社会開発調査部報告書

PEOPLE'S DEMOCRATIC REPUBLIC OF YEMEN

STUDY

ON

THE IMPROVEMENT OF MA'ALLA AND TAWAHI SEWERAGE SYSTEM IN ADEN

FINAL REPORT

VOL. 2
MAIN REPORT

JANUARY, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the People's Democratic Republic of Yemen, the Japanese Government decided to conduct a study on the Improvement of Ma'alla and Tawahi Sewerage System in Aden and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to the People's Democratic Republic of Yemen a survey team headed by Mr. Heiichiro Makino, Tokyo Engineering Consultants Co. Ltd., from December, 1988 to March, 1989, and from June to September, 1989.

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

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

I wish to express my sincerest appreciation to the officials concerned of the Government of the People's Republic of Yemen for their close cooperation extended to the team.

January, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

January, 1990

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir:

LETTER OF TRANSMITTAL

It is our pleasure to submit to you the Final Report of the Study on the Improvement of Ma'alla and Tawahi Sewerage System in Aden, in People's Democratic Republic of Yemen.

The field survey and study have been conducted during the period from November, 1988 to January, 1990.

This Report consists of four volumes: VOLUME ONE - Summary Report which provides the summary of the study and recommendations; VOLUME TWO - Main Report, which describes the results of the study and analysis; VOLUME THREE - Appendices which contains the details of various technical studies; VOLUME FOUR - Drawings, which contains maps and drawings.

We hope that realization of the proposed schemes would greatly contribute to improve the sanitary and environmental conditions in Aden.

Finally, we take this opportunity to express our sincere gratitude to Japan International Cooperation Agency, Ministry of Construction of the Government of Japan, the Embassy of Japan in Aden, Advisory Committee and the officials concerned of the Government of People's Democratic Republic of Yemen which gave useful advice to the Study Team during the study period.

Respectfully yours,

Heiichiro Makino

Heiichiro Makino
Team Leader
for the
Study on the Improvement of
Ma'alla and Tawahi Sewerage System

STUDY

ON

THE IMPROVEMENT OF MA'ALLA AND TAWAHI

SEWERAGE SYSTEM IN ADEN

IN

PEOPLE'S DEMOCRATIC REPUBLIC OF YEMEN

FINAL REPORT

CONSTITUENT VOLUMES

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ABBREVIATION

Agencies

ABC	Aden Bunkering Company
AFESD	Arab Fund for Economic and Social Development
ANA	Aden News Agency
ARC	Aquaculture Research Center
CSO	Central Statistical Organization
DANIDA	Danish International Development Agency
GDLG	The General Directorate for Local Government
HA	Highway Authority
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
JTS	John Taylor & Sons Consulting Civil Engineers
MOC	Ministry of Construction
MOF	Ministry of Finance
MOFA	Ministry of Foreign Affairs
MOFW	Ministry of Fish Wealth
MOP	Ministry of Planning
NCEP	National Council of Environmental Protection
PCEP	Public Corporation for Electric Power
PDRY	People's Democratic Republic of Yemen
PSF	Price Stabilization Fund
PWC	Public Water Corporation
UNDP	United Nations Development Program
UNICEF	United Nations International Children's Emergency Fund
WPCF	Water Pollution Control Federation
YPA	Yemen Port Authority
YTC	Yemen Telecommunication

Technical Terms

STP	Sewage Treatment Plant
P/S	Pumping Station
B.M.	Bench Mark
T.B.M.	Temporary Bench Mark
BOD	Biochemical Oxygen Demand

COD	Chemical Oxygen Demand
T-P	Total Phosphorus
T-N	Total Nitrogen
NH_4-N	Ammonia Nitrogen
K-N	Kjeldahl Nitrogen
pH	The reciprocal of the logarithm of the hydrogen-ion concentration
DO	Dissolved Oxygen
SS	Suspended Solids
TS	Total Solids
MPN	Most Provable Number
ACP	Asbestos Cement Pipe
DCIP	Ductile Cast Iron Pipe
PVC	Polyvinyl Chloride Pipe
RCP	Reinforced Concrete Pipe
VCP	Vitrified Clay Pipe

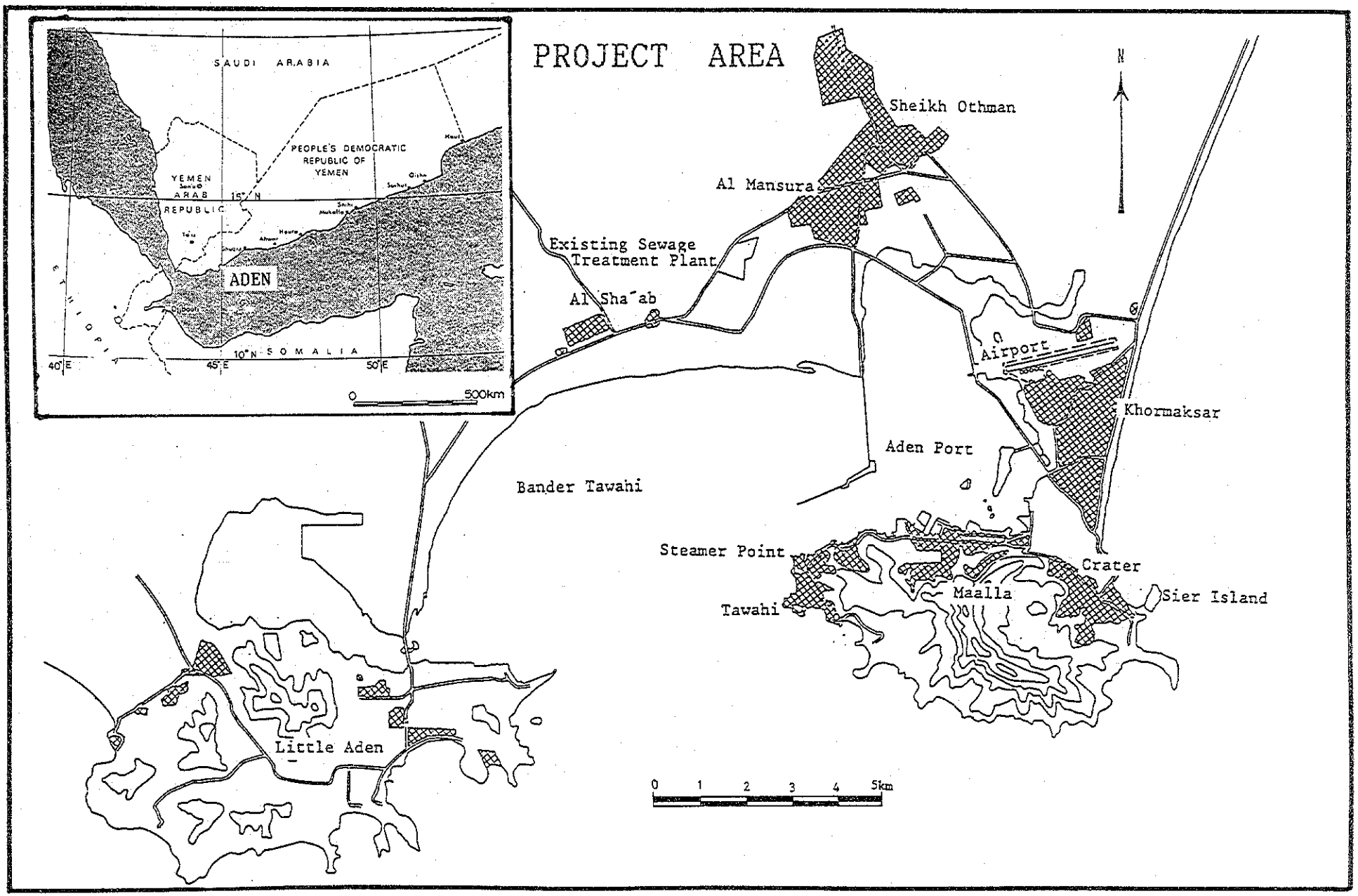
Units

km	Kilometer
m	Meter
cm	Centimeter
mm	Millimeter
ft	Foot, Feet
in or "	Inch
km^2	Square Kilometer
ha	Hectare
m^2	Square Meter
cm^2	Square Centimeter
m^3	Cubic Meter
l	Liter
ml	Milliliter
cm^3	Cubic Centimeter
g	Gram
mg	Milligram

lcd	Liter per Capita per Day
gcd	Gram per Capita per Day
mg/l	Milligram per Liter
ppm	Part per Million
y	Year
d	Day
hr	Hour
min	Minute
sec	Second
a.m.	Ante Meridiem
p.m.	Post Meridiem
V	Volt
kV	Kilovolt
W	Watt
kW	Kilowatt
kWh	Kilowatt Hour
US$	US Dollar
YD	Yemen Dinar
Fils	1/1,000 Dinar
JY	Japanese Yen
DM	Deutsche Mark

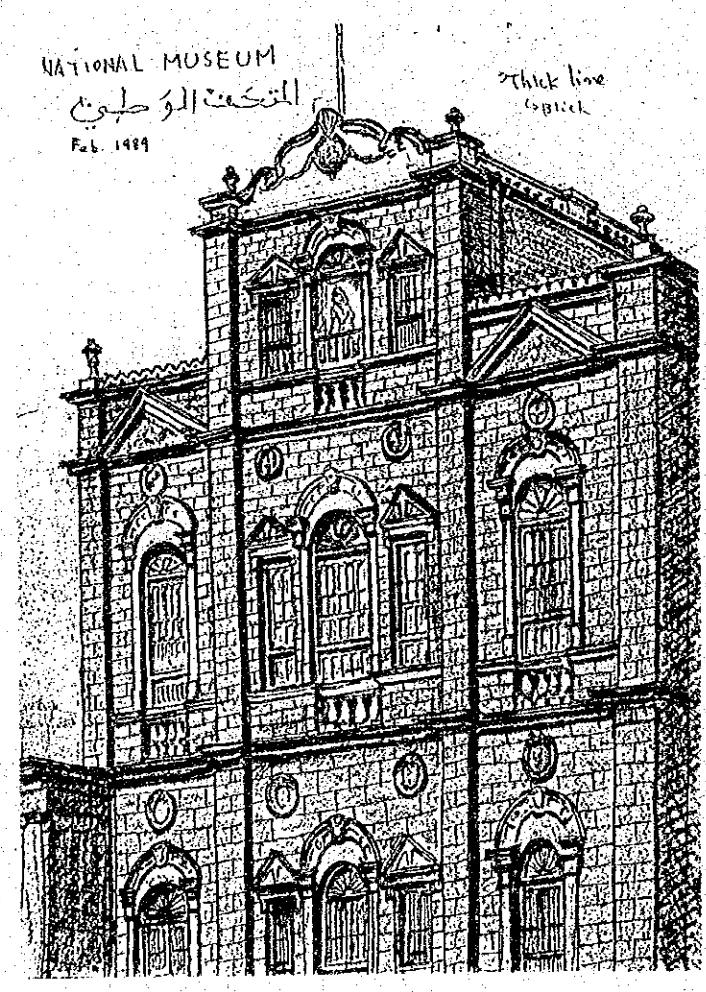
Others

C&A	Civil and Architectual
M&E	Mechanical and Electrical
DPS 2010	Development Pricipal Scheme for the Year 2010


PROJECT AREA
SAUDI ARABIA
PEOPLE'S DEMOCRATIC REPUBLIC OF YEMEN
YEMEN ARAB REPUBLIC
ADEN
Djibouti
ETHIOPIA
SOMALIA
15° N
10° N
40° E
45° E
50° E
500km
N
Sheikh Othman
Al Mansura
Existing Sewage Treatment Plant
Al Sha'ab
Airport
Khormaksar
Aden Port
Bander Tawahi
Steamer Point
Crater
Maalla
Tawahi
Sier Island
Little Aden
0 1 2 3 4 5km

CHAPTER ONE

INTRODUCTION



CHAPTER ONE

INTRODUCTION

1.1 Project Background

Aden, the capital of the People's Democratic Republic of Yemen (hereafter referred to as PDRY), lies at the southern tip of the Arabian peninsula, 170 km east of the mouth of the Red sea and bordered by the Indian Ocean on the south. Aden lies at a longitude of 45° 02 east and at a latitude of 12° 50 north.

Aden is an ideal natural port and has an important position in the trade between the Orient and the Occident. It has been prosperous as an intermediate port of the spice trade from ancient times.

The urbanization of Aden began with its conquest by Britain in 1839 (1839-1967), which introduced modern water supply and sewerage systems into the capital, and laid the foundation of the present features of Aden. The Capital Municipality Aden extends along the inner harbor, and consists of the districts of Tawahi, Ma'alla and Crater in the south, Khormaksar in the east, Al-Mansura, Sheikh Othman and Dar Saad in the north, and Little Aden in the west, covering an area of 20,800 ha with the total population of over 300,000 at present.

There are, at present, sewerage systems but without proper treatment of wastewater except Al-Mansura, Sheikh Othman. Most of the wastewater collected through sewer reticulations are discharged directly to Aden Port, Bander Tawahi and the Gulf of Aden.

The result of this discharge of wastewater is gross pollution, resulting in septicity and offensive odor in the harbor at many discharge points. The deterioration of sewerage systems in the area, particularly in the urban built-up districts, has become deplorable and measures against the pollution are urgently required.

In order to improve the aging sewerage system in Ma'alla and Tawahi districts, the Government of PDRY made a request to the Government of Japan for a master plan and a feasibility study for the improvement of sewerage system in the southern part of Aden.

In response to the official request of the Government of PDRY, the Government of Japan decided to carry out a study on the improvement of the sewerage system in Ma'alla, Tawahi and Khormaksar in Aden (hereafter referred to as the Study) in accordance with the relevant laws and regulations in force in Japan.

The Japan International Cooperation Agency (hereafter referred to as JICA), the official agency responsible for the implementation of technical cooperation programs of the Government of Japan, undertakes the Study in close cooperation with the authorities concerned of the Government of PDRY, according to the Scope of Work signed on July 17th, 1988.

The General Directorate for Local Government (hereafter referred to as GDLG) shall act as counterpart agency to the Japanese study team and also as a coordination body in relation to the other relevant organizations for smooth implementation of the Study.

The study team organized by JICA was dispatched to Aden in December, 1988. They stayed in Aden until March, 1989 to conduct the first on-site survey and data collection. The Interim Report was submitted to GDLG in late June, 1989, at the beginning of the second on-site survey. Inclusion of the Khormaksar district into the feasibility study area was agreed on by both governments and the Scope of Work was accordingly amended in July, 1989. Supplemental surveys in Khormaksar district was conducted during the second on-site survey period from June to September, 1989. This Draft Final Report is prepared in accordance with the amended Scope of Work, and presents the outcome of the Study carried out both in Aden and Japan. Comments on the Progress Reports and on the Interim Report made by the authorities concerned of the PDRY government are duly reflected in this Report.

1.2 Objectives of the Study

The objectives of the Study are to formulate a master plan of a sewerage system in the Khormaksar, Crater, Ma'alla and Tawahi districts and to carry out a feasibility study for the improvement of Ma'alla and Tawahi sewerage system.

The Study consists of the following items:

(1) To formulate a master plan for the basic concept of sewerage scheme in the four above mentioned districts.

(2) To carry out a feasibility study for the improvement of Ma'alla, Tawahi and Khormaksar sewerage systems.

(3) To transfer technology to the Yemen counterpart personnel from the Japanese study team throughout the Study.

1.3 Scope of the Study

The following will serve as the scope of the Study.

1.3.1 Study Area

(1) The Study area of the master plan will cover Khormaksar, Crater, Ma'alla and Tawahi districts.

(2) The Study area of the feasibility study will cover Ma'alla, Tawahi and Khormaksar districts.

1.3.2 Target Years

The target year of the master plan is 2010.
For the feasibility study, 2000 is considered as the target year.

1.3.3 Contents of the Study

The Study comprises field surveys and data collection in PDRY and analytical and design work both in PDRY and Japan, and more specifically includes the following work items:

(1) Data collection and analysis

- Population
- Land use
- City development plan

- Natural condition
- Soil and geological condition
- Water use, water quantity and quality
- Sewerage and related facilities
- Present sanitary conditions
- Institution and financial condition
- Previous studies

(2) Field Survey

- Water and waste quality survey
- Topographic survey
- Survey of the existing facilities

(3) Formation of Basic Concept

- Target year
- Proposal of alternatives
- Consideration from economic, financial and social point of view
- Selection of appropriate master plan

(4) Discussion of Progress Report(1)

(5) Analysis Work for Formation of Basic Concept

- Water pollution analysis of Tawahi Bay
- Design criteria
- Design flow rates and sewage characteristics
- Alternative study on sewerage system
- New sewerage facilities
- Rehabilitation and improvement of the existing facilities
- Estimation of project cost
- Reuse of treated effluent and sludge
- Implementation program
- Organizational arrangement and staffing schedule
- Financial and economic analysis

(6) Explanation of the Interim Report

(7) Second On-site Work in Aden

(8) Feasibility Study

- Sewerage facility planning
- Cost estimation
- Procurement planning of construction materials and estimation of manpower requirement

(9) Institutional and Organizational Planning

- Appropriate institutional format
- Institutional Organization
- User charge system

(10) Project Evaluation

- Financial evaluation
- Economic evaluation
- Environmental and social evaluation

(11) Implementation Program

- Implementation schedule
- Disbursement schedule

(12) Explanation and discussion of the Draft Final Report

(13) Preparation and Submission of the Final Report

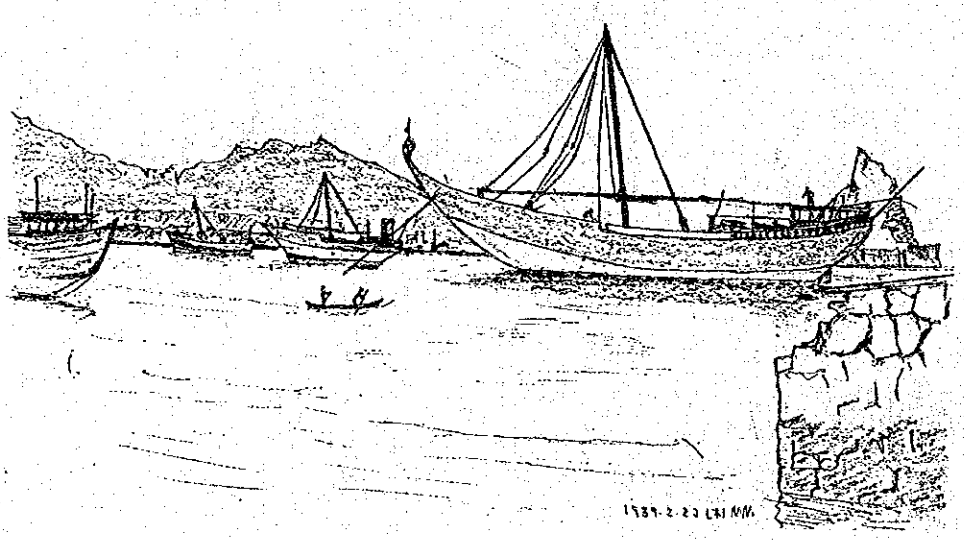
1.4 Undertaking of the Study

The Government of PDRY has accorded privileges, immunities and other benefits to the study team, and through the authorities concerned, taken necessary measures to facilitate smooth conduct of the Study.

