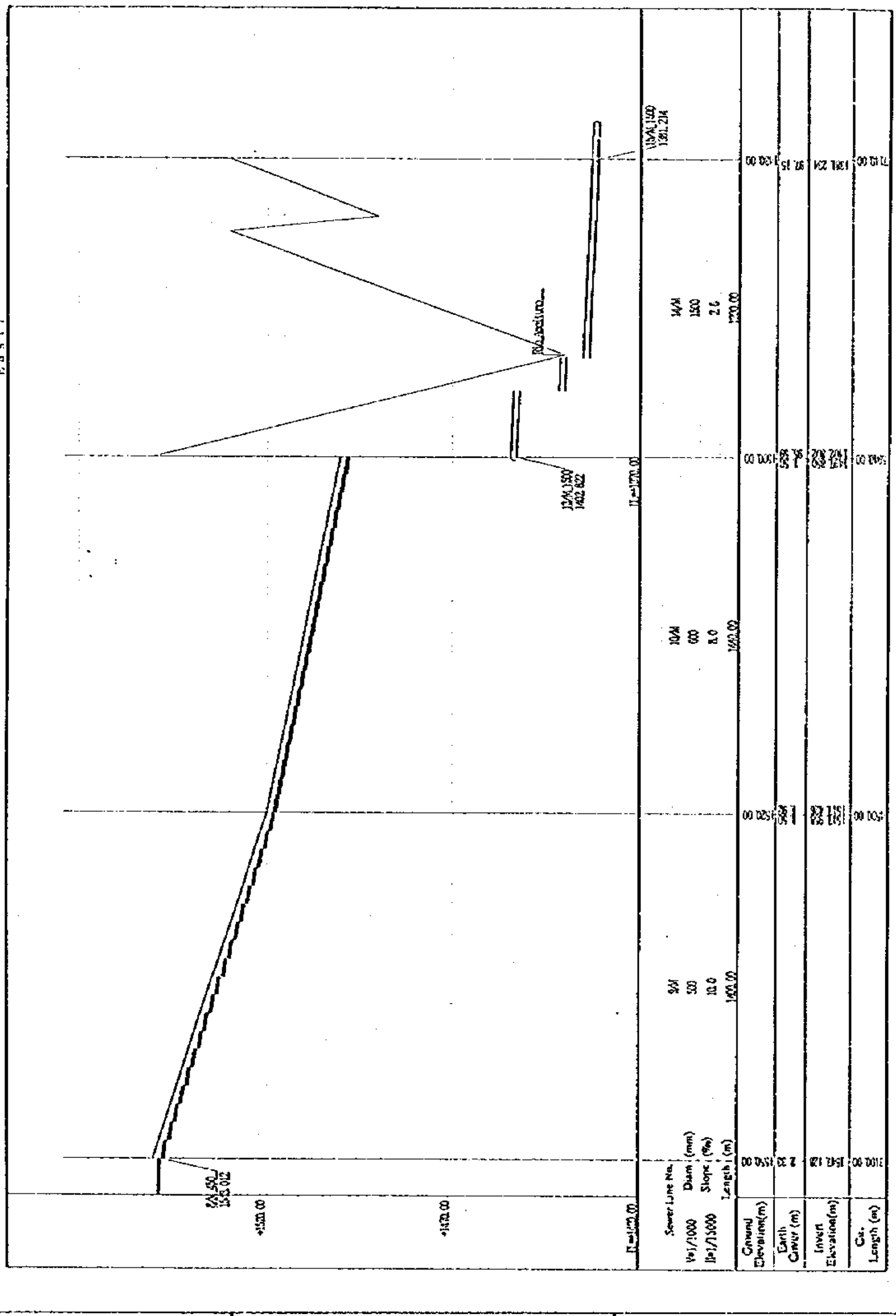
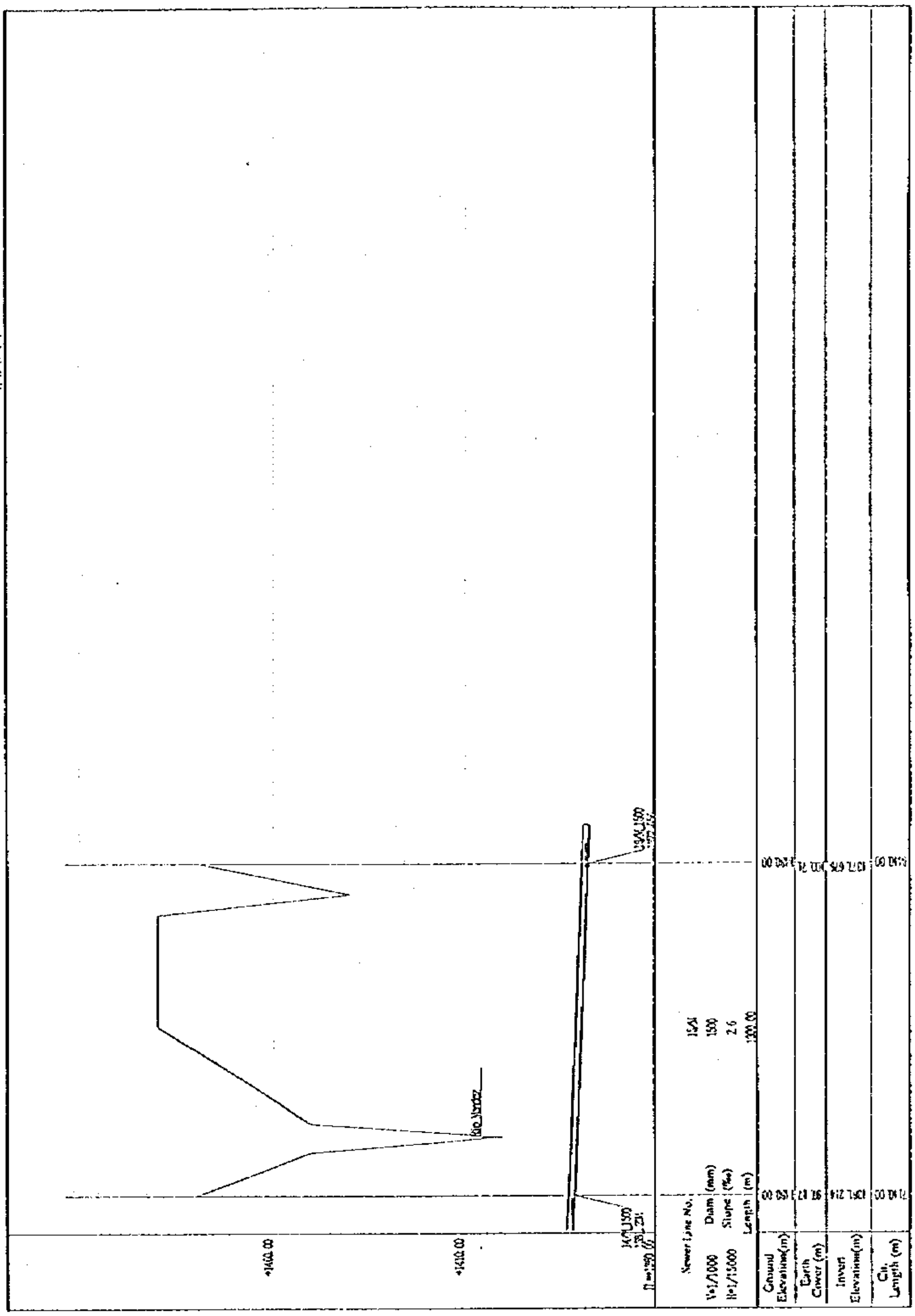
Fig. L - 59



THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LONGITUDINAL SECTION OF MAIN COLLECTOR SEWER FOR EAST 1 REGION (7/10)

Fig. L - 60



THE REPUBLIC OF GUATEMALA

GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)

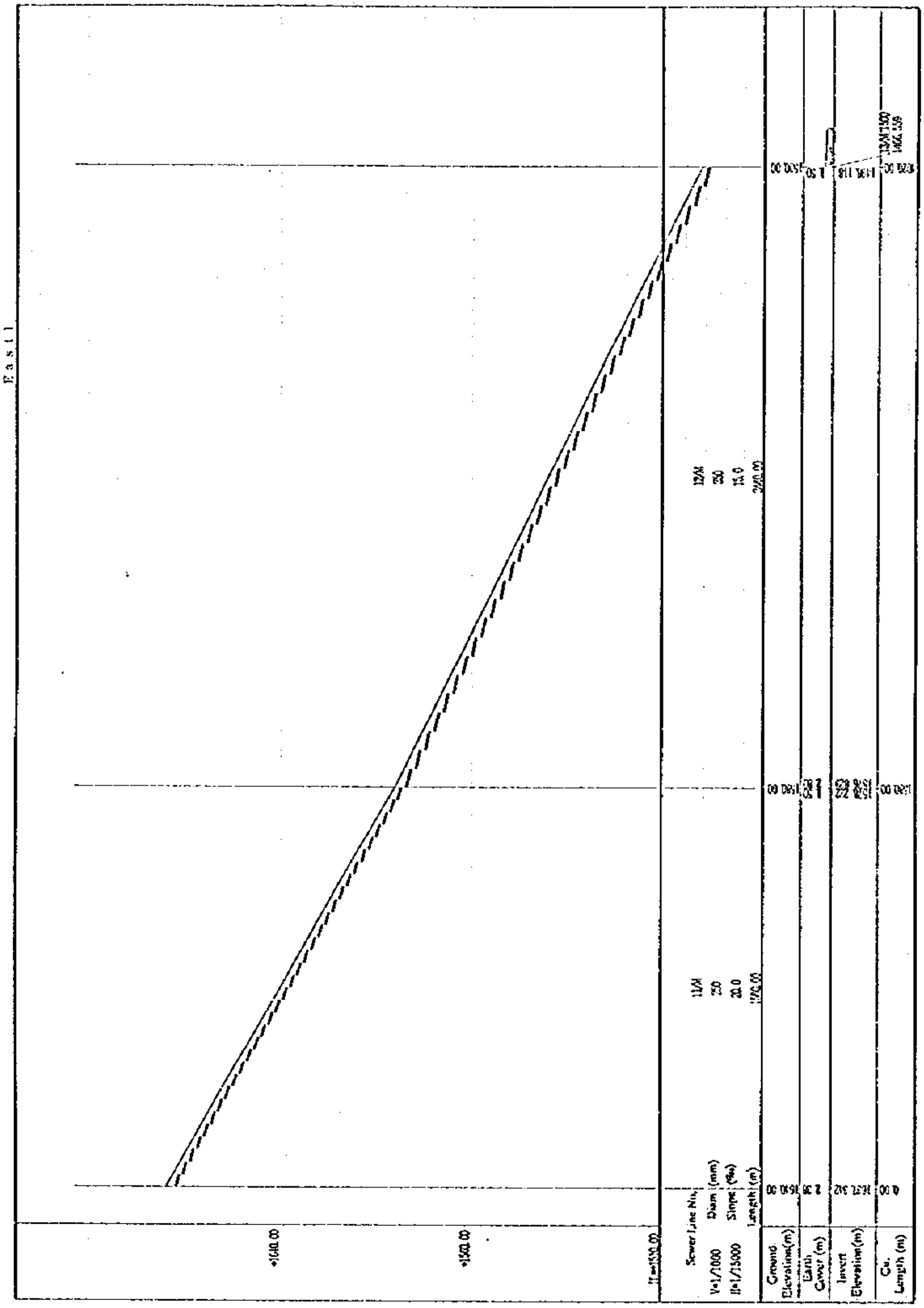
THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA

JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

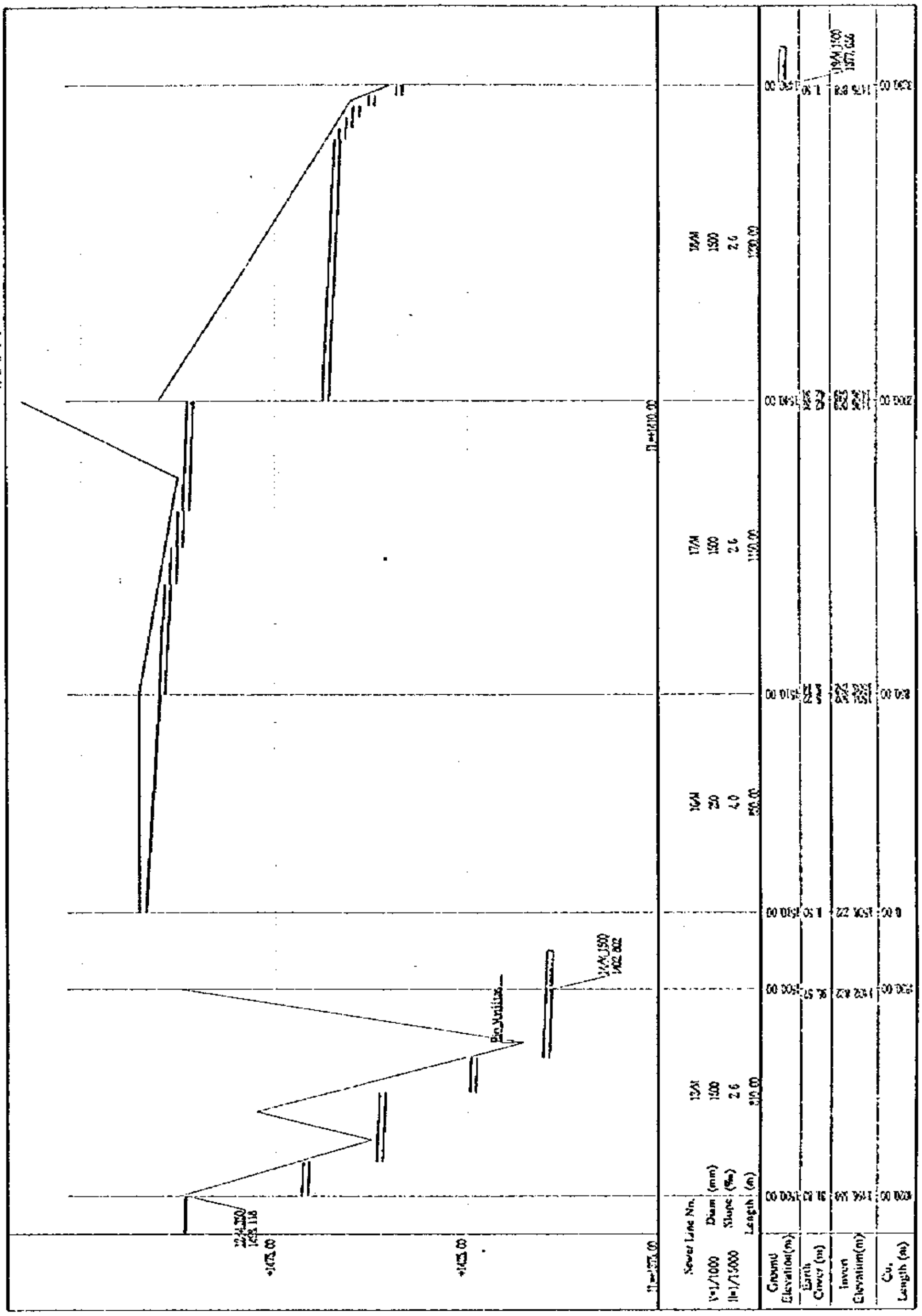
LONGITUDINAL SECTION OF MAIN COLLECTOR SEWER FOR EAST 1 REGION (8/10)

Fig. L - 61



THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LONGITUDINAL SECTION OF MAIN COLLECTOR SEWER FOR EAST 1 REGION (9/10)

Fig. L - 62



THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LONGITUDINAL SECTION OF MAIN COLLECTOR SEWER FOR EAST 1 REGION (10/10)

SUPPORTING REPORT M

TREATMENT PLANT DESIGN

SUPPORTING REPORT M
TREATMENT PLANT DESIGN
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M TREATMENT PLANT DESIGN

M1 INTRODUCTION

This Supporting Report contains preliminary design calculations and layout plan of wastewater treatment plants (WWTPs) for Master Plan and Feasibility Study. Layout plans for Feasibility study namely Central Region WWTP and South 3 Region WWTP are based on topographical survey results, which are described in Supporting Report Q.

Table M-1, M-8 show outline of treatment facilities based on preliminary design calculations. Table M-2 to M-7 show the treatment process flow diagram and the design calculations to size the facilities at each treatment plant for Master Plan. Table M-9, M-10 show the same for Feasibility Study.

The preliminary proposed layout plan for each treatment plants are shown in Fig. M-1 to M-3 for Master Plan. At Master Plan stage, detailed topography of wastewater treatment plant sites are not known. Therefore the layout plans have been prepared based on the assumption that the WWTP site slope at a constant gradient and of rectangular shape. Fig. M-4, M-5 show proposed layout plan for Feasibility study.

DESIGN CALCULATION FOR MASTER PLAN

Table M-1 Outline of Treatment Facilities

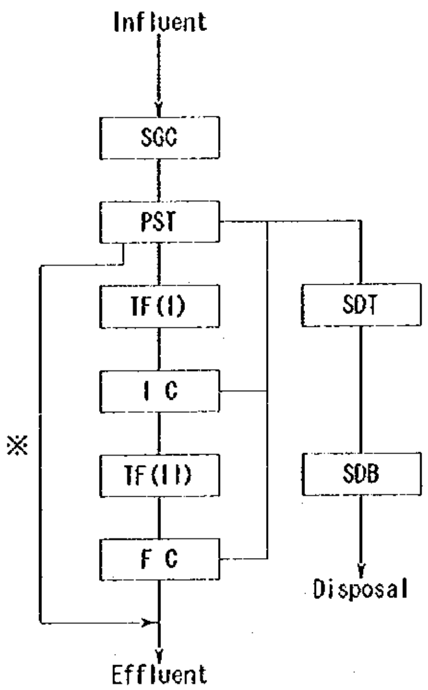
Facility	Central		North1		South1		South2		South3		East1	
	Dimensions	No.	Dimensions	No.	Dimensions	No.	Dimensions	No.	Dimensions	No.	Dimensions	No.
Primary Sedimentation Tank	φ13.00m×h 11.89m	40	φ12.50m×h 11.46m	16	φ13.50m×h 12.33m	10	φ13.50m×h 12.33m	8	φ12.50m×h 11.46m	12	φ13.00m×h 11.89m	20
Trickling Filter (First Step)	φ 39.00m×h 2.00m	40	φ 38.00m×h 2.00m	16	φ 41.00m×h 2.00m	10	φ 40.00m×h 2.00m	8	φ 38.00m×h 2.00m	12	φ 39.00m×h 2.00m	20
Intermediate Clarifier	φ13.00m×h 11.89m	40	φ12.50m×h 11.46m	16	φ13.50m×h 12.33m	10	φ13.50m×h 12.33m	8	φ12.50m×h 11.46m	12	φ13.00m×h 11.89m	20
Trickling Filter (Second Step)	φ 39.00m×h 2.00m	20	φ 38.00m×h 2.00m	8	φ 41.00m×h 2.00m	5	φ 40.00m×h 2.00m	4	φ 38.00m×h 2.00m	6	φ 39.00m×h 2.00m	10
Final Clarifier	φ18.00m×h 16.22m	40	φ17.50m×h 15.79m	16	φ18.50m×h 16.66m	10	φ18.50m×h 16.66m	8	φ17.50m×h 15.79m	12	φ18.00m×h 16.22m	20
Sludge Digester Tank	φ17.50m×h 9.75m	40	φ17.50m×h 9.75m	16	φ18.00m×h 10.00m	10	φ18.00m×h 10.00m	8	φ17.00m×h 9.50m	12	φ18.00m×h 10.00m	20
Sludge Drying Bed	W 40.00m×L100.00m	20	W 40.00m×L100.00m	8	W 40.00m×L110.00m	5	W 40.00m×L110.00m	4	W 40.00m×L 95.00m	6	W 40.00m×L105.00m	10
Design Flowrate Daily Average m³/d	238,000		89,000		64,000		51,000		66,000		121,000	
Daily Maximum m³/d	261,000		97,000		70,000		55,000		72,000		131,000	
Hourly Maximum m³/d	390,000		144,000		103,000		86,000		107,000		196,000	
Hourly Maximum Wet Weather m³/d	1,087,000		—		—		—		—		—	
Sludge Generation t/d	90.0		49.8		24.3		19.3		25.0		45.8	

Source : Study Team

Design Calculation
for
Central Region Wastewater Treatment Plant
(Master Plan)

Table M-2 (1/6) Design Calculation for Master Plan (Central WWTP)

Item	Calculation
Design Flowrate	Daily Average 238,000 m³/d Daily Maximum 261,000 m³/d Hourly Maximum 390,000 m³/d Hourly Maximum Wet Weather 1,087,000 m³/d
Treatment Process Flow Diagram	



Legend
S G C - Screen·Grit Chamber
P S T - Primary Sedimentation Tank
T F(I) - Trickling Filter (First Step)
I C - Intermediate Clarifier
TF(II) - Trickling Filter (Second Step)
F C - Final Clarifier
S D T - Sludge Digester Tank
S D B - Sludge Drying Bed

※ Primary Treated Excess Wet Weather Flow
(3×Hourly Maximum Flow - 1×Hourly Maximum Flow)

Table M-2 (2/6) Design Calculation for Master Plan (Central WWTP)

Item	Calculation
1. Primary Sedimentation Tank	
a)Required Capacity	
Design Flowrate	261,000 m³/d (D.M.), 1,087,000 m³/d (H.M.W.W.F.)
Overflow Rate	50.0 m³/m²·d
Retention Time	2.0 h (D.M.) 0.5 h (H.M.W.W.F.) D.M. : Daily Maximum H.M.W.W.F : Hourly Maximum Wet Weather Flow
Required Surface Area	$= \dfrac{261,000}{50.0} = 5,220$ m²
b)Dimensions	Diameter R = 13.00 m Depth D = 11.89 m Angle θ = 60 ° Number 40 Tanks (h1 = 1.50 m, h2 = 10.39 m)
c)Check	
Overflow Rate (D.M.)	$= \dfrac{261,000}{5,309} = 49.2$ m³/m²·d
Retention Time (D.M.)	$= \dfrac{23,840}{261,000} \times 24 = 2.2$ h
Retention Time (H.M.W.W.F.)	$= \dfrac{23,840}{1,087,000} \times 24 = 0.5$ h
Sludge Generation	= 261,000 × 154 × 10^-6 ÷ 0.01 = 4,019 m³ = 100 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 100$ m³/Tank (h3 = 5.74 m , r1 = 0.50 m , r2 = 3.81 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 397$ m³/Tank (h4 = 4.65 m , r2 = 3.81 m , r3 = 6.50 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 199$ m³/Tank (h1 = 1.50 m , R = 13.00 m) V = V1 + V2 = 596 m³/Tank ΣV = V × Number of Tanks = 596 × 40 = 23,840 m³

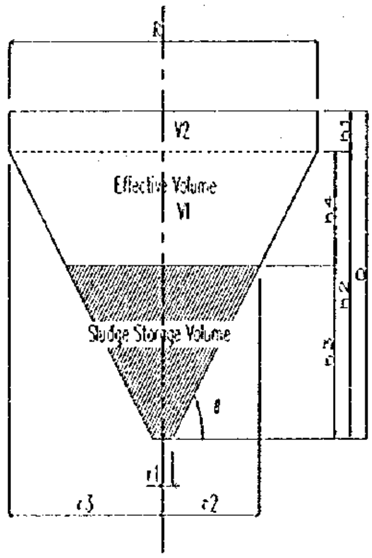


Table M-2 (3/6) Design Calculation for Master Plan (Central WWTP)

Item	Calculation
2. Trickling Filter	
1)First Step	
a)Required Capacity	
Design Flowrate	261,000 m^3/d
BOD Loading	1.0 kg·BOD/m^2·d
Influent BOD Load	= 261,000 × 182 × 10^-3 = 47,502 kg/d
Required Cross -Sectional Area	$= \frac{47,502}{1.0} = 47,502\ m^2$
b)Dimensions	Diameter 39.00 m Bed Depth 2.00 m Number 40 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 39.00^2 \times 40 = 47,784\ m^2$
BOD Loading	$= \frac{47,502}{47,784} = 1.0$ kg·BOD/m^2·d
Hydraulic Loading	$= \frac{261,000}{47,784} = 5.5$ m/d
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.
3)Second Step	
a)Required Capacity	
Design flowrate	261,000 m^3/d
BOD Loading	1.0 kg·BOD/m^2·d
Influent BOD Load	= 261,000 × 91 × 10^-3 = 23,751 kg/d
Required Cross -Sectional Area	$= \frac{23,751}{1.0} = 23,751\ m^2$
b)Dimensions	Diameter 39.00 m Bed Depth 2.00 m Number 20 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 39.00^2 \times 20 = 23,892\ m^2$
BOD Loading	$= \frac{23,751}{23,892} = 1.0$ kg·BOD/m^2·d
Hydraulic Loading	$= \frac{261,000}{23,892} = 10.9$ m/d

Table M-2 (4/6) Design Calculation for Master Plan (Central WWTP)

Item	Calculation
3.Final Clarifier a)Required Capacity	
Design Flowrate	261,000 m³/d
Overflow Rate	25.0 m³/m²·d
Retention Time	3.0 h
Required Surface Area	$= \dfrac{261,000}{25.0} = 10,440$ m²
b)Dimensions	Diameter R = 18.00 m Depth D = 16.22 m Angle θ = 60 ° Number 40 Tanks (h1 = 1.50 m, h2 = 14.72 m)
C)Check	
Overflow Rate	$= \dfrac{261,000}{10,179} = 25.6$ m³/m²·d
Retention Time	$= \dfrac{66,280}{261,000} \times 24 = 6.1$ h
Sludge Generation	= 261,000 × 70 × 10^-6 ÷ 0.01 = 1,827 m³ = 46 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 46 m³/Tank (h3 = 4.25 m , r1 = 0.50 m , r2 = 2.95 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 1,275 m³/Tank (h4 = 10.47 m , r2 = 2.95 m , r3 = 9.00 m) $V2 = \dfrac{\pi \times h1}{4} \times$ R^2 = 382 m³/Tank (h1 = 1.50 m , R = 18.00 m) V = V1+V2 = 1,657 m³/Tank ΣV = V × Number of Tanks = 1,657 × 40 = 66,280 m³

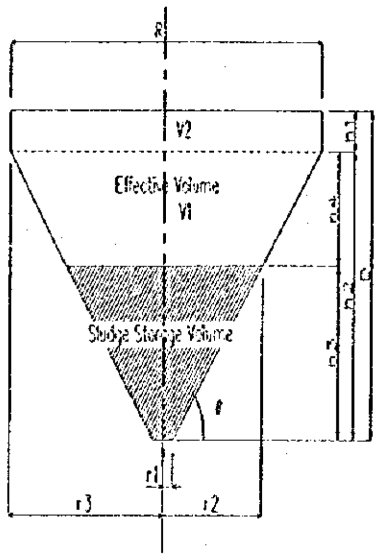


Table M-2 (5/6) Design Calculation for Master Plan (Central WWTP)

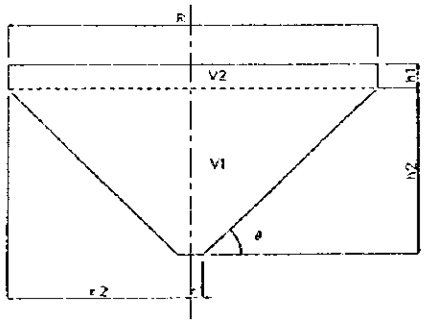
Item	Calculation
4.Sludge Digester Tank (Open Tank)	
a)Required Capacity	
Design Flowrate	238,000 m³/d (Daily Average)
Retention Time	47 days (Unheated Anaerobic Digestion)
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 238,000 × 280 × 0.8 × 10^-6 + 0.84 = 53.3 + 0.84 = 54.1 t/d
Influent Sludge Volume	$= \frac{53.3}{0.06} + 12.0 = 900$ m³/d (Raw Sludge Concentration 6%)
Required Volume	= 900 × 47 = 42,300 m³ 
b)Dimensions	Diameter R = 17.50 m Depth D = 9.75 m Angle θ = 45 ° Number 40 Tanks (h1 = 1.50 m, h2 = 8.25 m)
	$V1 = \frac{\pi \times h2}{3} (r1^2 + r1 \times r2 + r1^2) = 701$ m³/Tank (h2 = 8.25 m , r1 = 0.50 m , r2 = 8.75 m)
	$V2 = \frac{\pi \times h1}{4} \times R^2 = 361$ m³/Tank (h1 = 1.50 m , R = 17.50 m)
	V = V1 + V2 = 1,062 m³/Tank
	ΣV = V × Number of Tanks = 1,062 × 40 = 42,480 m³
c)Check	
Retention Time	$= \frac{42,480}{900} = 47$ days

Table M-2 (6/6) Design Calculation for Master Plan (Central WWTP)

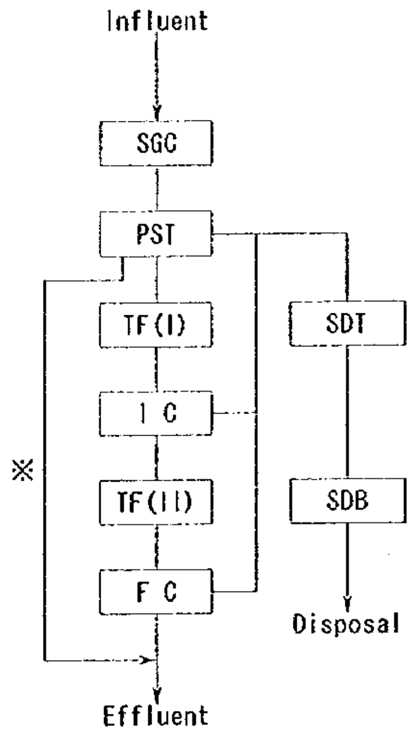
Item	Calculation
5.Sludge Drying Bed	
a)Required Capacity	
Influent Solid Quantity	= Digested Solids
	$= 53.3 \times (1 - (0.65 \times 0.5)) = 36.0$ t/d
	Volatile Solid Concentration of Raw Sludge : 65 %
	Volatile Solid Removal Rate : 50 %
Dried Sludge Quantity	$= \frac{36.0}{1-0.6} = 90.0$ t/d
	(Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg・SS/m²・yr.
Required Area	$= \frac{36.0 \times 365}{0.16} = 82,125$ m²
b)Dimensions	Width 40.00 m
	Length 100.00 m
	Number 20 tanks
c)Check	
Area	$= 40.00 \times 100.00 \times 20 = 80,000$ m²
Solids Loading	$= \frac{36.0}{80,000} \times 365 \times 10^3 = 164.3$ kg・SS/m²・yr

Design Calculation
for
North 1 Region Wastewater Treatment Plant
(Master Plan)

Table M-3 (1/6) Design Calculation for Master Plan (North1 WWTP)

Item	Calculation		
Design Flowrate	Daily Average	89,000	m³/d
	Daily Maximum	97,000	m³/d
	Hourly Maximum	144,000	m³/d

Treatment Process Flow Diagram



Legend
S G C - Screen·Grit Chamber
P S T - Primary Sedimentation Tank
T F(I) - Trickling Filter (First Step)
I C - Intermediate Clarifier
TF(II) - Trickling Filter (Second Step)
F C - Final Clarifier
S D T - Sludge Digester Tank
S D B - Sludge Drying Bed

Table M-3 (2/6) Design Calculation for Master Plan (North1 WWTP)

Item	Calculation
1. Primary Sedimentation Tank	
a)Required Capacity	
Design Flowrate	97,000 m^3/d
Overflow Rate	50.0 $m^3/m^2 \cdot d$
Retention Time	2.0 h
Required Surface Area	$= \dfrac{97,000}{50.0} = 1,940\ m^2$
b)Dimensions	Diameter R = 12.50 m Depth D = 11.46 m Angle $\theta = 60°$ Number 16 Tanks (h1 = 1.50 m, h2 = 9.96 m)
c)Check	
Overflow Rate	$= \dfrac{97,000}{1,963} = 49.4\ m^3/m^2 \cdot d$
Retention Time	$= \dfrac{8,528}{97,000} \times 24 = 2.1\ h$
Sludge Generation	$= 97,000 \times 154 \times 10^{-6} \div 0.01 = 1,494\ m^3$ $= 93\ m^3/Tank$ (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 93\ m^3/Tank$ (h3 = 5.58 m , r1 = 0.50 m , r2 = 3.72 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 349\ m^3/Tank$ (h4 = 4.38 m , r2 = 3.72 m , r3 = 6.25 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 184\ m^3/Tank$ (h1 = 1.50 m , R = 12.50 m) $V = V1 + V2 = 533\ m^3/Tank$ $\Sigma V = V \times \text{Number of Tanks} = 533 \times 16 = 8,528\ m^3$

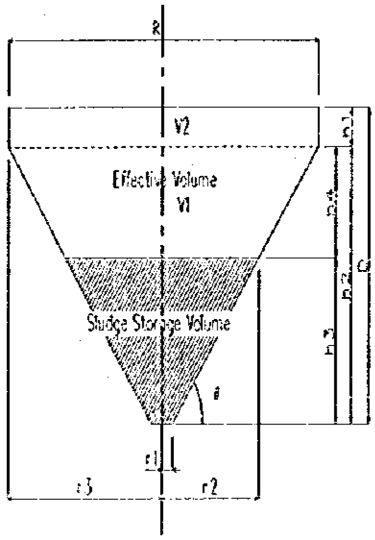


Table M-3 (3/6) Design Calculation for Master Plan (North1 WWTP)

