CHAPTER 9

REHABILITATION PLAN OF EXISTING SEWERS

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9.1 General

In the Study Area there are six (6) trunk sewers which were constructed in 1984. Most of them are located along the storm water drainage canal. However, in some places, some of the sewers cross the drainage canals.

Because of the lack of proper maintenance for the sewers and drainage canals, these sewers are seriously damaged. The main cause of the damage is the heavy erosion of soil in the earthen canals. The existing sewerage network in the Study Area is shown in Fig. 9.1.

In the Study Area, a separate system for wastewater discharge is adopted in principle and the proposed interceptor should collect only wastewater through the existing trunk sewers. However, under the present conditions most of wastewater due to damaged sewers is discharged into the existing canal and flow into the Lagoon.

In order to collect wastewater discharged from the Study Area, rehabilitation of these damaged sewers is indispensable. In this Chapter, rehabilitation guidelines for repair/improvement of canals and sewers are presented as a recommendation.

The extension works of the existing sewers to connect with the proposed interceptor will be necessary for some trunk sewers and these works are also proposed.

The capacity of the central trunk main is also reviewed for increased inflow from the Study Area. In the case of insufficient capacity of the existing sewers, improvement methods are proposed.

9.2 Site Survey on Existing Sewers

A site reconnaissance survey on the existing six (6) trunk sewers was conducted by means of a preliminary survey. This survey covers only the visible section. Therefore, the underground section is not included.

The total length of the existing trunk sewers in the Area is about 35.3 km and the diameter of these sewers are in the range of 200 mm to 800 mm. Dimensions of the six trunk sewers are shown in Table 9.1.

1) 1A.B-2A.B-3A.B Trunk Sewer

These trunk sewers exist at the west end of the proposed South Interceptor. All of these trunk sewers combine flow in downstream and discharge it to the Ebric lagoon. The outfall of these sewers were originally made 80 meters long in the Lagoon but at present, the outfall are completely lost and no sewer pipes exist.

a) 1A and 1B Trunk Sewers run along the left and right bank, respectively, of the drainage canal. 1A Trunk Sewer is 1300 m long and diameter of the concrete pipe is 300 mm. Some manholes have no covers and are filled with sediments and garbage.

The sewer, however, functions well even though it has a relatively small flow.

1B Trunk Sewer of concrete pipe is 500 mm in diameter and 1,300 m long. Some manholes have no covers and are filled with sediments and garbage. The sewer functions only partially.

The drainage canal has a concrete lining only for 40 m stretch. Most part of the canal is earthen 6 to 12 m wide and 1 to 3 m deep. Wastewater discharges directly into the canal at many places. Garbage is also dumped in the canal.

b) A small collector joins with the Trunk Sewer from the east side. This collector is used concrete pipe having a diameter and length of 300 mm and about 600 m, respectively. This collector doesn't function at all.

c) 2A and 2B Trunk Sewers run along the left and right bank of the drainage canal, respectively.

2A Trunk Sewer is 1500 m long and has a diameter of 500 mm. There are some manholes with no covers and are filled up with sediments and garbage. Overflow of wastewater was observed at two manholes. The collector functions downstream only.

2B Trunk Sewer is 1500 m long having a 500 mm in diameter. Concrete pipe is used for the sewer. Some manholes have a sediment problem. The whole stretch of this sewer doesn't function.

The drainage canal is mostly an earthen channel that is 6 to 12 m wide and 1 to 3 m deep. Individual wastewater is directly discharged into this canal at many points making it smell badly. Garbage dumping sites exist in the canal.

d) 3A and 3B Trunk Sewers run along the drainage canal on both sides, left bank and right bank, respectively.
3A Trunk Sewer is 2500 m long and is of concrete pipe having a diameter of 300 mm. This sewer functions well.

3B Trunk Sewer is 2500 m long and is of concrete pipe having a diameter of 300 mm. All the manholes have no covers and the sewer does not function due to the blockage of the pipes with sediments. The canal is lined by earth with a width and depth of 5 to 7 m and 1 to 3 m, respectively. Wastewater discharges directly into the canal at many points and has an unpleasant odor. Dumped garbage was observed in the canal.

2) UNIWAX Trunk Sewer

This trunk sewer meets Port Bouet Trunk Sewer about 4,200 m before outfall to the lagoon. Pipes are made of concrete and partially asbestos. The diameter of both types of pipes is 800 mm. This UNIWAX crosses a drainage canal. The location is before the confluence of two drainage canals from the UNIWAX area and the Port Bouet area. This sewer joins with Port Bouet Trunk Sewer about 50 m downstream of the canal's confluence.

The confluence of the two canals is completely destroyed due to excessive erosion and forms waterfall of about 10 meter in depth. The Port Bouet Trunk Sewer, which crosses the drainage canal just upstream of the confluence, is completely lost at this point. This sewer is lost again before connection to the UNIWAX sewer after crossing the canal. The Port

Bouet sewer is 600 mm in diameter and is made of concrete.

The UNIWAX sewer crosses the canal again at about 1,700 m downstream from the confluence. The sewer crosses the canal in an aqueduct type supported by H steel pile. The asbestos pipes are broken and half of the wastewater is discharged into the canal.
The trunk sewer is partially located under resident houses. Some of the manholes could not be identified. Some manholes do not have covers. And some are filled with sediments and garbage.

The drainage canals at the upstream stretch of the waterfall have concrete linings. The downstream earthen canal is about 6 to 12 m wide and 3 to 10 m deep except in the waterfall basin area.

Direct inflow of wastewater into the canal is observed at many places. Wastewater flows in the canal all the times. This causes serious environmental problems.

3) 21-22 Trunk Sewer

This trunk sewer is about 2,500 m long and is a concrete pipe 300 mm to 400 mm in diameter. At the crossing point with drainage canal, the sewer pipe is PVC (Polyvinyl chloride).
About a 1,600 m stretch of this sewer seems to function well but the remaining part is more or less damaged by excessive erosion of the earthen drainage canal and does not function. Some manholes are filled with sand and garbage.

The upstream stretch of about 1,000m is a rectangular type lined by concrete. The rest is an earthen canal. The width and depth of the earthen canal is about 6 m to 12 m and 1 m to 6 m, respectively. At the border between the concrete and earthen canal, the soil is eroded about 1 m.

In the upstream stretch of the drainage canal which flows through a populated area, the inflow of domestic wastewater, sediments and garbage are observed at many places.

4) 25-26-27 Trunk Sewer

This trunk sewer is about 3000 m long and is a concrete pipe with a diameter of 400 mm to 500 mm. The drainage canal which runs almost parallel to the Trunk Sewer forms a waterfall at about 1.4 km upstream from the Lagoon. This waterfall is about 15 m deep and 30 m wide. This waterfall exists at the end of the concrete lined drainage canal and has formed over the last 8 to 10 years as a result of erosion.

The Trunk Sewer is completely destroyed at this point and no more sewer pipe exists downstream.

At the upstream stretch, some manholes have no covers and are filled with garbage and sediments. Some manholes are outstanding above the ground because of soil erosion around them.

The drainage canal in the uppermost stretch of about 400 m is lined with concrete rectangular or trapezoidal. The rest is earthen canal. The downstream stretch after the waterfall is heavily eroded. The channel is 15 m deep and 15 m wide.

In the drainage canal, domestic wastewater discharges at many points and dumped garbage can also be observed.

5) 33-34 Trunk Sewer

This trunk sewer is about 1500 m long and installed under the existing road on the left bank of the storm water drainage canal and discharges wastewater from about 240 ha of the housing area into the drainage canal before emptying into the Banco Bay.

This concrete pipe trunk sewer is 300 mm in diameter and seems to function well without any problem.

The canal is of concrete lining and rectangular in cross section and the road is paved. Hence any future risk of damage of the sewer pipes due to erosion is not expected. The catchment basin is highly developed for housing. Therefore, sediment run-off from the basin will be quite small.

The connection of the existing sewer with new interceptor is possible without any difficulty.

6) 35-36 Trunk Sewer

This trunk sewer is installed along the small river from west to east at the end of Banco Bay. This trunk sewer is estimated to cover about 360 ha of the sewerage design area and is designed to discharge wastewater into the Banco Bay through pipes 200 mm in diameter.

This sewer, however, does not function at present because of a heavy accumulation of sediment in the manholes and pipes. The covers of some manholes are lost.

At the upstream end of the valley, a small quantity of sewage inflow is observed but it disappears after a short distance because of infiltration into the sandy soils.

The small river flows in the valley of about 20 m high hills (EL.40m~50m) on both sides and enters into the Banco Bay. The river is channeled for only a 1,800 m stretch of its downstream run and has a concrete lining. In the upstream stretch, it is a natural river. The river and canal are filled with sediment. In the valley, there are only a few houses.

Cliffs of the valley are of silty sand which is easily eroded by heavy rainfall resulting in sediment run-off.

For restoration of the trunk sewer, rehabilitation of the manhole cover and removal of sediment from the pipes is necessary. Basically, sediment control work and river improvement will be crucial.

In the existing plan, the trunk sewer is indicated to have connection with sewers in the right bank of the canal but actually the connection exists in the left bank. The actual conditions of sewer connection are not identified in the site.

9.3 Storm Water Run-off and Canal Structures crossing New Interceptor

The southern interceptor along the Ebrie lagoon crosses the existing canals. The crossing structures of the proposed urban road have not yet been planned. These crossing structures would be box-culvert or bridge. In order to assume the sections of drainage canal at crossing points, storm water run-off was roughly estimated for interceptor planning. The catchment area for each drainage basin is shown in Fig. 9.2.

1) Storm Water Run-off

Run-off discharge of each drainage basin was estimated under the following conditions:

i) Drainage basins were divided based on the topographic map of 1998 and drainage system plan of 1998.

ii) Land use patterns were assumed based on the 1998 land use map and aerial photographs of 1997.

iii) Run-off coefficients and rainfall intensity were estimated based on the "Instructions Techniques relatives aux Reseaux d'Assainissement des Agglomerations" of Direction of Water, Ministry of Public Works and Transportation. Run-off coefficient of each drainage basin is shown in Table 9.3.

iv) Rational method (Methode Rationnelle) was adopted for estimation of run-off discharge as follows:

$$Q=1/360 \times C \cdot I \cdot A$$

Where; Q: Storm water run-off in m^3/s

C: run-off coefficient

I: Rainfall intensity

$I = a \cdot t^b$ for 5-year return period; $a = 418$, $b = -0.37$

for 10-year return period; $a = 460$, $b = -0.37$

A: Catchment area in ha

v) Run-off discharges were calculated for a 5-year return period for canal design and a 10-year return period for road crossing structures.

Run-off discharge for each drainage basin is shown in Table 9.4 and 9.5, respectively.

2) Proposed Canal Sections

The proposed cross sections are normally decided upon by considering the design velocity and sections of its upstream and downstream stretches.

However, there are no design sections nor planned longitudinal profiles. Therefore, in this Study, the sections were estimated considering a design velocity of about 3 meters per second. The required section of box culvert was decided upon by using the Manning's Equation shown as follows:

$$V = 1/n \times R^{2/3} I^{1/2}$$

where V: velocity of flow, m/s

n: coefficient of roughness (smooth-surfaced concrete box-culvert, n=0.013)

R: hydraulic radius (m)

I: hydraulic gradient

Proposed canal section is shown in Table 9.6.

9.4 Recommendation on Guidelines for Rehabilitation of Damaged Sewers

9.4.1 Rehabilitation of Existing Sewers

As described in Section 9.2, the existing trunk sewers are heavily damaged especially in downstream stretches. These damaged or lost trunk sewers should be rehabilitated or reconstructed in order to connect them to the new interceptor. Among the damaged sewers, those damaged due to heavy erosion of the canal should be reconstructed shifting the route at a safe distance away from the erosion along the canal because canal rehabilitation to the original section is actually impossible.

The rehabilitation and reconstruction method would be different for each case of trunk sewer. Hence in this Study, the guidelines of rehabilitation/reconstruction is presented for each case.

The locations of damaged sewers are shown in Fig.9.3 and recommended reconstruction sewer routes are shown in Fig.9.4 and 9.5.

Recommended guidelines for rehabilitation and reconstruction of damaged sewers is summarized in Table 9.7.

9.4.2 Improvement Plan for Storm Water Drainage Canals

In the Study Area, there are three major drainage canals which are heavily damaged by erosion, (the drainage canal along the 21-22 Trunk Sewer, along the 25- 26-27 Trunk Sewer, and along the UNIWAX Trunk Sewer).

These eroded/ damaged canals have been causing serious environmental problems such as the danger of slope failure to riverine people, damage to the existing concrete lined canal, destruction of structures crossing the canals and environmental degradation of the Lagoon due to an excessive sediment run-off.

The downstream stretch of the concrete lined canal is like a natural small river affected by serious erosion to both the river banks and bed. Especially, the end of the concrete lined section of the canal drops like a waterfall with about a 10 m head. Therefore, it is almost impossible to retrieve it to the original section.

In order to mitigate degradation of erosion, proper countermeasures should be proposed based on the storm water drainage master plan and new survey data. However, there is neither a reviewed master plan nor any new topographic survey data. Hence, in this Study, the results of preliminary considerations based on a site reconnaissance survey and existing data are shown.

Major proposed countermeasures would be the construction of a check dam, a consolidation dam, drop structure and bank protection.
Possible countermeasures for three major damaged canals are shown in Fig. 9.6 to 9.8.

9.5 Review of Central Trunk Sewer

The Sewerage and Drainage Master Plan of Abidjan was initially formulated in 1971 based on the 1969 Abidjan Urban Master Plan and this Master Plan was revised in 1981 with a target year of 1995. The sewerage facilities have been implemented since 1975 as Phase I and recently, a pre-treatment plant and a sea outfall have been constructed for an objective population of 3 million as Phase III.
The existing Central Trunk Sewer, in principle, has been constructed based on the 1981 Master Plan. Regarding pump facilities, however, they were not completed to full size.

Most of them only have about half of their proposed capacity.

In this JICA study for the western district of Abidjan, the target is set for the year 2003. Hence, the capacities of the existing sewerage facilities were reviewed taking the projected future population of Abidjan into account.

9.5.1 Objective Sewerage Facilities and their Existing Capacity

The proposed interceptor from the western district is to be connected to the existing S1 Pumping Station. Hence, the following sewerage facilities were reviewed for their capacities:

- Trunk Sewer between S1 Pumping Station and Koumassi Pre-Treatment Plant
  - Length: about 2,600 m
- Trunk Sewer between Koumassi Pre-Treatment Plant and the ocean outfall
  - Length: about 3,800 m including 1200 m long ocean outfall
- S1 Pumping Station with two (2) pumps - 0.576 m3/s (total 1.152 m3/s)
- 7J1 Pumping Station with three (3) pumps - 0.53 m3/s (total 1.590 m3/s)
- Koumassi Pre-Treatment Plant with two pumps - 0.91 m3/s (total 1.820m3/s)

The dimensions of each trunk sewer are shown in Table 9.8. The flow capacity of each trunk sewer was estimated based on the installation conditions as shown in Figs 9.9 and 9.10. The results are also shown in Table 9.8.

9.5.2 Present and Future Wastewater Flow

Wastewater flows from the western and other districts were estimated for the years of 1998 (present), 2003 (JICA Study target year), 2005 and 2015. These wastewater flows were calculated based on the data of projected population by BNETD.

Wastewater flow at each section is shown in the Table 9.8 for review of trunk sewer.

Wastewater flow at each pumping station is shown in Table 9.9.

9.5.3 Evaluation of Existing Capacity and Improvement Plan

1) Pumping Station

At present, all existing pumping stations satisfy the required capacities. But in 2003, wastewater flow is estimated to be two times of the present value and existing facilities would not be enough. According to the Master Plan, these pumping stations are to be reinforced making them about two times bigger in scale than the existing one. Spaces for the additional pumps have already been reserved in the building of each pumping station. After installation of these additional pumps, S1 and 7J1 pumping stations will be able to receive sewage flow up to the year 2005.

Regarding the Koumassi PT Plant, among the two pumping stations, pumps for ocean outfall only have an 8 m total head. In order to discharge the sewage flow of the year 2003, these pumps should have a total head of about 20 m (see Fig 9.11). Hence, the existing four (4) pumps each with a capacity of 0.45 m3/s should be replaced in addition to four (4) new pumps. However, instead of eight (8) pumps, four (4) pumps with each capacity of 0.90 m3/s are recommended to be installed.

2) Trunk Sewers

Table 9.17 shows the flow capacity of each section, and the present and future (2003) sewage flows. Under the present condition, the existing sewer pipes can satisfy the required capacity at any point. In the year 2003, two stretches between S1 P/S and 7J1P/S do not have enough capacity for the design discharge. These stretches, however, are only 125 m (45 m and 80 m) and would be able to run design discharge without any negative backwater effect on their upstream stretches.

In the stretches between 7J1 P/S and Koumassi Pre-Treatment Plant, the 140 m section has on 85 % of the discharge capacity and the 510 m section has 95 % for the required capacity. These stretches are also able to run design discharge with head of backwater which doesn't give any negative effects such as over flow from manhole etc.

The timing for improving of the existing sewerage facilities should be decided upon with due consideration given to the actual sewer connection ratio, the actual sewage volume, etc.

TABLE 9.1 DIMENSION OF EXISTING TRUNK SEWERS IN WEST DISTRICT OF ABIDJAN

Unit: km

Name of Trunk Sewer	Diameter of Sewer Pipe (ϕ:mm)									Remarks
	200	250	300	400	500	600	700	800	1000	(Total)
1A			1.37							
1B					1.37					
2A					1.40					
2B			1.40							
3A			2.40							
3B			2.40							
Others		0.47	0.80							
Collector				0.40					0.90	12.91
UNIWAX		0.55			1.04	3.55		4.46		9.60
PORT BOUET II			0.10	1.30		2.43				3.83
21-22		0.78	0.07	1.69						2.54
25-26-27		1.20	0.12	0.25	1.43					3.00
33-34			1.45							1.45
35-36	1.99									1.99
Total	1.99	3.00	10.11	3.64	5.24	5.98	0	4.46	0.9	35.32

TABLE 9.2 AVERAGE RUN-OFF COEFFICIENT OF EACH DRAINAGE BASIN

Number of Drainage Basin	Residential Area	Pavement Road	Unpavement Road	Forest and Open Land	Average Run-off Coefficient
	0.6	0.9	0.10	0.3	
1	* 0.3	0.05	0.05	0.6	0.41
2	0.4	0.05	0.05	0.5	0.44
3	0.2	0.05	0.05	0.7	0.38
4	0.7	0.05	0.05	0.2	0.53
5	0.8	0.05	0.05	0.1	0.56
6	0.6	0.05	0.05	0.3	0.5
7	0.5	0.05	0.05	0.3	0.50
8	0.5	0.05	0.05	0.4	0.47
9	0.5	0.05	0.05	0.4	0.47
10	0.5	0.05	0.05	0.4	0.47

Note : * Figure shows rate of land occupation (%)

TABLE 9.3 RUN-OFF DISCHARGE FOR 5-YEAR RETURN PERIOD

No of Drainage Basin	Catchment Area (ha)	Distance (m)	Time of Inflow (min)	Velocity (m/s)	Time of Flow (min)	Concentration Time (t) (min)	Run-off Coefficient (c)	Rainfall Intensity $i = 418xt^{-0.37}$	Run-off Discharge $Q = 1/360ciA$ ($m^{3/s}$)
1	270	300	20	1.5	33.3	53.3	0.41	96	29.5
2	220	2500	20	1.5	27.8	47.8	0.44	100	26.9
3	540	5000	20	1.5	55.6	75.6	0.38	84	48.1
4	80	2000	5	1.5	22.2	27.2	0.53	123	14.5
5	60	1000	5	1.5	11.1	16.1	0.56	150	14.00
6	1960	7500	20	1.5	83.3	103.3	0.50	75	204.6
7	120	1000	10	1.5	11.1	21.1	0.5	135	22.5
8	160	2000	5	1.5	22.2	27.2	0.47	123	25.7
9	90	1500	5	1.5	16.7	21.7	0.47	134	15.7
10	430	3000	5	1.5	33.3	38.3	0.47	108	60.9

TABLE 9.4 RUN-OFF DISCHARGE FOR 10-YEAR RETURN PERIOD

No of Drainage Basin	Catchment Area (ha)	Distance (m)	Time of Inflow (min)	Velocity (m/s)	Time of Flow (min)	Concentration Time (t) (min)	Run-off Coefficient (c)	Rainfall Intensity $i = 460xt^{-0.37}$	Run-off Discharge $Q = 1/360ciA$ ($m^{3/s}$)
1	270	300	20	1.5	33.3	53.3	0.41	96	32.49
2	220	2500	20	1.5	27.8	47.8	0.44	100	29.58
3	540	5000	20	1.5	55.6	75.6	0.38	84	52.92
4	80	2000	5	1.5	22.2	27.2	0.53	123	15.96
5	60	1000	5	1.5	11.1	16.1	0.56	150	15.36
6	1960	7500	20	1.5	83.3	103.3	0.50	75	225.15
7	120	1000	10	1.5	11.1	21.1	0.50	135	24.81
8	160	2000	5	1.5	22.2	27.2	0.47	123	28.31
9	90	1500	5	1.5	16.7	21.7	0.47	134	17.31
10	430	3000	5	1.5	33.3	38.3	0.47	108	67.03

TABLE 9.5 PROPOSED CANAL SECTIONS FOR 10-YEAR RETURN PERIOD

No of Drainage Basin	Stormwater Run-off (m^3/s)	Proposed Box Culvert Size (m) width	height	Gradient (‰)	Velocity (m/s)	Flow Capacity (m^3/s)
1	32.6	6.00	3	0.9	2.8	42.9
2	32.6	6.00	3	0.9	2.8	42.9
3	53	8	4	0.7	3	81.5
4	16	3.80	2	1.7	2.9	19
5	15.4	3.80	2	1.7	2.9	19
6	225.9	8.00 x 3	5	0.5	2.8	283.5
7	24.8	4.80	2.4	1.3	2.9	28.4
8	28.4	3.80 x 2	2	1.7	2.9	37.6
9	17.3	3.80	2	1.7	2.9	19
10	66.8	6.00 x 2	3	0.9	2.9	85.8

The height of box culvert was decided taking into account water depth with clearance of about 10% of the height

TABLE 9.6 RECOMMENDED GUIDELINE FOR REHABILITATION AND RECONSTRUCTION OF DAMAGED SEWERS

Name of Trunk Sewer	Damage	Rehabilitation	Reconstruction	Cost (in 1,000 FCFA)
1A/1B 2A/2B 3A/3B	Loss of manhole cover Blockage of manhole and pipes due to sediments and garbage	Removal of sediments and garbage by manual or cleaning machine	Manhole cover	183,000
UNIWAX	Loss of pipes due to erosion, Breakage of pipe on the bridge, Lost of manhole cover Blockage of manhole and pipe	Replace of damaged pipe. Removal of sediments and garbage by manual or cleaning machine	Change the route of canal crossing and shifting the pipeline. Install of new manhole cover	87,000
21-22	Loss of pipes due to erosion, Lost of manhole cover Blockage of manhole and pipe	Removal of sediments and garbage by manual or cleaning machine	Change the route of canal crossing and shifting the pipeline. Install of new manhole cover	22,000
25-26-27	Loss of pipes due to erosion, Lost of manhole cover Blockage of manhole and pipe	Removal of sediments and garbage by manual or cleaning machine	Change the route of canal crossing and shifting the pipeline. Install of new manhole cover	16,000
33.34	No damage			
35.36	Loss of manhole cover Blockage of manhole and pipes due to sediments and garbage	Removal of sediments and garbage by manual or cleaning machine	Improvement of drainage canal with concrete lining, Sediment run-of control of the catchment nearby	60,000