The Government of Japan, through JICA, has taken necessary measures to dispatch the study team to PDRY and to transfer technology to the PDRY counterpart personnel in the course of the Study.

CHAPTER TWO

PRESENT CONDITIONS OF THE STUDY AREA



CHAPTER TWO

PRESENT CONDITIONS OF THE STUDY AREA

2.1 Introduction

This chapter provides background information and data to be used in Chapter Three to estimate future wastewater production and disposal, and to establish the basis for sewerage systems planning, and in Chapters Four and Five to develop specific proposals for both the Long Term and the First Phase Programs covering the period 1990 through 2010.

This chapter therefore presents the conditions in the study area, population and land use, existing water and sanitation service levels, wastewater production patterns, and environmental problems in the area. The data is largely based on field surveys and investigations, specially undertaken on two occasions for this feasibility study from December 1988 through March 1989, and June through September 1989 by the JICA study team in the study area. All the previous studies and information collected by the present study, as listed in "References" of this report, have been reviewed and, where necessary, revised in the light of the current conditions in the area.

The data presented herein are, therefore, more up-to-date than those in previous reports and studies. Unless otherwise stated, all cost data in this report are at December 1988 prices. The planning period adopted for the First Phase Program is up to 2000 and for the Long Term Program, up to 2010.

Detailed data obtained and calculations for engineering and financial studies are separately provided in Volume Three "Appendices". Corresponding reference numbers are indicated as needed for convenience. Volume Four "Drawings" contains maps and drawings which illustrate proposed sewerage systems.

2.2 Natural Conditions

2.2.1 Location, Topography and Geology

(1) Location

PDRY is bounded in the north by the Kingdom of Saudi Arabia, in the northwest by the Yemen Arab Republic, in the south by Gulf of Aden and Arabian Sea, in the east by the Sultanate of Oman and in the west by the Bab-al-Mandab Strait.

Greater Aden, the capital and the largest city in PDRY, occupies the south-western corner of the Arabian Peninsula as well as Asia.

It looks upon Africa through the Bab-al-Mandab Strait south of the Red Sea. The city lies at a longitude 45° 02 east and at a latitude 12° 50 north, at Khormaksar.

(2) Topography

The most decisive topographic component is Tawahi Bay. To the north and northeast of Greater Aden are major areas of flat sand dunes. In the west and the south of Greater Aden there are mountainous areas.

Aden peninsula, a former island of volcanic origin now linked to the continent by a sandy tombolo, is composed of steep mountains rising to about 600 m. Lava of late Miocene or Pliocene ages to recent times overlie the coastal plain and form the sea cliffs at Aden. Crater is the oldest district and is built on the rocky remains of a former crater. The level of roads vary from +10.3 m YPAD*1 to +4.5 m. Ma'alla and Tawahi have developed on a littoral road with ground level from +10.3 m to +2.9 m. Most of the available land in the above districts has already been built up.

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*1 YPAD: Yemen Port Authority Datum, hereafter all the levels are indicated by this datum.

Khormaksar is built on the tongue of sand linking the former island to the continent, and the ground level varies from +2.7 m to +3.7 m. The ground water level is about +1.50 m which is rather higher than those in other districts. The permeability coefficient in this area is 1.5 cm/sec, and was obtained in field surveys.

Sheikh Othman, Mansura and Dar Saad districts are located north-east of the bay, on the sandy plains formed by the Wadi Tuban, enclosing the bay.

The present coastal plain, bordering the Gulf of Aden, is about 50 km wide at its widest location north of Aden. The plain is a depositional feature superimposed on a marine bench cut in Oligocene and Miocene sediments and crystalline rocks, subsequent to the last movements of the rift fault blocks. The coastal plain has been built up in stages from alluvial material brought by innumerable short wadis which drain the ramped mountain ranges of the hinterland.

Along the coast between Al Mukalla and Aden, a number of fishing villages are supplied by wells within half a mile from the shore. The water levels are a few feet above mean sea level and probably represent wedges of fresh water floating on sea water.

Domestic water from shallow-wells 10-20 m deep normally contained 900 ppm to 400 ppm salinity.

(3) Geology

The Aden Trap Series is part of an extensive elongated outcrop of volcanic rocks associated with the Red Sea and Abyssinian rifts. The association of volcanicity with the east African rift system, with the west Arabian (Red Sea) and Levantine rifts, and with rifting in other regions is well known.

The geology of PDRY is broadly divisible into three parts, viz. the sedimentary plateau of the eastern part, the tectonically uplifted main basement block of the western part, and a structurally depressed area in the southwest, mainly covered by volcanic rocks of the Aden Trap Series.

The results of a study of the geological history of the western part of the PDRY is summarized in the order of ages as follows

a. Precambrian Age

i. Deposition of sediments, probably upon a planed surface of older gneiss, accompanied by volcanic activity.

ii. Folding and regional metamorphism of sedimentary and mafic igneous rocks to form the Aden Metamorphic Group, accompanied by syntectonic granite invasion, granitization, and magmatization. The metamorphism was mainly of mesozonal type, reaching grades appropriate to the almandine-anphibolite facies.

b. Late Cretaceous to Tertiary Age

Volcanic activity in the southwest of the region, resulting in formation of the Aden Trap Series in the Late Cretaceous to Tertiary age. Intrusion of alkalic granite and of silicic and mafic dikes.

c. Late Miocene or Pliocene to Recent

Volcanic activity resulting in the Aden Volcanic Series, from the late Miocene or Pliocene to recent age.

d. Pliocene and Pleistocene to Recent

Formation of superficial deposits, terraces, raised beaches, and dune sands, from Pliocene and Pleistocene times onward.

Certainly since the Mesozoic time and probably since the end of the Precambrian the region has undergone intermittent epeirogenic movements, which continued until recent time and was associated with faulting. Faulting is probably of ancient origin with repeated rejuvenation along old trends. A phase of faulting in the Red Sea trend dating from at least late Cretaceous until late Eocene time is recognized. The main phase of faulting in the Gulf of Aden trend dates book to early Miocene time.

Table 2.1 shows the relation between geological ages and unit names.

Table 2.1 Rock Units of Western PDRY

Age	Unit name used in this report
Pliocene and Pleistocene to Recent	Eolian (dune sands) Superficial deposits, including alluvium, loess, silt, sand, gravel, and terrace and raised beach deposits
Late Miocene or Cenozoic to Recent	Aden Volcanic Series
Late Cretaceous to Tertiary	Alkaline granite Aden Trap Series
Precambrian	Intertectonic calc-alkaline granite Intertectonic intermediate mafic plutonic intrusions Syntecto Aden Metamorphic Group Older gneiss

2.2.2 Climatic Conditions

(1) General Characteristics

Greater Aden area is situated within the seashore strip of Afro-Asian climatic region of the tropical-zone of northern hemisphere.

The general characteristics of climatic conditions in Aden are summarized as follows.

a. High temperatures throughout the year with small seasonal differences.

b. High relative humidity throughout the year.

c. Scarcity of rainfall with average annual rainfall of 68 mm.

d. Relatively stable seasonal wind directions, with the prevailing wind directions in winter being eastward and southward to westward in summer, with transition periods in October/November and April/May.

Climatic data mentioned below have been obtained for the period 1971 to 1987 at the meteorological station in Khormaksar (Aden Airport).

(2) Air Temperature

Average daily maximum and minimum and absolute maximum and minimum, and monthly average temperatures are shown in Table 2.2. During the period of observation, the absolute maximum and minimum air temperature was 41.8°C in June and 15.0°C in January respectively. Monthly average temperatures vary from 25.5°C in January to 32.3°C in June.

(3) Relative humidity

Average monthly relative humidity are given in Table 2.2. Average annual relative humidity during the period of observation was 71% with a maximum of 75% in March and April and a minimum of 66% in July.

The maximum relative humidity was 92% in August and the minimum was 32% in June, July and August.

(4) Rainfall

Monthly rainfalls are shown in Table 2.2. Average annual rainfall is 68.0 mm. More than half the annual rainfall is recorded in a four month period from February to May.

Monthly air temperature, relative humidity and rainfall are shown in Figure 2.1.

(5) Wind

The prevailing winter wind in the Gulf of Aden is the easterly which swings southeasterly in the straits of Bab al Mandab. In May the humidity sometimes rises and the winds are variable. From June to September they blow steadily from the west into the main current of the southwest monsoon in the Arabian Sea and bring occasional violent storms. A dry northerly wind which is known in Aden as the kawi (hot iron) blows occasionally in the Gulf of Aden during the southwest monsoon. Monthly wind directions are shown in Table 2.3 and Figure 2.2.

Table 2.2 Climatological Statistics (1971 to 1987)

(12° 50 N 42° 02 E)

	Temperature(°C)					Relative Humidity(%)			Rainfall(mm)
Month	Mean Max.	Daily Min.	Absolute Max.	Absolute Min.	Mean Daily	Mean	Mean Max.	Mean Min.	Mean
Jan.	28.4	23.1	30.3	15.0	25.5	70	88	48	3.6
Feb.	28.7	23.0	32.0	16.4	25.7	72	91	50	11.1
Mar.	30.0	24.3	32.6	18.0	26.9	75	91	51	8.1
Apr.	31.9	25.7	38.0	19.0	28.6	75	91	41	7.5
May	34.1	27.6	39.3	21.9	30.7	73	91	37	11.6
Jun.	36.4	29.0	41.8	24.5	32.3	68	91	32	0.3
Jul.	36.2	28.7	41.0	22.5	32.0	66	91	32	2.1
Aug.	35.8	27.9	39.8	22.1	31.4	67	92	32	4.6
Sep.	35.1	28.3	40.0	23.5	31.3	71	91	37	9.7
Oct.	32.7	25.0	38.0	18.2	28.9	69	90	37	5.7
Nov.	30.6	22.8	35.9	16.4	26.8	69	89	35	1.1
Dec.	29.0	23.1	31.0	16.0	25.9	71	90	47	2.6
Ave.	32.4	25.7	36.6	19.5	28.8	70.5	90.5	39.9	68 mm/year

Source: Meteorological Station

Table 2.3 Wind Direction (1971 to 1987)

(in %)

Month	Direction N	NE	E	SE	S	SW	W	NW	Calm
Jan.	4	4	51	38	2	0	1	0	5
Feb.	2	3	69	25	1	0	0	0	3
Mar.	2	4	62	30	1	0	0	1	7
Apr.	1	3	67	27	1	0	1	0	4
May	2	5	60	28	1	3	1	0	10
Jun.	4	6	20	26	5	25	12	2	19
Jul.	4	5	16	14	5	42	12	2	15
Aug.	4	6	18	23	7	30	11	1	18
Sep.	3	7	31	32	5	15	6	1	16
Oct.	3	12	44	34	4	1	2	0	11
Nov.	4	4	58	31	1	0	0	0	8
Dec.	3	10	42	41	4	0	0	0	9
Annual	30	5.8	44.8	29.2	3.1	9.7	3.8	0.6	10.4

Source: Meteorological Station

(6) Evaporation

Evaporation data obtained at Lahej Station which is nearest to the study area for 16 years from 1973 to 1988 are shown in Table 2.4 and Figure 2.3. Evaporation varies from a low of 6.8 mm/day in January to a high of 12.7 mm/day in August with an average of 9.7 mm/day.

Table 2.4 Evaporation

(mm/day)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Ave. Evap. (1973-1988)	6.8	7.9	9.0	10.1	10.9	11.3	12.1	12.7	10.3	9.5	8.4	7.0	9.7

