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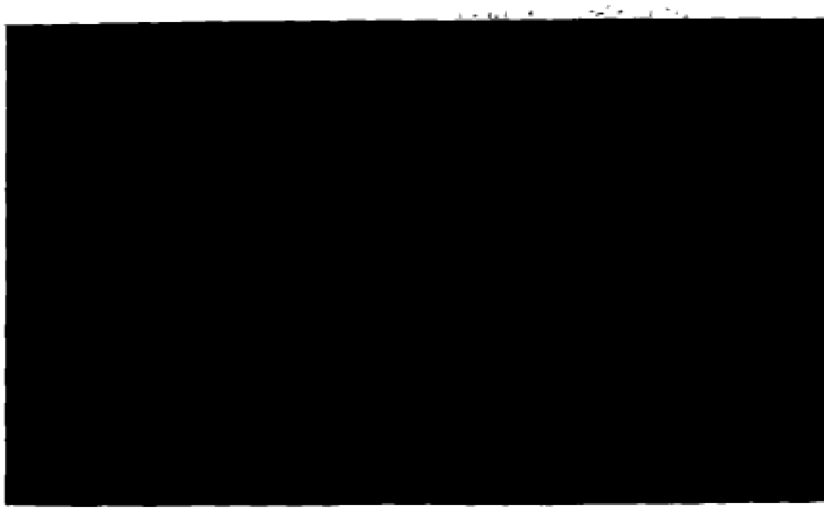

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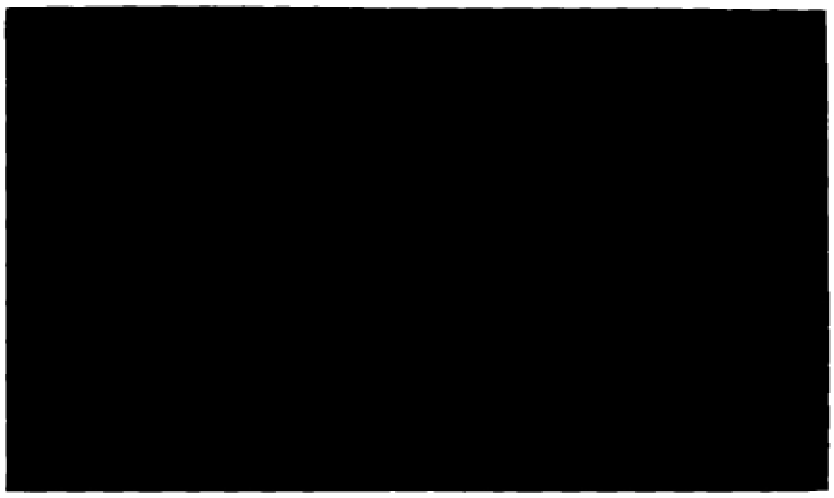

ALTERNATIVE SOLUTIONS
FOR
VILLLAGE WASTEWATER DISPOSAL

- Al Hajar village as case study -

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CONTENTS I

ANNEXES

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Summary

The joint Yemen-Netherlands evaluation mission of September 1987 recommended to develop an integrated public health programme with small-scale affordable solutions for sanitation improvements. The present report follows this advice and tries to compare a number of alternative solutions for the wastewater problems of private houses from a technical, social and financial point of view. As basis for this comparison, a World Bank methodology has been used.

The study is directed to the village of Al Hajar, which has 1007 inhabitants. The village has a RIRDP watersupply scheme, there are many places where wastewater flows freely through the village and the health situation of the population is rather poor compared to other villages. The village can be divided in two parts: 1) a compact village on top of the hill and 2) scattered houses on the slopes of the hill.

For the village on top of the hill the following options have been compared: 1) conventional sewerage, 2) pour-flush toilets with small bore sewer system, 3) pour-flush toilets with vaults and 4) improved baladih toilets with a separate disposal system for wastewater.
Only options 2) and 4) are technically feasible. The costs of both options are comparable. The user convenience of a small bore sewer system is much higher. As there are also social objections against the acceptance of improved baladih toilets, a small bore sewer system is the most appropriate technology for this part of the village. The total costs of such a small bore sewer system are circa YR 1 500 000, which means YR 15 000 per house or YR 2500 per equivalent.

For the new houses scattered on the hill the following options have been compared: 5) pour-flush toilets with pits, 6) pour-flush toilets with septic tanks and 7) improved baladih toilets.
The results of this are that in a situation with a sandy soil a total pit, which costs about YR 10 000, is the best solution. In a situation with rock or hardrock a septic tank with drainfield is the preferable technology. The costs of such a system are about YR 17 000.

A sanitation scheme for all the houses in Al Hajar includes four different new sanitation technologies. As the project has no experience with the implementation of any of this technologies, it is not advisable to start with all new technologies at the same time.
The total costs of a sanitation scheme for all the houses in Al Hajar will be nearly YR 2 000 000, which means YR 15 000 per household or YR 2 500 per equivalent. Such an amount of money is not a justified investment because it means that almost the whole budget for saniation schemes will be spent in only one village Furthermore, the required village contribution (25%) is far beyond the capacity of the village community.
Altogether it is not advisable to start with the implementation of such an expensive scheme in Al Hajar. It is necessary to gain experience in villages with a much easier physical and social structure.

ABBREVIATIONS

CB	= Concrete blocks
CI	= Cast iron
Dfl	= Dutch guilders
GS	= Galvanized steel
IHEC	= Improvement of Health Environment Committee
LCA	= Liter per capita per year
LCD	= Liter per capita per day
MCH	= Mother and Child Health
PF	= Pour-flush
PVC	= Polyvinyl chloride
RC	= Reinforced concrete
RIRDP	= Rada Integrated Rural Development Project
RWES	= Rural Women Extension Section
US$	= United States dollar
YR	= Yemen riyal

1 INTRODUCTION

In 1983 the RIRDP made an inquiry into the sanitation situation in the Al Bayda Province. From a villages survey in the province it appeared that over 90% of the people considered their existing sanitation systems unhealthy and there was a general interest in improvement of the existing sanitation systems (ref.11).
In March 1984 the RIRDP decided to start with the implementation of four types of sanitation pilot projects. The implementation of the first pilot project, the construction of improved baladih toilets in Al Khilaw, started in December 1984. The start of this project was difficult and resulted in severe financial and organizational problems. After this failure the emphasis was put on the second pilot activity, the construction of sanitary facilities at mosques. This activity was much more successful, demonstrated by a big number of requests for new projects. The resulting workload for the sanitation staff was too high and had an adverse effect on the development of other sanitation activities.
This imbalance of the sanitation programme was one of the main comments of the joint Yemen-Netherlands evaluation mission of September 1987. It was recommended to develop an integrated public health programme with small-scale affordable solutions for sanitation improvements (ref.12).

The present report follows this advice and compares a number of alternative solutions for private houses from a technical, social and financial point of view.
This study is directed to the village of Al Hajar, which is often mentioned as a pilot village for sanitation activities. The physical infrastructure of the village is complicated (on top of a rocky hill) and the village is a good example for a theoretical case study. Several of the technical problems which can be faced during the execution of a sanitation programme in any village in the province are gathered in Al Hajar. The results of this study are generally applicable and form the basis for the implementation of sanitation necessities for private houses.
On the other hand the complexity and the size of Al Hajar reveal that this village is not really suitable for the start of a new project activity. Such an activity should be carried out in a small village with an easier structure which guarantees a bigger chance of success.

The basis of this study is that all houses in the village should be covered by the sanitation programme. However, activities inside the houses, like construction of toilets and bathrooms, are the responsibilty of the house owner, and the RIRDP is only involved from the point where the wastewater leaves the houses.

The first part of this report deals with the various alternative solutions for wastewater disposal, while the second part (annexes) deals with design criteria and cost estimates.
In the report exchange rates of 1 US$ = YR 11 and 1 Dfl = YR 5 have been used.

2 THE VILLAGE OF AL HAJAR

2.1 General

Al Hajar is a big village at a distance of 25 kilometers (1 hour drive) south-west of Rada town. It is one of the main villages in the mountainous subdistrict Sabah (Rada district, Al Bayda Province). Figure 1 shows the situation around the village.

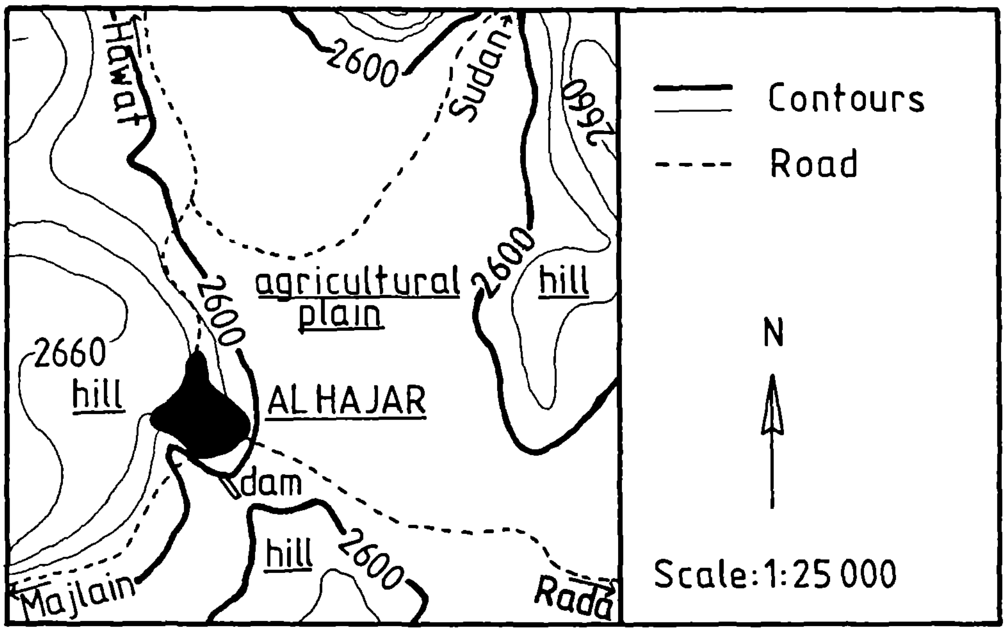

Figure 1: Situation around Al Hajar.
Based upon topographical map 1: 50.000, sheet 1444 D1.

The old center of the village is built compactly on a steep hill bordering a plain which is used for agricultural purposes. The new houses of the village are built scattered over the top and on the slopes of this hill and on the slope of the hill on the other side of an old dam (see figure 2). This old dam is the relic of an irrigation system which was based upon the surplus of rain on the agricultural plain. The reservoir behind the dam is filled up completely with sediments.

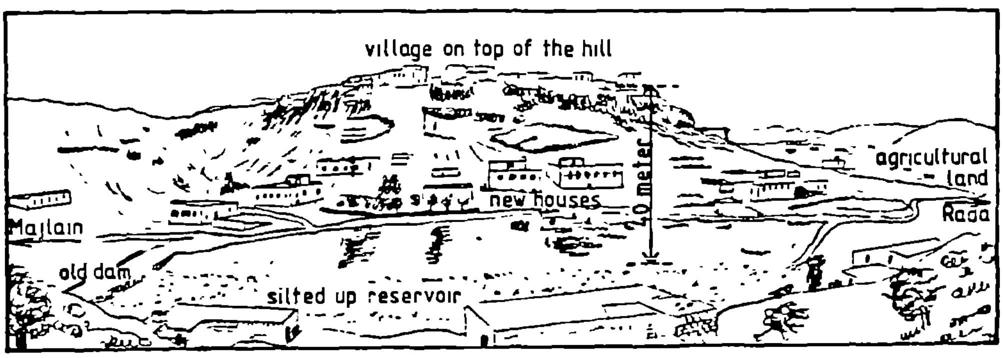

Figure 2: The village Al Hajar.

2.2 Population

According to the survey the village has 1007 inhabitants of which 420 (42%) are adults and 587 (58%) are children (June 1987). The total number of houses surveyed is 125.
Figure 3 gives a summary of the results of the population survey, see for more details annex A1. In this figure no of equivalents means no of adults + 0.5 * [no of children]; this parameter is needed for the calculations in chapter 6 and 7.

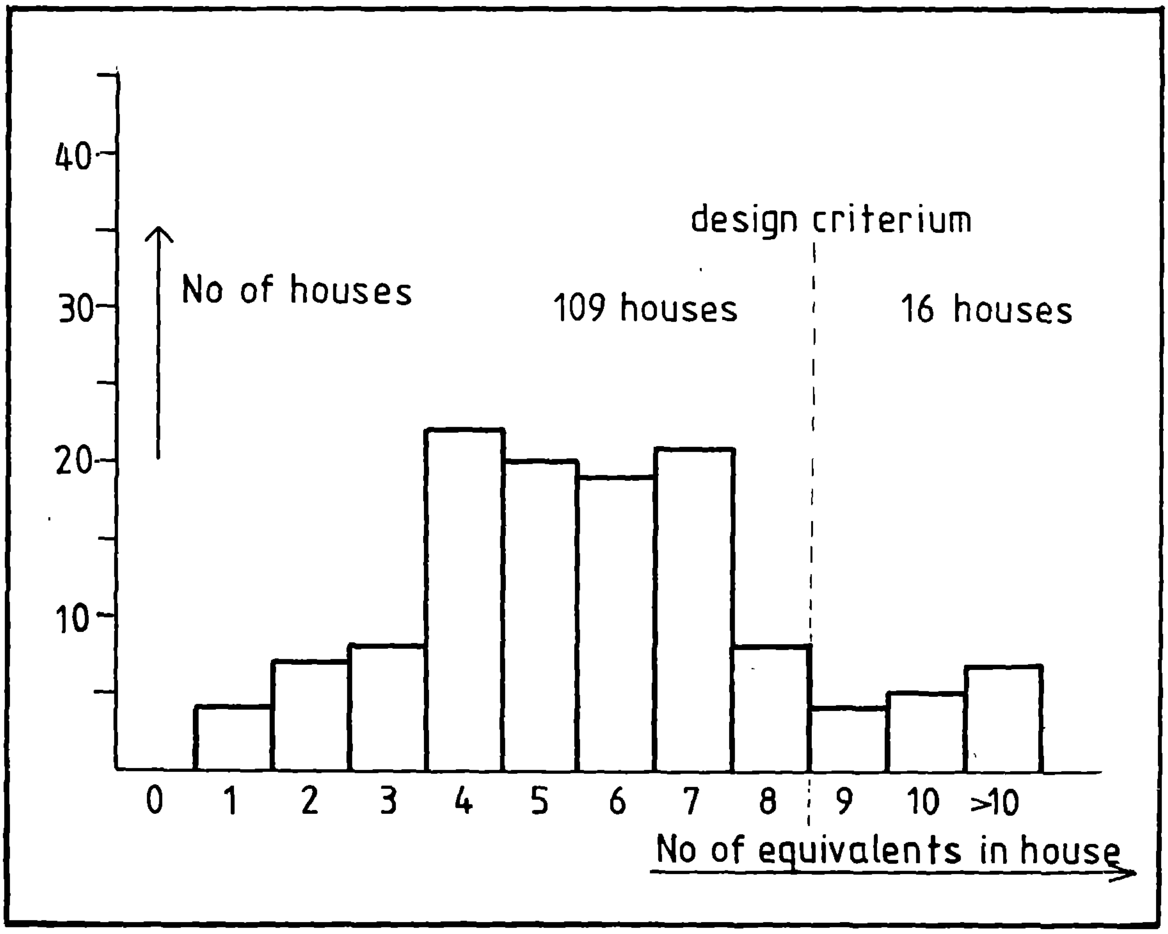

Figure 3: Results of the population survey carried out in June 1987.

A part of the male population used to work abroad and this reflects on the socio-economical structure of the village. There is a big difference in wealth between the people who have been abroad and the ones who stayed in the village.

Communal facilities in the village are the school, the health centre of the MCH-clinic Rada and four mosques. Furhermore there is a generator for the supply of electricity during the evening hours.

3 RIRDP ACTIVITIES IN AL HAJAR

3.1 Watersupply

The water supply scheme of the village was built by the RIRDP in 1984. The system functions well, see for more details chapter 4.1.

3.2 Sanitation

Pilot activities.
In February 1985 a first reconnaissance visit was made to Al Hajar which had been selected by the MCH-clinic Rada and the RIRDP as possible pilot village for improved sanitary facilities. In September 1985 Mr. Mustafa from the clinic and Mr. Dan Bekker, sanitary engineer of the RIRDP, paid a visit to the village in order to discuss proposals for the sanitation pilot projects in this second pilot village (first pilot village was Al Khilaw). After discussions the following was agreed upon:

1 To provide the central mosque with toilet and washing facilities similar to those in the mosque of Al Khilaw with a village contribution of 30% ;
2 To provide the school with toilet facilities also with a village contribution of 30 % ;
3 To provide three houses with improved baladih toilets and home gardens with a village contribution to be determined later.

1) In November 1985 the RIRDP started with the construction of the sanitary facilities at the mosque without any village contribution. The reason to abandon the village contribution was that the construction of the sanitary facilities at the mosque was a complete new activity of the RIRDP. The facility was completed in March 1986 and included an aqua privy tank with three toilets, a drainfield with trees and a washing place with 9 taps. After a short time it became clear that the drainfield didn't function well and caused wastewater nuisance in the centre of the village.
2) The sanitary facilities at the school were not built. The reasons for this are not clear.
3) The improved baladih toilets and home gardens were not constructed due to the fact that this activity faced big financial problems in the first pilot village, Al Khilaw.

Improvement of Health Environment Committee.
In the proposed action programme of the Improvement of Health Environment Committee (IHEC), submitted in January 1987, Al Hajar was mentioned as a pilot village for an integrated approach to sanitation (ref. 6). This means:

- create awareness about health hazards due to poor sanitary facilities,
- provision of improved sanitary facilities at individual houses, schools and mosques plus e.g. a small bore sewer system, and
- organization of a garbage collection system.

In order to gain experience in the village it was decided to start with the garbage collection.

Garbage collection.
In March 1987 the Sanitation subsection and the Rural Women Extension Section made a draft proposal concerning garbage disposal and health education. This proposal was discussed in a meeting with the Project management and it was advised to include also wastewater disposal.
In June 1987 a first survey in Al Hajar was carried out: the houses were numbered, the population was counted and the existing sanitary facilities of the houses were listed. See annex A1 for the results.

Low cost sanitation.
The joint Yemen-Netherlands evaluation mission of September 1987 advised to develop an integrated public health programme (ref. 12). For such a programme it will be necessary to develop low cost options for sanitation improvements. This means no sewerage or other expensive solutions for the wastewater problems of Al Hajar. With this advice in mind, a second, more elaborate survey was carried out in May 1988.

3.3 Rural Women Extension Section (RWES).

Since May 1986 the RWES is involved in discussions concerning Al Hajar. Because sanitary measures which ask for a broad community involvement were to be expected, the RWES decided to make Al Hajar a concentration village of the section.
Since March 1988 health education takes place on a regular basis. Since then 12 visits were paid to the village which resulted in 6 health education sessions. Topics brought up by the women are discussed while the health education specialist tries to involve as much as possible the personal and environmental health aspects of the topics in the discussions. Until now the audience visiting the sessions varies very much, resulting in the same discussions being repeated quite often. As a result, the health education specialist is still hesitant concerning the level of improved hygiene awareness.

3.4 Dutch visitors to Al Hajar.

In November 1985 H.R.H. Prince Claus of the Netherlands visited the old dam in Al Hajar and discussed possibilities for rehabilitation.
In December 1986 Mr. M. Damme, Chief of the Development Co-operation (Asia) Department of the Netherlands Ministry of Foreign Affairs, visited the village and showed much interest for the rehabilitation of the old dam system.
As a result of these visits, a senior expert on land and water conservation, Mr T. Janssen, visited Al Hajar again in February 1987. His conclusions were: 'It will be technically possible to excavate the reservoir at the dam site. However, the economic benefits of the re-excavation works are negligible in comparison to the cost (YR 2 000 000). Any decision on excavating the reservoir for historical reasons should therefore be taken on historical grounds only, leaving aside considerations of direct economic benefits.' (ref. 13).

Altogether there is a long list of activities, visits and commitments; and the people of Al Hajar expect a lot from the RIRDP and the Dutch government. It is questionable if this forms a good base for starting a new project activity like village sanitation improvement.

4 EXISTING SITUATION

4.1 Watersupply.

The RIRDP received a request for a watersupply scheme in 1979. In the last quarter of 1983 the village had drilled a borehole and the scheme was completed in the third quarter of 1984 (ref. 5).
The scheme consists of a borehole, a 75 m^3 masonry reservoir and distribution lines. The scheme is in good condition. On several places the quality of the house connections could be improved considerably. Most houses use water storage tanks on the roof.
The houses have watermeters and the estimated water consumption is 50 lcd. Most of the water comes from the reservoir, but sometimes women go out to wash clothes in the wadi. The reservoir is filled every 2 days. The price of the water is YR 5/m^3 (ref. 5).
The information about the quantity of water available in the borehole is not uniform and there are rumours that there is not enough water during the dry season.
The result of chemical analysis of the water shows that the chemical quality of the drinking water is reasonable. Information about the bacteriological quality of the water is not available yet.

4.2 Sanitary facilities.

Excreta disposal.

See also chapter 5.2 for an explanation of different toilet systems.
In general the houses in Al Hajar have baladih toilets. Baladih means local and such a toilet is most commonly found on the first floor of the house with a separate discharge of liquid and solid excreta. The urine falls on the floor in front of the squatting hole and flows through a small gutter and a pipe in the wall to outside. Cleansing water follows the same way. The usually small quantities of liquid fall on the ground where they infiltrate or evaporate. The solid excreta (faeces) drop through a hole in the floor into a compost pit beneath. Ash from the kitchen oven is added to the pit in order to keep the contents dry. The composted solid waste can be removed through a hole in one of the walls facing outside and the compost is used as fertilizer. There is only 1 composting room and the compost will always contain fresh faeces and with that a lot of pathogens and helminth ova. During operation the hole in the composting room is closed with rubble stones. In order to avoid bad smells, the squatting hole is sometimes covered with a lid (ref. 14).
In Al Hajar the composting room is not always beneath the squatting place and quite often the faecal materials drop freely in a corner beside the house. This results in big health hazards (ref.14).

A few of the old houses have changed the baladih toilet system to a pour-flush toilet system. This results in a free disposal of a mixture of urine, faeces and flush water on the streets. Such bad smelling spots give nuisance to the population and create big health hazards.

In the new part of the village more houses have either a pour-flush toilet system or a cistern-flush toilet system. Most of the house owners have constructed some pipes so that the wastewater is disposed at a place further away from the house, and there are even houses for which the owner constructed a total pit ('bayara').
Table 1 gives the results of the survey on the existing sanitary facilities carried out in June 1987.

Table 1: Existing sanitary facilities in Al Hajar in June 1987.

No of houses without toilet:	8 (7%)
No of houses with baladih toilet:	103 (82%)
No of houses with pour-flush toilet without pit:	11 (9%)
No of houses with pour-flush toilet and pit:	3 (2%)
Total no of houses:	125 (100%)

The information in table 1 has been collected by asking the people about their toilet facilities and it seems that the results are not according to the real situation. Good information about existing toilet facilities can only be gained by personal inspection of the bathrooms. During the surveys of June 1987 and May 1988, fresh excreta were found on several places between and behind the houses. This supports the idea that the number of houses without a toilet is bigger than the number found in the survey (8). Another reason can be that the people don't use the toilet in their houses.

Disposal of other wastewater flows (sullage).

When a house has a baladih toilet system, there is a separate wastewater flow from bathroom and kitchen (sullage). In most cases this water leaves the house through a pipe and drops on the ground. When the quantity of water is small the water infiltrates in the soil and the excess of water evaporates into the air. The introduction of a watersupply scheme will probably give an increased waterconsumption. This results in a bigger quantity of wastewater which often exceeds the evaporation rate and infiltration capacity of the soil. This gives free flowing streams of wastewater which create health hazards and nuisance. In houses with a pour-flush toilet system the sullage goes most often straight to the street and this gives the same problems and nuisance. In only 3 cases the owner of the house made provisions for disposal of the sullage in the pit which is also used for the disposal of the wastewater from the toilet.

