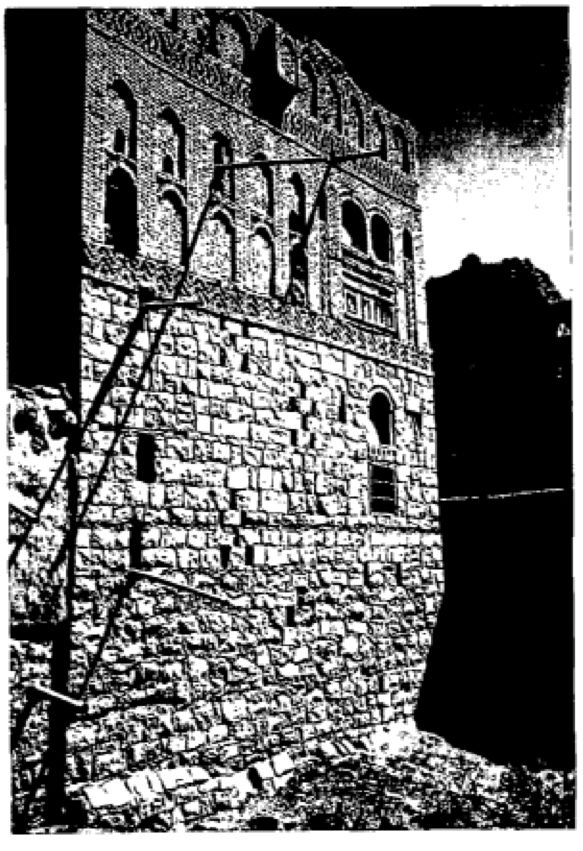
Republic of Yemen
Ministry of Municipalities and Housing
Ministry of Energy and Water
National Water and Sewerage Authority

Kingdom of the Netherlands
Ministry of Development Cooperation
Directorate General of Development Cooperation

Rada Water Supply and Sanitation Project

January 1997



FINAL REPORT

Euroconsult
DHV Consultants BV
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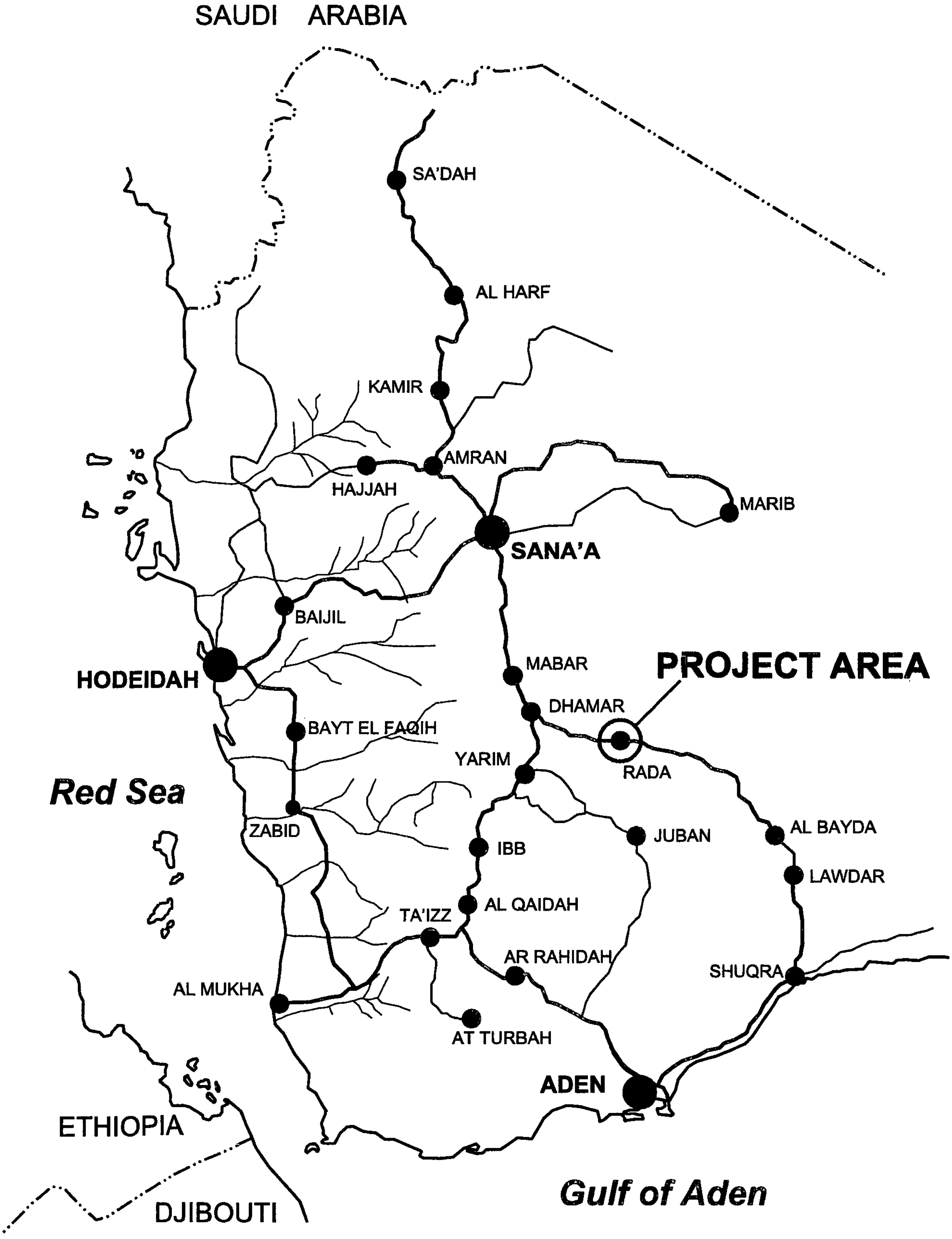
SAUDI ARABIA
SA'DAH
AL HARF
KAMIR
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MARIB
SANA'A
BAIJIL
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PROJECT AREA
DHAMAR
BAYT EL FAQIH
YARIM
RADA
Red Sea
ZABID
JUBAN
AL BAYDA
IBB
LAWDAR
AL QAIDAH
TA'IZZ
AR RAHIDAH
SHUQRA
AL MUKHA
AT TURBAH
ADEN
ETHIOPIA
DJIBOUTI
Gulf of Aden

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ABBREVIATIONS AND ACRONYMS

BOD	biochemical oxygen demand
COD	chemical oxygen demand
CPO	Central Planning Office
DGIS	Directorate-General for International Cooperation of the Netherlands Ministry of Foreign Affairs
DIP	Direct Improvement Programme
EHE	environmental health education
GTZ	Gesellschaft für Technische Zusammenarbeit, German Agency for Technical Cooperation
LCCD	Local Council for Community Development
MCUPH	Ministry of Construction, Urban Planning and Housing
MMH	Ministry for Municipalities and Housing
MOR	Municipality of Rada
NWSA	National Water and Sewerage Authority
O&M	operation and maintenance
RIRDP	Rada Integrated Rural Development Project
RUA	Rada Urban Area
RUDP	Rada Urban Development Project
RWSSP	Rada Water Supply and Sanitation Project
TA	technical assistance
YAR	Yemen Arab Republic
YER	Yemen Riyal

ACKNOWLEDGMENTS

Euroconsult, DHV Consultants and Agro Vision Holland wish to express their gratitude for the assistance and co-operation received from officials at central and provincial level who have been involved in the design and construction phases of the project.

In particular we should like to acknowledge the contributions made to the success of the project by the Ministry of Construction, Urban Planning and Housing, the National Water and Sewerage Authority and the NWSA Rada Branch, the Royal Netherlands Embassy in Sana'a, and the Baladiya of the Rada Urban Area.

Finally, special thanks go to the various Monitoring Missions headed by Mr. C.D. van der Wildt, without whose encouraging, enthusiastic but also critical support the project would not have become as successful as it is.

1 INTRODUCTION

In the period 1980-1982 the Rada Urban Development Project was carried out with Dutch financial assistance. The project resulted in a comprehensive urban development plan, including preliminary designs for the improvement of water supply, sewerage, drainage and solid waste disposal.

As a follow-up to this project the Rada Water Supply and Sanitation Project (RWSSP) started, in January 1988. Its aim was to improve the public health situation in the Rada Urban Area (RUA) by introducing well-functioning water supply, wastewater disposal, drainage and solid waste collection and disposal facilities, accompanied – and partly preceded – by an extensive environmental health education and community information campaign. The project aimed at improving the public health situation by providing adequate water supply, sewerage, drainage and solid waste disposal systems for the Rada urban area, in combination with public health and community information programmes for introducing these systems and their proper use. In addition, the project aimed at strengthening the institutions charged with the operation and maintenance of the introduced facilities. To enable these institutions to carry out their tasks properly, operation and maintenance equipment has also been procured under the project.

Parallel to an inception and detailed design period that started in April 1988, a direct improvement programme (DIP) was carried out, aimed at the rehabilitation of existing drainage and solid waste collection facilities, and supported by an environmental health education programme. The DIP activities were concluded in the second half of 1989.

Whereas the solid waste collection and disposal programme started in November 1988, implementation of the other facilities was taken up in the second half of 1991. The solid waste disposal component was also the first to be completed: transfer of equipment and other solid waste components to the Baladiya (municipality) took place on 31 July 1993.

The water supply works were implemented in different contracts, starting with well drilling (contract awarded on 4 November 1991), followed by mechanical/electrical works and civil works contracts, including completion of well field, reservoir, installations at NWSA compound, wastewater treatment plant and NWSA office (award of contract on 12 March 1992).

Well drilling (Contract 1) was completed by January 1993, the mechanical/electrical works (Contract 3) by January 1995, and the Civil Works (Contract 2) by February 1996.

The water distribution and sewerage systems were implemented and commissioned in a phased manner, starting with districts II and III (April 1995), and followed, in that order, by districts VI and XI (November 1995), districts IV, VIII, IX, X, V and XII (December 1995), and districts I and VII (February 1996).

Towards the end of the project (by November 1994) the decision was taken to proceed with the implementation of earlier proposed surface drainage works. These were completed by July 1996. At the same time also works in parts of two extension areas (districts XXIII (3-A) and XXV) were finished, the inclusion of which in the RWSSP had been decided by the end of 1995. Against some surplus funds additional materials were ordered for further works in the extension areas, to be implemented by the NWSA Rada Branch itself, as soon as it would have established its administrative system and operation and maintenance procedures in an acceptable manner.

In June 1996 the decision was taken to grant a more independent status to the Rada NWSA Branch, as a pilot case for decentralisation. From that moment on support would also be provided by the German GTZ agency.

The project was formally terminated by the end of January 1997, with the end of the defects liability period for the mechanical and electrical works, civil works and rainwater drainage works.

2 BACKGROUND

2.1 Location

The project area is located in the Al Bayda Province of the Republic of Yemen, formerly Yemen Arab Republic (YAR). It comprises the Rada Urban Area which consists of the communities of Rada and Musalla, and the urbanising area of As Safiyah in between these two. It is the area within and along the ring road shown in the master plan of Rada, and is located at a distance of 55 km from Dhamar, the nearest major town, 160 km from the national capital Sana'a and 105 km from the provincial capital Al Bayda, on the national highway.

The northern boundary of the town is formed by the Wadi Qam Attah, a temporary water course; the Dhamar - Al Bayda highway forms the southern boundary, with agricultural areas on the western and eastern boundaries of the town.

2.2 Administrative status

Rada is the largest settlement in the Al Bayda Province, Al Bayda itself being the seat of the provincial government and the second town in size. The main function of Rada is that of an administrative and commercial centre in the almost exclusively agricultural Rada District.

Rada is one of Yemen's so-called secondary towns. It is situated at an altitude of 2100 m above sea level. Soil conditions are rather mixed, with sandy soil and volcanic outcrops.

The town area is subdivided in 18 districts, as shown in Fig. 2.1. Of these, districts I-XII are considered part of the actual RUA, whereas districts XX-XXV are considered extension areas.

2.3 Population and population growth

Information about the existing population size and distribution was collected at the start of the project[1], and updated for the extension areas later[2]. Towards the end of 1989 various town development scenarios were investigated[3], but this did not lead to a revision of the design population figures as shown in Table 2-1. In this table the population data for 1995 and 2010 for the extension areas are based on the Conceptual Design Report for the Extension Districts; all others on the Final Design Report. The conclusions of population surveys in the extension area were that, whereas the forecast for the total population within the extension areas as mentioned in the Final Design Report was correct, the distribution within these areas was different from what had been foreseen. Altogether, the 1995 population in the built-up part of the extension areas was slightly higher in 1995 than had been assumed (10,242 persons, against 8,622 earlier), whereas the 2010 projection is lower (15,957 against 27,350).

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1 See: "Inception Report, Volume 1 - Main Report", RWSSP, July 1988. Data was obtained from the Rada Urban Development Project (1980 - 1982).

2 See: "Final Design Report of Extension Districts of Rada", November 1995.

3 See: "A broad outline on master planning aspects of Rada Urban Area", RWSSP, September 1989

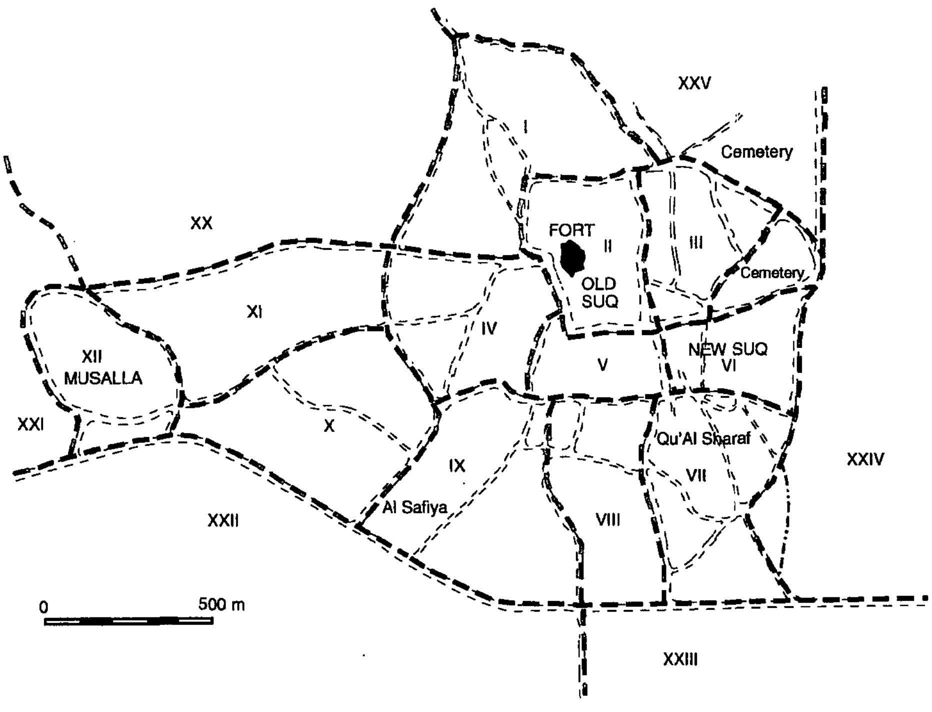


Fig. 2.1 Districts of Rada

Table 2-1 Population forecast per district

District No.	Surface [ha]	1988		1995		2010	
		Density [c/ha]	Population	Density [c/ha]	Population	Density [c/ha]	Population
I	25.0	160	4,000	211	5,264	263	6,500
II	13.5	239	3,225	274	3,705	296	4,000
III	13.8	199	2,750	229	3,159	247	3,400
Cemetery	4.5	-	-	-	-	-	-
IV	19.8	146	2,900	168	3,331	181	3,600
V	8.5	400	3,400	414	3,521	427	3,650
VI	12.5	100	1,250	115	1,436	124	1,550
VII	20.9	148	3,100	170	3,561	184	3,850
VIII	18.4	125	2,300	144	2,642	167	3,050
IX	30.2	96	2,900	122	3,690	164	5,000
X	27.6	60	1,655	170	4,680	197	5,450
XI	18.7	53	1,000	151	2,826	219	4,100
XII	17.8	154	2,750	177	3,159	191	3,400
Sub-Total	231.2	135	31,231	177	40,972	206	47,550
Cemetery	7.6	-	-	-	-	-	-
XX	102.3	10	1,000	-	1,926	-	3,001
XXI	13.3	11	150	-	1,150	-	1,792
XXII	86.5	9	800	-	1,638	-	2,552
XXIII	44.2	11	500	-	2,538	-	3,954
XXIV	102.0	12	1,250	-	2,305	-	3,591
XXV	16.4	12	200	-	685	-	1,067
Cemetery	7.9	-	-	-	-	-	-
TOTAL	611.4	57	35,131	-	51,214	-	63,507

2.4 Existing situation

2.4.1 General

Rada and Musalla are old settlements with many traditional Yemen houses in a typical Yemen lay-out. Situated on old trading routes, Rada has functioned as a regional centre for a long time. The present connections to the region are formed by the Dhamar-Al Bayda road (since 1981), some regional feeder roads and many tracks.

The climate is semi-desert, temperate, with much sunshine. Annual rainfall amounts to 225 mm, with temperatures ranging from 2°C to 22°C in the coolest, and 15°C to 30°C in the hottest months. Usually there is a lot of dust.

The housing in the area is privately developed, the town character being that of a traditional Yemen mountainous settlement, mostly built with 2-3 storied mud houses. Recently erected buildings include single-storey modern hospitals and multi storied houses with reinforced concrete skeleton.

South of the fortress the old commercial functions can be found in the old suq, whereas most newer commercial functions are concentrated near the new suq. A number of simple industries, mainly manufacturing building materials, can be found outside the centres, in the newer development areas, mostly close to or in residential areas. There too are several schools, some new public buildings (including hospital, mother and child clinic, police station), petrol stations, garages, etc.

From 1980 onwards, the Rada Urban Area underwent an important development. In the period 1980-1982 the Rada Urban Development Project was carried out, with Dutch financial assistance. The project resulted in a comprehensive urban development plan, including preliminary designs for the improvement of water supply, sewerage, drainage and solid waste disposal. As a follow-up the Rada Water Supply and Sanitation Project (RWSSP) started in 1988, within the framework of the Netherlands-Yemeni bilateral co-operation.

With the completion of water supply, sewerage, stormwater drainage and solid waste disposal facilities, Rada has become an attractive place for people to settle down, with a network of public works, primary and secondary schools, hospitals, pharmacies and a relatively abundant supply of goods which altogether provide a quality of life that is well above the Yemen average.

2.4.2 Water supply

Before the start of RWSSP three larger and a few smaller water supply systems existed in the Rada Urban Area, each serving a part of the town. Together these systems served about 93% of the houses in the town, through un-metered house connections. The largest system was co-operatively owned; the others private.

There used to be a remarkable difference between the older[4] and the newer districts[5], with 86% of the houses in the older districts having a connection to the existing collective water supply system,

[4] i.e. with most of the houses built before 1980, viz. districts I - VIII , XII.

[5] i.e. where the majority of the houses was built after 1980, viz. districts IX - XI.

whereas in the newer districts 80% of the houses obtained their water from private sources, generally boreholes. From these sources usually a larger and more regular supply could be obtained, though at higher cost. In older as well as newer districts there were houses with both sources of supply and a limited number with no connection at all. In the last case water was usually obtained from a neighbour or relative close by.

Each supply system had its own distribution network, of which the larger pipes were buried, but all smaller pipes, including connections, were located above ground.

The perceived quality of the water supplied by the existing systems, as determined during a *water quality and use survey* in February/March 1989, is illustrated in Fig. 2.2. The bar graphs in that figure show, per district, the impression of the inhabitants on the taste of the water (saline - sweet) and their reasons for obtaining water from outside sources (mainly water trucks): quality and/or quantity of the distributed water.

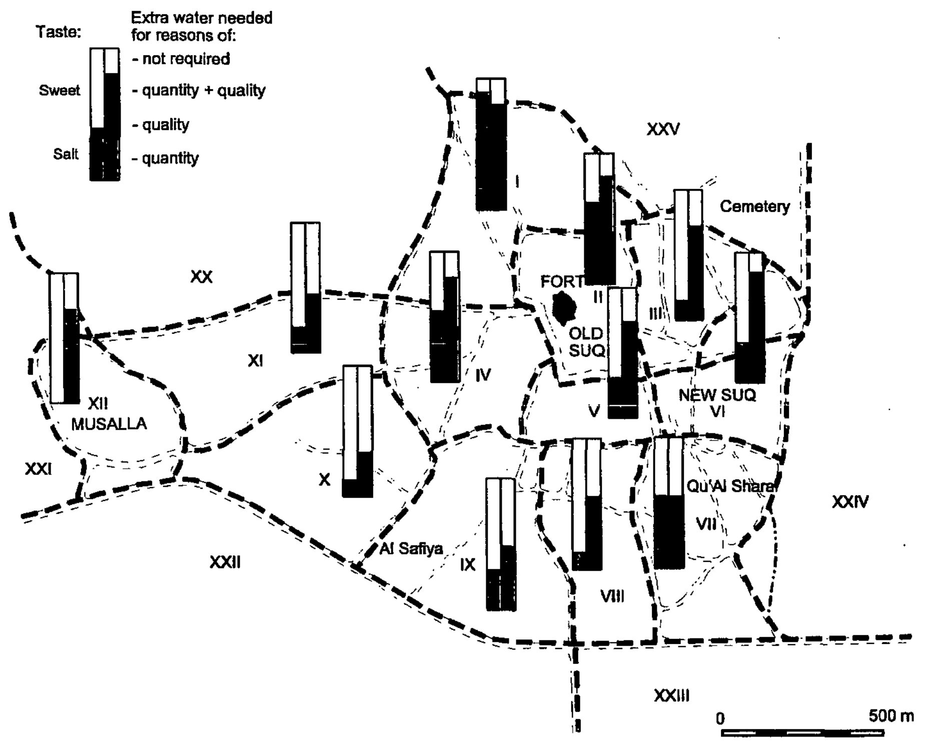


Fig. 2.2 Taste of water and reasons for obtaining water from outside

Connections to one of the old water supply systems

2.4.3 Wastewater disposal

The rapid development in Yemen since 1962 resulted in many changes in the social/cultural habits of the Yemeni people. Because of the increasing water consumption also the amount of and problems caused by wastewater grew. Since groundwater exploitation started in 1972 the average water consumption rose from 10 - 15 l/c/day to about 50 l/c/day. Moreover, especially flushing toilets had become rather common.

In the past wastewater was discharged by bucket and thus spread over a large area. Also excreta were discharged to public areas. After the introduction of piped water supply the wastewater situation caused severe problems, especially in the densely populated areas. At locations where wastewater cannot be drained or infiltrated into the sub-soil, the water became stagnant and formed a considerable hazard to public health. This problem was compounded by the solid waste situation. The topsoil was clogged and wastewater started to run off through small gutters, dug in the sandy streets.

In the whole of Rada more than half of the wastewater was disposed of in soakaway pits. Only now and then wastewater was used for the garden. If human solid waste was disposed of separately, this was always done in special facilities. On the other hand, where modern, cistern flush toilets were used, wastewater was always disposed of in either a soakaway or, sometimes, a sewer system. Altogether, about one-third of the wastewater in Rada was ending up in the streets, posing health hazards.

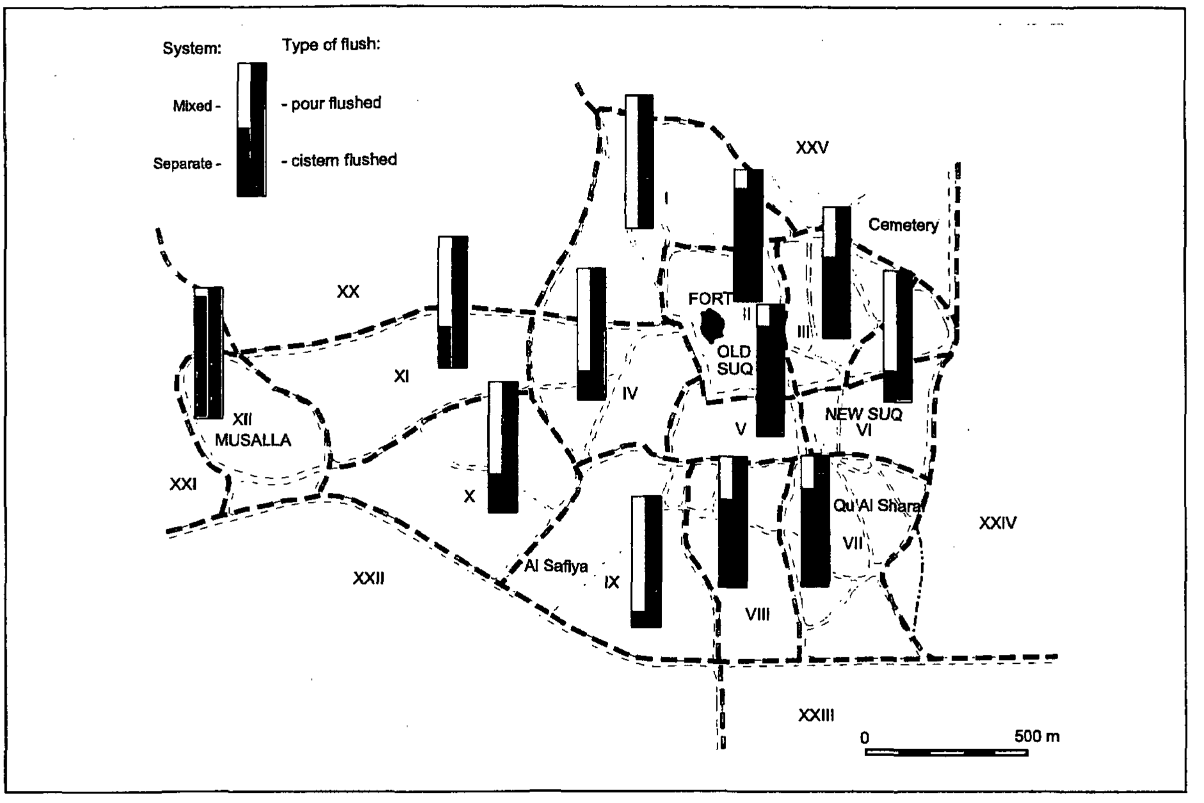


Fig. 2.3 Types of toilets in use before start of RWSSP

Fig. 2.3 indicates the type of toilet in use at the start of the project. The bars show, per district, the percentages of inhabitants using:

- the traditional, separate system: urine and stools are disposed of separately;
- the mixed disposal system, as commonly used elsewhere in the world, with a single disposal point for urine and stools;
- of the latter:
  - the pour-flushed system: only a little water used for flushing away excreta;
  - the cistern-flushed system: 8 - 12 litres of water used per flush, as in a conventional water closet

2.4.4 Stormwater disposal

In Rada no special rainwater drainage system existed. This is mainly because traditionally the people settled at locations with high natural gradients, and partly due to the relatively few days of rain per year.

In densely populated hilly areas of the town rainwater that is not stored in micro depressions was discharged by runoff along footpaths and streets. This water was transported to the lower parts of town and collected at natural field depressions and on the plains at the outskirts, where it disappeared through infiltration.

In less densely populated areas the rainwater did not in general cause any runoff, but infiltrated into the subsoil, while a minor part evaporated. Only during exceptional rainstorms runoff took place. Due to the west-east oriented gradient of the surface, large volumes of runoff passed through the densely populated areas in the middle and southern parts of the old city, on their way to the plains east of the town.

The northern part of the town drains directly into the Wadi Al Arsh, which runs in a west-east direction immediately north of it.

Although it is clear that rainwater drainage problems existed already in the past, the situation — especially in the densely populated areas — had become worse over the years. This has several reasons:

- As a result of the fast urban growth in the last decade before the start of the project, many depressions that had traditionally been reserved for rainwater collection, had gradually been built up with houses and other buildings. This not only disturbed the old drainage pattern, but also increased the number of buildings exposed to flooding.
- The road drainage was very poor. The increasingly motorised traffic, in combination with the absence of a road drainage system, ruined the existing unpaved roads more and more. Especially as a result of the water remaining in the holes, the top soil softened and the holes were deepened by the traffic. Large holes with a depth of over half a metre were a common result of this cumulative process.
- Through the increasing volume of solid waste and the absence of an effective garbage collection system, drainage courses were often blocked by solid waste. Field depressions which had not yet been built up, proved to be an ideal spot for dumping refuse. Rainwater mixed with waste water was collected in these depressions.

In case of heavy rainstorms, parts of the town were flooded for days, and stagnant pools formed which directly endangered the public health situation, and caused flooding of buildings, especially in the old city centre.

Streets flooded after rainfall

2.4.5 Solid waste disposal

At the start of the project, the Rada Municipality had no appropriate organisation with sufficient collection equipment and technical facilities to implement regular solid waste collection and disposal activities. Several years earlier a waste disposal system had been introduced by the Municipality, but, due to an impractical design of the containers and a lack of manpower, it did not achieve the envisaged results. Moreover, the introduction of the system was not accompanied by a corresponding environmental health education programme.

At the start of the project 28 persons were dealing with garbage collection activities from time to time, but without proper terms of reference. The Rada Municipality had 5 vehicles at its disposal. A number of sites around Rada were used as dumping places for garbage, a major site being along the Al Bayda road, at a distance of about 4 km from Rada.

3 PROJECT IMPLEMENTATION

3.1 Consultants assignment

The Rada Water Supply and Sanitation Project started in January 1988, when a consortium formed by Euroconsult, DHV Consultants BV and Agro Vision Holland was awarded the contract to provide consultancy services. These aimed at improving the public health situation in the Rada Urban Area by introducing well-functioning water supply, wastewater disposal, drainage and solid waste collection and disposal facilities, accompanied — and partly preceded — by an extensive environmental health education and community information campaign.

3.2 Scope of the project

The project has been carried out in three phases:
- concept and inception phase;
- design phase;
- construction and implementation phase.

The concept and inception phase started immediately after mobilisation of the consultant, and was completed with the preparation of an Inception Report. This report, submitted in July 1988, laid down the basis for the design of the physical components (water supply, sewerage and wastewater treatment, stormwater drainage and solid waste disposal), while addressing the approach for environmental health education and institutional aspects.

The Inception Report also indicated the components for a Direct Improvement Programme, mainly geared towards drainage and solid waste aspects, which should be started immediately after the concept and inception phase.

The design phase, which started immediately after the inception phase, was concluded with the submission of a draft Final Design Report and a draft Plan of Operations in June 1989. Both were finalised in December 1989.

After a period of preparing detailed designs and floating tenders, physical implementation started in November 1991, to be completed — including additional work in two extension areas — by July 1996.

3.3 Project duration

3.3.1 Original time planning

At the onset of the project, its entire duration was foreseen as 36 months, in 2 phases of about 18 months each:
- a design, direct improvement (DIP), tender preparation and tendering phase, and
- an implementation phase.

Health education activities would take place throughout the entire project period.

After an initial period of preparing conceptual designs, setting up an environmental health and community development plan, and implementing the Direct Improvement Programme, details for the implementation of the project were laid down in a Plan of Operations, based on and appearing simultaneously with the Final Design Report of December 1989.

3.3.2 Plan of Operations

The Plan of Operations was based on a time schedule whereby all works would be completed and handed over by mid-1993, as follows:

Table 3-1 Implementation schedule, planned and actual

No.	Description	Plan of Operations		Actual	
		Start	Completion	Start	Completion
1	Well drilling and construction: - detailed designs and tender documents - construction	 May 1990 Feb. 1991	 Aug. 1990 May 1991	 - Nov. 1991	 July 1991 Nov. 1992
2	Mechanical and electrical works for water supply: - detailed designs and tender documents - supply and installation	 March 1990 Jan. 1991	 Aug. 1990 Jan. 1992	 April 1992 July 1993	 Aug. 1991 Jan. 1995
3	Reservoir and compound: - detailed designs and tender documents - construction	 Jan. 1990 April 1991	 July 1990 Dec. 1991	 - (*)	 Aug 1991 April 1995
4	Procurement of pipes (water supply and sewerage): - preparations up to tender documents - supply	 March 1990 Jan. 1991	 July 1990 Nov. 1992	 - (*)	 Aug. 1991 -
5	Pipe laying (water supply and sewerage) - detailed designs and tender documents - pipe laying transmission main/sewer	 Aug. 1989 June 1991	 July 1990 Jan. 1992	 - (*)	 Aug. 1991 April 1995
6	Distribution and sewer system, Districts II and III - pipe laying	Jun. 1991	Jan. 1992	(*)	April 1995
7	Distribution and sewer system, Districts I - XII: - pipe laying	Feb. 1992	June 1993	(*)	Feb. 1996
8	Sewage Treatment Plant: - detailed designs and tender documents - construction	 March 1990 March 1991	 July 1990 Jan. 1993	 - (*)	 Aug. 1991 Dec. 1995
9	Drainage Works: - detailed designs and tender documents - construction	 Jan. 1992 Jan. 1993	 July 1992 June 1993	 - May 1995	 - June 1996

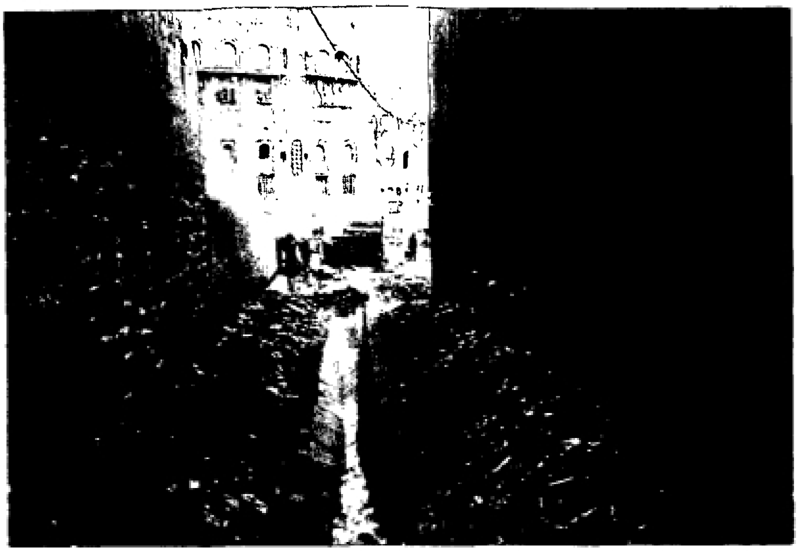
(*) Contrary to what was assumed in the Plan of Operations, most of the civil works (procurement and laying of pipes, construction of reservoir, compound and wastewater treatment plant, and installation of distribution systems) were all awarded as one single contract, the execution of which started in March 1992. Because of this it is not always possible to determine the exact time when construction of an individual component started or was completed. When months have been indicated, they refer to the moment when the respective component was basically completed, even though minor activities, e.g. landscaping, might still have to be carried out.

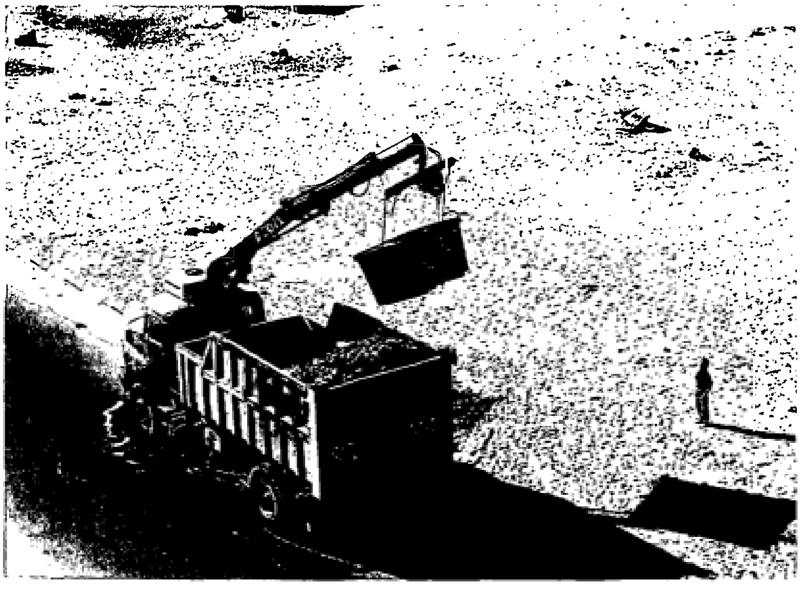
3.3.3 Actual implementation

3.3.3.1 Pre-construction phases

Immediately after the mobilisation period the following activities were carried out:
preparation of conceptual designs and provisional cost estimates;

- preparation and implementation of an environmental health programme and community development activities;
- preparation and start of the direct improvement programme (DIP), aimed at removing the most obvious constraints to a sanitary environment as quickly as possible:
  - garbage disposal crash programme (cleaning of the Harat al Hafra canal, clearing of solid waste from depression areas, removing solid waste from other major dumping sites in the town, distribution of waste containers, demolishing and removal of ruins, information campaigns, etc.), completed by the first week of October 1988. During this campaign 500 tonnes of garbage were collected in 20 days;
  - construction of workshop and upgrading of heavy equipment and rolling stock, by the Operations section;
  - preparation of demonstration and information materials by the EHE section;
  - design and tendering for surface drainage works under DIP (incl. Harat al Hafra canal): start of regular surface drainage/upgrading, filling up shallow depressions and levelling of roads by 3-11-1988; award of contract for Harat al Hafra surface drainage works, including installation of pumping stations in 2 deep depressions, soakaways in shallow depressions, and drainage channels: 22-11-1988;
- prior to the start of the technical activities within the DIP, an environmental health education programme was started, which included:
  - selection, training and assignment of counterpart staff, and training of volunteers;
  - organisation of social hearings;
  - religious training;
  - collaboration with the Environmental Health Department of MMH;
  - involvement of Primary Schools, MCH clinic, Non-Formal Education Centre for Women;
  - production of TV spots;
  - training of assistant sanitarians and sanitarians;
  - door-to-door information campaigns and target group information campaigns;
  - development of information and demonstration materials for the environmental health education and public information campaigns
- regular solid waste collection activities were started on 3 November 1988, together with the surface drainage/road levelling programme;
- preparation of a Draft Inception Report (July 1988);
- execution of various surveys:
  - soil test programme
  - geoelectric and geomagnetic surveys of well field
  - aerial surveys and mapping
  - test drilling in well field
  - topographical, pipe routing and alignments, geoelectric and geomagnetic surveys
- preparation of Final Design Report and Plan of Operations (December 1989).





