SANITATION FOR SITE AND SERVICE SCHEMES

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- a technical and economic appraisal of sanitation alternatives for urban Kenya.

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TABLE OF CONTENTS

page

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Abstract:

This paper reviews some of the current sanitary engineering problems that result from the use of conventional waterborne sewerage in site and service housing schemes in Kenya. Three alternatives are proposed and are compared with the conventional dwerage system. These are: pour flush toilets and improved aqua privy toilets on small-bore UPVC sewers and improved ventilated pit latrines (ROECs) with both on on - and off site sullage water disposal options. The study is based on a synethetic neighbourhood model and uses an improved household water supply service, employing automatic self-closing taps. The economic costing exercises have been "shadow priced" and are based on the average incremental cost method. The results of this brief study indicate not only that huge cost savings can be achieved with the combined use of modern materials and technique but that in addition the proposed alternatives are likely to perform better technically than the conventional system in low-income housing areas. The paper emphasises the need to establish demonstration projects from which lessons can be learnt and techniques further developed.

1.0 PREFACE

This study was a single handed illustrative exercise completed in a short period of time. It provides information about possible sanitation alternatives for site and service schemes but by no means covers all such possible alternatives.

The housing site is a simulated one and drawings should be considered as indicative rather than as actual design drawings. Costings are as accurate and detailed as possible within the study time allowed. Where assumptions are made these are clearly expressed in the appropriate section of the study. In general the potentially numerous variables have been restricted to achieve manageable comparisons without necessitating computer assistance. This was considered to be outside the scope of the present paper.

Therefore the results of the study cannot automatically be transferred to every site and service scheme in Kenya. Every site has his own particular characteristics which will be determining factors in designing the least cost technically acceptable solution. Various other sanitation alternatives are not considered not because they are not available but because they are too numerous.

Despite all these limitations it is hoped that planners, engineers and economists who have an interest in supplying urban low income families with their basic needs at prices they can afford, will find this study useful.

2.0 INTRODUCTION

The recent national census which revealed that Kenya's population shot up by 50 percent over the last decade has caused a lot of concern to the country's planners and has underlined the clear need for an urgent review of present planning methodologies. Kenya's annual growth rate of 3.9 percent is one of the highest if not the highest figure in the world. Over the remaining years of this century capital resources will be strained to the limits, reflecting the economic and social move towards industralisation. Natural population increase in the urban areas combined with rural-urban migration will exacerbate an already deteriorating housing situation. Particularly, the growth of families in the low-income bracket (K.Shs.200 - K.Shs.1,400 monthly) will become a serious liability for urban councils.

Official house construction for the low income population has always been a meagre percentage of actual needs. Therefore, the current trend of the Kenyan Government is to move away from actual house building to the provision of services only. The current implementation of site and service schemes and squatter upgrading programmes reflect this trend.

In the sanitation field, it is becoming clear, that conventional sewerage is both too costly and frequently inappropriate for the situation.

This study will try to identify some of the possible alternatives.

3.0 LIMITATIONS OF THE STUDY

3.1 The model layout

The study uses a simulated model housing layout adapted from (Caminos, 1978) and is reasonably typical of up-country site and service schemes in Kenya (see figure 1). The model is an area of 16 ha and comprises of 320 plots. The landuse pattern is as follows:

55.2% residential
29.7% circulation
15.1% public space

In the Second Urban World Bank Project the following design criteria are used:

60% residential
20% circulation
20% public space

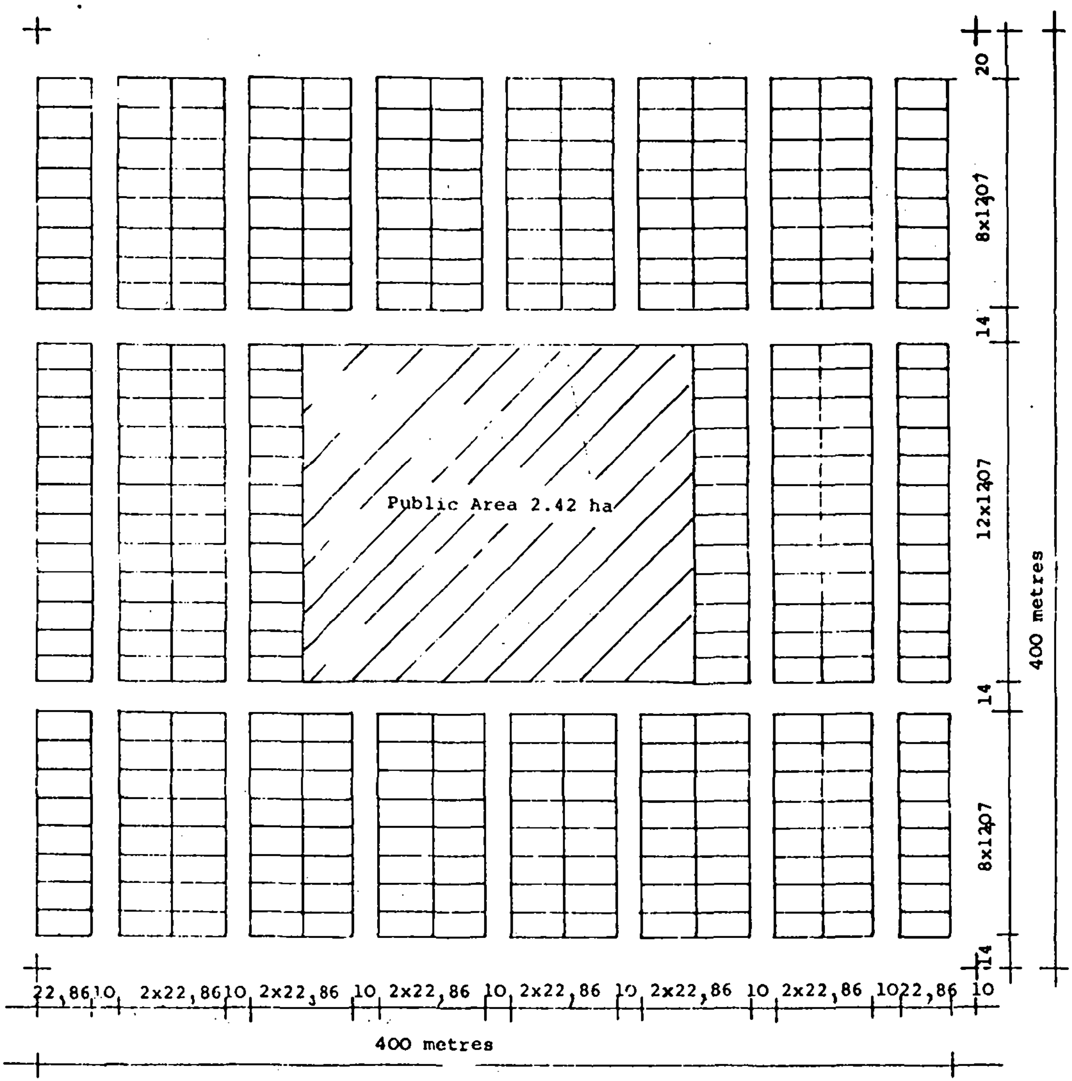
In these schemes only 50% of the plots have car access.

3.2 The plot layout

The plot layout is based on the current plot sizes in site and service schemes outside Nairobi. The National Housing Corporation guidelines stipulate a plot size of 12,5 m x 23,5 m (294 m^2). (National Housing Corporation 1974).

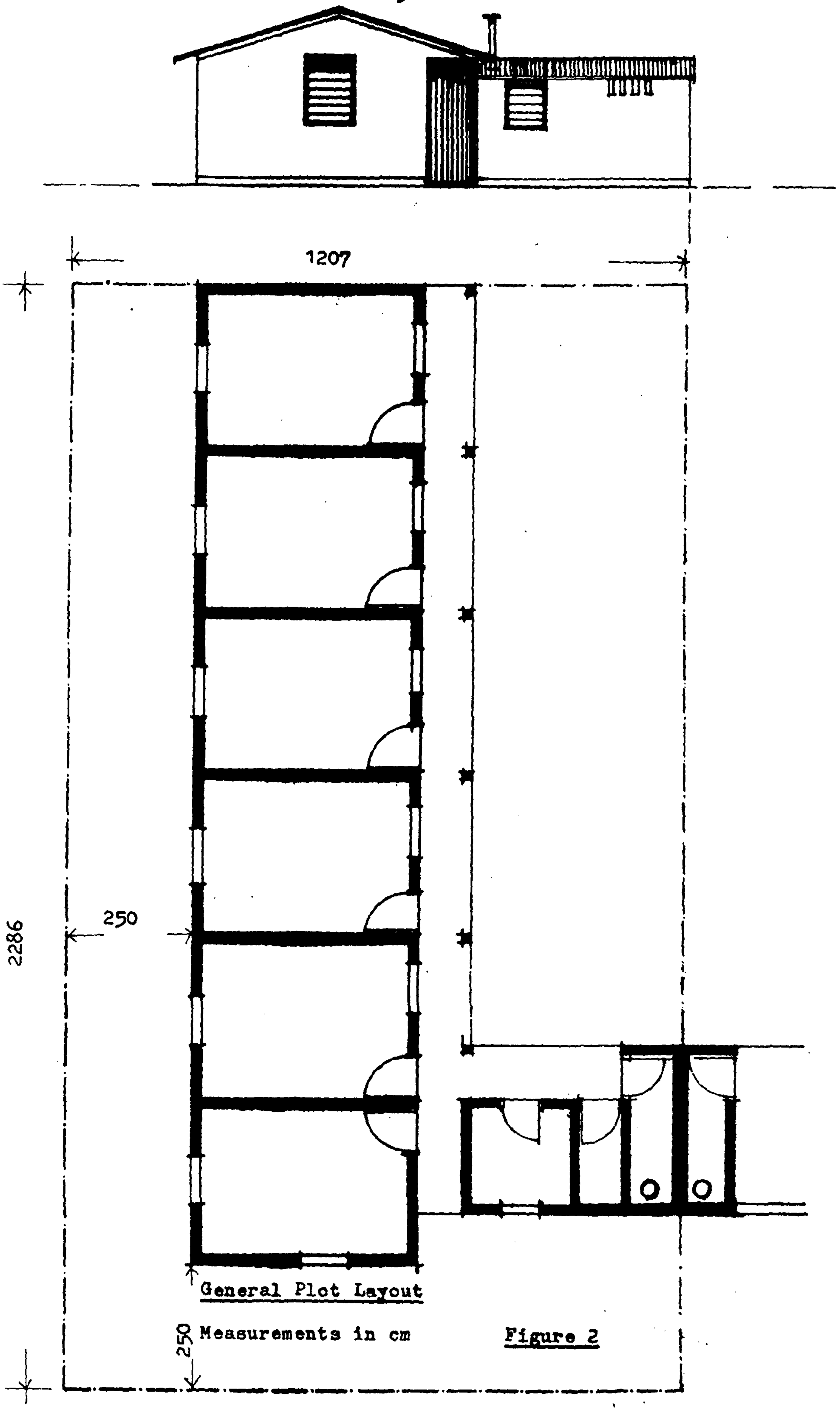
The plot sizes used in this study are slightly modified to 12,07 m x 22,86 m (276 m^2) to fit into the site model. This plot size has been used to relate it to the existing situation, despite the fact that the plot ratio (width to depth) of about 1:2 is not physically efficient and should be more in the range of 1:3.

