In connection with the green belt project, treatment plant sites in Alternatives 2 and 3 are located at most suitable points to reuse the effluent for irrigation. If the effluent from the treatment plant in Ma'alla is planned, additional pumping station and force mains to deliver the effluent to the green belt zone becomes necessary. In case of the Alternative 1A, the effluent can not be reused for any purpose. Therefore, Alternatives 1A and 1B are inferior to Alternatives 2 and 3 in this respect.

Based on the considerations mentioned above, Alternative 3 is recommended as the basis for the long term program.

4.1.4 Pumping and Force Main System

A study on the alternative pumping and force main systems had been conducted to find out the most appropriate system for Alternative 3, since the construction of the four pumping stations and force mains to send the sewage from the four districts to the treatment plant are the main tasks of the project, and their costs account for more than half of the total construction cost.

There are two basic issues regarding pumping and force main systems for the study area, viz. single force main line versus double force main lines, and intermediate pumping versus multi-continuous transfer systems.

A section of the force main of approximately 5 km from Khormaksar P/S to the treatment plant can be constructed either with single or double force main lines. In addition, there are two pumping systems technically available, viz. intermediate pumping and multi-continuous transfer systems. Intermediate pumping system is the relay system where sewage from one pumping station is pumped to the wet well in the next one and pumped again with sewage flow to the second one. On the other hand, in multi-continuous transfer system, sewage pumped from the first pumping station continues to flow to the final STP without dropping into the wet well of the next station.

Combining the two issues, the four following cases are considered as the pumping and force main system.

Case-1 Multi-continuous Transfer System, Single Line

All the sewage from the four districts are pumped by each district

pumping station and flow in a single force main to the STP. Each district pumping station has a pumping capacity equal to the peak flow of the district.

Case-2 Intermediate System, Single Line

A single force main line for all the four district is constructed as in Case-1. However, pumping system is intermediate, where sewage from the Tawahi P/S is pumped twice in Ma'alla P/S and Khormaksar P/S to the STP. Therefore, capacities of Ma'alla and Khormaksar P/S are the accumulated peak flows of upstream districts.

Case-3 Multi-continuous Transfer System, Double Lines

Instead of a single force main line in Cases-1 and -2, two lines, one for Ma'alla and Tawahi, another for Crater and Khormaksar are to be constructed. Each line is operated as a multi-continuous transfer system.

Case-4 Intermediate System, Double Lines

Two force main lines as in Case-3, and each pumping station is operated on intermediate pumping system.

Schematic diagrams of the four cases are shown in Figure 4.5.

Construction costs of the four cases were estimated as shown in Table 4.2. Construction costs both for the long term program and the first phase program for Ma'alla and Tawahi districts are presented in the table.

As shown in the table, construction costs of the single force main line (Cases -1 and -2) are less expensive than those of double force main lines (Cases-3 and -4) for long term program. However, for the first phase program, construction costs of the double force mains are apparently lower than those of the single force main line. This is due to a fact that larger diameter of force mains are constructed from Khormaksar P/S to the STP at the initial stage in case of a single force main line. Additionally, Khormaksar P/S should be constructed at the initial stage for the intermediate pumping system (Case-2). Therefore, if staged construction, which is probably the case for the project, is considered, and the implementation of the second phase is deferred by several years, construction of double force main lines becomes more

advantageous from economic view point.

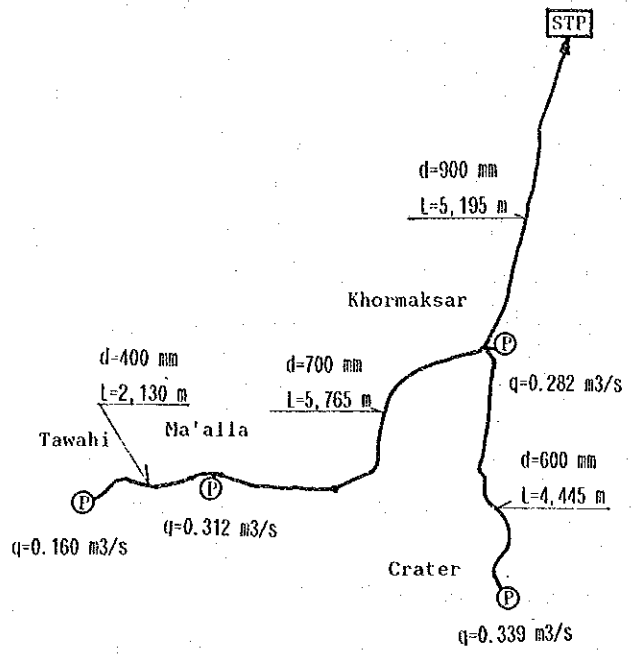
Moreover, there is a serious technical problem in multi-transfer single line system (Case-1) in case of staged construction. Pump operation in Tawahi P/S is very difficult at the initial stage until Crater P/S and Khormaksar P/S become operational. High motor power for Tawahi P/S which is required at full operation of the four pumping stations will pump more flow than designed when other pumping stations are not in operation. This will result in frequent shutting on and off of motors and pumps, which in turn cause shortening of the useful life of the machinery. Therefore, if Tawahi P/S is included in the first phase program, multi-continuous transfer single line system (Case-2) should be omitted.

From the above, Cases-1 and -2 are sifted out from economic and technical view point. Difference of construction costs of the other two cases for the first phase program is small and not decisive. Furthermore, there is not any marked advantage nor disadvantage for both cases from technical view point. Therefore, either of Cases-3 or -4 is recommended for the project and selection is left for the basic design stage of the project, although cost estimation in this section will be based on Case-3.

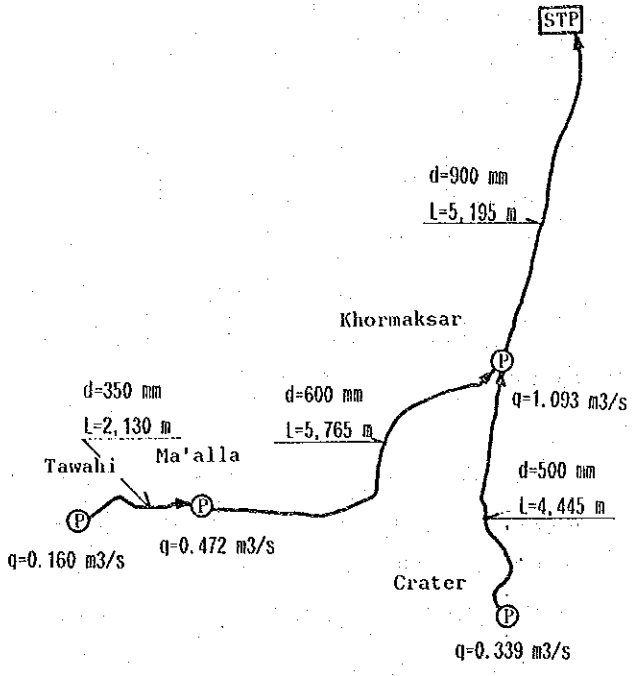
Table 4.2 Construction Cost for Four Cases

(Unit: YD 1,000)

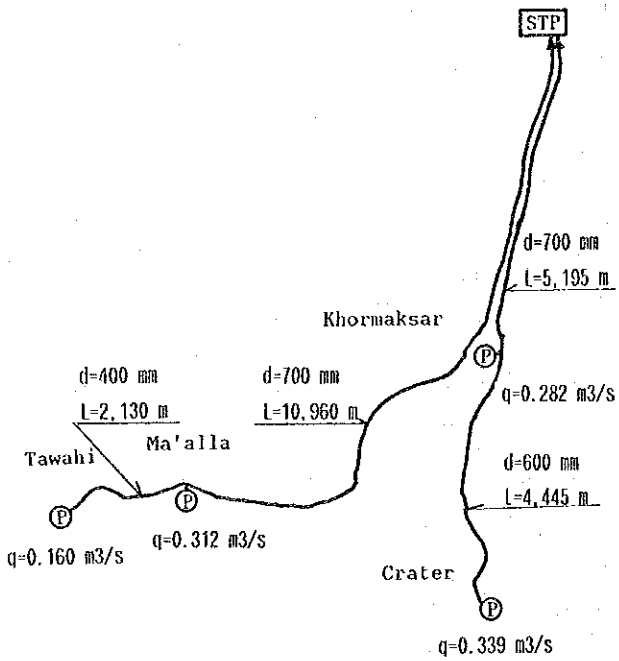
Phase	Facility	Case-1	Case-2	Case-3	Case-4
Long Term (Four Districts)	P/S	2,161	3,147	2,099	2,789
	Force Main	4,188	3,928	4,718	4,598
	Total	6,349	6,075	6,817	7,387
First Phase (Ma'alla & Tawahi)	P/S	1,080	2,157	1,017	1,273
	Force Main	3,274	3,119	2,704	2,681
	Total	4,354	5,276	3,721	3,954



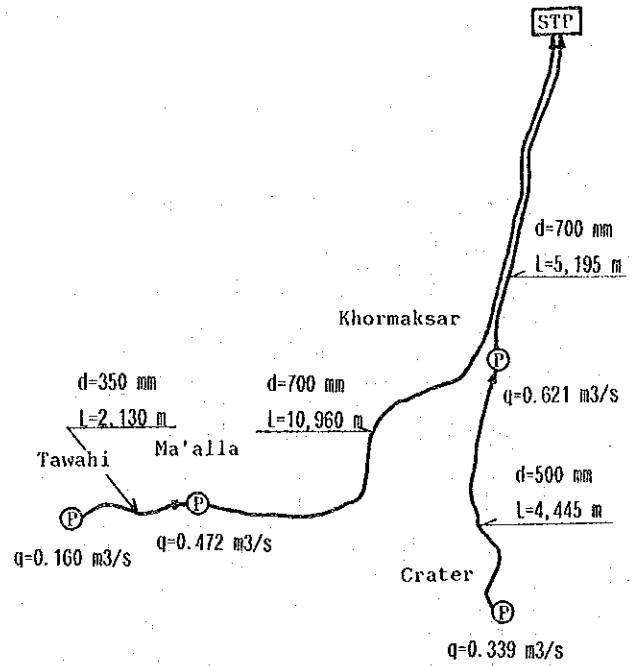
Case-1 Multi-continuous Transfer System, Single Line



Case-2 Intermediate Puming System Single Line



Case-3 Multi-continuous Transfer System, Double Lines



Case-4 Intermediate Puming System, Double Lines

Figure 4.5 Alternative Pumping and Force Main Systems

4.2 Sewerage Works to be Provided under Long Term Program

Based on the proposed sewerage system selected in Section 4.1 and studies on the existing sewerage systems described in Appendices C, F and I, all the sewerage works to be provided under the long term program to satisfy conditions in the study area in 2010 are identified and proposed in this section.

All the works under the long term program are classified into two categories, viz. major works and district works. Major works are defined as those which are necessary to pump and deliver the sewages from the four districts to the proposed STP. These are composed of four pumping stations, one in each district, force mains to connect pumping stations and STP, and a sewage treatment plant. On the other hand, district works are defined as those which compose district sewerage networks. These works include replacement or new construction of gravity sewers, rehabilitation of the existing pumping stations and improvement of sweeper passages.

4.2.1 Major Works

Major works to be provided under the long term program are summarized as follows. As discussed in the previous Section 4.1, the multi-continuous transfer system of double force main lines is recommended for the project. The following outline design of the major facilities is based on this system.

(1) Sewage Treatment Plant

Location: North of Khormaksar along the Abyan Road as indicated on Drawing No.51 in Volume Four.

Treatment Process: Stabilization pond process with an anaerobic pond, a facultative pond and two stages of maturation ponds in series.

Capacity: 48,800 m^3/d

Inlet work: Screen (manually operated), Parshal flume and flow recorder

Effluent disposal: Open channel to the sea, reuse for irrigation

Treated effluent is proposed to be used for the green belt project. Facilities required for the project are not identified at present. However, water level in the second maturation pond can allow an about 2 m head for delivery of the effluent. It is considered sufficient to irrigate the greenery around the treatment plant site.

Design details of the treatment plant are shown in Appendix G in Volume Three and in Drawings 52 to 55 in Volume Four.

(2) Pumping Stations

There are four major pumping stations in each of the four districts. Design details are shown in Appendix G in Volume Three and in Drawings 47 to 50 in Volume Four. Design outlines are summarized as follows.

i. Tawahi P/S

Design Flow: 9.6 m3/min
Pump Capacity (per unit): 4.8 m3/min
Total head: 52 m
Diameter of pumps: 200 mm
Number of units: 3 (including 1 standby)
Motor power: 415 V, 90 kW
Voltage: 11 KV
Type of pump: Screw volute
Control method: Automatic (by water level) and manual
Ancillary equipment: Generator, Screen (manually operated)
Substructure: Wet well and dry well made of reinforced concrete.

ii. Ma'alla P/S

Design Flow: 18.7 m3/min
Pump Capacity (per unit): 9.4 m3/min
Total head: 40 m
Diameter of pumps: 250 mm
Number of units: 3 (including 1 standby)
Motor power: 415 V, 120 kW
Voltage: 11 KV
Type of pump: Screw volute
Control method: Automatic (by water level) and manual
Ancillary equipment: Generator, Screen (manually operated)
Substructure: Wet well and dry well made of reinforced concrete

iii. Crater P/S

Design Flow: 20.3 m3/min
Pump Capacity (per unit): 10.2 m3/min
Total head: 43 m
Diameter of pumps: 250 mm
Number of units: 3 (including 1 standby)
Motor power: 415 V, 140 kW
Voltage: 11 KV
Type of pump: Screw volute
Control method: Automatic (by water level) and manual
Ancillary equipment: Generator, Screen (manually operated)
Substructure: Wet well and dry well made of reinforced concrete

iv. Khormaksar P/S

Desin Flow: 16.9 m3/min
Pump Capacity (per unit): 8.5 m3/min
Total head: 33 m
Diameter of pump: 250 mm
Number of unit: 3 (including 1 standby)
Motor power: 415 V, 90 kW
Voltage: 11 KV
Type of pump: Screw volute
Control method: Automatic (by water level) and manual
Ancillary equipment: Generator, Screen (manually operated)
Structure: Wet well and dry well made of reinforced concrete

(3) Force Main

Double force main lines, one for Ma'alla and Tawahi districts and another for Crater and Khormaksar districts, will be constructed. The former line is divided into two sections and the latter into three sections. Design outline of each section is described below. Plans and profiles of the force mains are shown in Drawings Nos.15 to 35, and 36 to 44, respectively, in Volume Four.

i. Tawahi P/S to Ma'alla P/S

Diameter: 400 mm
Length: 2,130 m
Material: DCIP

ii. Ma'alla P/S to STP
Diameter: 700 mm
Length: 10,960 m
Material: DCIP

iii. Crater P/S to Khormaksar P/S
Diameter: 600 mm
Length: 4,445 m
Material: DCIP

iv. Khormaksar P/S delivery line
Diameter: 450 mm
Length: 105 m
Material: DCIP

v. Khormaksar to STP
Diameter: 700 mm
Length: 5,195 m
Material: DCIP

4.2.2 District Works

Sewerage works to be provided in each district under the long term program are identified from a study on the existing sewerage system. These works are classified into the following three work items.

(1) Gravity sewers

Replacement of the existing sewers or installation of new gravity sewers have been planned. Capacities of the existing sewer pipes were calculated and checked with design sewage flows. As a result of the calculation, which is presented in Appendix F, certain sections of sewers were found to be insufficient to accommodate design flows. Diversion of sewer routes or replacements by larger size pipes are considered for these sections. New pipe lines to presently unsewered areas and new gravity mains to proposed pumping stations are also included in this work.

(2) Rehabilitation of pumping stations

There are more than 30 pumping stations in the four districts at present. Of the whole pumping stations, 20 pumping stations are identified as part of the public sewerage system for which Aden Municipality is responsible. There are 3 in Ma'alla, 1 in Tawahi and in Crater, and 15 in Khormaksar. Other pumping stations are either military or private facilities, and their rehabilitation is the responsibility of military authorities or private establishments. Therefore, rehabilitation of these pumping stations is excluded from the project.

All the mechanical equipment in 20 pumping stations will be replaced once by 2010. Buildings and substructures are classified into two groups, one group which can continue to be used, and another which requires re-building, depending on the present condition.

Three pumping stations in Ma'alla, Crater and Khormaksar, which will be substituted by new major pumping stations, will be abandoned.

(3) Improvement of sweeper passage

A total of 131 sweeper passages still remain in Ma'alla and Tawahi districts. Under the long term program, all of the sweeper passages are proposed to be improved to underground pipe collection system. Completion of this improvement work eliminate the bucket system for night soil collection.

Brief descriptions of these works in each district are as follows.

(1) Ma'alla District

i. Gravity sewers

Three sections of gravity sewers measuring a total of 1,943 m will be replaced or newly constructed. Locations of sewer sections proposed are shown in Drawings Nos.15 to 18 in Volume Three. These are summarized in Table 4.3 below.

Table 4.3 Gravity Sewer Work, Ma'alla

Section No.	M1	M2	M3
Location	Ma'alla Main road,	To unsewered Alshuly Area	To unsewered Alhabil Area
Purpose	Replacement of the existing main	New Construction	New Construction
Diameter (mm)	600	200	200
Length (m)	884	250	360
Material	VCP	VCP	VCP

ii. Pumping stations

The following three pumping stations are proposed to be rehabilitated as shown in Table 4.4 below.

Table 4.4 Rehabilitation of Pumping Stations, Ma'alla

Name of P/S	Dakka	Dolphin	Obstruction Pier
No.	102	103	104
Replacement of Pump Unit	Yes	Yes	Yes
Re-building of Structure	No	Yes	Yes
Diameter of Pump (mm)	150	100	100
Number of units	3	2	2
Motor Power (kW)	7	7	5
Type of Pump	Submersible	Submersible	Submersible

Note: Number of pump units include one standby.

iii. Improvement of sweeper passage

Number and total length of sweeper passages by areas which will be improved are shown in Table 4.5 below.