Source: Meteorological Station

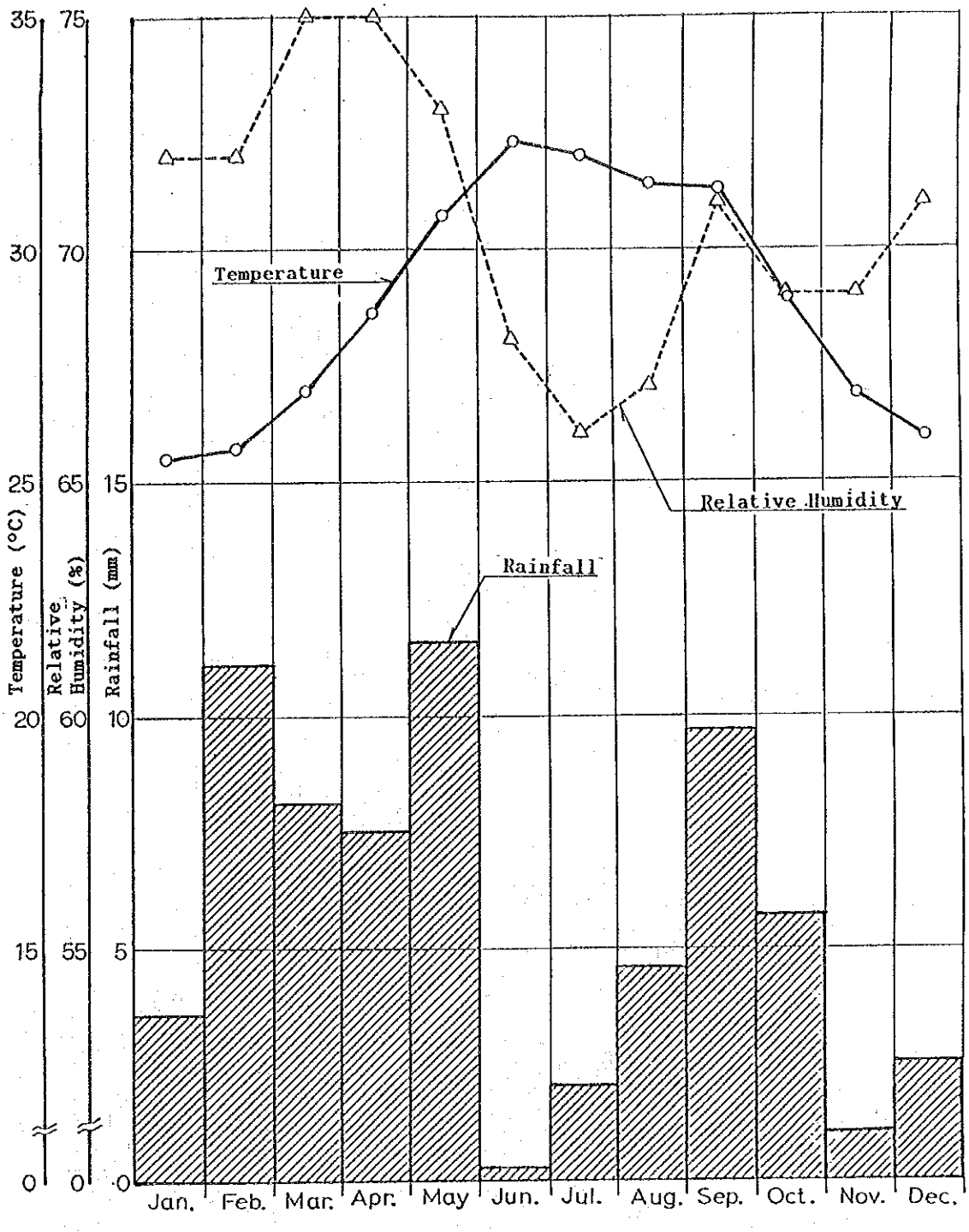


Figure 2.1 Monthly Mean Temperature, Relative Humidity and Rainfall

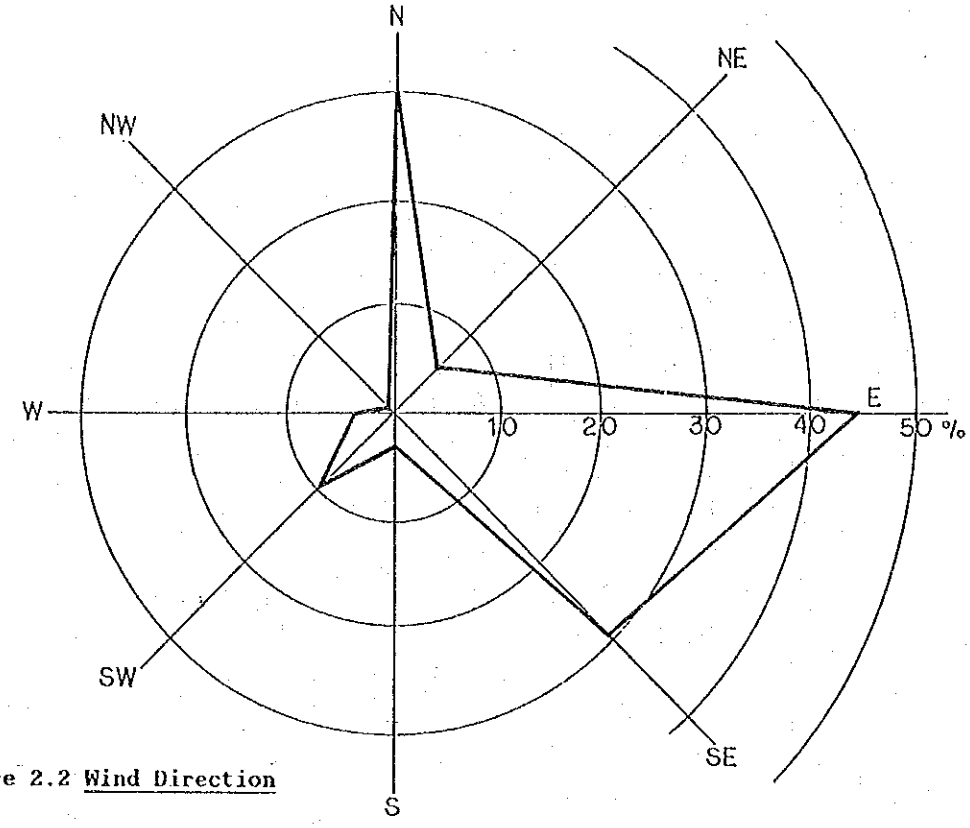


Figure 2.2 Wind Direction

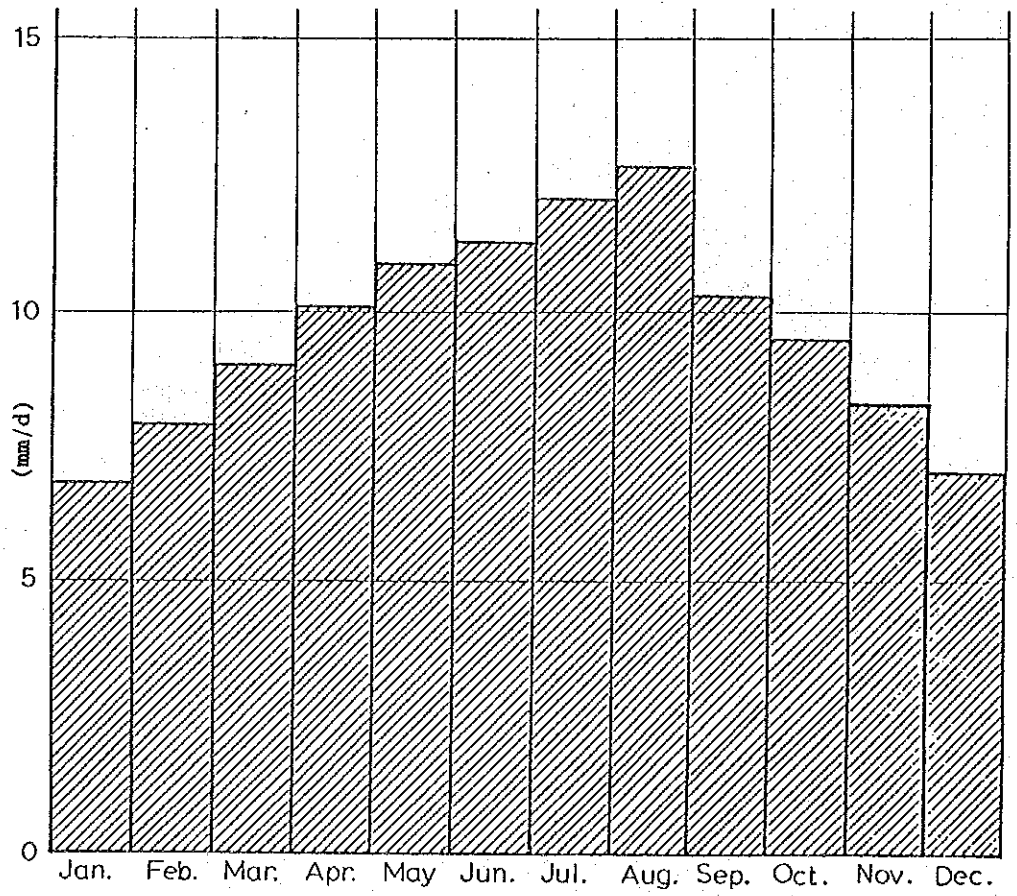


Figure 2.3 Evaporation

2.3 Socio-Economic Condition

2.3.1 Macro-Economic Review

The People's Democratic Republic of Yemen (PDRY) is one of the least developed countries (LLDC) in the world, with per capita GNP of US$ 480 in 1986. The economy of the PDRY is dualistic in nature, with a modern sector i.e. refinery, port and industries, is centered around Aden, and a traditional subsistence sector i.e. agriculture and fishing along the coastal areas.

After independence, the economy was strained by the reduced activity in the port and refinery in 1970s. However, due to the boom in the neighboring oil exporting countries, the economy recovered, particularly with increases in the workers' remittances and foreign aid, which became major sources of foreign currency to the country. In 1980s, the economy again slowed down and showed extreme vulnerability to deterioration in the external economic environment.

The gross domestic product (GDP) is estimated at current prices and no estimates of the detailed structure of expenditures are available. According to the Ministry of Planning, increases in GDP growth at factor cost were recorded at more than 10% between 1983 and 1984, whilst growth dropped dramatically to -9% in 1986 because of internal disturbances in January of that year which adversely affected the national investment program. The economy, however, subsequently recovered to achieve growth of 5.7% in 1987.

In terms of GDP at constant 1985 prices, the real growth rates increased by less than 4% in 1983 and 1984 while GDP sharply declined by more than 9% in 1986 and revived to reach 3% in 1987. The details are summarized below:

Table 2.5 Change in Gross Domestic Product

(Unit: YD million)

	1983	1984	1985	1986	1987
GDP (factor cost)	289.6	320.9	320.3	291.6	308.1
- % increase	10.5	10.8	-0.2	-9.0	5.7
GDP (constant price) *1	308.5	316.2	313.0	282.5	290.2
- % increase	3.5	2.5	-1.0	-9.7	2.7

Note: *1: IMF estimates

2.3.2 Sectoral Review

(1) Agriculture

The agriculture sector, which employs more than 40% of the total labor force and which utilizes substantial amounts of government expenditures, has contributed only 12-14% to the GDP in the last five years. Cultivated land can not easily expand due mainly to limited irrigation facilities. Besides, recent floods in 1982 damaged the agricultural infrastructure. Nevertheless, the overall development of the sector has improved since 1985 and the output of most crops increased in 1986, showing an average rise of about 14% in production.

The agriculture sector in PDRY can be divided into three institutional categories i.e. (1) state farm, (2) cooperatives and (3) private farmers. The state farm, though supported closely by the government, accounts for 15% of the agricultural output in 1985 and 1986. The cooperatives, which are managed better than the state farm, have contributed around 40% of the output. In spite of significant governmental investment in state farm and cooperatives, more than 50% of the total production is accounted for by private farmers.

In principle, prices of agricultural products are set so as to provide producers and marketing organizations with adequate incentives to sustain and expand operations. In reality, however, price adjustment lags behind cost increases resulting in an erosion of profitability and incentives. In general, prices of major crops in PDRY are higher than international levels. The government finances the gap between the international prices and domestic prices from the Price Stabilization Fund (PSF). Through the PSF, export crops and import-substitution crops are encouraged by the government.

(2) Fisheries

Because of Yemen's long coastline, there is ample potential in the fishery sector for earning foreign exchange and satisfying domestic food requirements. Fisheries constituted about 50% of the total exports till 1986, while its share went down to 20% in 1987 due to rapid increase in petroleum product exports. The annual fish catch dropped to 89,500 tons in 1987 from 91,400 tons in 1986.

Fish production is carried out by five sub-sectors i.e. public, cooperative, mixed, private and foreign sub-sectors. Foreign company catch almost half the total production. The public and cooperative sub-sectors, which specialize in high value species for export, account for around 40% and the private sector accounts for the remainder. The major species are surface water fish, deep water fish, cuttlefish and lobsters. The Ministry of Fish Wealth tries to diversify the export market. Lobsters are now air-freighted to Italy and France and live lobster export is also under study. Newer markets in Egypt and Jordan are being explored.

The Aquaculture Research Center (ARC) which was newly established by Japan's grant aid has commenced shrimp/cuttlefish/mullet farming projects. It is expected that the Center will contribute to fishery sector development in the country in the future.

(3) Industry

The industrial sector in Yemen comprises largely light consumer goods, agro-based commodities and petrochemical related products for the domestic market. The exports of manufactured products other than petroleum products are limited to cotton, salt, leather, carpets and cigarettes and constitute a small portion of the total exports. The Government enacted the investment promotion law in 1981 in order to attract foreign capital, including from Yemenis abroad. Nevertheless, the number of the industrial establishments have not increased significantly until now.

The public enterprises, which account for a substantial portion of establishments, produced 70% of the total industrial output in 1987. The private sector contributes 17% of the total production. The major constraints in the manufacturing sector in PDRY are: 1) limited domestic market, 2) shortage in skilled workers, 3) lack of local inputs supply and 4) wage and salary incentives problems.

The oil refinery industry is rather exceptional in the country. The Aden petroleum refinery, which is, in fact, the single largest industrial establishment, employs around 2,300. It was established in 1954 by British Petroleum, and transferred to Yemeni ownership in 1977. The annual refining capacity is 8.5 million metric tons mainly for foreign crude producers. Due to

competition with other advanced refineries in neighboring countries, however, refinery operation has declined substantially recently. In order to alleviate the monetary crunch, the refinery has started asphalt and LPG production for domestic use and export.

2.3.3 Five-Year Development Plans

Development planning for PDRY was first initiated in the three-year development plan which covered April 1971 - March 1974. It was then followed by successive five-year plans extending from April 1974 - December 1978, 1981-85 and 1986-90. During the period of 1979-1983, a five-year development plan was prepared for implementation, but the plan itself was largely modified in 1981 and thus had to be reshaped as the second five-year plan (1981-1985).

The first three-year plan, which was made just after independence, emphasized the transportation sector in order to provide necessary infrastructure to link all the governorates together. The next two five-year plans placed priority on productive sectors such as agriculture, fisheries and industries. Sectoral allocations of development expenditure under the first and second five-year plans on actual basis are shown in table below:

Table 2.6 Sectoral Allocation of Development Expenditures

(Unit: YD million)

	1974-80		1981-85	
	Actual	%	Actual	%
Agriculture	72.7	23.0	84.4	12.4
Fisheries	35.9	11.3	37.4	5.5
Industry	24.3	7.6	20.6	3.0
Power	13.0	4.1	102.0	15.0
Oil/Mineral	15.7	5.0	63.1	9.2
Construction	11.0	3.5	13.2	1.9
Trans/Communication	76.0	24.0	152.4	22.3
Trade	3.5	1.1	33.6	4.9
Water Supply	2.2	0.7	28.5	4.2
Social Services	62.3	19.7	147.5	21.6
Total	316.6	100.0	682.7	100.0

Source: Statistical Year Book 1985-1986,
Central Statistical Organization

For the third five year plan which is now underway, priority is given to the geological and mineral resource survey sector (17% of the total investment) so as to further tap natural resources, particularly oil exploration and to earn necessary foreign exchange. Sectoral allocations are as follows.

Table 2.7 Third Five-Year Plan, 1866-1990

(Unit: YD million)

	1986	1987	1988	1989	1990
Agr/Fish	19.5	19.7	18.8	16.4	15.5
Ind/Pow/Oil	42.3	43.1	35.3	24.5	19.0
Geol/Min	14.4	20.1	22.9	21.3	24.3
Com/Cons	34.0	33.1	26.7	23.9	20.3
Social	36.8	31.8	19.3	17.5	11.8
Total	147.0	147.8	123.0	103.6	90.9

Source: Ministry of Planning

2.3.4 Public Finance

The public finance of the Central Government constitutes (1) ordinary (current) budget and (2) development (investment) budget for a fiscal year which coincides with the calendar year. The preparation of an annual budget usually starts in September when the ministries submit budget proposals to the Ministry of Finance for current budget and proposals to the Ministry of Planning for development budget.

The two budgets are then compiled as an unified budget under the control of the Ministry of Finance. Through negotiations carried out towards December, the Ministry of Finance and the Ministry of Planning pass their final proposals on to the Supreme Council of Planning, the Council of Ministers, and the Party Central Committee for their comments and approvals. By the end of December, the budget proposals are finally approved by the People's Supreme Council.

(1) Revenues

During 1982 and 1984, domestic revenues grew in nominal terms by more than 10% per annum. It declined, however, by 3% in 1985 and further dropped by 15% in 1986 because of internal disturbances. In 1987 the revenue rose sharply by 25% reflecting improved economic activities and particularly, contribution of public corporations.

a. Domestic Revenues

The most important domestic revenue source has been the contributions from the various public sector entities. It has accounted for more than 40% of the total domestic receipts over the last three years. In addition, there are three other principal sources of revenues which are (1) taxes on profits of public sector enterprises, (2) indirect taxes on commodities, mostly cigarettes, beer and qat and (3) import duties, which have, however, declined recently due to import contraction. The tax revenues altogether constitute 45% of the total revenues. Details of Government revenues are illustrated in the following table:

Table 2.8 Domestic Revenues of Central Government

(Unit: YD Thousand)

	1985	1986	1987
Direct Tax	16,385	13,570	17,473
Indirect Tax	61,693	51,362	53,583
Public Sector	59,565	49,972	75,020
Services Fees	5,524	6,418	8,376
Transfer	775	902	1,152
Capital Revenue	1,525	94	171
Total	145,467	122,318	155,775

Source: Ministry of Finance

b. External Borrowings

Reflecting the scarcity of domestic resources, the country, in addition to the above domestic revenues, is dependent on external resources. Particularly, in order to make up for the gap between available domestic sources and investment expenditures, foreign financial sources have been constantly sought. The following is the sources of financing development projects for 1983-1987:

Table 2.9 Source of Development Expenditures: 1983-1987

(Unit: YD Thousand)

	1983	1984	1985	1986	1987
Total Exp.	149,400	158,800	131,900	102,900	114,900
Domestic:	79,900	92,200	70,600	45,300	45,400
Govt Resources	60,900	64,500	48,300	38,400	38,400
Banking System	8,600	19,400	17,000	3,200	2,600
Self-financing	10,400	8,300	5,300	3,700	4,400
Foreign:	69,500	66,600	61,300	57,600	69,500
(% of Total)	(46.5)	(41.9)	(46.5)	(56.0)	(60.5)

Source: Ministry of Planning

The table exhibits that foreign resources cover nearly one half of the total development expenditures during this period, and in 1987, the share had gone up significantly to 60.5%.

With such considerable loan drawing, the long-term external debt has increased from US$ 945 million in 1983 to US$ 1,658 million in the mid 1988. Bilateral aid constitutes more than 70% of the long-term debt, of which the main donors are U.S.S.R. (more than 50% of the external debt) and China (8%), whilst the rest is from international organizations, viz. the World Bank and the Arab Fund for Economic and Social Development (AFESD).

The debt service ratio rose to 15.8% in 1987 (the latest ratio in 1988 is not available). Nevertheless, according to the Bank of Yemen, the external loans have been made available with an average interest rate of just over 2%. It is

expected, therefore, that the debt service obligations have still remained manageable.

(2) Expenditures

The expenditures of the central government consist of the current outlay and development outlay. The total expenditures, including the current and development outlay have declined from YD 314.6 million in 1985 to YD 300.1 million in 1987.

a. Current Expenditures

The largest share of the ordinary expenditures have been the wages and salaries of the government personnel which have constituted more than 50% of the total outlay and have remained constant for 1985-87. Administrative expenditure, viz. materials and supplies, which were curtailed substantially in 1986 because of internal conflict, whereas transfer payments, comprising pensions, subsidies to PSF (Price Stabilization Fund), contributions to public entities and so forth, have remained at the rate about 15% over the last three years. The current expenditures are as follows:

Table 2.10 Current Expenditures

(Unit: YD Thousand)

	1985	1986	1987
Personnel	90,700	90,900	98,600
Administration	54,900	45,100	48,100
Transfer	24,000	23,900	25,700
Capital	14,100	8,600	12,800
Total	183,700	168,500	185,200

Source: Ministry of Planning

b. Development Expenditures

Although the year 1986 was the first year of the third development plan, the development outlay was greatly constrained to YD 102.9 million in 1986 compared with YD 132.0 million in 1985 and then recovered slightly to YD 114.9 million in 1987.

As for the sectoral allocation, power development has received the largest portion of more than 20% followed by mineral survey (17%), social service (15.2%), transport (14.8%), and agriculture sector (13.0%). Over the last three years, mineral survey and power sector expenditures have increased rapidly while transport/communication and social service sector spending have declined substantially. The propotion for the water supply sector to the total has risen from 4.9% in 1985 to 6.6% in 1987. Development expenditures by economic activities are given in the following table:

Table 2.11 Investment Expenditures

(Unit: YD Thousand)

	1985	1986	1987
Agriculture	14,000	11,300	14,900
Fishery	2,000	2,300	5,800
Industry	2,600	2,300	3,600
Mineral Survey	12,600	11,300	19,500
Power	23,500	33,100	27,100
Water Supply	6,500	4,900	7,600
Oil refinement	10,400	600	0
Construction	2,400	200	100
Trade/Hotel	4,600	1,400	1,800
Transport/Com	24,800	14,200	17,000
Social Service *1	28,700	21,200	17,500
Total	132,100	102,800	114,900

Note: *1) Sewerage sector investments are included.

Source: Ministry of Planning

2.4 Population and Land Use

2.4.1 National Census

The last population census was carried out in 1988, 15 years after the previous census in 1973. The results of the census are now being processed by the Central Statistical Organization, and is yet to be published. Preliminary results have been obtained regarding the Aden Governorate population. Population distribution in the four districts in 1988 was given by CSO in June 1989, before publication. These figures are shown in Table 2.12 below.

