmax	62,396	17.33	1.24	54,390	15.11	1.20
AVERAGE Qave	50,264	13.96	1.00	45,165	12.55	1.00
MINIMUM Qmin	42,045	11.68	0.84	33,790	9.39	0.75

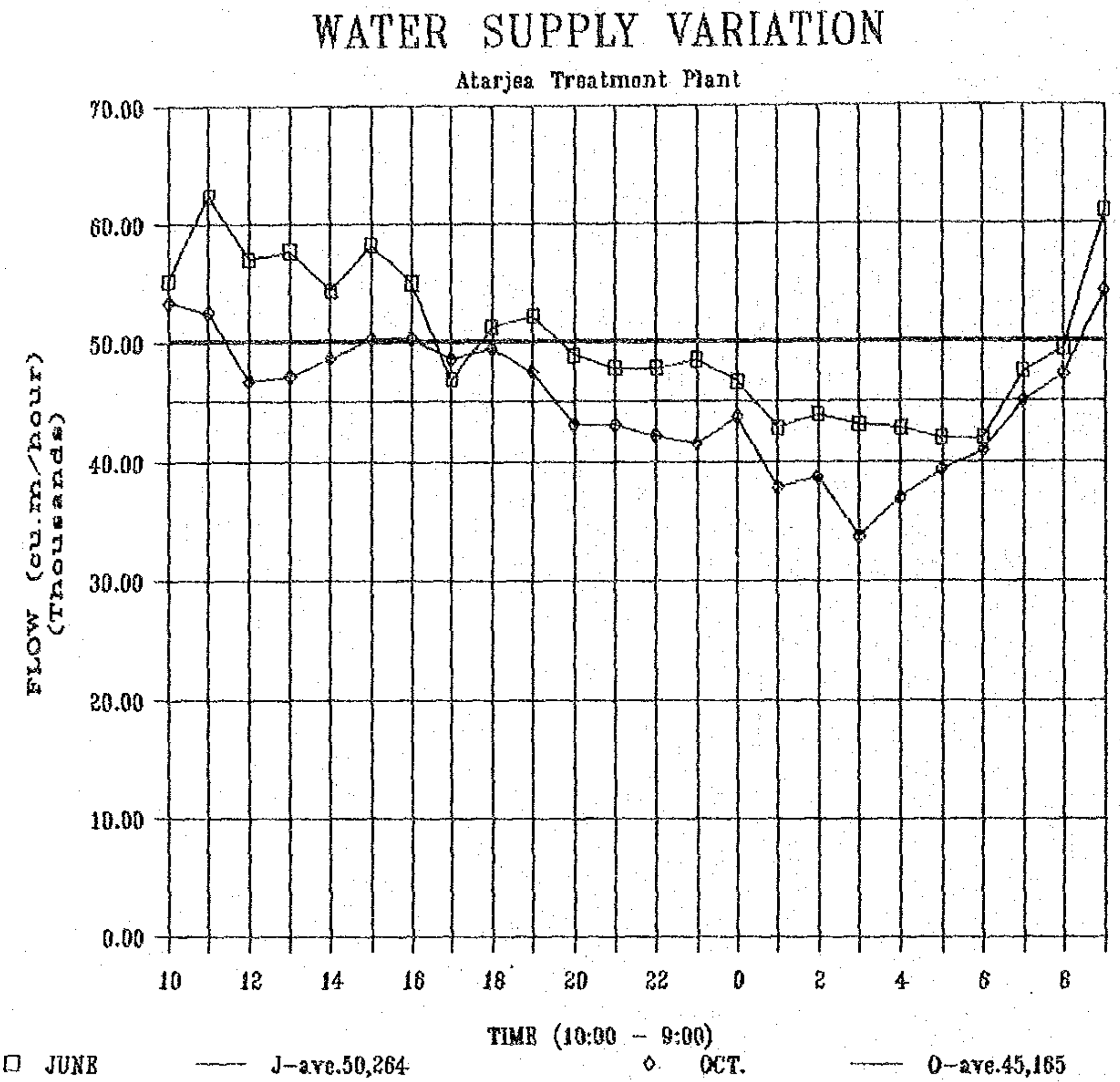


FIGURE 5-5 WATER SUPPLY AMOUNT
(ATARJEA TREATMENT PLANT)

Ratio of Water from Atarjea to Total Water Supply Amount	64.45 %	
Supply Ratio to the Southern District	53.13 %	
Supply Ratio to the Surco Drainage Area	55.68 %	
Effective Ratio	53.73 %	
Discharge Ratio	90 %	

then:

$$\text{Reduction in Sewage Quantity} = 1.41 \times 0.6445 \times 0.5313 \times 0.5568 \times 0.5373 \times 0.9 = 0.130\ m^3/s$$

Therefore, it may be deducted that the 0.130 m^3/s decrease in sewage flow was due to the water consumption decrease, if the relation of water consumption and water supply amount from the Atarjea Treatment Plant is strong and SEDAPAL supplies water at a constant rate from the other water sources. This relation, however, is not firm based on the previous survey data. TABLE 5-3 shows the records of previous flow measurements conducted by SEDAPAL from February 25 to March 2, 1988, and TABLE 5-4 shows the water supply amount from the Atarjea Plant during same period. The comparison of flow rate variation of the two sets of data are plotted in FIGURE 5-6. This graph implies a weak or erratic relationship between these data, probably owing to the existence of wells and water sources owned by SEDAPAL and private entities aside from the Atarjea Plant.

TABLE 5-4 WATER SUPPLY AMOUNT FROM ATARJEA TREATMENT PLANT

DATE (1988)	Daily cu.m/day	average cu.m/sec	Rate avg. = 1
2 / 25	1,299,739	15.04	1.02
26	1,269,370	14.69	1.00
27	1,269,150	14.69	1.00
28	1,243,690	14.39	0.98
29	1,260,050	14.58	0.99
3 / 1	1,236,639	14.31	0.97
2	1,301,430	15.06	1.03
MAXIMUM Qmax	1,301,430	15.06	1.03
AVERAGE Qavg	1,268,581	14.68	1.00
MINIMUM Qmin	1,236,639	14.31	0.98

Source : SEDAPAL

TABLE 5-3 SEWAGE FLOW MEASUREMENT (1988)

DATE		SURCO Qmax m3/s.	SURCO Qave m3/s.	SURCO Qmin m3/s.	CIRCUNVALACION Qmax m3/s.	CIRCUNVALACION Qave m3/s.	CIRCUNVALACION Qmin m3/s.	BALNEARIOS DEL SUR Qmax m3/s.	BALNEARIOS DEL SUR Qave m3/s.	BALNEARIOS DEL SUR Qmin m3/s.	TOTAL Qave m3/s.
2 /	25	4.103	3.406	2.407	1.471	1.097	0.911	0.226	0.161	0.090	4.664
	26	4.012	3.261	2.391	1.328	1.086	0.791	0.203	0.148	0.102	4.495
	27	4.606	3.420	2.399	1.464	1.156	0.949	0.227	0.156	0.095	4.732
	28	4.094	3.346	2.344	1.194	1.029	0.834	0.182	0.150	0.104	4.525
	29	4.551	3.591	2.328	1.407	1.105	0.839	0.349	0.218	0.124	4.914
3 /	1	4.358	3.597	2.606	1.502	1.104	0.844	0.365	0.209	0.101	4.910
	2	4.772	3.809	2.728	1.464	1.125	0.844	0.359	0.234	0.105	5.168
MAXIMUM Qmax		4.772	3.809	2.728	1.502	1.156	0.949	0.365	0.234	0.124	5.199
AVERAGE Qave		4.357	3.490	2.458	1.404	1.100	0.859	0.273	0.182	0.103	4.773
MINIMUM Qmin		4.012	3.261	2.328	1.194	1.029	0.791	0.182	0.148	0.090	4.438

Source : SEDAPAL

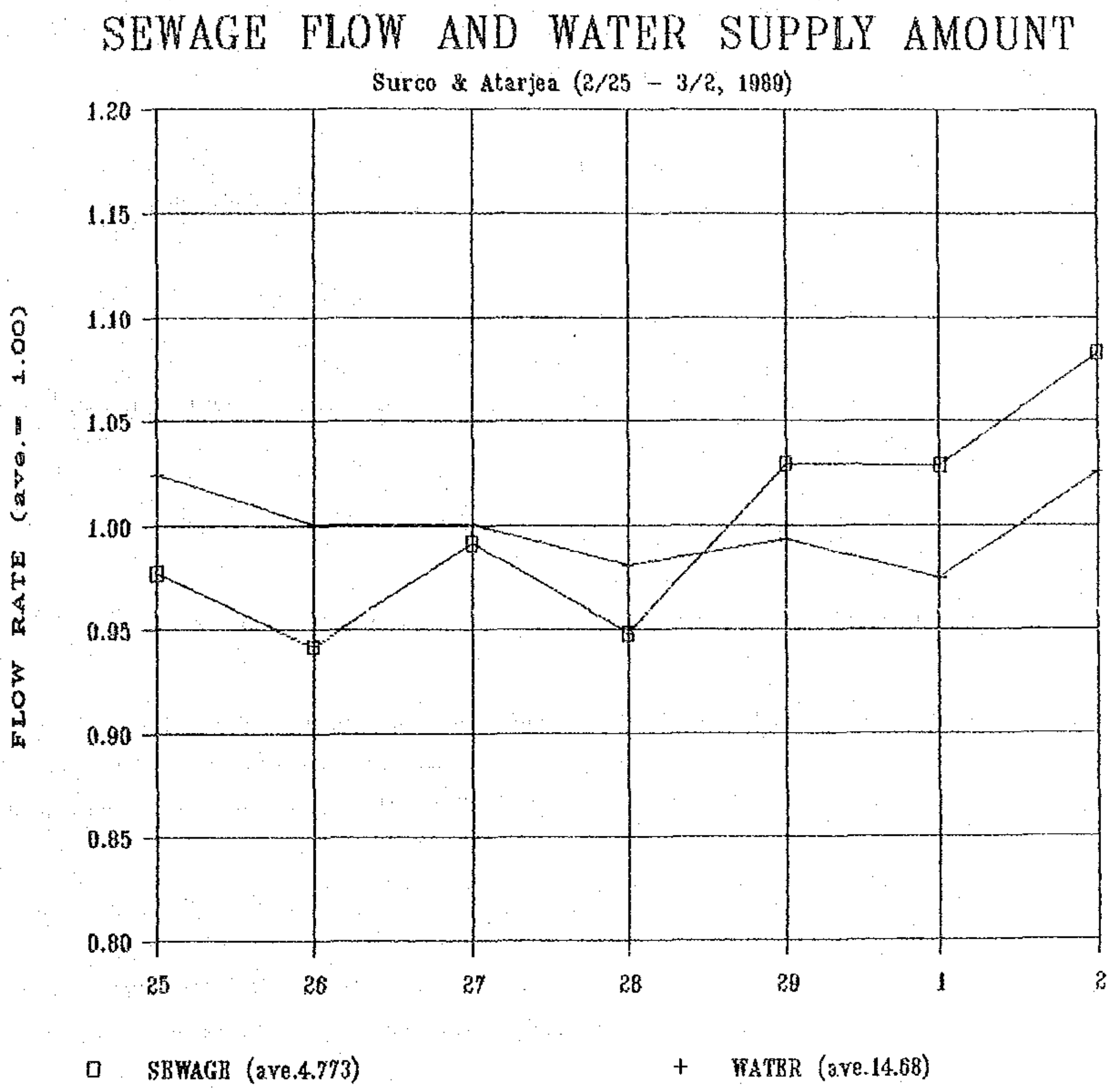


FIGURE 5-6 RELATION OF SEWAGE FLOW AND WATER SUPPLY AMOUNT

Any possible intrusion from the Surco River, was checked before and during the measurement activity. If indeed the decrease of flow was due to the stoppage of intrusion, then the said 0.407 m^3/s can be regarded as an intrusion flow. However, there is no definite evidences of the existence of such intrusion except for the survey result obtained in this study. The difference in sewage flow cannot be accounted for fully by the decrease in sewage discharge. Thus, the measured decrease in sewage flow is defined and broken down for the purpose of the Study as follows:

Decrease in Sewage Discharge (Generation)	0.13 m^3/s
Stoppage of Intrusion	0.28 m^3/s
TOTAL	0.41 m^3/s

(2) Average Sewage Quantity

The average quantity of sewage flow obtained from measurements made so far are summarized as follows:

- 5.370 m^3/s (May 31, 1989)
- 4.963 m^3/s (October 19, 1989)
- 4.773 m^3/s (Average, February 25 to March 2, 1988)

Although the 1988 figure was obtained during the summer season with favorable water source condition, it is comparatively small. The average sewage flow is calculated as the mean value of the 1988 and May 1989 data.

$$Qavg = (5.370 + 4.773) / 2 = 5.072 \; m^3/s = \text{ around } 5.0 \; m^3/s$$

The October 1988 figure is omitted due to absence of intrusion water. Therefore, 5.0 m^3/s is deemed an appropriate average sewage flow value for 1989.

(3) Estimation of Sewage Flow Balance

Domestic Sewage

The estimated present population data given in Chapter 4 are summarized in TABLE 5-5, categorized according to district, main sewer, and service group.

TABLE 5-5 POPULATION DISTRIBUTION OF EACH DISTRICT (1989)

DISTRICT	TOTAL AREA (ha)	TOTAL POPULATION	DRAINAGE AREA (ha) MAIN SEWER	AREA	POPULATION D/S HIGH	D/S LOW	INDIRECT
LIMA	34	8,100	Surco, Locumba	34	5,270	2,030	800
ATE	795	81,000	Vitarte, No.21	567	21,370	32,350	4,040
			La Molina, Circunvalacion	228	8,600	13,010	1,630
			Sub Total	795	29,970	45,360	5,670
BARRANCO	273	48,100	Costanero, No.23	273	26,940	14,240	6,920
CHORRILLOS	918	159,100	Costanero, No.23	331	11,470	25,010	20,880
			Circunvalacion	252	8,730	19,040	15,900
			Villa Marina Proyecto	335	11,620	25,320	21,130
			Sub Total	918	31,820	69,370	57,910
EL AGUSTINO	350	102,600	Vitarte, No.21	350	13,340	45,140	44,120
LA MOLINA	1,460	66,400	La Molina, Circunvalacion	1,460	59,760	6,640	0
LA VICTORIA	845	270,900	Surco, Locumba	845	197,760	46,050	27,090
MIRAFLORES	407	50,900	Costanero, No.23	407	39,700	11,200	0
SAN BORJA	1,046	56,800	Surco, Locumba	89	2,510	1,980	340
			Vitarte, No.21	55	1,550	1,220	210
			No.22	902	25,490	20,090	3,420
			Sub Total	1,046	29,540	23,290	3,970
SAN ISIDRO	274	21,000	No.22	209	12,970	3,040	0
			Costanero, No.23	65	4,040	950	0
			Sub Total	274	17,010	3,990	0
S.J. DE MIRAFLORES	90	9,700	La Molina, Circunvalacion	90	1,460	7,470	770
SAN LUIS	356	64,100	Surco, Locumba	301	29,260	17,770	7,160
			Vitarte, No.21	55	5,350	3,250	1,310
			Sub Total	356	34,610	21,020	8,470
SANTIAGO DE SURCO	2,685	191,000	Vitarte, No.21	32	960	1,120	200
			No.22	207	6,180	7,220	1,330
			Surco	819	24,470	28,550	5,240
			Costanero, No.23	581	17,360	20,250	3,720
			La Molina, Circunvalacion	1,046	31,250	36,450	6,700
			Sub Total	2,685	80,220	93,590	17,190
SURQUILLO	413	101,200	No.22	34	5,030	2,750	500
			Surco	159	23,770	12,860	2,340
			Costanero, No.23	220	32,880	17,790	3,230
			Sub Total	413	61,730	33,400	6,070
VILLA EL SALVADOR	955	225,900	Villa El Salvador	955	2,260	169,430	54,210
V.M. DEL TRIUNFO	1,316	275,700	Villa El Salvador	225	1,410	40,540	5,190
			V.M. Del Triunfo	1,091	6,860	196,560	25,140
			Sub Total	1,316	8,270	237,100	30,330
TOTAL	12,217	1,732,500		12,217	639,660	829,320	263,520

Legend: D/S; Direct Service, INDIRECT; Indirect service
HIGH; High consuming group, LOW; Low consuming group

With reference to the Design Standard of SEDAPAL, the estimated actual water supply amount, the results of sewage flow measurement, and the Guidelines in Japan, the per capita domestic sewage quantity for different service groups is projected as follows (refer to APPENDIX 8 for details.):

- for Direct Service High Water Consuming Group 210 liters/capita/day
- for Direct Service Low Water Consuming Group 180 liters/capita/day
- for Indirect Service Group 110 liters/capita/day

The computed domestic sewage quantities using the above assumptions are summarized in TABLE 5-6.

TABLE 5-6 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

Industrial Wastewater

According to the latest data prepared by SEDAPAL, quantity of Industrial Wastewater estimated is at 0.323 m^3/s, which is adopted for the Study (refer to APPENDIX 3).

Unknown Intrusion Water

Intrusion water of unknown origin, which is suspected mainly from the Surco River irrigation canal system, is estimated at 0.28 m^3/s as discussed earlier.

Sewage Flow Balance

Based on the above assumptions, the breakdown and flow balance of estimated average sewage quantity of 5.0 m^3/s is summarized as shown in TABLE 5-7 and FIGURE 5-7.

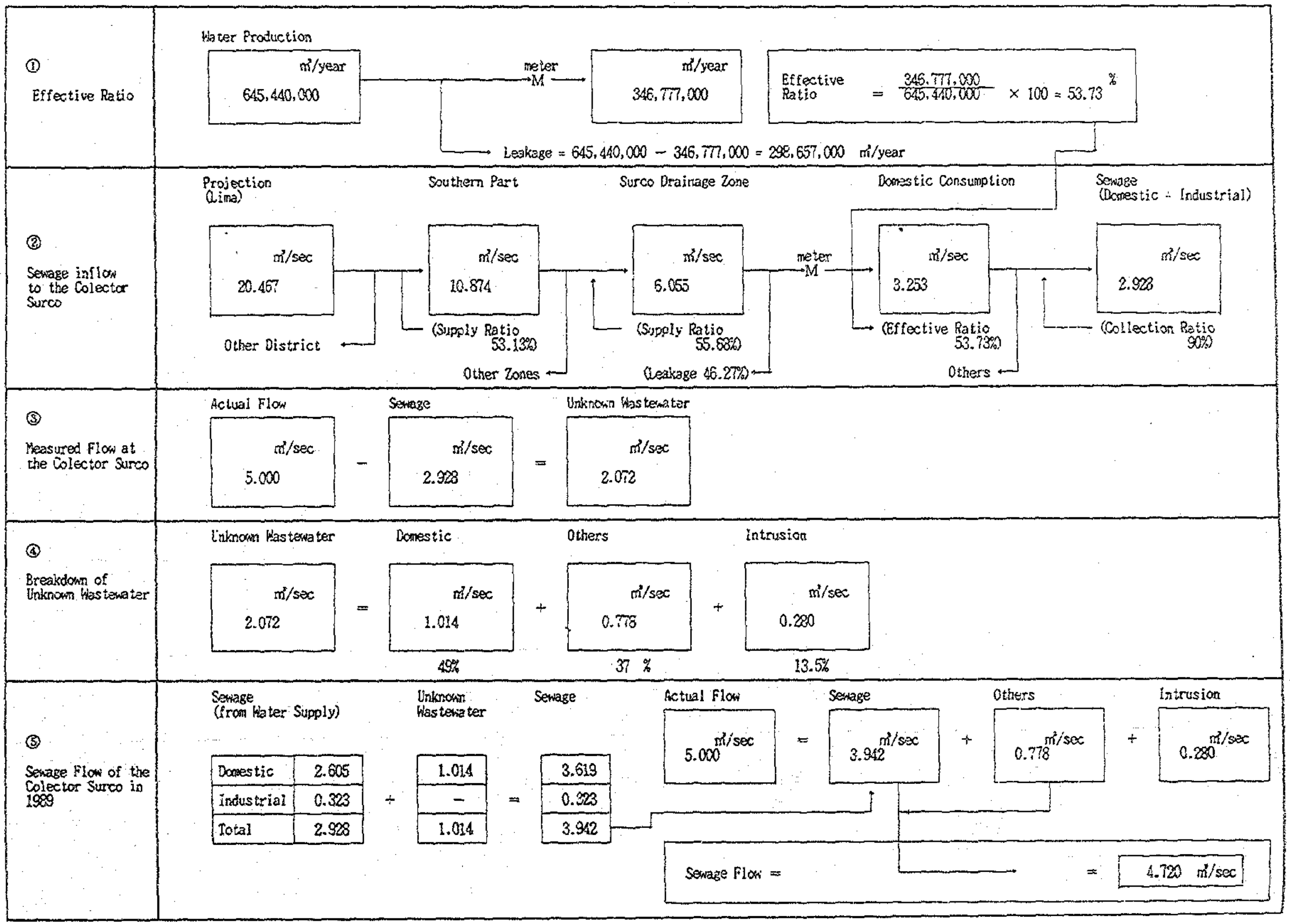
TABLE 5-7 CALCULATION OF PLANNED SEWAGE FLOW (1989)

Item	Unit	Domestic Sewage			Sub-total	Industrial Wastewater	Other Wastewater	Sub-total	TOTAL
		D/S.H	D/S.L	I D					
Population *1	person	639,660	829,320	263,520	1,732,500				
Per Capita Sewage Flow	ℓ/capita/day	210	180	110					
Sewage Flow *2	m^3/sec	1.555	1.728	0.336	3.619	0.323	0.778	1.101	4.720
Daily Sewage Quantity	m^3/day	134,352	149,299	29,030	312,682	26,006	69,120	95,126	407,808

* 1 Population served by the San Juan STP is excluded.