TABLE 9.7 FLOW CAPACITY OF CENTRAL TRUNK SEWER FROM S1 PUMPING STATION TO SEA

N° of sewer	Internal Diameter (mm)	Distance (m)	Gradient (%0)	Volocity m/s	Quantity of flow m3/s	Type of Flow	Design Sanitary Wastewater m3/s in 1998	Design Sanitary Wastewater m3/s in 2003	Remarks
S1 Pumping Station									
1	1000	622	-	0.96	0.76	Pressure	0.76	2.09	A
				2.66	2.09				
2	1200	130	12.00	3.8	4.298	Gravity	0.76	2.09	A
3	1400	45	0.44	0.77	1.195	Gravity	0.76	2.09	B
4	1400	45	2.00	1.73	2.663	Gravity	0.76	2.09	A
5	1400	80	0.90	1.15	1.77	Gravity	0.76	2.09	B
6	1400	550	2.00	1.73	2.663	Gravity	0.76	2.09	A
7	1800	40	3.30	2.66	6.642	Gravity	0.76	2.09	A
8	1800	800	0.60	1.09	2.774	Gravity	0.76	2.09	A
9	1800	665	1.00	1.45	3.69	Gravity	0.76	2.09	A
10	2000	70	1.00	1.55	4.869	Gravity	0.76	2.09	A
7J1 Pumping Station									
11	800	150	-	2.75	1.38	Pressure	1.38	2.81	A
				5.59	2.81				
12	1400	140	1.70	1.58	2.432	Gravity	1.38	2.81	C
13	1400	625	2.70	2	3.079	Gravity	1.38	2.81	A
14	1400	510	2.00	1.73	2.663	Gravity	1.38	2.81	C
15	1800	340	1.70	1.86	4.733	Gravity	1.38	2.81	A
16	1800	95	2.35	2.18	5.547	Gravity	1.38	2.81	A
17	1800	806	1.10	1.5	3.817	Gravity	1.38	2.81	A
18	2.70 x 1.00	8.5	level	0.51	1.38	Pressure	1.38	2.81	A
				1.04	2.81		1.38	2.81	
19	1800	1905	1.10	1.5	3.817	Gravity	1.38	2.81	A
Koumassi Pumping Station									
20	1400	2600	-	1.21	1.87	Pressure	1.87	3.38	A
				2.2	3.38				
21	1200	1200	-	1.65	1.87	Pressure	1.87	3.38	A
				2.99	3.38				

Remark:

A: enough capacity in 2003
B : capacity more than 80% in 2003
C : insufficient capacity in 2003

TABLE 9.8 REQUIRED PUMP CAPACITY IN 2003

Name of P/S	Pump Type	Description	Required No of Pump	Capacity of Pump (m3/S)	Design Wastewater in 2003 (m3/s)	Remark
S1 P/S	Vertical Axis Pump	0.35m3/s x 15m ($0.576m^3/s$ x 8.4m)	6 (2)	2.1	2.09	Four additional pumps will be required
7J1 P/S	Vertical Axis Pump	0.47m3/s x 12m ($0.53m^3/s$ x 10.2m)	6 (3)	2.82	2.81	Four additional pumps will be required
Koumassi Pre-Treatment Plant	Screw Pump	0.91m3/s x 4m ($0.91m^3/s$ x 4m)	4 (2)	3.64	3.38	Two additional pumps will be required
	Submerged Pump	0.91m3/s x 20m ($0.45m^3/s$ x 8m)	4 (4)	3.64	3.38	All existing pumps should be replaced by new ones with higher head

( ) : Existing pump capacity and number of existing pump

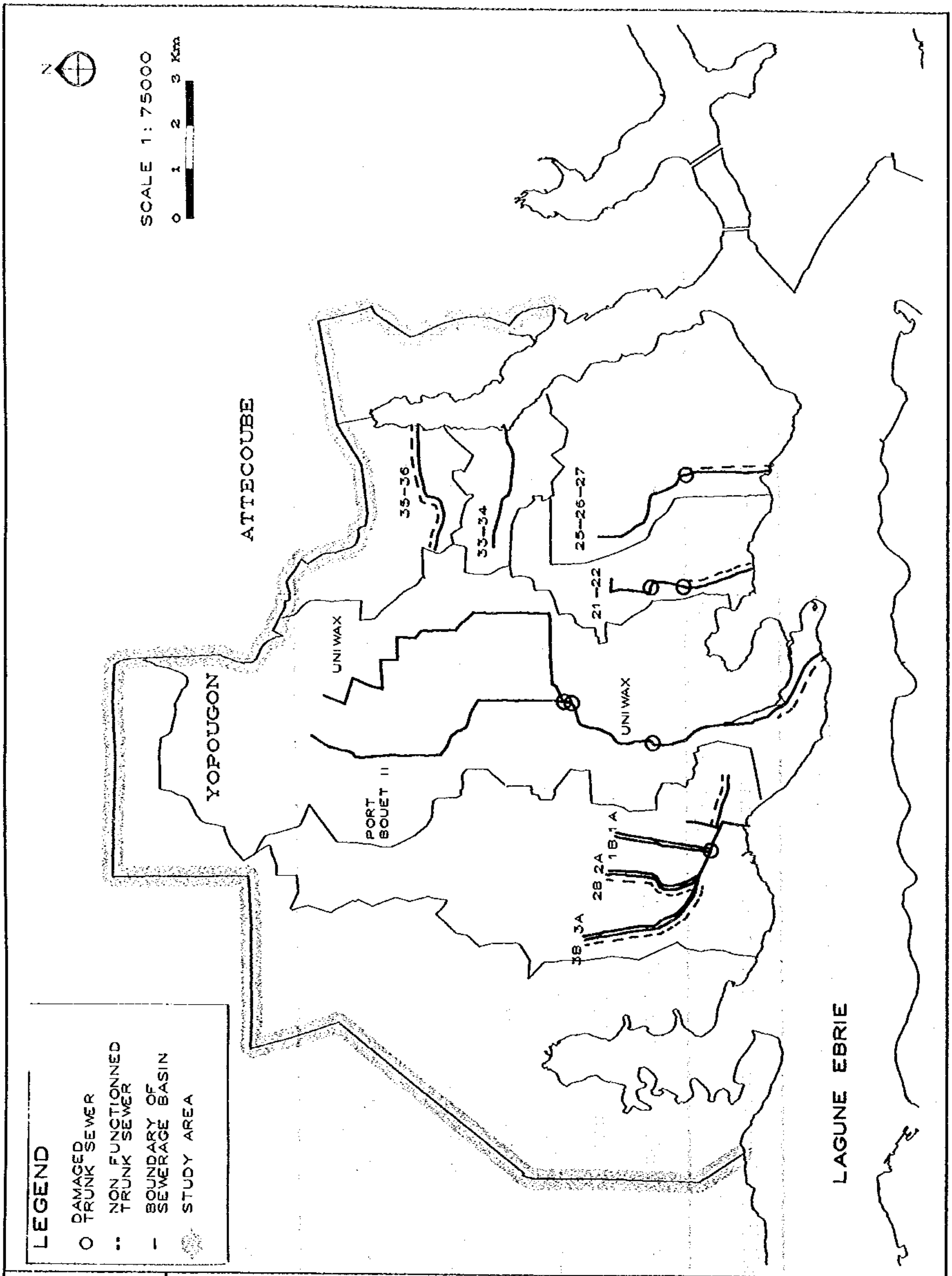

FIG. 9.1	EXISTING CONDITIONS OF SEWERAGE NETWORK IN STUDY AREA

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT
OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

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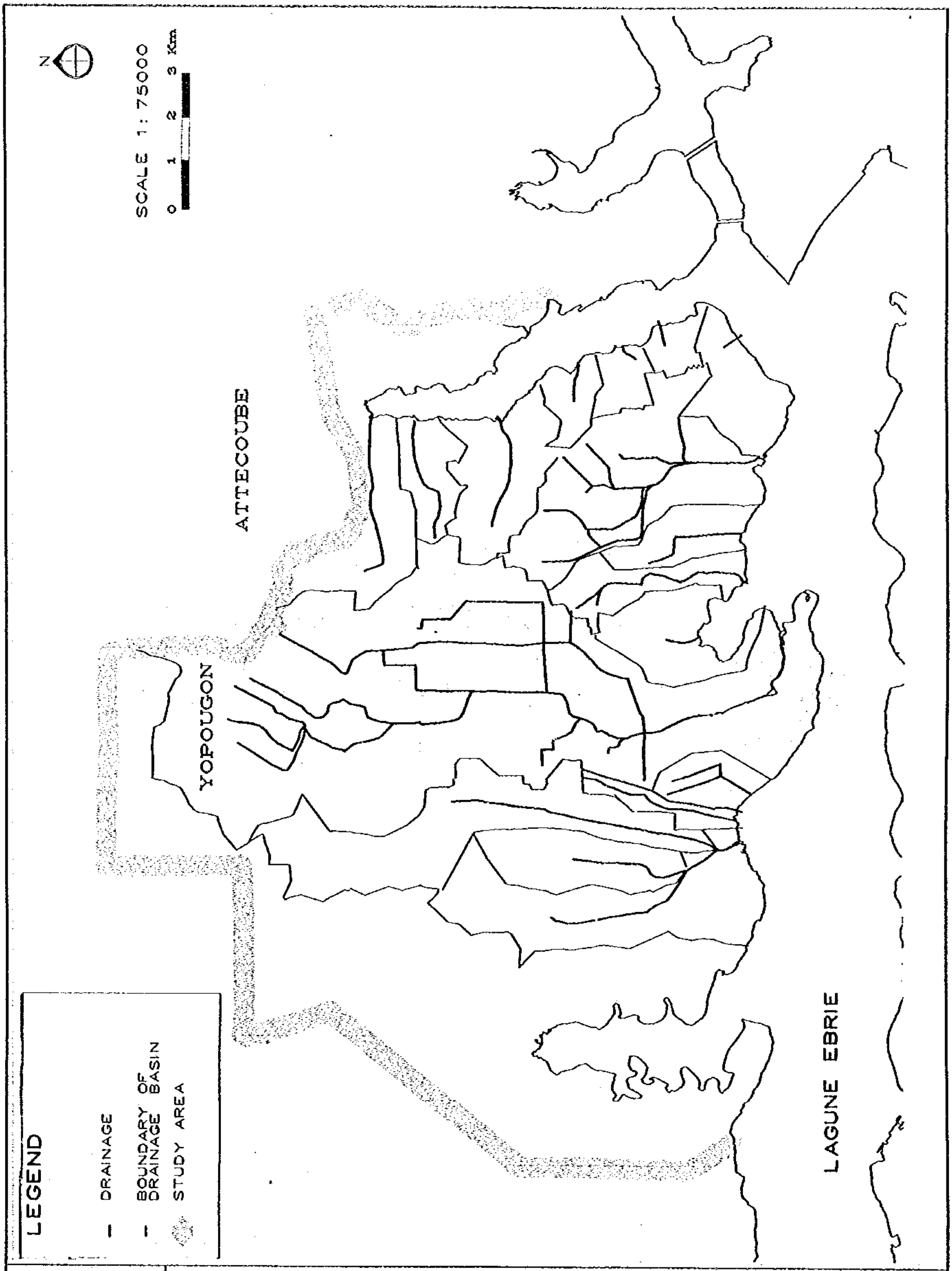


FIG. 9.2 CATCHMENT AREA OF EACH DRAINAGE BASIN

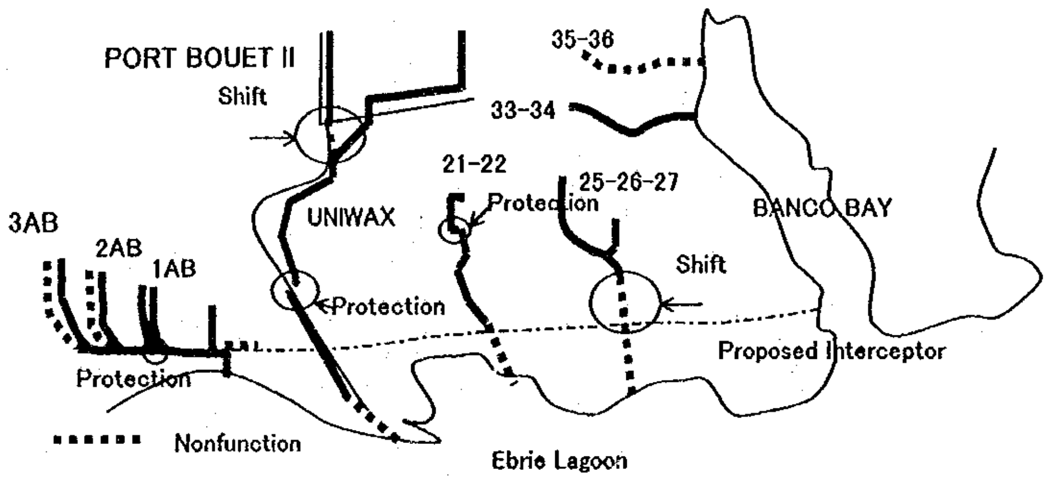


FIG. 9.3	LOCATION OF DAMAGED SEWERS

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

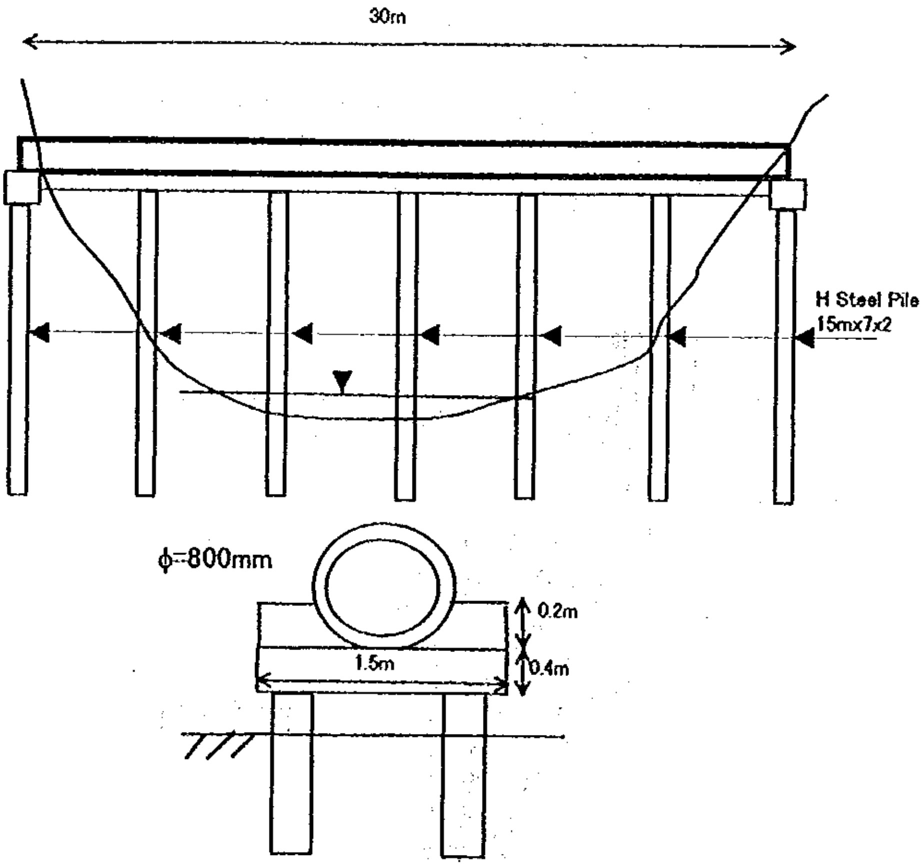
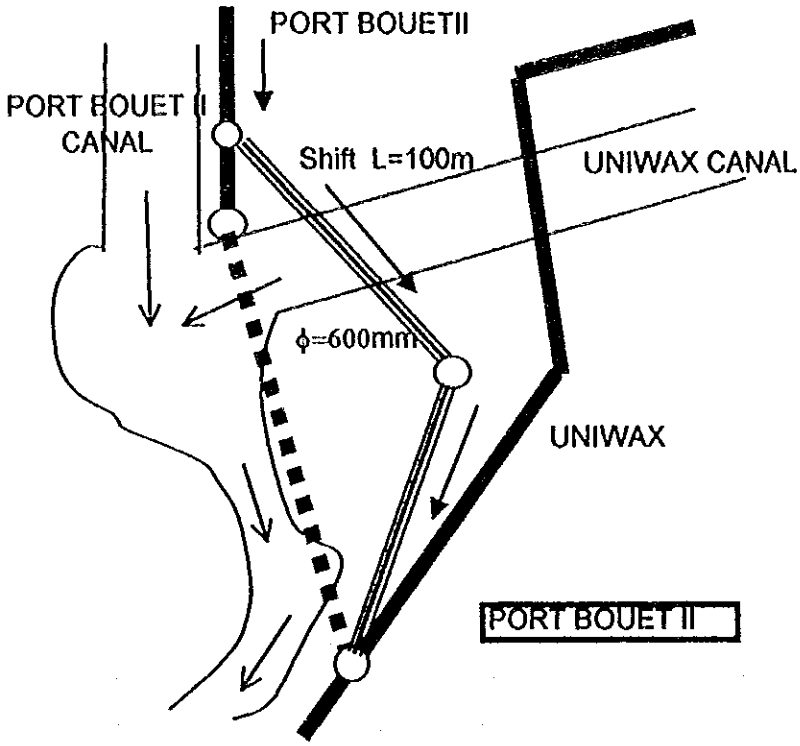


FIG. 9.4	RECONSTRUCTION PLAN OF SEWER PIPE BRIDGE OF UNIWAX TRUNK SEWER

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE



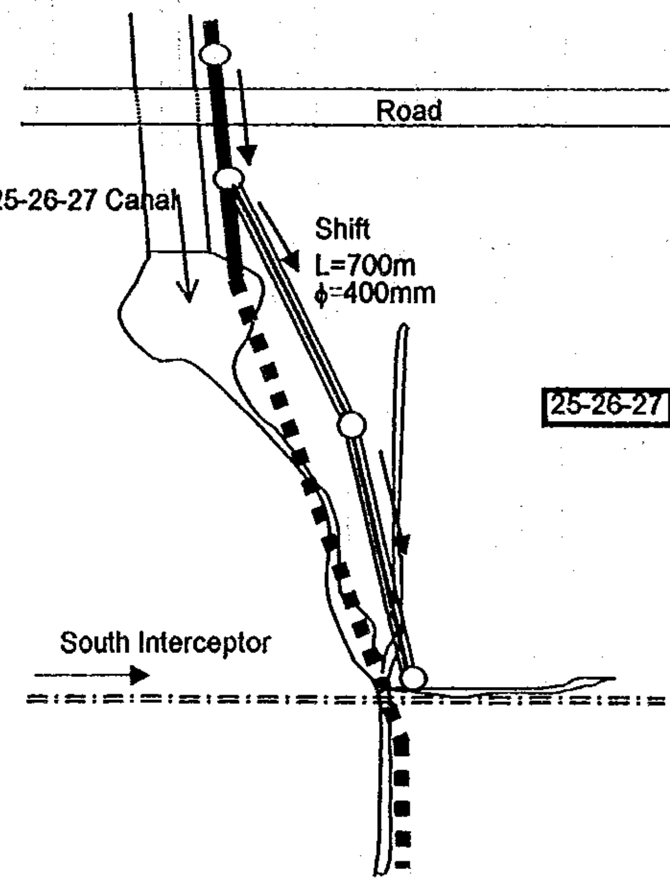


FIG. 9.5	LAYOUT OF NEW SEWER ROUTES OF PORT BOUET II AND 25-26-27 TRUNK SEWER

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

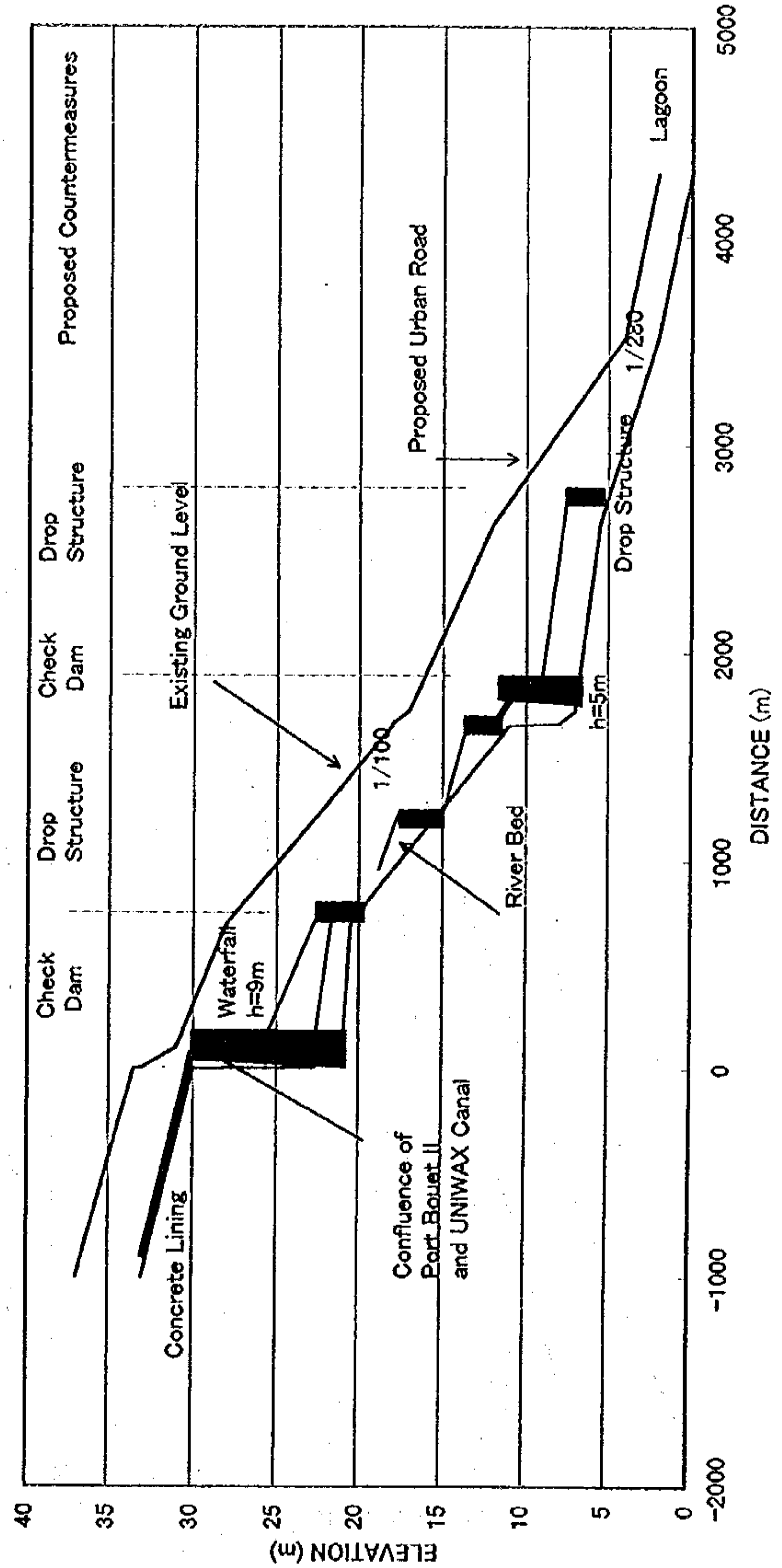


FIG. 9.6	POSSIBLE COUNTERMEASURES FOR UNIWAX CANAL

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT
OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