Table 2.12 Census Records

District	Population 1973	Population 1988	Annual Growth Rate (%)
Ma'alla	47,044	53,404	0.85
Tawahi	16,444	18,815	0.90
Crater	54,261	59,725	0.64
Khormaksar	14,768	19,658	1.93
Sub-total	132,517	151,602	0.90
Greater Aden	240,370	-	
Aden Governorate	291,376	418,755	2.4
PDRY Total	1,590,275	2,345,266	2.6

Total Aden Governorate population increased from 291,376 in 1973 to 418,755 in 1988. On the other hand, in the four districts, population increased from 132,517 in 1973 to 151,602 in 1988. Out of the total population increment over the 15 years, the four districts accounted for less than 15 %. Therefore, the ratio of the population of the four district to the total governorate population decreased from 45 % in 1973 to 36 % in 1988.

Annual growth rates of Aden Governorate and the whole country are 2.4 % and 2.6 % respectively, for the 15 year period from 1973 to 1988. On the other hand, annual growth rates for the same period in the four districts are in the range

from 0.64 % in Crater to 1.93 % in Khormaksar, and 0.90 % as a whole for the four districts. Population growth rates in the four districts are again far below the national average or the governorate average.

This is a reflection of the recent development trend in Greater Aden. As will be mentioned in the next section, the four districts were already developed prior to 1973, and recent developments have been concentrated in other districts.

2.4.2 Present Land Use

Present land use in the Greater Aden was investigated under the study carried out for DPS 2010. Detailed land use categories were developed and urban areas in 1980 were identified according to these categories. Land use pattern in 1980 and areas of each category are shown in Figure 2.4, and Table 2.13. Total area of Greater Aden is 49,088 ha, of which built-up areas account for 5,032 ha or 10.2 %. The rest of the land is occupied by mostly noninhabitable areas, such as sand dunes, mountains and water bodies. Agricultural area and various kinds of military facilities are included in the rest. Built-up areas are further classified into three categories, viz. residential, non-residential and under development areas. Component areas of residential and non-residential areas are shown in Table 2.14.

Since 1980, new developments have been occurring in several places in Greater Aden. Most of these are, however, located outside the four districts, as a result of which no significant changes have occurred in the four districts since 1980.

The four districts are already fully developed, and there is little land for further development. This is mainly because of the topographic condition of the districts. Three districts, viz. Ma'alla, Tawahi and Crater are surrounded by barren and ragged mountains. Steep hillsides around these districts are unlikely to be developed in the foreseeable future for housing, industrial and other such purposes, except for special facilities such as those for tourism and military purposes.

Khormaksar district lies on low and flat land, and the airport forms the physical boundary of the district. Although removal of the airport from the

present location and construction of new one outside the urbanized areas is recommended in the future in DPS 2010, this will happen beyond 2010. Expansion of Khormaksar district will be limited physically by the airport by that time.

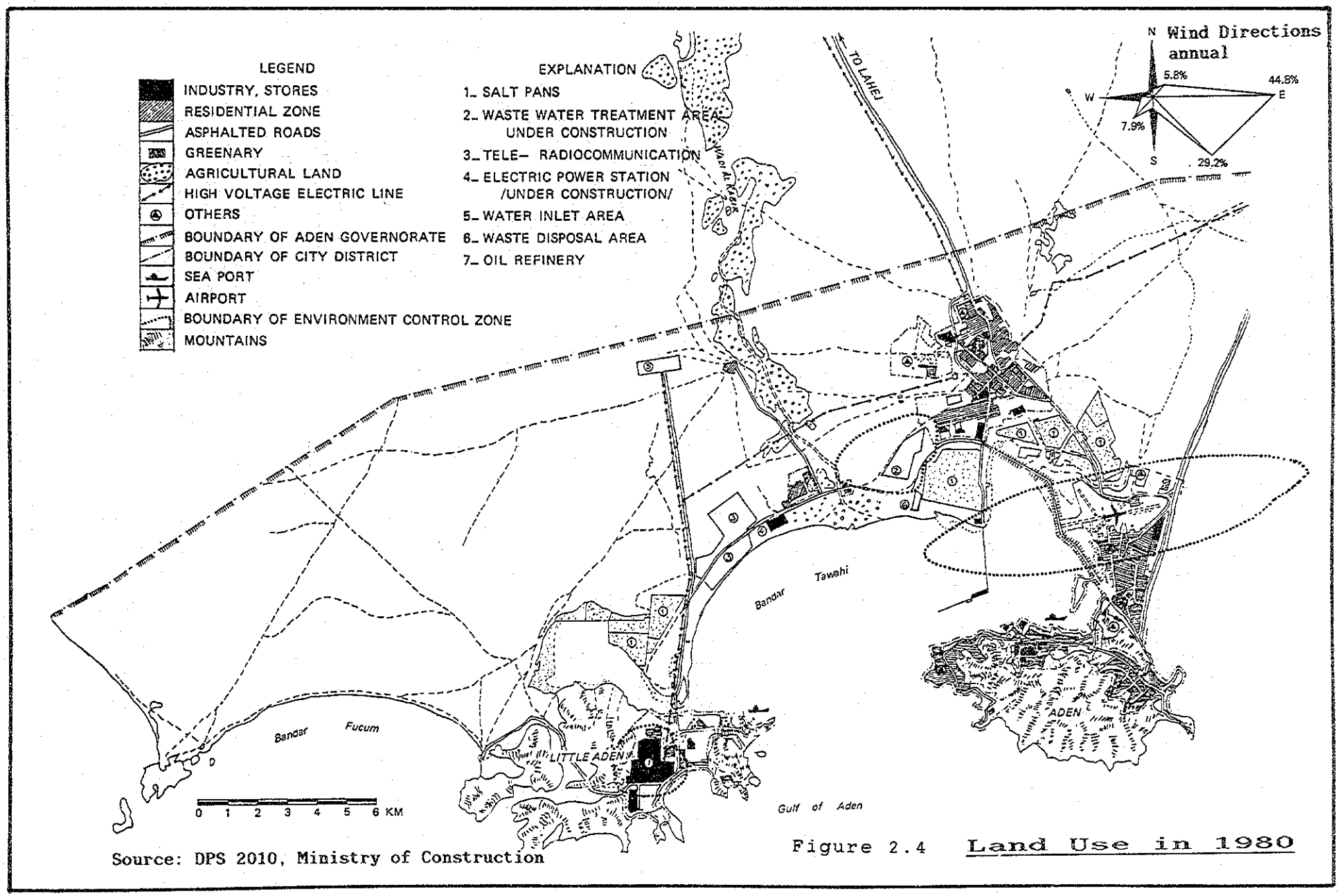
Land reclamation has been carried out along the sea coast in Ma'alla since the British era in the 1950s, and work are still continuing in some parts. Most of the reclaimed areas are earmarked as port area to be used for special purposes. Port facilities and factories related to them have been and will be constructed on reclaimed land.

The four districts are classified into residential, commercial and institutional areas. Almost all the government buildings of national and governorate levels are scattered in the four districts. There are also several sizable military facilities in Tawahi and Khormaksar districts. Port facilities and some industries related to port activity are located in Ma'alla and Tawahi. Some factories are located in the four districts, however, they are small in number and scale. There are no large industrial estates in the four districts.

Table 2.13 Land Use in Greater Aden

Category	Area (ha)	Percentage (%)
1. Built-up Area		
- Residential Zone	1,670	3.4
- Non-residential Zone	1,916	3.9
- Under Developed Zone	1,445	2.9
Sub-total	5,031	10.2
2. Unbuilt-up Area		
- Agricultural Zone	1,016	2.1
- Sand Dunes and Low Land	37,824	77.1
- Mountain Area	3,442	7.0
- Roads	111	0.2
- Military Area	340	0.7
- Waters	1,326	2.7
Sub-total	44,059	89.8
Total	49,090	100.0

Source: DPS 2010, Ministry of Construction



Source: DPS 2010, Ministry of Construction

Figure 2.4 Land Use in 1980

Table 2.14 Land Use Details in Built-up Area

Category	Area (ha)	Percentage (%)
1. Residential Zone		
- Housing	926.0	25.8
- Services and Sport	66.0	1.8
- Greenery	48.9	1.4
- Parking within Public Centers	4.6	0.1
- Streets and Squares	474.5	13.2
- Manufacturing, Stores and Engineering Works	150.0	4.2
Sub-total	1,670.0	46.5
2. Non-residential Zone		
- Industry	505.9	14.1
- Engineering Works	487.3	13.6
- Stores	21.3	0.6
- Services of Nationwide Importance	88.0	2.5
- Seaport and Airport	478.0	13.3
- Area of Special Use	213.0	5.9
- Cemeteries, Waste Disposal etc.	46.0	1.3
- Beaches	44.5	1.3
- Roads and Corridors of High Voltage Lines	30.0	0.8
- Garages (buses, lorries, taxi, cars)	2.0	0.1
Sub-total	1,916.0	53.5
Total	3,586.0	100.0

Source: DPS 2010, Ministry of Construction

2.5 Public Health Conditions

2.5.1 Medical and Health Services

The Ministry of Health is solely responsible for medical and health services in PDRY. There are 32 hospitals, 20 medical centers, 1 maternity center and 359 primary health care units in the whole country in 1987 administered by the ministry. A total of 3,955 beds in the medical establishments are available. Of the total, 1,580 beds or 40 % of the total are concentrated in the Aden Governorate. Thus, number of beds per population in the Aden Governorate is more than double the national average of 17.3 beds per ten thousand persons.

In 1987, a total of 707 physicians, 435 medical assistants and 2,928 nurses were working in the medical establishments mentioned above. The number of physicians and nurses has been increasing significantly in recent years, and is nearly three times the 272 physicians and 1,013 nurses in 1980. Construction of a new general hospital in Crater district has commenced recently, and it is expected to open to serve the public in a few years. It will help raise the level of medical services in Greater Aden.

The numbers of medical establishments, physicians and nurses in PDRY in 1980, 85, 86 and 87, and the distribution of the beds among the six governorates are shown in Tables 2.15 and 2.16 respectively.

Table 2.15 Number of Medical Establishments and Medical Personnel in PDRY

	1980	1985	1986	1987
1. Medical Establishment				
- Hospitals	27	32	32	32
Number of Beds	2,757	3,177	3,177	3,454
- Medical Centers	13	19	19	20
Number of Beds	333	441	441	471
- Maternity Centers	-	1	1	1
Number of Beds	30	30	30	30
Total Number of Beds	3,120	3,648	3,648	3,955
Number of Beds per Ten Thousand of Population	16	16	17	17.3
2. Medical Personnel				
- Physicians (total)	272	557	610	707
- Physicians (local, of total)	114	423	476	553
- Medical Assistants	435	478	644	NA
- Nurses	1,013	2,395	NA	2,928
Number of Physicians per Ten Thousand Population	1	3	3	3.1

Source: Statistical Year Book

Table 2.16 Number of Beds in Medical Establishments by Governorates (1987)

Aden	Lahej	Abyan	Shabwa	Hadramout	Mahra	Total
1,580	746	405	275	824	148	3,978

Source: Statistical Year Book

2.5.2 Incidence of Diseases

Inadequate piped water supply system and poor sanitary facilities are obviously one of the main causes of water borne diseases historically. Sewerage service ratio and the number of water borne diseases, such as cholera, shows good correlation. However, incidence of infectious diseases has been decreasing remarkably in recent years in most developing countries regardless of the level of sewerage service. This tendency is mainly due to the spread of medical services. Low incidence of water borne diseases are hence not necessarily an indication of a high level of sewerage service.

The reported number of water borne infectious diseases in Greater Aden are shown in Table 2.17 below. As shown in the table, incidence of these diseases has been still at a high level, suggesting unsatisfactory sanitary conditions in the Municipality.

Table 2.17 Reported Number of Water Borne Infectious Diseases

Disease	1980	1985	1986	1987	Ratio per 1,000 habitant 1987 *
Dysentary	71,995	115,567	132,016	160,982	479
Poliomyelitis	6	32	11	26	-
Typhoid and Paratyphoid	63	33	145	528	2
Infectious Hepatitis	15,682	5,681	5,806	8,244	25
Enteritis and Other Diarrhoeal Diseases	1,579	-	-	7,814	23
Bilharzia	2,903	4,615	3,867	4,458	13

Source: Statistical Year Book

* Greater Aden population is estimated at 336,000 in 1987

2.6 Aden Port and Tawahi Bay

2.6.1 Aden Port

The history of the Aden Port dates back to ancient times. It has been playing a vital role as a trading port in the region because of its geographical location. The importance of the Aden Port increased when the era of great navigation started in the 15th century. The role of the port changed gradually as navigation method itself changed. After the fuel of ships changed from coal to petroleum in this century, bunkering of oil became one of the major activities of the port in addition to the historical role of trade.

There are two harbors in Aden, the Inner Harbor in the vicinity of Ma'alla and Tawahi districts and the Little Aden Harbor at the western end of the Tawahi Bay. The Little Aden Harbor was constructed in the 1950s as a port for petroleum shipment to and from the Little Aden Refinery originally erected by British Petroleum. The Little Aden harbor hence serves exclusively for petroleum. On the other hand, the Inner Harbor has broader port functions, such as international and domestic trade, fishery and bunkering. There is also a navy base in the Inner Habor.

Improvements of the Inner Harbor both in the sea and on the land have been started as early as in the 1950s and are still under way at present. Dredging of channels and reclamation of land by dredged materials are being carried out in the vicinity of Ma'alla district. Construction of wharves, on which new port facilities mainly for handling of cargoes will be located, is almost complete on reclaimed land. The appearance of this area will change significantly in the near future. On the other hand, port areas in Tawahi are divided into several small areas specified for particular uses, such as fishery, tourist and military uses. There are no such large scale land reclamation as that in Ma'alla.

2.6.2 Tide Level

Tide levels at Steamer Point in 1988 and 1989 are shown in Table 2.18. Monthly high and low, and mean high and low tide levels in the tide table are presented in the table. Highest levels are +2.2 to +2.5 m (datum is 1.34 m below mean sea level), and lowest levels are -0.2 to +0.3 m, thus having maximum difference of

levels of approximately 2.5 m. Monthly mean high levels are in a range from +1.8 to +2.0 m, and mean low levels +0.6 to +1.0 m.

2.6.3 Tawahi Bay

The inner part of the Tawahi Bay is surrounded by vast sandy coast. The depth of the coastal waters in this part is very shallow and vast muddy lands appear at low tide. There were several huge salt pans in the coastal area previously. However, most of the salt pans are not in use since a new salt plant was put into operation in Al Mansura. Utilization of the coastal area for other purposes than salt production is very limited at present. One exception is a coupled power station and desalination plant in Hiswa. Three units of thermal power generators are in operation and installment of the other two units are under way at present. The desalination plant, designed to utilize steam from the power station, is expected to start in 1990. Fresh water produced by the desalination plant will be mixed with groundwater for the water supply system.

No recreational areas exist in the coastal area of the Tawahi Bay. They are located just outside the bay, beyond the two tips of Aden Peninsula at the eastern end and Little Aden Peninsular at western end. Small bays, such as the Gold Mohur Bay and the Conquest Bay in the east and the Ghadir Bay in the west, are utilized for many recreational purposes including picnicking, sea bathing, fishing and diving. The inner coastal area of the Tawahi Bay will unlikely be used for this purpose in the future.

Table 2.18 Tide Levels at Steamer Point

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1988												
Highest												
Day	19	19	19	16	14	1	1	30	27	25	22	19
Time	0646	2137	2048	1928	1807	1915	2009	0933	0813	0652	0533	0330
Level	2.33	2.49	2.53	2.52	2.43	2.29	2.18	2.23	2.30	2.36	2.37	2.28
Lowest												
Day	19	16	16	18	16	30	29	27	28	26	23	22
Time	1401	1303	1237	0256	0156	0154	0141	0116	1535	1430	1331	1322
Level	-0.15	0.02	0.02	0.16	0.07	-0.12	-0.18	-0.05	-0.01	-0.15	-0.14	-0.03
Mean High												
Level	2.01	2.03	2.04	2.02	1.99	1.92	1.87	1.82	1.80	1.81	1.88	1.92
Mean Low												
Level	0.84	0.84	0.85	0.94	0.95	0.88	0.73	0.63	0.66	0.77	0.85	0.90
1989												
Highest												
Day	12	9	9	6	4	1	1	20	17	15	12	11
Time	2337	2220	2103	1946	1824	1703	1728	0946	0828	0707	0548	0515
Level	2.34	2.48	2.56	2.59	2.55	2.43	2.17	2.19	2.26	2.36	2.42	2.39
Lowest												
Day	8	6	6	8	6	4	2	17	18	16	13	12
Time	1415	1356	1250	0315	0211	0156	0103	0133	1548	1443	1341	1331
Level	-0.05	0.04	0.26	0.10	-0.04	-0.09	-0.06	-0.01	0.02	-0.19	-0.25	-0.21
Mean High												
Level	2.04	2.04	2.04	2.02	2.00	1.93	1.86	1.81	1.78	1.83	1.89	1.97
Mean Low												
Level	0.88	0.83	0.86	0.94	0.92	0.88	0.74	0.65	0.67	0.73	0.84	0.86

Source: Tide Table, Proudman Oceanographic Laboratory

Note: Time; The first two digits indicate hour and the last two indicate minute.

Levels are in meter, datum is 1.34 m below mean sea level.

2.7 Existing Organization

2.7.1 National Level

The highest political power in PDRY rests with the People's Supreme Council which is led and guided by the Yemen Socialist Party. The Council approves the general fundamentals for the function of the Presidium, the Council of Ministers and the other state organs and takes the necessary decisions in this matter. The Council of Ministers is the highest administrative and executive organ of state power. Organization of the government is shown in Figure 2.5.

General Directorate for Local Government (GDLG), which is one of the member-bodies of the Council of Ministers under direct control of the Prime Minister's office, is responsible for sewerage projects in PDRY at the national level. GDLG had formerly been called the Ministry of Local Government until its name was changed three years ago, but the Ministry's role and responsibility were taken over by GDLG in total. There are five departments in GDLG, organization of which is shown in Figure 2.6. Roles and responsibilities of each department are as follows.