* 2 0.280 m^3/s out of 5.000 m^3/s is assumed to be from "acequia".

FIGURE 5-7 SEWAGE FLOW BALANCE OF COLECTOR SURCO (1989)



5.2.2 Intake Points

Sewage flow measurements at three planned intake points were also conducted 2 times at 24 hour periods from June 6 to 7, and from October 24 to 25, 1989. The results are shown in TABLE 5-8 and FIGUREs 5-8 to 5-10 (refer to APPENDIX 7, for details).

TABLE 5-8 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
Average Qave	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

Based on these data, the average flow at intake point No.1 increased by around 17 % (0.36 to 0.42 m^3/s), while the flow at intake point No.3 decreased by around 7 % (2.76 to 2.58 m^3/s) from the first measurement to the second measurement. These changes seem to be normal fluctuations in daily sewage discharge.

On the other hand, the flow at intake point No.2 decreased greatly by around 60 % from 0.12 to 0.05 m^3/s. Although the second measuring point is located upstream of the first one, the amount of contributory sewage inflow between these points is not expected to be large. This big variation of sewage flow is the scheduling of water supply distribution by area. SEDAPAL periodically shifts the distribution of water supply from one area to another because of the insufficient capacity of the water supply system, thus there is not enough available water amount to be supplied simultaneously to all areas. The service area upstream of the second measuring point is covered by the district of Villa Maria del Triunfo which has poor water supply service. SEDAPAL has been concentrating its effort for the improvement of water supply service in the area. Therefore, the sewage flow at this point is expected to increase rapidly in accordance with the improvement of water supply services.

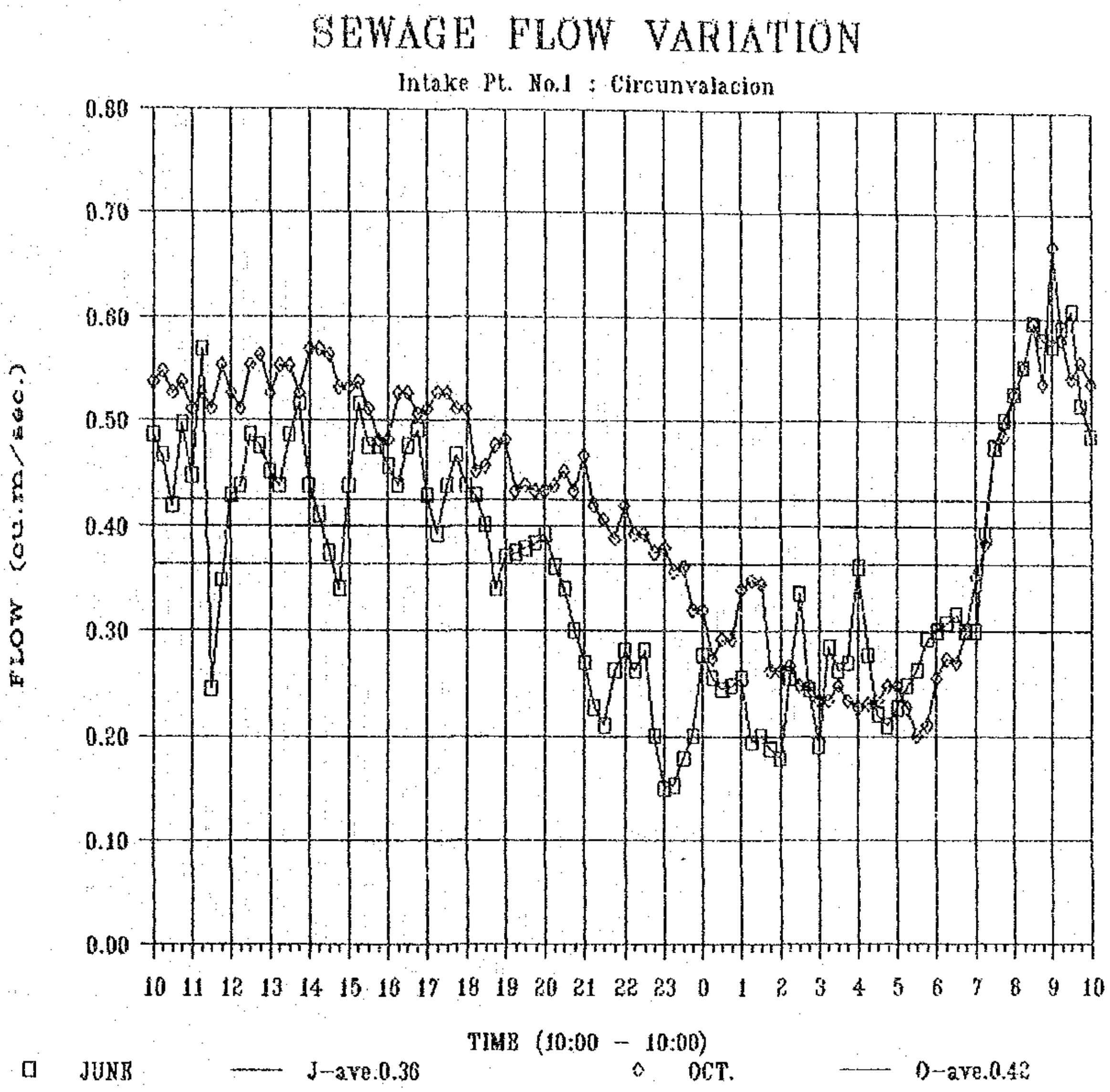


FIGURE 5-8 RESULT OF SEWAGE FLOW MEASUREMENT (INTAKE POINT NO. 1)

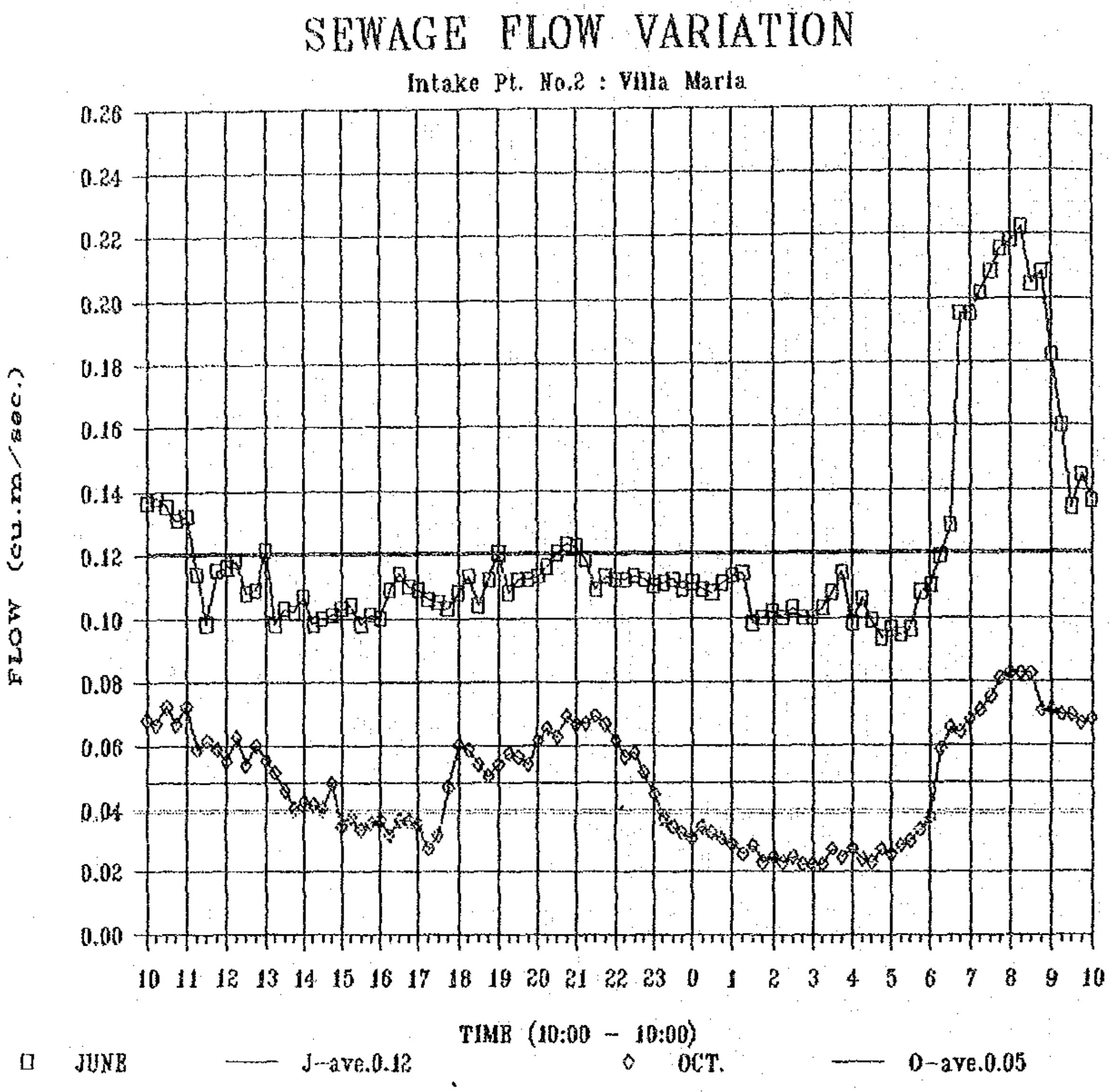


FIGURE 5-9 RESULT OF SEWAGE FLOW MEASUREMENT (INTAKE POINT NO.2)

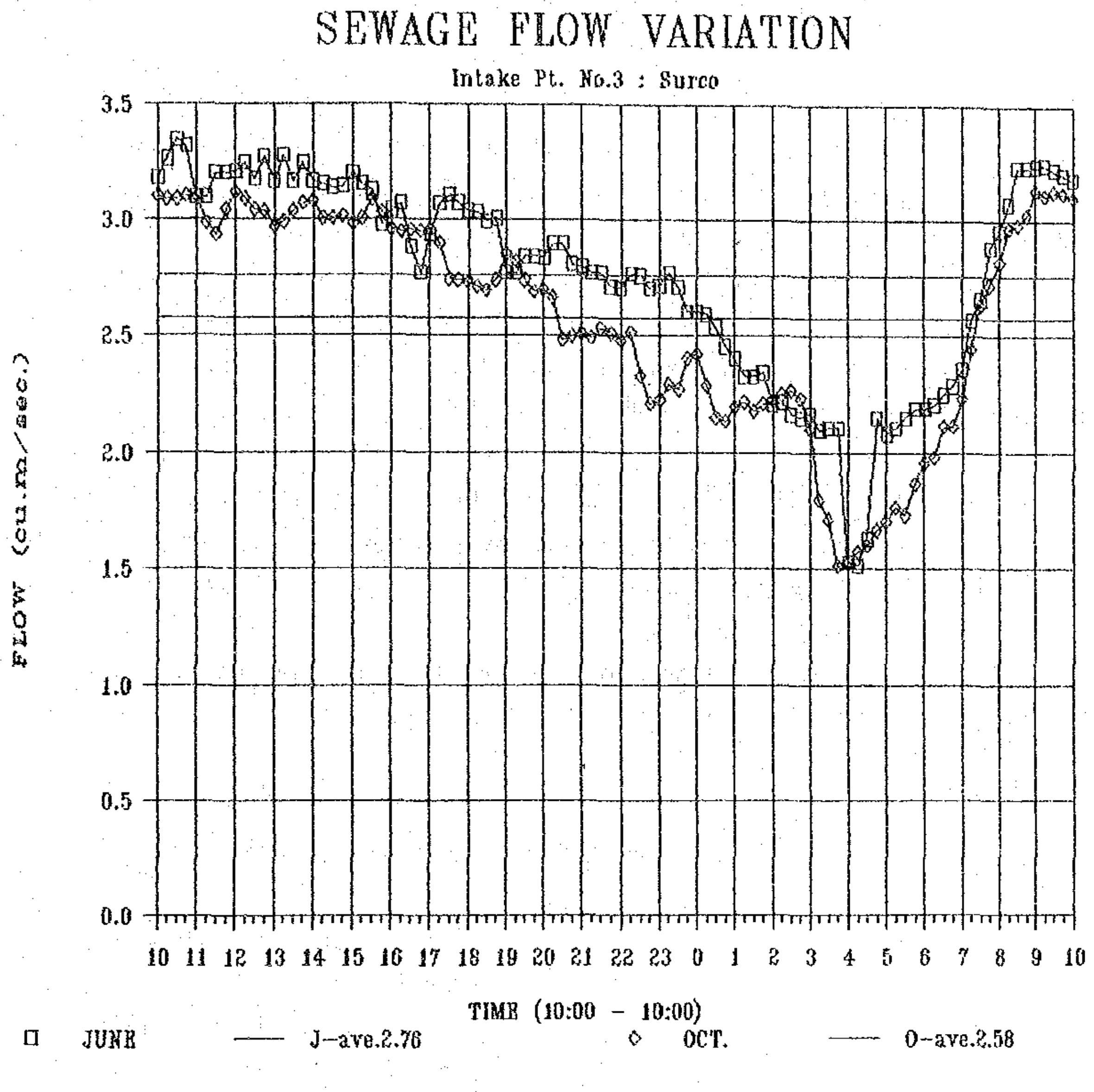


FIGURE 5-10 RESULT OF SEWAGE FLOW MEASUREMENT (INTAKE POINT NO. 3)

5.3 Future Sewage Quantity

5.3.1 Surco Outfall

Domestic Sewage

The projected population in the year 2000 given in Chapter 4 is summarized as shown in TABLE 5-9, categorized according to district, main sewer, and service group.

Per capita sewage discharge adopted for different service groups is the same as that in 1989, wit:

- for Direct Service High Water Consuming Group 210 liters/capita/day
- for Direct Service Low Water Consuming Group 180 liters/capita/day
- for Indirect Service Group 110 liters/capita/day

The calculated domestic sewage quantities in the year 2000 based on the above assumptions are shown in TABLE 5-10.

TABLE 5-10 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

Quantity of industrial wastewater in the year 2000 is projected at 0.355 m^3/s assuming an increase of 10 % from the 1989 figure.

TABLE 5-9 POPULATION DISTRIBUTION OF EACH DISTRICT (2000)

DISTRICT	TOTAL AREA (ha)	TOTAL POPULATION	DRAINAGE AREA (ha) MAIN SEWER	AREA	POPULATION D/S HIGH	D/S LOW	INDIRECT
LIMA	34	8,500	Surco, Locumba	34	5,530	2,130	840
ATE	3,851	135,600	Vitarte, No.21	3,623	47,200	71,440	8,930
			La Molina, Circunvalacion	228	2,970	4,500	560
			Sub Total	3,851	50,170	75,940	9,490
BARRANCO	273	47,400	Costanero, No.23	273	26,540	16,120	4,740
CHORRILLOS	2,973	180,900	Costanero, No.23	331	11,440	40,200	5,720
			Circunvalacion	553	9,320	22,970	14,570
			Villa Marina Proyecto	2,089	15,420	40,570	20,690
			Sub Total	2,973	36,180	103,740	40,980
EL AGUSTINO	381	139,700	Vitarte, No.21	381	18,160	107,570	13,970
LA MOLINA	2,504	211,300	La Molina, Circunvalacion	2,504	190,170	21,130	0
LA VICTORIA	845	277,100	Surco, Locumba	845	202,280	47,110	27,710
MIRAFLORES	407	53,200	Costanero, No.23	407	41,500	11,700	0
SAN BORJA	1,046	55,500	Surco, Locumba	89	2,460	1,940	330
			Vitarte, No.21	55	1,520	1,200	200
			No.22	902	24,880	19,620	3,350
			Sub Total	1,046	28,860	22,760	3,880
SAN ISIDRO	274	22,400	No.22	209	13,840	3,250	0
			Costanero, No.23	65	4,300	1,010	0
			Sub Total	274	18,140	4,260	0
S.J. DE MIRAFLORES	1,162	172,400	La Molina, Circunvalacion	90	2,000	10,280	1,070
			Villa El Salvador	1,072	23,860	122,470	12,720
			Sub Total	1,162	25,860	132,750	13,790
SAN LUIS	356	69,800	Surco, Locumba	301	31,870	21,250	5,900
			Vitarte, No.21	55	5,820	3,880	1,080
			Sub Total	356	37,690	25,130	6,980
SANTIAGO DE SURCO	3,193	315,900	Vitarte, No.21	32	1,330	1,550	230
			No.22	207	8,600	10,030	1,840
			Surco	1,181	49,070	57,250	10,520
			Costanero, No.23	581	24,140	28,170	5,170
			La Molina, Circunvalacion	1,192	49,540	57,790	10,620
			Sub Total	3,193	132,680	154,790	28,430
SURQUILLO	413	103,100	No.22	34	5,180	2,800	510
			Surco	159	24,210	13,100	2,380
			Costanero, No.23	220	33,500	18,120	3,300
			Sub Total	413	62,890	34,020	6,190
VILLA EL SALVADOR	2,627	419,000	Villa El Salvador	2,627	8,380	335,200	75,420
V.M. DEL TRIUNFO	2,753	475,300	Villa El Salvador	286	1,480	42,960	4,940
			V.M. Del Triunfo	2,467	12,780	370,550	42,590
			Sub Total	2,753	14,260	413,510	47,530
TOTAL	23,092	2,687,100		23,092	859,290	1,507,860	279,950

Legend: D/S; Direct Service, INDIRECT; Indirect service
HIGH; High consuming group, LOW; Low consuming group

Unknown Intrusion Water

Intrusion water from unknown source, which is suspected to come from the Surco River irrigation canal system, will be eliminated by the year 2000.

Other Wastewater

Other wastewater, such as residue of sewage flow balance calculation was estimated at 0.778 m^3/s in the year 1989. An accurate definition of this wastewater is difficult with the available limited insufficient data. It, however, includes among others, inaccuracy of assumption, inaccessible intrusion from leaking water supply system, and unaccountable wastewater discharge from commercial and production activities. This wastewater quantity is projected to decrease to 60 % of its present level in the year 2000 as a result of repair and improvement of defective water supply system and equipment at both the supply side and user side.

Sewage Flow Balance

Based on the above assumptions, flow balance of sewage quantity is summarized as shown in TABLE 5-11.

TABLE 5-11 CALCULATION OF PLANNED SEWAGE FLOW (2000)

Item	Unit	Domestic Sewage			Sub-total	Industrial Wastewater	Other Wastewater	Sub-total	TOTAL
		D/S.H	D/S.L	I D					
Population	person	899,290	1,507,860	279,950	2,687,100	—	—	—	—
Per Capita Sewage Flow	ℓ/capita/day	210	180	110	—	(1989x1.1)	(1989x0.6)	—	—
Sewage Flow *1	m^3/sec	2.186	3.142	0.356	5.684	0.355	0.467	0.822	6.506
Daily Sewage Quantity	m^3/day	188,900	271,400	30,800	491,100	30,700	40,300	71,000	562,100

* 1 Water intrusion from acequia will be stopped by the year 2000.

5.3.2 Intake Points

Available sewage flow at the intake points can be calculated on the assumption adopted for sewage quantity projection discussed previously. TABLE 5-12 shows the population distribution by main sewer in year 2000. Based on this table, domestic sewage flow at each intake point is projected as shown in TABLE 5-13.