Table 4.5 Improvement of Sweeper Passages, Ma'alla

Area	Number (locations)	Length (m)
Old Ma'alla	22	1,037 m
Flour Mill	10	685 m
PCEP	1	50 m
Dakka	2	54 m
Sheik Asshag	18	878 m
Total	53	2,704 m

(2) Tawahi District

i. Gravity sewers

Three sections of gravity sewers extending for a total of 1,255 m will be constructed. Locations of sewer sections are shown in Drawing 21 in Volume Four. These are summarized as shown in Table 4.6 below.

Table 4.6 Gravity Sewer Work, Tawahi

Section No.	T1	T2	T3
Location	Bingisar	AICP Area	Cunning Market
Purpose	New Main	New Main	Diversion
Diameter (mm)	300 - 400	300	200
Length (m)	690	350	215
Material	VCP	VCP	VCP

ii. Pumping stations

One existing pumping station is proposed to be re-built under the long term program. Specifications of the new pump unit are as follows;

Specifications of new pump unit for
Abkari shopping center P/S (201)

- Diameter: 80mm
- Number of pump units: 2 (including 1 standby)
- Motor power: 3.7kw
- Type of pump: Submersible

iii. Improvement of sweeper passage

Number and total length of sweeper passage by areas are shown in Table 4.7 below.

Table 4.7 Improvement of Sweeper Passages, Tawahi

Area	Number (location)	Length (m)
Cunning Market	71	2,280 m
Bingisar	5	162 m
Hedjuff	2	69 m
Total	78	2,511 m

(3) Crater District

The existing sewers in the district can be used without any modification or replacement up to 2010. There are no sweeper passages in Crater. No gravity sewers or improvement of sweeper passage are proposed. The main pumping station near Immigration Office will be abandoned when the new Crater P/S will be commissioned. Therefore, work to be done in the long

term program in the district is limited to re-building the new structure of Front Bay P/S with a provision for new pump units. Specifications of new units are as follows.

Specifications of new pump unit for Front Bay P/S (302)

- Diameter: 100 mm
- Number of units: 2 (including 1 standby)
- Motor power: 11 kW
- Type of pump: Submersible

(4) Khormaksar District

i. Gravity sewers

Capacities of the existing sewer pipes are found to be sufficient to flow by gravity in 2010 from hydraulic calculations. Replacement of sewers for this purpose is not necessary in the district. However, damages caused by hydrogen sulfide gas are most serious in the district because of pipe material and topographic conditions of the district. At present pipes are broken at many locations and repair work is being carried out by Aden Municipality.

A field survey to investigate the conditions of the damaged pipes was carried out by the study team and estimation of the total length of the sewer pipes to be replaced has been made, based on the results of the survey. Details of the survey and estimates are presented in Appendix I.

Length of the presently damaged sewer pipes which require immediate repairs and of those which will likely have to be replaced by 2010 are estimated by sewerage zones as shown in Table 4.8.

Table 4.8 Length of Future Pipe Replacement, Khormaksar

Zone	Total Length of Sewer (m)	Damaged Pipe Length(1989) (m)	Damaged Pipe Length(90-2010) (m)	Total Length of Replacement (m)
H	1,960	550	630	1,180
J	2,694	735	75	810
E	2,244	250	1,100	1,350
C	1,863	270	850	1,120
G	1,919	245	905	1,150
K	501	60	240	300
B	1,455	640	815	1,455
L	2,610	75	705	780
M	2,902	720	150	870
Total	18,148	3,545	5,470	9,015

ii. Pumping stations

The following 15 pumping stations require replacement of machinery or entire re-building as shown in Table 4.9.

Table 4.9 Rehabilitation of Pumping Stations, Khormaksar

Name of P/S	Al Madina	Behind Libyan Embassy	Near Traffic Office	Near Cuban Embassy	Al Mukhtar G
No.	401	402	403	404	405
Replacement of Pump Unit	Yes	Yes	Yes	Yes	Yes
Re-building of Structure	Yes	Yes	No	Yes	Yes
Diameter of Pump (mm)	150	80	80	80	80
Number of Units	2	3	2	3	2
Motor Power (kW)	15.0	3.7	2.2	2.2	3.7
Type of Pump	Submersible	Submersible	Submersible	Submersible	Submersible

Name of P/S	Near Mini. of Education	October Quarter	Near Al Yemda Office	Central Market	Military Area
No.	406	407	408	409	410
Replacement of Pump Unit	Yes	Yes	Yes	Yes	Yes
Re-building of Structure	No	No	No	No	Yes
Diameter of Pump (mm)	150	150	80	80	80
Number of Units	2	3	2	2	3
Motor Power (kW)	11.0	15.0	2.2	2.2	2.2
Type of Pump	Submersible	Submersible	Submersible	Submersible	Submersible

Name of P/S	Dobiwara 2	Dobiwara 1	Dobiwara 3	Comminuter Station	Near Milk Factory
No.	412	413	414	415	417
Replacement of Pump Unit	Yes	Yes	Yes	Yes	Yes
Re-building of Structure	No	Yes	Yes	No	Yes
Diameter of Pump (mm)	80	80	80	100	80
Number of Units	2	2	2	2	2
Motor Power (kW)	2.2	2.2	2.2	2.2	2.2
Type of Pump	Submersible	Submersible	Submersible	Submersible	Submersible

4.3 Project Cost

4.3.1 Construction Cost

Construction cost for the sewerage works proposed in Section 4.2 is estimated in this section. Cost for this scale of construction work varies significantly depending on source of finance, construction period, bidding procedure and contract method under the present circumstances in Aden. Therefore, for the estimation of the construction cost, the following assumptions are made.

(1) All the work will be done under one contract. Although division of the work into more than one contract is possible, coordination among contractors will require additional time and cost. Therefore, for simplification of estimation, division of work into more than one contract have not been considered.

(2) Materials and equipment are assumed to be imported from the following countries taking into account availability in Aden and experience in work of similar nature in Aden.

Mechanical and electrical equipment:	Japan
Ductile cast iron pipe:	Japan
Vitrified clay pipe:	West Germany
Cement:	European countries
Steel Bars:	European countries
Construction machines:	Japan

(3) Laborers necessary for construction work are assumed to be tranported from third countries such as Bangladesh and Sri Lanka. It is a common practice for this scale of construction work in Aden.

(4) All costs for procurement and transportation of construction machines and equipment are included in the project cost. It is assumed that these machines and equipment are not to be re-exported.

(5) Provision of temporary accommodations for all foreign staff including administration staff, engineers and laborers is included in the contract.

As described in the next section, the project is divided into two phases. Thus, the total project cost is the sum of the costs for the first and the second phases. Table 4.10 shows the total project cost and that of the first phase, and Tables 4.11 and 4.12 show the breakdown of the direct construction cost, divided into by districts and work items. Contingency in Table 4.10 includes only physical contingency of 5 % of the sum of the direct construction cost and provisional sums, and therefore does not include price escalation. Price escalation should be included to estimate the project cost according to the implementation schedule. Project cost for the first phase program inclusive of the price escalation is presented in the next chapter. Details of cost estimation are presented in Appendix L in Volume Three. All costs are indicated at December 1988 price levels. Exchange rates for conversion of foreign currencies are as of December 1988 as shown below.

1 YD = 380 JY
1 YD = 2.92 US$
1 YD = 3.91 DM

All costs are divided into foreign currency and local currency portions according to the local availability of goods and services.

Total project cost for the long term program up to 2010 was estimated to be approximately YD 23.7 million at December 1988 price level. Project cost for the first phase program is approximately YD 11.4 million. Of these total project costs, YD 20.4 million (86.2 %) for the long term program and YD 9.9 million (87.7 %) for the first phase program are foreign currency portion. The local currecy portions are small and YD 3.3 million (13.8 %) and YD 1.4 million (12.3 %) respectively.

For the long term program, the largest portion of the direct construction cost is accounted for by the force mains, YD 4.7 million (34.5 %) . This is followed by sewage treatment plant, YD 3.5 million (25.4 %) and major pumping stations YD 2.1 million (15.3 %). Construction cost for the three items of the district facilities is relatively small, YD 3.4 million (24.7 %) all together.

In addition to the total project cost mentioned above, approximately YD 715 thousand will be required as additional cost for improvement of the sewerage facilities in extra catchment areas. This cost covers construction of on site sewage disposal systems in MOI camp and Al Arish village both of which are located north of the airport and rehabilitation of a total 17 pumping stations located in military and government areas in Tawahi and Khormaksar districts. Details of systems and breakdown of cost are presented in Appendices M and N.

Table 4.10 Project Cost, Long Term and First Phase Programs

(unit: YD 1,000)

Classification and Work Item	Long Term			First Phase		
	F.C.	L.C.	Total	F.C.	L.C.	Total
Direct Cost						
1. Sewage Treatment Plant	1,951	1,531	3,482	843	621	1,464
2. Major Pumping Stations	2,077	40	2,117	1,015	20	1,035
3. Force Main	4,669	279	4,948	2,741	164	2,905
4. Gravity Sewers	1,781	331	2,112	557	76	633
5. Rehabilitation of Pumping Stations	629	23	652	198	7	205
6. Improvement of Sweepers' Passages	518	51	569	518	51	569
7. Sub-total Direct Construction Cost	11,625	2,255	13,880	5,872	939	6,811
Indirect Cost						
8. Provisional Sums	6,545	694	7,239	3,158	370	3,528
9. Sub-total	18,170	2,949	21,119	9,030	1,309	10,339
10. Physical Cotingency 5 % of 9	909	147	1,056	452	65	517
11. Sub-total	19,079	3,096	22,175	9,482	1,374	10,856
12. Engineering Cost 9 % of 11	1,634	262	1,896	813	114	927
13. Total Project Cost	20,713	3,358	24,071	10,295	1,488	11,783

Table 4.11 Construction Cost for Major Facility

(unit: YD 1,000)

Facilities	First Phase			Second Phase			Long Term Total		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
1. Sewage Treatment Plant									
- Civil & Architectural	682	621	1,303	946	910	1,856	1,628	1,531	3,159
- Mechanical & Electrical	161	-	161	162	-	162	323	-	323
- Total	843	621	1,464	1,108	910	2,018	1,951	1,531	3,482
2. Pumping Stations									
2.1 Tawahi P/S									
- Civil & Architectural	95	10	105	-	-	-	95	10	105
- Mechanical & Electrical	376	-	376	-	-	-	376	-	376
- Total	471	10	481	-	-	-	471	10	481
2.2 Ma'alla P/S									
- Civil & Architectural	94	10	104	-	-	-	94	10	104
- Mechanical & Electrical	450	-	450	-	-	-	450	-	450
- Total	544	10	554	-	-	-	544	10	554
2.3 Crater P/S									
- Civil & Architectural	-	-	-	93	10	103	93	10	103
- Mechanical & Electrical	-	-	-	491	-	491	491	-	491
- Total	-	-	-	584	10	594	584	10	594
2.4 Khormaksar P/S									
- Civil & Architectural	-	-	-	93	10	103	93	10	103
- Mechanical & Electrical	-	-	-	385	-	385	385	-	385
- Total	-	-	-	478	10	488	478	10	488
Total P/S	1,015	20	1,035	1,062	20	1,082	2,077	40	2,117
3. Force Main									
3.1 Tawahi P/S to Ma'alla P/S	268	23	291	-	-	-	268	23	291
3.2 Ma'alla P/S to STP	2,473	141	2,614	-	-	-	2,473	141	2,614
3.3 Crater P/S to Khormaksar P/S	-	-	-	859	71	930	859	71	930
3.4 Khormaksar P/S Derivery Line	-	-	-	12	0	12	12	0	12
3.5 Khormaksar to STP	-	-	-	1,057	44	1,101	1,057	44	1,101
Total Force Main	2,741	164	2,905	1,916	115	2,031	4,669	279	4,948
Grand Total	4,599	805	5,404	4,086	1,045	5,131	8,697	1,850	10,547

Note: Costs are direct cost basis.

Table 4.12 Construction Cost for District Facilities

(unit: YD 1,000)

District	Works	First Phase			Second Phase			Long Term Total		
		F.C.	L.C.	Total	F.C.	L.C	Total	F.C.	L.C.	Total
Ma'alla	Gravity Sewers									
	- Sectiin M1	214	29	243	-	-	-	214	29	243
	- Section M2	44	3	47	-	-	-	44	3	47
	- Section M3	65	4	69	-	-	-	65	4	69
	Total	323	36	359	-	-	-	323	36	359
	Rehabilitation of P/S (3 Nos.)									
	- Civil & Architectural	96	5	101	-	-	-	96	5	101
	- Mechanical & Electrical	11	-	11	-	-	-	11	-	11
	Total	107	5	112	-	-	-	107	5	112
	Improvement of Sweepers' Passage (53 Locations)	265	26	291	-	-	-	265	26	291
	Total Ma'alla	695	67	762	-	-	-	695	67	762
Tawahi	Gravity Sewers									
	- Sectiin T1	128	27	155	-	-	-	128	27	155
	- Section T2	56	12	68	-	-	-	56	12	68
	- Section T3	50	1	51	-	-	-	50	1	51
	Total	234	40	274	-	-	-	234	40	274
	Rehabilitation of P/S (1 No.)									
	- Civil & Architectural	26	2	28	-	-	-	26	2	28
	- Mechanical & Electrical	65	-	65	-	-	-	65	-	65
	Total	91	2	93	-	-	-	91	2	93
	Improvement of Sweepers' Passage (79 Locations)	253	25	278	-	-	-	253	25	278
	Total Tawahi	578	67	645	-	-	-	578	67	645
Crater	Gravity Sewers	-	-	-	-	-	-	-	-	-
	Rehabilitation of P/S (1 Nos.)									
	- Civil & Architectural	-	-	-	24	2	26	24	2	26
	- Mechanical & Electrical	-	-	-	11	-	11	11	-	11
	Total	-	-	-	35	2	37	35	2	37
	Improvement of Sweepers' Passage	-	-	-	-	-	-	-	-	-
	Total Crater	-	-	-	35	2	37	35	2	37
Khormaksar	Gravity Sewers	-	-	-	1,224	255	1,479	1,224	255	1,479
	Rehabilitation of P/S (8 Nos.)									
	- Civil & Architectural	-	-	-	193	13	206	193	13	206
	- Mechanical & Electrical	-	-	-	203	1	204	203	1	204
	Total	-	-	-	396	14	410	396	14	410
	Improvement of Sweepers' Passage	-	-	-	-	-	-	-	-	-
	Total Khormaksar	-	-	-	1,620	269	1,889	1,620	269	1,889
Total		1,273	134	1,407	1,655	271	1,926	2,928	405	3,333

Note: Costs are estimated on direct cost basis.

4.3.2 Operation and Maintenance Cost

Operation and maintenance cost for all facilities proposed for the long term program is estimated, based on manpower and electrical power requirements. Manpower requirements are limited to laborers working at sites and administrative and engineering staff in the head office are not included. Laborers involved in sewer cleaning, operation and maintenance of pumping stations and sewage treatment plant have been estimated based on length or capacity of the facility. Electrical power requirement is estimated based on motor power and daily average sewage flow. Present unit prices at December 1988 level are used for labor and electric power costs. In addition to these costs, maintenance cost for repair including cost for spare parts is estimated as a proportion of construction costs.

When all the facilities are completed, approximately YD 0.4 million will be required anually. Breakdown of operation and maintenance cost by facilities are shown in Table 4.13 below.

Table 4.13 Operation and Maintenance Cost

Facility	O & M Cost (YD 1,000/anum)			
	Labor	Power	Repair Cost	Total
Sewers	80	-	20	100
P/S	94	125	30	249
STP	26	11	20	57
Total	200	136	70	406

4.4 Implementation Schedule

The implementation schedule for the long term program has been developed to complete all the works identified in the previous section by 2010. Implementation of the project depends upon the availability of funding in PDRY, since it involves a heavy investment, mostly in foreign currency. Although the availability of funding is not assured at present, the long term program is recommended to be implemented in two stages, taking into account the amount of total project cost and urgency of the works.

Details of the work to be implemented under the first and the second phase programs are as follows.

First Phase Program

(1) Engineering service

- Detailed design of all the facilities under the first phase program.
- Preparation of contract documents
- Evaluation of tenders
- Construction supervision

(2) Preparatory work

- Procurement, shipping and transportation of materials and equipment
- Survey of the construction sites
- Erection of site office, accommodation and other temporary facilities

(3) Major works

- Construction of two sections of force main, from Tawahi P/S to Ma'alla P/S, and from Ma'alla to the new treatment plant
- Construction of two main pumping stations, Tawahi P/S and Ma'alla P/S
- Construction of sewage treatment plant, the first one of the three process trains, inlet work, administration building and ancillary facilities

(4) District works

The following work in Ma'alla and Tawahi districts

- Construction and replacement of gravity sewers
- Improvement of sweepers' passages
- Rehabilitation of the existing pumping stations

Second Phase Program

(1) Engineering service

Similar to those in the first phase program

(2) Preparatory work

(3) Major works

- Construction of three sections of force main, from Crater P/S to Khormaksar junction, from Khormaksar P/S to the junction, and from the junction to the new treatment plant
- Construction of two main pumping stations, Crater P/S and Khormaksar P/S
- Construction of sewage treatment plant, two remaining process trains

(4) District works

- Replacement of damaged sewers in Khormaksar
- Rehabilitation of existing pumping stations

The first and the second phase programs are assumed to commence in 1990 and in 2001, respectively, as shown in Figure 4.6. The period necessary for each work item are estimated based on its nature and work load. As a result, the first and the second phase programs are approximately four years each, including construction for three years.

Although district works in Crater and Khormaksar districts are assumed to be implemented under the second phase program for the purpose of cost estimation, these works may be necessitated before 2001, as damage to sewers and breakdown of pumps occur. Furthermore, implementation of the second phase program is flexible, and accelerated commencement before 2001 is desirable, if it is possible.