Municipality Dept.	Sewerage works Cleansing Public Health
Planning and Development Dept.	Counterpart department to the Ministry of Planning Rural development
Finance Dept.	Financial adjustment of local governments
Establishment Dept.	Counterpart department to the Ministry of Labor and Civil Service Adjustment of manpower
Local Council Dept.	Preparation of concerned laws, regulations and ordinances Attendance at the meetings of People's Local Councils

Sewerage and public health projects are under the responsibility of the Municipal Department. Responsibilities of the department regarding sewerage projects are as follows.

(1) Preparation of the sewerage project development plan for the national five year plan and for the annual investment plan.

(2) Preparation of detailed designs, tender documents and provision of supervision for project implementation financed by foreign countries or international agencies.

(3) Arrangement of domestic finance for improvement of sewerage works and provision of supervision for project implementation.

(4) Preparation of laws and regulations related to sewerage works.

(5) Improvement of manpower and provision of training.

Figure 2.5 Organization of PDRY Government

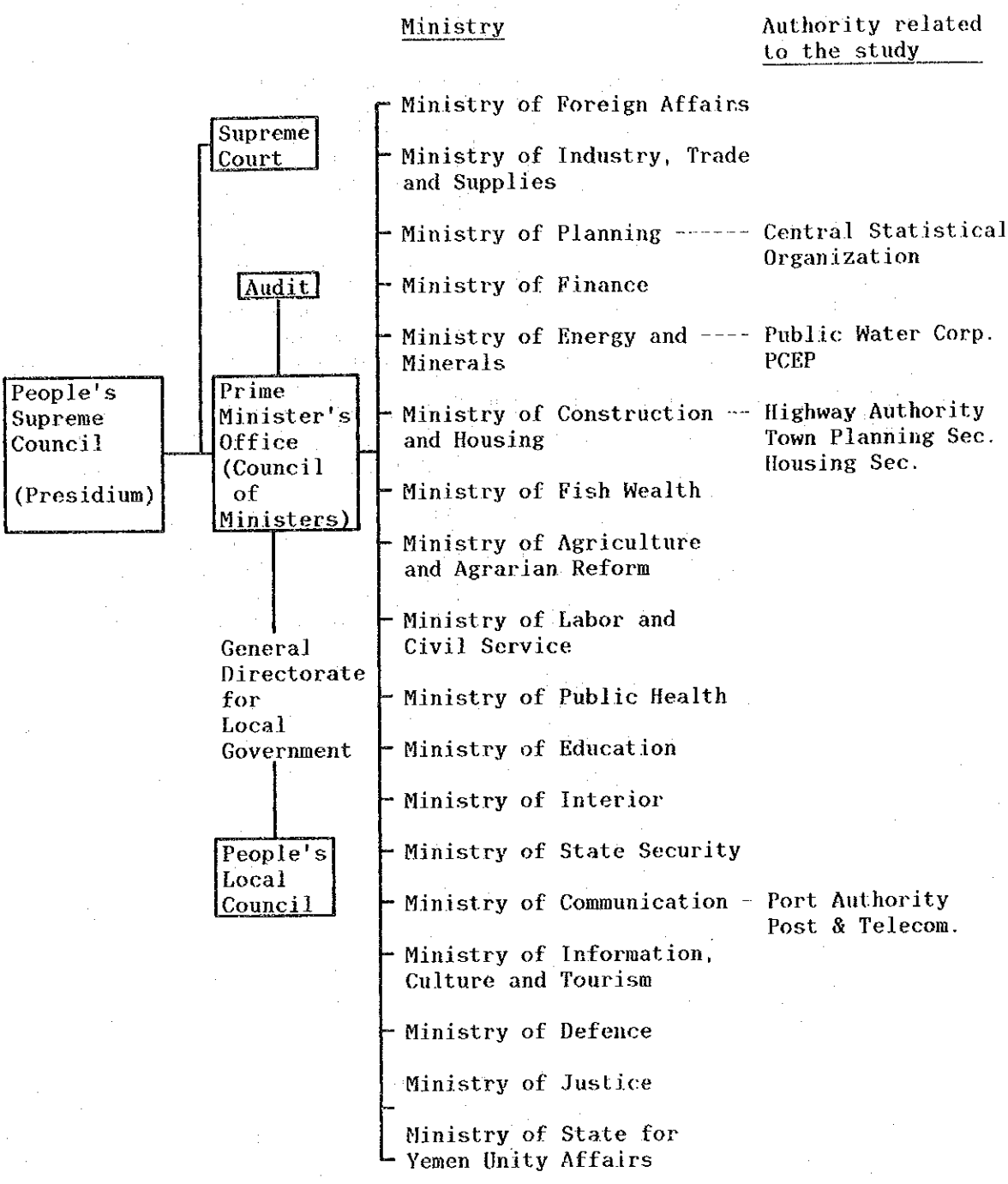
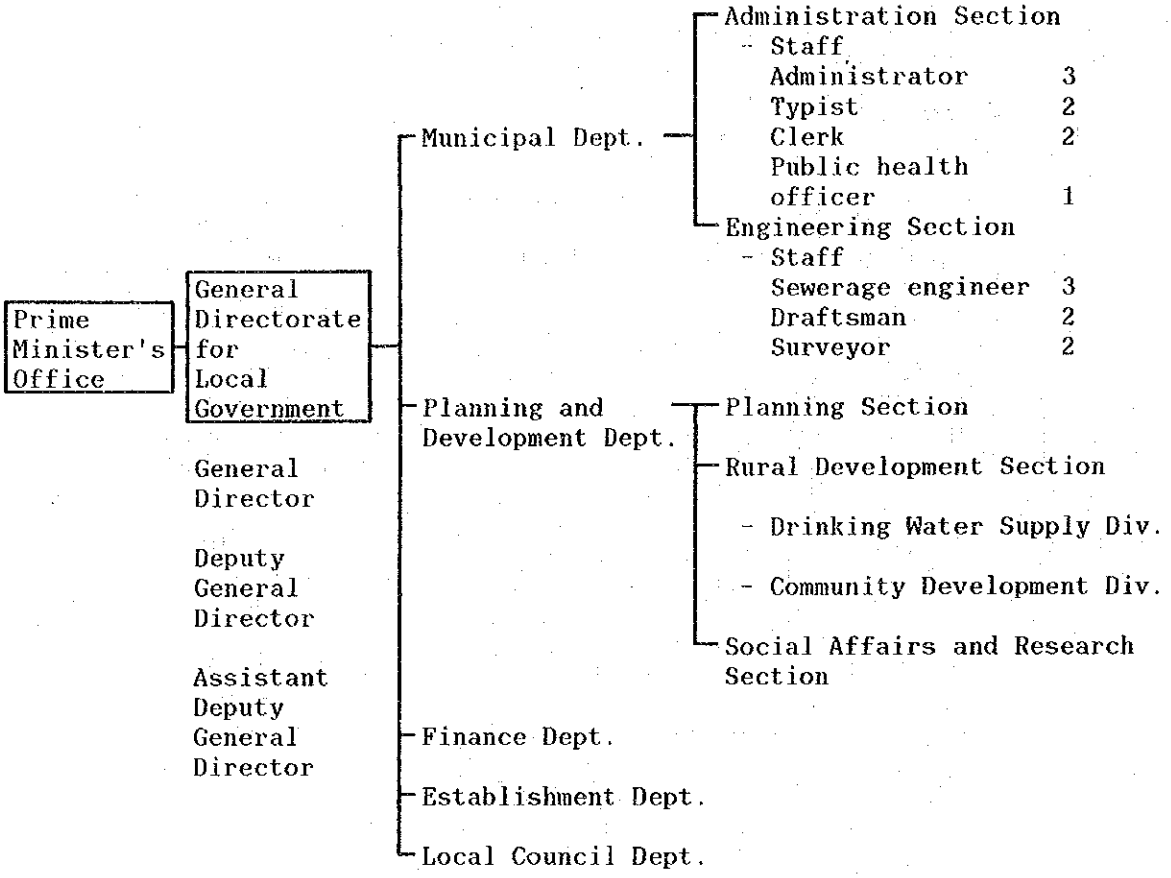


Figure 2.6 Organization of General Directorate for Local Government



2.7.2 Local Level

There are six governorates in PDRY. They are Aden, Lahej, Abyan, Shabwa, Hadramout and Al Mahra. In each governorate, a People's Local Council (PLC) is established. PLC administrates local affairs through its execution office, i.e. governorate office. Administratively, governorates are divided into districts, and districts are further divided into centers. The Aden Governorate consists of four districts and eight centers. Geographically, Aden Governorate is composed of Greater Aden on the mainland and Socotora Island. Three districts of Al Shaab, Al Meena and Seera form Greater Aden, and the fourth district is on Scotora Island. Al Meena District consists of Ma'alla and Tawahi Centers, and Seera District consists of Crater and Khormaksar Centers.

The Aden Capital Municipality is one of the three organizations under executive office of PLC and administers the Greater Aden area. Operation and maintenance of the sewerage system is under the responsibility of the Environmental Health Department of the Aden Capital Municipality. There are three sections in the Environmental Health Department, viz. Drainage and Pump, Public Health and Cleansing Sections. The Drainage and Pump Section operates and maintains the sewerage system through its three district offices. The organization of the Aden Capital Municipality is shown in Figure 2.7.

The sewerage system in Aden has long history, dating back to the 1940s. Experience has been accumulated in operation and maintenance of the sewerage system since then. At present, Aden's sewerage system is the most advanced system in PDRY and Aden is the only city that has a sewage treatment plant. The management system is a well organized one and the sewerage facilities are well maintained in spite of a severe shortage of qualified staff and spare parts.

The responsibilities of the Section are classified as follows.

(1) Operation and maintenance of pumping stations and treatment plant, and improvement of faulty equipment.

(2) Inspection and improvement of sewers, outfalls, manholes and septic tanks.

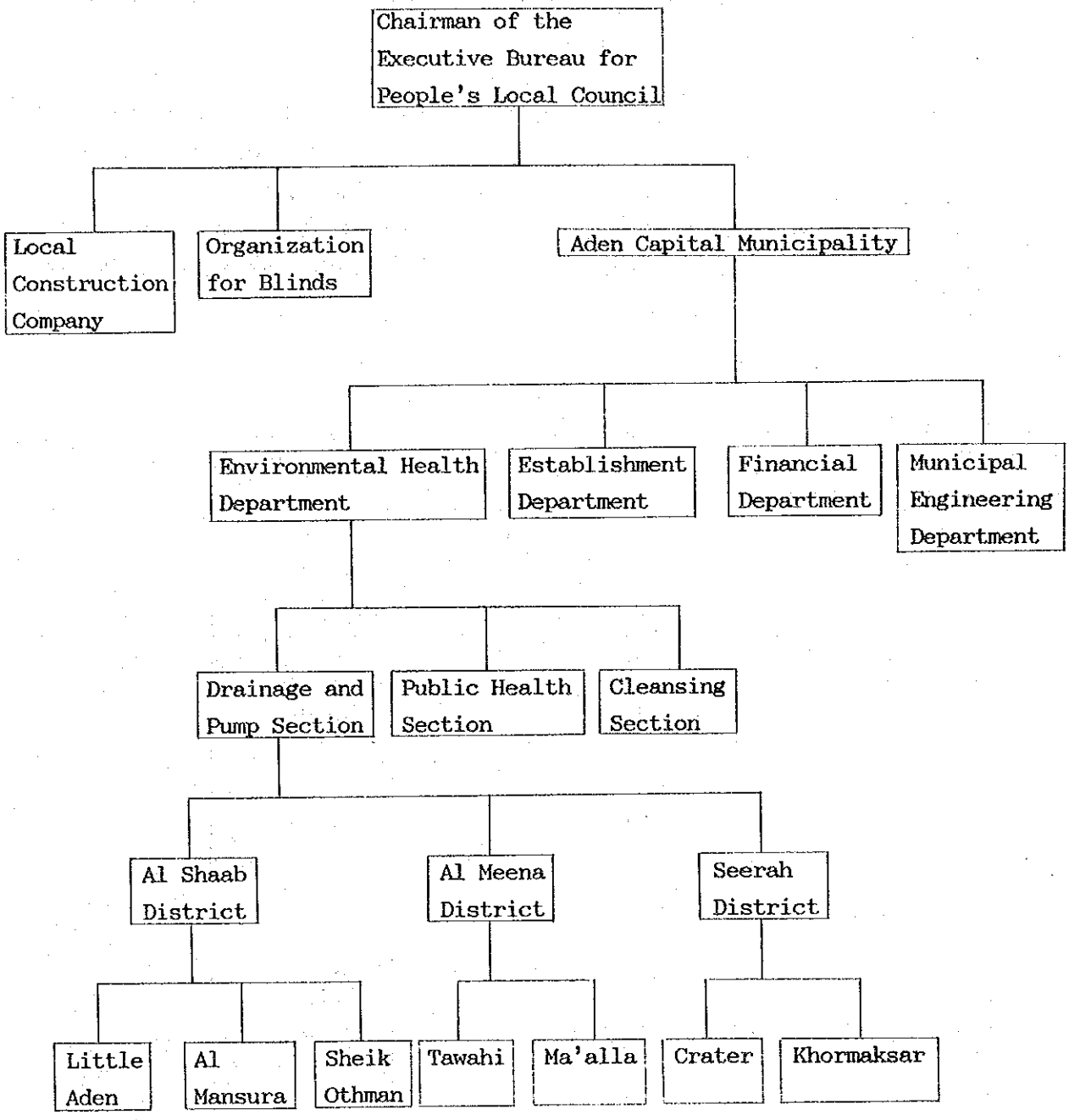
(3) Replacement of sweeper passages by underground sewers.

(4) Construction of new sewers in unsewered areas.

(5) Maintenance of technical drawings and reports.

The Environmental Health Department suffers from a constant budget deficit in carrying out its full responsibilities mentioned above. Insufficient number of qualified engineers and skilled laborers prevent the Department from maintaining a satisfactory level of service to the users.

Figure 2.7 Organization of the Aden Governorate Office



2.7.3 Existing Staff in Aden Municipality

The existing staff level in the Environmental Health Department by classified sections and job classification are shown in Table 2.19. Breakdown of Pump and Drainage Section staff by districts is shown in Table 2.20. Characteristics of the staff are shown in Table 2.21.

Although the present staff levels in the Pump and Drainage Section is less than the budgeted number as a whole, this section is staffed with fairly adequately. In particular, engineers, technicians, skilled and semi-skilled laborers are available in sufficient number. Therefore, the present staffing levels of the Pump and Drainage Section can be considered to be a reasonable basis for the estimation of future requirements.

Table 2.19 Existing Staff Levels in Environmental Health Department

Section	Drainage and Pump		Public Health		Cleansing		Total	
	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual
Professional Engineers	6	5	-	-	-	-	6	5
Assistant Engineers	2	2	-	-	-	11	2	13
Chief Superintendents	-	-	-	2	-	-	0	2
Supervisors	20	29	4	6	2	23	26	58
Technicians	-	-	4	22	83	-	87	22
Skilled Craftmen	22	26	4	-	8	-	34	26
Semi-skilled Operators and Craftmen's Mates	30	38	80	-	68	-	178	38
Drivers	20	17	-	4	632	5	652	26
Technical Clerk	3	-	-	-	-	-	3	-
Lobourers	264	173	-	19	-	30	264	222
Watchmen	10	-	-	-	-	-	10	0
Total	377	290	92	53	793	69	1,262	412

Table 2.20 Existing Staff in Drainage and Pump Section by Districts

District	Al-Shaab	Al-Meena	Seera	Total
Professional Engineers	1	2	2	5
Assistant Engineers	2	-	-	2
Supervisors	12	7	10	29
Skilled Craftmen	13	3	10	26
Semi-Skilled Operators and Craftmen's Mates	10	13	15	38
Drivers	8	2	7	17
Labourers and Watchmen	52	48	73	173
Total	98	75	117	290
Centers	Little Aden, Al-Mansura, Sheik Othman	Tawahi Ma'alla	Crater Khormaksar	
Sewerage Service Area (ha)	—	291	495	
Length of Sewer (m)	—	26,768	24,592	
Number of Pump Station	—	10	19	

Table 2.21 Characteristics of Present Staff in Drainage and Pump Section

	Total Number	Average age	Length of Service (year)	Average Salary (YD/mon.)	Qualifications
Professional Engineers	5	35	5-20	100	University
Assistant Engineers	2	40	28	110	
Supervisors	29	37	20	90	Intermediate School
Skilled Craftmen	26				
Masons	10	40	15	90	
Electricians	7	30	15	90	
Machinists	4	30	15	90	
Carpenters/Timbermen	5	30	20	80	
Semi-Skilled Operators and Craftmen's Mates P/S Operators	38	38	20	90	Secondary School
Drivers	17	35	20	80	Intermediate School
Labourers & Watchmen	173	30	25	90	
Total	290	30-40	5-28	80-110	

2.8 Laws and Ordinances

2.8.1 Laws

The Constitution of PDRY was proclaimed on 30th November, 1970. The last amended Constitution has been approved by the People's Supreme Council during its session held on 31st October, 1978.

In reference to economic activities, the Constitution stipulates the following.

> The State shall lay the comprehensive plans for the development of the national economy, the rational investment of all the resources,.....(Article 12)
>
> The State shall also own the principal means of production in industry and agriculture. It shall further own and undertake, by itself, the services of the ports, banks, insurance, post, telecommunications and all the other basic services necessary for the development of the society.....(Article 14)
>
> The democratic centralization is the principle of the administration of the national economy in the People's Democratic Republic of Yemen. Such means the combination of the State's central leadership of the economic activity and the creative initiatives of the organs of the state's local authorities, the productive establishments, the mass organizations and all the workers. (Article 21)
>
> The organs of the central state authority shall work for supporting the People's Local Councils, developing their functions and extending their powers by means of the continuous transfer of their rights and duties to the organs of the state local authority in accordance with the development of the political, economical and social relations.

From these Articles, it is clear that the central state authority has to prepare the five year national economic development plan, and that the state shall undertake sewerage service as one of the basic services for the development of the society. For execution of the service, the Constitution requires the cooperation between central and local authorities.