TABLE 5-13 COVERED POPULATION AND SEWAGE QUANTITY OF EACH INTAKE POINT

INTAKE POINT, PHASE / MAIN SEWER		CLASSIFICATION			
		TOTAL	D/S HIGH	D/S LOW	INDIRECT
No.1	Population	278,310	217,910	54,530	5,870
Colector Circunvalacion	Unit Q (lpcd)		210	180	110
	Total Q (m^3/s)	0.651	0.530	0.114	0.007
No.2	Population	425,920	12,780	370,550	42,590
Emisor General	Unit Q (lpcd)		210	180	110
Villa Maria del Triunfo	Total Q (m^3/s)	0.857	0.031	0.772	0.054
No.3	Population	883,910	441,950	364,120	77,840
Colector Surco	Unit Q (lpcd)		210	180	110
	Total Q (m^3/s)	1.932	1.074	0.759	0.099
Remaining	Population	1,098,960	226,650	718,660	153,650
	Unit Q (lpcd)		210	180	110
	Total Q (m^3/s)	2.244	0.551	1.497	0.196
TOTAL	Population	2,687,100	899,290	1,507,860	279,950
	Unit Q (lpcd)	5.683	210	180	110
	Total Q (m^3/s)	5.684	2.186	3.142	0.356

In addition, the projected industrial wastewater is distributed to each point in consideration of the present locational condition of the industries, as follows:

Intake Point No. 1 : 0.036 m^3/s (10 %)
Intake Point No. 2 : 0.000 m^3/s (0 %)
Intake Point No. 3 : 0.264 m^3/s (80 %)
Others : 0.035 m^3/s (10 %)
Total : 0.355 m^3/s

TABLE 5-12 COVERED POPULATION OF EACH INTAKE POINT (2000)

INTAKE POINT	MAIN SEWER	DISTRICT	TOTAL AREA (ha)	AREA	TOTAL POPULATION TOTAL	D/S HIGH	D/S LOW	INDIRECT	COVER RATIO (%)	COVERED POPULATION TOTAL	D/S HIGH	D/S LOW	INDIRECT
No.1	La Molina,	ATE	3,851	220	8,030	2,970	4,500	560	100	8,030	2,970	4,500	560
Phase I	Circunvalacion	LA MOLINA	2,504	2,504	211,300	190,170	21,130	0	100	211,300	190,170	21,130	0
		SANTIAGO DE SURCO	3,193	1,192	117,950	49,540	57,790	10,620	50	58,980	24,770	28,900	5,310
	TOTAL									278,310	217,910	54,530	5,870
No.2	V.M. Del Triunfo	V.M. DEL TRIUNFO	2,753	2,467	425,920	12,780	370,550	42,590	100	425,920	12,780	370,550	42,590
Phase I	TOTAL									425,920	12,780	370,550	42,590
No.3	Surco, Locumba	LIMA	34	34	8,500	5,530	2,130	840	100	8,500	5,530	2,130	840
Phase II		LA VICTORIA	845	845	277,100	202,280	47,110	27,710	100	277,100	202,280	47,110	27,710
		SAN BORJA	1,046	69	4,730	2,460	1,940	330	100	4,730	2,460	1,940	330
		SAN LUIS	356	301	59,020	31,870	21,250	5,900	100	59,020	31,870	21,250	5,900
		Sub Total								349,350	242,140	72,430	34,780
	Vitarte, No.21	ATE	3,851	3,623	127,570	47,200	71,440	8,930	100	127,570	47,200	71,440	8,930
		EL AGUSTINO	381	381	139,700	18,160	107,570	13,970	100	139,700	18,160	107,570	13,970
		SAN BORJA	1,046	55	2,920	1,520	1,200	200	100	2,920	1,520	1,200	200
		SAN LUIS	356	55	10,780	5,820	3,880	1,080	100	10,780	5,820	3,880	1,080
		SANTIAGO DE SURCO	3,193	32	3,160	1,330	1,550	280	100	3,160	1,330	1,550	280
		Sub Total								284,130	74,030	185,640	24,460
	No.22	SAN BORJA	1,046	902	47,850	24,880	19,620	3,350	100	47,850	24,880	19,620	3,350
		SAN ISIDRO	274	209	17,090	13,840	3,250	0	100	17,090	13,840	3,250	0
		SANTIAGO DE SURCO	3,193	207	20,470	8,600	10,030	1,840	100	20,470	8,600	10,030	1,840
		SURQUILLO	413	34	8,490	5,180	2,800	510	100	8,490	5,180	2,800	510
		Sub Total								93,900	52,500	35,700	5,700
	Surco	SANTIAGO DE SURCO	3,193	1,181	116,840	49,070	57,250	10,520	100	116,840	49,070	57,250	10,520
		SURQUILLO	413	159	39,690	24,210	13,100	2,380	100	39,690	24,210	13,100	2,380
		Sub Total								156,530	73,280	70,350	12,900
	TOTAL									883,910	441,950	364,120	77,840
Remain.	La Molina,	SANTIAGO DE SURCO	3,193	1,192	117,950	49,540	57,790	10,620	50	58,980	24,770	28,900	5,310
	Circunvalacion	S.J. DE MIRAFLORES	1,162	90	13,350	2,000	10,280	1,070	100	13,350	2,000	10,280	1,070
		Sub Total								72,330	26,770	39,180	6,380
	Costanero, No.23	BARRANCO	273	273	47,400	26,540	16,120	4,740	100	47,400	26,540	16,120	4,740
		CHORRILLOS	2,973	331	57,360	11,440	40,200	5,720	100	57,360	11,440	40,200	5,720
		MIRAFLORES	407	407	53,200	41,500	11,700	0	100	53,200	41,500	11,700	0
		SAN ISIDRO	274	65	5,310	4,300	1,010	0	100	5,310	4,300	1,010	0
		SANTIAGO DE SURCO	3,193	581	57,480	24,140	28,170	5,170	100	57,480	24,140	28,170	5,170
		SURQUILLO	413	220	54,920	33,500	18,120	3,300	100	54,920	33,500	18,120	3,300
		Sub Total								275,670	141,420	115,320	18,930
	Villa El Salvador	S.J. DE MIRAFLORES	1,162	1,072	159,050	23,860	122,470	12,720	100	159,050	23,860	122,470	12,720
		VILLA EL SALVADOR	2,627	2,627	419,000	8,380	335,200	75,420	100	419,000	8,380	335,200	75,420
		V.M. DEL TRIUNFO	2,753	286	49,380	1,480	42,960	4,940	100	49,380	1,480	42,960	4,940
		Sub Total								627,430	33,720	500,630	93,080
	Circunvalacion	CHORRILLOS	2,973	553	46,860	9,320	22,970	14,570	100	46,860	9,320	22,970	14,570
	Villa Marina Proyecto	CHORRILLOS	2,973	2,089	76,680	15,420	40,570	20,690	100	76,680	15,420	40,570	20,690
	TOTAL									1,098,970	226,650	718,670	153,650
		TOTAL								2,687,110	899,290	1,507,870	279,950

Legend: D/S; Direct Service, INDIRECT; Indirect service
HIGH; High consuming group, LOW; Low consuming group

Other wastewater is distributed at each intake point in accordance with the ratio of sewage flow consisting of domestic sewage and industrial wastewater to total flow, as follows:

Intake Point No. 1 : 0.053 m^3/s (11 %)
Intake Point No. 2 : 0.066 m^3/s (14 %)
Intake Point No. 3 : 0.172 m^3/s (37 %)
Others : 0.176 m^3/s (38 %)
Total : 0.467 m^3/s

The available sewage flow at each intake point is then summed up as follows:

TABLE 5-14 SEWAGE QUANTITY OF EACH INTAKE POINT

INTAKE POINT, 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

On the other hand, sewage quantity to be taken at each intake point in the case of Alternative E_1 (refer to Chapter 6), which was judged as an optimum plan in subsection 7.6, was planned as follows:

Phase I (Intake points 1 & 2) : 1.0 + 1.0 m^3/s
Phase II (Intake point 3) : 2.0 m^3/s

Therefore, enough sewage flow is available at intake point No.3 in the year 2000. Intake point No.2 will have almost the same quantity as planned intake amount. Intake point No.1, however, will have insufficient sewage flow. To secure additional sewage flow for Phase 1 project, the following measures are recommendable (refer to APPENDIX 9):

(1) Transmission of sewage from Colector Vitarte to Colector Circunvalacion by installation of new interceptor

The sewage flowing in the Colector Vitarte which will continue down to intake point No.3 can be intercepted by a 2.5 km long interceptor to the Colector Circunvalacion. This interceptor can convey the necessary amount of sewage to a place located upstream of intake point No.1. Available additional sewage quantity that can be collected by this interceptor is estimated at 0.39 m^3/s, which is almost equivalent to the surplus flow at intake point No.3.

(2) Interception of sewage collected by the Emisor General Villa El Salvador

The transmission line of Phase 1 project, which runs through Villa El Salvador, can collect the sewage discharged from its southern part into its gravity section. The available sewage quantity expected to be collected by this measure is approximately half of the total sewage discharged from Villa El Salvador, which is around 0.4 m^3/s.

With supporting measures, the available sewage volume estimated above will, therefore, meet the planned intake quantities. In addition to those measures, rapid improvement of water supply system shall be made in the area, especially in Villa Maria del Triunfo. These estimation can be realized if the water supply system is operating efficiently as planned.

Above-mentioned estimation is based to some extent on various uncertain assumptions. The degree of uncertainty of assumptions is such that the possibility of wide deviation in available sewage quantity is great, to the detriment of the Project or otherwise. For example, the population in the districts of Ate and La Molina is increasing rapidly at present, a trend which is expected to contribute to the considerable increase of available sewage flow at intake points Nos. 1 and 3. However, it is difficult to predict confidently the population increase for such type of districts. On the other hand, adverse water supply conditions in Lima would result to decrease in the sewage discharge. Therefore, it is recommendable to adopt the planned intake quantities as obtained in this Study. The recommended measures to secure additional sewage flow shall be taken in consideration with the actual condition after the completion of the project.

If it is difficult to secure the planned intake quantity for the system of Phase 1 project by any of the proposed measures, pumping of sewage from the Colector Surco to the Phase 1 system would be another possible alternative solution.

5.4 Present Sewage Quality

5.4.1 BOD5 and Suspended Solid

As for raw sewage quality, past record and the results of water quality analyses executed in this Study for Main Sewers, San Juan STP and Carapongo STP are presented in TABLE 5-15 (refer to APPENDIX 5 for details).

Range of values of raw sewage quality taken from existing facilities at different sampling times are summarized as follows:

a. BOD5

	Range(mg/l)	Average(mg/l)
Main Sewers :	146 - 333	227
San Juan STP :	214 - 300	252
Carapongo STP:	130 - 280	187

b. Suspended Solid (SS)

	Range(mg/l)	Average(mg/l)
Main Sewers :	152 - 289	239
San Juan STP :	88 - 306	221
Carapongo STP:	171 - 590	298

BOD concentration in the Carapongo STP is lower than in other facilities because of the high ratio of unknown water intrusion (mainly from irrigation canal) to sewer.

In this Project raw sewage will be diverted from the Colector Surco and the Colector Circunvalacion. From TABLE 5-15, average values in both main sewers are summarized as follows:

	BOD5 (mg/l)	SS (mg/l)
Colector Surco :	231 - 333 (avg.269)	241 - 300 (avg.270)
Colector Cir. :	146 - 233 (avg.185)	152 - 278 (avg.228)

TABLE 5-15 Raw Sewage Quality in Main Sewers and San Juan STP

Location	Date	BOD5(mg/l)	SS(mg/l)	Remarks
1. Main Sewer				
- Colector Surco	88.11	333	241	SEDAPAL
	89. 6.19	277*1	-	Avg. of 24 hrs. sampling
	89.10. 9	233	268	
	89.10.19	231*1	300*1	Avg. of 24 hrs. sampling
(Average)		(269)	(270)	
- Colector Circunvalacion	88.11	146	152	SEDAPAL
	89. 6.19	190*1	-	Avg. of 24 hrs. sampling
	89.10. 9	169	278	
	89.10.19	233*1	253*1	Avg. of 24 hrs. sampling
(Average)		(185)	(228)	
- Colector B. del Sur	89. 6.19	240*1	-	Avg. of 24 hrs. sampling
	89.10.19	220*1	184*1	Avg. of 24 hrs. sampling
(Average)		(230)	(184)	
(AVERAGE)		(227)	(239)	
2. San Juan STP	89. 4.12	263	306	
	89. 6. 7	300	206	
		230	88	
	89.10. 9	214	282	
(AVERAGE)		(252)	(221)	
3. Carapongo STP	88.10	165.3	338.3	Monthly Avg.
	11	207	181.8	ditto
	12	137	309.4	ditto
	89. 1	193	417	ditto
	2	179	252	ditto
	3	197	332	ditto
	4	229	590	ditto
	5	167	286	ditto
	5.24	280	-	
		230	-	
	6.9	150	251	
	6	162	348	Monthly Avg.
	7	173	224	ditto
	8	213	259	ditto
	9	130	171	ditto
	10.25	(95)*2	(96)*2	
	10	177	219	Monthly Avg.
(AVERAGE)		(187)	(298)	

*1: Geometric average value based on measured flow.
*2: Not included in average value
Source of data of Monthly Avg.: SEDAPAL

5.4.2 Heavy Metals

There is high possibility that the treated sewage will be reused for irrigation in the San Bartolo Plain after the completion of the Project.

In case that treated sewage is used for irrigation, it is important to consider the presence and concentration of heavy metals in sewage. TABLE 5-16 shows the comparison of the result of analyses and the Water Quality Standards for irrigation in Peru regarding heavy metals (refer to APPENDICES 5 and 10). Class - III of the Water Quality Standards shall be applied for irrigation based on the General Law of Water in Peru.

TABLE 5-16 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.

According to the results of the analyses, Lead and Iron concentrations were higher than the standard values while other items were below the standards. However, the data analyzed was for raw sewage whereas treated sewage from Stabilization Ponds will be used for irrigation in this

Project. Concentration of Lead and Iron in treated water will definitely be lower than in raw sewage because heavy metals will settle more or less in the ponds, hence concentration of these metals will be below the standard value once sewage is treated. In addition, even though raw sewage is being used for irrigation in many places in Lima, there has been no reported damage by heavy metals so far.

It may be considered from the above analyses that heavy metal concentration is not a problem in the planned reuse of treated sewage for irrigation. However, in consideration of (a) the harm long-term accumulation of heavy metals can bring to the human body, (b) inflow of industrial wastewater, and (c) slightly high concentration of heavy metals in drinking water supplied by SEDAPAL, it is recommended that the following actions be taken in the near future:

i. Consolidation of the Standards for receiving of industrial wastewater,

ii. Establishment of the control system for industrial wastewater quality, and

iii. Upgrading of the level of water purification.

5.5 Projected Sewage Quality

5.5.1 General

Projected sewage quality for the design of sewage treatment plant will be investigated and decided in accordance with the following two view points.

a) Present sewage quality in existing facilities

b) Per capita pollutant loading

5.5.2 Present Sewage Quality in Existing Facilities

As discussed in section 5.4, average raw sewage quality of the Colector Surco and the Colector Circunvalacion from which the sewage will be diverted in this Project are summarized as follows:

	BOD_5 (mg/l)	SS (mg/l)
Colector Surco:	231 - 333 (avg.269)	241 - 300 (avg.270)
Colector Cir. :	146 - 233 (avg.185)	152 - 278 (avg.228)

5.5.3 Projection of Sewage Quality based on the Per Capita Pollutant Loading

The pollutant loading per capita varies with the standard of living in the drainage area. Values reported in the references are as follows:

- World Bank, Technical Paper
  - Urban area in developing country : BOD = 40 - 50 g/capita/day
  - USA and Western Europe : BOD = 60 - 80 g/capita/day
- Actual planned values in Japan
  - BOD = 60 - 90 g/capita/day
  - SS = 44 - 60 g/capita/day

With reference to these data, BOD discharge per capita per day is set at D/S.H - 60 g/capita/day, D/S.L - 40 g/capita/day and I.D - 25 g/capita/day for the project. Estimation of total pollutant loadings at present (1989) and in the target year (2000) are shown in TABLE 5-17.

TABLE 5-17 Estimation of Total BOD5 Loading

ITEM	1989	2000
1.Domestic Sewage		
D/S.H.	639,660 x 60 g/capita/day x 10^{-3} = 38,380 kg/day	899,290 x 60 g/capita/day x 10^{-3} = 53,957 kg/day
D/S.L.	829,320 x 40 x10^{-3} = 33,173 kg/day	1,507,860 x 40 x 10^{-3} = 60,314 kg/day
I.D	263,520 x 25 x 10^{-3} = 6,588 kg/day	279,950 x 25 x 10^{-3} = 6,999 kg/day
2.Industrial Wastewater	26,006 m^3/day x 200 mg/l*1 x 10^{-3} = 5,201 kg/day	28,598 m^3/day x 200 mg/l*1 x 10^{-3} = 5,720 kg/day
3.Other Wastewater	69,120 m^3/day x 200 mg/l*1 x 10^{-3} = 13,824 kg/day	55,296 m^3/day x 200 mg/l*1 x 10^{-3} = 11,059 kg/day
TOTAL	97,166 kg-BOD/day	138,049 kg-BOD/day

*1: estimated average value.

Result of calculation for BOD5 concentration of raw sewage is:

<u>1989</u>

$$BOD5 = \frac{97,166 \text{ kg-BOD/day}}{432,000 \text{ m}^3\text{/day}} \times 10^3 = 225 \text{ mg/l}$$

<u>2000</u>

$$BOD5 = \frac{138,049 \text{ kg-BOD/day}}{574,905 \text{ m}^3\text{/day}} \times 10^3 = 240 \text{ mg/l}$$

5.5.4 Decision of Design Sewage Quality

Taking into account the above-mentioned data and the following supporting analyses and factors, design sewage quality is decided as follows:

BOD5: 250 mg/l

SS: 250 mg/l

a. Flow ratio of Colector Surco and Colector Circunvalacion is approximately 7 to 3 according to the results of flow measurement conducted in the Study (refer to APPENDIX 7), and flow of Colector Surco with high BOD concentration is bigger than that of Colector Circunvalacion. Therefore, BOD concentration of mixed raw sewage from both main sewers will be high to some degree.

For example, if ratio of diversion flow is same as the ratio of actual flow, BOD_5 concentration of mixed raw sewage will be:

Surco:	269 x 0.7 = 188.3
Circunvalacion:	185 x 0.3 = 55.5
Total (Mixed raw sewage)	244 mg/l

b. Result of estimation of sewage quality based on the per capita pollutant loading is appropriate value considering the present sewage quality.

c. To cope with the inflow load fluctuation and to secure the treated sewage quality, it is better that design load for treatment plant is set up at higher value.

d. Considering the present sewage quality, SS concentration is nearly equivalent to BOD_5 value.

CHAPTER 6

ALTERNATIVES

CHAPTER 6 ALTERNATIVES

6.1 General

This Study is conducted to establish the appropriate plan for the Project for the following purposes:

(1) To convey the sewage discharged from the southern part of Lima to the plain of San Bartolo for treatment, as a measure against the pollution of sea water along the Chira Coast, and

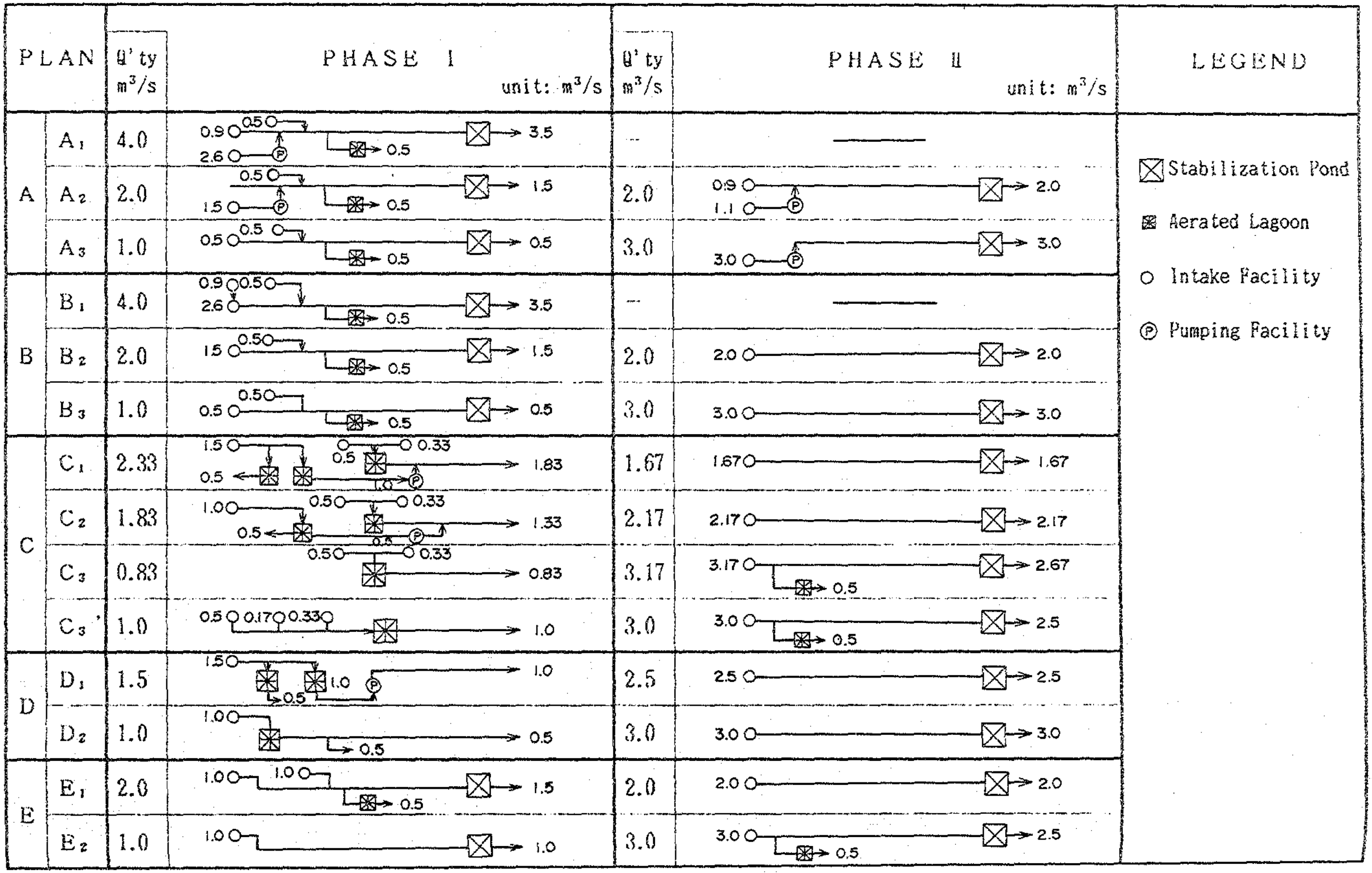
(2) To supply irrigation water to the plain to promote greening and agricultural production.