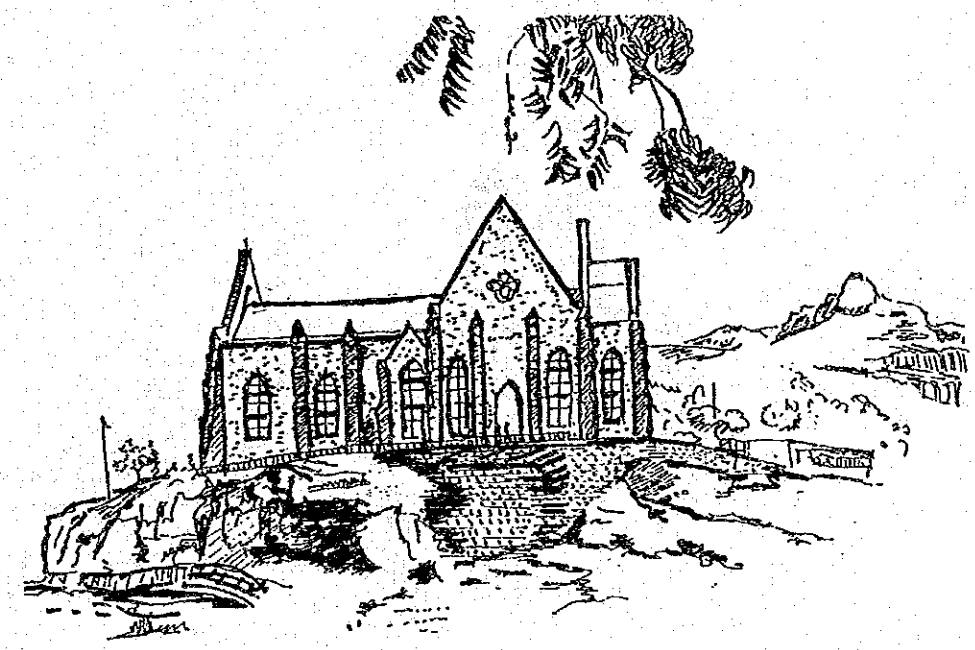
Figure 4.6 Implementation Schedule

Work Item	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
I First Phase Program																					
1. Engineering Service	(14)		(31)																		
2. Preparatory Work			(21)																		
3. Major Works																					
- Force Main			(20)																		
- Pumping Station			(16)																		
- Sewage Treatment Plant			(16)																		
4. District Works																					
- Gravity Sewer			(10)																		
- Improvement of Sweepers' Passage				(15)																	
- Rehabilitation of Pumping Station				(14)																	
II Second Phase Program																					
1. Engineering Service												(14)		(31)							
2. Preparatory Work													(22)								
3. Major Works																					
- Force Main														(27)							
- Pumping Station														(16)							
- Sewage Treatment Plant														(27)							
4. District Works																					
- Gravity Sewer														(27)							
- Rehabilitation of Pumping Station															(19)						

Note: Figures in parentheses are periods in month.

CHAPTER FIVE

FIRST PHASE PROGRAM



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CHAPTER FIVE

FIRST PHASE PROGRAM

5.1 Introduction

Sewerage facilities to be constructed and improved under the first phase program have been identified in Chapter Four. These facilities are limited to those necessary for collection, pumping and treatment of the sewage from Ma'alla and Tawahi. This section describes the engineering details for the construction and improvement of these facilities.

The results of the topographic survey conducted in order to decide the location of the facilities and to obtain the precise topographic condition of the sites are described. Construction sites for the sewage treatment plant and two main pumping stations have been confirmed with GDLG, Aden Municipality and other authorities concerned.

The results of the soil test for the determination of the most appropriate borrow pit for the construction of embankment for the STP are presented together with their evaluation. Soils from the Sheik Othman borrow pit was considered most suitable for the embankment because of the properties of the soil and its proximity to the construction site.

In view of the nature and magnitude of the construction work, selection of the appropriate construction materials, equipment and methods is of importance for the financial viability of the project. Among the various possible alternatives, the most suitable ones are selected and recommended based on a detailed technical and economic evaluation.

Preliminary engineering design of all the main facilities under the first phase program has been carried out. These include new gravity trunk sewers, force mains, main pumping stations and sewage treatment plant. Drawings of the facilities are attached in Volume Four of the current report.

Project cost inclusive of construction and operation and maintenance costs for the first phase program has been estimated, based on the design of the facilities and construction method recommended. Implementation schedule for the

first phase is proposed taking into account the urgency of the project and the work load of construction.

5.2 Field Survey

5.2.1 Topographic Survey

Topographic survey was carried out during the first and second on-site work, from December 1988 to March 1989, and from June to September 1989 respectively. Topographic survey includes the following specific items.

(1) Leveling survey of the force main route including confirmation of the official bench marks of the Highway Authority

(2) Leveling survey of the existing sewers and manholes which will connect to the new trunk sewers or of which capacities need to be checked

(3) Plain table survey at proposed major pumping stations

(4) Leveling and confirmation of the present condition of the proposed STP site

Description and results of the survey are summarized below and details are presented in Appendix B.

(1) Leveling survey of the force main route

A total length of 19 km of the possible force main route as shown in Figure 5.1 was surveyed. Official bench marks established by the Highway Authority of the Ministry of Construction were used for the survey. One temporary bench mark was established by the study team at a convenient location for sewerage planning, at the roundabout in front of the Aden Hotel in Khormaksar.

Levels are plotted in Drawings No. 9 through No. 14 in Volume Four and force main profiles in Drawings No. 36 through No. 44.

(2) Leveling survey of the existing sewers and manholes

Leveling survey of the existing sewers and manholes was carried out at the following places in Ma'alla and Tawahi for the purpose of evaluating existing sewer capacities. The results of the evaluation are presented in Appendix C. Locations are shown in Figure 5.2. Level of the existing manholes obtained from the survey were also used in designing the new gravity sewers.

a. along the four existing trunk sewer lines

b. manholes in 10 sections in Ma'alla and 2 sections in Tawahi of the existing sewer lines.

(3) Plain table survey at proposed main pumping stations

Plain table survey was carried out at the four proposed major pumping stations to confirm the construction sites. Ma'alla main pumping station is proposed to be located in the immediate vicinity of the existing Hedjuff P/S as illustrated in Figure 5.3. Enough area for construction is available within the property of the Municipality. The Tawahi major pumping station is proposed to be located at the site near the Marine Training Center of YPA where the old warehouse is located as illustrated in Figure 5.4. The site is the property of YPA. An agreement was reached by YPA and GDLG for the use of the site. The old warehouse will be demolished for the construction of the pumping station.

The sites for the Crater and Khormaksar main pumping stations are illustrated in figures in Appendix B.

(4) Leveling and confirmation of present condition of the proposed STP site

Ground level and condition of the proposed STP site, such as topography, possible obstacles to the construction and groundwater level were surveyed to confirm the availability of sufficient area and to obtain data for the designing of STP. It was confirmed with GDLG that construction area of approximately 82 ha is available at the proposed site as illustrated in Figure 5.5.

5.2.2 Underground Cables and Pipes

There are five kinds of underground pipes and cables which may affect the construction of the sewerage facilities in the study area. Kinds of pipes and cables, and their responsible authorities are as follows.

(1) Water supply --------- PWC
(2) Electric supply ------ PCEP
(3) Telephone ------------ Telecom Office
(4) Oil ------------ Aden Refinery
Aden Bunkering Company
(5) Sewer ------------ Aden Municipality

Information and location maps of these pipes and cables have been collected from the authorities concerned. Pipes and cables crossings of force mains are indicated on the Drawings No. 36 to No. 44.

5.2.3 Soil Test

In order to determine the most suitable borrow pit site for the construction of embankment at STP, soil tests were carried out both in Aden and Japan. Initially four possible borrow pit sites were selected as shown in Figure 5.6 on the suggestion of GDLG and Aden Municipality. Distance from the STP site to each borrow pit is as follows.

- Bir Omar 27 km
- Sheik Othman 13 km
- Hiswa 15 km
- Dar Sa'ad 21 km

The following three items were tested by the laboratory of MOC and Aden University.

a. Soil grading
b. Unit weight
c. Permeability coefficient

After the first results had been obtained, two samples from Sheik Othman and

Dar Sa'ad were taken back to Japan for further testing. The results of the tests are presented in Appendix J.

From the results of the tests and to minimize cost, i.e. the shortest distance to the construction site, Sheik Othman site is considered most suitable as borrow pit.