The Law No.17, 1977 (The Local Administration Law) was enacted on 2nd June, 1977 in accordance with the Constitution.

The Law requires the People's Local Council and their executive bureaus to take measures to protect citizens' health and to fight against diseases. According to the Law, sanitary services inclusive of sewerage shall be undertaken by the People's Local Council and their executive bureaus. At present, planning, design and construction of sewerage systems are undertaken by GDLG, and maintenance and operation are undertaken by the People's Local Council established in the provinces, districts and centers.

Responsibilities to be assumed by the People's Local Councils are as follows.

(1) Management and development of health affairs in accordance with the programs approved by the government and taking the steps leading to up-keep of the health of citizens and their ability to work and produce and especially the campaign against illness and diseases and encourage abiding by health conditions and establishment of care institutions and organizations of their functions.

(2) Supervision and control of works of administrative departments attached to it, to improve and develop them and those departments under them.

(3) Discussion of their annual budget submitted by lower Councils to higher Councils which in turn submit it to the concerned bodies in the central authority.

(4) Submission of proposals to ministries relating to the appointment or transfer of posts for the purpose of carrying out tasks assigned to them.

As a result, this law does not stipulate construction of a sewerage system, but only general sanitary affairs.

2.8.2 Sewerage and Drainage Works Ordinance of Aden Municipality, 1955

This Ordinance was enacted before the independence and is still effective at present. The Ordinance stipulates the following.

(1) All public sewers and drains and sewage disposal works within any municipality shall be vested in the Council of the Municipality for the purpose of this Ordinance.

(2) A Council may cause to be erected, constructed, equipped and carried on sewerage or drainage works within or without the municipality.

(3) For the purpose of carrying out any drainage or sewerage works, a Council may-

a. cause such sewers, drains and pipes to be made, laid, altered, deepened, covered and maintained, either within or without the Municipality as may be necessary for effectively disposing of the sewage or drainage of the Municipality or any portion thereof from time to time cause to be made and maintained all such reservoirs, sluices, engines, ventilation shafts and other works as may be necessary for cleansing and ventilating such sewers, drains and pipes;

b. carry such sewers, drains, or pipes through, across or under any public road, street, square or open space, or any place laid out as, or intended for a public road, street, square or open space either within or without the Municipality, without paying compensation, and, after giving reasonable notice in writing to the owner or occupier of the intention to do so, perform the same in respect of private lands within or without the Municipality, upon making compensation for any damage done, the amount whereof shall be determined, in default of agreement, by arbitration;

c. from time to time alter, enlarge, divert, discontinue, close up or destroy any sewers, drains or pipes under the control of the Council;

d. construct any works within or without the Municipality for the purpose of receiving, storing, disinfecting, purifying or otherwise disposing of any sewage or drainage;

e. in any case where, owing to the contour of the ground, or for other reasons, it is difficult to connect for sewerage purposes any premises within the Municipality direct with a public sewer maintained by the Council, the Council may subject to the provisions of paragraph b. of this section, make connections with and utilize any private drain or private ground so as to connect such premises with any public sewer:

Provided that upon such connection being made the said drain with which connection is so made shall, from the point of such connection to the point of junction with the public sewer, be considered and used as a combined or joint drain, and the cost of connection, repair and maintenance of such combined or joint drain shall, as far as the same shall not fall to be borne by the Council, be paid and borne by the owners of the premises respectively served thereby, in such proportion as the Council shall from time to time adjust and settle.

(4) A Council, its officers and servants shall, at all times, have right to access to private property for the inspection, maintenance, alteration or repair of all sewers, drains, pipes, shafts or other conveniences which are under the control of the Council, and may do all things necessary to uncover and expose all sewers, drains, pipes, shafts or other conveniences for the purpose of inspection, alteration or repair:

Provided that the Council shall repair all damage caused by the exercise of the powers conferred by this section.

(5) A Council may establish, maintain and carry on any such sewerage farm or sewage disposal works either within or without the Municipality as may be necessary or advisable for the requirements of the Municipality, and may farm the same and dispose of the produce thereof; and neither the Council nor any person shall be liable for any damage or nuisance which is caused by the proper and ordinary conduct of any sewage farm or sewage disposal works established, maintained or carried on under the

provisions of this Ordinance.

(6) A Council shall, by notification published in the Gazette or in such other manner as the Council may by resolution direct, give at least thirty days' notice of its intention to commence work on the construction or extension of any sewer outside the Municipality and any owner, lessee or occupier or any person affected by the intended work may object to such work by written notice served on the Municipal Secretary within the said period of thirty days, and such work shall thereupon not be commenced without the consent of the Governor unless the objection is withdrawn. In the event of an objection not being withdrawn, the Governor shall appoint such number of persons as he considers necessary to inquire into the propriety of the intended work and the objections thereto.

(7) Any person who, without the prior consent in writing of a Council shall-

a. erect or cause to be erected any building or other structure over any sewer, drain, or pipe vested in or constructed under the authority of the Council; or

b. excavate open up or remove, or cause to be excavated, opened up or removed, the ground under or near to any such sewer, drain or pipe; or

c. make or cause to be made any opening into any such sewer, drain or pipe for the purpose of discharging sewage or drainage into the same or otherwise; or

d. injure or destroy, or cause to be injured or destroyed any such sewer, drain or pipe, or any works or things in connection with,

shall be guilty of an affiance and shall be liable on conviction to a fine not exceeding one thousand shillings or to imprisonment for a period not exceeding six months or to both such fine and imprisonment.

A Council may alter, demolish or otherwise deal with any building or

structure so erected as it may think fit, or may make good any such damage, or may close up any such opening, and the expenses so incurred shall be recoverable from the offender.

(8) A Council may make by-laws prescribing the sums to be charged for the use of the Council's drains, sewers or sewerage works, and these charges shall for all purposes be deemed to be charged for sanitary services, and shall be recoverable from the owner of any land or premises which are connected with such drains, sewers or sewerage works.

(9) A Council may-

a. carry out any work in connection with the installation or improvement of a drainage or sewerage system on any land or premises, after giving reasonable notice to the occupier thereof and may connect any such system with the Council's drains or sewers, and may recover from the owner of such land or premises the expenses incurred in such work, including a reasonable charge for supervision, and if the work is undertaken without the interposition of a contractor, for the use of tools and plant; or

b. advance to the owner of any land or premises the amount of any expenses incurred or to be incurred by him in the execution of any such drainage or sewerage work on such land or premises.

The Council may agree to accept payment of such expenses and repayment of such advances in such installments, at such times, upon such conditions as the Council may determine.

Such expenses and advances, together with the interest thereon, shall be a charge upon the land or premises in respect of which the same are incurred or made, and shall be paid to the Council by the owner thereof for the time being, and the installments thereof as they fall due shall be recoverable from the present or future owner of the land or premises in any competent Court.

The Council shall keep at the Municipal Office a register of all expenses incurred and advances made under the total amounts thereof, the

installments in which the same are payable, the land or premises in respect of which the same have been incurred or made, and the balances for the time being outstanding; and shall keep such register open at all reasonable times for inspection by any person, free of charge. Such register, and any extract therefrom, certified by the Municipal Secretary or by any other person authorized by the Council shall, in any proceedings for the recovery of such expenses, advances or interest thereon, or any installments thereof, be prima facie evidence of the matters contained therein.

Nothing in this section shall limit or affect the power of the Council to execute any work which the Council is by law, or by any by-law in force in the Municipality, empowered to execute or to recover the cost of executing such work from any person who is liable thereof.

The fact that the British Army had to complete the modern sewerage system in Aden during their colonial rule was reflected in the character of this Ordinance. However, the contents of this Ordinance cover all the necessary regulations to execute all sewerage works. Collection of sewerage service charge is prescribed in the Ordinance. However, collection was stopped since independence in 1969.

At present, there is a wide recognition among the authorities concerned to enact a new sewerage law and to review the Ordinance. Resolution 59/81 of the Council of Ministers directed PLC to establish a water and sewerage department in its governorate office. However, this resolution has not fully been realized until now mainly due to the following two reasons. There are considerable differences between service levels of water supply and sewerage. The other reason is the considerable difference in the service levels of the sewerage system in governorates or major cities. Aden had been the only one city that was provided with modern sewerage system until Mukalla sewerage system was completed in 1988. The other major cities in PDRY have yet to be provided with modern sewerage systems.

A draft of new sewerage act was prepared in 1982, and discussion has been continued until now. It is proposed in the draft that local governments be made responsible for construction, operation and maintenance of sewerage systems. Collection of sewerage charge is also to be considered. On the other hand, a

socio-economic study for the improvement of the institutional and legal arrangement is currently under way by GDLG, with Arab Social and Economic Development Fund financing.

2.9 Water Supply System

2.9.1 General

The water supply system in Greater Aden has a long history, and is well developed. Water supply systems developed individually in the past have been combined and linked to each other, and now form an integrated Greater Aden water supply system. At present, almost all the residents in the Greater Aden are supplied with piped water. Water supply facilities are well maintained by Public Water Corporation (PWC).

The source of the water in Aden is limited to groundwater which is taken from aquifer of wadis. Scarcity and limitation of available groundwater resources is the most serious problem for water supply in the future, since groundwater is the sole sources of water for all use in the region.

Domestic use including community use accounts for a dominant portion of water consumption. Industrial water consumption follows domestic consumption, since there are some large scale industries such as Aden Refinery. Supply to ships and to port facilities is an unique water consumption in the Aden water supply system. Water tariff has long been established, and water charges categorized by consumers have been collected satisfactorily.

A water Supply Mater Plan was prepared by a French consulting firm in 1979 based on long term projections of water demands. Development of physical systems, particularly, development of new well fields and installation of transmission mains, has been implemented in line with recommendation by the Master Plan under World Bank financing.

The master plan was revised before the implementation of the Stage 2 Project in 1986 by a British consultant. Target year of the long term program was extended by 10 years to 2010, and water demands were reviewed taking into account the planning fundamentals recommended by DPS 2010, resulting in higher projections than those by the previous Master Plan. Stage 2 Project up to 1995 was modified in accordance with the revised projections. Use of distilled water from the Hiswa Desalination Complex, which is expected to be commissioned by the end of 1989, was included in addition to development of new well fields. At present, PWC is implementing various development projects in the line with

recommendations made by the revised Master Plan with financing from various international and local sources.

2.9.2 Physical Systems

There were three well fields in Greater Aden Sheik Othman, Bir Ahmed and Bir Nasir all of which are located in Wadi Tuban. However, Wadi Tuban Aquifer is totally overexpoited by water supply and irrigation, resulting in high salinity of Sheik Othman well water. Thus Sheik Othman well field was closed in 1984. In order to resolve this problem and to meet growing demand, a new well field in Wadi Bana has recently been developed at some 50 km distance northeast of Aden. At present, Greater Aden is supplied by two aquifers, Wadi Tuban and Wadi Bana. Water sent from the new well field in Wadi Bana is transferred to Bir Nasir and then supplied to Aden.

In addition, a new well field to be developed in Upper Tuban, which was proposed in the revised Master Plan, will also send its water to Bir Nasir. Bir Nasir will play a role of a transmission center of water from remote well fields to Aden and of main well fields as well. Hiswa Desalination Complex will be a new source of water in the near future. When the desalination plant becomes operational, Bir Ahmed will change its present function to being supplier of groundwater for blending with distilled water from the desalination plant.

There are three main water works in Aden, viz. Sheik Othman, Isthmus and Little Aden, which receive water from well fields and distribute to their service areas. Location of these water works, transmission mains and distribution mains are illustrated in Figure 2.8.

All the four districts in the study area are supplied from Isthmus water works consisting of pumping stations and storage tanks. Distribution systems from Isthmus to the four districts are as follows.

(1) Crater

Crater district is fed from the Main Pass masonry reservoir built in the 1930s on the site of an old fort at elevation +97 m. The reservoir is separated into two compartments, one of 5,400 m^3 capacity serving Crater

and the other of 6,700 m^3 capacity serving Ma'alla and Tawahi.

The Crater network is fed by a single 12" asbestos cement pipe. A 12" pipe links Crater network to Khormaksar network, which can be used for emergency supplies to either network.

A small booster pumping station at the southern end of the district, at Ras Marshag serves consumers in a small area.

(2) Ma'alla

The Ma'alla network is supplied from the Main Pass reservoir through a 12" cast iron pipe which forms the trunk main of the network. The network is generally in good condition except in the reclaimed area along the sea, where corrosion of metal parts occur. A 4,500 m^3 balancing tank known as Ma'alla Class C tank was added in 1964.

(3) Tawahi and Steamer Point

Tawahi and Steamer Point, as far as Gold Mohur beach, are supplied from Main Pass reservoir through a 16" spun iron pipe which traverses the full length of Ma'alla district. Where it leaves Ma'alla, the 16" diameter is reduced to 12". This 12" pipe runs along the coast as far as Steamer Point. It supplies Tawahi and low-lying areas in Steamer Point, and an old 900 m^3 masonry tank at elevation +17 m. This tank then supplies the Rock House booster pumping station, which in turn supplies high-lying areas of Steamer Point.

(4) Khormaksar

Khormaksar network is supplied from the Isthmus through a 16" pipe linked directly to the network. Jebel Hadid tanks, which act as compensating tanks, are located at the end of a 12" pipe. They consist of two identical reservoirs made of steel panels built in 1964 on the site of the former fort. Each has a capacity of 2,250 m^3 at an elevation +75 m. The network consists essentially of class 20 asbestos cement pipes. Two 12" pipes provide emergency links, one with Ma'alla, the other with Crater.

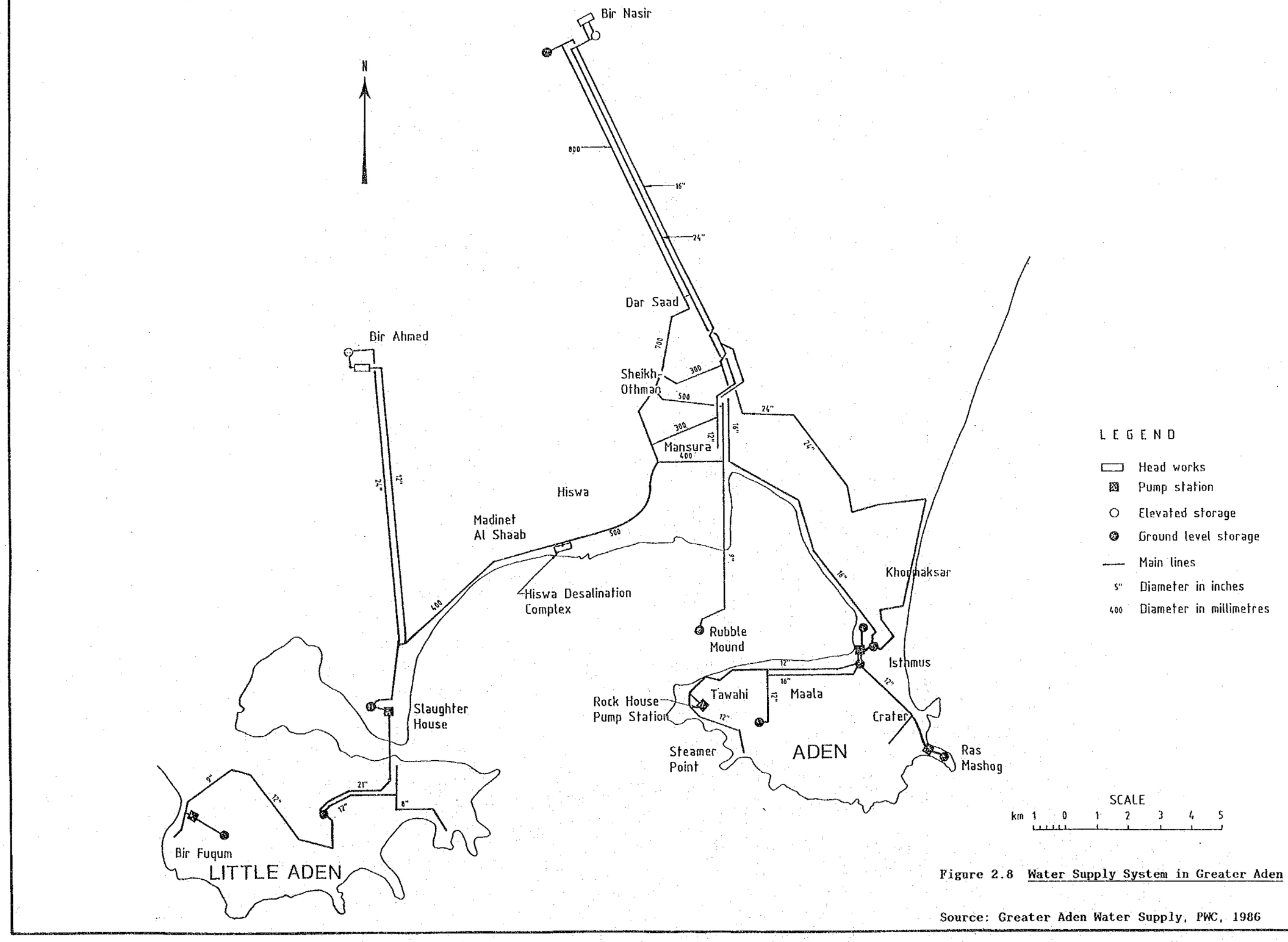


Figure 2.8 Water Supply System in Greater Aden

Source: Greater Aden Water Supply, PWC, 1986

2.9.3 Water Consumption

Water consumption in Greater Aden in 1978 and 1984 were investigated when the Water Supply Master Plan and the revised Master Plan were prepared, respectively. Total consumption in Greater Aden increased from 34,450 m^3/d in 1978 to 45,510m^3/d in 1984 (both on daily average basis), by 32 % or 4.7 % per annum as shown in Table 2.22. Annual increase rate was higher than the population growth rate for the same period, implying that the per capita water consumption increased during these 6 years.