Site Layout



measurements in metres

Figure 1



General Plot Layout

Measurements in cm

Figure 2

3.3 The house layout

The house layout is one of the standard National Housing Corporation plans of six rooms, each of 12 m^2, in a row (see figure 2). Built up area is 110 m^2, which results in a total plot coverage of 40%. According to the present building bylaws every room can accommodate 3 persons, this will result in a total plot occupancy of 18 persons, resulting in a gross density of 360 pers/ha i.e. about 5,760 persons in the model layout at a net density of 450 pers/ha : a representative figure for up-country low cost urban housing.

3.4 The service layout

The services are assumed to be located in the streets. This is a discrepancy with current practice since most of the newer site and service schemes provide back-to-back services. However, from an engineering point of view, street services are preferred in a self-build scheme because they are then on public land. Any cost increase resulting from front services will be more or less the same for all the studied alternatives and, therefore, this will level out in the comparative cost analysis and is not considered to be important.

3.5 Site conditions

Site conditions are assumed to be optimum for every chosen alternative in the model. Actual site conditions will of course differ and should therefore become an important design parameter in the choice of the appropriate solution. In Chapter 13 some conclusions with regards to this aspect are included. However, to make this model workable, the variables with regard to site conditions are excluded.

4.0 SANITARY ENGINEERING CONSTRAINTS IN SITE AND SERVICE SCHEMES

4.1 Non waterborne sewerage

When the site and service programme was written, non waterborne sewerage was anticipated and pit latrines were proposed. During the implementation stage, the pit latrines were abandoned and all the site and service schemes have been implemented with conventional waterborne sewerage (van Straaten 1977).

4.2 Construction

At the start of the site and service programme, it was expected that house construction on the plot would occur simultaneously with the construction of the services on the site being built by a contractor. In practice this did not happen (for several understandable reasons) and sites were allocated to the allottees only when the work of the contractor was complete and fully accepted by the council. Theperiod between the handing over of the site to the council and actual plot occupancy has been normally 1-2 years (Chana et al 1979). In this period manhole covers have disappeared - council officials claim that contractors return to the site and steal the covers. To avoid further thefts,the engineer in charge has little option but to store the remaining covers in his yard. He will only replace these covers if a reasonable amount of plots are occupied. The uncovered manholes have been used as dumping places for garbage and have often become completely filled up. However, during this period, some plots are completely built up and occupants start to use their toilets with obvious resulting problems.

4.3 Gradual development

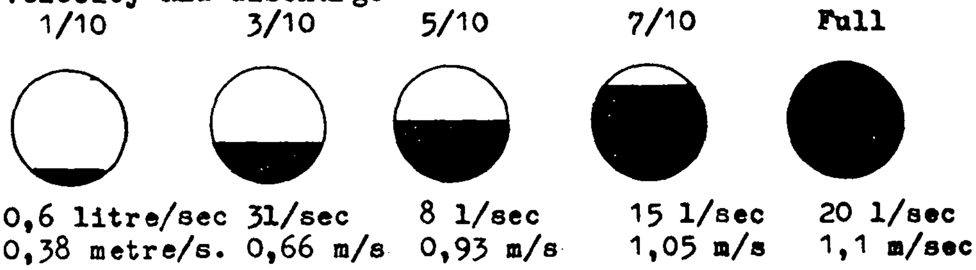
Unlike other housing schemes in which occupancy is almost instantaneous, site and service schemes are based on the gradual development of housing. It is planned that the owner will build from the materials loan two rooms and by subletting one room will earn enough money to give him the opportunity to build another room and so on. Therefore, plot occupancy will gradually increase, and it will take years before the scheme has reached its designed density. However, sewers designed for the ultimate design flow are already in place before the first occupants arrive on the scheme. Investments which are only fully utilized after, for example, 10 years are very wasteful from an economic point of view.

4.4 Self-cleansing velocities

However, there are other more serious problems with sewer performance in site and service schemes. Observations in low income housing estates reveal that water consumption is very seldom above 75 litres/person/day (Waweru 1978). Sewerage engineers assume that 80% of the waterflow will be returned to the sewer (return flow factor). One site and service plot, if fully occupied, will therefore generate in 24 hours 1,080 litres of sewage or on average 0,0125/sec. Due to peaks in water consumption, for example in the morning, engineers assume that peak flows will be 2-3 times greater than the average flow. Therefore, the peakflow contribution of a site and service plot is a maximum of 0.0375 litres/sec. (18 persons per plot).

Because of the relatively high solids content of sewage (low income people normally do not use soft toilet paper but use more solid waste materials such as newspapers, corn cobs and coconut husks) self-cleansing velocities of 0.9 - 1.0 metres/sec should be reached once a day. This self cleansing velocity should occur at the peakflows. A full flowing 6" sewer at a gradient of 5 percent will discharge 50 litres/sec at a velocity of 2.8 metres/sec. If, however, the discharge is below this figure, for hydraulic reasons the velocity will drop also (see figure 3).

Illustrating the effect of depth of flow upon velocity and discharge

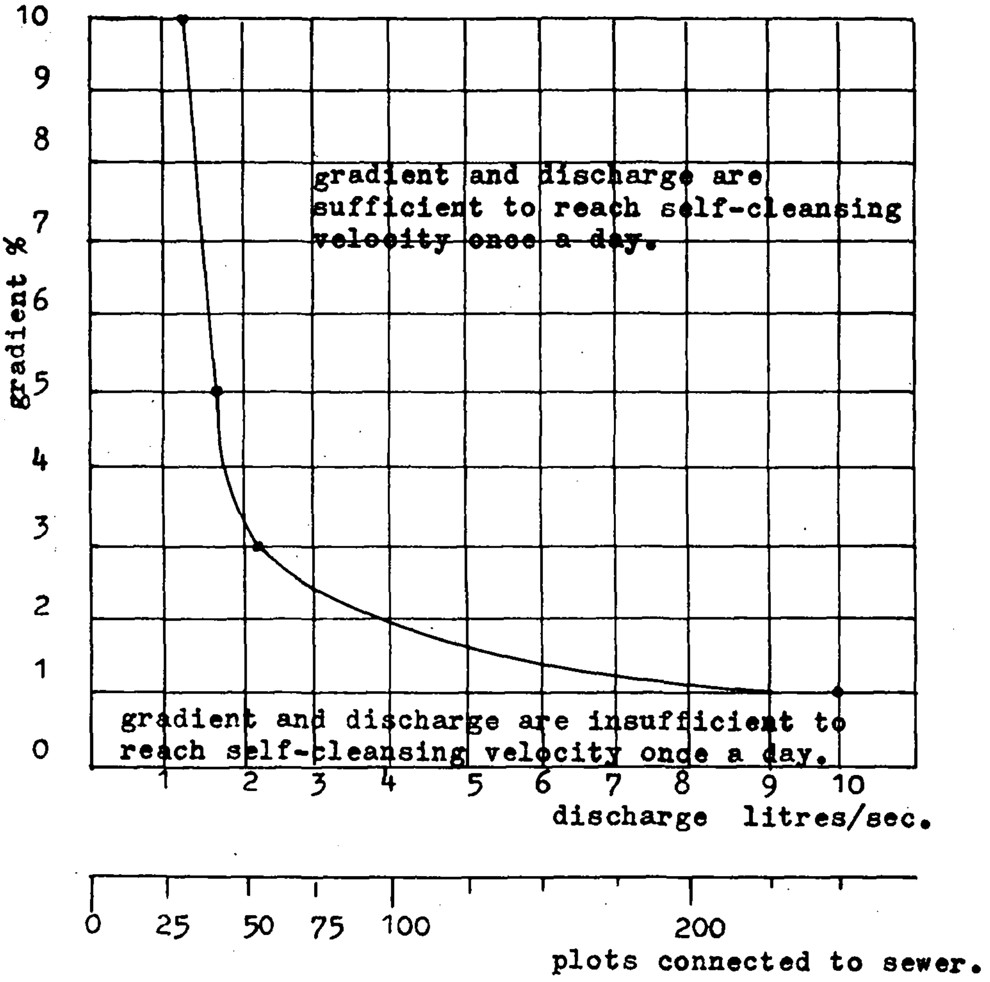


Calculated for a 160 mm UPVC sewer laid at 1:100

<u>Figure 3</u>

Gradients of 5 percent or higher are very seldom reached due to the fact that sites than become unsuitable for low cost housing construction. Figure 4 expresses the minimum gradient necessary to transport a certain flow at 1 metre/sec in a 6" sewer. The relation between plots and these flows is also shown. The problem with conventional sewerage is that a self cleansing velocity will be reached only when a certain number of plots contribute their wastes to the sewer. In practice, this means that very large lengths of sewer runs will not be self cleansing in site and service developments and blockages are likely to occur regular.

Relationship between gradient and discharge to reach a self-cleansing velocity of 1 metre/sec.



Calculated for a 160 mm UPVC sewer pipe, 75 litres/person sewage flow, peak flow 3x average flow, minimum self-cleansing velocity 1 m/sec. once aday.

Figure 4

Nevertheless, this relationship between water consumption and sewer design is rarely given adequate consideration. It seems that engineers are content to apply the standard design formula despite the fact that these were not developed for low water consuming communities. Moreover, it seems that engineers are prepared to make false assumptions simply to make this conventional technology work at least on paper. An example of this is afforded by the World Bank 2nd Urban

Project in which design criteria for water supply is based on 60 litres/cap/day (a reasonable assumption) but where design criteria for the sewerage system is based on the generation of 120 litres/capita/day of sewage (Nairobi City Council 1978).

In addition, house building will not develop in a planned sequence along the sewer line. Ideally house development should start at the lower end of the sewer laterals and gradual move upwards. In practice, house development in site and services schemes occur at random over the site, depending on the financial capabilities of the allottee. This is very difficult to assess in the allocation phase. Observations of sewer flows in site and service schemes confirm that flows are insufficient to keep the solids in suspension.

4.5 Pipe materials

Current practice is to construct sewers out of the cheapest material available. Most of the sewers constructed in Kenya are made from concrete. The joining is mostly done by rigid cemented joints. However, it is considered extremely bad engineering practice to construct short rigid pipes connected with rigid joints. Due to settlements in the soil, rigid pipelines will crack at the joints after a certain period and will become a reason for blockages. Rigid pipes should be joined with rubber rings but this does not appear to be a popular technique in Kenya.

Widespread failures have occurred where cemented joints are used. The tendency to crack or shrink, the possibility of poor workmanship in installing the joint, the incorrect composition of the mix are causes for unsatisfactory performance. A joint or junction in a sewerline must be essentially water tight, resistant to root penetration, durable, reasonably flexible and then unaffected by soil conditions. Cemented joints do not fulfill these criteria and sewer troubles can often be traced to joint performance.

4.6 Corrosion

Because of extremely low flows in sewer pipes, the sewage turns septic and slime accumulates on the sewer walls under the water level. The slime provides an excellent breeding environment for sulphide producing organism. Sulphides thus formed escape into the sewer atmosphere in the form of H_2S. The gas dissolves in condensed moisture on the walls of the pipes where it is converted into sulphuric acid. The acid causes deterioration mostly in the crown of the sewer. See figure 5. (Barnard 1967)

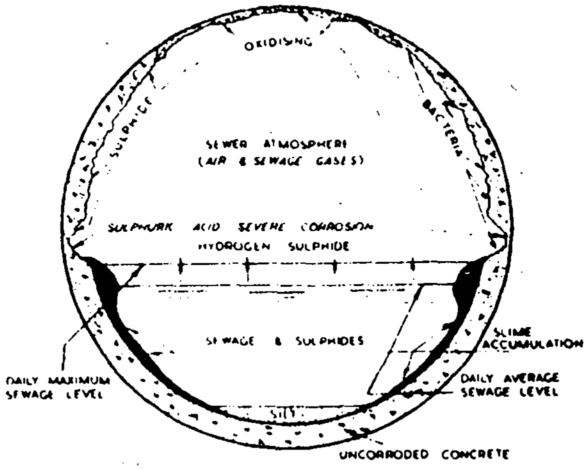


Figure 5

Severe attack can lead to collapse of sewers and concrete sewer pipes are particularly vulnerable to this phenomena. For example, a 15 year old sewer pipe in Athi River was found completely corroded away at the crown. The lifetime of sewers can be severely reduced in this way. Plastics are not sensitive to this type of corrosion however.