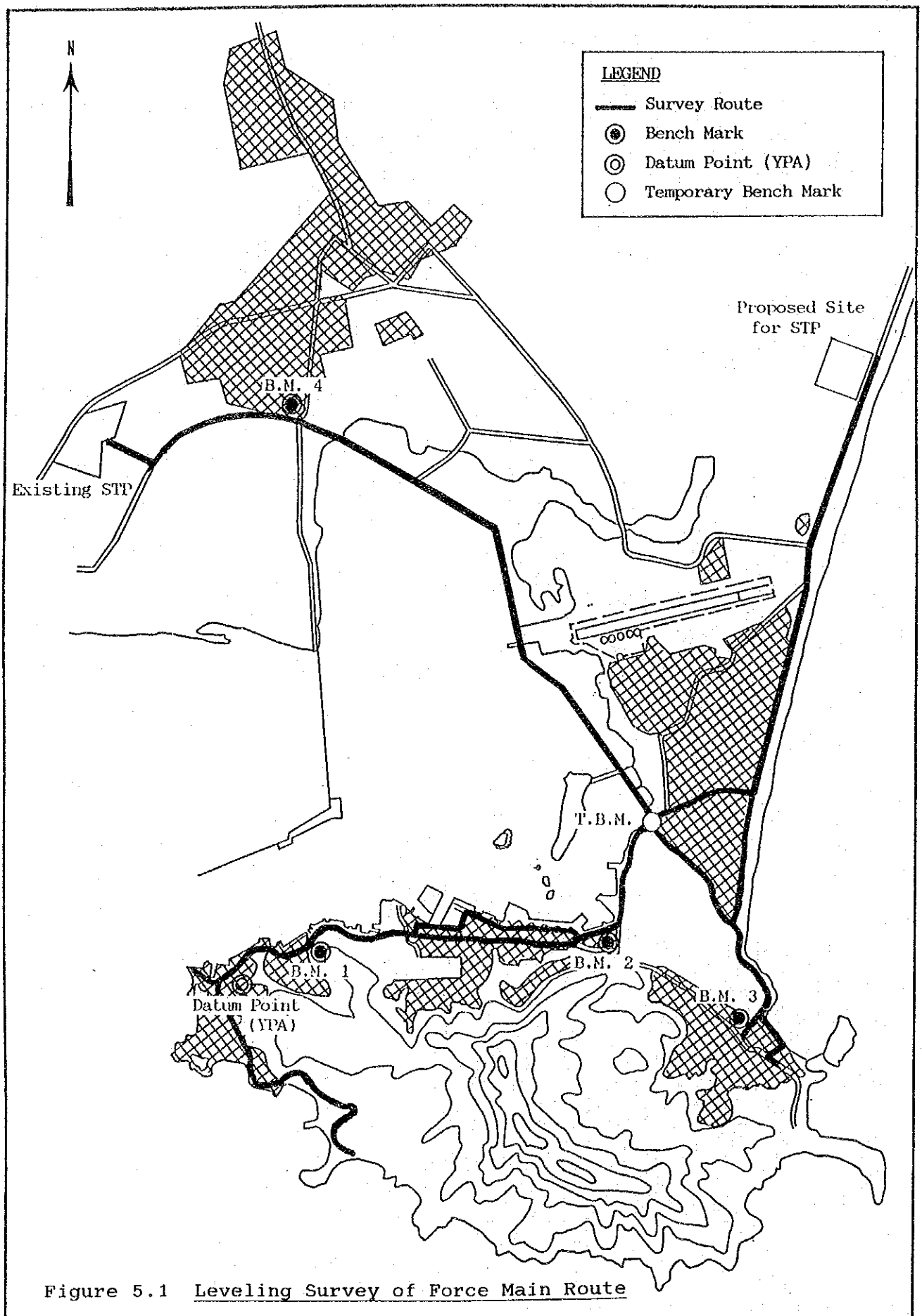

Figure 5.1 Leveling Survey of Force Main Route

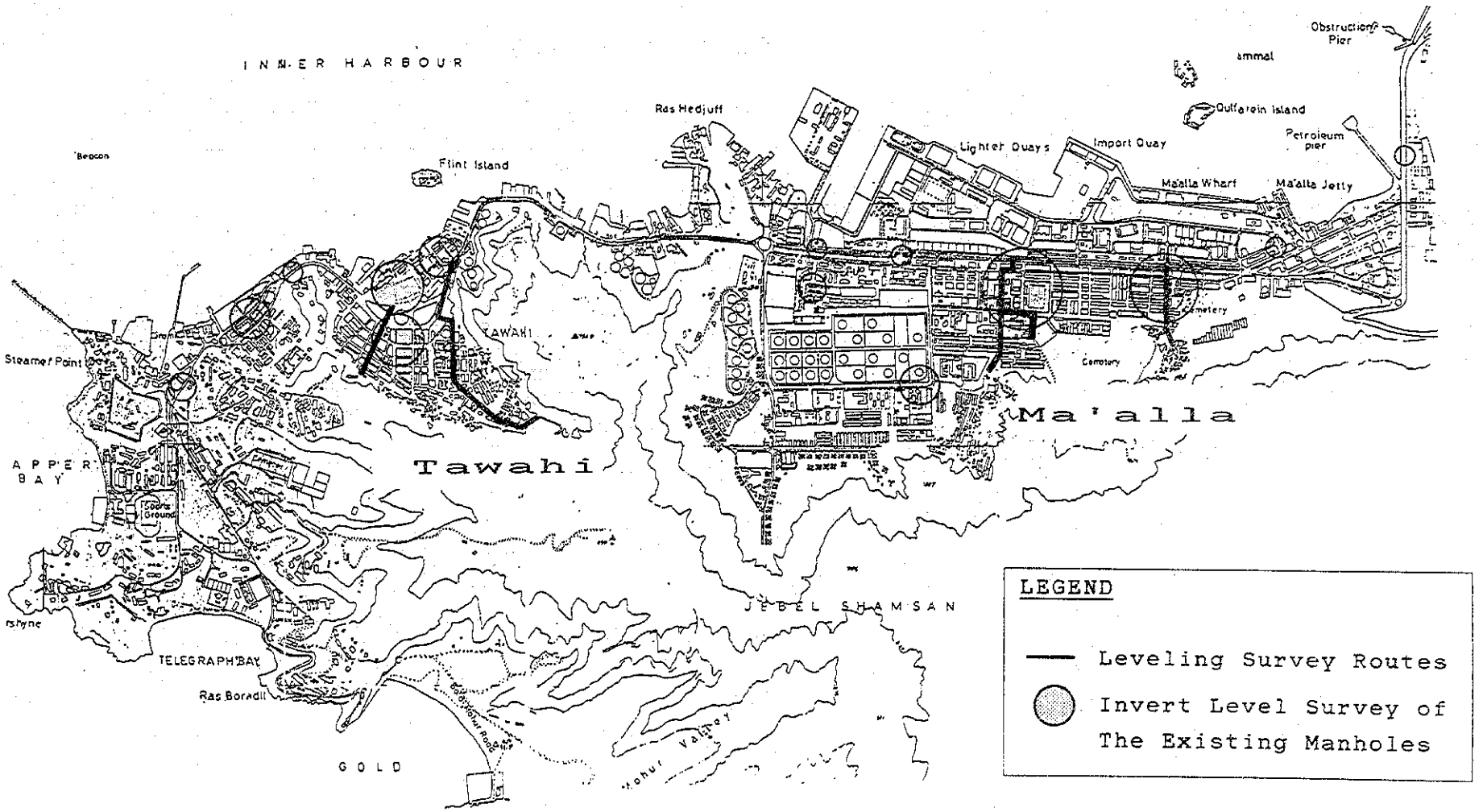

Figure 5.2 Leveling Survey of Existing Sewers and Manholes

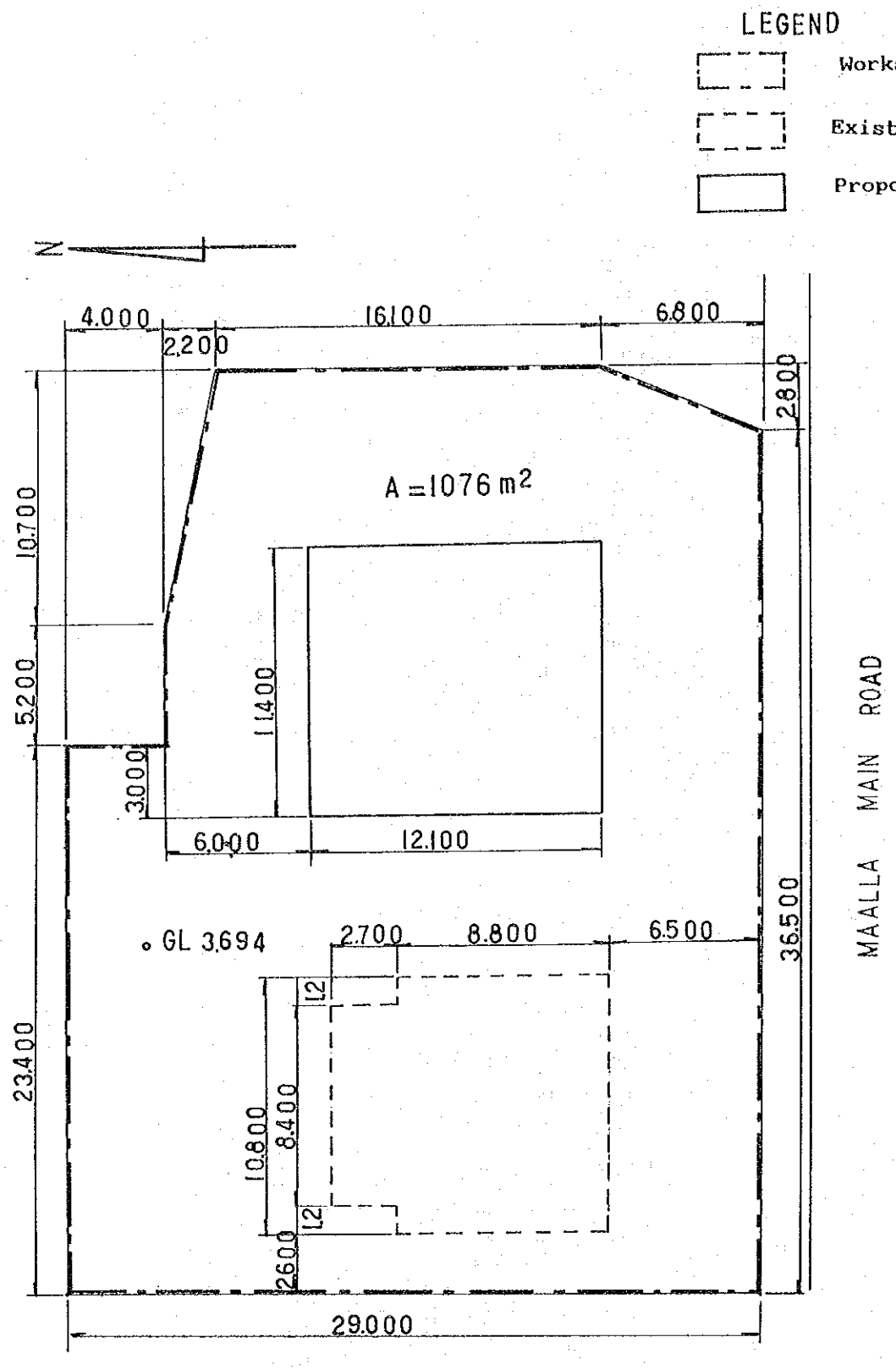

Figure 5.3 Plan of Maalla Pumping Station

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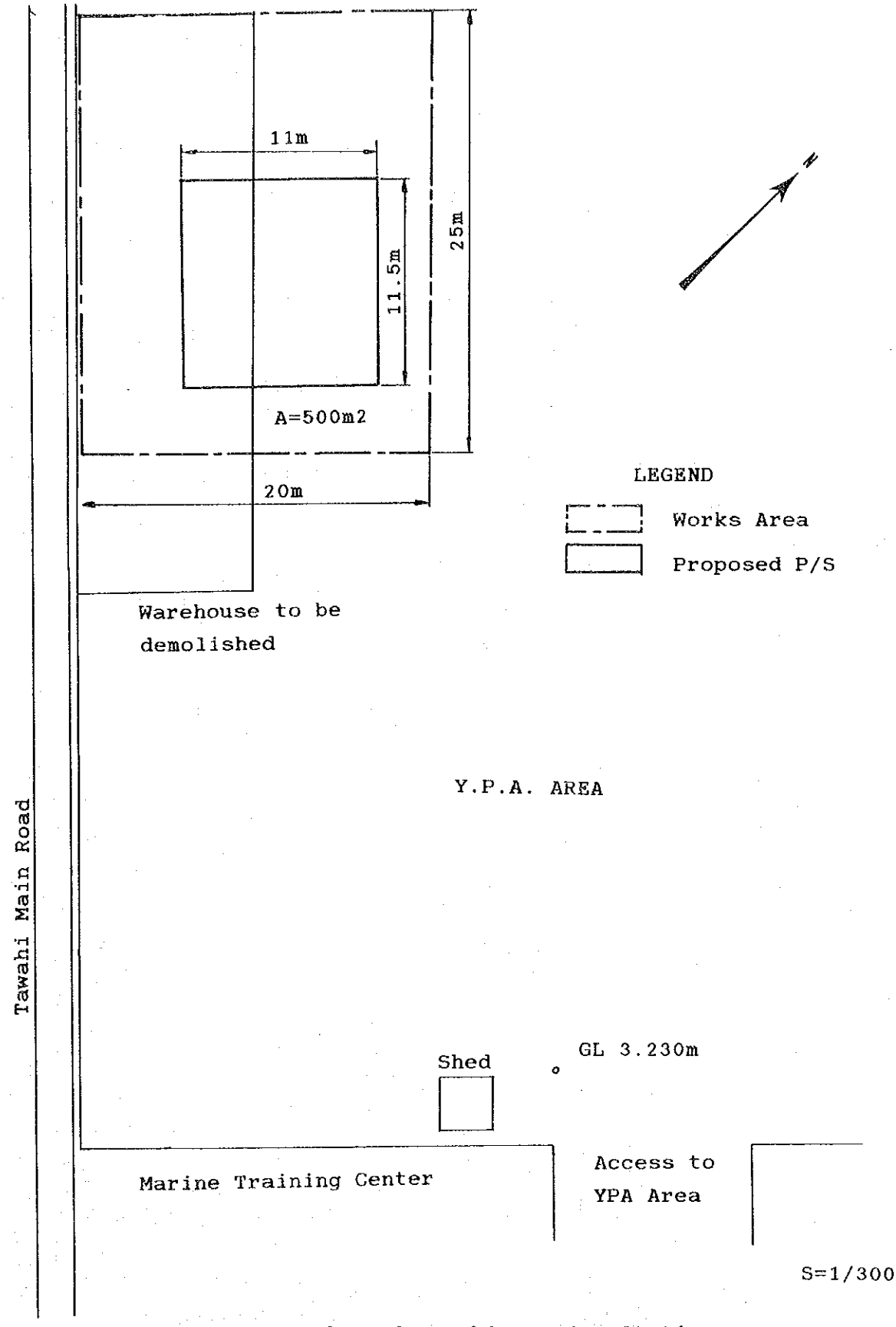


Figure 5.4 Plan of Tawahi Pumping Station

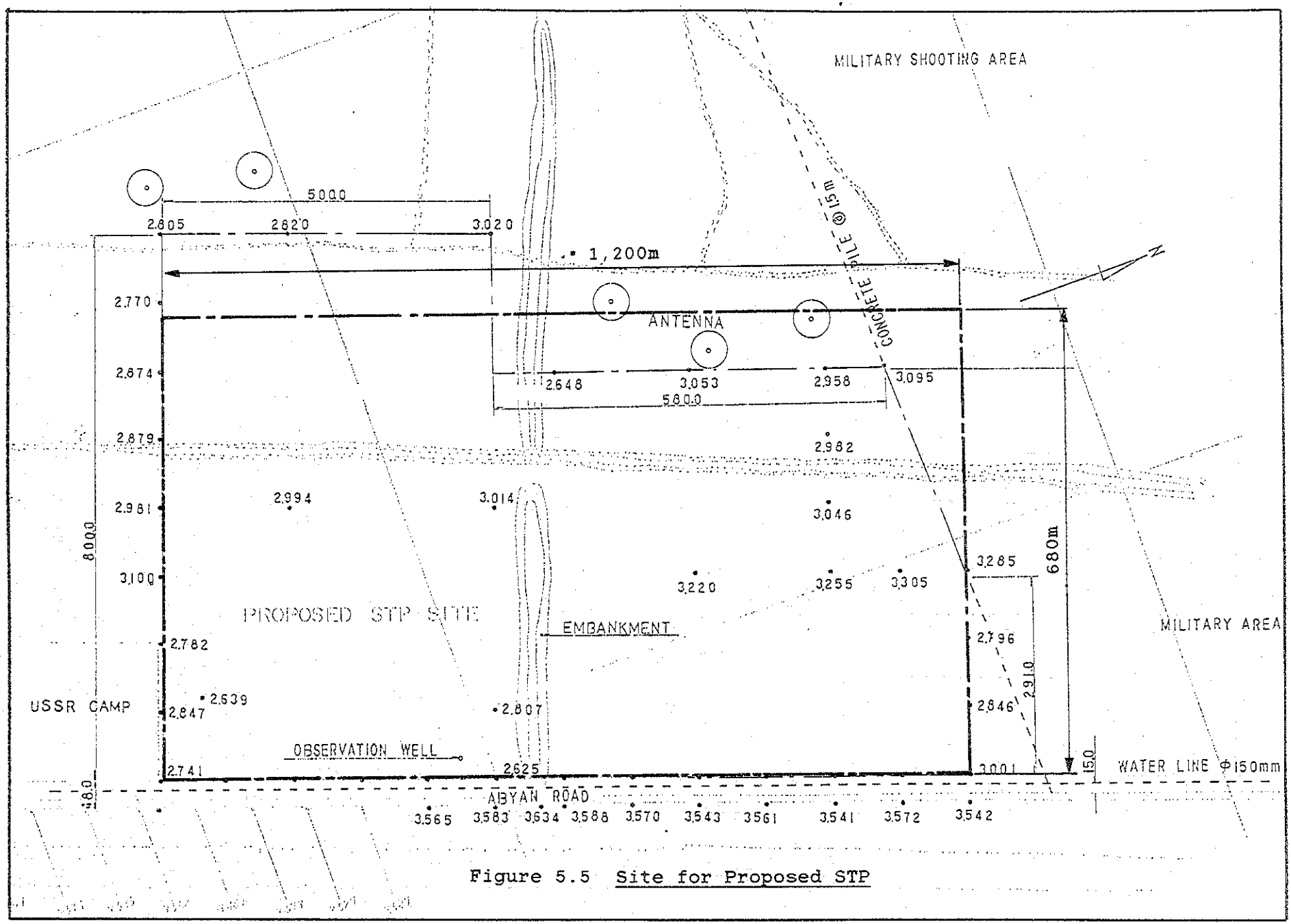


Figure 5.5 Site for Proposed STP

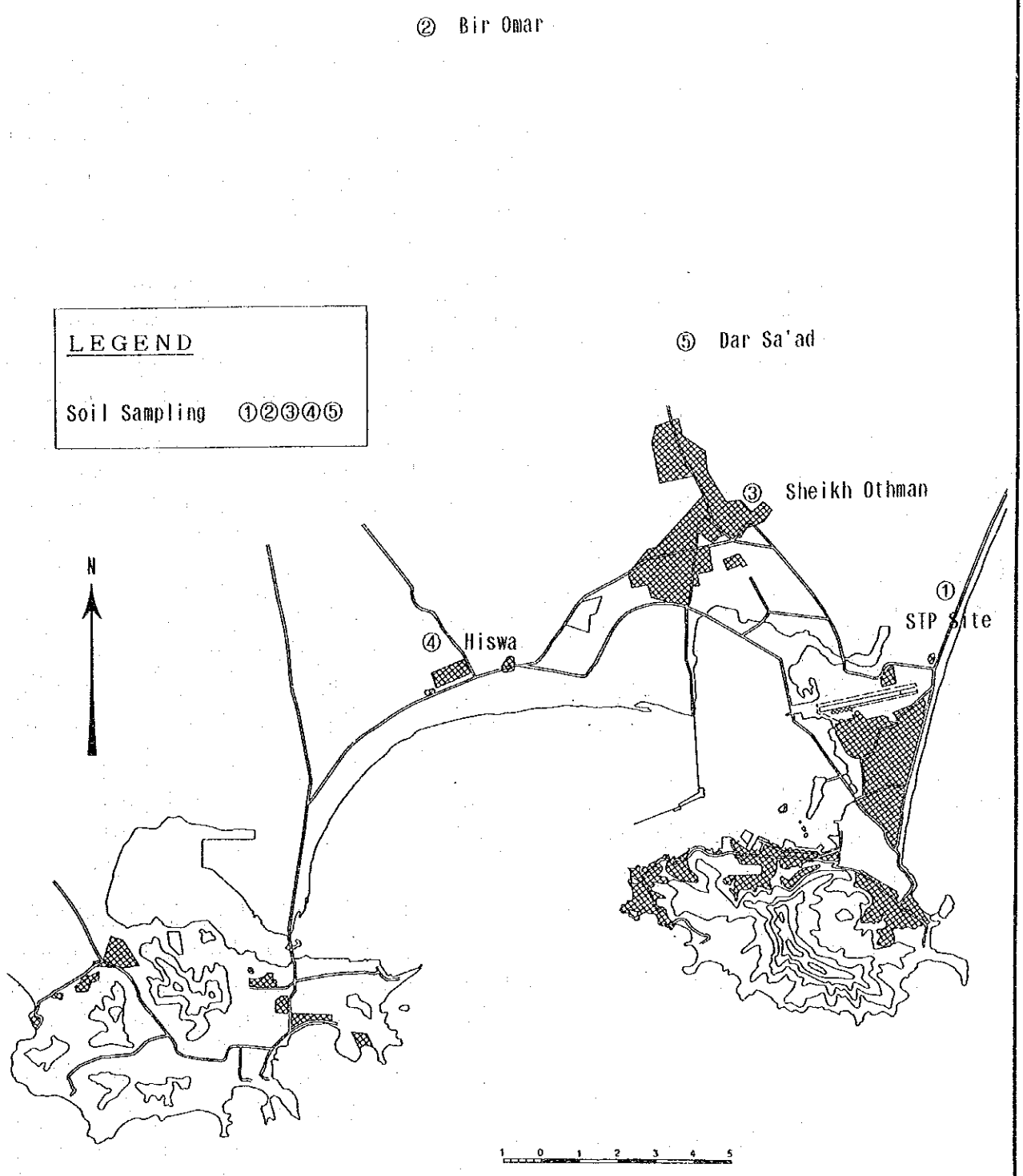


Figure 5.6 Location for Soil Sampling

5.3 Construction Materials, Methods and Equipment

5.3.1 General

Presently, most of construction materials, mechanical and electrical equipment for the major sewerage facilities such as gravity sewers, force mains, pumping stations and treatment plant, and construction machines both for permanent and temporary work facilities are not locally available in Aden. These materials and equipment are to be imported from foreign countries.

Natural conditions in Aden are not favorable for construction of sewerage facilities. High temperatures and high organic components of sewage tend to cause hydrogen sulphide built up. High salinity of soils and aggregates because of proximity to sea may be a cause for corrosion of equipment and structures.

Skilled and non-skilled laborers for construction work are in short supply in Aden. Qualified specialist required for operation and maintenance of the sewerage system are difficult to employ.

The above mentioned factors in the study area should be taken into account in selecting suitable materials, construction methods and equipment. Materials should have adequate strength and resistance against corrosion caused by hydrogen sulphide gas attack and aggressive soils to ensure sufficiently long useful life. Equipment should be durable and robust, and easy to maintain at the same time. Most importantly, materials and equipment should be economical as well as satisfy technical requirements.

All the materials and equipment necessary for the construction of the sewerage facilities for the project have been identified and several alternatives have been studied to select the most suitable ones for the study area. The selection process and recommended materials and equipment are summarized below.

5.3.2 Materials

(1) Concrete

Sand and gravel suitable for concrete aggregate are available in and around Aden. However, it is necessary to check the content of sodium chloride, which should be less than 0.1 %. Since most of the sewerage structures are subject to hydrogen sulphide attack, high quality sulphate-resisting portland cement is recommended. The actual specifications of concrete mixes and strength are to be decided during final design. However, in view of the importance of preventing not only structural failure but groundwater infiltration also, all concrete for sewerage should be dense and properly cured to obtain the full advantage of quality control.

(2) Anti-Sulphide Protection for Concrete Substructures

All the substructures shall be protected by sheet or other methods from hydrogen sulphide gas attack. The following protection methods of concrete substructures are to be utilized.

a. Protection Boad for External Surfaces

Anti-sulphide protection for external surfaces is called "tanking by protection boad", and it comprises of two layers of water proof polythene membranes. Tanking of all surfaces of concrete structures shall be provided.

b. PVC protection Sheet for Internal Surface

Internal surfaces are to be lined so that it can protect the concrete structure against hydrogen sulphide gas from raw sewage. The internal surfaces of all pumping stations, manholes and screen chamber in intermittent contact with sewage shall be lined with a sort of plastic or rubber sheeting keyed or bonded into the concrete at the time of frame work.

Four practical lining methods, widely used in many countries, have been

evaluated. These are lining by i) paints, ii) soft PVC sheet, iii) hard PVC sheet and iv) rubber sheet. Although lining by paints is most widely used and least expensive among the four methods, it is not recommended for the project because of the frequent occurrence of cracks. Rubber sheeting is not considered suitable because of the poor adhesion to concrete. Sheeting with either soft or hard PVC is the option available of which, soft PVC sheeting is considered more suitable than hard PVC sheeting because of the lower cost and the variety applications.

c. Epoxy Lining for the Surface of Invert Concrete (Foot Fold)

Since invert concrete is designed to control the flow so as not to cause hydraulic loss and is not a structure facility, lining with epoxy resin mortar is adopted. Further, mortar lining is very convenient to make any configuration of invert.

(3) Pipe Materials

Sewer pipes currently used in Aden for gravity sewer lines are ACP, VCP and CP. Other materials, such as PVC, RCP and fiber reinforced mortar pipe (RPM) are widely used for gravity sewers in many countries. For sewer pipe materials, careful consideration is to be given to the problems of corrosion by sulphide build-up. Collapse of existing ACP sewers at many locations in the study area is a serious problem in Aden Municipality.

Preference is therefore given to use of corrosion resistant materials, such as VCP, PVC and RPM in order that the sewers to be installed will have a useful life of many decades, as desired. VCP and PVC are recommended for the project. Although RPM has excellent properties, it is not recommended for the construction because it is costly. VCP and PVC with sufficient strength in various diameters, and various fittings suitable for the project are available.

RCP and CP are not suitable in Aden because of the corrosion caused by hydrogen sulphide. Pipe protection for these pipes against corrosion is difficult and expensive. Strength of ACP and CP is not sufficient in case of very shallow or deep sewers. Production of ACP has been stopped in many countries because of its carcinogenic nature.

For force mains, DCIP is recommended for its superioring over CIP and SP. The features of DCIP for use in force mains are summarized as follows.

a. Strong and flexible enough for the internal hydraulic pressure and external load
b. Excellent in corrosion resistance
c. Excellent in watertightness of joints

Internal surface of DCIP is to be protected by fusion bonded powder epoxy coating or other material with high resistance against the corrosion by hydrogen sulphide and erosion. Cement mortar lining which is usually applied to DCIP for water supply should not be used.

The outside of DCIP is to be protected by polyethylene sleeve from corrosive soils. Polyethylene sleeving method is widely used because this method is simple and inexpensive.

(4) Manhole Materials

Four types of manhole which are applicable for the project have been evaluated. These are i) cast-in-place concrete, ii) resin concrete, iii) concrete block and iv) precast concrete.

Resin concrete has excellent chemical resistance, but its cost is considerably high. Thus it is not recommended for the project. Concrete block and precast concrete are not recommended because of difficulties in adjustment at construction site and relatively high cost for importing pre-fabricated parts.