Activities carried out during Direct Improvement Programme:

top: construction of drainage channel;

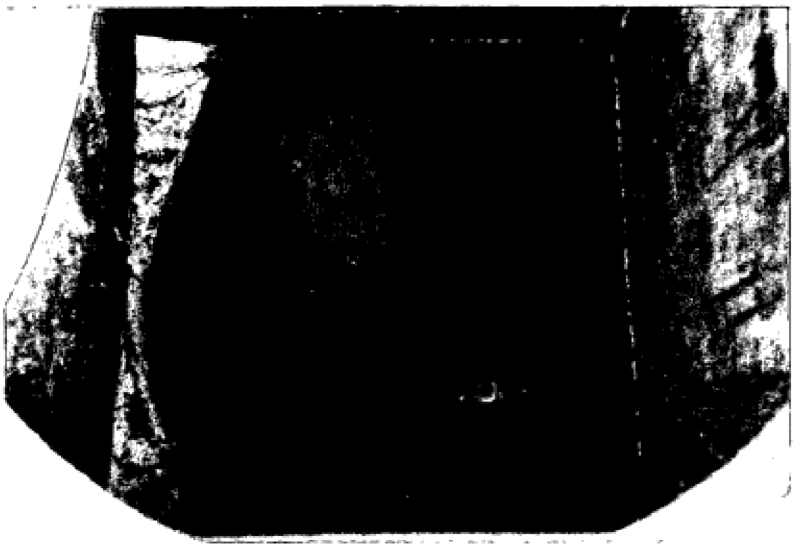
centre and bottom: solid waste cleaning drive

3.3.3.2 *Construction phase*

The actual construction phase was terminated considerably later than had been assumed in the Plan of Operations (see Table 3-1 above), for a number of reasons:

- land acquisition and establishing right of way hampered progress especially prior to 1995;
- the mechanical/electrical contractor under-estimated the efforts required for customs clearing, which resulted in a considerable delay in the start of the actual construction activities of Contract 3;
- the Gulf War caused delays, especially in the period January - May 1991;
- due to the armed conflict in Yemen, all works were suspended from 4 May 1994 to 9 August 1994. During this period, all expatriate staff of the consultant and the contractor was repatriated. During August - October 1994 inspection and rehabilitation took place for both Contract 2 (Civil Works) and Contract 3 (Mechanical and Electrical Works). Works were taken up again in October 1994. Altogether the civil war resulted in an interruption of the normal construction for about 7 months, while spawning various unsolved issues, such as complex suspension claims by contractors, which hampered a speedy resumption of the normal construction activities. Because of this the project execution for civil works was extended till 15 January 1996, with the defects liability period ending on 31 January 1997;
- in the course of the project repeatedly issues of security hampered normal progress. Acts of sabotage or wilful destruction of materials and works were experienced, whereby especially parts of the sewer system and manholes were clogged with stones and other rubbish, or damaged. In addition, the staff of the contractor has been threatened or molested in the course of the execution of the civil works, and in several cases materials were stolen. Repeatedly project cars were hijacked at gun point, which led to a series of measures that considerably restricted the consultants' freedom of movement, especially outside Rada. These security issues have been discussed during several occasions, in the presence of local authorities and representatives of the Royal Netherlands Embassy, and although in general they could be solved, project activities more than once suffered because of them;
- the introduction of a Financial Information System (FIS) by NWSA Rada Branch, as envisaged in the Report of Discussions of November 1994, was not yet realised by the end of 1996. Also the rather late recruitment of staff for the Rada Branch, as well as budget, tariff and salary problems, are a serious constraint for the proper functioning of the Branch, and have delayed the handing over of works in the past;
- the decision to proceed with the surface drainage works was taken only towards the end of 1994, as a result of which these works could be completed only in the course of 1996;
- only by the end of 1995 clearance was given to cover some water distribution and sewerage activities in two of the extension areas; these could be completed in the course of 1996 as well.

The complete full water supply and wastewater facilities, except those in the extension areas, were handed over to the NWSA Rada Branch in February 1996; the surface rainwater drainage system was officially handed over to the Rada Municipality in July 1996.



Damage incurred during suspension period because of civil war:

top: damage caused by purposely blocking manholes with large stones

centre: blocked manholes and broken sewer pipes

bottom: damage to bottom sealing in treatment plant

3.3.4 Implementation schedule

3.3.4.1 Basic project components

Solid waste
The official transfer of solid waste collection and disposal to the Municipality of Rada took place in March 1994.

Contract 1 (Well Drilling Works)

Submittal of tenders:	14 July 1991
Approval of Tender Evaluation Report:	29 September 1991
Award of contract signed:	4 November 1991
Awarded to:	General Trading and Drilling Co. Abdulla Ahmed Al Kohali, of Sana'a, Yemen
Works completed:	22 November 1992.

Contract 2 (Civil Works)

Submittal of tenders:	4 August 1991
Approval of Tender Evaluation Report:	25 November 1991
Award of contract signed:	12 March 1992
Awarded to:	Archirodon Construction (Overseas) Co. S.A., an originally Greek firm.
Works completed (basic contract: 12 districts):	4 February 1996
Completion of works in extension areas:	30 June 1996.

The progress for this contract is shown in the diagram on page 20.

Contract 3 (Mechanical/Electrical Works)

Submittal of tenders:	4 August 1991
Approval of Tender Evaluation Report:	25 November 1991
Award of contract signed:	12 March 1992
Awarded to:	Nettenbouw International, The Netherlands.
Start of works (mobilisation):	1 July 1993
Works completed:	31 January 1995.

3.3.4.2 Additional project components

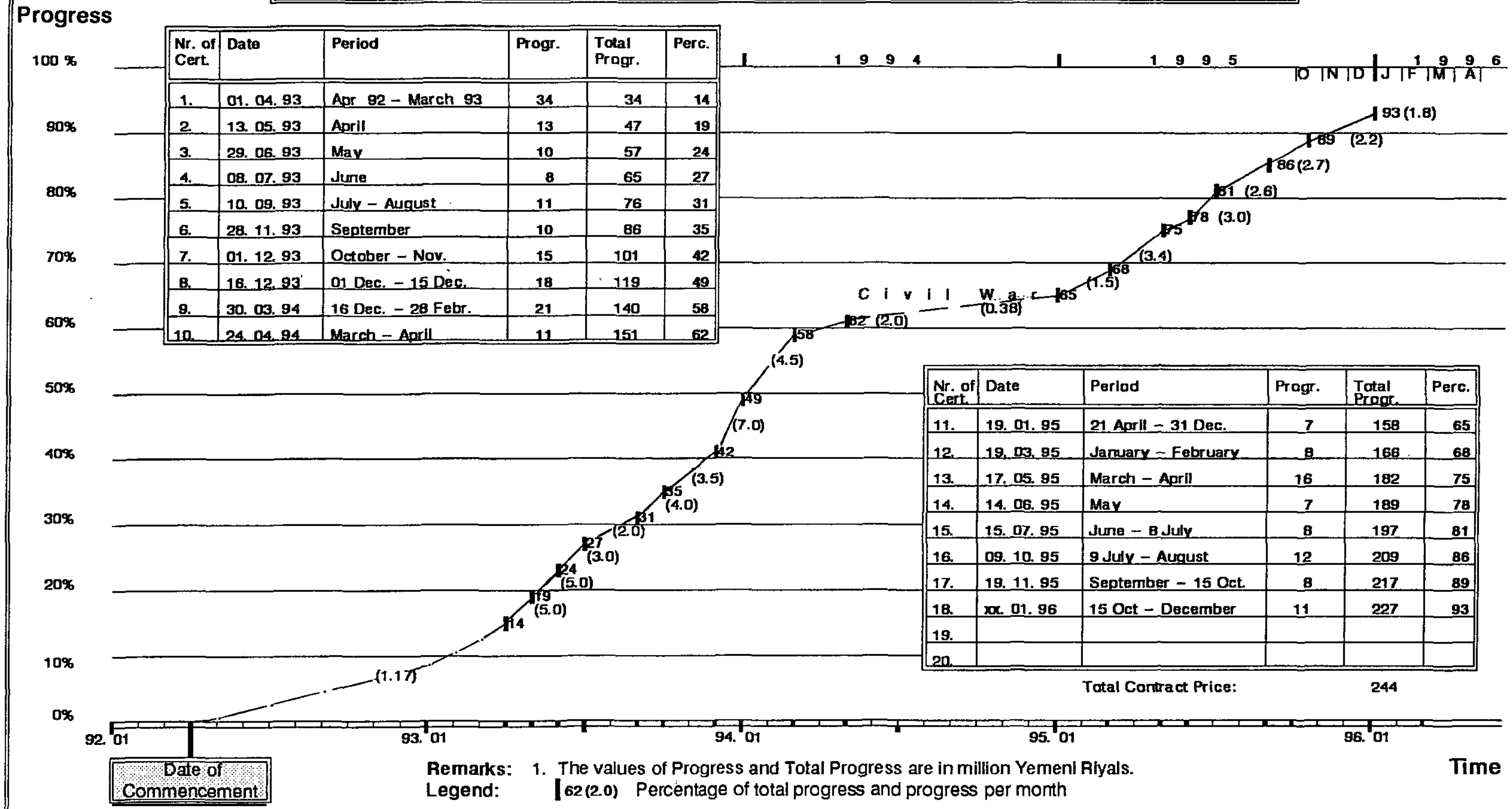
Contract 4 (Surface rainwater drainage)

Approval of tender:	March 1994
Re-tender:	December 1994
Award of contract signed:	27 April 1995
Awarded to:	Sheba General Construction Company, of Taiz, Yemen
Start of works:	2 May 1995
Works completed:	31 May 1996

Extension areas
Surveys and detailed designs for the extension of the water supply and sewerage for 5 so-called extension districts (XX-XXV) started in October 1994 and were completed by the end of 1995. In two of these districts limited civil works were taken up (water distribution system and sewerage system) and completed by June 1996.

RADA WATER SUPPLY AND SANITATION PROJECT
CONTRACT 2 – CIVIL WORKS

PROGRESS BY PERIODS IN PERCENTAGE OF TOTAL PROGRESS



Nr. of Cert.	Date	Period	Progr.	Total Progr.	Perc.
1.	01. 04. 93	Apr 92 – March 93	34	34	14
2.	13. 05. 93	April	13	47	19
3.	29. 06. 93	May	10	57	24
4.	08. 07. 93	June	8	65	27
5.	10. 09. 93	July – August	11	76	31
6.	28. 11. 93	September	10	86	35
7.	01. 12. 93	October – Nov.	15	101	42
8.	16. 12. 93	01 Dec. – 15 Dec.	18	119	49
9.	30. 03. 94	16 Dec. – 28 Febr.	21	140	58
10.	24. 04. 94	March – April	11	151	62

Nr. of Cert.	Date	Period	Progr.	Total Progr.	Perc.
11.	19. 01. 95	21 April – 31 Dec.	7	158	65
12.	19. 03. 95	January – February	8	166	68
13.	17. 05. 95	March – April	16	182	75
14.	14. 06. 95	May	7	189	78
15.	15. 07. 95	June – 8 July	8	197	81
16.	09. 10. 95	9 July – August	12	209	86
17.	19. 11. 95	September – 15 Oct.	8	217	89
18.	xx. 01. 96	15 Oct – December	11	227	93
19.					
20.					

Total Contract Price: 244

Remarks: 1. The values of Progress and Total Progress are in million Yemeni Riyals.
Legend: ▌62 (2.0) Percentage of total progress and progress per month

4 APPROACH

4.1 General

The Rada Water Supply and Sanitation Project started as a follow-up of the Rada Urban Development Project. Aiming at improving the public health situation in the town by providing adequate solid waste disposal, water supply, sewerage/wastewater disposal and surface rainwater drainage facilities, designs for the physical works were prepared based on the requirements for the year 2010, when the population would have reached a level of around 75,000. Implementation of physical works, however, was limited to a first phase with the year 1995 as the design horizon, and focusing on the more central and urbanised part of the town (districts I-XII as shown on page 6). The number of people to be covered with facilities implemented under the project was thus 50,000.

First proposals for the type and capacity of facilities to be provided under the project, were given in the Inception Report (July 1988), and worked out in more detail in the Final Design Report (December 1989) while the proposed manner of implementation and required fund flows were given in the Plan of Operations that was submitted simultaneously with the Final Design Report. In the meantime the various technical options had been discussed with the Client and with Monitoring Missions fielded by the Netherlands Government.

Towards the conclusion of the physical implementation, i.e. from the end of 1994 onwards, technical training of NWSA Rada Branch staff was undertaken, and a comprehensive operation and maintenance (O&M) manual prepared for use by the Branch. No such manual was considered necessary for solid waste collection and disposal, the equipment for which had already been handed over by March 1994. For these activities, "hands-on" training was given in the period 1988-1992.

From October 1994 until the end of 1995 detailed designs were prepared for extension districts XX-XXV; construction of a part of the proposed works started in 1995, in extension areas XXIII and XXV. It was completed by June 1996.

4.2 Solid waste

The collection and disposal of solid waste in Rada has received attention from the very beginning of the project. Already during the DIP programme a successful waste collection and removal campaign was held, which resulted in the collection of 500 tonnes of waste within a period of 20 days. After collector trucks and waste containers had been procured, and a suitable landfill site for waste disposal identified, the solid waste activities were handed over to the Rada Municipality in March 1994.

Table 4-1 Basic data solid waste collection and disposal

Actual number of containers in Rada Urban Area	270	
Number of people served	40,000	
Served area (districts I - XII and part of districts XX - XXV)	315	ha
Total volume of garbage collected monthly	1,875	m^3
Volume of garbage collected per working day	73	m^3
Average volume of garbage collected per day	62.4	m^3

Table 4-1 Basic data solid waste collection and disposal (continued)

Weight of monthly collected garbage	375,000	kg
Weight of garbage collected per working day	14,600	kg
Average weight of garbage collected per day	12,500	kg
Average solid waste density	200	kg/m³
Average compaction grade	4.00	
Average weight collected per capita and per day	0.31	kg
Average volume collected per capita and per day	1.55	l
Design average weight produced per capita and per day	0.45	kg
Average weight of full truckload	9,000	kg
Full compactor truck rides per month	42	
Full compactor truck rides per working day	1.6	
Full compactor truck rides per day	1.4	
Average container handling time excluding landfill ride	2.0	min
Average container handling time including landfill ride	2.5	min
Average daily compactor time (2 compactors operating)	10	hrs
Present average distance of compactor per working day	36	km
Average container density in served area	0.9	containers/ha
People served by one container	130	people/cont.
Average walking distance to containers	30	m
Maximum walking distance for 80% of people	55	m
Average filling rate emptied containers	30	%
Average filling rate all containers	20	%

Details of the solid waste collection and disposal system are given in chapter 5.

4.3 Water supply

The new Rada water supply system is designed to serve an estimated 1995 population of 50,000 people. In a second phase, for which detailed designs have been prepared, but the implementation of which is not part of the project, the system should be extended to serve 75,000 people, being the projected 2010 population at an assumed population growth rate of 3% per year.

Table 4-2 Design features, water supply

No.	Design horizon (year)	Phase 1 1995	Phase 2 2010
1	Population[6]	50,000	75,000
2	Residential demand [litres per head per day]	50	70
3	Population served	95%	100%
4	Net residential demand [m³/day]	2,375	5,250
5	Non-residential demand in m³/day (= 10% of residential demand)	238	525
6	Net water demand - Sub-total	2,613	5,775
7	Maximum day demand (= 1.2 x average demand) [m³/day]	3,135	6,930
8	Unaccounted for water (=20% of maximum day demand)	627	1,386
9	Maximum day demand = Required production capacity	3,762	8,316

[6] 1988 population: 35,000

The design of the water supply system is based on NWSA criteria which allow a net per capita water consumption of 50 l/c/day in 1995, against 70 l/c/day in the year 2010. It has been envisaged that by 1995 95% of the population in the served areas will be connected to the system, to grow to 100% by the year 2010. Taking into account non-residential demands, peak demands and water losses (24% of the average daily demand), the water supply has been designed for a production capacity of 3,762 m³/day in 1995 and 8,316 m³/day in the year 2010.

The system, which is based on groundwater abstraction, has been set up in such a way that major components either have a capacity sufficient for Phase 2 (power supply, chlorination system, major parts of the trunk mains and distribution system) or can be duplicated to reach that capacity (wells, transmission main, reservoir chamber). The decision whether or not to adopt a construction in phases was taken on economic considerations.

So as not to disturb the day-to-day life in Rada unnecessarily, the construction of the water supply distribution system and sewer systems, which together account for a sizeable part of the civil works, was taken up in a phased manner, starting with the districts II and III, and subsequently the other districts. A total of 5 phases were therefore introduced, in such a way that the wastewater treatment plant would be operational at the end of Phase 4.

The water supply system is discussed in more detail in chapter 5. For technical details reference is made to the Final Design Report (December 1989) and the Operation and Maintenance Manual.

4.4 Sewerage/Wastewater treatment

Both the housing density in Rada and the adverse soil conditions render on-site sanitation unsuitable except for isolated cases. For that reason a central sewer system with wastewater treatment plant was selected. As was mentioned in the previous paragraph, a phased implementation of this system was decided upon, in combination with the water distribution system. Only in the outskirts and for stand-alone houses the use of septic tanks or soakaways has been assumed.

Table 4-3 Design features, sewerage

No.	Design horizon (year)	Phase 1 1995	Phase 2 2010
1	Population	50,000	75,000
2	Wastewater production as percentage of water consumption	80%	80%
3	Population connected to sewer system	85%	90%
4	Total average wastewater production [m³/day]	1,881	4,158
5	Pollution strength of wastewater[7]:		
	Biochemical Oxygen Demand (BOD)	1,136	812
	Kjeldahl Nitrogen (N_{KJ})	266	190
	Suspended solids (SS)	1,126	812

7 The absolute discharge of BOD, N_{KJ} and suspended solids per inhabitant is the same in both cases; the difference in strength is caused by the larger volume of wastewater discharged

During the design phase, several options for the treatment of wastewater have been investigated, including:

a. facultative ponds
b. anaerobic ponds in series with facultative ponds
c. upflow anaerobic sludge blanket filtration (UASB) reactors, in series with facultative ponds;
d. oxidation ditch
e. UASB reactors in series with oxidation ditch
f. preclarification followed by activated sludge treatment
g. preclarification followed by trickling filters

Of these, options a, d and e have been worked out in more detail. During discussions with representatives of the Client and the Netherlands Government, and based more on ease of operation than on cost aspects and effluent quality, option a (anaerobic pond - facultative pond) was finally selected.

The sewerage and wastewater disposal system is discussed in more detail in chapter 7. For technical details reference is made to the Final Design Report (December 1989) and the Operation and Maintenance Manual.

4.5 Stormwater drainage

The stormwater drainage system for Rada has been designed to allow stormwater to be collected and discharged, in a controlled manner, to allocated areas. Although the average rainfall in Rada is very low (around 200 mm/year) rain intensities can be extremely high. Before the start of the project the situation was such that after heavy rainfall, parts of the town were flooded for several days, sometimes weeks. After construction of the new drainage system, all water will have left the town after 2½ hours.

Several options for stormwater drainage have been compared:

- combined sewer system for foul water and stormwater
- separate stormwater drains (pipes)
- stormwater channels
- road pavement, shaped like a shallow V

Based on various parameters, which included cost, ease of maintenance (especially the danger of clogging of closed conduits) and traffic safety, the last option was selected. After discussions with the Ministry of Urban Planning and Housing, however, the road profile was changed to a "roof shape" (shallow inverted V). After new rainfall data had become available the computer modelling of the system was redone[8], using the new road profiles. Also the adjustments in road levels that followed from the optimisation of the sewer system design, and changes in the master planning of Rada were taken into account in the new calculations.

The stormwater drainage system is discussed in more detail in chapter 8. For technical details reference is made to the Final Design Report (December 1989).

[8] RWSSP, Final Design Report - Surface Rain Water Drainage Works (October 1993)

4.6 Environmental Health Education Programme

A programme that extends and improves the water supply situation only, will not necessarily lead to a significant decline in incidence rates of water-borne, water-washed and water-based diseases. Extended water supply increases the amount of waste water, which might result in the creation of more breeding places for water-related insect vectors and diseases caused by deficient sanitation.

A water supply project will thus generally not improve the public health situation unless the project is integrated with relevant public health facilities, such as solid waste collection and disposal, drainage and sewerage. This was realised from the onset of the project, which therefore was set up as an integrated one, involving water supply, sewerage, stormwater drainage and solid waste disposal, and started with a clean-up campaign as part of a Direct Improvement Programme. These activities were carried out in conjunction with health education programmes, in order to execute preventive strategies simultaneously with the acceptance of the facilities created. To that effect an Extension and Training Section was set up within the RWSSP organisation.

Main activities of the Extension and Training Section included:

- organisation of social hearings
- training of volunteers
- participation in the DIP (Direct Improvement Programme)
- collaboration with the Environmental Health Department of the MMH (Ministry of Municipalities and Housing)
- attendance to seminars and workshops
- religious teaching
- involvement of the primary schools
- involvement of the MCH (Mother & Child Health) clinic
- involvement of the Non-Formal Education Centre for Women
- production of TV spots
- involvement of scouting groups
- creation of an Information Centre

A more detailed description of the activities carried out by the Extension and Training Section of RWSSP is given in chapter 9.

Examples of information leaflets issued by Extension & Training Section

5 SOLID WASTE DISPOSAL

5.1 General set-up

Under RWSSP a system was set up, comparable to that in a number of other towns in Yemen, whereby containers with a volume of either 1 m^3 or 1.6 m^3 are distributed over the town, and emptied by container trucks. The collected waste is then dumped at a sanitary landfill site outside the town.

The various waste collection and disposal activities were as follows:

- implementation of a crash programme within the framework of the Direct Improvement Programme;
- selection and training of local operating staff;
- design of regular collection routings for compactor trucks;
- preparation of the selected landfill, and training of landfill staff;
- distribution of containers, immediately following after execution of crash programmes, and in accordance with designed routing;
- investigation into an appropriate additional waste collection system for three districts in the centre of Rada: Harat Al Hafrah, Harat Faqish and Harat Al Qata;
- making necessary road improvement;
- starting regular waste collection and disposal activities;
- monitoring of routing schedules and implementation of necessary adjustments.

During the crash programme on solid waste disposal that was carried out as part of the DIP, special attention was given to the depression areas, where garbage had been allowed to accumulate before:

- small depressions were cleared with the use of additional 1.6 m^3 containers, which were placed there temporarily and later redistributed over the district. A group of 5 - 10 sweepers was able to clean a depression area in two days or less;
- large depression areas were cleaned with the use of:
    - a suction truck,
    - a wheel loader or excavator with a small bucket,
    - tipper trucks,
    - a group of about 20 sweepers.

Regular garbage disposal services started on 3 November 1988, in the old suq area (15 containers). Services were extended to the new suq area (11 containers) and hospital (2 containers) by 23 November 1988, and subsequently over the entire town. The solid waste activities were handed over to the Rada Municipality in March 1994.

5.2 Collection system

5.2.1 Rolling stock

At the start of the RWSSP activities, the Rada Municipality had at its disposal 3 tipper trucks, a water sprayer suction vehicle and a wheel loader. After implementation of the solid waste programme in Rada, the rolling stock comprised:

- for solid waste collection and disposal:
  - 3 compactor trucks, of which 2 were in regular operation and the third stand-by
  - 1 skip truck
  - 4 pickups
  - 3 motorcycles
  - 1 bus
  - 2 holder tractors
- for maintenance of roads and surface drainage system:
  - 1 tipper truck
  - 1 tipper truck with crane
  - 1 grader
  - 1 bulldozer
  - 1 hydraulic excavator
  - 1 compactor roller
  - 1 backhoe loader

5.2.2 Collection system design

During the baseline survey in Rada it was found that the garbage is mostly brought to the containers by children, in small quantities. Usually a bucket (47%) or a small plastic bag that one gets in all shops (25%) are used to transport the waste. The storage facilities at the houses are also small, and usually consists of buckets and plastic bags as well.

The fact that these storage facilities are small and usually uncovered, also means that they will have to be emptied often. The general impression is, therefore, that garbage is brought often to the containers: once every day or every two days, or possibly twice a week, in portions at most equivalent to the production of one family. In the case of individual persons, small households, shops, etc., the storage facilities may be full after a longer period.

The new waste collection system was designed on the basis of the following parameters, numeric data on which was collected through monitoring the actual situation in Rada, as well as in other cities in Yemen: Sana'a, Dhamar, Hodeidah and a number of secondary cities:

- population data (population distribution and growth per district);
- relevant social data;
- number of containers in Rada, original siting, routing and collection procedures;
- topographical and physical data of Rada, including town structure, master planning aspects, status of the roads;
- produced garbage (weight and volume);
- filling rates of containers;
- container densities;
- walking distances;
- people served by 1 container;
- container handling times in different areas;
- compaction grades;
- average solid waste densities;
- number of truckloads per day;
- compactor truck times per day.

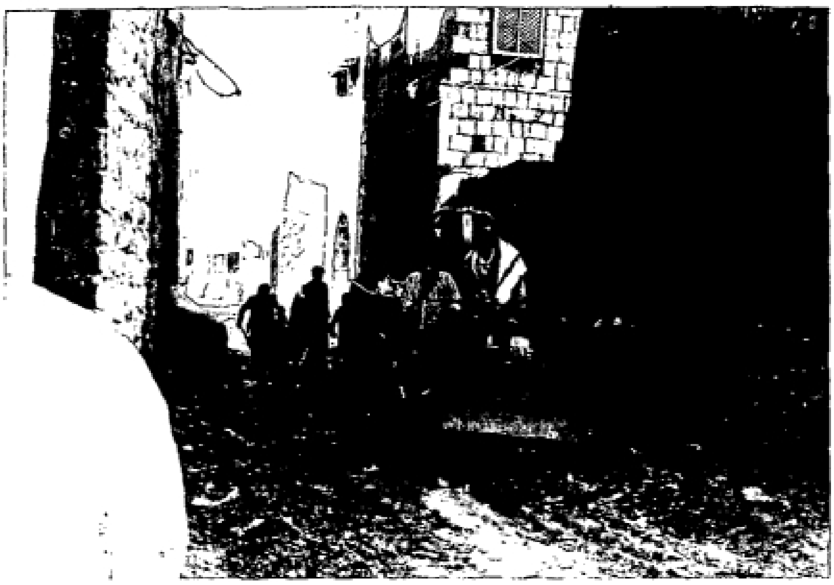
Statistical calculations and a computer simulation were used to determine the numbers and locations of containers, the frequency of emptying the containers that would be required to prevent overflowing of the containers, and the numbers and types of equipment to be used in waste collection. To that effect comparisons were made between compactor trucks, skip trucks, pickup cars and tipper trucks, taking into account their respective capacities and running costs. Finally a mix between these types of rolling stock was proposed, as indicated in paragraph 5.2.1. The results of the calculations are shown in Tables 5-1 and 5-2:

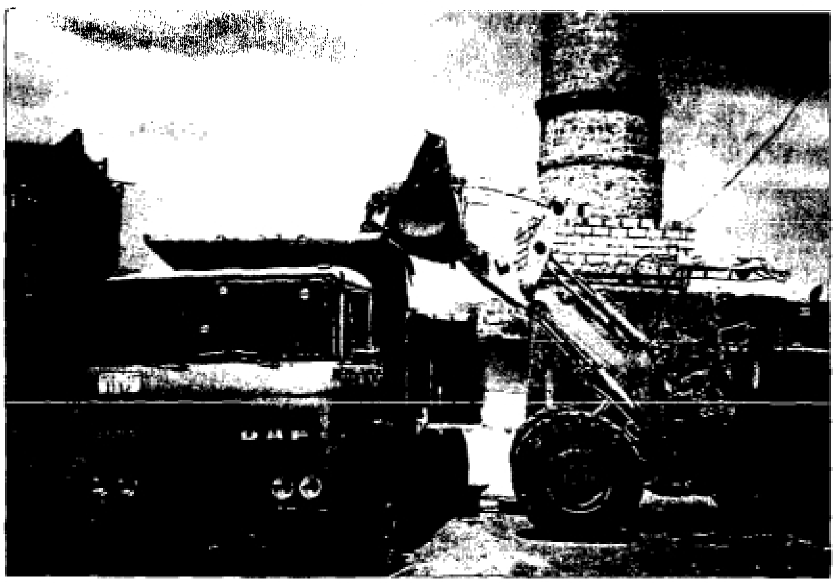
Table 5-1 Results of calculations/computer simulation, solid waste collection

Description	Districts		
	I - XII	XX - XXV	Total
Number of containers, 1.6 m^3	170	18	188
Number of containers, 1.0 m^3	105	36	141
Total number of containers	275	54	329
People served by one container	131	114	128
Fill rate, when collected 2 x per week [%]	75	75	75
Fill rate, when collected 3 x per week [%]	50	50	50
Container density [containers/ha]	1.2	0.2	0.6
Max. walking distance for 80% of the people served [m]	45	128	73
Average walking distance [m]	24	69	39
Compactor time [hrs/day]:			
2 x per week collection schedule	3.82	0.75	4.57
3 x per week collection schedule	5.73	1.13	6.85
Actual number of containers (per December 1992):			
1.6 m^3 containers	126	52	178
1.0 m^3 containers	64	24	88

Table 5-2 Data on collection system, based on 1992 data

District	Area	Garbage production	Number of containers			People per	Walking distance	
Number	[ha]	[kg/day]	1.0 m^3	1.6 m^3	Total	container	80%	Average
I	25.0	2,106	4	28	32	146	44	24
II	13.5	1,571	3	21	24	145	338	20
III	13.8	1,399	2	18	20	149	42	22
IV	19.8	1,413	1	20	21	150	49	26
V	8.5	1,561	0	23	23	151	30	16
VI	12.5	609	11	2	13	104	49	26
VII	20.9	1,410	7	18	25	134	46	25
VIII	18.4	1,120	7	12	19	131	49	27
IX	30.2	1,497	25	5	30	111	50	27
X	27.6	1,349	26	3	29	103	49	26
XI	18.7	815	19	0	19	95	50	27
XII	17.8	1,339	0	20	20	149	47	26
Sub-Total	227	16,230	105	170	275	131	45	24
XX	102.3	708	10	4	14	112	135	73
XXI	13.3	106	1	1	2	118	129	70
XXII	86.5	566	12	1	13	97	129	70
XXIII	44.2	354	4	3	7	112	126	68
XXIV	102.0	885	7	8	15	131	130	71
XXV	16.4	142	2	1	3	105	117	63
Sub-Total	365	2,761	36	18	54	114	128	69
TOTAL	591	18,991	141	188	329	128	73	39





top: holder tractor, for use in congested areas

centre: tipper truck being loaded by bulldozer

bottom: emptying compactor truck at solid waste disposal site

The facilities provided under the project are as follows:

- 2 compactor trucks, each serving half of the town, with a third truck as stand-by. The trucks empty containers on a daily basis, except Fridays, driving 30 - 40 km per day, of which 2 x 10 km is for driving to the landfill site and back;
- other rolling stock, as indicated in paragraph 5.2.1. The holder tractors are used especially in those areas where local conditions, such as narrow roads, prevent the use of regular compactor trucks;
- about 400 containers, of 1 m³ and 1.6 m³ volume; of these, 80 containers, located around the market and other special areas, are to be emptied daily, whereas the remaining ones are to be emptied 2 or 3 times per week.

Health education activities obviously remain necessary:

top: waste deposited not in but at the side of containers;

bottom: containers not deposited in the special waste container areas (see paragraph 8.4.2.3)

The garbage collection system is based on the premise that people throw their garbage in the containers. However, littering of streets and special places like markets is common, justifying a number of sweepers as well. As a general rule of thumb would be to have about one sweeper for every 1,000 inhabitants, as is the case in Sana'a, Aden, Dhamar and Sa'da. For Rada a group of 24 sweepers is considered sufficient, their main tasks being as follows:

- daily tasks:
    - sweeping of the central market
    - sweeping of other small markets
    - sweeping around the containers
- tasks to be performed twice a week:
    - sweeping of commercial areas
- tasks to be performed once a week:
    - sweeping of all roads
    - sweeping along with the Holder trucks in the less accessible areas

5.3 Disposal site

Before the start of the project, a number of sites outside Rada were used as garbage dumping places, with a major site along the Al Bayda road at about 4 km from Rada. As this site is located in the region earmarked for drinking water abstraction, it became necessary to identify a suitable sanitary landfill. Already during the inception period a survey was carried out, in close co-operation with the Rada Municipality, the Al Bayda Governorate and the Ministry of Municipalities and Housing, to establish the most suitable site for establishing a sanitary landfill.

A suitable landfill site was identified 9 km east of Rada, on the Rada - Al Bayda road, which has a sufficient capacity for the next 20 years.

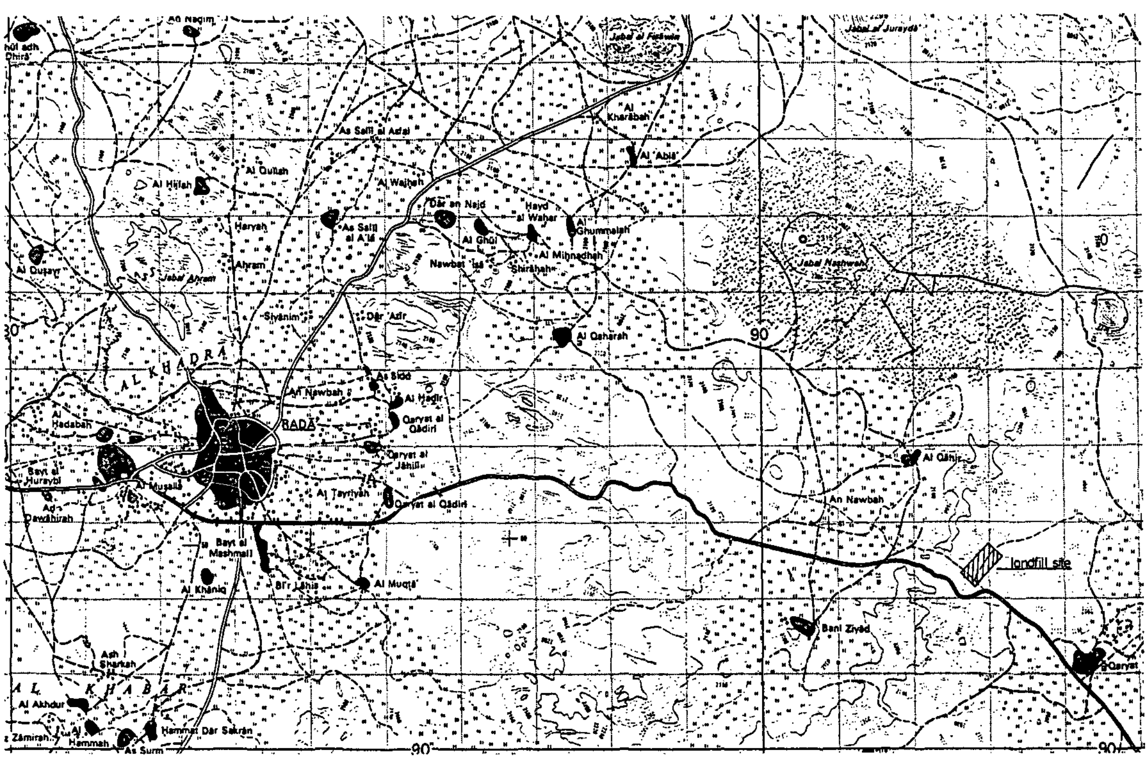


Fig. 5.1 Location of landfill site

5.4 Operational issues

Limiting conditions for the success of solid waste collection and disposal in Rada have been:

- poor road status for most of the duration of the project, made worse by the excavation works for the water distribution and sewer systems. Only with the completion of the stormwater drainage system a major restructuring of the roads in the town was accomplished;
- physical situation in Rada: traffic and other obstacles, making access by compactor trucks difficult or even impossible;
- weak organisation and administrative set-up of the waste collection and disposal services under the Rada Municipality;
- (lack of) social behaviour of the people;
- social patterns of work force, motivation;
- available heavy equipment, its performance and specifications;
- available containers;
- financial means.

One particular problem that needs to be faced by the Municipality in relation to waste disposal, is the matter of special waste types, such as:

- ***hospital waste***, such as old medicines, syringes, pathological and infectious material, which is collected by compactor trucks and mixed with ordinary household waste, thus presenting a health risk especially for the compactor truck labourers. It is essential that this waste be dealt with adequately, either by direct combustion or by land filling at a separate spot, with direct backfilling. In the latter case the hospital waste needs to be collected at the hospital and packed in special-quality plastic bags;
- ***slaughter waste:*** in the absence of appropriate slaughtering facilities, animals are slaughtered in an unhygienic manner, with dogs eating from the waste meat and spreading the bones. The liquid waste is absorbed by the ground, whereas the solid waste component is simply dumped. In this manner the dogs can also act as carriers of dangerous parasites that can also affect human beings. The only effective remedy against this situation is the construction of a slaughterhouse, which by itself may be a profitable undertaking, as well as a service whereby the slaughter waste is collected in 5 m^3 containers, and daily removed to the landfill site where it is covered right away;
- ***oil waste*** from private workshops is often stored and later sold for heating, to cement block factories or to grease wooden casings. The major part is thus recycled. Nevertheless the soil at some petrol stations appears to be heavily polluted, although no details are available. It has been recommended to place a big tank near the municipal workshop into which waste oil could be disposed of;
- ***car wrecks.*** Facilities for the removal of car wrecks are not available, so that wrecks are scattered over town. It has been proposed that these wrecks are removed to a certain part of the landfill, which is already used for a limited number of cars, using the skip loader and dump truck.

Especially the weak organisational structure and lack of qualified staff, aggravated/caused by a lack of funds, have continued to plague the solid waste collection and road maintenance activities of the Rada Municipality. In spite of the repeatedly expressed readiness of the RWSSP to provide material and institutional support, the apparent inability of the Municipality to arrange for adequate organisational, administrative and financial conditions has caused the results of the solid waste activities to remain disappointing.

In general there has been a lack of planning and effective management throughout the organisation, there has not been an adequate monitoring or processing and analysis of available data, along with insufficient supervision of workers. In addition, there has been no generation of income whatsoever, neither through a solid waste tariff system, nor through a system of fines for illegal dumping and misuse of containers, except for a general contribution by shops and restaurants, which pay a yearly fee.

Although it might be assumed that everybody is aware of the existence of the solid waste collection and disposal system, there is still no optimal use of containers. Much garbage is still thrown beside containers, at local dump sites and in depressions. The fact that waste collection has not been functioning adequately will have contributed to this phenomenon, thus obstructing the considerable progress that had been made earlier in educating and informing the population. Garbage disposal apparently continues to have a low priority in the minds of the Rada population, as compared with other services such as water and electricity.

6 WATER SUPPLY

6.1 Lay-out

The water supply system for the Rada Urban Area comprises the following elements:

a. well field
b. collector/transmission main
c. chlorination installation
d. storage reservoir
e. transmission and distribution system

Their lay-out is shown schematically in Fig. 6-1; a piping and instrumentation diagram of the water supply system is shown in Fig. 6-2.