Item	Calculation
2. Trickling Filter	
1)First Step	
a)Required Capacity	
Design Flowrate	97,000 m^3/d
BOD Loading	1.0 $kg \cdot BOD/m^3 \cdot d$
Influent BOD Load	$= 970.000 \times 182 \times 10^{-3} = 17,654$ kg/d
Required Cross -Sectional Area	$= \dfrac{17,654}{1.0} = 17,654\ m^2$
b)Dimensions	Diameter 38.00 m Bed Depth 2.00 m Number 16 Tanks
c)Check Cross-Sectional Area	$= \dfrac{\pi}{4} \times 38.00^2 \times 16 = 18,146\ m^2$
BOD Loading	$= \dfrac{17,654}{18,146} = 1.0\ kg \cdot BOD/m^3 \cdot d$
Hydraulic Loading	$= \dfrac{97,000}{18,146} = 5.3$ m/d
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.
3)Second Step	
a)Required Capacity	
Design flowrate	97,000 m^3/d
BOD Loading	1.0 $kg \cdot BOD/m^3 \cdot d$
Influent BOD Load	$= 97,000 \times 91 \times 10^{-3} = 8,827$ kg/d
Required Cross -Sectional Area	$= \dfrac{8,827}{1.0} = 8,827\ m^2$
b)Dimensions	Diameter 38.00 m Bed Depth 2.00 m Number 8 Tanks
c)Check Cross-Sectional Area	$= \dfrac{\pi}{4} \times 38.00^2 \times 8 = 9,073\ m^2$
BOD Loading	$= \dfrac{8,827}{9,073} = 1.0\ kg \cdot BOD/m^3 \cdot d$
Hydraulic Loading	$= \dfrac{97,000}{9,073} = 10.7$ m/d

Table M-3 (4/6) Design Calculation for Master Plan (North1 WWTP)

Item	Calculation
3.Final Clarifier	
a)Required Capacity	
Design Flowrate	97,000 m³/d
Overflow Rate	25.0 m³/m²·d
Retention Time	3.0 h
Required Surface Area	$= \dfrac{97,000}{25.0} = 3,880$ m²
b)Dimensions	Diameter R = 17.50 m Depth D = 15.79 m Angle θ = 60 ° Number 16 Tanks (h1 = 1.50 m, h2 = 14.29 m)
c)Check	
Overflow Rate	$= \dfrac{97,000}{3,848} = 25.2$ m³/m²·d
Retention Time	$= \dfrac{24,528}{97,000} \times 24 = 6.1$ h
Sludge Generation	$= 97,000 \times 70 \times 10^{-6} \div 0.01 = 679$ m³ $= 42$ m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 42$ m³/Tank (h3 = 4.09 m , r1 = 0.50 m , r2 = 2.86 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 1,172$ m³/Tank (h4 = 10.20 m , r2 = 2.86 m , r3 = 8.75 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 361$ m³/Tank (h1 = 1.50 m , R = 17.50 m) $V = V1 + V2 = 1,533$ m³/Tank $\Sigma V = V \times$ Number of Tanks $= 1,533 \times 16 = 24,528$ m³

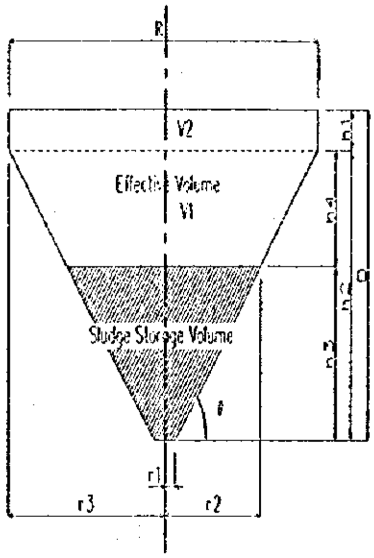


Table M-3 (5/6) Design Calculation for Master Plan (North1 WWTP)

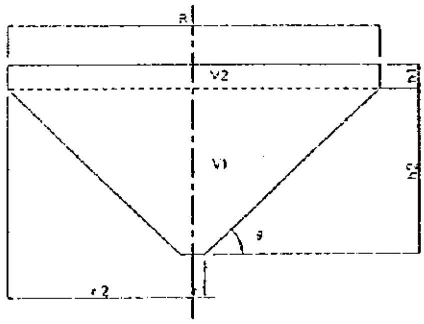
Item	Calculation
4.Sludge Digester Tank (Open Tank)	
a)Required Capacity Design Flowrate	89,000 m³/d (Daily Average)
Retention Time	47 days (Unheated Anaerobic Digestion)
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 89,000 × 280 × 0.8 × 10^-6 + 1.25 = 19.9 + 1.25 = 21.2 t/d
Influent Sludge Volume	$= \frac{19.9}{0.06} + 17.9 = 349.9$ m³/d (Raw Sludge Concentration 6%)
Required Volume	= 349.9 × 47 = 16,445 m³
b)Dimensions	Diameter R = 17.50 m Depth D = 9.75 m Angle θ = 45 ° Number 16 Tanks (h1 = 1.50 m, h2 = 8.25 m)  $V1 = \frac{\pi \times h2}{3} (r1^2 + r1 \times r2 + r1^2) = 701$ m³/Tank (h2 = 8.25 m , r1 = 0.50 m , r2 = 8.75 m) $V2 = \frac{\pi \times h1}{4} \times R^2 = 361$ m³/Tank (h1 = 1.50 m , R = 17.50 m) V = V1 + V2 = 1,062 m³/Tank ΣV = V × Number of Tanks = 1,062 × 16 = 16,992 m³
c)Check	
Retention Time	$= \frac{16,992}{350} = 49$ days

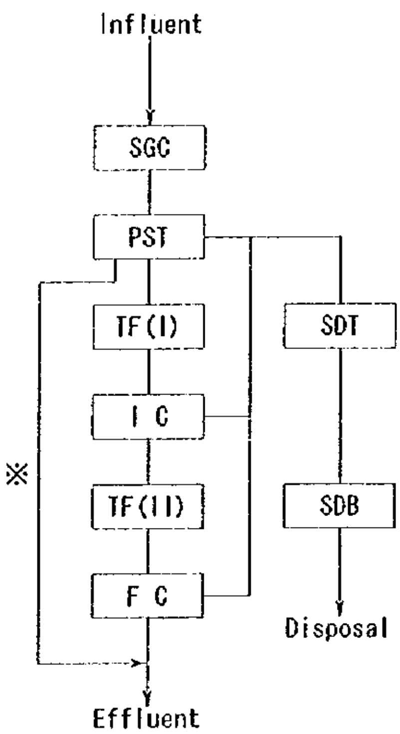
Table M-3 (6/6) Design Calculation for Master Plan (North1 WWTP)

Item	Calculation
5.Sludge Drying Bed	
a)Required Capacity	
Influent Solid Quantity	= Digested Solids = 19.9 × (1 − (0.65 × 0.5)) = 19.9 t/d Volatile Solid Concentration of Raw Sludge : 65 % Volatile Solid Removal Rate : 50 %
Dried Sludge Quantity	$= \frac{19.9}{1 - 0.6} = 49.8$ t/d (Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg·SS/m²·yr.
Required Area	$= \frac{19.9 \times 365}{0.16} = 45,397$ m²
b)Dimensions	Width 40.00 m Length 100.00 m Number 8 Tanks
c)Check	
Area	= 40.00 × 100.00 × 8 = 32,000 m²
Solids Loading	$= \frac{19.9}{32,000} \times 365 \times 10^3 = 227$ kg·SS/m²·yr

Design Calculation
for
South 1 Region Wastewater Treatment Plant
(Master Plan)

Table M-4 (1/6) Design Calculation for Master Plan (South1 WWTP)

Item	Calculation
Design Flowrate	Daily Average 64,000 m³/d Daily Maximum 70,000 m³/d Hourly Maximum 103,000 m³/d
Treatment Process Flow Diagram	(see diagram and legend below)



Legend
- S G C - Screen·Grit Chamber
- P S T - Primary Sedimentation Tank
- T F(I) - Trickling Filter (First Step)
- I C - Intermediate Clarifier
- TF(II) - Trickling Filter (Second Step)
- F C - Final Clarifier
- S D T - Sludge Digester Tank
- S D B - Sludge Drying Bed

Table M-4 (2/6) Design Calculation for Master Plan (South1 WWTP)

Item	Calculation
1. Primary Sedimentation Tank	
a)Required Capacity	
Design Flowrate	70,000 m³/d
Overflow Rate	50.0 m³/m²·d
Retention Time	2.0 h
Required Surface Area	$= \frac{70,000}{50.0} = 1,400$ m²
b)Dimensions	Diameter R = 13.50 m Depth D = 12.33 m Angle θ = 60 ° Number 10 Tanks
c)Check	(h1 = 1.50 m, h2 = 10.83 m)
Overflow Rate	$= \frac{70,000}{1,431} = 48.9$ m³/m²·d
Retention Time	$= \frac{6,640}{70,000} \times 24 = 2.3$ h
Sludge Generation	= 70,000 × 154 × 10^-6 ÷ 0.01 = 1,078 m³ = 108 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \frac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 108$ m³/Tank (h3 = 5.91 m , r1 = 0.50 m , r2 = 3.91 m)
Effective Volume	$V1 = \frac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 449$ m³/Tank (h4 = 4.92 m , r2 = 3.91 m , r3 = 6.75 m) $V2 = \frac{\pi \times h1}{4} \times R^2 = 215$ m³/Tank (h1 = 1.50 m , R = 13.50 m) V = V1 + V2 = 664 m³/Tank ΣV = V × Number of Tank = 664 × 10 = 6,640 m³

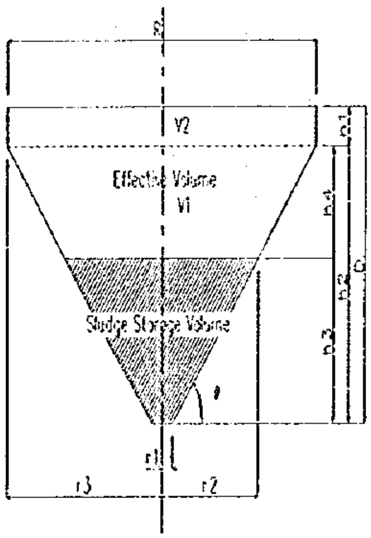


Table M-4 (3/6) Design Calculation for Master Plan (South1 WWTP)

Item	Calculation
2. Trickling Filter	
1)First Step	
a)Required Capacity	
Design Flowrate	70,000 m³/d
BOD Loading	1.0 kg·BOD/m²·d
Influent BOD Load	= 70,000 × 182 × 10^-3 = 12,740 kg/d
Required Cross -Sectional Area	$= \frac{12,740}{1.0} = 12,740$ m²
b)Dimensions	Diameter 41.00 m Bed Depth 2.00 m Number 10 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 41.00^2 \times 10 = 13,203$ m²
BOD Loading	$= \frac{12,740}{13,203} = 1.0$ kg·BOD/m²·d
Hydraulic Loading	$= \frac{70,000}{13,203} = 5.3$ m/d
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.
3)Second Step	
a)Required Capacity	
Design flowrate	70,000 m³/d
BOD Loading	1.0 kg·BOD/m²·d
Influent BOD Load	= 70,000 × 91 × 10^-3 = 6,370 kg/d
Required Cross -Sectional Area	$= \frac{6,370}{1.0} = 6,370$ m²
b)Dimensions	Diameter 41.00 m Bed Depth 2.00 m Number 5 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 41.00^2 \times 5 = 6,601$ m²
BOD Loading	$= \frac{6,370}{6,601} = 1.0$ kg·BOD/m²·d
Hydraulic Loading	$= \frac{70,000}{6,601} = 10.6$ m/d

Table M-4 (4/6) Design Calculation for Master Plan (South1 WWTP)

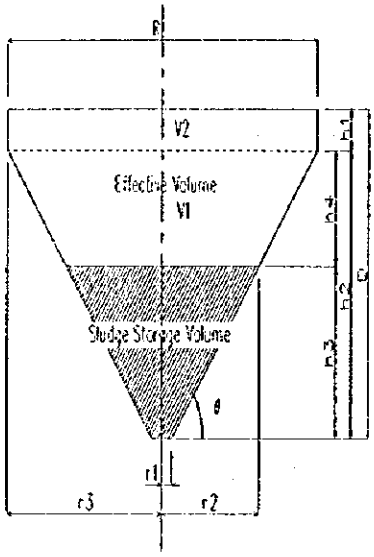
Item	Calculation
3.Final Clarifier	
a)Required Capacity	
Design Flowrate	70,000 m³/d
Overflow Rate	25.0 m³/m²·d
Retention Time	3.0 h
Required Surface Area	$= \dfrac{70,000}{25.0} = 2,800$ m²
b)Dimensions	Diameter R = 18.50 m Depth D = 16.66 m Angle θ = 60 ° Number 10 Tanks (h1 = 1.50 m, h2 = 15.16 m) 
c)Check	
Overflow Rate	$= \dfrac{70,000}{2,688} = 26.0$ m³/m²·d
Retention Time	$= \dfrac{17,890}{70,000} \times 24 = 6.1$ h
Sludge Generation	= 70,000 × 70 × 10^-6 ÷ 0.01 = 490 m³ = 49 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 49$ m³/Tank (h3 = 4.35 m , r1 = 0.50 m , r2 = 3.01 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 1,386$ m³/Tank (h4 = 10.81 m , r2 = 3.01 m , r3 = 9.25 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 403$ m³/Tank (h1 = 1.50 m , R = 18.50 m) V = V1 + V2 = 1,789 m³/Tank ΣV = V × Number of Tanks = 1,789 × 10 = 17,890 m³

Table M-4 (5/6) Design Calculation for Master Plan (South1 WWTP)

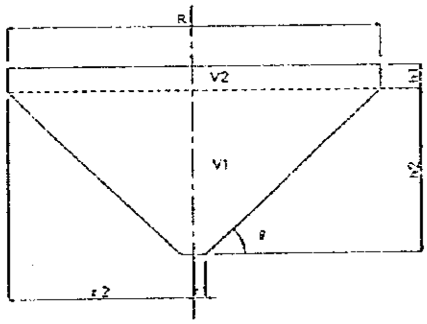
Item	Calculation
4.Sludge Digester Tank (Open Tank)	
a)Required Capacity Design Flowrate	64,000 m³/d (Daily Average)
Retention Time	47 days (Unheated Anaerobic Digestion)
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 64,000 × 280 × 0.8 × 10^-6 + 0.02 = 14.3 + 0.02 = 14.3 t/d
Influent Sludge Volume	$= \frac{14.3}{0.06} + 0.3 = 238.3$ m³/d (Raw Sludge Concentration 6%)
Required Volume	= 238.3 × 47 = 11,200 m³
b)Dimensions	Diameter R = 18.00 m Depth D = 10.00 m Angle θ = 45 ° Number 10 Tanks (h1 = 1.50 m, h2 = 8.50 m)  $V1 = \frac{\pi \times h2}{3} (r1^2 + r1 \times r2 + r1^2) = 763$ m³/Tank (h2 = 8.50 m , r1 = 0.50 m , r2 = 9.00 m) $V2 = \frac{\pi \times h1}{4} \times R^2 = 382$ m³/Tank (h1 = 1.50 m , R = 18.00 m) V = V1 + V2 = 1,145 m³/Tank ΣV = V × Number of Tanks = 1,145 × 10 = 11,450 m³
c)Check Retention Time	$= \frac{11,450}{238} = 48$ days

Table M-4 (6/6) Design Calculation for Master Plan (South1 WWTP)

Item	Calcultion
5.Sludge Drying Bed	
a)Required Capacity	
Influent Solid Quantity	= Digested Solids
	= 14.3 × (1 − (0.65 × 0.5)) = 9.7 t/d
	Volatile Solid Concentration of Raw Sludge : 65 %
	Volatile Solid Removal Rate : 50 %
Dried Sludge Quantity	$= \frac{9.7}{0.4} = 24.3$ t/d
	(Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg·SS/m²·yr.
Required Area	$= \frac{9.7 \times 365}{0.16} = 22,128$ m²
b)Dimensions	Width 40.00 m
	Length 110.00 m
	Number 5 Tanks
c)Check	
Area	= 40.00 × 110.00 × 5 = 22,000 m²
Solids Loading	$= \frac{9.7}{22,000} \times 365 \times 10^{3} = 160.9$ kg·SS/m²·yr

Design Calculation
for
South 2 Region Wastewater Treatment Plant
(Master Plan)

Table M-5 (1/6) Design Calculation for Master Plan (South2 WWTP)

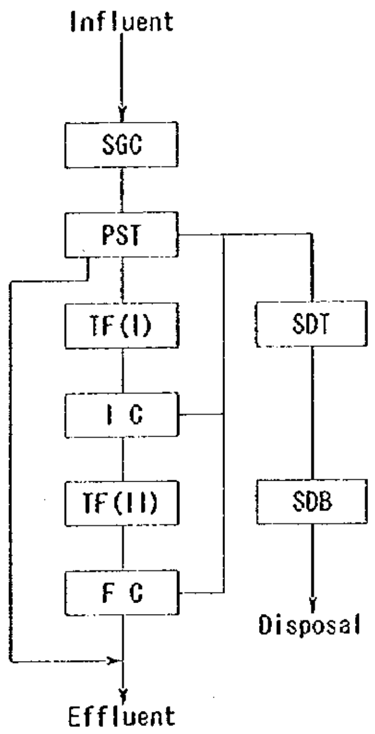
Item	Calculation
Design Flowrate	Daily Average 51,000 m³/d Daily Maximum 55,000 m³/d Hourly Maximum 86,000 m³/d
Treatment Process Flow Diagram	 Legend S G C - Screen·Grit Chamber P S T - Primary Sedimentation Tank T F(I) - Trickling Filter (First Step) I C - Intermediate Clarifier TF(II) - Trickling Filter (Second Step) F C - Final Clarifier S D T - Sludge Digester Tank S D B - Sludge Drying Bed

Table M-5 (2/6) Design Calculation for Master Plan (South2 WWTP)

Item	Calculation
1. Primary Sedimentation Tank	
a)Required Capacity	
Design Flowrate	55,000 m³/d
Overflow Rate	50.0 m³/m²·d
Retention Time	2.0 h
Required Surface Area	$= \dfrac{55,000}{50.0} = 1,100$ m²
b)Dimensions	Diameter R = 13.50 m Depth D = 12.33 m Angle θ = 60 ° Number 8 Tanks
c)Check	(h1 = 1.50 m, h2 = 10.83 m)
Overflow Rate	$= \dfrac{55,000}{1,145} = 48.0$ m³/m²·d
Retention Time	$= \dfrac{5,336}{55,000} \times 24 = 2.3$ h
Sludge Generation	= 55,000 × 154 × 10^-6 ÷ 0.01 = 817 m³ = 106 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 106$ m³/Tank (h3 = 5.86 m , r1 = 0.50 m , r2 = 3.88 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 452$ m³/Tank (h4 = 4.97 m , r2 = 3.88 m , r3 = 6.75 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 215$ m³/Tank (h1 = 1.50 m , R = 13.50 m) V = V1 + V2 = 667 m³/Tank ΣV = V × Number of Tanks = 667 × 8 = 5,336 m³

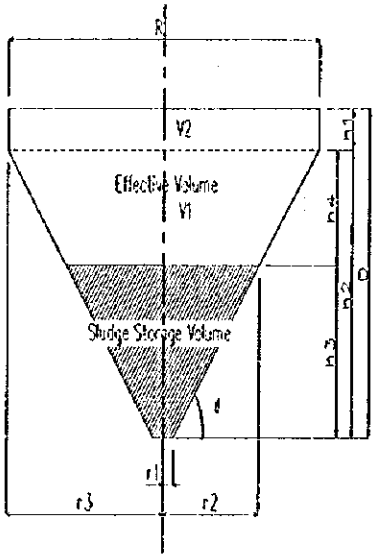


Table M-5 (3/6) Design Calculation for Master Plan (South2 WWTP)

Item	Calculation
2. Trickling Filter	
1)First Step	
a)Required Capacity	
Design Flowrate	55,000 m³/d
BOD Loading	1.0 kg·BOD/m³·d
Influent BOD Load	= 55,000 × 182 × 10^-3 = 10,010 kg/d
Required Cross -Sectional Area	$= \frac{10,010}{1.0} = 10,010$ m²
b)Dimensions	Diameter 40.00 m Bed Depth 2.00 m Number 8 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 40.00^2 \times 8 = 10,053$ m²
BOD Loading	$= \frac{10,010}{10,053} = 1.0$ kg·BOD/m³·d
Hydraulic Loading	$= \frac{55,000}{10,053} = 5.5$ m/d
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.
3)Second Step	
a)Required Capacity	
Design flowrate	55,000 m³/d
BOD Loading	1.0 kg·BOD/m³·d
Influent BOD Load	= 55,000 × 91 × 10^-3 = 5,005 kg/d
Required Cross -Sectional Area	$= \frac{5,005}{1.0} = 5,005$ m²
b)Dimensions	Diameter 40.00 m Bed Depth 2.00 m Number 4 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 40.00^2 \times 4 = 5,027$ m²
BOD Loading	$= \frac{5,005}{5,027} = 1.0$ kg·BOD/m³·d
Hydraulic Loading	$= \frac{55,000}{5,027} = 10.9$ m/d

Table M-5 (4/6) Design Calculation for Master Plan (South2 WWTP)

Item	Calculation
3.Final Clarifier	
a)Required Capacity	
Design Flowrate	55,000 m³/d
Overflow Rate	25.0 m³/m²·d
Retention Time	3.0 h
Required Surface Area	$= \dfrac{55,000}{25.0} = 2,200$ m²
b)Dimensions	Diameter R = 18.50 m Depth D = 16.66 m Angle θ = 60 ° Number 8 Tanks (h1 = 1.50 m, h2 = 15.16 m)
c)Check	
Overflow Rate	$= \dfrac{55,000}{2,150} = 25.6$ m³/m²·d
Retention Time	$= \dfrac{14,320}{55,000} \times 24 = 6.2$ h
Sludge Generation	= 55,000 × 70 × 10^-6 ÷ 0.01 = 385 m³ = 48 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 48 m³/Tank (h3 = 4.32 m , r1 = 0.50 m , r2 = 2.99 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 1,387 m³/Tank (h4 = 10.84 m , r2 = 2.99 m , r3 = 9.25 m) $V2 = \dfrac{\pi \times h1}{4} \times$ R^2 = 403 m³/Tank (h1 = 1.50 m , R = 18.50 m) V = V1+V2 = 1,790 m³/Tank ΣV = V × Number of Tanks = 1,790 × 8 = 14,320 m³

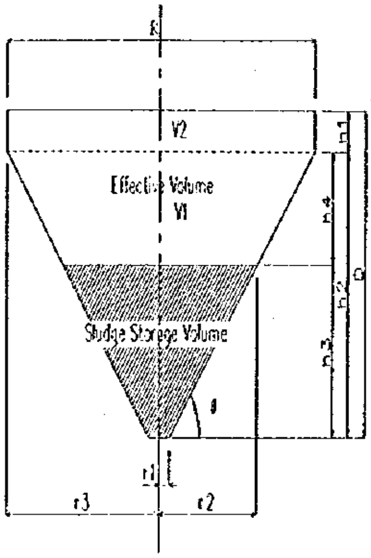


Table M-5 (5/6) Design Calculation for Master Plan (South2 WWTP)

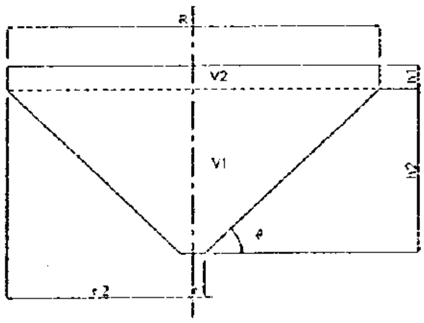
Item	Calculation
4.Sludge Digester Tank (Open Tank)	
a)Required Capacity	
Design Flowrate	51,000 m³/d (Daily Average)
Retention Time	47 days (Unheated Anaerobic Digestion)
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 51,000 × 280 × 0.8 × 10^-6 + 0.06 = 11.4 + 0.06 = 11.5 t/d
Influent Sludge Volume	$= \dfrac{11.4}{0.06} + 0.9 = 190.9$ m³/d (Raw Sludge Concentration 6%)
Required Volume	= 190.9 × 47 = 8,972 m³
b)Dimensions	Diameter R = 18.00 m Depth D = 10.00 m Angle θ = 45 ° Number 8 Tanks (h1 = 1.50 m, h2 = 8.50 m)  $V1 = \dfrac{\pi \times h2}{3} (r1^2 + r1 \times r2 + r1^2) = 763$ m³/Tank (h2 = 8.50 m , r1 = 0.50 m , r2 = 9.00 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 382$ m³/Tank (h1 = 1.50 m , R = 18.00 m) V = V1 + V2 = 1,145 m³/Tank ΣV = V × Number of Tanks = 1,145 × 8 = 9,160 m³
c)Check	
Retention Time	$= \dfrac{9,160}{191} = 48$ days

Table M-5 (6/6) Design Calculation for Master Plan (South2 WWTP)

Item	Calculation
5.Sludge Drying Bed	
a)Required Capacity	
Influent Solid Quantity	= Digested Solids
	$= 11.4 \times (1 - (0.65 \times 0.5)) = 7.7$ t/d
	Volatile Solid Concentration of Raw Sludge : 65 %
	Volatile Solid Removal Rate : 50 %
Dried Sludge Quantity	$= \frac{7.7}{0.4} = 19.3$ t/d
	(Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg·SS/m²·yr.
Required Area	$= \frac{7.7 \times 365}{0.16} = 17,566$ m²
b)Dimensions	Width 40.00 m
	Length 110.00 m
	Number 4 Tanks
c)Check	
Area	$= 40.00 \times 110.00 \times 4 = 17,600$ m²
Solids Loading	$= \frac{7.7}{17,600} \times 365 \times 10^{3} = 159.7$ kg·SS/m²·yr

Design Calculation
for
South 3 Region Wastewater Treatment Plant
(Master Plan)

Table M-6 (1/6) Design Calculation for Master Plan (South3 WWTP)

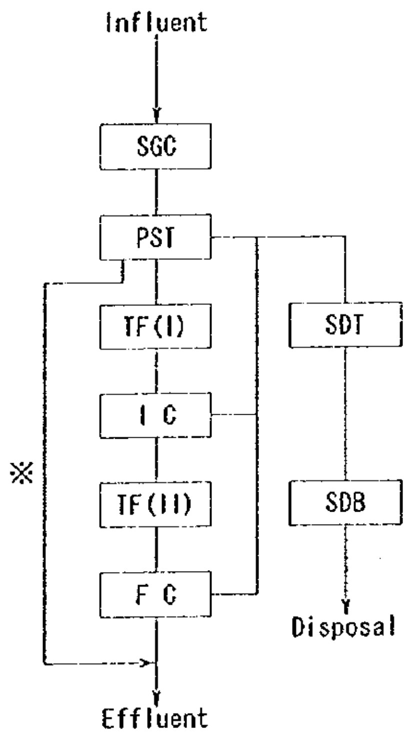
Item	Calculation
Design Flowrate	Daily Average 66,000 m^3/d Daily Maximum 72,000 m^3/d Hourly Maximum 107,000 m^3/d
Treatment Process Flow Diagram	 Legend S G C - Screen·Grit Chamber P S T - Primary Sedimentation Tank T F(I) - Trickling Filter (First Step) I C - Intermediate Clarifier TF(II) - Trickling Filter (Second Step) F C - Final Clarifier S D T - Sludge Digester Tank S D B - Sludge Drying Bed

Table M-6 (2/6) Design Calculation for Master Plan (South3 WWTP)

Item	Calculation
1. Primary Sedimentation Tank	
a)Required Capacity	
Design Flowrate	72,000 m³/d
Overflow Rate	50.0 m³/m²·d
Retention Time	2.0 h
Required Surface Area	$= \frac{72,000}{50.0} = 1,440$ m²
b)Dimensions	Diameter R = 12.50 m Depth D = 11.46 m Angle θ = 60 ° Number 12 Tanks
c)Check	(h1 = 1.50 m, h2 = 9.96 m)
Overflow Rate	$= \frac{72,000}{1,473} = 48.9$ m³/m²·d
Retention Time	$= \frac{6,408}{72,000} \times 24 = 2.1$ h
Sludge Generation	= 72,000 × 154 × 10^-6 ÷ 0.01 = 1,109 m³ = 92 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 92 m³/Tank (h3 = 5.56 m , r1 = 0.50 m , r2 = 3.71 m)
Effective Volume	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 350 m³/Tank (h4 = 4.40 m , r2 = 3.71 m , r3 = 6.25 m) $V2 = \frac{\pi \times h1}{4} \times R^2 = 184$ m³/Tank (h1 = 1.50 m , R = 12.50 m) V = V1 + V2 = 534 m³/Tank ΣV = V × Number of Tanks = 534 × 12 = 6,408 m³

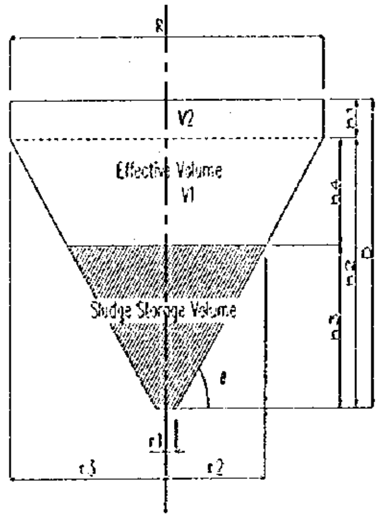


Table M-6 (3/6) Design Calculation for Master Plan (South3 WWTP)

Item	Calculation
2. Trickling Filter	
1)First Step	
a)Required Capacity	
Design Flowrate	72,000 m^3/d
BOD Loading	1.0 kg·BOD/m^2·d
Influent BOD Load	= 72,000 × 182 × 10^-3 = 13,104 kg/d
Required Cross -Sectional Area	$= \frac{13,104}{1.0} = 13,104\ m^2$
b)Dimensions	Diameter 38.00 m Bed Depth 2.00 m Number 12 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 38.00^2 \times 12 = 13,609\ m^2$
BOD Loading	$= \frac{13,104}{13,609} = 1.0$ kg·BOD/m^2·d
Hydraulic Loading	$= \frac{72,000}{13,609} = 5.3$ m/d
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.
3)Second Step	
a)Required Capacity	
Design flowrate	72,000 m^3/d
BOD Loading	1.0 kg·BOD/m^2·d
Influent BOD Load	= 72,000 × 91 × 10^-3 = 6,552 kg/d
Required Cross -Sectional Area	$= \frac{6,552}{1.0} = 6,552\ m^2$
b)Dimensions	Diameter 38.00 m Bed Depth 2.00 m Number 6 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 38.00^2 \times 6 = 6,805\ m^2$
BOD Loading	$= \frac{6,552}{6,805} = 1.0$ kg·BOD/m^2·d
Hydraulic Loading	$= \frac{72,000}{6,805} = 10.6$ m/d

Table M-6 (4/6) Design Calculation for Master Plan (South3 WWTP)

Item	Calculation
3.Final Clarifier	
a)Required Capacity	
Design Flowrate	72,000 m³/d
Overflow Rate	25.0 m³/m²·d
Retention Time	3.0 h
Required Surface Area	$= \dfrac{72,000}{25.0} = 2,880$ m²
b)Dimensions	Diameter R = 17.50 m Depth D = 15.79 m Angle θ = 60 ° Number 12 Tanks (h1 = 1.50 m, h2 = 14.29 m)
c)Check	
Overflow Rate	$= \dfrac{72,000}{2,886} = 24.9$ m³/m²·d
Retention Time	$= \dfrac{18,396}{72,000} \times 24 = 6.1$ h
Sludge Generation	= 72,000 × 70 × 10^-6 ÷ 0.01 = 504 m³ = 42 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 42$ m³/Tank (h3 = 4.09 m , r1 = 0.50 m , r2 = 2.86 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 1,172$ m³/Tank (h4 = 10.20 m , r2 = 2.86 m , r3 = 8.75 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 361$ m³/Tank (h1 = 1.50 m , R = 17.50 m) V = V1 + V2 = 1,533 m³/Tank ΣV = V × Number of Tanks = 1,533 × 12 = 18,396 m³

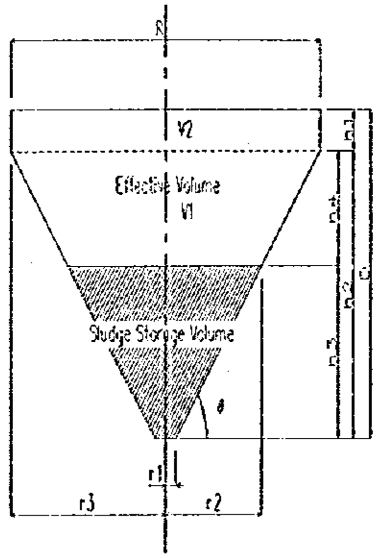


Table M-6 (5/6) Design Calculation for Master Plan (South3 WWTP)

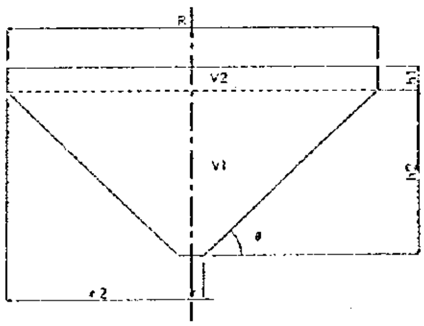
Item	Calculation
4.Sludge Digester Tank (Open Tank)	
a)Required Capacity	
Design Flowrate	66,000 m³/d (Daily Average)
Retention Time	47 days (Unheated Anaerobic Digestion)
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 66,000 × 280 × 0.8 × 10^-6 + 0.02 = 14.8 + 0.02 = 14.8 t/d
Influent Sludge Volume	$= \frac{14.8}{0.06} + 0.3 = 247.3$ m³/d (Raw Sludge Concentration 6%)
Required Volume	= 247.3 × 47 = 11,623 m³
b)Dimensions	Diameter R = 17.00 m Depth D = 9.50 m Angle θ = 45 ° Number 12 Tanks (h1 = 1.50 m, h2 = 8.00 m)  $V1 = \frac{\pi \times h2}{3} (r1^2 + r1 \times r2 + r1^2) = 643$ m³/Tank (h2 = 8.00 m , r1 = 0.50 m , r2 = 8.50 m) $V2 = \frac{\pi \times h1}{4} \times R^2 = 340$ m³/Tank (h1 = 1.50 m , R = 17.00 m) V = V1 + V2 = 983 m³/Tank ΣV = V × Number of Tanks = 983 × 12 = 11,796 m³
c)Check	
Retention Time	$= \frac{11,796}{247} = 48$ days