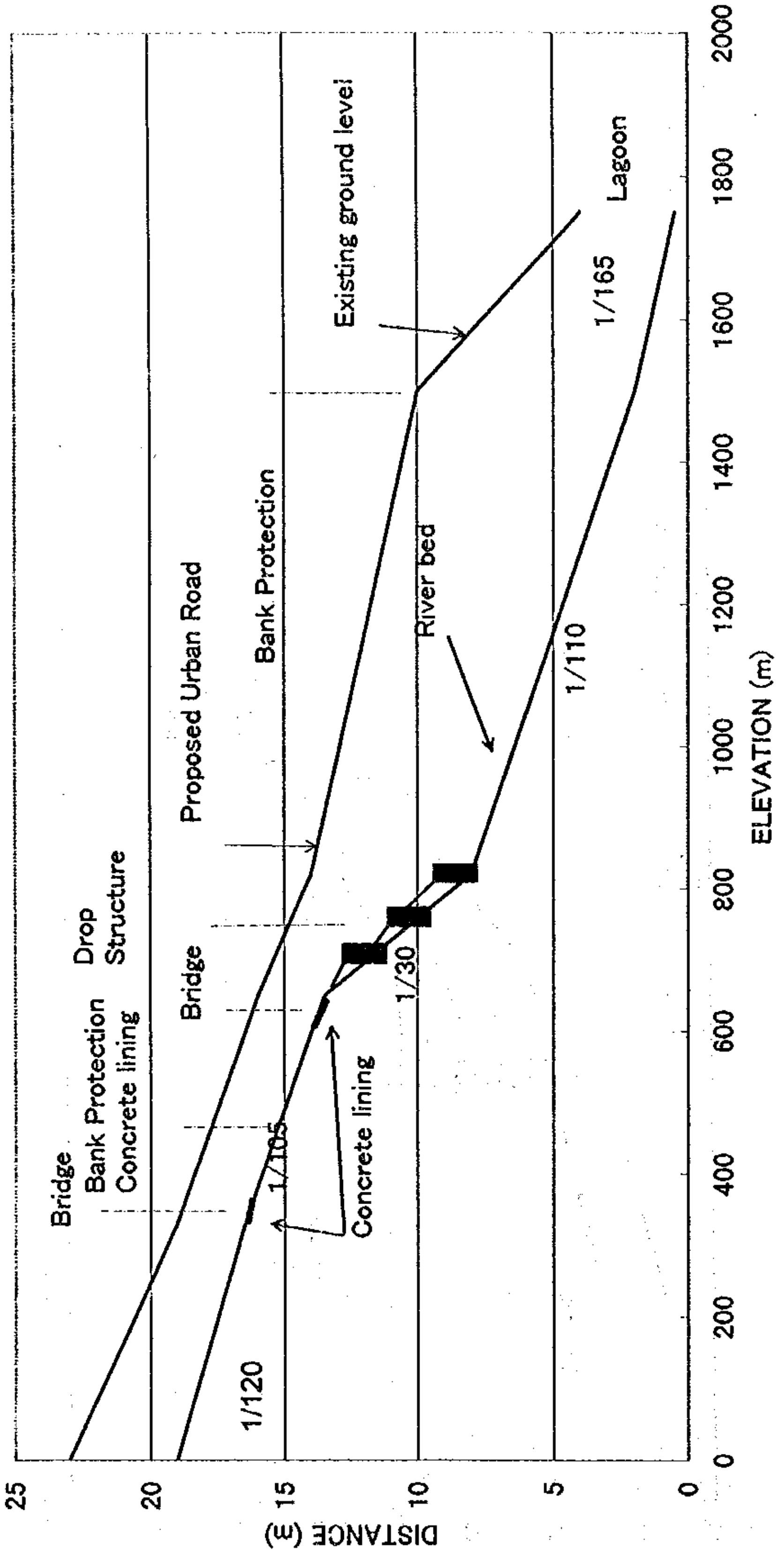


FIG. 9.7	POSSIBLE COUNTERMEASURES FOR 21-22 CANAL

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

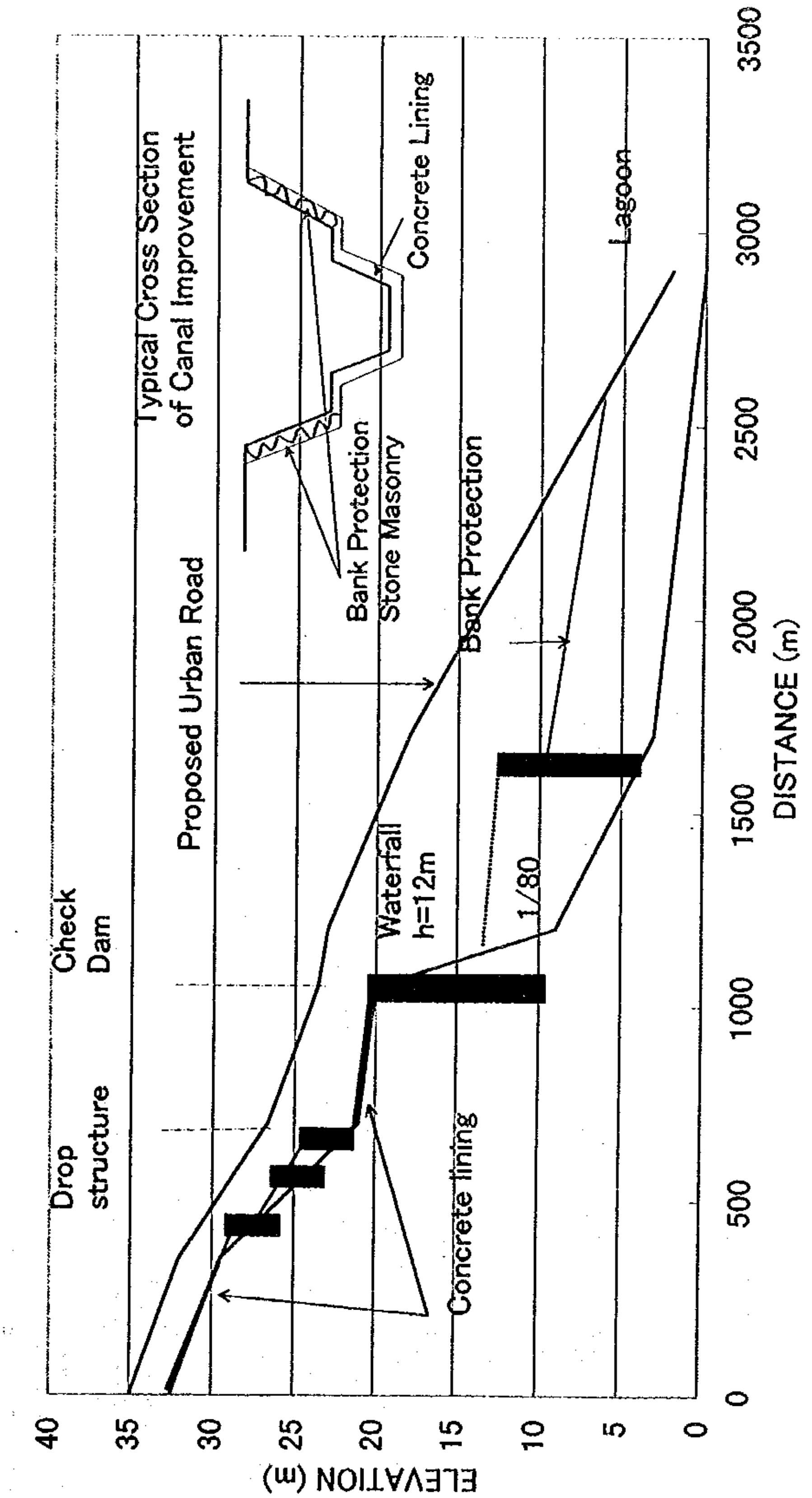


FIG. 9.8	POSSIBLE COUNTERMEASURES FOR 25-26-27 CANAL

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT
OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

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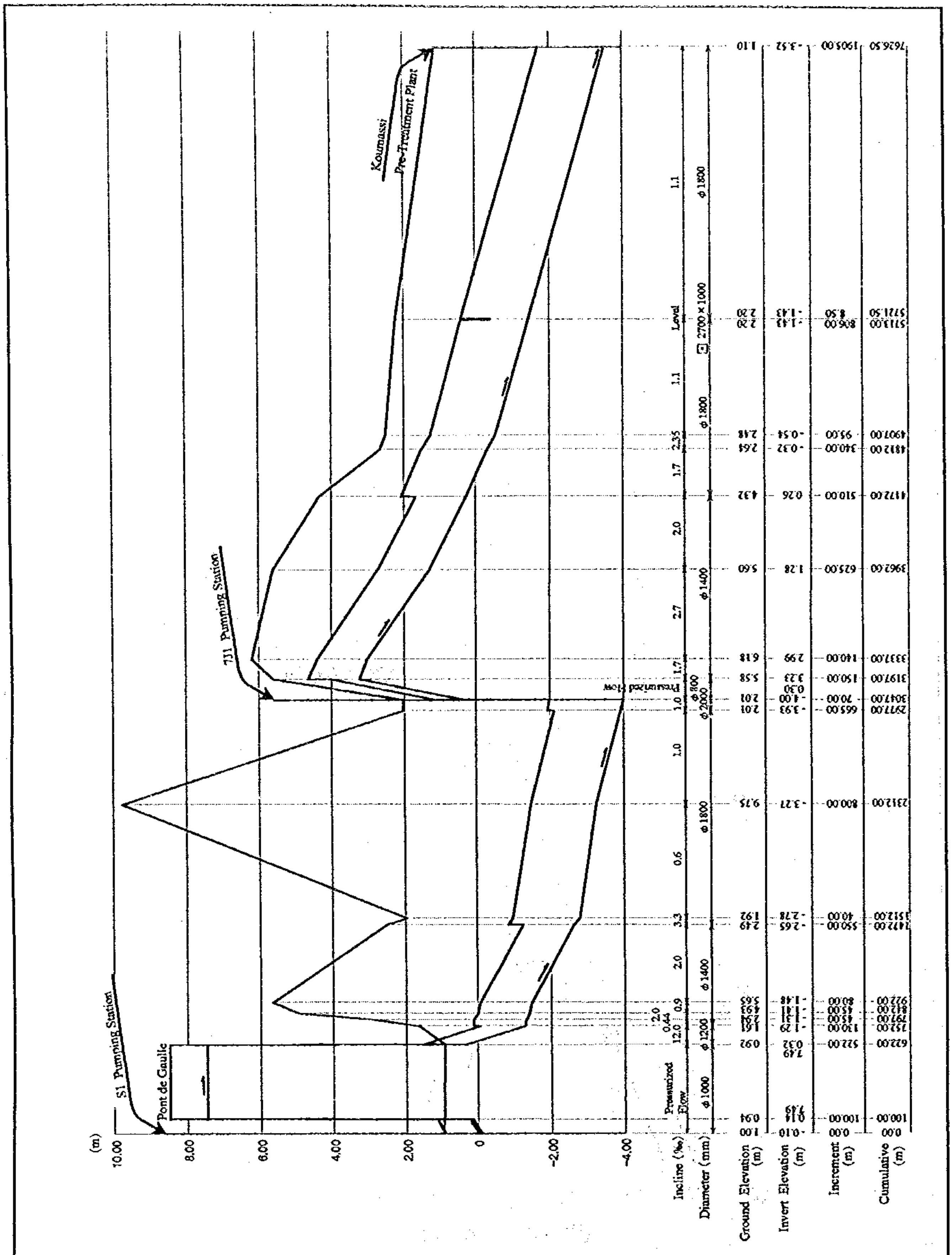

FIG. 9.9	LONGITUDINAL PROFILE OF CENTRAL TRUNK SEWER BETWEEN S1 P/S AND KOUMASSI PRE-TREATMENT PLANT

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT
OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

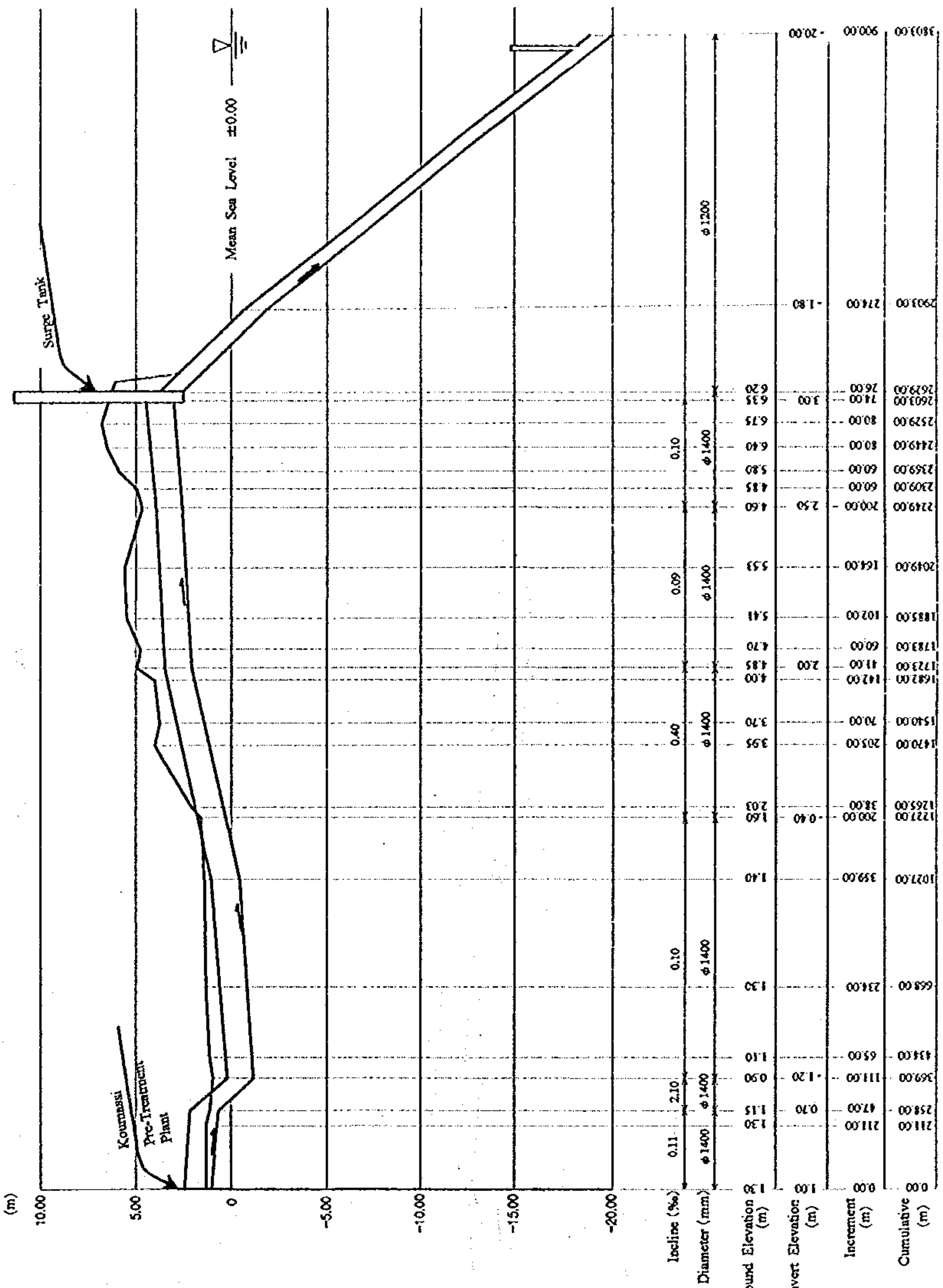

FIG. 9.10	LONGITUDINAL PROFILE OF SEWERAGE PIPE LINE BETWEEN KOUMASSI PRE-TREATMENT PLANT AND OCEAN OUTFALL

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

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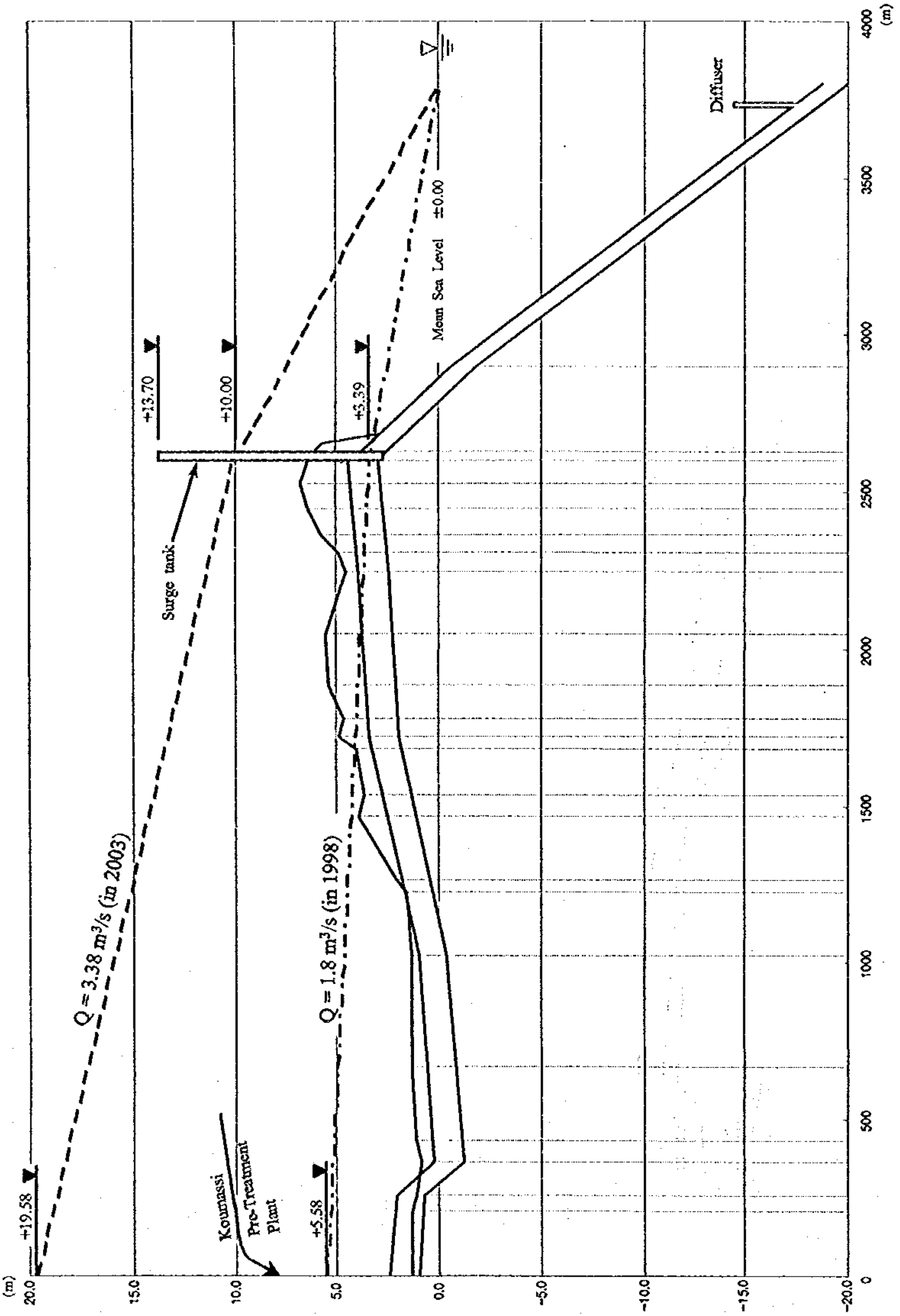


FIG. 9.11	HYDRAULIC GRADIENT OF SEWAGE FLOW BETWEEN KOUMASSI PRE-TREATMENT PLANT AND OCEAN OUTFALL

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

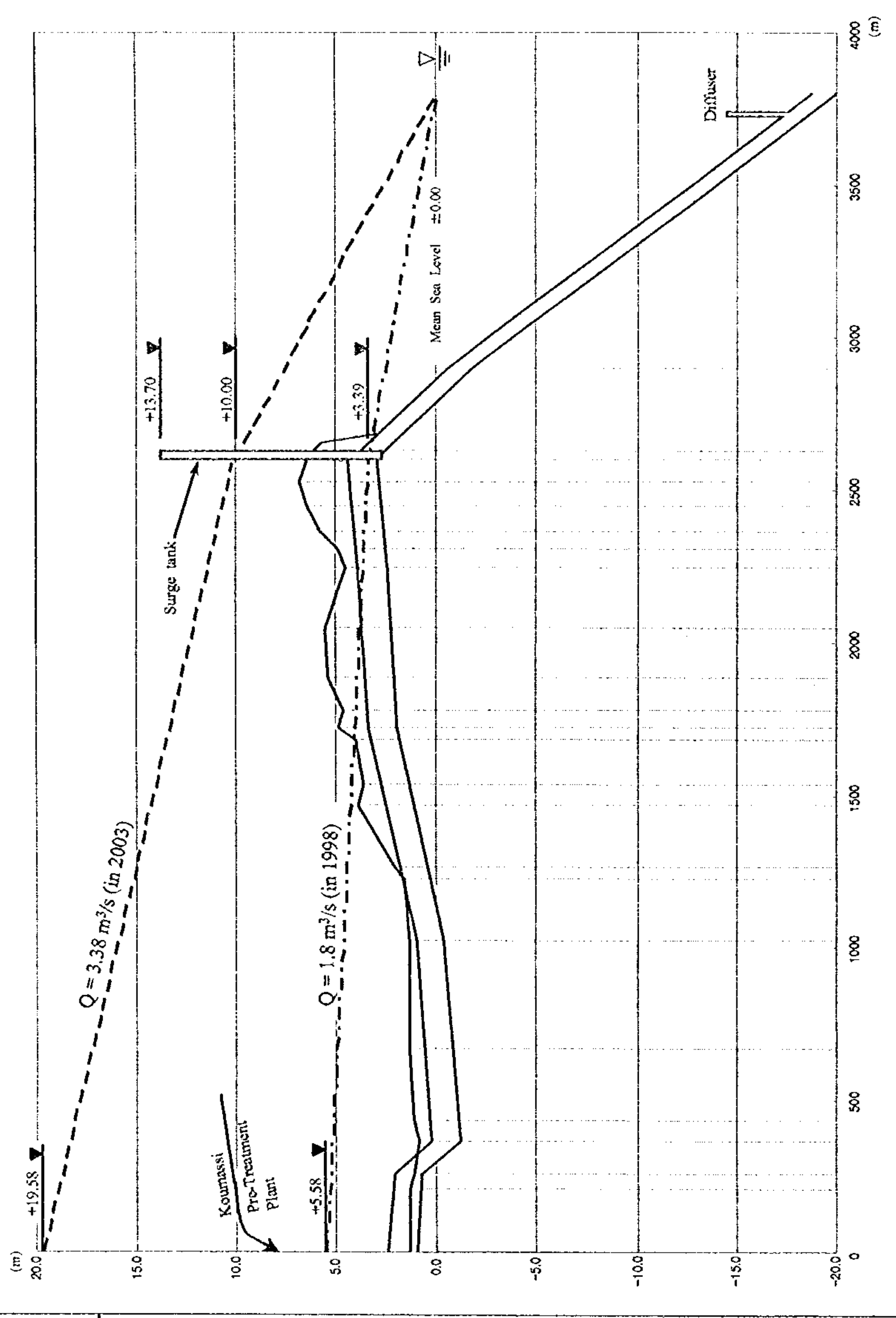


FIG. 9.11	HYDRAULIC GRADIENT OF SEWAGE FLOW BETWEEN KOUMASSI PRE-TREATMENT PLANT AND OCEAN OUTFALL

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

CHAPTER 10

INITIAL ENVIRONMENTAL EXAMINATION

CHAPTER 10 INITIAL ENVIRONMENTAL EXAMINATION

10.1 Environmental Condition

In the Study Area, the strong population growth and inadequate infrastructure services have been causing extensive and serious environmental problems. Inefficient solid waste collection and disposal facilities are contributing to environmental degradation such as blocking of street drains, flooding, odor and spread of disease. Accumulation of eroded soils, plants, garbage etc. in the drainage canals without any maintenance is contributing to breeding ground for flies and vermin, blocking of flow, foul odors and visual offense. The natural drainage of the dumping ground in Attécoubé is towards the lagoon creating the risks from leachates. The dumping ground is not well developed, not controlled and are not within the environmental standards. In addition, there are many illegal dumping sites in the area causing odors and other offensive problem.