4.3 Garbage

There is no garbage collection system in Al Hajar and the people throw their garbage on the street or down from the rocks. After some time most of it is digested or eaten by animals, but materials like tins, glass and plastics remain.
This refuse is an excellent breeding place for flies and rats, especially when it is mixed with wastewater flows. These animals play an important role in the transmission of many diseases. Another health risk is that refuse causes wounds so that people, and especially

children, are more susceptible for disease-causing organisms, such as bacteria, viruses and parasitic worms. Chickens and dogs will scavenge on the refuse and as a result of this the waste will be spread and a part of it be brought back into the houses.
The people of Al Hajar are aware of the problems related with garbage and they requested for assistance by the project. In March 1987 a draft proposal concerning garbage disposal was drawn up, but the Project management advised to include also the wastewater disposal. See also chapter 3.2. In September 1988 the people requested again for a garbage collection system and the village has now been included in the programme.

4.4 Health

According to information from Mr. Ahmed Hobabi, director of the MCH-clinic Rada, the village faces several health problems common in Yemen like skin diseases and diarrhoea. After consultation with the primary health worker of Al Hajar, Dr Yang Bhadur of the MCH-clinic Rada reported as follows: 'Other than the above mentioned skin diseases and diarrhoea, the village has been found to have quite a remarkable problem of chest infections, helmenthiasis (almost all children have worm manifestation) and often outburst of malaria. Pyrexias (fever) of unknown origin is a common complaint. Some cases of tuberculosis also exist in the elderly people though no regular check up was ever done to screen also the young children'.
A survey carried out by the Rural Women Extension Section of the RIRDP in September 1988 indicated that of the 26 children being weighed, 11 (42%) were underweight. The situation of the children in the age group 2-4 years was bad as 78% of the children were underweight. See for more details table 2. Underweight of children is related to low feeding frequency, poor hygiene and frequent diarrhoea. The impression of the MCH- and the RWES-staff is that the hygienic situation in Al Hajar is poor compared to other villages.

Table 2: Results of the survey of children weight in Al Hajar.

age group	no of children with good weight	no of children underweight	total no of children in age group
0-1 year	13 (76%)	4 (24%)	17 (100%)
2-4 year	2 (22%)	7 (78%)	9 (100%)
Total	15 (58%)	11 (42%)	26 (100%)

5 INTRODUCTION ON THE PROPOSED SANITATION PROGRAMME

5.1 The process of sanitation programme planning

As a basis for the sanitation programme of Al Hajar, World Bank publications in the series entitled Appropriate Technology for Water Supply and Sanitation have been used. Volume 11 of this series, A Sanitation Field Manual (ref.3), gives a methodology for planning a sanitation programme. The planning of a sanitation programme is the process by which the most appropriate technology for a given community is identified, designed and implemented. The most appropriate technology is defined as that which provides the most socially and environmentally acceptable level of service at the least economic cost. In other words: all feasible alternatives should be examined and the most economically, socially and environmentally appropriate one adopted.

The process of selecting the appropriate technology begins with an examination of all the alternatives available for improving sanitation. There will usually be some technologies that can be readily excluded for technical or social reasons.
When these exclusions have been made, cost estimates are prepared for the remaining technologies.
The final step in identifying the most appropriate sanitation technology rests with the intended beneficiaries. Those alternatives that have survived technical, social and economical exclusion are presented to the community with their attached financial price tags, and the users themselves decide what they are willing to pay for. In this context, it means beneficiaries and the community, including the RIRDP, which will support the sanitation programme financially and technically.

5.2 Toilet systems

For a correct understanding of the proposal some information about different toilet systems will be given.

The basic toilet system is a plate with a hole in the middle and a pit beneath. There is no water seal and no flushing. As there is a direct contact between the toilet room and the pit there is often nuisance of flies and bad smell. The construction of a pit becomes both difficult and expensive in rocky ground and a pit is less suitable in situations where water is used for anal cleansing. A modified version of this toilet system, a Ventilated Improved Pit (VIP) latrine, gives less smells and is a good option in situations where only a small amount of water is available (10-20 lcd).

An improvement is a pour-flush toilet system with a shallow water seal below the plate. The toilet is flushed manually with a bucket and this needs 2 l/flush. The water seal, an U-shaped pipe filled with 15-25 mm of water, prevents the passage of flies and odours. This system doesn't require a multiple tap in-house level of water supply. Pour-flush toilets are particularly suitable in situations where water is used for

anal cleansing.
If properly used and maintained, pour-flush toilets are free from fly and mosquito nuisance and provide health benefits similar to cistern-flush toilets.

Another improvement is a cistern-flush toilet system which has a bigger water seal. The toilet is flushed by emptying a cistern which hangs above the toilet and this needs 10-20 l/flush. This system requires a multiple tap in-house level of water supply and a minimal water consumption of 100 lcd.
This system has been developed in western countries which have enough water and money to afford it. As water is scarce and expensive in Yemen it is not justified to use 10-20 liter of clean, potable water for each flush of the toilet.
A cistern-flush toilet system doesn't have bigger health benefits than a pour-flush toilet system (ref.2).

5.3 Water requirements

Water supply service levels influence the choice of sanitation technologies strongly. All sanitation technologies have a minimal required and a maximum permissible level of waterconsumption.
Water-borne systems, like conventional sewerage use large volumes of drinking water merely to transport wastes along pipes. For the proper functioning of a conventional sewerage system a minimal water consumption of 100 lcd is necessary (ref.2). This is only possible by a multiple tap in-house level of watersupply. As the estimated water consumption in Al Hajar is 50 lcd (ref.5), a conventional sewerage system is technically not feasible.
A pour-flush toilet system needs 10 lcd for flushing, anal cleansing and cleaning of the toilet room (ref.2). For this, it is not necessary to have a multiple tap in-house level of watersupply. A sewered pour-flush system needs more water and a minimal water consumption of 50 lcd is a safe design criterium (ref.3). This is a quantity which is available in Al Hajar.
A (modified) baladih toilet system needs only a small quantity, 3 lcd, for anal cleansing and cleaning of the toilet room. Because of the introduction of water supply schemes the waterconsumption has been increased. This results in bigger quantities of wastewater, which often exceeds the infiltration capacity of the soil.

The primary objective of a sanitation programme must be the improvement of public health. This objective can be fully achieved by sanitation technologies which are much simpler and cheaper than conventional sewerage and which do not require such large volumes of clean drinking water. With a water consumption of 50-100 lcd the following options for sanitation are feasible (ref. 2).:
- Pour-flush toilets with pits,
- Pour-flush toilets with vaults,
- Pour-flush toilets with small bore sewer system,
- Pour-flush toilets with septic tanks,
- Pit latrines.

All these options, except for the pit latrines, will be worked out in chapter 6 and 7.

Pit latrines are not feasible in Al Hajar because the ground is rocky and water is used for anal cleansing. Besides, the people will not accept this technology because it means a step back in comparison with the existing baladih toilet system. Instead of the pit latrine, a modified baladih toilet will be included in the study.

5.4 Sanitation programme Al Hajar

For a good comparison of the feasible alternatives for Al Hajar the village is divided in two parts:

1) The village on top of the hill. The houses are built closely together and there is limited space. As the structure of the ground is hardrock, on-site systems like pits and septic tanks with soakaways are technically not feasible. For this part of the village an off-site disposal system is required.
The following alternatives will be compared:
* Conventional sewerage, see chapter 6.1.
* Pour-flush toilets with small bore sewer system, see chapter 6.2.
* Pour-flush toilets with vaults, see chapter 6.3.
* Improved baladih toilets, see chapter 6.4.

2) The new houses scattered on the slopes of the hill and on both sides around the old dam. These houses are built at greater distances from each other and on-site disposal systems like pits and septic tanks with soakaways are possible. The structure of the ground varies. The choice of a system, which treats the wastewater of an individual house, merely depends on the wish of the house owner and the costs of the excavation.
For this part of the village the following options will be compared:
* Pour-flush toilets with pits, see chapter 7.1.
* Pour-flush toilets with septic tanks, see chapter 7.2.
* Improved baladih toilets, see chapter 7.3.

Based upon this comparison, a proposal for a sanitation programme for Al Hajar will be presented in chapter 8. This will include recommendations for the most appropriate technology and cost estimates for the proposed systems.

A sanitation programme for Al Hajar encounters several problems like:
- the structure of the underground; digging in the rocky underground for the construction of pipes and soakaways is very difficult and expensive,
- the structure of the village; there is a big variation in situations and standardization to one or two, most appropriate, sanitation technologies is almost impossible,
- the position of the village on top of the hill; the final disposal of the wastewater is far away from the place of production,
- the installation of flush toilets in some houses; this creates waste-water problems which require a sewer system for proper disposal,
- the willingness and interest of the village people to cooperate seems to be low; there is no strong social feeling within the village.

5.5 Design criteria

For the calculations of the options presented in chapter 6 and 7 the following design criteria have been used:

C = WATERCONSUMPTION PER CAPITA PER DAY = 100 lcd.
This value has been used for the design of the watersupply scheme. Compared with the actual waterconsumption of 50 lcd (ref.5), this is largely sufficient.

I = ESTIMATED INFILTRATION VELOCITY IN THE SOIL
Sewage in toilet pit: 20 l/m^2 day.
Sewage in total pit: 50 l/m^2 day.
Effluent from septic tank and sullage: 80 l/m^2 day.
Effluent from treatment tank: 150 l/m^2 day.

N = INTERVAL BETWEEN SUCCESSIVE DESLUDGING OPERATIONS
Septic tank: 3 years.
Treatment tank: 3 years.
Interceptor tank: 3 years.
These values are choosen as a compromise between user convenience and costs for construction of extra storage capacity.

N_C= INTERVAL BETWEEN SUCCESSIVE COMPOST REMOVALS = 1 year.

N_P= NUMBERS OF YEARS OF CONTINUOUS PIT USE = 10 years.

N_V= INTERVAL BETWEEN SUCCESSIVE EMPTYING OPERATIONS VAULT = 20 days.

P = NUMBER OF PERSONS PER HOUSEHOLD = 8.
- As children produce less wastewater than adults, it is necessary to use the amount of equivalent persons (with children counting for 0.5) instead of the total persons; see figure 1 in chapter 2.2.
- It is not right to use the average value of the equivalent persons because this will give problems in many households. With the use of a value of 8 equivalent persons per household, 87% of the households are covered.

Q = WASTEWATER FLOW PER CAPITA PER DAY = 80 lcd.
With the assumption that the ratio between wastewater production and waterconsumption = 0.8, this value can be calculated from the waterconsumption per capita per day, C.

S = SLUDGE ACCUMULATION PER CAPITA PER YEAR
Septic tank: 40 lca.
Treatment tank: 10 lca.
Interceptor tank: 35 lca.

S_C= SOLID WASTE AND ASH PRODUCTION PER CAPITA PER YEAR = 100 lca.

T_H= HYDRAULIC RETENTION TIME
Septic tank for 1 house: 3 days.
Treatment tank in small bore-sewer system: 1 day.
Interceptor tank in small bore-sewer system: 0.7 day (see annex B1)

6 SANITATION TECHNOLOGIES FOR THE VILLAGE ON TOP OF THE HILL

In this chapter the possible solutions for the wastewater problems in the village on top of the hill will be presented. This part of the village consists of an old part with the houses built very closely together and a more recent part with modern houses around it. It is not expected that the number of houses and the population in the old part of the village will increase; the opposite effect, a depopulation of the old village, seems to be more realistic. At the borders of the more recent part of the village some place for construction of new houses still exists. As the growth trends are not clear yet, it is impossible to take this potential growth into account. In the future it might be necessary to extend the proposed sanitation systems.
For the dimensioning of the schemes it has been assumed that the population of both the old part and the more recent part of the village on top of the hill will remain at the same level for the coming years.

6.1 Conventional sewerage

General:
Conventional sewerage is a high in cost, advanced sanitation technology. Excreta are deposited in a cistern-flush toilet system from where they are flushed away by 10-20 liters of clean, potable water into a network of underground sewer pipes. See figure 4. These sewer pipes also receive other domestic wastewater such as water from washing and bathing. The pipes transport the wastewater to a treatment plant, where the solid and liquid parts of the wastewater are separated and treated to remove most of the organic pollutants present in the wastewater. Generally 30-40% of the domestic water consumption is used for toilet flushing.

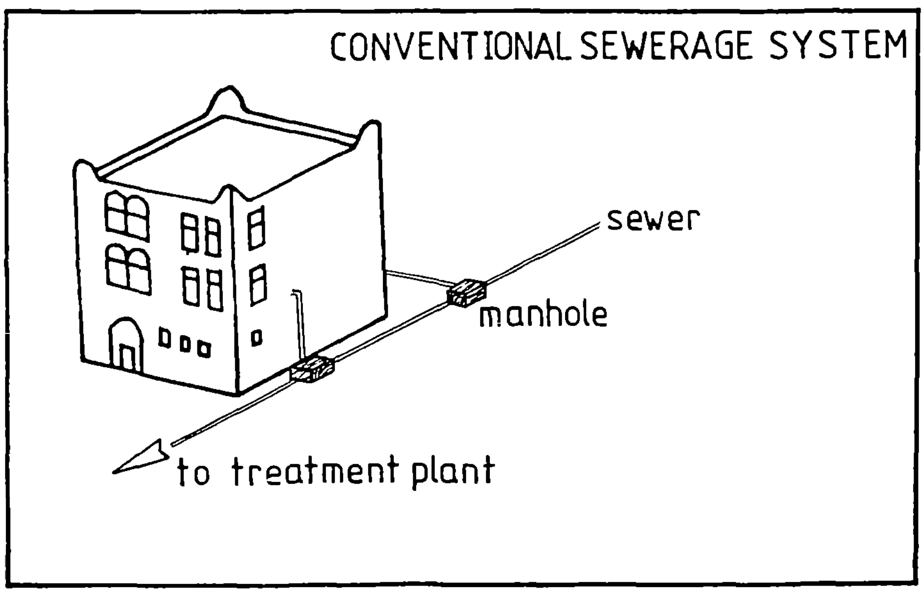

Figure 4: A conventional sewerage system.

Wateruse:
A conventional sewerage system can be installed only in communities with individual-house water connections. The water consumption should be more than 100 lcd. As the estimated water consumption in Al Hajar is 50 lcd, a conventional sewerage system will not function properly.

Advantages:
- user convenience is big.
- meets strong social desire for cistern-flush toilets.

Disadvantages:
- very high construction and operation costs.
- a minimal water consumption requirement of 100 lcd. If not enough water is used for flushing, the system blocks.
- the need for skilled labour for the construction.

Technical:

From a technical point of view the construction of a conventional sewerage system in Al Hajar faces the following problems:
- sewer lines must be laid in straight lines.
- sewer lines should have a minimum slope in order to ensure a peak flow with a minimum self-cleansing velocity of 1 m/sec. This velocity is required to resuspend and transport solid material that may have settled down during periods of lower flows.
- sewer lines should not have a slope too big in order to avoid clogging of the pipes due to the fact that the flushing water flows over the excreta instead of pushing them forward. This maximum permissible slope depends on the diameter and type of pipe and the quantity of wastewater. However, many villages in Yemen are located on steep hills and in many cases it will be unavoidable to exceed this maximum permissible slope.

To meet all this requirements it is necessary to excavate in solid rock and to demolish existing houses. This kind of activities are far beyond the scope and aim of the sanitation programme.

Financial and social:

It can be concluded that the construction of a conventional sewerage system meets many technical obstacles. As the costs of such a system are far beyond the possibilities of the local community, the economical and social aspects of conventional sewerage have not been studied in more detail.

6.2 Pour-flush toilets with small bore sewer system

General:
A small bore sewer system only receives the liquid part of household wastewater for off-site treatment and disposal. Faeces, grit, grease and other troublesome solids which might cause obstruction in the sewers are separated from the waste flow in interceptor tanks. This are single compartment septic tanks wich are installed at the places where the wastewater from the houses enters the sewers. See figure 5. The solids which accumulate in the interceptor tanks are removed periodically by a vacuum tanker for safe disposal.

Wateruse:
The minimal water consumption should be 50 lcd (ref.15), a requirement which is met in Al Hajar.

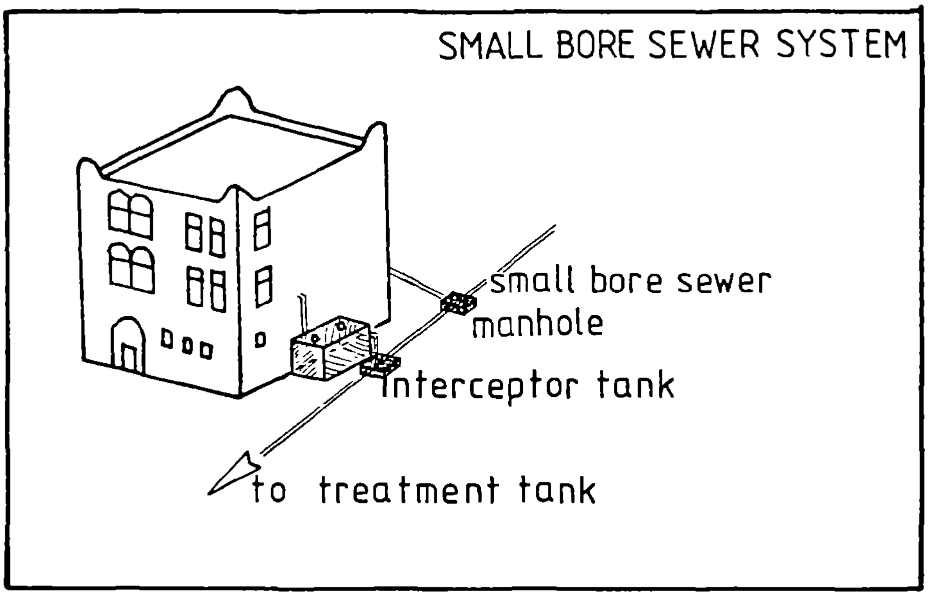

Figure 5: A small bore sewer system.

Advantages:
- reduced water requirements; large quantities of water are not needed for transport of solids; small bore sewers can be employed without fear of blockages in situations where domestic water consumption is low.
- reduced excavation costs; with the troublesome solids removed, there is no need to lay the pipes in a straight alignment with a uniform gradient in order to maintain a minimum flow velocity for self-cleansing; the sewers can follow the natural topography more closely than conventional sewerage.
- reduced material costs; peak flows which the small bore sewers must be designed to handle are lower and the sewers can be smaller.
- lower costs of operation and maintenance than conventional sewerage.
- level of service comparable to conventional sewerage.
- more flexible than conventional sewerage.
- needs less skill in its construction than conventional sewerage.

Disadvantages:
- need for periodical desludging of the interceptor tanks. This needs a strong organization for maintenance.
- experience with the system is limited and mixed.
- illegal connections without interceptor tanks could create serious operational problems because the sewers are not designed for the transport of solids.

Technical:

A small bore sewer system for Al Hajar consists of:

House connections.
- Each household has to construct his own (pour-flush) toilet facility inside the house and should make the connection between the outlet of the wastewater pipe and the interceptor tank.

Interceptor tanks.
- Each household has its own interceptor tank. In some cases it will be possible to combine houses, but in the cost estimate it is supposed that every house has its own interceptor tank.
- The size of the interceptor tank is based upon a minimum liquid retention time of 0.7 days and a desludging frequency of once every 3 years. See annex B1.
- The interceptor tank should have an effective volume of 2.0 m^3 and internal dimensions of 2.0 m * 1.0 m * 1.2m (L*W*H). See annex B1 for a technical specification. Annex E1 gives a drawing of such an interceptor tank.
- A single-compartment interceptor tank is sufficient to remove enough solids to avoid settling of solids in the sewers. This means that the sludge accumulation in an interceptor tank will be less than in a double-compartment septic tank (35 lca instead of 40 lca).
- The structure of the ground is hardrock. Reinforced concrete tanks, which can be constructed above the ground and which cost about YR 6000 are cheaper than tanks made of concrete blocks, which should be buried and which cost aproximately YR 13000.
- The interceptor tanks should be located at places where they can be reached by a small vacuum tanker for desludging. This is a very difficult point in Al Hajar. For certain houses, which are located just a little bit down the hill, it will be impossible to meet this demand. In certain cases it will be necessary to connect these houses to the sewer system without the construction of an interceptor tank. In these cases, the small-bore sewers will function as conventional sewerage and if the number of 'illegal' connections is limited, this can be accepted. For the treatment of the wastewater from these 'illegal' connections the small bore sewer system will include treatment tanks (big septic tanks) at the end of the sewer lines.

Sewers.
- It is possible to construct the sewers in a way that the whole system will function on gravity flow. Pumps for lifting are not needed.
- There will be 7 main sewer lines, see also map 1 & 2 in annex F.

- The pipes should have a minimal diameter of 100 mm (4"). Even when this size is not necessary for the quantity of water, it is recommended for cleaning the pipes in case blockages occurs.
- In the centre of the village the sewers will be constructed of 4" cast iron pipes, which should be buried just below the surface of the ground. The construction of a buried cast iron, 4" sewer in rock costs YR 182 per meter, see annex C11.
- At the border of the village the sewers will be made of 4" galvanized steel (GS) pipes, which will be laid on the surface of the rocks. It is true that these GS pipes will corrode by aggressive substances in the wastewater. However, experience with the use of GS pipes for the transport of wastewater in Ash Sharaf (Al Baydah) shows that they can function properly for at least 10 years.

  As digging in the steep rock is almost impossible, PVC pipes are not feasible.

  Cast iron pipes should be fixed properly. A requirement which can not be met on the rocks with many corners and changes of direction.

  At the moment, GS pipes seems to be the most reasonable solution. However, it will be worthwhile to visit other projects and agencies in order to make use of their experience in this field.

  The construction of a GS, 4" sewer on the surface of the rocks costs YR 133 per meter (including bends and junctions), see annex C11.
- Ventilation of the sewer pipes is not necessary because the sewers will be laid on a continuous negative gradient.

Manholes.
- Small manholes (0.7 * 0.7 * 0.5 m) will be constructed at places where:
  * the interceptor tanks are connected to the system,
  * the sewer pipes have a big change in vertical or horizontal direction,
  * the distance to another manhole is more than 50 meters (only in the village).

  See annex E4 for a drawing of a small manhole.

  A small manhole costs YR 1100 (excavation in rock), see annex C6.
- Big manholes (1.0 * 1.0 * 0.8 m) will be constructed at places where:
  * pipe junctions should be made,
  * before the entrance of the treatment tanks.

  See annex E3 for a drawing of a big manhole.

  A big manhole costs about YR 1600 (excavation in rock), see annex C6.

Treatment tanks
- At the end of each sewer line a treatment tank will be constructed. This is in fact a big septic tank which will catch the solids of the houses which don't have interceptor tanks. This can be houses where it is impossible to construct accessible interceptor tanks or houses which are connected illegally. Besides this the treatment tank will also catch the solids which are not retained in the interceptor tanks.
- The size of the treatment tanks depends on the number of people served by the sewer line. For reasons of standardization, there will be three treatment tanks with a volume of 16.5 m^3 and four treatment tanks with a volume of 11 m^3, see annex B2 for a technical description. Annex E2 gives a drawing of a 16.5 m^3 treatment tank.

- A double-compartment treatment tank will function better than a single-compartment tank. A sludge accumulation of 10 lca seems to be a good value for the sludge accumulation as a result of the 'illegal' connections and accumulation of remaining solids from the interceptor tanks.
- The size of the treatment tanks is based upon a liquid retention time of 1 day and a desludging frequency of once every 3 years.
- The treatment tanks will be constructed on places where access for a vacuum tanker for desludging is available.
- It is possible to choose between treatment tanks of concrete blocks and reinforced concrete. The prices of both types of tanks for 100 and 150 equivalents are given in annex C2 and C3. In situations with a rocky underground reinforced concrete tanks are cheaper due to the fact that they can be constructed above groundlevel . A reinforced concrete treatment tank for 100 eq. costs about YR 19 000; such a tank for 150 eq. costs approximately YR 24 000.