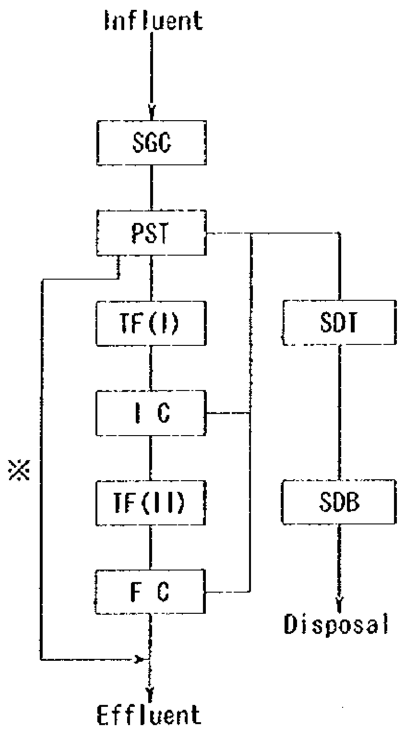
Table M-6 (6/6) Design Calculation for Master Plan (South3 WWTP)

Item	Calculation
5.Sludge Drying Bed	
a)Required Capacity	
Influent Solid Quantity	= Digested Solids
	= 14.8 × (1 − (0.65 × 0.5)) = 10.0 t/d
	Volatile Solid Concentration of Raw Sludge : 65 %
	Volatile Solid Removal Rate : 50 %
Dried Sludge Quantity	$= \frac{10.0}{0.4} = 25.0$ t/d
	(Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg・SS/m²・yr.
Required Area	$= \frac{10.0 \times 365}{0.16} = 22,813$ m²
b)Dimensions	Width 40.00 m
	Length 95.00 m
	Number 6 Tanks
c)Check	
Area	= 40.00 × 95.00 × 6 = 22,800 m²
Solids Loading	$= \frac{10.0}{22,800} \times 365 \times 10^{3} = 160.1$ kg・SS/m²・yr

Design Calculation
for
East 1 Region Wastewater Treatment Plant
(Master Plan)

Table M-7 (1/6) Design Calculation for Master Plan (East1 WWTP)

Item	Calculation
Design Flowrate	
	Daily Average 121,000 m^3/d
	Daily Maximum 131,000 m^3/d
	Hourly Maximum 196,000 m^3/d
Treatment Process Flow Diagram	



Legend
S G C - Screen·Grit Chamber
P S T - Primary Sedimentation Tank
T F(I) - Trickling Filter (First Step)
I C - Intermediate Clarifier
TF(II) - Trickling Filter (Second Step)
F C - Final Clarifier
S D T - Sludge Digester Tank
S D B - Sludge Drying Bed

Table M-7 (2/6) Design Calculation for Master Plan (East1 WWTP)

Item	Calculation
1. Primary Sedimentation Tank	
a)Required Capacity	
Design Flowrate	131,000 m^3/d
Overflow Rate	50.0 $m^3/m^2 \cdot d$
Retention Time	2.0 h
Required Surface Area	$= \dfrac{131,000}{50.0} = 2,620\ m^2$
b)Dimensions	Diameter R = 13.00 m Depth D = 11.89 m Angle θ = 60 ° Number 20 Tanks
c)Check	(h1 = 1.50 m, h2 = 10.39 m)
Overflow Rate	$= \dfrac{131,000}{2,655} = 49.3\ m^3/m^2 \cdot d$
Retention Time	$= \dfrac{11,920}{131,000} \times 24 = 2.2\ h$
Sludge Generation	$= 131,000 \times 154 \times 10^{-6} \div 0.01 = 2,017\ m^3$ $= 101\ m^3/Tank$ (Solid Concentration 1%)
Sludge Storage Volume	$= \dfrac{\pi \times h3}{3} (r1^2 + r1 \times r2 + r2^2) = 101\ m^3/Tank$ (h3 = 5.75 m , r1 = 0.50 m , r2 = 3.82 m)
Effective Volume	$V1 = \dfrac{\pi \times h4}{3} (r2^2 + r2 \times r3 + r3^2) = 397\ m^3/Tank$ (h4 = 4.64 m , r2 = 3.82 m , r3 = 6.50 m) $V2 = \dfrac{\pi \times h1}{4} \times R^2 = 199\ m^3/Tank$ (h1 = 1.50 m , R = 13.00 m) $V = V1 + V2 = 596\ m^3/Tank$ $\Sigma V = V \times$ Number of Tanks $= 596 \times 20 = 11,920\ m^3$

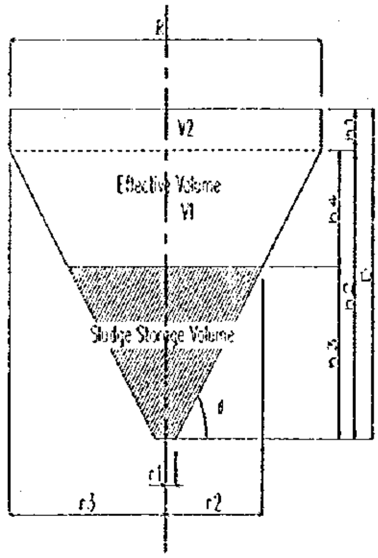


Table M-7 (3/6) Design Calculation for Master Plan (East1 WWTP)

Item	Calculation
2. Trickling Filter	
1)First Step	
a)Required Capacity	
Design Flowrate	131,000 m^3/d
BOD Loading	1.0 $kg \cdot BOD/m^2 \cdot d$
Influent BOD Load	$= 131,000 \times 182 \times 10^{-3} = 23,842$ kg/d
Required Cross -Sectional Area	$= \frac{23,842}{1.0} = 23,842\ m^2$
b)Dimensions	Diameter 39.00 m Bed Depth 2.00 m Number 20 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 39.00^2 \times 20 = 23,892\ m^2$
BOD Loading	$= \frac{23,842}{23,892} = 1.0\ kg \cdot BOD/m^2 \cdot d$
Hydraulic Loading	$= \frac{131,000}{23,892} = 5.5$ m/d
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.
3)Second Step	
a)Required Capacity	
Design flowrate	131,000 m^3/d
BOD Loading	1.0 $kg \cdot BOD/m^2 \cdot d$
Influent BOD Load	$= 131,000 \times 91 \times 10^{-3} = 11,921$ kg/d
Required Cross -Sectional Area	$= \frac{11,921}{1.0} = 11,921\ m^2$
b)Dimensions	Diameter 39.00 m Bed Depth 2.00 m Number 10 Tanks
c)Check Cross-Sectional Area	$= \frac{\pi}{4} \times 39.00^2 \times 10 = 11,946\ m^2$
BOD Loading	$= \frac{11,921}{11,946} = 1.0\ kg \cdot BOD/m^2 \cdot d$
Hydraulic Loading	$= \frac{131,000}{11,946} = 11.0$ m/d

Table M-7 (4/6) Design Calculation for Master Plan (East1 WWTP)

Item	Calculation
3.Final Clarifier	
a)Required Capacity	
Design Flowrate	131,000 m³/d
Overflow Rate	25.0 m³/m²·d
Retention Time	3.0 h
Required Surface Area	$= \frac{131,000}{25.0} = 5,240$ m²
b)Dimensions	Diameter R = 18.00 m Depth D = 16.22 m Angle θ = 60 ° Number 20 Tanks (h1 = 1.50 m, h2 = 14.72 m)
c)Check	
Overflow Rate	$= \frac{131,000}{5,089} = 25.7$ m³/m²·d
Retention Time	$= \frac{33,140}{131,000} \times 24 = 6.1$ h
Sludge Generation	= 131,000 × 70 × 10^-6 ÷ 0.01 = 917 m³ = 46 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 46 m³/Tank (h3 = 4.25 m , r1 = 0.50 m , r2 = 2.95 m)
Effective Volume	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 1,275 m³/Tank (h4 = 10.47 m , r2 = 2.95 m , r3 = 9.00 m) $V2 = \frac{\pi \times h1}{4} \times R^2$ = 382 m³/Tank (h1 = 1.50 m , R = 18.00 m) V = V1 + V2 = 1,657 m³/Tank ΣV = V × Number of Tanks = 1,657 × 20 = 33,140 m³

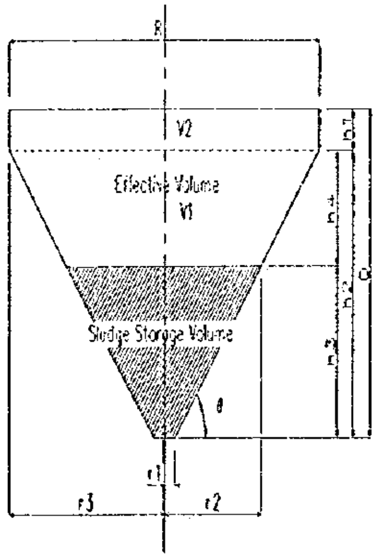


Table M-7 (5/6) Design Calculation for Master Plan (East1 WWTP)

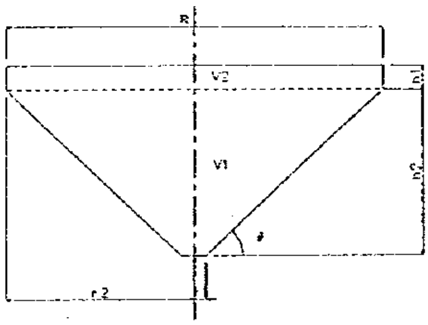
Item	Calculation
4.Sludge Digester Tank (Open Tank)	
a)Required Capacity	
Design Flowrate	121,000 m³/d (Daily Average)
Retention Time	47 days (Unheated Anaerobic Digestion)
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 121,000 × 280 × 0.8 × 10^-6 + 0.46 = 27.1 + 0.46 = 27.6 t/d
Influent Sludge Volume	$= \frac{27.1}{0.06} + 6.6 = 458.6$ m³/d (Raw Sludge Concentration 6%)
Required Volume	= 458.6 × 47 = 21,554 m³
b)Dimensions	 Diameter R = 18.00 m Depth D = 10.00 m Angle θ = 45 ° Number 20 Tanks (h1 = 1.50 m, h2 = 8.50 m) $V1 = \frac{\pi \times h2}{3} (r1^2 + r1 \times r2 + r1^2) = 763$ m³/Tank (h2 = 8.50 m , r1 = 0.50 m , r2 = 9.00 m) $V2 = \frac{\pi \times h1}{4} \times R^2 = 382$ m³/Tank (h1 = 1.50 m , R = 18.00 m) V = V1 + V2 = 1,145 m³/Tank ΣV = V × Number of Tanks = 1,145 × 20 = 22,900 m³
c)Check	
Retention Time	$= \frac{22,900}{459} = 50$ days

Table M-7 (6/6) Design Calculation for Master Plan (East1 WWTP)

Item	Calculation
5.Sludge Drying Bed	
a)Required Capacity	
Influent Solid Quantity	= Digested Solids
	= 27.1 × (1 − (0.65 × 0.5)) = 18.3 t/d
	Volatile Solid Concentration of Raw Sludge : 65 %
	Volatile Solid Removal Rate : 50 %
Dried Sludge Quantity	$= \frac{18.3}{0.4} = 45.8$ t/d
	(Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg・SS/m²・yr.
Required Area	$= \frac{18.3 \times 365}{0.16} = 41,747$ m²
b)Dimensions	Width 40.00 m
	Length 105.00 m
	Number 10 Tanks
c)Check	
Area	= 40.00 × 105.00 × 10 = 42,000 m²
Solids Loading	$= \frac{18.3}{42,000} \times 365 \times 10^{3} = 159$ kg・SS/m²・yr

DESIGN CALCULATION FOR FIRST STAGE PROJECT

Table M-8 Outline of Treatment Facilities for the First Stage Project (Alternative 1 and Alternative 2)

FACILITY	CENTRAL			SOUTH 3 (PINULA COLLECTOR)			SOUTH 3 (HERMOSA COLLECTOR)		
	Dimensions	No.		Dimensions	No.		Dimensions	No.	
		Ultimate	First Stage		Ultimate	First Stage		Ultimate	First Stage
Primary Sedimentation Tank	B10.0m x L30.0m x h10.0m	20	15	φ11.0 m x h 10.0 m	12	8	φ9.5 m x h 9.0 m	4	-
Trickling Filter (First Step)	φ39.0 m x h 2.0 m	40	-	φ34.0 mx h 2.0 m	12	8	φ29.0 m x h 2.0 m	4	-
Intermediate Clarifier	B10.0 m x L30.0 m x h10.0 m	20	-	φ11.0 m x h 10.0 m	12	8	φ9.5 m x h9.0 m	4	-
Trickling Filter (Second Step)	φ39.0 m x h 2.0 m	20	-	φ34.0 m x h 2.0 m	6	4	φ29.0 mx h 2.0 m	2	-
Final Clarifier	B10.0 m x L30.0 m x h 1.0 m	40	-	φ11.0 m x h 1.0 m	24	16	φ9.5 m x h 9.0 m	8	-
Sludge Digester Tank	φ17.5 m x h10.0 m	40	-	φ15.5 m x h 9.0 m	12	-	φ14.0 m x h 8.0 m	4	-
Sludge Drying Bed	W 40.0 m x L 100.0 m	20	15	W 40.0 mx L 80.0m	6	5	W 30.0 m x L 80.0 m	2	-
Anaerobic Pond (h = 3.0 m)	BA 13.0 m x 13.0 m SA 31.0 m x 31.0 m	2	1	BA 1.0 m x 1.0 m SA 19.0 m x 19.0 m	2	1	BA 1.0 m x 1.0 m SA 19.0 m x 19.0 m	1	-
Facultative Ponds (h = 2.0 m)	BA 120.0 m x 60.0 m SA 132.0 m x 72.0 m	2	1	BA 52.0 m x 26.0 m SA 64.0 m x 38.0 m	2	1	BA 20.0 m x 40.0 m SA 32.0 m x 52.0 m	1	-
DESIGN BASIS Design Flowrate	Ultimate	First Stage		Ultimate	First Stage		Ultimate	First Stage	
Daily Average, m3/d	238,000	179,000		52,700	33,000		13,300	-	
Daily Maximum, m3/d	261,000	196,000		57,500	36,000		14,500	-	
Hourly Maximum, m3/d	390,000	293,000		85,500	53,500		21,500	-	
Hourly Maximum Wet weather, m3/d	1,087,000	879,000		-	-		-	-	
Sludge Generation, t/d	90	71		20	19		5	-	

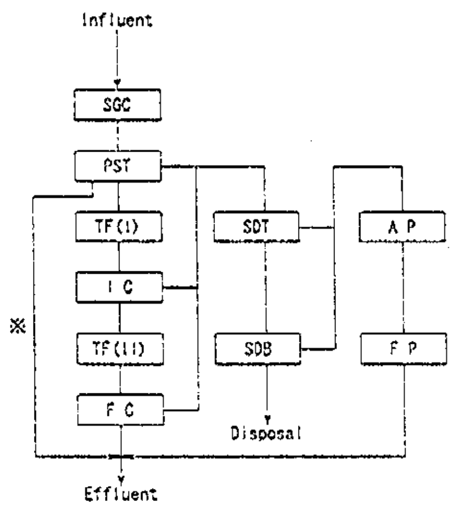
Note : BA....Bottom Area, SA....Surface Area
Source: Study Team

Design Calculation
for
Central Region Wastewater Treatment Plant
(First Stage)

Table M-9 (1/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate		First Stage	
Design Flowrate	Daily Average	238,000 m³/d	Daily Average	179,000 m³/d
	Daily Maximum	261,000 m³/d	Daily Maximum	196,000 m³/d
	Hourly Maximum	390,000 m³/d	Hourly Maximum	293,000 m³/d
	Hourly Maximum Wet Weather	1,087,000 m³/d	Hourly Maximum Wet Weather	879,000 m³/d
Treatment Process Flow Diagram	(see diagram below)		(see diagram below)	

Treatment Process Flow Diagram — Ultimate



Legend
S G C - Screen·Grit Chamber
P S T - Primary Sedimentation Tank
T F(I) - Trickling Filter (First Step)
I C - Intermediate Clarifier
TF(II) - Trickling Filter (Second Step)
F C - Final Clarifier
S D T - Sludge Digester Tank
S D B - Sludge Drying Bed
A P - Anaerobic Pond
F P - Facultative Pond

※ Primary Treated Excess Wet Weather Flow
(3×Maximum Hourly Flow - 1×Maximum Hourly Flow)

Treatment Process Flow Diagram — First Stage

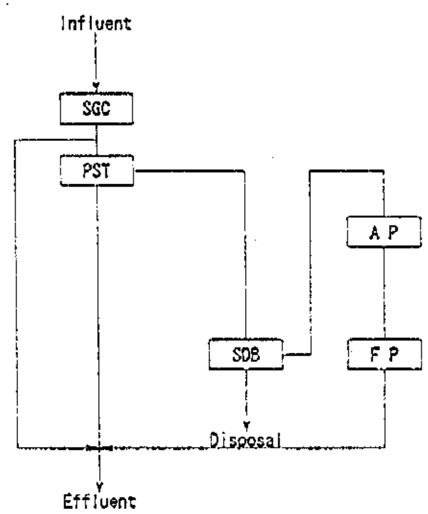
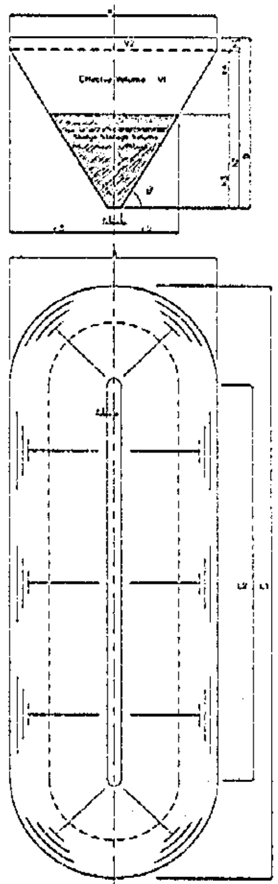


Table M-9 (2/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate	First Stage
1. Primary Sedimentation Tank a)Required Capacity Design Flowrate Overflow Rate Retention Time	261,000 m³/d (D.M.), 1,087,000 m³/d (H.M.W.W.F.) 50.0 m³/m²·d 2.0 h (D.M.) 0.5 h (H.M.W.W.F.) D.M. : Daily Maximum H.M.W.W.F : Hourly Maximum Wet Weather Flow	196,000 m³/d (D.M.), 879,000 m³/d (H.M.W.W.F.) 50.0 m³/m²·d 2.0 h (D.M.) 0.5 h (H.M.W.W.F.) D.M. : Daily Maximum H.M.W.W.F : Hourly Maximum Wet Weather Flow
Required Surface Area	$= \frac{261,000}{50.0} = 5,220$ m²	$= \frac{196,000}{50.0} = 3,920$ m²
b)Dimensions	Diameter R = 10.00 m Length L1 = 30.00 m Depth D = 10.00 m Angle θ = 62.1° Number 20 Tanks (h1 = 1.50 m, h2 = 8.50 m, L2 = 20.00 m)	Diameter R = 10.00 m Length L1 = 20.00 m Depth D = 10.00 m Angle θ = 62.1° Number 15 Tanks (h1 = 1.50 m, h2 = 8.50 m, L2 = 20.00 m)
c)Check		
Surface Area	= (π × r3^2+R×L2)×Number of Tanks = 5,571 m²	= (π × r3^2+R×L2)×Number of Tanks = 4,178 m²
Overflow Rate (D.M.)	$= \frac{261,000}{5,571} = 46.8$ m³/m²·d	$= \frac{196,000}{4,178} = 46.9$ m³/m²·d
Retention Time (D.M.)	$= \frac{20,980}{261,000} \times 24 = 1.9$ h	$= \frac{15,735}{196,000} \times 24 = 1.9$ h
Retention Time (H.M.W.W.F.)	$= \frac{20,980}{1,087,000} \times 24 = 0.5$ h	$= \frac{15,735}{879,000} \times 24 = 0.4$ h
Sludge Generation	= 261,000 × 154 × 10^-6 ÷ 0.01 = 4,019 m³ = 201 m³/Tank (Solid Concentration 1%)	= 196,000 × 154 × 10^-6 ÷ 0.01 = 3,018 m³ = 201 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$\frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 87.5 m³ $\frac{(r1+r2)\times 2}{2}$ × h3 × L2 = 463.8 m³ = 87.5 + 463.8 = 551 m³/Tank (h3 = 5.74 m, r1 = 0.50 m, r2 = 3.54 m, L2 = 20.00 m)	$\frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 87.5 m³ $\frac{(r1+r2)\times 2}{2}$ × h3 × L2 = 463.8 m³ = 87.5 + 463.8 = 551 m³/Tank (h3 = 5.74 m, r1 = 0.50 m, r2 = 3.54 m, L2 = 20.00 m)



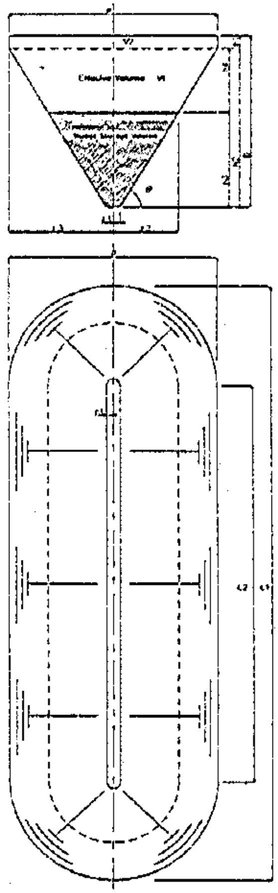


Table M-9 (3/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate	First Stage
Effective Volume	$\frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 159.6 m³ $\frac{(r2+r3)\times 2}{2}$ × h4 × L2 = 471.4 m³ V1 = 159.6 + 471.4 = 631 m³/Tank (h4 = 2.76 m , r2 = 3.54 m , r3 = 5.00 m , L2 = 20.00 m) V2 = $\frac{\pi \times h1}{4}$ × R^2 + R × L2 × h1 = 418 m³/Tank (h1 = 1.50 m , R = 10.00 m , L2 = 20.00 m) V = V1 + V2 = 631 + 418 = 1,049 m³/Tank ΣV = V × Number of Tanks = 1,049 × 20 = 20,980 m³	$\frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 159.6 m³ $\frac{(r2+r3)\times 2}{2}$ × h4 × L2 = 471.4 m³ V1 = 159.6 + 471.4 = 631 m³/Tank (h4 = 2.76 m , r2 = 3.54 m , r3 = 5.00 m , L2 = 20.00 m) V2 = $\frac{\pi \times h1}{4}$ × R^2 + R × L2 × h1 = 418 m³/Tank (h1 = 1.50 m , R = 10.00 m , L2 = 20.00 m) V = V1 + V2 = 631 + 418 = 1,049 m³/Tank ΣV = V × Number of Tanks = 1,049 × 15 = 15,735 m³

Table M-9 (4/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate	First Stage
2. Trickling Filter		
1)First Step		
a)Required Capacity		
Design Flowrate	261,000 m³/d	
BOD Loading	1.0 kg-BOD/m²·d	
Influent BOD Load	= 261,000 × 182 × 10^-3 = 47,502 kg/d	
Required Cross -Sectional Area	= 47,502 / 1.0 = 47,502 m²	
b)Dimensions	Diameter R = 39.00 m Depth D = 2.00 m Number 40 Tanks	
c)Check		
Cross-Sectional Area	= 19.50^2 × π × 40 = 47,784 m²	
BOD Loading	= 47,502 / 47,784 = 1.0 kg-BOD/m²·d	
Hydraulic Loading	= 261,000 / 47,784 = 5.5 m/d	
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.	
3)Second Step		
a)Required Capacity		
Design flowrate	261,000 m³/d	
BOD Loading	1.0 kg-BOD/m²·d	
Influent BOD Load	= 261,000 × 91 × 10^-3 = 23,751 kg/d	
Required Cross -Sectional Area	= 23,751 / 1.0 = 23,751 kg/d	
b)Dimensions	Diameter R = 39.00 m Depth D = 2.00 m Number 20 Tanks	
c)Check		
Cross-Sectional Area	= 19.50^2 × π × 20 = 23,892 m²	
BOD Loading	= 23,751 / 23,892 = 1.0 kg-BOD/m²·d	
Hydraulic Loading	= 261,000 / 23,892 = 10.9 m/d	

Table M-9 (5/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate	First Stage
3.Final Clarifier a)Required Capacity		
Design Flowrate Overflow Rate Retention Time	261,000 m³/d 25.0 m³/m²·d 3.0 h	
Required Surface Area	$= \frac{261,000}{25.0} = 10,440$ m²	
b)Dimensions	Diameter R = 10.00 m Diameter L1 = 30.00 m Depth D = 10.00 m Angle θ = 62.1 ° Number 40 Tanks (h1 = 1.50 m, h2 = 3.50 m, L2 = 20.00 m)	
c)Check Overflow Rate (D.M.)	$= \frac{261,000}{11,142} = 23.4$ m³/m²·d	
Retention Time (D.M.)	$= \frac{41,960}{261,000} \times 24 = 3.9$ h	
Sludge Generation	= 261,000 × 70 × 10^-6 ÷ 0.01 = 1,827 m³ = 46 m³/Tank (Solid Concentration 1%)	
Sludge Storage Volume	$\frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 87.5 m³ $\frac{(r1+r2) \times 2}{2}$ × h3 × L2 = 463.8 m³ = 87.5 + 463.8 = 551 m³/Tank (h3 = 5.74 m, r1 = 0.50 m, r2 = 3.54 m, L2 = 20.00 m)	

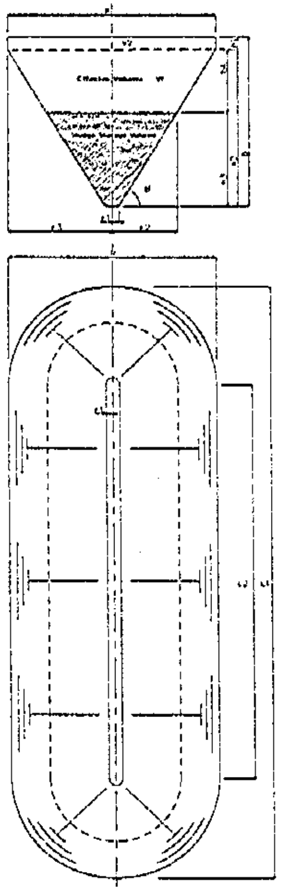


Table M-9 (6/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate	First Stage
Effective Volume	$\frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 159.6 m³ $\frac{(r2+r3)\times 2}{2}$ × h4 × L2 = 471.4 m³ V1 = 159.6 + 471.4 = 631 m³/Tank (h4 = 2.76 m , r2 = 3.54 m , r3 = 5.00 m , L2 = 20.00 m) V2 = $\frac{\pi \times h1}{4}$ × R^2 + R × L2 × h1 = 418 m³ (h1 = 1.50 m , R = 10.00 m , L2 = 20.00 m) V = V1 + V2 = 631 + 418 = 1,049 m³/Tank ΣV = V × Number of Tanks = 1,049 × 40 = 41,960 m³	

Table M-9 (7/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

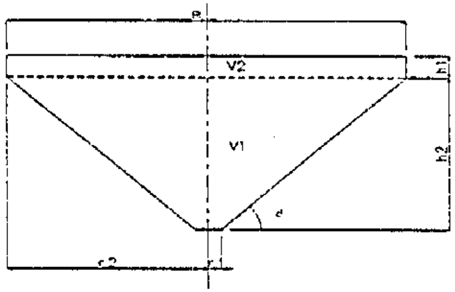
Item	Ultimate	First Stage
4.Sludge Digester Tank (Open Tank)		
a)Required Capacity		
Design Flowrate	238,000 m³/d (Daily Average)	
Retention Time	47 days (Unheated Anaerobic Digestion)	
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 238,000 × 280 × 0.8 × 10^-6 + 0.84 = 53.3 + 0.84 = 54.1 t/d	
Influent Sludge Volume	$= \frac{53.3}{0.06} + 12.0 = 900$ m³/d (Raw Sludge Concentration 6%)	
Required Volume	= 900 × 47 = 42,300 m³	
b)Dimensions	 Diameter R = 17.50 m Depth D = 10.00 m Angle θ = 45.87 ° Number 40 Tanks (h1 = 1.50 m, h2 = 8.50 m) $V1 = \frac{\pi \times h2}{3}$ (r1^2+r1×r2+r1^2) = 723 m³/Tank (h2 = 8.50 m , r1 = 0.50 m , r2 = 8.75 m) $V2 = \frac{\pi \times h1}{4} \times$ R^2 = 361 m³/Tank (h1 = 1.50 m , R = 17.50 m) V = V1 + V2 = 1,084 m³/Tank ΣV = V × Number of Tanks = 1,084 × 40 = 43,360 m³	
c)Check		
Retention Time	$= \frac{43,360}{900} = 48$ days	

Table M-9 (8/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate	First Stage
5.Sludge Drying Bed		
a)Required Capacity		
Influent Solid Quantity	= Digested Solids	= Raw Sludge + Septage from Sanitation Facility
	= 53.3 × (1 − (0.65 × 0.5)) = 36.0 t/d	= 179,000 × 280 × 0.55 × 10^-6 + 0.84
	Volatile Solid Concentration of Raw Sludge : 65 % Volatile Solid Removal Rate : 50 %	= 27.6 + 0.84 = 28.4 t/d
Dried Sludge Quantity	$= \frac{36.0}{1-0.6} = 90.0$ t/d	$= \frac{28.4}{1-0.6} = 71.0$ t/d
	(Moisture Content of Dried Sludge: 60 %)	(Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg・SS/m²・yr.	160 kg・SS/m²・yr.
Required Area	$= \frac{36.0 \times 365}{0.16} = 82,125$ m²	$= \frac{27.6 \times 365}{0.16} = 62,963$ m²
b)Dimensions	Width 40.00 m Length 100.00 m Number 20 tanks	Width 40.00 m Length 100.00 m Number 15 tanks
c)Check		
Area	= 40.00 × 100.00 × 20 = 80,000 m²	= 40.00 × 100.00 × 15 = 60,000 m²
Solids Loading	$= \frac{36.0}{80,000} \times 365 \times 10^3 = 164.3$ kg・SS/m²・yr	$= \frac{27.6}{60,000} \times 365 \times 10^3 = 167.9$ kg・SS/m²・yr

Table M-9 (9/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

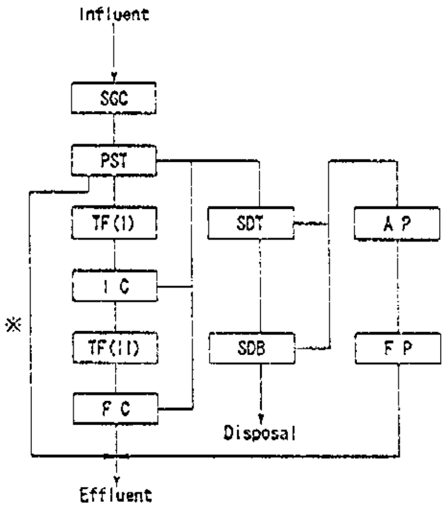
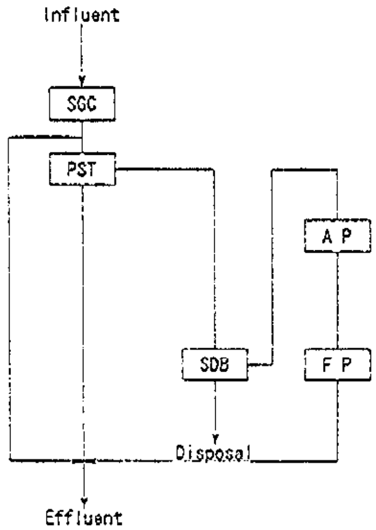
Item	Ultimate	First Stage
6. Waste Stabilization Pond (for Supernatant Liquor)		
1) Anaerobic Ponds		
a) Required Capacity Design Flowrate	= Supernatant Liqquor from Digester Tank and Sludge Drying Bed ≒ Influent Sludge Volume from Digester Tank + Digested Sludge Volume - Dried Sludge Volume (Digested Sludge Volume = Influent Sludge Volume for Sludge Drying Bed) $= 900 + \frac{36.0}{0.06} - 90 = 1,410$ m³/d	= Supernatant Liquor from Sludge Drying Bed ≒ Influent Sludge Volume to Sludge Drying Bed − Dried Sludge Volume $= \frac{27.6}{0.06} + 12 - 71 = 401$ m³/d
Volumetric Loading Rate(BOD)	= 20T − 100 = 20 × 17 − 100 = 240 g/m³/d	= 20T − 100 = 20 × 17 − 100 = 240 g/m³/d
Water Quality (BOD)	= 500 mg/L	= 500 mg/L
Required Pond Volume	$= \frac{500 \times 1,410}{240} = 2,938$ m³	$= \frac{500 \times 401}{240} = 835$ m³
b) Dimensions	Cross-sectional Shape: Trapezoid Bottom Area: 13m × 13m (169 m²) Surface Area: 31m × 31m (961 m²) Water Depth: D = 3.0 m Side Slope: 1:3 Number: 2 Ponds Effective Volume: 1,533 m³/Pond	Cross-sectional Shape: Trapezoid Bottom Area: 13m × 13m (169 m²) Surface Area: 31m × 31m (961 m²) Water Depth: D = 3.0 m Side Slope: 1:3 Number: 1 Ponds Effective Volume: 1,533 m³/Pond
c) Check		
Retention Time	$= \frac{1,533 \times 2}{1,410} = 2.2$ days	$= \frac{1,533}{401} = 3.8$ days
Volumetric Loading Rate(BOD)	$= \frac{500 \times 1410}{1,533 \times 2} = 229$ g/m³/d	$= \frac{500 \times 401}{1,533} = 131$ g/m³/d
d) Effluent Quality(BOD)		
Removal Rate	= 2T + 20 = 2 × 17 + 20 = 54 %	= 2T + 20 = 2 × 17 + 20 = 54 %
Effluent Quality	= (1 - 0.54) × 500 = 230 mg/L	= (1 - 0.54) × 500 = 230 mg/L

Table M-9 (10/10) Design Calculation for First Stage Project (Alternative 1 : Central WWTP)