In pursuit of these objectives, five (5) alternatives, namely Alternatives A to E are developed in this Study. These alternatives are further broken down into 2 to 4 sub-alternatives in accordance with the phased implementation plan. Major differences of the alternatives are:

1) Transmission route to San Bartolo (50 m line, 100 m line),
2) Existence of pumping station,
3) Sewage intake points (variation of 4 intake points), and
4) Sewage intake amount (4 m^3/s in total).

Planning principles and outline of each alternative are described in following sections. FIGURE 6-1 shows the summary of schematic plan of alternatives.

FIGURE 6-1 SCHEMATIC PLAN OF ALTERNATIVES



PLAN		Phase I Q'ty m³/s	Phase II Q'ty m³/s
A	A1	4.0	-
	A2	2.0	2.0
	A3	1.0	3.0
B	B1	4.0	-
	B2	2.0	2.0
	B3	1.0	3.0
C	C1	2.33	1.67
	C2	1.83	2.17
	C3	0.83	3.17
	C3'	1.0	3.0
D	D1	1.5	2.5
	D2	1.0	3.0
E	E1	2.0	2.0
	E2	1.0	3.0

6.2 Principles for Planning

The following fundamental planning principles are established as bases in the development of alternative plans:

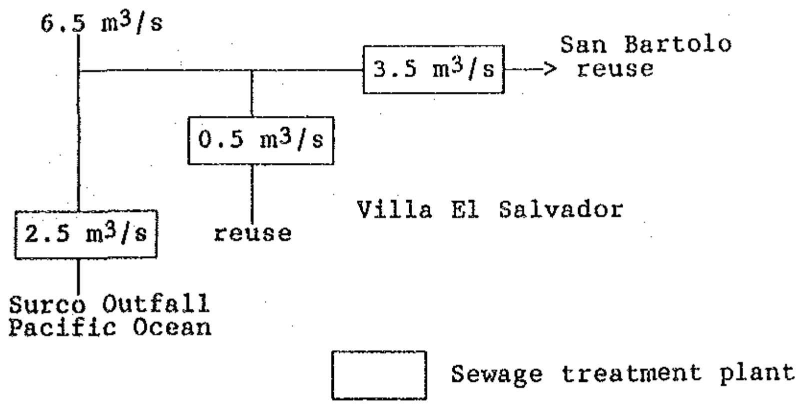
(1) The total amount of raw sewage being discharged from the Surco outfall shall be treated. The subject of the feasibility study, however, is limited to the above-mentioned scope of the Project, which is from intake points of the existing sewer to sewage treatment plants for the transmitted sewage (See FIGURE 6-2).

(2) The total outflow is 6.5 m^3/s in or 560,000 m^3/d daily average (hereinafter the quantity of sewage is expressed as daily average except otherwise specified) in the year 2000, of which 4.0 m^3/s or 350,000 m^3/d is to be treated in San Bartolo, or otherwise to be treated on the way to San Bartolo to a possible amount which may be limited by the area of land acquired for treatment plant. In the latter case, the balance from 4.0 m^3/s is to be treated in San Bartolo.

The remaining 2.5 m^3/s or 210,000 m^3/d is to be treated by an optimum treatment method at the Cerro La Chira site which is owned by SEDAPAL.

(3) The 0.5 m^3/s of sewage out of the above-mentioned 4.0 m^3/s is to be supplied to the irrigation areas in Villa El Salvador.

(4) Flow Balance of Sewage is as follows:



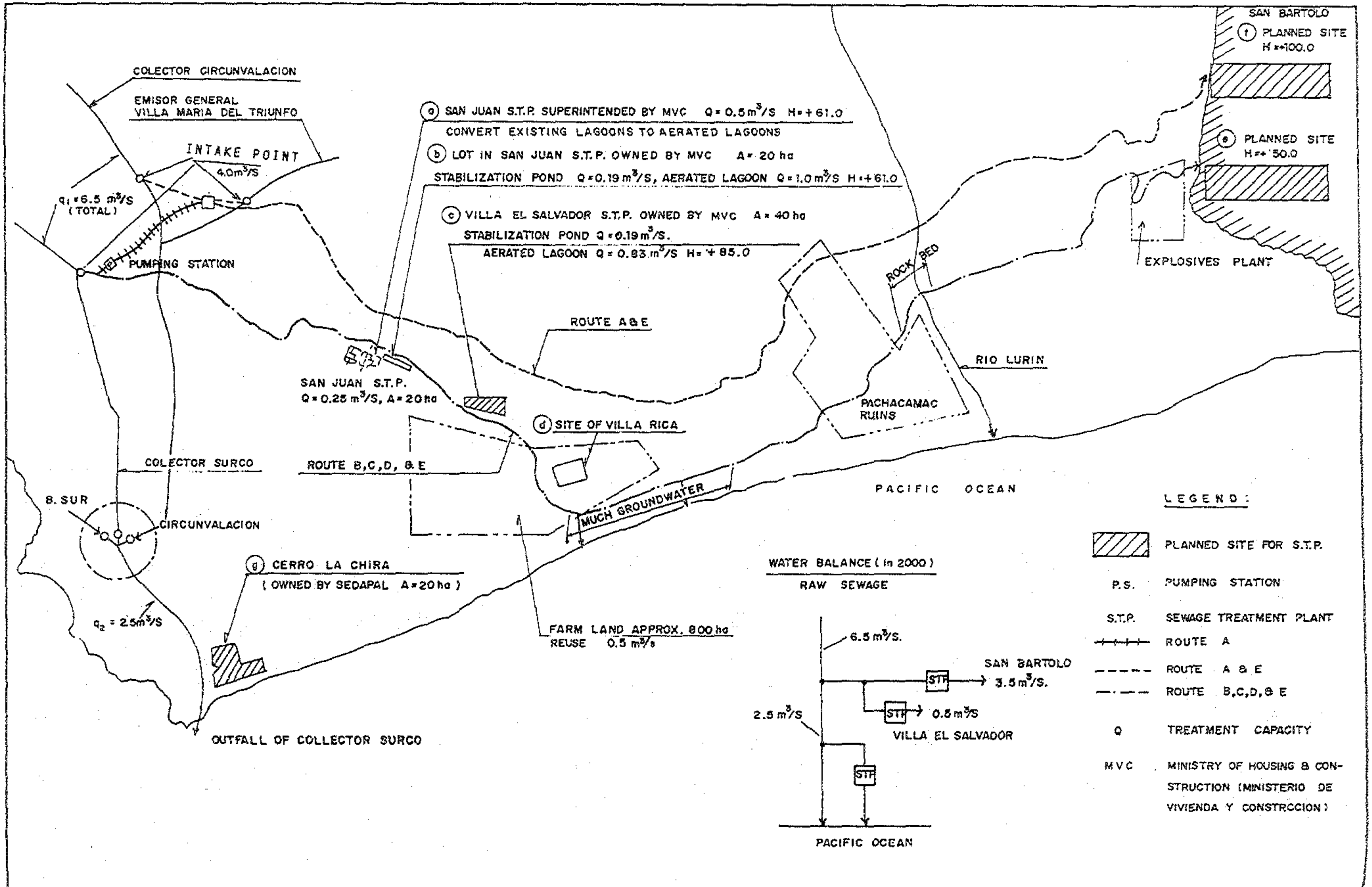


FIGURE 6-2 LAYOUT PLAN OF ALTERNATIVES

The elevation at which the raw sewage or the treated water shall reach San Bartolo is set at +100.0 m or +50.0 m.

(5) The aerated lagoon method is adopted for the plant to be built in the northern area of Rio Lurin (right bank) in order to utilize the limited land area more effectively, and the stabilization pond method for the southern area of Rio Lurin (left bank) because it is hard to avail of electric power supply in the area while land acquisition is comparatively easy (refer to APPENDIX 11).

(6) Since the scale of the sewage transmission plan to San Bartolo is very large, a phased plan shall be drawn up. The whole plan is divided into the Phase I plan and the Phase II plan. The Phase I plan contains the first stage of the work, while the Phase II plan contains the second, and then the third,....,the Nth.

(7) In order to realize benefits from the project in early stage, a plan in which treatment plants are constructed at possible locations nearest the sewage discharging district is considered.

(8) Sewage-intake points shall be located at places where the amount of sewage generated is great and available potential head is high.

(9) Measures to be taken for the inverted siphon

In principle, inverted siphon structure shall be avoided. However, in this Project inverted siphon is adopted unavoidably due to geographic feature (refer to APPENDIX 12). To secure appropriate operation and maintenance, screens and grit chambers (to be used for removing large size particles) are provided next to the sewage-intake facilities, because it is feared that clogging might happen in the inverted siphon section. Since sand and silt is apt to deposit easily on the lowest section of the inverted siphon, it is better to remove them beforehand. In addition, fittings for drainage shall be provided in each inverted siphon section to remove the deposit in the pipeline.

(10) Selection of pipe materials

Ductile cast iron pipe :

To be used for force main and inverted siphon sections (inner pressure: more than 4 kg/cm^2)

Reinforced concrete pipe :

To be used for gravity flowing sections.

Prestressed concrete pipe :

To be used for inverted siphon sections. (inner pressure : less than 4 kg/cm^2)

Fiber glass Reinforced Plastic Mortar Pipe (FRPM pipe):

To be used in place where the soil contains high salinity, and in area where the groundwater is salt intruded.

Open channel lined with concrete:

To be used for gravity flowing sections only when it is located in a thinly populated area.

(11) Prospective sites for the treatment plant are the following (refer to APPENDIX 11 for detail):

TABLE 6-1 Prospective Sites for STP

Location	Area	Requirement for Acquisition
a) Existing San Juan Stabilization Pond	10 ha	Approval of Ministry of Housing and Construction
b) San Juan	35 ha	Moving of plantation
c) Villa El Salvador	40 ha	Moving of plantation and school, Existing lagoon
d) Villa Rica	40 ha	Much fund for land acquisition
e) San Bartolo (Elevation 100 m)	60 ha x 7	Easy to acquire
f) San Bartolo (Elevation 50 m)	60 ha x 7	Easy to acquire
g) Cerro La Chira	20 ha	Planned site for future project of SEDAPAL

d)-Villa Rica is shelved this time because of difficulty in raising necessary funds. g)-Cerro la Chira is reserved for future project.

The maximum sewage treatment capacity of each available proposed site is as shown in the following table (refer to APPENDICES 13 and 14).

TABLE 6-2 Available Sewage Treatment Capacity

Location	Stabilization Pond	Aerated Lagoon
a. San Juan STP	--	0.5 m^3/s
b. San Juan	0.19 m^3/s	1.0 m^3/s
c. Villa El Salvador	0.19 m^3/s	1.0 m^3/s
e. San Bartolo	0.5 m^3/s x 7	--
f. San Bartolo	0.5 m^3/s x 7	--

6.3 Outline of Alternatives

6.3.1 Alternative A (Pumping and Gravity Flow)

(1) In this plan, sewage from the southern part of Lima is transmitted to +100 m elevation line at San Bartolo, and then supplied to the irrigation areas after treatment, thereby contributing to the greening of the area as well as to the cultivation of agricultural crops (refer to FIGUREs 6-3 and 7-7).

(2) Sewage transmission method

The sewage is first lifted from the diversion points by pumping. Then starts gradually flowing down by gravity with the help of inverted siphons at mid-heights between the intake and San Bartolo. Since part of the sewage can be collected by gravity, it will be transmitted by gravity to the junction box at the end of the force main.

(3) To economize on the operation cost, the pump capacity should be minimized as much as practicable. Two suitable points are found out in this regard: Point A'(0.9 m^3/s) and Point D (0.5 m^3/s) are total of 1.4 m^3/s, where a high potential head enough to convey the sewage up to San Bartolo is available. On that account, the pump capacity is finally decided as:

$$4.0 - (0.9+0.5) = 2.6 \ m^3/s \ (225,000 \ m^3/d)$$

(4) Inverted siphon

In principle, the sewage transmission route is planned so that the sewage can flow down by gravity, but when the topographic features do not allow it, the inverted siphon structure must then be adopted. Taking the ease of maintenance into consideration, drains are provided at the lowest section of inverted siphons. Drainage pipe will be connected to existing sewers, river and sea.

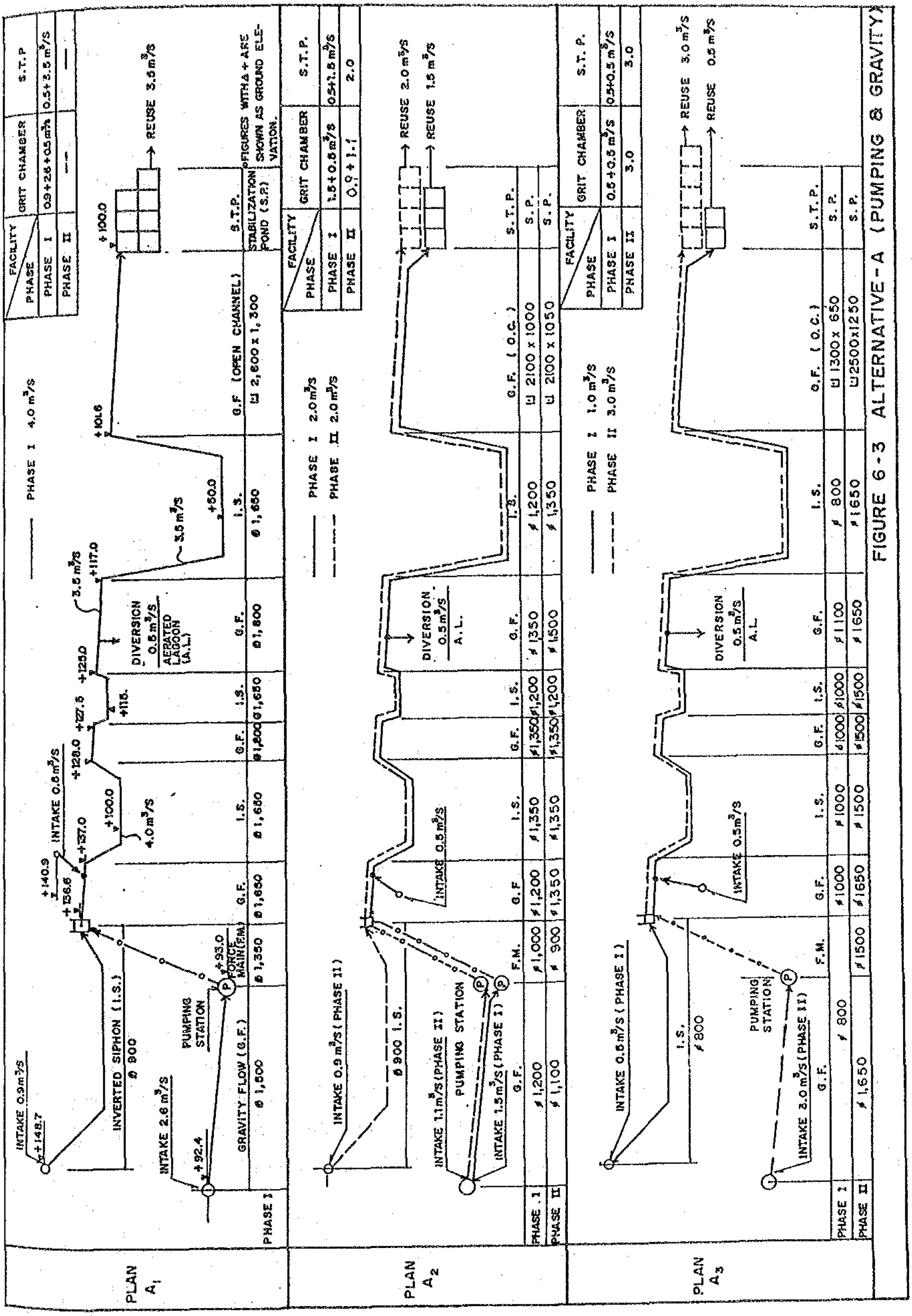


FIGURE 6-3 ALTERNATIVE-A (PUMPING & GRAVITY)

(5) Sewage treatment plant

a. Villa EL Salvador

It is hard to acquire a site with an area enough to construct the sewage treatment plant with a capacity of 0.5 m^3/s in Villa EL Salvador. Possible sewage treatment quantity in case stabilization pond system is adapted in Villa El Salvador is as follows:

	Available Area (ha)	Possible Q (m^3/s)
(b) San Juan	35	0.19
(c) Villa El Salvador	40	0.19
Total	75	0.38

Around more 24 ha of land is necessary for the treatment of remaining sewage (0.5 - 0.38 = 0.12 m^3/s).

However, it is hard to acquire such a large area in the vicinity, therefore, aerated lagoon system is adopted because of the following reasons:

i) Sufficient treatment is possible even if the area of the site is small.

ii) Stable treatment effect which emits less odor is expectable. There are many houses in the surrounding area.

b. San Bartolo

The stabilization pond method is adopted in this plan because of the reasons that the land acquisition is still easy, the ambient temperature is stable throughout the year, duration of sunshine is long enough thereby making the treatment more efficient, and few complaints would be expected about bad odor owing to the sparsely populated environmental conditions.

The size of the treatment plants is estimated to be 60 ha x 7 places.

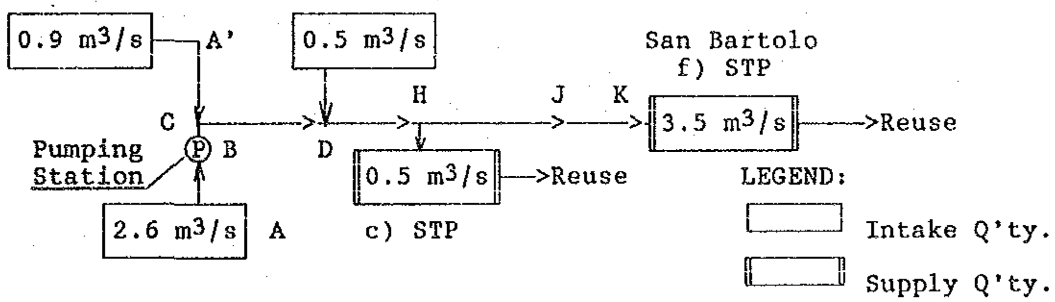
The exact locations of the plants cannot be specified at this time because the agricultural development plan is not yet distinct or definite.

(6) Open channel

An open channel structure is applied to the transmission route starting from point J to point K because it is presumed that the areas have very low possibility of being converted into residential districts neither at present nor in the future.

(7) For plan A_1, the planned sewage quantities are as follows.