Soakaways and drainfields.
- The final disposal of the wastewater from the treatment tanks will be in soakaways or drainfields.
- Drainfields have two big advantages: the construction costs are much lower and the water can be reused for agriculture.
- For a drainfield it will be necessary that the owner of the field agrees with the construction. During the technical survey only one farmer agreed, but it should be possible to convince more people of the possibilities for reuse of the wastewater for growing of firewood or animal fodder.
- Technical specifications for soakaways and drainfield are given in annex B3 and B4.
- This proposal assumes the construction of:
  * 3 soakaways with a diameter of 2.5 m and a depth of 11 meter, costs per soakaway circa 48 000 (excavation in rock);
  * 3 soakaways with a diameter of 2.5 m and a depth of 7 meter, costs per soakaway circa 32 000 (excavation in rock);
  * 1 drainfield with a total length of 107 meter, costs are YR 5 500 (excavation in sand).
- See annex E6 for a drawing of a soakaway and annex E5 for a drawing of a drainfield.

A small bore sewer system is a <u>technically</u> appropriate sanitation system in the centre of Al Hajar where the wastewater flows exceed the absorptive capacity of the soil.

<u>Financial:</u>
The total costs of a small bore sewer system for Al Hajar (98 houses and 2 mosques, 592 equivalents) are circa YR 1 750 000. These costs are specified in annex D1, see also the maps in annex F.

The total costs of the small bore sewer system can be reduced by the construction of drainfields instead of soakaways for the final disposal of the effluent from the treatment tanks. This change has also another positive effect as the water will be reused for agriculture. As stated above, it will be necessary to have the approval of the landowner.

The savings of this modification are about YR 250 000 and the costs of such a modified small bore sewer system are circa YR 1 500 000. See annex D2 for a specification. As the costs of the scheme are already high, this modification should be accepted by the villagers.

In most sanitation programmes it is common that the community contributes towards the construction costs. This contribution could be either in money, in kind or in labour. A contribution in labour can for example include the excavation works and for this it is useful to split the total costs of a scheme in:
- Costs for excavation, these are strongly influenced by the nature of the ground and it is difficult to make a good estimate for this cost item.
- Costs for construction activities; these are determined by the prices of the materials on the local market and are more or less fixed.
- Costs for unforseen and transport, this is a fixed cost item of 15% of the grand total costs.

Table 3 gives a division of the total costs of a modified small bore sewer system with drainfields.

Table 3: Cost division of a modified small bore sewer system, annex D2.

Cost item	Costs	% of TOTAL COSTS
Construction costs	YR 1 127 561	(75%)
Excavation costs	YR 182 630	(12%)
Unforseen and transport	YR 196 529 +	(13%) +
TOTAL COSTS	YR 1 506 720	(100%)

The total costs are YR 1 500 000, or YR 15 000 (US$ 1400) per household and YR 2500 (US$ 230) per equivalent (1 US$ = YR 11).

The literature gives only two useful other cost estimates as comparison:
- in Rio Grande do Norte (Brazil) the construction costs per household were only US$ 325 (ref.8),
- in Westboro, Wisconsin, USA, the construction costs were US$ 2890 per household, 1977 level (ref.4).

Social:

Small bore sewers provide a similar level of service as conventional sewerage and for the householder there is little difference between the systems, provided that the interceptor and treatment tanks are desludged regularly.
There are no social objections against a small bore sewer system.

Operation and maintenance:

Small bore sewers require little maintenance. The maintenance of the interceptor and treatment tanks is limited to yearly inspection and solids removal when necessary. The tanks are cleaned by pumping the contents to a vacuum tanker for hauling to a suitable disposal site. Land spreading or dumping are the most common methods for sludge disposal. Periodic flushing of the sewer mains is recommended to insure against blockages and to remove most accumulations of solids.

6.3 Pour-flush toilets with vaults

General:
A vault toilet, popular in Japan and other countries in the Far East, is essentially a pour-flush toilet discharging into a watertight vault which stores the wastewater for some 2 to 4 weeks. It is then removed by a vacuum tanker and taken away for treatment. See figure 6.

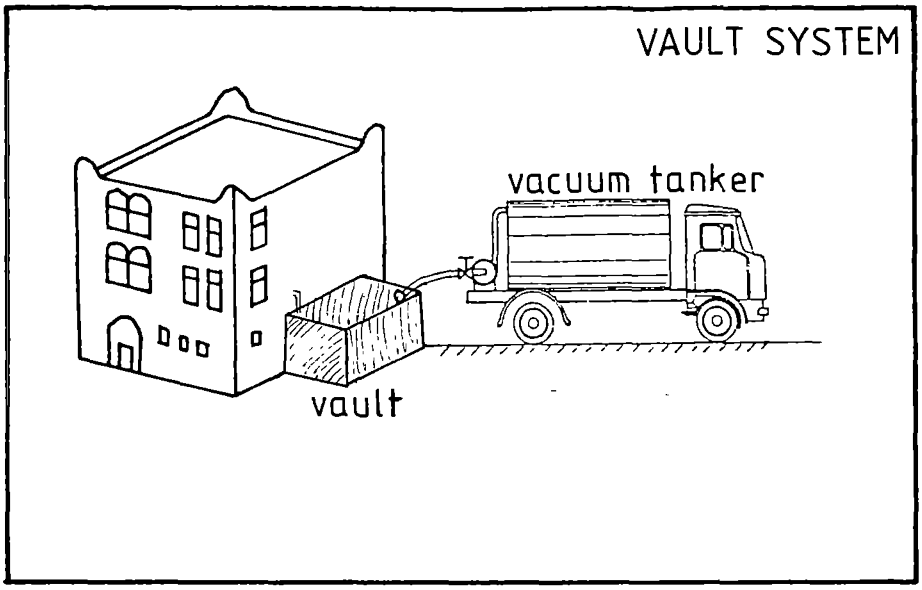

Figure 6: A vault system.

Wateruse:
The system is almost independant of the quantity of water used. The waterconsumption determines the frequency of emptying.

Advantage:
- very flexible system.

Disadvantages:
- high operating costs.
- demands a high level of municipal organization.
- requires a good operating vacuum tanker, which has access to the individual houses.
- requires treatment plant for the disposal of collected wastewater.

Technical:
A vault toilet system for Al Hajar consists of:

House connections.
- Each household has to construct his own (pour-flush) toilet facility inside the house and make the connection between the outlet of the wastewater pipe and the vault.

Vaults.
- Each household has its own vault. In special cases it will be possible to combine houses, but in the cost estimate it is supposed that every house has its own vault.

- The vault should have an effective volume of 13.2 m^3 and internal dimensions of 3.0 m * 2.2 m * 2.0 m (L*W*H). See annex B5 for a technical specification. In the old centre of Al Hajar it is not always possible to find for each house enough space for the construction of such a big tank.
- The structure of the ground is hardrock. A reinforced concrete vault, 0.5 m buried, costs circa YR 20 000, see annex C7.
- The vaults should be located at places where they can be reached easily by a vacuum tanker. Many places in the old centre of Al Hajar are not accessible for a big vacuum tanker and for these houses a vault toilet system is technically not feasible.

Treatment plant.
- The collected wastewater should be treated in, for example, an oxidation pond.
- As a vault toilet system is technically not feasible for all houses, the specifications and costs of this treatment plant are not worked out in more detail.

From a technical point of view, a vault toilet system is not feasible because many houses can not be included as explained above.
Emptying of the vaults regularly needs a high level of municipal organization. This is a difficult point for villages like Al Hajar.

Financial:

Table 4 gives a cost estimate, supposing that all the houses in the old village get a vault toilet system.

Table 4: Cost estimate of a vault toilet system in Al Hajar.

Cost item	Excavation costs (YR/m^3)	Unit	Quantity	Unit price	Costs (YR)
RC Vaults	1500	nr	97	20 380	1 976 860
Treatment plant					PM
grand total					YR 1 976 860
15 % unforseen and transport					YR 296 529 +
TOTAL COSTS					YR 2 273 389

The total costs are about YR 2 300 000, or YR 23 000 (US$ 2100) per household and YR 3800 (US$ 350) per equivalent (excluding costs for a treatment plant). This is high in comparison with other systems.
Moreover the operation and maintenance costs of the system are high and from a financial point of view a vault toilet system is unattractive.

Social:

There is a strong sociocultural resistance against this system:
- the people don't appreciate the storage of a big amount of wastewater close to the houses.
- the people don't believe in an organization which empties the vaults on a regular basis.
- the people don't have experience with the system; there is even no recognition of the system from television or abroad.

6.4 Improved baladih toilets

General:
An improved baladih toilet fits with the traditional habits of excreta disposal. The existing baladih toilet system separates the solid and liquid waste and is described in chapter 4.2. The solid waste is collected in a composting room, mixed with ash from the kitchen and used as fertilizer on the land. The liquid waste is brought outside, where it evaporates or infiltrates. The main objection against this system is that the compost contains fresh faecal material and with that pathogens and helminth ova are liable to exist.
The improved baladih toilet system doesn't handle the wastewater flows from kitchen and bathroom and it will be necessary to construct a separate disposal system for these wastewater flows. See figure 7.
The modifications of the baladih toilet have the purpose to convert the solid excreta to a safe, pathogen free end product that can be used as fertilizer on the land and which does not create health hazards for the workers on the land and the consumers of the agricultural products.

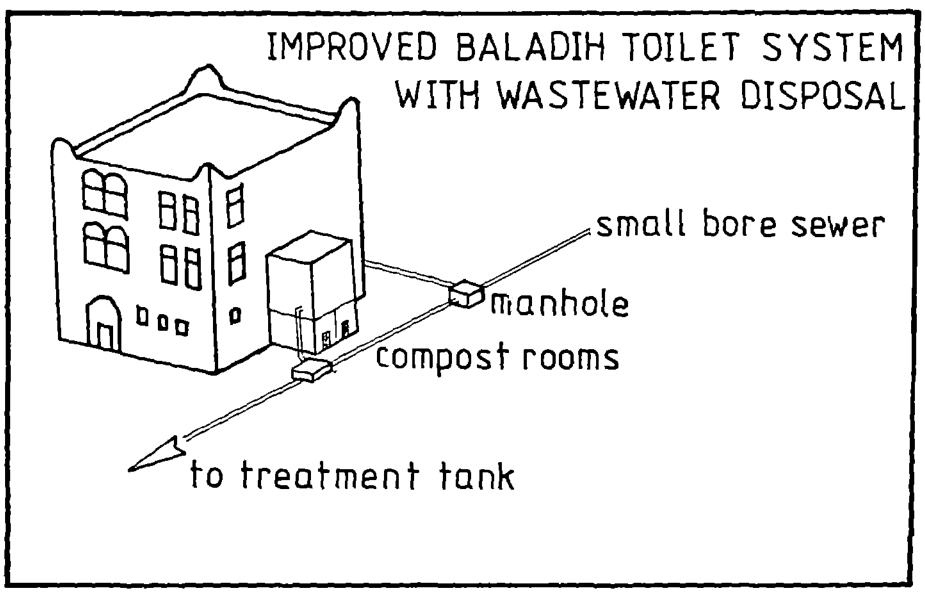

Figure 7: An improved baladih toilet system

The main improvements of an existing baladih toilet are:
- construction of two composting rooms, which can be used alternately and which guarantee a minimum composting time of 1 year in order to destroy pathogens and helminth ova,
- construction of ventilation pipes in order to avoid bad smells inside the toilet room,
- construction of a suitable squatting hole cover,
- conveyance of liquid excreta through a pipe to a disposal system.

Wateruse:
The toilet system requires a very small quantity of water of 3 lcd as cleansing water and for cleaning the gutter for the disposal of liquids. When more water is used, the disposal system for the liquids (infiltration in the ground and evaporation) will be overloaded.

Advantages:
- fits with the existing sanitation habits.
- compost can be used as fertilizer.
- very low usage of water.

Disadvantages:
- people see this as an old fashioned sanitation system.
- no solution for other wastewater flows, see also below.
- possibility of bad odors.
- fly breeding.
- needs strict organization for emptying the compost rooms regularly.

Technical:

An improved baladih toilet system for Al Hajar consists of:

Toilets.
- Each household has its own composting rooms.
- The size of the composting rooms is based upon a minimal composting time of 1 year.
- The composting rooms should have an effective volume of 2.3 m^3 and internal dimensions of 1.6m * 1.2m * 1.2m (L*W*H). See annex B6 for a technical specification.
- The nature of the ground is hardrock. The construction of 2 composting rooms with concrete blocks costs YR 4900, see annex C7.
- The composting rooms should be constructed next to and preferably under the toilet room. This is in most cases no problem.

From a technical point of view it is possible to construct improved baladih toilets.
The improved baladih toilet system doesn't handle the wastewater flows from kitchen and bathroom and it will be necessary to construct a separate wastewater disposal system as described below.

Wastewater disposal system.
- When the total wastewater flow (wastewater from toilet, kitchen and bathroom) from a house with an improved baladih toilet exceeds the evaporation rate and infiltration capacity of the soil, it is necessary to construct a system for safe disposal of these flows.
- Some houseowners have already constructed a pour-flush toilet system and many have the intention to do so. The introduction of improved baladih toilets will not solve the problems created by the pour-flush toilets and it will be necessary to construct a system for safe disposal of the wastewater flows.
- The above mentioned problems show that it will be necesary to construct a wastewater disposal system which mainly deals with the wastewater from kitchens and bathrooms but which also copes with wastewater of the pour-flush toilets. This means the construction of a sullage sewer system with additional interceptor tanks for houses with a pour-flush toilet.
- It is advisable to leave open the possibility for future upgrading of this sullage sewer system to a full small bore sewer system. This means that the sullage sewer system should be the same as the system described in chapter 6.2 without the interceptor tanks.

- The wastewater disposal system includes the same components as described in chapter 6.2 under the items sewers, manholes, treatment tanks and soakaways/drainfields.

Financial:
The total costs of a modified baladih toilet system with a separate wastewater disposal system for Al Hajar are listed in table 5. It is assumed that there are no pour-flush toilets at all.
The total quantities of the wastewater disposal system are taken from the description of the small bore sewer system.

Table 5: Cost estimate of a modified baladih toilet system with a separate wastewater disposal system in Al Hajar.

Cost item	Excavation costs (YR/m³)	Quantity	Unit price	Costs (YR)	% of TOTAL
RC compost rooms	1500	97	4 900	475 300	35%
RC treatm. tank (150)	800	3	24 411	73 233	5%
RC treatm. tank (100)	800	4	19 341	77 364	6%
Drainfield (150)	100	3	8 280	24 840	2%
Drainfield (100)	100	4	5 580	22 320	2%
Manholes (big)	800	42	1 620	68 040	5%
Manholes (small)	800	89	1 100	97 900	7%
C.iron pipe, 4",incl.lay.	800	725 m'	182	131 950	10%
GS pipe, 4",incl.laying	-	1588 m'	133	211 204	15%
grand total			YR	1 182 151	87%
15 % unforseen and transport			YR	177 323	13%
TOTAL COSTS			YR	1 359 474	100%

The total costs of the improved baladih toilet system with a wastewater disposal system are circa YR 1 400 000, or YR 14 000 (US$ 1261) per household and YR 2300 (US$ 209) per equivalent.

Social:
It is doubtfull whether the people will accept this system because they see it as an old fashioned way for sanitation. During visits in western countries they saw much more sophisticated cistern-flush toilets, which are in fact not suitable for a country with big water shortages. Moreover, the costs are comparable with a pour-flush toilet system which offers much more convenience to the users than an improved baladih toilet system.

6.5 Conclusions

This chapter describes four possible solutions for the wastewater problems in the village on top of the hill. The technical, financial and social aspects of each option are elaborated and translated in an advice on feasiblity. Table 6 gives a summary of the results.

Table 6: Results of the study into four different options for the wastewater problems in the village on top of the hill.

	Technical feasibility	Social feasibility	Financial Costs (YR)
Conventional sewerage	-	++	too high
Small bore sewer system	+	+	1 506 720
PF toilets with vaults	-	-	2 273 389
Improved baladih toilets(*)	+	+/-	1 359 474

(*) = including disposal system for wastewater.

From a technical point of view a small bore sewer system and an improved baladih toilet system are the only feasible sanitation technologies for this part of the village.

An improved baladih toilet system is technically feasible but the construction of these toilets will not solve the wastewater problems in the center of the village. It will be necessary to construct a separate wastewater disposal system and the total costs of both systems (improved baladih toilets together with a wastewater disposal system) are comparable with the costs of a small bore sewer system. At almost the same costs it is possible to construct a small bore sewer system which offers the people a much higher grade of user convenience.
Furthermore there are social objections against improved baladih toilets because people see it as an old fashioned way of waste disposal.

The total costs of all studied systems are high. The costs of a small bore sewer system are approximately YR 1 500 000 (US$ 136 974), or YR 15 000 (US$ 1400) per household or YR 2500 (US$ 230) per equivalent.

7 SANITATION TECHNOLOGIES FOR INDIVIDUAL HOUSES

In this chapter solutions for the wastewater problems of individual houses will be presented. These are the houses scattered on the slopes of the hill and on both sides around the old dam. These houses are built at greater distances from each other and on-site disposal systems are possible.
For a good comparison of the different solutions, the costs of a total system, including manholes and sewers, will be compared for a standard situation. A standard situation is defined as a house with 8 equivalents, a wastewater production of 80 lcd and a distance between the house and the final disposal place (pit, drainfield or soakaway) of 12 meter. The nature of the underground may vary (sand, rock or hardrock).

All possible solutions for the disposal of the wastewater from individual houses include sewer pipes in order to transport the wastewater from the house to the treatment facility or the final disposal place. For reasons of efficiency, the technical considerations of the construction of sewer pipes will be discussed in general:
- In the standard situation the distance between the house and the final disposal place is 12 meter.
- The pipes should have a diameter of 100 mm (4") and should have a minimal slope of 1:50 (ref.9).
- When the ground is rock or hardrock the sewers will be constructed of 4" cast iron pipes, to be buried just below the surface of the ground
- When the ground is sand or weathered rock the sewers will be constructed of 4" PVC pipes, which should be buried at a depth of at least 30 cm below the surface. When the sewers have to pass roads, the depth should be at least 60 cm below ground surface. For a sewer at a depth of 30 cm, a trench (0.5 m * 0.5 m) should be dug. The bottom should be filled with a 10 cm thick bed of sand. Sand will also be used for filling up the whole trench after laying the pipe.
- When the construction of PVC or cast iron pipes is impossible (too many corners on hardrock or slope with loose stones) the sewers will be made of galvanized steel (GS) pipes. This is not an ideal situation, but better solutions are not known yet.
- The construction costs (inclusive procurement, excavation and installation) of 4" sewers with different types of pipes in situations with different excavation costs are given in table 7. See also annex C11.

Table 7: Construction costs (inclusive procurement, excavation and installation) of 4" sewers with different types of pipe.

Nature of soil	Excavation costs (YR/m3)	Construction costs 4" sewer per meter PVC	Cast iron	GS (*)
SAND	100	YR 79	YR 154	YR 133
ROCK	800	YR 254	YR 182	YR 133
HARDROCK	1500	YR 429	YR 210	YR 133

(*) = construction above the ground; when PVC or cast iron pipes are not suitable.

7.1 Pour-flush toilet with pit.

General:
In this system the waste of the toilet and the other wastewater flows from the house (kitchen and bathroom) are transported through a pipe to a so called total pit outside the house. See figure 8. The solid wastes (sludge) settle on the bottom of the pit, where bacteria digest them and the volume is reduced with 70%. The liquid waste infiltrates through the walls of the pit into the ground. The size of the pit is based upon the volume needed for the storage of sludge and the area needed for the infiltration of the liquid wastes.
It is also possible that only the solid and liquid wastes of the toilet are disposed in a so called toilet pit. It will be necessary to take separate measures for the safe disposal of the other domestic wastewater flows (kitchen and bathroom). Solutions for this are the construction of a soakaway or a drainfield. It is obvious that such a toilet pit can be smaller than the above mentioned total pit.
When a pit is full, it is neccesary to remove the solids or to construct a new pit.
Three houseowners in Al Hajar constructed already a total pit for the disposal of the wastewater from toilet, bathroom and kitchen.

Wateruse:
As the infiltration capacity of the soil is the limiting factor in the design of the pit volume, the quantityof water used in the house is important for the pit volume. In general, pour-flush toilets with pits are suitable in situations where the waterconsumption is 10-100 lcd.

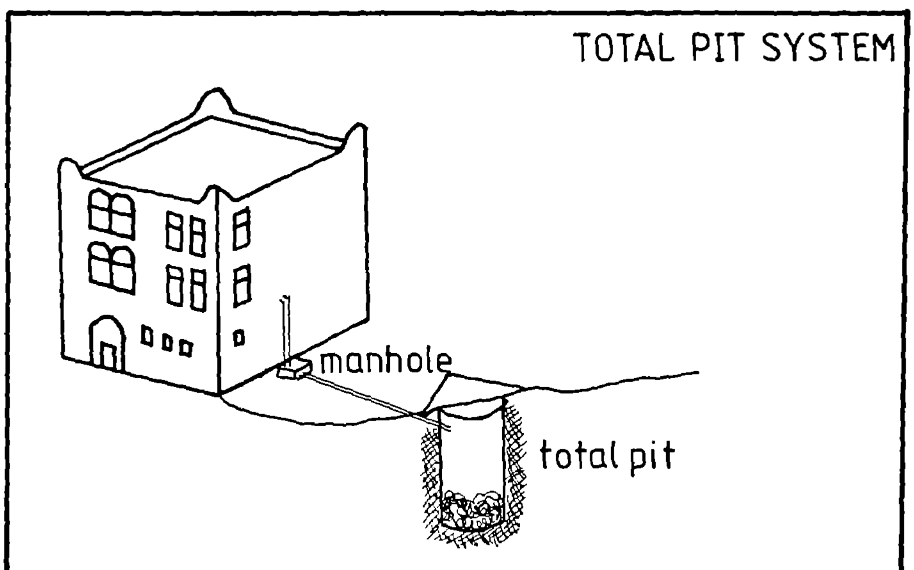

Figure 8: A total pit system.

Advantages:
- low water requirements.
- no municipal involvement.
- low annual costs for maintenance.
- the system is already accepted by the people.
- system can be upgraded to a system with small-bore sewers.

Disadvantages:
- expensive at places with hard rock where digging is expensive.
- when the pit is filled, the pit must be emptied or a new one built. As the design period for continuous pit use is 10 years, this disadvantage is of minor importance.
- in the case of a toilet pit it is necessary to construct a separate sullage disposal system.

Technical:
A standard design for a (total or toilet) pit for a house in Al Hajar consists of:

Pit.
- The size of the pit is based upon minimal 10 years of continuous pit use without emptying or renewal.
- A total pit has a volume of 12.0 m^3 , a diameter of 2.0 m and a depth of 3.7 m. See annex B7 for a technical specification. Annex E7 gives a drawing of such a pit.
- A toilet pit has a volume of 6 m^3, a diameter of 1.5 m and a depth of 3.3 m. See annex B7 for a technical specification.

Manhole.
- A big manhole will be constructed at the place where the wastewater leaves the house. See annex E3 for a drawing and annex C6 for a cost estimation.

Sewers.
- See the remarks in the introduction of this chapter.

In the case of a toilet pit it is necessary to construct a separate system for the disposal of the sullage. Such a system includes manholes, sewers and either a soakaway or a drainfield:

Manholes.
- A small manhole will be constructed at the place where the sullage leaves the house.
- A big manhole will be constructed at the inlet point of the drainfield, see the drawing in annex E5 .

Soakaway.
- The soakaway has a diameter of 1.5 m, a depth of 2.5 m and a volume of 4.5 m^3. See annex B3 for a technical specification. Annex E6 gives a drawing of such a soakaway.

Drainfield.
- A drainfield should have dimensions of 6.0 m * 0.5 m * 0.85 m (L*W*D) See annex B4 for a technical specification. Annex E5 gives a drawing of a drainfield.

Both systems, total and toilet pit, are technically feasible when there is space to excavate the pits and (if necessary) to construct a soakaway or drainfield.