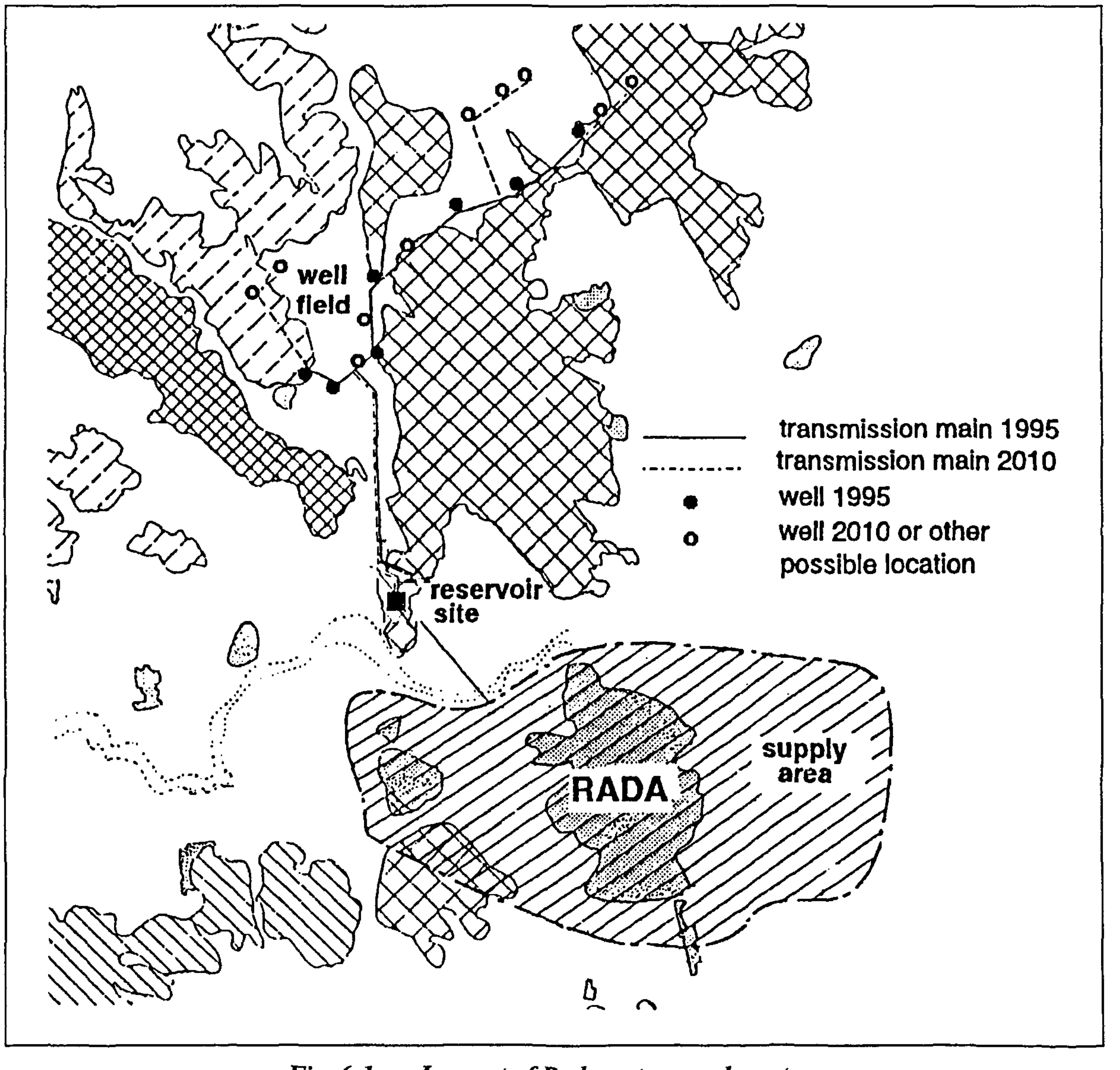


Fig. 6-1 Lay-out of Rada water supply system

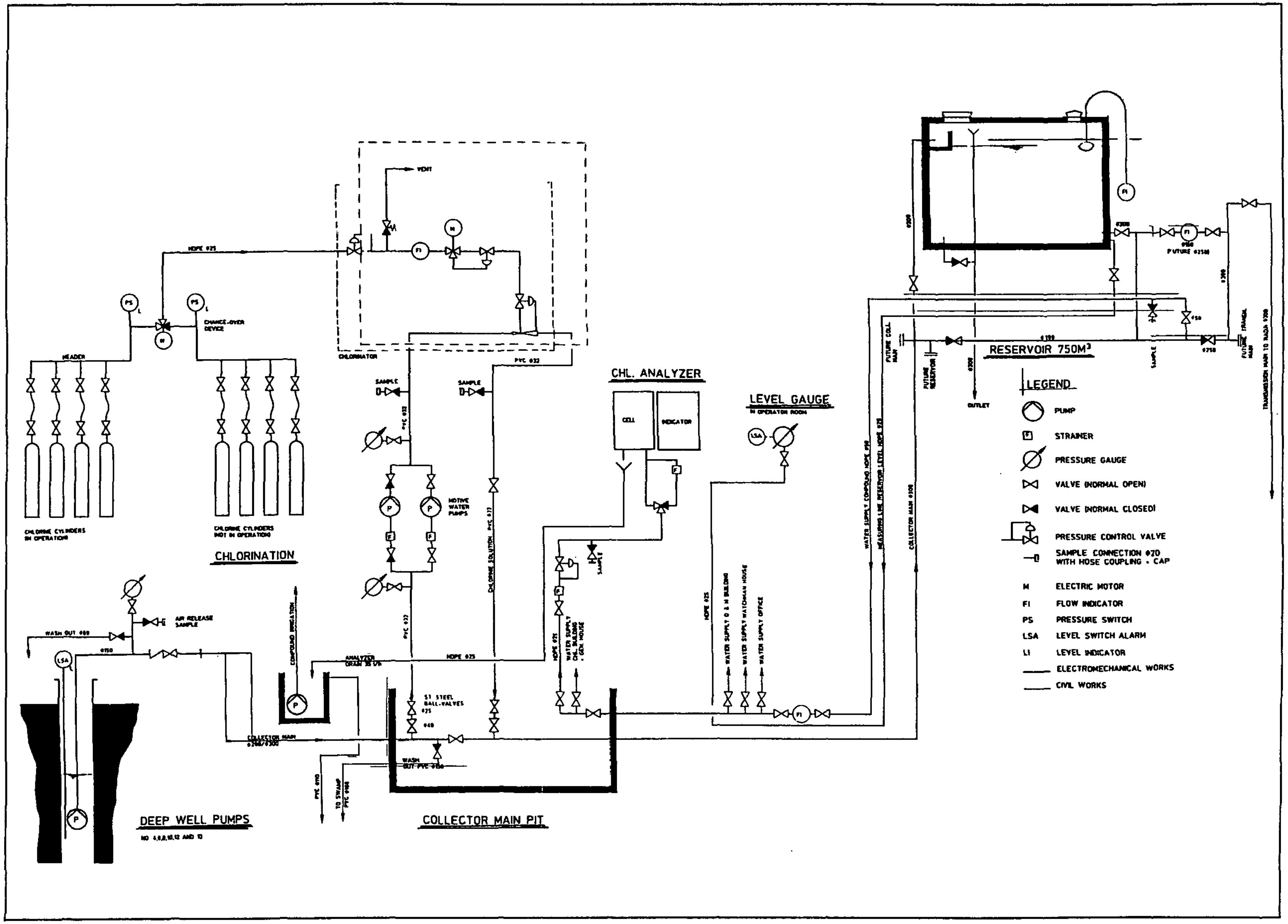


Fig. 6-2 Piping and instrumentation diagram of Rada water supply system

A total of 6 deepwells (5 production wells and 1 stand-by) pump water from a well field north of Rada (about 0.8 km north of Qaryat Al Hadabah) to a storage reservoir located at an elevated site immediately north of the built-up area of Rada. Just upstream of the reservoir gaseous chlorine is added to the water in the transmission main at the so-called NWSA site, as a safety disinfection measure. At the NWSA site, which is located at the foot of the elevated reservoir area, also the NWSA offices and generator house are located.

From the reservoir the water gravitates to the distribution system, which is laid out as a looped network, with one loop per district. Within each district loop there is a secondary and tertiary distribution system, which are fed through two or more district meters. The lay-out of the distribution system is such that volumetric checks of water flows can easily be accommodated, thus allowing for an adequate water loss reduction/prevention programme.

The entire water supply distribution network is based on private connections provided with house water meters; there are no public taps. For fire fighting, flushing and cleaning, and for O&M purposes, 18 fire hydrants have been incorporated in the distribution system.

6.2 Water demand

6.2.1 Basic water demand

The water supply system has been designed in accordance with the population forecast for the year 2010 (see Table 2-1) and the parameters mentioned in Table 4-2 (*Design features, water supply*). The basic water demand thus includes net domestic demand, non-domestic demand (taken as 10% of domestic demand) and unaccounted for water (taken at 20% of net consumption on the maximum day). The maximum day factor, which is an indication for seasonal fluctuations in water consumption, is taken as 1.2 (on the day with maximum consumption the water consumption is 20% higher than the yearly average).

Total water demand for the years 1995 and 2010 is given in Table 6-1; the projected water demands per district are given in Table 6-2. The demand per district is given for the year 2010 only, as both distribution and reticulation systems in the districts are built directly for the ultimate (2010) demand.

Table 6-1 Total water demand

Year:	1995			2010		
	[m^3/day]	[m^3/h]	[l/s]	[m^3/day]	[m^3/h]	[l/s]
Average total consumption	2,613	109	30.2	5,775	241	66.8
UFW	627	26	7.3	1,386	58	16.0
Total average day demand	3,240	135	37.5	7,161	299	82.8
Maximum day consumption	3,135	131	36.3	6,930	289	80.2
UFW	627	26	7.3	1,386	58	16.0
Total maximum day demand	3,762	157	43.6	8,316	347	96.2
Maximum hour demand		244	67.7		539	150.0

Table 6-2 Water demand per district in the year 2010

District No.	Population	Average consumption [m3/h]	Max. day consumption [m3/h]	Leakage	Max. day demand [m3/h]	Peak demand [m3/h]
I	6,500	20.9	25.0	5.0	30.0	46.7
II	4,000	12.8	15.4	3.1	18.5	28.7
III	3,400	10.9	13.1	2.6	15.7	24.4
IV	3,600	11.6	13.9	2.8	16.6	25.9
V	3,650	11.7	14.1	2.8	16.9	26.2
VI	1,550	5.0	6.0	1.2	7.2	11.1
VII	3,850	12.4	14.8	3.0	17.8	27.7
VIII	3,050	9.8	11.7	2.3	14.1	21.9
IX	5,000	16.0	19.3	3.9	23.1	35.9
X	5,450	17.5	21.0	4.2	25.2	39.2
XI	4,100	13.2	15.8	3.2	18.9	29.5
XII	3,400	10.9	13.1	2.6	15.7	24.4
XX	7,000	22.5	27.0	5.4	32.3	50.3
XXI	1,050	3.4	4.0	0.8	4.9	7.5
XXII	5,600	18.0	21.6	4.3	25.9	40.2
XXIII	3,600	11.6	13.9	2.8	16.6	25.9
XXIV	8,800	28.2	33.9	6.8	40.7	63.2
XXV	1,400	4.5	5.4	1.1	6.5	10.1
Total:	75,000	240.6	288.8	57.8	346.5	539.0

6.2.2 Fluctuations in demand

Fluctuations in water demand occur as the result of seasonal changes in water consumption, and as the result of the daily pattern of life, where bathing, food preparation, laundry etc. each have their influence on the water consumption. Whereas the influence of seasonal fluctuations is relatively small, as expressed in the maximum day factor of 1.2, the fluctuations during the day are more pronounced:

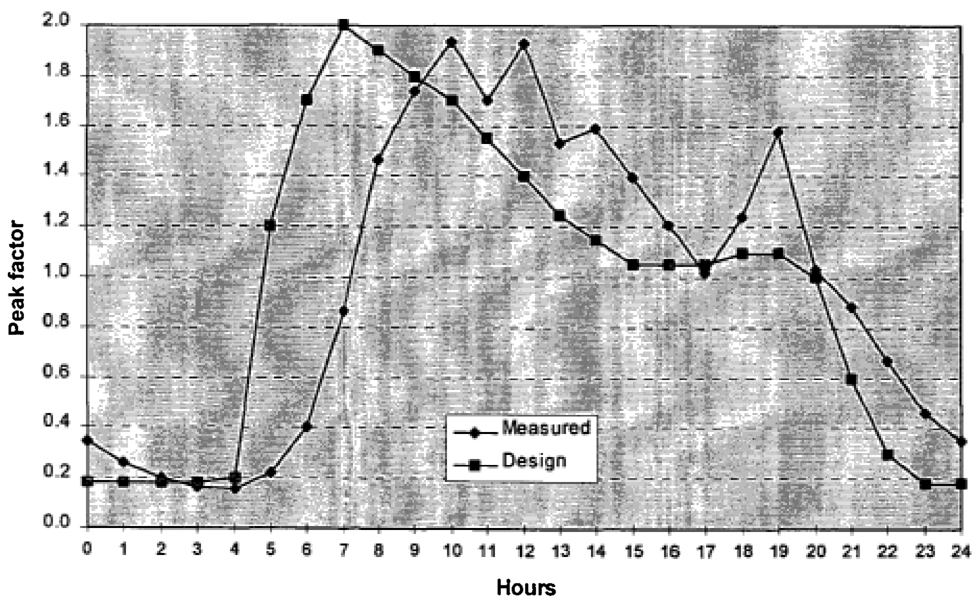


Fig. 6-3 Variations in water demand over the day

For the design of the Rada system demand fluctuations during the day were assumed on the basis of experience in other, comparable countries, as no reliable information was available for towns in Yemen: there was simply no town at the time where 24-hour supply of water without restrictions was taking place. To check the assumptions on demand variations, as soon as the new distribution system was operating normally, the hourly variation in water consumption was established by reading the bulk water meter at the reservoir site. Both the demand fluctuations used in the design and those actually measured in the course of 1996, are shown in Fig. 6-3. As can be seen from this figure there is a good correlation between the assumed and actual variations, although in practice the peaks in consumption appear later than assumed, and with a clearer peak in the late afternoon.

In the design of the water supply system the production and treatment units, inclusive of the transmission system up to the reservoir, are based on the maximum day demand, i.e. the demand on the day with maximum water consumption in a year. Any differences between supply and demand caused by the variations in water consumption during the day are levelled out by the storage capacity of the reservoir; from the reservoir to the town the maximum instantaneous water demand must be accommodated by the system. For this reason both the reservoir and the transmission and distribution system downstream of it are designed for the maximum hour demand during the maximum day (peak demand as indicated in Table 6-2).

6.3 Water sources

6.3.1 Selection of water source

A detailed description of the hydrology and the water resources of the Rada Basin is presented in the water resources study of Al Bayda Province by Ilaco, 1984. According to this study the main aquifers in the area are formed by the Cretaceous Tawilah sandstone in the east and north of the Rada catchment, and the overlying Tertiary and Quaternary volcanic rocks in the south and west of the area. In the vicinity of Rada no feasible streams are found, and springs – although several can be found in the surroundings – are no realistic alternative for public water supply either. Deep groundwater was, therefore, the only feasible option.

Two potential locations for well fields exist near Rada, north and south of the town, respectively. On the basis of a groundwater study carried out in 1983/84 by the Rada Integrated Rural Development Project the northern site was selected. Reasons for that were the lower irrigation activity in the north, and the main groundwater flow being from the Northwest to the Southeast.

Because of the complicated groundwater situation in the Rada Basin, in 1986 a groundwater model study was carried out by RIRDP[9] in order to:
- determine the groundwater potential of the area;
- make credible forecasts of water levels under different exploitation scenarios, to find the optimum abstraction regime;
- use it as a water management tool for determining the effect of different abstraction scenarios on the groundwater table.

The Rada catchment and model area are shown in Fig. 6.4:

9 see "Ground water model of the Rada Basin", Ilaco, 1990

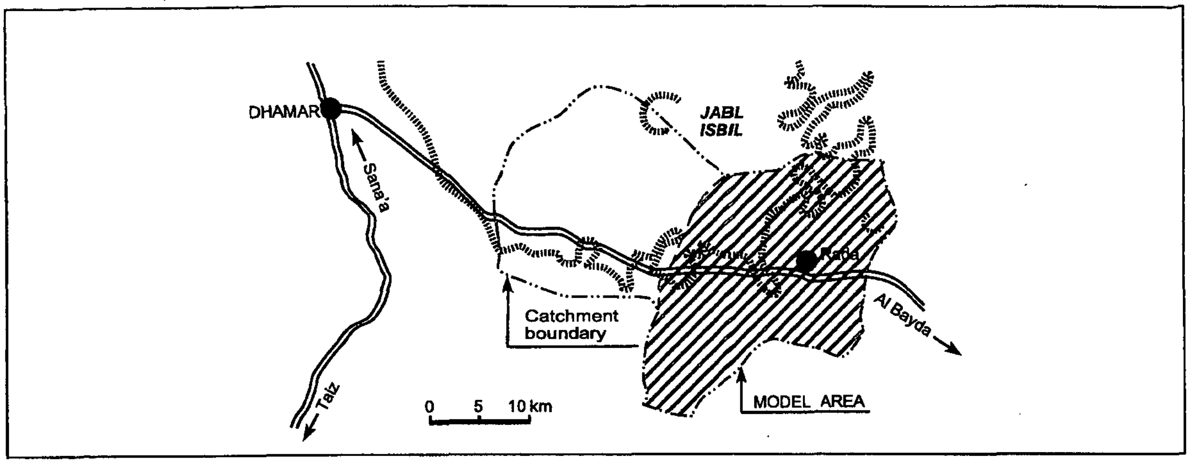


Fig. 6-4 Rada catchment and model area

After the model had been calibrated, planning runs were made under different scenarios: autonomous development, extra abstraction for the water supply of Rada, and reduction of the private abstraction. It was shown that when the abstraction continues uncontrolled, the aquifers in a large part of the area will be depleted in the course of time, with brackish water starting to flow in the direction of the central area around Rada, as shown in Fig. 6.5:

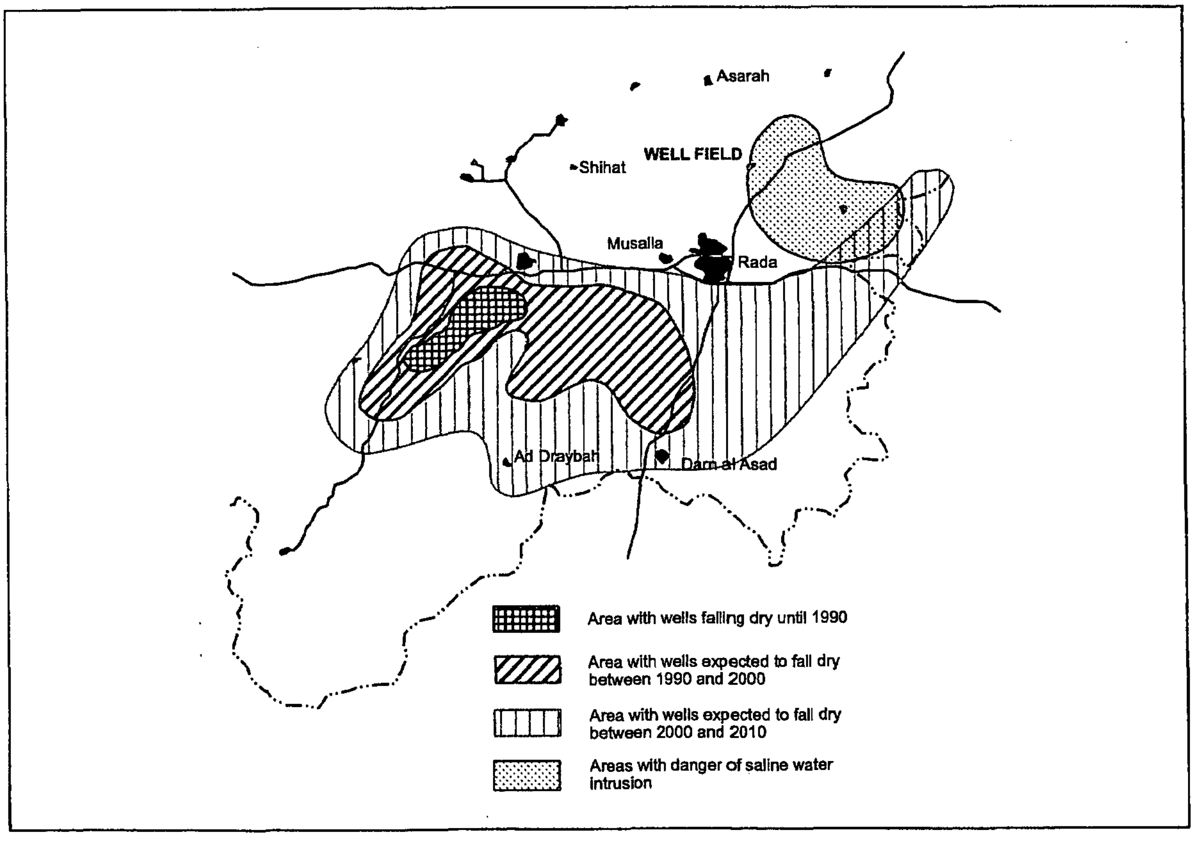


Fig. 6.5 Endangered area for groundwater depletion and saline water intrusion

The model indicated, however, that the area selected for the new well field would be secure for the coming decades, with an extra drop in water level in the order of 20 m in the well field itself.

Fig. 6.6 shows the basic fall in water levels between 1994 and 2010, without the influence of abstracting water from the new well field; the influence of the latter is shown in Fig. 6.7.

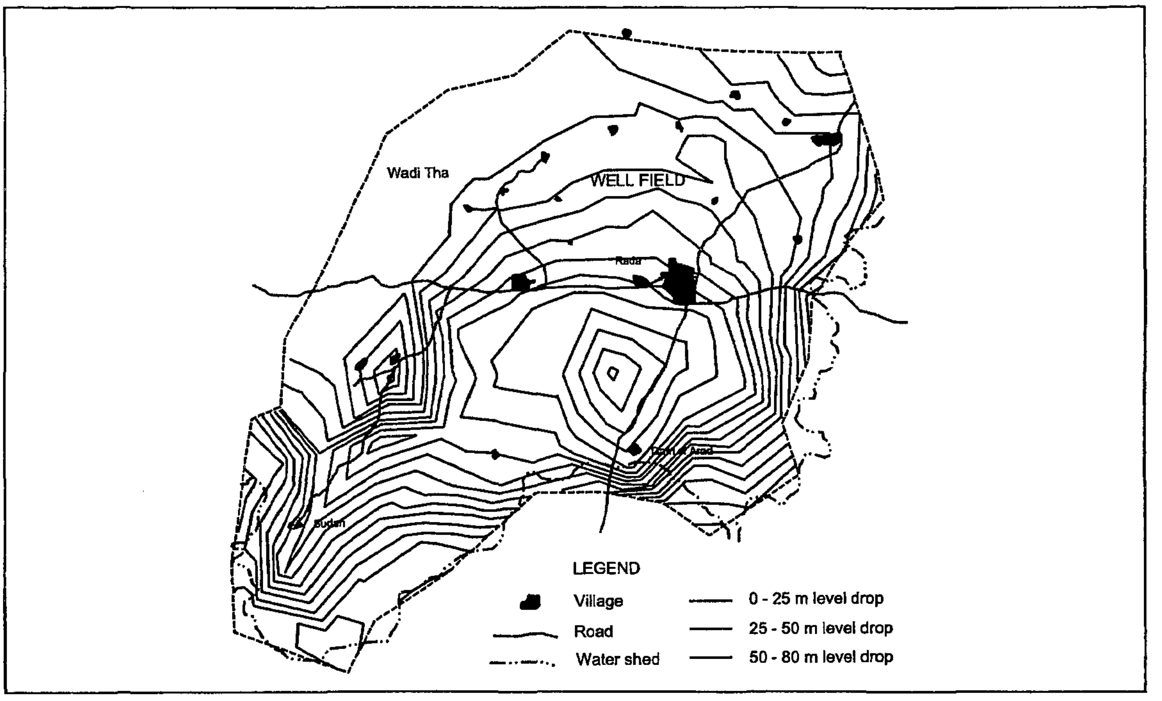


Fig. 6.6 Fall of water level in the Rada basin between 1994 and 2010, excl. well field

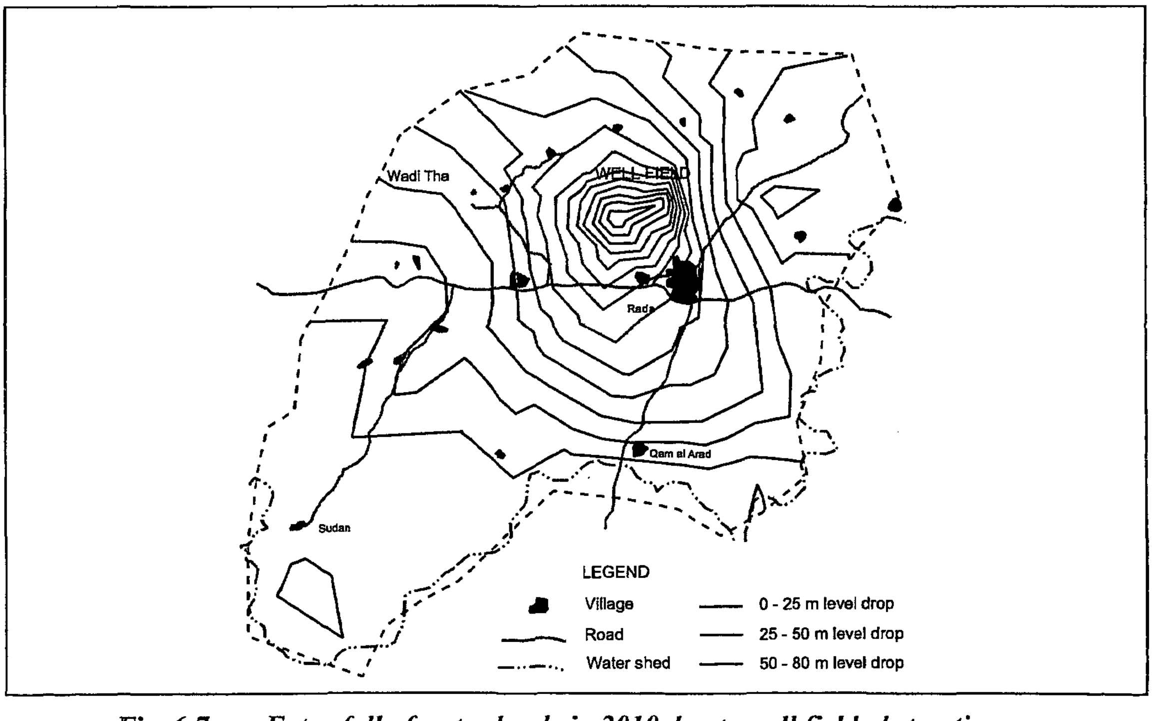


Fig. 6.7 Extra fall of water levels in 2010 due to well field abstraction

Drilling rig and crew on site

Lowering of submersible pump

Submersible pump and riser pipe assembled, ready for lowering in borehole

6.3.2 Boreholes

The well field is located approximately 800 m north of Qaryat Al Habadah, the north-western-most part of the Rada Urban Area. A detailed site investigation, including an electro-magnetic survey and geo-electric soundings, was carried out in 1988, indicating 18 suitable sites on fracture zones and dikes[10]. Disregarding sites that would be too close together, a total of 12 sites remain, as shown in Fig. 6.8:

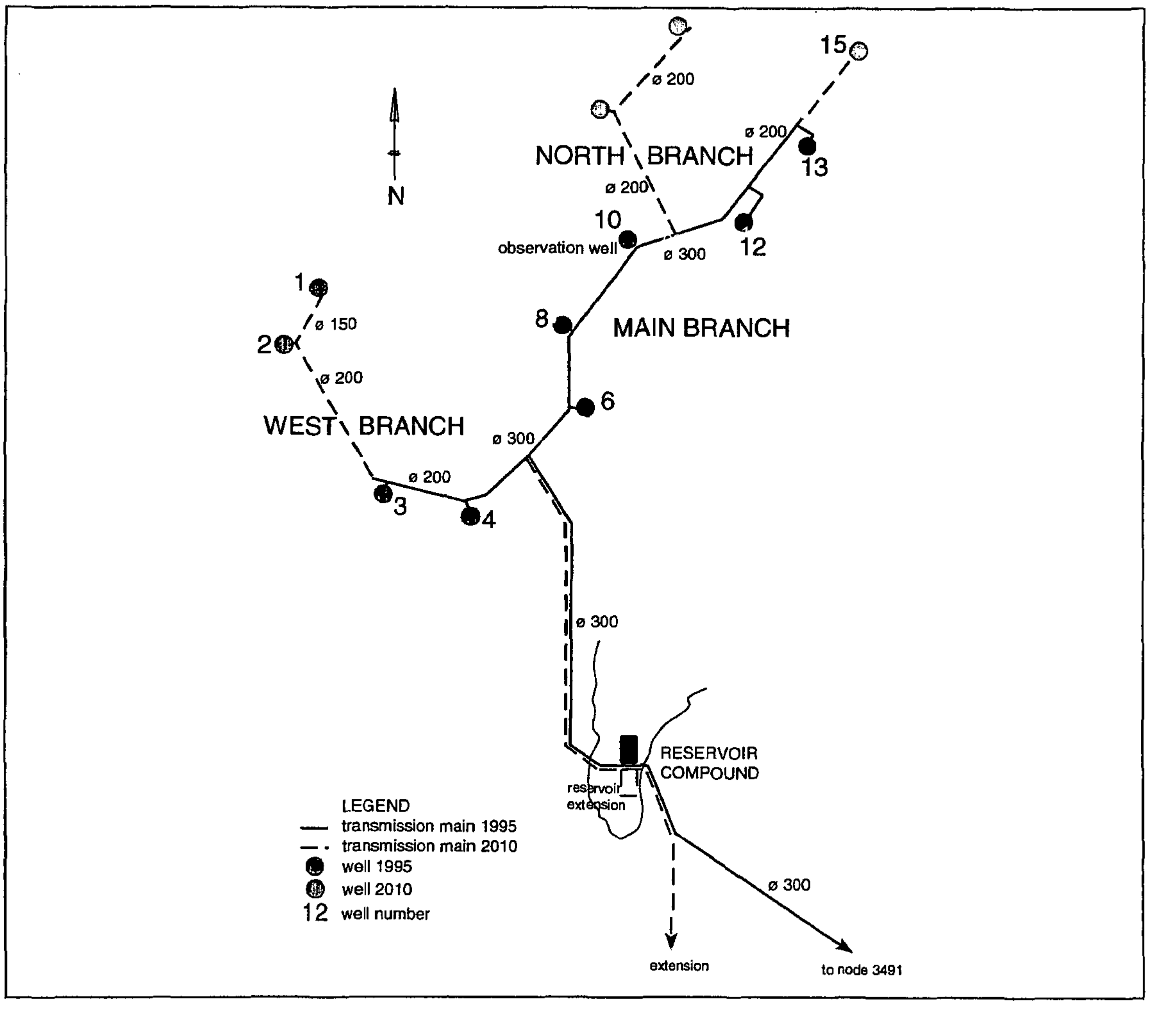
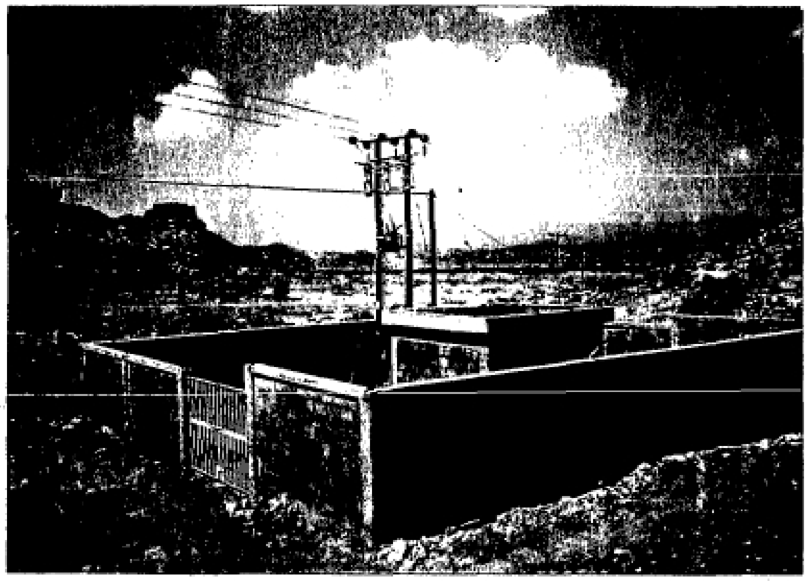


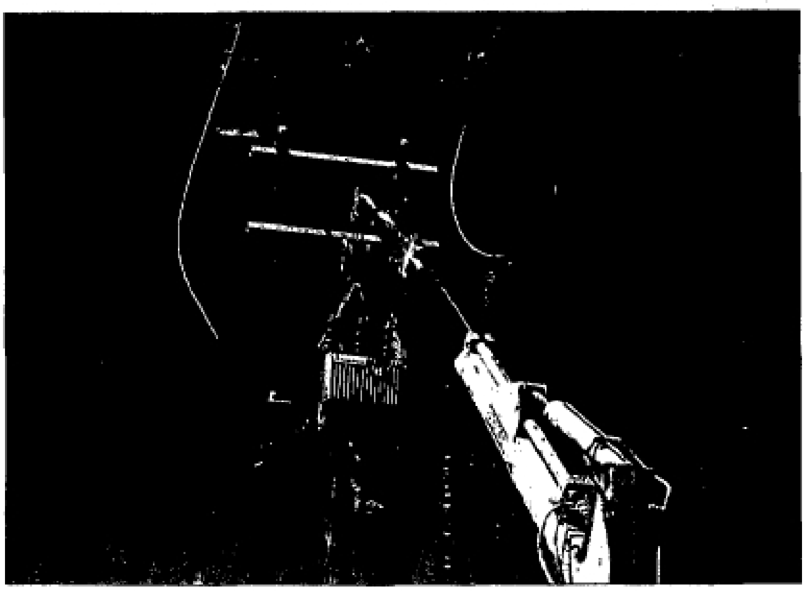
Fig. 6.8 Lay-out of well field (schematic)

The required source capacity is 43.6 l/s for Phase 1 (1995) and 96.2 l/s for Phase 2 (2010). With an average long-term capacity of about 10 l/s per borehole and some stand-by capacity, at least 6 deepwells are required for Phase 1 and 11 for Phase 2.

For Phase 1 boreholes have been drilled at 7 locations, in the following order: 13, 10, 6, 4, 8, 12 and 3, in the period June-November 1992. Of these boreholes one (No. 10) has a low yield, and is therefore used as an observation well; the other 6 are used as production wells.

10 Report on the site selection for drilling boreholes for the water supply of Rada Urban Area, November 1988





top: construction of pump house

centre: completed well with boundary wall

bottom: fitting pole-mounted transformer at well site

Table 6-3 Design data deepwells

Design data	Deepwell No.					
	3	4	6	8	12	13
Period of construction: start	29/10/92	08/09/92	09/08/92	22/09/92	06/10/92	04/06/92
finish	11/11/92	08/10/92	18/09/92	27/10/92	06/11/92	14/08/92
X co-ordinate	418.20	667.00	1002.20	984.50	1682.70	1986.80
Y co-ordinate	6670.10	6539.30	6740.20	7264.40	7713.80	8056.90
Surface elevation [m + MSL]	2145.55	2144.28	2150.19	2158.17	2177.00	2170.00
Total drilling depth [m]	165	162	226	210	204	198
Casing/screen diameter [inches]	12	12	12	12	12	12
Bottom of casing [m - GL]	162.00	157.00	220.00	205.60	200.00	190.00
Total screen length [m]	62.20	58.00	52.20	92.80	81.20	34.80
Gravel pack: top [m - GL]	25	48	80	37	60	34
bottom [m - GL]	165	157	220	210	203	198
Static water level [m - GL]	19.55	17.20	20.40	28.50	70.12	63.52
Step draw-down test duration [minutes]	4 x 60	4 x 60	4 x 60	4 x 60	4 x 60	4 x 60
Constant discharge test duration [min]	3000	3000	3000	3000	3000	3000
Draw-down [m] at production of 10 l/s	1.63	1.34	50.06	13.23	0.20	0.75
Maximum well capacity [l/s][11]	111	61	12.5	28	44	62

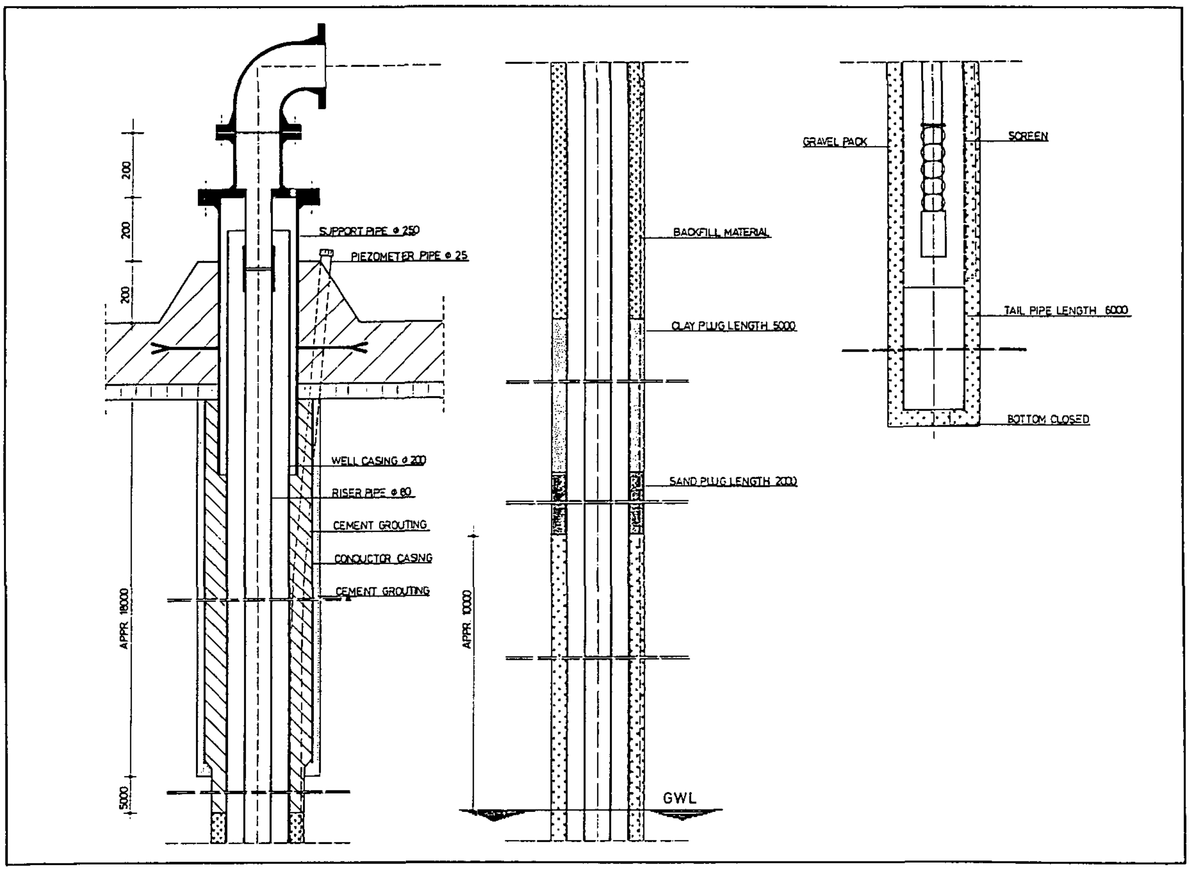


Fig. 6.9 Typical deepwell details

11 Defined at a draw-down of 100 m; the casing diameter (and power supply) restrict the actual maximum well capacity to considerably lower values

Table 6-3 illustrates that there are considerable differences in yield between the deepwells, as shown by the (theoretical) maximum well capacities in the bottom row. Well 3 has the highest potential, followed by wells 4 and 13, next well 12 and finally wells 8 and 6.

The standard deepwell diameter is 16 inch (Ø 400 mm) over the top 18 m; below that the diameter is 12 inch (Ø 300 mm). The top of each deepwell is provided with a 14 inch (Ø 350 mm) conductor casing over approximately 15 m, whereas the actual casing pipe and well screen have a diameter of 8 inch (Ø 200 mm). The annular openings between the conductor casing and the soil, and between the conductor casing and the regular casing have been filled with cement grouting. A gravel pack has been placed up to 10 m above groundwater level; on top of it a sand plug of 2 m length and a clay plug of 5 m length have been placed. Each deepwell is provided with a Ø 25 mm piezometer pipe. Unfortunately, due to vandalism several piezometers have meanwhile become clogged and rendered useless.