1) Existing Sewerage System

The existing sewerage system project, which consists of six trunk sewers, was not completed. Therefore, the wastewater of the Study Area could not be disposed of to the Gulf of Guinea as per the Master Plan. The trunk sewers are discharging wastewater into the lagoon, resulting in high pollution of the lagoon water, and posing a serious threat to the environment and the sanitary condition of the communities.

Most of the trunk sewers are installed parallel with the drainage canals and some crosses the unfinished-drainage canals downstream. The sewers that had passed through the unfinished-drainage are washed away due to insufficient foundation, heavy soil erosion and the current of the drainage water. Also, inadequate maintenance over the years has caused the choking of some manholes and sewers with garbage, litters, solids, etc..

2) Existing Drainage System

For improvement of the drainage system, the construction of concrete lining for the drainage was started from upstream. However, the construction has not finished in downstream until now. This has exacerbated the erosion of downstream land. During rains, soil erosion takes place in the unfinished-drainage canals in downstream. Due to the continuous erosion over the years, unfinished-drainage has gone deeper than 10 m and wider than 5-8 m. This led to the collapse of the sewer that had crossed the unfinished-drainage.

10.2 General Scope of Environmental Concern

The Initial Environmental Examination has been undertaken to evaluate the impacts that may result from the proposed Project. This examination includes detailed evaluations of the existing reports and investigations of the environmental criteria and standards as well as laws, rules and regulations. On-site inspections were also conducted to all relevant aspects of the Study. The Study Team interviewed the concerned ministry officials and staff of the different institutions involved in the environmental protection and conservation for additional information.

After thorough investigations, the Study Team has found seven critical concerns that must be thoroughly addressed and evaluated, namely;

i) Resettlement of inhabitants
ii) Pollution during installation of interceptor across the Banco Bay
iii) Pollution from wastewater disposal in the Gulf of Guinea
iv) Surplus excavated material disposal problem
v) Odors and screenings/grit disposal problem
vi) Effect of industrial wastewater on the material of the sewer
vii) Regulations and institutions related to environment/water sector management

Apart from these concerns, excavation, and construction of interceptor and pumping stations are expected to result in temporary adverse impact (air pollution, traffic disturbance, buried public facilities disturbance, etc). However, these effects can be mitigated through awareness of environmental concerns during the design and construction stage of the Project.

The objectives of the sewerage facilities are to improve public health, and sanitation and environmental condition. The proposed sewerage facilities project imparts a strong positive (beneficial) impact on the living environment of the people of Abidjan in general.

Seven critical concerns as mentioned-above are evaluated as follows:

10.2.1 Resettlement of Inhabitants

The path of the proposed interceptor is the urban road, which is expected to be completed in year 2002 under the Sea Port Plan. However, according to Ministère des Infrastructures Economique, a portion of the road from the Banco Bay to the vicinity of the power plant in Azito (about 5.4 km) is expected to be completed in year 2001. There are some scattered houses in the vicinity of the proposed pumping stations. The exact number of the households to be resettled will depend on the final chosen location.

10.2.2 Pollution during Installation of Interceptor across Banco Bay

A thick deposit of sludge underlies the Banco Bay, which is 5 km in length, 0.7 km in width and has about 10 m water depth. Accumulation of sludge is the result of pollutants that are coming by a variety of sources, including domestic, industrial and agricultural sources in addition to garbage, eroded soils, plants etc that come along with run-off water.

The diffusion of silts in the waterway during the installation of interceptor across the Bay may damage the fish habitat and ecology of the Bay. However, the pile-supported pipe laying method proposed in the Study will eliminate or minimize the diffusion of silts in the waterway. Moreover, the total construction across the Bay will be divided into stages. The length of each stage could be decided based on the final location of interceptor in the Bay and use of waterway for navigation. The construction area of each stage could be isolated with the waterway by enclosing it with sheets to minimize further the diffusion of silts in the waterway.

10.2.3 Pollution from Wastewater Disposal in Gulf of Guinea

After the completion of the proposed Project, the total amount of wastewater discharged into the Gulf of Guinea through the ocean outfall will be increased substantially. The wastewater, which composed of domestic, commercial and industrial wastewater, is discharged to the ocean only after a simple pre-treatment at the Koumassi Sewage pre-treatment plant in which minimal amount of pollutant load is removed. The wastewater contains human and hospital waste, which poses a public health hazard through parasitic infections and various waterborne diseases. The harmful effects to the aquatic life in the Gulf of Guinea may occur due to the discharged of the untreated domestic, commercial and industrial wastewater.

10.2.4 Surplus Excavated Material Disposal Problem

The interceptor will be installed after the construction of the planned urban road. Consequently, a large amount of surplus excavated material after the backfill will be generated. However, there is enough open space in the Study Area to dispose of the surplus excavated material without any problem.

10.2.5 Odors and Screenings/Grit Disposal Problem

After the completion of the Project, odors and screenings/grit disposal problem will occur from the pumping stations. A careful attention was given to the control of odors in the design of the pumping stations. In the manhole type pump station under hermetically condition and deposits, sulfides which is the principal cause of odor could be generated easily. To prevent odors problem, ventilation pipe for suction and exhaust will be installed. There are some scattered houses in the vicinity of the proposed pumping stations. In the future, it is expected that more houses will be built around the simplified and standard type pumping stations. The following countermeasures are recommended in the design of the pumping stations:

- The pumping stations should secure wider area than required for the pumping station construction only to install deodorization etc. device in the future.
- Green zone should be developed around the pumping stations to mitigate odors diffusion in the surroundings
- The area of the pumping station should be fenced with wire or steel panels.
- The odors from the grit chambers, waste collection facilities, and pump-well should be exhausted using fan and exhaust tower in the future.

The five pumping stations are proposed to be constructed along the proposed interceptor. The quantity of grit and screenings generated in the pumping stations is expected to be approximately 0.005 m3 grit and 0.001 m3 screenings per 1,000 m3 of sewage inflow. The total amount of sewage volume in year 2003 is estimated to be 61,000 m3/day. Consequently, the quantity of grit and screenings from the proposed pumping stations will be around 0.31 m^3 and 0.06 m^3 per day, respectively, which can be disposed of in the sanitary landfill since the amount is not much to cause any extra problem to the landfill.

10.2.6 Effect of Industrial Wastewater on Material of Sewer

In Abidjan, the prevailing practices of most of the industries are direct discharge to the sewerage system almost without any treatment. The untreated industrial wastewater may be containing some harmful compounds to cause corrosion of the sewer. A careful attention was given for prevention of corrosion in the design of the proposed interceptor.

Côte d'Ivoire has norms and standards defined in terms of concentration and flux both. The Ivorian Government has recently taken several actions, including environmental legislation and regulations, strengthening of institutions etc. to control the pollution. The new legislation, the Code of Environment (Le Code de l'Environment Law No. 96-766 of November 3, 1996), forecasts the Principle of Polluter-Pay, which will lead, after its implementation, the industries to be more involved to control the industrial pollution through the establishment of treatment facilities. The new regulations and legislation under formulation is expected to be enforced strictly to prevent discharge of industrial wastewater unacceptable to the sewerage system in the future.

10.2.7 Regulations and Institutions related to Environment/Water Sector Management

A rigid legal and regulatory framework and the establishment of standards and criteria are necessary to achieve the desired environmental outcomes that will affect environmental protection. In Côte d'Ivoire, there are no water quality standards for raw water used for drinking, standards for protection of aquatic ecosystem in fresh water, standards for protection of aquatic ecosystem in marine waters, and standards for recreation and aesthetics values. Because of this lack of standards, waterbodies in the country have not been classified as to their most beneficial or intended use. The relevant acts and regulations existing and under preparation, treaties, and organization pertaining to the protection and conservation of the water resources/environment in Côte d'Ivoire are presented in APPENDIX H of the Supporting Report.

CHAPTER 11

SELECTION OF URGENT WORKS FOR FEASIBILITY STUDY

CHAPTER 11 SELECTION OF URGENT WORKS FOR FESIBILITY STUDY

11.1 Proposed Facilities of Revised Master Plan

The proposed sewerage facilities of the interceptor based on the revised master plan are as follows:

1) Trunk sewers to be connected to the interceptor

1-2-3 A.B Trunk Sewer: Design Flow	Q=0.233 m^3/s
UNIWAX Trunk Sewer:	Q=0.537 m^3/s
21-22 Trunk Sewer:	Q=0.118 m^3/s
25-26-27 Trunk Sewer:	Q=0.104 m^3/s
33-34 Trunk Sewer:	Q=0.027 m^3/s
35-36 Trunk Sewer:	Q=0.051 m^3/s

2) Characteristics of the proposed facilities

Interceptor:

between 1-2-3 AB T/S and UNIWAX T/S	L = 1.6 km, Ø = 500 mm
between UNIWAX T/S and 21-22 T/S	L = 2.0 km, Ø = 800 mm
between 21-22 T/S and 25-26-27 T/S	L = 1.6 km, Ø = 900 mm
between 25-26-27 T/S and Exist. T/S	L = 4.7km, Ø = 900 mm
exist. T/S along Bd. de la paix	L = 2.4 km, Ø = 1000 mm
from exist. T/S to S1 Pumping Station	L = 1.6 km, Ø = 900 mm
between 33-34 T/S and BW junction	L = 1.0 km, Ø = 250 mm
between 35-36 T/S and 33-34 T/S	L = 1.2 km, Ø = 200 mm

Pumping Station:

P1 P/S (at 1-2-3 AB T/S)	Number of pump: 4	
	Capacity: 0.233 m^3/s	Total head: 38 m
P2 P/S (at UNIWAX T/S)	Number of pump: 4	
	Capacity: 0.537 m^3/s	Total head: 27 m
P3 P/S (at 21-22 T/S)	Number of pump: 3	
	Capacity: 0.118 m^3/s	Total head: 20 m

P4 P/S (at 25-26-27 T/S)	Number of pump: 3	
	Capacity: 0.104 m^3/s	Total head: 11 m
P5 P/S (at 33-34 T/S)	Number of pump: 3	
	Capacity: 0.027 m^3/s	Total head: 16 m
P6 P/S (at 35-35 T/S)	Number of pump: 3	
	Capacity: 0.051 m^3/s	Total head: 26 m

The layout of the proposed facilities is shown in Fig.13.1.

11.2 Selection of Objective Sewerage Facilities for Feasibility Study

The sewerage facilities proposed by the revised master plan are planned for the target year of 2003 and the entire Project, in principle, should be implemented in a short term. However, it is not realistic under the conditions of a low sewer connecting ratio and a poor sewage collecting system in the area.

Hence, the objective facilities for the urgent works were selected considering effective use of the facilities as follows:

1) Trunk sewers to be connected with the interceptor

- 1-2-3 A.B Trunk Sewer
- UNIWAX Trunk Sewer
- 21-22 Trunk Sewer
- 25-26-27 Trunk Sewer
- 33-34 Trunk Sewer

As for the 35-36 Trunk Sewer, the total length of the sewer does not function and no inflow of sewage is recognized. This trunk sewer is recommended to be connected after rehabilitation of the sewer together with the drainage canal and soil erosion control work of the basin.

2) Characteristics of the proposed priority facilities

Interceptor:

between 1-2-3 AB T/S and UNIWAX T/S	L=1.6 km,Ø=500 mm
between UNIWAX T/S and 21-22 T/S	L=2.0 km, Ø=800 mm
between 21-22 T/S and 25-26-27 T/S	L=1.6 km, Ø=900 mm
between 25-26-27 T/S and Exist. T/S	L=4.7km, Ø=900 mm
exist. T/S along Bd. de la paix	L=2.4 km, Ø=1000 mm
from exist. T/S to S1 Pumping Station	L= 1.6 km, Ø =900 mm
between 33-34 T/S and BW junction	L= 1.0 km, Ø=250 mm

Pumping Station:

P1 P/S (at 1-2-3 AB T/S)	Number of pump: 3	
	Capacity: 0.233 m^3/s	Total head: 38 m
P2 P/S (at UNIWAX T/S)	Number of pump: 3	
	Capacity: 0.537 m^3/s	Total head: 27 m
P3 P/S (at 21-22 T/S)	Number of pump: 3	
	Capacity: 0.118 m^3/s	Total head: 20 m
P4 P/S (at 25-26-27 T/S)	Number of pump: 3	
	Capacity: 0.104 m^3/s	Total head: 11 m
P5 P/S (at 33-34 T/S)	Number of pump: 2	
	Capacity: 0.027 m^3/s	Total head: 16 m

The priority facilities for urgent works are shown in Fig. 12.1

CHAPTER 12

PRELIMINARY DESIGN OF SEWERAGE FACILITIES

CHAPTER 12 PRELIMINARY DESIGN OF SEWERAGE FACILITIES

12.1 Sewerage System Layout

The general layout of sewerage system is shown in Fig. 12.1. The major facilities in this Study are the South, West, and East Interceptors. Table 12.1 describes their locations and lengths, necessary pumping stations and others associated facilities.

12.2 Interceptor

12.2.1 South and West Interceptors

There are two types of flow systems in this project; the pressure and gravity flow. For the interceptor in Yopougon, where the south and west interceptors are planned, the pressure flow system is adopted.

Regarding installation depth for the interceptor, it is considered to use at least 1.5 m of earth covering. However, the depth is dependent on the soil condition, pavement and traffic load. The open cut method is recommendable as the construction method for the interceptor because of cost and ease of construction. A typical cross section of interceptor is shown in Fig. 12.2 and Fig. 12.3.

As for material for interceptor, ductile cast iron pipe lined with mortar is recommended because of the pressure flow and ease of installation. A push on joint type is recommended for ductile cast iron pipe.

As interceptor appurtenances, an air relief valve, blow-off valve and blow-off chamber should be installed. Air relief valves are provided in long pipelines to permit the release of air which accumulates at high points and to prevent negative pressures from building up when the lines are drained. These valves are automatic in operation, opening to release accumulated air and closing when the pipe is full.

Provision of the sludge rejection is indispensable for the removal of deposits in the interceptor.

A blow-off valve and a blow-off chamber should be considered as a sludge rejection facility, which are installed at the lower part where sludge can be easily collected. If there is no drainage to be discharged, provision of a small storage pit of about 100 m^3 should be required.

12.2.2 Interceptor Crossing Banco Bay

The geological conditions of the Banco Bay crossing site were estimated based on the previous geological survey results carried out for bridge planning in 1979.

In the Banco Bay crossing section, sewer pipes will be installed on the plate supported by three piles having a maximum length of 45 m driven into the foundation layer.

The total length of the under water section will be about 800 m. The pipes will be connected to about a 30 m length on the land and installed on the plate and fixed under water.

The distance between two supports (24 m) was decided based on the strength of the pipes and ease of construction.

The steel pipe is recommended because of ease of installation. These pipes are protected by a bitumen coating outside and by an epoxy resin containing glass fibers against corrosion inside. The details of the supporting plate and foundation piles are shown in Fig. 12.4 and Fig. 12.5.

12.2.3 East Interceptor

The flow system of this section will be gravity.
As for the material of the interceptor sewer pipes, a centrifugal reinforced concrete is recommended because of inner low pressure.
In this section, there is a previously installed sewer pipeline of about 2300 m long. This pipeline was constructed in 1990 based on the existing master plan.
The pipeline has enough flow capacity and is possible to use as a part of the proposed east

interceptor. The existing rubber joints, however, will be reinforced by epoxy resin and water swelling sealant against an expected low pressure in the pipe.

In the section of new construction, an open cut method and jacking method will be adopted to install the pipes. A jacking method will be used for the section of main road crossing near the Hou Phouet Boigny Bridge to avoid heavy traffic and underground structures under the bridge. In the remaining sections, an open -cut method will be used.
Typical cross section of interceptor is shown in Fig. 12.6.

12.3 Pumping Stations

12.3.1 Basic Conditions

The five (5) pumping stations together with the interceptor were selected as the priority project facilities. They are P1 (1-2-3 A/B T/S), P2 (UNIWAX T/S), P3 (21-22 T/S), P4 (25-26-27 T/S), and P5 (33-34 T/S) pumping stations.

The amount of wastewater in 2003 for each pumping station is shown in Table 12.2. The design hydraulic load for component facilities such as screens and grid chambers at P1 P/S and P2 P/S are summarized in Table 12.3.
The P3 and P4 pumping stations should be equipped with a simplified pit. P5 P/S will be of manhole type without pit and grit chamber.

12.3.2 Design of Pumping System

The pumping stations were planned based on the design criteria as discussed previously. The features of each pumping station are summarized in the following. Further details of the capacity and hydraulic computations of the pumping stations are shown in Appendix F in the Supporting Report.

1) P1, P2 pumping station

P1 and P2 pumping stations will be of standard type. These pump stations have a relatively large amount of wastewater flow compared to the other pumping stations and need high pump head. These pumping stations are composed of the following facilities:

(1) Screen

The function of the screen is to remove the garbage and the large floatable obstacles manually or automatically for protection of the pump.

(2) Grit chamber

The function of the grit chamber is to settle the grit in the channel for protection of the pump impellers.

(3) Wet-well

(4) Dry-well

A pump room should have enough space for easy removing of the pumps, the motors and other auxiliary equipment. An adequate ventilation system should be provided for the dry-well (pump room).

Drawings of P1 and P2 pumping stations are shown in Fig. 12.7 and Fig. 12.8.

2) P3, P4 and P5 pumping stations

The pump type of the P3, P4 and P5 pumping stations will be the submersible type by taking into account the amount of wastewater inflow. Generally, for small scale pumping, simplified type with a simplified pit and manhole type without a pit will be adopted.

The P3 and P4 pumping stations will be of a simplified type and P5 P/S will be the manhole type.

For submersible pumps, a flywheel will be one of the countermeasures against water hammer. The size of the submersible pump manhole should be decided upon by considering the space for two pump sets which are for operation and for stand-by. A manual screen should also be provided for protection of the pump.

Drawings of the P3, P4 and P5 pumping stations are shown in Fig. 12.9, Fig. 12.10 and Fig. 12.11.

12.3.3 Pump Operation Control

Each pumping station or unit will have at least one stand-by pump. The pumps will be designed to have sufficient capacity to handle wastewater flow in excess of the estimated maximum inflow. To prevent the intermittent operation of pumps, an instrumentation system, including warning sensors and indicators, should be provided at each pumping station.

12.3.4 Selection of Pump Type and Number

1) Selection of Pump Type

In selecting equipment for a pumping station, many different aspects of the pumping system must be considered. Evaluated factors are as follows:

(1) Design flow rates and flow ranges
(2) Location of a pumping station
(3) Force main design
(4) System head-capacity characteristics

After evaluation of these factor, the number and sizes of the pumps, the type of drive, and the optimum size of the force main will be selected.

Horizontal screw type of pumps will be applied for the S1 and S2 pumping station based on the above mentioned evaluation and the result of the water hammer analysis.

Submersible pumps will be applied for P3 P/S, P4 P/S and P5 P/S considering the design flow rate and its range.

2) Number of Pump

The number of pumps in the small type pumping station should be selected considering the following:

- Correspondence to the emergency
- Ease of maintenance
- Inflow rate of wastewater

The two to four units of pump are recommended. In this case, adoption of the same size pumps is also recommended.

Characteristics of each pumping station are shown in Table 12.4.

12.3.5 Analysis and Countermeasure of Water Hammer

The occurrence of water hammer in approximately a 6.0 km length of the interceptor is complicated because the sudden stopage of pumps due to power and machine failure and variation in inflow quantity at each pumping station. To prevent the occurrence of negative pressure inside the interceptor due to water hammer, the air valves and the surge tanks in the interceptor route together with the fly wheel to avoid the rapid stopage of the pump are provided. The strength of the interceptor corresponds to the rise and fall of pressure in the interceptor.

For the maximum water hammer, it was assumed that all pumps stopped simultaneously. The following cases were investigated and solved using a computer:

Case 1: No countermeasure against water hammer
Case 2: Countermeasure against water hammer using surge tank and flywheel.

The results of the above-mentioned cases are shown in Fig. 12.12, Fig. 12.13 and Fig. 12.14. According to the results, water column separation (becoming more than -10 m) occurs in Case 1. In case 2, it was decided upon to use a combination of surge tank and flywheel as a water hammer countermeasure.

1) Universal Surge Tank

According to the water hammer analysis a surge tank is required at three places. The capacity of the tanks is closely related to the water hammer. The optimum capacity of the tanks is decided upon by the repeated calculation of the water hammer analysis. The surge tanks will be placed on the high ground near the pumping stations. The tanks will be a circular type. The capacity of each surge tank is shown in Table 12.5. The features of surge tanks are shown in Fig. 12.15.

2) Regulation Tank

The sewage inflow over the long distance in the pressure interceptor under anaerobic condition may cause generation of sulfides. Therefore, it is important to take countermeasures for odor control and sulfides reduction at the discharge tank. Otherwise, carry of sulfides under anaerobic condition in the downstream gravity interceptor may result in its corrosion. To prevent this, a ventilation pipe for suction and exhaust should be installed at the discharge tank. Similar measures should be taken in a gravity interceptor.

12.3.6 Ventilation and Odor Countermeasures of Pumping Stations

In the manhole type pump station under hermetically conditions, and deposits of sulfides which is the principal cause of odor is easily generated. To prevent odor generation, ventilation a pipe for suction and exhaust should be installed.

In the future, it is expected that residences will be built around the pumping stations. The odor problem may occur in the operation of the pumping station. Therefore, it is necessary to consider the following countermeasures:

- The pumping stations should secure a wider area than required in order to perform the necessary construction to install a deodorization etc. device in the future.
- Steel panels to mitigate odor diffusion in the surroundings should be used as fences around the pumping stations..
- The odor from the grit chambers, waste collection facilities, and pump wells must be exhausted by using fans or exhaust towers in the future.

12.3.7 Operation and Maintenance

A cyclic start and stop system should be used as an operation control method, which is effective for keeping the electric motor's switch on-off frequency within permissible range and each pumps' operation frequency equal.

An electric generator facility is not necessary in the pumping station since the power supply from the electric company is reliable. Power failure are infrequent and each cut is relatively short. When the pump stops operating because of power failure, the overflow would be discharged into the existing pipe located at downstream of the pumping station.

The O&M of the collectors would be mainly the pumping station and its O&M and functional maintenance through periodic inspections. In terms of O&M and periodic inspections, the systemization based on the size and control method of the pumping station. It is also important to establish the structures that are able to feedback the historical experiences, such as accidents, in order to prevent future problems.

The method of operation, management, inspection has to be disclosed by manuals and rules. As a part of the establishment of the managerial structure, abnormal warning systems have to be installed for each pumping station where no one stays. The reporting of abnormal situations to the person responsible for the facility need the cooperation of the residents: Hence, to increase the recognition and enlightenment towards the sewerage system is indispensable.