Financial:
The costs of pit systems for a standard situation are given in table 8. See annex D3 for details.

Table 8: Cost estimates for total pit systems

System	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
1 Total pit	9 864	21 267	31 635
2 Toilet pit with soakaway	10 148	21 926	31 634
3 Toilet pit with drainfield	9 735	18 213	24 620

A total pit system is preferable because the price difference with toilet pit systems is small and the construction is easier.

Excavation works (pit, soakaway, drainfield) are good possibilities for the houseowner to contribute in the construction costs of pit systems. Table 9 gives a summary of the excavation costs as a percentage of the total costs, see annex D3 for more details.

Table 9: Excavation costs as a percentage of the total costs.

System	Excavation costs (%) in situation with: SAND	ROCK	HARD ROCK
1 Total pit	12 %	45 %	57 %
2 Toilet pit with soakaway	10 %	38 %	50 %
3 Toilet pit with drainfield	9 %	28 %	38 %

Social:
A pour-flush toilet with a total pit has a user convenience which is comparable with a conventional sewerage system.
There are no social objections against total pits and the construction of pits is a common 'modern' sanitation technology in the province. People prefer it above other sanitation technologies because it removes the wastes definitely from the living environment. In general people prefer to excavate a new pit instead of emptying the existing one.
The construction costs vary strongly with the nature of the underground. In situations with sand it is a least-cost solution for the disposal of domestic wastewater.

7.2 Pour-flush toilet with septic tank.

General:
A septic tank is a watertight settling tank which receives the excreta and flushwater from the toilet and all other household wastewater. In the septic tank the solids settle to the bottom of the tank where they are digested anaerobically, and a layer of scum is formed at the surface. The mean hydraulic retention time in the tank is usually 1 to 3 days. From a health point of view the effluent from a septic tank is as dangerouse as raw sewage and should be discharged to either a soakaway or drainfield. See figure 9.
Although digestion of the settled solids is reasonably effective, some sludge accumulates. The tank should be desludged once every 3-4 years in oredr to remove sludge, grit and grease.
In a double-compartment septic tank the suspended solids settle much better than in a septic tank with only one compartment.
A septic tank is preferable in cases where the excavation of a pit is impossible or too expensive.

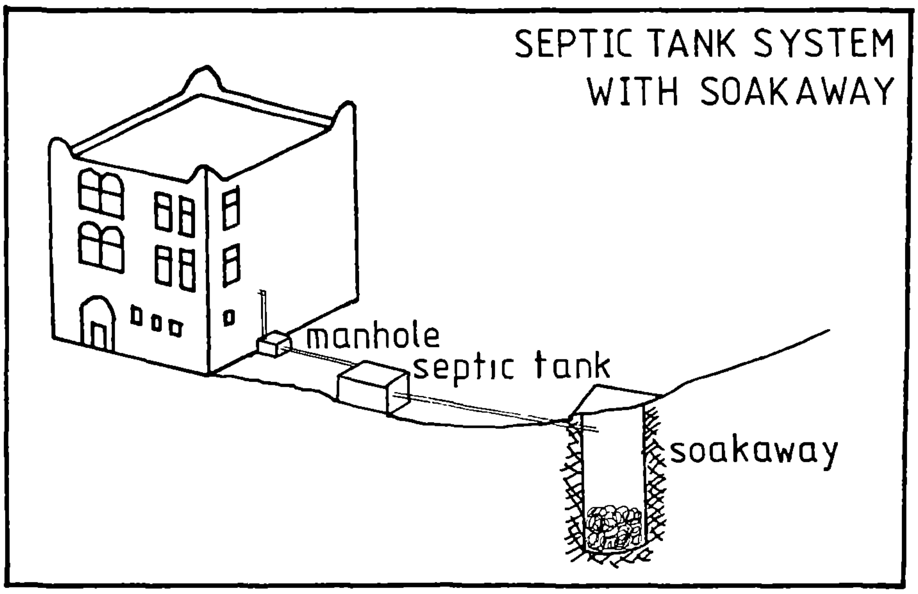

Figure 9: A septic tank system with soakaway.

Wateruse:
A septic tank is suitable in situations with individual-house waterconnections. The minimum water consumption should be 50 lcd.

Advantages:
- low level of municipal involvement.
- system can be upgraded to a system with small bore sewers.
- flexible and adaptable to individual household requirements.
- when there is a drainfield: reuse of wastewater for growing of trees.

Disadvantages:
- only for houses that have an in-house water supply and sufficient land for the final disposal of the liquids.
- sensitive to use of chemicals inside the house.
- need for periodically desludging of the septic tanks.

Technical:

A standard design for a septic tank for a house in Al Hajar consists of:

Septic tank.
- The size of the septic tank is based upon a liquid retention time of 3 days and a desludging frequency of once every 3 years.
- The septic tank should have an effective volume of 3.2 m^3 and internal dimensions of 2.25 m * 1.2 m * 1.4 m (L*W*H). See annex B8 for a technical specification. Annex E8 gives a drawing.
- A double-compartment septic tank will function better than a single-compartment tank.

Manhole.
- A big manhole will be constructed at the place where the wastewater leaves the house. See annex E3 for a drawing and annex C6 for a cost estimate.

Sewers.
- See the remarks in the introduction of this chapter.

For the final disposal of the wastewater it is necessary to construct either a soakaway or a drainfield:

Soakaway.
- A soakaway has a volume of 4.5 m^3, a diameter of 1.5 m and a depth of 2.5 m. See annex B3 for a technical specification. Annex E6 gives a drawing of such a soakaway.

Drainfield.
- A drainfield should have dimensions of 6.0 m * 0.5 m * 0.85 m (L*W*D) See annex B4 for a technical speecification. Annex E5 gives a drawing of a drainfield.
- At the inlet point of the drainfield, a big manhole will be constructed.

A septic tank system is technically feasible, when there is space for the construction of a final disposal system (soakaway, drainfield).

Financial:

The costs of septic tank systems for a standard situation are given in table 10. See annex D4 for details.

Table 10: Cost estimate of septic tank systems.

System	Cost (YR) in situation with: SAND	ROCK	HARD ROCK
Reinforced concrete tank with soakaway	14 163	20 173	25 148
Concrete blocks tank with soakaway	14 763	27 373	38 949
Reinforced concrete tank with drainfield	13 751	16 460	18 134
Concrete blocks tank with drainfield	14 350	23 660	31 936

Table 11 gives a summary of the excavation costs as a percentage of the total costs, see annex D4 for more details.

Table 11: Excavation costs as a percentage of the total costs.

System	Excavation cost (%) in situation with: SAND	ROCK	HARD ROCK
Reinforced concrete tank with soakaway	4 %	21 %	32 %
Concrete blocks tank with soakaway	9 %	28 %	52 %
Reinforced concrete tank with drainfield	3 %	6 %	8 %
Concrete blocks tank with drainfield	8 %	32 %	43 %

Social:
Pour-flush toilets with septic tanks provide a similar level of service as a pour-flush toilet with a total pit.
There are no social objections against a septic tank system.
The only problem is the need for a regular desludging of the septic tanks.

7.3 Improved baladih toilets

General:

An improved baladih toilet fits with the traditional habits of excreta disposal and is already described in chapter 6.4.
The improved baladih toilet system doesn't handle the wastewater flows from kitchen and bathroom and it will be necessary to take separate measures for the safe disposal of these flows. Solutions for this are the construction of a soakaway or a drainfield. In order to minimize health hazards it is good to use this system also for the disposal of the liquid wastes of the toilet. See figure 10.

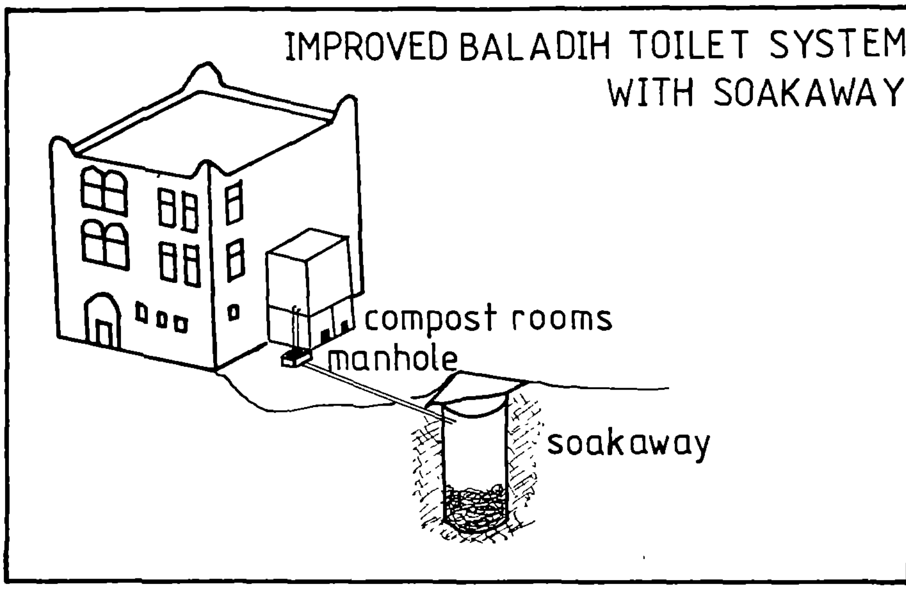

Figure 10: Improved baladih toilet system with soakaway.

Technical:

A standard design for an improved baladih toilet system for a house in Al Hajar consists of:

Toilet.
- The size of the composting rooms is based upon a minimal composting time of 1 year.
- The composting rooms should have an effective volume of 2.3 m^3 and internal dimensions of 1.6m * 1.2 m * 1.2 m (L*W*H). See annex B6 for a technical specification.
- The composting rooms should be constructed next to and preferably under the toilet room.

It is necessary to construct a separate system for the disposal of the liquid waste from kitchen, bathroom and toilet. Such a system includes manholes, sewers and either a soakaway or a drainfield:

Manholes.
- A small manhole will be constructed at the place where the sullage leaves the house.

- A big manhole will be constructed at the inlet point of the drainfield, see the drawing in annex E3.

Soakaway.
- The soakaway has a diameter of 1.5 m, a depth of 2.5 m and a volume of 4.5 m^3. See annex B3 for a technical specification. Annex E6 gives a drawing of such a soakaway.

Drainfield.
- A drainfield should have dimensions of 6.0 m * 0.5 m * 0.85 m (L*W*D) See annex B4 for a technical specification. Annex E5 gives a drawing.

From a technical point of view it is possible to construct improved baladih toilets with a separate disposal system for the liquid wastewater flows from the house.

Financial:
The costs of an improved baladih toilet system for a standard situation are given in table 12. See annex D5 for details.

Table 12: Cost estimates of improved baladih toilet systems

System	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
1 I.baladih T with soakaway	9 921	15 367	19 779
2 I.baladih T with drainfield	9 508	14 069	-

Table 13 gives a summary of the excavation costs as a percentage of the total costs, see annex D5 for more details.

Table 13: Excavation costs as a percentage of the total costs.

System	Excavation costs (%) in situation with: SAND	ROCK	HARD ROCK
1 I.baladih T with soakaway	4 %	23 %	34 %
2 I.baladih T with drainfield	3 %	17 %	-

Social:
The user convenience of an improved baladih toilet system is lower than of pour-flush toilets.
It is doubtful whether the people will accept this improved baladih toilet system because they see it as an old fashioned way of sanitation.
The demand for the use of the compost as fertilizer is low. The use of this compost is labour intensive, the user convenience is low and people prefer to use artificial fertilizer.
The costs of an improved baladih toilet system, including a good disposal system for the wastewater flows, are comparable with the costs of a pour-flush toilet with a total pit. It is clear that the latter is preferred.

7.4 Conclusions

In this chapter three different options for the solution of the wastewater problems of a standard house are described. A standard house is defined as a house with 8 equivalents, a wastewater production of 80 lcd and a distance between the house and the final disposal place of 12 meter. The technical, financial and social aspects of each option are studied in situations when the underground consists of respectively sand, rock or hardrock. Table 14 gives a summary of the results.

Table 14: Results of the study into solutions for the wastewater problems of a standard house.

	Technical feasibility	Social feasibility	Financial Costs (YR)
SAND			
Total pit	++	++	9 864
Toilet pit with soakaway	++	+	10 148
Toilet pit with drainfield	++	+	9 735
RC septic tank with soakaway	++	+	14 163
CB septic tank with soakaway	++	+	14 763
RC septic tank with drainfield	++	+	13 751
CB septic tank with drainfield	++	+	14 350
Impr.B.Toilet with soakaway	++	+/-	9 921
Impr.B.Toilet with drainfield	++	+/-	9 508
ROCK			
Total pit	+/-	++	21 267
Toilet pit with soakaway	+/-	+	21 926
Toilet pit with drainfield	+	+	18 213
RC septic tank with soakaway	+/-	+	20 173
CB septic tank with soakaway	+/-	+	27 373
RC septic tank with drainfield	++	+	16 460
CB septic tank with drainfield	+/-	+	23 660
Impr.B.Toilet with soakaway	+/-	+/-	15 367
Impr.B.Toilet with drainfield	++	+/-	11 654
HARD ROCK			
Total pit	-	++	31 635
Toilet pit with soakaway	-	+	31 634
Toilet pit with drainfield	+/-	+	24 620
RC septic tank with soakaway	-	+	25 148
CB septic tank with soakaway	-	+	38 949
RC septic tank with drainfield	+	+	18 134
CB septic tank with drainfield	-	+	31 936
Impr.B.Toilet with soakaway	+/-	+/-	19 779
Impr.B.Toilet with drainfield	+	+/-	12 765

Remark: drainfields are always constructed on a place with an underground consisting of sand.
RC = reinforced concrete,
CB = concrete blocks.

The results of the study will be used for the selection of the technical, financial and social most optimal solution. The process of selection will be discussed separately for each situation of the underground:

SAND
In the situation with a sandy underground, all studied alternatives are technically feasible and the choice of a system depends mainly on financial and social factors.
Septic tank systems are much more expensive than the other systems and should be excluded on financial grounds.
Total pits have a strong social preference while improved baladih toilets face social objections. As the construction costs of both systems are almost equal it is clear to choose a total pit system.

ROCK
In the situation with a rocky underground some alternatives are technically less feasible because the excavation in the rock is difficult.
From a social point of view, the construction of new improved baladih toilet system faces objections.
From the technical and social feasible alternatives, a reinforced concrete septic tank with a drainfield is the most favourable because the construction costs are reasonable compared to other systems.

HARD ROCK
When the underground consists of hard rock, most alternatives are technically not feasible.
Also here exist social objections against improved baladih toilets.
From the technical and social feasible alternatives, a reinforced concrete septic tank with a drainfield is the cheapest and most favourable solution.

The above described comparison of sanitation technologies for a standard house forms only a basis for the selection of the most appropriate sanitation technology for an individual house. Every house has its own specific circumstances with regard to structure of the underground, possibilities of the available space and personal wishes of the houseowner. It is impossible to give a general, for every house applicable solution and every case should be considered individually. The results of this individual selection of the most appropriate sanitation technology are presented in table 15. See annex A2 for more details.

Table 15: Proposed sanitation systems for the individual houses.

Sanitation system	No of houses	No of equiv.	Total costs (YR)	Costs per equiv.
Total pit	21	132	207 144	1569
Septic tank with drainfield	10	53	164 600	3106
Septic tank with soakaway	6	31	121 038	3904
Total	37	216	492 782	2281

8 PROPOSAL

This report describes different options for the solution of the wastewater problems in Al Hajar. The comparison of the options concerning technical, economical and social feasibility results in the selection of the most appropriate sanitation technologies. Table 16 gives a summary of the results.

Table 16: Proposed sanitation systems for Al Hajar.

Sanitation system	No of houses	No of equiv.	Total costs (YR)	Costs per house YR	Costs per house US$
Small bore sewer system	98	592	1 506 720	15 375	1398
Total pit	21	132	207 144	9 864	897
Septic tank with drainfield	10	53	164 600	16 460	1496
Septic tank with soakaway	6	31	121 038	20 173	1834
TOTAL	135	808	1 999 502	14 811	1346

A sanitation system for all the houses in Al Hajar includes four different sanitation technologies. The project has no experience with the implementation of any of these technologies yet and it is not advisable to start with all new technologies at the same time. It would be better to gain experience with every system separately in different villages before combining the systems in one village.
Especially the implementation of a small bore sewer system will meet with technical obstacles for which there are hardly satisfactory solutions yet. Examples of these problems are the impossibility to construct an interceptor tank for every house, the difficulties with the selection of the pipe materials and the big distance between the place of production and final disposal of the wastewater.

Table 17 gives the costs of a sanitation system for the whole village.

Table 17: Cost estimate of a sanitation system for Al Hajar

	YR	US$ (*)	Dfl (*)
Total costs scheme	1 999 502	181 773	399 900
Costs per house	14 811	1 346	2 962
Costs per equivalent	2 475	225	495

(*) : 1 US$ = YR 11; 1 Dfl = YR 5.

With a village contribution of 25% of the total costs, the RIRDP has to pay nearly Dfl 300 000. The budget for sanitation schemes for 1988/1989 (budget item 13.6.2.8) is Dfl 400 000, of which Dfl 23 912 has already been spent (30/11/1988).
When the RIRDP executes the sanitation scheme in Al Hajar almost the entire budget for sanitation schemes will be spent in only one village.

The investment costs per household are nearly YR 15 000. With a village contribution of 25 % , each household has to pay YR 3700. In comparison with an assumed monthly income of YR 1500, this is a very big sum. The literature states that: 'low- and middle-income groups will typically be able to afford to spend only 2-3 per cent of their income on sanitation, although they may be prepared to spend larger sums over a short period of time' (ref.1). For Al Hajar this means an expenditure of YR 30-40 per month only. The big difference between costs of the sanitation scheme and the possibilities of the population to contribute leads to the question whether such an expensive sanitation scheme is a justified investment. One of the cheapest sanitation technologies , "a total pit" for each house, costs approximately YR 10 000 per house. In this case the total scheme for 135 houses will cost YR 1 350 000. With a contribution of 25% each houseowner has to pay YR 2500. This is still an amount which is beyond the capacity of the village community.

Altogether it is not advisable to start with the implementation of such an expensive sanitation scheme in the village of Al Hajar. It is better to gain experience in villages with a much easier physical and social structure.
Moreover, it remains necessary to develop cheaper sanitation technologies and in certain cases it will be necessary to abandon technical requirements. The most important question is whether it is possible to construct good functioning sewer pipes with a slope which exceeds the maximum permissible slope of a conventional sewerage system. When this is possible, it is not necessary to construct so many interceptor tanks and the sanitation scheme will be much cheaper. In some places the people started with the construction of such sewers and the project should develop this idea further by a try and error method.

The implementation of sanitation systems is a new project activity and should be directed to pilot villages which satisfy the following conditions:
- distance to the RIRDP office should be not more than 20 km or 30 minutes driving.
- the village should be small, 20-30 houses is a maximum.
- the physical structure of the village should be simple so that it is possible to cover the village by 1 or 2 sanitation technologies.
- the nature of the underground should be homogeneous and in the first villages preferably sandy.
- the distance between the place of production and final disposal of the wastewater should be short.
- the village should have a water supply scheme (preferably from RIRDP)
- the social structure of the village should be homogeneous and strong.
- there should be a reliable village representative.
- the village should show interest for the sanitation activities.
- the villagers should be prepared to pay their share in the construction costs.

When a village meets these requirements, the RIRDP should carry out a survey and prepare a proposal. This report about Al Hajar contains all required elements for the writing of such a proposal.

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GLOSSARY

Anaerobic: living or taking place without air or oxygen.
Baladih: from the country (arabic).
Bayara: pit (arabic).
Cistern-flush toilet: toilet which is fushed by emptying a cistern which hangs above the toilet; this needs 10-20 liter water per flush.
Composting: a biological process in which various organisms under controlled conditions break down organic matter.
Desludging: removing accumulated sludge from septic tanks, etc.
Digestion: the breaking down of organic waste by bacteria.
Effluent: the liquid outflow from a sewage treatment plant or septic tank.
Equivalent: no of adults + 0.5 [no of children].
Evaporation: process in which water goes into the air.
Excreta: mixture of faeces and urine from human beings.
Faeces: solid waste from the body, excreted from the bowel.
Helminth: a worm; either free-living or parasitic.
Infiltration: process in which water goes into the soil.
Interceptor tank: one compartment small septic tank.
Masonry: made of stones or blocks.
Ova: eggs (singular: ovum).
Pathogen: a microscopic organism which causes disease.
Pit: hole in the ground which receives wastewater from the house.
Pour-flush toilet: a toilet with a shallow water seal below the plate. The toilet is flushed manually with a bucket and this needs 2 l/flush.
Retention time: time that water or excreta are retained in e.g. a septic tank.
Sanitation: excreta disposal, and cleanliness in relation to excreta disposal.
Scum: solid material, with fats, oils, grease, and soaps, floating on the water surface of a septic tank, etc.
Sedimentation: the process by which suspended soild particles in water are allowed to settle out to the bottom of e.g. a tank.
Septic tank: a sealed settling chamber receiving wastewater from a dwelling.
Sewage: human excreta diluted by water.
Sewer: a pipe used for the transport of wastewater.
Sewerage: a network of sewer pipes.
Sludge: a mixture of solids and water deposited on the bottom of e.g. a septic tank.
Soakaway: an arrangement to promote seepage of effluent into the ground.
Sullage: domestic wastewater not containing excreta.
Treatment tank: big septic tank for the purification of the wastewater from the small bore sewer system.
Urine: liquid waste from the body.
Vault: tank used for the storage of wastewater.
VIP-latrine: ventilated improved pit latrine, a pit latrine provided with a ventilation pipe connected to the top of the pit.