All deepwells are provided with 16-stage Grundfos SP 45-16 electric submersible pumps, which have a rated capacity of 36 m^3/h at 120 m head each. They are fed by an 11 kV overhead line from the NWSA compound (see paragraph 6.5).

Each deepwell pump unit hangs free in the well casing, supported by the well head and connected by 3 inch galvanised steel riser pipe. The well head is located just outside the deepwell pump house, to facilitate easy removal of the deepwell pump by means of a tripod or truck-mounted hoist.

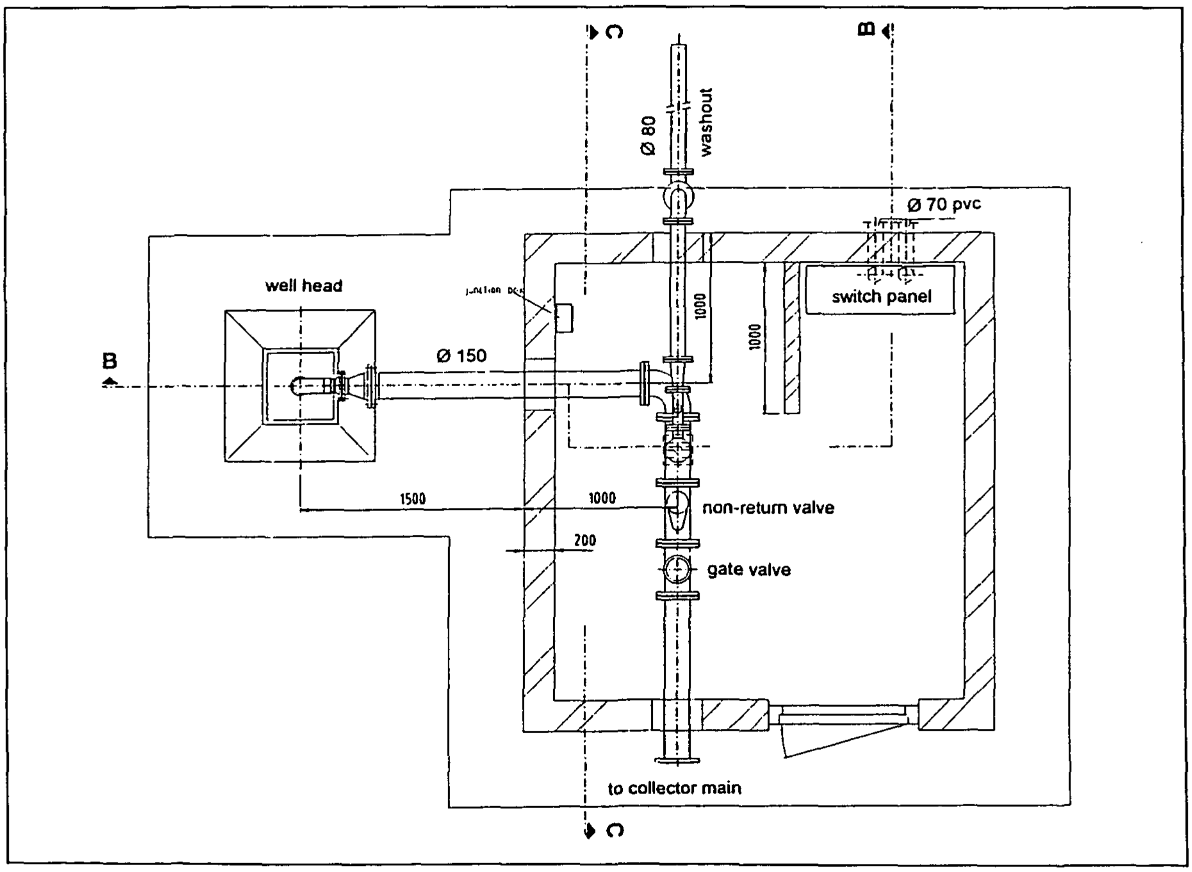
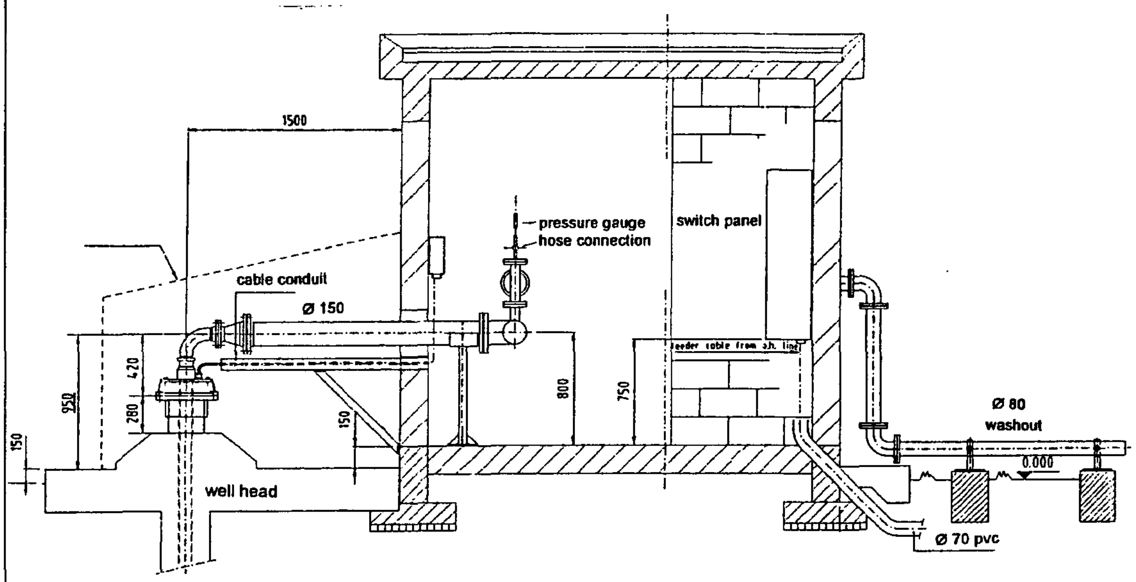
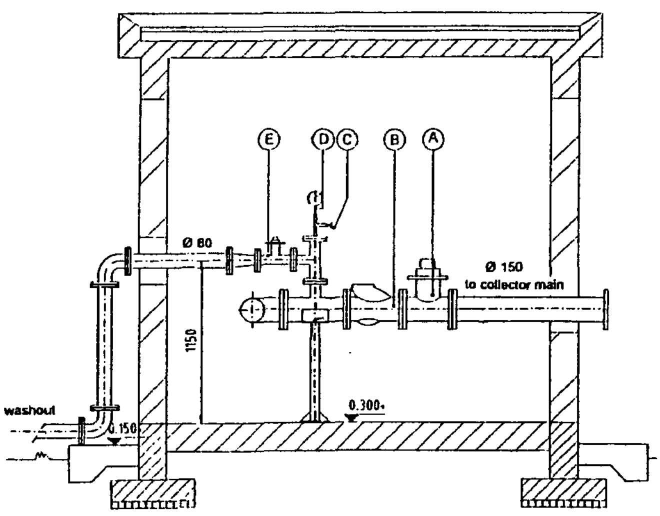


Fig. 6.10 Plan of deepwell pump house



CROSS SECTION B - B

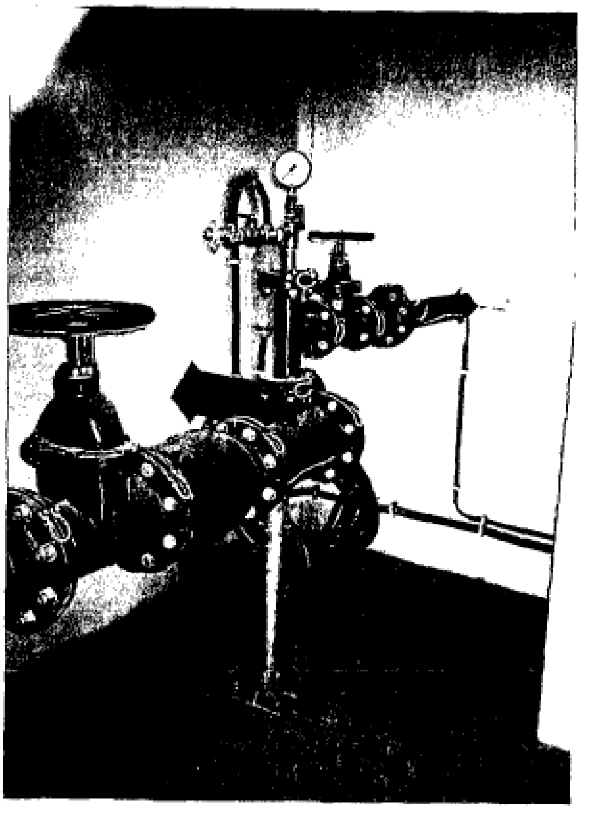


A gate valve Ø 150 (valve No. 1)
B non-return valve
C air release valve/ sample cock with 1" hose coupling
D pressure gauge
E gate valve Ø 50 (valve No. 2)

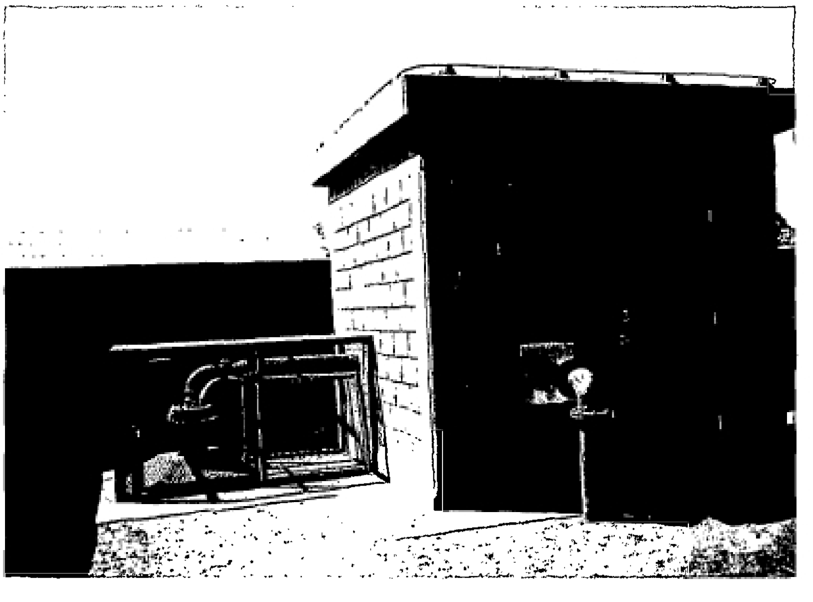
CROSS SECTION C - C

Fig. 6.11 Deepwell pump house, sections

Switch panel inside pump house



Piping inside pump house



Well house No. 13, with well head in protective casing at left

Inside the pump house there is a switch panel for local control of the pump (which is normally remotely controlled from the operation room at the NWSA compound), a wash-out, non-return valve and gate valve for operating the wash-out. A Ø 150 discharge pipe runs underground to connect to the collector main. A valve in the discharge pipe allows the connection between the borehole and the collector main to be shut off. Details are given in Fig. 6-10 (plan of deepwell pump house) and 6-11 (sections).

A comparison between static water levels measured in the deepwells in the period August-November 1992 and in March 1994 is given in Table 6-4. Except for well No. 3 where flush water from the collector main had infiltrated into the well, all wells show a lowering of the water level by several metres, as predicted in the model study.

Table 6-4 Static well water levels

Static water level[12]	Deepwell No.					
	3	4	6	8	12	13
Measured in August-November 1992	21.85	17.45	20.55	29.28	70.27	63.67
Measured in March 1994	20.3	21.7	25.0	32.0	73.0	66.7

6.3.3 Groundwater quality

Samples of the groundwater were taken from the boreholes at the end of the long duration pump test of 3000 minutes and analysed in Sana'a. The results of these analyses are indicated in the columns '1992' in Table 6-5. The first analysis, for borehole 13, was done at the Water Laboratory of the Ministry of Electricity and Water, whereas the other analyses were done at the NWSA Laboratory. The analysis for borehole 13 was considered unreliable[13], so that no analysis results for 1992 are given for this borehole. The general conclusion of the analysis done in 1992 was that the over-all chemical composition of the water from the production wells is acceptable for drinking water, except possibly for the fluoride content which is slightly too high in individual wells. The average fluoride content for the Rada water supply was 1.06 mg/l or well below the maximum recommended concentration of 1.5 mg/l, however.

In October 1996 most of the analyses were repeated by a laboratory expert from NWSA Head Office, using Hach equipment available at the NWSA Branch office in Rada. These results are listed in the columns '1996' of Table 6-5.

A comparison of the results from 1992 with those from October 1996 shows that in general the results are similar, with a few notable exceptions:

- for well No. 4 the sulphate and fluoride results are quite different. As the area is generally rich in fluoride, and the 1992 data were also quite different from those in the nearby well No. 3, it is likely that the 1992 analysis was not correct;
- for well No. 6 also different sulphate and fluoride results were obtained. For the same reasons as given above, it is assumed that the 1992 results are not correct;

12 measured from top of piezometer pipe

13 See "Final Report Well Drilling Works and Pumping Tests", paragraph 6.2, page105, RWSSP, August 1993

- for wells Nos. 8 and 12 no explanation can be given for the differences in EC between 1992 an 1996. Possibly no temperature correction was applied in 1992, whereas in 1996 the EC was calculated at 25°C.

Table 6-5 Water quality of deepwells in well field

Groundwater quality	Deepwell No.											
	3		4		6		8		12		13	
Sampling	1992	1996	1992	1996	1992	1996	1992	1996	1992	1996	1992	1996
Hardness [mg/l $CaCO_3$]	277	257	280	260	269	266	256	256	248	245	-	257
Electr. cond. [µS/cm]	838	867	845	864	847	882	788	875	829	901	-	894
T.D.S. [mg/l]	545	563	549	561	551	573	512	568	539	585	-	581
Turbidity [FTU]	-	1	-	0	-	0	-	0	-	-	-	-
Alkalinity [mg/l $CaCO_3$]	240	220	236	219	236	235	232	226	228	214	-	223
Bicarbonates [HCO_3^-]	293	268	288	267	288	287	283	278	278	261	-	272
pH	7.43	-	7.25	-	7.13	-	7.12	-	7.40	-	-	-
Aggressivity [SI]	0.39	-	0.21	-	0.11	-	0.14	-	0.43	-	-	-
Ca^{2+} [mg/l]	65.7	62.4	68.9	61.6	71.0	65.2	64.0	58	59.3	60.8	-	61.2
Mg^{2+} [mg/l]	27.6	24.5	26.2	25.8	22.3	25	23.3	27	24.3	22.8	-	25.3
Na^+ [mg/l]	83.8	80	79.3	80	51.0	83	77.2	80	81.9	80	-	80
K^+ [mg/l]	6.5	-	6.8	-	6.8	-	6.8	-	7.1	-	-	-
Fe^{2+} [mg/l]	0.06	0	0.03	0.01	0.05	0.04	0.06	0.0	0.02	0.01	-	0.01
free CO_2 [mg/l]	35	-	32	-	31	-	30	-	32	-	-	-
Cl^- [mg/l]	120.0	113	116.0	115	97.7	115	103.	106	119.	121	-	110
SO_4^{2-} [mg/l]	38	41	30	41	26	36	0	35	8	32	-	38
F^- [mg/l]	1.86	1.85	nil	1.74	nil	1.57	27	1.74	24	2.03	-	2.20
NO_3^- [mg/l]	12.8	14.5	13.0	14.1	11.8	15.8	1.73	14.5	1.72	12.8	-	11.9
NO_2^- [mg/l]	-	0.016	-	0.018	-	0.002	12.8	0.003	15.4	0.004	-	0.002
							-		-			

6.4 Collector/Transmission system

The collector/transmission system of Rada serves to transport water from the well field to the water distribution system in town. It is a ductile iron pipeline, consisting of four sections:

Section I collector main at the well field, to which the individual deepwells are connected
Section II collector main from well field to chlorination plant (NWSA compound)
Section III collector main from chlorination plant to storage reservoir
Section IV transmission main from storage reservoir to distribution system

With minor exceptions, all pipes are ductile iron pipes of 50 bar test pressure, of the spigot-and-socket type, with an internal cement mortar lining and externally protected by a metallic zinc coating and a bituminous layer. For the lay-out of the water transmission system see Fig. 6-8.

6.4.1 Section I

The collector system consists of 3 branches:

- **west branch**, with deepwells 3 and 4; pipeline diameters: Ø 200 and 300 mm. An extension to well locations 1 and 2 is foreseen for the second stage (year 2010), with pipeline diameters of Ø 150 and 200 mm;
- **main branch**, with deepwells 6, 8, 12 and 13. Deepwell 10 is situated near this section, but functions as observation well only. The main branch and west branch join in the vicinity of well location No. 5, from where the transmission main branches off to the chlorination site. Pipeline diameters: Ø 200 and 300 mm. An extension to well site 15 is foreseen for the year 2010 (pipeline Ø 150 and 200 mm);

Transmission main between NWSA compound and storage reservoir:

top: view of transmission main going up to the plateau;

bottom: view during connection of pipe sections

- **north branch**, with proposed wells 16 through 18. None of these have been drilled as yet. A T-junction on the main branch, in between well sites Nos. 11 and 12 allows for connecting the north branch at a later stage. The envisaged pipeline diameters are: Ø 150 and 200 mm.

Each individual deepwell is connected to the collector main through a Ø 150 mm cement-lined, externally bitumen-coated, ductile iron pipe, in which a Ø 150 gate valve is incorporated.

A total of 3 section valves and two double-acting air valves are incorporated in the Section I collector main, with three non-return valves near junctions of pipe sections, to prevent water from other sections flowing back into a section in case a leak would develop there.

6.4.2 Section II

Section II joins the collector system from a T-connection near well site No. 5 and runs parallel to the ridge on which the storage reservoir is located, up to the chlorination plant at the NWSA compound. For Phase 1 section II is a single Ø 300 mm pipeline; for Phase 2 a doubling of the pipeline is anticipated.

6.4.3 Section III

Section III is the continuation of section II, from the chlorination plant to the storage reservoir. Similar to section II, for Phase 1 a single Ø 300 mm pipeline has been laid, to be doubled for Phase 2.

6.4.4 Section IV

Section IV connects the storage reservoir with the distribution system. Again, for Phase 1 a single Ø 300 mm pipeline has been laid, to be doubled during Phase 2. The second transmission main will follow a different route, however. A special wadi crossing, whereby the pipeline is protected by a 20 cm thick reinforced concrete slab, is incorporated in this section, at about 790 m from the reservoir site.

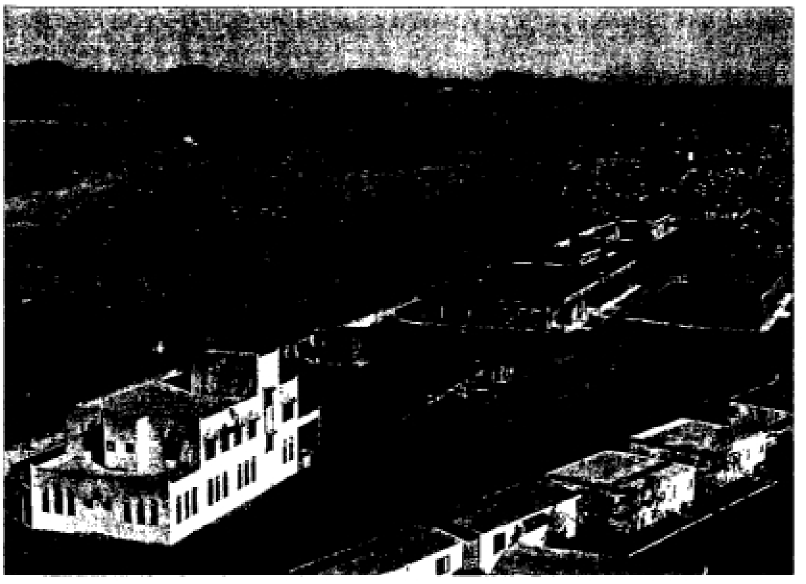
Table 6-6 Summary of collector/transmission system data

Section	Branch	From	To	Dia.[mm]	Length[m]
I	West	Well 3 connection	Reducer 300 - 200	200	272
		Reducer 300 - 200	Well 4 connection	300	10
		Well 4 connection	Junction Main-West	300	236
	Main	Junction Main-West	Well 6 connection	300	123
		Well 6 connection	Well 8 connection	300	526
		Well 8 connection	Air valve	300	487
		Air valve	Junction Main-North	300	285
		Junction Main-North	Air Valve	200	389
		Air Valve	Well 12 connection	200	25
		Well 12 connection	Well 13 connection	200	306
II	-	Junction Main-West	Chlorination pit	300	1,134
III	-	Chlorination pit	Reservoir	300	875
IV	-	Reservoir	Wadi crossing	300	786
		Wadi crossing	Node 3491	300	460

6.5 NWSA compound

The NWSA compound is situated along the transmission main, at the foot of the hill on which the storage reservoir is located. It contains the following:

- chlorination plant
- O&M building with main control centre
- generator building
- NWSA Branch office, stores and workshops.



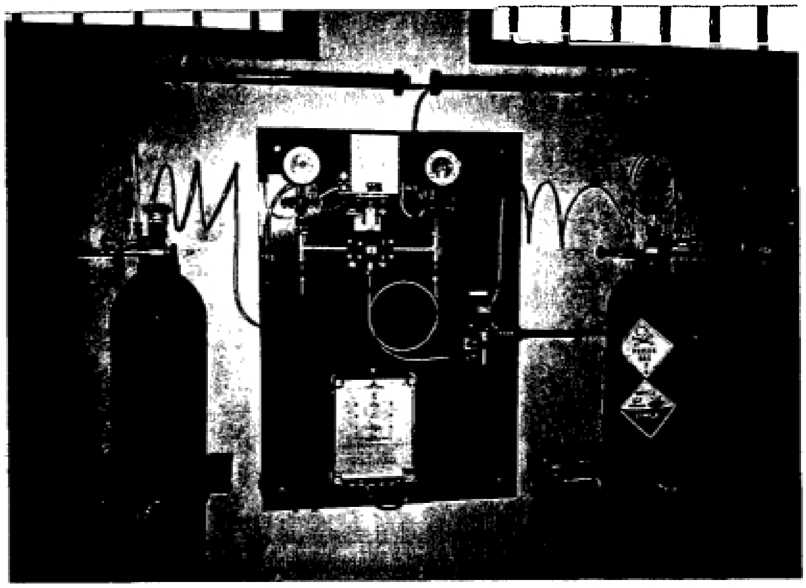
Aerial view of NWSA compound: from bottom left to top right: NWSA Branch office with guard house, O&M building, chlorination building and generator building. The blue building is the pipe store

Chlorination building during construction, as seen from the generator building

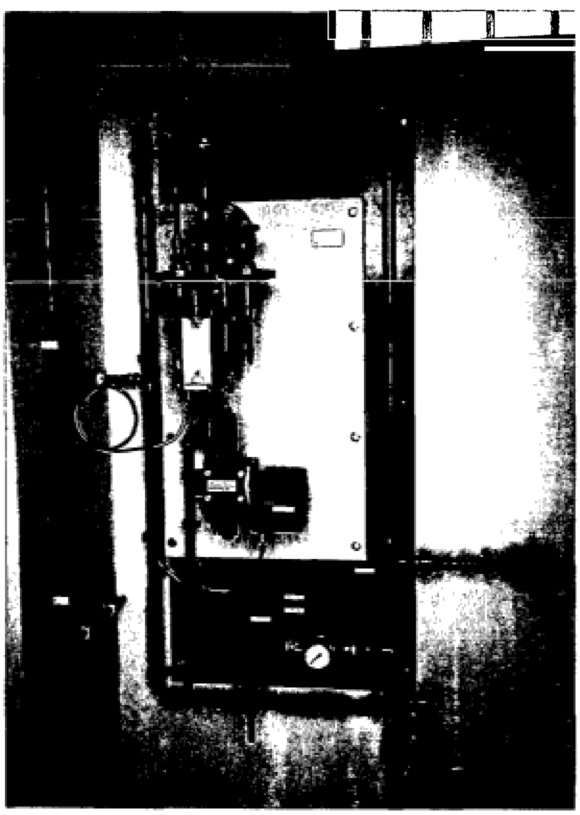
6.5.1 Chlorination plant

The treatment of the deepwell water is restricted to a safety chlorination with gaseous chlorine, to create a residual chlorine level of 0.1 - 0.2 mg/l at the periphery of the distribution system.

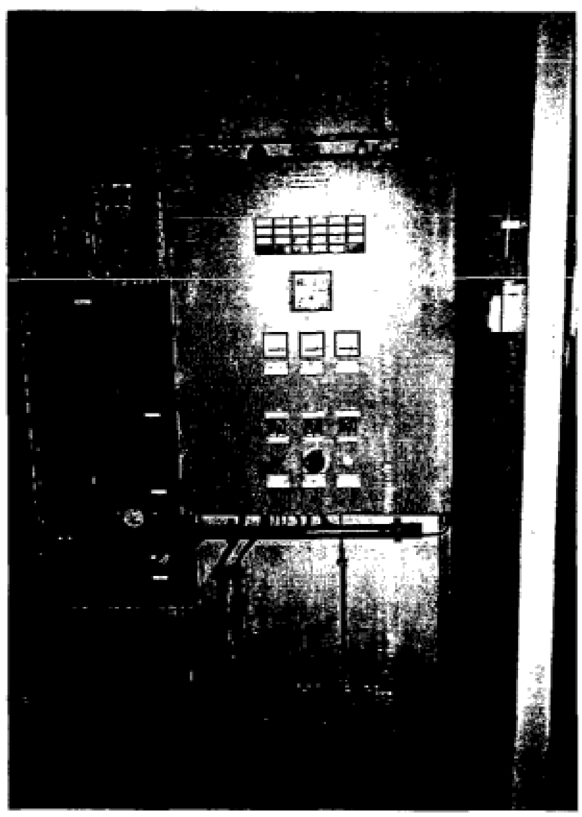
Motive water (and water for local use on the NWSA compound) is abstracted from the reservoir through a Ø 50 mm HDPE pipeline that runs back to the compound, parallel to the collector main between the chlorination pit and the reservoir. Upon arrival at the chlorination plant the motive water is pumped by a booster pump (Grundfos CR 4-30; 2 pumps installed, of which 1 stand-by) through a V-notch chlorinator (Wallace & Tiernan A-761-G) with a capacity of 50-1000 g Cl_2 per hour, and injected into the collector main. The chlorinator is fed with chlorine through an automatic change-over device to which two banks of each 4 chlorine cylinders of 65 kg (gross weight) are connected. One of these banks is in operation; the other stand-by (or empty, waiting for replacement).



Manifold with chlorine gas cylinders



V-notch chlorinator



Control panel and analyser

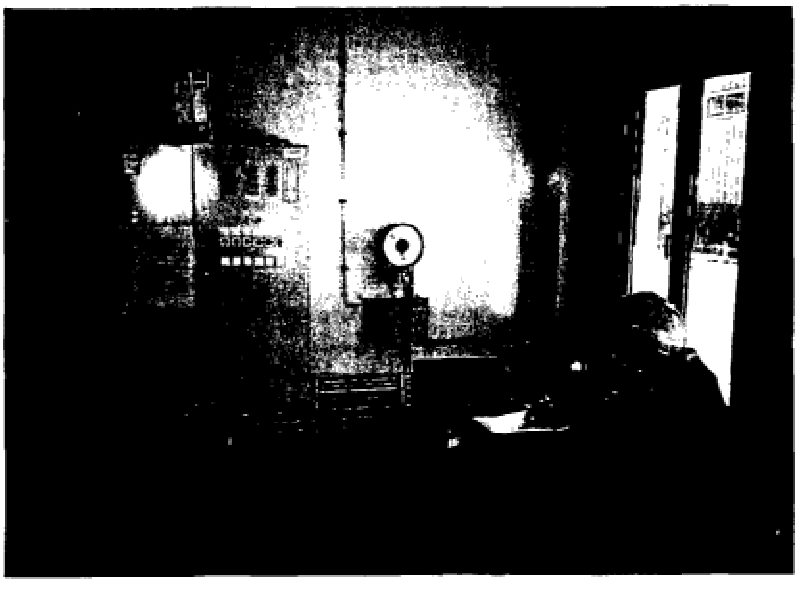
The chlorine installation also comprises two half-open storage areas for full and empty chlorine cylinders (16 each), an automatic chlorine analyser, and safety provisions (emergency and eye shower, alarm installation and automatic ventilation system). Gas protection suits and compressed air masks are stored at the main control centre. Details of the chlorination building are given in Fig. 6-12.

The chlorine dosing is automatically controlled by a ratio switch, which opens in proportion to the number of deep well pumps running. A continuous analysis of the residual chlorine content in the reservoir water, taken from the Ø 50 mm HDPE pipeline, is carried out by means of a Depolox 3 automatic chlorine analyser.

6.5.2 Main control centre

Operation of the deepwells, and monitoring of the chlorination installation, generators and storage reservoir is co-ordinated at the main control centre in the O&M building. Equipment for remote control of the deepwell pumps and for monitoring the motive water pumps of the chlorination plant, generators and storage reservoir level, is contained in a wall-mounted control panel. The water level in the storage reservoir is shown on a level indicator which is connected to the outlet piping of the reservoir through a Ø 25 mm HDPE pipeline. An acoustic high water alarm sounds when the water in the reservoir exceeds a pre-set limit.

According to an established daily routine the operator at the main switchboard in the O&M building switches deepwell pumps on and off in accordance with the water level in the reservoir, which is monitored at 30-minute intervals. A rotation schedule has been established for the generator sets and deepwell pumps, to distribute running hours as equally as possible over the various units.



Main control centre with operating panel and reservoir water level indicator at back

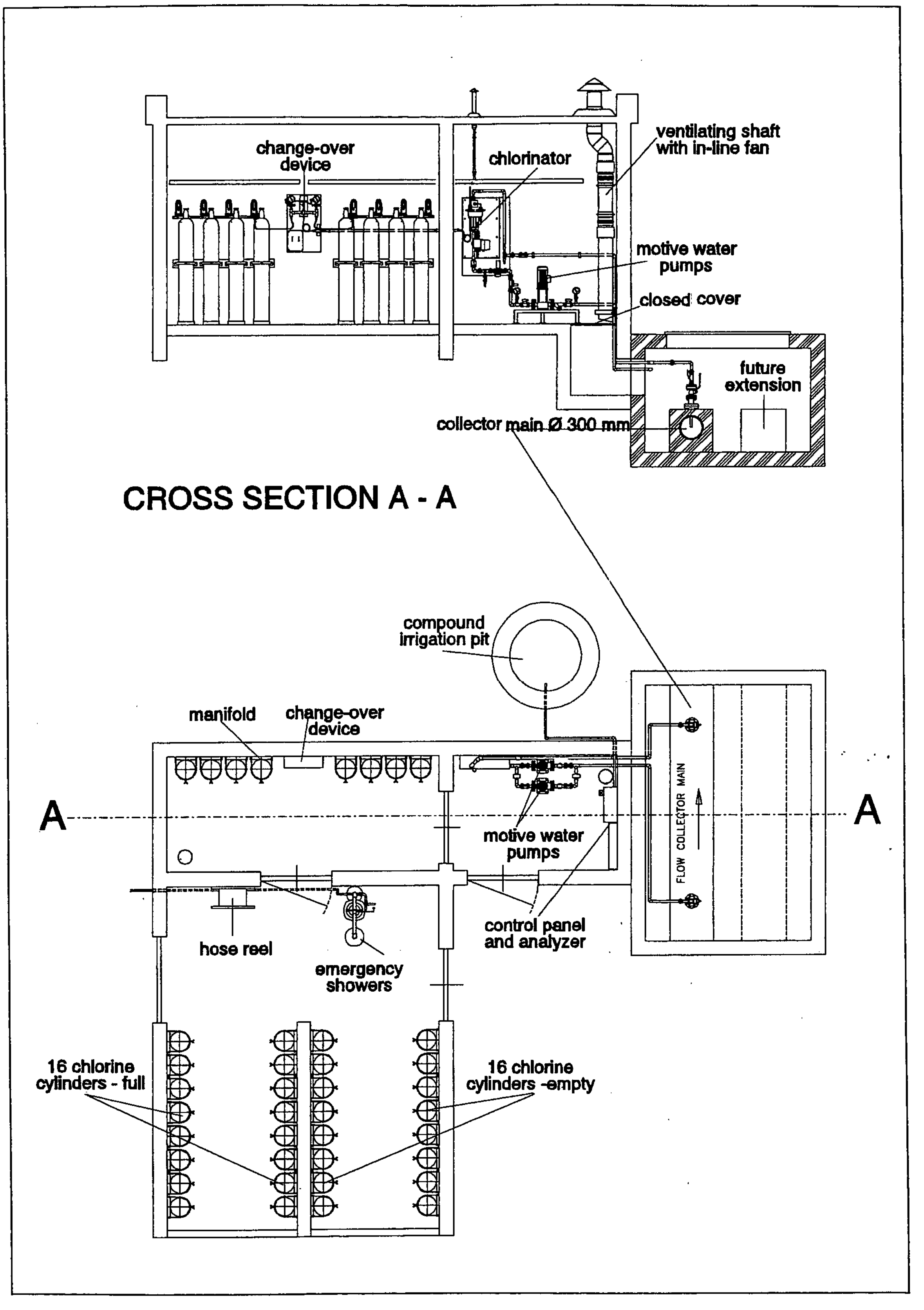
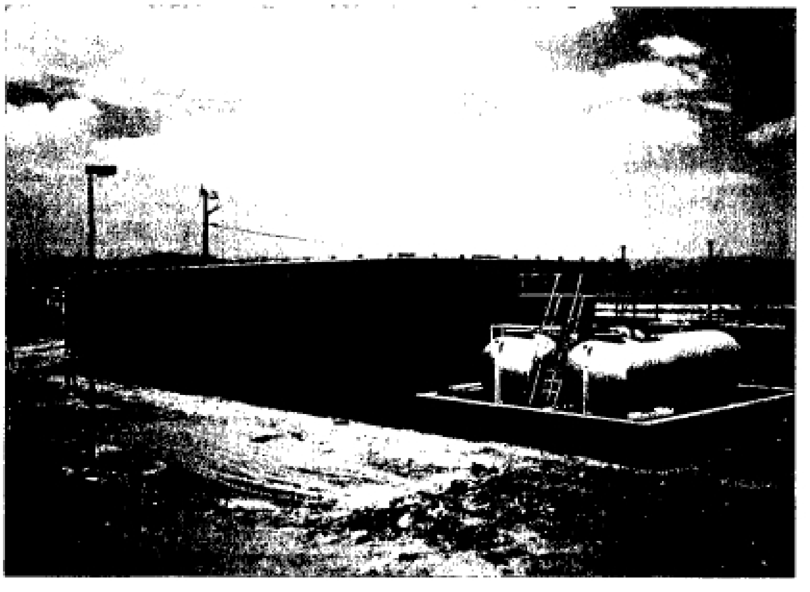


Fig. 6-12 Chlorination building

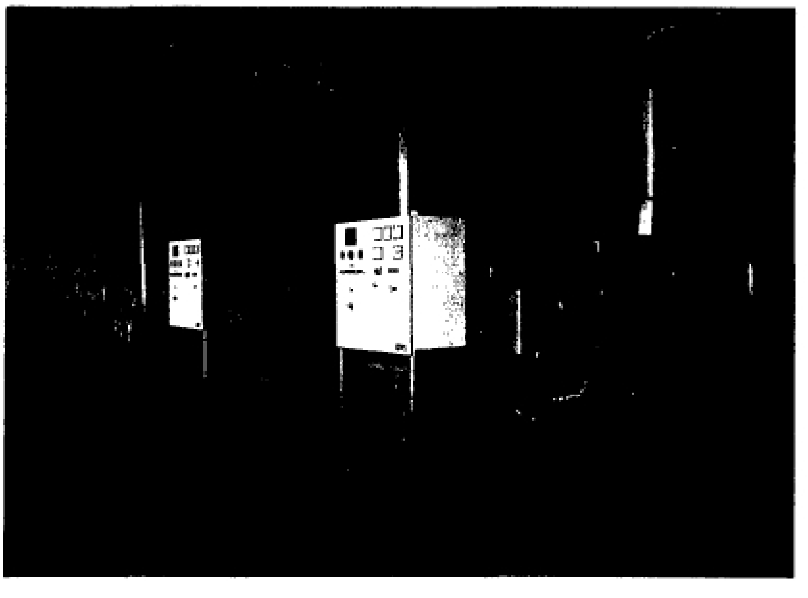
6.5.3 Generator building

The generator building houses the main components for the power supply to the water supply system:

- diesel generator sets: 4 Cummins 6BT 5.9 G2 sets, each with an output of 91 kW at 1500 rpm, connected to Stamford UC 274 D-23 generators providing 90 kVA continuous output each. Under normal conditions not more than 2 sets need to be in operation during Phase 1;
- transformers, make Merlin Gerin: one 400 kVA step-up transformer 380 V - 11 kV, and one 50 kVA step-down transformer 11 kV - 380 V;
- medium voltage (MV) and low voltage (LV) switchboards, make Merlin Gerin.