Cast-in-place type is recommended for the project due to its least cost and availability of the protection of borded by it.

Three types of manhole cover, viz. i) ductile cast iron, ii) reinforced concrete and iii) fiber reinforced plastic (FRP), are compared. Ductile cast iron cover is recommended because of its strength, durability and medium prices. Reinforced concrete cover is not recommended because of difficulty in protecting it against corrosion by hydrogen sulphide, although it is lowest in cost. Fiber reinforced plastic has excellent

resistance to corrosion by chemicals, but it is prohibitively high and not recommended for the project.

Ductile cast iron may be corroded by hydrogen sulphide to some extent. However, it has enough durability when corroded, which was confirmed from the observation of the covers made of cast iron in the existing system. Manhole covers can be replaced easily when broken at worst. Thus, protection of internal surfaces is provided by inexpensive paint and other means such as double cover by FRP is not considered.

There are three anti-corrosive materials for steps. These are i) polypropylene coated steel bar steps, ii) stainless steel ladder and iii) FRP ladder. High quality stainless steel required for sufficient protection against hydrogen sulphide gas is prohibitively expensive. The other two methods are applicable for the project because of their sufficient durability and reasonable cost.

(5) Embankment

Since the proposed STP consists of the stabilization pond process, and large ponds are to be constructed by embankments, soil with suitable property should be obtained in large quantities. Soil at the proposed STP site is highly permeable and not suitable for the construction of the embankment as it is now. Well graded and sufficiently low permeability soils should be obtained from borrow pit outside the STP site or measures to improve the soil properties should be taken. At present, the embankment is assumed to be constructed solely by transported soil. However, further considerations should be given at detailed design stage to find out the most economical embankment construction.

As mentioned in the previous subsection, borrow pit in Sheik Othman is considered most appropriate because of the property of the soil and the short distance from the construction site.

Several kinds of the slope protection of the embankment have been compared. These are i) precast concrete plate, ii) masonry, iii)asphalt facing, iv) cast-in-place concrete and v) rubber sheet. Among the five alternative

protection methods, asphalt facing and rubber sheeting are found to be expensive for construction in Aden. The remaining three methods are economical and applicable for the project. Cast-in-place concrete is recommended because of its simple construction in the shortest time.

(6) Building

Buildings to be constructed for the first phase include the superstructure of the main pumping stations and three existing pumping stations to be re-built and an administration building in STP. Superstructures of the pumping stations are proposed to be constructed with reinforced concrete, taking into account the fact that it is the same material that for the substructure and the function of the building. The administration building is also proposed to be constructed with reinforced concrete. However, other materials such as masonry can be applied to this building. Design of and material selection for the administration building should be determined at the detailed design stage.

(7) Sweeper Passage

Five materials for the inspection chamber construction and two materials for the connection pipe construction have been compared for the improvement of the sweepers passage. The five materials for the inspection chamber are i) cast-in-place concrete, ii) precast concrete, iii) resin concrete, iv) Clay. From consideration of the cost and since there is little probability of hydrogen sulphide gas generation, cast-in-place concrete is recommended. The other three materials except resin concrete can be used for the project because of their reasonable cost and simple construction.

Two materials for the connection pipe are i) VCP and ii) PVC. Either of the two materials are suitable for the project and the difference in their respective costs is small.

5.3.3 Mechanical and Electrical Equipment and Instrumentation

(1) General

In view of the present condition of the study area, the following criteria

are considered for the selection of the mechanical and electrical equipment. Particular attention have been paid to protection of the equipment against high temperature, hydrogen sulphide gas, sand and dust and the high salinity levels which may be encountered.

a. Durability

All equipment should be durable for the expected life time under the harsh conditions mentioned above. This is especially important since all equipment is to be imported from foreign countries and repair is not easy.

b. Ease and Simplicity of Operation and Maintenance

Skilled technicians, particularly those for the sewerage sector are difficult to employ. Repair of complicated machinery is also difficult in Aden. Therefore, ease and simplicity of operation and maintenance is an important factor in the selection.

c. Minimal Requirement for Electric Power

Electric power tariff in Aden is high compared with prices of other goods. Moreover, Aden Municipality is paying for it at the higher rate under the commercial category. Thus, the selection of the equipment which require the least electric power will reduce the operation and maintenance cost significantly.

Other factors such as prevention of odour and noise nuisance to the nearby areas, safety of workers and frequency and duration of electric power failures are taken into account in selecting individual equipment and the total system as well.

(2) Electric Power

PCEP maintains the power supply grid system in Aden and the following current voltages are available.

- High voltage 11 kV, 3 phases, 50 Hz

- Medium voltage 415V 3 phase, 240V 1 Phase 50 Hz

All the main pumping stations and STP will receive 11 kV high voltage current. STP will receive 415 V medium voltage.

According to the information obtained from PCEP, power failure of more than one hour duration occurs 1 to 2 times a year for 3 to 4 hours duration on an average.

(3) Pumping Station

Types of Pumps

Two types of pumps are recommended for the project, vertical shift screw volute type for major pumping stations, and submersible type for the rehabilitation of existing pumping stations. The reasons for their selection are as follows.

Vertical shaft screw volute pump

- High pump head and its fluctuation because of long force mains
- Position of motors above ground level
- Ease of operation and maintenance resulting from non-clog type of pump structure

Submersible pump

- Relatively small capacities and low pump head
- Minimum space requirement for substructures
- Ease of setting and demounting

Discussions on submersible pump for the rehabilitation of existing facilities are presented in Appendices G and H.

Diameter and Number of Units

Diameter and number of units should be determined based on the design flow and its fluctuations. Generally, the greater the number of units, are

available the more flexible the operation following flow fluctuation. However, as the number of units increase, the diameter of pumps become smaller, sometimes too small for a sewage pump. Also, the initial cost for a greater number of small pumps is higher than that for a lesser number of large pumps. Each pump should be of the same diameter taking into account the interchangeability of parts.

In case of Ma'alla and Tawahi pumping stations, three pump units including one standby unit each having the capacity equal to half the peak flow have been planned.

Control of Pump

Simple automatic control (on/off) by water levels is provided. Sequence of operation of two or more units is programmed by a built in control device. On/off can also be done manually. Sophisticated remote and central control is not considered. At least one person is to be stationed all day at each of the major pumping stations for operation.

Generator

Two major pumping stations will be provided with generators to ensure continuous operation during power failure to prevent overflow of raw sewage in the service area. Generators are diesel driven and their capacities are to be determined based on the minimum power requirement for normal operation of pumps.

Emergency bypass piping to discharge sewage during power failure from the major pumping stations can be considered instead of providing generators. Advantages and disadvantages of the two methods should further be examined at the detailed design stage.

Counter Measures against Water Hammer

Counter measures against water hammer should be considered for major pumping stations since long force mains are connected to these stations. Counter measures are provided by mechanical means and surge tanks are not provided.

Screens

Screens are provided in the major pumping stations ahead of pumps to remove screenings for protection of pumps. Screens are manually raked and no mechanical raking device nor shredding device is provided.

Gates

In order to ensure the safety of pumps, gates are provided at proper positions of inlet works for shutting off sewage flow.

Ventilation and Lighting

For the safety of workers, sufficient ventilation and lighting should be provided in the working area. Ventilation is provided by electric fans which exhaust the air from the dry well.

(4) Sewage Treatment Plant

Gate

Two sets of sluice gates made of cast iron will be provided at the head of the screen chamber for isolation.

Screen

Two sets of manually raked fine bar screens will be provided before Parshall flume to remove screenings. Removed screenings are stored at the site and then transferred to the final disposal site.

Flow Measurement

Flow measurement is provided by Parshall flume at the inlet. This system comprises of a couple of flumes, level meters, integraters, recorders and circular scale indicators. In addition to the flow measurement equipment, scales will be attached to the weirs in the inlet work and discharging chambers for flow measurement by observation.

Sewage Characteristics Analysis

Characteristics of the raw sewage and treated effluent should routinely be analyzed at the treatment plan. Analysis will be conducted by conventional test methods in the laboratory attached to the administration building. Items to be analyzed and specifications of the equipment should be decided at the next stage of the design. However, no advanced automatic equipment for analysis are considered.

5.3.4 Construction Methods

(1) Sewers

There are two construction methods applicable for pipe laying, the open-cut method without sheeting and with sheeting. The open-cut method with sheeting is applicable where the sewer will be laid shallow in the ground such as branch sewer, force main and sweeper's passages. Excavation of rocky ground can be done without sheeting. For deep sewer construction, the open-cut method with sheeting may be used.

Where the groundwater table is high, dewatering is necessary, which can be accomplished either by potable submersible pumps or by well point method.

No special construction such as jacking and tunneling is necessary.

(2) Pumping Stations

Ma'alla pumping station will be constructed at the site of the existing Hedjuff pumping station approximately 10 m away. The existing pumping station can continue to operate during the construction of the new pumping station. When the new pumping station is completed, the inlet sewer is to be diverted to it.

Tawahi pumping station will be constructed at the site near YPA Marine Training center. The construction site is occupied by an old warehouse at present, which should be demolished before construction. No other obstacles exist there.

The construction of pumping stations may pose particular problems because of high groundwater levels and the type of the subsoil at the sites. The normal method of excavation is to use sheet pile with a series of wellpoints or pumps for drainage. Excavation may encounter large stones or other waste materials dumped in the past when the land was reclaimed.

(3) Sewage Treatment Plant

Construction site for the sewage treatment plant is rather isolated from the built-up areas and may have less impacts on the surrounding area than the construction of the pumping stations. In addition, no technically difficult construction method is required. However, since the construction of the sewage treatment plant will require a long period of time , approximately two years at one site, sequencing and arrangement of individual work items is important. Strict construction supervision, particularly for the embankment and pond bottom lining, should be provided to ensure compliance with the design. The following work schedule is recommended for the construction.

a. Preparatory work

Construction of temporary access roads to and inside the site including a new temporary road from Sheik Othman borrow pit.

b. Leveling of the ground

Leveling the pond construction area to the average ground elevation of +2.9 m.

c. Excavation of the bottom of the anaerobic pond area

d. Embankment and piping

Construction of the embankment by piling up and compaction of the soils transported from the borrow pit to the top level of embankment. Connection pipes between ponds should be installed.

e. Finishing of embankment

Finishing of the configuration of the embankment by scraping and compaction.

f. Slope protection

Providing slope protection of embankment with cast-in-place concrete.

g. Service roads

Construction of service roads around ponds and other facilities.

h. Civil and architectural structures

Construction of an inlet, an administration building, distribution chambers and a discharge channel.

i. Ancillary works

Construction of gates, fence and ancillary works.

5.4 Preliminary Engineering Design

Preliminary engineering design of the sewerage facilities under the first phase program has been carried out based on the selected construction materials, equipment and construction methods discussed in the previous subsections. The design is presented in Volume Three, Appendices and drawings contained in Volume Four.

Number of Appendix and drawings for each facility are as follows.

(1) Major Facilities

a. Force main	Appendix G -- hydraulic calculation Drawing Nos.36 to 40 -- profile Drawing No.58 --------- typical cross sections
b. Ma'alla and Tawahi P/S	Appendix G -- hydraulic calculation, pump specifications Drawing Nos.47 and 48 -- plan, section, single line diagram
c. STP	Appendix G -- design and hydraulic calculations Drawing Nos.51 to 55 -- plan, hydraulic profile, structure details

(2) District Works

a. Gravity sewers	Appendix F -- hydraulic calculation Drawing Nos.15 to 20 --- plan Drawing Nos.45 and 46 -- profile Drawing No.56 ----- structural details of manholes
b. Rehabilitation of existing P/S	Appendix G -- pump specifications standard structures
c. Improvement of sweepers' passage	Drawing No.59 -- general plan and details

5.5. Implementation Schedule and Project Cost

5.5.1 Introduction

Construction cost of all the facilities is the first phase program has been estimated together with that for the second phase. The framework for the implementation schedule of the first phase has been developed with a perspective on the long term program. Construction cost and implementation schedule for the first phase were presented in Chapter Four.

In this section, a detailed implementation schedule for the first phase program, which has been developed,based on that in the previous chapter, is presented. Commencement of the first phase program is assumed to be the earliest possible time, i.e. the second quarter of 1990, in view of the urgency of the project and the indication of high priority by PDRY government.

The project cost for the first phase has been calculated by developing a disbursement schedule based on the implementation schedule. The construction period for the individual facilities and a payment schedule to the contractor has been assumed on the past experience of similar projects, which is also internationally acceptable. Price escalation factors are included in estimating the construction cost. Costs other than construction cost have been estimated considering conditions in the study area.

5.5.2 Implementation Schedule

The second quarter of 1990 is considered the earliest possible commencement period for the first phase program, taking into account the necessary procedures to be undertaken, after the completion of this study, among the governmental agencies and between PDRY government and bilateral or multi-lateral funding agencies. The implementation schedule presented here has been developed taking this earliest possible date as the starting date of the first phase.

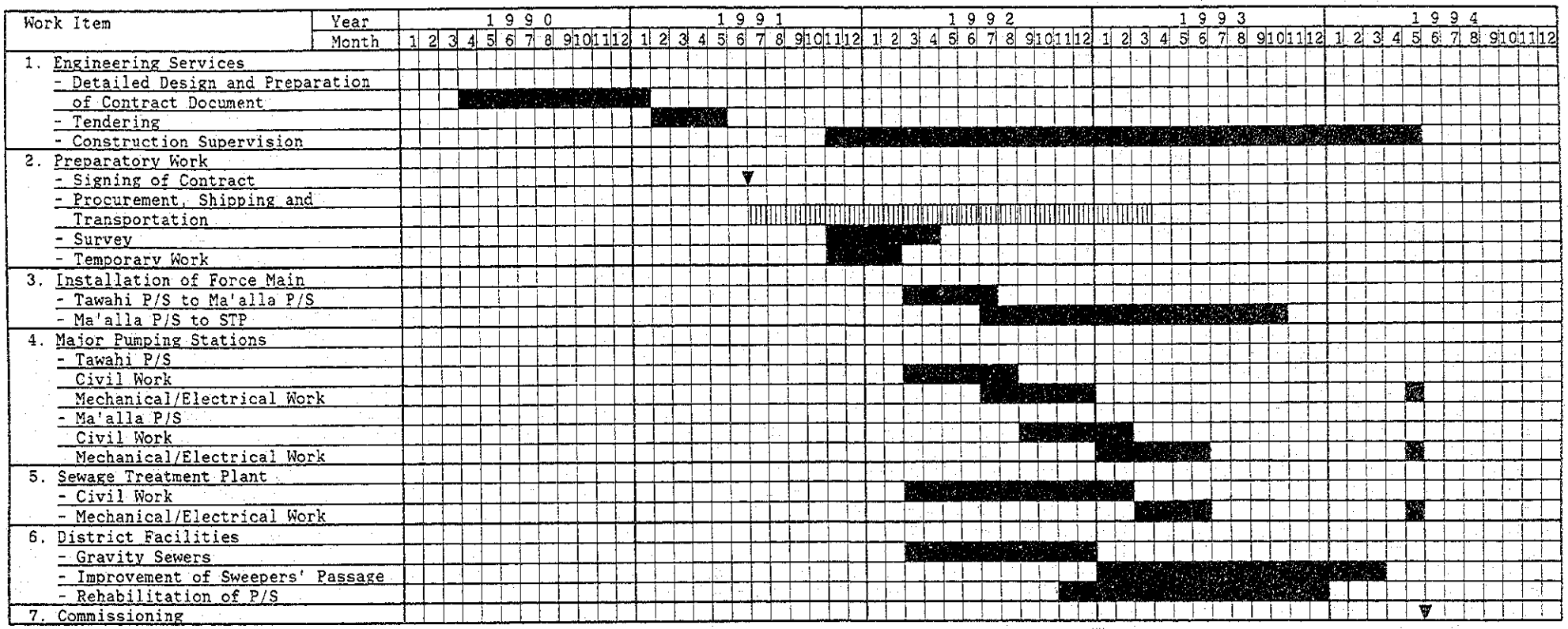
Detailed design and preparation of the tender documents to cover all the facilities requires a 10 months period. The bidding and the evaluation of tenders is assumed to be completed in a minimum of 4 months.

Since Aden is somewhat remote from the countries of origin of materials and equipment which should be imported for the project, a reasonable time for shipment and transportation to the site has been estimated and included in the schedule. Construction of temporary works which include special requirements for the project, such as accommodation facilities for foreign engineers and laborers is also included.

Construction at the site will start 9 months after the signing of the contract and will continue for 24 months. Construction period of each facility has been calculated considering the optimum utilization of the work force and construction machinery which should inevitably be imported from foreign countries. The sewage treatment plant will start operation 35 months after signing of the contract.

Implementation schedule indicating breakdowns of work items is shown in Figure 5.7.

Figure 5.7 First Phase Implementation Schedule



5.5.3 Project Cost

The disbursement schedule for estimation of the project cost for the first phase program has been developed, based on the implementation schedule described in the previous subsections. Conditions to be satisfied for payment and allocation of the construction cost to the respective years are described in Section 7.15 Financial Projection.

The following price escalation factors are adopted in cost estimate.

Foreign currency portion	5 % per annum
Local currency portion	2 % per annum

Physical contingency is assumed to be a low rate of 5 %, taking into account the depth of the preliminary engineering design.

The total project cost is approximately YD 13.1 million of which foreign and local currency portions are YD 11.6 million (89 %) and YD 1.5 million (11 %) respectively, as shown in Table 5.1. The breakdown of the project cost payable in respective years is presented in Section 7.1.5.

Table 5.1 Project Cost for the First Phase Program

(unit: YD 1,000)

Classification and Work Item	F.C.	L.C.	Total
Direct Cost			
1. Sewage Treatment Plant	843	621	1,464
2. Major Pumping Stations	1,015	20	1,035
3. Force Main	2,741	164	2,905
4. Gravity Sewers	557	76	633
5. Rehabilitation of P/S	198	7	205
6. Improvement of S. Passage	518	51	569
7. Total Direct Cost	5,872	939	6,811
Indirect Cost			
8. Provisional Sums	3,158	370	3,528
9. Sub-total (7+8)	9,030	1,309	10,339
10. Physical Contingency (5 % of 9)	452	65	517
11. Engineering Cost	813	114	927
12. Sub-total (9+10+11)	10,295	1,488	11,783
13. Price Escalation	1,746	104	1,850
14. Total Project Cost	12,041	1,592	13,633

Note 1. Construction cost is estimated at December 1988 price.
2. Engineering cost does not include price escalation.