RESULTS OF THE SURVEY IN AL HAJAR
DATE: 16 AND 17 JUNE 1987
BY: Aart van der Horst and Saif Ahmed

	PERSONS			TOILET			REMARKS
House number	No of adults	No of children	No of equiv.	Baladih toilet	Pour-flush	No toilet	
1	5	6	8	x			
2	4	4	6	x			
3	2	4	4	x			
4	2	9	7	x			
5	2	10	7	x			
6	4	5	7	x			
7	2	4	4	x			
8	5	3	7	x			
9	2	10	7	x			
10	3	6	6	x			
11	3	6	6	x			
12	2	6	5	x			
13	4	9	9		x		
14	3	7	7		x		Total pit
15	2	9	7			x	
16	4	2	5		x		Total pit
17	4	2	5	x			
18	4	3	6	x			
19	4	2	5	x			
20	2	8	6	x			
21	4	2	5	x			
22	1	0	1	x			
23	4	12	10	x			
Mosque			10				RIRDP toilets
24	8	16	16	x			
25	2	2	3	x			
26	4	6	7	x			
27	8	13	15	x			4 families
28	8	7	12	x			2 families
29	2	5	5	x			
30	4	5	7	x			
31	3	4	5	x			
32	3	1	4	x			
33	4	6	7	x			
Mosque			10				
34	2	3	4	x			
35	2	5	5	x			
36	3	1	4	x			
37	2	7	6	x			
38	5	3	7	x			
39	3	0	3	x			
40	4	5	7	x			
41	2	0	2	x			
42	2	0	2			x	
43	3	3	5	x			
44	6	4	8	x			
45	5	7	9	x			
46	4	4	6	x			
47	4	5	7	x			
48	2	3	4	x			
49	4	4	6	x			

RESULTS OF THE SURVEY IN AL HAJAR
DATE: 16 AND 17 JUNE 1987
BY: Aart van der Horst and Saif Ahmed

	PERSONS			TOILET			REMARKS
House number	No of adults	No of children	No of equiv.	Baladih toilet	Pour-flush	No toilet	
50	2	3	4	x			
51	6	7	10		x		
52	3	3	5	x			
53	4	3	6	x			
54	8	15	16	x			
55	6	13	13	x			3 families
56	2	5	5	x			
57	6	3	8	x			
58	3	4	5	x			
59	2	5	5	x			
60	3	5	6	x			
61	2	2	3	x			
62	3	6	6		x		
63	6	1	7			x	
64	7	6	10		x		
65	2	2	3	x			
66	2	3	4	x			
67	2	4	4	x			
68	4	10	9	x			
69	2	3	4	x			
70	5	9	10	x			
71	6	10	11	x			
72	2	2	3	x			
73	2	0	2	x			
74	2	1	3	x			
75	4	3	6	x			
76	4	3	6	x			
77	2	6	5	x			
78	4	7	8	x			
79	6	4	8	x			
80	4	6	7	x			
81	3	5	6	x			
82	6	5	9	x			
83	2	0	2	x			
84	6	8	10	x			
85	2	1	3			x	
86	6	4	8	x			
87	4	6	7	x			
88	2	0	2	x			
89	6	2	7	x			
90	4	6	7	x			
91	2	4	4			x	
92	3	6	6			x	
93	2	2	3	x			
94	1	0	1	x			
95	1	0	1	x			
96	2	0	2	x			
97	2	4	4	x			
98	2	6	5	x			
99	1	0	1	x			

RESULTS OF THE SURVEY IN AL HAJAR
DATE: 16 AND 17 JUNE 1987
BY: Aart van der Horst and Saif Ahmed

	PERSONS			TOILET			REMARKS
House number	No of adults	No of children	No of equiv.	Baladih toilet	Pour-flush	No toilet	
100	2	3	4		x		
101	2	4	4	x			
102	4	4	6	x			
103	5	4	7	x			
104	2	8	6	x			
105	2	4	4	x			
106	2	4	4	x			
107	3	9	8	x			
Mosque			10				no toilets
109	2	0	2			x	
110	2	3	4		x		
111	4	8	8	x			
112	3	3	5	x			
113	2	3	4		x		
Mosque			10				PF toilets
115	4	4	6		x		
116	2	6	5			x	
117	2	3	4	x			
118	2	6	5	x			
119	2	5	5	x			
120	2	6	5	x			
121	4	0	4	x			
122	3	8	7	x			
123	2	3	4	x			
124	4	6	7		x		
125	4	4	6		x		
126	2	4	4		x		
127	8	14	15		x		Soakaway
TOTAL 125	420	587	779	103	14	8	

Houses added during the second survey in May 1988
(most of them are under construction)

10A	?	?	8(*)
15A	?	?	8(*)
15B	?	?	8(*)
15C	?	?	8(*)
20A	?	?	8(*)
52A	?	?	8(*)
59A	?	?	8(*)
82A	?	?	8(*)
119A	?	?	8(*)
EXTRA 9			72(*)

(*) = estimated

PROPOSED SANITATION SYSTEM PER HOUSE

House number	No of equiv.	Small bore sewer system	Total pit	Septic T drain-field	Septic T soak-away	Costs (YR)	Remarks
1	8		x			9864	
2	6		x			9864	
3	4		x			9864	
4	7		x			9864	
5	7		x			9864	
6	7		x			9864	
7	4	sewer 6					
8	7		x			9864	
9	7	sewer 6					
10	6	sewer 6					
11	6	sewer 6					
12	5	sewer 6					
13	9		x			9864	
14	7						Total pit ready
15	7	sewer 6					
16	5	sewer 5					
17	5		x			9864	
18	6	sewer 5					
19	5	sewer 5					
20	6	sewer 5					
21	5	sewer 5					
22	1	sewer 5					
23	10	sewer 1					
Mosque	10	sewer 1					
24	16	sewer 1					
25	3	sewer 7					
26	7	sewer 1					
27	15	sewer 1					
28	12	sewer 1					
29	5	sewer 7					
30	7	sewer 7					
31	5	sewer 1					
32	4	sewer 1					
33	7	sewer 7					
Mosque	10	sewer 7					
34	4	sewer 7					
35	5	sewer 7					
36	4	sewer 2					
37	6	sewer 7					
38	7	sewer 7					
39	3	sewer 7					
40	7	sewer 7					
41	2	sewer 7					
42	2						Not included yet
43	5	sewer 7					
44	8	sewer 7					
45	9	sewer 1					
46	6	sewer 1					
47	7	sewer 1					
48	4	sewer 1					
49	6	sewer 1					

PROPOSED SANITATION SYSTEM PER HOUSE

House number	No of equiv.	Small bore sewer system	Total pit	Septic T drain-field	Septic T soak-away	Costs (YR)	Remarks
50	4	sewer 4					
51	10	sewer 4					
52	5	sewer 4					
53	6	sewer 4					
54	16	sewer 4					
55	13	sewer 4					
56	5	sewer 1&4					
57	8	sewer 1					
58	5	sewer 1					
59	5	sewer 4					
60	6	sewer 4					
61	3	sewer 3					
62	6						Not included yet
63	7	sewer 3					
64	10	sewer 3					
65	3	sewer 3					
66	4	sewer 1&3					
67	4						Not included yet
68	9						Not included yet
69	4	sewer 3					
70	10	sewer 3					
71	11	sewer 7					
72	3	sewer 3					
73	2	sewer 7					
74	3	sewer 3					
75	6	sewer 7					
76	6	sewer 3					
77	5	sewer 3					
78	8	sewer 3					
79	8	sewer 3					
80	7	sewer 3					
81	6	sewer 3					
82	9	sewer 2					
83	2	sewer 7					
84	10	sewer 2&7					
85	3	sewer 7					
86	8	sewer 3					
87	7	sewer 3					
88	2	sewer 2					
89	7	sewer 2					
90	7	sewer 2					
91	4	sewer 2					
92	6	sewer 2					
93	3	sewer 2					
94	1	sewer 2					
95	1	sewer 2					
96	2	sewer 2					
97	4	sewer 2					
98	5	sewer 2					
99	1	sewer 2					

PROPOSED SANITATION SYSTEM PER HOUSE

House number	No of equiv.	Small bore sewer system	Total pit	Septic T drain-field	Septic T soak-away	Costs (YR)	Remarks
100	4		x			9864	
101	4			x		16460	
102	6				x	20173	
103	7			x		16460	
104	6		x			9864	
105	4			x		16460	
106	4			x		16460	
107	8		x			9864	
Mosque	10		x			9864	
109	2		x			9864	
110	4			x		16460	
111	8			x		16460	
112	5			x		16460	
113	4			x		16460	
Mosque	10		x			9864	
115	6			x		16460	
116	5				x	20173	
117	4		x			9864	
118	5		x			9864	
119	5		x			9864	
120	5				x	20173	
121	4				x	20173	
122	7				x	20173	
123	4				x	20173	
124	7			x		16460	
125	6		x			9864	
126	4		x			9864	
127	15						Total pit ready
10A	8(*)	sewer 6					
15A	8(*)	sewer 6					
15B	8(*)	sewer 6					
15C	8(*)	sewer 6					
20A	8(*)	sewer 5					
52A	8(*)	sewer 4					
59A	8(*)	sewer 3					
82A	8(*)	sewer 2					
119A	8(*)		x			9864	
TOTAL 134	851		21	10	6	492 782	

(*) = estimated

Technical specification INTERCEPTOR TANK FOR SMALL BORE SEWER SYSTEM

The design of the interceptor tanks is based on the Brazilian septic tank code (ref.7), presented in ref.4.

Interceptor tanks are designed to provide space for three separate functions:

1 Solids retention:

For this, the wastewater should stay long enough in the tank to allow the suspended solids to settle to the bottom.

The retention time (T_H) can be calculated with the following formula:

$$T_H = 1.5 - 0.3 \log (P * Q) \qquad (1)$$

where T_H = minimum mean hydraulic retention time (days)
P = number of persons
Q = wastewater flow (lcd)

The tank volume required for sedimentation is therefore given by:

$$V_H = P * Q * T_H \qquad (2)$$

where V_H = volume needed for sedimentation (liter)
P = number of persons
Q = wastewater flow (lcd)
T_H = hydraulic retention time (days), see equation (1)

The depth required for sedimentation can be calculated with the following formula:

$$D_H = V_H / A \qquad (3)$$

where D_H = minimal depth for sedimentation (cm).
V_H = volume for sedimentation (liter).
A = surface of the interceptor tank (m^2).

This D_H should have a minimal value of 35 cm.

---

2 Storage of solids:

The volume required for storage of solids is based upon the following formula:

$$V_S = P * N * S \qquad (4)$$

where V_S = volume required for storage of solids (liter)
P = number of persons
N = interval between successive desludging operations (years)
S = sludge accumulation/pc/pyear

This volume for sludge storage can be combined with the surface of the interceptor tank to calculate the depth required for the sludge storage:

$$D_S = V_S / A \quad (5)$$

where D_S = minimal depth for sludge storage (cm).
V_S = volume for sludge storage (liter).
A = surface of the interceptor tank (m^2)

---

3 Storage of scum:

The depth required for the scum storage (D_{SC}) is estimated:

$$D_{SC} = 10 \text{ cm} \quad (6)$$

The total minimum depth of the interceptor tank (D_T) can be calculated from the minimal required depths for sedimentation, sludge storage and scum storage:

$$D_T = D_H + D_S + D_{SC} \quad (7)$$

This D_T should have a minimal value of 90 cm.

===

For the calculations of the size of the interceptor tanks for 1 house the following design criteria have been used:

P = number of persons = 8
Q = wastewater flow (lcd) = 80 lcd
N = interval between successive desludging operations = 3 years
S = sludge accumulation/pc/pyear = 35 liter (*)
A = surface of the interceptor tank = 2 m^2
(*): This is less than for a septic tanks (40 lca) because the retention time in the interceptor tank is short and there is only one compartment.

This gives:
- a retention time, T_H. 0.7 days (equation 1)
- a volume for sedimentation, V_H: 448 liter (equation 2)
- a sedimentation depth, D_H 35 cm (equation 3)
- a volume for solids storage, V_S: 840 liter (equation 4)
- a sludge depth, D_S. 42 cm (equation 5)
- a scum depth, D_{SC}: 10 cm (equation 6)

This means that the interceptor tank should have a minimal height (D_T) of (35 + 42 + 10)= 87 cm. (equation 7)
As D_T should be at least 90 cm, an interceptor tank with overall internal dimensions of 2m * 1m * 1.2 m (L*W*H) and an effective volume of 2000 liter, as shown in annex E1 is suitable.

The costs for such an interceptor tank are (see annex C1):

Excavation in	Excavation costs (YR/m^3)	Costs of a reinforced concrete interceptor tank	Costs of a concrete blocks interceptor tank
SAND	100	YR 5520	YR 6010
ROCK	800	YR 5870	YR 9510
HARD ROCK	1500	YR 6220	YR 13010

Technical specification <u>TREATMENT TANK FOR SMALL BORE SEWER SYSTEM</u>

This tanks are designed to provide space for two separate functions:

1 Solids retention:

The tank volume required for sedimentation is given by:

$$V_H = P * Q * T_H \qquad (8)$$

where V_H = volume needed for sedimentation (liter)
P = number of persons
Q = wastewater flow (lcd)
T_H = hydraulic retention time (days)

2 Storage of solids:

The volume required for storage of solids is based upon the following formula:

$$V_S = P * N * S \qquad (9)$$

where V_S = volume required for storage of solids (liter)
P = number of persons
N = interval between successive desludging operations(years)
S = sludge accumulation/pc/pyear

So the total volume of the treatment tank can be calculated with the following formula:

$$V = [Q * T_H + N * S] * P \text{ liter} \qquad (10)$$

==

For the calculations of the size of a treatment tank for wastewater from the small-bore sewers the following design criteria have been used:

P	= number of persons	= 100 or 150
Q	= wastewater flow (lcd)	= 80 lcd
T_H	= retention time	= 1 day
N	= interval between successive desludging operations	= 3 years
S	= sludge accumulation/pc/pyear	= 10 liter

The number of persons for the sewer lines are based upon the results of the survey, see also Annex D1:

Sewer line	Number of equivalents	Design criterium for treatment tank
sewer 1	129	150 equivalents
sewer 2	69	100 equivalents
sewer 3	108	150 equivalents
sewer 4	75	100 equivalents
sewer 5	36	100 equivalents(*)
sewer 6	67	100 equivalents
sewer 7	108	150 equivalents

(*) this is high, but it is expected that in the future several new houses will be connected to this sewer line.

A treatment tank for 150 persons should have.
- a volume for sedimentation, V_H: 12 000 liter (equation 8)
- a volume for solids storage, V_S: 4 500 liter (equation 9)
- a total volume, V: 16 500 liter (equation 10)

A treatment tank with overall internal dimensions of 4.25 m * 2.4 m * 1.8 m (L*W*H) and an effective volume of 16524 liter is suitable, see also the figure in annex E2.

A treatment tank for 100 persons should have:
- a volume for sedimentation, V_H: 8 000 liter (equation 8)
- a volume for solids storage, V_S: 3 000 liter (equation 9)
- a total volume, V: 11 000 liter (equation 10)

A treatment tank with overall internal dimensions of 3.85 m * 1.8 m * 1.8 m (L*W*H) and an effective volume of 11088 liter is suitable.

The tanks can be constructed from either concrete blocks or reinforced concrete. A tank made from concrete blocks should be buried in the ground, a tank made from reinforced concrete can be constructed for a big part above the ground. Only 50 cm of the lower part should be buried in the ground.
The construction costs of this treatment tanks in situations with different excavation costs are: (see also annex C2 and C3)

Excavation in:	Excavation costs (YR/m³)	Costs of a reinforced concrete treatment tank for 150 persons	Costs of a concrete blocks treatment tank for 150 persons
SAND	100	YR 19 511	YR 21 432
ROCK	800	YR 24 411	YR 42 432
HARD ROCK	1500	YR 29 311	-

Excavation in:	Excavation costs (YR/m³)	Costs of a reinforced concrete treatment tank for 100 persons	Costs of a concrete blocks treatment tank for 100 persons
SAND	100	YR 15 841	YR 17 107
ROCK	800	YR 19 341	YR 32 507
HARD ROCK	1500	YR 22 841	-

So in all cases the construction of reinforced concrete treatment tanks above the ground is cheaper than the construction of treatment tanks with concrete blocks.

Technical specification <u>SOAKAWAY</u>

The dimensions of a soakaway pit are based upon the following formula:

$$A = \frac{P * Q}{I} \text{ meter}^2 \quad (11)$$

where: A = infiltration area of the soakaway (m^2)
P = number of persons
Q = wastewater flow (lcd)
I = infiltration rate ($l/m^2/d$)

===

For the soakaways for the final disposal of the effluent from the treatment tanks in the small-bore sewer system the following design criteria have been used:

P = number of persons = 100 or 150
Q = wastewater flow (lcd) = 80 lcd
I = infiltration rate ($l/m^2/d$) = 150 $l/m^2/d$(*)
(*): This is higher than for a drainfield (80 $l/m^2/d$) because this water has passed both the interceptor tank and the treatment tank.

A soakaway for 150 persons should have a minimal infiltration area of 80 m^2. A soakaway with a diameter of 2.5 m and a depth of 11 m, which has an infiltration area of 86 m^2 and a volume of 54 m^3 is good.

A soakaway for 100 persons should have a minimal infiltration area of 53 m^2. A soakaway with a diameter of 2.5 m and a depth of 7 m, which has an infiltration area of 55 m^2 and a volume of 34 m^3 is good.

===

For a soakaway for the disposal of the effluent from a septic tank or the sullage for <u>1 house</u> the following design criteria have been used:

P = number of persons = 8
Q = wastewater flow (lcd) = 80 lcd
I = infiltration rate ($l/m^2/d$) = 80 $l/m^2/d$

The soakaway should have a minimal infiltration area of 8 m^2. A soakaway with a diameter of 1.5 m and a depth of 2 m, which has an infiltration area of 9.4 m^2 and a volume of 3.5 m^3 is good.
As the upper 0.5 m of the soakaway is not suitable for infiltration the soakaway should have a depth of 2.5 m.

===

The costs for such soakaways depend very much on the excavation costs:

Excavation in:	Excavation costs (YR/m^3)	Soakaway for 1 house (Annex C10)	Soakaway for 100 persons (Annex C4)	Soakaway for 150 persons (Annex C4)
SAND	100	YR 2239	YR 8 489	YR 10 489
ROCK	800	YR 5389	YR 32 289	YR 48 289
HARD ROCK	1500	YR 8539	-	-

Technical specification DRAINFIELD

The dimensions of the trenches of a drainfield are based upon the following formula:

$$L = \frac{P * Q}{2 * D * I} \quad \text{meter} \qquad (12)$$

where:
- L = length of trench (m)
- P = number of persons
- Q = wastewater flow (lcd)
- D = effective depth of trench (m)
- I = infiltration rate ($l/m^2/d$)

==

For the drainfields for the final disposal of the effluent from the treatment tanks in the small-bore sewer system the following design criteria have been used:

P	= number of persons	= 100 or 150
Q	= wastewater flow (lcd)	= 80 lcd
D	= effective depth of trench (m)	= 0.7 m
I	= infiltration rate ($l/m^2/d$)	= 80 $l/m^2/d$

A drainfield for 150 persons should have trenches with a total length of 107 meter. The dimensions of the trench will be 107m * 0.5m * 0.85m (L*W*D), see also the figure in annex E5.
A drainfield for 100 persons should have trenches with a total length of 71 meter. The dimensions of the trench will be 71m * 0.5m * 0.85m (L*W*D).

==

For a drainfield for the disposal of the effluent from a septic tank or the sullage for 1 house the following design criteria have been used:

P	= number of persons	= 8
Q	= wastewater flow (lcd)	= 80 lcd
D	= effective depth of trench (m)	= 0.7 m
I	= infiltration rate ($l/m^2/d$)	= 80 $l/m^2/d$

With these design criteria, the drainfield should have trenches with a total length of 6 meter. The dimensions of the trench will be 6.0m * 0.5m * 0.85m (L*W*D).

==

The costs for such drainfields are:

Excavation in:	Excavation costs (YR/m^3)	Drainfield for 1 house (Annex C10)	Drainfield for 100 persons (Annex C5)	Drainfield for 150 persons (Annex C5)
SAND	100	YR 540	YR 5 580	YR 8 280
ROCK	800	YR 2640	YR 27 280	YR 40 480
HARD ROCK	1500	-	-	-

Technical specification <u>VAULT</u>

The dimensions of a vault are based upon the following formula:

$$V_v = P * Q * N_v \qquad (13)$$

where:
V_v = volume of the vault (liter)
P = number of persons
Q = wastewater flow (lcd)
N_v = interval between successive emptying operations (days)

For a vault for 1 house the following design criteria have been used:

P	= number of persons	= 8
Q	= wastewater flow (lcd)	= 80 lcd
N_v	= interval between successive emptying operations	= 20 days

With this design criteria, the vault should have a minimal volume of 12 800 liter.
A vault with internal dimensions of 3.0 m * 2.2 m * 2.0 m (L*W*H) and an effective volume of 13 200 liter is good.

The costs of such a vault are, see annex C7:

- in hardrock: YR 20 380,
- in rock: YR 17 230.

Technical specification COMPOST TOILET

A compost toilet consists of two compost rooms which are each used alternately for 1 year. The compost rooms only receive the solid wastes which are mixed with ashes from the kitchen.
The liquid wastes from the toilet and the wastewater flows from kitchen and bathroom will be disposed together in either a soakaway or a drainfield.

The dimensions of 1 compost room are based upon the following formula.

$$V_c = 1.33 * P * S_c * N_c \quad (14)$$

where:
V_c = volume of a compost room (liter)
P = number of persons
S_c = solid waste + ash production/pc/pyear
N_c = interval between successive compost removals

==

For 1 compost room for 1 house the following design criteria have been used.

P = number of persons = 8
S_c = solid waste + ash production/pc/pyear = 100 lca
N_c = interval between successive compost removals = 1 year

With this design criteria, 1 compost room should have a minimal volume of 1064 liter
So a compost room with overall internal dimensions of 0.8 m * 1.2 m * 1.2 m (L*W*H) and an effective volume of 1152 liter is good

For a proper functioning of the system it is necessary that there are two compost rooms with a total volume of 2304 liter and a separate disposal facility for the liquid wastes and the sullage.

The costs of 2 compost rooms on hardrock are YR 4900 (see annex C7).

For the disposal facility for sullage and liquid wastes we can choose either a drainfield or a soakaway, see annex B3 and annex B4
A drainfield is only suitable on places with a sandy underground; a soakaway is also suitable on places with a rocky underground.
The construction costs of a compost toilet with a facility for disposal of liquid wastes and wastewater from kitchen and bathroom are.

Excavation in:	Excavation costs (YR/m³)	Costs of a compost toilet with drainfield	Costs of a compost toilet with soakaway
SAND	100	YR 5 020	YR 6 719
ROCK	800	YR 7 330	YR 10 079
HARD ROCK	1500	. -	YR 13 439

Technical specification PIT

A total pit receives all the wastewater from a house. This means wastewater from the toilet, the kitchen and the bathroom.

A toilet pit receives the wastewater from a pour-flush toilet only. In this case it will be necessary to construct another facility for the disposal of the wastewater from kitchen and bathroom.

===

The pit is designed to provide space for two different functions:

1 Storage of solids:

The volume required for storage of solids is given by:

$$V_S = P * N_P * S \qquad (15)$$

where:
- V_S = volume required for storage of solids (liter)
- P = number of persons
- N_P = number of years of continuous pit use (year)
- S = sludge accumulation/pc/pyear

2 Liquid infiltration:

The area required for liquid infiltration is given by:

$$A = \frac{P * Q}{I} \text{ meter}^2 \qquad (16)$$

where:
- A = infiltration area of the pit (m^2)
- P = number of persons
- Q = wastewater flow (lcd)
- I = infiltration rate ($l/m^2/d$)

===

For the calculations of the size of a total pit for 1 house the following design criteria have been used:

P	= number of persons	= 8
N_P	= number of years of continuous pit use	= 10 year
S	= sludge accumulation/pc/pyear	= 40 lca
Q	= wastewater flow (lcd)	= 80 lcd
I	= infiltration rate ($l/m^2/d$)	= 50 $l/m^2/d$ (*)

(*) This is less than for the infiltration in a soakaway (80 $l/m^2/d$) because in this case the water will contain much more suspended materials resulting in a lower infiltration capacity.

This gives:
- a volume for solids storage, V_S: 3200 liter (equation 15)
- an area for infiltration, A: 12.8 m^2 (equation 16)

When the total pit diameter is 2.0 meter this gives:
- 1.1 m depth for solids storage (3454 liter);
- 2.1 m depth for liquid infiltration (13.2 m^2);
- 0.5 m depth on the top, which is not useful.

So the total pit should have a depth of 3.7 m and a diameter of 2.0 m.
===

For the calculations of the size of a toilet pit for 1 house the following design criteria have been used:

P	=	number of persons	=	8
N_p	=	number of years of continuous pit use	=	10 year
S	=	sludge accumulation/pc/pyear	=	40 lca
Q	=	wastewater flow (lcd)	=	10 lcd (#)
I	=	infiltration rate ($l/m^2/d$)	=	20 $l/m^2/d$ (*)

(#) This is the estimated quantity for a pour-flush toilet.
(*) This is low because the wastewater from the toilet will contain much suspended materials which will clog the sides of the pit.

This gives:
- a volume for solids storage, V_s: 3200 liter (equation 15)
- an area for infiltration, A: 4.0 m^2 (equation 16)

When the toilet pit diameter is 1.5 meter this gives:
- 1.9 m depth for solids storage (3356 liter);
- 0.9 m depth for liquid infiltration (4.2 m^2);
- 0.5 m depth on the top, which is not useful.