4.7 Summary

In summary, the following problems can be listed for conventional waterborne sewerage:-

- house building can start only when the services are completely installed;
- the disappearance of manhole covers and blockages of sewers before full occupation;
- in the first years actual flows are far below ultimate design flows;
- as a result of low water consumption and a high amount of solids self cleansing velocities cannot be reached;
- poor jointing techniques;
- corrosion in concrete sewers due to sulphuric acid.

Ideally an appropriate sanitation system should cope with these problems. Hence the need for alternative sanitation systems is inevitable.

5.0 ECONOMIC COSTING OF SANITATION TECHNOLOGIES

Before the sanitation alternatives are reviewed in Section 6.0, it is necessary to say something about how the comparative economic costing has been undertaken. The approach adopted is the "average incremental cost" method using "shadow prices" for the main inputs.

A good explanation of this approach is given by Mara et al, 1978 and Kalbermatten et al, 1978, and is quoted extensively below.

> "The basic purpose behind economic costing is to develop a price tag for a good or service which represents the opportunity cost to the national economy of producing that good or service. Translated into practice, this purpose can be summarized in three principles to be followed in preparing cost estimates".

5.1 Economic costs

> " The first principle is that all costs to the economy, regardless of who incurs them, should be included. In comparing costs of public goods such as water or sanitation, too often only costs which the public utility pays are considered in a cost comparison. The costs borne by the household are often ignored. In analysing the financial implications of alternative technologies such a comparison would be appropriate. However, for an economic comparison (i.e. for the determination of the least cost solution) it is necessary to include all costs attributable to a given alternative whether borne by the household, the utility, the national government, or whomever."

5.2 Pricing

> " Once the relevant costs to include have been identified, the second costing principle concerns the prices which should be used to value those costs. Since the objective of economic costing is to develop figures which reflect the cost to a particularly country of producing a good or service, the economist is concerned that unit prices

represent the actual resource endowment of that country. Thus a country with abundant labor will have relatively inexpensive labor costs in terms of labor's alternative production possibilities. Similarly, a country with scarce water resources will have expensive water costs, in the economic sense, regardless of the regulated price charged to to the consumer. Only by using prices which reflect <u>actual</u> resource scarcities can one ensure that the least cost solution will make the best use of a country's physical resources."

"Because governments often have diverse goals which may be only indirectly related to economic objectives, some market prices may bear little relation to real economic costs. For this reason it is often necessary to "shadow price" observed, or market, prices to arrive at meaningful component costs of a sanitation technology."

In the economic costing of sanitation technologies there are four shadow rates which normally need to be incorporated into the analysis. These are:

(1) the unskilled labor wage shadow factor;
(2) the foreign exchange shadow factor;
(3) the social or "opportunity" cost of capital; and
(4) the shadow price of water, land and other direct inputs.

These are briefly discussed in turn.

"<u>Unskilled labor</u>. Many governments enact minimum wage legislation. The normal effect of this is that unskilled labor is economically overvalued; that, the financial reward (pay) of an unskilled laborer is higher than that he would receive in the absence of minimum wage legislation. Because his economic value is less than his wage, however, employees will be reluctant to hire him. Thus where minimum wages are set above the real productivity of unskilled labor, unemployment generally results (of course, unemployment happens for other reasons as well). If a country has a very large pool of unemployed laborers, the unskilled labor wage shadow factor would be close to zero because there is almost no cost to the national economy which results from employment of such people, as they would be otherwise unemployed and so be producing nothing. On the other hand, if a country has few unemployed unskilled workers, then the shadow factor would be one as this situation is an indication that the free market forces of supply and demand are in effect. Generally the shadow factor for unskilled labor in developing countries is in the range of 0.6 to 1. "

" Foreign exchange. Many governments do not permit free exchange of their national currency in the international money markets. Instead, they fix its value in terms of the currency of a major trading partner such as the US or Japan. Sometimes this results in the currency being overvalued: imports thus cost fewer units of the national currency than they would if the government allowed the currency to trade freely on the international market, and exports are overpriced in terms of their foreign currency value. Sometimes this same result is achieved not by an overvalued domestic currency but by a system of import restrictions and/or export taxes. Whenever such a system exists it is likely that the foreign exchange shadow factor will be different from one. The foreign exchange shadow factor is the ratio of the shadow exchange rate (what the currency would be worth in a freely trading international market) to the official exchange rate fixed by the government; expressed in this way the shadow factor is thus greater than one whenever the local currency is overvalued or import restrictions are high. Suppose a government fixes its official rate of exchange at 10 units of its national currency (unc) to the US dollar, but that in the free market 15 unc are required to purchase one US dollar; the foreign exchange shadow factor is thus 1.5. Suppose further that a municipality in the same countries wishes to import a nightsoil vacuum tanker which has a direct foreign exchange cost at the border of US$ 10,000: it would have to pay only 100,000 unc for the tanker, but the true economic or "shadowed" cost to the country's economy is 1.5 times this amount, i.e., 150,000 unc, and this is the price that has to be used in evaluating the economic cost of the nightsoil collection system the municipality wishes to adopt.""

"*Opportunity cost of capital*. This is defined as the marginal productivity of additional investment in its best alternative use. It can also be thought of as the price (or yield) of capital. In countries where capital is abundant, such as the industrialized countries of Europe, one expects the yield to be relatively low. This is because capital has already been employed in its most productive uses and is now being substituted for labor or other inputs in less and less profitable areas. In many developing countries, however, capital is a scarce commodity and therefore has a high opportunity cost. A government might decide for socio-political reasons to make available loans to householders at a low rate of interest to enable them to build, say, ventilated improved pit latrines. The economic cost of this decision is the yield which the government would have received had it invested its capital in the best alternative way - for example by buying shares in a well-managed industrial enterprise. The opportunity cost of capital is thus expressed as a percentage; in developing countries it usually ranges from 10% to 20%."

"*Water, land, and other direct inputs*. The prices of some inputs of sanitation systems are controlled by governments or incorporate government subsidies. For example, land for the construction of waste stabilization ponds may be owned by the government because it is near a public airport. The government may decide to transfer it to the sewerage authority for no financial cost. However, its <u>economic</u> cost should be calculated as what it would have been worth had it been sold on the market to a farmer or industry which wished to locate there. Usually a good approximation of this shadow cost can be obtained by reviewing recent sales records of similar land in the area."

"Other prices which may need adjustment to reflect real resource costs are those of publicly produced outputs such as water and power. It is usually not possible to estimate directly what a free market price would be for these items because the government normally has a monopoly in their production. However, according to economic theory, free market forces will push the price of a good to the marginal cost of its production. Thus the shadow price of water or power can be approximated by calculating its incremental production cost."

5.3 Incremental costing

"<u>The third principle of economic costing is that incremental rather than average historical costs should be used</u>. This principle rests upon the idea that sunk costs should be disregarded in making decisions about future investments. In analyzing the real resource cost of a given technology, it is necessary to value the components of that technology at their actual replacement cost rather than at their historical price. In the case of sanitation systems this is particularly important in the evaluation of water costs. Because cities develop their least expensive sources of water first, it generally becomes more and more costly (even excluding the effect of inflation) to produce and deliver an additional litre of water as the city's demand grows. By using the average cost of producing today's water one is often seriously under-estimating the cost of obtaining water in the future. The decision to install a water carried sewerage system will increase the newly served population's water consumption by around 50 to 70 percent. Thus, in calculating the costs of such an alternative, it is extremely important to properly value the cost of the additional water required."

"Just as costs incurred in the future have a lower present value than those incurred today, benefits received in the future are less valuable than those received immediately. In the case of deriving per capita costs, this means that serving a person five years hence is not worth as much as serving the same person now. To divide the cost of a sewerage system by its design population would understate its real per capita cost when compared with that of a system which is fully utilized upon completion."

"A good method that has been used to overcome this problem of differing capacity utilization rates across systems is the average incremental cost (AIC) approach. The per capita AIC of a system is calculated by dividing the sum of the present value of construction (C) and incremental operating and maintenance (O) costs by the sum of the present value of incremental persons served (N)."

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

where t = time, years

T = design, lifetime, years (measured from start of project at $t = o$)

C_t = construction costs incurred in year t

O_t = incremental (from year $t=0$) operation and maintenance costs incurred in year t

N_t = additional people (from year t=0) served in year t

r = opportunity cost of capital, percent times 10^{-2}

It is essential that all costs used in the equation have been appropriately shadow priced" (Mara, 1978) (Kalbermatten 1978). Appropriate shadow pricing is a very complex issue, therefore several bold assumptions have been made for this study. Therefore, it is recommended to make a further analysis of this aspect in any future report.

5.4 Input costs and conversion factors

The following input costs and conversion factors have been used for the calculations in this study.

Hourly unskilled labour wage K.Shs.2.30+ housing allowance of K.Shs.90 monthly; working week consists of fifty working hours.

Estimated opportunity cost for land K.Shs. 40,000 per ha

The following figures have been obtained from World Bank economists in the Nairobi Office.

Opportunity cost of capital	12%
Urban unskilled labor factor	1
Foreign Exchange factor	1,4
Foreign Exchange rate	1 US$ = K.Shs.7.5

The average incremental cost approach is also appropriate for economic costing in the water supply sector. In effect, the AIC is the ratio of the discounted stream of the additional costs over the discounted stream of the additional demand satisfied. For Nairobi, the choice of the discounting period is a complex one. A fast increasing demand bears on several components with a wide variety of capacity yields and useful lives.

Fortunately, in 1977 the World Bank studied this aspect in some detail and the following figures are taken from those studies (World Bank 1976).

Economic Costs (AIC)of Water Supply for Nairobi

(in K.Shs./1000 litres, January 1975 prices)

Capital cost of supply to town	1.711
Capital cost of distribution network in town	0.287
Operating cost of supply	
- power and chemicals	0.221
- others	0.074 +
Total water cost of supply	2.293

Several items for the building industry are manufactured locally, with the help of imported machinery, out of imported raw materials. This is, for example, the case with UPVC pipe, polyethylene pipe, galvanised iron pipe, reinforcement, galvanised iron sheeting etc. The assumption is made that 50% of the local sales price is needed for foreign currency and 50% is local currency.

Some items are completely imported including fittings for pipes, manhole covers, water meters, valves, toilet pans and flushing cisterns, machinery, fuel, etc. The assumption is made for those items that 75% of the local sales price is needed for foreign currency and 25% for local currency. Sales tax, as levied by the government on sold products, is not included in the prices.

Costing of the sanitation options have been based on these assumptions. However, great difficulties were experienced in establishing appropriate prices for waste stabilization ponds. The cost of ponds is very much dependent on location, gradient of the site, soil conditions etc. The assumed figure of K.Shs.100 per m^3 of pond is, therefore, a rough estimate, abstracted out of several tender documents. If sites are unfavourable, this figure can easily be increased by 100%. Therefore, actual costing cannot be done with these figures and the designer or economist should verify these prices in any particular situation. However, these prices have only a marginal effect on comparative studies.