The main maintenance work of pipelines is the removing of deposits and it is assumed that it would be carried out twice a year. The method for removing the deposit is to flush them out through the blow-off valve under high velocity by operating all of the installed pumps.

12.3.8 Foundation

The foundation of the pumping station should be constructed prudentially because the precise equipment such as pumps, motors, electrical panels and so on will be installed.
According to the soil survey at each proposed pumping station site, unsuitable soil layer for the bearing stratum was not observed. As a result of computation, the spread foundation is recommended.

TABLE 12.1 FACILITIES OF PROPOSED SEWERAGE SYSTEM

Interceptor

Name of Interceptor	Location		Distance (km)
	from	to	
South Interceptor	1-2-3 AB	UNIWAX	1.40
	UNIWAX	21-22	2.14
	21-22	25-26-27	1.57
	25-26-27	coast of Banco Bay	3.95
West Interceptor	33-34	coast of Banco Bay	0.9
Crossing Banco Bay	west edge of Banco Bay	east edge of Banco Bay	0.8
	east edge of Banco Bay	north edge of existing sewer	0.2
East Interceptor	north edge of existing sewer	south edge of existing sewer	2.30
	south edge of existing sewer	S1 P/S	1.58

Pumping Station

Name	Trunk Sewer to be connected
P1 P/S	1-2-3 AB
P2 P/S	UNIWAX
P3 P/S	21 - 22
P4 P/S	25 - 26 - 27
P5 P/S	33 - 34

Additional major facilities

- surge tank
- regulation tank
- air relief valve
- blow-off chamber

TABLE 12.2 DESIGN FLOW RATE OF EACH PUMPING STATION

Name of Pumping Station	Flow Rate in 2003 (m^3/s)
P1 Pumping Station	0.233
P2 Pumping Station	0.537
P3 Pumping Station	0.118
P4 Pumping Station	0.104
P5 Pumping Station	0.027

TABLE 12.3 DESIGN HYDRAULIC LOAD

Component Units	Hydraulic Load
1. Screens Velocity of flow though bars	0.5 to 0.8 m/sec
2. Grit chambers Surface loading Detention time Velocity of flow though channel	$1800m^3/m^2/day$ 30 to 60 seconds 0.3m/sec

TABLE 12.4 CHARACTERISTICS OF PUMP AT EACH PUMPING STATION

Pumping Station	Type of Pump	Descriptions	Quantity
P1 p/s	φ200 Horizontal Type Screw Volute Pump	$4.66^{m3/mm}$ x 38^{m} x 55^{kw}	3
P2 p/s	φ300 Horizontal Type Screw Volute Pump	$10.74^{m3/mm}$x27^{m}x110^{kw}	3
P3 p/s	φ200 Submersible Type Screw Volute Pump	$3.54^{m3/mm}$ x 20^{m} x 22^{kw}	3
P4 p/s	φ200 Submersible Type Screw Volute Pump	$3.13^{m3/mm}$ x 11^{m}x 11^{kw}	3
P5 p/s	φ100 Submersible Type Screw Volute Pump	$1.62^{m3/mm}$ x 16^{m} x 11^{kw}	2

TABLE 12.5 CAPACITY OF EACH SURGE TANK

Name of Surge Tank	T1	T2	T3
Diameter (m)	3.00	3.00	3.000
Height (m)	12.699	10.984	4.909
Capacity of Tank (m^3)	90	78	35

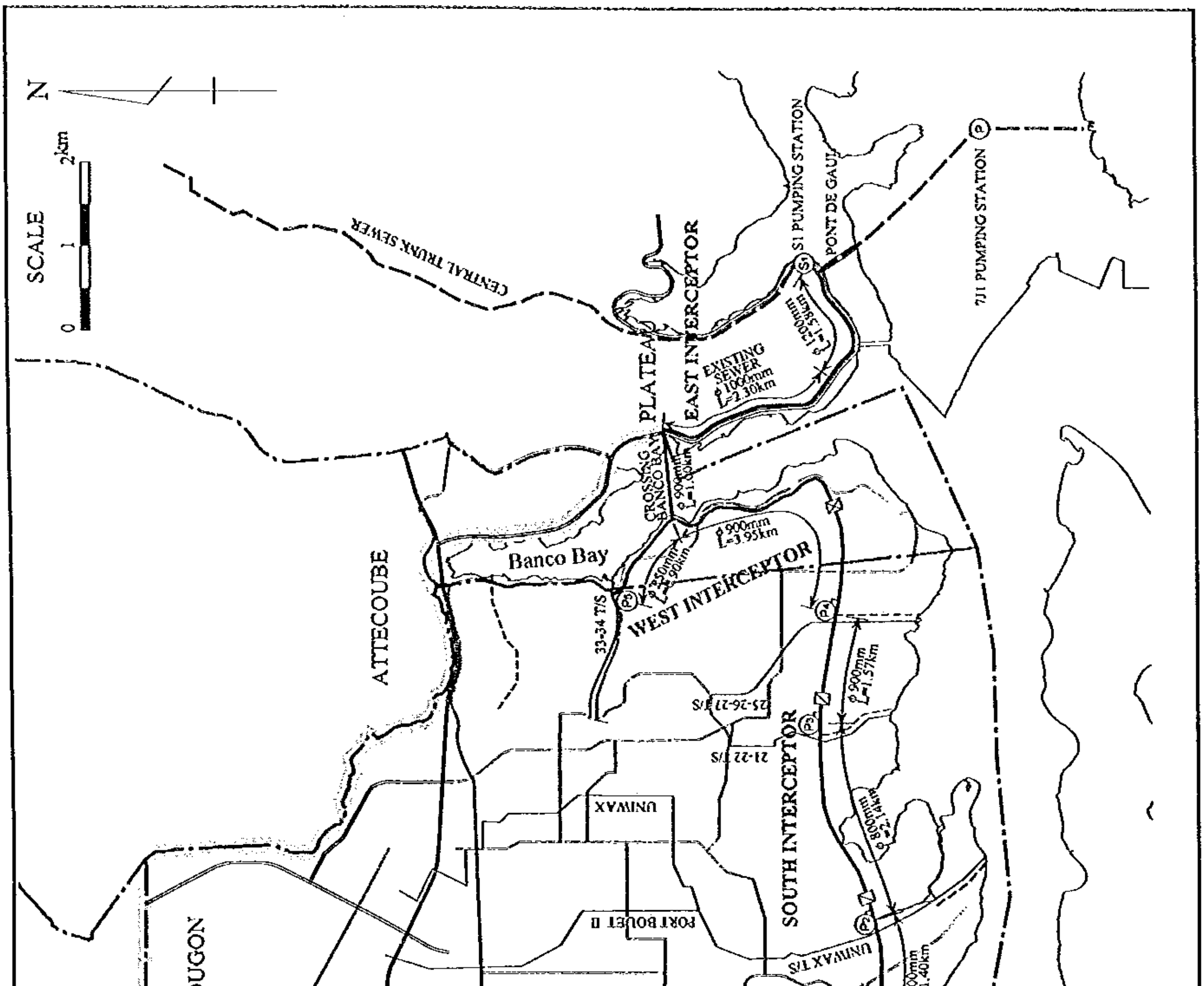
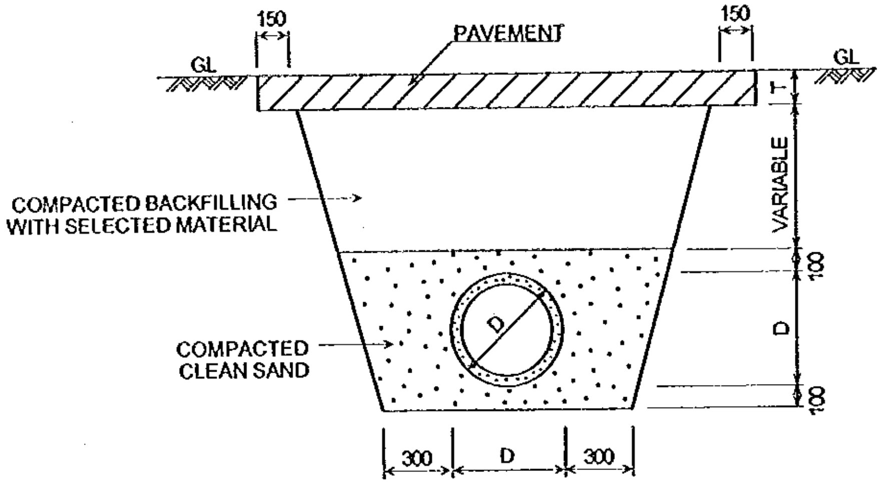


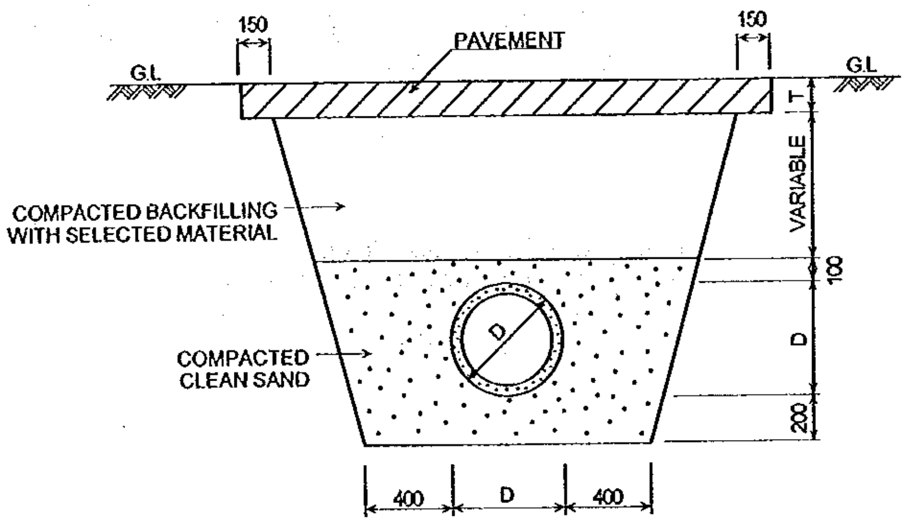
FIG 12.1	SEWERAGE SYSTEM LAYOUT

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE



TYPICAL CROSS SECTION
(DUCTILE CAST IRON PIPE ϕ =500mm)

NOT TO SCALE

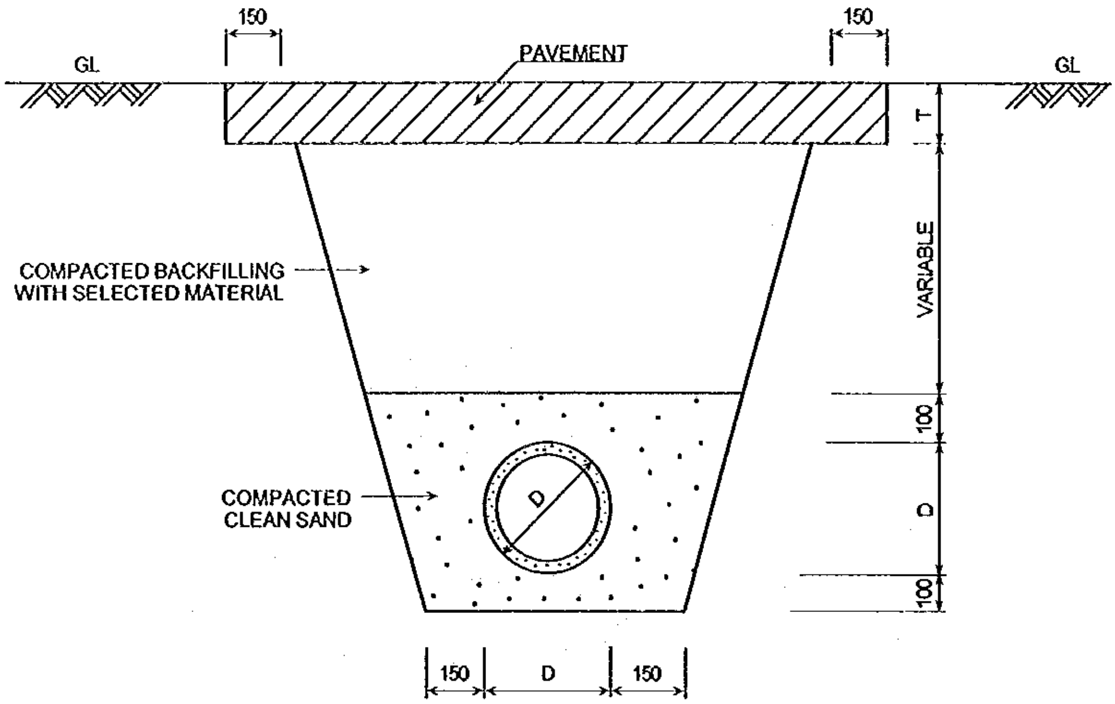


TYPICAL CROSS SECTION
(DUCTILE CAST IRON PIPE ϕ =800, 900mm)

NOT TO SCALE

FIG 12.2	TYPICAL CROSS SECTION OF SOUTH INTERCEPTOR

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE



TYPICAL CROSS SECTION
(DUCTILE CAST IRON PIPE ϕ =250mm)

NOT TO SCALE

FIG 12.3	TYPICAL CROSS SECTION OF WEST INTERCEPTOR

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

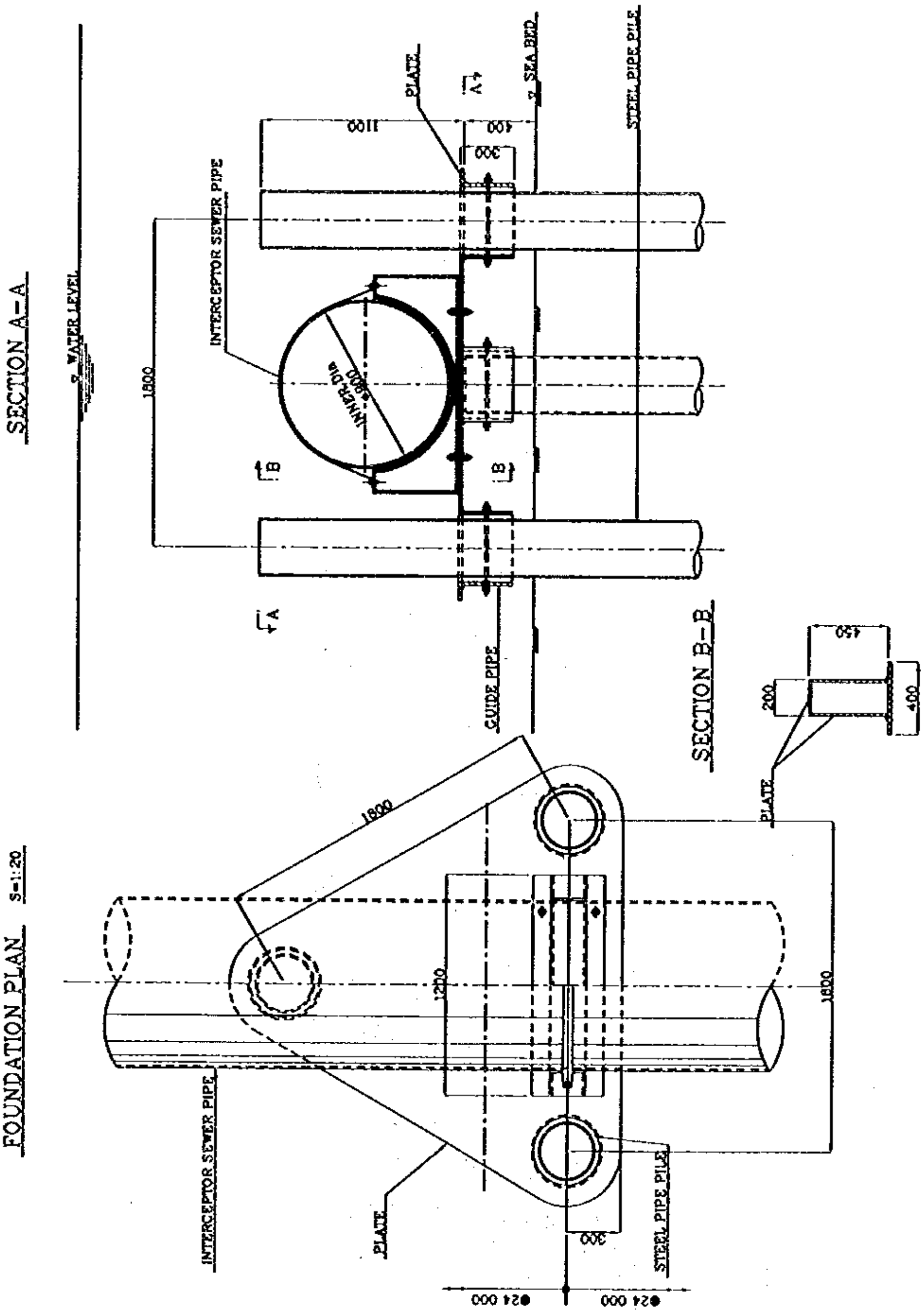


FIG 12.4	DETAILES OF SEWER PIPELINE SUPPORTING PILES

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

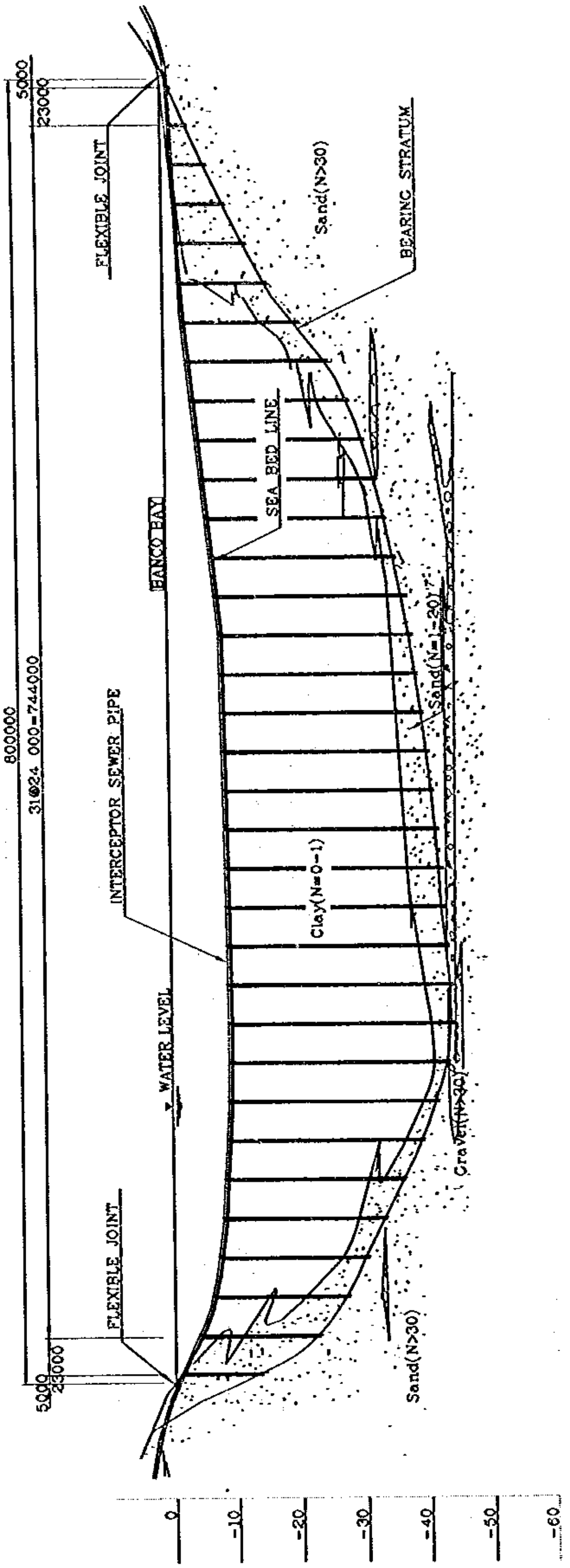
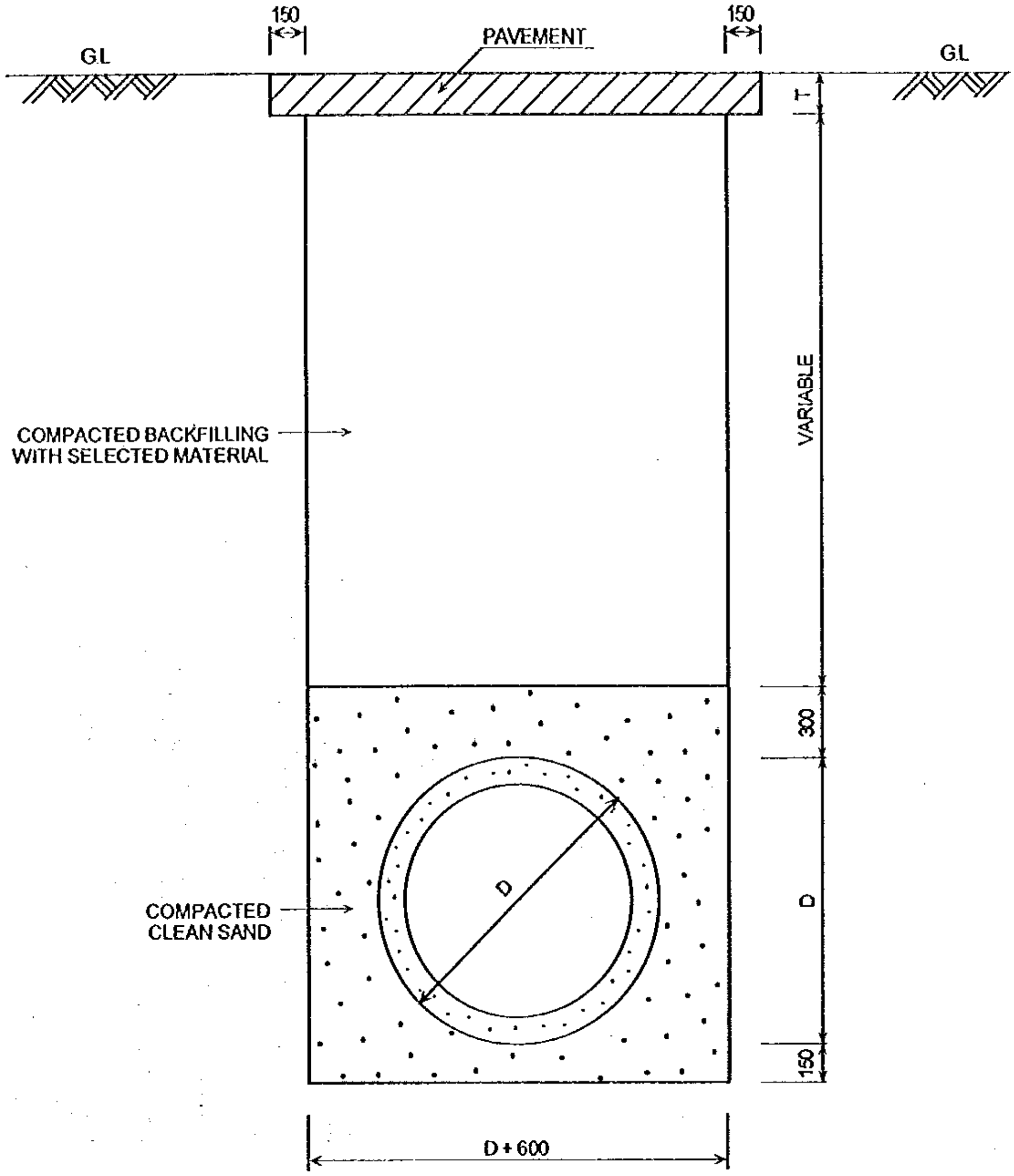