Total plan: Q=0.9+0.5+2.6=4.0 m^3/s (Quantity of sewage intake)

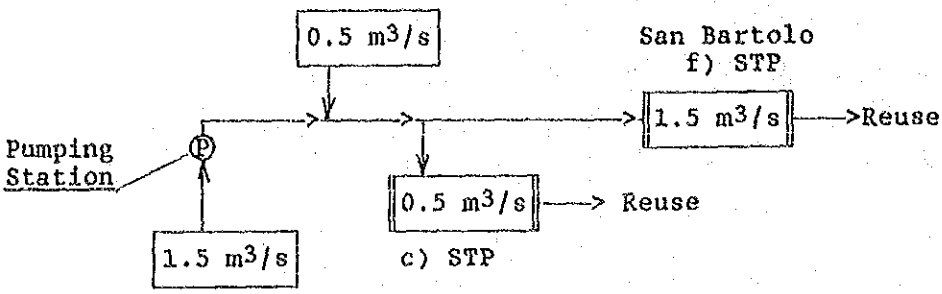


In this plan, the quantity of sewage intake is set at 4.0 m^3/s.

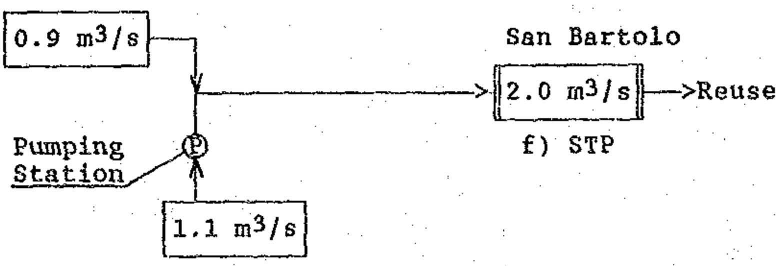
Because a large amount of funds is necessary for this plan, phased construction plans (A_1=Q, A_2=Q/2, A_3=Q/4) are recommended and briefly described in the following item of discussion.

(8) For plan A_2, the planned sewage quantities are as follows.

i) Phase I: $Q=1.5+0.5=2.0\ m^3/s$



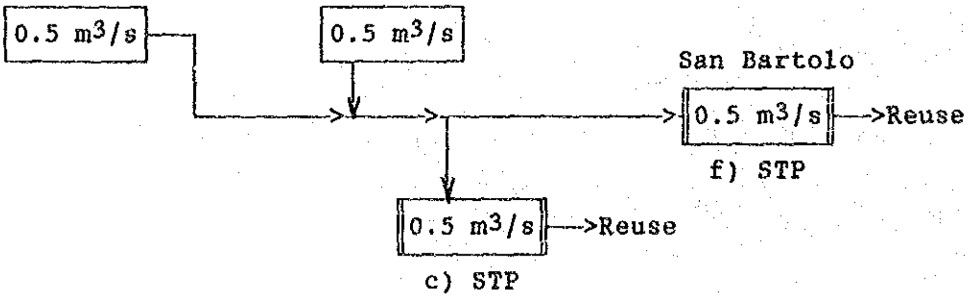
ii) Phase II: $Q=0.9+1.1=2.0\ m^3/s$



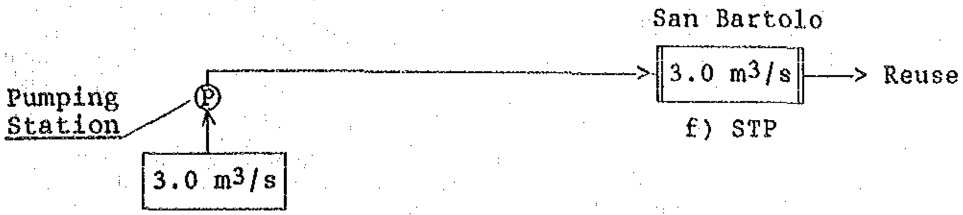
In plan A_3, the scope contained in the first phase of A_2 is further reduced.

(9) For plan A_3, the planned sewage quantities are as follows.

i) Phase I: $Q=0.5+0.5=1.0\ m^3/s$



ii) Phase II: Q=3.0 m^3/s



This plan is disadvantageous in that the pump capacity of Phase II plan becomes comparatively larger owing to the scale-down of the first phase, on the other hand, the investment cost for Phase I is correspondingly reduced.

6.3.2 Alternative B (Gravity Flow)

(1) In this plan, sewage from the southern part of Lima is conveyed to +50 m elevation line at San Bartolo, and then supplied to the irrigation after treatment, thereby contributing to the greening of the area as well as to cultivation of agricultural crops (refer to FIGUREs 6-4 and 7-8).

(2) Sewage transmission method

The sewage transmission in this plan starts from the diversion points by gravity flow. The sewage is then transmitted from San Juan, via Villa El Salvador, Lomo de Corvina beach and Pachacamac up to San Bartolo, alternately passing through gravity flow sections and inverted siphon sections.

(3) Sewage treatment plant

a. Villa El Salvador

Refer to subsection 6.3.1 (5).

b. San Bartolo

The stabilization pond method is adopted in this plan because of the reasons that the available land is ample and acquisition is still easy,

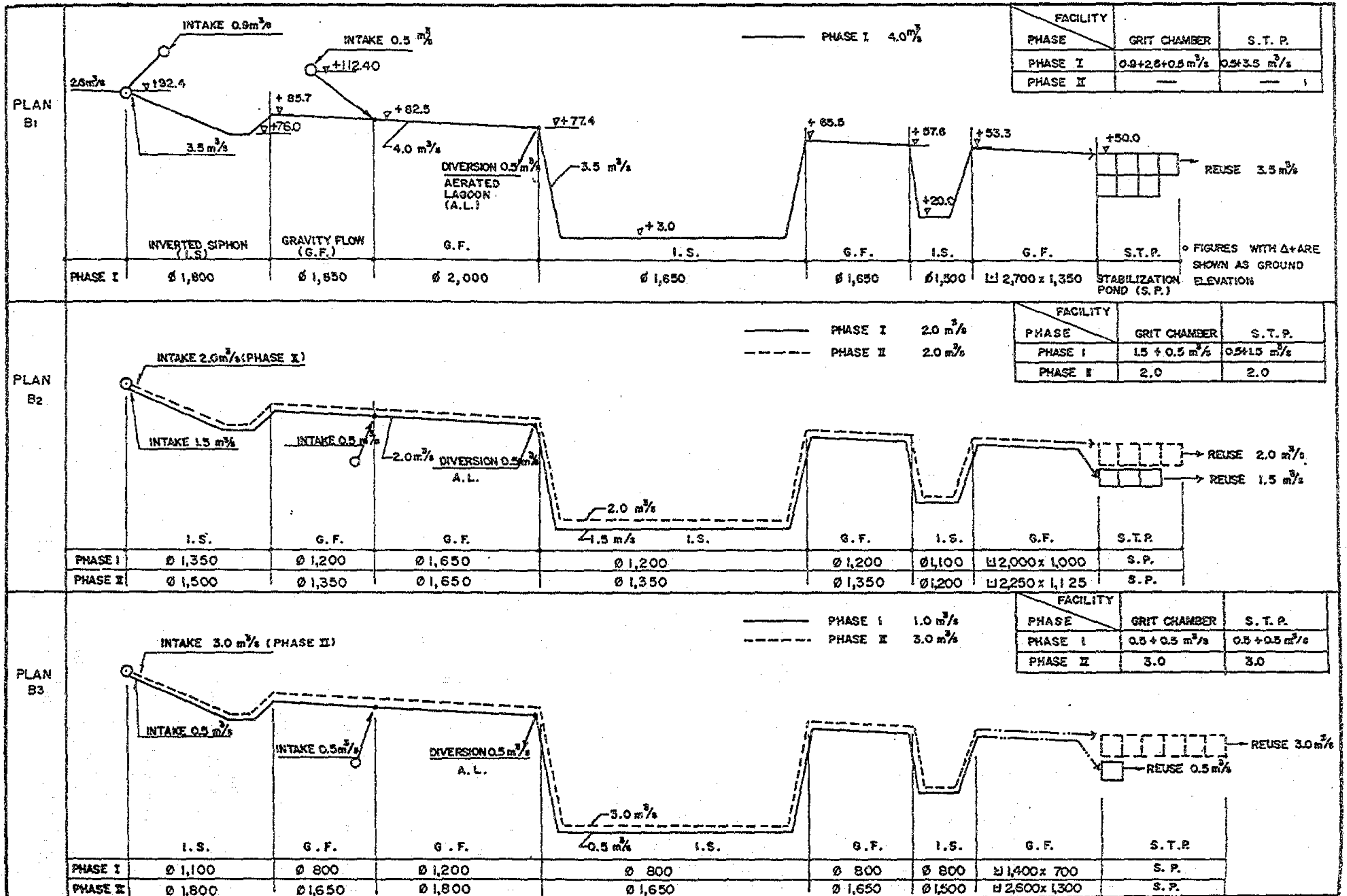


FIGURE 6-4 ALTERNATIVE -B (GRAVITY)

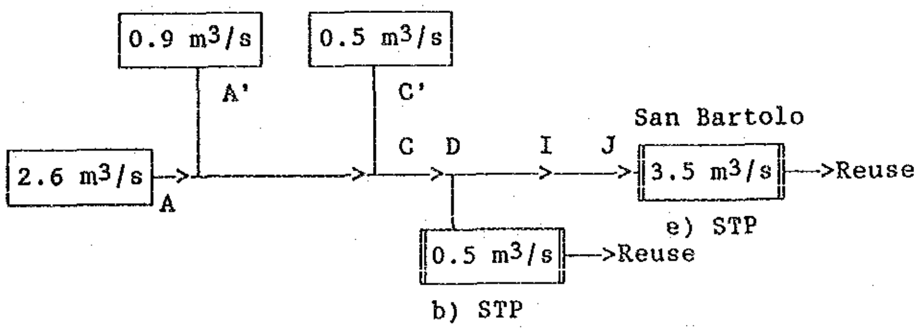
ambient temperature is stable throughout the year, duration of sunshine is long enough thereby making the treatment more efficient, and few complaints are expected about bad odor owing to the sparsely populated environmental conditions. The size of the treatment plants is estimated to be 60 ha x 7 places. The exact locations of the plants cannot be specified at this time because the agricultural development plan is not yet distinct or definite.

(4) Open channel

An open channel structure is applied to the transmission route starting from point I to point J because it is presumed that the areas have very low possibility of being converted into residential districts neither at present nor in the future.

(5) For plan B_1, the planned sewage quantities are as follows.

Total plan: Q=0.9+2.6+0.5=4.0 m^3/s

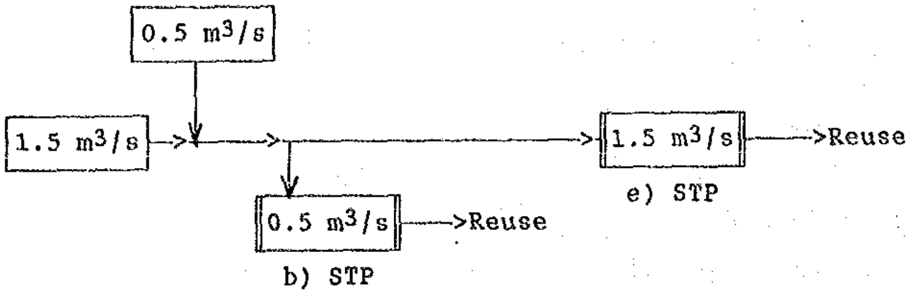


In this plan, sewage intakes of 0.9 m^3/s and 0.5 m^3/s from points A' and C', respectively are set because the sewage flow at point A is not expected to reach the total of 4.0 m^3/s when this plan is implemented in the next two to three years.

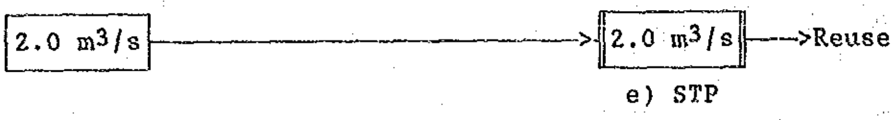
The quantity of sewage intake in this plan is set at 4.0 m^3/s. Because a large amount of funds is necessary for this plan, a scale-down of the first phase is proposed as described in the following item of discussion.

(6) For plan B_2, the planned sewage quantities are as follows.

i) Phase I: $Q=1.5+0.5=2.0\ m^3/s$



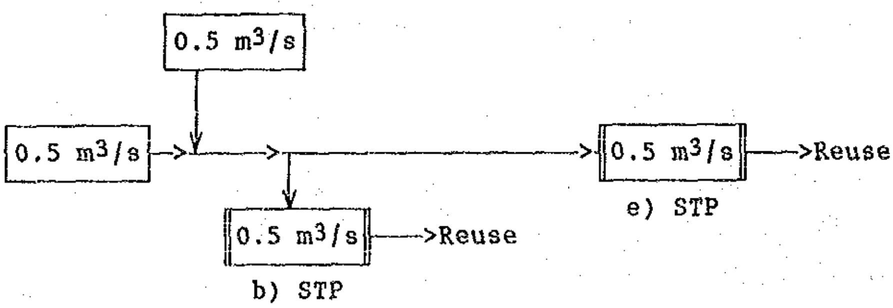
ii) Phase II: $Q=2.0\ m^3/s$



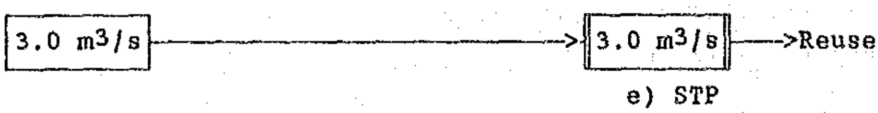
In plan B_3, the scope of the first phase of B_2 is further reduced.

(7) For plan B_3, the planned sewage quantities are as follows.

i) Phase I: $Q=0.5+0.5=1.0\ m^3/s$



ii) Phase II: $Q=3.0\ m^3/s$



6.3.3 Alternative C (Gravity Flow and Pumping)

(1) In this plan, sewage from the southern part of Lima is first treated at the right bank of the Rio Lurin to an extent which the area of the acquired land will allow and then transmitted to +50 m elevation line at San Bartolo to be supplied to the irrigation areas.

In fact, it is practically impossible to acquire a sufficient area of land for the treatment plants in the zone between San Juan and the Rio Lurin river because almost all of the lands in this zone are already fully developed. Under this circumstances, the maximum treatment capacity (q m^3/s) corresponding to the available land area in the zone, namely Parque Zonal No.6, is planned as a Phase I plan of this Alternative C.

In the Phase II plan, on the other hand, the treatment plants are going to be erected in San Bartolo like in plan B in order to treat the remaining (4-q) m^3/s of sewage (refer to FIGUREs 6-5 and 7-9 to 12).

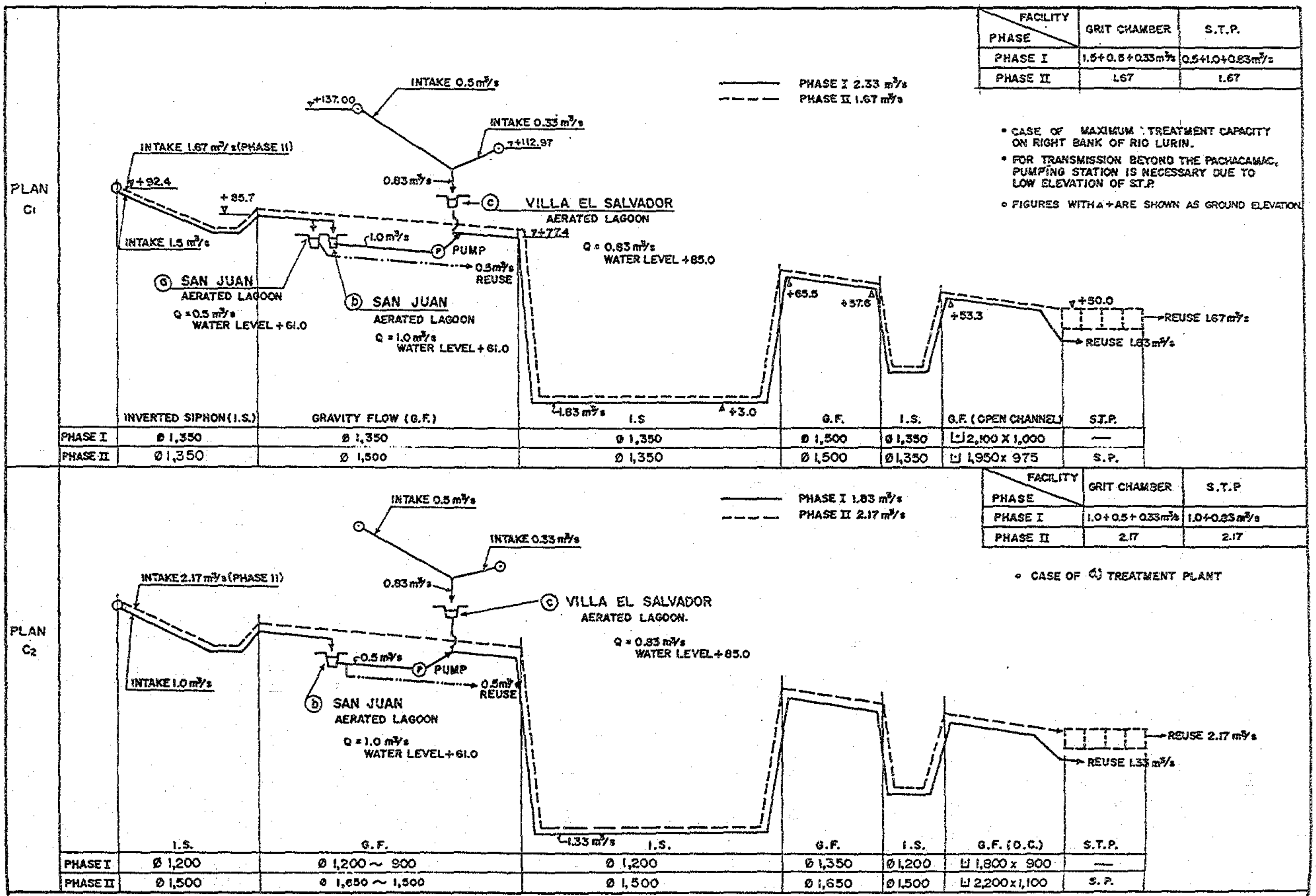
(2) Sewage transmission method

The sewage transmission in this plan starts from the diversion points by inverted siphon flow to the treatment plants for treatment.

Out of the total treated water, 0.5 m^3/s (43,000 m^3/day) is going to be supplied to the irrigation areas in Villa El Salvador, while the remaining amount is to be supplied to the irrigation areas in San Bartolo by pumping and gravity flow including inverted siphon.

(3) Sewage treatment method

The aerated lagoon method is adopted for the treatment plants of this plan which are to be erected on the right bank of the Rio Lurin because of the following reasons:



Plan C1

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

	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+0.33 m³/s	1.0+0.83 m³/s
PHASE II	2.17	2.17

	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 6-5 ALTERNATIVE-C (GRAVITY + PUMPING)

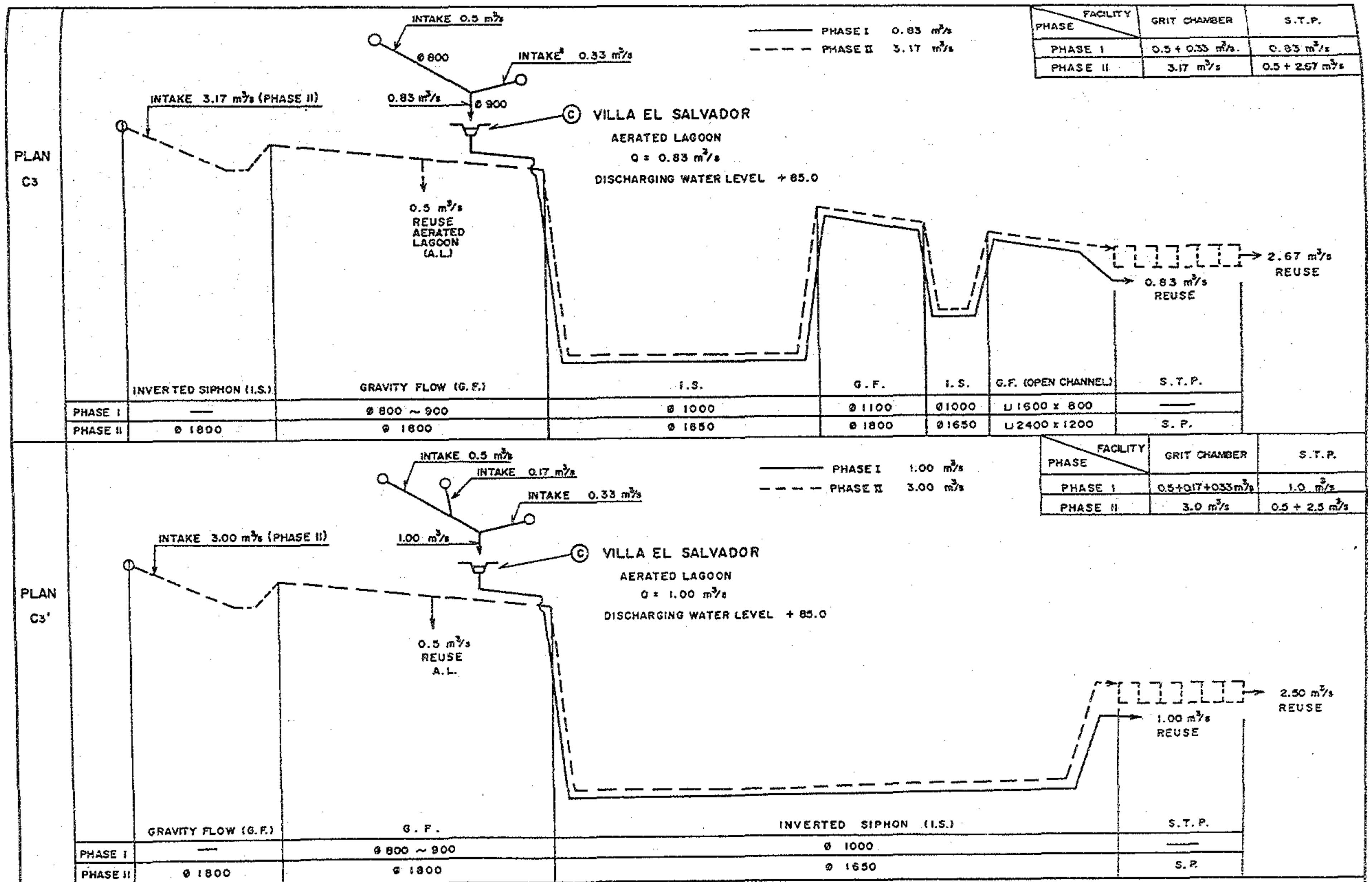


FIGURE 6-5 (CONT'D)

a) The land area enough to meet the expected quantity of treatment is difficult to acquire.