Benefits for each alternative are not costed because they are assumed to be equal for each alternative.

6.0 SANITATION OPTIONS REVIEWED

The following sanitation options have been chosen for the model study:

1. Conventional waterborne sewerage
2. Sewered pour flush toilets
3. Sewered aqua privy toilets
4. ROECS in a phased development.

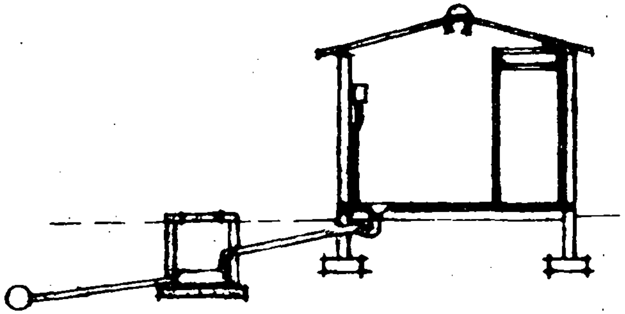
6.1 The conventional waterborne sewerage (Figure 6)

This system is chosen because it is the technology currently in use in site and service schemes. However, the present study incorporates some improvements to the conventional sewer system. Lateral and house connection sewers are 160 mm and 110 mm respectively. UPVC sewer pipes according to ISO dimensions are produced in Kenya and a wide range of fittings for ISO diameters are available in Europe. This should give an improvement in performance compared with the ordinary concrete sewer with cemented joints. The individual plot connection contains a flush toilet and a water tap. The provision of a shower is left to the individual.

6.2 The sewered pour flush toilets (Figure 7)

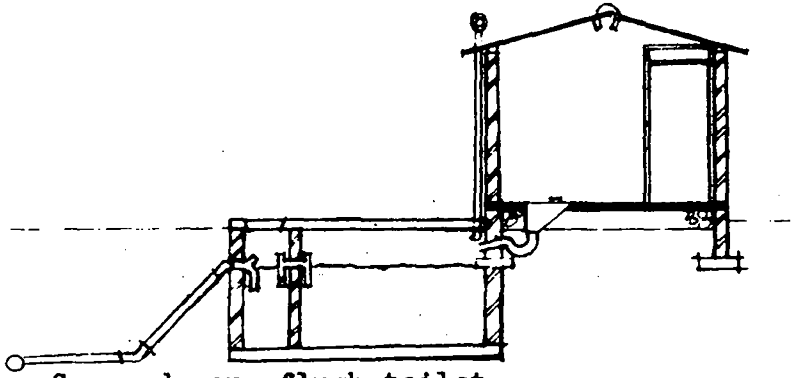
The sewered pour flush toilet is a logical adaptation of the conventional waterborne sewerage system. The main idea is to reduce the amount of flushing water and to keep the solids out of the sewers. Pour flush toilets are now used in East Asia and have become successful. There pour flush toilets are mostly provided with individual soakaways. This option is not considered in this study but could become a valid option for the first years in a site and service scheme. Total waste water flows will then be low and, if soils are sufficiently permeable, this could be done.

This system costed here, however, uses small bore UPVC sewers of 63 mm laterals and 40 mm plot connections. The number of manholes is drastically reduced (since the chance of a blockage in the sewerline has become almost nil)



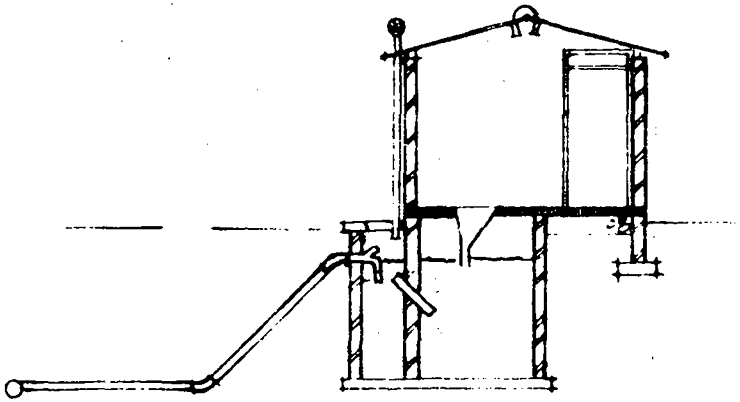
Conventional waterborne sewerage

Figure 6



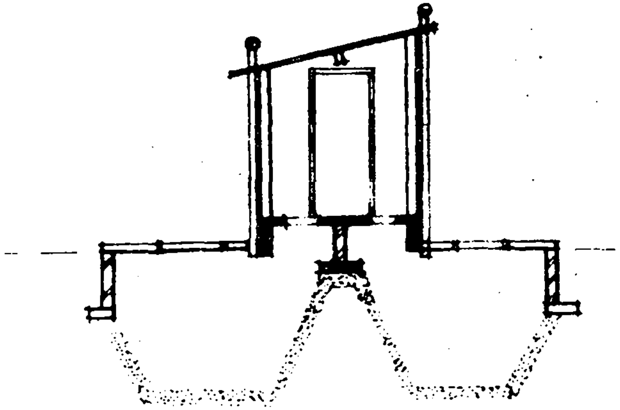
Sewered pour flush toilet

Figure 7



Sewered aqua privy toilet

Figure 8



Reeds Odourless Earth Closet

Figure 9

without infringing on the roddability of the sewer. Rodding points are provided to make the sewer accessible for cleaning.

The water distribution system is based on an improved system as discussed in more detail in "Water supply improvements for upgrading areas" (de Kruijff 1979). Courtyard services with a "Fordilla" automatic self-closing tap, which dispense with expensive watermeters, are provided on every plot.

There will be little difference in performance of this system for the user when compared with the conventional waterborne sewerage system.

6.3 The sewered aqua privy toilet (Figure 8)

Aqua privies have already been used for several years in Africa, often without much success. However, the high number of failures can often be traced to poor technical design. The system proposed here is based on an improved version of the aqua privy, which will eliminate earlier design failures. There is very little difference between the pour flush toilet and the aqua privy, however, the aqua privy has two main advantages over the pour flush toilet.

Firstly, it is able to deal with bulky anal cleansing material. The water seal can hardly be blocked with this material or in case of a blockage it will be easy to rod through. Secondly, a temporary water shortage (as often occurs in Kenyan towns) will not make the system unusable. The disadvantage is that the system needs more careful construction than the pour flush toilet. The tank should be watertight and the effluent pipe should be carefully positioned in relation to the down pipe of the squatting plate to maintain the water seal. The water distribution system and the sewer system is exactly the same as in the sewered pour flush toilet system. There will be very little difference in user convenience between the conventional sewerage, pour flush and aqua privy toilet systems.

6.4 Reeds Odourless Earth Closet (ROEC) (Figure 9)

Reeds odourless earth closet is basically an improved pit latrine with a composting process. ROECs have been very successful in Southern Africa (Blackmore 1978). The ROEC as used in this study, is calculated for a two years lifetime. After two years, a second ROEC has to be used and when this becomes full, the first one will be emptied and reused. Pathogens have become almost harmless in the two years storage period and, therefore, emptying can be done by manual labour. The dug out compost can be used as fertilizer. Since ROECs have no water requirements at all, the water supply is considered to be communal in the first years. The water system will be upgraded later to individual plot-connections similar to the pour flush and aqua privy toilet systems.

However, ROECs demand a separate system for the safe disposal of waste water. Two options are costed here. If the soils are sufficiently permeable, the wastewater can be disposed off in a soakaway pit after first passing a small settlement tank. If soils are not permeable enough, waste water should be disposed off in a small bore sewer similar to those used in the other systems. In the first years, user convenience is considerably less than the other systems. However, when the individual plot water supply system is installed, the system is comparable with the other systems.

6.5 Individual toilet blocks grouped in a central space

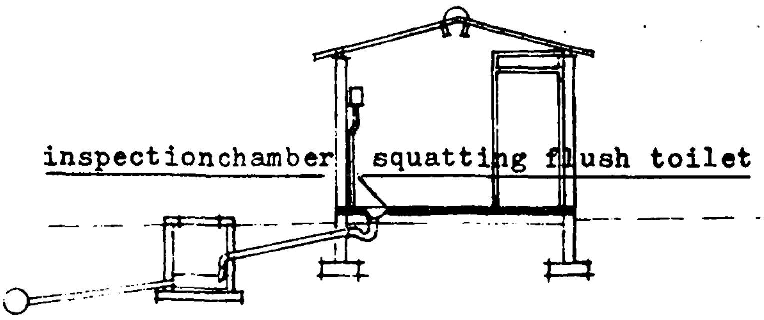
This option, as used in the World Bank Second Urban Project upgrading schemes, is not studied in detail. The system is based on grouped individual toilet cubicles away from the house. Every plot is provided with such a cubicle. However, the distance to the house can be 50 metres or more. By grouping the cubicles together in a central space, considerable savings can be achieved in service lengths and building costs.

But serious doubts can be expressed about the usefulness of this type of service. Children may not use this facility and even adults may not use it after dark. Also water has still to be carried to the plot. If the aim is to achieve health benefits, it is unlikely that this type of system will be satisfactory.

In the following Sections, each of the sanitation alternatives are considered in most detail and costed using the principles outlined in Section 5.0.

7.0 CONVENTIONAL SEWERAGE

Several problems with this type of service have already been identified in earlier Sections. This Chapter gives only a brief additional overview of design considerations for conventional sewerage. (Figure 10)



Conventional waterborne sewerage

Figure 10

7.1 The toilet

The conventional cistern-flush toilet is basically a water seal squatting plate or pedestal unit in which excreta are deposited and then flushed away (by 10 litres of water if a high level flushing cistern is used). The flushing water is clean potable water. The excreta is discharged via an underground sewerage network to a sewage treatment plant.

7.2 Gulley traps

For waste water disposal, the British system, which is adopted in Kenya, requires that sullage pass first over an outside gulley trap before it is permitted to enter the foul sewer. However, observations in low income housing estates reveal that gulley traps are often unattended and become filthy, ideal breeding places of mosquitoes.

7.3 Manholes

Manhole spacing is another controversial issue. At present manholes are constructed at summits, at changes of diameter, direction and gradient and where main sewers join. Manholes are provided primarily for the purpose of access to sewers for inspection and maintenance, and their presence enables blockages to be easily located. The maximum manhole spacing in Kenya is 60 metres on a 9" sewer. However, with modern rodding equipment, manhole spacings of 245 metres have been used in the USA.

Because of the high number of manholes in Kenya, their cost is between 25-45% of the total cost of a sewerage scheme. This is a large sum and, in fact, it may well have reached the point where the cost savings achieved by eliminating manholes at certain points may be greater than the occasional expense of excavating down to sewers in case accidental blockages occur.

Some form of flexibility in sewer lines near the manholes should be provided, however, this is usually neglected.

The system has the following general disadvantages above those mentioned earlier.

7.4 Economics

1. The system is very expensive. Only a small part of the present population is served by a flush toilet (5% of the population excluding Nairobi in 1972) the capital outlay required to provide such a service is enormous.

7.5 Water needs

2. The system is very extravagant with water. It is not uncommon to find that 40-60 litres /capita/day of potable water is needed for the flushing of the toilet pan. This is both expensive and wasteful. Large quantities of an often scarce resource are used to transport small quantities of excreta to a treatment works.