So the pit should have a depth of 3.3 m and a diameter of 1.5 m.
===

The costs for such pits depend very much on the excavation costs, see annex C8::

Excavation in:	Excavation costs (YR/m^3)	Total pit for 1 house	Toilet pit for 1 house
SAND	100	YR 6 289	YR 2 389
ROCK	800	YR 14 689	YR 6 589
HARD ROCK	1500	YR 23 089	YR 10 789

Technical specification SEPTIC TANK

Septic tanks are designed to provide space for two different functions:

1 Solids retention:

The tank volume required for sedimentation is given by:

$$V_H = P * Q * T_H \qquad (17)$$

where V_H = volume needed for sedimentation (liter)
P = number of persons
Q = wastewater flow (lcd)
T_H = hydraulic retention time (days)

2 Storage of solids:

The volume required for storage of solids is based upon the following formula:

$$V_S = P * N * S \qquad (18)$$

where V_S = volume required for storage of solids (liter)
P = number of persons
N = interval between successive desludging operations(years)
S = sludge accumulation/pc/pyear

So the total volume of the septic tank can be calculated with the following formula:

$$V = [Q * T_H + N * S] * P \text{ liter} \qquad (19)$$

==

For the calculations of the size of the septic tank for 1 house the following design criteria have been used:

P	= number of persons	= 8
Q	= wastewater flow (lcd)	= 80 lcd
T_H	= retention time	= 3 days
N	= interval between successive desludging operations	= 3 years
S	= sludge accumulation/pc/pyear	= 40 liter

This gives:

- a volume for sedimentation, V_H:	1920 liter	(equation 8)
- a volume for solids storage, V_S:	960 liter	(equation 9)
- a total volume, V:	2880 liter	(equation 10)

So a septic tank with overall internal dimensions of 2.25 m * 1.2 m * 1.4 m (L*W*H) and an effective volume of 3240 liter is suitable, see also the figure in Annex E9.

Such a tank can be constructed from either concrete blocks or reinforced concrete.
A septic tank made of concrete blocks should be buried in the ground, so the excavation costs are an important factor in the total costs.

A septic tank made of reinforced concrete can be constructed for a big part above the ground. Only 20 cm of the lower part should be buried in the ground. The total costs are almost independant from the excavation costs.
The construction costs of a septic tank in situations with different excavation costs are. (see also Annex C9)

Excavation in	Excavation costs (YR/m^3)	Costs of a reinforced concrete septic tank	Costs of a concrete blocks septic tank
SAND	100	YR 7789	YR 8310
ROCK	800	YR 8349	YR 14610
HARD ROCK	1500	YR 8909	YR 20910

So in all cases the construction of a reinforced concrete septic tank above the ground is cheaper.

Bill of quantities for: <u>INTERCEPTOR TANK</u>, reinforced concrete.
2 m long, 1 m width, 1.2 m high; V_{eff} = 2000 l; 3 years use.
8 persons; 80 lcd; T_H = 0.7 day; S = 35 lca; 0.2 m buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	0.5	1500	750
4	Reinforced concrete	m^3	1.4	3300	4620
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	-	170	-
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	1	300	300
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	-	80	-

GRAND TOTAL — In hardrock: YR 6220
Price level: October 1988. — In rock: YR 5870
In sand: YR 5520

Bill of quantities for: <u>INTERCEPTOR TANK</u>, concrete blocks.
2 m long, 1 m width, 1.2 m high; V_{eff} = 2000 l; 3 years use.
8 persons; 80 lcd; T_H = 0.7 day; S = 35 lca; completely buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	5.0	1500	7500
4	Reinforced concrete	m^3	0.7	3300	2310
5	Blocks (40*20*20, solid)	m^2	9.0	190	1710
6	Blocks (40*20*15, hollow)	m^2	-	170	-
7	Plastering (1:2.5, water resistant)	m^2	8.0	70	560
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	1	300	300
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	1	80	80

GRAND TOTAL — In hardrock: YR 13010
Price level: October 1988. — In rock: YR 9510
In sand: YR 6010

Bill of quantities for: TREATMENT TANK FOR 150 PERSONS,
reinforced concrete

4.25 m long, 2.4 m width, 1.8 m high; V_{ef} = 16 524 l; 3 years use.
150 persons; 80 lcd; T_H = 1 day; S = 10 lca; 0.5 m buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	7.0	1500	10500
4	Reinforced concrete	m^3	5.0	3300	16500
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	4.3	170	731
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	2	350	700
9	Manhole lids, steel, 30 cm	nr	2	300	600
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	1	80	80

GRAND TOTAL — In hardrock: YR 29 311
Price level: October 1988. — In rock: YR 24 411
In sand: YR 19 511

Bill of quantities for: TREATMENT TANK FOR 150 PERSONS,
concrete blocks

4.25 m long, 2.4 m width, 1.8 m high; V_{ef} = 16 524 l; 3 years use.
150 persons; 80 lcd; T_H = 1 day; S = 10 lca; completely buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	30.0	800	24000
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	2.7	3300	8910
5	Blocks (40*20*20, solid)	m^2	28.0	190	5320
6	Blocks (40*20*15, hollow)	m^2	4.3	170	731
7	Plastering (1:2.5, water resistant)	m^2	24.5	70	1715
8	Manhole lids, steel, 50 cm	nr	2	350	700
9	Manhole lids, steel, 30 cm	nr	2	300	600
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	3.2	80	256

GRAND TOTAL — In rock: YR 42 432
Price level: October 1988. — In sand: YR 21 432

Bill of quantities for: <u>TREATMENT TANK FOR 100 PERSONS,</u>
reinforced concrete

3.85 m long, 1.8 m width, 1.8 m high; V_{ef} = 11 088 l; 3 years use.
100 persons; 80 lcd; T_H = 1 day; S = 10 lca; 0.5 m buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	5.0	1500	7500
4	Reinforced concrete	m^3	4.0	3300	13200
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	3.3	170	561
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	2	350	700
9	Manhole lids, steel, 30 cm	nr	2	300	600
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	1	80	80

GRAND TOTAL — In hardrock: YR 22 841
Price level: October 1988. — In rock: YR 19 341
In sand: YR 15 841

Bill of quantities for: <u>TREATMENT TANK FOR 100 PERSONS,</u>
concrete blocks

3.85 m long, 1.8 m width, 1.8 m high; V_{ef} = 11 088 l; 3 years use.
100 persons; 80 lcd; T_H = 1 day; S = 10 lca; completely buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	22.0	800	17600
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	2.0	3300	6600
5	Blocks (40*20*20, solid)	m^2	24.0	190	4560
6	Blocks (40*20*15, hollow)	m^2	3.3	170	561
7	Plastering (1:2.5, water resistant)	m^2	21.0	70	1470
8	Manhole lids, steel, 50 cm	nr	2	350	700
9	Manhole lids, steel, 30 cm	nr	2	300	600
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	2.7	80	216

GRAND TOTAL — In rock: YR 32 507
Price level: October 1988. — In sand: YR 17 107

Bill of quantities for: <u>SOAKAWAY FOR TREATMENT TANK FOR 150 PERSONS</u>
2.5 m diameter, 11 m deep; A_{inf} = 86 m^2
150 persons; 80 lcd; I = 150 l/m^2d

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	54.0	800	43200
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	1.4	3300	4620
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	0.7	170	119
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	-	80	-
	GRAND TOTAL	In rock:			YR 48 289
	Price level: October 1988	In sand:			YR 10 489

Bill of quantities for: <u>SOAKAWAY FOR TREATMENT TANK FOR 100 PERSONS</u>
2.5 m diameter, 7 m deep; A_{inf} = 55 m^2
100 persons; 80 lcd; I = 150 l/m^2d

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	34.0	800	27200
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	1.4	3300	4620
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	0.7	170	119
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	-	80	-
	GRAND TOTAL	In rock:			YR 32 289
	Price level: October 1988.	In sand:			YR 8 489

Bill of quantities for: <u>DRAINFIELD FOR TREATMENT TANK FOR 150 PERSONS</u>
107 m long, 0.5 m width, 0.85 m deep, A_{inf} = 150 m^2
150 persons; 80 lcd; I = 80 l/m^2d

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	46	100	4600
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	-	3300	-
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	-	170	-
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	-	350	-
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	46	80	3680
	GRAND TOTAL	in sand:		YR	8280
	Price level: October 1988.	in rock:		YR	40480

Bill of quantities for: <u>DRAINFIELD FOR TREATMENT TANK FOR 100 PERSONS</u>
71 m long, 0.5 m width, 0.85 m deep, A_{inf} = 99 m^2
100 persons; 80 lcd; I = 80 l/m^2d

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	31	100	3100
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	-	3300	-
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	-	170	-
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	-	350	-
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	31	80	2480
	GRAND TOTAL	in sand:		YR	5580
	Price level: October 1988.	in rock:		YR	27280

Bill of quantities for: <u>SMALL MANHOLE</u>

0.7 m long, o.7 m width, 0.55 m high; 0.3 m buried

Nr	Description	Unit	Quan-tity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	0.2	1500	300
4	Reinforced concrete	m^3	0 1	3300	330
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	1	170	170
7	Plastering (1:2.5, water resistant)	m^2	2	70	140
8	Manhole lids, steel, 50 cm	nr	-	350	-
9	Manhole lids, steel, 30 cm	nr	1	300	300
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	-	80	-
	GRAND TOTAL	In hardrock:			YR 1240
	Price level: October 1988.	In rock:			YR 1100
		In sand:			YR 960

Bill of quantities for: <u>BIG MANHOLE</u>

0.96 m long, 0.96 m width, 0.75 m high; 0.45 m buried.

Nr	Description	Unit	Quan-tity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	0.4	1500	600
4	Reinforced concrete	m^3	0.1	3300	330
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	2.0	170	340
7	Plastering (1:2.5, water resistant)	m^2	4 0	70	280
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	-	80	-
	GRAND TOTAL	In hardrock:			YR 1900
	Price level: October 1988.	In rock:			YR 1620
		In sand:			YR 1340

Bill of quantities for: VAULT

3.0 m long, 2.2 m width, 2 m high; V_{eff} = 13 200 liter; 20 days use.
8 persons; 80 lcd; 0.5 m buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	4.5	1500	6750
4	Reinforced concrete	m^3	4.0	3300	13200
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	-	170	-
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	1	200	-
11	Backfill	m^3	1	80	80

GRAND TOTAL — In hardrock: YR 20 380
Price level: October 1988. — In rock: YR 17 230

Bill of quantities for: 2 COMPOST ROOMS

1.6 m long, 1.2 m width, 1.2 m high; V_{eff} = 2304 l; each 1 year use.
8 persons; N_C = 1 year; S_C = 100 lca; 0.1 m buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	0.3	1500	450
4	Reinforced concrete	m^3	0.5	3300	1650
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	10	170	1700
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	2	350	700
9	Manhole lids, steel, 30 cm	nr	~~-~~	~~300~~	~~-~~
10	PVC pipes, 4", 6 m'	nr	2	200	400
11	Backfill	m^3	-	80	-

GRAND TOTAL — In hardrock: YR 4900
Price level: October 1988. — In rock: YR 4690
In sand: YR 4480

Bill of quantities for: <u>TOTAL PIT FOR 1 HOUSE</u>

2 m diameter, 3.7 m deep; A_{inf} = 13.2 m^2; V_s = 3454 l; 10 years use.
8 persons; 80 lcd; I = 50 l/m^2; S = 40 lca.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	12.0	1500	18000
4	Reinforced concrete	m^3	1.4	3300	4620
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	0.7	170	119
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	-	80	-

GRAND TOTAL	In hardrock:	YR 23 089
Price level: October 1988.	In rock:	YR 14 689
	In sand:	YR 6 289

Bill of quantities for: <u>TOILET PIT FOR 1 HOUSE</u>

1.5 m diameter, 3.3 m deep; A_{inf} = 4.2 m^2; V_s = 3356 l; 10 years use
8 persons; 10 lcd; I = 20 l/m^2; S = 40 lca.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	6.0	1500	9000
4	Reinforced concrete	m^3	0.4	3300	1320
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	0.7	170	119
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	-	80	-

GRAND TOTAL	In hardrock:	YR 10 789
Price level: October 1988.	In rock:	YR 6 589
	In sand:	YR 2 389

Bill of quantities for: SEPTIC TANK FOR 1 HOUSE, reinforced concrete
2.25 m long, 1.2 m width, 1.4 m high; V_{ef} = 3240 l; 3 years use.
8 persons; 80 lcd; T_H = 3 days; S = 40 lca; 0.2 m buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	0.8	1500	1200
4	Reinforced concrete	m^3	1.9	3300	6270
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	1.7	170	289
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	2	300	600
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	-	80	-

GRAND TOTAL	In hardrock:	YR 8909
Price level: October 1988.	In rock:	YR 8349
	In sand:	YR 7789

Bill of quantities for: SEPTIC TANK FOR 1 HOUSE, concrete blocks
2.25 m long, 1.2 m width, 1.4 m high; V_{ef} = 3240 l; 3 years use.
8 persons; 80 lcd; T_H = 3 days; S = 40 lca; completely buried.

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	9.0	800	7200
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	0.9	3300	2970
5	Blocks (40*20*20, solid)	m^2	13.0	190	2470
6	Blocks (40*20*15, hollow)	m^2	-	170	-
7	Plastering (1:2.5, water resistant)	m^2	10.0	70	700
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	2	300	600
10	PVC pipes, 4", 6 m'	nr	1	200	200
11	Backfill	m^3	1.5	80	120

GRAND TOTAL	In hardrock:	YR 20910
Price level: October 1988.	In rock:	YR 14610
	In sand:	YR 8310

Bill of quantities for: <u>SOAKAWAY FOR 1 HOUSE</u>

1.5 m diameter, 2.5 m deep; A_{inf} = 9.4 m^2

8 persons; 80 lcd; I = 80 l/m^2d

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	4.5	1500	6750
4	Reinforced concrete	m^3	0.4	3300	1320
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	0.7	170	119
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	1	350	350
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	-	80	-

GRAND TOTAL — In hardrock: YR 8539; In rock: YR 5389; In sand: YR 2239

Price level: October 1988.

Bill of quantities for: <u>DRAINFIELD FOR 1 HOUSE</u>

6 m long, 0.5 m width, 0.85 m deep; A_{inf} = 8.4 m^2

8 persons; 80 lcd; I = 80 l/m^2d

Nr	Description	Unit	Quantity	Unit price	Costs (YR)
1	Excavation sand	m^3	3.0	100	300
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	-	1500	-
4	Reinforced concrete	m^3	-	3300	-
5	Blocks (40*20*20, solid)	m^2	-	190	-
6	Blocks (40*20*15, hollow)	m^2	-	170	-
7	Plastering (1:2.5, water resistant)	m^2	-	70	-
8	Manhole lids, steel, 50 cm	nr	-	350	-
9	Manhole lids, steel, 30 cm	nr	-	300	-
10	PVC pipes, 4", 6 m'	nr	-	200	-
11	Backfill	m^3	3	80	240

GRAND TOTAL — In sand: YR 540; In rock: YR 2640

Price level: October 1988.

Bill of quantities for: PVC SEWER PIPE, per meter.
0.5 m buried

Nr	Description	Unit	Quan-tity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	0.25	1500	375
10	PVC pipes, 4", 6 m'	nr	0.17	200	34
11	Backfill	m^3	0.25	80	20
	GRAND TOTAL	In hardrock		YR	429
	Price level: October 1988.	In rock:		YR	254
		In sand:		YR	79

Bill of quantities for: CAST IRON SEWER PIPE, per meter.
0.2 m buried

Nr	Description	Unit	Quan-tity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	0.04	800	32
3	Excavation hard rock	m^3	-	1500	-
	Cast iron pipes, 4", 2 m'	nr	0 5	300	150
11	Backfill	m^3	-	80	-
	GRAND TOTAL	In hardrock:		YR	210
	Price level: October 1988.	In rock:		YR	182
		In sand.		YR	154

Bill of quantities for: GS SEWER PIPE, per meter.
on the surface

Nr	Description	Unit	Quan-tity	Unit price	Costs (YR)
1	Excavation sand	m^3	-	100	-
2	Excavation rock	m^3	-	800	-
3	Excavation hard rock	m^3	-	1500	-
	GS pipes, 4", 6m', including 30%.	nr	0.17	780	133
11	Backfill	m^3	-	80	-
	GRAND TOTAL	On hardrock		YR	133
	Price level: October 1988.	On rock·		YR	133
		On sand:		YR	133

DETAILS OF THE SMALL BORE SEWERS

SEWER 1

HOUSE NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
56	3	1	1	-	-	30
57	8	1	1	-	-	12
49	6	1	1	-	-	3
48	4	1	1	-	-	15
58	5	1	1	-	-	21
46	6	1	-	1	-	51
47	7	1	1	-	-	-
45	9	1	1	1	-	12
24	16	1	1	-	-	12
66	2	1	2	-	-	24
26	7	1	-	1	-	18
27	15	1	-	-	-	-
28	12	1	-	-	-	-
23	10	1	2	-	45	-
Mosque	10	-	1	-	-	28
31	5	1	-	1	21	-
32	4	1	3	1	60	-
ST	-	-	-	-	-	12
TOTAL 16	129	16	16	5	126	238

SEWER 2

HOUSE NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
36	4	1	2	-	36	-
98	5	1	1	1	12	-
99	1	1	1	-	27	-
97	4	1	1	1	9	-
96	2	1	1	-	6	-
95	1	1	4	1	70	-
90	7	1	1	-	18	-
92	6	1	1	-	46	-
93	3	1	1	1	9	-
94	1	1	1	1	9	-
84	5	1	-	1	12	-
82	9	1	-	-	-	-
89	7	1	1	-	21	-
91	4	1	2	1	40	-
82A	8	1	1	1	20	-
88	2	1	-	-	-	-
ST	-	-	-	-	170	-
TOTAL 16	69	16	18	8	505	-

DETAILS OF THE SMALL BORE SEWERS

SEWER 3

HOUSE NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
74	2	1	1	-	-	18
63	7	1	3	-	-	33
59A	8	1	1	-	-	9
64	10	1	2	-	-	21
61	3	1	1	-	12	-
65	3	1	-	1	48	-
74	1	1	1	-	-	12
66	2	1	-	1	-	15
72	3	1	-	-	-	-
70	10	1	4	-	39	-
76	6	1	1	-	12	-
69	4	1	-	1	18	-
77	5	1	1	3	80	-
81	6	1	1	-	-	9
30	7	1	1	-	-	9
86	8	1	1	-	24	-
87	7	1	1	1	9	-
79	8	1	1	-	15	-
78	8	1	1	-	24	-
ST	-	-	-	-	-	12
TOTAL 19	108	19	21	7	281	138

SEWER 4

HOUSE NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
56	2	-	1	-	-	24
60	6	1	2	3	89	9
59	5	1	-	-	-	-
50	4	1	1	-	-	14
53	6	1	1	1	-	28
55	13	1	-	-	-	-
54	16	1	2	1	48	-
51	10	1	1	-	-	18
52A	8	1	1	-	8	-
52	5	1	1	-	30	-
ST	-	-	-	-	-	12
TOTAL 10	75	9	10	5	175	105

DETAILS OF THE SMALL BORE SEWERS

SEWER 5

HOUSE NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
19	5	1	1	4	68	-
22	1	1	1	-	24	-
21	5	1	1	-	12	-
18	6	1	2	-	21	-
20	6	1	1	-	12	-
20A	8	1	1	-	21	-
16	5	1	1	-	29	-
ST	-	-	-	-	-	12
TOTAL 7	36	7	8	4	187	12

SEWER 6

HOUSE NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
12	5	1	1	-	27	-
10	6	1	-	1	6	-
10A	8	1	1	-	28	-
11	6	1	-	-	-	-
9	7	1	1	1	45	-
15	7	1	1	-	18	-
15A	8	1	1	-	18	-
15B	8	1	-	1	42	-
15C	8	1	-	-	-	-
7	4	1	1	-	42	-
ST	-	-	-	-	-	24
TOTAL 10	67	10	6	3	226	24

DETAILS OF THE SMALL BORE SEWERS

SEWER 7

HOUSE NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
73	2	1	2	1	-	9
71	11	1	1	-	-	36
44	8	1	-	1	-	18
43	5	1	-	1	-	21
25	3	1	-	-	-	-
29	5	1	-	-	-	-
40	7	1	-	1	-	9
75	6	1	1	-	-	21
83	2	1	1	-	-	21
38	7	1	2	1	-	31
39	3	1	-	1	-	21
85	3	1	-	-	-	-
84	5	1	-	-	-	-
37	6	1	1	1	-	9
41	2	1	-	-	-	-
30	7	1	-	1	17	-
35	5	1	-	-	31	-
34	4	1	1	-	0	-
33	7	1	1	-	40	-
Mosque	10	1	-	2		
ST	-	-	-	-	-	12
TOTAL 20	108	20	10	10	88	208

TOTAL

SEWER NUMBER	NUMBER OF EQUIVALENTS	INTERCEPTOR TANK	SMALL MANHOLE	BIG MANHOLE	GS PIPE(m)	PVC PIPE(m)
SEWER 1	129	16	15	5	126	238
SEWER 2	69	16	18	8	505	0
SEWER 3	108	19	21	7	281	138
SEWER 4	75	9	10	5	175	105
SEWER 5	36	7	8	4	187	12
SEWER 6	67	10	6	3	226	24
SEWER 7	108	20	10	10	88	208
TOTAL 98	592	97	89	42	1588	725

COST CALCULATIONS SMALL BORE SEWER SYSTEMS

1 Basic system

Cost item	Excavation costs (YR/m³)	Quantity	Costs incl. excavation	Costs excl. excavation
RC interceptor tanks	1500	97	603 340	530 590
RC treatm. tank (150)	800	3	73 233	56 433
RC treatm. tank (100)	800	4	77 364	61 364
Soakaway (150 equiv.)	800	3	144 867	15 267
Soakaway (100 equiv.)	800	3	96 867	15 267
Drainfield (100 equiv.)	100	1	5 580	2 480
Manholes (big)	800	42	68 040	54 600
Manholes (small)	800	89	97 900	83 660
Cast iron pipe, 4", incl.lay.	800	725 m	131 950	108 750
GS pipe, 4", incl. laying	-	1588 m	211 204 +	211 204 +
Grand total			YR 1 510 345	1 139 615
15 % unforseen and transport			YR 226 552 +	
TOTAL			YR 1 736 897	

Cost division:	- costs of construction:	YR 1 139 615	66 %
	- costs of excavation:	YR 370 730	21 %
	- unforseen and transport:	YR 226 552 +	13 % +
TOTAL		YR 1 736 897	100 %

2 Modified system

Cost item	Excavation costs (YR/m³)	Quantity	Costs incl. excavation	Costs excl. excavation
RC interceptor tanks	1500	97	603 340	530 590
RC treatm. tank (150)	800	3	73 233	56 433
RC treatm. tank (100)	800	4	77 364	61 364
Drainfield (150 equiv.)	100	3	24 840	11 040
Drainfield (100 equiv.)	100	4	22 320	9 920
Manholes (big)	800	42	68 040	54 600
Manholes (small)	800	89	97 900	83 660
Cast iron pipe, 4", incl.lay.	800	725 m	131 950	108 750
GS pipe, 4", incl. laying	-	1588 m	211 204 +	211 204 +
Grand total			YR 1 310 191	1 127 561
15 % unforseen and transport			YR 196 529 +	
TOTAL			YR 1 506 720	

Cost division:	- costs of construction:	YR 1 127 561	75 %
	- costs of excavation:	YR 182 630	12 %
	- unforseen and transport:	YR 196 529 +	13 % +
TOTAL		YR 1 506 720	100 %

COST CALCULATIONS PIT SYSTEMS

1 TOTAL PIT SYSTEM

1.1 COST ESTIMATION TOTAL PIT

Cost item	Quantity	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Total pit	1	6 289	14 689	23 089
Manhole (big)	1	1 340	1 620	1 900
PVC pipe, 4"	12 m	948	-	-
Cast iron pipe, 4"	12 m	-	2 184	2 520
Grand total		8 577	18 493	27 509
15 % unforseen and transport		1 287	2 774	4 126
TOTAL COSTS		9 864 (US$ 897)	21 267 (US$ 1933)	31 635 (US$ 2876)

1.2 COST DIVISION TOTAL PIT

Cost item	Costs (YR) in situation with. SAND	ROCK	HARD ROCK
Construction	7 377 (75%)	8 893 (42%)	9 509 (30%)
Excavation pit	1 200 (12%)	9 600 (45%)	18 000 (57%)
Unforseen and transp.	1 287 (13%)	2 774 (13%)	4 126 (13%)
TOTAL COSTS	9 864 (100%)	21 267 (100%)	31 635 (100%)