Item	Ultimate	First Stage
2)Facultative Ponds a)Required Capacity Design Flowrate	= 1,410 m³/d	= 401 m³/d
Surface Loading Rate(BOD)	= 350 × (1.107 − 0.002T)^T-25 = 350 × (1.107 − 0.002 × 17)^T-25 = 199 kg/ha/day	= 350 × (1.107 − 0.002T)^T-25 = 350 × (1.107 − 0.002 × 17)^T-25 = 199 kg/ha/day
Influent BOD Load	= 1,410 × 230 × 10^-3 = 324 kg/day	= 401 × 230 × 10^-3 = 92 kg/day
Required Surface Area	$= \frac{324}{199}$ = 1.63 ha = 16,300 m²	$= \frac{92}{199}$ = 0.46 ha = 4,600 m²
b)Dimensions	Cross-sectional Shape: Trapezoid Bottom Area: 120m × 60m (7.200 m²) Surface Depth: 132m × 72m (9.504 m²) Mid depth Area: 126m × 66m (8.316 m²) Water Depth: D = 2.0 m Side Slope: 1:3 Number: 2 Ponds Effective Volume: 16,656 m³/Pond	Cross-sectional Shape: Trapezoid Bottom Area: 120m × 60m (7.200 m²) Surface Area: 132m × 72m (9.504 m²) Mid depth Area: 126m × 66m (8.316 m²) Water Depth: D = 2.0 m Side Slope: 1:3 Number: 1 Ponds Effective Volume: 16,656 m³/Pond
c)Check Retention Time	$= \frac{16,656 \times 2}{1,410}$ = 23.6 days	$= \frac{16,656}{401}$ = 41.5 days
Surface Loading Rate (at Mid depth)	$= \frac{324}{1.26 \times 0.66 \times 2}$ = 195 kg/ha/day	$= \frac{92}{1.26 \times 0.66}$ = 111 kg/ha/day
d)Effluent Quality (BOD)	$= \frac{230}{1 + 0.26 \times 23.6}$ = 32.2 mg/L WHERE KT = 0.3 × (1.05)^T-20 = 0.3 × (1.05)^17-20 = 0.26	$= \frac{230}{1 + 0.26 \times 41.5}$ = 19.5 mg/L WHERE KT = 0.3 × (1.05)^T-20 = 0.3 × (1.05)^17-20 = 0.26

Design Calculation
for
South 3 Region Wastewater Treatment Plant
(First Stage)

Table M-10 (1/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)
a) Facilities for Pinula Collecter

Item	Ultimate		First Stage	
Design Flowrate	Daily Average	52,700 m³/d	Daily Average	33,000 m³/d
	Daily Maximum	57,500 m³/d	Daily Maximum	36,000 m³/d
	Hourly Maximum	85,500 m³/d	Hourly Maximum	53,500 m³/d
Treatment Process Flow Diagram				

Ultimate flow diagram:

Legend
S G C - Screen·Grit Chamber
P S T - Primary Sedimentation Tank
T F(I) - Trickling Filter (First Step)
I C - Intermediate Clarifier
TF(II) - Trickling Filter (Second Step)
F C - Final Clarifier
S D T - Sludge Digester Tank
S D B - Sludge Drying Bed
A P - Anaerobic Pond
F P - Facultative Pond

※ Primary Treated Excess Wet Weather Flow
(3×Maximum Hourly Flow - 1×Maximum Hourly Flow)

First Stage flow diagram:

Table M-10 (2/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

a) Facilities for Pinula Collecter

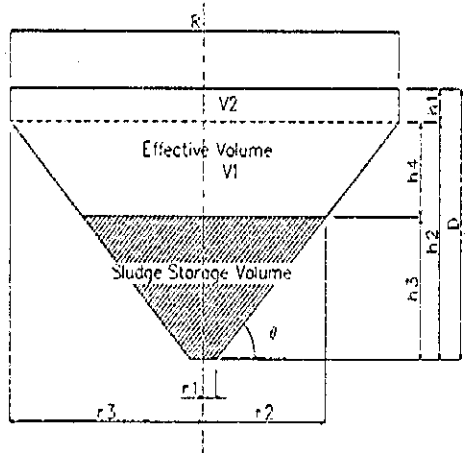
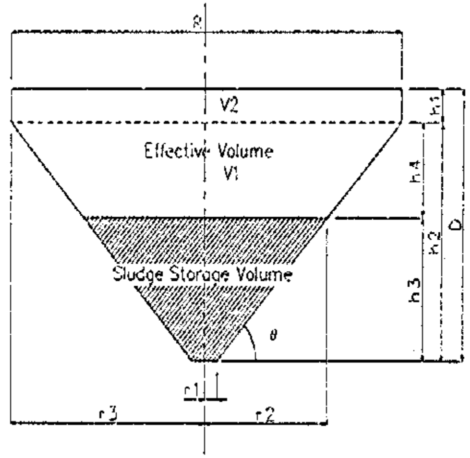
Item	Ultimate	First Stage
1. Primary Sedimentation Tank a)Required Capacity Design Flowrate Overflow Rate Retention Time	57,500 m³/d (D.M.). 50.0 m³/m²·d 2.0 h (D.M.) D.M. : Daily Maximum H.M.W.W.F : Hourly Maximum Wet Weather Flow	36,000 m³/d (D.M.). 50.0 m³/m²·d 2.0 h (D.M.) D.M. : Daily Maximum H.M.W.W.F : Hourly Maximum Wet Weather Flow
Required Surface Area	$= \frac{57,500}{50.0} = 1,150$ m²	$= \frac{36,000}{50.0} = 720$ m²
b)Dimensions	Diameter R = 11.00 m Depth D = 10.00 m Angle θ = 59.5 ° Number 12 Tanks (h1 = 1.50 m, h2 = 8.50 m)  	Diameter R = 11.00 m Depth D = 10.00 m Angle θ = 59.5 ° Number 8 Tanks (h1 = 1.50 m, h2 = 8.50 m) 
c)Check Overflow Rate	$= \frac{57,500}{1,140} = 50.4$ m³/m²·d	$= \frac{36,000}{760} = 47.4$ m³/m²·d
Retention Time	$= \frac{4,128}{57,500} \times 24 = 1.7$ h	$= \frac{2,752}{36,000} \times 24 = 1.8$ h
Sludge Generation	= 57,500 × 154 × 10^-6 ÷ 0.01 = 886 m³ = 74 m³/Tank (Solid Concentration 1%)	= 36,000 × 154 × 10^-6 ÷ 0.01 = 554 m³ = 69 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 95 m³/Tank (h3 = 5.56 m , r1 = 0.50 m , r2 = 3.77 m)	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 95 m³/Tank (h3 = 5.56 m , r1 = 0.50 m , r2 = 3.77 m)
Effective Volume	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 201 m³/Tank (h4 = 2.94 m , r2 = 3.77 m , r3 = 5.50 m) $V2 = \frac{\pi \times h1}{4} \times$ R^2 = 143 m³/Tank (h1 = 1.50 m , R = 11.00 m) V = V1 + V2 = 344 m³/Tank ΣV = V × Number of Tanks = 344 × 12 = 4,128 m³	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 201 m³/Tank (h4 = 2.94 m , r2 = 3.77 m , r3 = 5.50 m) $V2 = \frac{\pi \times h1}{4} \times$ R^2 = 143 m³/Tank (h1 = 1.50 m , R = 11.00 m) V = V1 + V2 = 344 m³/Tank ΣV = V × Number of Tanks = 344 × 8 = 2,752 m³

Table M-10 (3/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

a) Facilities for Pinula Collecter

Item	Ultimate	First Stage
2. Trickling Filter 1)First Step a)Required Capacity		
Design Flowrate BOD Loading Influent BOD Load	57,500 m³/d 1.0 kg·BOD/m³·d = 57,500 × 182 × 10^-3 = 10,465 kg/d	36,000 m³/d 1.0 kg·BOD/m³·d = 36,000 × 182 × 10^-3 = 6,552 kg/d
Required Cross -Sectional Area	$= \frac{10,465}{1.0} = 10,465$ m²	$= \frac{6,552}{1.0} = 6,552$ m²
b)Dimensions	Diameter R = 34.00 m Depth D = 2.00 m Number 12 Tanks	Diameter R = 34.00 m Depth D = 2.00 m Number 8 Tanks
c)Check Cross-Sectional Area	= 17.00 ^2 × π × 12 = 10,895 m²	= 17.00 ^2 × π × 8 = 7,263 m²
BOD Loading	$= \frac{10,465}{10,895} = 1.0$ kg·BOD/m²·d	$= \frac{6,552}{7,263} = 0.9$ kg·BOD/m²·d
Hydraulic Loading	$= \frac{57,500}{10,895} = 5.3$ m/d	$= \frac{36,000}{7,263} = 5.0$ m/d
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.	Intermediate clarifier is the same size as primary sedimentation tank.
3)Second Step a)Required Capacity		
Design flowrate BOD Loading Influent BOD Load	57,500 m³/d 1.0 kg·BOD/m³·d = 57,500 × 91 × 10^-3 = 5,233 kg/d	36,000 m³/d 1.0 kg·BOD/m³·d = 36,000 × 91 × 10^-3 = 3,276 kg/d
Required Cross -Sectional Area	$= \frac{5,233}{1.0} = 5,233$ m²	$= \frac{3,276}{1.0} = 3,276$ m²
b)Dimensions	Diameter R = 34.00 m Depth D = 2.00 m Number 6 Tanks	Diameter R = 34.00 m Depth D = 2.00 m Number 4 Tanks
c)Check Cross-Sectional Area	= 17.00 ^2 × π × 6 = 5,448 m²	= 17.00 ^2 × π × 4 = 3,632 m²
BOD Loading	$= \frac{5,233}{5,448} = 1.0$ kg·BOD/m²·d	$= \frac{3,276}{3,632} = 0.9$ kg·BOD/m²·d
Hydraulic Loading	$= \frac{57,500}{5,448} = 10.6$ m/d	$= \frac{36,000}{3,632} = 9.9$ m/d

Table M-10 (4/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

a) Facilities for Pinula Collecter

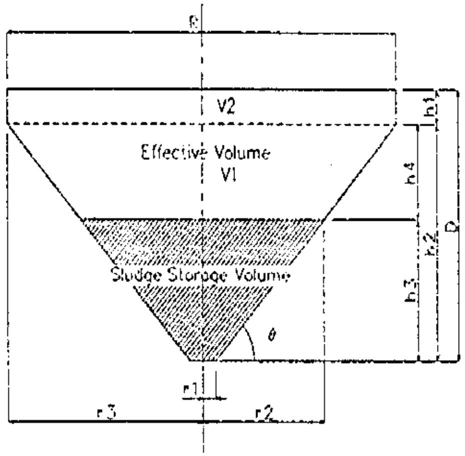
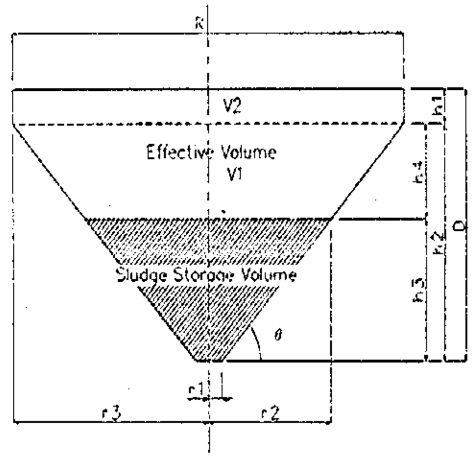
Item	Ultimate	First Stage
3.Final Clarifier a)Required Capacity	 	
Design Flowrate Overflow Rate Retention Time	57,500 m³/d 25.0 m³/m²·d 3.0 h	36,000 m³/d 25.0 m³/m²·d 3.0 h
Required Surface Area	$= \frac{57,500}{25.0} = 2,300$ m²	$= \frac{36,000}{25.0} = 1,440$ m²
b)Dimensions	Diameter R = 11.00 m Depth D = 10.00 m Angle θ = 59.5 ° Number 24 Tanks (h1 = 1.50 m, h2 = 8.50 m)	Diameter R = 11.00 m Depth D = 10.00 m Angle θ = 59.5 ° Number 16 Tanks (h1 = 1.50 m, h2 = 8.50 m)
c)Check Overflow Rate	$= \frac{57,500}{2,281} = 25.2$ m³/m²·d	$= \frac{36,000}{1,521} = 23.7$ m³/m²·d
Retention Time	$= \frac{9,504}{57,500} \times 24 = 4.0$ h	$= \frac{6,336}{36,000} \times 24 = 4.2$ h
Sludge Generation	= 57,500 × 70 × 10^-6 ÷ 0.01 = 403 m³ = 17 m³/Tank (Solid Concentration 1%)	= 36,000 × 70 × 10^-6 ÷ 0.01 = 252 m³ = 16 m³/Tank (Solid Concentration 1%)
Sludge Storage Volume	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 44 m³/Tank (h3 = 4.09 m , r1 = 0.50 m , r2 = 2.91 m)	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 44 m³/Tank (h3 = 4.09 m , r1 = 0.50 m , r2 = 2.91 m)
Effective Volume	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 253 m³/Tank (h4 = 4.41 m , r2 = 2.91 m , r3 = 5.50 m) $V2 = \frac{\pi \times h1}{4} \times$ R^2 = 143 m³/Tank (h1 = 1.50 m , R = 11.00 m) V = V1 + V2 = 396 m³/Tank ΣV = V × Number of Tanks = 396 × 24 = 9,504 m³	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 253 m³/Tank (h4 = 4.41 m , r2 = 2.91 m , r3 = 5.50 m) $V2 = \frac{\pi \times h1}{4} \times$ R^2 = 143 m³/Tank (h1 = 1.50 m , R = 11.00 m) V = V1 + V2 = 396 m³/Tank ΣV = V × Number of Tanks = 396 × 16 = 6,336 m³

Table M-10 (5/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

a) Facilities for Pinula Collecter

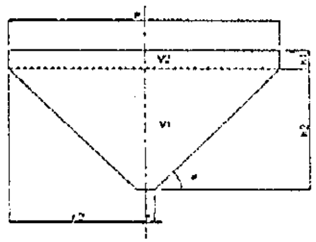
Item	Ultimate	First Stage
4.Sludge Digester Tank (Open Tank)		
a)Required Capacity Design Flowrate	52,700 m³/d (Daily Average)	
Retention Time	47 days (Unheated Anaerobic Digestion)	
Influent Solid Quantity	= Raw Sludge + Septage from Sanitation Facility = 52,700 × 280 × 0.8 × 10^-6 + 0.02 = 11.8 + 0.02 = 11.8 t/d	
Influent Sludge Volume	$= \frac{11.8}{0.06} + 0.3 = 197.0$ m³/d (Raw Sludge Concentration 6%)	
Required Volume	= 197.0 × 47 = 9,259 m³	
b)Dimensions	Diameter R = 15.50 m Depth D = 9.00 m Angle θ = 46 ° Number 12 Tanks (h1 = 1.50 m, h2 = 7.50 m)  $V1 = \frac{\pi \times h2}{3}$ (r1^2+r1×r2+r1^2) = 504 m³/Tank (h2 = 7.50 m , r1 = 0.50 m , r2 = 7.75 m) $V2 = \frac{\pi \times h1}{4}$ × R^2 = 283 m³/Tank (h1 = 1.50 m , R = 15.50 m) V = V1 + V2 = 787 m³/Tank ΣV = V × Number of Tanks = 787 × 12 = 9,444 m³	
c)Check		
Retention Time	$= \frac{9,444}{197} = 48$ days	

Table M-10 (6/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)
a) Facilities for Pinula Collecter

Item	Ultimate	First Stage
5.Sludge Drying Bed		
a)Required Capacity		
Influent Solid Quantity	=Digested Solids = 11.8 × (1 − (0.65 × 0.5)) = 8.0 t/d Volatile Solid Concentration of Raw Sludge : 65 % Volatile Solid Removal Rate : 50 %	= Raw Sludge + Septage from Sanitation Facility = 33.000 × 280 × 0.8 × 10^-6 + 0.02 = 7.4 + 0.02 = 7.4 t/d
Dried Sludge Quantity	$= \frac{8.0}{0.4} = 20.0$ t/d (Moisture Content of Dried Sludge: 60 %)	$= \frac{7.4}{0.4} = 18.5$ t/d (Moisture Content of Dried Sludge: 60 %)
Solids Loading	160 kg-SS/m²·yr.	160 kg-SS/m²·yr.
Required Area	$= \frac{8.0 \times 365}{0.16} = 18,250$ m²	$= \frac{7.4 \times 365}{0.16} = 16,881$ m²
b)Dimensions	Width 40.00 m Length 80.00 m Number 6 Tanks	Width 40.00 m Length 80.00 m Number 5 Tanks
c)Check		
Area	= 40.00 × 80.00 × 6 = 19,200 m²	= 40.00 × 80.00 × 5 = 16,000 m²
Solids Loading	$= \frac{8.0}{19200} \times 365 \times 10^3 = 152.1$ kg-SS/m²·yr	$= \frac{7.4}{16000} \times 365 \times 10^3 = 168.8$ kg-SS/m²·yr

Table M-10 (7/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

a) Facilities for Pinula Collecter

Item	Ultimate	First Stage
6.Waste Stabilization Pond (for Supernatant Liquor)		
1)Anaerobic Ponds		
a)Required Capacity Design Flowrate	=Supernatant Liqquor from Digester Tank and Sludge Drying Bed ≒Influent Sludge Volume from Digester Tank + Digested Sludge Volume - Dried Sludge Volume (Digested Sludge Volume = Influent Sludge Volume for Sludge Drying Bed) $= 197 + \frac{8.0}{0.06} - 20 = 310$ m³/d	=Supernatant Liquor from Sludge Drying Bed ≒Influent Sludge Volume to Sludge Drying Bed − Dried Sludge Volume $= \frac{7.4}{0.06} + 0.3 - 18.5 = 105$ m³/d
Volumetric Loading Rate(BOD)	= 20T − 100 = 20 × 17 − 100 = 240 g/m³/d	= 20T − 100 = 20 × 17 − 100 = 240 g/m³/d
Water Quality (BOD)	= 500 mg/L	= 500 mg/L
Required Pond Volume	$= \frac{500 \times 310}{240} = 646$ m³	$= \frac{500 \times 105}{240} = 219$ m³
b)Dimensions	Cross-sectional Shape: Trapezoid Bottom Area: 1m × 1m (1 m²) Surface Area: 19m × 19m (361 m²) Water Depth: D = 3.0 m Side Slope: 1:3 Number: 2 Ponds Effective Volume: 381 m³/Pond	Cross-sectional Shape: Trapezoid Bottom Area: 1m × 1m (1 m²) Surface Area: 19m × 19m (361 m²) Water Depth: D = 3.0 m Side Slope: 1:3 Number: 1 Ponds Effective Volume: 381 m³/Pond
c)Check		
Retention Time	$= \frac{381 \times 2}{646} = 1.2$ days	$= \frac{381}{105} = 3.6$ days
Volumetric Loading Rate(BOD)	$= \frac{500 \times 646}{381 \times 2} = 424$ g/m³/d	$= \frac{500 \times 105}{381} = 138$ g/m³/d
d)Effluent Quality(BOD) Removal Rate	= 2T + 20 = 2 × 17 + 20 = 54 %	= 2T + 20 = 2 × 17 + 20 = 54 %
Effluent Quality	= (1 - 0.54) × 500 = 230 mg/L	= (1 - 0.54) × 500 = 230 mg/L

Table M-10 (8/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

a) Facilities for Pinula Collecter

Item	Ultimate	First Stage
2)Facultative Ponds a)Required Capacity Design Flowrate	= 310 m³/d	= 105 m³/d
Surface Loading Rate(BOD)	= 350 × (1.107 − 0.002T)^T-25 = 350 × (1.107 − 0.002 × 17)^T-25 = 199 kg/ha/day	= 350 × (1.107 − 0.002T)^T-25 = 350 × (1.107 − 0.002 × 17)^T-25 = 199 kg/ha/day
Influent BOD Load	= 310 × 230 × 10^-3 = 71 kg/day	= 105 × 230 × 10^-3 = 24 kg/day
Required Surface Area	$= \frac{71}{199}$ = 0.36 ha = 3,600 m²	$= \frac{24}{199}$ = 0.12 ha = 1,200 m²
b)Dimensions	Cross-sectional Shape: Trapezoid Bottom Area: 52m × 26m (1,352 m²) Surface Depth: 64m × 38m (2,432 m²) Mid depth Area: 58m × 32m (1,856 m²) Water Depth: D = 2.0 m Side Slope: 1:3 Number: 2 Ponds Effective Volume: 3,736 m³/Pond	Cross-sectional Shape: Trapezoid Bottom Area: 52m × 26m (1,352 m²) Surface Depth: 64m × 38m (2,432 m²) Mid depth Area: 58m × 32m (1,856 m²) Water Depth: D = 2.0 m Side Slope: 1:3 Number: 1 Ponds Effective Volume: 3,736 m³/Pond
c)Check Retention Time	$= \frac{3,736 \times 2}{310}$ = 24.1 days	$= \frac{3,736}{105}$ = 35.6 days
Surface Loading Rate (at Mid depth)	$= \frac{71}{0.58 \times 0.32 \times 2}$ = 191 kg/ha/day	$= \frac{24}{0.58 \times 0.32}$ = 129 kg/ha/day
d)Effluent Quality (BOD)	$= \frac{230}{1 + 0.26 \times 24.1}$ = 31.7 mg/L WHERE KT = 0.3 × (1.05)^T-20 = 0.3 × (1.05)^17-20 = 0.26	$= \frac{230}{1 + 0.26 \times 35.6}$ = 22.4 mg/L WHERE KT = 0.3 × (1.05)^T-20 = 0.3 × (1.05)^17-20 = 0.26

Table M-6 (9/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

b) Facilities for Hermosa Collecter

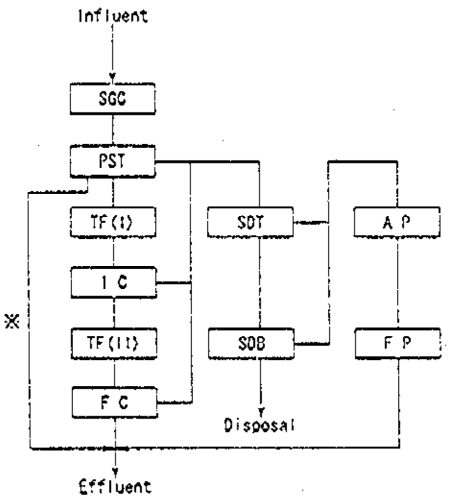
Item	Ultimate	First Stage
Design Flowrate	Daily Average 13,300 m³/d Daily Maximum 14,500 m³/d Hourly Maximum 21,500 m³/d	
Treatment Process Flow Diagram	 Legend S G C - Screen·Grit Chamber P S T - Primary Sedimentation Tank T F(I) - Trickling Filter (First Step) I C - Intermediate Clarifier TF(II) - Trickling Filter (Second Step) F C - Final Clarifier S D T - Sludge Digester Tank S D B - Sludge Drying Bed A P - Anaerobic Pond F P - Facultative Pond ※ Primary Treated Excess Wet Weather Flow (3×Maximum Hourly Flow - 1×Maximum Hourly Flow)	

Table M-6 (10/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

b) Facilities for Hermosa Collecter

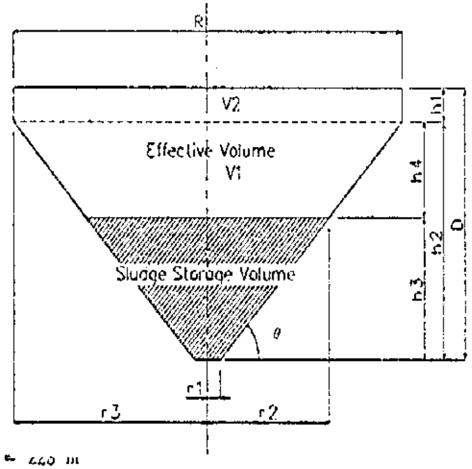
Item	Ultimate	First Stage
1. Primary Sedimentation Tank		
a)Required Capacity		
Design Flowrate	14,500 m³/d (D.M.),	
Overflow Rate	50.0 m³/m²·d	
Retention Time	2.0 h (D.M.)	
	D.M. : Daily Maximum	
	H.M.W.W.F : Hourly Maximum Wet Weather Flow	
Required Surface Area	$= \frac{14,500}{50.0} = 290$ m²	
		
b)Dimensions	Diameter R = 9.50 m	
	Depth D = 9.00 m	
	Angle θ = 60.5 °	
	Number 4 Tanks	
	(h1 = 1.50 m, h2 = 7.50 m)	
c)Check		
Overflow Rate	$= \frac{14,500}{284} = 51.1$ m³/m²·d	
Retention Time	$= \frac{856}{14,500} \times 24 = 1.4$ h	
Sludge Generation	= 14,500 × 154 × 10^-6 ÷ 0.01 ≒ [illegible] m ≒ 56 m³/Tank (Solid Concentration 1%)	
Sludge Storage Volume	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 90 m³/Tank	
	(h3 = 5.56 m , r1 = 0.50 m , r2 = 3.65 m)	
Effective Volume	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 108 m³/Tank	
	(h4 = 1.94 m , r2 = 3.65 m , r3 = 4.75 m)	
	$V2 = \frac{\pi \times h1}{4} \times$ R^2 = 106 m³/Tank	
	(h1 = 1.50 m , R = 9.50 m)	
	V = V1 + V2 = 214 m³/Tank	
	ΣV = V × Number of Tanks = 214 × 4 = 856 m³	

Table M-6 (11/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

b) Facilities for Hermosa Collecter

Item	Ultimate	First Stage
2. Trickling Filter 1)First Step a)Required Capacity		
Design Flowrate BOD Loading Influent BOD Load	14,500 m³/d 1.0 kg·BOD/m³·d = 14,500 × 182 × 10^-3 = 2,639 kg/d	
Required Cross -Sectional Area	$= \frac{2,639}{1.0} = 2,639$ m²	
b)Dimensions	Diameter R = 29.00 m Depth D = 2.00 m Number 4 Tanks	
c)Check Cross-Sectional Area	= 14.50 ^2 × π × 4 = 2,642 m²	
BOD Loading	$= \frac{2,639}{2,642} = 1.0$ kg·BOD/m³·d	
Hydraulic Loading	$= \frac{14,500}{2,642} = 5.5$ m/d	
2)Intermediate Clarifier	Intermediate clarifier is the same size as primary sedimentation tank.	
3)Second Step a)Required Capacity		
Design flowrate BOD Loading Influent BOD Load	14,500 m³/d 1.0 kg·BOD/m³·d = 14,500 × 91 × 10^-3 = 1,320 kg/d	
Required Cross -Sectional Area	$= \frac{1,320}{1.0} = 1,320$ m²	
b)Dimensions	Diameter R = 29.00 m Depth D = 2.00 m Number 2 Tanks	
c)Check Cross-Sectional Area	= 14.50 ^2 × π × 2 = 1,321 m²	
BOD Loading	$= \frac{1,320}{1,321} = 1.0$ kg·BOD/m³·d	
Hydraulic Loading	$= \frac{14,500}{1,321} = 11.0$ m/d	

Table M-6 (12/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

b) Facilities for Hermosa Collecter

Item	Ultimate	First Stage
3.Final Clarifier		
a)Required Capacity		
Design Flowrate	14,500 m³/d	
Overflow Rate	25.0 m³/m²·d	
Retention Time	3.0 h	
Required Surface Area	$= \frac{14,500}{25.0} = 580$ m²	
b)Dimensions	Diameter R = 9.50 m Depth D = 9.00 m Angle θ = 60.5 ° Number 8 Tanks (h1 = 1.50 m, h2 = 7.50 m)	
c)Check		
Overflow Rate	$= \frac{14,500}{567} = 25.6$ m³/m²·d	
Retention Time	$= \frac{2,104}{14,500} \times 24 = 3.5$ h	
Sludge Generation	= 14,500 × 70 × 10^-6 ÷ 0.01 = 102 m³ = 13 m³/Tank (Solid Concentration 1%)	
Sludge Storage Volume	$= \frac{\pi \times h3}{3}$ (r1^2+r1×r2+r2^2) = 41 m³/Tank (h3 = 4.09 m , r1 = 0.50 m , r2 = 2.82 m)	
Effective Volume	$V1 = \frac{\pi \times h4}{3}$ (r2^2+r2×r3+r3^2) = 157 m³/Tank (h4 = 3.41 m , r2 = 2.82 m , r3 = 4.75 m) $V2 = \frac{\pi \times h1}{4} \times$ R^2 = 106 m³/Tank (h1 = 1.50 m , R = 9.50 m) V = V1 + V2 = 263 m³/Tank ΣV = V × Number of Tanks = 263 × 8 = 2,104 m³	

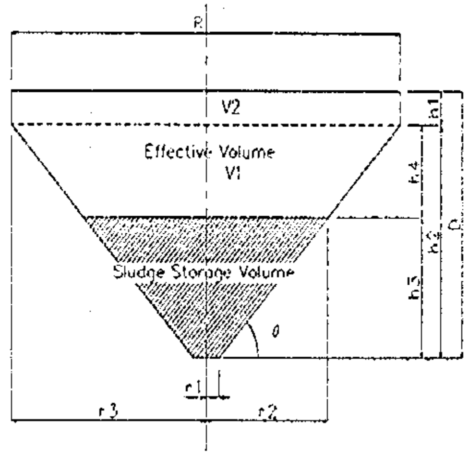


Table M-6 (13/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)
b) Facilities for Hermosa Collecter

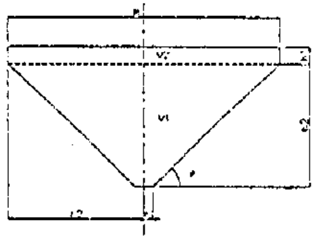
Item	Ultimate	First Stage
4.Sludge Digester Tank (Open Tank)		
a)Required Capacity		
Design Flowrate	13,300 m³/d (Daily Average)	
Retention Time	47 days (Unheated Anaerobic Digestion)	
Influent Solid Quantity	= Raw Sludge = 13,300 × 280 × 0.8 × 10^-6 = 3.0 t/d	
Influent Sludge Volume	$= \frac{3.0}{0.06} = 50.0$ m³/d (Raw Sludge Concentration 6%)	
Required Volume	= 50.0 × 47 = 2,350 m³	
b)Dimensions	 Diameter R = 14.00 m Depth D = 8.00 m Angle θ = 45° Number 4 Tanks (h1 = 1.50 m, h2 = 6.50 m) $V1 = \frac{\pi \times h2}{3} (r1^2 + r1 \times r2 + r1^2) = 359$ m³/Tank (h2 = 6.50 m , r1 = 0.50 m , r2 = 7.00 m) $V2 = \frac{\pi \times h1}{4} \times R^2 = 231$ m³/Tank (h1 = 1.50 m , R = 14.00 m) V = V1 + V2 = 590 m³/Tank ΣV = V × Number of Tanks = 590 × 4 = 2,360 m³	
c)Check		
Retention Time	$= \frac{2,350}{50} = 47$ days	

Table M-6 (14/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)
b) Facilities for Hermosa Collecter

Item	Ultimate	First Stage
5.Sludge Drying Bed		
a)Required Capacity		
Influent Solid Quantity	=Digested Solids	
	= 3.0 × (1 − (0.65 × 0.5)) = 2.0 t/d	
	Volatile Solid Concentration of Raw Sludge : 65 % Volatile Solid Removal Rate : 50 %	
Dried Sludge Quantity	$= \frac{2.0}{0.4} = 5.0$ t/d	
	(Moisture Content of Dried Sludge: 60 %)	
Solids Loading	160 kg•SS/m²•yr.	
Required Area	$= \frac{2.0 \times 365}{0.16} = 4,563$ m²	
b)Dimensions	Width 30.00 m Length 80.00 m Number 2 Tanks	
c)Check		
Area	= 30.00 × 80.00 × 2 = 4,800 m²	
Solids Loading	$= \frac{2.0}{4,800} \times 365 \times 10^3 = 152.1$ kg•SS/m²•yr	

Table M-6 (15/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)
b) Facilities for Hermosa Collecter

Item	Ultimate	First Stage
6. Waste Stabilization Pond (for Supernatant Liquor)		
1) Anaerobic Ponds		
a) Required Capacity Design Flowrate	= Supernatant Liquor from Digester Tank and Sludge Drying Bed = Influent Sludge Volume from Digester Tank + Digested Sludge Volume - Dried Sludge Volume (Digested Sludge Volume = Influent Sludge Volume for Sludge Drying Bed) $= 50 + \frac{2.0}{0.06} - 5 = 78 m^3/d$	
Volumetric Loading Rate(BOD)	$= 20T - 100 = 20 \times 17 - 100 = 240\ g/m^3/d$	
Water Quality (BOD)	= 500 mg/L	
Required Pond Volume	$= \frac{500 \times 78}{240} = 163\ m^3$	
b) Dimensions	Cross-sectional Shape: Trapezoid Bottom Area: 1m × 1m (1 m²) Surface Depth: 19m × 19m (361 m²) Water Depth: D = 3.0 m Side Slope: 1:3 Number: 1 Ponds Effective Volume: 381 m³/Pond	
c) Check		
Retention Time	$= \frac{381}{78} = 4.9$ days	
Volumetric Loading Rate(BOD)	$= \frac{500 \times 78}{381} = 102\ g/m^3/d$	
d) Effluent Quality(BOD) Removal Rate	$= 2T + 20 = 2 \times 17 + 20 = 54\ \%$	
Effluent Quality	$= (1 - 0.54) \times 500 = 230$ mg/L	

Table M-6 (16/16) Design Calculation for First Stage Project (Alternative 2 : South3 WWTP)