The environmental logic and expense of the whole process can be called into question: a conventional waterborne sewerage system means adding 40 litres of expensively treated and transported water to ½ litre of excreta per person per day and thereafter treating the sewage thus produced in order to remove the excreta before the effluent can be discharged back into a lake or river. Sewage treatment costs are often higher even than those for water treatment and present particular problems in developing countries. Considerable management skills are required to supervise the process. Observations show that streams, which may be the main water source for individuals downstream, often become polluted.

In fact, it is very doubtful if water can be made available in large enough quantities to fulfill the conventional sewerage requirements for urban Kenya.

If it is assumed, for example, that 50% of the present urban population is served with a flush toilet (50% of 1.5 million people) and that the target should be to serve 100% of the urban population by the year 2000 (100% of 9 million) then there will be an additional water requirement of approximately 600 million litres daily or about ten times the present demand. It is extremely doubtful if these water sources can be found in the near vicinityof the urban centres or that they can be developed cheaply enough to serve the low income population.

However, if the waterflow into conventional sewerage systems, is limited to below 70 litres/capita/day, sewers cease to function. Blockages will result and, therefore, the maintenance costs will become high.

7.6 Unplanned settlements

It is almost impossible to introduce conventional sewerage into squatter settlements. Firstly it is very difficult to establish the necessary straight runs through unplanned areas. Secondly, squatter settlement sites are often unsuitable for low cost housing developments and are frequently located on very steep or almost flat land. The latters causes severe sanitation problems since areas can then only be served with the assistance of pumping stations which are costly and require high maintenance. Low water consumption in squatter areas is another obvious problem.

7.7 Summary

In summary, conventional waterborne sewerage appears to have so many serious disadvantages for low-income urban housing that it cannot really be considered as an appropriate technology. In addition, as will be seen later, its costs are prohibitive for replication on the required scale. Rural areas cannot be served at all with this system.

7.8 Basic data and design criteria for the model study

Water Supply.

- Every house is individually connected to the water supply and provided with one water tap and one toilet (high level cistern).
- The connection is metered with a stop cock and only front services are considered. See Figure 12.
- A 4" water supply main is located along one of the main streets.
- The minimum head at the point of connection under peak demand conditions is known to be about 25 metres (35 psi).
- The minimum allowable pressure at taps is 20 metres, thus allowing a head loss of 5 metres across the distribution network.
- Extra flow capacity for fires is not considered.
- The water distribution system is a combination of looped and branched networks shown in Figure 8.
- The individual house connection is ½" gal. iron.
- The connection to two plots is ¾" polyethelyne pipe materials and upwards materials only. Above 2" UPVC.
- Gate valves are provided for every branch and part of the loop.
- Water consumption per person per day is assumed to be 75 litres.
- The peak hourly flow is assumed to be 3 times greater than the average flow.
- Sewage disposal (see Figure 13.)
- The average sewage flow is considered to be 80% of the water supply.
- The peak hourly flow is assumed to be 3 times greater than the average flow. The minimum velocity to retard settling of sediment is assumed to be 0.9 metres/second but may go as low as 0.45 m/sec for the first 40 metres of every upper branch. (If site gradients are less than 10%, the majority of the sewers are not self cleansing. Pumping costs and extra excavation costs are not considered.)

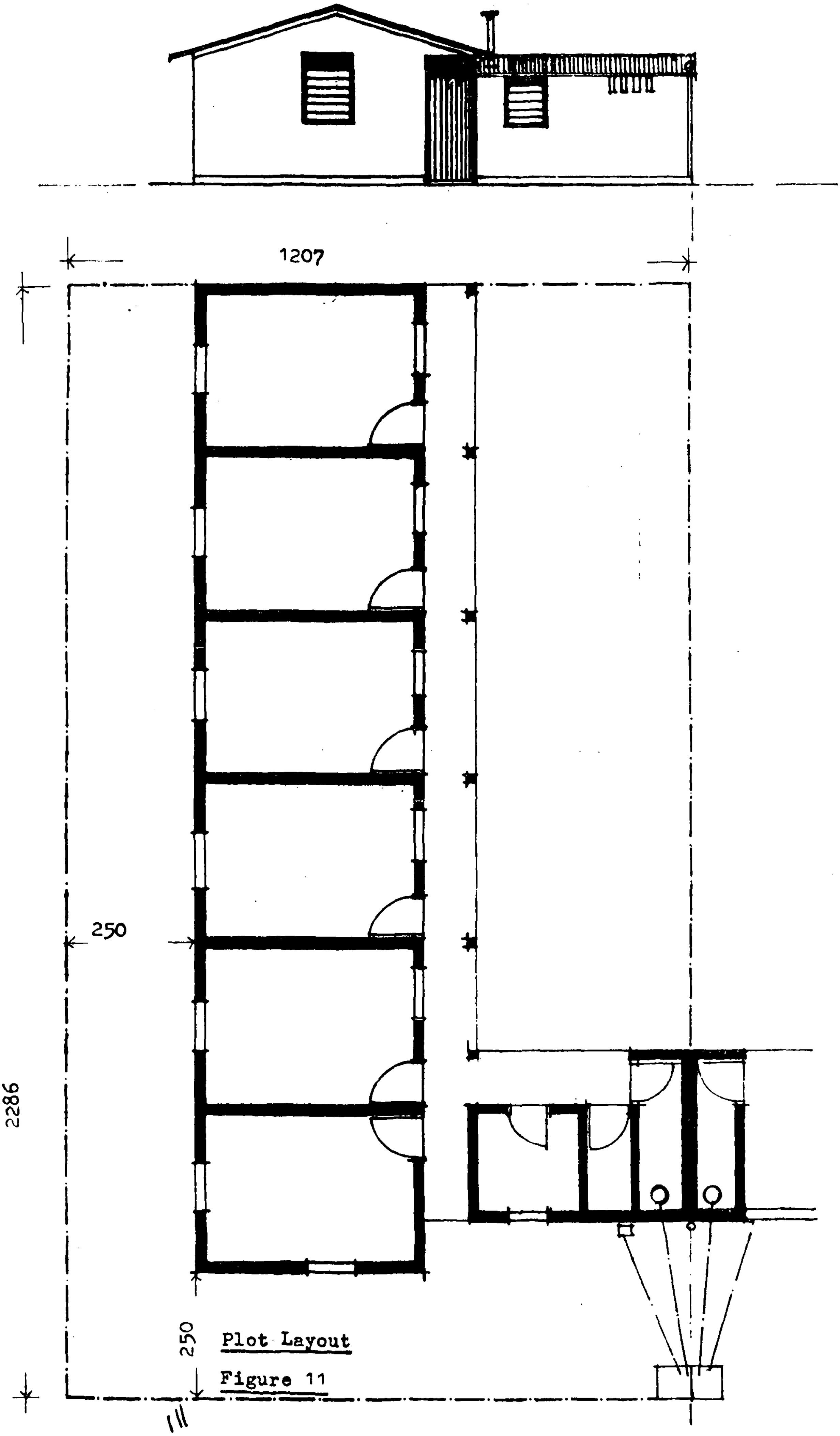
- Every plot is provided with an inspection chamber but these may be grouped together.
- Individual house connections up to two plots is by 110 mm UPVC sewer.
- Main laterals are 160 mm UPVC.
- The main collector pipe is assumed to be 9" concrete.
- Distances between manholes on 160 mm sewer lines are not greater than 45 metres and on 9" sewers not greater than 60 metres.
- Connections from the inspection chambers to the main lateral sewers is by means of Y branches if no existing manhole is available on the lateral sewerline.
- Depth of sewer is a minimum 1,20 metres under roads.

Sewage treatment.

Mean lowest monthly temperature 17^0.
Ultimate design flow 80% x 320 x 18 x 0,075 = 345 m^3/day
Maximum permissable surface loading 220 kg/ha/day
Daily per capita BOD contribution 40 grams
Effluent flow 10^8 Faecal Coliform per 100 ml.
Permissible effluent flow from ponds is Faecal coliforms less than 100 per 100 ml.

Calculations are based on the formulas as presented in "Sewage treatment in Hot climates" (Mara, 1976)

Size of anaerobic pond 1	3450 m^3	575 m^2
facultative pond	6900 m^3	4688 m^2
maturation pond 1	2415 m^3	1610 m^2
" 2	2415 m^3	1610 m^2
" 3	2415 m^3	1610 m^2
Total	17595 m^3	