Table 2.22 shows water consumption by user categories. Dominant water consumption is domestic use, which accounts for 54.7 % in 1978, and 50.5 % in 1984, and when it is combined with community and public organization consumption, it reaches 64.1 % and 70.9 % respectively. The second largest consumer is military, although its water usage did not show any increase for the period. Commercial and industrial consumption accounts for a rather small percentage, 15.5 % and 13.0 % in 1978 and 1984, respectively, of the total water consumption. Water consumption by port activity is a unique water usage in Aden, which includes supply to ships.

Table 2.23 shows water consumption in 1984 by districts. Of the four districts, Ma'alla and Crater districts are considered as residential areas and most of the water consumption is for domestic use. On the other hand, consumption by public organization is the largest and that by military is substantial in Tawahi. In Khormaksar, consumption by military and public organization accounts for more than half the water consumption. Water consumption by category reflects characteristics and present land use pattern of the four districts.

Table 2.22 Water Consumption in Greater Aden in 1978 and 1984

Category	1978 (m^3/d)	1978 (%)	1984 (m^3/d)	1984 (%)	1984/1978
Domestic	18,840	54.7	23,000	50.5	1.22
Community	3,240	9.4	3,380	7.4	1.04
Public Organization	NA	-	5,900	13.0	-
Sub-total	22,080	64.1	32,280	70.9	1.46
Commercial & Industry	5,370	15.5	5,900	13.0	1.10
Military	6,220	18.1	6,050	13.3	0.97
Port Activities	780	2.3	1,280	2.8	1.64
Sub-total	12,370	35.9	13,230	29.1	1.07
Total	34,450	100.0	45,510	100.0	1.32

Note: Figures for 1978 by Master Plan 1979, and those for 1984 by revised Master Plan 1986.
Category follows those by revised Master Plan, and Public Organization was not classified by Master Plan 1979.

Table 2.23 Water Consumption by Districts

Category	Ma'alla		Tawahi		Crater		Khormaksar		Sub-total		Others		Total G. Aden	
	(m3/d)	(%)	(m3/d)	(%)	(m3/d)	(%)	(m3/d)	(%)	(m3/d)	(%)	(m3/d)	(%)	(m3/d)	(%)
Domestic	4,080	71.8	1,460	35.1	5,470	81.2	1,900	23.4	12,910	52.2	10,090	48.5	23,000	50.5
Community	390	6.9	160	3.9	440	6.5	580	8.7	1,570	6.4	1,810	8.7	3,380	7.4
Public Organization	770	13.6	1,520	36.6	480	7.1	2,370	29.2	5,140	20.8	760	3.6	5,900	13.0
Sub-total	**5,240**	**92.3**	**3,140**	**75.7**	**6,390**	**94.8**	**4,850**	**59.7**	**19,620**	**79.4**	**12,660**	**60.8**	**32,280**	**70.9**
Commercial & Industry	230	4.0	70	1.7	320	4.7	120	1.5	740	3.0	5,160	24.8	5,900	13.0
Military	-	-	850	20.5	30	0.5	2,830	34.8	3,710	15.0	2,340	11.3	6,050	13.3
Port Activities	210	3.7	90	2.2	-	-	330	4.0	630	2.6	650	3.1	1,280	2.8
Sub-total	**440**	**7.7**	**1,010**	**24.3**	**350**	**5.2**	**3,280**	**40.3**	**5,080**	**20.6**	**8,150**	**39.2**	**13,230**	**29.1**
Total	**5,680**	**100**	**4,150**	**100**	**6,780**	**100**	**8,130**	**100**	**24,700**	**100**	**20,810**	**100**	**45,510**	**100**

Source: Greater Aden Water Supply, PWC, 1986

2.9.4 Water Tariff

The present water tariff applied to consumers in Greater Aden is shown in Table 2.24. As shown in the table, highly progressive rates are adopted for domestic consumers, although the lowest rate is adopted for this category. Special consideration was given to low income consumers who can use water up to 600 gallons/month free of charge. On the other hand, relatively high rates are applied to other consumers, such as foreigners, commercial, government and industry.

Individual water consumption is metered and recorded every two months by PWC.

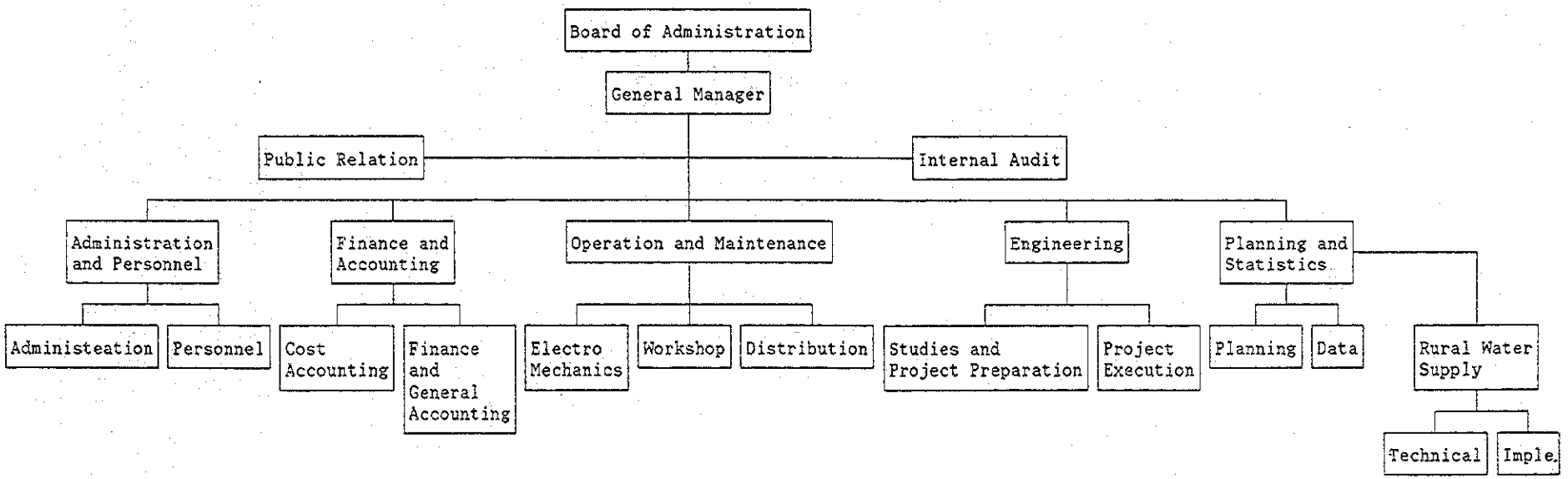
Table 2.24 Water Tariff

Category	Amount of use (gallon/month)	Fee (fills/100gallon)
Domestic	- 600	free
	601 - 6600	30
	6601 -	65
Commercial	flat rate	159
Industry	flat rate	105
Government	flat rate	133
Foreigner	flat rate	170

2.9.5 Organization and Management

Water supply system in Greater Aden is operated under the management of the Public Water Corporation (PWC), a public corporation under the Ministry of Energy and Minerals. PWC was established in 1970. It is responsible for the planning, design, and construction of potable water supply systems and for the operation and maintenance of these systems not only in Aden but also in the other major urban centers in PDRY.

Figure2.9 Public Water Corporation(PWC) Organization Chart



PWC is divided into five departments under the general manager. The organizational chart of PWC is shown in Figure 2.9.

2.9.6 Development Plan

Recommendations for long term development up to 2000 made by the Water Supply Master Plan are summarized below.

The main difficulty in developing Aden water supply is the severe scarcity of water resources. Greater Aden is presently supplied from the Wadi Tuban aquifer. This aquifer, which also supplies local agricultural needs is, according to available data, already overpumped. The present yearly volume pumped for water supply, 17 to 18 million m^3, cannot be increased.

Any increase in water supply must therefore come from another source. The Wadi Bana aquifer, 50 km north-east of Bir Nasir, appears to be the nearest aquifer able to supply several million m^3 of water per year. On the basis of these considerations, a flexible master plan is proposed:

(1) The district distribution networks, which represent less than one third of the cost and are difficult to modify since they are in built up areas, will be designed to meet highest consumption demand.

(2) The supply system to be implemented step by step will be based on supply from Wadi Tuban and Wadi Bana aquifers feeding compensating reservoirs at Bir Nasir from which the district distribution networks are fed by gravity. However the possibility of adding a 22,500 m^3/day desalination plant at Madinat Al Shaab will be considered in the design of Madinat Al Shaab - Sheikh Othman - Mansura network. Adding desalination plants at Khormaksar near the Isthmus will not pose any problems, except acquisition of suitable land, as they will directly feed the Isthmus reservoirs.

Subsequent to the Master Plan, various studies on water resources including groundwater from Wadi Tuban and Wadi Bana, and desalination were carried out. The Master Plan was revised by a British consultant in 1986 taking into account the results of these studies. A long term strategy up to 2010 together with short term strategy up to 1995 (Stage 2) was established based on the revised

projection for water demand. The main points of the strategies are summarized below.

(1) Water Demand

Water demand in 1995 and 2010 was estimated to be 43.5 million m^3/year (119,000 m^3/d) and 71.3 million m^3/year (195,000 m^3/d), respectively, based on the medium projection.

(2) Groundwater Production

Maximum projection of the existing and recently developed well fields are considered as follows.

Bir Nasir	12.0 million m^3/year
Bir Ahmed	4.4 million m^3/year
Wadi Bana	9.0 million m^3/year

In addition to the above well fields, development of a new well field in Upper Wadi Tuban was recommended based on the results of the recent study as follows.

Upper Wadi Tuban	10.5 million m^3/year

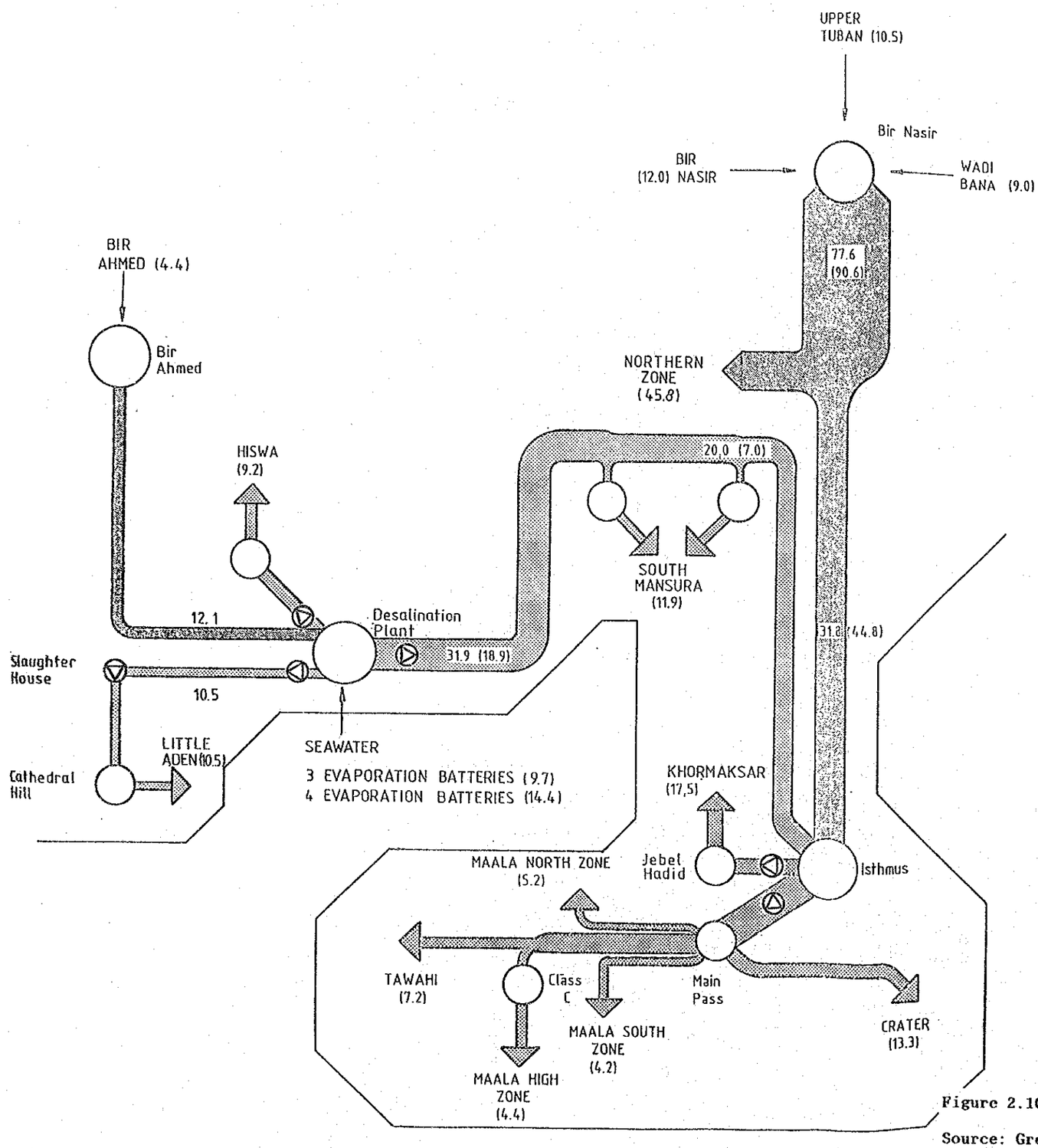
Thus, the total groundwater production which can be maintained without aquifer mining in the foreseeable future is estimated to be 35.9 million m^3/year (98,000 m^3/d).

(3) Desalinated Water

Since groundwater production is limited to the above mentioned figures, the only possible water resource to make up the deficit is from desalination of sea water. At present, four evaporation batteries (3 duty, 1 standby), each having a capacity of 4.9 million m^3/year (13,400 m^3/d) are being constructed at Hiswa Desalination Complex. The total capacity of the desalination plant is sufficient to satisfy the demand in 1995 and some years afterwards. However, development of new desalination capacity is required by 2010. Installation of additional

four evaporation batteries at Hiswa Desalination Complex is recommended, although location of the plant depends on the future distribution of water demand and development of new techniques for desalination.

Water resources and bulk water distribution systems in Greater Aden in 1995 and 2010 recommended by the revised Master Plan are shown in Figures 2.10 and 2.11.



LEGEND

Bir Nasir	Bulk Storage Reservoir
Main Pass	Service Reservoir
Slaughter House	Principal Pumping Station
CRATER (13.3)	Distribution Zone with Peak Day Demand in $1000m^3$
904	Major Conveyance Route with Peak Day Supply in $1000m^3$
	Blended Desalinated Water
	Groundwater
	Groundwater/Blended Desalinated Water
———	Coast Line
UPPER TUBAN (12.0)	Source of supply with Production in Mm^3/yr

NOTES

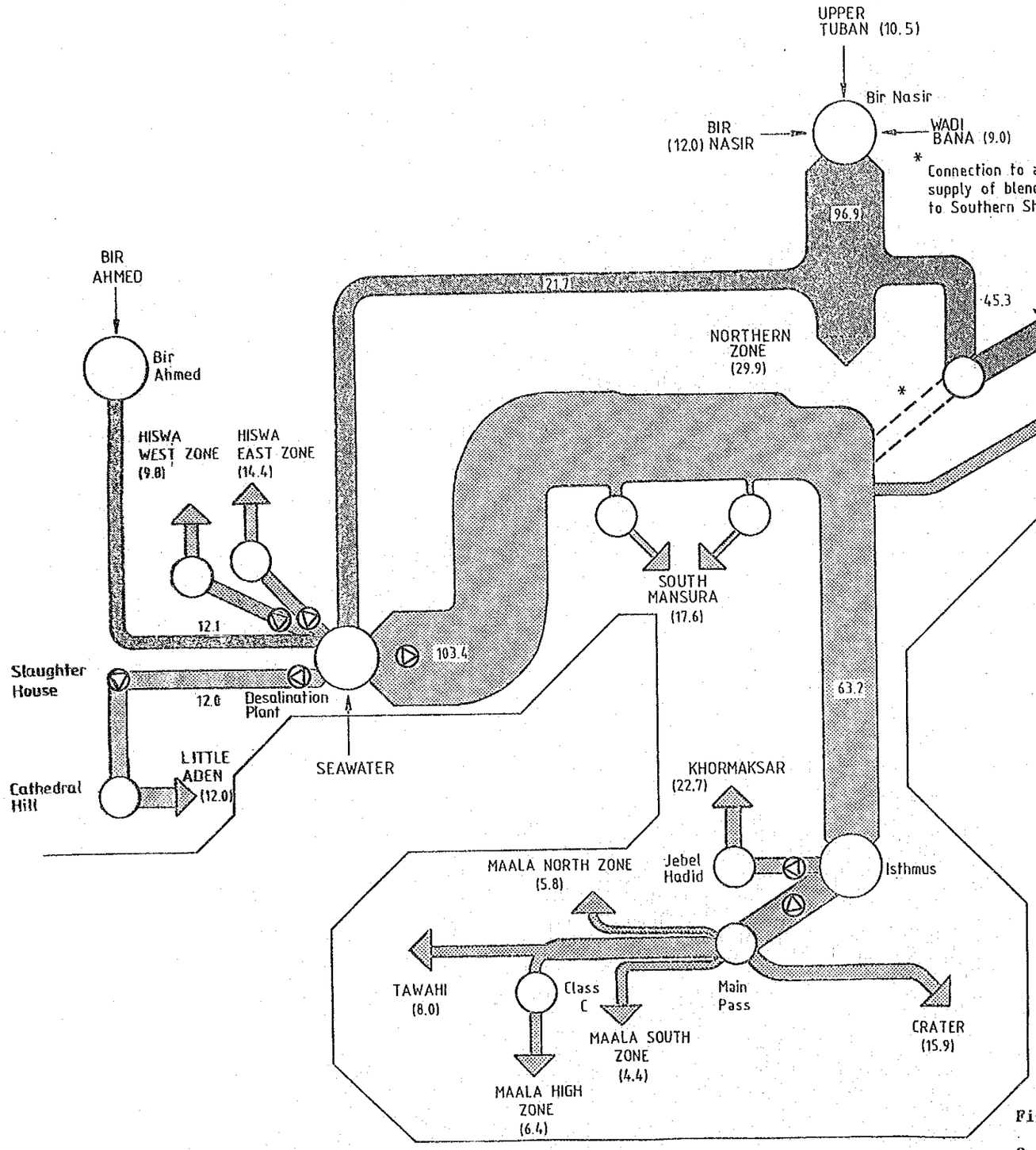
(1) Conveyance supplies for Stage 2 planning horizon are given for alternative desalination programmes

31.9 (18.9) 3 Duty Evaporation Batteries
2 Duty Evaporation Batteries

(2) Supplies for Stage 3 scheme are shown with production of Northern Westfields exceeding nominal capacity by 12% in order to meet peak day demand

Figure 2.10 Schematic Diagram of Bulk Conveyance System in 1995 (Stage 2)

Source: Greater Aden Water Supply, PWC, 1986



LEGEND

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	Groundwater
	Groundwater/Blended Desalinated Water
	Coast Line
UPPER TUBAN (12.0)	Source of supply with Production in Mm^3/yr

NOTES

(1) Conveyance supplies for Stage 2 planning horizon are given for alternative desalination programmes

31.9 3 Duty Evaporation Batteries
(18.9) 2 Duty Evaporation Batteries

(2) Supplies for Stage 3 scheme are shown with production of Northern Westfields exceeding nominal capacity by 12% in order to meet peak day demand

Figure 2.11 Schematic Diagram of Bulk Conveyance System in 2010 (Stage 3)

Source: Greater Aden Water Supply, PWC, 1986

2.10 Sewage Quantities and Characteristics

2.10.1 Sewage Quantity

In order to estimate the present sewage flows in the project area, water consumption records were sought from PWC pumping stations. Waters supplied to Ma'alla and Tawahi districts are pumped from the Isthmus water works. The six latest months' flow rates from October 1988 to March 1989 to the two districts are as follows.