If the stabilization pond method is adopted, only 0.19+0.19=0.38 m^3/s ((b) + (c)), of sewage can be treated, which is merely one fifth (1/5) that of the aerated lagoon method. This degree of sewage curtailment is hardly enough to meet the required measures against pollution along Chira coast.

Consequently, the aerated lagoon method is taken into consideration in this plan, as it can treat a volume of sewage five times as much as when stabilization pond method is employed hence land utilization is optimized.

b) Surroundings of the prospective sites for the treatment plants to be located between San Juan and Parque Zonal No.26 are being converted into residential areas year by year, hence careful attention must be paid to the odor and esthetics. In fact, densely built residential districts are now already very close to and almost facing the eastern part of the existing plants, and complaints about the odor arise from the residents frequently especially during times of cloudy weather.

Under this circumstances, if the stabilization pond method is adopted, the following matters are well presumed:

In summer season, the weather is good and the duration of sunshine is long enough to make the treatment more efficient, thus it would preclude complaints from nearby residents about the odor.

However, in the winter season, the sunshine is not enough because of the frequent occurrence of dense fogs brought about by the Humboldt Cold Current and long lasting cloudy weather. These conditions will inevitably decrease the treatment efficiency and then consequently cause the emission of bad odor which may lead to troubles with nearby residents.

The aerated lagoon method can be said more advantageous in that it is not affected by the weather as opposed to the stabilization pond method, and moreover, capable of producing stable quality of treated water.

c) On the other hand, the aerated lagoon method consumes a very large amount of electricity, and the aerator which is a component of this method has a weak point, namely its short service life.

When 1.0 m^3/s of sewage is treated through the aerated lagoon process, approximately 7,140,000 kWH/year of electricity is consumed, which is equal to about 8% of the total electric power consumption of SEDAPAL. The electricity charge for this consumption amount is:

7,140,000 kWH/year x 0.025 US$/kWH = 178,500 US$/year

If the replacement cost for the aerator is set aside as reserve, the treatment cost for 1 m^3 is:

413,000,000/(86,400 m^3/day x 365 x 15) = 0.873 Yen/m^3
= 0.0062 US$/$m^3$ (2)

where: Price of aerator: Approx. Yen 413,000,000
Service life: 15 years

Consequently, the treatment cost will be:

(1) (2)
(0.0057 + 0.0062) x 86,400 x 365 = 375,000 US$/year

(4) Proposed site for treatment plants

a) San Juan treatment plant

If the stabilization pond method which is now adopted to the existing treatment plants is converted into the aerated lagoon method, the treatment capacity will increase by 0.5 m^3/s.

Conversion from stabilization pond to aerated lagoon method will involve additional excavation of the upper 10 ponds to a depth of 3.0m from the present water depth of 1.3 m and the provision of an aerator.

The increase in capacity is:

$$65{,}200-21{,}600 = 43{,}600\ m^3/day = 0.5\ m^3/s$$

The water level of the sedimentation basin is set at elevation +61.0 m.

b) Proposed site for planned new San Juan treatment plant

The treated water from the existing San Juan treatment plant has been used to irrigate this site for twenty years, resulting to the successful implementation of the greening plan for the area which is now used as a recreation zone.

In order to construct the planned treatment plant, the following conditions must be fulfilled (with the consent of the residents):

The treatment plant should be built at a sufficient distance from the residential districts; the trees removed because of the construction work must be transplanted, or otherwise new trees should be planted within the vicinity to compensate for the removal of trees, thereby maintaining the total greenery in the area.

The maximum treatment capacity of this plant is 1.0 m^3/s, and the water level of the sedimentation basin is at elevation +61 m.

c) Proposed site for Villa El Salvador treatment plant

The site is now used as a park which is locally known as Parque Zonal No.26, and is under the administration of Ministry of Housing and Construction.

Inside the park, there are a primary school, four privately built and owned stabilization ponds, and numerous young trees that were planted a few years ago.

In order to implement the construction plan of the treatment plant, the following conditions must be satisfied: relocation of the primary school and transplanting of removed or planting of new trees; careful and continuous or sustained supply of the agricultural water to the rightful users of the existing ponds even during construction period.

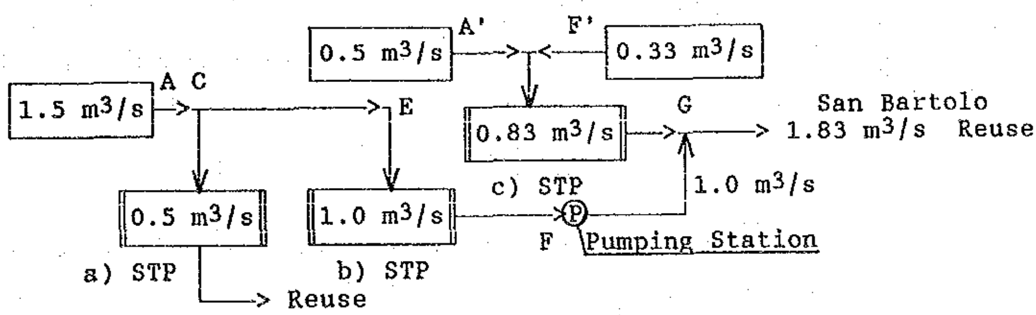
The maximum treatment capacity is only 0.83 m^3/s owing to the special topographic and geometric features of the area which has a very steep surface gradient and a triangular shape.

The water level of the sedimentation basin is at election +85.0 m, which is 24.0 m higher in potential head than that of the sites in a) and b) previously discussed. On that account, the treatment plant of c) is more advantageous as the sewage transmission can be attained across Pachacamac only by gravity flow.

The disadvantage of this plan, however, is that available sewage from the nearby districts is not enough.

(5) For plan C_1, the planned sewage quantities are as follows.

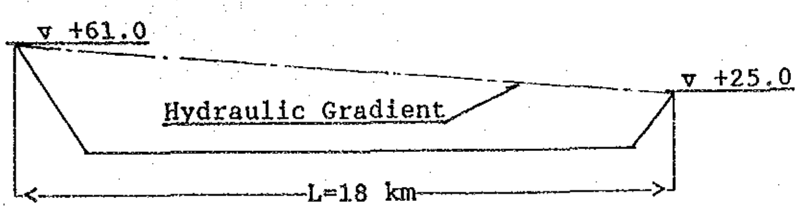
i) Phase I: $Q=1.5+0.5+0.33=2.33\ m^3/s$



All of the available lands in this district are used in this plan.

ii) Considerations on relay pumping station

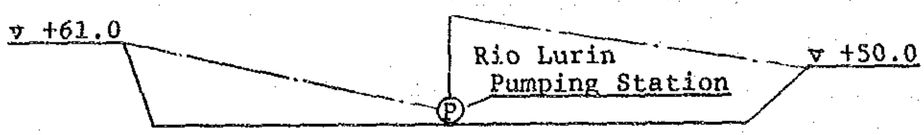
The water level of the sewage treatment plant b) in plan C_1 above is at elevation +61.0 m while the elevation of the Pachacamac is +65.4 m, therefore, water transmission to San Bartolo through this route is impossible. Then the next route is considered instead.



This new route runs along Pan American Highway up to Arica, then turns left from there. The plan to use this route is also shelved because of the following reasons:

As long as 18 km of inverted siphon section is needed for this route; the maintenance is very difficult because of the long distance of the inverted siphon section; and, the inverted siphon section might burst at some points due to the corrosion of the prestressed concrete pipes as often experienced by SEDAPAL.

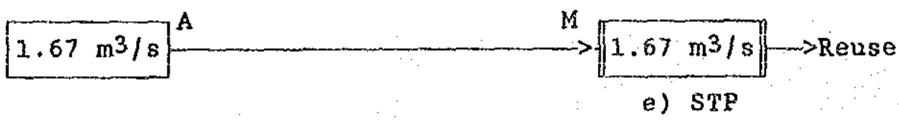
Then the following plan, in which a new relay pumping station is added on the right bank of the Rio Lurin, is considered.



However, this plan is still more disadvantageous than plan C_1 in that the necessary pump head is more than 50 m and the transmission route is much longer.

Finally, plan C_1 is adopted wherein the relay pumping station is located just next to the treatment plant b) as shown in plan C_1 which can make the head much lower, thereby considerably increasing economic benefit.

iii) Phase II : $Q=1.67\ m^3/s$

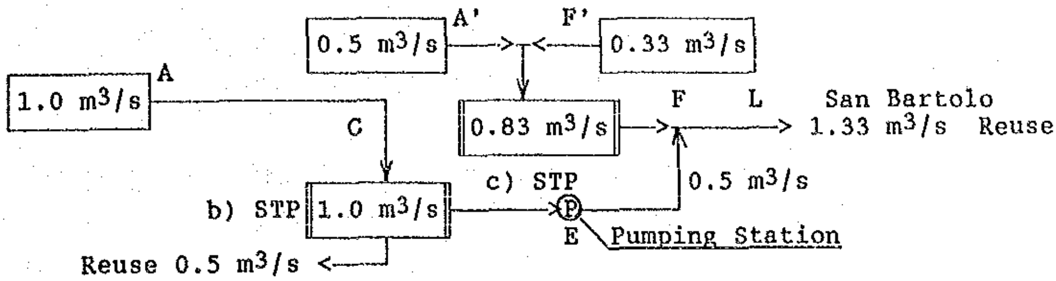


The route adopted into this plan is the same as that of plan B_1.

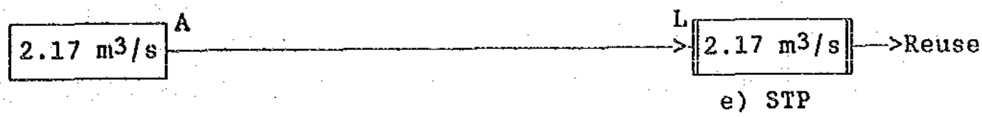
(6) For plan C_2, the planned sewage quantities are as follows.

Plan C_2 differs from plan C_1 only in that the treatment plant a) in plan C_1 is excluded.

i) Phase I : $Q=1.0+0.5+0.33=1.83\ m^3/s$



ii) Phase II : $Q=2.17\ m^3/s$



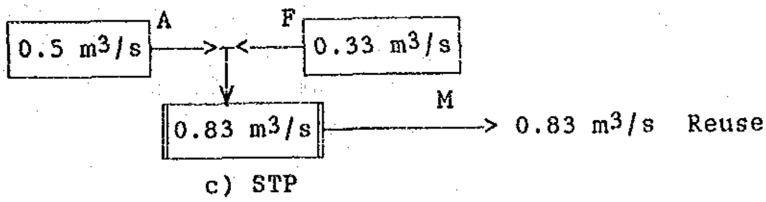
The route adopted into this plan is the same as that of plan B_1.

(7) For plan C_3, the planned sewage quantities are as follows.

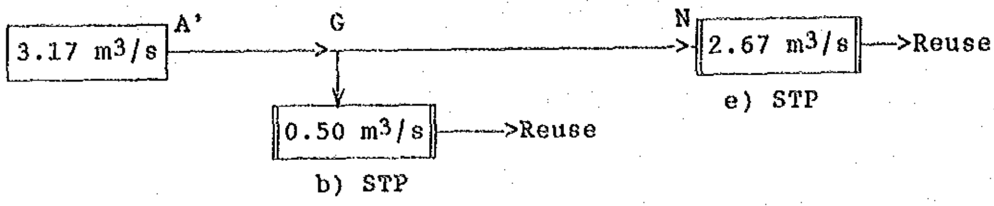
Plan C_3 differs from plan C_1 in that the treatment plants a) and b) in plan C_1 are excluded. The potential head at the treatment plant c) is high enough to convey water to San Bartolo without the help of relay pumping station.

Since the sewage intake is only $0.83\ m^3/s$, $0.5\ m^3/s$ of the diversion is not provided in the Phase I of this plan.

i) Phase I: $Q=0.5+0.33=0.83\ m^3/s$



ii) Phase II: $Q=3.17\ m^3/s$



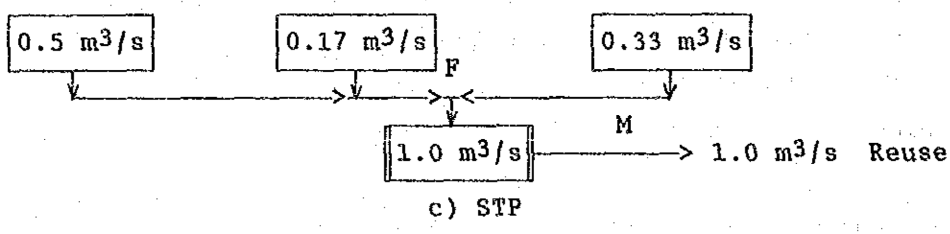
The route adopted in this plan is the same as that of plan B_1.

(8) Plan C_3' is a modified plan of C_3 in case the passage through the Pachacamac Ruins is not allowed.

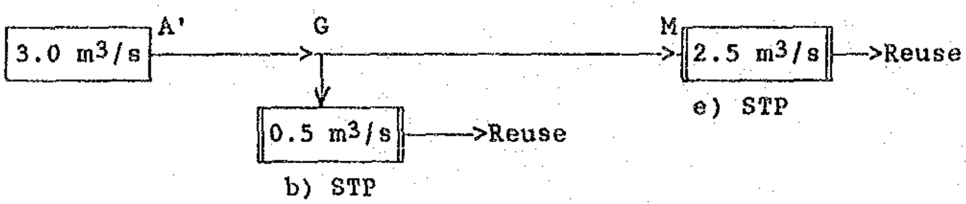
The route of this plan runs along the same way as that of plan C_3 from point A to point I. However, after point I, the route runs along the Pan American Highway to San Bartolo.

This plan requires longer inverted siphon span in comparison with the plan C_3, hence has the disadvantages in terms of difficult maintenance and high possibility of accidents. To adopt this plan, study on the installation of a booster pumping station at the bank of the Rio Lurin which is at the middle point of the planned route, shall be conducted.

i) Phase I: $Q=0.5+0.17+0.33=1.0\ m^3/s$



ii) Phase II: $Q=3.0\ m^3/s$



6.3.4 Alternative D (Gravity Flow and Pumping)

(1) In this plan, sewage from the southern part of Lima is first treated at the right bank of the Rio Lurin and then conveyed to +50 m elevation line at San Bartolo to be supplied to the irrigation areas.

In fact, it is practically impossible to acquire a sufficient area of land for the treatment plants in the zone between San Juan and the Rio Lurin because almost all of the lands in the zone are already fully developed. Under this circumstances, the maximum treatment capacity (q m^3/s) corresponding to the available land area in the zone is planned as a Phase I of this plan D.

In the Phase II, on the other hand, the treatment plants are going to be erected in San Bartolo like as in plan B in order to treat the remaining (4-q) m^3/s of sewage.

The contents of this plan D is the same as that of plan C in principle, but the proposed site for treatment plant in this plan is same as that for treatment plant b) (refer to FIGUREs 6-6, 7-13 and 7-14).

(2) Sewage transmission method

The sewage transmission in this plan starts from the diversion points with inverted siphon and gravity flow to the treatment plants for treatment. Out of the total treated sewage, 0.5 m^3/s is going to be supplied to the irrigation areas of Villa El Salvador, while the remaining amount is to be supplied to the irrigation areas of San Bartolo by pumping and gravity flow.

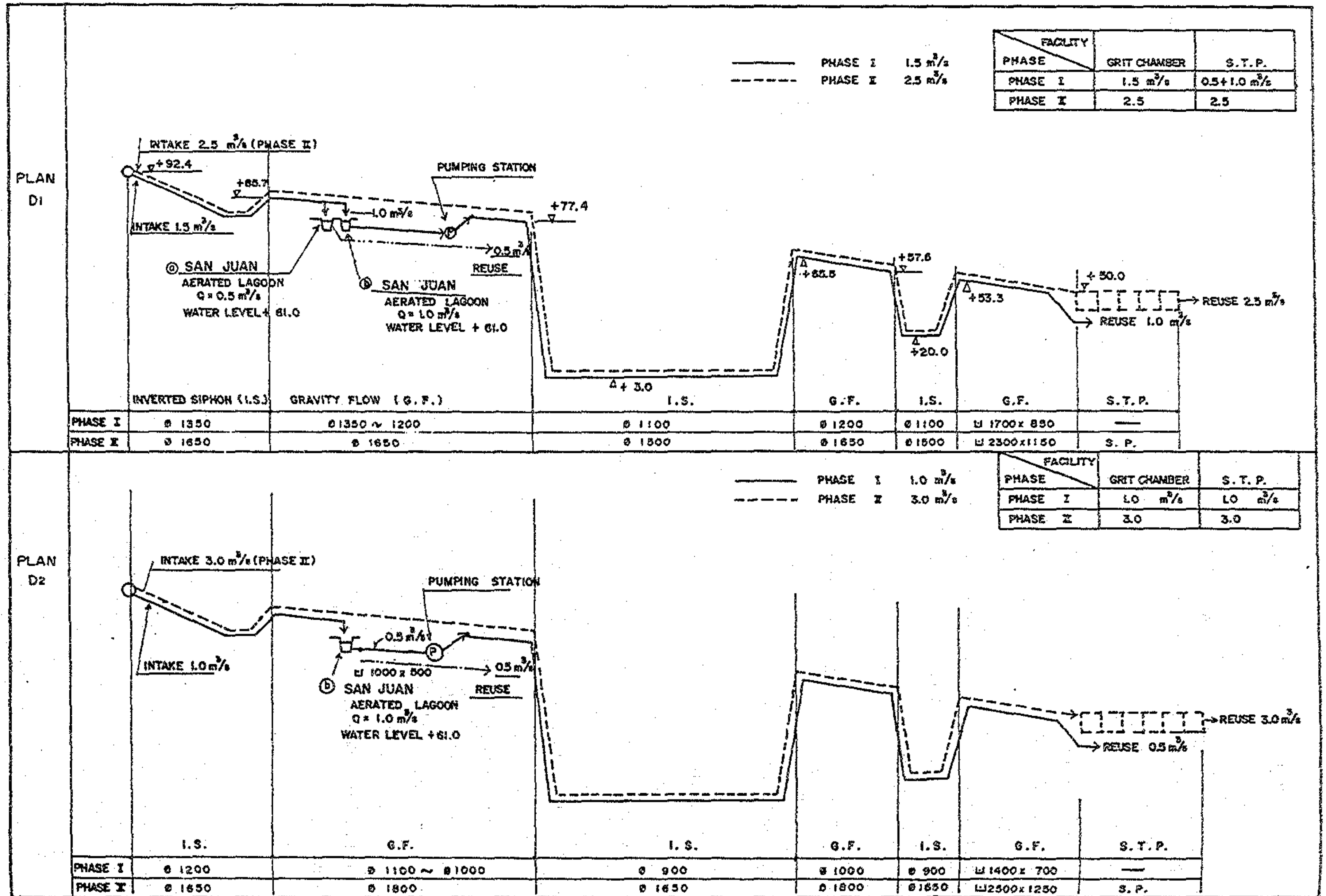


FIGURE 6 - 6 ALTERNATIVE-D (GRAVITY + PUMPING)

(3) Sewage treatment method

The aerated lagoon method is adopted in the treatment plant to be constructed on the right bank of the Rio Lurin (refer to paragraph 6.3.3 (3)).