Plot Layout

Figure 11

111

Conventional Water Supply

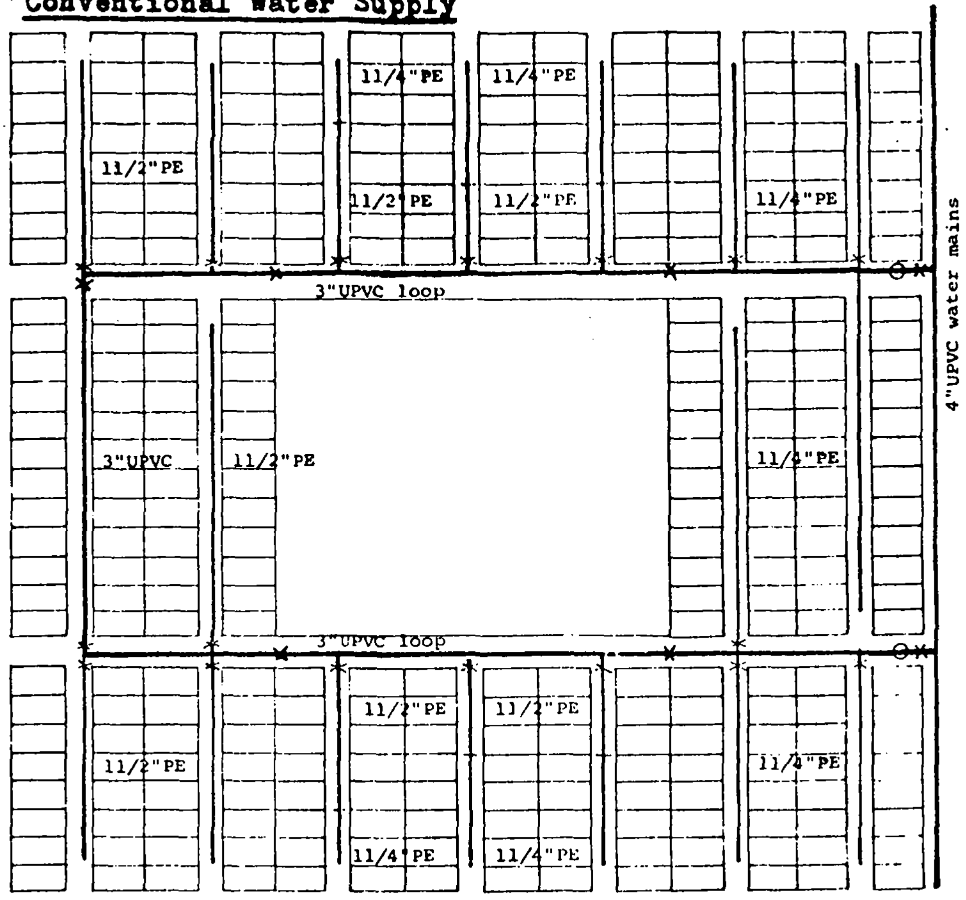


Figure 12

Conventional Sewerage Collection

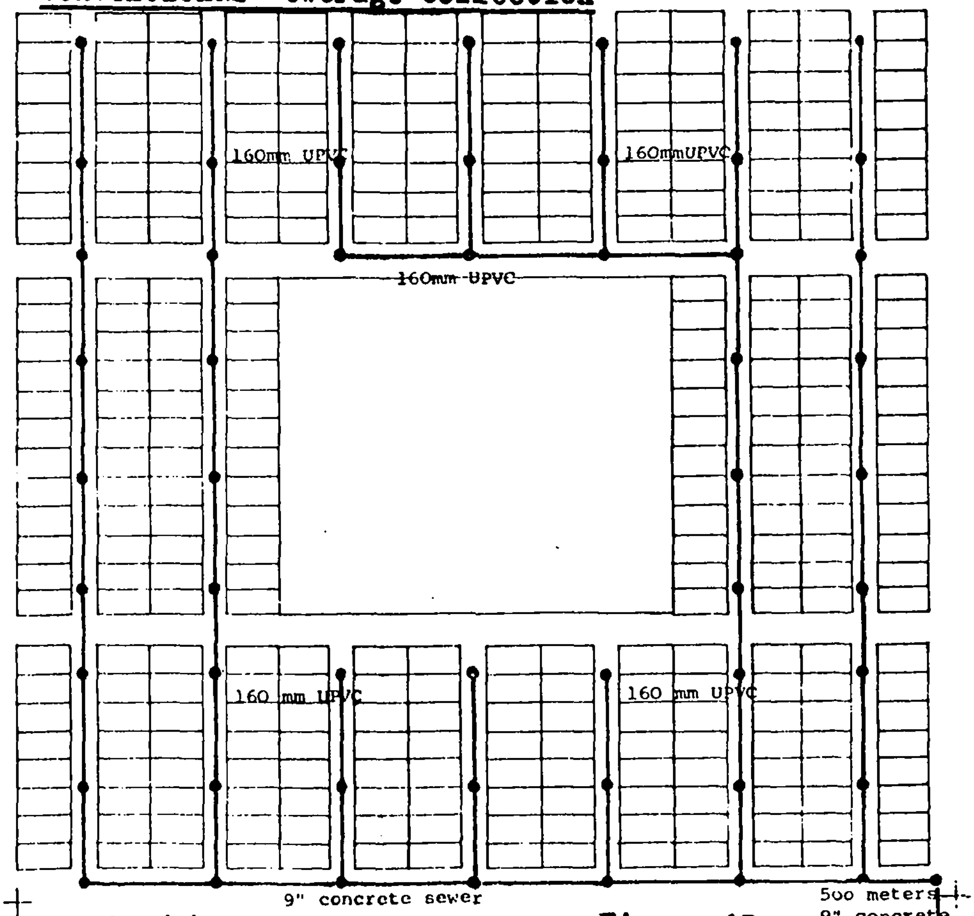


Figure 13

Conventional Sewerage

Accounting prices

COSTS PER PLOT.

	ON PLOT COSTS	WATER SUPPLY		SEWAGE COLLECTION	SEWAGE TREATMENT
		pipes/fitt.	meters		
Materials					
-local	1,618	173	113	856	Land costs
-imported (x 1,4)	1,807	258	365	711	267
Labour					Construction
-skilled	475	43	9	148	5,498
-unskilled	491	65	9	329	
Subtotal	4,391	539	496	2,044	5,765
Engineering design	220	51	--	102	275
Total	4,611	1,086		2,146	6,040
Yearly maintenance	44	20			57
Lifetime years	40	40	20	40	40

Desluiging anaerobic ponds,
year 10, kshs 431,-.

Sewer maintenance year 2, kshs 31
yearlo, kshs 20

COSTS PER SCHEME

	ON PLOT COSTS	WATER SUPPLY		SEWAGE COLLECTION	SEWAGE TREATMENT
		pipes/fitt.	meters		
Materials					Land costs
-local	517,760	55,410	36,055	273,950	2.136hA x Kshs 40,000 =
-imported (x 1,4)	578,368	82,672	116,781	227,640	Kshs 85,344
Labour					Construction
-skilled	152,000	13,600	2,830	47,346	17,595m^3 x Kshs 100 =
-unskilled	157,120	21,008	2,762	105,428	1,759,500
Subtotal	1.405,248	172,690	158,428	654,364	1,844,844
Engineering design	70,262	16,555	--	32,718	87,975
Total	1.475,510	347,673		687,082	1,932,819
Yearly maintenance	14,080	6,400			18,432
Lifetime years	40	40	20	40	40

Desludging anaerobic ponds,
year 10, kshs 138,000.

Sewer maintenance,year 2,kshs 9,815
year10,kshs 6,543

CONVENTIONAL SEWERAGE
ACCOUNTING COSTS (in 1000 kshs) and PERSONS SERVED. (Constant base year prices, 1979.)

year	on plot costs		water supply		sewage collec.		sewage treat.		total	persons
	cap	o&m	cap	o&m	cap	o&m	cap	o&m		
xxxx	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxxxx	xxxxx
01	738	0	174	0	327	0	1009		2248	0
02	738	0	174	0	327	0	924		2163	0
03	0	14	0	6	0	10	0	18	48	1280
04	0	14	0	6	0	10	0	18	48	1940
05	0	14	0	6	0	9	0	18	47	2560
06	0	14	0	6	0	9	0	18	47	3200
07	0	14	0	6	0	8	0	18	46	3740
08	0	14	0	6	0	8	0	18	46	4480
09	0	14	0	6	0	7	0	18	45	5120
10	0	14	0	6	0	7	0	18	45	5760
↓										
18	0	14	0	6	0	7	0	156	183	5760
19	0	14	0	6	0	7	0	18	45	5760
↓										
22	0	14	158	6	0	7	0	18	203	5760
23	0	14	0	6	0	7	0	18	45	5760
↓										
39	0	14	0	6	0	7	0	18	45	5760
40	0	14	0	6	0	7	0	18	45	5760
41	0	14	0	6	0	7	0	18	45	5760
42	0	14	0	6	0	7	0	18	45	5760

Total sum of present values 4553.08 / 30744

8.0 THE SEWERED POUR FLUSH TOILET SYSTEM

The sewered pour flush toilet system has 5 parts:

1. The pour flush pan
2. A short length of 110 mm UPVC sewer pipe laid at not less than 1:40.
3. A small two compartment septic tank with a ventpipe
4. A network of small bore sewers
5. A sewage treatment facility in the form of waste stabilization ponds.

A typical arrangement is shown in schematic form in Figure 14.

Sewered pour flush toilet

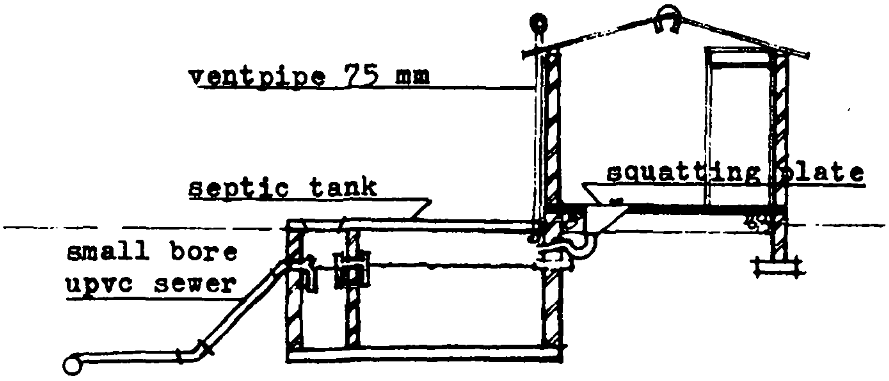


Figure 14

8.1 The Pour Flush Pan

The pans are based on the design that approximately 1-2 litres of water are poured in by hand to flush out the excreta. This type of toilet can be installed inside the house.

The pan can be made of several different materials. Reinforced concrete, ferrocement and sulphur cement are usually the cheapest but glass reinforced plastic, high density molded rubber or PVC and ceramics can also be used. Cost and aesthetics are the important criteria, apart from strength and rigidity. A variety of finishes can be applied to concrete or ferro cement squatting plates (for example alkali resistant gloss paint and polished marble chippings) or the concrete itself can be coloured. Aesthetics are often extremely important to the users and should never be ignored by engineers and planners.

Figure 15 shows a good design for a ferro cement squatting plate.

Squatting plates should be cast in an oiled timber mold, for ease of construction. If the scale of manufacture is large, a steel mold may be preferable.

Pedestal pour flush toilet pans have essentially the same design as for cistern-flush toilets but with a smaller water seal (generally 15-20 mm) and a smaller exposed surface area and volume of water (around 75 cm^2 and 2 litres respectively). A low cost ceramic design from Colombia is shown in Figure 16.

In the ultimate phase the pour flush pans can be upgraded to cistern flush pans with only a slight modification, the highest standard of convenience can be achieved.

8.2 The disposal pipe

The pipe from the squatting plate to the septic tank should be as short as possible. The steeper the gradient the better, but a minimum gradient of 2.5% is essential. The pipe should be made out of smooth material, preferably a 110 mm UPVC pipe.

8.3 The septic tank

Essentially, septic tanks are small, rectangular chambers, usually sited just below ground level which receive both excreta and flushwater from flush toilets and all other household wastewater. The mean hydraulic retention time