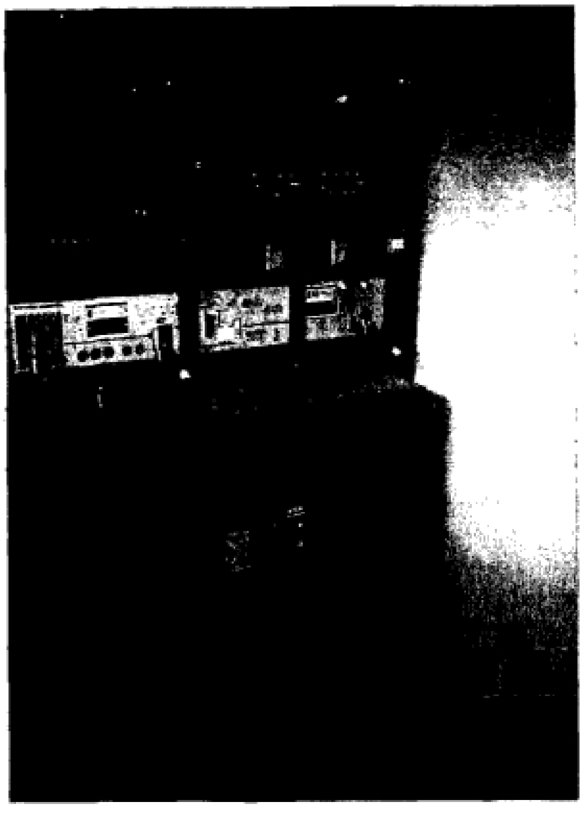


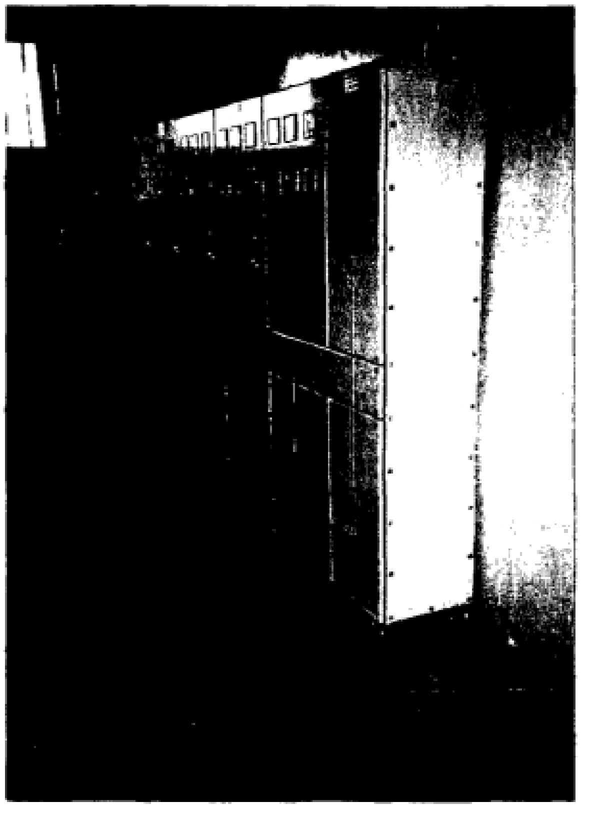
Generator building with fuel storage at right

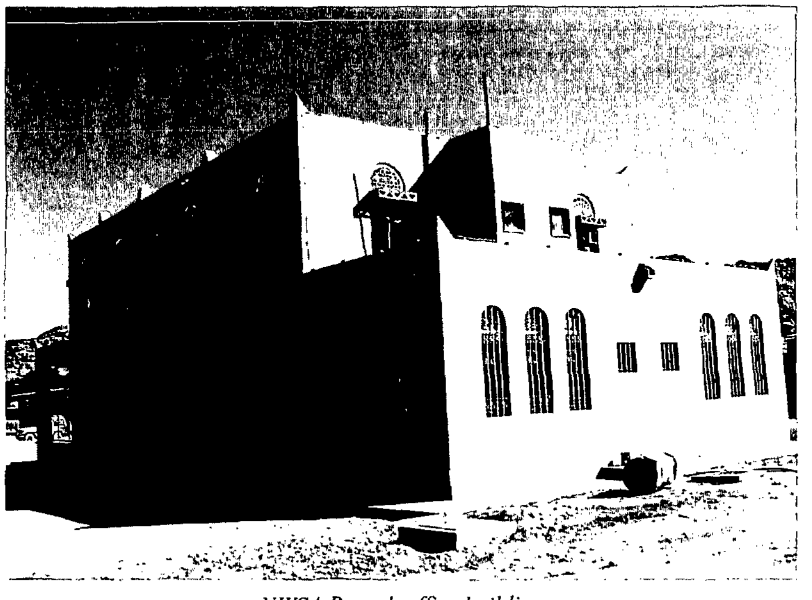


Diesel generating sets inside generator building

The diesel generator sets generate power at 400 V level (LV). To transport the generated power to the deepwell houses the voltage is raised from 400 V to 11 kV (MV) by means of the step-up transformer. An 11 kV overhead line of approximately 3.5 km length connects the generator


Power control cabinets in generator building


Control panels for generator sets


NWSA Branch office building

building to the well field. Each pump house there is provided with a 50 kVA pole-mounted step-down transformer to lower the power to the required level of 400 V.

Though not necessary because of the limited distance that has to be bridged, the power to the compound is also supplied from the 11 kV step-up transformer, to enable a future connection to the national MV grid. The connection of Rada to the national system was realised in the course of 1996, but due to the weakness of the power distribution network within the town itself the supply of power was not sufficiently reliable to switch over to the public power supply as yet, while no connection between the site and the distribution network existed either. The MV switchboard will need to be extended with a second incoming switch unit, to allow the system to be connected to the national grid; space for an additional unit has been reserved.

All power required for the motive water pumps in the chlorination plant, and for the control panels in the O&M building as well as for lighting for the entire compound, is provided by the on-site power supply system. All buildings on the compound, as well as all pump houses in the well field, are provided with lightning protection and grounding facilities.

6.5.4 NWSA Branch office, stores and workshops

In addition to the main control centre, the O&M building houses general and drawing offices, an engineering office, water laboratory, main store, water meter workshop, valve workshop, welding workshop and workshop office. Although space for a car workshop is available in the building as well, the decision was taken to have car repair and maintenance done externally, at least for the time being.

The NWSA Branch office, housing the management, and the financial and administrative sections, is located in a separate office building. In addition, a separate pipe store is located on site.

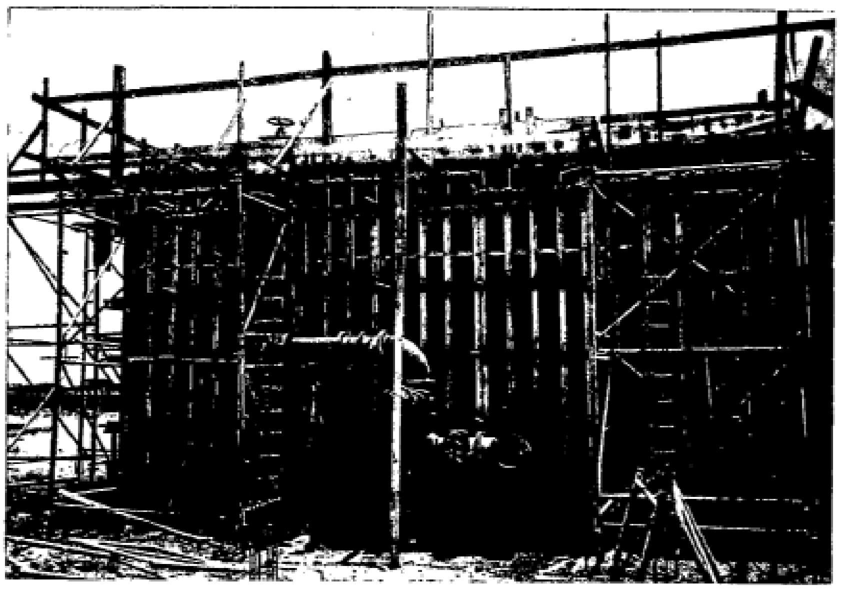
6.6 Storage reservoir

Levelling out of the differences between the output of the deepwell pumps and the actual water demand for town supply takes place in a storage reservoir which is located on a hill above the NWSA compound. Its elevation is such that the entire town can be supplied from the reservoir by gravity.

For Phase 1 (design horizon 1995) a single reservoir chamber with a nominal capacity of 750 m^3 has been constructed, to be doubled for Phase 2 (design horizon 2010).

Table 6-7 Main parameters, storage reservoir

Description		
No. of reservoir chambers		1
Internal length of chamber	[m]	29.00
Internal net width of chamber	[m]	8.00
Internal height of chamber	[m]	4.10
Bottom level reservoir	[m + MSL]	2170.00
Invert level inflow pipe	[m + MSL]	2173.60
Invert level outflow pipe	[m + MSL]	2170.15
Level overflow weir	[m + MSL]	2173.90
Invert level washout/drain pipe	[m + MSL]	2169.90
Invert level transmission main	[m + MSL]	2169.40
Gross volume between reservoir bottom and roof	[m^3]	951
Net volume between:		
top outflow pipe and alarm level of water level indicator	[m^3]	731
top outflow pipe and overflow weir level	[m^3]	800



Storage reservoir:

top: during construction

bottom: reservoir and pipe gallery just before completion

The reservoir chamber is provided with a baffle in the shape of a longitudinal wall over 25 m, to prevent short-circuiting of water between inlet and outlet points, leaving a net internal width at either side of the dividing wall of 4.00 m.

All piping is Ø 300 mm ductile iron, except for the section in which the bulk water meter is incorporated, which is Ø 150 mm DI. The reservoir piping is concentrated in a pipe gallery that – after construction of the second chamber – will be located in between the two chambers. In that gallery also the following additional provisions are located:

- motive water take-off (Ø 50 mm HDPE pipe) for feeding the chlorinator and local water supply at the NWSA compound;
- bulk water meter Ø 150 mm (Woltmann water meter with horizontal helix, removable mechanism and magnetic drive. Range: 1.4 - 500 m^3/h);

- Ø 25 HDPE measuring line, connected to the water column gauge and alarm pressure switch at the MCC. The reservoir is also equipped with a mechanical, float-controlled level indicator.

Provisions are available for connecting a second transmission main between the reservoir outlet piping and the town distribution network. A by-pass valve is installed between the incoming collector main and the outgoing distribution main, to allow the reservoir to be by-passed for cleaning or repair.

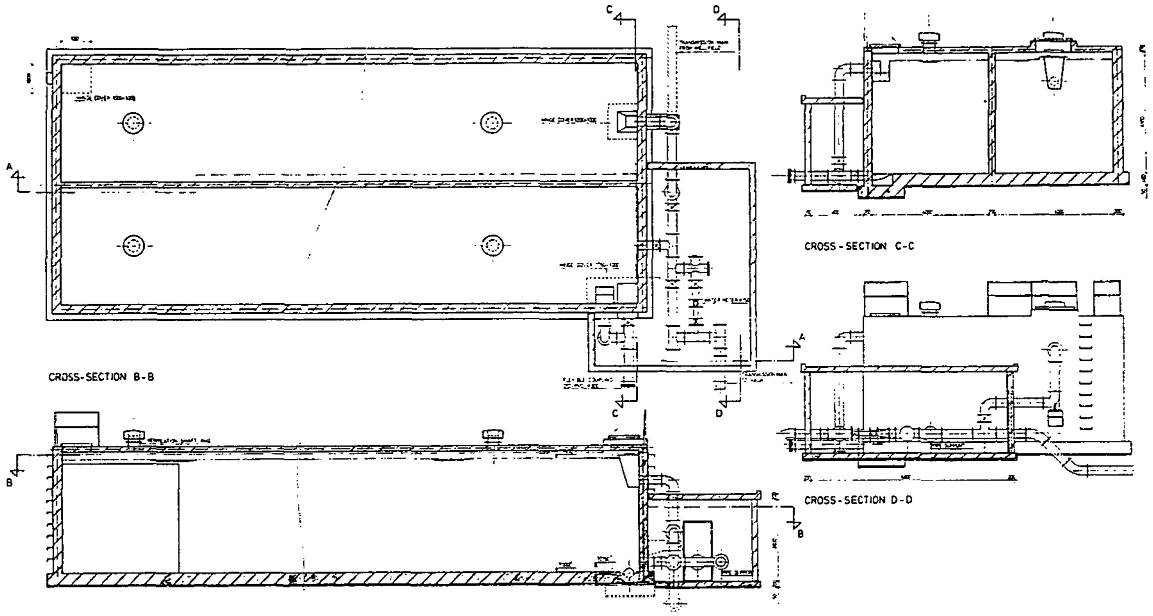


Fig. 6.13 Storage reservoir

6.7 Distribution and reticulation system

6.7.1 Introduction

The Rada distribution system brings water to the individual consumers through a network of pipes. Water from the storage reservoir is transported to the system through a transmission main, which feeds the distribution system at the border of Districts XI and XX. In the second phase another transmission main will be constructed along a different pipe route, connecting to the distribution network north of Musalla where Districts XI, XII and XX meet. The storage reservoir is located at a level which allows supply to the town under gravity. Under all conditions the pressure in the whole distribution network is positive, which prevents contamination of the water with pollutants from outside.

The Rada system is sub-divided in twelve districts for Phase 1 and another five for Phase 2. The distribution network consists of a primary system and in each district three sub-systems, with standardised pipe size and pipe material. The primary system and secondary systems are connected in district water meter chambers, located at the border of the districts (Fig. 6.14). The sub-systems are (1) the secondary system, encircling the district, (2) the tertiary system which brings water into streets, and (3) the service lines which connect to individual consumers. Each district can be monitored and fully controlled from the district water meter chamber(s). Non-return valves make certain that water which enters the district cannot leave the area.

The distribution and reticulation systems have been designed on the basis of a computerised hydraulic network simulation. Several operational conditions have been modelled, including fire flow under peak demand conditions. Under all conditions a residual head of at least 20 m above street level should be maintained, without the pressure in the system exceeding 50 m water column (5 bar) at any point of the distribution system, to prevent excessive leakage.

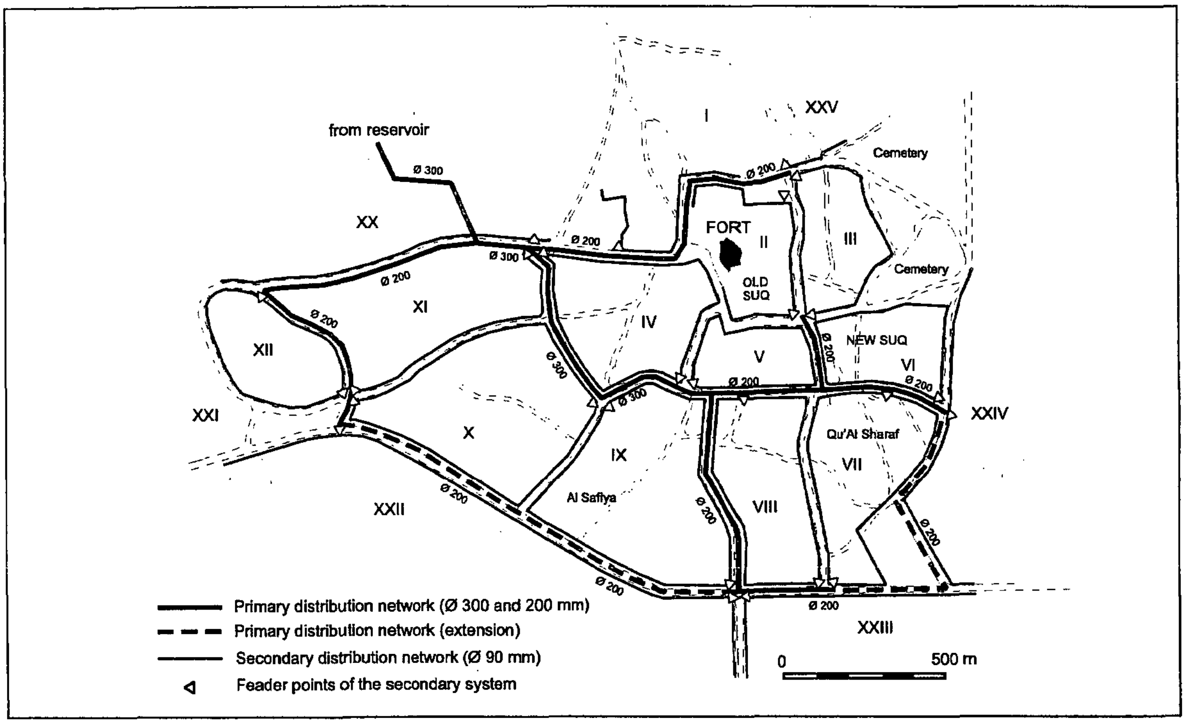


Fig. 6.14 Primary and secondary distribution system

Table 6-8 Summary of pipe data per sub-system (actual)

Sub-system	Pipe material and pipe size	Total length, Phase 1 (1995)
Primary system	ductile iron - 300 mm ductile iron - 200 mm ductile iron - 200 mm	1,280 m 4,092 m (*) 4,312 m
Secondary and tertiary system	HDPE - 90/79.8 mm HDPE - 50/44.2 mm	20,298 m (*) 22,998 m 38,877 m (*) 41,138 m
Customer service line	HDPE - 25/21 mm	28,880 m (*) 32,151 m

Note: (*) total length including pipes laid in priority extension areas (Districts XXIII / 3-A + XXV)

6.7.2 Primary distribution system

The primary distribution system consists of ductile iron pipes, Ø 300 mm and 200 mm. The system starts near Qaryat Al Hadabah, where the transmission main from the reservoir ends. The branched primary system has a Ø 300 mm pipe to the centre of the town and Ø 200 mm branches located along the borders of the districts. Connecting mains will be laid between these branches in Phase 2, after which a so-called looped system will have been obtained (see Fig. 6-14). Until then, the branched nature of the system will limit the flexibility of operation somewhat and can, in case of major repairs, affect larger groups of consumers than in case of a looped system. Such major interventions, however, are not expected in the early years of the newly constructed system.

The transmission main will be doubled in Phase 2; the second main will connect to the Ø 200 mm primary distributor, in Musalla. The primary system in this area will then be completed by another Ø 200 mm ductile iron pipe completing the loop south of the town. Similar pipes must be laid in Phase 2 to complete the south-eastern and north-eastern loops of the system. Apart requiring these additional pipes, the existing primary system has a capacity that is sufficient to cater for the water demand in the year 2010, including all extension areas.

The primary system supplies water to each district, occasionally at one but usually at two locations; at these locations district water meter chambers have been constructed. The primary system connects to only the secondary system of each of the districts and not to lower category pipes. Non-return valves in the district water meter chambers make sure that water cannot flow to another district or enter from another district.

Section valves in the primary system allow the disconnection of part of the mains, which means that in Phase 1, when the system is still a branched system, the whole part downstream of such a closed valve is no longer supplied. In Phase 2, when the primary system is a fully looped system, each pipe section can be isolated without affecting supply in other parts of the system.

The primary mains have been laid along existing roads, which facilitates inspection of pipes and operation of water meters and valves in the easily accessible district chambers.

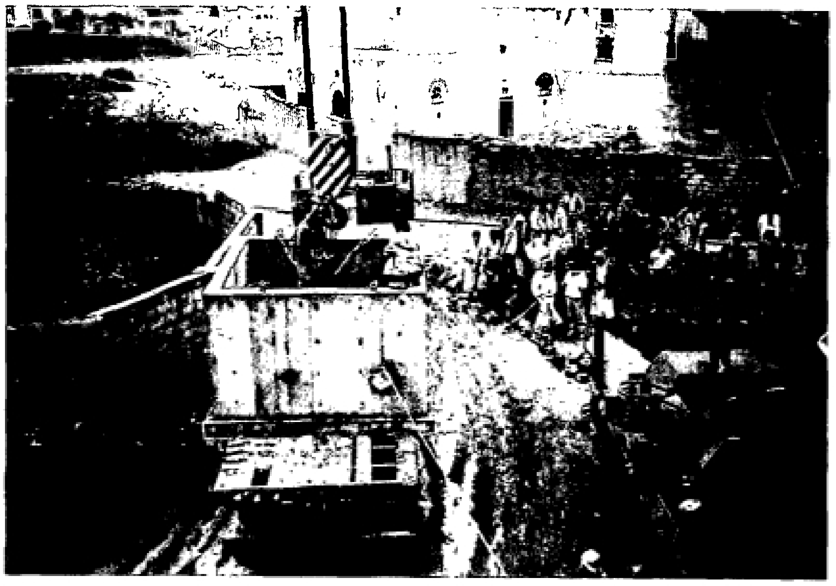
6.7.3 Secondary distribution system

Each district has its own independent secondary distribution system, consisting of a Ø 90 mm HDPE pipe that encircles the district. Normally this secondary system is connected to the primary system at two locations. Occasionally, however, the system encircles only the main part of the district or is connected to the primary system at one location only. The secondary system, however, is always a looped system (except in District XI).

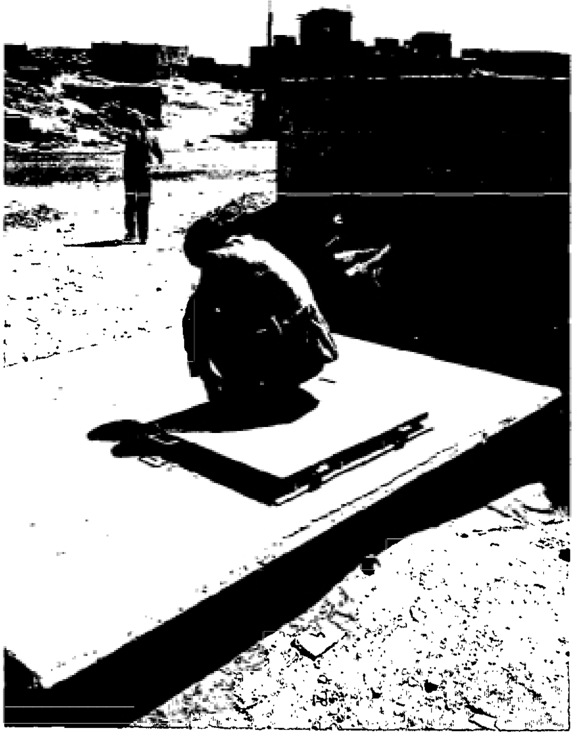
Water supplied to the district can be controlled and measured at the connections between the primary and secondary systems in underground district water meter chambers. Such a chamber includes the following items, starting from the primary main:

- one 50 mm gate valve in the main between the primary and the secondary system
- one 50 mm bulk water meter
- one 80 mm non-return valve
- two 80 mm gate valves in the two 80 mm secondary mains to the district
- a branch-off to a fire hydrant (if required)

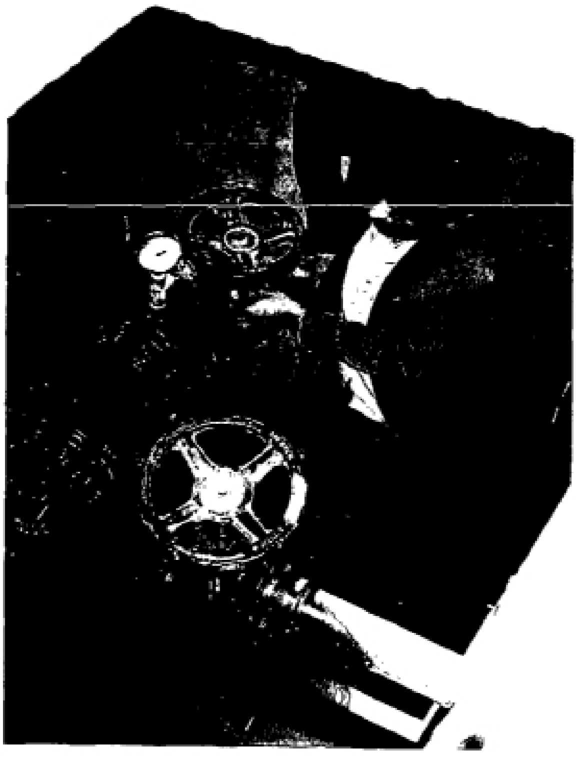
To isolate a district, the valves in the (two) district water meter chamber(s) must be closed.



Pre-cast district water meter chambers on transport



District meter chamber with manhole cover



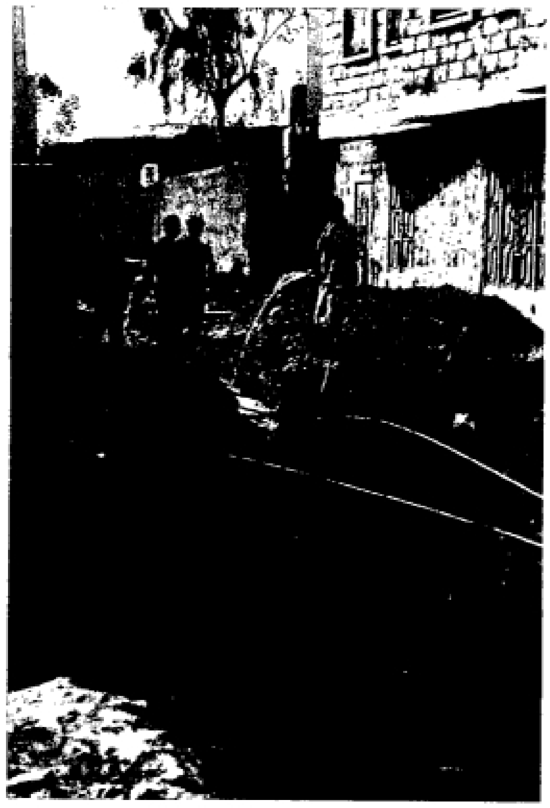
Opening flow to a district and checking the pressure

6.7.4 Tertiary distribution system

In the district a system of Ø 50 mm HDPE pipes further distributes the water from the Ø 90 mm secondary main at the boundary of the district into the streets. There is always a 50 mm gate valve between the secondary main and the tertiary distribution main.
In most cases the tertiary main is connected to the secondary system at two locations, with isolating gate valves at both locations; closing these valves takes the main out of operation. If tertiary mains are interconnected, three or more valves have to be operated to isolate one of the mains; the other mains in this combination are then also out of operation and supply to all consumers along these mains is interrupted.

Pressure in the service mains in the higher parts of Musalla varies during the day between 7.5 and 25 mwc and during the night between 12.5 and 30 mwc. For 3% of the houses in Musalla it is not possible to maintain a pressure of at least 10 mwc on the connection at all times. However, pressure is always positive, which means that the system is always full and under pressure. Roof tanks must assist in the day-time supply of these connections.

Excavation of trench for distribution pipes



Existing water pipes criss-crossing trench

6.8 House connections

The lowest category of pipes is the consumer service line, a Ø 25 mm HDPE main that is connected to the secondary or tertiary HDPE mains; direct connection to the larger size, primary system ductile iron pipes is not allowed. One service line can supply up to four house connections.

All house connections are provided with a non-return valve and a water meter; a stopcock and a gate valve in the line allow for interrupting supply to the house and replacement of the meter. Table 6-9 gives an overview of projected and actual numbers of house connections.

Table 6-9 Numbers of house connections (Phase 1)

District	Projected connections	Possible connections, based on		Connections realised per November 1996
		reticulation system[14]	house-to-house survey	
I	542	no data available on division over individual districts	322	309
II	437		296	317
III	373		207	221
IV	393		184	175
V	462		264	263
VI	311		178	166
VII	421		460	463
VIII	313		193	178
IX	393		255	238
X	225		196	163
XI	136		127	115
XII	437		380	353
Sub-Total	4,443	3,426	3,062	2,961
XX	143	-	430	-
XXI	21	-	260	-
XXII	114	-	370	-
XXIII	71	no data	570	111
XXIV	179	-	520	-
XXV	9	no data	160	90
Sub-Total	557	235	2,310	201
Grand Total	5,000	3,661[15]	5,372	3,162

The table shows, that – whereas the total number of house connections that could conceivably be realised is approximately the same as assumed earlier – the distribution of house connections over the various districts is considerably different, with a much larger proportion now being attributed to the so-called extension areas[16]. Of these only parts of districts XXIII/3-A and XXV are incorporated in the existing new water supply system, which sets the maximum attainable number of connections at 3,062 + 123 + 93 = 3,278, or: about two-thirds of the target number of 5,000 set for 1995. Even though by mid-November 1996 around 92% of the potential number of house connections had indeed been realised, this still implies that with the existing spread of the distribution system the potential revenue source is considerably smaller than earlier expected (see also Chapter 11).

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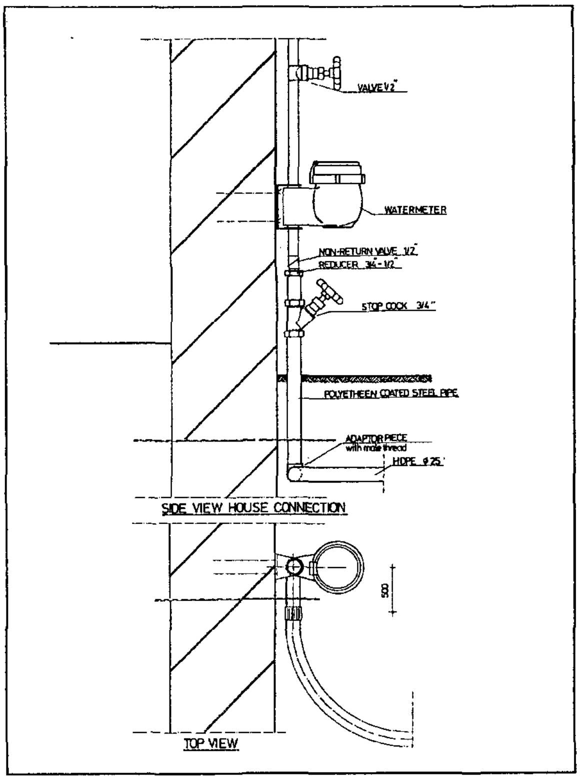
14 Potential number of house connections on the basis of which the HDPE connection clusters Ø 25 and Ø 50 mm have been constructed

15 for priority extension areas XXIII/3-A and XXV only

16 data for districts I - XII is based on the actual situation, with all house owners having been contacted in a house-to-house survey; for the extension areas the new data is based on extensive surveys carried out in 1995, as laid down in the "Final Design Report of Extension Districts of Rada" of November 1995



Details of typical house connection

Illegal use of HC without water meter

For various reasons it may not be possible to realise a 100% connection ratio for the 3,278 connections mentioned above:

- thinking that connections would be free of charge, several house owners applied for more than one connection to the same house. Once if became clear that connection fees would be charged, they generally paid for a single connection only. This applies to about 2% of the total number of potential connections;
- several houses have meanwhile collapsed, are otherwise not occupied, or under construction (3% of the number of potential connections);
- shops do generally not apply for water connections.

In the design phase of the project it was assumed that for Phase 1 a total of 5,000 house connections could be realised, of which 4,500 would be for residential use, 100 for schools and mosques, and 400 for commercial purposes. Most of the connections (4,825 or 96.5%) would be ¾ inch, with ½ inch water meters; the remainder being 1½ inch connections with 1 inch water meters. In practice a lower percentage of 1 inch water meters is being installed: by mid-November only 60 1-inch water meters had been installed on a total number of 3,013 house connections, or: 2% only.

Materials for a total of 4,924 house connections (4,755 of ½ inch and 169 of 1 inch) have been handed over to the NWSA Rada branch, which is in charge of realising the connections, so that a substantial stock for new connections is still available.

Of the still remaining potential connections a few (estimated at about 50 for the entire town) are to houses of which the occupants cannot afford to pay for a connection. It is the intention to apply materials that are still available by the end of the project to connect these houses, which are often occupied by elderly single women.

6.9 Fire hydrants

Eighteen fire hydrants, with a capacity of 10 l/s each, are connected to the primary distribution system of Phase 1, inclusive of the priority extension areas. All hydrants are of the below ground type, which limits damage by traffic; a gate valve between the hydrant and the distribution main can be closed if the hydrant is leaking or has to be replaced. To use the hydrant, a vertical standpipe with nozzles has to be placed on the hydrant, after which hoses can be connected.

As there is no fire brigade in Rada, the system will initially not be used for fire fighting. However, the Municipality (Baladiya) could consider procuring some length of fire hose and one or two standpipes and train volunteers in the use of these for fire fighting.

An important use of the hydrants is for flushing the sewer system under the routine maintenance programme. Hydrants can be opened and water will flow into the next downstream manhole. A hose from the hydrant to the manhole could limit the hinder to the community. Hydrants give easy access to the water supply system and for that reason can be used to measure pressure in the system, check for sounds as part of a leak detection programme, and function as wash-out to flush water mains. The hydrants can also be used to flush the streets for cleaning, thus preventing rubbish from ending up in the sewer manholes, either by accident or on purpose.

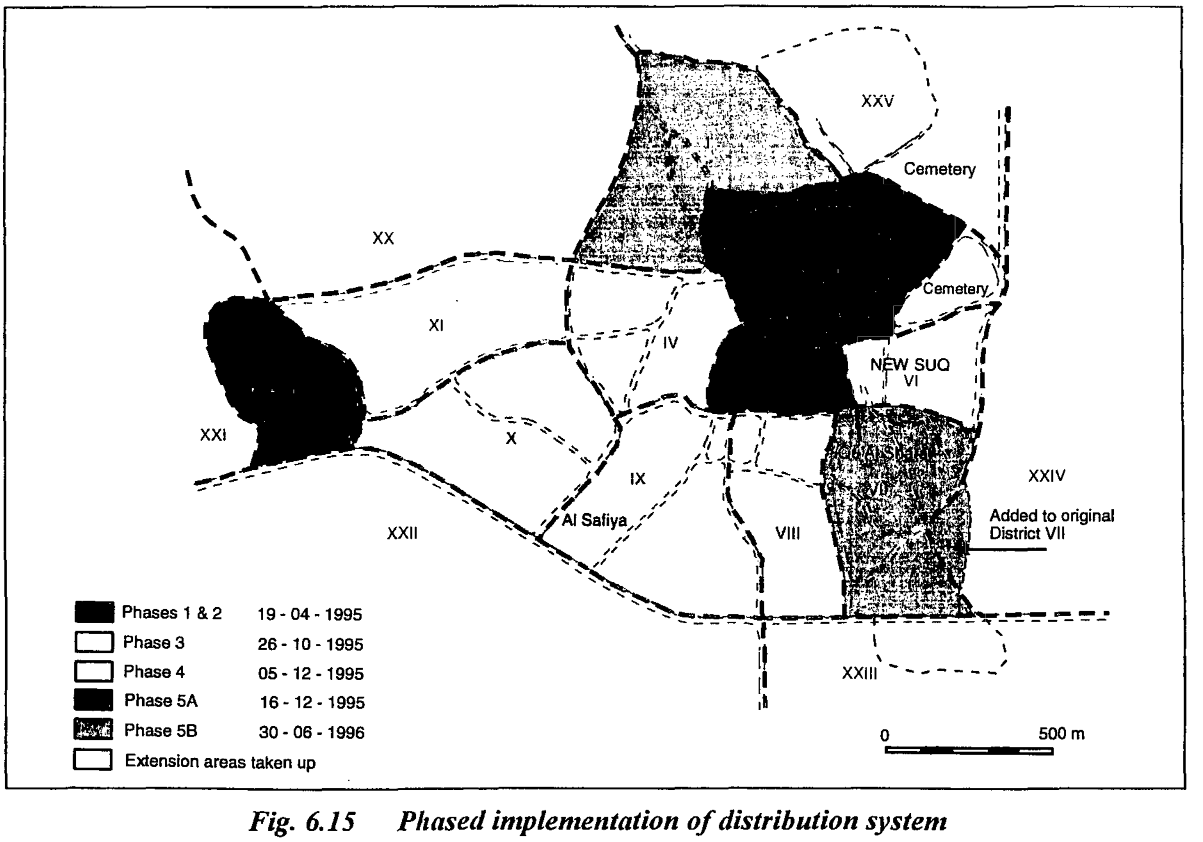


Fig. 6.15 Phased implementation of distribution system

6.10 Commissioning of the water supply system

6.10.1 Construction of distribution system

From the very beginning, after the well field, treatment facilities and reservoir had been completed, it has been the intention to construct (and hand over to NWSA) the water supply distribution system in a phased manner, among other things to restrict disruption of traffic in town as little as possible. Construction of the system started in districts II and III, which were handed over in April 1995, and ended with the priority extension areas, which were handed over in July 1996. The phasing of implementation is shown in Fig. 6.15.

6.10.2 Installation of house connections

At the start of the construction of the tertiary distribution systems in the districts, a house-to-house inventory was made of the required numbers of house connections, for water supply as well as sewerage. For water supply the piping for the connections was laid as part of the ongoing works on the distribution system, but ending with the stop cock. Both the check valve and water meter would be installed only after the client would have paid the connection fee. In addition the NWSA Branch decided that connections would be given only if – for the relevant house – also a connection to the sewer system had been made.

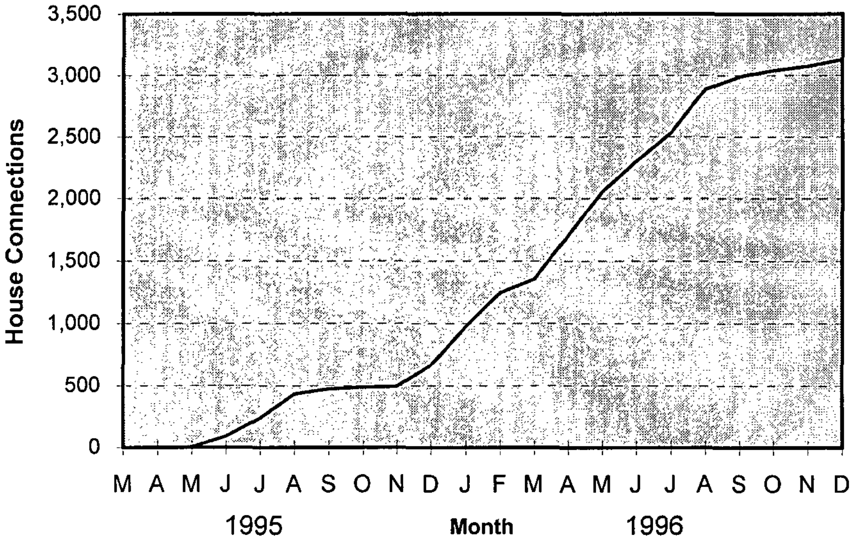


Fig. 6.16 Numbers of house connections for water supply

This policy had several consequences:

- a larger number of connections was applied for than could eventually be realised (see paragraph 6.8);
- illegal use of water became widespread, as it proved very easy to connect a hose or piping to the service piped, whereas a relatively higher cost was involved in making the connection to the sewer system.

For that reason it was later decided to put the emphasis more on completing the water supply house connections by installing water meters, and – temporarily – relaxing the requirement that the sewer connection should have been made first.

The growth in numbers of house connections, starting from April 1995, is visualised in Fig. 6.16.

6.10.3 Water consumption

Daily water consumption, from the moment the water supply system became operational in April 1995, is indicated in Fig. 6.17. The data is based on daily readings of the bulk water meter at the reservoir.

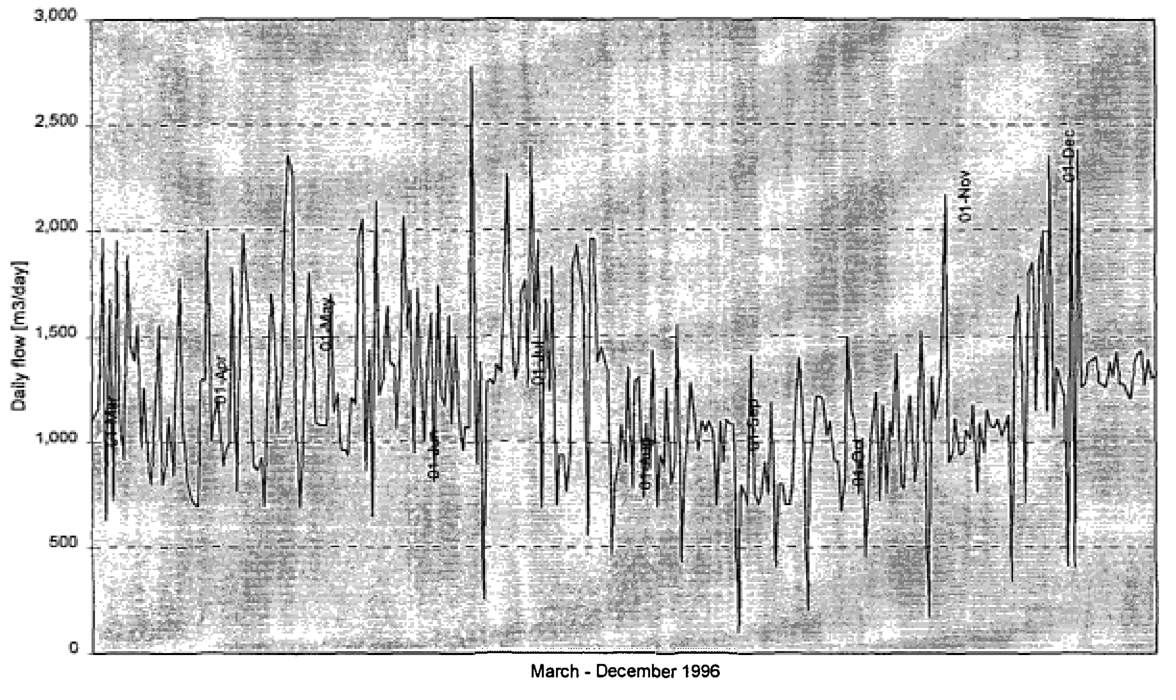


Fig. 6.17 Daily water consumption

The graph shows a somewhat downward trend, which is due both to seasonal influences and the expected increase in water tariff. The rather erratic peaks in the graph might be due to unreliable readings of the bulk water meter as well as – to some extent – the continuing use of ground and roof tanks.