Water Supplied to Ma'alla and Tawahi from Isthmus

(unit: m^3/d)

	1988			1989		
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Ma'alla	8,390	8,138	8,715	8,255	7,865	8,478
Tawahi	6,188	5,814	5,926	6,068	5,920	5,449
Total	14,578	13,952	14,641	14,323	13,785	13,927

Water supplied to Tawahi district includes consumption in military and government facilities. Also, these figures include system leakage in the pipelines, which is estimated by PWC to be 20 - 23 % of the supplied water. According to the observations made by Aden Municipality, the total volume of sewage flow into the sewerage system is 95 % of the water consumed in households. If system leakage and losses in household are reasonably assumed to be 20 % and 5 % respectively, sewage flows from the two districts based on the above figures are calculated as follows.

Wastewater Flow from Ma'alla and Tawahi

(unit: m^3/day)

	1988			1989		
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Ma'alla	6,376	6,185	6,623	6,274	5,977	6,443
Tawahi	4,703	4,419	4,504	4,612	4,499	4,141
Total	11,079	10,604	11,127	10,886	10,476	10,584

Thus present sewage flow in the two districts is considered to be approximately 11,000 m^3/d. Water consumption in Ma'alla and Tawahi in 1984 was estimated to be 5,680 m^3/d and 4,150 m^3/d respectively, totaling 9,830 m^3/d as shown in Table 2.23 in the previous section. Increase of water consumption for the 5 year period is 12 %.

As mentioned above, sewage flow in Tawahi includes those from military facilities and population contributing to water consumption in the area is difficult to estimate. Per capita sewage flow is calculated by using sewage flow and population in Ma'alla. Daily average sewage flow calculated from the above table is approximately 6,300 m^3/d. On the other hand, present population is estimated to be 53,404. Therefore per capita sewage flow is:

$$6,300 / 53,404 = 0.118 \ m^3/capita/d \quad (= 118 \ lcd)$$

PWC estimated average per capita water consumption in 1984 for the entire city of Aden to be 97 lcd. Presently in Ma'alla district, commercial establishments and government buildings are mixed with residential areas, which justify the higher per capita sewage flow in Ma'alla.

The study team carried out round the clock sampling at Hedjuff P/S on 20/21 and 26/27 February. Sewage flows on these days from pump operation records were 3,968 and 4,522 m^3/d. Sewage flow from C-class housing area bypasses the pumps in Hedjuff P/S, and flow rate is considered to be 1,400 - 1,500 m^3/d from the population in the area. The measured flows at Hedjuff P/S are in good agreement with calculated sewage flow mentioned above. Figures in the above table can therefore be considered to be present sewage flow in Ma'alla.

If per capita sewage flow of 118 lcd is applied to the three other districts, Tawahi, Crater and Khormaksar, total domestic sewage flow from the four districts is calculated to be approximately 17,900 m^3/d.

2.10.2 Sewage Characteristics

The study team conducted sampling and analysis of the raw sewage from Al Shaab STP and Hedjuff P/S during the period of the first on-site work. Sampling was carried out twice for 24 hours at each sampling point. Average figures of items analyzed are shown in Table 2.25 below. Details of the sampling method and

results of analysis are described in Appendix D of the current report.

Table 2.25 Characteristics of Raw Sewage

Items Analyzed	Unit	Sampling Point			
		Al Shaab STP		Hedjuff P/S	
		1st	2nd	1st	2nd
Temperature	(°C)				
ambient		25.1	24.8	25.7	26.2
water		29.6	29.0	29.0	29.2
pH		7.4	7.5	7.1	7.5
CODmn	(mg/l)	174	136	150	126
CODcr	(mg/l)	763	662	632	794
BOD5	(mg/l)	384	328	321	326
SS	(mg/l)	339	407	251	274
NH4-N	(mg/l)	43	44	53	67
K-N	(mg/l)	-	62	-	65
T-P	(mg/l)	-	11	-	13

Although raw sewage to the Al Shaab STP includes industrial wastewater, at most 25 % of the total flow, distinct differences are not recognized between the figures in the above table. Sewage to Al Shaab STP and to Hedjuff P/S are considered to be of domestic origin. Figures regarding organic components in the above table are, in general, higher than those of industrialized countries such as Japan, but still in the normal range of domestic sewage. High concentration of organic components are mainly due to low water consumption mentioned in the previous section. In consideration of the results of the analysis and the conditions of the existing sewerage systems connected to Al Shaab STP and Hedjuff P/S, the above figures can be taken as representative for the Greater Aden and will therefore be the basis for future projection for the project.

Per capita waste loading in term of BOD5 can be calculated based on the per capita sewage flow and average BOD5 concentration. Per capita sewage flow estimated in the previous section is 118 lcd for Ma'alla. Average BOD5 concentration for Ma'alla (Hedjuff P/S) in the above table is 324 mg/l.

Therefore, per capita BOD5 loading is obtained as follows.

$$118 \times 324 \times 10^{-3} = 38.2 \text{ gcd}$$

Compared with per capita BOD loadings in industrialized and developing countries, this figure is reasonable (Ref. No.8).

2.11 Existing Sewerage System

2.11.1 General

The four districts, viz. Ma'alla, Tawahi, Crater and Khormaksar are provided with water-borne sewerage system. The oldest sewerage system was constructed in Crater in the 1940s. Sewer pipes installed in those days are still in use in Crater. In 1957, sewerage systems in Ma'alla and Tawahi were constructed. In 1963, overall improvement work was carried out in Crater and a new sewerage system was constructed in Khormaksar. The existing sewerage facilities were shaped in the present form in the 1960s. At present, most of the residents in the four districts except for those inhabiting limited unsewered areas are provided with water-borne sewerage system.

No treatment works have been constructed for the existing sewerage system, and all sewage collected in the four districts is discharged to the sea by ocean outfalls. Present disposal of raw sewage without treatment causes pollution of sea water, particularly in the Inner Harbor.

It is understood that the nuisance caused by the deficiencies in the existing system has produced complaints from the harbor and other authorities and the shortcomings in the systems are detrimental to the development of tourism and trade and thus affect the potential for earning foreign currency. There is considerable need to eradicate deficiencies in the sanitation system serving individual households but progress in this direction is inhibited by shortcomings in the sewerage system.

There are a total of 30 pumping stations in operation at present in the study area, and these are generally well maintained by daily inspection. However, some pumping stations are in very bad condition because of deteriorating mechanical equipment and structures. In addition to these pumping stations operated by Aden Municipality, there are a number of small pumping stations which are not operated by the Municipality. These pumping stations are attached to public and individual premises, and normally operated by the organizations such as airport, hospital and military authorities. However, when these pumping stations are in repair, Aden Municipality is called on to inspect and restore the facility.

High temperature, sediments in sewer pipes, septic tanks at the end of sweeper passages and frequent force mains are the causes of hydrogen sulfide gas generation resulting in damage to concrete and steel structures. Asbestos cement pipes, cast iron pipes, concrete pipes and manholes at many locations subject to hydrogen sulfide built up are badly damaged. Also, salinity in the groundwater or in the mist brought by winds or in fine aggregates cause corrosion of concrete structures.

There are certain small portions of unsewered areas inhabited by low income residents, where bucket system is in use for night soil collection, and these are a health hazard. Besides unsewered areas, there still remain open channel sewage collection systems called sweeper passage. Raw sewage from households discharged to an open channel flows to a septic tank before entering underground sewer pipes. This open channel collection system poses a health hazard to the public. These systems will have to be converted to a sewer system.

Sewerage facilities in the four districts are summarized by components, viz. sewers in Table 2.26, pumping stations in Table 2.27, ocean outfalls in Table 2.28 and sweeper passages in Table 2.29.

Description of the existing sewerage systems in the four districts follows. Details of the existing sewerage facilities in the four districts are illustrated on the drawings in Volume Four and tabulated in Appendix C of the current report.

Table 2.26 Existing Sewers in the Four Districts

District	Planning Area (ha)		Sewer Length (m) Diameter (mm)													Number of Manhole
			100	125	150	175	200	225	250	300	375	400	450	600	750	Total	
Ma'alla	279	ACP	-	-	-	-	-	1496	-	-	-	430	-	-	-	1926	451
		CIP	-	-	658	-	-	-	-	-	-	-	-	-	-	658	
		VCP	-	-	6289	-	-	3354	-	-	-	-	-	-	-	9643	
		CP	-	-	1610	-	-	810	-	3769	-	1364	-	-	-	7553	
		Total	-	-	8557	-	-	5660	-	3769	-	1794	-	-	-	19780	
Tawahi	87	ACP	-	-	304	-	-	-	-	-	-	-	-	-	-	304	291
		CIP	-	-	14	-	-	-	-	-	-	-	-	-	-	14	
		VCP	-	-	4817	-	-	1853	-	-	-	-	-	-	-	6670	
		CP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Total	-	-	5135	-	-	1853	-	-	-	-	-	-	-	6988	
Crater	235	ACP	302	-	-	-	-	3901	-	527	-	539	260	458	783	6770	88
		CIP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		VCP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		CP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Total	302	-	-	-	-	3901	-	527	-	539	260	458	783	6770	
Khormaksar	418	ACP	535	677	592	932	387	10619	1229	1442	1151	258	-	-	-	17822	164
		CIP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		VCP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		CP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Total	535	677	592	932	387	10619	1229	1442	1151	258	-	-	-	17822	
Total	1019	ACP	837	677	896	932	387	16016	1229	1969	1151	1227	260	458	783	26822	994
		CIP	-	-	672	-	-	-	-	-	-	-	-	-	-	672	
		VCP	-	-	11106	-	-	-	-	-	-	-	-	-	-	16313	
		CP	-	-	1610	-	-	810	-	3769	-	1364	-	-	-	7553	
		Total	837	677	14284	932	387	22033	1229	5738	1151	2591	260	458	783	51360	

Table 2.27 Existing Puming Stations in the Four Districts

District	Ma'alla	Ma'alla	Ma'alla	Ma'alla	Tawahi	Tawahi	Tawahi	Tawahi	Tawahi	Tawahi	Tawahi	Crater	Crater	K-maksar	K-maksar
Name of P/S	Hedjuff	Dakka	Dolphin	O. pier	Abkari	Alfath	Military	Military	Military	Military	M.Defence	E	Front Bay	Al Madina	C
Number of P/S	101	102	103	104	201	202	203	204	205	206	207	301	301	401	402
Pump Unit	2 (1)	3 (1)	2 (1)	2 (1)	2 (1)	4 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	3 (1)	2 (1)	3 (1)	3 (1)
Diameter (mm)	150	150	100	76	75	100	100	75	100	100	100	300	100	150	150
Motor Power (kW)	10	6.5	6.25	3.75	3	31.25	NA	NA	3.1	NA	3.1	35	7.5	5	10
Condition of Machinery	Fairly Good	Good	Fairly Good	Bad	Bad	Bad	Bad	Fairly Good	Out of Order	Out of Order	Bad	Good	Good	Good	Fairly Good
Condition of Structure	Good	Good	Good	Fairly Good	Bad	Fairly Good	Fairly Good	Bad	Fairly Good	Can not see	Bad	Bad	Bad	Bad	Bad

District	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar	K-maksar
Name of P/S	D	E	G	H	J	L	M	P	A	Dobiwala 2	Dobiwala 1	Dobiwala 3	Comminuter	Tareq	I
Number of P/S	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417
Pump Unit	2 (1)	3 (1)	3 (1)	2 (1)	3 (1)	2 (1)	2 (1)	3 (1)	3 (1)	2 (1)	2 (1)	2 (1)	2 (1)	1 (-)	2 (1)
Diameter (mm)	100	100	100	150	150	100	150	150	150	100	100	100	80	80	100
Motor Power (kW)	7.5	7.5	7	4	10	5	7	7	7	7.5	11	7.5	2	2	7.5
Condition of Macinery	Good	Good	Good	Good	Good	Good	Good	Bad	Good	Good	Fairly Good	Good	Good	Good	Good
Condition of Structure	Fairly Good	Bad	Bad	Good	Good	Good	Bad	Bad	Bad	Good	Good	Fairly Good	Good	Can not see	Bad

Note: Number of P/S refers to Figures 2.12 to 2.15.
Figures in parentheses in pump unit are number of standby unit.

Table 2.28 Existing Ocean Outfalls in the Four Districts

District	No. *1	Location	Dia. (mm)	Length (m)	Material	Support *2
Ma'alla	OF1	Hedjuff	457	325	ACP	C.C
Tawahi	OF1	Recreation Ground	150	150	VCP	C.C
	OF2	Clock Tower	150	10	CIP	C.C
	OF3	Nashwan	225	30	VCP	C.C
	OF4	Crescent Hotel	225	10	VCP	C.C
	OF5	Ras Tarshyne	150X2	*4	CIP	C.S
Crater	OF1	Front Bay *3	375	-	CIP	C.C
	OF2	Holkat Bay	450	1,800	CIP	C.S
Khormakasar	OF1	Comminuter Station	738	738	ACP/CIP	C.S

Note: *1 Number refers to Figures 2.12 to 2.15
*2 C.C; Concrete Cover
C.S; Concrete Support
*3 not used at present
*4 broken

Table 2.29 Existing Sweeper Passages in the Four Districts

District Ma'alla 53 Nos. TotalLength 2,563 m

No.	Length (m)	No.	Length (m)	No.	Length (m)	No.	Length (m)
Area Old Ma'alla		MS21	44	Area Dakka		SS16	66
MS1	92	MS22	40	MS34	26	SS17	63
MS2	85	Old Ma'alla Sub-total 22 Nos. 1,027 m		MS35	28	SS18	22
MS3	37			Dakka Sub-total 2 Nos. 54 m		Sheik Asshag Sub-total 18 Nos. 836 m	
MS4	89	Area Flour Mill					
MS5	24	MS23	92	Area Sheik Asshag		Ma'alla Total 53 Nos. 2,563 m	
MS6	40	MS24	116	SS1	38		
MS7	23	MS25	189	SS2	41		
MS8	58	MS26	58	SS3	38		
MS9	41	MS27	101	SS4	38		
MS1M	62	MS28	10	SS5	43		
MS11	23	MS29	99	SS6	48		
MS12	50	MS30	9	SS7	31		
MS13	34	MS31	40	SS8	77		
MS14	18	MS32	13	SS9	72		
MS15	43	Flour Mill Sub-total 10 Nos. 627 m		SS10	76		
MS16	59			SS11	57		
MS17	46	Area PCEP		SS12	60		
MS18	41	MS33	19	SS13	25		
MS19	65	PCEP Sub-total 1 Nos. 19 m		SS14	11		
MS20	13			SS15	30		

District Tawahi 77 Nos. Total Length 2,434 m

No.	Length (m)	No.	Length (m)	No.	Length (m)	No.	Length (m)
Area Cunning Market		TS21	20	TS42	12	TS63	8
TS1	120	TS22	12	TS43	18	TS64	19
TS2	50	TS23	12	TS44	29	TS65	40
TS3	42	TS24	12	TS45	51	TS66	6
TS4	3	TS25	42	TS46	34	TS67	26
TS5	46	TS26	8	TS47	19	Cunning Market Sub-total 67 Nos. 2,076 m	
TS6	25	TS27	22	TS48	19		
TS7	16	TS28	6	TS49	34	Area Bingisar	
TS8	44	TS29	32	TS50	18	TS68	36
TS9	44	TS30	34	TS51	46	TS69	36
TS10	44	TS31	46	TS52	46	TS70	36
TS11	54	TS32	43	TS53	46	TS71	36
TS12	73	TS33	32	TS54	36	TS72	18
TS13	35	TS34	36	TS55	36	TS73	45
TS14	26	TS35	8	TS56	36	TS74	24
TS15	8	TS36	45	TS57	36	TS75	86
TS16	24	TS37	45	TS58	20	TS76	20
TS17	18	TS38	45	TS59	9	TS77	21
TS18	48	TS39	33	TS60	31	Bingisar Sub-total 10 Nos. 358 m	
TS19	11	TS40	9	TS61	44		
TS20	19	TS41	33	TS62	24		

Note: There is no sweepers's passage in Crater and Khormaksar districts.