2 TOILET PIT WITH SOAKAWAY

2.1 COST ESTIMATION TOILET PIT WITH SOAKAWAY

Cost item	Quantity	Costs (YR) in situation with. SAND	ROCK	HARD ROCK
Toilet pit	1	2 389	6 589	10 789
Manhole (big)	1	1 340	1 620	1 900
Soakaway	1	2 239	5 389	8 539
Manhole (small)	1	960	1 100	1 240
PVC pipe, 4"	24 m	1 896	-	-
Cast iron pipe, 4"	24 m	-	4 368	5 040
Grand total		8 824	19 066	27 508
15 % unforseen and transport		1 324	2 860	4 126
TOTAL COSTS		10 148 (US$ 923)	21 926 (US$ 1993)	31 634 (US$ 2876)

COST CALCULATIONS PIT SYSTEMS

2 2 COST DIVISION TOILET PIT WITH SOAKAWAY

Cost item	Costs (YR) in situation with SAND	ROCK	HARD ROCK
Construction	7 774 (77%)	10 666 (49%)	11 758 (37%)
Exc. pit & soakaway	1 050 (10%)	8 400 (38%)	15 750 (50%)
Unforseen and transp	1 324 (13%)	2 860 (13%)	4 126 (13%)
TOTAL COSTS	10 148 (100%)	21 926 (100%)	31 634 (100%)

3 TOILET PIT WITH DRAINFIELD

3.1 COST ESTIMATION TOILET PIT WITH DRAINFIELD

Cost item	Quantity	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Toilet pit	1	2 389	6 589	10 789
Manhole (big)	2	2 680	3 240	3 800
Drainfield	1	540	540	540
Manhole (small)	1	960	1 100	1 240
PVC pipe, 4"	24 m	1 896	-	-
Cast iron pipe, 4"	24 m	-	4 368	5 040
Grand total		8 465	15 837	21 409
15 % unforseen and transport		1 270	2 376	3 211
TOTAL COSTS		9 735 (US$ 885)	18 213 (US$ 1656)	24 620 (US$ 2238)

3 2 COST DIVISION TOILET PIT WITH DRAINFIELD

Cost item	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Construction	7 565 (78%)	10 737 (59%)	12 109 (49%)
Ex.	900 (9%)	5 100 (28%)	9 300 (38%)
Unforseen and transp.	1 270 (13%)	2 376 (13%)	3 211 (13%)
TOTAL COSTS	9 735 (100%)	18 213 (100%)	24 620 (100%)

COST CALCULATIONS SEPTIC TANK SYSTEMS

1 SEPTIC TANKS WITH SOAKAWAY

1.1 COST ESTIMATES SEPTIC TANKS WITH SOAKAWAY

Cost item	Quantity	Costs (YR) in situation with: SAND		ROCK		HARD ROCK	
RC septic tank	1	7789		8349		8909	
Blocks septic tank	1		8310		14610		20910
Manhole (big)	1	1340	1340	1620	1620	1900	1900
Soakaway	1	2239	2239	5389	5389	8539	8539
PVC pipe, 4"	12 m	948	948	-	-	-	-
Cast iron pipe, 4"	12 m	-	-	2184	2184	2520	2520
Grand total		12316	12837	17542	23803	21868	33869
15 % unforseen & transp.		1847	1926	2631	3570	3280	5080
TOTAL COSTS		14163	14763	20173	27373	25148	38949
	US$:	(1288)	(1342)	(1834)	(2488)	(2286)	(3541)

1.2 COST DIVISION REINFORCED CONCRETE SEPTIC TANK WITH SOAKAWAY

Cost item	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Construction	11 786 (83%)	13 302 (66%)	13 918 (55%)
Exc. soakaway + tank	530 (4%)	4 240 (21%)	7 950 (32%)
Unforseen and trans.	1 847 (13%)	2 631 (13%)	3 280 (13%)
TOTAL COSTS	14 163 (100%)	20 173 (100%)	25 148 (100%)

1.3 COST DIVISION CONCRETE BLOCKS SEPTIC TANK WITH SOAKAWAY

Cost item	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Construction	11 487 (78%)	16 203 (59%)	13 619 (35%)
Exc. soakaway + tank	1 350 (9%)	7 600 (28%)	20 250 (52%)
Unforseen and trans.	1 926 (13%)	3 570 (13%)	5 080 (13%)
TOTAL COSTS	14 763 (100%)	27 373 (100%)	38 949 (100%)

COST CALCULATIONS SEPTIC TANK SYSTEMS

2 SEPTIC TANKS WITH DRAINFIELD

2.1 COST ESTIMATES SEPTIC TANKS WITH DRAINFIELDS

Cost item	Quantity	Costs (YR) in situation with: SAND		ROCK		HARD ROCK	
RC septic tank	1	7789		8349		8909	
Blocks septic tank	1		8310		14610		20910
Manhole (big)	2	2680	2680	3240	3240	3800	3800
Drainfield	1	540	540	540	540	540	540
PVC pipe, 4"	12 m	948	948	-	-	-	-
Cast iron pipe, 4"	12 m	-	-	2184	2184	2520	2520
Grand total		11957	12478	14313	20574	15769	27770
15 % unforseen & transp.		1794	1872	2147	3086	2365	4166
TOTAL COSTS		13751	14350	16460	23660	18134	31936
	US$:	(1250)	(1305)	(1496)	(2151)	(1649)	(2903)

2.2 COST DIVISION REINFORCED CONCRETE SEPTIC TANK WITH DRAINFIELD

Cost item	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Construction	11 577 (84%)	13 373 (81%)	14 269 (79%)
Exc. drainfield + tank	380 (3%)	940 (6%)	1 500 (8%)
Unforseen and trans.	1 794 (13%)	2 147 (13%)	2 365 (13%)
TOTAL COSTS	13 751 (100%)	16 460 (100%)	18 134 (100%)

2.3 COST DIVISION CONCRETE BLOCKS SEPTIC TANK WITH DRAINFIELD

Cost item	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Construction	11 278 (79%)	13 074 (55%)	13 970 (44%)
Exc. drainfield + tank	1 200 (8%)	7 500 (32%)	13 800 (43%)
Unforseen and trans.	1 872 (13%)	3 086 (13%)	4 166 (13%)
TOTAL COSTS	14 350 (100%)	23 660 (100%)	31 936 (100%)

COST CALCULATIONS IMPROVED BALADIH TOILET SYSTEMS

1 IMPROVED BALADIH TOILET WITH SOAKAWAY

1.1 COST ESTIMATION IMPROVED BALADIH TOILET WITH SOAKAWAY

Cost item	Quantity	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
RC compost rooms	1	4 480	4 690	4 900
Manhole (small)	1	960	1 100	1 240
Soakaway	1	2 239	5 389	8 539
PVC pipe, 4"	12 m	948	-	-
Cast iron pipe, 4"	12 m	-	2 184	2 520
Grand total		8 627	13 363	17 199
15 % unforseen and transport		1 294	2 004	2 580
TOTAL COSTS		9 921 (US$ 902)	15 367 (US$ 1397)	19 779 (US$ 1798)

1.2 COST DIVISION IMPROVED BALADIH TOILET WITH SOAKAWAY

Cost item	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Construction	8 177 (82%)	9 763 (64%)	10 449 (53%)
Excavation soakaway	450 (4%)	3 600 (23%)	6 750 (34%)
Unforseen and trans.	1 294 (13%)	2 004 (13%)	2 580 (13%)
TOTAL COSTS	9 921 (100%)	15 367 (100%)	19 779 (100%)

2 IMPROVED BALADIH TOILET WITH DRAINFIELD

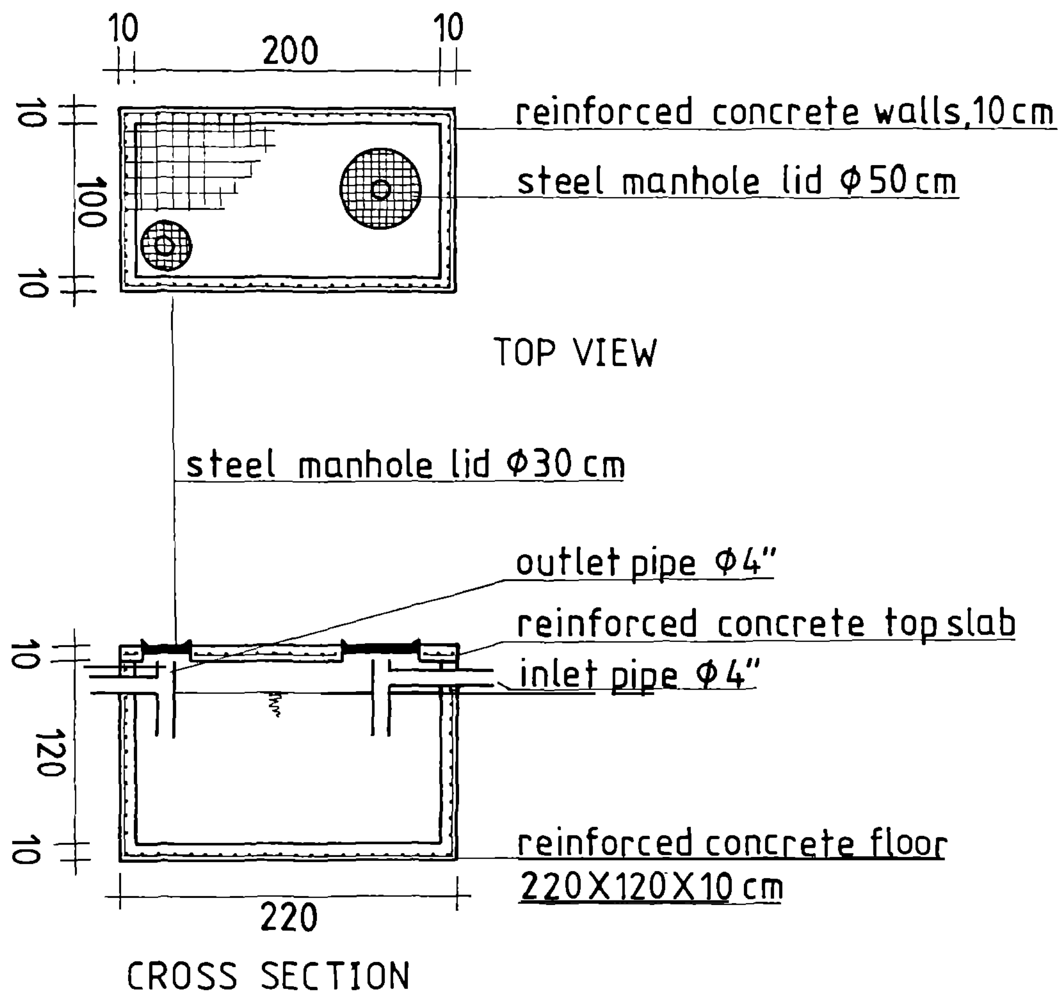
2.1 COST ESTIMATION IMPROVED BALADIH TOILET WITH DRAINFIELD

Cost item	Quantity	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
RC compost rooms	1	4 480	4 690	4 900
Manhole (big)		1 340	1 620	1 900
Drainfield	1	540	540	540
Manhole (small)	1	960	1 100	1 240
PVC pipe, 4"	12 m	948	-	-
Cast iron pipe, 4"	12 m	-	2 184	2 520
Grand total		8 268	10 134	11 100
15 % unforseen and transport		1 240	1 520	1 665
TOTAL COSTS		9 508 (US$ 864)	11 654 (US$ 1059)	12 765 (US$ 1160)

COST CALCULATIONS IMPROVED BALADIH TOILET SYSTEMS

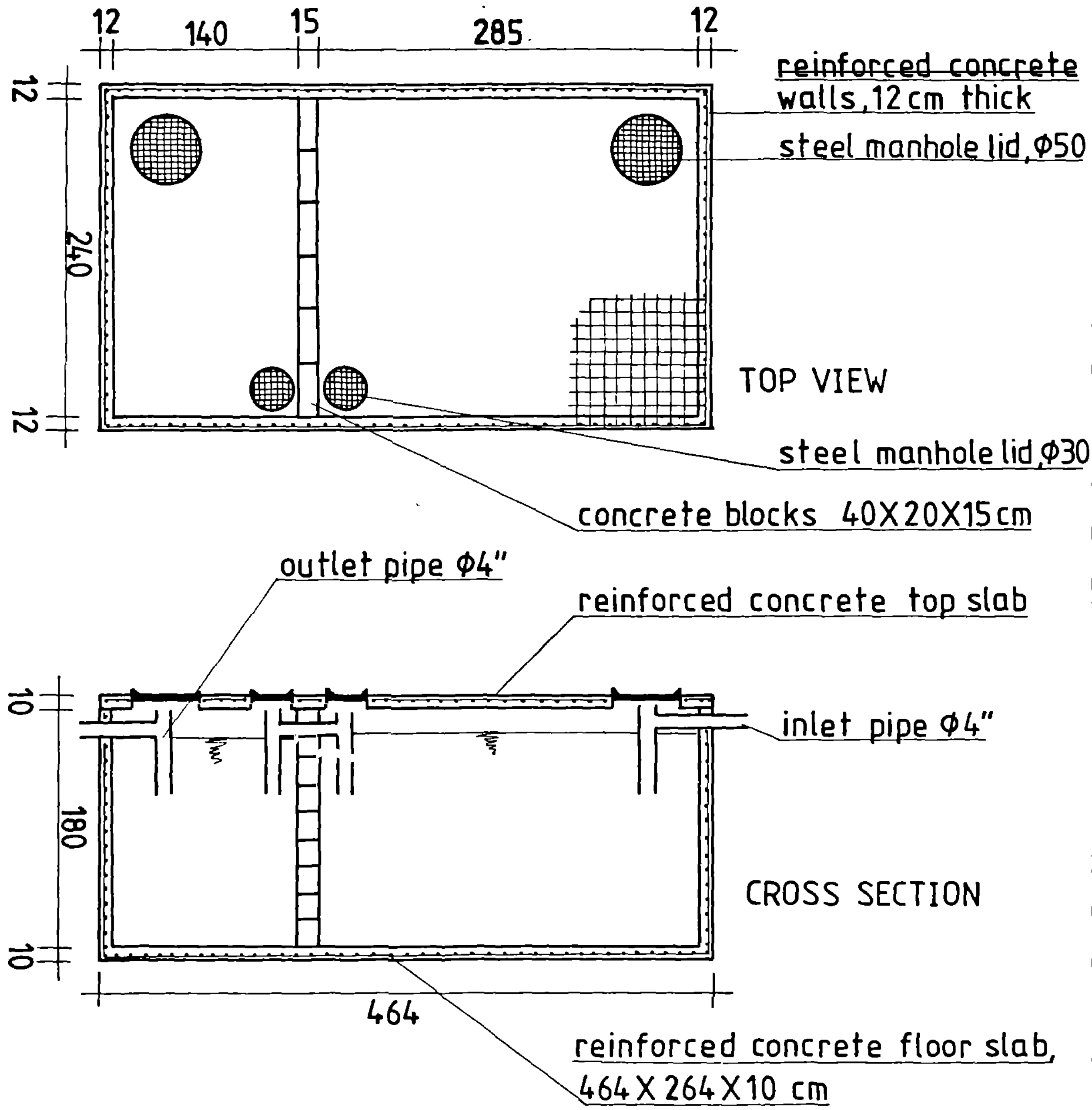
2.2 COST DIVISION IMPROVED BALADIH TOILET WITH DRAINFIELD

Cost item	Costs (YR) in situation with: SAND	ROCK	HARD ROCK
Construction	7 968 (84%)	9 834 (84%)	10 800 (85%)
Excavation drainfield	300 (3%)	300 (3%)	300 (2%)
Unforseen and trans.	1 240 (13%)	1 520 (13%)	1 665 (13%)
TOTAL COSTS	9 508 (100%)	11 654 (100%)	12 765 (100%)



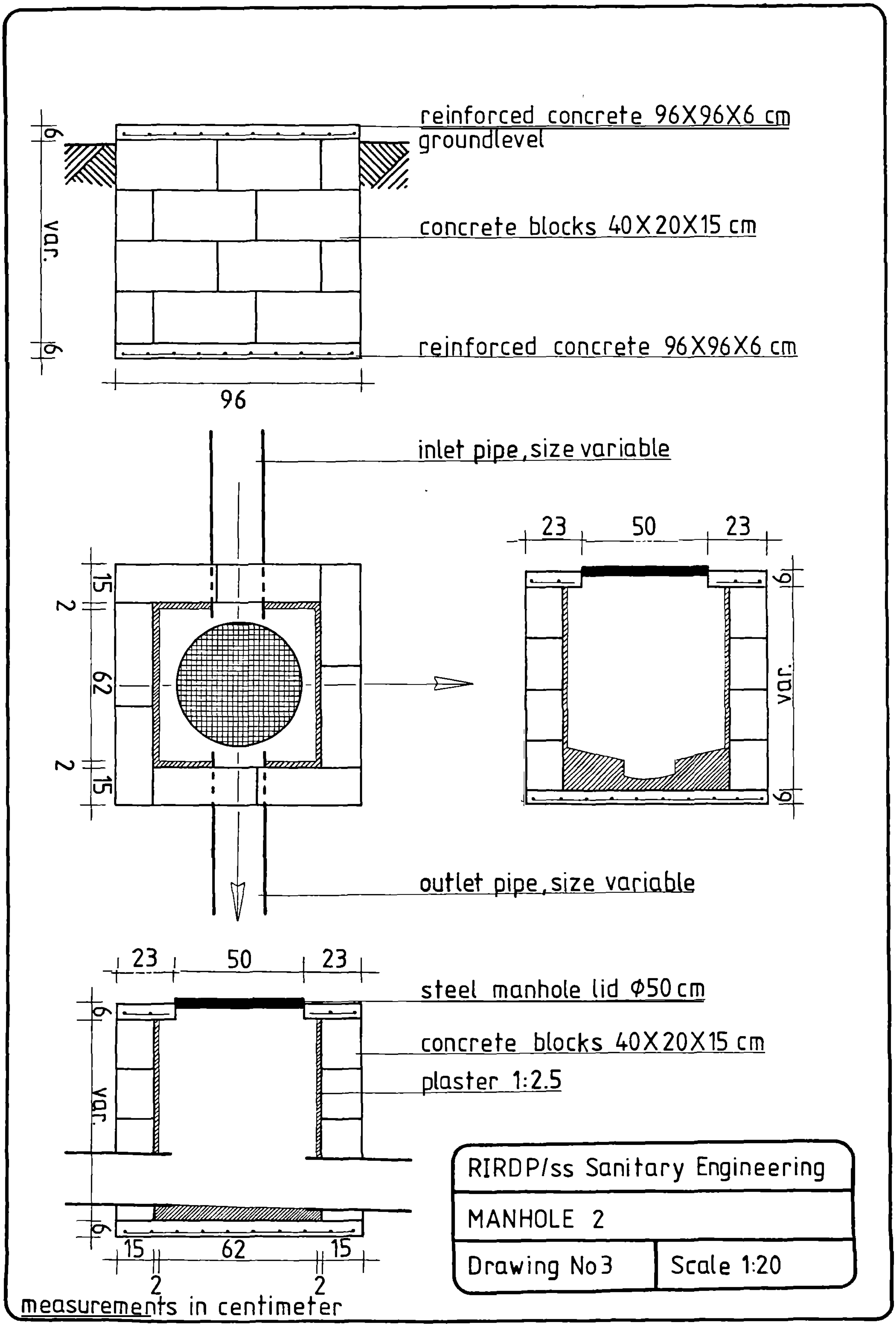
RIRDP/ss Sanitary Engineering	
INTERCEPTOR TANK	
Drawing No 1	Scale 1:50

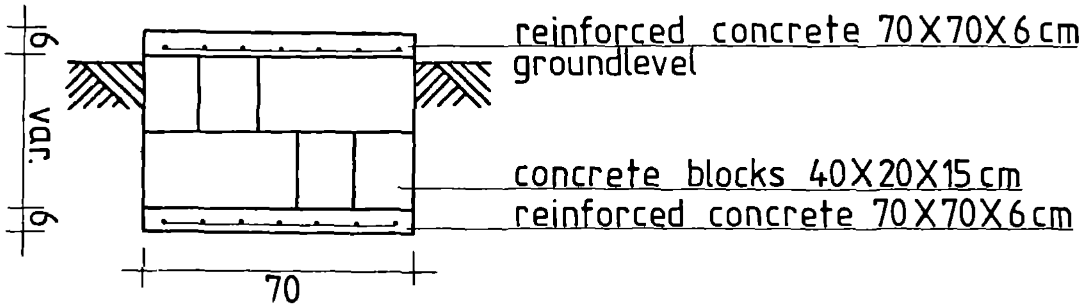
measurements in centimeter

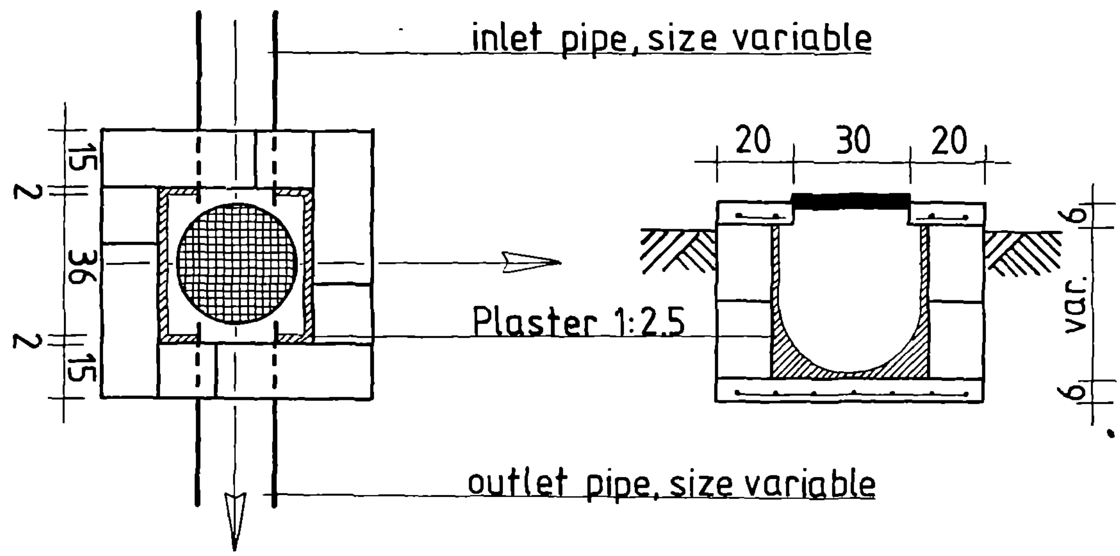


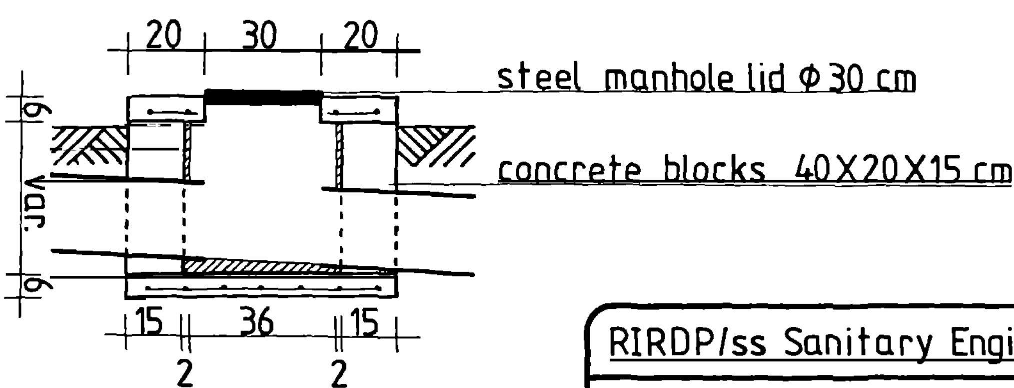
RIRDP/ss Sanitary Engineering	
TREATMENT TANK, 150 equiv.	
Drawing No 2	Scale 1:50

measurements in centimeter


reinforced concrete 96X96X6 cm
groundlevel
concrete blocks 40X20X15 cm
reinforced concrete 96X96X6 cm
var.
96
inlet pipe, size variable
outlet pipe, size variable
23 50 23
var.
steel manhole lid Φ50 cm
concrete blocks 40X20X15 cm
plaster 1:2.5
15 62 15
RIRDP/ss Sanitary Engineering
MANHOLE 2
Drawing No 3
Scale 1:20
measurements in centimeter