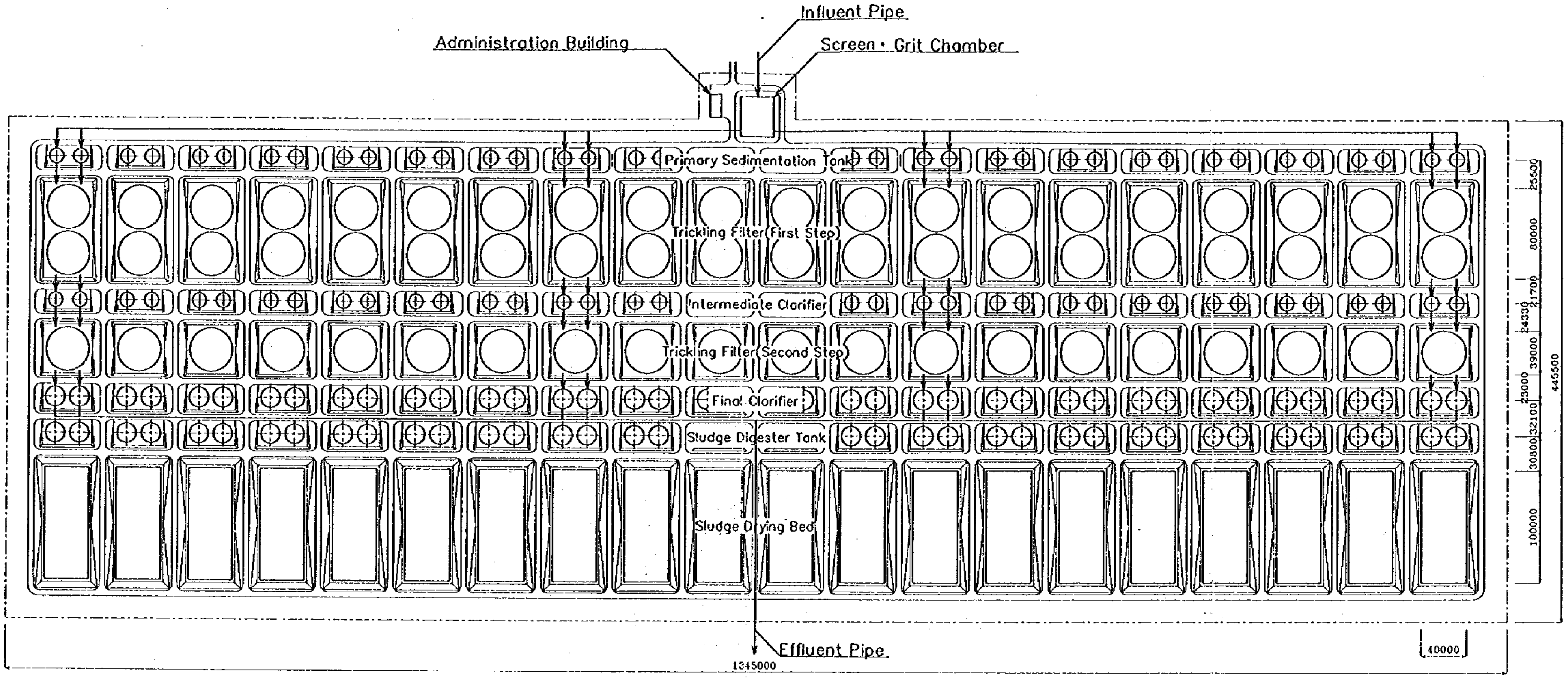
b) Facilities for Hermosa Collecter

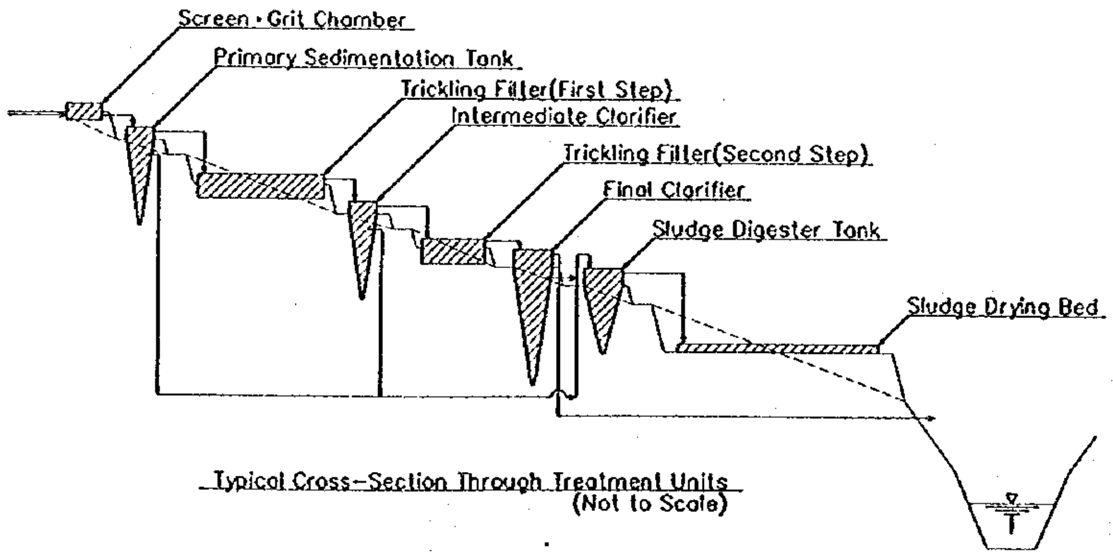
Item	Ultimate	First Stage
2)Facultative Ponds a)Required Capacity Design Flowrate	= 78 m³/d	
Surface Loading Rate(BOD)	= 350 × (1.107 − 0.002T) ^ T-25 = 350 × (1.107 − 0.002 × 17) ^ T-25 = 199 kg/ha/day	
Influent BOD Load	= 78 × 230 × 10^-3 = 18 kg/day	
Required Surface Area	$= \frac{18}{199} = 0.09$ ha = 900 m²	
b)Dimensions	Cross-sectional Shape: Trapezoid Bottom Area: 20m × 40m (800 m²) Surface Depth: 32m × 52m (1,664 m²) Mid depth Area: 26m × 46m (1,196 m²) Water Depth: D = 2.0 m Side Slope: 1:3 Number: 1 Ponds Effective Volume: 2,416 m³/Pond	
c)Check Retention Time	$= \frac{2,416}{78} = 31.0$ days	
Surface Loading Rate (at Mid depth)	$= \frac{18}{0.26 \times 0.46} = 151$ kg/ha/day	
d)Effluent Quality (BOD)	$= \frac{230}{1 + 0.26 \times 31.0} = 25.4$ mg/L WHERE KT = 0.3 × (1.05)^T-20 = 0.3 × (1.05)^17-20 = 0.26	

LAYOUT PLAN FOR MASTER PLAN

Fig. M - 1

Layout Plan for Master Plan
(Central WWTP)





Typical Cross-Section Through Treatment Units
(Not to Scale)

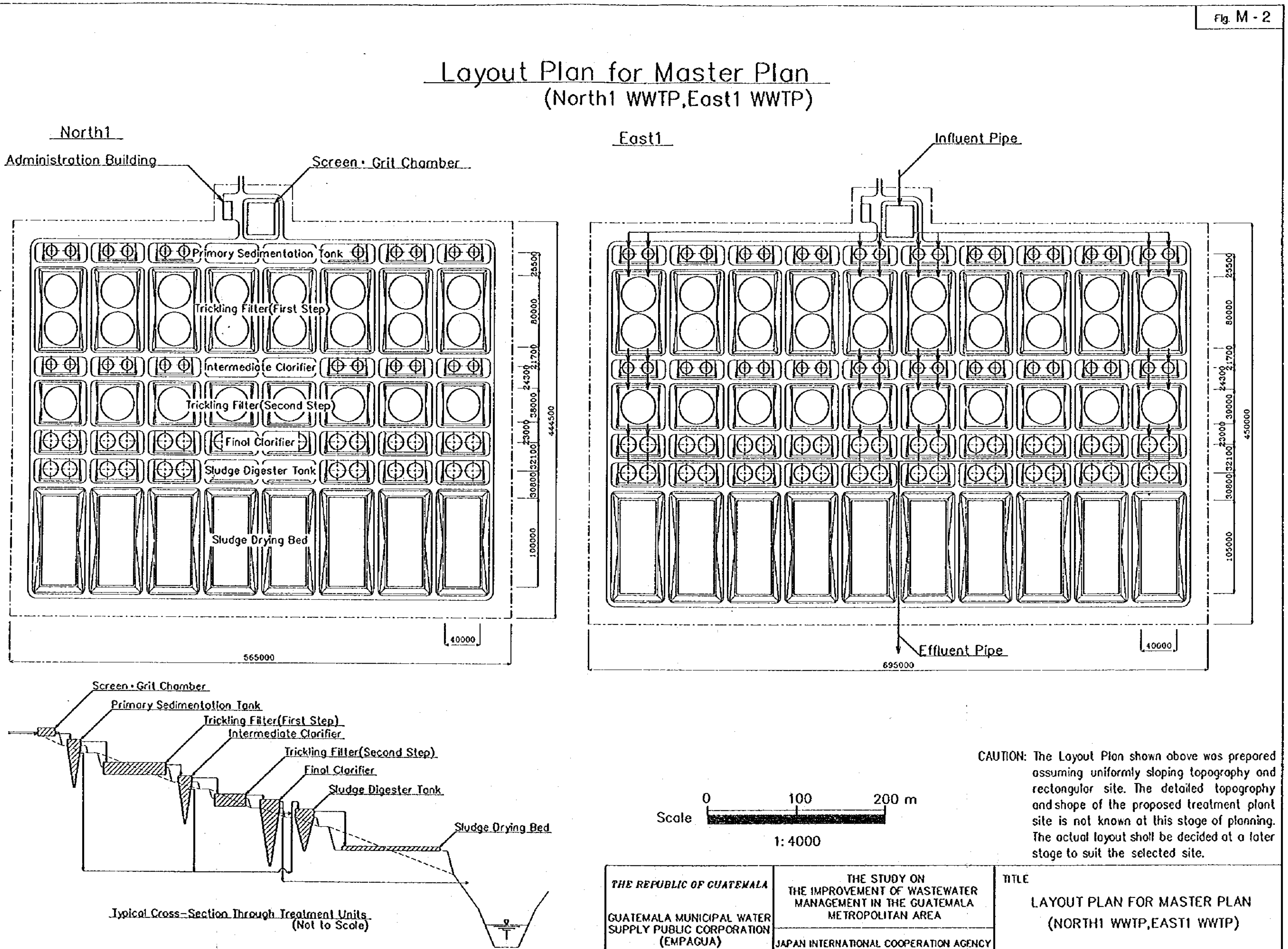
Scale 0 100 200 m

1: 4000

CAUTION: The Layout Plan shown above was prepared assuming uniformly sloping topography and rectangular site. The detailed topography and shape of the proposed treatment plant site is not known at this stage of planning. The actual layout shall be decided at a later stage to suit the selected site.

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LAYOUT PLAN FOR MASTER PLAN (CENTRAL WWTP)

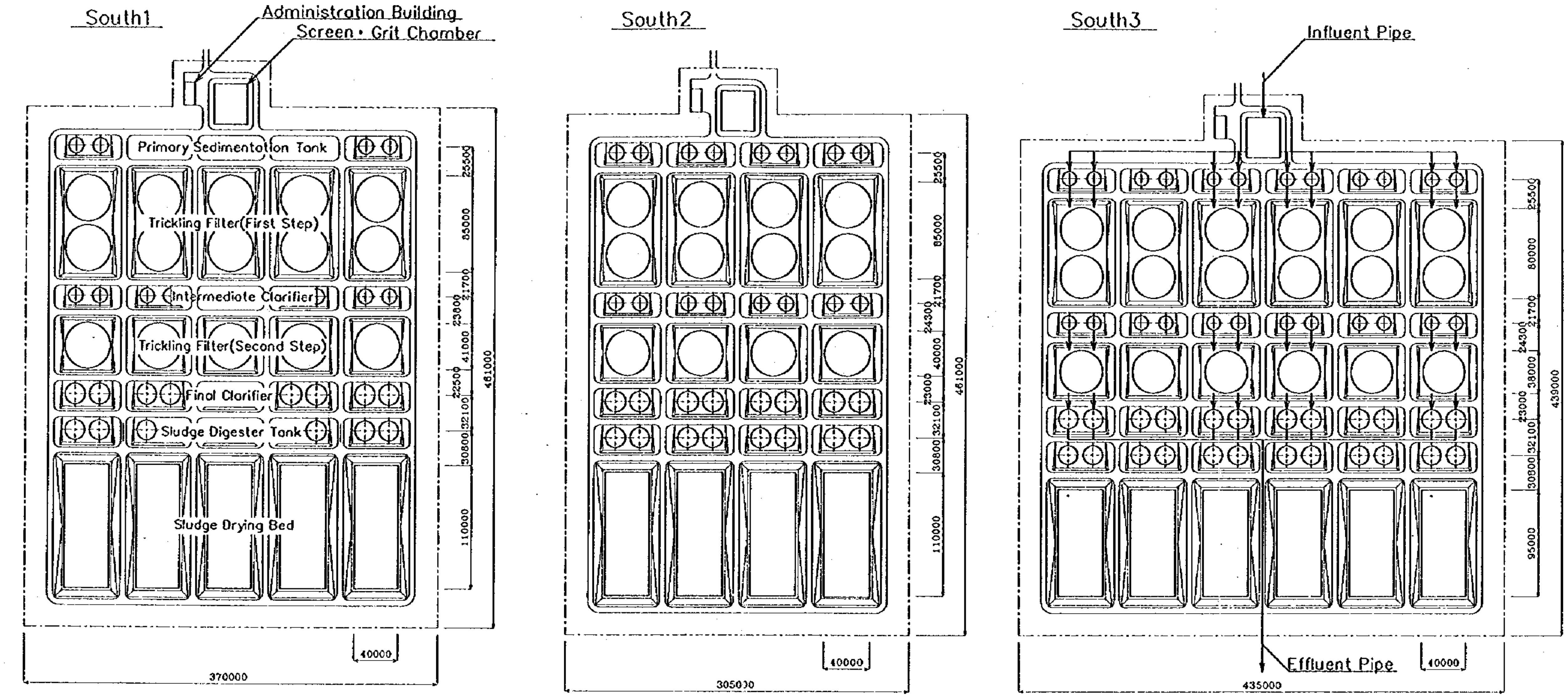
Layout Plan for Master Plan
(North1 WWTP,East1 WWTP)

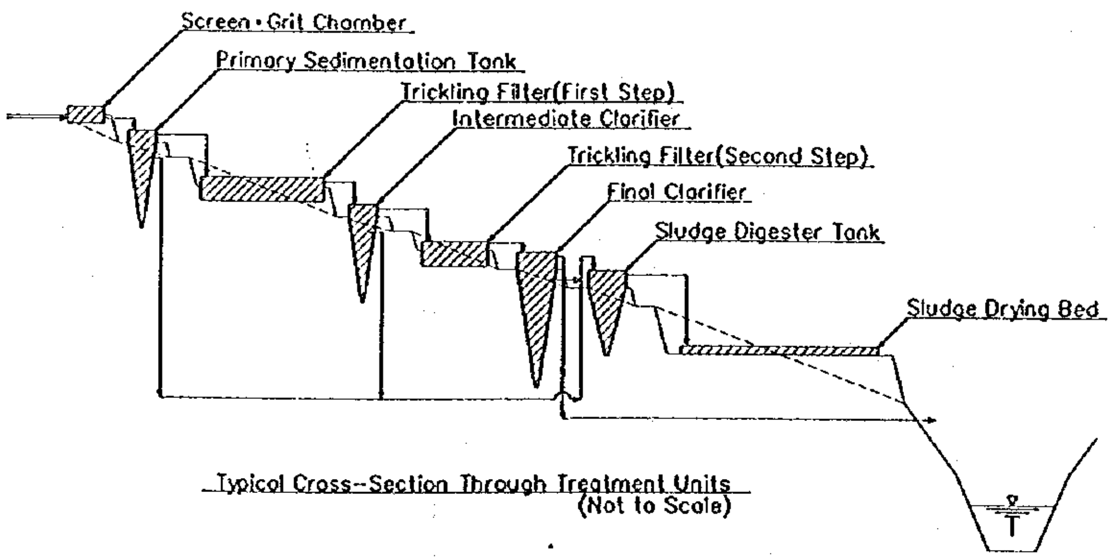


CAUTION: The Layout Plan shown above was prepared assuming uniformly sloping topography and rectangular site. The detailed topography and shape of the proposed treatment plant site is not known at this stage of planning. The actual layout shall be decided at a later stage to suit the selected site.

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LAYOUT PLAN FOR MASTER PLAN (NORTH1 WWTP,EAST1 WWTP)

Layout Plan for Master Plan
(South1 WWTP,South2 WWTP,South3 WWTP)





Typical Cross-Section Through Treatment Units (Not to Scale)

Scale 0 100 200 m

1: 4000

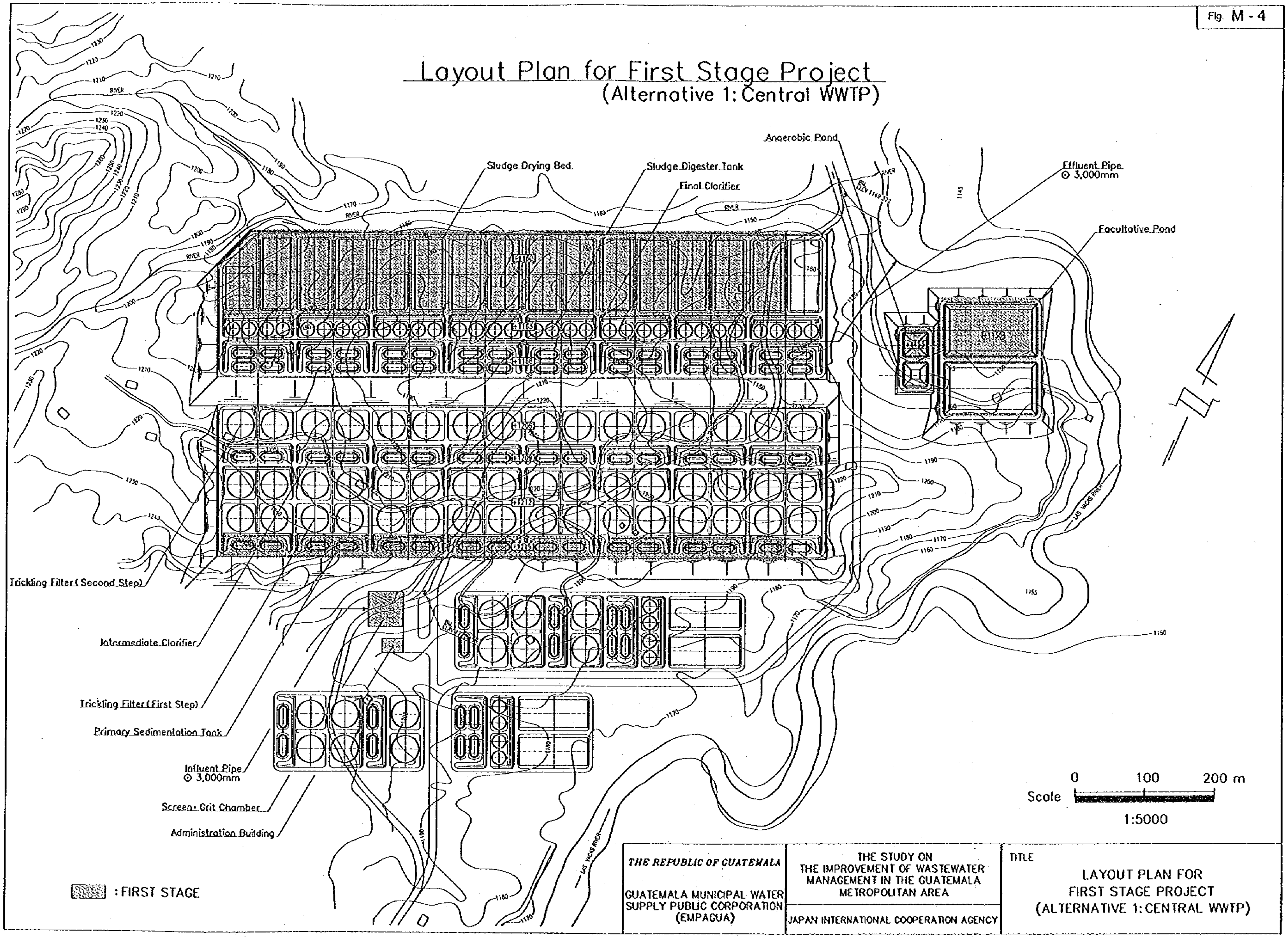
CAUTION: The Layout Plan shown above was prepared assuming uniformly sloping topography and rectangular site. The detailed topography and shape of the proposed treatment plant site is not known at this stage of planning. The actual layout shall be decided at a later stage to suit the selected site.

THE REPUBLIC OF GUATEMALA	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA	TITLE
GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	JAPAN INTERNATIONAL COOPERATION AGENCY	LAYOUT PLAN FOR MASTER PLAN (SOUTH1 WWTP,SOUTH2 WWTP, SOUTH3 WWTP)

LAYOUT PLAN FOR FIRST STAGE

Fig. M - 4

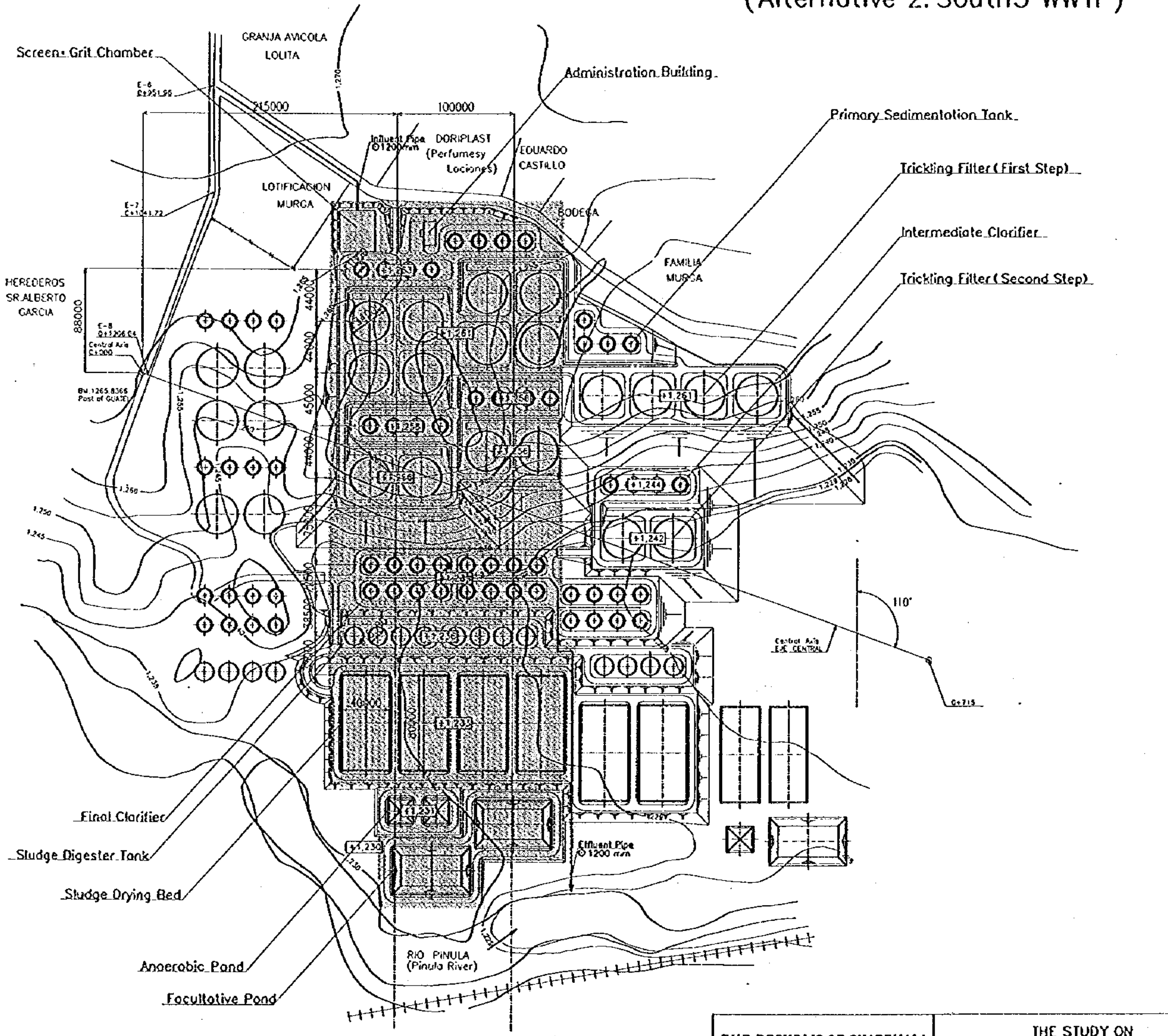
Layout Plan for First Stage Project
(Alternative 1: Central WWTP)

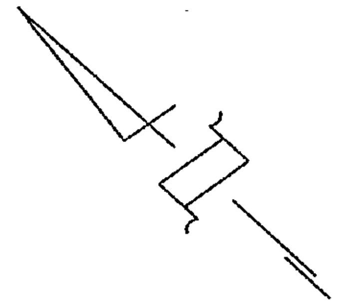


THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LAYOUT PLAN FOR FIRST STAGE PROJECT (ALTERNATIVE 1: CENTRAL WWTP)

Fig. M-5

Layout Plan of Wastewater Treatment Plant
(Alternative 2: South3 WWTP)





EST.	P.O.	RUMBO	DIST.
6	7	S 47° 17' 00" W	89.76
7	8	S 68° 35' 20" W	164.32
8	BM	S 89° 54' 00" W	13.90

EST.	P.O.	RUMBO	DIST.
E-8	Central Axis 0+000	N 21° 42' 00" W	5.94
Central Axis 0+000	Central Axis 0+715	S 21° 42' 00" E	715.00

Scale 0 100 200 m

1:4000

[shaded box] : FIRST STAGE

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LAYOUT PLAN FOR FIRST STAGE PROJECT (ALTERNATIVE 2: SOUTH3 WWTP)

SUPPORTING REPORT N

SANITATION SYSTEM

SUPPORTING REPORT N
SANITATION SYSTEM

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N SANITATION SYSTEM

N1 General

To improve environmental conditions in high risk and medium risk settlements as identified in UNICEF survey "Caracterization de Las Areas Precarias En La Ciudad De Guatemala (1991), wastewater generated should be collected and treated before discharging to river bodies. Most of these settlements lack drainage facilities and are located close to the ravine and have poor accessibility. Hence these settlements are difficult to connect to the proposed sewerage system and are considered to be covered by Sanitation System. Sanitation system consists of (1) a collection system to convey the wastewater from the community and (2) treatment and effluent disposal system.

Sanitation system of Central Region and South 3 Region are identified among the priority projects in Chapter 11. Further financial Evaluation showed that it is recommendable to cover sanitation system in second stage, however this chapter intends to give an idea of sanitation system of South 3 Region and Central Region (first stage).

N2 Settlements to be Covered by Sanitation System

Settlements which are proposed to be implemented in first stage of Central region project and second stage of south 3 region project are mentioned below in Table N - 1 and their location is shown in Fig. N - 1 (a-g) and Fig. N - 2 (a-b) respectively.

Population of these settlements have been adapted from UNICEF survey and future population in 2015 is assumed to be same as that of present population. Further it is important to comment that most of these settlements are slum or high risk areas and the above assumption holds good but some settlements have possibility of population expansion. Loma Blanca which is located in the suburbs of South 3 Region has lot of unutilized land in the settlement which will be occupied by houses in future. Hence sanitation system is designed for the population forcasted in the year 2015.

Also possibility of illegal invasion in slums can not be ruled out. For example it was reported in the Newspaper "Prensa Libre" dated 29 February 1996 that about 150 families invaded the settlement Incienso.

Table N - 1 Settlements to be Provided with Sanitation System

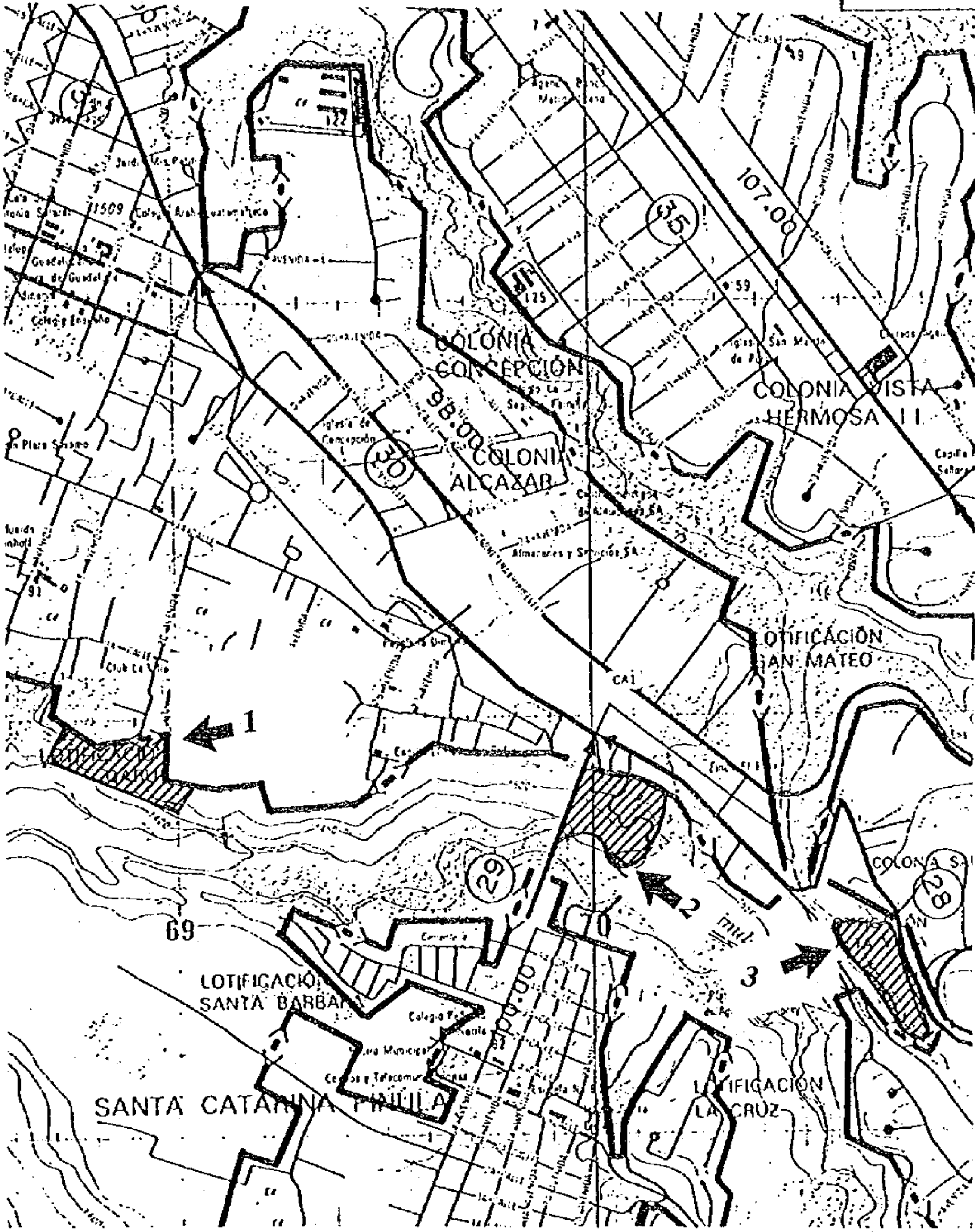
S. No.	Name of settlement	Zone	Population[a]	Estimated Area (ha)[b]
	CENTRAL REGION			
1	Final	14	500	16
2	El Pilar	14	1,500	48
3	El Cambary	14	300	7
4	Campo Seco	16	1,200	6
5	Finca El Carmen	6	1,000	6
6	Modrno San Antonio	6	1,000	6
7	Jocotales	6	2,600	17
8	Quintanal	6	3,700	24
9	Santa Faz	6	600	4
10	El Tuerto	1	500	4
11	Colinas I y II	1	900	7
12	Bethania Sec I	1	1,400	11
13	Bethania Sec III	7	1,600	11
14	Bethania Sec IV	7	400	3
15	Seis de Octubre	7	1,500	10
16	Joya I	7	2,500	16
17	Joya II	7	2,500	16
18	Joya III	7	2,500	16
19	La Joya IV	7	1,500	10
20	Colon. Argueta	2	2,000	26
21	Incienso	3	4,200	19
	Total		33,900	283
	SOUTH 3 REGION			
1	Loma Blanca I	12	900[c]	9
2	Loma Blanca II	12	1000[c]	9
3	Plaza de Toros	13	1,000	24
	Total		2900	42

[a] Adapted from UNICEF Survey "Caracterizacion De Las Areas Precarias En La Ciudad De Guatemala", (1991) and population in the year 2015 is assumed to be same as that of present.

[b] Estimated Area = (Population / Population Density of the respective Zone)

[c] Population expansion is taken into account and is mentioned for the year 2015.