Operation and maintenance cost after the completion of the first phase program was estimated as shown in Table 5.2 in the same manner described in the previous Section 4.3.2. These costs are limited to those required for the operation and maintenance of the existing facilities in Ma'alla and Tawahi and new facilities completed under the first phase program. Labor cost was estimated based on the manpower requirements directly involved in operation and maintenance work, and thus does not include administrative staff in the head office.

Annual operation and maintenance cost is estimated to be approximately YD 194 thousand. However, the cost is estimated by using present salaries and electric tariff rate and thus does not include price escalation.

Table 5.2 Operation and Maintenance Cost for the First Phase Program

(unit: YD 1,000)

Facility	Operation and Maintenance Cost			
	Labor	Power	Repair	Total
Sewers	40	-	10	50
Pumping Stations	47	53	10	110
Sewage Treatment Plant	13	11	10	34
Total	100	64	30	194

5.5.4 Alternative Site for STP

Approximately 40 % of the total direct construction cost is accounted for by the construction cost of the force mains. If the sewage treatment plant is located nearer to the service area, the length of the force main can be reduced and this in turn well reduce the project cost for the first phase significantly.

There is one possible site near the Abyan Road where Al Arish village is located at present. If the site can be used for construction on condition that consent of the residents is obtained with sufficient compensation, the distance of the force main can be reduced by 1.7 km resulting in the reduction of the construction cost by YD million.

No change is envisaged in the engineering and in the environmental impact with this modification.

CHAPTER SIX

INSTITUTIONAL ARRANGEMENT

CHAPTER SIX
INSTITUTIONAL ARRANGEMENT

6.1 Proposed Organizational Structure

6.1.1 Possible Alternative Organizational Structure for the Long Term Program

Theoretically various types of organizational structures for the implementation of sewerage projects are considered. However, taking into consideration the present situation in Aden Municipality and PDRY as a whole, possible organizations for implementation of the proposed project are limited.

Although the study area is limited to four districts, alternative organizational arrangements for sewerage projects in the whole Aden Municipality are discussed in this section.

As mentioned in Sections 2.7 and 2.8, a legal framework for sewerage work has not been well developed in PDRY. The Local Government Law of 1977 placed the responsibility for sewerage service with the People's Local Council under the overall direction of GDLG. However, this law only provides a broad framework of powers and duties in relation to sanitation services inclusive of sewerage service. The institutional and legal framework is currently under review by the government.

Aden is the only municipality in PDRY that has Townships and Municipal Ordinance which provides a detailed framework for drainage and other sanitary facilities. The Ordinance was enacted in 1945 before the Local Government Law and is not necessarily appropriate for present conditions in Aden. The Ordinance provides the People's Local Council in Aden with the power to i) construct and maintain sewers, drains and other works for the collection and disposal of sewage, and ii) regulate the drainage of premises including powers of inspection and enforcement. However, construction of major sewerage facilities are at present under the responsibility of GDLG, and the role of Aden Municipality for the major construction is limited to technical assistance.

On the other hand, the Resolution 59/81 of the Council of Ministers directs the People's Local Councils in each governorate to establish a Water and Sewerage

Department for i) the operation and maintenance of water supplies and ii) the treatment and disposal of wastes. The Resolution also directs that the necessary preparatory work to establish those departments should be carried out when sewerage projects are implemented. Before the Resolution, the Sewerage Department was established in Aden Municipality, and water supply services were carried out by PWC, which was established in 1970.

The institutional and legal arrangements and present practice are somewhat confusing. The study team considers that firstly a legal framework on the national level is to be provided. However, in consideration of the present situation mentioned above, possible alternative organizational arrangements regarding sewerage projects limited to Greater Aden only, is presented. Discussion on the following two possible alternative organizations for sewerage projects in Aden are developed for the long term program. Other alternative arrangements, such as a specified unit in the central government taking full responsibility for sewerage service, are not considered because of the local nature of the service.

Alternative-1 Sewerage Department of Aden Municipality

Aden Municipality is empowered to execute sewerage projects as well as the other public service projects. In addition to the present responsibility for operation and maintenance of the sewerage facilities, responsibility for construction is assumed by the Municipality, through its Sewerage Department. This Alternative leads to the realization of the provisions in Townships and Municipal Ordinance.

Alternative-2 Independent Public Corporation for Sewerage Service

A new Public Corporation is established to carry out sewerage service. This Corporation will assume full responsibility for construction, operation and maintenance, and collection of sewerage charges. Integration of this Corporation with PWC is a possible modification of this Alternative for the future.

Both Alternatives are developed on the same concept that GDLG, as a central government agency, continues to assume a responsibility for policy making, planning, budgeting central government subsidy and training at national level. Advantages and disadvantages envisaged for the two alternatives are discussed below.

Alternative-2 has a significant advantage theoretically because it is to achieve full autonomy. Higher service level can be provided by a Corporation. However, sewerage service activity is public in nature and not so financially profitable in comparison with other public services such as water supply and electric power services. It is therefore financially difficult to operate the Corporation, unless prohibitively high sewerage charges are allowed. High rate of sewerage charge to sustain the financial independence of the Corporation would most likely not obtain public consensus. Integration with PWC will also impose a financial burden on the new Corporation for the same reason. Further, a possible disadvantage of the alternative is that it may require time consuming efforts for legislative and administrative procedures.

On the other hand, Alternative-1 has the advantage that this arrangement can be achieved with a minimum modification to the existing organizational structure. The present Environmental Health Department is to be separated to establish an independent and expanded Sewerage Department. There exists no problem from this division of the Environmental Health Department, since there had been a Sewerage Department before the current Environmental Health Department was created. Another advantage is that efforts required for legislative and administrative procedures are minimal for this alternative. Modification of the Townships and Municipal Ordinance in line with the recommendation made in this section is not considered to be difficult. As mentioned previously, sewerage service is local in nature and it is most appropriate for the local administration to assume the responsibility for operation and maintenance together with construction, based on local requirements. However, financial dependence would be inevitable for the Sewerage Department. It is proposed that a sewerage charge system to cope with the requirement for adequate operation and maintenance cost be introduced. Sewerage charge should be collected through the present PWC water charge collecting system since surcharge on water charge is proposed. Modification of the Department to handle this work can be limited to a minimum extent. However, financial support from the central government for capital investment is indispensable.

Based on the above discussions, Alternative-1, is recommended for the long term program.

6.1.2 Proposed Organizational Structure for the First Phase Program

Under the concept developed and recommended in the previous section, a more practical organizational arrangement is proposed for the first phase program. Construction of the sewerage facilities is proposed to be taken over by Aden Municipality for the long term program. GDLG's function will be limited to those required for central government agency. However, implementation of the first phase program under the organizational arrangement proposed for the long term program is considered extremely difficult for the following reasons.

(1) Major sewerage projects have been implemented under the control of GDLG, and Aden Municipality lacks experience in managing such kind of work.

(2) Qualified and experienced staff for major sewerage construction is totally insufficient and this limited staff is, at present, found only in GDLG and Aden Municipality. This can not be transferred to any other organization because they assume the responsibility for other projects or duties.

For the implementation of the first phase program, which should be as long as possible, a more practical organizational arrangement based on the present situation is considered. Our proposals are described below.

(1) GDLG will assume the responsibility for the implementation of the project, including planning, design and construction.

(2) Budgetary provision for the project will be made by GDLG. This includes coordination with other government authorities and negotiation with foreign agencies to seek for internal and external funds.

(3) For engineering aspects, including preparation of tender documents, evaluation of bids and construction supervision, maximum utilization of engineering consultants is recommended.

(4) Cooperation with Aden Municipality particularly in engineering affairs should be sought. A technical committee for the first phase program is recommended to be established with representatives from GDLG, Aden Municipality and other government agencies in this regard. Participation of the Aden Municipality staff at every stage of the project should be encouraged.

(5) On-the-job training for both GDLG and Aden Municipality staff throughout the duration of the project should be provided to the maximum extent possible.

6.2 Staffing Requirements

6.2.1 Existing Staff in Aden Municipality

In order to estimate the staffing requirements for the long term program, the existing situation regarding staffing for the sewerage service was looked into. Operation and maintenance of the sewage facilities are at present carried out by Aden Municipality. Therefore, staffing levels and capabilities in the Pump and Drainage Section of Environmental Health Department was studied.

Existing staff members in the Department classified by Section and job classification are shown in Table 2.22 in Chapter 2. Breakdown of staff member of the Pump and Drainage Section by districts are shown in Table 2.23. Characteristics of the staff are shown in Table 2.24.

As mentioned in Chapter 2, the Pump and Drainage Section of the Environmental Department is staffed with a fairly reasonable number of engineers, technicians, skilled and semi-skilled laborers. Therefore, the present staff levels in each category are made the basis for estimation of future requirements.

6.2.2 Staffing Requirements for the Long Term Program

Staffing requirements for the long term program is estimated based on the proposed sewerage facilities for the project. This is limited to those required for operation and maintenance of the sewerage facilities in the four districts. Although we propose that Aden Municipality assume responsibility for the construction of sewerage facilities, since this will require additional staff, the overall view of staffing for the sewerage project in the Greater Aden is not clear at present. Moreover, information on requirements for operation and maintenance for the sewerage facilities in the other districts is not available.

For the estimation of the staff requirements, the following assumptions are made.

(1) The two current district offices, viz. Al Meena and Seera, are integrated into one for more efficient and effective utilization of manpower and equipment since all the four districts have one common sewage treatment plant.

(2) All the sewerage facilities proposed will be completed by 2010, as mentioned in Chapter 4. Among them, new facilities are a sewage treatment plant, four major pumping stations and force mains. Highly sophiscated automatic central control systems are not envisaged.

(3) Efficiency of maintenance work will be improved resulting from more strict management and/or introduction of machines and equipment, etc.

The result of the estimation is shown in Table 6.1.

Comparison of the proposed levels with the present levels is also shown in Table 6.1. The total staff levels proposed for the long term program requires 79 less people than the present number. This excess include i) non-skilled laborers (64), ii) semi-skilled operators and craftmen's mates (12) and iii) supervisors (11). Other job classifications are deficient in numbers. In particular, the total number of the professional engineers and assistant engineers at present are only half of the number required.

The reasons for excess staff levels in these three job classifications may be due to additional work which the Aden Municipality is forced to carry out at present. Replacement of the damaged sewers in Khormaksar district and repairing of the damaged pumping stations of military areas and private properties are the main additional work which are not required under normal conditions. When the long term program is implemented, this additional work is no longer necessary. When the STP starts operation and the effluent is reused for the green belt project, new staff will be required for that project. Levels of the staff can not be estimated at present. However, it is possible to shift the excess staff from the Environmental Health Department to the new project. On the other hand, the other job classifications for which there is a deficiency in staff levels at present, in particular professional engineers and assistant engineers, should be filled by recruiting new members or shifting from the other positions.

6.2.3 Staffing Requirements for the First Phase Program

The first phase program is proposed to be implemented under the present organizational arrangement described in Section 6.1.2. GDLG is proposed to assume the responsibility for the construction and improvement of the sewerage facilities. Aden Municipality will cooperate with GDLG in the engineering aspects of the project. In addition, Aden Municipality is proposed to assume the responsibility for operation and maintenance of all the sewerage facilities to be constructed under the first phase program and existing facilities as well.

GDLG successfully implemented the Sheik Othman and Mukalla sewerage projects a couple of years ago with the present staff in the Municipal Department. New members have been added in the department since then. Currently no other major project is under way. Therefore, these new additional staff members are not required for the first phase program of the project.

Additional staff for operation and maintenance is required in the Environmental Health Department of Aden Municipality. All the staff for the sewage treatment plant, shown in Table 6.1, should be recruited or shifted from other positions by the time when the plant is commissioned, which is expected to be in 1995. Two professional engineers, one for treatment and another for maintenance, should be recruited as soon as possible since they should participate in the design and construction stages of the project. Two presently vacant assistant engineer positions in the pumping stations and sewers should also be filled as soon as possible for the same reason. The other positions can be filled by mobilization of the present staff.

6.2.4 Training Program

The existing training activities, which are considered one of the necessary measures to remedy the shortage of the qualified staff, have been found to be insufficient. No facilities are available for the training of the staff managing the sewerage system in PDRY.

Concerted efforts should be made to develop a long term training program with an initial short term strategy to meet the immediate needs for the training of the existing staff to improve the existing level of operation and maintenance and to meet the future manpower requirements of the proposed project.

GDLG is considered a key central agency for training and training courses should be provided for the various public sector works including sewerage. The need for the training should be communicated to the higher levels of the government and sufficient budget should be allocated for development and implementation of an effective program. Cooperation with Aden Municipality is sought for the development and implementation of the sewerage sector training program.

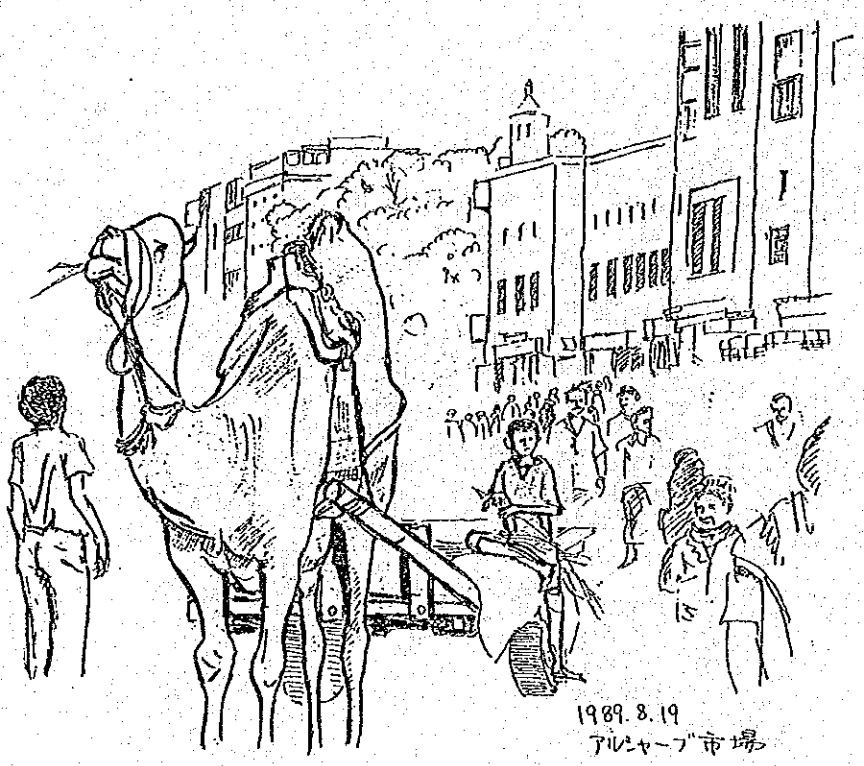
In view of the present staff levels in the Environmental Health Department, training for the staff directly involved in the operation and maintenance, supervisors and skilled craftmen in particular, should be provided since new mechanical and electrical equipment will be introduced as the proposed project is implemented. The training for the staff should therefore be based on a practical on-the-job training. Chances to obtain practical knowledge and skills to operate machines and equipment should be provided as much as possible by using the actual ones on the sites.

Table 6.1 Estimated Staff for Operation and Maintenance for the Long Term Program

Job Classification	Proposed Number				Present Number	Surplus/ Deficit
	Sewer	P/S	STP	Total		
Profesional Engineers				6	4	-2
Operations Manager	-	1	-	1		
Area Engineers	2	-	-	2		
Engineer(Treatment)	-	-	1	1		
Engineer(Maintenance)	1	-	1	2		
Assistant Engineers	1	1	-	2	-	-2
Supervisors				6	17	+11
Superintendents	1	1	1	3		
Foremen	1	1	1	3		
Skilled Craftmen				14	13	-1
Pipelayers	4	-	-	4		
Vehicle Fitters	-	2	-	2		
Electricians	-	2	-	2		
Pump Fitters	-	2	-	2		
Machinists	-	2	2	4		
Semi-skilled operators and Craftmen's mates				16	28	+12
P/S Operators	-	8	-	8		
Electrician's Mates	-	2	-	2		
Pump Fitters Mates	-	2	-	2		
Vehicle Fitters Mates	-	2	-	2		
Water qualty analyst	-	-	2	2		
Drivers	2	8	1	11	9	-2
Technical Cerk	-	-	1	1	-	-1
Non-skilled				57	121	+64
Watchmen	6	3	1	10		
Labourers	34	10	3	47		
Total	48	45	12	113	192	+79

CHAPTER SEVEN

PROJECT EVALUATION



CHAPTER SEVEN

PROJECT EVALUATION

7.1 Financial Analysis

7.1.1 Financial Aspects Relating to the Sewerage Sector

The Local People's Council is responsible for solid and liquid wastes disposal in the country. The General Directorate for Local Government (GDLG), which coordinates and allocates the necessary budget on a whole, undertakes design and construction of new sanitation projects, whereas the local governorates carry out operation and maintenance services for the existing sewerage network. There are, however, only two established waste disposal systems in PDRY viz. in Greater Aden and in Mukalla.

Due to the limited financial resources of the country, adequate investment has not been allocated in the sewerage sector under the development plans. As sewerage charges are not levied, the local governorates are required to generate financial source for operation and maintenance expenses from their own revenues, in addition to the annual subsidy given by the GDLG. As stated earlier, the budget for the sewerage sector comprises (1) the current budget and (2) the development budget. Complete financial data is not available. The current budget figures for 1986 are as follows:

Table 7.1 Current Budget for the Sewerage Sector in 1986

(Unit: YD)

	GDLG	Aden	Mukalla	Abyan
Personnel	5,040	239,681	70,560	42,840
Administration	175	21,956	2,520	1,530
Maintenance	-	56,000	3,617	2,821
Total	5,215	317,637	76,697	47,191

	Lahej	Shabwa	Mahra	Total
Personnel	22,680	12,960	7,920	401,681
Administration	1,215	810	495	28,701
Maintenance	2,125	1,020	912	66,495
Total	26,020	14,790	9,327	496,877

The major item in the current budget is personal emoluments, which account for more than 80% of the total expenditure. It should be noted that the above budget allocated through the GDLG was not all that was spent by the local governorates, as other income of the governorates were also combined to cover the total cost for sewerage services.