6.10.4 Water quality in distribution system

On 22 October 1996 coliform tests were carried out on water from the distribution system at the Al Salaam school, the Al Naqoos mosque and Mr. Ahmed Bouri's shop in Al Musalla. In all cases the coliform test was negative, indicating the absence of coliform bacteria in the distributed water.

On the same date residual chlorine tests were carried out on water from the distribution system at the chlorination room, the NWSA Branch tap, the laboratory tap, the Al Salaam school, the Al Naqoos mosque, the residence of Mr. Saleh Al-Baqal, Mr. Ahmed Bouri's shop and the Al Nakhlah mosque. The tests showed residual chlorine of 0.18 mg/l at the first 3 locations (all at the NWSA compound), and 0.16 mg/l at the other locations. These results comply with the targets set for residual chlorine.

Temporary arrangements for laboratory at NWSA compound

7 WASTEWATER DISPOSAL

7.1 Lay-out of wastewater disposal system

The wastewater disposal system for Rada consists of the following elements:

- sewer system
- transmission sewer from sewer system to treatment plant
- wastewater treatment plant

The lay-out is shown schematically in Fig. 7.1.

A system of tertiary and secondary sewers connects to three main collectors, serving the northern, middle and southern system, respectively. The collectors convey the wastewater to a point north-east of the town, from where a transmission main transports it to the wastewater treatment plant by gravity. The wastewater treatment plant is a lagoon system, consisting of 4 anaerobic ponds, 3 facultative ponds and 4 infiltration basins.

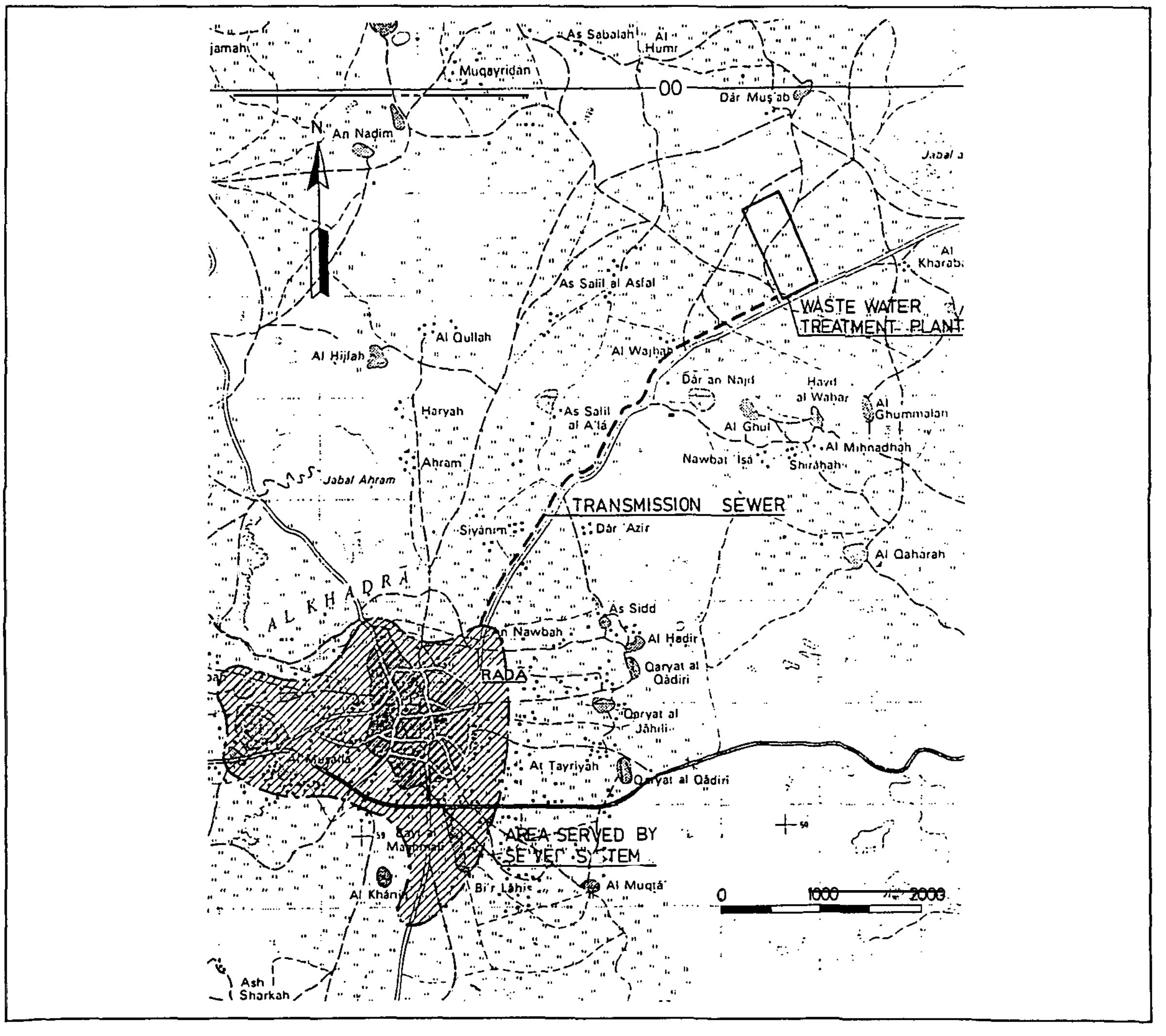


Fig. 7.1 Lay-out of wastewater disposal system

7.2 Wastewater production

The wastewater production per district for the years 1995 and 2010 is given in Table 7-1. It is based on the assumption that – as an average – 85% of the population of Rada will be connected to the sewer system in Phase 1, and 90% in Phase 2, by the year 2010. For both phases it has been assumed that 80% of the water taken from the water supply system ends up in the sewer system.

Table 7-1 Wastewater production per district

District No.	Surface [ha]	1995 Population	1995 % served	1995 Sewage production [m³/h]	2010 Population	2010 % served	2010 Sewage production average [m³/h]	2010 Sewage production average [l/s/ha]	2010 Sewage production peak [l/s/ha]
I	25.0	5,264	100	9.2	6,500	100	16.7	0.19	0.34
II	13.5	3,705	100	6.5	4,000	100	10.3	0.21	0.39
III	13.8	3,159	100	5.5	3,400	100	8.7	0.18	0.33
IV	19.8	3,331	100	5.8	3,600	100	9.2	0.13	0.24
V	8.5	3,521	100	6.1	3,650	100	9.4	0.31	0.57
VI	12.5	1,436	100	2.5	1,550	100	4.0	0.09	0.16
VII	20.9	3,561	100	6.2	3,850	100	9.9	0.13	0.24
VIII	18.4	2,642	100	4.6	3,050	100	7.8	0.12	0.22
IX	30.2	3,690	100	6.4	5,000	100	12.8	0.12	0.22
X	27.6	4,680	100	8.2	5,450	100	14.0	0.14	0.26
XI	18.7	2,826	100	4.9	4,100	100	10.5	0.16	0.29
XII	17.8	3,159	100	5.5	3,400	100	8.7	0.14	0.25
XX	102.3	2,211	40	1.5	7,000	75	13.5	0.04	0.07
XXI	13.3	332	40	0.2	1,050	85	2.3	0.05	0.09
XXII	86.5	1,769	40	1.2	5,600	75	10.8	0.03	0.06
XXIII	44.2	1,105	40	0.8	3,600	75	6.9	0.04	0.08
XXIV	102.0	2,763	40	1.9	8,800	65	14.7	0.04	0.07
XXV	16.4	442	40	0.3	1,400	85	3.1	0.05	0.10
TOTAL	591.4	49,594	85	78.0	75,000	90	173.0	0.08	0.24

	1995		2010	
Average wastewater production:	78	m³/h	173.8	m³/h
	1,881	m³/day	4,158	m³/day
Peak factor:	2.04		1.86	
Maximum wastewater production:	160	m³/h	322	m³/h
	44.3	l/s	89.5	l/s

7.3 Sewer system

The sewerage system for Rada is a so-called separate system, i.e. stormwater is disposed of separately from the wastewater. The reason for this is that rainfall in Rada, even though the average annual rainfall is very low, can have a high intensity, resulting in a rainfall to sewage ratio of 100:1 to 300:1 or more. To dimension the sewers for the combined flow would result in very large pipe diameters (up to 1.5 m), not only raising costs substantially, but also giving rise to siltation of the sewers during normal flow conditions, because of the low flow velocities that would be generated by the wastewater alone. The stormwater disposal system is mentioned separately, in chapter 8.

The Rada sewer system is a branched network of uPVC pipes, incorporating three levels of public sewer network. Starting from the house connections these are: the tertiary system, the secondary system and the primary system. The trunk mains of the primary system come together at a location north-east of the Rada cemetery, where they connect to a single trunk sewer. This transport main connects the collection system in the town with the waste water treatment, further north.

The topography of Rada allows for a sewer system that fully discharges under gravity; the wastewater flows from individual houses to the treatment plant without the need for any pumping station[17].

A break-down of the sewer system for Phase I is presented in Table 7-2:

Table 7-2 Summary of sewer system components, Phase 1

Description		Length of sewer pipe laid [m] or number of units		Handed over to NWSA	Reserved for Districts
		Districts I - XII	Distr. XXIII/XXV	Rada branch	XX and XXIV
uPVC sewer Ø 110 mm	[m]	24,382	2,566	33,145	-
uPVC sewer Ø 160 mm	[m]	45,551	2,993	1,927	-
uPVC sewer Ø 200 mm	[m]	3,931	1,213	151	-
uPVC sewer Ø 250 mm	[m]	1,417	-	100	-
uPVC sewer Ø 315 mm	[m]	1,808	-	13	-
uPVC sewer Ø 400 mm	[m]	5,458	-	-	-
uPVC sewer Ø 500 mm	[m]	921	-	-	-
House connection boxes	[Nos.]	4,023	378	-	-
Manholes with 1 connection	[Nos.]	150	11	-	13
Manholes with 2 connections	[Nos.]	808	38	-	52
Manholes with 3 connections	[Nos.]	312	24	-	7
Manholes with 4 connections	[Nos.]	43	1	-	2
Manholes in rocky areas	[Nos.]	-	25	-	-
Ø 110 sewer with concrete cover	[Nos.]	5,835	1,141	-	-
Ø 160 sewer with concrete cover	[Nos.]	7,032	517	-	-

The sewers must be dimensioned for the maximum hourly discharge. The peak factor used for calculating such discharge for wastewater is different from that for water supply. For a given area it can be calculated as follows:

maximum hourly discharge factor $P = 1.5 + 2.5\sqrt{q}$ (with P not exceeding 3),
in which q = average hourly flow of wastewater, expressed in litres per second.

7.3.1 House connections and tertiary sewer system

7.3.1.1 House connections

The public sewer system starts at a small inspection box, constructed near each house; at this inspection box the private and usually vertical in-house plumbing is connected to the horizontal tertiary sewer system. In most cases the existing piping inside the houses had to be adjusted and the current septic tank or cesspit disconnected and taken out of operation completely. Continued use of septic tank or pit is discouraged as otherwise wastewater flows in the pipes become too small, resulting in siltation of the pipe.

The inspection box is constructed in front of the house, or at the boundary of the plot if the house has a front yard or for some other reason does not immediately border the street. In either case the inspection box forms the boundary between the private, in-house plumbing system and the public NWSA-owned tertiary main. The box is considered to be part of the communal system and was

17 Originally a sewage pumping station was planned at Harat Al Qana. Because of the difficulties in powering such an isolated pumping station, later the sewer design was modified to allow discharge of the sewage under gravity, albeit with some difficulty. All materials required for constructing the sewage pumping station have been supplied, however, and are in the possession of the NWSA Rada branch.

Digging trenches for sewer pipes

Tertiary sewers in rocky area

Example of tertiary sewer with concrete cover

constructed together with the tertiary system; however, the house owner is assumed to maintain and clean the box.

The inspection box has a concrete cover that can be removed for inspection and maintenance. The pipes on both sides of the box are accessible from this box, to remove any deposit or address blockages, might these occur. Any larger, solid material that is flushed down the in-house system is trapped in the inspection box due to the lower flow velocity (transport capacity) of the wastewater when it enters the box. The house owner is required to remove these blockages when they occur.

A Ø 110 uPVC pipe connects the in-house plumbing with the inspection box and the box with the tertiary sewer in the street. Also the tertiary sewer itself is a Ø 110 uPVC pipe, except when it is longer than 25 m; then a Ø 160 pipe is used. Larger pipes are not recommended as they might lead to deposits, considering the low wastewater flows in Rada. Larger pipes would also make the system unnecessarily more expensive. The pipes are under a gradient of 1:150.

Table 7-3 gives an overview of the projected and actual numbers of house connections:

Table 7-3 Numbers of sewerage house connections (Phase 1)

District	Projected connections	Revised number of connections, based on		Connections realised per December 1996
		tertiary system[18]	house-to-house survey	
I	542	no data available on division over individual districts	372	263
II	437		297	262
III	373		207	192
IV	393		184	24
V	462		282	232
VI	311		178	102
VII	421		460	334
VIII	313		193	84
IX	393		256	43
X	225		195	102
XI	136		127	69
XII	437		457	290
Sub-Total	4,443	4,023	3,158	1,998
XX	no data available on division over individual districts	-	-	-
XXI		-	-	-
XXII		-	-	-
XXIII		no data	127	86
XXIV		-	-	-
XXV		no data	93	80
Sub-Total	47	378	220	166
Grand Total	4,500	4,401[19]	3,378	2,164

From the start of commissioning the system it has been the intention to have potential customers connect to the sewer system before their water supply house connection would be formally given (including water meter). In practice, however, this approach could not be strictly followed for several reasons:

- many house owners were hesitant to incur expenses for connecting their in-house plumbing to the sewer house connection pit, so that the NWSA Branch refused to install the house water

18 Potential number of house connections on the basis of which the house connection boxes have been constructed

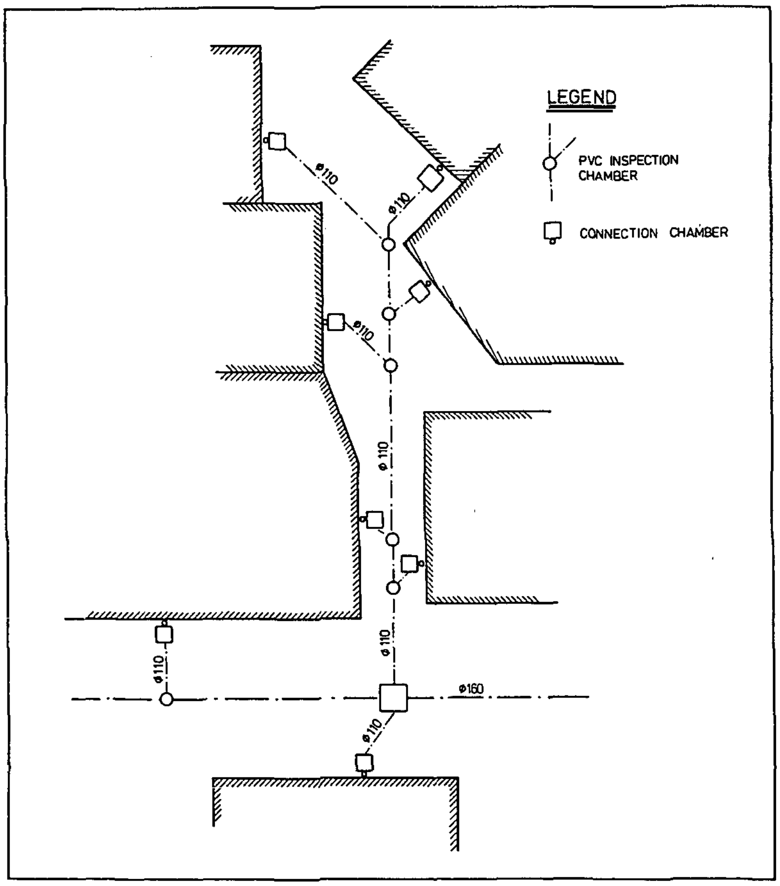
19 for priority extension areas XXIII/3-A and XXV only

meters, even in those cases where the water supply connection fee had already been paid. People then started to use the water supply connection illegally by connecting hoses directly to the riser pipe. To curb such illegal water use, the Branch had to modify its policy and complete all paid-for water supply house connections irrespective of the status of connection to the sewer system. Simultaneously, the efforts were stepped up to urge the people to connect to the sewer system;

- in several cases water is used but no or hardly any wastewater produced, as in the case of concrete blocks factories, so that no sewer connection is required or even possible;
- waste water from car washing is not allowed to enter the sewer system as it contains grease and diesel and would, therefore, jeopardise the functioning of the treatment plant;
- some houses (8 by November 1996) have a technical problem to connect to the sewer system as the toilets are located too low to be able to discharge to the tertiary system by gravity. These toilets will have to be relocated to a higher level inside the house before a connection is technically possible.

All together, the number of connections to the sewer system is lagging behind that to the water supply system. Other problems that were experienced are:

- the use of inferior materials or shoddy workmanship in making connections to the HC pits;
- the fact that often only toilets are connected to the sewer, while grey wastewater (from kitchens and bathrooms, is still discharged directly into the street.



Typical lay-out of tertiary system in narrow streets

In both cases RWSSP and NWSA Branch staff have continuously pressed the inhabitants of the relevant houses to take corrective measures, generally with success.

The total number of sewer connections may eventually turn out to be higher than that of water supply connections: whereas the pressure on the system allows more than one water meter to be connected to a single rising main, the location and elevation of toilets within a house may render it necessary to connect to different HC pits, thereby raising the number of such connections.

As in the case of the water supply system, around 50 households are expected to lack the financial means of paying for a house connection. Within the available funds the RWSSP will connect these by the end of the project period.

7.3.1.2 Tertiary sewer system

The Ø 110 uPVC tertiary sewer pipes are usually located in alleys and smaller streets, not accessible for vehicular traffic; they can, however, also be in streets that are wide enough for smaller cars to enter. Construction of the tertiary piped system differs in details, depending on these traffic conditions.

7.4 Secondary sewer system

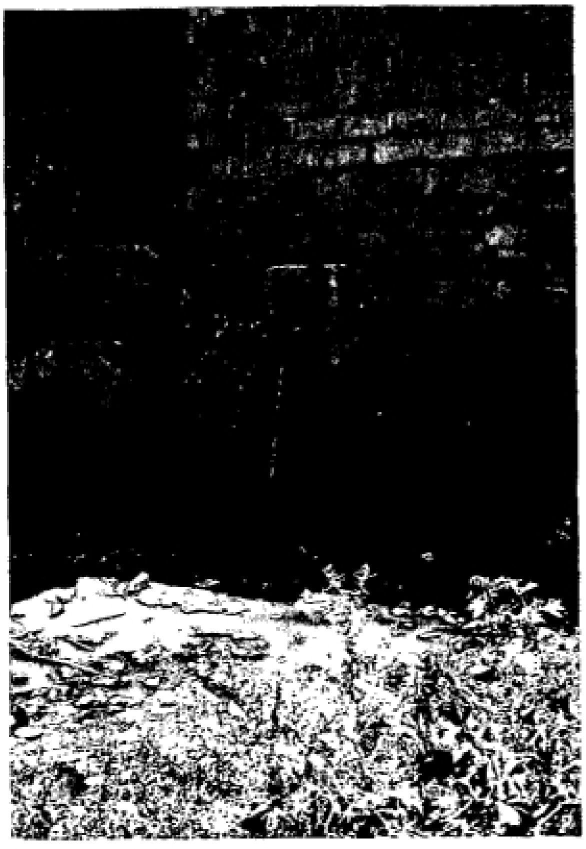
The secondary system connects the tertiary pipes with the primary system. Connections between these systems are not made directly, but to manholes, except for connections of tertiary to secondary pipes in rocky soils; then Y-connections are used. The secondary sewer system is always located in streets with vehicular traffic.

All secondary sewer pipes are made of uPVC pipe Ø 160 mm. In principle they are laid parallel to the ground surface, but with a minimum gradient of 1:300.

7.5 Primary sewer system

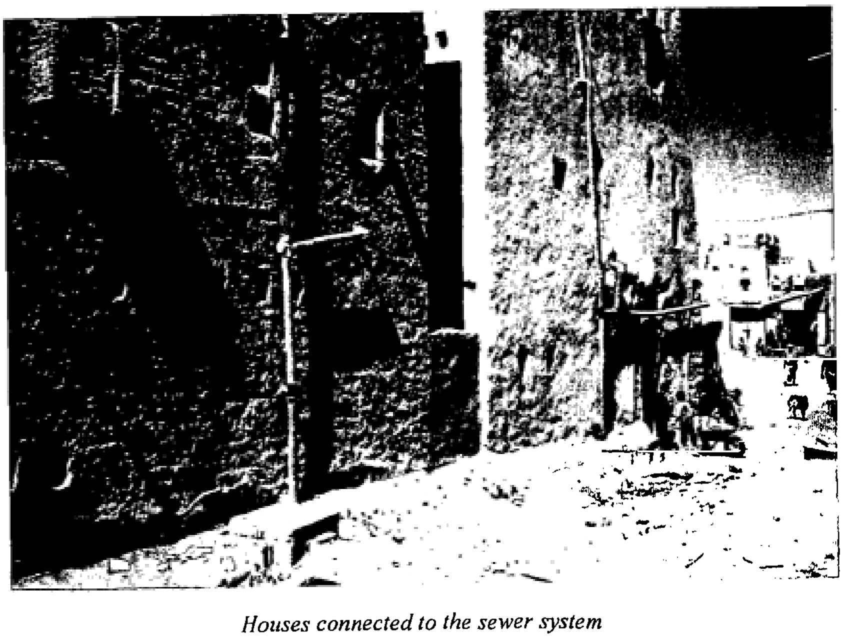
The primary system collects wastewater from the secondary system; connections are made at manholes only. There are three main collectors, which run west-east. The Southern and Middle collectors connect east of the cemetery and the New Suq. The Northern collector joins the system north of the cemetery; from here the wastewater is transported to the treatment plant. The Northern collector itself consists of two branches (see Fig. 7.2).

The primary system consists of uPVC pipes with a minimum diameter of 200 mm; other nominal pipe sizes are 250 mm, 315 mm and 400 mm. The pipes are laid under gradients varying from 1:500 to 1:100.



Not yet connected to the sewer system

House connection box to sewer



Houses connected to the sewer system

Secondary sewer with pipes for connecting to tertiary system

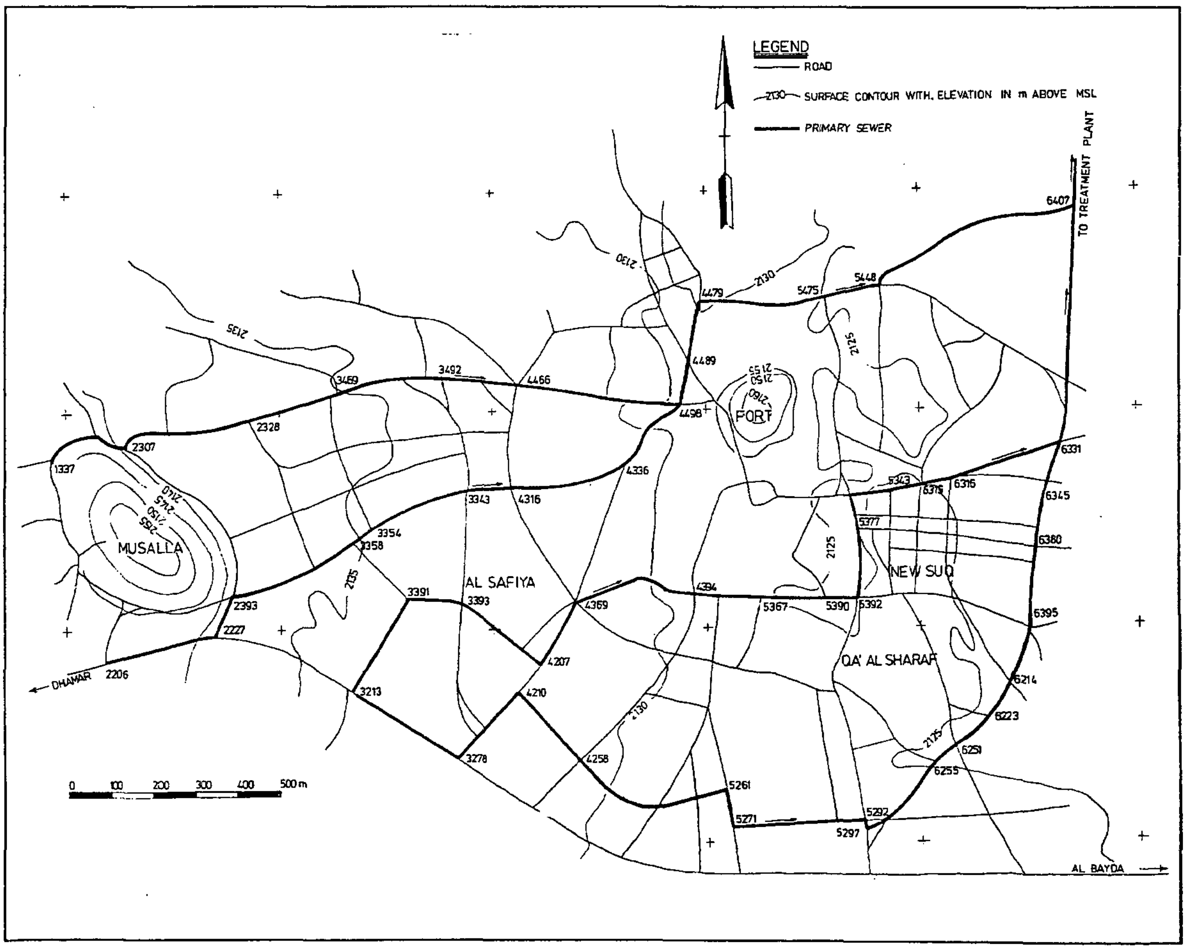


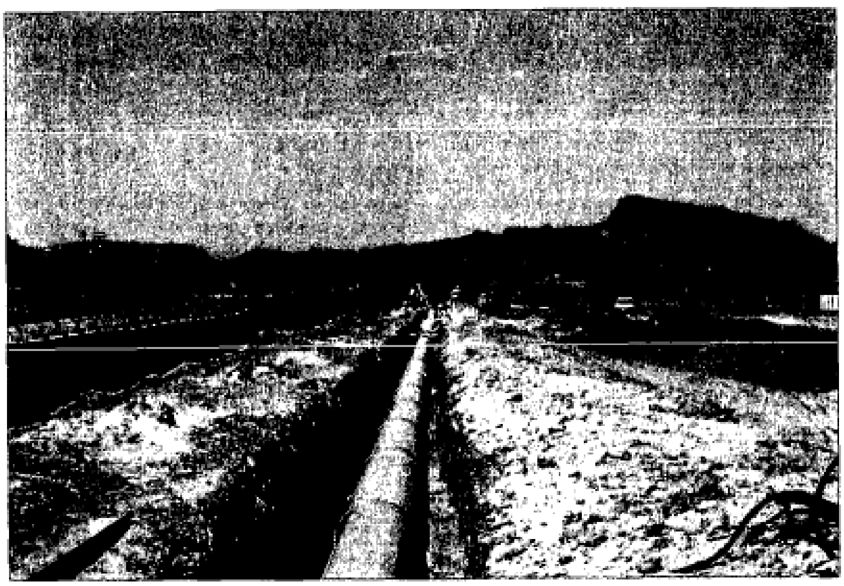
Figure 7.2 Rada sewer system - Trunk main lay-out

7.5.1 Manholes

As illustrated in Table 7-2, the sewer system for Districts I-XX has a total of 1,313 sewer manholes, with another 99 in the priority extension areas, Districts XXIII/3-A and XXV. At every connection of the tertiary to the secondary sewers there is a manhole, except in rocky soils, where Y-connections are used. In secondary and primary mains manholes are located at every connection and crossing of pipes, and further at a minimum distance between manholes of 50 m. In narrow streets/alleys without crossings the maximum distance between manholes may be 75 m. The manholes are made of reinforced concrete, having a diameter equal to the pipe diameter plus 0.50 m, with a minimum of 0.90 m.

7.5.2 Transmission sewer

A uPVC transmission sewer connects manhole No. 212 at the periphery of the sewer system with the wastewater treatment plant. Between manholes No. 212 and 253, over a length of 3,869 m, the average gradient is 1:309, and Ø 400 pipes have been used. Over the last 920 m the gradient is much less: 1: 788, so that over that distance Ø 500 pipes have been used.



Transmission sewer during construction

7.6 Wastewater treatment

7.6.1 Description of treatment plant

7.6.1.1 Lay-out

The Rada wastewater treatment plant (WWTP) is based on the lagoon technology. In lagoons (or ponds, when man-made) natural processes decompose the organic pollution present in the wastewater. The WWTP consist of two types of ponds, of the anaerobic and the facultative type.

The implementation of the WWTP has been planned in two stages. The currently built first stage has a treatment capacity of 42,750 population equivalents (p.e.), while the second stage, designed for the 2010 horizon, has a planned capacity of 67,500 p.e. The expected flows and loads, based on the data presented in Table 4-3 (page 23) are shown in Table 7-3.

Table 7-3 Design flows and loads

horizon			1995	2010	1995	2010
population served		-	42,750	67,500	concentration	
flow	average	m³/day	1,881	4,158		
	peak	m³/hour	160	322		
load	BOD_5	kg/d	2,138	3,375	1,136	812
	TSS	kg/d	2,138	3.375	1,136	812
	NKj	kg/d	500	790	266	190

The Rada plant is composed of the following units (see Fig. 7-3):

- inlet works, containing screens and a flow measuring device
- 4 anaerobic ponds
- 3 facultative ponds in Phase 1; 3 additional facultative ponds in Phase 2
- 4 infiltration basins
- 2 recirculation pumps (portable)

The design criteria for the process units are summarised in Table 7-5.

Table 7-5 Design criteria of process units

process unit	parameter		unit	value
screen	bar spacing		mm	20
	maximum flow		m^3/h	350
venturi	maximum flow		m^3/h	350
anaerobic ponds	hydraulic retention time		days	5
	BOD removal		%	50
facultative ponds	BOD loading	summer	kg BOD/(ha.d)	480
		winter	kg BOD/(ha.d)	180
infiltration ponds	average infiltration rate		$m^3/(m^2.d)$	0.26

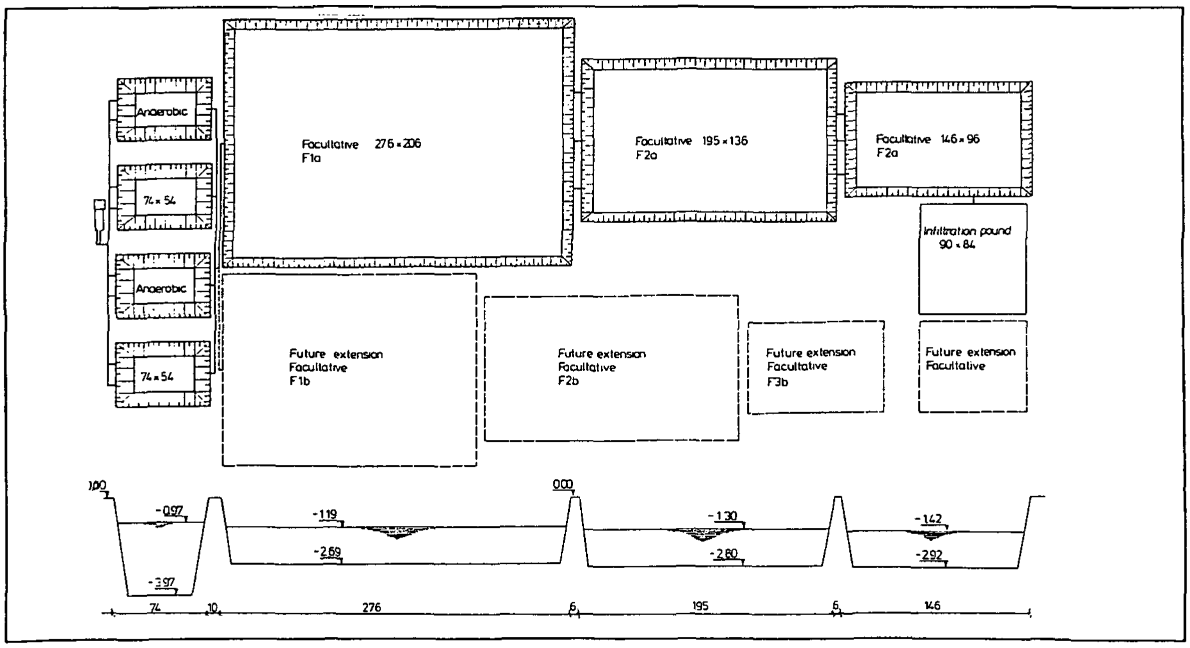


Fig. 7-3 Layout and longitudinal profile of treatment plant

The units are completed with splitter boxes, inter-pond connections and a recirculation/by-pass pipeline. The plant is operated entirely under gravity. The only pumps that are present are used for recirculating the water from the final pond to a preceding pond and for emptying and draining the anaerobic ponds.

7.6.1.2 *Screen*

The screen consists of a rack of bars, with a total width of 0.60 m. The clearance between bars is 20 mm. A backup screen is placed in a by-pass, to be used in case the screen needs repair. In the screen the coarse material from the wastewater is retained. The materials that stay behind are called 'screenings'. These have to be removed periodically and must be disposed of in a proper way. A closed container should be used for temporary storage. The town's solid waste collection service is the most appropriate facility for final disposal.

7.6.1.3 *Flow measurement*

The flow measuring device is a Venturi flume. The width of the gorge is 0.30 m and the maximum water level 0.35 m, allowing a maximum flow of 90 l/s (325 m^3/hour). Downstream of the Venturi flume, a splitter box enables the distribution of the incoming sewage over the anaerobic ponds.

7.6.1.4 *Anaerobic ponds*

In the anaerobic ponds, a large part of the organic waste is removed. Four anaerobic ponds have been constructed, each with a volume of 6,920 m^3 and a water depth of 3.00 m, which is sufficient for Phase 2. The effluent of the anaerobic ponds is led to a splitter box, from where it can be directed to facultative pond *F1a* or to the recirculation/by-pass line. In Phase 2 the effluent of the anaerobic ponds can be distributed over both facultative ponds *F1a* and *F1b*.

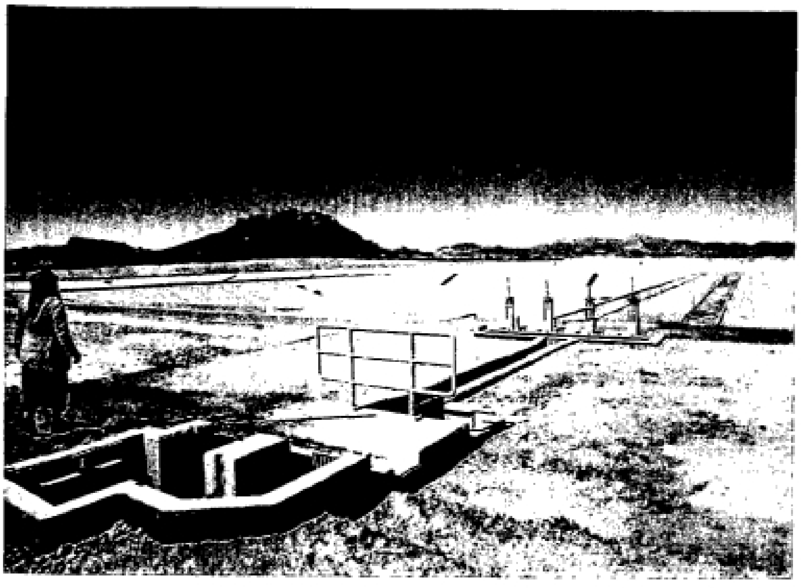
The anaerobic ponds have the purpose to remove a considerable part of the BOD and most of the suspended solids (SS) present in the wastewater. Also most of the parasites (worm eggs) are removed in these ponds. BOD and SS removal takes place through two processes:

- sedimentation
- biological conversion

The settleable parts that are present in the wastewater will settle to the bottom, as a result of the low water velocity in the pond. Lighter components, such as fats and greases, will float to the surface. The sediment will gradually be degraded by biological processes, but also the soluble organic matter will partly be decomposed. The expected BOD removal of the anaerobic ponds is 50% in winter. Worm eggs (or helminth eggs) are removed by sedimentation. This implies that the eggs are accumulated in the sludge.

The anaerobic ponds are designed on the basis of an average hydraulic retention time of 5 days. This is equivalent to a BOD loading of 0.23 kg BOD/(m^3.d). At this loading, a minimum BOD removal of 50% is expected in winter. The ponds should be operated between 0.11 and 0.40 kg BOD/(m^3/d).

The ponds are earthen structures, 3.50 m deep, provided with a bottom sealing of 1.5 mm thick HDPE sheets to prevent seepage into the ground. The sealing continues to the top of the dike. The bottom of the ponds and inner slope of the dikes are protected by 10 cm thick reinforced concrete slabs. For the bottom this is necessary to support the weight of small vehicles used for sludge removal; for the dikes to prevent erosion by wave action, vegetation and rodents.



Inlet box with screens, Venturi flume, splitter box; anaerobic ponds at the back

Anaerobic pond, empty

Facultative pond

Table 7-5 Main dimensions of anaerobic ponds

Description	
Number of ponds	4
Material	earthen dikes
Sealing	bottom and dikes sealed with 1.5 mm HDPE
Protection against erosion etc.	dikes protected with reinforced concrete slabs, 10 cm thick
Slope of dikes	1: 3
Internal bottom dimensions	32.2 x 47 m
Internal top of dike dimensions	53.3 x 68 m
Levels[1]) top of dike	+ 6.38 m
water	+ 5.88 m
bottom	+ 2.88 m
invert inlet pipe	+ 4.88 m
[1]) 0 = 2100 m + MSL	
Net volume each	6920 m^3

7.6.1.5 *Facultative ponds*

In the facultative ponds the secondary treatment takes place. For Phase 1 three ponds have been constructed. The ponds are operated in series and are numbered *F1a*, *F2a* and *F3a*. For Phase 2 another series of three ponds will be required, numbered *F1b*, *F2b* and *F3b*. All ponds are 1.50 m deep. The surface areas and volumes of the ponds are presented in Table 7-6.

The purpose of the facultative ponds is to remove BOD, suspended solids, some of the nitrogen, the helminth eggs that possibly pass the anaerobic ponds and a considerable part of the pathogens. Worm eggs are removed by sedimentation. Since the retention time is long – 77 days in the three facultative ponds in total (Phase 1) – the possibility of an egg to reach the effluent is nil. The pathogens are removed as a result of three mechanisms: spontaneous die-off, consumption by other organisms and ultraviolet radiation from sunlight.

In the lower part of the ponds, anaerobic conditions prevail. The processes that take place in that part are the same as those in an anaerobic pond. The main result of the anaerobic processes is a high degree of decomposition of the sediment. In the upper part, aerobic conditions occur, sometimes during the whole day, but at least during the daylight hours. The dissolved oxygen is generated by algal activity and by the action of wind.