Fig. N - 1 (a)



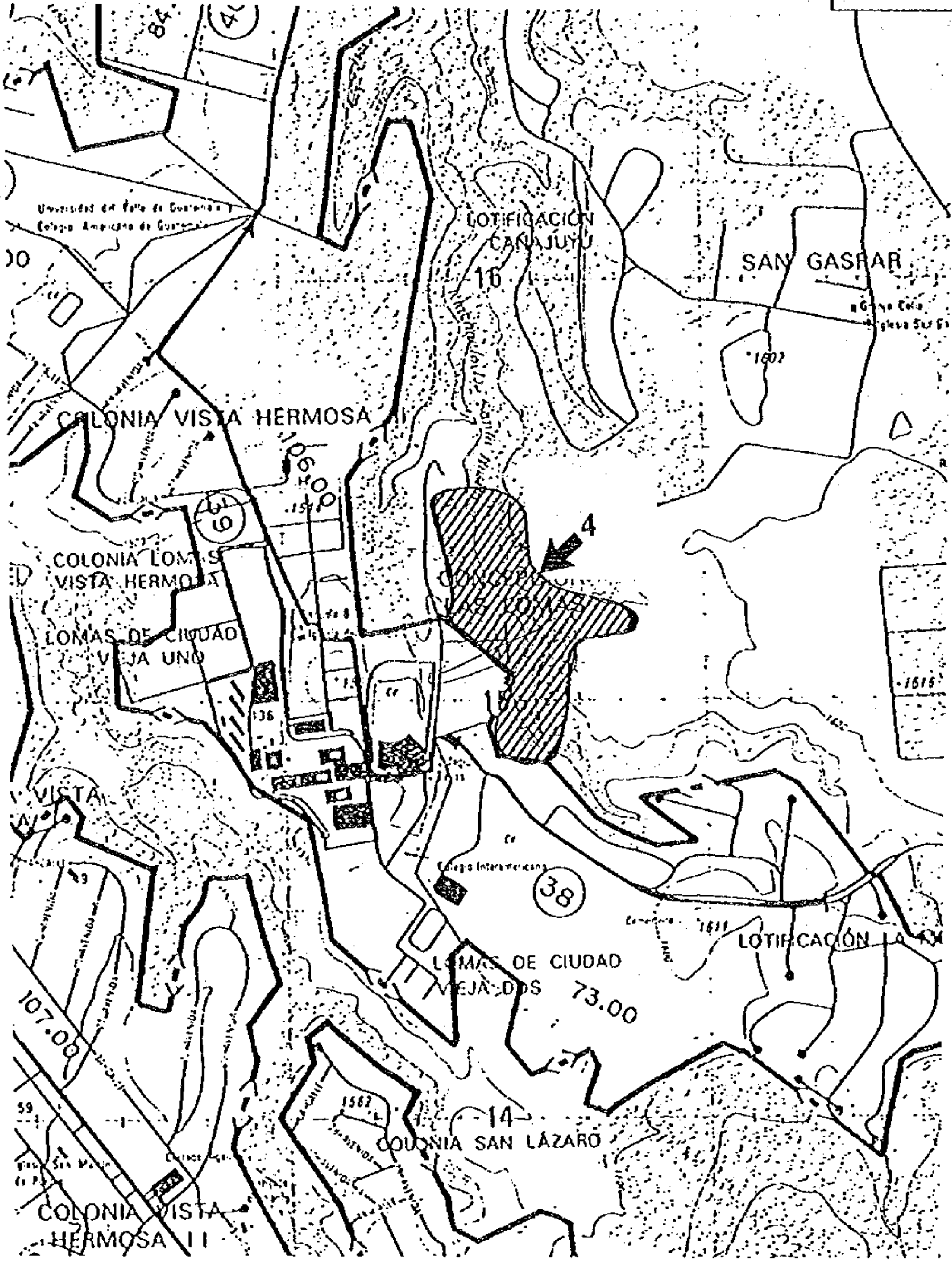
Scale 1 : 15,000

Legend

Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN CENTRAL REGION

Fig. N - 1 (b)



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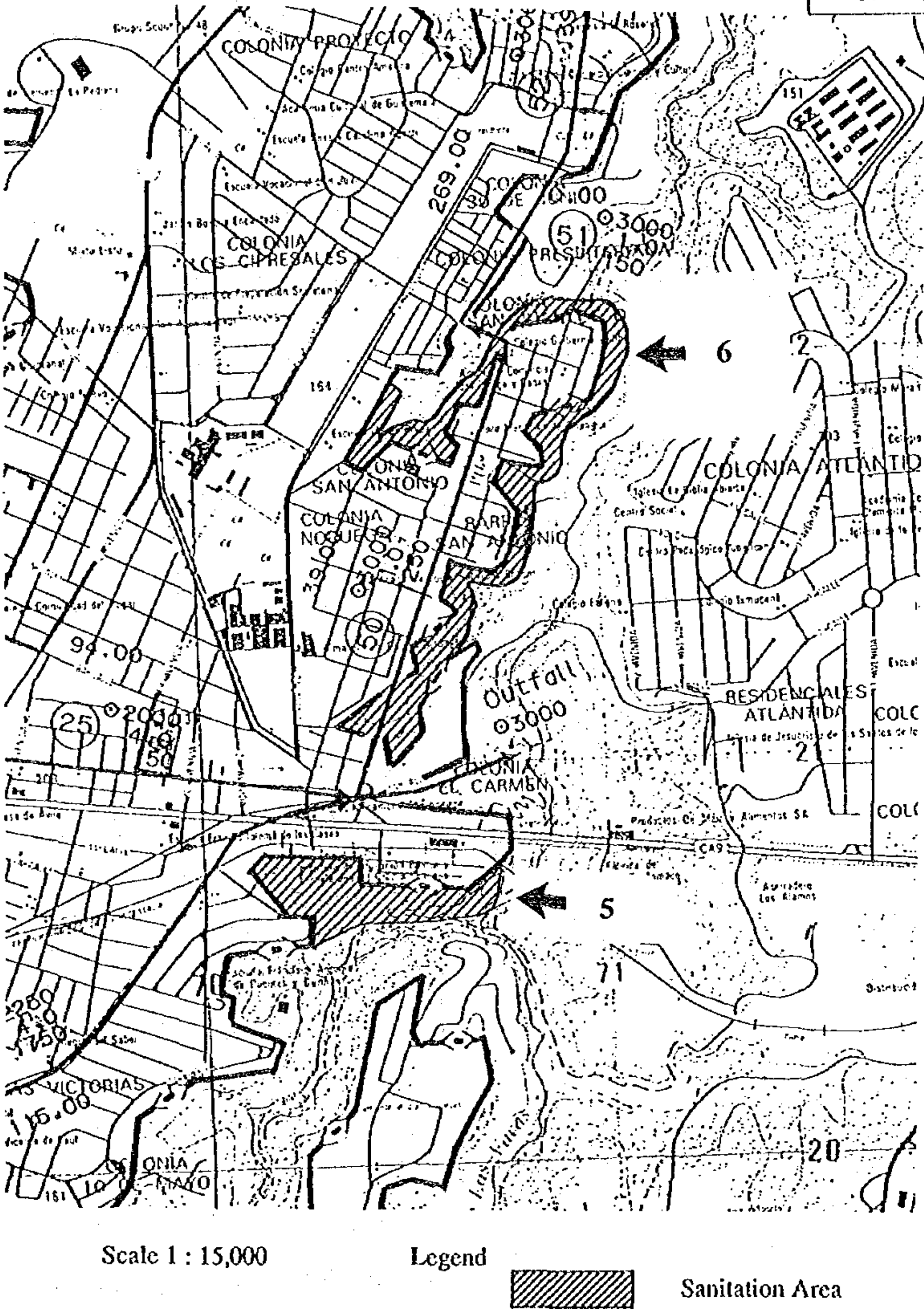
Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN CENTRAL REGION

Fig. N - 1 (c)



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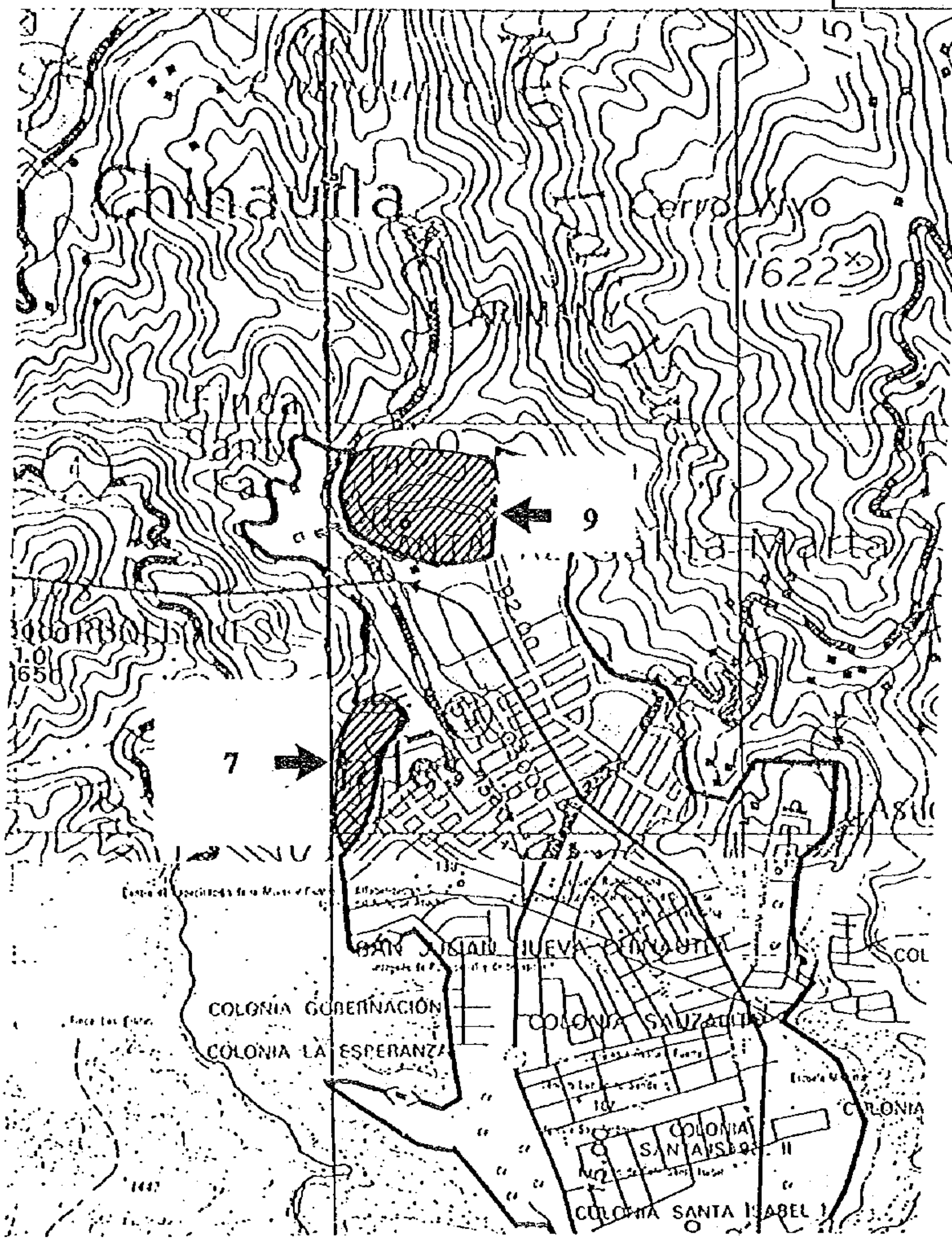
Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN CENTRAL REGION

Fig. N - 1 (d)



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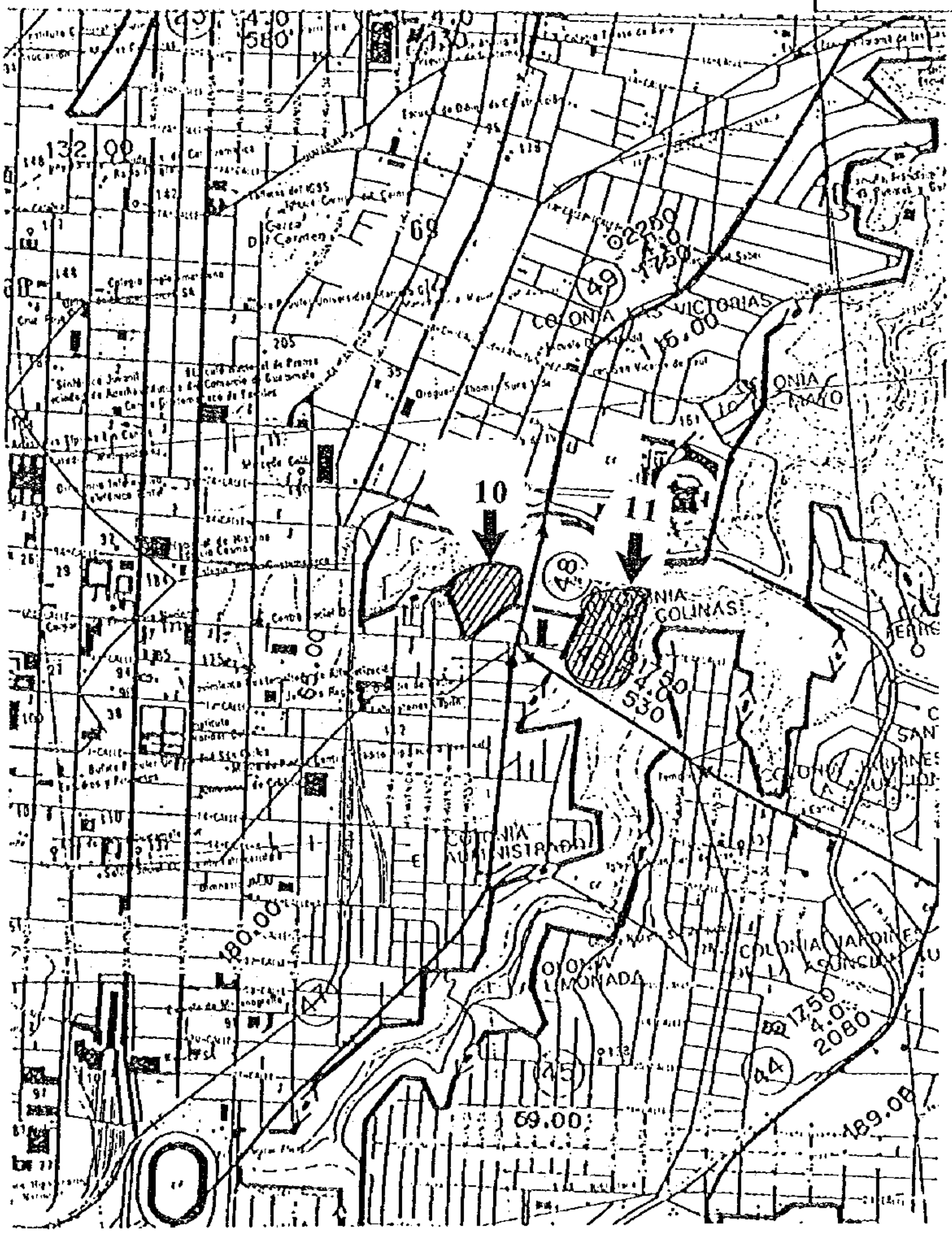
Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN CENTRAL REGION

Fig. N - 1 (c)



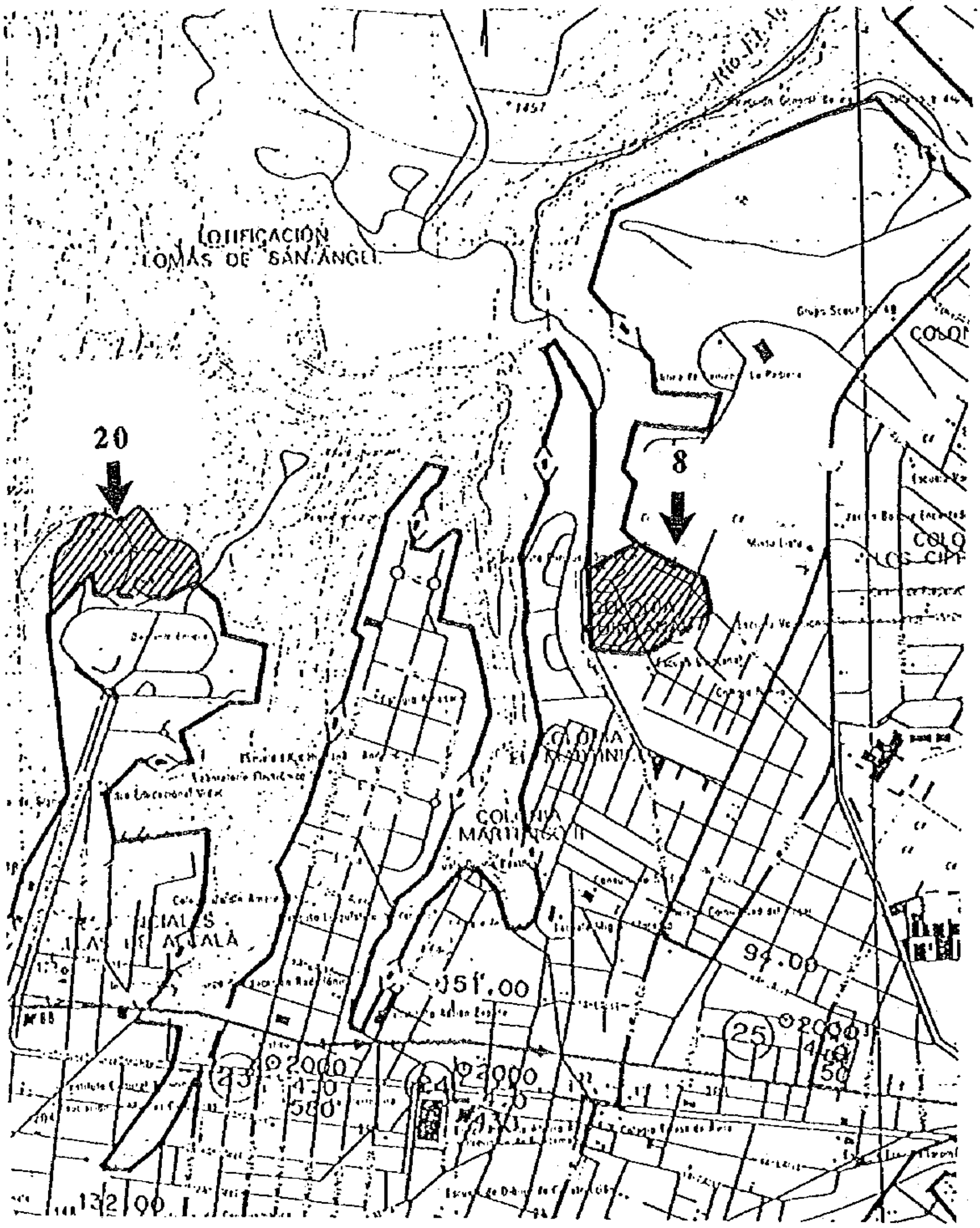
Scale 1 : 15,000

Legend

Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN CENTRAL REGION

Fig. N - 1 (f)



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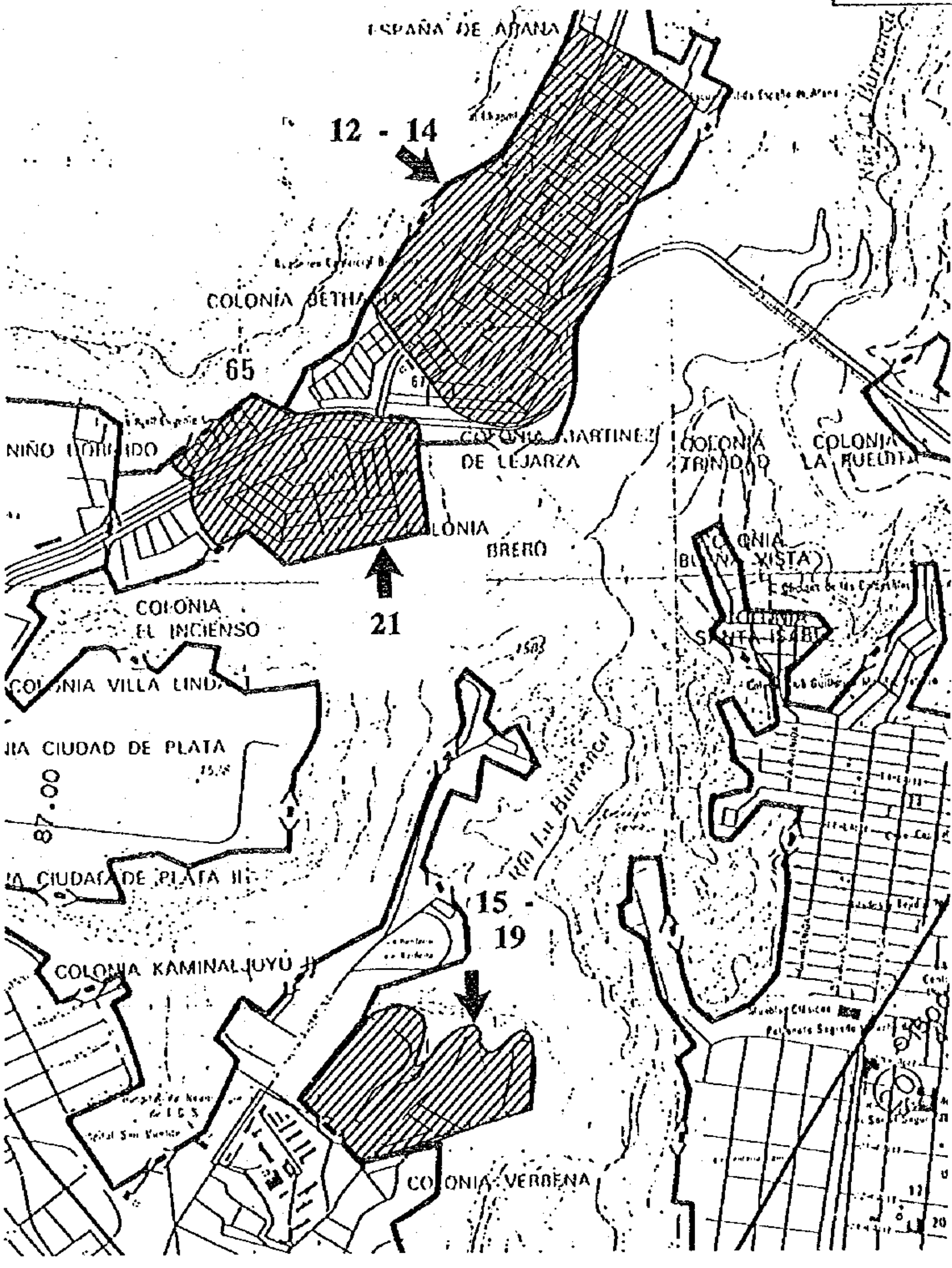
Legend

Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN CENTRAL REGION

Fig. N - 1 (g)



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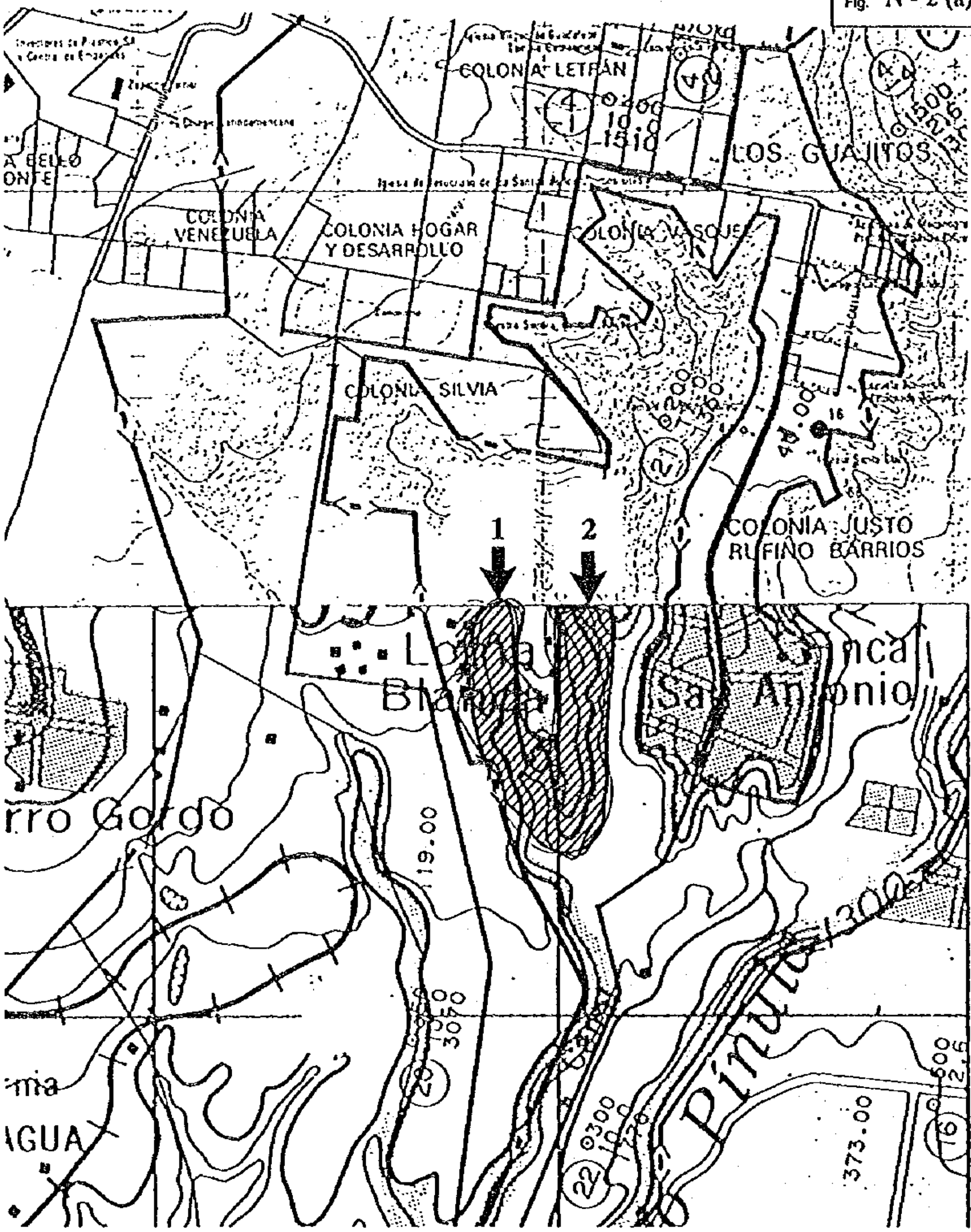
Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN CENTRAL REGION

Fig. N - 2 (a)



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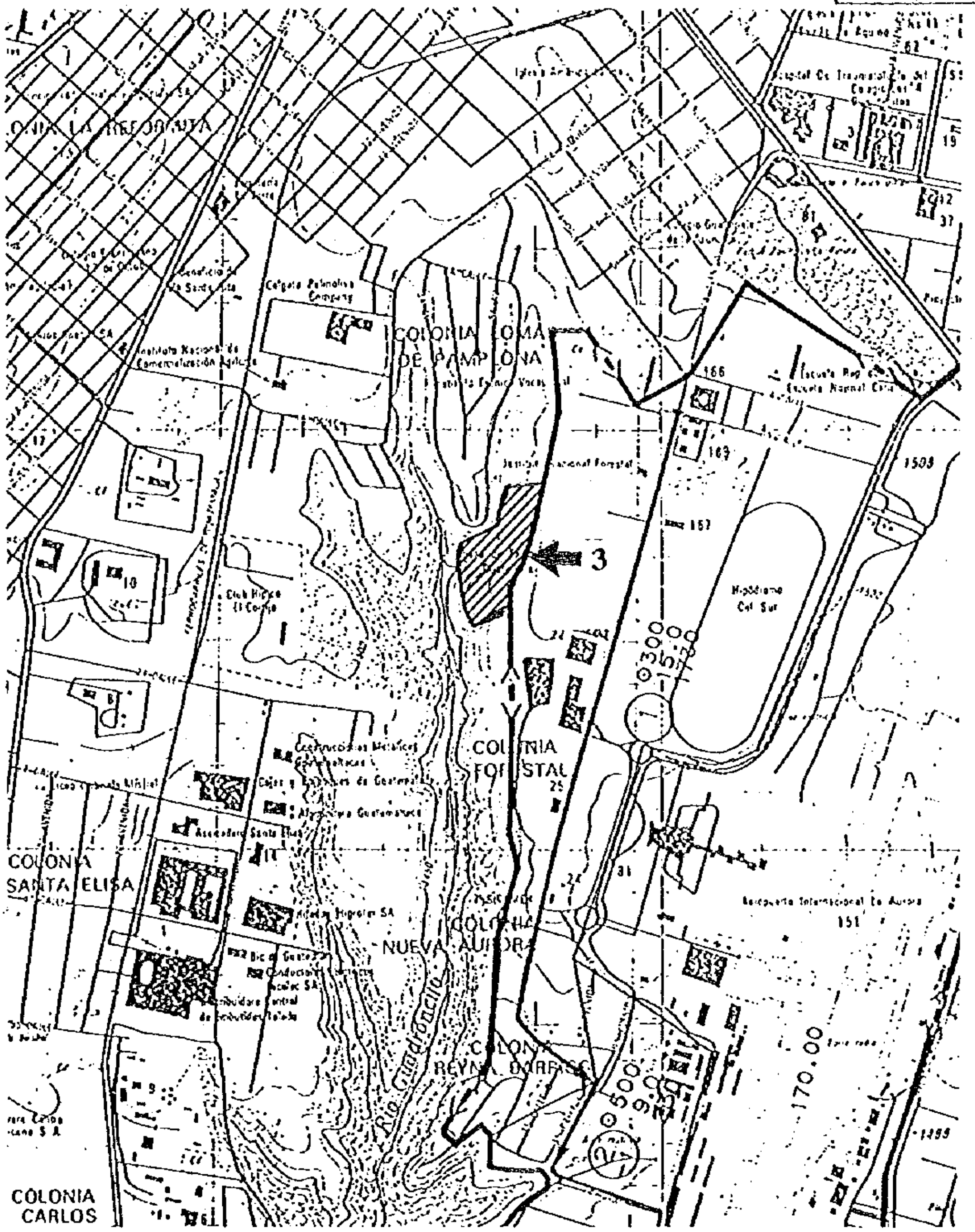
Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN SOUTH 3 REGION

Fig. N - 2 (b)



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Sanitation Area

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE LOCATION OF SANITATION AREA IN SOUTH 3 REGION

N3 Sanitation Collection System

A Conventional Gravity sewerage system is proposed for collecting and transporting the wastewater to the community sanitation treatment facility. The design criteria are briefly summarized below.

- Minimum cover between the top of the sewer and road surface should be one meter.
- Minimum diameter of sewer considered (excluding house connection) is 200mm.
- Minimum flow velocity allowed in the sewer is 0.6 m/sec.
- Maximum flow velocity allowed in the sewer is 3.0 m/sec.
- Manning equation is used to determine the sewer capacity.
- Manhole should be provided at each change in direction, change in grade and change in sewer diameter, and should not exceed the maximum spacing shown below:

Sewer diameter (mm)	Maximum Manhole Spacing (m)
300 or less	50
600 or less	80

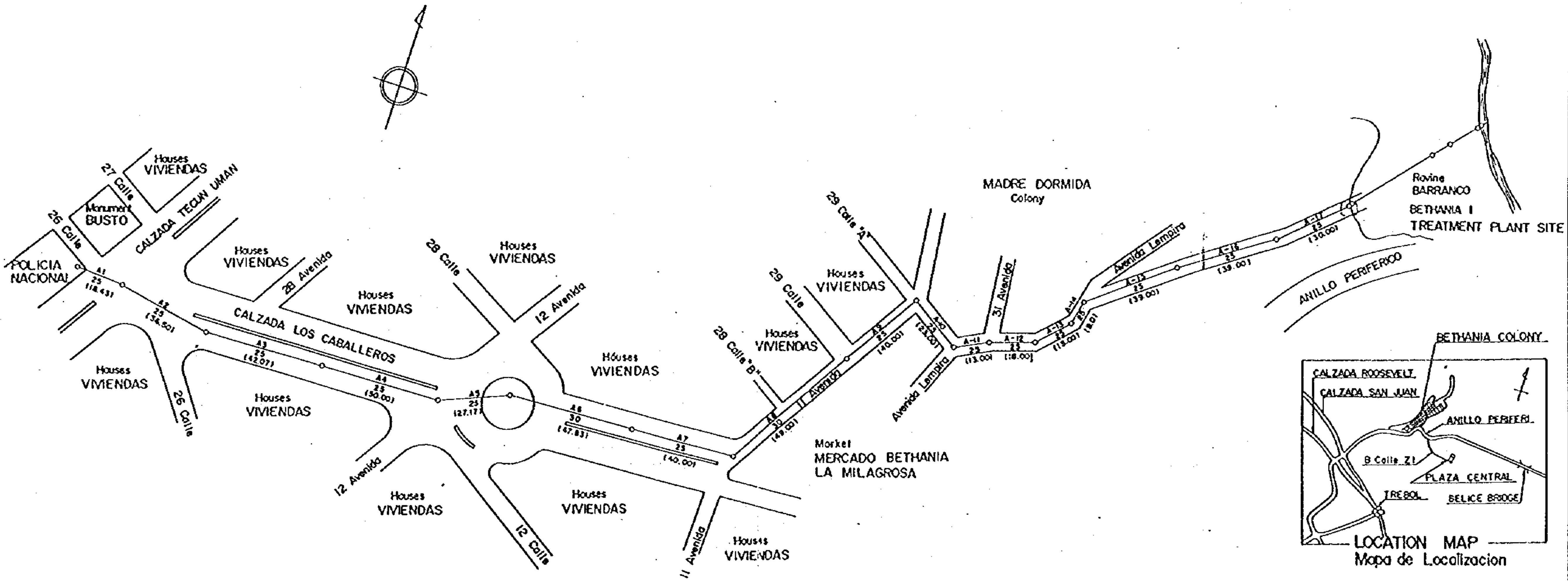
Table N - 2 describes length of sewer required in each settlement for Central and South 3 Region. Most of the settlements require sewer even less than 200 mm, however in this report minimum diameter considered is 200 mm. Sewer network plan and profile of main sewer for the typical settlements are shown from Fig. N - 3 to Fig. N - 12.