For the treatment plant to be constructed in San Bartolo, the stabilization pond method is adopted. (refer to paragraph 6.3.1 (5).)

(4) Proposed site for treatment plants are as follows:

a) San Juan treatment plant

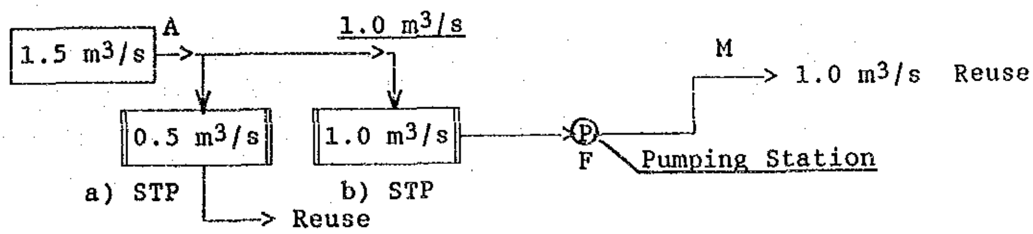
Planned capacity : 0.5 m^3/s.
Water level of the sedimentation basin: +61.0 m.

b) Proposed site for new San Juan treatment plant

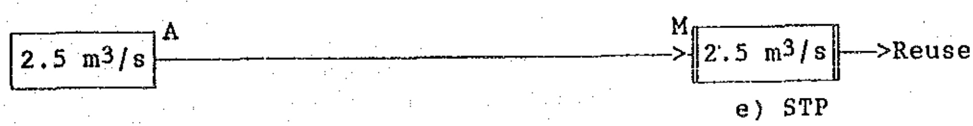
Planned capacity : 1.0 m^3/s.
Water level of the sedimentation basin: +61.0 m.

(5) For plan D_1, the planned sewage quantities are as follows:

i) Phase I: Q=1.5 m^3/s



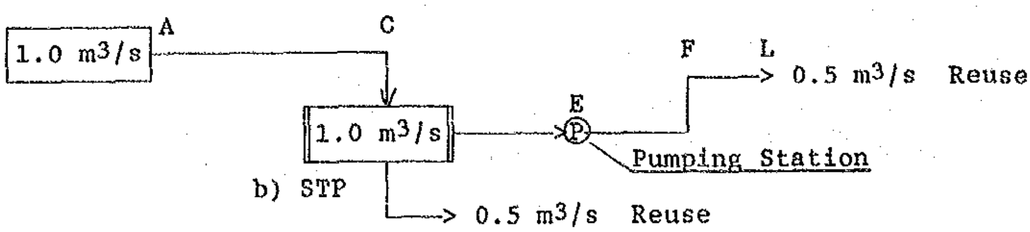
ii) Phase II: Q=1.0 m^3/s



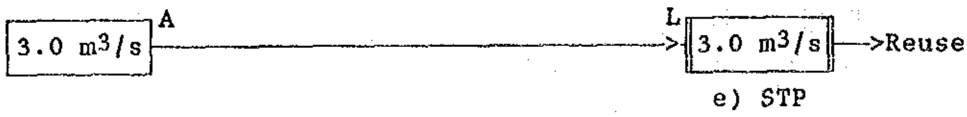
The route adopted in this plan is the same as that of plan B_1.

(6) For plan D_2, the planned sewage quantities are as follows.

i) Phase I : Q=1.0 m^3/s



ii) Phase II: Q=3.0 m^3/s



The route adopted in this plan is the same as that of plan B_1.

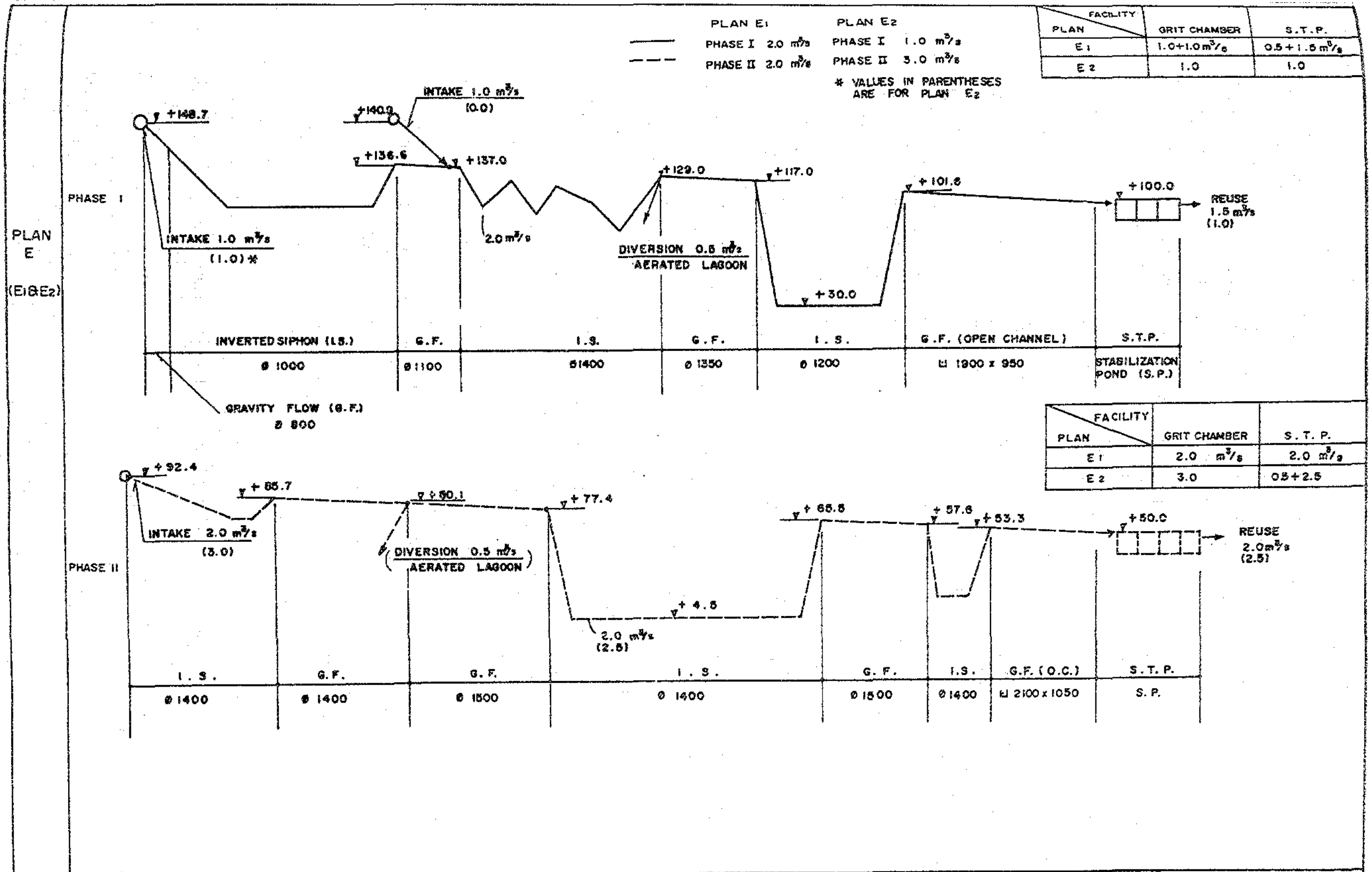
6.3.5 Alternative E (Gravity Flow)

(1) In this plan, sewage from the southern part of Lima is transmitted to San Bartolo, and then supplied to the irrigation areas after treatment, thereby contributing to the greening of the area as well as to cultivation of the agricultural crops.

In phase I of this plan E, the target elevation at San Bartolo is +100.0 m, while in the Phase II plan, the goal is set at elevation +50.0 m (refer to FIGUREs 6-7 and 7-15).

(2) The contents of Phase I plan of this plan E is almost the same as that of plan A except that pumping facilities are not included in this plan E.

On the way to Villa El Salvador, 0.5 m^3/s of the diversion point is also provided in this plan with aerated lagoon treatment system.



FACILITY / PLAN	GRIT CHAMBER	S.T.P.
E1	1.0+1.0 m³/s	0.5+1.5 m³/s
E2	1.0	1.0

FACILITY / PLAN	GRIT CHAMBER	S.T.P.
E1	2.0 m³/s	2.0 m³/s
E2	3.0	0.5+2.5

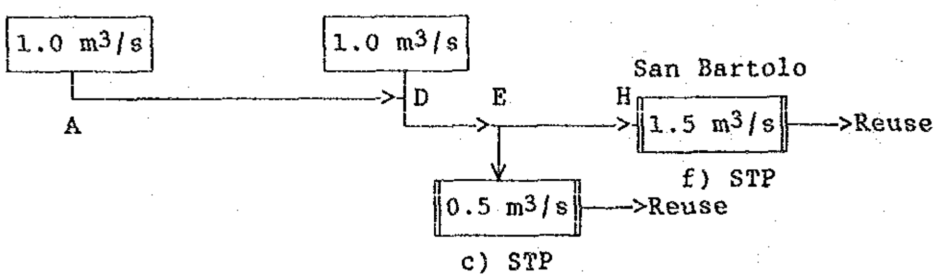
FIGURE 6 - 7 ALTERNATIVE - E (GRAVITY)

(3) In Phase I, the plan to pass through the Pachacamac Ruins is shelved because of the dim possibility of attaining approval from government authorities. However, depending upon results of detailed investigation on the ruins, this scheme may be possible using the route in plan B. Therefore, plan for Phase II will be the same as plan B except for the intake facility at points A' and C'.

(4) Plan E_1 is as follows:

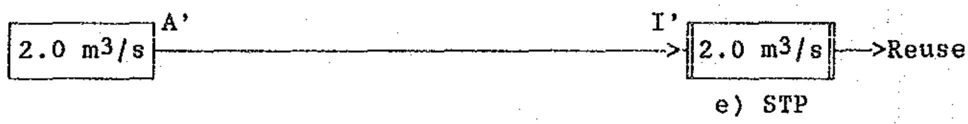
i) In the Phase I of the plan E_1, the planned sewage quantities are as follows.

$Q=0.5+1.5=2.0\ m^3/s$



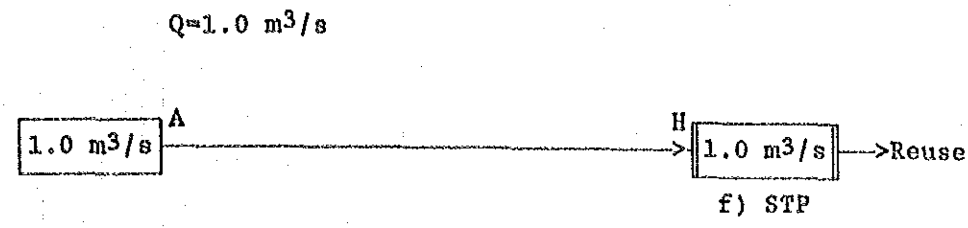
ii) In the Phase II of the plan E_1, the planned sewage quantities are as follows.

$Q=2.0\ m^3/s$

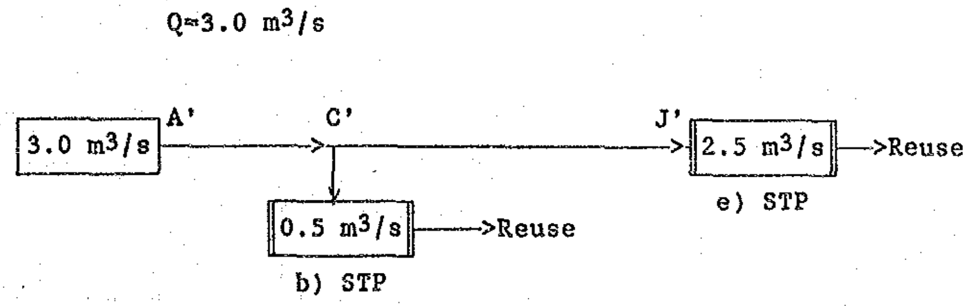


(5) Plan E_2 is as follows:

i) In the Phase I of the plan E_2, the planned sewage quantities are as follows.



ii) In the Phase II of the plan E_2, the planned sewage quantities are as follows.



6.4 Summary of Planned Sewage Quantity

The sewage quantity planned for each alternatives are summarized in TABLE 6-3.

TABLE 6-3 Summary of Planned Sewage Quantity

			TOTAL PROJECT											
			PHASE I						PHASE II					
Plan	Location of STP		(a) SAN JUAN STP	(b) SAN JUAN	(c) VILLA EL SALVADOR	(e) SAN BARTOLO	(f) SAN BARTOLO	Total	(b) SAN JUAN	(c) VILLA EL SALVADOR	(e) SAN BARTOLO	(f) SAN BARTOLO	Total	REMARKS
	Treatment Method		Aerated Lagoon			Stabilization Pond			Aerated Lagoon		Stabilization Pond			
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_5			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 7

PRELIMINARY ENGINEERING DESIGN OF ALTERNATIVES

CHAPTER 7 PRELIMINARY ENGINEERING DESIGN OF ALTERNATIVES

7.1 General

Based on the concept developed in Chapter 6, the preliminary engineering designs of each alternative were prepared in order to obtain the basic data for cost estimation. This chapter presents the principles applied and considered in the design work and outlines of designed facilities of some alternatives.

Major facilities necessary to be constructed for the Project are:

1) Intake Facility
2) Transmission Facility
3) Pumping Facility
4) Sewage Treatment Facility

7.2 Intake Facility

Intake facilities are provided to collect planned amount of sewage from existing main sewers installed in the southern part of Lima.

7.2.1 Design Considerations

The following basic considerations were taken into account in the design of the intake facilities.

(1) The facility shall be constructed at the place where planned sewage amount can be taken.

(2) In principle, the facility shall be constructed at the place high enough to enable transmission of sewage to the destination by gravity (including inverted siphon).

(3) The structure shall have the capability to intake planned amount of sewage and not to intake excessive amount.

(4) The structure shall have the capability to eliminate large substances and sedimentable particles from the sewage to prevent of clogging and obstruction of sewage flow.

(5) The facility shall not make the environment of surrounding area worse.

Based on the above considerations, it was found advantageous to have the sewage intakes at points on the Colector Surco, the Colector Circunvalacion, the Emisor General Villa Maria del Triunfo and the Emisor General Villa El Salvador.

TABLE 7-1 shows the allocation of sewage intake based on discussion in Chapter 6.

TABLE 7-1 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.

7.2.2 Outline of Facility

Structure of the intake facility may be of the weir type or sluice gate type.

The weir type intake facility has an advantage in that mechanical equipment is not necessary for its operation, and comparatively stable flow can be diverted without any operation. However, a large space is necessary for its construction, and it is comparatively difficult to change the sewage flow direction for diversion works without stopping the flow of sewage.

The sluice gate type intake facility does not require large space. However, it is disadvantageous in the aspect that some mechanical equipment is necessary and stability of diversion flow is less that of the weir type intake facility.

Considering the condition of the proposed intake points, e.g., traffic conditions, road width, etc., the sluice gate type intake facility is recommendable to be adopted for the Project. Because of the necessity of grit sedimentation facility for the succeeding inverted siphon, the intake facility will be unified with a grit chamber. A typical drawing of such intake facility is shown in FIGURE 7-1.

As an example, the design outline of intake facilities for alternative plan E_1 is as follows:

(1) The facilities will be designed in accordance with the following sewage intake program taking the result of sewage quantity projection into consideration:

Phase I	1 m^3/s from the Colector Circunvalacion
	1 m^3/s from the Emisor General Villa Maria del Triunfo
Phase II	2 m^3/s from the Colector Surco

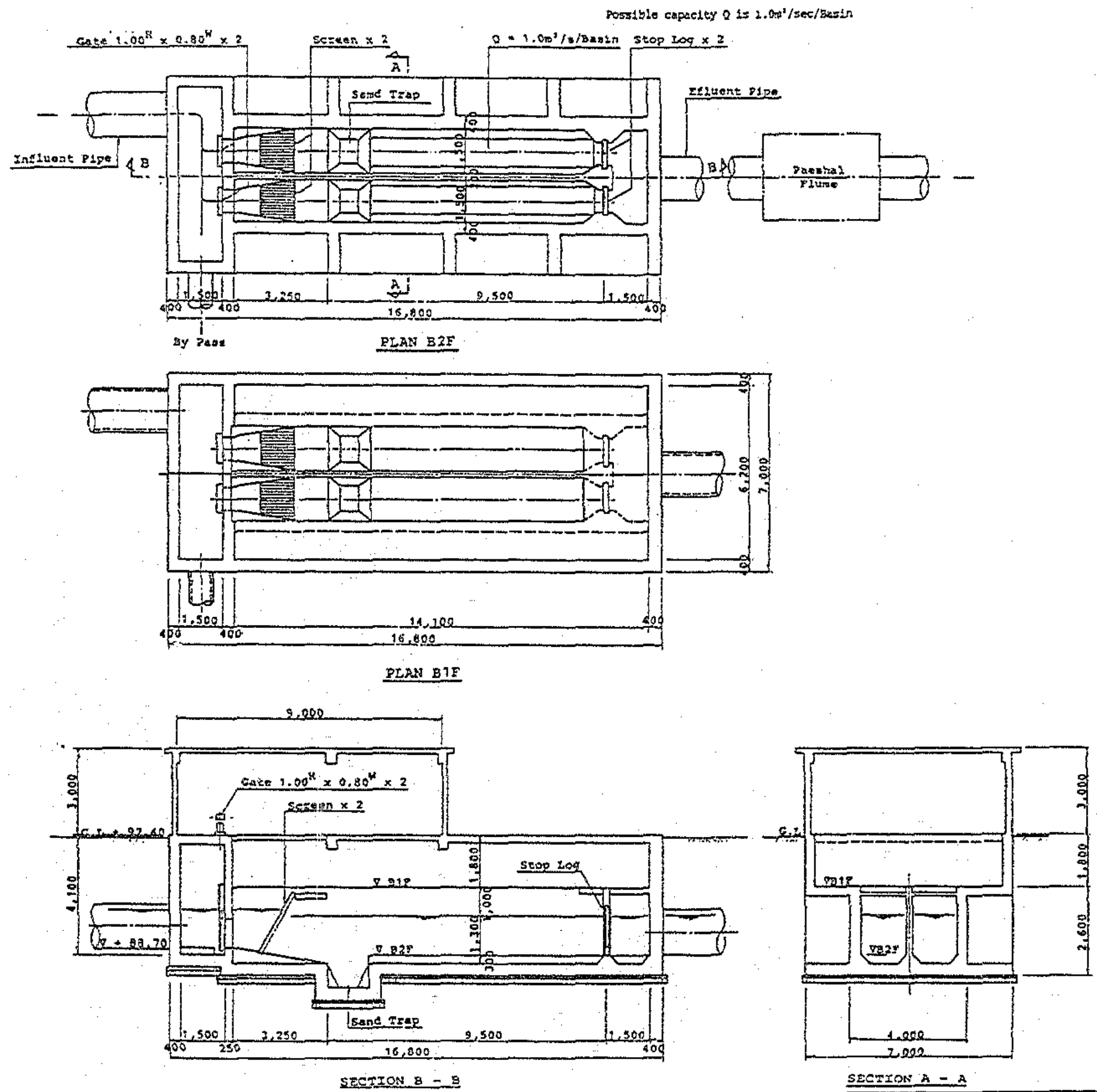


FIGURE 7-1 Intake Facility

SEDAPAL

Servicio de Agua Potable y Alcantarillado de Lima

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

TITLE: Intake Facility

SCALE: as above | DATE: - -'90 | DRAWING No.:

JAPAN INTERNATIONAL COOPERATION AGENCY

(2) The facilities will be constructed at the following locations (see FIGURE 7-2):

Phase I	Intake Point No.1 :	Colector Circunvalacion at GL +148m
	Intake Point No.2 :	General Emisor Villa Maria del Triunfo at GL +137 m
Phase II	Intake Point No.3 :	Colector Surco at GL +92 m

From intake points Nos. 1 & 2, the sewage is transmitted by gravity to a place with a ground elevation of 100 m in San Bartolo Plain. The sewage from intake point No.3 flows by gravity down to a place with a ground elevation of 50 m in San Bartolo Plain.