The facultative ponds are 2 m deep earthen structures. The water depth is 1.50 m, although the depth of the most important layer, the aerobic part – roughly the depth to which light can penetrate – is usually between 10 and 50 cm. The larger water depth was chosen in order to prevent the growth of plants, even after some accumulation of sludge has taken place. Plants are not desired, since they take away light from the algae and offer hatching places for many insects, particularly mosquitoes. The bottom and the dikes are sealed against seepage with a 1.5 mm HDPE lining, which is protected from physical damage by a layer of sand. The dikes are protected with 10 cm reinforced concrete slabs to prevent erosion by wave action, vegetation and rodents. A concrete beam at the bottom of the slope prevents the slabs from sliding down, while protecting the rim of the HDPE lining and pinning it down

Table 7-6 Specifications of facultative ponds

pond No.	surface area at half depth [ha]	volume [m³]	dimensions [m]		level in m, relative to 2100m + MSL			number of inlets	maximum BOD load [kg BOD/day]	
			top of dike	bottom	top of dike	water	bottom		winter (15 °C)	summer (25 °C)
F1a	5.35	80,300	302 x 189.2	290 x 177.2	+5.98	+5.48	+3.98	4	960	2600
F2a	2.51	37,700	222 x 124.5	210 x 112.5	+5.87	+5.37	+3.87	3	450	1200
F3a	1.25	18,800	152 x 94	140 x 82	+5.75	+5.25	+3.75	2	225	610
F1b	3.10	46,500			+7.20	+5.66	+4.16		560	1500
F2b	1.46	21,900			+5.50	+4.85	+3.35		265	710
F3b	0.73	11,000			+4.85	+4.35	+2.85		130	360
depth of all ponds: 1.50 m										

7.6.1.6 Infiltration ponds

The final disposal of the treated wastewater can be either to an irrigation scheme, the wadi or infiltration ponds. For the time that reuse of effluent is not possible, infiltration is preferred over discharge into the wadi. Four infiltration basins have thus been designed to infiltrate the treated wastewater for groundwater recharge. For Phase 1, two basins have been built, one of 110 x 33 m surface area and one of 109 x 33 m.

The ponds are earthen structures of 2.10 to 3.00 m deep. Their bottom consists of loose sand, to allow infiltration, with the inside part of the dikes protected against erosion by 10 cm thick concrete slabs. With a maximum water level of 1.50 m above the bottom, a storage capacity is available of 6,441 m^3 in the first and 6,384 m^3 in the second basin. The ponds are designed for an average infiltration rate of 0.26 $m^3/(m^2.d)$. The initial capacity of each pond is expected to be approx. 1800 m^3/day, but this capacity will gradually decrease as the bottom gets clogged with organic matter. The dimensions of the ponds are given in Table 7-7.

Table 7-7 Specifications of the infiltration basins

pond number	surface area at bottom [ha]	dimensions [m]		levels [m above 2100 m + MSL]		
		top of dike	bottom	top of dike	max. water	bottom
Ia	0.36	123.5 x 46.5	110 x 33	+5.50	+4.75	+3.25
Ib	0.36	127 x 33	109 x 33	+5.50	+4.00	+2.50
dimensions of ponds Ic and Id subject to change						

7.6.2 Plant operation

7.6.2.1 Phase 1

During Phase 1 (1995) the raw wastewater, after having passed the screen and the venturi, is directed to two of the anaerobic ponds. The effluent of these ponds flows to the first facultative pond (*F1a*), then to the second (*F2a*) and the third facultative pond (*F3a*), and finally to the infiltration basins. When required, effluent of the *F3a* pond, supposing this has a relatively high content of dissolved oxygen, can be recycled to the *F1a* pond. Since the anaerobic ponds must be kept strictly anaerobic, recirculation over these ponds would only be counterproductive. As soon as one of the anaerobic ponds is filled with sludge for more than 50% of its volume, the sludge must be removed.

As an alternative operation mode, one of the anaerobic ponds can be operated in series downstream of one or two other anaerobic ponds. The advantages of such mode of operation are a higher removal efficiency, a high organic load on the first anaerobic ponds, an increase in treatment capacity and/or a reduced load on the facultative ponds. This approach can be followed during Phase 1 as well as Phase 2.

7.6.2.2 Phase 2

During Phase 2 the raw wastewater, after passing the screen and the venturi, is distributed over three anaerobic ponds. The effluent of these ponds is distributed over the *F1a* and the *F1b* ponds. From the *F1a* pond the water flows to the *F2a* and *F3a* ponds; from the *F1b* pond it flows to the *F2b* and *F3b* ponds. The effluent of the *F3a* and *F3b* ponds is infiltrated in the same infiltration basins as used in Phase 1. Recirculation from the *F3b* pond to the *F1b* pond is possible.

7.6.2.3 Sludge removal

Although the facultative ponds do not receive large quantities of suspended solids, the turn-over of sludge or suspended solids from upstream ponds as well as the die-off of algae result in a slow build-up of sediment. This sediment has to be removed as soon as the layer produces operational problems, such as growth of plants in the pond, or bulking of sludge to the surface.

It is expected that sediment needs to be removed once every 8 - 15 years in the *F1* pond, and at even a lower frequency for *F2* and *F3*. Two methods may be applied for removal of the sediment: emptying or dredging:

- emptying is suitable for the small ponds only, and should take place in summer, when the remaining facultative ponds can handle a higher load;
- dredging is a common method for desludging, whereby a submersible pump, suspended from a raft, and with its intake 0.20 - 0.30 m above the bottom, is used to remove the sludge, which is then discharged into one of the anaerobic ponds.

The infiltration ponds are operated in cycles. After having been in service for some time, the pond's bottom starts to clog and the infiltration rate goes down, resulting in a sharp rise in water level. It is then necessary to interrupt the feeding of this pond and take another into operation. The pond that was operated is left to dry. At its bottom a layer of organic matter has developed, which must be cracked using a plough or a cultivator. After a number of years, a layer of 30 to 50 cm of the sand must be renewed.

7.6.3 Wastewater flows

During several days in September 1996 both the water production and wastewater flow to the treatment plant have been monitored. The water production was measured at the reservoir by reading the bulk water meter; at the wastewater treatment plant a double reading was carried out: using the Venturi flume as well as a V-notch that was specially installed for the purpose. The readings for Thursday 19 September and Friday 20 September 1996 are given in Fig. 7.4. Here the V-notch readings are used for the sewage flow, as this device provided more accurate results at the flow rate levels experienced at the time.

The figure clearly shows that the sewage flow arriving at the wastewater treatment plant shows similar variations during the day as the water consumption, but with a delay of several hours. As was to be expected the delay was longer with lower flows, and shorter when flow rates were

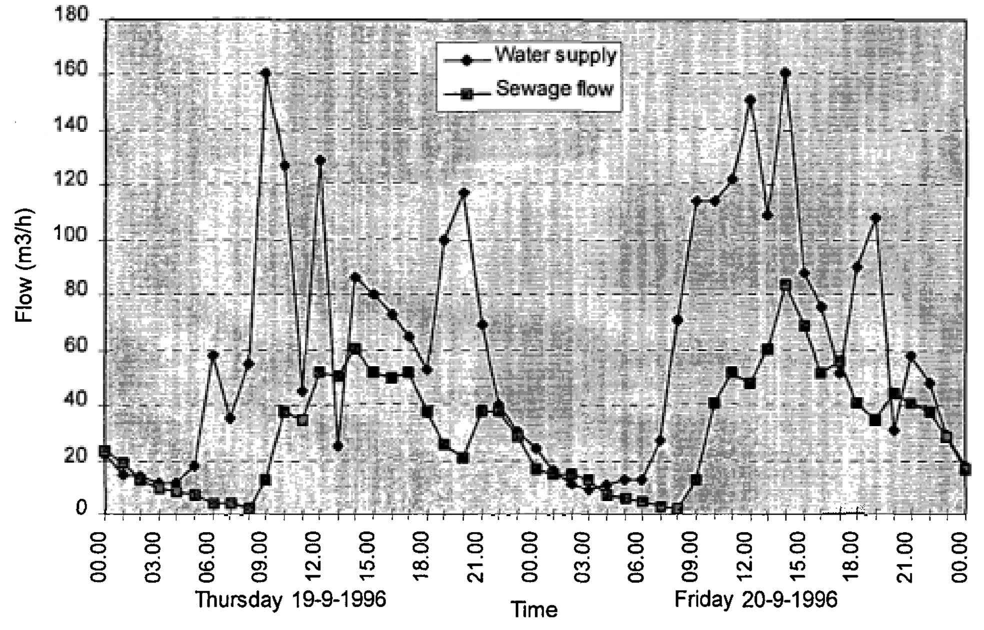


Fig. 7.4 Water supply and wastewater flows

higher. Another observation is that – whereas the design assumed that 80% of the water consumed would find its way into the sewer system, in fact about half of that volume (40% of water consumption) was recorded as inflow to the wastewater treatment plant. This may be explained by the fact that – as mentioned earlier – often only the toilets are connected to the sewer system, whereas the so-called 'grey wastewater' is still discharged locally. The ratio between water and wastewater production is illustrated clearly in the cumulative production graph of Fig. 7.5, drawn up over the period 24 - 27 September 1996.

7.6.4 Wastewater quality

In October and December 1996 several wastewater analyses were carried out, the results of which are given in Table 7-8. Taking into account the relatively short time that the wastewater treatment plant has been operational, the effluent quality is reasonable. In spite of the extremely low loading of the plant, the reduction in suspended solids and COD was limited to 73.2% and 69.8% only.

Table 7-8 Wastewater quality

Parameter	Unit	Location: Influent to treatment plant	Effluent anaerobic pond No. 3	Effluent facultative pond No. 1
Temperature	°C	25	20	20
Electrical conductivity at 25°C	µS/cm	3,907	3,300	3,399
Ammonia, NH_4	mg/l	289	193	67.5
Total Suspended Solids TSS	mg/l	952	385	255
Oil	mg/l	2	3	
Biological Oxygen Demand BOD_5	mg/l	> 700	512	250
Chemical Oxygen Demand COD	mg/l	1,446	753	436
Total coliforms / 100 ml	MPN	> 1,600	> 1,600	> 1,600

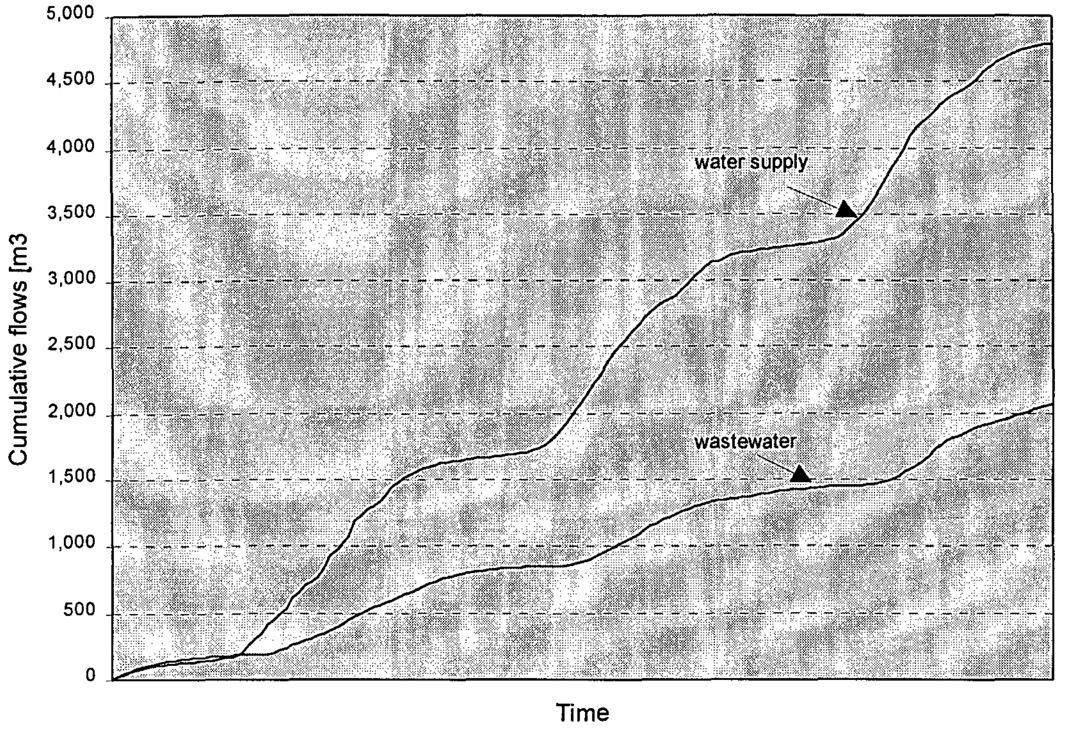


Fig. 7.5 Cumulative water and wastewater flows

7.6.5 Reuse of effluent

Reuse of effluent from the wastewater treatment plant has been the subject of several studies[20]. The conclusion was that the potential of wastewater stabilisation ponds or effluent for fish production in Yemen appears to be minimal, taking into account the actual water quality conditions and the lack of aquacultural practices and experiences.

To avoid any health risk or objections by the local population, preference was given to constructing infiltration ponds in the treatment plant, over discharge into a wadi. For any reuse of effluent, agricultural purposes are considered a more viable application than recreational use, e.g. for a green belt as in Aden, or for domestic or industrial water reuse.

Taking into account the expected effluent quality, a plan has been proposed for agricultural development with effluent reuse in the area of Rada. The plan comprises site selection, land reclamation, type of farming, cropping patterns, irrigation requirements, irrigation scheme, as well as institutional aspects and costs/benefits. Potential sites identified in the plan are indicated in Fig. 7.6 on the next page. The irrigation project would be located in a basin of about 200 ha, just north of the treatment plant, and would cover an area of initially 13.4 ha, to be expanded to 40.5 ha by the year 2010. The implementation of such reuse project is obviously beyond the scope of NWSA, however, and has, therefore, not become a part of the RWSSP programme.

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20 "Water Sanitation Performance of Wastewater Treatment Plants", RWSSP, October 1992, and "Feasibility Study on Reuse of the Effluent from Rada Waste Water Treatment Plant", RIRDP, October 1992

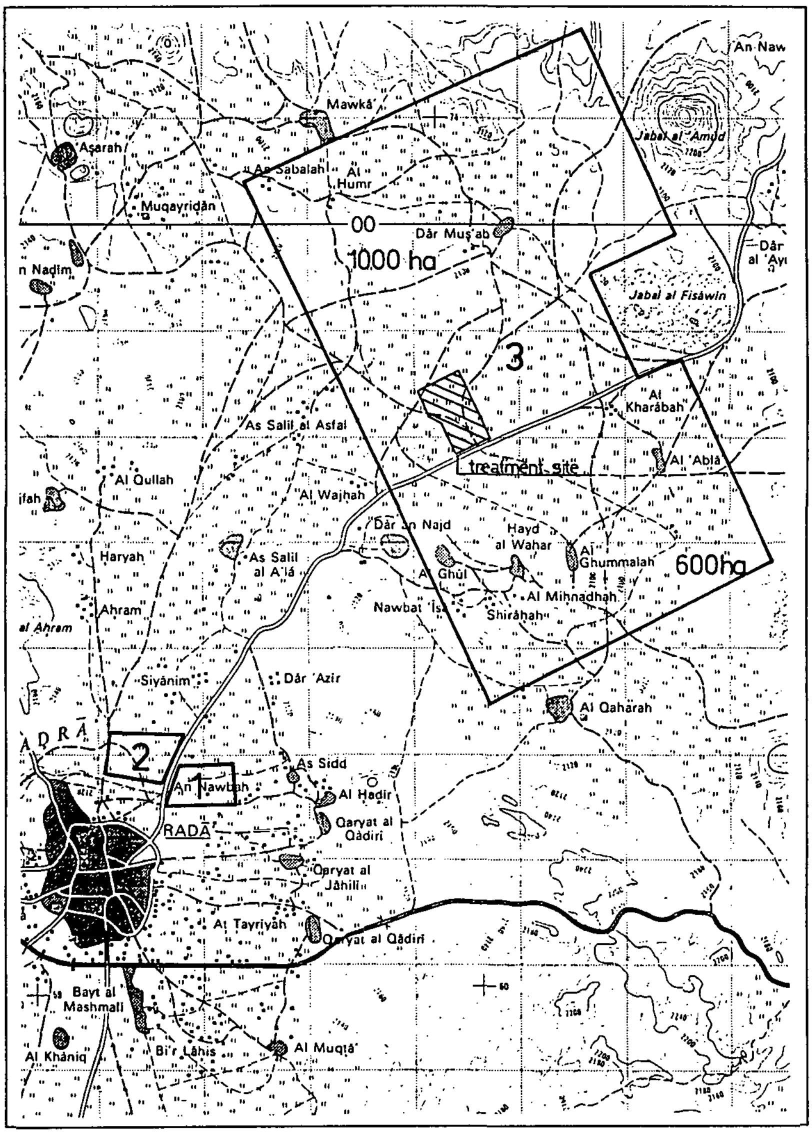


Fig. 7.6 Potential sites for agricultural development plan

8 STORMWATER DRAINAGE

8.1 Drainage pattern

In Rada the ground level has a general slope of 1:150 to 1:100 from west to east. The rainwater can be discharged without pumping, except for some low areas in the town, which needed to be filled up first. In the town 4 separate rainwater drainage basins may be distinguished: Northeast, Northwest, Middle and South, as shown in Fig. 8.1.

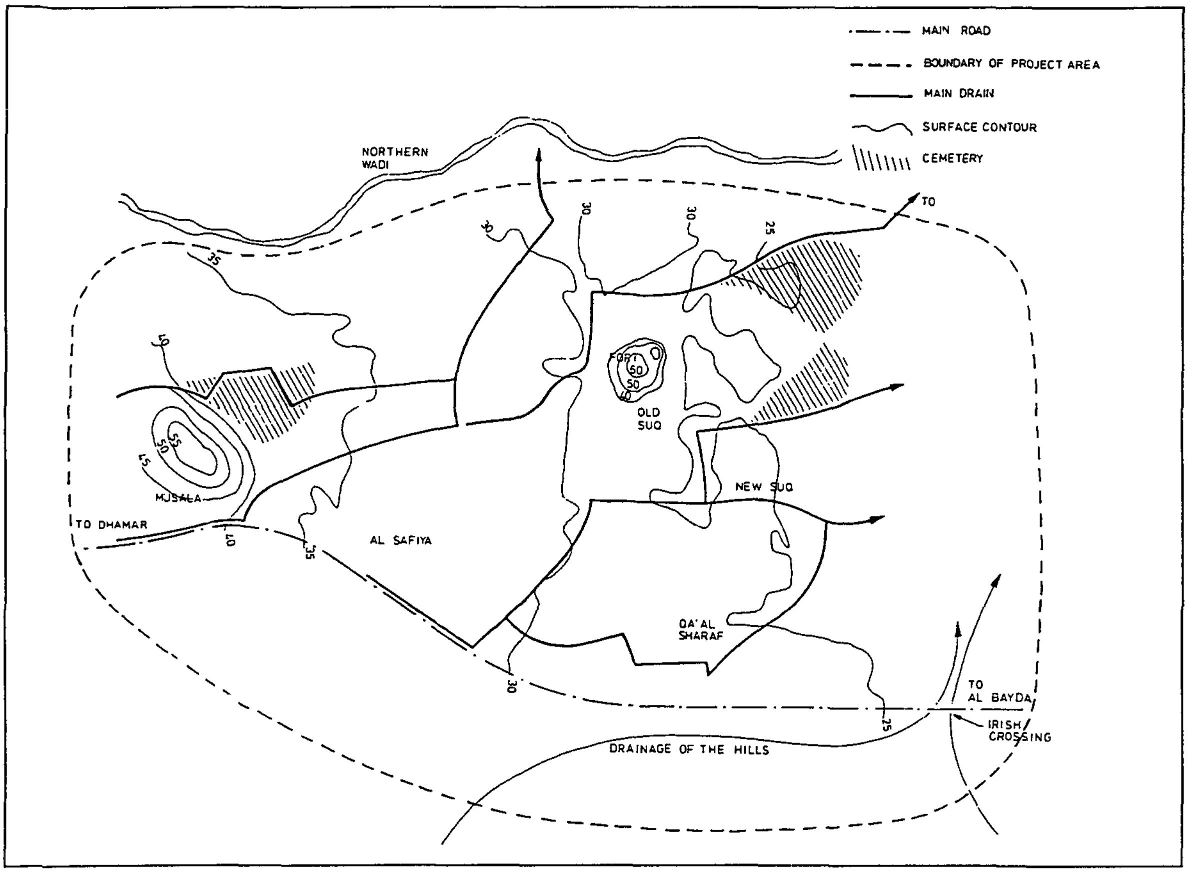


Fig. 8.1 Macro drainage pattern of the Rada area

There is a non-perennial river bed (wadi Al-Arsh) north of Rada, to which the north-western basin can discharge; water from the other basins spills on agricultural land east of the town. Rainwater falling south of the road from Dhamar to Al-Bayda does not enter the town and is discharged along this road to the east.

8.2 Design basis

Because of the low annual rainfall, in combination with high rain intensities, the construction of a combined sewer system would not be economical, hence a separate system was selected, whereby the existing roads would serve as rainwater channels after being paved (road surface drainage system). The aim of the system is to have water off the streets within 2½ hours at the most, which constitutes a considerable improvement compared with the previous situation, when streets would remain submerged for at least a week after heavy rainfall.

Rainfall data, collected by the RIRDP project in the vicinity of Rada over the period 1977-1992, has been used for calculating the so-called design storm, on the basis of which the required capacity of the rainwater 'channels' was determined with the CYCLONE computer model. The calculations given in the Final Design Report have later been revised on the basis of fresh information on rainfall and actual ground levels[21], using a new design storm:

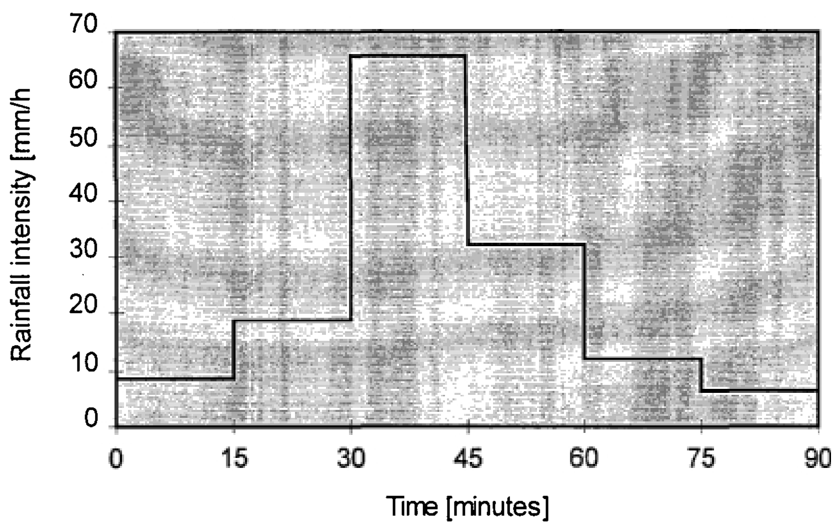


Fig. 8.2 Design storm (return period of 2 years)

Already at the beginning of the RWSSP, as a part of the DIP, a road maintenance and levelling programme was carried out, one of its goals being the improvement of surface drainage, especially for controlling the run-off to selected depression sites. Heavy equipment available with the Baladiya but upgraded by the project, was used for this purpose, under the supervision of the project.

For the final system, originally a shallow "V-shape" road profile had been proposed, because then the water would always be free to pass street crossings (whereas the higher centre line of roads with a normal profile would create an obstruction, requiring a stormwater sewer to pass underneath the crossing). Also kerb stones and sidewalks could have been lower that way. However, after deliberations with the Ministry of Urban Planning and Housing the road profile was changed to the more traditional "roof shape", with side slopes of 2%. Changes have also been made in the general lay-out: a number of roads are no longer included in the system, mainly in the northern part of the town, because a changed infrastructure made them either impossible to construct, or no longer useful for drainage purposes. On the other hand, some roads have been added in the eastern part of the town.

21 See "Above Ground Stormwater Drainage in an Urban Area", M.Sc. thesis of Jeroen Kluck, Delft University of Technology, October 1991, and "Final Detailed Design, Surface Rain Water Drainage Works", RWSSP, October 1993

8.3 Lay-out

The areas north of the town, along the old Al Bayda road next to the cemetery, have been chosen for dewatering, which means that the ring road will become the main drainage channel to collect and transport water from the southern and middle systems. The designated lands are fallow and agricultural lands with a total surface area of at least 100 ha, so that farmers will have the opportunity to make use of the rainwater on their lands. The total volume of water to be discharged during the design storm amounts to 32,500 m^3, which implies an average water depth of about 3 cm.

The drainage system consists of a primary, secondary and tertiary system. Both the tertiary and secondary systems consist of unpaved roads that are designed specifically to dewater on to the primary asphalted roads. The final levels of the tertiary, secondary and primary drainage systems have been adapted to the final design results of the sewer system and final elevations of manholes, which determine the final street levels.

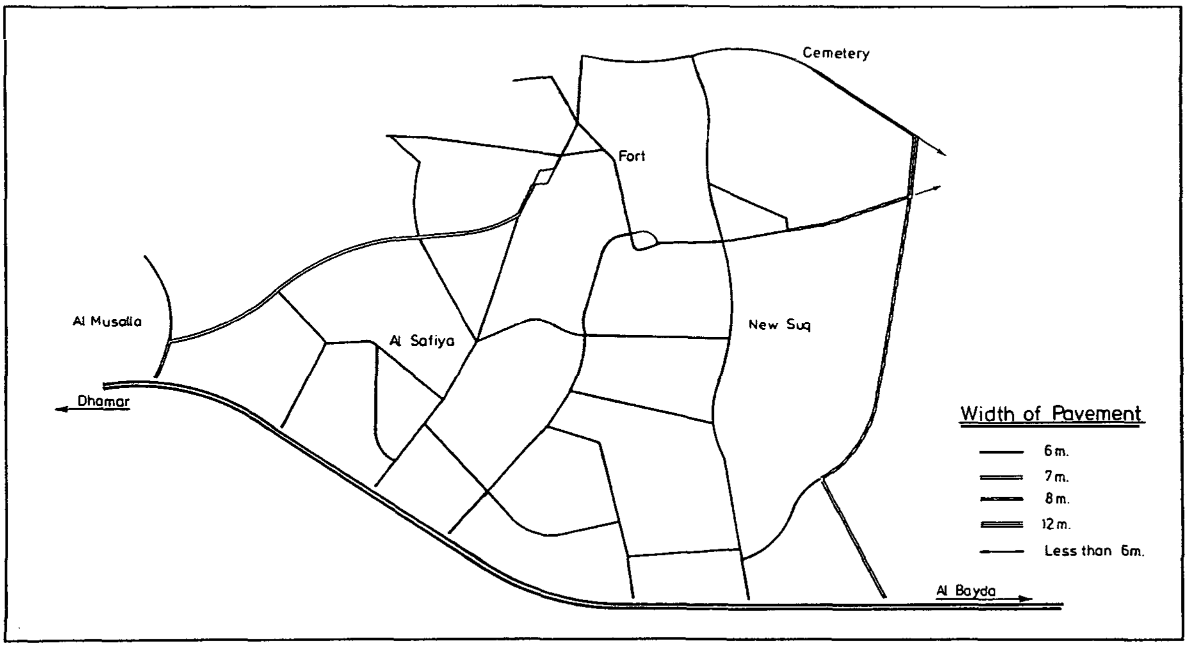


Fig. 8.2 Lay-out of stormwater drainage system, with road widths

8.4 Construction details

8.4.1 Roads

The roads have been constructed in such a way that their surface and kerbs are virtually impermeable. Because the surface rainwater drainage system must be used as normal roads as well, some adaptations were necessary to allow a normal traffic flow, also at locations where drainage itself would not require any special measures to be taken.

Grader being used, in town centre

Graded road, with manhole up to future pavement level

Normally, a width of 6 m has been used; only near the outlets of the system a width between kerbs of 7 m has been used, to cope with the access water. In addition to this, some major truck access roads to the town have been brought to 7 m as well, whereas in other parts local conditions (narrow roads) have dictated widths smaller than 6 m.

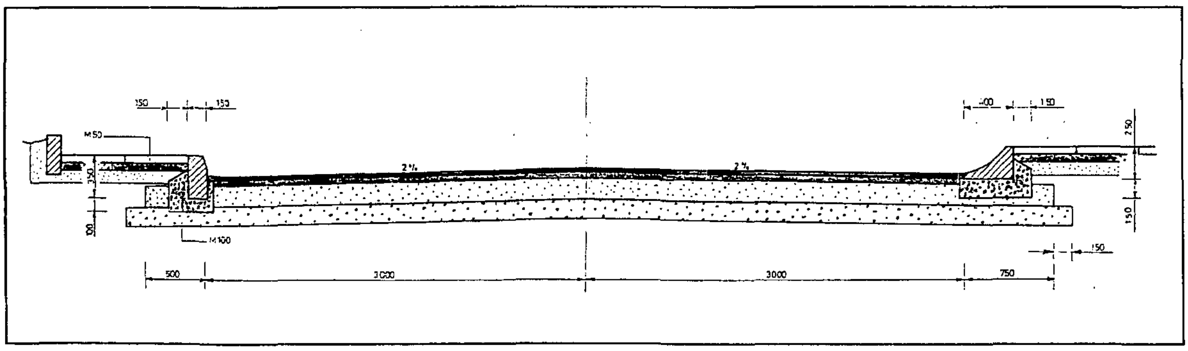
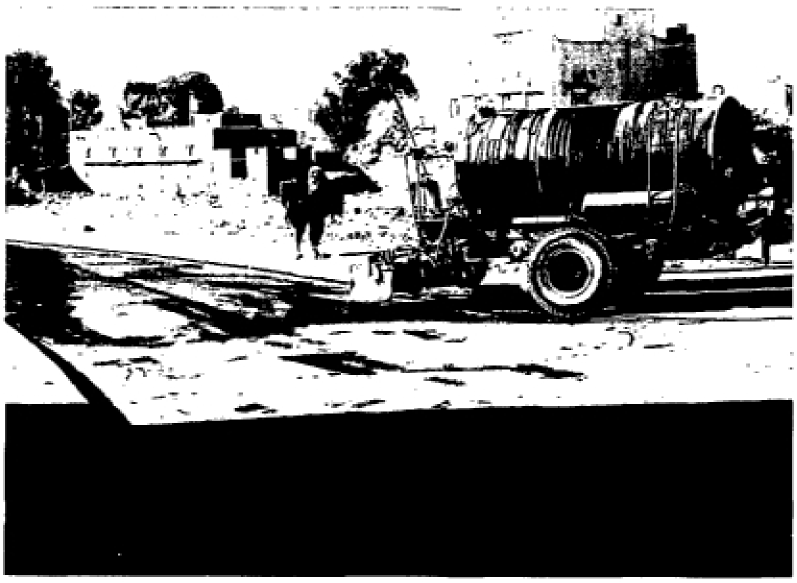
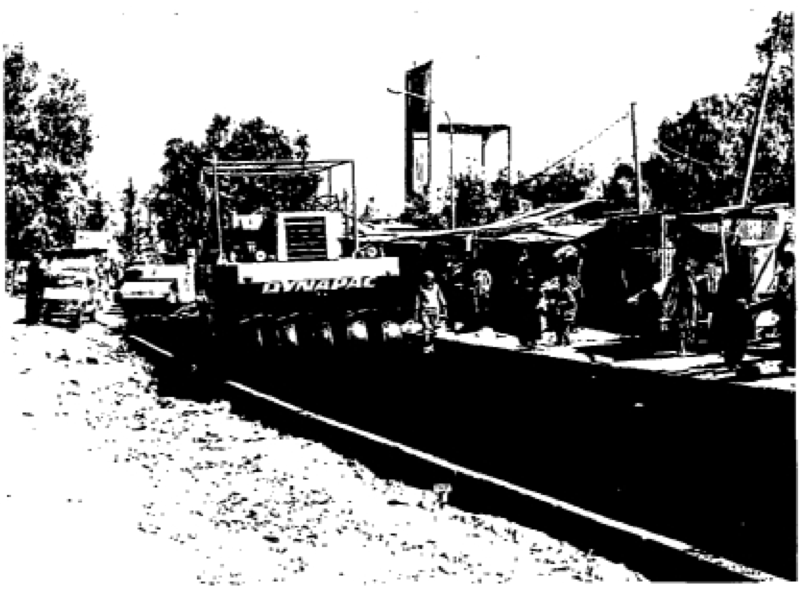


Fig. 8.3 Road profile





Surface drainage works:

applying tack coat (top); laying binder course (centre); compacting binder course (bottom)

Placing kerb stones (top) and laying concrete tiles for sidewalks (bottom)

A total of about 12.5 km of roads have been paved as part of the surface rainwater drainage programme:

Table 8.1 Roads paved for surface drainage

Road width	Length [m]
less than 6 m	430.80
6 m	8,983.30
7 m	2,037.65
8 m	1,015.75
12 m	73.25
Total	12,540.75

The camber of the pavement is 2%, to create sufficient velocity of the water at low quantities and to diminish the wet profile in case of small showers. As sedimentation is then inevitable, with a slope of 2% this will occur along the kerb only, where it can easily been removed.

To reduce maintenance requirements to the maximum extent possible, a low-maintenance surface rainwater drainage system has been built, with an expected lifetime of 20 years without major maintenance. Based also on favourable experience gained in Sana'a, a pavement with a total thickness of 37 cm has been laid, from top to bottom:

- asphalt wearing course 3 cm
- asphalt binder course 4 cm
- base course (stone base 0/40) 15 cm
- sub-base (improved subgrade) 15 cm

For traffic safety, speed bumps have been installed, with a total length of 190 m. These have such a shape that overspeeding is prevented while the flow of water is hardly interrupted. The speed bumps have been installed near dangerous junctions, schools, playgrounds and the hospital, all on indication by the Rada Municipality Office.

8.4.2 Kerbs, sidewalks, container areas

8.4.2.1 Kerbs

The kerbs are shaped in such a way as to keep all surface rainwater on the street while not posing insurmountable obstacles for vehicles that enter or leave the road. Kerbs along the roads are specially designed to cope with the conditions prevailing in Yemen, and especially Rada, with a different shape where cars must cross them. The height of the kerbs varies with the expected water level in the surface rainwater drainage system (read: on the road). At the beginning of each drainage system the kerbs will have standard dimensions, or: 15 cm effective height, with a maximum height of 35 cm in the downstream areas.

In certain parts of the downstream system, mainly in Bank Street, the old Al Bayda road, and south of the cemetery, special solutions had to be found, either because of considerable level differences between the road surface and the adjacent shops, or because the narrow street prevented the application of mechanical pavement.

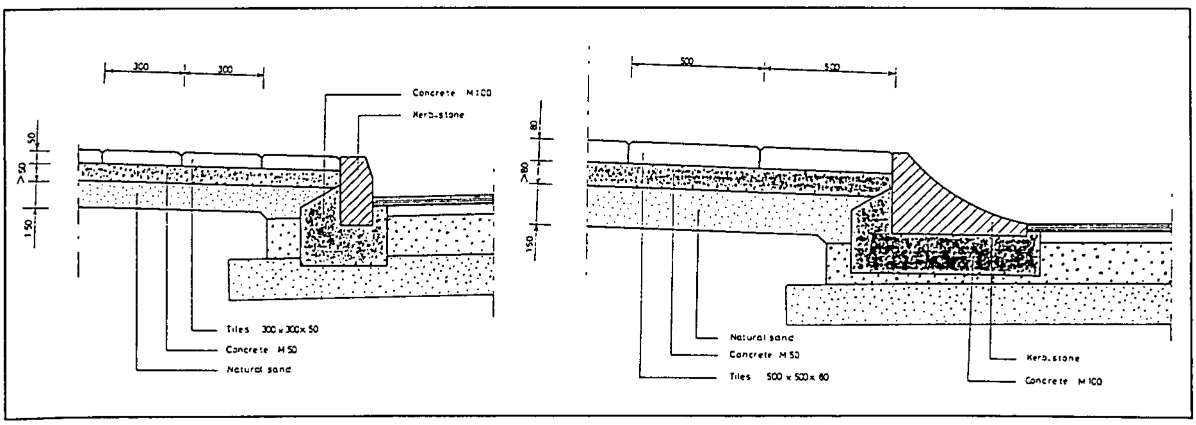


Fig. 8.3 Details of kerb structure

A total of 30.7 km of kerbs have been laid as part of the surface rainwater drainage system, as follows:

Table 8.2 Lengths of kerbs

Type	Description	Total length [m]
1-A	Normal kerb; effective height 0.15 m	15,633.90
1-B	Normal kerb; effective height 0.20 m	1,332.60
1-C	Normal kerb; effective height 0.25 m	1,965.70
1-D	Normal kerb; effective height 0.30 m	3,913.70
1-E	Normal kerb; effective height 0.35 m	2,957.80
2-A	Kerb for vehicle crossing; effective height 0.15 m	2,855.50
2-B	Kerb for vehicle crossing; effective height 0.20 m	238.60
2-C	Kerb for vehicle crossing; effective height 0.25 m	1,851.20
Total		30,749.00

8.4.2.2 *Sidewalks*

Side walks have been constructed in principle along all roads, except for the water outlet roads. The main reason for the construction of sidewalks is to avoid penetration of water from pools standing behind the kerbs, into the road's base as this would weaken that base in an unacceptable manner. Another reason is to protect the kerbs themselves from damage by cars crossing over them, also at places where no kerbs of Type 2 have been installed.

Near the outlet the water level will be so high that rather than kerbs stone masonry walls have been built. As that area is either agricultural land or cemetery, no side walks are required there. The standard width of the sidewalks is 1m, but at places where this is not possible, a reduced width of 0.50 m has been used. In the old city centre left-over pieces of the rock cutting industry, laid in a 5 cm layer of sand mortar, have been used for paving the sidewalks; in the remainder of the town concrete tiles 30 x 30 x 5 cm have been used, also in 5 cm of sand mortar. In total, 23,912 m^2 of sidewalks have been constructed, including 815 m^2 with rock cuttings

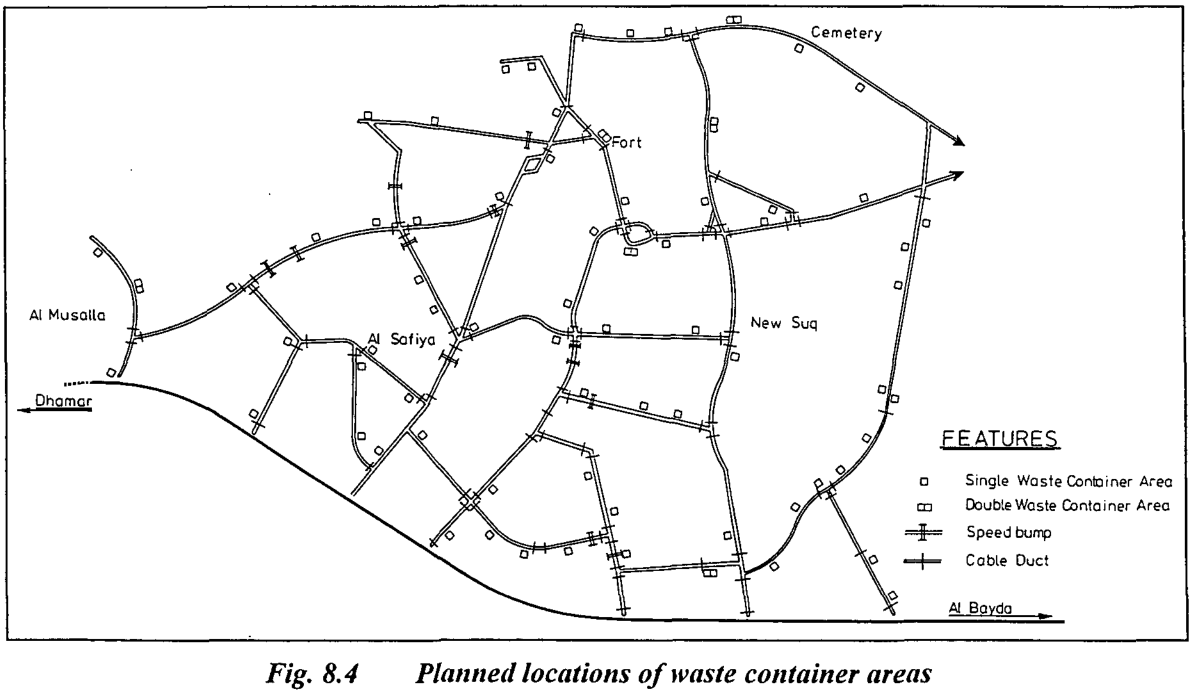


Fig. 8.4 Planned locations of waste container areas

Waste container area, for single container

8.4.2.3 Waste container areas

Special waste container areas have been constructed to obtain a good and permanent location for the waste containers. These areas have a pavement of concrete tiles, similar as for pavement, but in a 10 cm thick sand mortar layer. Each waste container area is surrounded by a 60 cm high stone wall with a thickness of 40 cm, except for the side facing the road. An added advantage of the wall is that little children can climb onto it for disposing the garbage. Excess garbage, when applicable, will be kept within the wall, which means that the area is easy to clean. Since the floor of the waste container areas has the same elevation as the kerb, waste will not be flushed out onto the road and transported in the drainage system, but remain concentrated in the waste container area.