With regard to the development budget, there have been only three major sewerage projects in recent years in the country i.e., (1) Sheik Othman Project, (2) Mukalla (phase I) Project and (3) Mukalla (phase II) Project. Among the three projects, Mukalla (phase II) or Sherij sewerage project was financed by grant aid from DANIDA (Danish International Development Agency). The development outlays for the sewerage sector for the years 1982-1988 are shown below:

Table 7.2 Development Budget for Sewerage Sector:1982-1988

(Unit: YD)

	Aden	Mukalla	Sherij
1982	3,958,000	-	-
1983	4,560,000	-	-
1984	3,213,800	2,000,000	-
1985	1,164,000	2,245,300	-
1986	-	2,431,335	1,500,000
1987	-	2,818,000	1,830,000
1988	-	400,000	605,000
Total	12,895,800	9,894,635	3,935,000

Source: GDLG

Over the past seven years, the total investments have amounted to YD 26.7 million of which YD 3.9 million was provided by Danish grant aid program. During this period, average annual sector investment excluding Danish aid amounted to about YD 3.3 million, which is about 2.5% of the total national development investment.

As Mukalla project has come to an end, the allocation of development investment

to the sewerage sector will be curtailed. It is expected, therefore, that in order to improve insufficient sewerage service level in Greater Aden as well as other major municipalities, the budget for investment expenditure needs to be substantially raised.

7.1.2 Financial Position of Aden Municipality

(1) Revenues

There are two main sources of revenue for the Municipality i.e. Municipal revenues and central Government contributions (subsidies). The former is further sub-divided into seven items which are taxes, licenses, rent, market fees, other fees, miscellaneous and profits whereas the latter comes from car registration fees, beer tax and Housing Ministry compensation. Among the various sub-items, the major contribution is from property (e.g. buildings) tax (22%), commercial license fee (9%), qat sale fee (13%) from Municipal revenue source and beer tax (16%), Housing Ministry compensation (9%) from Government sources. The summary of the revenues for 1987-1989 is illustrated in the flowing table:

Table 7.3 Revenues of Aden Municipality (1984-1988)

(Unit: YD)

	1984	1985	1986	1987	1988
Taxes	739,633	813,422	738,925	718,331	1,024,187
Licenses	322,187	355,180	328,337	371,529	327,753
Rent	16,012	27,938	21,446	26,320	33,341
Market Fees	720,622	751,575	679,294	701,841	476,484
Other Fees	53,287	48,708	50,960	57,335	67,530
Miscellaneous	217,348	198,358	131,124	260,828	373,301
Profits	46,501	61,133	26,966	24,336	12,036
Government Subsidy	1,578,508	1,485,318	1,093,106	1,220,270	955,679
Total	3,685,098	3,741,652	3,070,158	3,380,790	3,270,311

Source: Aden Municipality

(2) Expenditures

The expenditures of the Municipality are grouped into four departments i.e. Personnel, Finance, Municipal Engineering and Environmental Health Departments. Each department has three major outlays such as emoluments (wages and salaries), administrative expenses and transfer expenses (pension fund). Previously, capital (investment) expenditures were included in the recurrent budget, however this is now listed in the capital (investment) budget separately under the five-year plan. Nevertheless there have been no large capital expenditures in the Municipality development programs in recent years.

Personnel emoluments account for 63.7% of the total in 1988. In particularly, the Environment Health Department has the largest staff, which amounts to 65.1% of the total emoluments of the Municipality. By department, the Municipal Engineering Department and the Environment Health Department take equal share of about 40% of the total expenditures. For Environment Health Department, the emoluments account for as much as 94.7% of the total department expenditures. The operation and maintenance costs for sewerage sector excluding personnel expenses account for only 1.2% in 1988. The summary of the annual expenditures for the Municipality is shown below:

Table 7.4 Expenditures of Aden Municipality (1984-1988)

(Unit: YD)

	1984	1985	1986	1987	1988
Personnel Dept.	86,378	90,432	95,033	94,717	89,750
Financial Dept.	188,033	386,702	201,148	264,933	325,352
Engineering Dept.	1,692,632	2,033,748	1,559,687	1,282,446	1,297,461
Env. Health Dept.	1,283,024	1,330,277	1,345,247	1,333,569	1,334,685
Total	3,250,067	3,841,159	3,201,115	2,975,665	3,047,248

Source: Aden Municipality

Table 7.4 shows that the Municipal expenditures is predominantly personnel

emoluments, which leaves extremely limited funds available for operation and maintenance of sewerage services. The dependence on scarce central government contributions and inability of the Municipality internally to generate significant amounts of funds for investment account for the inadequate sewerage service coverage and service level to the population.

The overall balance between revenue and expenditure showed deficit in 1985 and 1986 and a surplus in recent years. The reason for this surplus is that at the time of mid-term review in the fiscal year, the expenditure plans were adjusted and curtailed to meet the expected revenue forecasts. The financial gaps for 1984-1988 are as follows:

Table 7.5 Financial Deficit of Aden Municipality

(Unit: YD Thousand)

	1984	1985	1986	1987	1988
Revenues	3,685	3,742	3,070	3,381	3,270
Expenditure	3,250	3,841	3,201	2,976	3,047
Balance	+435	-99	-131	+405	+223

With regard to recurrent expenditures for sewerage services, recent fiscal data are summarized as follows:

Table 7.6 Expenditures for Sewerage Sector, Aden

(Unit: YD)

	1987	1988	1989
Maintenance			
- Sewer Network	12,960	17,549	19,935
- Pumping Station	19,995	17,505	19,008
Equip./Facilities	-	-	-
Total	32,955	35,054	38,943

Source: Aden Municipality

Table 7.6 shows that during the last three years, new capital outlay for procurement of pumping and other equipment has been nil, while maintenance expenditures for the network and pumping stations have increased by 9.0% on an average. Under the limited budget resources the Environment Health Department has been unable to provide appropriate maintenance for the existing old sewerage system. It should be noted, therefore, that the present financial position for the sector is not adequate to cater for necessary operation and maintenance service and for rehabilitation work in Aden.

7.1.3 First Phase Investment Plan

As seen in the chapter four, the total estimated project cost including price escalation contingency is YD 13,633 thousand, with a foreign exchange component of YD 12,041 thousand (88%). It is projected that the first phase of long-term investment plan will be disbursed on a yearly basis as follows.

Table 7.7 First Phase Investment Plan

(Unit:YD1,000)

Item		1990	1991	1992	1993	1994	Total
1. Installation of Force Main	F/C	-	542	1,574	481	144	2,741
	L/C	-	32	95	28	9	164
	Total	-	574	1,669	509	153	2,905
2. Major Pumping Station	F/C	-	503	263	249	-	1,015
	L/C	-	10	5	5	-	20
	Total	-	513	268	254	-	1,035
3. Sewage Treatment Plant	F/C	-	85	303	303	152	843
	L/C	-	62	223	223	113	621
	Total	-	147	526	526	265	1,464
4. District Facilities	F/C	-	127	734	245	167	1,273
	L/C	-	13	77	26	18	134
	Total	-	140	811	271	185	1,407
5. Indirect Costs	F/C	-	737	983	983	455	3,158
	L/C	-	87	115	115	53	370
	Total	-	824	1,098	1,098	508	3,528
6. Physical Contingency (5%)	F/C	-	100	193	113	46	452
	L/C	-	10	26	20	9	65
	Total	-	110	219	133	55	517
7. Engineering Services	F/C	231	164	161	161	96	813
	L/C	32	23	23	23	13	114
	Total	263	187	184	184	109	927
8. Total	F/C	231	2,258	4,211	2,535	1,060	10,295
	L/C	32	237	564	440	215	1,488
	Total	263	2,495	4,775	2,975	1,275	11,783
9. Price Escalation (F/C:5%, L/C:2%)	F/C	12	231	664	546	293	1,746
	L/C	1	10	35	36	22	104
	Total	13	241	699	582	315	1,850
10.Grand Total	F/C	243	2,489	4,875	3,081	1,353	12,041
	L/C	33	247	599	476	237	1,592
	Total	276	2,736	5,474	3,557	1,590	13,633

Note F/C:Foreign Currency
L/C:Local Currency

On an annual basis, the foreign currency of the project cost would increase from YD 243 thousand in 1990 to YD 1,353 thousand in 1994 with a peak of YD 4,875 thousand in 1992. In view of the tight financial status of the government of PDRY, various external sources of funding should be sought to finance the proposed project. Since it is a sewerage service improvement project which generally produces very low rate of financial return, a grant assistance program will be most appropriate for financing under a bilateral aid program from developed countries.

7.1.4 Tariff and Affordability

(1) Sewerage Tariff

No user charge are presently levied in the country and sewerage operations are totally dependent on central government and municipal budget funds. The current division of responsibility for water supply and sewerage services is not considered adequate for effective management of the vastly expanded system. In particular, the absence of a cost recovery system in the sewerage sector has also been placing a heavy burden on municipality finances, resulting in slow and tardy expansion of the service and consequent deterioration of the environment.

GDLG and the Aden Municipality recognized the need for consolidating the sewerage service and making that entity financially viable by introducing, in stages, sewerage charges for industrial, commercial and domestic users. Several organizational structures were considered for such an entity, including a joint organization for water supply and sewerage and strengthening the present department of the Aden Municipality. However, to date, no firm decision has been reached at the governmental level.

(2) Creation of New Tariff for the Sewerage Sector

During the field study by the study team, the household income survey in Aden was not allowed to be undertaken. Instead, the statistical data and information on average household monthly income in the Municipality were collected from various sources. The Central Statistical Organization (CSO), which is an official statistical organization in PDRY, compiles average wages and salaries of personnel of ministries and public corporations. This

information can be thought to be a yardstick of mean family income. The estimate made by the CSO shows that the total mean of family income of government employees is YD 82.4 per month.

Table 7.8 Wages for Ministries and Public Corporations in 1987

(Unit: YD)

Department	Wages
Productive Sector	
Industry	71.9
Energy & Mineral	88.5
Agriculture	64.0
Fish	86.0
Construction	80.5
Communication	92.0
Non-Productive Sector	
Health	61.5
Education	61.5
Aden University	104.3
Culture	74.0
Local Governorate	66.5
Finance	77.5
Planning	78.8
Labor	69.5
Justice	71.6
Foreign Affairs	163.8
Bank of Yemen	73.4
Total Mean	82.4

It was also estimated that an average water bill per family amounted to YD 1.6 per month. If this estimation is taken as proxy, the proportion of the water expenses against monthly family income would be around 1.9%.

In conjunction with implementation of the project, it is proposed that introduction of the sewerage tariff should be seriously considered in the

form of surcharge on water charges in order to cover at least recurrent operation and maintenance costs. Sewerage and water charges would be combined for billing and collection based on meter readings of water consumption.

Currently, all households connected to the public water system are metered and are billed every two months. PWC had previously encountered some difficulties in collecting water charges on time and PWC is now sub-contracting the fee collection work to the Post Office under Ministry of Communication, which in turn receives handling charges of Fil 70 per bill. Due to the extensive network of post offices in Aden, collection rates have been improved and have resulted in greatly contributing to efficient fee collection.

Likewise, it is proposed that at the time of adoption of sewerage tariff, the present water billing and collection system should be fully utilized without any change in the organizational structure of Aden Municipality.

(3) Financial Status of PWC

For the last three years, the operation of Public Water Corporation (PWC) has not expanded very much. The volume of water production has remained flat at around 30.0 million m^3/year and amount of water sold was recorded at 22.7 million m^3/year. The reasons for the flat level of operation are attributable to a severe water shortage in Mukalla as well as the effects of implementation of new increased water tariff in 1986. The details of the operational status of PWC is shown below:

Table 7.9 Operation Status of PWC

	1985	1986	1987	1988
Water Production (M m^3)	29.74	28.85	29.29	30.89
Unaccounted for Water (%)	25.00	24.00	25.30	26.60
Water Sales (M m^3)	22.30	21.92	21.89	22.66
Average Tariff (YD/m^3)	0.135	0.164	0.190	0.197

Source: Public Water Corporation (PWC)

The latest income statement reveals that PWC has generated operating revenues sufficient to cover i) operating expenses, ii) increases in working capital, iii) debt service obligations and iv) a portion of the investment program. PWC changed the tariff structure in 1988 substantially increasing the rates. In case of domestic users, the increment was more than 60% while in the industrial and commercial categories, increments were 62% and 77% respectively.

PWC has a guiding principle which stipulates that the tariff level should fully cover all operating expenditures and debt service obligations. The financial position of PWC for the period of 1985-88 is shown as follows:

Table 7.10 Revenues and Expenditures of PWC (1985-88)

(Unit: YD thousand)

	1985	1986	1987	1988
Water Sales	3,010	3,596	4,160	4,460 (90.0 %)
Meter Rental	49	148	154	151 (3.0 %)
New Connections	75	53	61	62 (1.3 %)
Network Expansion	451	210	444	256 (5.2 %)
Other	-	35	40	25 (0.5 %)
Total Revenues	3,585	4,042	4,859	4,954 (100.0 %)
Wages & Salaries	911	967	1,036	1,165 (46.3 %)
Energy, Fuel & Chem.	716	788	878	872 (34.7 %)
Distribution (O & M)	207	204	179	165 (6.6 %)
Administration	257	213	324	291 (11.6 %)
Bad Debt	13	15	19	20 (0.8 %)
Total Operating Costs	2,104	2,187	2,436	2,513 (100.0 %)
Depreciation	440	723	1,023	1,098
Income Tax	885	962	1,189	1,141
Net Income	156	170	211	202

Source: PWC

(4) Sewerage Surcharge Rate and O & M Cost

According to the PWC financial report, water sales revenues were YD 3.60 million, YD 4.16 million and YD 4.46 million in 1986, 1987 and 1988, respectively. Out of this total, the revenues from Greater Aden reached YD 3.11 million, YD 3.74 million and YD 3.69 million in 1986, 1987 and 1988, respectively.

If a 10 per cent surcharge rate was applied to water revenues, it was estimated that the sewerage revenues for Aden Municipality would amount to YD 311.0 thousand, YD 374.0 thousand and YD 369.0 thousand in 1986, 1987 and 1988, respectively. Out of this amount, the project area viz. Ma'alla and Tawahi would generate YD 68.0 thousand, YD 79.0 thousand and YD 77.0 thousand as a sewerage revenue in 1986, 1987 and 1988, respectively, which would be sufficient to cover O & M costs so far incurred. It should be noted here that though the water revenue is different for domestic consumers, community, commercial, industrial consumers and other, the surcharge applied to the total revenue from Greater Aden area irrespective of the consumer categories.

Table 7.11 Water Revenue and Accrued Sewerage Revenue

(Unit: YD Thousand)

	1986	1987	1988
O & M Cost	33	35	39
Water Revenues			
: Greater Aden	3,110	3,740	3,690
: Project Area	678	789	771
10% Surcharge	68	79	77

Source: PWC, IBRD Report, and the study team estimate

Note: Water revenues from the project area have proportionally decreased in the total revenues of Greater Aden in accordance with changes in share of population distribution.

It is estimated that the annual operation and maintenance costs for the newly constructed treatment plant, pumping stations and pipeline networks

under the project would amount to YD 162 thousand in 1995 and YD 194 thousand in 2000 and onward in terms of 1989 prices. Taking an inflation rate of 3% into account, O & M would cost YD 193 thousand in 1995 and YD 268 thousand in 2000. It is suggested that the sewerage tariff should be set at levels which at least generate sufficient revenue to cover operation and maintenance costs. Details, are given in the following table (A sensitivity analysis with surcharge of 20% and 30 % is done as well).

Table 7.12 Sewerage Surcharge Rates and O & M Cost

(Unit: YD Thousand)

	1995	1996	1997	1998	1999	2000
O & M Costs	193	203	221	233	252	268
Water Revenues						
: Greater Aden	4,037	4,092	4,141	4,197	4,247	4,304
: Project Area	787	798	787	776	764	753
10% Surcharge	79	80	79	78	76	75
20% Surcharge	157	160	157	155	153	151
30% Surcharge	236	239	236	233	229	226

(Source: PWC, IBRD report, and the study team estimate)

Note: 1) Water revenues are expected to increase by 2.0% per annum.
2) O & M costs are assumed to increase by 3% per annum.
3) The share of Greater Aden in total revenues is expected to decrease over the years to come.
4) The present water tariff is assumed to remain unchanged.

It is estimated that from the calculation made above a surcharge of 30.0 per cent of water charges would be required at least to provide revenue for sewerage facilities' operation and maintenance costs. Since there is time allowance available prior to commencement of new sewerage system in 1995, it is recommended that an appropriate cost recovery system such as the adoption of tariff policy for sewerage services should be initiated by the government.

(5) Affordability

According to the available statistical information, the monthly income of the family in Aden is estimated between YD 50 - YD 100 with mean income of YD 73 in 1986. And PWC reports that the average monthly water bill per family was calculated at YD 1.6 (24.2 m^3) in Aden in 1988. If household water consumption increases by 2.0% annually, the average monthly water consumption per family would be 27.8 m^3 in 1995 and 30.7 m^3 in 2000. The monthly water bill would become YD 3.4 in 1995 and YD 3.8 in 2000 on condition that present water tariff structure remains unchanged.

If it is assumed that the average income would grow by 2.5% per annum, the income in 1995 and 2000 would be YD 90.4 and YD 101.8 respectively. If a 30.0% sewerage surcharge is levied on the monthly water charge, the combined water and sewerage charge as a percentage of projected 1995 and 2000 average household income per month would be as indicated in Table 7.13.