FIG 12.5	LONGITUDINAL PROFILE OF BANCO BAY CROSSING STRUCTURE

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE



TYPICAL CROSS SECTION
(CENTRIFUGAL REINFORCED CONCRETE PIPE ϕ =1200mm)

NOT TO SCALE

FIG 12.6	TYPICAL CROSS SECTION OF EAST INTERCEPTOR

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

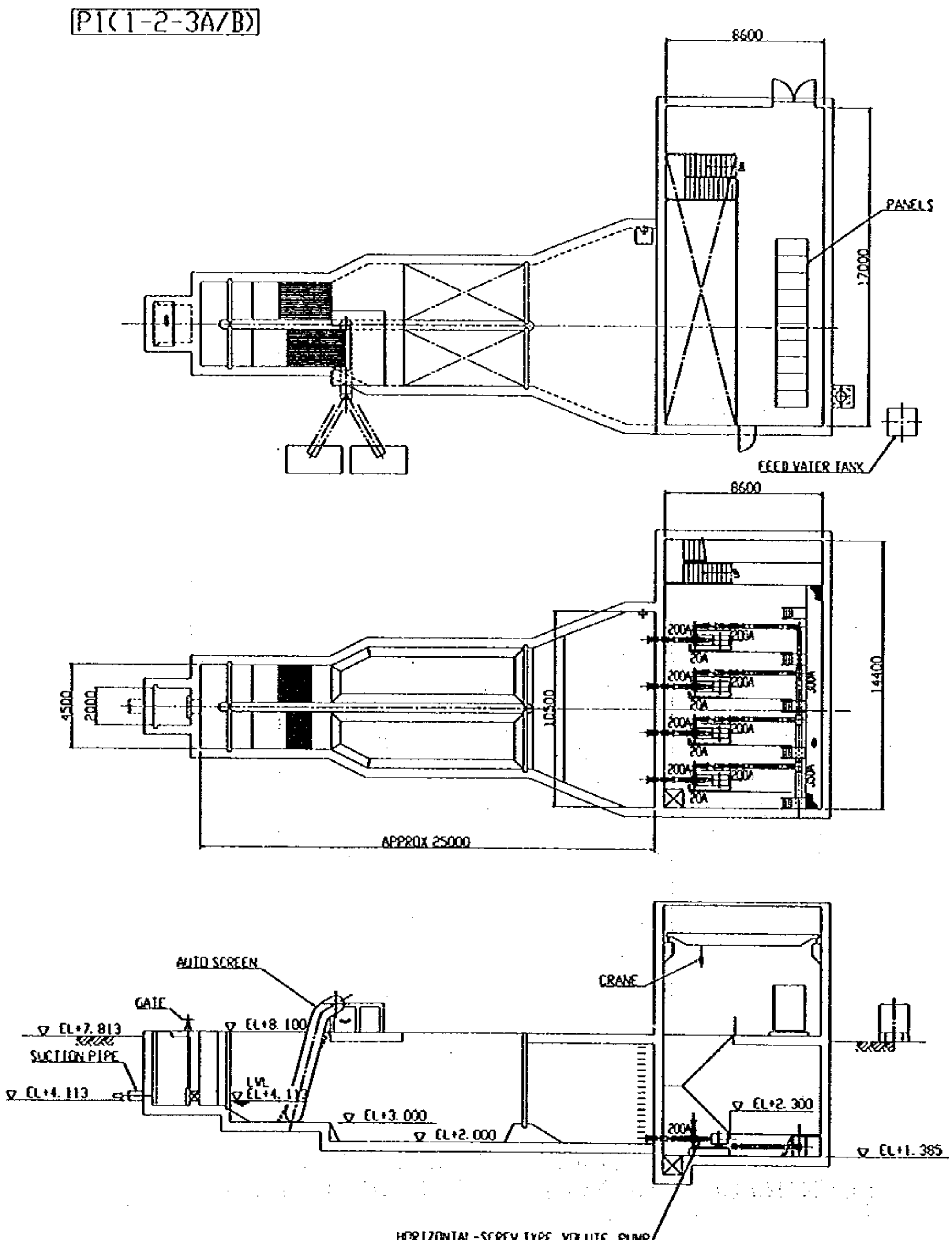


FIG 12.7	GENERAL PLAN OF P1 PUMPING STATION

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

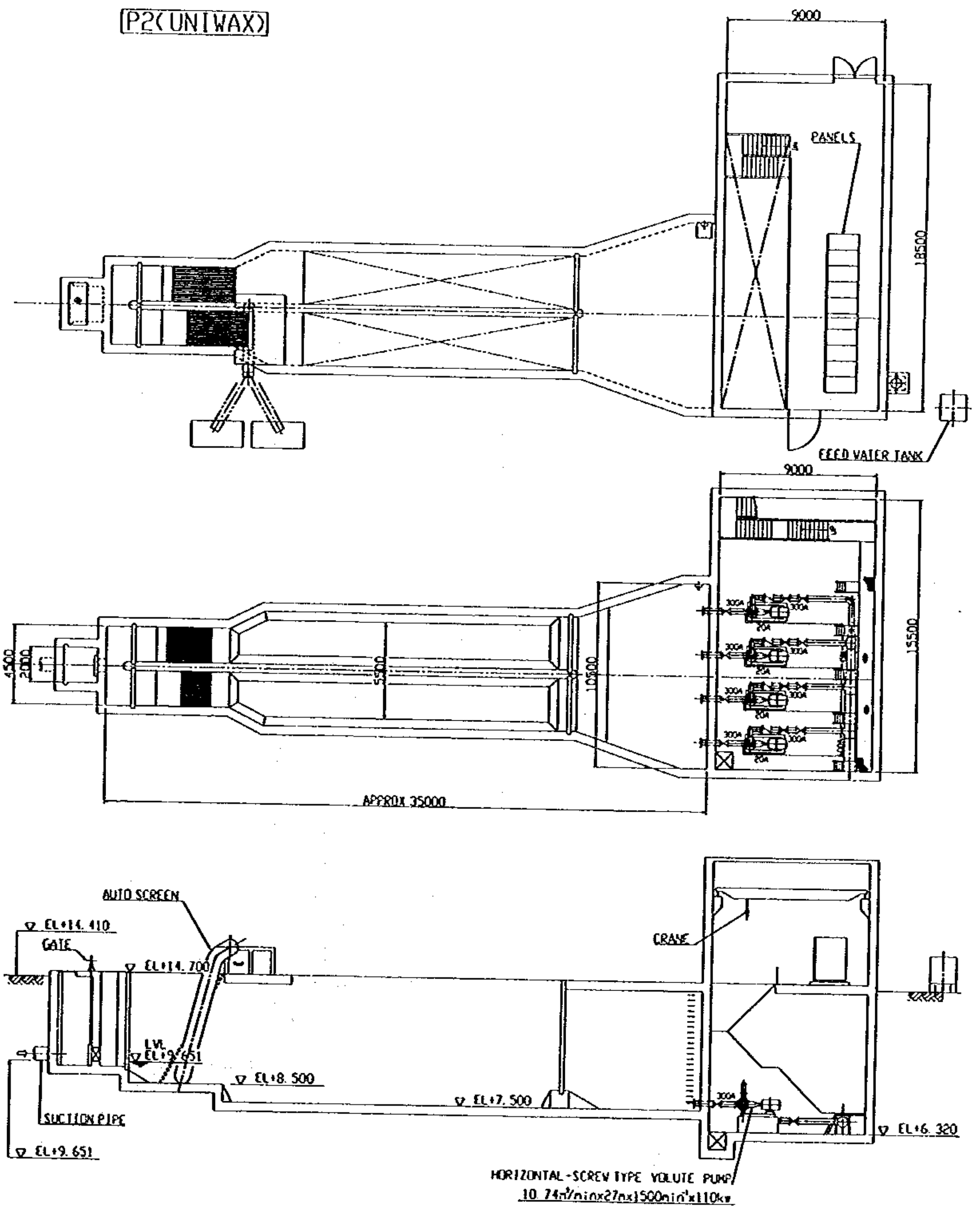


FIG 12.8	GENERAL PLAN OF P2 PUMPING STATION

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT
OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

P3(21-22)

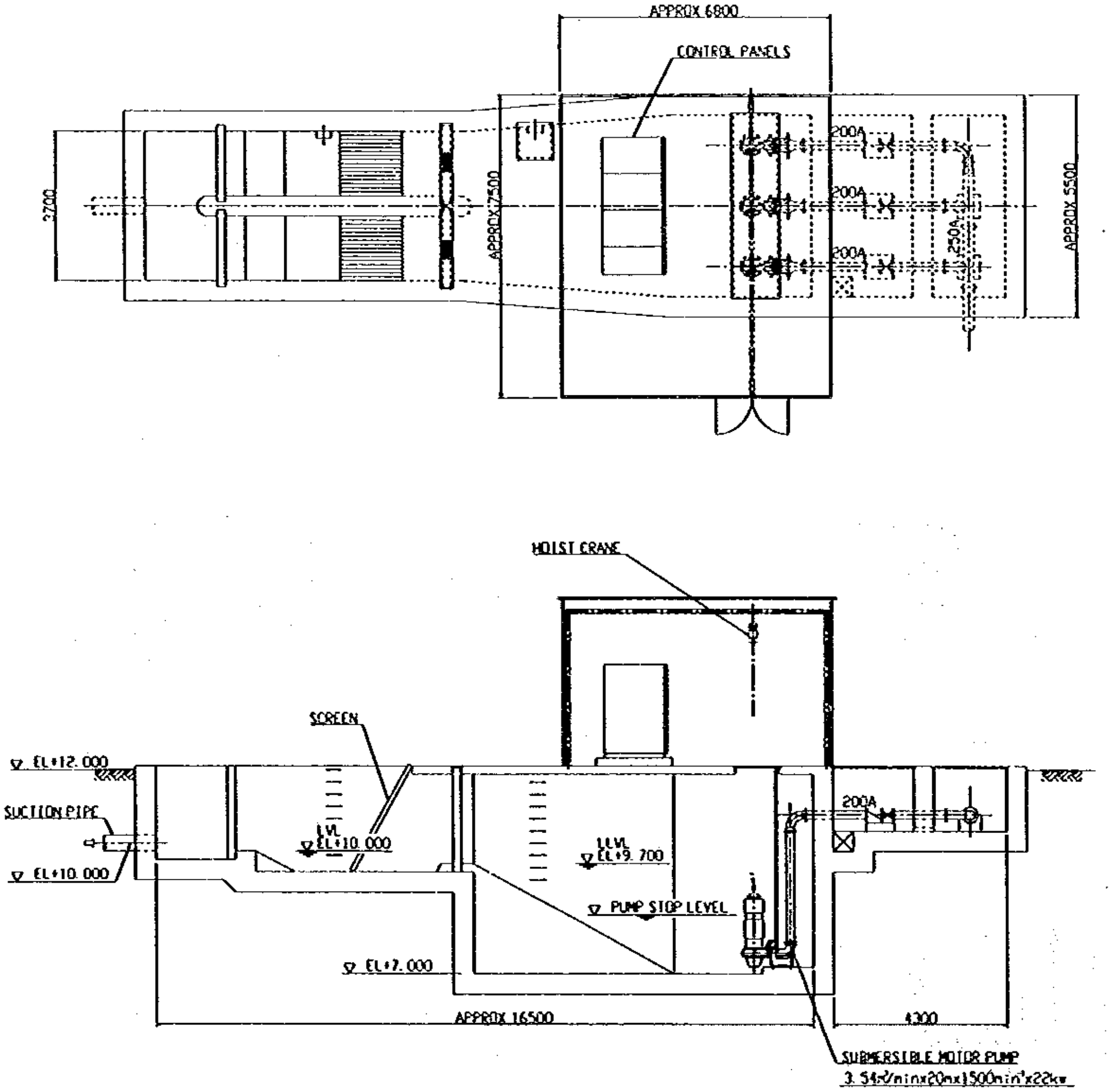


FIG 12.9	GENERAL PLAN OF P3 PUMPING STATION

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT
OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

JICA

[P4(25-26-27)]

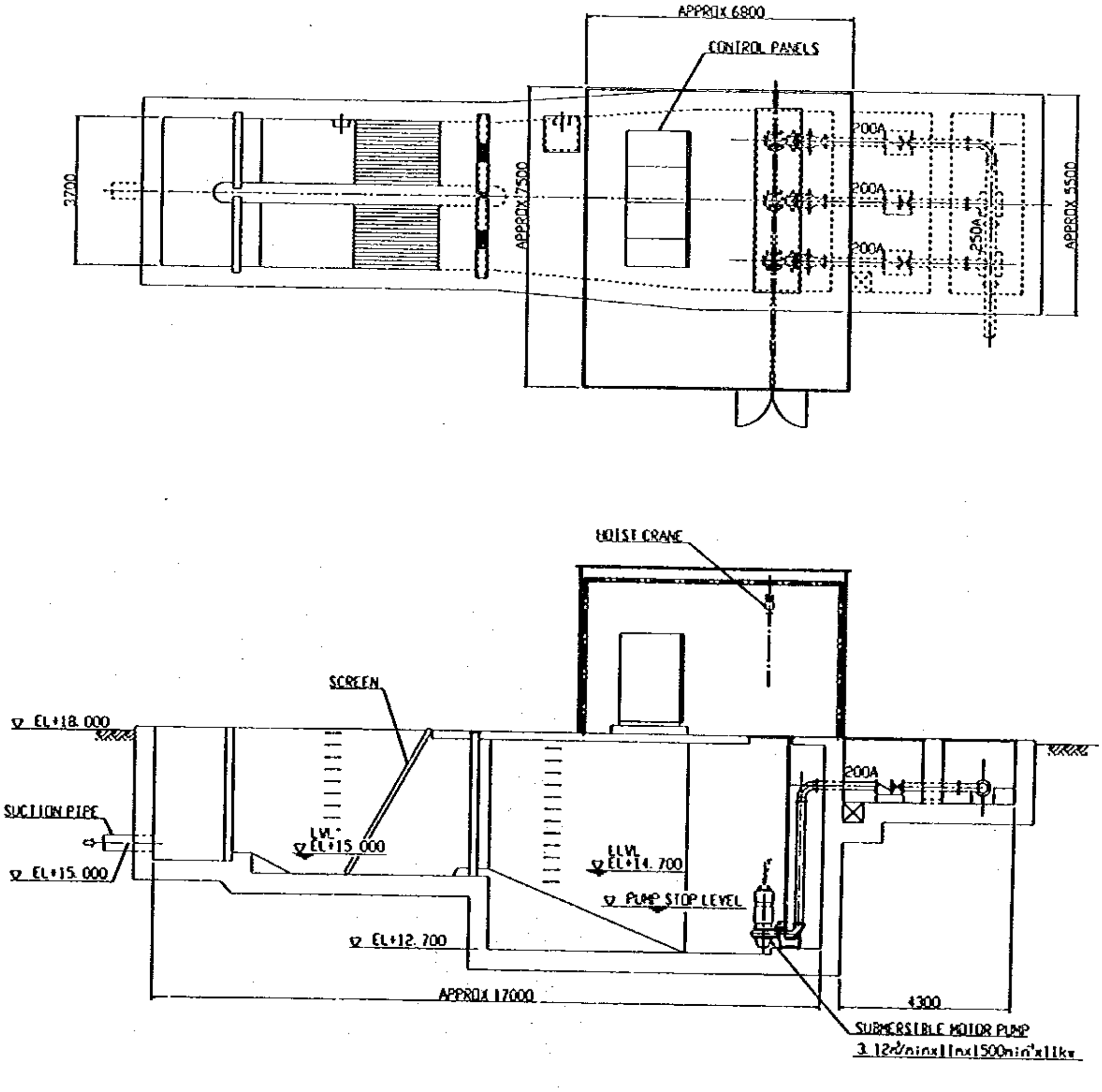


FIG 12.10	GENERAL PLAN OF P4 PUMPING STATION

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT
OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