Table N - 2 Length of Sewers Required for Each Settlement

S. No.	Name of Settlement	Zone	Dia of main Sewer (mm)	Length (Km)
	CENTRAL REGION			
1	Final	14	200	3.7
2	El Pilar	14	200	11.1
3	El Cambary	14	200	1.7
4	Campo Seco	16	200	1.4
5	Finca El Carmen	6	200	1.5
6	Modrno San Antonio	6	200	1.5
7	Jocotales	6	200~250	3.8
8	Quintanal	6	200~300	5.5
9	Santa Faz	6	200	0.9
10	El Tuerto	1	200	0.9
11	Colinas I y II	1	200	1.6
12	Bethania Sec I	1	200	2.5
13	Bethania Sec II	7	200~250	3.0
14	Seis de Octubre	7	200	2.2
15	Joya I	7	200~250	3.8
16	Joya II	7	200~250	3.8
17	Joya III	7	200~250	3.8
18	La Joya IV	7	200	2.3
19	Colon. Argueta	2	200~250	5.9
20	Incienso	3	200~400	4.3
	Total			65.2
	SOUTH 3 REGION			
1	Loma Blanca I	12	200	2.0
2	Loma Blanca II	12	200	2.0
5	Plaza de Toros	13	200	5.6
	Total			9.6

Note Bethania III and IV are considered as one community and is mentioned as Bethania II

Fig N - 3



Note : Sewer Diameter = 200 mm (unless otherwise specified)

Scale 1 : 2000

Legend

Sewer line

Slope

(Length)

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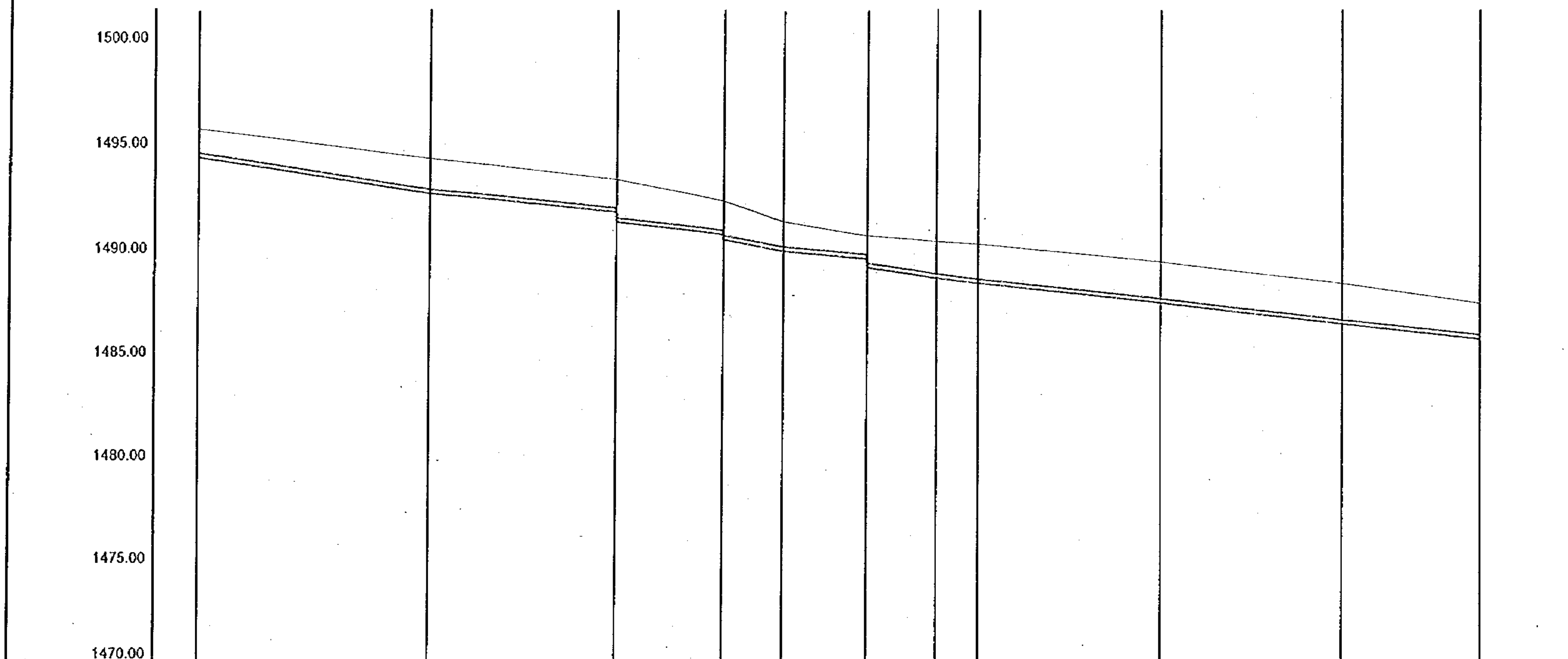
Bethania - I



Sewer Line No.	A-8	A-9	A-10	A-11	A-12	A-13	A-14	A-15	A-16	A-17
V=1/200 Dia. (mm)	200	200	200	200	200	200	200	200	200	200
H=1/1000 Slope (‰)	30	25	25	25	25	25	25	25	25	25
Length (m)	49.00	40.00	23.00	13.00	18.00	15.00	9.00	39.00	39.00	29.66

Ground Elevation (m)	Earth Cover (m)	Invert Elevation (m)	Cu. Length (m)
1495.62	1.07	1494.32	262.00
1494.36	1.28	1492.85	311.00
1493.34	1.26	1491.85 / 1491.35	351.00
1492.30	1.29	1490.78 / 1490.28	374.00
1491.38	1.19	1489.96	387.00
1490.76	1.02	1489.51 / 1489.01	405.00
1490.30	1.43	1488.64	420.00
1490.09	1.45	1488.41	429.00
1489.40	1.74	1487.43	468.00
1488.19	1.51	1486.45	507.00
1487.39	1.45	1485.71	536.66

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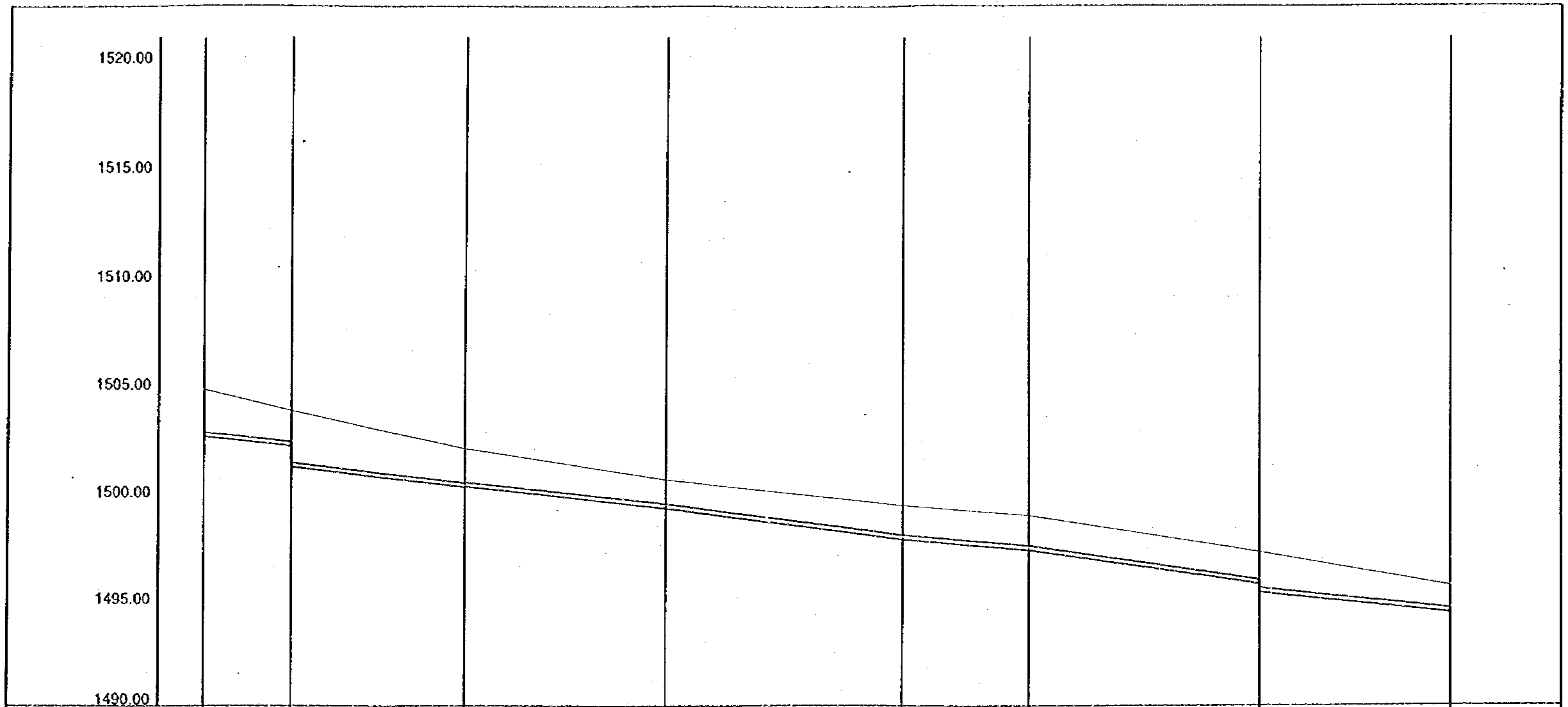
JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

PROFILE OF MAIN SEWER FOR BETHANIA I

Fig. N- 4 (b)

Bethania - I



Sewer line No.	A-1	A-2	A-3	A-4	A-5	A-6	A-7
V=1/200 Dia. (mm)	200	200	200	200	200	200	200
H=1/5000 Slope (‰)	25	25	25	25	25	30	25
Length (m)	18.43	36.50	42.07	50.00	27.17	47.83	40.00

Ground Elevation (m)	1504.84	1503.86	1502.00	1500.73	1499.22	1498.94	1497.13	1495.62
Earth Cover (m)	2.00	1.48	1.53	1.31	1.05	1.45	1.08	1.07
Invert Elevation (m)	1502.61	1502.15 1501.15	1500.24	1499.19	1497.94	1497.26	1495.82 1495.32	1494.32
Cu. Length (m)	0.00	18.43	54.93	97.00	147.00	174.17	222.00	262.00

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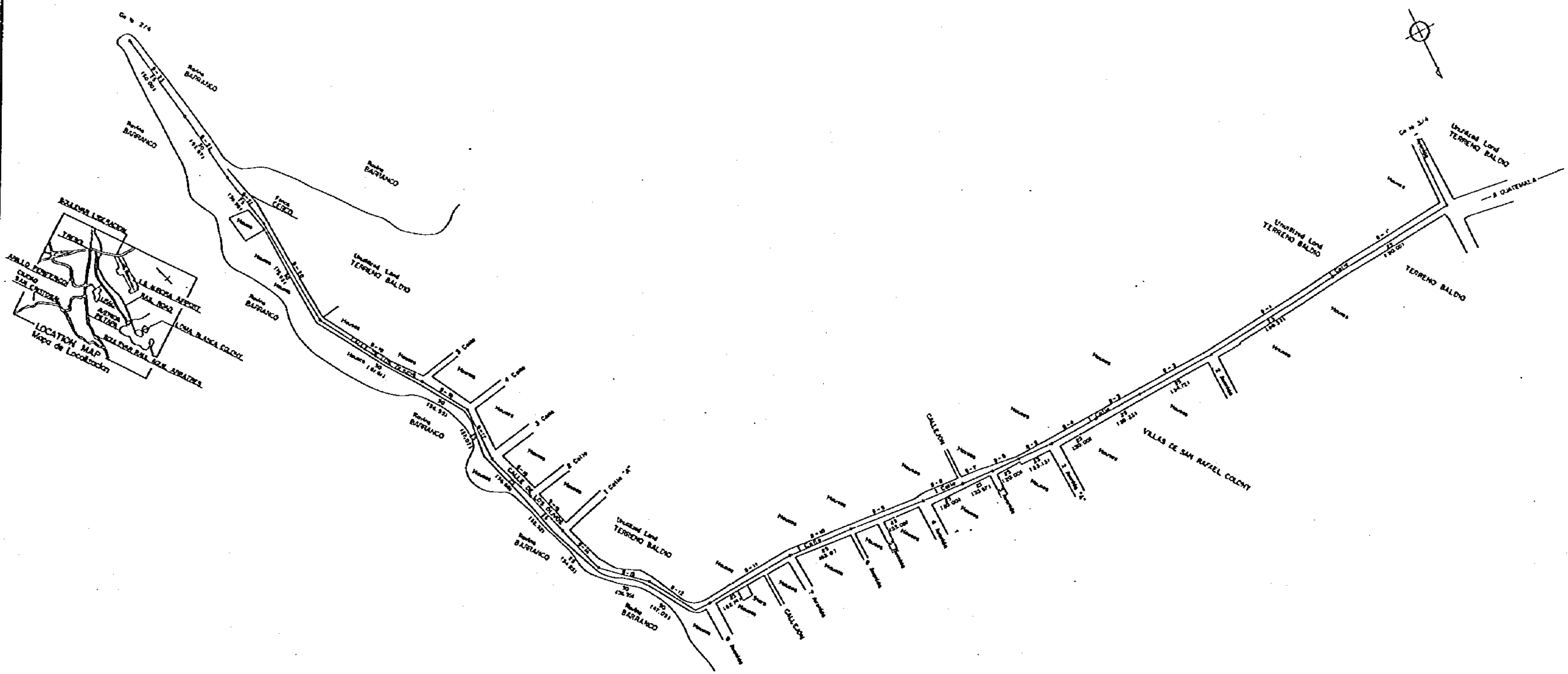
Fig. N - 5



Note : Sewer Diameter = 200 mm (unless otherwise specified)

Scale 1 : 3000

Legend

Sewer line

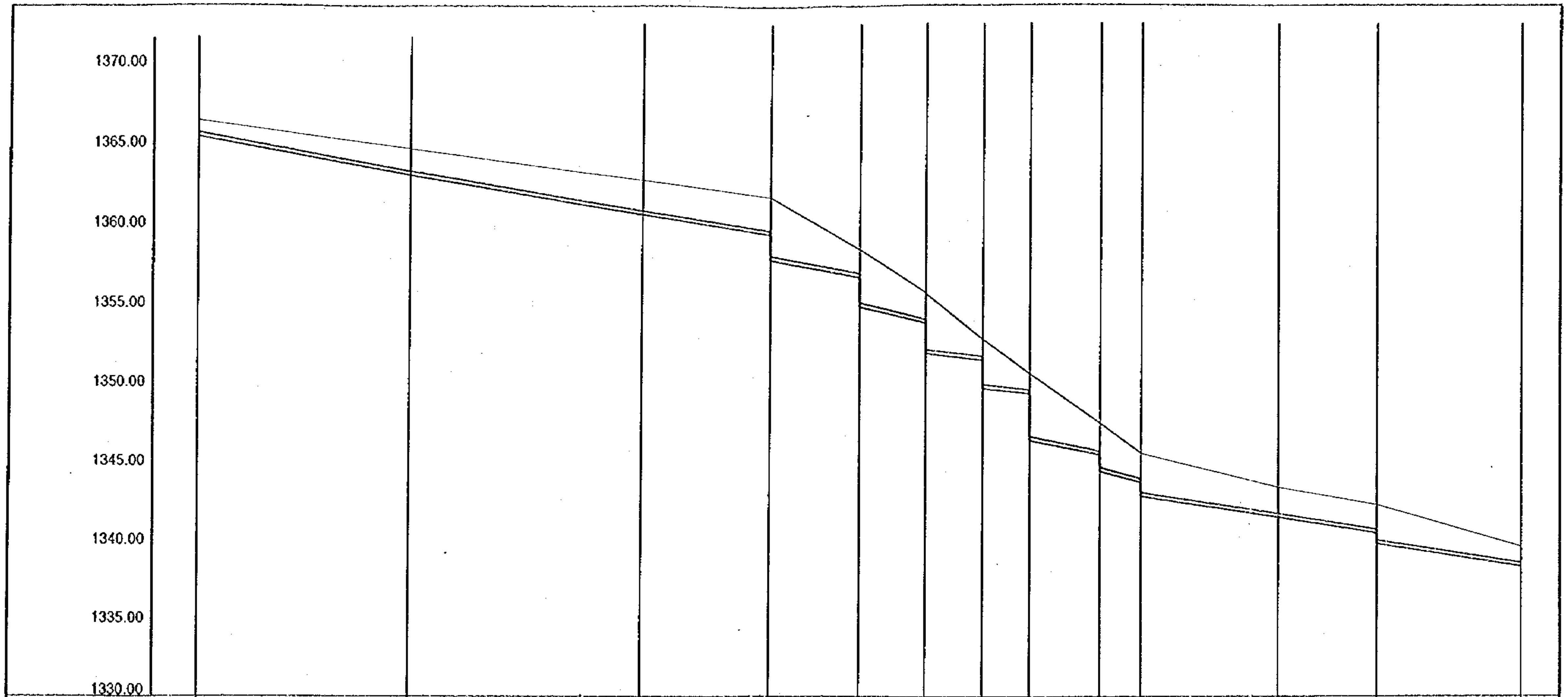
Slope

(Length)

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE MAIN SEWER NETWORK PLAN FOR LOMA BLANCA II

Fig. N - 6 (a)

Loma Blanca - II



Sewer Line No.	B-1'	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11
V=1/400 Dia. (mm)	200	200	200	200	200	200	200	200	200	200	200	200
H=1/2000 Slope (‰)	25	25	25	25	25	25	25	25	25	25	25	25
Length (m)	90.0	98.57	54.72	38.25	30.00	23.13	20.00	30.97	20.00	53.09	43.00	62.74

Ground Elevation (m)	1366.40	1364.60	1362.63	1361.56	1358.19	1355.55	1352.77	1350.37	1347.36	1345.41	1343.21	1342.14	1339.66
Earth Cover (m)	1.00	1.45	1.95	2.25	1.34	1.45	1.25	1.10	1.87	1.42	1.55	1.56	1.15
Invert Elevation (m)	1365.17	1362.92	1360.45	1359.08 1357.58	1356.62 1354.62	1353.87 1351.87	1351.29 1349.54	1349.04 1346.04	1345.26 1344.26	1343.76 1342.76	1341.43	1340.35 1339.85	1338.28
Cu. Length (m)	0.00	90.00	188.57	243.29	281.54	311.54	334.67	354.67	385.64	405.64	458.73	501.73	564.47

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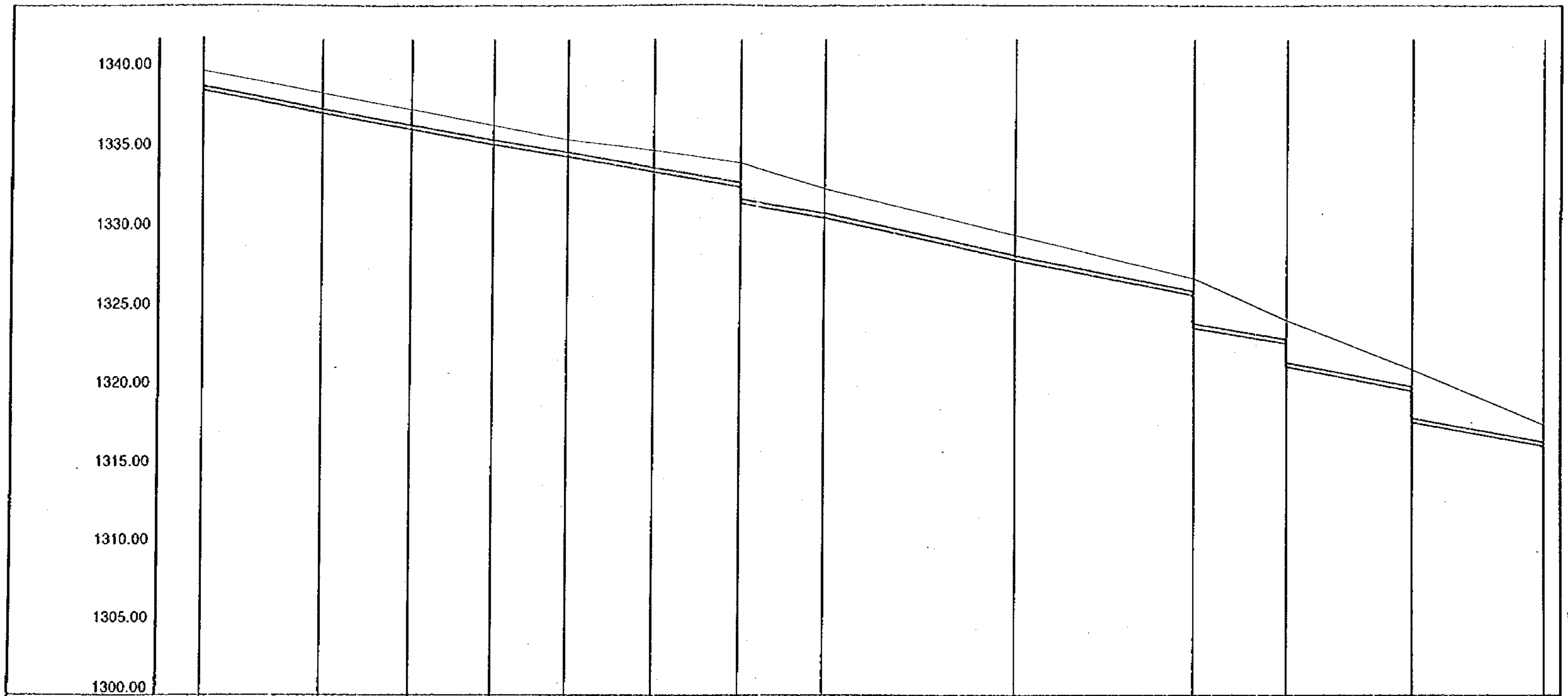
Fig. N - 6 (b)

Loma Blanca - II



Sewer Line No.	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19	B-20	B-21	B-22	B-23
V=1/400 Dia. (mm)	200	200	200	200	200	200	200	200	200	200	200	200
H=1/2000 Slope (‰)	30	30	25	25	25	25	30	30	30	25	30	25
Length (m)	47.03	36.35	34.83	32.52	36.68	37.07	36.55	81.61	75.92	39.95	53.87	60.00

Ground Elevation (m)	1339.66	1338.19	1337.11	1336.16	1335.34	1334.59	1333.84	1332.30	1329.26	1326.60	1323.92	1320.71	1317.14
Earth Cover (m)	1.15	1.09	1.10	1.02	1.00	1.18	1.36	1.92	1.33	1.00	1.27	1.18	1.11
Invert Elevation (m)	1338.28	1336.87	1335.78	1334.91	1334.10	1333.18	1332.25 1331.25	1330.15	1327.70	1325.42 1323.42	1322.42 1320.92	1319.30 1317.30	1315.80
Cu. Length (m)	564.47	611.50	647.85	682.68	715.20	751.88	788.95	825.50	907.11	983.03	1022.98	1076.85	1136.85

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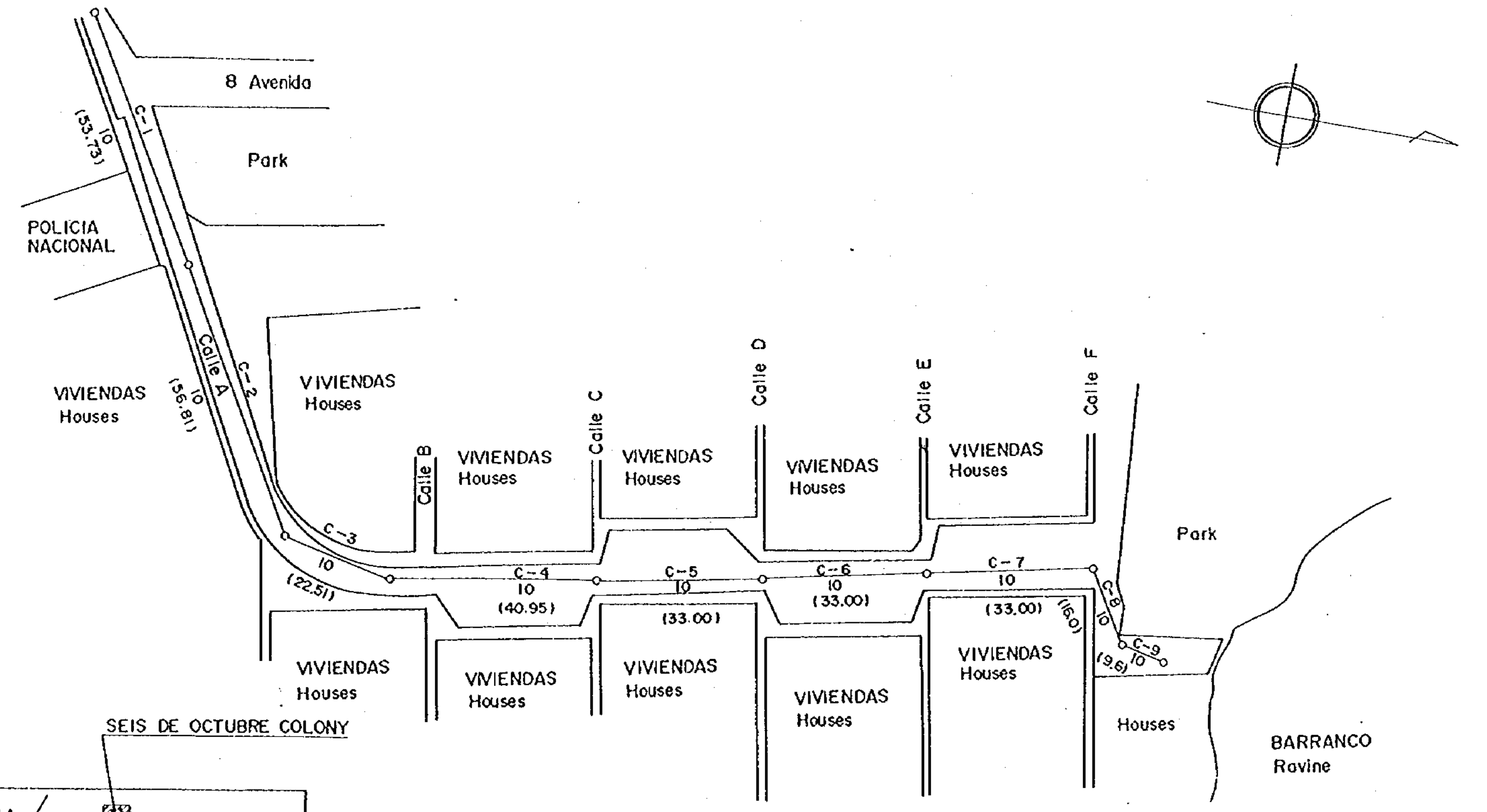
JAPAN INTERNATIONAL COOPERATION AGENCY

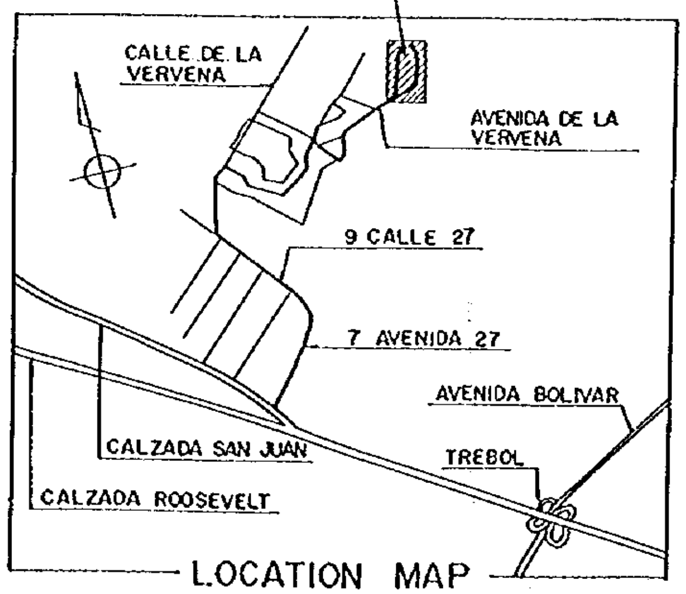
TITLE

PROFILE OF MAIN SEWER FOR LOMA BLANCA II

Fig. N - 7



SEIS DE OCTUBRE COLONY



LOCATION MAP
Mapa de Localizacion

Note : Sewer Diameter = 200 mm (unless otherwise specified)

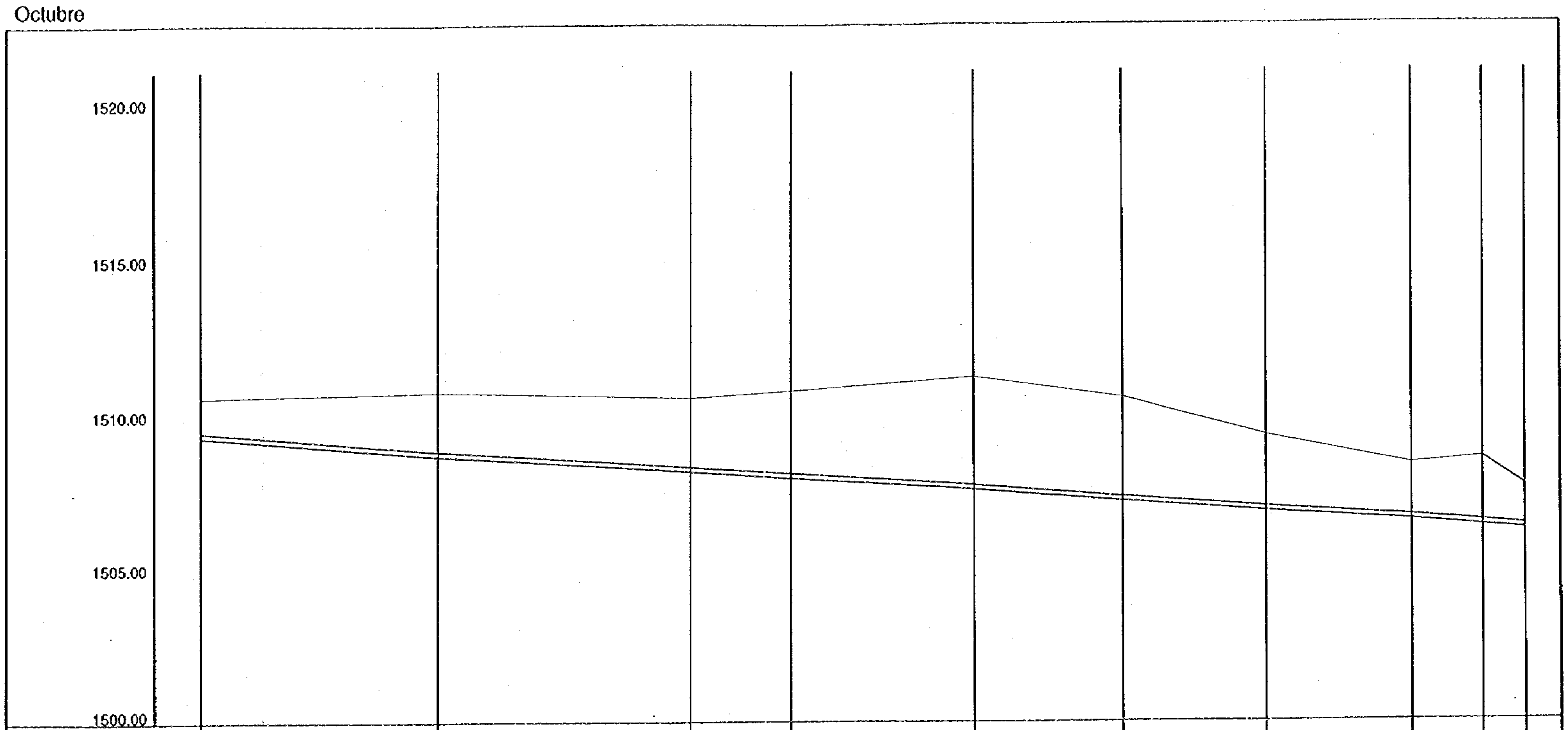
Scale 1 : 1000

Legend

Sewer line
Slope
(Length)

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE MAIN SEWER NETWORK PLAN FOR SEIS DE OCTUBURE

Fig. N - 8



Sewer Line No.			C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9
V=1/200	Dia.	(mm)	200	200	200	200	200	200	200	200	200
H=1/1500	Slope	(‰)	10	10	10	10	10	10	10	10	10
	Length	(m)	53.73	56.81	22.51	40.95	33.00	33.00	33.00	16.00	9.63

Ground Elevation (m)	1510.73	1510.86	1510.81	1510.88	1511.05	1510.50	1509.23	1508.40	1508.64	1507.63
Earth Cover (m)	1.20	1.87	2.39	2.69	3.27	3.05	2.11	1.61	2.01	1.10
Invert Elevation (m)	1509.30	1508.76	1508.19	1507.96	1507.55	1507.22	1506.89	1506.56	1506.40	1506.30
Cu. Length (m)	0.00	53.73	110.54	133.05	174.00	207.00	240.00	273.00	289.00	298.63

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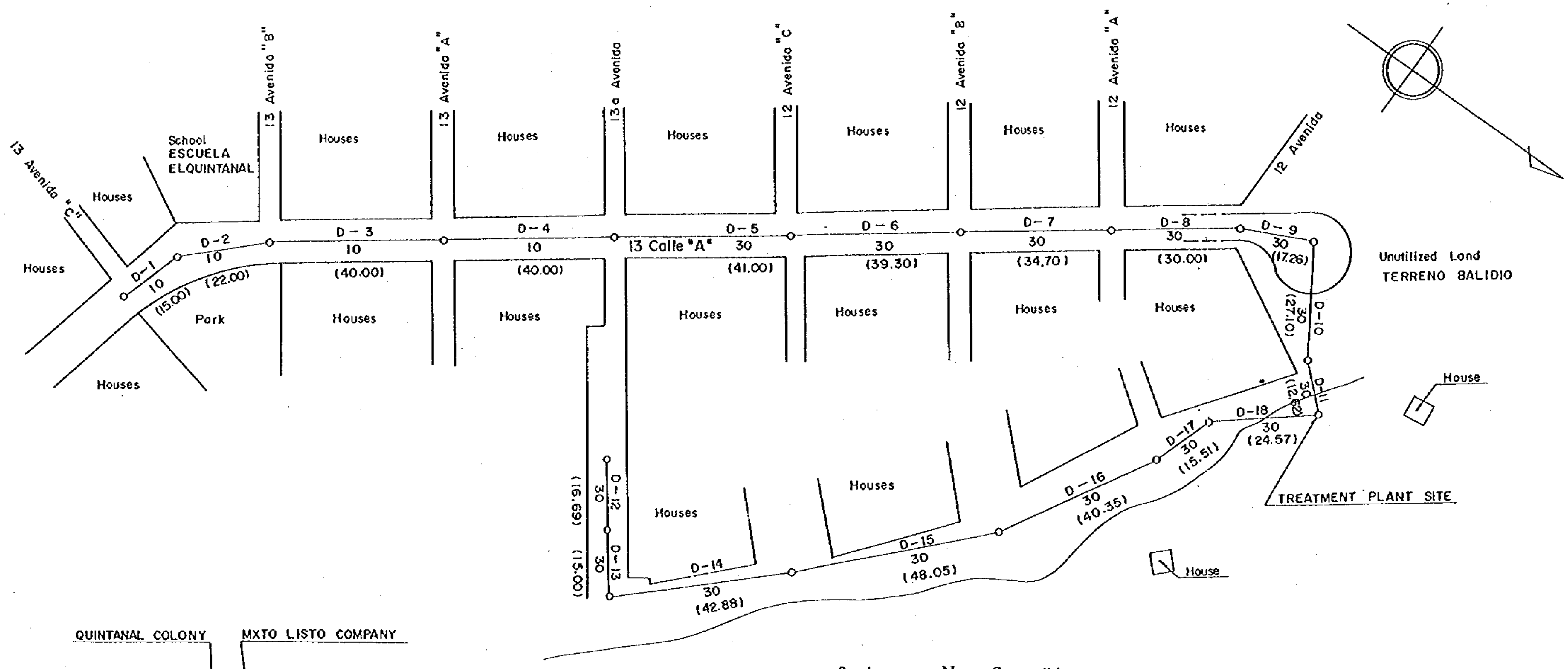
JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

PROFILE OF MAIN SEWER FOR SEIS DE OCTUBURE

Fig. N - 9



Note : Sewer Diameter = 200 mm (unless otherwise specified)

D1 to D4 sewer pipe has diameter of 250 mm.