SQUATTING PLATE AND WATER SEAL UNIT DETAILS FOR INDIAN P–F TOILET WITH COMPLETELY DISPLACED PIT

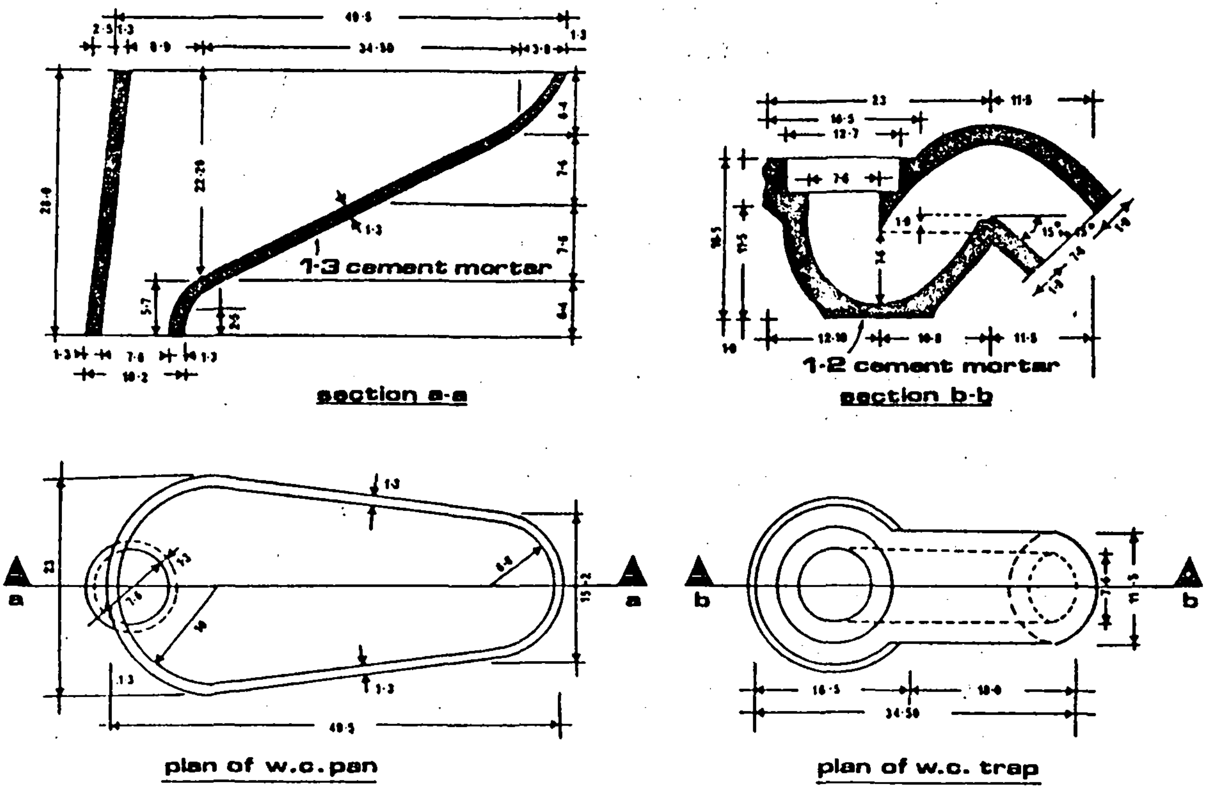
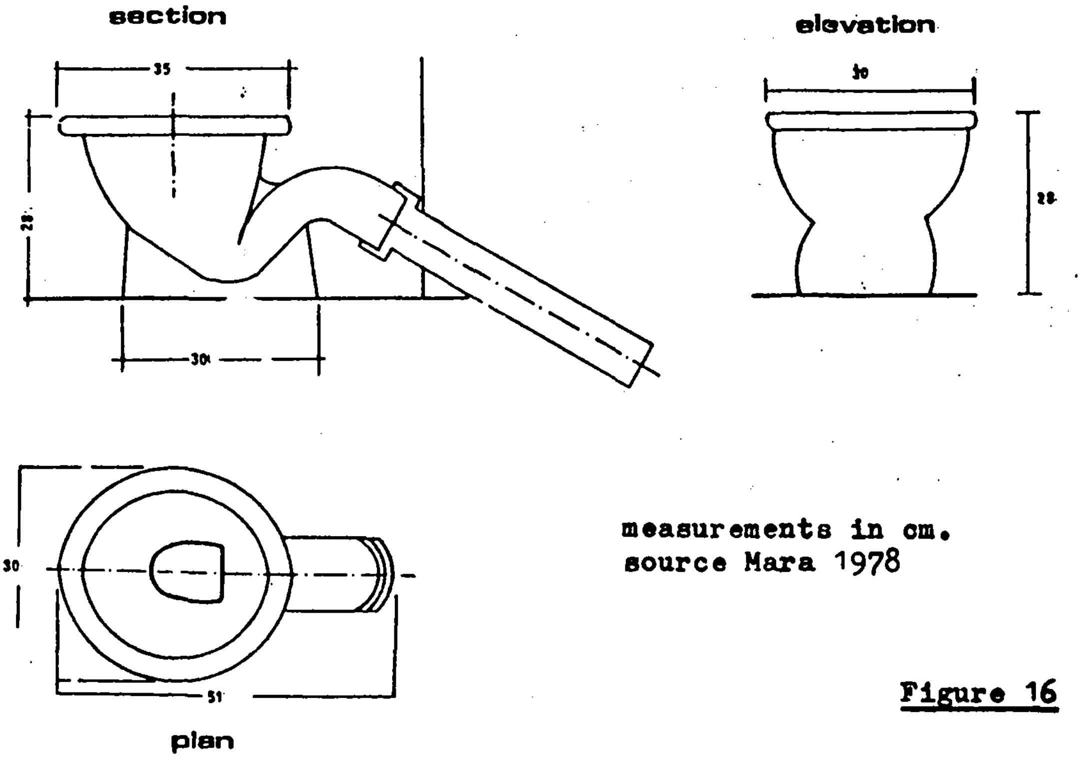


Figure 15

THE COLOMBIAN CERAMIC P–F PEDESTAL UNIT



measurements in cm.
source Mara 1978

Figure 16

in the tank is usually 1-3 days. During this time the solids settle to the bottom of the tank where they are digested anaerobically. A thick crust of scum is formed at the surface and this helps to maintain anaerobic conditions. Although digestion of the settled solids is reasonably effective, some sludge accumulates (approximately 0.03-0.04 m^3 per user per year) and the tank must be desludged at regular intervals, usually once very 1-5 years. The effluent from septic tanks is, from a health point of view, as dangerous as raw sewage and so is ordinarily discharged to soakaways or leaching fields; it should not be discharged to surface waters without further treatment. Although septic tanks are most commonly used to treat the sewage from individual households, they can be used as a communal facility for populations up to about 300.

A two-compartment septic tank is now generally preferred to one with only a single compartment as the suspended solids concentration in its effluent is considerably lower. The first compartment is usually twice the size of the second. The liquid depth is 1-2 m and the overall length to breadth ratio 2-3 to 1. Experience has shown that in order to provide sufficiently quiescent conditions for effective sedimentation of the sewage solids, the liquid retention time should be at least 24 hours. Two-thirds of the tank volume is normally reserved for the storage of accumulated sludge and scum, so that the size of the septic tank should be based on 3 days retention at start-up; this ensures that there is at least 1 day retention just prior to each desluding operation. Sludge accumulates at the rate of 0.03-0.04 m^3 per person per year and thus knowing the number of users, the interval between successive desludging operations (which are required when the tank is one third full of sludge) is readily calculated.

Excreta and pour flush water only are discharged into the first compartment of the septic tank and sullage only to the second compartment. The two compartments are interconnected. The contents of the first compartment are able to overflow into the second compartment, however, sullage water cannot flow into the first compartment. This arrangement eliminates the very high degree of hydraulic disturbance caused by high sullage flows which, in single compartment tanks, would resuspend and prematurely flush out some of the settled excreta. It thus permits a considerable higher retention time of excreta in the tank and hence is able to achieve a substantially increased destruction of excreted pathogens. The volume of the first compartment should be calculated on the basis of 0.15 m^3 per user. The nominal hydraulic retention time in the second or sullage compartment need be only 12 hours, subject to a minimum volume of 0.5 m^3.

A vent pipe is provided to enable the gas to escape from the septic tank. The vent pipe has to be properly screened.

The effluent of the second compartment can be disposed off in a soakaway pit if condition permits, but this option is not considered here.

8.4 A network of small-bore sewers

Since all but the smallest solids are retained in the septic tank, it is not necessary to ensure self cleansing velocities of 1 metre/sec in the receiving sewers. A high safety factor can be achieved by giving special attention to the design of the effluent disposal pipe in the sullage compartment (see figure 17). The effluent disposal pipe is a 50 cm long drop pipe of 40 mm UPVC in which the open end is reduced to a 25 mm opening. Furthermore, the bottom 30 cm of the pipe is slotted with a hacksaw to ensure that only effluent can enter the sewer. In case of a blockage in the 40 mm plot connection sewer, access is available via de Y junction in the sullage compartment. In case that particles greater than 25 mm will enter the effluent pipe not the sewer pipe becomes blocked but the outside of the effluent disposal pipe which can be easily cleaned. It is then the allottees (who are responsible for the septic tank) who have to take action and not the council.

Design of effluent disposal pipe

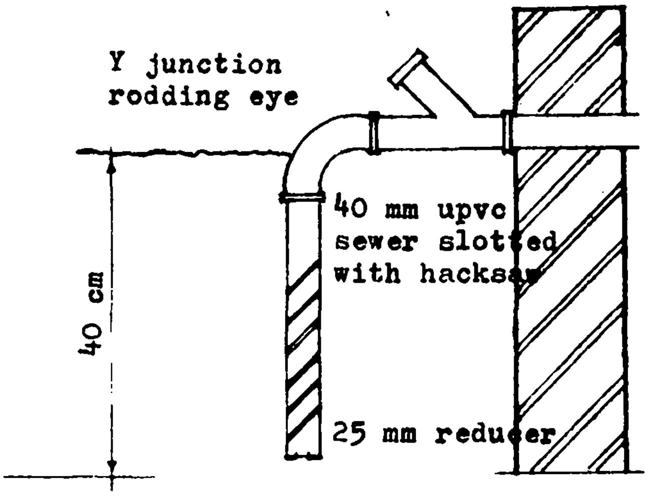


Figure 17

The lateral sewers have a dimension of 63 mm. This is still 2.5 times the largest particle that can enter the sewer system and is a much higher safety factor than that of the conventional sewer system.

A self cleansing velocity of 0.3 m/sec is recommended for design purposes. Because the sullage water carries no solids greater than 25 mm, it would be possible to utilize small bore sewers more. A 63 mm UPVC sewer laid at a gradient of 1% will discharge 1.5 litres/sec at 0.6 m/sec. This is the equivalent of 2700 persons connected with pour flush toilets or half of the final population of the model.

A 110 mm UPVC pipe laid at a gradient of 1% can discharge 7 litres/sec at 0.9 m/sec, or the equivalent of 12600 persons, more than twice the model scheme.

The number of manholes can be drastically reduced since maintenance requirements will be low but in case blockages do occur, the lateral sewer can still be rodded by means of rodding eyes, which are substituted for manholes. (see Figure

18) (Marley).

Where there are manholes, these should be of the sealed access type, as shown in Figure 19 (Marley) to prevent accidental deposit of debris through the manhole into the sewer.

Rodding eye

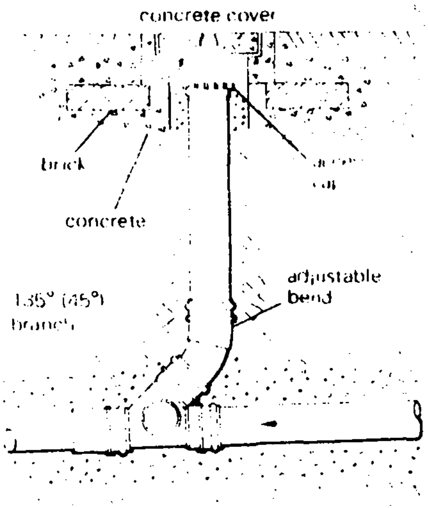


Figure 18

Sealed access manhole

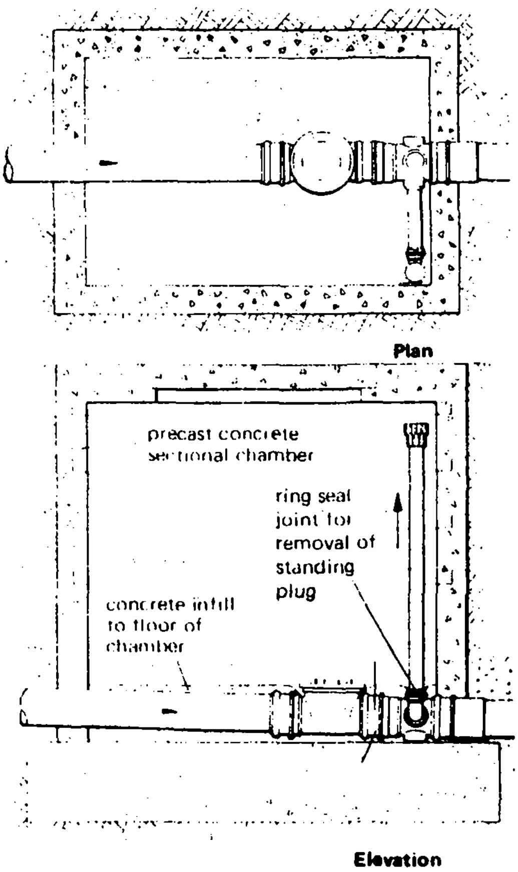


Figure 19

The effluent of the septic tanks is highly septic, and therefore concrete sewers should not be used. The recommended material for use in Kenya is UPVC, because this material is highly resistant to corrosion. Furthermore, joints and branch connections are readily available. The sewered pour flush system achieves considerable economies in pipe and excavation costs as compared with the conventional sewerage system.