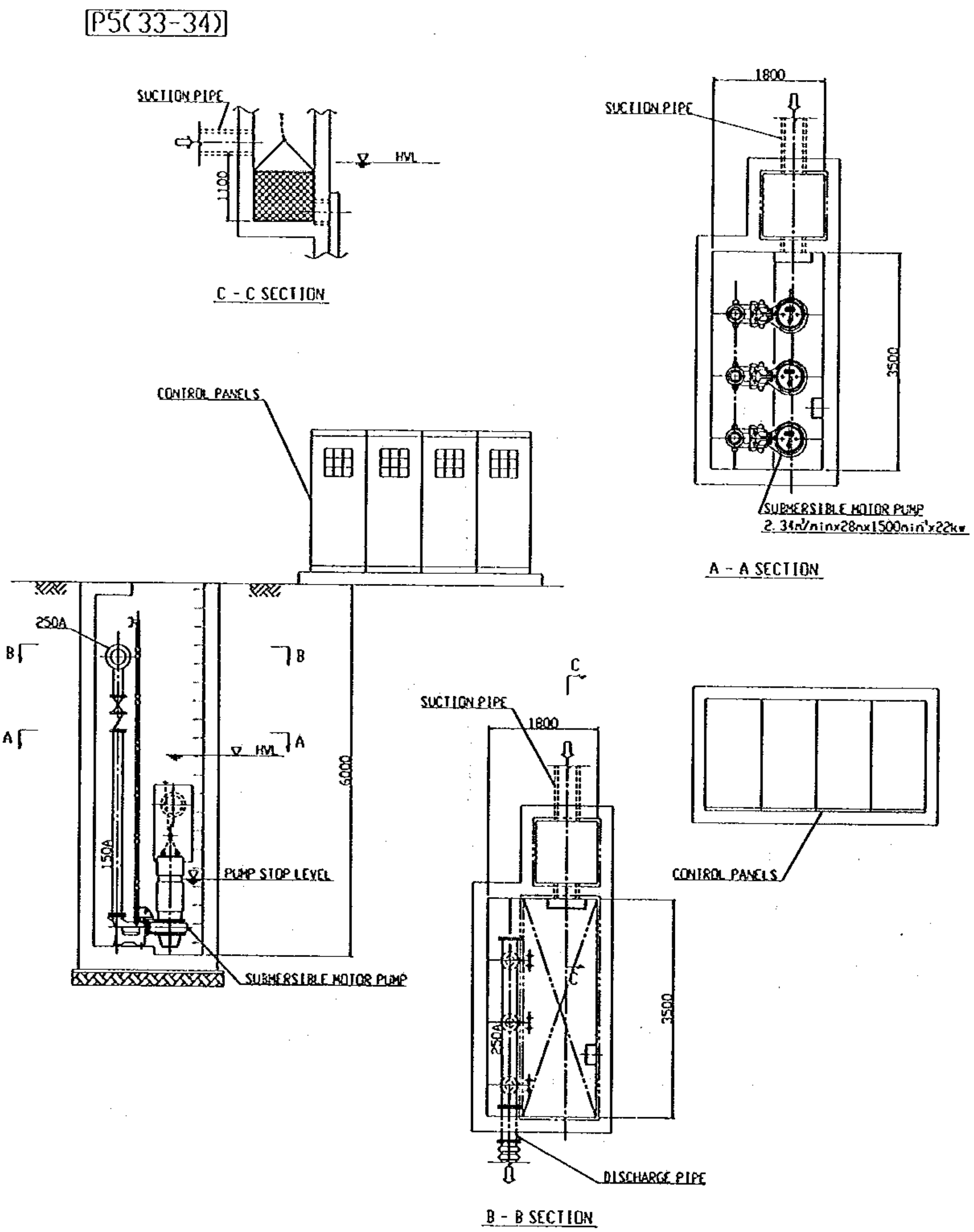


FIG 12.11	GENERAL PLAN OF P5 PUMPING STATION

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

JICA

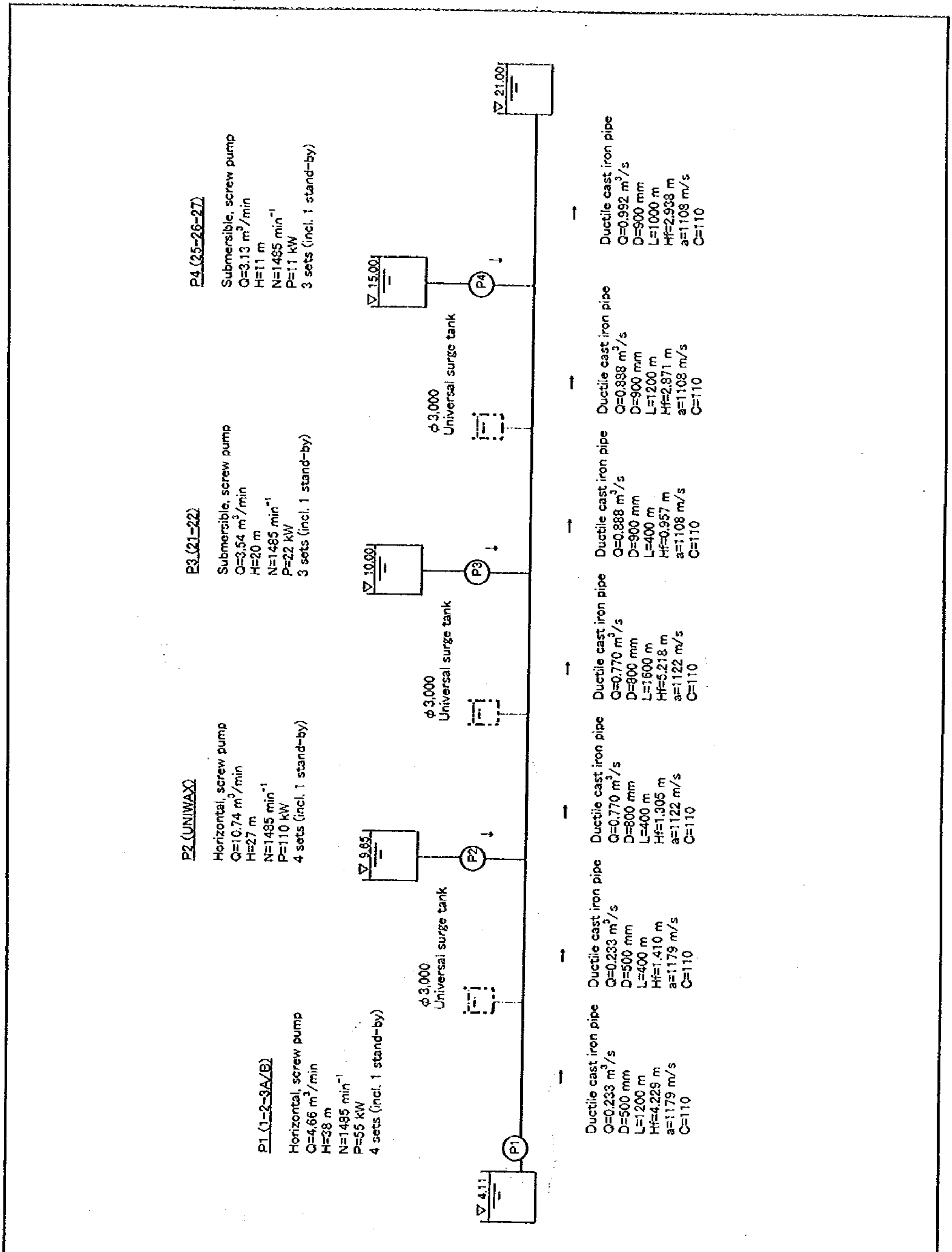


FIG 12.12	PIPELINE DIAGRAM

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

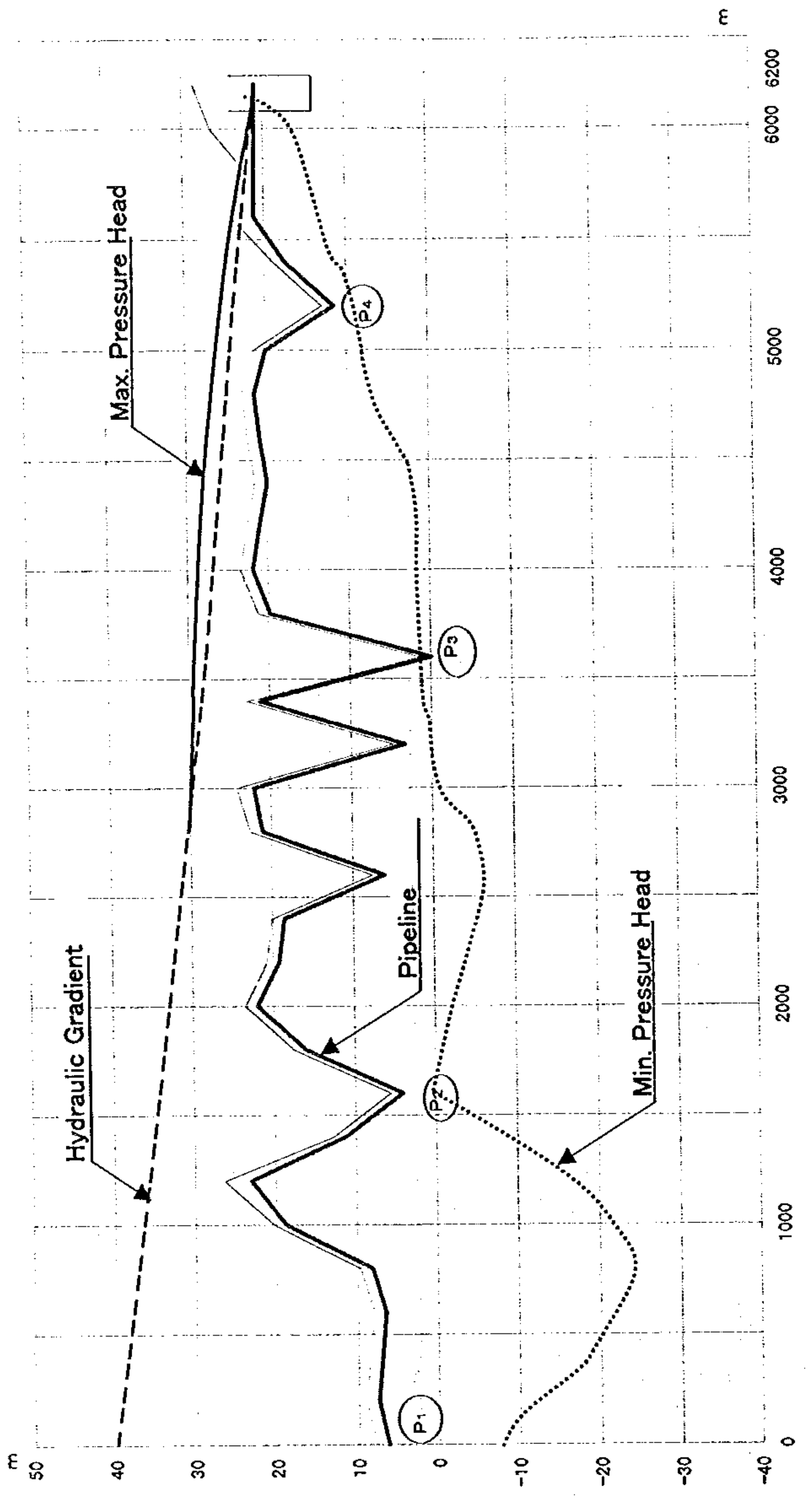


FIG 12.13	MAX. AND MIN. HEAD LINE UNDER WATER HAMMER PHENOMENON —CASE 1—

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

JICA

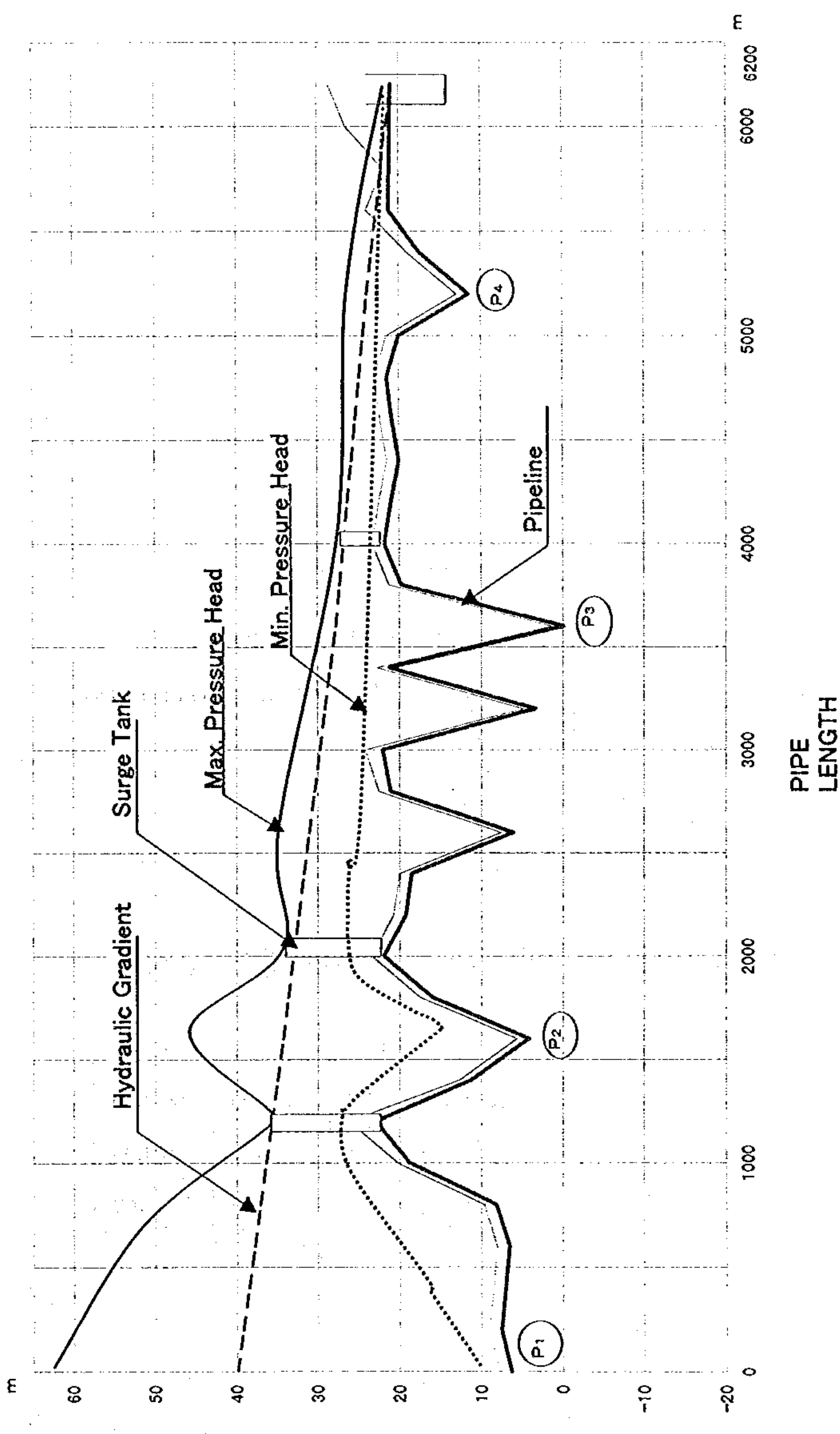
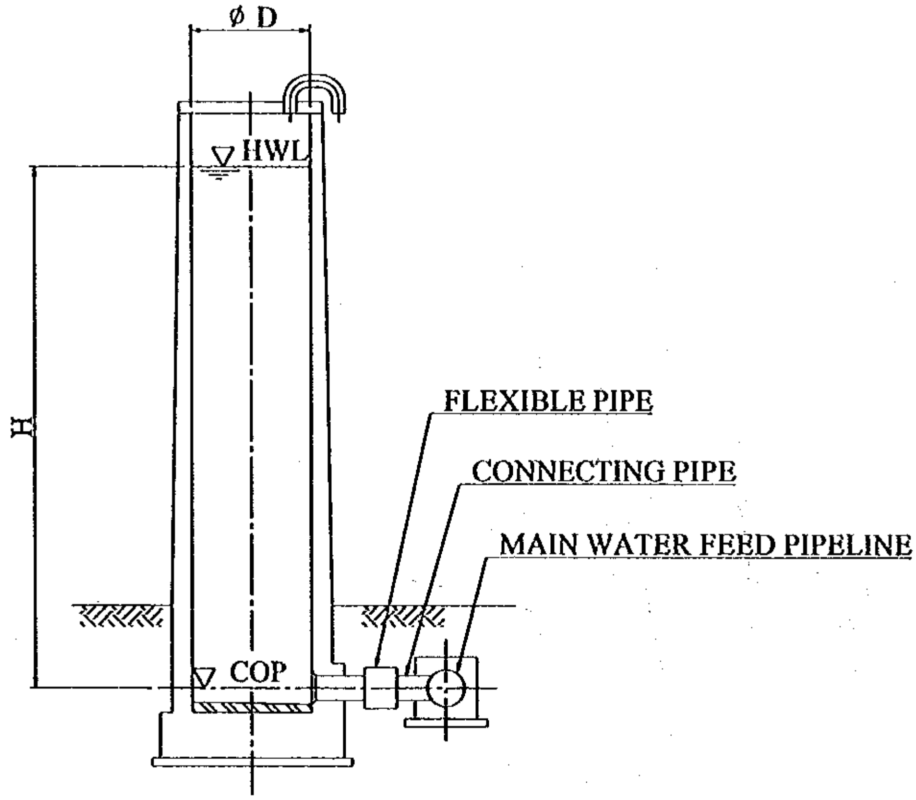


FIG 12.14	MAX. AND MIN. HEAD LINE UNDER WATER HAMMER PHENOMENON —CASE 2—

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

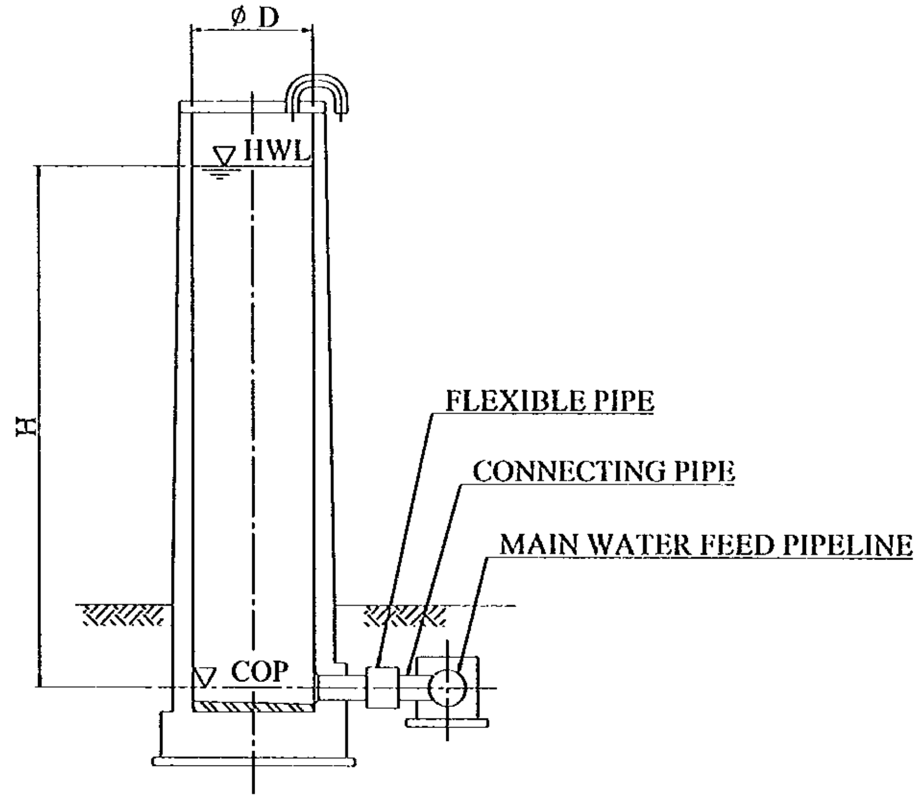


OUTLINE FOR UNIVERSAL SURGE TANK

NO.	PLACE	QTY	ø D	H	∇HWL	∇COP
1	P1~P2	1	ø3000	+12.699	+35.699	+23.000
2	P2~P3	1	ø3000	+10.984	+32.984	+22.000
3	P3~P4	1	ø3000	+4.909	+26.809	+21.900

FIG 12.15 GENERAL PLAN OF SURGE TANK

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE



OUTLINE FOR UNIVERSAL SURGE TANK

NO.	PLACE	QTY	øD	H	∇HWL	∇COP
1	P1~P2	1	ø3000	+12.699	+35.699	+23.000
2	P2~P3	1	ø3000	+10.984	+32.984	+22.000
3	P3~P4	1	ø3000	+4.909	+26.809	+21.900

FIG 12.15 GENERAL PLAN OF SURGE TANK

THE FEASIBILITY STUDY ON SEWERAGE FACILITIES IN WESTERN DISTRICT OF ABIDJAN CITY IN THE REPUBLIC OF COTE D'IVOIRE

CHAPTER 13

IMPLEMENTATION PROGRAM

CHAPTER 13 IMPLEMENTATION PROGRAM

13.1 Implementation Program

13.1.1 Construction Materials

1) Procurement of Sewer Pipes

Three kinds of sewer pipes are assumed to be used in the preliminary design stage, i.e., ductile cast-iron (DCI) pipes, centrifugal reinforced concrete (RC) pipes and steel pipes.

DCI pipes are unique goods that have only a few manufacturers in the world. The procurement of DCI pipe is, therefore, assumed as importation from Europe. The unit price of DCI pipe is based on the market price of FOB at UK port and adjusted considering customs, insurance and freight and transportation cost inside Abidjan.

In case of RC pipes there are a few reputed manufacturers in Abidjan. RC pipes are to be procured domestically at lower prices.
The import of steel pipe products from foreign countries was considered costly and uneconomical. The possibility of domestic procurement of steel pipes has been sought. There are a few manufacturers of steel tubes, pipes and/or tanks in Abidjan, and those companies have the technology and capabilities of processing (bending, welding) of steel sheet to manufacture steel pipes.
Steel sheet may be imported from European countries economically, and combining this with the technology of Ivorian manufacturers and the process of inner coating of steel pipes by mortar, the necessary quantity of steel sewer pipes can be provided domestically.

2) Procurement of Pump Equipment

It is assumed that the pump equipment will be imported from Japan at this stage but not limited to this method.
The unit cost of pump equipment for a pumping station includes the costs for design, manufacture in Japan, workshop tests, spare parts, delivery and installation, based on FOB

Tokyo prices and is to be adjusted considering customs, insurance and freight.

13.1.2 Capability of Local Construction Companies

Three stages of construction projects of sewerage facilities had been implemented over the past 24 years in Abidjan and several of the local construction companies were engaged in the projects as main contractors and/or sub-contractors. Therefore, those companies in the region have experience with the equipment and a key staff to carry out the construction works at an acceptable level.

Although a significant labor force will be needed when construction starts, there would be no serious difficulty in finding common labor. But skilled labor, foremen and construction supervisors at various levels could pose some difficulty in their availability.

The project of sewerage facilities often involves construction work of a large scale, such as for pumping stations. The complicated method and equipment, such as tunneling under existing urban structures using the jacking method requires the skill and experience of the contractors. For such important portions of the construction work would require experienced foreign contractors, and the dispatching of expatriate engineers and the instruction of them.

13.1.3 Construction Method

The construction schedule, arrangement and methods of works of each component of the interceptor system have been determined in accordance with the planned scope and type of work required for the construction.

The construction work of the Project can be classified into three major components, i.e., (1) laying of interceptor sewer pipe, (2) crossing of Banco Bay and (3) construction of pumping stations. The construction methods for each component are described as follows:

1) Interceptor

For the laying of an interceptor sewer, there will be two applicable construction methods: one is the open-cut method and another is the tunneling method.
The open-cut method is applicable where the sewer size is seen as being small - medium and the traffic condition allows. Most of the sewers in the Yopougon area where the laying work is to be done along newly developed road could be constructed using this method, while the open-cut method with earth-retaining by steel sheet piles will be necessary in the Attécoubé - Plateau area where sewer laying is to be done along the existing road.
The tunneling method may be used for laying of large sewer or deep construction where sewer cannot be detoured due to heavy traffic or the presence of underground structures. This method will be applied for about 200m of sewer laying detouring Pont de F.H. Boigny and connecting to the S1 Pumping Station.

2) Banco Bay Crossing

The construction method applied to the 800m section of the interceptor crossing the Banco Bay is planned by the Supported Seabed Pipe-Laying (SSPL) Method. This method is based on the common concept to the construction method applied to the trunk sewer crossing the Ebrié Lagoon between Marcory and Blocosso in the third stage project of sewerage facilities in Abidjan.
The water depth of the Banco Bay is known as to be about 10 - 12 m. Under the sea bottom there exists sedimentation of a poor cohesive soil layer (SPT-N value=0 – 1) of about 30m in thickness. Further under the cohesive soil layer there exists the sand layer (SPT-N value=1 - above 50). In the SSPL Method, platforms supported by pile foundations reaching up to the sand layer are to be laid above the seabed at regular intervals. Interceptor sewer (fabricated by connecting steel pipes of 900 mm in diameter and 6 meters in length with welding) is to be laid on the platforms and cross the Bay of Banco. The intervals between platforms are designed as to be 24 meters.

The procedure of the construction works is supposed as follows.

(1) The foundation piles (steel pipe piles of 300 mm in diameter, 3 piles at one foundation) are to be driven along the designed alignment at regular intervals of 24 meters. The work of driving and welding piles will be conducted from a flat barge on

the sea surface. The length of a pile needed to reach from water surface up to the subsoil sand layer is assumed to be 45 meters.

(2) The longitudinal alignment of pipe laying is to be designed based on the profile of the sea bottom precisely surveyed along the laying plan and alignment.

(3) After soft mud and sand in the foundation piles are removed up to the pipe bottom, cement mortar is to be injected into the piles. And, after the hardening of the mortar by one-week curing, divers will cut off the underwater portion of the foundation piles at a point along the designed longitudinal alignment of pipe laying. This series of work will be conducted from a flat barge on the sea surface.

(4) A platform is to be fixed on the trimmed top of the foundation pile at the sea bottom and the interceptor pipe is to be settled on the platform. The interceptor pipes (steel pipes of 900 mm in diameter and 6 m in unit length) are to be welded at an onshore site and will be drawn out by the offshore flat barge and laid-settled on the sea bottom.

It is assumed that the series of work of laying the interceptor crossing the Banco Bay will require an eight month period. As the work on the sea surface is necessary, the implementation program should be planned to avoid the rainy season (May and June in particular) when stormy days and the disturbance of the sea surface are frequent.

3) Pumping Stations

Construction of two major pumping stations (P1:1-2-3 A/B and P2:UNIWAX) and three minor stations (P3:21-22, P4:25-26-27 and P5:33-34) are considered in the flow system of the interceptor plan.

According to the results of the subsoil condition surveys, it is known that the ground water level is rather higher at GL-1.5 m at the location of P2 pumping station. And, at the P5 pumping station, which is located along the shore of Banco Bay, it is known that the level of the ground water is also higher.

In the process of constructing the sub-structures (underground water basin) of those pumping stations, the ground has to be excavated up to GL-5 to - 6 meters and excavation with timbering by sheet piles is considered necessary at those points.

13.1.4 Implementation Schedule

The construction project is assumed to proceed along the implementation schedule shown in Table 13.1. Main assumptions given to the construction schedule are as follows:

(1) The first year is to be used for the period of Basic Design and Financial Arrangements, which consists of the process of the application for a loan from a financial institute by the governmental agency and appraisal of the project.

(2) The first half of the second year is to be used for detail design and the process of pre-qualification of contractor and tender.

(3) The third quarter of the second year is to be used for contract procedures and mobilization. The construction process is to be started at the last quarter of the second year (2001) and will be completed at the end of 2003.

(4) Monthly precipitation and average number of rainy days in Abidjan is shown in Table 13.2. The two months, May and June, are regarded as the peak of rainy season and the number of rainy days account for two thirds of the days in those two months. The construction schedule is planned so that the pipe laying works in the lowland area and crossing the Banco Bay will not be affected by the disturbances of the rainy season.

13.2 Cost Estimate

13.2.1 Basis of Cost Estimate

1) Unit Price of Labor, Material and Equipment

The unit price of each element, such as labor, major material and major equipment were determined on the basis of the data collected in the field investigation in June and July 1999 in Abidjan. The social and market conditions of Abidjan are to be taken into account to determine the unit cost of each construction work.

2) Basic Cost of the Work

The basic costs of the construction work were obtained by accumulating the labor cost, material cost, equipment cost for the assumed typical and preliminary design. The cost of general temporary work (20% of the accumulated direct cost for each construction work) and indirect cost (30% of the summation of the cost for direct construction works and general temporary work) which consists of overhead expenses, profit and so on are to be added.

The construction methods, equipment and labor, and speed of work are applied in accordance with STANDARDS FOR COST ESTIMATIONS OF PUBLIC WORKS (Ministry of Construction, the Government of Japan, 1999).

3) Exchange Rate of the Imported Materials

The basic costs for imported goods are estimated based on the exchange rate of currencies as follows (an average during the period from March to August 1999).

	J Yen
France Franc	19.503
CFA Franc	0.19503
UK Pound	195.43
US Dollar	120.38

4) Construction Cost for Planned Facilities

After the preliminary design of the proposed facilities and equipment is prepared based upon the topographic and geographic survey, the quantities of work of such designed facilities and equipment are estimated.

The construction costs of all the work and facilities are estimated and divided into the local currency portion and the foreign currency portion depending on the components of materials or works.

The local currency portion is the estimated cost of the materials, equipment, labor and products that are available to be procured domestically in Côte d'Ivoire. The foreign currency portion is the estimated cost of the imported materials and services such as steel products, DCI pipes, use of imported construction equipment and/or employment of expatriate engineers.

Considering the above aspects for each component of work, the proportion of the local currency and foreign currency was introduced to the unit prices in the breakdown of the cost estimate.

13.2.2 Total Investment Cost

The total cost of the construction and installation of proposed facilities for the feasibility study is summarized as shown in Table 13.3. The total project cost comprises the following items:

- Direct construction cost estimated for the preliminary design of facilities,
- Engineering fee of consulting services for the stages of design and construction,
- Physical contingency for the construction work.

(1) Direct Construction Cost

The details of the quantities of work and the direct costs estimated for each component of the work are described in Table 13.3.

(2) Engineering Fee

The engineering fee was estimated by taking into account the provision of the following scope of services:

- Topographic surveys and investigations of subsoil conditions required in the stages of Basic design and Detail design,
- Detailed design of all the facilities and equipment,
- Construction supervisory services for a two and a half year period.

(3) Physical contingency

A physical contingency is required for the construction work and is estimated empirically as 10% of the summation of construction cost.

The yearly expenditure of construction costs of the main items of the facilities with the respective quantities are shown in Table 13.4 in accordance with the planned construction schedule (Table 13.1).