D-5 to D-11 sewer pipe has diameter of 300 mm.

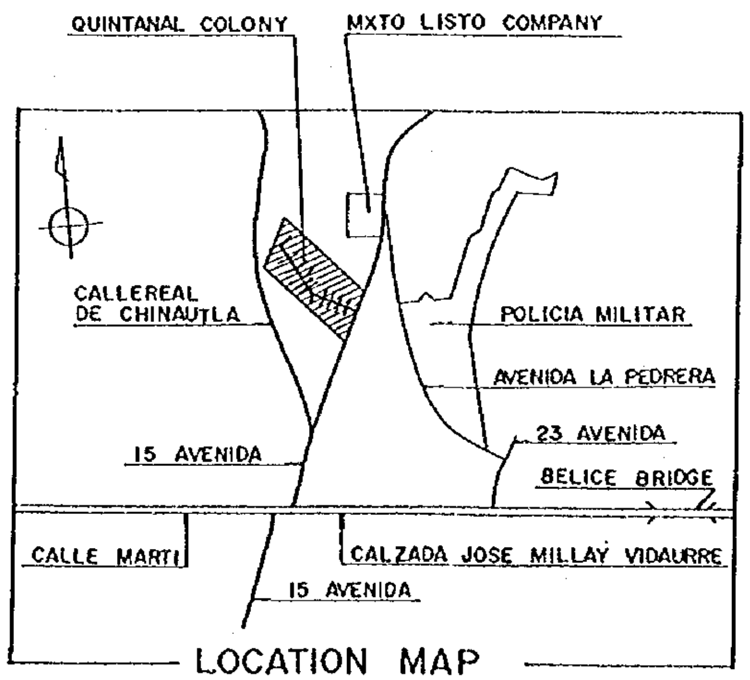
Scale 1 : 1000

Legend

Sewer line

Slope

(Length)

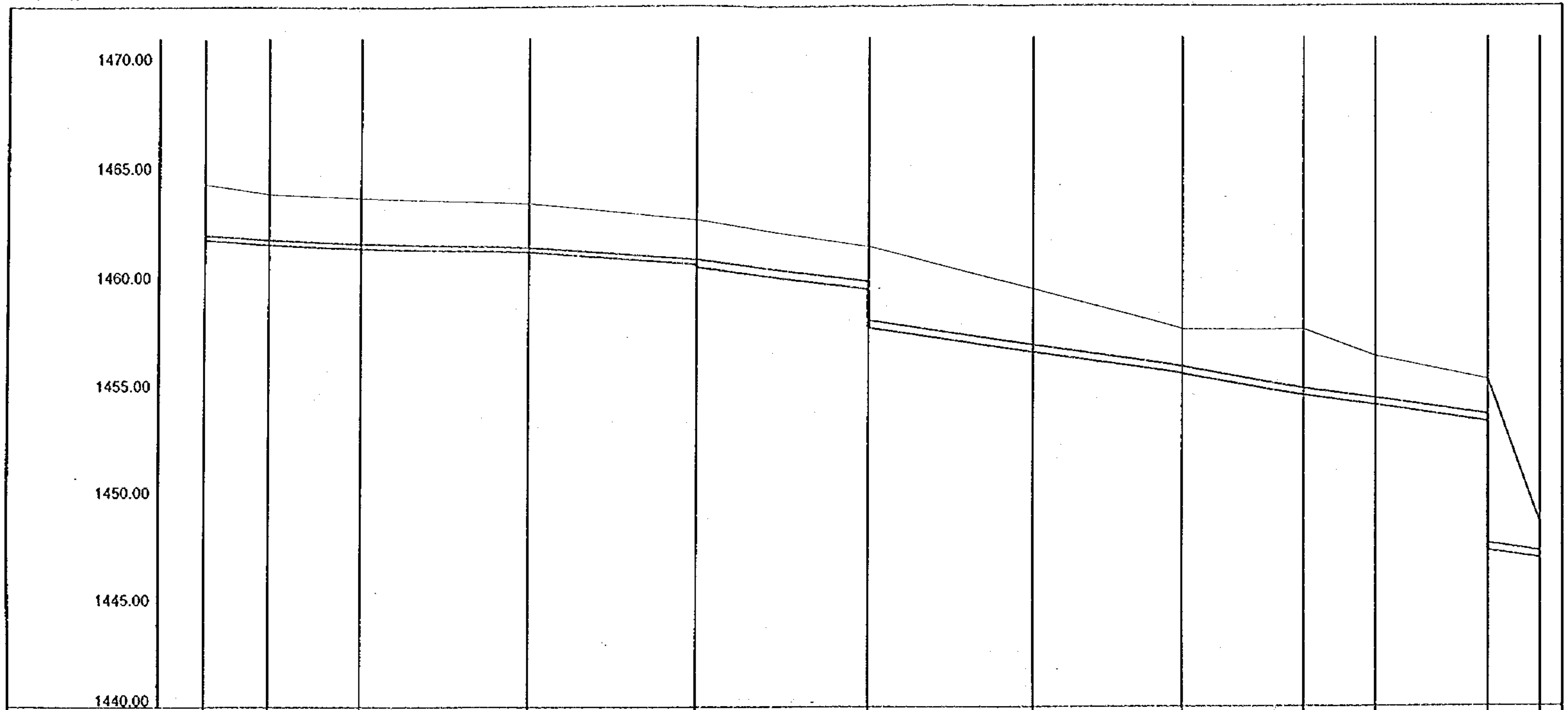


LOCATION MAP

Mape de Localizacion

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE MAIN SEWER NETWORK PLAN FOR QUINTANAL

Quintanal



Sewer Line No.	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11
V=1/200 Dia. (mm)	250	250	250	250	300	300	300	300	300	300	300
H=1/1500 Slope (‰)	10	10	10	10	30	30	30	30	30	30	30
Length (m)	15.00	22.00	40.00	40.00	41.00	39.30	34.70	30.00	17.26	27.10	12.62

Ground Elevation (m)	1464.06	1463.96	1463.83	1463.27	1462.64	1461.42	1459.37	1457.55	1457.55	1456.14	1455.05	1448.60
Earth Cover (m)	2.00	2.05	2.14	1.98	1.75	1.76	2.39	1.61	2.51	1.62	1.35	1.27
Invert Elevation (m)	1461.78	1461.63	1461.41	1461.01	1460.61 1460.56	1459.33 1457.83	1456.65	1455.61	1454.71	1454.19	1453.37 1447.37	1447.00
Cu. Length (m)	0.00	15.00	37.00	77.00	117.00	158.00	197.30	232.00	262.00	279.26	306.36	318.38

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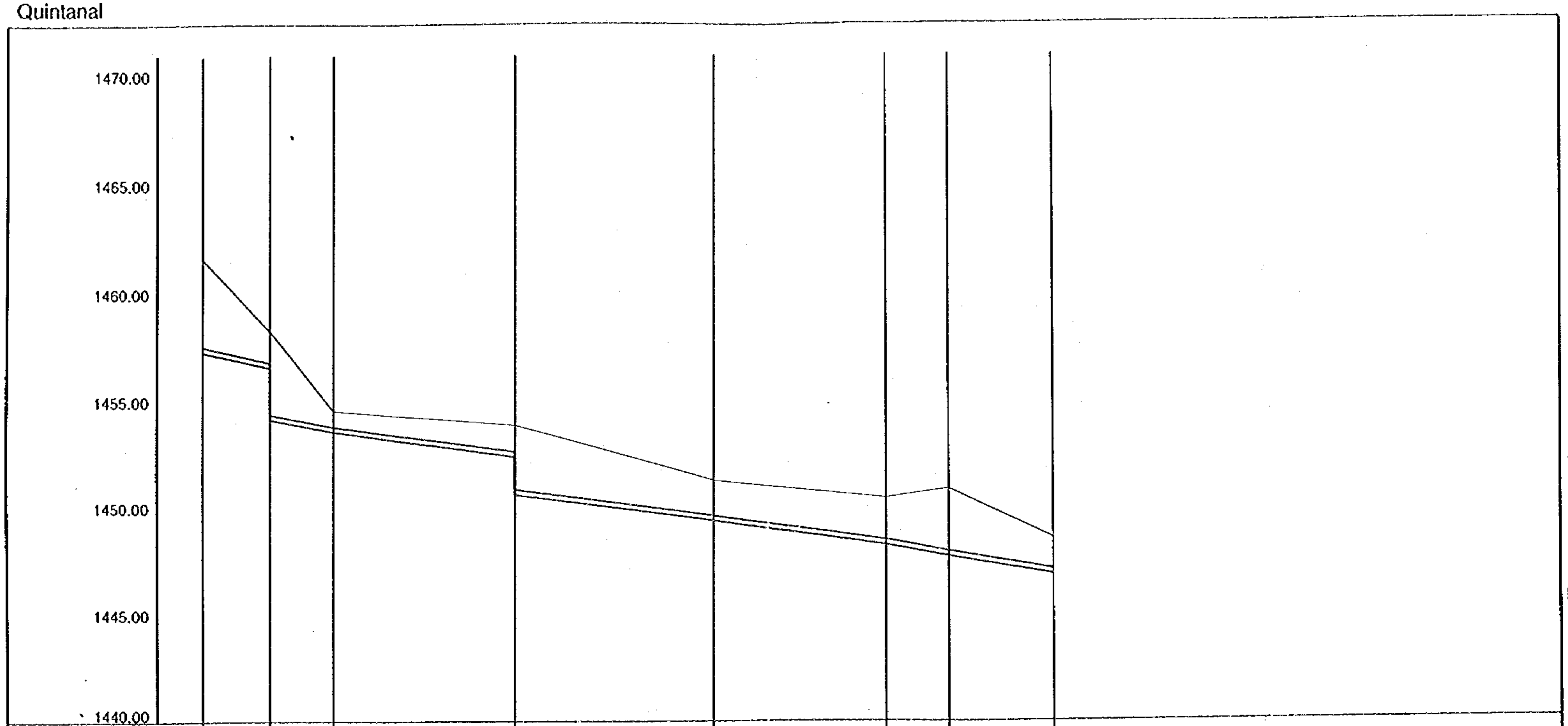
Fig. N - 10 (b)

Quintanal



Sewer Line No.			D-12	D-13	D-14	D-15	D-16	D-17	D-18
V=1/200	Dia.	(mm)	200	200	200	200	200	200	200
H=1/1500	Slope	(‰)	30	30	30	30	30	30	30
	Length	(m)	16.69	15.00	42.88	48.05	40.35	15.51	24.57

Ground Elevation (m)	1461.58	1458.05	1454.87	1453.97	1451.34	1450.45	1450.92	1448.60
Earth Cover (m)	4.27	1.24	1.01	1.40	1.71	2.03	2.97	1.39
Invert Elevation (m)	1457.08	1456.58 1454.08	1453.63	1452.34 1450.84	1449.40	1448.19	1447.72	1446.98
Cu. Length (m)	0.00	16.69	31.69	74.57	122.62	162.97	178.48	203.43

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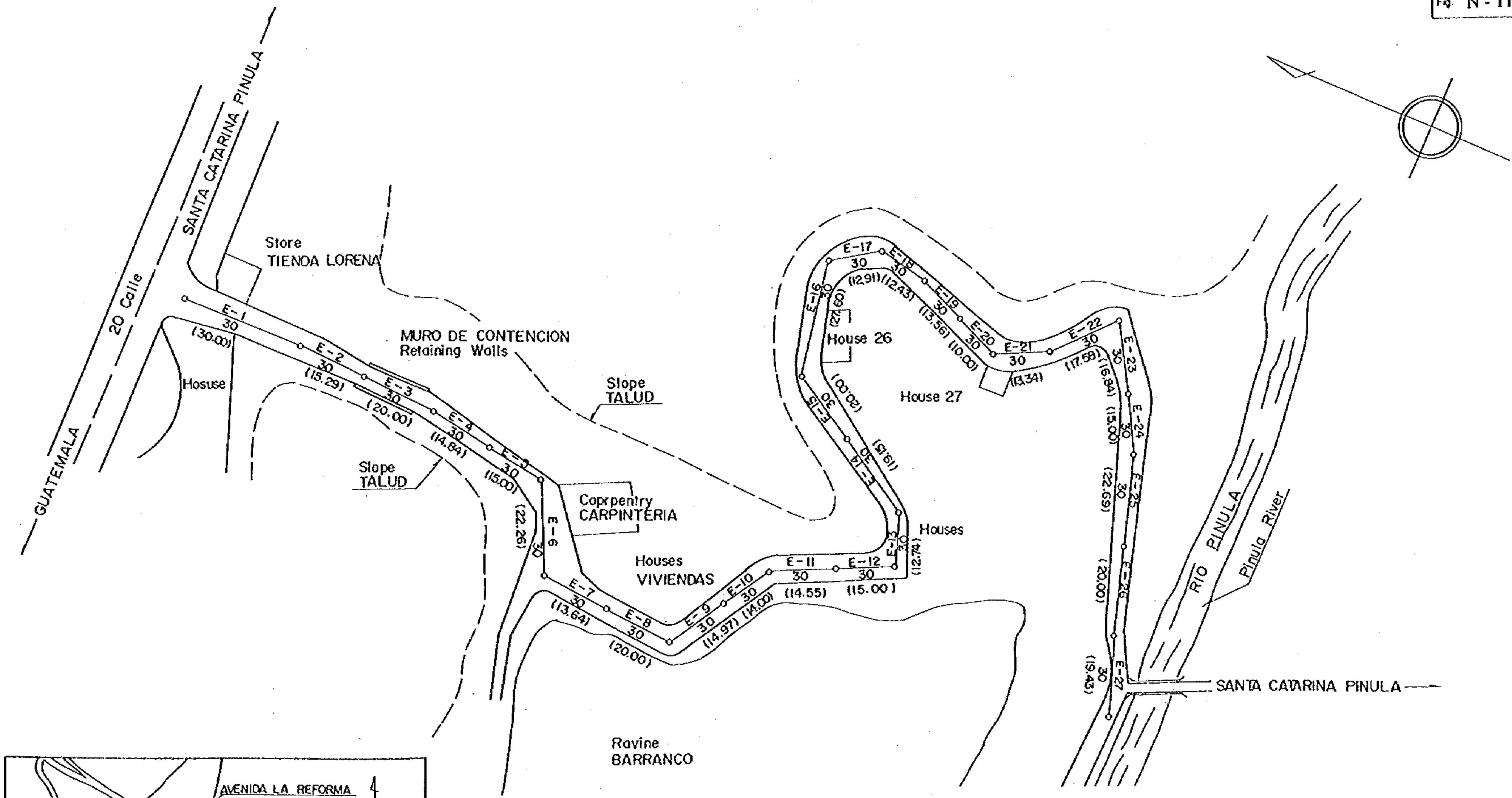
Fig. N - 11



LOCATION MAP
Mapa de Localizacion

Note : Sewer Diameter = 200 mm (unless otherwise specified)

Scale 1 : 1000

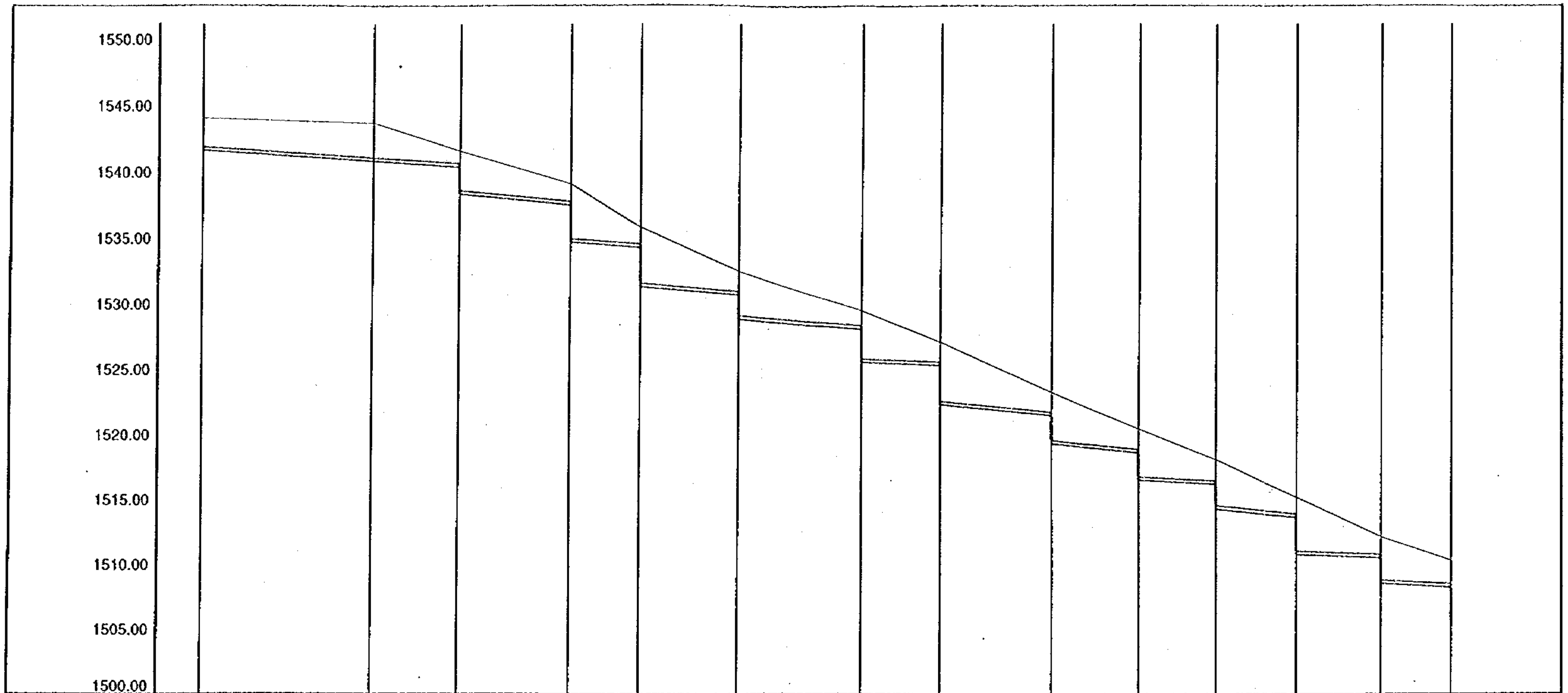
Legend

Sewer line
Slope
(Length)

THE REPUBLIC OF GUATEMALA GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)	THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE MAIN SEWER NETWORK PLAN FOR EL PILAR

Fig N - 12 (a)

El Pilar



Sewer Line No. — V=1/400, H=1/2000

Sewer Line No.	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-10	E-11	E-12	E-13
Dia. (mm)	200	200	200	200	200	200	200	200	200	200	200	200	200
Slope (‰)	30	30	30	30	30	30	30	30	30	30	30	30	30
Length (m)	30.00	15.29	20.00	14.84	15.00	22.26	13.64	20.00	14.97	14.00	14.55	15.00	12.74

Ground Elevation (m)	Earth Cover (m)	Invert Elevation (m)	Cu. Length (m)
1544.04	2.00	1541.81	0.00
1543.98	2.84	1540.91	30.00
1541.86	1.18	1540.45 / 1538.45	45.29
1539.09	1.00	1537.85 / 1534.85	65.29
1535.97	1.34	1534.40 / 1531.40	80.13
1532.82	1.64	1530.95 / 1528.95	95.13
1529.71	1.20	1528.28 / 1525.78	117.39
1527.02	1.42	1525.37 / 1522.37	131.03
1523.07	1.07	1521.77 / 1519.27	151.03
1520.50	1.45	1518.82 / 1516.82	166.00
1518.09	1.46	1516.40 / 1514.40	180.00
1515.16	1.00	1513.96 / 1510.96	194.55
1512.14	1.40	1510.51 / 1508.51	209.55
1510.28	1.92	1508.13 / 1505.63	222.29

THE REPUBLIC OF GUATEMALA

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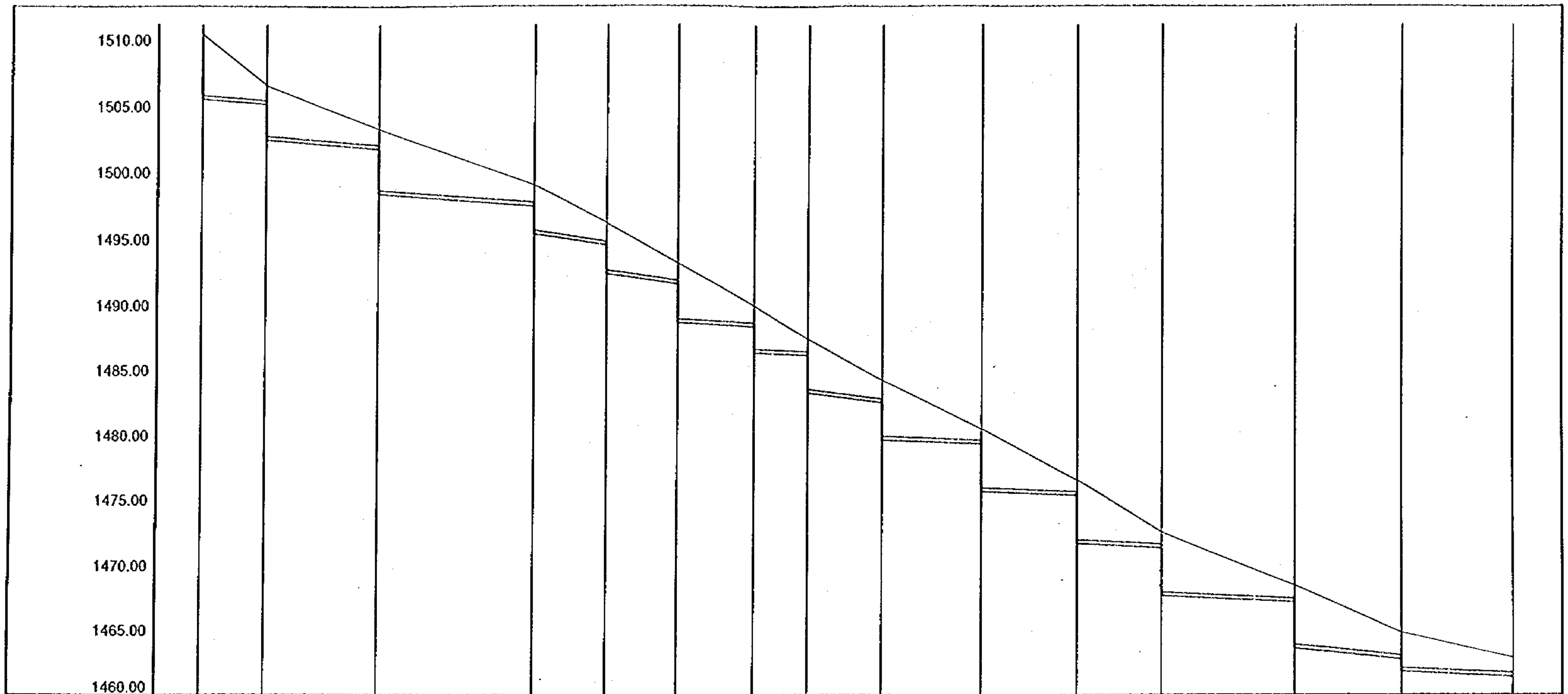
JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

PROFILE OF MAIN SEWER FOR EL PILAR

Fig. N - 12 (b)

El Pilar



V=1/500
H=1/1000

Sewer Line No.	E-14	E-15	E-16	E-17	E-18	E-19	E-20	E-21	E-22	E-23	E-24	E-25	E-26	E-27
Dia. (mm)	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Slope (‰)	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Length (m)	19.15	20.00	27.60	12.91	12.43	13.56	10.00	13.34	17.58	16.84	15.00	22.69	20.00	19.43

	Ground Elevation (m)	Earth Cover (m)	Invert Elevation (m)	Cu. Length (m)
1	1510.28	1.92	1508.13 1505.63	222.29
2	1506.88	1.60	1505.05 1502.55	241.44
3	1503.33	1.15	1501.95 1498.45	261.44
4	1499.03	1.18	1497.62 1495.12	289.04
5	1496.32	1.36	1494.73 1492.23	301.95
6	1493.34	1.25	1491.86 1488.86	314.38
7	1490.00	1.32	1488.45 1486.45	327.94
8	1487.50	1.12	1486.15 1483.15	337.94
9	1484.25	1.27	1482.75 1479.75	351.28
10	1480.59	1.13	1479.22 1475.72	368.86
11	1476.44	1.00	1475.21 1471.71	385.70
12	1472.75	1.26	1471.26 1467.76	400.70
13	1468.59	1.28	1467.08 1463.58	423.39
14	1464.93	1.72	1462.98 1461.98	443.39
15	1462.95	1.32	1461.40	462.82

THE REPUBLIC OF GUATEMALA

GUATEMALA MUNICIPAL WATER SUPPLY PUBLIC CORPORATION (EMPAGUA)

THE STUDY ON THE IMPROVEMENT OF WASTEWATER MANAGEMENT IN THE GUATEMALA METROPOLITAN AREA

JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

PROFILE OF MAIN SEWER FOR EL PILAR

N4 Sanitation Treatment System

a) Treatment Process

The wastewater collected from the settlement is proposed to be treated at community plant. The sanitation treatment system consist of treatment and effluent disposal system. In Master plan following two alternatives were described:

- Septic tank followed by soil absorption well
- Septic tank with upflow anaerobic filter and effluent to be discharged to the river.

At present soil absorption system is being used for disposal of septic tank effluent in the study area, however in future most of the area is basically to be covered by sewerage system and settlements to be covered by sanitation system are located on the steep slope and are closer to the valley. Limited area is available for the treatment site in these settlements. Most of the settlements have river nearby.

Further soil percolation test conducted at five locations showed that soil is predominantly clay/clayey silt. And as the proposed septic tank system is closed to the valley, possibility of underground channel of porous materials can not be ruled out as found in Bethania II. (Ref. Supporting Report III for more details)

Based on the above site conditions, treatment system consisting of septic tank with upflow filter and effluent discharged to the river is preferred. By treating septic tank effluent through upflow anaerobic filter and then discharging into the river, possibility of contamination of ground water can be avoided. However for settlement Final and El Pilar, where Pinula river is used for domestic purposes at the downstream, septic tank effluent is proposed to be disposed by means of soil absorption system.

b) Design Criteria

Design criteria of sanitation treatment system are summarized below in the Table N - 3.

Table N -3 Design Criteria of Septic Tank and Upflow Anaerobic Filter

Facility	Item	Unit	Design Range	Applied
Septic Tank	Detention Time (Start up)	days	3	3
	Sludge accumulation rate	l/c/d	30-40	40
	Max.. sludge accumulation allowed before desludging		1/2-1/3 of tank	1/3 of tank
	Length : Width		2-3 : 1	2 : 1
	Clearance above liquid level	m	0.2-0.4	0.4
Upflow Anaerobic Filter	Detention time	hrs	6-8	8
	Max.. hydraulic loading	$m^3/d/m^2$	3.4	1.7
	Max.. height	m	0.9-1.5	1.2

References :

- Appropriate Technology for Water Supply and Sanitation : A Planner's Guide, World Bank 1980.
- Sewage Treatment in Hot Climates, Duncan Mara, (1976)
- Wastewater Engineering; Treatment, Disposal and Reuse, Metcalf & Eddy, Third Edition, (1991)
- Anaerobic Wastewater treatment-Attached growth and sludge Blanket Process, ENSIC, AIT (1986)
- Design Criteria Development of RBC and Anaerobic Filter system for Sewage Treatment, AIT (1983)

c) Treated Water Quality

Treated water Quality from sanitation treatment system is described below in the Table N - 4.

Table N - 4 Treated Water Quality from Sanitation Treatment System

Parameter	Removal Rate	Influent (mg/l)	Effluent (mg/l)
BOD5	75 %	330	83
SS	75 %	330	83

d) Design Details of Treatment System

Table N - 5 shows details of community plants for Central and South 3 Region. Design calculations for the community plant to serve 1000 people are shown in Table N -6 and details for typical settlements of Central and South 3 Region are shown from Fig. N - 13 to Fig. N - 17.

Table N - 5 Details of Community Treatment Plant

No.	Name of Settlement	Zone	Daily Maximum Flowrate m³/d	Septic Tank (LxWxD) m	Upflow Filter (LxWxD) m
	CENTRAL REGION				
1	Final	14	90	17.0x8.5x2.0	-
2	El Pilar	14	270	28.0x14.5x2.0	-
3	El Cambary	14	60	13.0x7.0x2.0	5.5x7.0x1.2
4	Campo Seco	16	220	25.5x13.0x2.0	10.5x13.0x1.2
5	Finca El Carmen	6	180	23.5x11.5x2.0	10.0x11.5x1.2
6	Modrno San Antonio	6	180	23.5x11.5x2.0	10.0x11.5x1.2
7	Jocotales	6	470	37.5x19.0x2.0	15.5x19.0x1.2
8	Quintanal	6	670	45.0x22.5x2.0	18.5x22.5x1.2
9	Santa Faz	6	110	18.5x9.0x2.0	7.5x9.0x1.2
10	El Tuerto	1	90	17.0x8.5x2.0	6.5x8.5x1.2
11	Colinas I y II	1	170	22.0x11.5x2.0	9.5x11.5x1.2
12	Bethania Sec I	1	260	28.0x14.0x2.0	11.5x14.0x1.2
13	Bethania Sec II	7	360	33.0x16.5x2.0	13.5x16.5x1.2
14	Seis de Octubre	7	270	28.0x14.5x2.0	11.5x14.5x1.2
15	Joya I	7	450	36.5x18.5x2.0	15.0x18.5x1.2
16	Joya II	7	450	36.5x18.5x2.0	15.0x18.5x1.2
17	Joya III	7	450	36.5x18.5x2.0	15.0x18.5x1.2
18	La Joya IV	7	270	28.0x14.5x2.0	11.5x14.5x1.2
19	Colon. Argueta	2	360	33.0x16.5x2.0	13.5x16.5x1.2
20	Incienso	3	760	47.5x24.0x2.0	20.0x24.0x1.2
	SOUTH 3 REGION				
1	Loma Blanca I	12	170	22.0x11.5x2.0	9.5x11.5x1.2
2	Loma Blanca II	12	180	23.5x11.5x2.0	10.0x11.5x1.2
3	Plaza de Toros	13	180	23.5x11.5x2.0	10.0x11.5x1.2

Note 1. Bethania III and IV are considered as one community and is mentioned as Bethania II.

Note 2. Effective dimensions of septic tank and upflow filter are mentioned above.

Note 3. LxWxD = Length x Width x Depth

Table N - 6 Design Calculation s for Community plant to serve 1000 people

Item	Calculation
Design Flowrate	Daily Average 165 lpcd = 165 m^3/day Daily Maximum 180 lpcd = 180 m^3/day
1.Septic tank	
A) Required Capacity	
Design flowrate	180 m^3/day
Detention time	3 days
Effective TankVolume	540 m^3
B) Check for sludge accumulation	
Sludge accumulation rate	0.04 m^3/capita/year
Frequency of desluddging (including factor of safety)	3 years
Sludge accumulation	120 m^3
Volume reserved for sludge accumulation	1/3 of tank Volume =180m^3
C) Dimensions	
Depth	2.0m
Area	270 m^2
length : Width	2 : 1
length	23.5 m
Width	11.5 m
2.Upflow Filter	
A) Required Capacity	
Filter media (void ratio)	20 - 25 mm broken stones (0.45)
Detention time	8 hrs
Design flow	180 m^3/day
Required void volume	60 m^3
Required filter volume	134 m^3
B) Dimensions	
Depth	1.2 m
Area	112 m^2
Width	11.5 m
length	10.0 m
C) Check for Hydraulic loading.	
Hydraulic loading to the filter	1.61 $m^3/m^2/d$
Recommended Hydraulic loading	1.7 $m^3/m^2/d$

e) Septage Treatment

It is proposed that septage be treated at the sludge treatment facility of the wastewater treatment plant to be constructed in the respective region. The quantity of septage is calculated based on a sludge accumulation rate of 0.04 m^3/capita/year. The quantity of septage to be desludged from each settlement in Central region and South 3 region are described below in the Table N - 7.

Table N -7 Quantity of Septage to be Desludged in the First Stage

S. No.	Name of Settlement	Zone	Septage to be desludged (m^3/year)
	CENTRAL REGION		
1	Final	14	20
2	El Pilar	14	60
3	El Cambary	14	12
4	Campo Seco	16	48
5	Finca El Carmen	6	40
6	Modrno San Antonio	6	40
7	Jocotales	6	104
8	Quintanal	6	148
9	Santa Faz	6	24
10	El Tuerto	1	20
11	Colinas I y II	1	36
12	Bethania Sec I	1	56
13	Bethania Sec II	7	80
14	Seis de Octubre	7	60
15	Joya I	7	100
16	Joya II	7	100
17	Joya III	7	100
18	La Joya IV	7	60
19	Colon. Argueta	2	80
20	Incienso	3	168
	Total		1,356
	SOUTH 3 REGION		
1	Loma Blanca I	12	36
2	Loma Blanca II	12	40
3	Plaza de Toros	13	40
	Total		116