Table 7.13 Average Monthly Water and Sewerage Charges per Household

(YD in 1988 prices)

Year	Family Income	Water Charge	Sewerage Charge	Total Combined	Percent of Average Income
1988	YD 76	1.6	0.48 (0.32)	2.08 (1.92)	2.7% (2.5%)
1995	YD 90.4	3.4	1.02 (0.68)	4.42 (4.08)	4.8% (2.5%)
2000	YD 101.8	3.8	1.14 (0.76)	4.94 (4.54)	4.9% (4.5%)

Note: Figures in parentheses show the case of 20% surcharge

The internationally accepted limit for the combined water and sewerage rates for the consumer is estimated at 3.0 to 5.0 per cent of the total monthly household income. Table 7.13 shows that if the sewerage surcharge is set at 30.0%, the proportion of combined water and sewerage charges against monthly income would be 4.8% in 1995, and 4.9% in 2000 which is within the 5.0% limit mentioned before.

The analysis indicates that the proposed combined water and sewerage charge

would fall within the affordability and willingness to pay limits of urban consumers in terms of the international standard.

7.1.5 Financial Evaluation

Due to Government regulations, financial information on Municipal treasury such as balance sheet, income statement had not been released to the study team except data on annual revenues and expenditures (1984-1988) of Aden Municipality.
Moreover, as there is no tariff policy for sewerage in PDRY, no revenues have accrued to the Government and Aden Municipality from sewerage services. In view of this, an ordinary financial analysis on the proposed project has become difficult.

Nevertheless the following assumptions have been made for calculating financial internal rates of return.

(1) Project Benefits

The benefits from the project are sewerage revenues resulting from the proposed sewerage tariff to be surcharged to water bill. Under the proposed project, water sales are forecasted based on the recent PWC projection. The water revenues are assumed to increase by 2.0%, yet the share of Greater Aden in total revenues is expected to decrease over the years. The present water tariff level is assumed to remain unchanged. Various surcharge rates have been tested to see sewerage service income and in this analysis, 10.0%, 20.0%, 30.0%, 50% and 60% are selected for estimating the respective project benefits.

(2) Project Costs

The Project costs here comprise investment costs for the first phase of the long-term development plan and its operation and maintenance costs. Physical contingency and price contingency are included in the cost.

(3) Internal Financial Return

Costs and benefit used in the analysis are expressed at 1989 price levels. Data for calculation of the financial rate of return on the proposed project investments by different surcharge rates are tested. The calculation results show that in case of surcharge rate of 10.0 % to even 60.0 % a financial rate of return is incomputable or negative.

The higher the tariff rate, the higher the project viability. However as seen before, the 30.0 % of surcharge level would be the maximum and 40.0 % or more would be more than affordable limit of the average household consumers to pay. In view of the above computation, the proposed project needs special set-up for reducing financial burdens of the Government.

It is recommended that efforts should be made to seek out external financial sources viz. grant assistance programs of multilateral and bilateral agencies. Unless sewerage tariff is newly introduced, the project would not meet the financial requirements of covering even operating and maintenance costs of the new system.

Table 7.14 Discounted Cash Flow of Project Incremental Costs and Benefits
(Base Case: 10%) (Unit: YD Thousand)

	Year	Investment	O & M Cost	Total Costs	Water Revenue	Sewerage Revenue	Total Benefits	Net Benefits
1	1990	276		276				-276
2	1991	2,736		2,736				-2,736
3	1992	5,474		5,474				-5,474
4	1993	3,557		3,557				-3,557
5	1994	1,590		1,590				-1,590
6	1995		193	193	787	79	79	-114
7	1996		203	203	798	80	80	-123
8	1997		221	221	787	79	79	-142
9	1998		233	233	776	78	78	-155
10	1999		252	252	764	76	76	-176
11	2000		268	268	753	75	75	-193
12	2001		276	276	750	75	75	-201
13	2002		285	285	742	74	74	-211
14	2003		293	293	739	74	74	-220
15	2004		302	302	735	74	74	-229
16	2005		311	311	729	73	73	-238
17	2006		321	321	719	72	72	-249
18	2007		330	330	713	71	71	-259
19	2008		340	340	706	71	71	-270
20	2009		350	350	700	70	70	-280
21	2010		361	361	698	70	70	-291
22	2011		372	372	691	69	69	-303
23	2012		372	372	691	69	69	-303
24	2013		372	372	691	69	69	-303
25	2014		372	372	691	69	69	-303
26	2015		372	372	691	69	69	-303
27	2016		372	372	691	69	69	-303
28	2017		372	372	691	69	69	-303
29	2018		372	372	691	69	69	-303
30	2019		372	372	691	69	69	-303
31	2020		372	372	691	69	69	-303
32	2021		372	372	691	69	69	-303
33	2022		372	372	691	69	69	-303
34	2023		372	372	691	69	69	-303
35	2024		372	372	691	69	69	-303

IRR Error

NPV -9347.77

B/C 0.025704

B-C -9347.77

NPV-C 9594.389

NPV-B 246.6144

Table 7.15 Discounted Cash Flow of Project Incremental Costs and Benefits

(Case-1: 20%) (Unit: YD Thousand)

	Year	Investment	O & M Cost	Total Costs	Water Revenue	Sewerage Revenue	Total Benefits	Net Benefits
1	1990	276		276				-276
2	1991	2,736		2,736				-2,736
3	1992	5,474		5,474				-5,474
4	1993	3,557		3,557				-3,557
5	1994	1,590		1,590				-1,590
6	1995		193	193	787	157	157	-36
7	1996		203	203	798	160	160	-43
8	1997		221	221	787	157	157	-64
9	1998		233	233	776	155	155	-78
10	1999		252	252	764	153	153	-99
11	2000		268	268	753	151	151	-117
12	2001		276	276	750	150	150	-126
13	2002		285	285	742	148	148	-136
14	2003		293	293	739	148	148	-146
15	2004		302	302	735	147	147	-155
16	2005		311	311	729	146	146	-166
17	2006		321	321	719	144	144	-177
18	2007		330	330	713	143	143	-188
19	2008		340	340	706	141	141	-199
20	2009		350	350	700	140	140	-210
21	2010		361	361	698	140	140	-221
22	2011		372	372	691	138	138	-234
23	2012		372	372	691	138	138	-234
24	2013		372	372	691	138	138	-234
25	2014		372	372	691	138	138	-234
26	2015		372	372	691	138	138	-234
27	2016		372	372	691	138	138	-234
28	2017		372	372	691	138	138	-234
29	2018		372	372	691	138	138	-234
30	2019		372	372	691	138	138	-234
31	2020		372	372	691	138	138	-234
32	2021		372	372	691	138	138	-234
33	2022		372	372	691	138	138	-234
34	2023		372	372	691	138	138	-234
35	2024		372	372	691	138	138	-234

IRR Error

NPV -9101.16

B/C 0.051408

B-C -9101.16

NPV-C 9594.389

NPV-B 493.2289

Table 7.16 Discounted Cash Flow of Project Incremental Costs and Benefits

(Case-2: 30%) (Unit: YD Thousand)

	Year	Investment	O & M Cost	Total Costs	Water Revenue	Sewerage Revenue	Total Benefits	Net Benefits
1	1990	276		276				-276
2	1991	2,736		2,736				-2,736
3	1992	5,474		5,474				-5,474
4	1993	3,557		3,557				-3,557
5	1994	1,590		1,590				-1,590
6	1995		193	193	787	236	236	43
7	1996		203	203	798	239	239	36
8	1997		221	221	787	236	236	15
9	1998		233	233	776	233	233	-0
10	1999		252	252	764	229	229	-23
11	2000		268	268	753	226	226	-42
12	2001		276	276	750	225	225	-51
13	2002		285	285	742	223	223	-62
14	2003		293	293	739	222	222	-72
15	2004		302	302	735	221	221	-82
16	2005		311	311	729	219	219	-93
17	2006		321	321	719	216	216	-105
18	2007		330	330	713	214	214	-116
19	2008		340	340	706	212	212	-128
20	2009		350	350	700	210	210	-140
21	2010		361	361	698	209	209	-152
22	2011		372	372	691	207	207	-165
23	2012		372	372	691	207	207	-165
24	2013		372	372	691	207	207	-165
25	2014		372	372	691	207	207	-165
26	2015		372	372	691	207	207	-165
27	2016		372	372	691	207	207	-165
28	2017		372	372	691	207	207	-165
29	2018		372	372	691	207	207	-165
30	2019		372	372	691	207	207	-165
31	2020		372	372	691	207	207	-165
32	2021		372	372	691	207	207	-165
33	2022		372	372	691	207	207	-165
34	2023		372	372	691	207	207	-165
35	2024		372	372	691	207	207	-165

IRR Error

NPV -8854.54

B/C 0.077112

B-C -8854.54

NPV-C 9594.389

NPV-B 739.8433

Table 7.17 Discounted Cash Flow of Project Incremental Costs and Benefits

(Case-3: 50%) (Unit: YD Thousand)

	Year	Investment	O & M Cost	Total Costs	Water Revenue	Sewerage Revenue	Total Benefits	Net Benefits
1	1990	276		276				-276
2	1991	2,736		2,736				-2,736
3	1992	5,474		5,474				-5,474
4	1993	3,557		3,557				-3,557
5	1994	1,590		1,590				-1,590
6	1995		193	193	787	394	394	201
7	1996		203	203	798	399	399	196
8	1997		221	221	787	394	394	173
9	1998		233	233	776	388	388	155
10	1999		252	252	764	382	382	130
11	2000		268	268	753	377	377	109
12	2001		276	276	750	375	375	99
13	2002		285	285	742	371	371	86
14	2003		293	293	739	369	369	76
15	2004		302	302	735	368	368	65
16	2005		311	311	729	364	364	53
17	2006		321	321	719	359	359	39
18	2007		330	330	713	356	356	26
19	2008		340	340	706	353	353	13
20	2009		350	350	700	350	350	-0
21	2010		361	361	698	349	349	-12
22	2011		372	372	691	345	345	-27
23	2012		372	372	691	345	345	-27
24	2013		372	372	691	345	345	-27
25	2014		372	372	691	345	345	-27
26	2015		372	372	691	345	345	-27
27	2016		372	372	691	345	345	-27
28	2017		372	372	691	345	345	-27
29	2018		372	372	691	345	345	-27
30	2019		372	372	691	345	345	-27
31	2020		372	372	691	345	345	-27
32	2021		372	372	691	345	345	-27
33	2022		372	372	691	345	345	-27
34	2023		372	372	691	345	345	-27
35	2024		372	372	691	345	345	-27

IRR Error

NPV -8361.31

B/C 0.128520

B-C -8361.31

NPV-C 9594.389

NPV-B 1233.072

Table 7.18 Discounted Cash Flow of Project Incremental Costs and Benefits

(Case-4: 60%) (Unit: YD Thousand)

	Year	Investment	O & M Cost	Total Costs	Water Revenue	Sewerage Revenue	Total Benefits	Net Benefits
1	1990	276		276				-276
2	1991	2,736		2,736				-2,736
3	1992	5,474		5,474				-5,474
4	1993	3,557		3,557				-3,557
5	1994	1,590		1,590				-1,590
6	1995		193	193	787	472	472	279
7	1996		203	203	798	479	479	276
8	1997		221	221	787	472	472	251
9	1998		233	233	776	466	466	233
10	1999		252	252	764	458	458	206
11	2000		268	268	753	452	452	184
12	2001		276	276	750	450	450	174
13	2002		285	285	742	445	445	160
14	2003		293	293	739	443	443	150
15	2004		302	302	735	441	441	139
16	2005		311	311	729	437	437	126
17	2006		321	321	719	431	431	111
18	2007		330	330	713	428	428	97
19	2008		340	340	706	424	424	84
20	2009		350	350	700	420	420	69
21	2010		361	361	698	419	419	58
22	2011		372	372	691	414	414	42
23	2012		372	372	691	414	414	42
24	2013		372	372	691	414	414	42
25	2014		372	372	691	414	414	42
26	2015		372	372	691	414	414	42
27	2016		372	372	691	414	414	42
28	2017		372	372	691	414	414	42
29	2018		372	372	691	414	414	42
30	2019		372	372	691	414	414	42
31	2020		372	372	691	414	414	42
32	2021		372	372	691	414	414	42
33	2022		372	372	691	414	414	42
34	2023		372	372	691	414	414	42
35	2024		372	372	691	414	414	42

IRR -0.09223

NPV -8114.70

B/C 0.154224

B-C -8114.70

NPV-C 9594.389

NPV-B 1479.686

7.2. Economic Analysis

7.2.1 Economic Analysis

All the project costs and benefits should be evaluated through economic analysis. Nevertheless it is noted that the economic benefits, particularly of the social sector project are hardly quantifiable. Nevertheless, there has been numerous efforts to try to establish appropriate method for economic evaluation of the sewerage sector project.

Traditionally, the economic benefits of the sewerage project are thought to be derived from the following contexts:

(a) Increase in values of the land adjacent to the sewerage scheme,
(b) Decrease in expenditures for health cares,
(c) Savings in expenditures for sewerage services by consumers
(d) Effect on increase in industry development, and
(e) Impact on tourism development due to sewerage improvement

In case of the present Project area, the land has been stipulated as the property of the nation by which private ownership has been restricted. In addition, the transactions of the land has been almost nil in PDRY. Thus project benefit from an increase in land values here is not relevant.

For health care expenditures, a household interview survey has been unfortunately prohibited during the field study and thus related data on family expenditures have been unobtainable. The possible savings in sewerage service expenditures are not computable in the Project area as no sewerage charges have been levied and private sewage collectors do not exist. The present industry and tourism sector are considered still at infant stage in general, yet impacts on their development by the sewerage service improvement in the long)run, for instance pollution control, will be substantial which, however, would pose difficult quantification problem.

The conventional method of the economic benefits calculation, therefore, seems to be not very appropriate for the proposed Project and arbitrary computation of these intangible benefits may mislead the conclusion.

(1) Average Incremental Costs (AIC)

As second best alternative of the economic evaluation, a method called an "average incremental costs (AIC)" approach has been recently introduced in case of project evaluation of a social sector project financed by the international organizations such as the World Bank.

The average incremental costs (AIC) method is designed to evaluate how the proposed project costs per wastewater flow would justify the present tariff level of the sewerage service. The AIC is computed by dividing the sum of the net present value (NPV) of the project construction costs and incremental operation and maintenance costs by the sum of the net present value of the total wastewater flow. The equation to be used is as follows:

$$AIC = \frac{\sum_{t=1}^{T} (C_t + O_t)/(1+r)^{t-1}}{\sum_{t=1}^{T} N_t/(1+r)^{t-1}}$$

where t = time in years
Ct = construction costs incurred in year t
Ot = incremental operation and maintenance costs
T = design lifetime in years
Nt = incremental wastewater flow in year t
r = opportunity cost of capital

In addition, the project costs estimated at market prices, in principle, need to be adjusted based on shadow pricing method/standard conversion factor method.

For the presently proposed Project, however, due to unavailability of the necessary construction materials, equipment facilities and even majority of skilled and unskilled labors in the country, the Project costs have been rather estimated at international prices i.e. c.i.f. prices. The available materials in the domestic market would be found

only in some of the construction aggregates such as sand, gravel and earth. In view of these pricing situations of the project inputs, both traded and non-traded goods, the standard conversion factor which converts prices in market into their values in accounting prices would be 1.0.

Taking these elements into consideration, the calculation results are shown as follows;

Table 7.19 Average Incremental Costs (AIC)

Discount Rates	3%	5%	10%
NPV Cost (YD Thousand)	17,648	15,281	11,685
NPV Flow (m3 thousand)	108,728	75,543	34,538
AIC (YD/m3)	0.159	0.198	0.338

The average incremental cost (AIC) of the Project is estimated to be 0.198 YD/m3 at a discount rate of 5% and 0.338 YD/m3 at a rate of 10%.

Table 7.20 Proposed Sewerage Tariffs

Surcharge Rates	30%	40%	60%	80%
Domestic Consumer (YD/m3)	0.037	0.049	0.074	0.098
Commercial Consumer (YD/m3)	0.105	0.140	0.210	0.280
Industrial Consumer (YD/m3)	0.069	0.092	0.139	0.185

It is necessary that the AIC estimated above should be compared with the tariff rates of the present sewerage system. However as there is no sewerage charges collected in Aden, the proposed tariff levels which have been discussed previously are examined instead.

As shown above, the currently proposed sewerage tariff of 0.037 YD/m3 with surcharge rate of 30% for domestic consumers appears to be far below the calculated average incremental cost of the Project. This is also true for other consumer categories such as commerce and industry. It is suggested, therefore, that based on the AIC method, the proposed Project can be justified in terms of economic analysis.

Table 7.21 Average Incremental Cost (AIC) Calculation

(Unit: YD Thousand)

	Year	Investment	O & M Cost	Total Costs	Total Flow (1,000m3)
1	1990	276		276	
2	1991	2,736		2,736	
3	1992	5,474		5,474	
4	1993	3,557		3,557	
5	1994	1,590		1,590	
6	1995		193	193	3,906
7	1996		203	203	4,317
8	1997		221	221	4,728
9	1998		233	233	5,140
10	1999		252	252	5,551
11	2000		268	268	5,962
12	2001		276	276	6,110
13	2002		285	285	6,257
14	2003		293	293	6,405
15	2004		302	302	6,552
16	2005		311	311	6,700
17	2006		321	321	6,700
18	2007		330	330	6,700
19	2008		340	340	6,700
20	2009		350	350	6,700
21	2010		361	361	7,437
22	2011		372	372	7,437
23	2012		372	372	7,437
24	2013		372	372	7,437
25	2014		372	372	7,437
26	2015		372	372	7,437
27	2016		372	372	7,437
28	2017		372	372	7,437
29	2018		372	372	7,437
30	2019		372	372	7,437
31	2020		372	372	7,437
32	2021		372	372	7,437
33	2022		372	372	7,437
34	2023		372	372	7,437
35	2024		372	372	7,437

Discount Rates (%)		
3%	5%	10%
NPV-Cost	NPV-Cost	NPV-Cost
17,648	15,281	11,685
NPV-Flow	NPV-Flow	NPV-Flow
108,728	75,543	34,538
AIC (YD/m3)	AIC (YD/m3)	AIC (YD/m3)
0.159	0.198	0.338