(3) The sewage amount to be taken is controlled with sluice gates in accordance with the indication of a Parshall flume type flow meter. Excess of sewage will be returned to the main sewer through bypass line.

(4) Screens and grit chambers will be installed.

(5) The facility will be constructed under the ground and properly covered to prevent the escape of bad odor. A small building with ventilation equipment will be installed on the structure for maintenance.

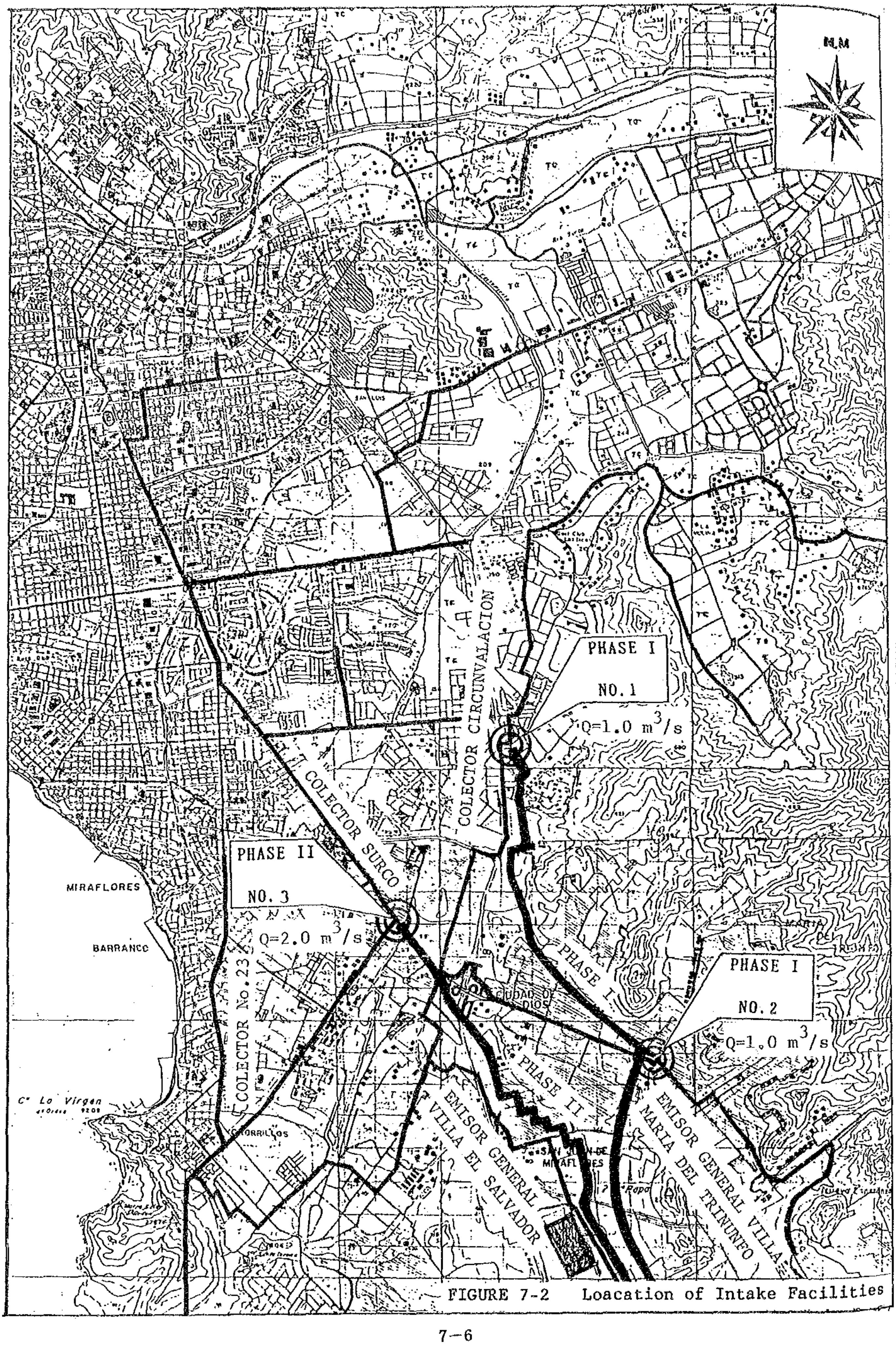


FIGURE 7-2 Loacation of Intake Facilities

7.2.3 Intake Plan and Fluctuation of Flow

Sewage flow at the intake points varies with time, thus, the intake facilities shall be designed in consideration of such fluctuations. For instance, the following factors and conditions were considered in the design of the intake facilities of Plan E_1.

(1) Phase I (Intake Points No. 1 and No. 2)

1) It is assumed that sewage flow will fluctuate in accordance with the planned daily variation curve which is taken as the average of flow curves based on actual measurements at the downstream end of the Colector Circunvalacion (refer to APPENDIX 15). This point was selected because here the current sewage flow is almost the same as the expected future sewage flow of the planned intake points.

2) The minimum intake sewage flow will be decided by the minimum sewage flow at the intake points, while the maximum intake sewage flow is limited to the minimum flow capacity of the transmission line. The minimum sewage flow shall, therefore, be at least at a level that would enable a minimum allowable velocity of 0.8 m/s in the inverted siphon sections. Total sewage flow amount shall also be at least at a level that would assure necessary intake amount. The planned daily variation curve for average intake amount of 1.0 m^3/s is presented in FIGURE 7-3.

3) The planned intake amount and desirable sewage flow at the intake points to assure an average intake amount of 1.0 m^3/s are summarized as follows:

i) Planned Intake Amount	Maximum:	1.170 m^3/s
	Average:	1.000 m^3/s
	Minimum:	0.745 m^3/s
ii) Desirable Sewage Flow at Intake Point	Maximum:	1.346 m^3/s
	Average:	1.016 m^3/s
	Minimum:	0.745 m^3/s

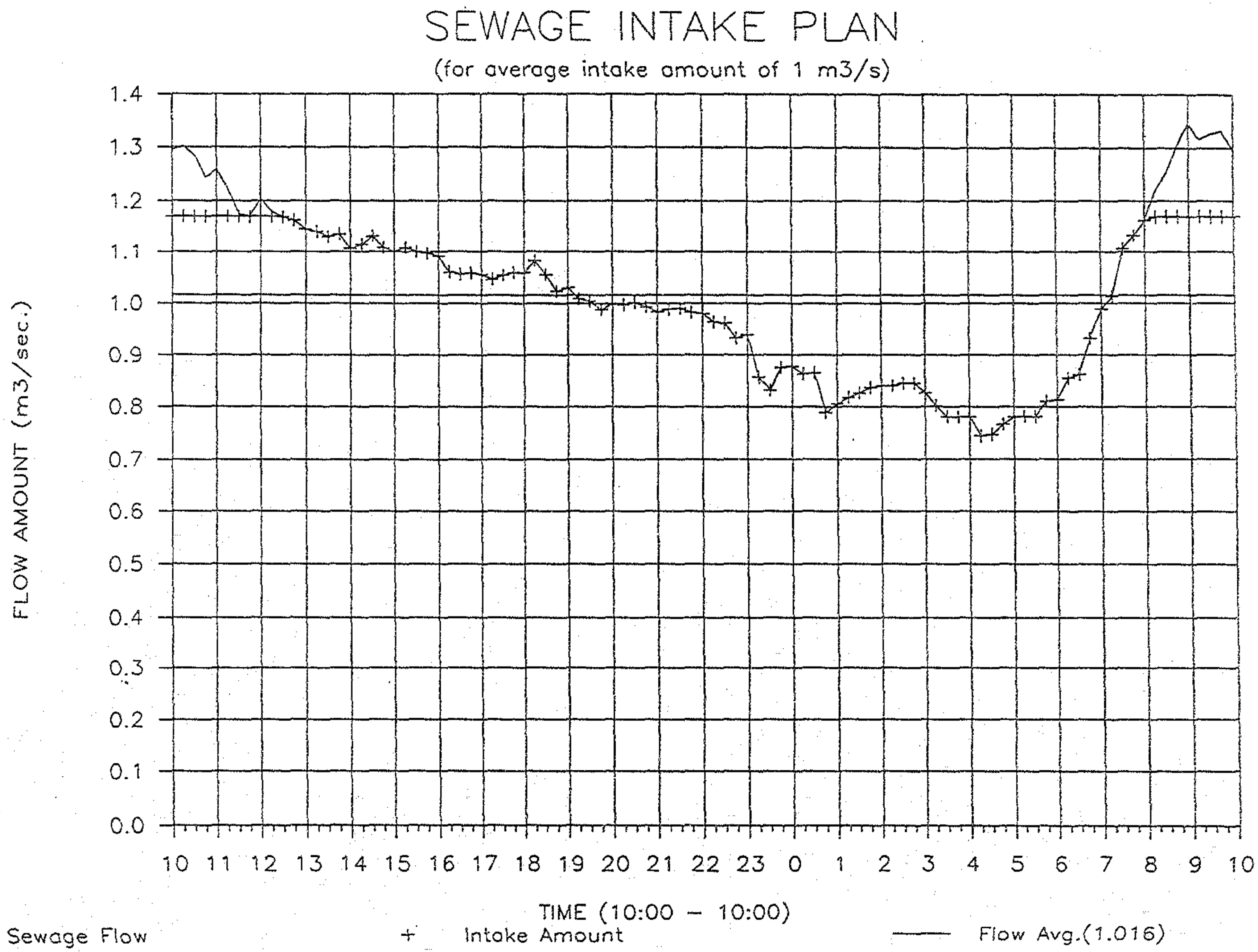


FIGURE 7-3 Planned Daily Sewage Variation Curve - 1.0 m^3/s

The average total intake amount of both intake points No.1 and No.2 shall exceed 1.2 m^3/s that would enable the allowable minimum flow velocity of 0.8 m/s in the inverted siphon section. If it is impossible, this plan will not be viable. (refer to FIGURE 7-16, inverted siphon section D-E.)

4) The calculated desirable sewage flow is greater than the planned future sewage flow at the intake points (No.1: 0.740 m^3/s, No.2: 0.923 m^3/s). Thus, alteration of sewer network and other appropriate measures including those presented in Subsection 5.3.2 shall be taken to secure desirable sewage flow at the intake points. On the other hand, the minimum sewage flow (0.745 m^3/s) exceeds the desirable minimum sewage flow (0.5 m^3/s each). Therefore, minimum flow velocity will exceed the allowable minimum flow velocity.

5) Structure of sewage intake is of weir type. Thus, the height of weir crest shall be set at a level that would enable diversion of the maximum planned intake amount. To decide the level and diameter of the diversion pipe, various factors such as the height of crest, the weir head at the time of maximum flow, the diameter and invert level of main sewer, and the water depth in sewer shall be considered. The Concept of the intake weir is shown in FIGURE 7-4.

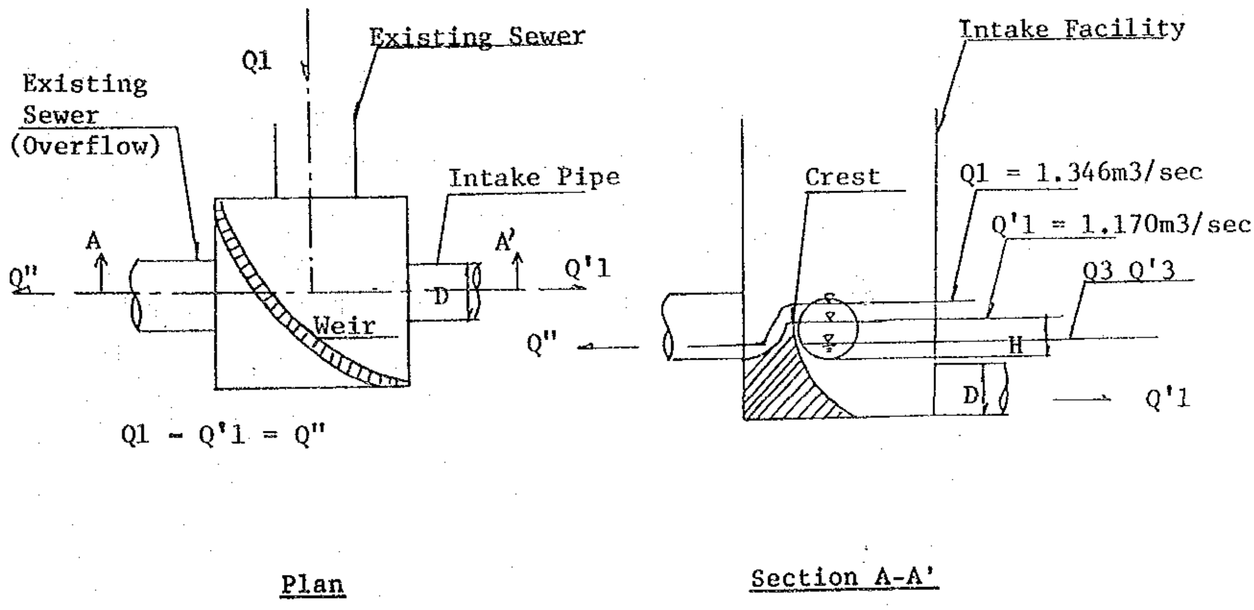


FIGURE 7-4 Concept of Intake Weir

(2) Phase II (Intake Point No. 3)

1) It is assumed that sewage flow will fluctuate in accordance with the planned daily variation curve which is taken as the average of flow curave based on actual measurements (refer to APPENDIX 15).

2) The minimum sewage flow shall, therefore, be at least at a level that would enable a minimum allowable velocity of 0.8 m/s in the inverted siphon sections. Total sewage flow amount shall also be at least at a level that would assure necessary intake amount. The planned daily variation curve for average intake amount of 2.0 m^3/s is presented in FIGURE 7-5.

3) The planned intake amount and desirable sewage flow at the intake points to assure an average intake amount of 2.0 m^3/s are summarized as follows:

i) Planned Intake Amount	Maximum:	2.061 m^3/s
	Average:	2.000 m^3/s
	Minimum:	1.370 m^3/s
ii) Planned Sewage Flow	Maximum:	2.881 m^3/s
	Average:	2.388 m^3/s
	Minimum:	1.370 m^3/s

4) The maximum planned intake amount (2.061 m^3/s) is less than the maximum flow capacity of transmission line (2.12 m^3/s). Also the minimum sewage flow (1.370 m^3/s) exceeds the desirable minimum sewage flow (2.0 m^3/s x 0.8 m/s / 1.2 m/s = 1.33 m^3/s).

5) The structure of sewage intake is of weir type and designed under the same concept as in Phase I facilities. The Concept of the intake weir is shown in FIGURE 7-6.

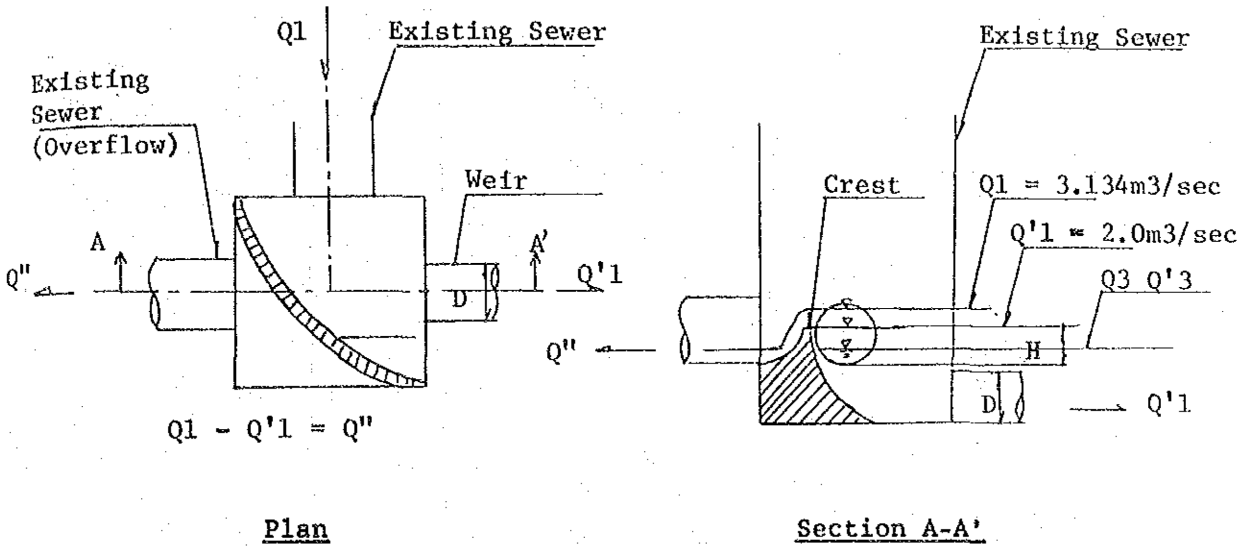


FIGURE 7-6 Concept of Intake Weir

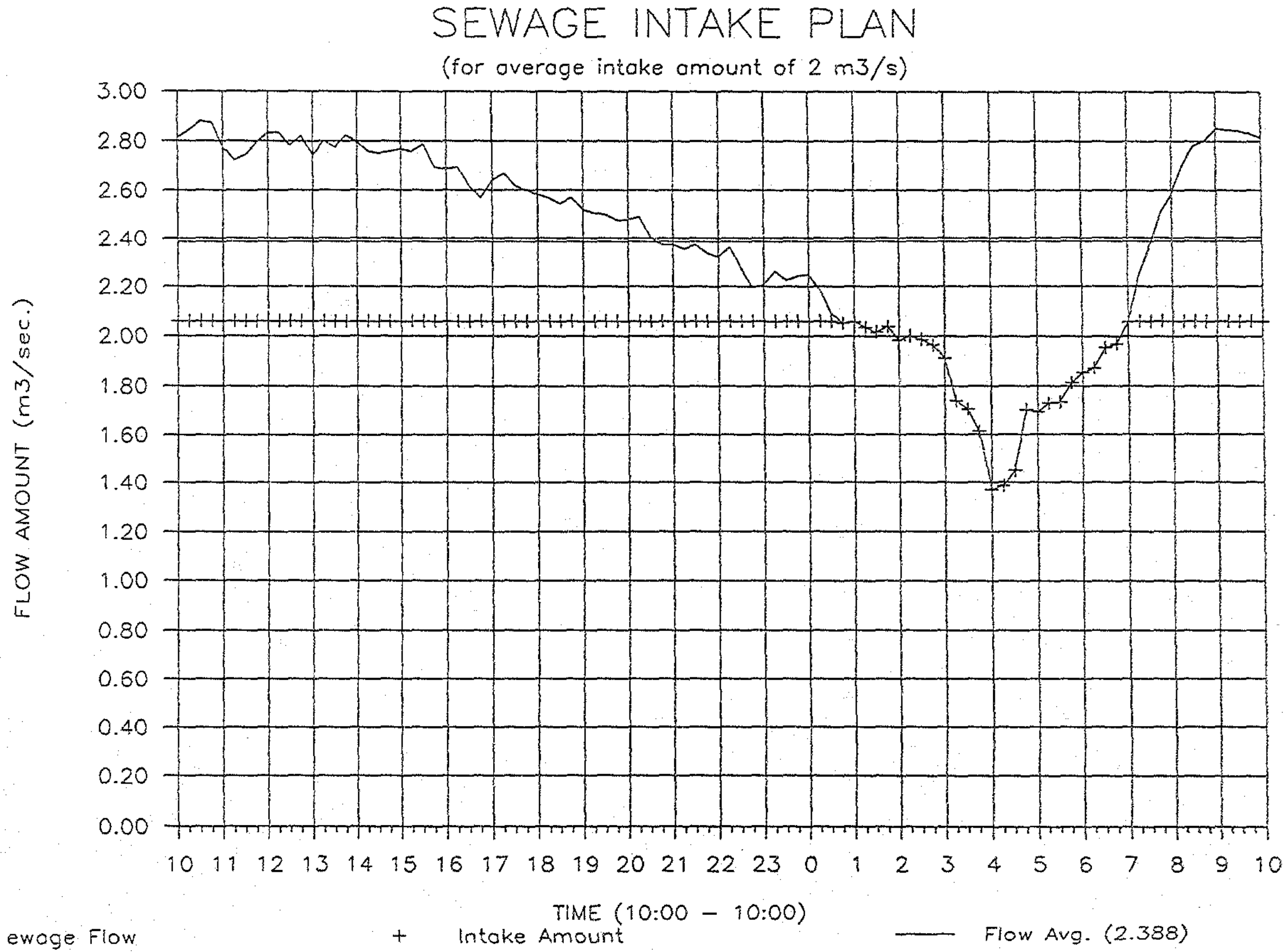


FIGURE 7-5 Planned Daily Sewage Variation Curve - 2.0 m^3/s