13.2.3 Operation and Maintenance Cost

Operation and maintenance costs for the proposed sewerage system are composed of i) sewer pipeline (interceptor), ii) pumping stations proposed.
Pumping stations costs are composed of electricity, repairing costs removal of sediments and garbage and personnel expenses. That for the sewer pipeline is composed of repair costs, daily inspections, cleaning work and personnel expenses. As for the frequency of the work, it is assumed that the pipeline will be inspected twice a year and cleaned at least every year by using thrusting rods and / or bucket machines, including power source, lubrication and minor equipment repair.

The annual O/M cost of the sewerage system is shown in Table 13.6. Moreover, there is further break down in Appendix G.

13.3 Financial Plan

13.3.1 Introduction

This study is related to the feasibility study on the sewerage system in the western district of Abidjan. Therefore, it does not cover the issues that deal with the sewerage system of the whole Abidjan City or the whole country. When discussing the financial plan of this study, the general tariff structure is considered as given but we will suggest future direction of the tariff improvement.

As for the sewerage system of Abidjan, three major organizations are involved: i.e., the central government (MLU), the technical center (BNETD) and the private company (SODECI). The division of labor among these three organizations is well established at some degree. The Study Team does not find any reason that replaces the current structure with other alternatives. The operation of SODECI is going pretty well. The next step will be the strengthen and expansion of the activity and financial basis of SODECI.

The facility planning and major rehabilitation are the responsibilities to the government. The budget for the construction and rehabilitation comes from the general budget and FNE (from the surcharge on water tariff, which is collected by SODECI).

The privatization of government activity is worldwide trend. Cote d' Ivoir' s privatization is considered as the success case in the Sub-Sahara Africa But the separation of three major functions (governmental authority (policy, planning, regulation and budgeting), technical center and operation) gives rise to some organizational issues that are covered later.

SODECI applied the tariff for sewerage service based on water consumption on July 1999. Until then, the tariff for sewerage service was not collected. Newly planned tariff is based on water consumption and involves the mechanism that facilitates the individual connection to the sewerage service.

It will take substantial time until the tariff collection system for sewerage service will work. But the Study Team can expect tariff collection by 2003. The fundamental issue is the existence of low-income population who cannot afford the tariff. Especially, the study area has huge low-income population and it is increasing day by day.

13.3.2 Scope of Financial Plan

As our project concentrates the construction of the interceptor, the Study Team establishes hypothetical business entity that covers the sewerage service in the study area (Yopougon and Attecoube).

13.3.3 Financial Policy on Cost Sharing

Due to the financial burden and spillover effects of sewerage facilities, the government (or grant, i.e. from outside of the hypothetical entity) should prepare the huge initial investment (Table 13.5 and Table 13.7). But in the sensitivity analysis in Chapter 14, the possibility of partial burden sharing by the entity will be examined.

As for O&M cost (Table 13.6 and Table 13.7), in principle, it should be covered by the tariff. At early stage some portion of water tariff should be allocated to sewerage service. Because the study area has huge population of low-income residents, internal subsidy from central business district, which involves high-income commercial activities, is inevitable.

13.3.4 Tariff Structure and Collection

The existing five tariff categories should be maintained. The high tariff for high-income group policy is supported. It is the fundamental philosophy of new tariff plan of July 1999, too. The collection from government organization should be emphasized. The incentive to improvement of tariff collection should be developed.

13.3.5 Financial Revenue

The estimate of financial revenue is described in Table 13.8. Strictly speaking the estimate of tariff revenue of the entity should be based on the number of contract by class, water consumption, tariff structure, collection rate, income level and future trend of all of them. But these data is not sufficiently available. Even some of them exist, the accuracy is not sure. The Study Team estimates financial revenue by macroscopic approach.

1) From 1998 financial report of SODECI, the water sales in Abidjan will be estimated proportionally by the invoiced water volume.

2) The above water sales includes not only water tariff but also all revenue including repair activity and several charges etc.

3) The water sales in the study area are computed from the whole Abidjan City data proportionally by population data. The population in these two does not always have water connection and sewerage connection. This estimate will stand for not actual sales but rather upper limit of available internal budget assigned to the two districts. Actually because these two district has huge low-income population, this formula implicitly assumes internal subsidy from commercial district with high tariff rate.

4) The allocation to the sewerage service is determined by the number of staff in the sewerage division, which is now around 10% of whole employees in SODECI. Actually current income from sewerage operation is only subsidy from government, which consists of about 4% of total revenue of SODECI.

5) As to the sales estimate for 2003, the Study Team considers population increases (our study team data), the increase of income per capita (3%, World Bank data) and the rate of inflation (3%, 1996-1997 level) to the 1998 base figure.

6) As to sewerage service tariff, in the long run, the Study Team recommends 40-60% of water tariff that is international standard level. The currently proposed tariff structure is the first step for this long-term goal. At the year of 2004, the Study Team assumes that 25% of water tariff will be collected as sewerage tariff. After 2011 in will be improved up to 40%. This level of sewerage tariff collection is critical to financial feasibility as shown in Chapter 14.

7) After the year of 2004, the population of the district will increase. So do the revenue and expenditure. The new additional investment will be required also. But our study period is limited by the year of 2003. Therefore, the scale of the hypothetical entity is limited at the one of 2003. The resulting revenue estimate is 1397 million FCFA in 2003 and 1565 million FCFA after 2011, at 1998 price.

13.3.6 Financial Expenditure

The estimate of financial expense is described in Table 13.9. The computing logic is same as in Sec. 13.3.5. The starting number is the expenditure of SODECI in 1998 (revenue minus profit).

In addition the expenditure estimated by the above process, the Study Team must add the O&M cost for the interceptor newly added by our study. This interceptor has tremendous positive effects that will be mentioned later in Chapter 14 but it does not have direct income increase. In addition to the interceptor, the Study Team strongly recommended the rehabilitation works in major trunk sewers but it is our understanding that the budget for the rehabilitation will be prepared outside of the project. The resulting expense estimate is 1326 Million FCFA in 2003 at 1998 price.

Under the several assumptions and conditions explained, this project if financially feasible if the initial investment covered without the burden of project accounting and if sewerage tariff will reach the one fourth of water tariff.

13.4 Institutional Plan

13.4.1 Introduction

The current division of labor among the central government (MLU), the national technical center (BNETD) and the private company (SODECI) is well organized. We do not find any reason that restructures current system. While the problems exist due to the separation of the authority, technology and operation, it is unwise to consolidate three organizations. It will make "big government" again. Rather the improvement within the current framework will be advised. The World Bank calls this issue as "the development of regulatory framework".

In the past SODECI was not aggressive in taking the investment risk and rather they confined their activity within operation. But recently SODECI started the investment with outside money by government assurance. It is advisable to expand SODECI's activity from operation to investment unless the government assured borrowing bring about hidden public external debt which is now controlled by the World Bank and IMF.

13.4.2 Organizational Development

1) It is recommended to improve and strengthen the policy planning capability of the central government. The World Bank emphasizes this issue as "regulatory framework".
2) It is recommended to strengthen SODECI as a private company. The substantial portion of the investment should be transferred to SODECI.
3) The large-scale rehabilitation program should be transferred to SODECI step by step.
4) The effective cost accounting system should be introduced. The revenue and cost should be classified by water supply and sewerage, by region, etc.

13.4.3 Human Resources Development

As advanced countries accumulated substantial knowledge and experience in the field of sewerage service. The staff in this country should be given the chance to study abroad and introduce advanced technology and management experience. The operation of the sewerage service in the City of Abidjan will be the model of the ones of local cities in this country. Therefore, the every effort should be concentrated in order to establish the sound sewerage operation in Abidjan. Human resources development should not be limited in technical aspect only but rather it should involve accounting, finance, marketing and personnel management etc.

13.4.4 Operation and Maintenance

Within the limit of the maintenance budget, the current O&M deserve substantial recognition. With the introduction of sewerage tariff, the O&M budget will increase resulting better management.

Major rehabilitation works should be separated from ordinary O&M. They requires huge investment as mentioned in this report.

TABLE 13.1 CONSTRUCTION SCHEDULE AND IMPLEMENTATION PROGRAM

Work Items	Year / Month	2000				2001				2002				2003			
		1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
0. Financial Arrangement											Rainy Season				Rainy Season		
1. Survey and Design Works			B/D			D/D											
2. Prequalification and Tender																	
3. Contract and Mobilization																	
Interceptor																	
4. 1-2-3 A/B -- UNIWAX	Open-cut 1.40 km																
5. UNIWAX -- 21-22	Open-cut 2.14 km																
6. 21-22 -- 25-26-27	Open-cut 1.57 km																
7. 25-26-27 -- Abobo-Doume	Open-cut 1.75 km						Rainy Season										
8. Abobo-Doume - 33-34	Open-cut 2.20 km (Branch) 0.9 km																
9. Crossing of Banco Bay	SSPL 0.8 km											8.0 months					
10. East of Crossing -- Attecoube	Open-cut (SP) 0.2 km																
11. Existing Sewer	Rehabilitation of Sewer 2.3 km																
12. End of Existing Sewer -- End of Access Road	Open-cut (SP) 0.37 km																
13. Underpass of Access to Pont de F. H. Boigny	Jacking Method 0.2 km														5.5 months		
14. Pont de F.H.B. -- S1 P/S	Open-cut (SP) 1.01 km																
Pumping Station											Fabrication of Equipment				Transport		
15. P1 (1-2-3 A/B) P/S											Civil Works		Building		Installation		Test
16. P2 (UNIWAX) P/S																	
17. P3 (21-22) P/S																	
18. P4 (25-26-27) P/S																	
19. P5 (33-34) P/S																	

TABLE 13.2 PRECIPITATION IN ABIDJAN

Month	Precipitation (mm)	Average* Number of Rainy Days	Average Temperature (degree in Celsius)
January	15.0	3.1	26.8
February	42.1	4.1	27.7
March	105.8	8.6	27.9
April	160.0	11.2	28.1
May	306.7	17.8	27.6
June	508.8	21.0	26.2
July	134.0	12.0	24.8
August	30.8	7.1	24.0
September	70.8	13.0	24.5
October	158.5	14.3	26.1
November	144.0	15.8	27.5
December	69.9	9.7	27.2
Yearly	1746.5	137.7	26.5

Source: SODEXAM, 1969 – 1998.

*: Atlas de Côte d'Ivoire (1979), Ministère du Plan de Côte d'Ivoire.

TABLE 13.3 SUMMARY OF CONSTRUCTION COST

Interceptor (Unit: 1,000 FCFA)

Section	Construction Method	Sewer Type / Diameter	Local	Foreign	Total
1. 1-2-3 A/B -- UNIWAX	Open-cut 1.40 km	DCI Pipe / 500 mm	115,459	381,932	497,391
2. UNIWAX -- 21-22	Open-cut 2.14 km	DCI Pipe / 800 mm	226,085	1,030,188	1,256,274
3. 21-22 -- 25-26-27	Open-cut 1.57 km	DCI Pipe / 900 mm	181,492	896,425	1,077,918
4. 25-26-27 -- Abobo-Doume	Open-cut 1.75 km	DCI Pipe / 900 mm	202,300	999,200	1,201,501
Abobo-Doume - 33-34	Open-cut 2.20 km	DCI Pipe / 900 mm	254,320	1,256,138	1,510,458
5. Branch Sewer from 33-34	Open-cut 0.90 km	DCI Pipe / 250 mm	64,939	161,962	226,901
6. Crossing of Banco Bay	SSPL 0.8 km	Steel Pipe / 900 mm	1,882,995	383,329	2,266,325
7. East of Crossing -- Attecoube	Open-cut (SP) 0.2 km	DCI Pipe / 900 mm	46,467	158,818	205,285
8. Existing Sewer (RC)	Rehabilitation of Sewer 2.3 km	RC Pipe / 1,000 mm	57,500	172,500	230,000
9. End of Existing Sewer -- End of Access Road	Open-cut (SP) 0.37 km	RC Pipe / 1,200 mm	119,852	100,540	220,392
10. Underpass of Access to Pont de F. H. Boigny	Jacking Method 0.2 km	RC Pipe / 1,200 mm	183,462	263,453	446,915
11. Pont de F.H.B. -- S1 P/S	Open-cut (SP) 1.01 km	RC Pipe / 1,200 mm	327,163	274,447	601,610

Pumping Station and Miscellaneous (Unit: 1,000 FCFA)

Name of Station	Division	Local	Foreign	Total
1. P1 P/S	Mechanical & Electrical Equip.		667,874	667,874
	Civil Works & Building	212,286	82,941	295,227
	Land Acquisition	1,200		1,200
2. P2 P/S	Mechanical & Electrical Equip.		832,982	832,982
	Civil Works & Building	319,113	126,304	445,417
	Land Acquisition	1,500		1,500
3. P3 P/S	Mechanical & Electrical Equip.		365,503	365,503
	Civil Works & Building	48,540	31,043	79,583
	Land Acquisition	450		450
4. P4 P/S	Mechanical & Electrical Equip.		324,993	324,993
	Civil Works & Building	23,121	19,240	42,360
	Land Acquisition	450		450
5. P5 P/S	Mechanical & Electrical Equip.		157,960	157,960
	Civil Works & Building	11,299	18,513	29,812
	Land Acquisition	300		300
6. Miscellaneous Works	Surge Tank, Regulation Tank, etc.	61,436	27,804	89,240

(Unit: 1,000 FCFA)

	Descriptions	Local	Foreign	Total
Construction Cost	(1)	4,337,829	8,734,089	13,071,918
Engineering Fee	(2) = (1) x 10 %	433,783	873,409	1,307,192
Physical Contingency	(3) = (1) x 10%	433,783	873,409	1,307,192
Land Acquisition	(4)	3,900	0	3,900
Total	(1) + (2) + (3) + (4)	5,209,295	10,480,907	15,690,202

TABLE 13.4 YEARLY CONSTRUCTION COST OF INTERCEPTOR SYSTEM

(Unit: 1,000 FCFA)

Interceptor	2000		2001		2002		2003	
Section	Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign
1. 1-2-3 A/B -- UNIWAX							115,459	381,932
2. UNIWAX -- 21-22					180,868	824,151	45,217	206,038
3. 21-22 -- 25-26-27					181,492	896,425		
4. 25-26-27 -- Abobo-Doume					202,300	999,200		
Abobo-Doume - 33-34					254,320	1,256,138		
5. Branch Sewer from 33-34					64,939	161,962		
6. Crossing of Banco Bay					1,506,396	306,663	376,599	76,666
7. East of Crossing -- Attecoube					46,467	158,818		
8. Existing Sewer (RC)							57,500	172,500
9. End of Existing Sewer -- End of Access Road					119,852	100,540		
10. Underpass of Access to Pont de F. H. Boigny							183,462	263,453
11. Pont de F.H.B. -- S1 P/S			327,163	274,447				

Pumping Station & Miscellaneous		2000		2001		2002		2003	
Name of Station		Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign
1. P1 P/S	Mechanic & Electric				66,787		200,362		400,724
	Civil & Building					148,600	58,059	63,686	24,882
	Land Acquisition			1,200					
2. P2 P/S	Mechanic & Electric				83,298		249,895		499,789
	Civil & Building					223,379	88,413	95,734	37,891
	Land Acquisition			1,500					
3. P3 P/S	Mechanic & Electric				36,550		109,651		219,302
	Civil & Building							48,540	31,043
	Land Acquisition			450					
4. P4 P/S	Mechanic & Electric				32,499		97,498		194,996
	Civil & Building							23,121	19,240
	Land Acquisition			450					
5. P5 P/S	Mechanic & Electric				15,796		47,388		94,776
	Civil & Building							11,299	18,513
	Land Acquisition			300					
6. Miscellaneous Works						36,861	16,682	24,574	11,122

(Unit: 1,000 FCFA)

	2000		2001		2002		2003	
	Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign
Construction Cost			327,163	509,378	2,965,475	5,571,845	1,045,191	2,652,866
Engineering Fee	65,067	131,011	65,067	131,011	130,135	262,023	173,513	349,364
Physical Contingency	0	0	32,716	50,938	296,547	557,184	104,519	265,287
Land Acquisition			3,900					
Total	65,067	131,011	428,847	691,327	3,392,157	6,391,052	1,323,223	3,267,516

TABLE 13.5 SUMMARY OF INVESTMENT

- Sewerage Development in Western District of Abidjan -

(1000FCFA, Price in 1999)

Year	2000	2001	2002	2003	Total
CIVIL	160,839	822,610	8,937,456	2,946,222	12,867,127
M&E	35,240	293,663	845,753	1,644,518	2,819,173
Investment (ex. Land)	196,079	1,116,273	9,783,208	4,590,740	15,686,300
LAND	0	3,900	0	0	3,900
Investment (inc. Land)	196,079	1,120,173	9,783,208	4,590,740	15,690,200

Note 1: Miscellaneous Works are included in the Civil Works.

Note2: Engineering Fee and Physical Contingency are allocated to Civil Works and Mechanical & Electrical Equipment proportionally

TABLE 13.6 SUMMARY OF O&M COST
- Sewerage Development in Western District of Abidjan -

(1000 FCFA, Price in 1999)

Year	Sewer Pipeline	Pump.St	Personnel	Total	Remarks
2000	0	0	0	0	Construction
2001	0	0	0	0	
2002	0	0	0	0	
2003	0	0	0	0	
2004	62,205	147,000	18,000	227,205	
2005	62,205	147,000	18,000	227,205	
2006	62,205	147,000	18,000	227,205	
2007	62,205	196,000	18,000	276,205	Adding Pump
2008	62,205	196,000	18,000	276,205	
2009	62,205	196,000	18,000	276,205	
2010	62,205	196,000	18,000	276,205	
2011	62,205	196,000	18,000	276,205	
2012	62,205	196,000	18,000	276,205	
2013	62,205	196,000	18,000	276,205	
2014	62,205	196,000	18,000	276,205	
2015	62,205	196,000	18,000	276,205	
2016	62,205	196,000	18,000	276,205	
2017	62,205	196,000	18,000	276,205	
2018	62,205	196,000	18,000	276,205	
2019	62,205	196,000	18,000	276,205	
2020	62,205	196,000	18,000	276,205	
2021	62,205	196,000	18,000	276,205	
2022	62,205	196,000	18,000	276,205	
2023	62,205	196,000	18,000	276,205	
2024	62,205	196,000	18,000	276,205	
2025	62,205	196,000	18,000	276,205	
2026	62,205	196,000	18,000	276,205	
2027	62,205	196,000	18,000	276,205	
2028	62,205	196,000	18,000	276,205	
2029	62,205	196,000	18,000	276,205	
2030	62,205	196,000	18,000	276,205	
2031	62,205	196,000	18,000	276,205	
2032	62,205	196,000	18,000	276,205	
2033	62,205	196,000	18,000	276,205	
2034	62,205	196,000	18,000	276,205	
2035	62,205	196,000	18,000	276,205	
2036	62,205	196,000	18,000	276,205	
2037	62,205	196,000	18,000	276,205	
2038	62,205	196,000	18,000	276,205	
2039	62,205	196,000	18,000	276,205	
2040	62,205	196,000	18,000	276,205	
2041	62,205	196,000	18,000	276,205	
2042	62,205	196,000	18,000	276,205	
2043	62,205	196,000	18,000	276,205	
2044	62,205	196,000	18,000	276,205	
2045	62,205	196,000	18,000	276,205	
2046	62,205	196,000	18,000	276,205	
2047	62,205	196,000	18,000	276,205	
2048	62,205	196,000	18,000	276,205	
2049	62,205	196,000	18,000	276,205	
2050	62,205	196,000	18,000	276,205	
2051	62,205	196,000	18,000	276,205	
2052	62,205	196,000	18,000	276,205	
2053	62,205	196,000	18,000	276,205	

TABLE 13.7 SUMMARY OF INVESTIMENT AND O&M COST

- Sewerage Development in Western District of Abidjan -

(1 mil FCFA, Price in 1999)

Year	M&E	CIVIL	LAND	Inv Total	O&M	Inv+O&M
2000	35	161	0	196	0	196
2001	294	823	4	1,120	0	1,120
2002	846	8,937	0	9,783	0	9,783
2003	1,645	2,946	1	4,592	0	4,592
2004	0	0	0	0	227	227
2005	0	0	0	0	227	227
2006	0	0	0	0	227	227
2007	0	0	0	0	276	276
2008	0	0	0	0	276	276
2009	0	0	0	0	276	276
2010	0	0	0	0	276	276
2011	0	0	0	0	276	276
2012	0	0	0	0	276	276
2013	0	0	0	0	276	276
2014	0	0	0	0	276	276
2015	0	0	0	0	276	276
2016	0	0	0	0	276	276
2017	0	0	0	0	276	276
2018	0	0	0	0	276	276
2019	0	0	0	0	276	276
2020	0	0	0	0	276	276
2021	0	0	0	0	276	276
2022	0	0	0	0	276	276
2023	0	0	0	0	276	276
2024	0	0	0	0	276	276
2025	32	0	0	32	276	308
2026	264	0	0	264	276	541
2027	761	0	0	761	276	1,037
2028	1,480	0	0	1,480	276	1,756
2029	0	0	0	0	276	276
2030	0	0	0	0	276	276
2031	0	0	0	0	276	276
2032	0	0	0	0	276	276
2033	0	0	0	0	276	276
2034	0	0	0	0	276	276
2035	0	0	0	0	276	276
2036	0	0	0	0	276	276
2037	0	0	0	0	276	276
2038	0	0	0	0	276	276
2039	0	0	0	0	276	276
2040	0	0	0	0	276	276
2041	0	0	0	0	276	276
2042	0	0	0	0	276	276
2043	0	0	0	0	276	276
2044	0	0	0	0	276	276
2045	0	0	0	0	276	276
2046	0	0	0	0	276	276
2047	0	0	0	0	276	276
2048	0	0	0	0	276	276
2049	0	0	0	0	276	276
2050	32	145	0	176	276	453
2051	264	740	0	1,005	276	1,281
2052	761	8,044	0	8,805	276	9,081
2053	1,480	2,652	0	4,132	276	4,408
2054	0	0	0	0	276	276
2055	0	0	0	0	276	276
2056	0	0	0	0	276	276
2057	0	0	0	0	276	276
2058	0	0	0	0	276	276
2059	0	0	0	0	276	276
2060	0	0	0	0	276	276

Note 1: Life of M&E is 25 years and life of Civil works is 50 Years.
Note 2: Salvage value is assumed 10 % in both M&E and Civil Works.

TABLE 13.8 ESTIMATE OF FINANCIAL REVENUE IN 1998

	(in 1 mill FCFA)	
1. Total Revenue of SODECI (1998)	36,725	
2. Abidjan portion of revenue	36725*73683/112993=23948	
3. Study Area portion of revenue	23948*(258,091+596,455)/2694,990=7530	
4. Sewerage portion of the revenue in the study area	7530*.1=753	
5. The 2003 figure	753*(328208+756644)/(250891+595455)*(1.03)^5 =1,118	
6. Newly collected sewerage tariff	=1118*0.25=279	up to 2010
	=1118*0.40=447	from 2011
7. Total Revenue	=1118+279=1397	up to 2010
	=1118+447=1565	from 2011

TABLE 13.9 ESTIMATE OF FINANCIAL EXPENSE

	(in 1 mill FCFA, Price in 1998)	
1. Total expense of SODECI (1998)	35,330	
2. Abidjan portion of revenue	35330*73683/112993=23039	
3. Study Area portion of revenue	23039*(258,091+596,455)/2694,990=7244	
4. Sewerage portion of the revenue in the study area	7244*.1=724	
5. The 2003 figure	724*(328208+756644)/(250891+595455)*(1.03)^5 =1075	
6. O&M cost for newly added interceptor	=227	until 2006
	=276	after 2007
7. Total Expense for study area	=1075+227=1302	until 2006
	=1075+276=1351	after 2007