A total of 64 waste container areas have been constructed, of which 57 for a single container (internal dimensions: 1.50 x 1.80 m) and 7 for two containers (1.80 x 3.00 m).

9 EXTENSION AND TRAINING ACTIVITIES

9.1 Objectives

Environmental health education and information are considered indispensable components of the RWSSP. For that reason activities in this field started even before the physical implementation of water supply, sewerage, drainage and solid waste disposal works had begun. Taking into consideration also the special role of women in promoting health awareness under Yemeni circumstances, during most of the period a female EHE/CP (environmental health education/ community participation) adviser formed part of the expatriate consultants team. Especially preceding and during the implementation of the project environmental health education played a major role in introducing and explaining the proper use of the improved water supply, sewerage, stormwater drainage and solid waste collection. The activities were also meant to seek co-operation from the population.

9.2 Extension and Training Section

In 1988, at the start of the project, the E&T (Extension and Training) section was established, with the following tasks:

- to inform the population of Rada during the introduction, implementation and proper use of the improved water supply, sewerage, stormwater drainage and solid waste collection and disposal, and to gain co-operation from the population;
- to provide environmental health education related to the above mentioned sectors;
- to provide and organise training on environmental health and community development.

From 1988 to 1992, the activities of the E&T section concentrated on the introduction and operation of the improved solid waste collection and disposal services, being the first actually implemented project component in the Rada Urban Area.

The project started the implementation of the new water supply and sewerage schemes in 1992. Consequently, the environmental health education and community participation services focused more and more on the environmental health issues related to these sanitation schemes. These services were considered even more important in view of the very significant differences between the old water supply and sewerage systems and the new ones to be introduced.

9.3 Approach of the extension campaigns

The extension approach used by the E&T section was based on the following principles:

- high coverage: essential information has to reach all households, as each household has to make the choice between the old traditional in-house facilities and the newly offered sanitation facilities individually;
- phased information delivery: information should be provided to the people in accordance with the progress of project activities. It would not be effective (and even counter-productive) to discuss services with and behaviour of people without any sign of physical improvement. The right information should be given at the right moment;
- dissemination of information should be in two directions: the exchange of information should not only be from the project to the people, but also from the people to the project. To enable monitoring of people's attitude towards newly introduced sanitation facilities, mass-

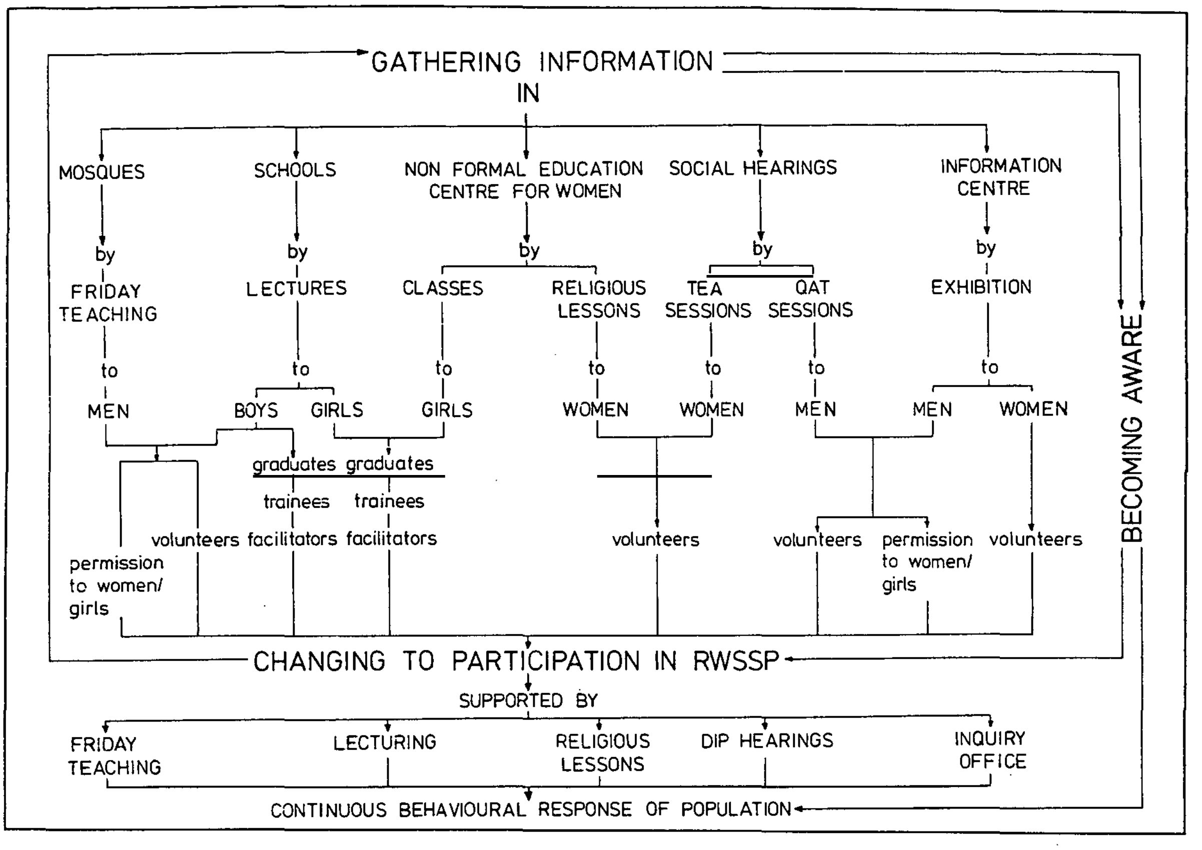


Fig. 9.1 ***Participation model***

media information campaigns have to be supplemented with:

- organising neighbourhood meetings, separately for men and women;
- establishing an information centre, with separate visiting hours for men and women;
- proper follow-up actions on questions and complaints expressed by the participants during meetings, at the information centre, NWSA Branch office and during house visits.

9.4 Information topics

During the project the following topics were covered:

- pre-service phase:
  - general information on project activities, environmental health issues, related prevailing diseases, etc.;
  - technical information on the proposed schemes;
  - information on construction works to be carried out by the contractors;
- construction of facilities:
  - information on in-house plumbing for drinking water supply and sewerage connections and their costs;
- operation and maintenance:
  - use and maintenance of in-house water supply and sewerage facilities;
  - economics of water consumption;
  - continued public health education.

9.5 Role of women in the EHE/CP programme

Though the activities of the E&T section addressed both the male and female inhabitants of Rada, the involvement of the women was considered especially important as in the Yemeni society they are the managers of in-house water supply and sanitation. Therefore the programme, from its beginning onwards, included neighbourhood visits directed towards the female household members, and carried out by the female staff of the section. Also the Information Centre that was established to inform the population and visualise the technical alternatives for in-house water supply and sanitation, has proven to be very successful, being located in a town area that is easily accessible for women, and having separate opening hours for women.

In the presentation of the environmental health and community participation programme, the active support of the population of Rada was essential. In each town district both male and female co-ordinators were identified to assist the E&T section with organising and conducting neighbourhood meetings, identifying other co-ordinators and disseminating EHE/CP messages. These co-ordinators played, as community representatives, a crucial role in the process of obtaining support for the proposed new facilities and subsequent co-operation in their operation.

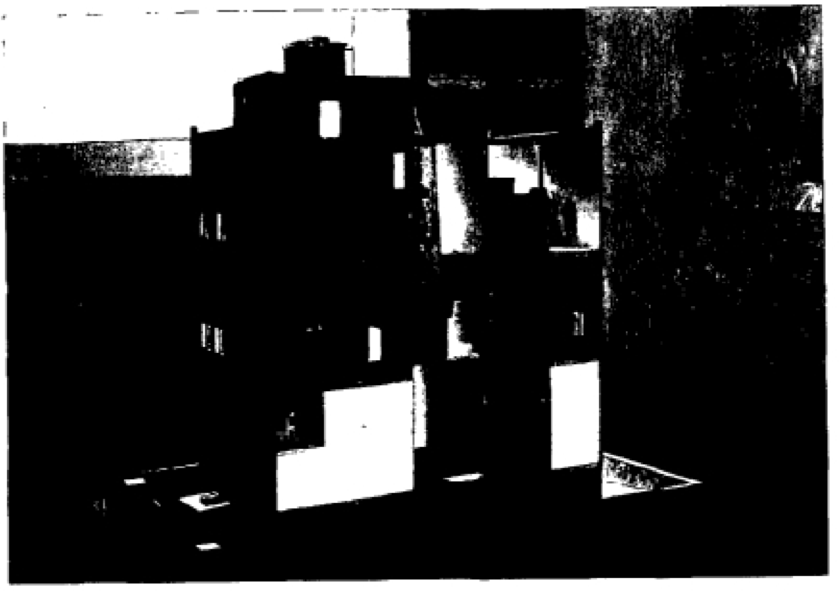
9.6 Dissemination methods used

The following dissemination methods were developed and used, separately or in combination with each other:

- written and pictorial information:
  - leaflets, distributed house-to-house, and containing general information on the new systems, on the contractors' activities in the area, on how to apply for and make proper house connections to the water supply and sewer systems, and possible consequences for the in-house plumbing ;
  - a quarterly newsletter "Friend of the Environment" was distributed to project staff, schools, offices and organisations in Rada. In total 27 newsletters were distributed in 1,400 copies each;
  - posters, cartoons, drawings and pictures;

  To prevent the relatively high illiteracy amongst women from defeating the purpose of the written information, school girls were given special education to explain these written materials to their mothers;
- production of TV spots, videos and movies, and demonstrations;
- district meetings with men, women and special target groups. Issues discussed during such meetings included: in-house plumbing; prevention of blockage of sewage and methods of de-blocking; flushing toilets; water meter reading; hygiene in the house, related to water and sewerage; economic use of water;
- special hearings during 'towahlahah' and 'tahseen';
- involvement of the Non-Formal Education Centre for Women;
- announcements using a car equipped with loudspeaker, and through mosques;
- training of intermediates, in particular school teachers, and providing them with teaching materials;
- establishment of an Information Centre, with separate opening hours for men and women;
- networking with similar projects and programmes.

In addition, meetings were organised with plumbers and shopkeepers, to inform them about the new facilities and to discuss the quality and availability of the required connection materials, while plumbers were trained in the construction of in-house water supply and sewerage facilities.



Open model of Yemeni house, showing water and sanitation plumbing, as used in the Information Centre for explaining the programme

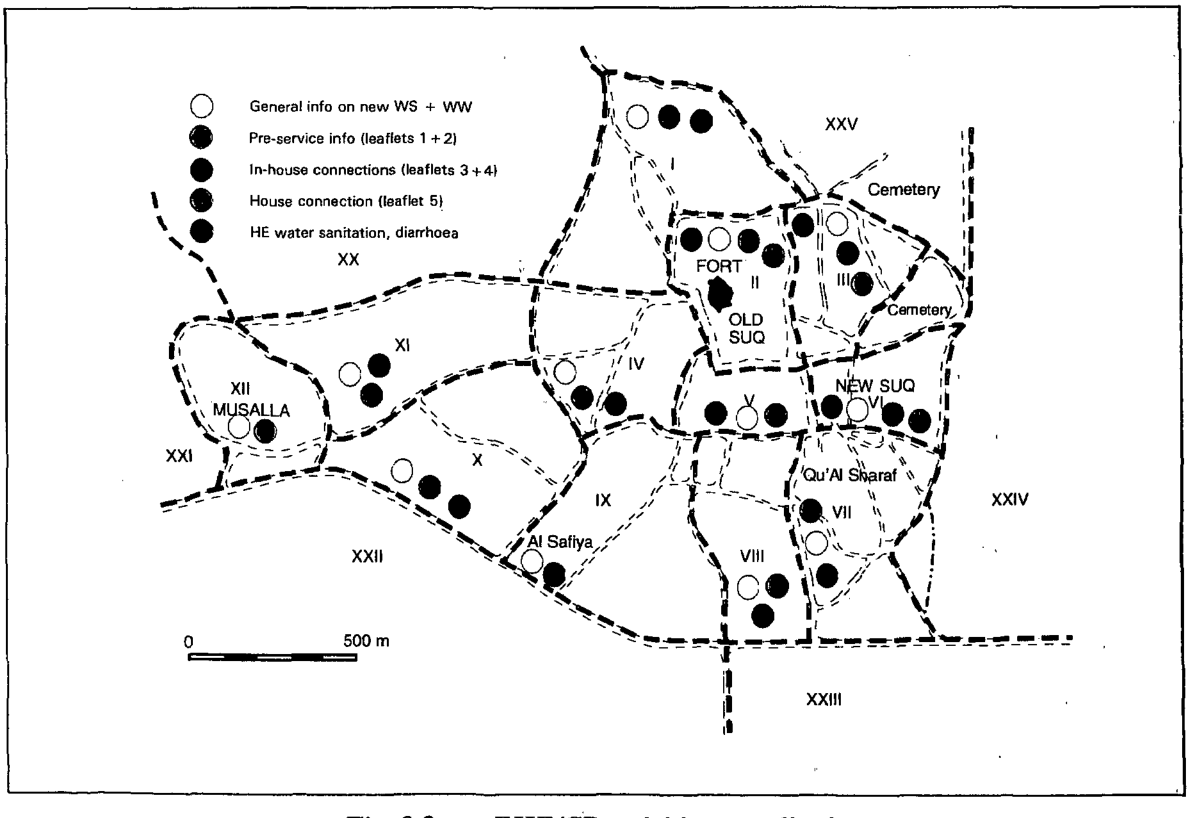


Fig. 9.2 EHE/CP activities, per district

Figure 9.2 shows the types of EHE/CP activities that have been carried out, per district.

The approach and materials developed in the project have drawn the special attention of other development projects in Yemen and are nowadays being used at other places in the country.

In the course of the project, 4 female and 2 male Yemeni extension workers were extensively trained by the project. At the beginning of the project activities also waste collection and disposal were included in the issues covered by the E&T section. After the solid waste component was handed over to the Municipality the section concentrated on the other issues, however. Regretfully, shortage of funds has resulted in a situation where no EHE staff is employed by the Municipality any longer.

A "Final Report Extension & Training Section" of August 1995 presents details about the activities undertaken during the project.

10 INSTITUTIONAL DEVELOPMENT

The sustainability of the introduced facilities requires that the recipient institutions have sufficient capacity to operate and maintain the facilities. The institutional development activities have been focused on:

- the NWSA Rada Branch, which was established in 1994, and is in charge of the operation and maintenance of the water supply and wastewater facilities; and
- the Rada Municipality, in charge of the operation and maintenance of the drainage and solid waste handling facilities.

So far the institutional development activities covered:

- development of the operation and maintenance procedures;
- preparation of a comprehensive operation and maintenance manual for the water supply and wastewater collection and treatment facilities, as well as the power generation facilities at the NWSA Compound in Rada;
- development of training curricula;
- training in the region and overseas;
- on-the-job training in the operation and maintenance of the facilities;
- determination of staffing requirements;
- preparation of job descriptions;
- determination of budget requirements and tariffs for cost recovery;
- development of organisational set-up for the recipient organisations.

The NWSA Rada Branch is still in a transition from project organisation, charged with supervision of construction works, to an O&M organisation.

It has been concluded that a more independent status of the Branch would be necessary to create the conditions for the sustainability of the water supply and wastewater facilities. A major breakthrough was reached in June 1996, when the Ministry of Electricity and Water, in close consultation with NWSA HQ, GTZ, the Royal Netherlands Embassy and the Consultancy Team of the project, basically agreed on a more independent status of the branch, as a pilot case for decentralisation including a review of the tariffs and adjustments of salaries to be paid. This decentralisation should finally lead to a certain degree of independence of the branch in:

- pricing policy;
- hiring and firing of staff, so that O&M operations can be carried out as efficiently as possible;
- salary and allowances structure;
- financial management, inclusive of budgeting and planning;
- technical and O&M management.

The Technical Assistance in the strengthening of the independent NWSA Rada Branch will cover:

- assistance in adjusting the staffing (both in quantitative and qualitative terms) according to the proposed responsibilities and organisational set-up;
- setting in place a mechanism for correct setting of tariff levels;
- development, introduction and implementation of a financial management system, taking into account the existing procedures and guidelines in this field, and covering:

- budget system and computerised accounting system;
- computerised billing system;
- procurement and inventory control system;

- development of personnel management system including salary and allowance structure;
- training in all operations;
- development of personnel/human resources development system covering remuneration and performance appraisal procedures;
- development of a customer management system covering promotion procedures and complaints handling;
- assessment of the tasks to be carried out in-house and contracted out to NWSA HQ and the private sector.

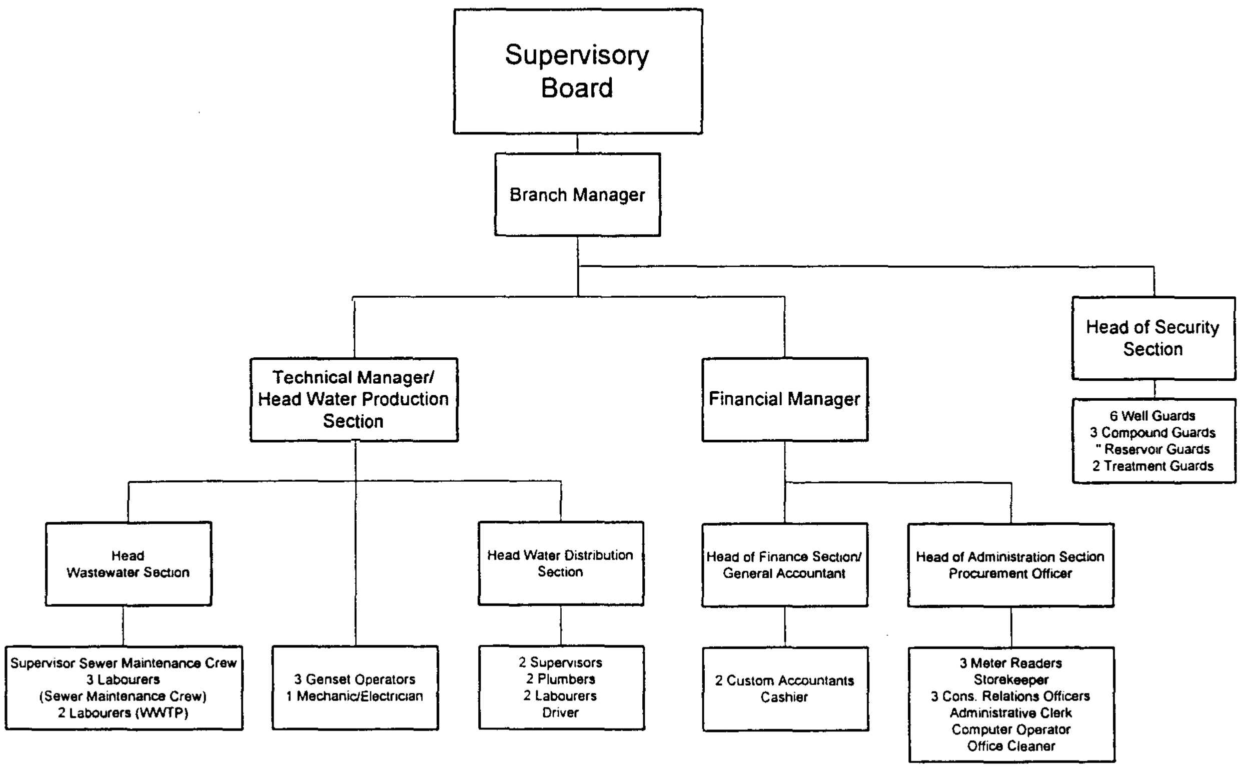


Fig. 10.1 Organisation of NWSA Rada Branch

11 COSTS

11.1 Financing

The Rada Water Supply and Sanitation Project was funded by the Governments of Yemen and The Netherlands, as shown in Table 11.1:

Table 11.1 ***Disbursements (millions)***

Netherlands disbursements (millions of guilders)

Year	1988 - 1990	1991	1992	1993	1994	1995	1996	1997	TOTAL
FA	-	-	7.5	12.7	12.2	4.1	4.5	1.5	42.5
TA(FA)	-	0.4	1.6	-	-	-	-	-	2.0
TA (Cons.)	9.9	2.7	3.4	3.8	3.0	2.5	2.0	0.5	27.8
TOTAL	9.9	3.1	12.5	16.5	15.2	6.6	6.5	2.0	72.3

Yemeni contribution (millions of Yemeni riyals, and corresponding values in millions of guilders)

Year	1988 - 1990	1991	1992	1993	1994	1995	1996	1997	TOTAL
in riyals	-	-	11.85	19.60	12.65	19.20	-	-	63.30
in guilders	-	-	1.875	3.100	2.000	3.025	-	-	10.00

Of the Netherlands contribution the row 'FA' indicates disbursements for the construction contracts, financed according to the Financial Assistance modality. The row 'TA(FA)' refers to disbursements for cars and heavy equipment, financed under Financial and Technical Assistance modalities. The row 'TA(Cons)' refers to the so-called consultancy budget, which has been financed under the Technical Assistance modality. The budget comprises not only consultancy aspects, however, as will be explained in paragraph 11.2.2.

The Yemeni contribution of YER 63.30 million refers to contributions to the water supply and sewerage construction works. Of this amount, YER 7.3 million[22] still has to be formally allocated, while having been approved in principle. In addition, an amount of YER 10.5 million was made available by MUPH in the years 1989-1993 for salary payments, while also the site for the vehicle workshop (about 1 hectare) was made available by the Ministry. Furthermore, a total of YER 22 million in counter value funds (NWSA: 14 million; MUPH: 8 million) has been made available for various activities under the project (YER 10 million) and for land acquisition for NWSA-related contracts (YER 12 million). Altogether, the Yemeni contribution thus amounts to YER 95.8 million.

11.2 Implementation costs

11.2.1 Construction costs

The total construction costs – exclusive of counterpart value funds (CVF) spent on preparatory works, fencing, land acquisition, etc. – amount to YER 278,583,663+ NLG 4,590,610, as shown in Table 11.2. There, Contract 2 includes the costs for the extension areas XXIII - XXV and the works and materials for the latest extension areas, XX and XXIV. Details, grouped per main component, are given in Table 11.4

22 YER = Yemen Riyal

Table 11.2 Final costs of contracts

Contract No.	Description	Final cost of work		Paid in:	
		YER	NLG	YER	NLG
1	Well drilling	4,425,682	-	885,136	486,034
2	Civil Works	254,142,938	-	50,828,588	32,154,836
3	Mechanical/Electrical Works	19,875,923	-	3,975,185	2,664,420
4	Surface Drainage Works	-	4,590,610	-	4,590,610
	TOTAL	278,444,543	4,590,610	55,688,909	39,895,900

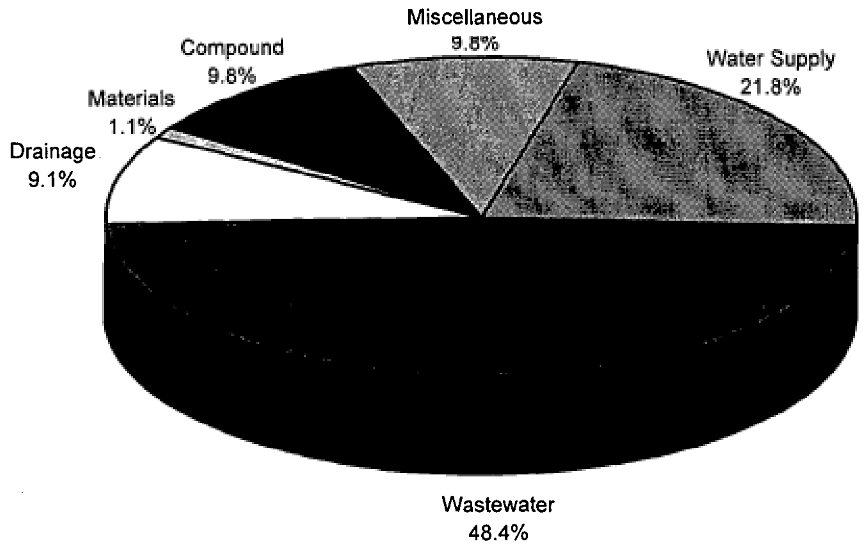
Table 11.3 Cost details (all in Yemeni Riyals, except for surface drainage works)

Description	Total Basic Cost	Extension Areas		Well drilling	M/E Works	TOTAL (YER)	Surface Drainage (NLG)
		XXIII-XXV	XX-XXIV				
WATER SUPPLY COMPONENT						***66,499,924***	
Boreholes	-			4,425,682		4,425,682	
Well pump houses	1,745,237				3,240,492	4,985,729	
Collector/Transmission main	14,023,275					14,023,275	
Chlorination plant	593,316				1,554,144	2,147,460	
Storage reservoir	2,893,346				79,396	2,972,742	
Water distribution system	18,623,302	2,262,314	576,974			21,462,590	
District water meter chambers	6,473,698	68,172				6,541,870	
House connections	8,613,036	309,065				8,922,101	
Fire hydrants	885,611	132,866				1,018,477	
WASTEWATER DISPOSAL SYSTEM						***147,899,458***	
Sewer house connections	12,119,421	1,298,865				13,418,286	
Sewers	66,415,676	4,856,983	1,306,625			72,579,285	
Sewage pumping station	77,525				255,296	332,821	
Sewer transmission main	5,675,287					5,675,287	
Wastewater treatment plant	55,893,779					55,893,779	
SURFACE DRAINAGE SYSTEM						***620,311***	***4,590,610***
Road pavement	620,311					620,311	2,041,809
Kerbs, speed bumps, guiding walls	-					-	1,1811,202
Sidewalks	-					-	1,267,863
Waste container areas	-					-	99,736
MATERIALS AND TOOLS						***3,380,749***	
Repair and maintenance equipment	1,856,045					1,856,045	
M/E spare parts	-				861,400	861,400	
Laboratory equipment	437,600					437,600	
Materials for WWTP O&M	75,704					75,704	
Diesel genset etc. for WWTP	150,000					150,000	
NWSA COMPOUND						***29,981,182***	
Compound buildings	216,800					216,800	
NWSA office building	4,775,843					4,775,843	
O&M building	6,795,988				254,935	7,050,923	
Generator house	1,134,089					1,134,089	
Generator sets	-				8,309,094	8,309,094	
Electrical installations	-				5,171,358	5,171,358	
Pipe storage	1,944,467					1,944,467	
Guard house	242,356					242,356	
External works	1,136,252					1,136,252	
MISCELLANEOUS						***30,062,918***	
Indicator and direction signs	94,042					94,042	
Temporary works	29,819,068					29,819,068	
Provisional sums	-				32,141	32,141	
Lightning protection and grounding	-				236,788	236,788	
Equipment manuals M/E	-				120,000	120,000	
Deducted for final testing etc.	-				- 239,121	- 239,121	
TOTAL	243,331,074	8,928,265	1,883,599	4,425,682	19,875,923	278,444,543	4,590,610

In the course of the project the rate of exchange between the Yemeni Riyal and the Netherlands Guilder has changed considerably. In order to be able to compare the costs of the various contracts the same rate of exchange should thus be taken into account for Contract 4 as for the earlier contracts, where a fixed exchange rate had been applied. Using that same exchange rate, the total construction costs would become equivalent to YER 305,529,143, subdivided as follows:

Table 11.4 Major construction cost components

Description	Yemen Riyals	%
Water Supply Component	66,499,924	21.8
Wastewater Disposal System (Sewerage + Treatment)	147,899,458	48.4
Surface Rainwater Drainage System (equivalent YER amount)	27,704,911	9.1
Materials and Tools	3,380,749	1.1
NWSA Compound	29,981,182	9.8
Miscellaneous and temporary works	30,062,918	9.9
TOTAL	305,529,143	100.0



11.2.2 Engineering costs

The consultancy budget of NLG 27.8 million was made available in 6 instalments, as follows:

Table 11.5 Instalments of Netherlands consultancy contribution

No.	Period	NLG
1	1988 - 1990	9,912,551
2	1991 through August 1993	8,310,204
3	September-October 1993	892,286
4	November 1993 through December 1994	3,743,057
5	01/01/1995 through 31/10/1995	2,439,780
6	01/11/1995 through 31/1/1997	2,497,643
	TOTAL	27,795,521

Although indicated as 'consultancy budget', this part of the total budget in fact includes several other types of costs, including heavy equipment, salaries and training costs for counterpart staff, and institutional development costs, while about one-third of the consultancy budget was spent on engineering costs, as indicated in Table 11.6.

Table 11.6 Composition of 'consultancy' budget

No.	Description	NLG (millions)	%
1	Equipment	2.300	8.3
2	Engineering-related cost	5.099	18.3
3	Extension and Training costs	5.099	18.3
4	Engineering costs: cars and hardware	5.099	18.3
5	Net engineering costs	10.199	36.8
	TOTAL	27.796	100.0

Equipment cost mentioned as item No. 1 comprises equipment support to the counterpart organisations: compactor trucks, drawing tools, spare parts, special equipment (e.g. video equipment), office furniture for NWSA/MSUPH, special computers and heavy equipment spares, for use by the counterpart organisations.

Engineering-related cost mentioned as item No. 2 includes salaries and training costs of counterpart staff. Together with parts of item No. 3 and 4 these costs in fact comprise an institutional support component which consumed approximately one-third to one half of the 'consultancy' budget. Included in this is support to the NWSA Rada Branch such as assistance in setting up the financial and administrative structure for the Branch, and training administrative and financial Branch staff, that has never been included in the consultancy contract, but which was considered indispensable to guarantee sustainability for the Branch.

Items 4 and 5 together form the Engineering costs, of which about one-third is hardware such as cars and furniture, which either has already been transferred, or will be transferred shortly. Net engineering costs, therefore, amount to around NLG 10.2 million. Compared with total project costs of around NLG 82.3 million (NLG 72.3 million in guilders and around NLG 10 million in riyals), the net engineering cost for the project, from the inception phase through full implementation, thus represents 12.4 %.

11.2.3 Extension and training costs

Extension and training costs comprise:

- costs incurred by the Extension & Training Section, including cost of expatriate and local staff, vehicles, printed matter (leaflets, brochures, etc.), publicity campaigns, setting up of Information Centre, etc.;
- cost of technical training to counterpart staff, notably on water supply and wastewater treatment, including participation in special training sessions and courses, also overseas;
- cost of preparation of operation and maintenance manuals for the water supply, sewerage and wastewater treatment components

11.3 Cost per capita

Based on the target population for Phase 1 (1995 population of 50,000 inhabitants), the per capita cost of the project amounts to NLG 82.3 million / 50,000 = NLG 1,646 per capita. If only cost of the implementation works is taken into account, the cost per capita become YER 305,529,143 / 50,000 = YER 6,110 per capita.

In fact the per capita cost is considerably lower since much of the infrastructure, e.g. the entire main water distribution network, as well as most of the trunk sewers and to a major extent also the wastewater treatment plant, are dimensioned for the Phase 2 population, i.e. for 75,000 inhabitants.

For several components the cost per capita would thus be lower, down to about 2/3 of the cost as calculated above. This is the more so as actual water demand – also due to the virtual absence of leakage in the system – is clearly lower than gross water consumption per capita before the new system became operational. This means that with the currently available technical facilities an even larger number of consumers can be accommodated than has been accounted for in the design, with correspondingly lower costs per capita and per house connection.

For the water supply system (cost of construction contracts: YER 66.5 million if taken separately; YER 96 million if the full cost of the NWSA compound is taken into account as well), the cost per house connection ranges from YER 12,400 to 30,400, depending on which number of house connections is taken into consideration: the number as currently realised, the number that may be realised without major additional cost, the number representing the current saturation level (as following from a house-to-house survey), or the projected number at the end of the second phase of the planning (for which additional investments would be required, however). For the wastewater collection and treatment system (construction cost: YER 147.9 million), the cost per house connection would range, for the same reasons, from YER 68,400 to YER 21,900:

Table 11.7 Cost per house connection

Component/ house connection situation:	Number of house connections	Yemen Riyal per house connection	Equivalent in Netherlands guilders	
			based on current rate of exchange	based on full cost of project in guilders
Water Supply component				
installed per 31 December 1996	3,162	21,000 - 30,400	255 - 368	5,700 - 8,000
all technical facilities in place	3,661	18,200 - 26,200	220 - 318	4,900 - 6,900
potential according to survey	5,372	12,400 - 17,900	150 - 217	3,300 - 4,700
maximum for second phase	7,500	8,900 - 12,800	108 - 155	2,400 - 3,400
Wastewater component				
installed per 31 December 1996	2,164	68,300	829	18,400
potential according to survey	3,378	43,800	531	11,800
maximum for first phase	4,500	32,900	399	8,900
maximum for second phase	6,750	21,900	266	5,900

At the current rate of exchange the equivalent cost in guilders would be ranging from NLG 108 to 368 per house connection for water supply, and from NLG 266 to 829 for sewerage and wastewater treatment, as shown above. These figures do not present a fully representative picture, however, as they do not include consultancy etc., while the rate of exchange of the Yemen Riyal declined considerably during the time, so that the equivalent value in guilders should be higher.

If – as the other extreme – all project costs, totaling at NLG 83.3 million, would be taken into account, and the percentages of Table 11.6 applied to that amount, the total cost of the water supply component would be NLG 17.941 or 25.431 million (without or with the NWSA compound), and the cost of the wastewater collection and treatment system NLG 39.833 million. Based on these figures, the cost per house connection would then range from NLG 2,400 to 8,000 per connection for water supply, and from NLG 5,900 to 18,400 per sewer connection.

It should be mentioned that this calculation method is not entirely realistic either, as it includes in the cost per house connection the considerable equipment contributions to the counterpart organisations, as well as institutional support and extension and training activities, so that the resulting investments per house connection are too high. Realistic investment costs per house connection lie somewhere in between the two extremes presented above.

12 FOLLOW-UP ACTIVITIES

12.1 General

With the last physical implementation works finished by mid-1996, the project was officially terminated by the end of January 1997, when the maintenance guarantee period of the contractors ended. Several complementary activities had been started earlier, however, and will continue also after January 1997. These focus on institutional support to the NWSA Rada Branch in general, and on support for operation and maintenance in particular (see Chapter 10).

Whereas it was originally foreseen that support to the NWSA Rada Branch would be provided by the German technical development co-operation agency GTZ with effect from July 1996, it has become clear that continuation of the Netherlands support will be required for some time at least. This support will concentrate on the fields of O&M and institutional support.

In order to build the capacity at the NWSA Rada Branch additional technical assistance is necessary in the following fields:
- support to the ongoing implementation of decentralisation proposals;
- guidance in the implementation of the improved administrative systems, including staff training;
- O&M support;
- (nation-wide) building of training capacity.

12.2 Support to the on-going implementation of decentralisation proposals

Additional support, to facilitate the elaboration and subsequent implementation of the decentralisation proposals, is considered crucial for the establishment of a successful Rada Branch. It must be realised, however, that the successful implementation of the proposals and hence the Branch's ability to sustain the implemented water supply and sanitation facilities is fully dependent on :
- the mandate that the Steering Committee receives from NWSA head office and the Minister of Water and Electricity to implement the decentralisation policies; and
- the time, the resources and the commitment that the members of the Steering Committee have to carry out their duties.

To enable the NWSA Rada Branch to effectively carry out its tasks, it should be supported by rules which clearly define its authority and responsibility. The development of the required legislation is proposed to be carried out as soon as the decentralisation proposals are elaborated.

According to the recently adopted Water Policies, the establishment of a Supervisory Board, to which the NWSA Branch should report, is seen as a part of the decentralisation process. These policies suggest the participation of local authorities and local leaders in such a Board. The need of local participation in the management of the Branch has also been expressed by several local leaders. Through the experience gained in the implementation of the RWSSP, the consultants support this idea in order to maintain good relations with the community and sustain the facilities.

12.3 Technical support in O&M

The Rada water scheme has been designed in such a way that volumetric checks of water flows can be easily accommodated, enabling the implementation of an adequate water loss reduction/prevention programme.

So far the implementation of the water loss programme have been hampered by an inadequate processing of the customer, district and bulk water meter readings. Therefore, the water loss reduction programme is proposed to be implemented as soon as the computerised billing/MIS system is fully operational. This training is proposed to be provided by the GTZ Water Supply Technicians.

The proper operation of the sewer system has been hampered by the slow implementation of sewer house connections and the late delivery of O&M equipment (in September 1996). Presently, connection to the sewer system is being promoted and it is expected that around the formal termination of the project the system can be properly operated.

Additional TA (mainly through local consultants) is deemed necessary to :
- develop an adequate sewer maintenance programme for the NWSA Rada Branch;
- train the NWSA staff in sewer maintenance.

Further additional support is proposed to be provided through regular visits of the GTZ water supply technicians to the Branch.

12.4 Implementation of administrative and reporting systems

Additional TA is necessary to guide the change-over from the existing accounting, billing and stores system to the newly developed system as well as to successfully implement the reporting and customer relations systems.

Together with the implementation of these systems, training is proposed to be provided. Special attention should thereby be given to :
- budget preparation and budget control;
- filling in the reporting forms
- interpretation of management information

It is proposed that, after the successful implementation of the improved administrative systems and decentralisation proposals, the performance monitoring of the Branch is taken over by GTZ.

12.5 Building of training capacity

In order to avoid that in future training becomes a one-off exercise, the Consultants propose to develop a training programme that can be replicated. To ensure continuity in training delivery, it is crucial that the proposed training courses for staff of the NWSA Rada Branch will be incorporated into existing institutions.

It should be determined which institutional set up best ensures sustainability and continuity of training. The role of actors (including the NWSA Rada Branch itself) in the water and sanitation sector in training needs assessment, training development and training delivery (on-the-job and off-the-job) should be specified and procedures detailed. Special attention should be given to the potential role of the private sector. In that respect also the option of developing a strategy for management assistance by the Netherlands Government to NWSA, in such a way that the Rada Branch could be operated as a semi-privatised enterprise, with guaranteed performance, merits further consideration.

Further training programmes, trainer's guides and training materials should be developed based on the knowledge, skills, attitudes and experience requirements for the different functions. A modular approach is proposed in training development.

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131. Quarterly Progress Report January - May 1996.

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