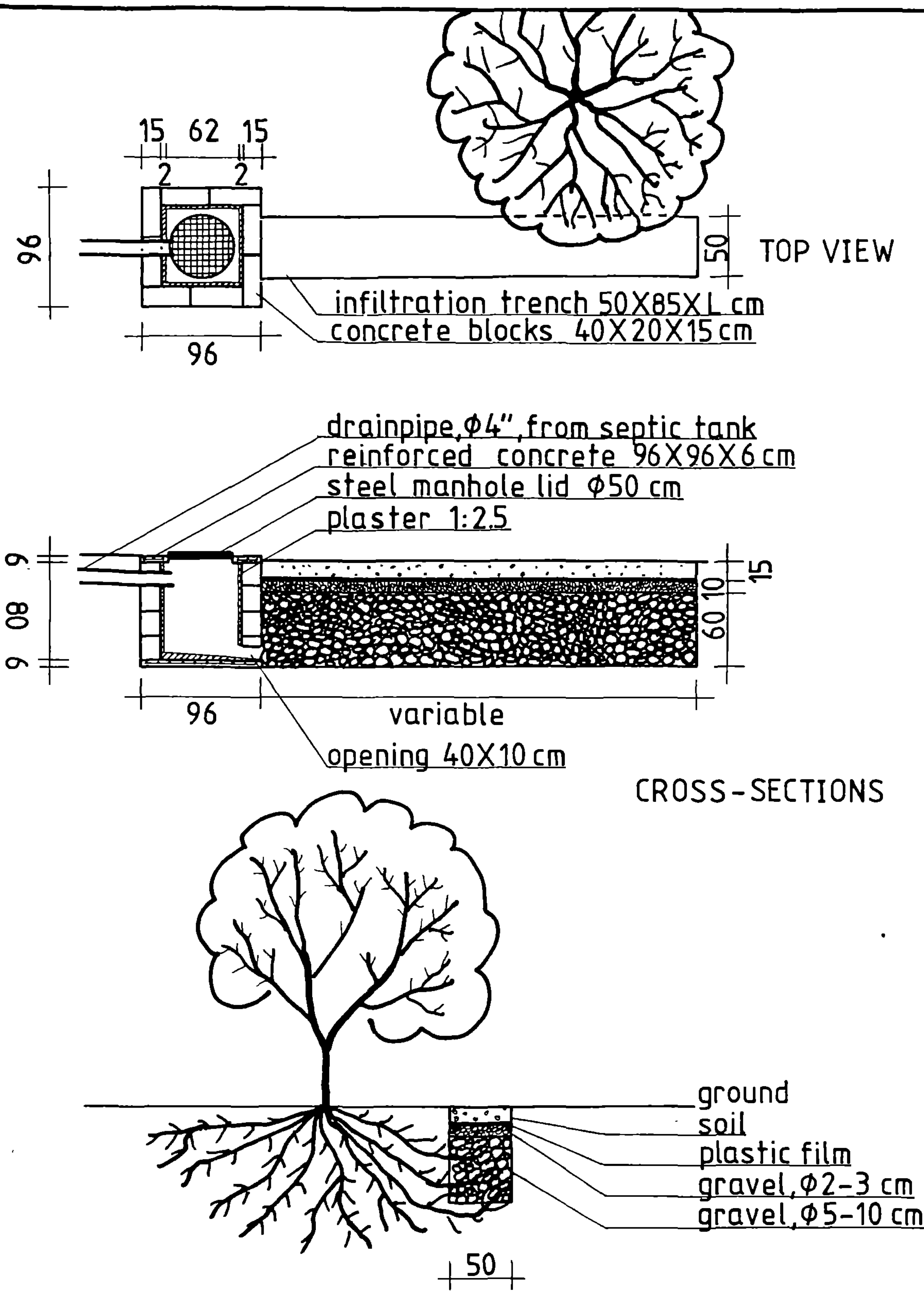




RIRDP/ss Sanitary Engineering	
MANHOLE 1	
Drawing No4	Scale 1:20

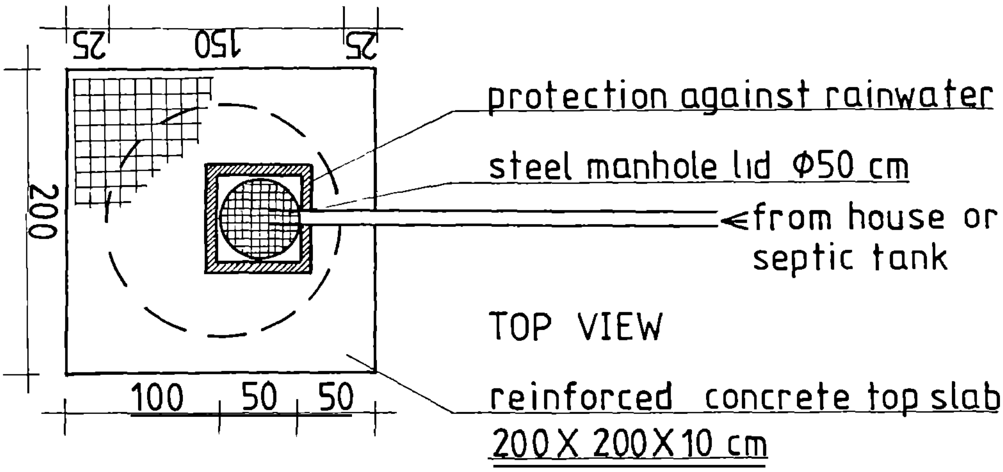
var. = variable

measurements in centimeter

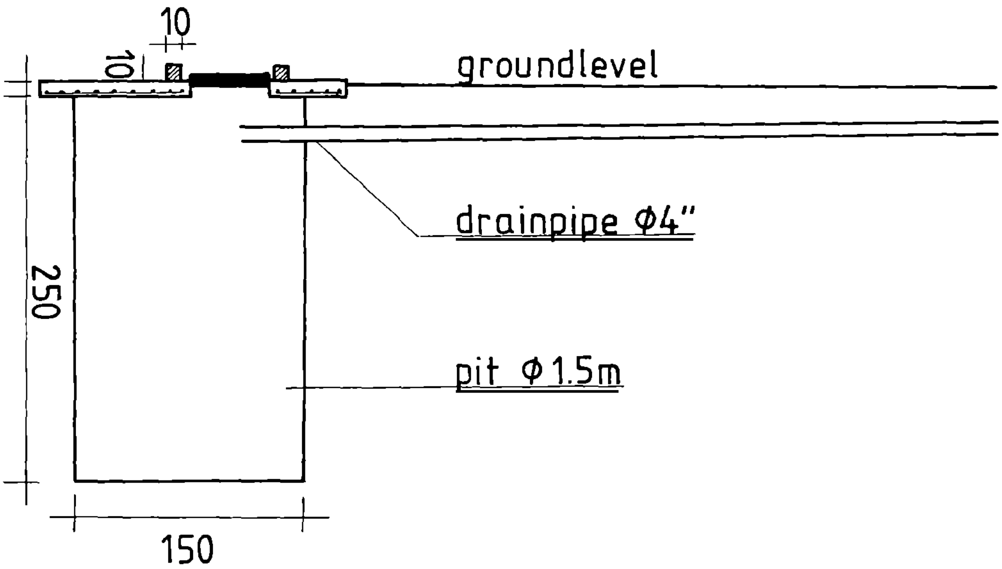


RIRDP/ss Sanitary Engineering	
DRAINFIELD	
Drawing No5	Scale 1:50

measurements in centimeter



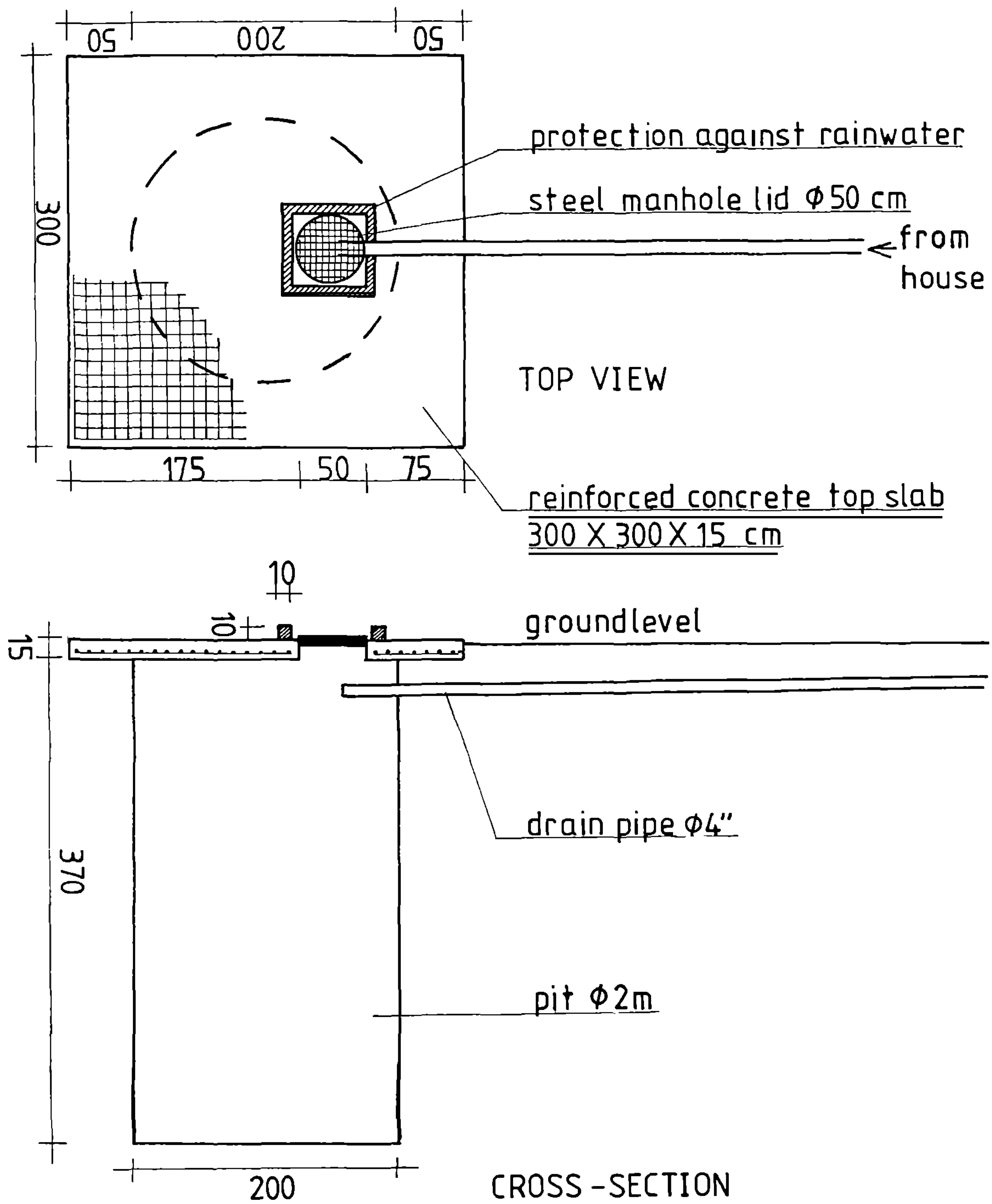
TOP VIEW



CROSS-SECTION

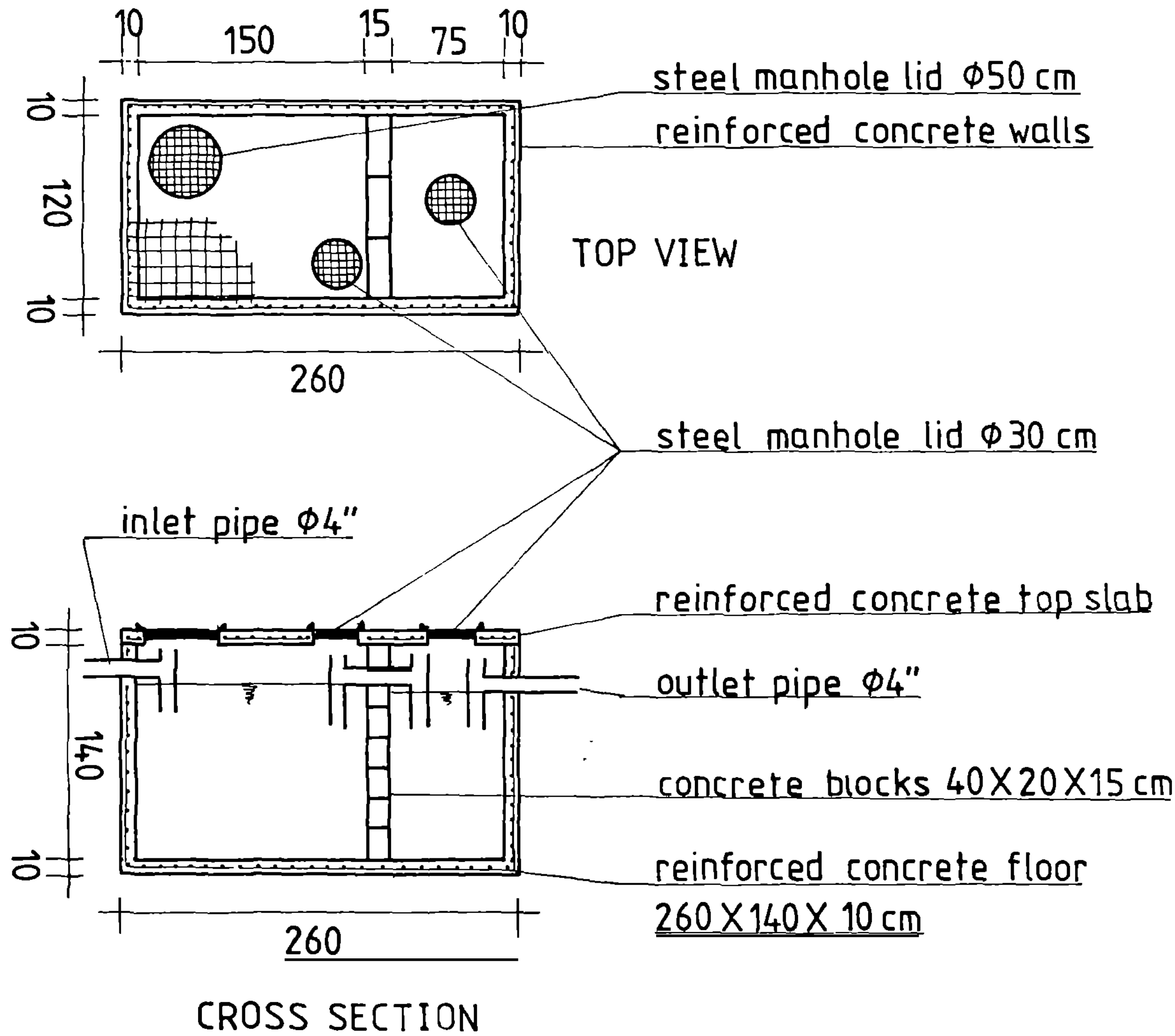
RIRDP/ss Sanitary Engineering	
SOAKAWAY	
Drawing No 6	Scale 1:50

measurements in centimeter



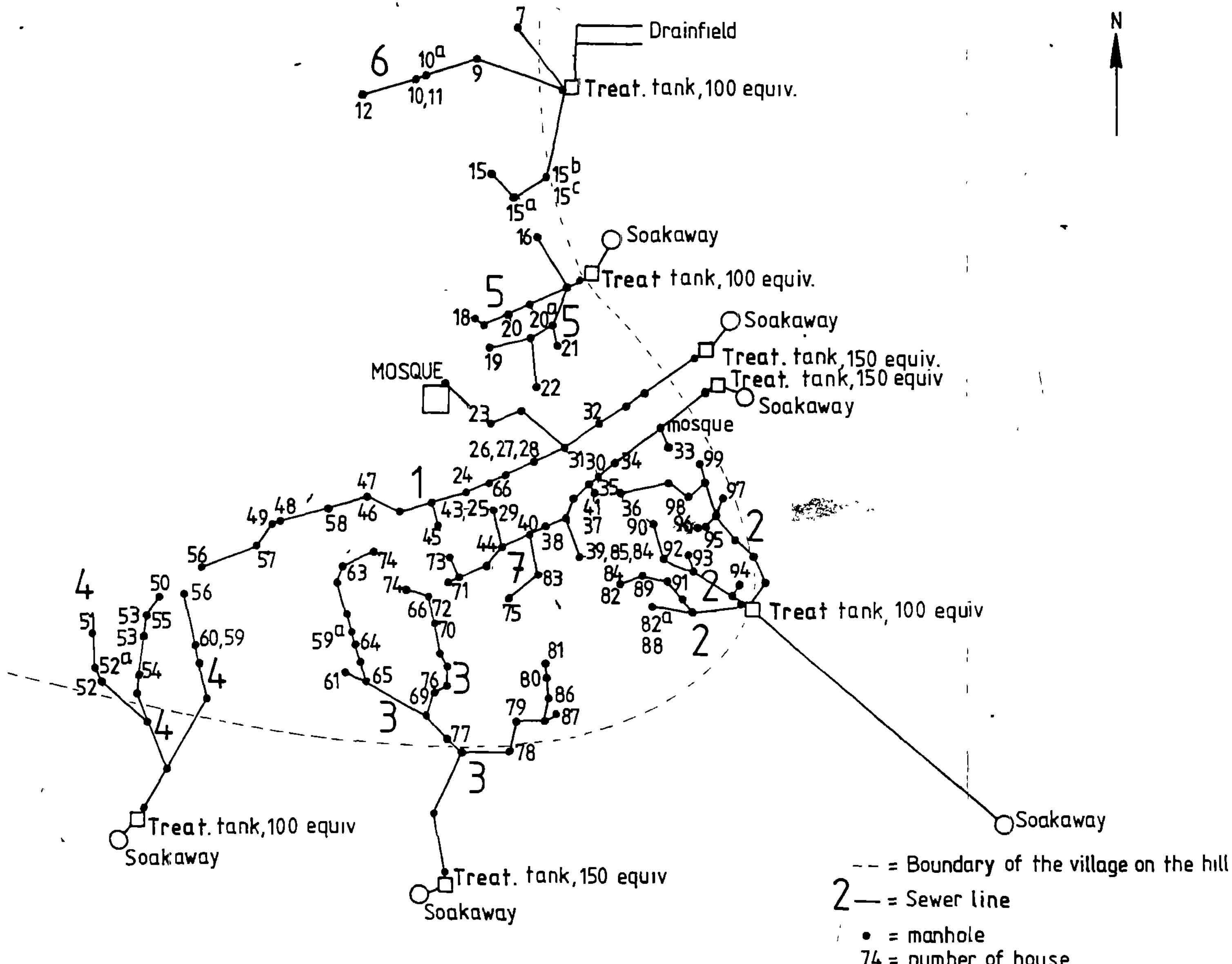
RIRDP/ss Sanitary Engineering	
TOTAL PIT	
Drawing No 7	Scale 1:50

measurements in centimeter



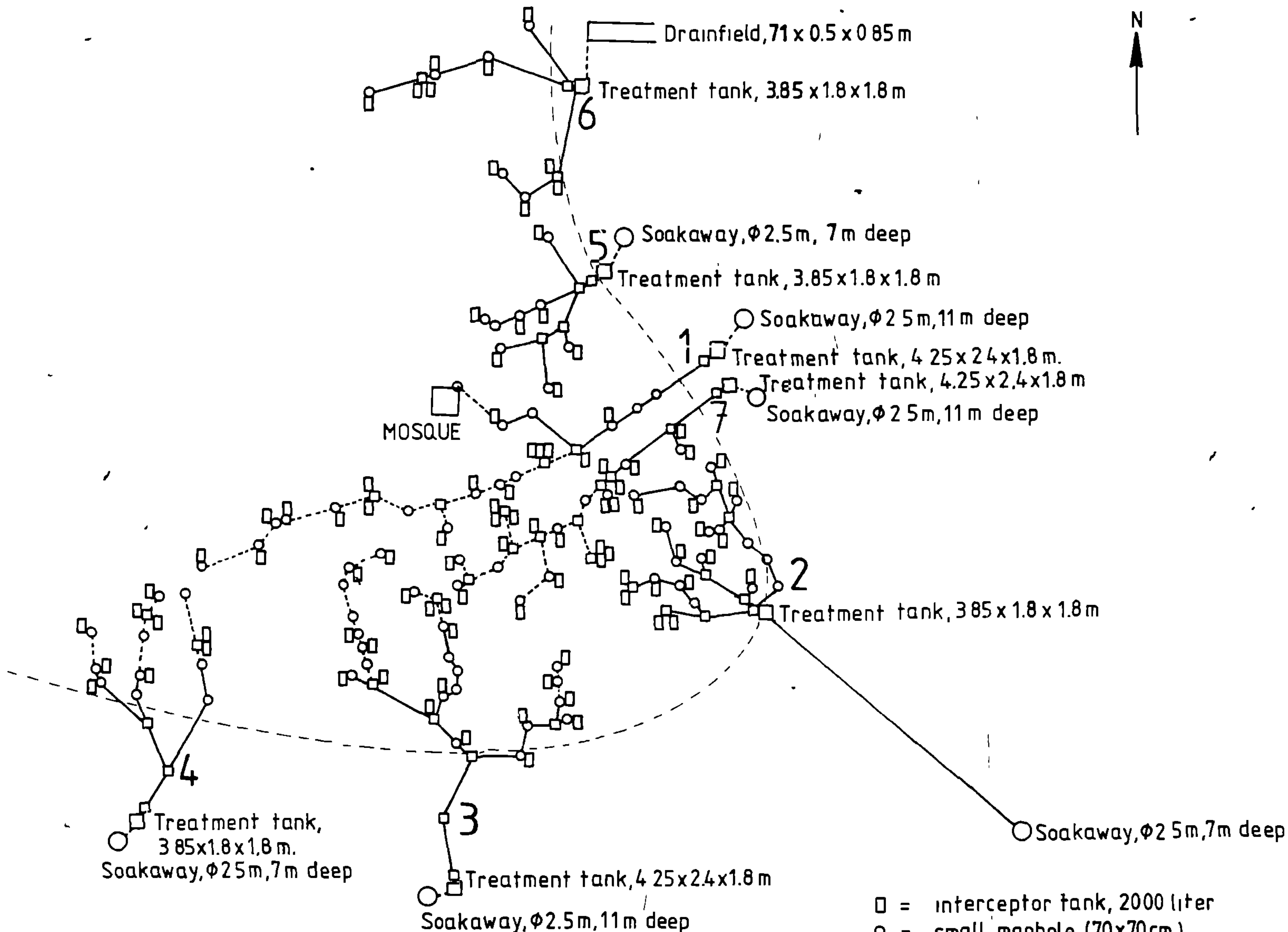
RIRDP/ss Sanitary Engineering	
SEPTIC TANK, 8 equiv.	
Drawing No 8	Scale 1:50

measurements in centimeter



GENERAL PLAN

RIRDP/ss Sanitary Engineering		
Small-bore sewer system AL HAJAR		
Map No1	Scale 1:2000	Date: 10-9-1988



▯ = interceptor tank, 2000 liter
○ = small manhole (70 x 70 cm.)
▫ = big manhole (96 x 96 cm.)

TECHNICAL DETAILS

----- Cast-iron pipe, Φ 4", buried
—— GS-pipe, Φ 4", on the surface
— — Boundary of the village on the hill

RIRDP/ss Sanitary Engineering		
Small-bore sewer system AL HAJAR		
Map No 2	Scale 1:2000	Date: 19-9-1988

[redacted] [redacted]