8.5 Sewage treatment by waste stabilization ponds

The effluent of the septic tanks is still highly pathogenic and still has a high BOD. This effluent should first be treated in ponds before it can be disposed off in streams or discharged to groundwater.

Waste stabilization ponds are large shallow ponds in which organic wastes are decomposed by micro-organism in a combination of natural processes involving both bacteria and algae. Their principal advantages are that they achieve very low survival rates of excreted pathogens at a much lower cost than any other form of treatment and with minimum maintenance requirements.

8.6 Water supply service

The simplest form of water service to individual households is a distribution line of one tap to every house.

An individual courtyard tap eliminates water carrying from outside the household and greatly facilitates cleanliness in water use.

Providing piped water to low income consumers by means of a single tap service, raises two problems: wasteful use and the collection of water rates. Generally, the instalation of metered water connections leads to decreased use because both leakages from fittings and waste of water will be reduced. It is, however uneconomical to install individual water meters since the price of a water meter may be more than the payment for the yearly amount of water.

Therefore, the use of a "fordilla" type of watervalve is proposed. This valve is a special self-closing tap, which is very difficult to tamper with. The tap is discussed in detail in "Water Supply improvements for upgrading areas" (de Kruijff, 1979).

Another positive effect of this automatic self-closing tap is that almost every person uses about the same amount of water. Observations in other countries show that the water consumption is likely to be between 25-40 litres per person per day. Therefore, it is easy to establish flat rates for water and thus avoid the costly and inefficient business of separate water payment collection.

8.7 Advantages and Disadvantages

Main advantages of the sewered pour flush toilet are:-

1. possible location inside the house
2. no odour or fly and mosquito breeding
3. minimal risks to health
4. low annual costs
5. ease of construction and maintenance
6. low water consumption compared with the conventional system.

Main disadvantages:-

1. sensitive to periodic water shortages
2. not suited for people who use bulky items for anal cleansing.

Recommended use in Kenya.

For those areas where in-house toilets should be provided and where bulky items will not be used for anal cleansing. It is, therefore, ideally suited for those people who use water for anal cleansing.

8.8 Basic data and design criteria for the model study

Water supply

- Every plot is connected to individual water supply.
- One Fordilla valve and one pour flush latrine on every plot.
- The septic tank is shared with the neighbour.
- Individual water connections are not metered, however branch connections are metered.
- Only front services are considered.
- No individual water storage is considered (see Figure 20).
- A 4" UPVC water supply is assumed to be located along one of the main streets.
- The minimum head at the point of connection under peak demand conditions is known to be about 25 metres. (35 psi).
- The minimum allowable pressure at the taps is 20 metres, thus allowing a headloss of 5 metres across the distribution network.
- Extra flow capacity for fires is not considered.
- The water distribution network is a combination of looped and branched networks. (see Figure 21).
- The individual house connection is of ½" gal. iron.
- The connection to two plots is ½" polyethylene.
- Pipe materials greater than ½" are polyethylene only.
- Gate valves are used for every branch and parts of the loop.
- Every plot is provided with a Fordilla valve with no water meter.
- Water consumption per person per day is assumed to be 40 litres.
- The peak hourly flow is assumed to be 3 times greater than the average flow for 24 hours.

Sewage disposal (See Figure 22)

- The average sewage flow is considered to be 80% of the water supply.

- The peak hourly flow is considered to be 2 times greater than the average flow.
- The first compartment of the septic tank is calculated on the basis of 0.12 m^3 per user and the second compartment on 0.02 m^3 per user with a minimum volume of 0.5^3. Total tank volume per two plots is therefore 36 x 0.12 + 36 x 0.02 = 5 m^3.
- The emptying cycle is taken as two years.
- Individual plot connections (up to 4 plots) is by 40 mm UPVC sewer connected by Y branches.
- Main laterals are 63 mm UPVC.
- Distances between rodding points are not greater than 50 metres and distances between manholes are not greater than 150 metres.
- Manhole covers are heavy duty.
- The minimum velocity to retard settling of sediment is assumed to be 0.3 metres/second but may go as low as 0.15 metres/sec for the first 50 metres of every upper branch.
- Depth of sewer is a minimum of 1.20 metres under roads.
- Every tank is vented by a 75 mm g i pipe.
- Wastewater drains via a gulley trap into the second compartment.

Sewage Treatment

Mean lowest monthly temperature 17^0

Ultimate design flow 80% x 320 x 18 x 0.03= 138 m^3 daily

Maximum permissible surface loading 220 kg/ha/day.

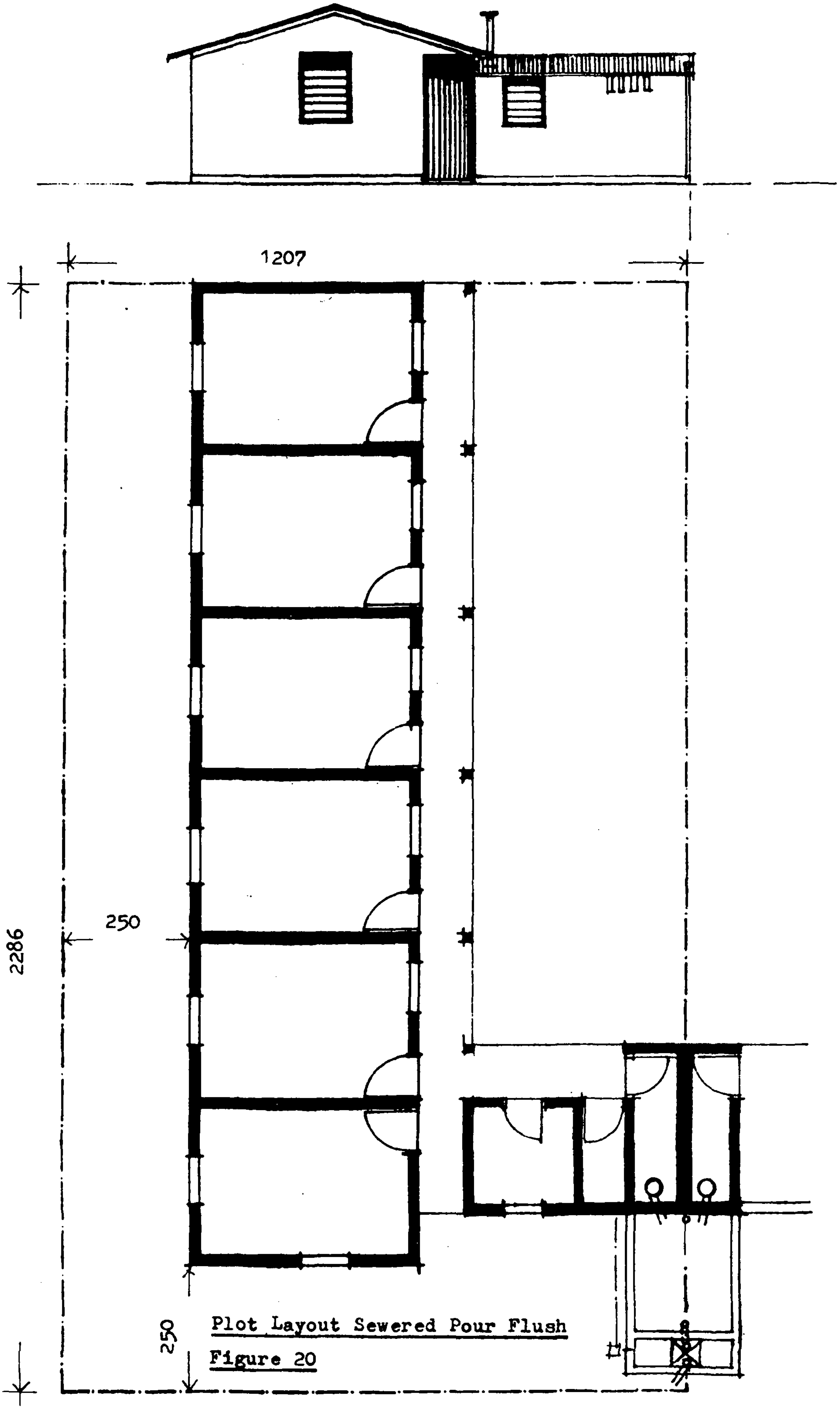
Daily per capita BOD contribution 40 grams

Effluent flow of septic tank 10^7 faecal coliform per 100 ml.

Permissable effluent flow from ponds is faecal coliform less than 100 per 100 ml.

Calculations are based on the formulas as presented in "Sewage Treatment in Hot Climates" (Mara 1976)

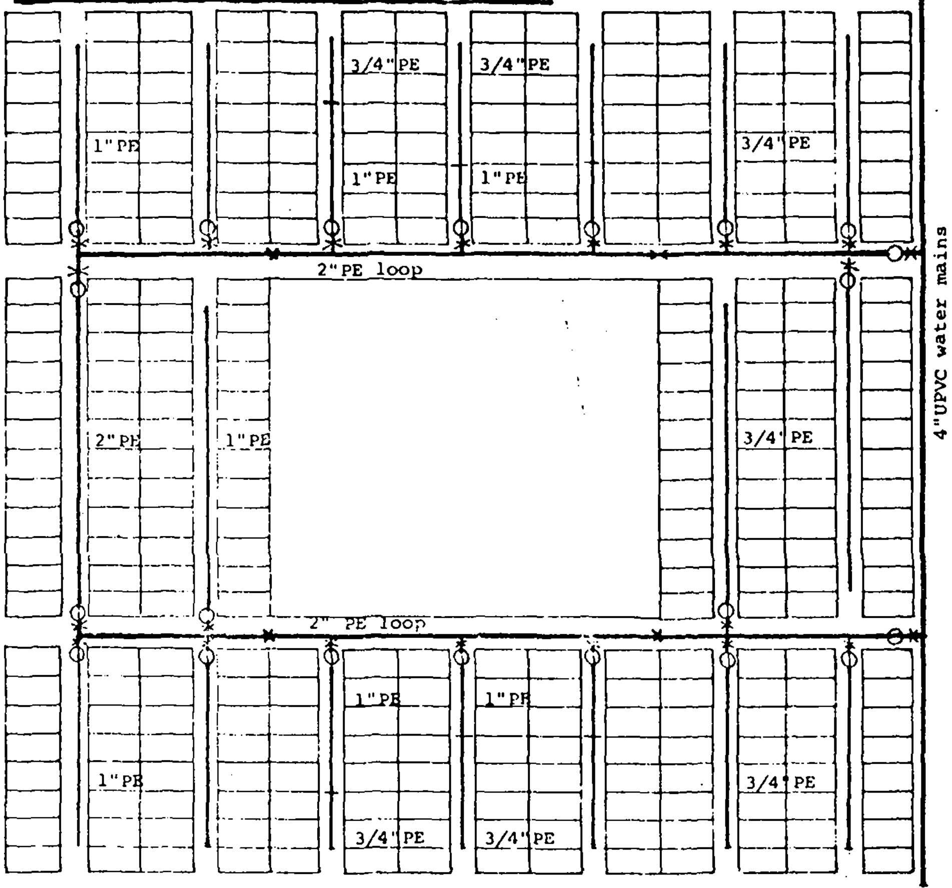
Size of	anaerobic pond	690 m^3	230 m^2
	facultative pond	3876 m^3	2584 m^2
	maturation pond	966 m^3	644 m^2
	maturation pond	966 m^3	644 m^2
	Total	6498 m^3	



Plot Layout Sewered Pour Flush

Figure 20

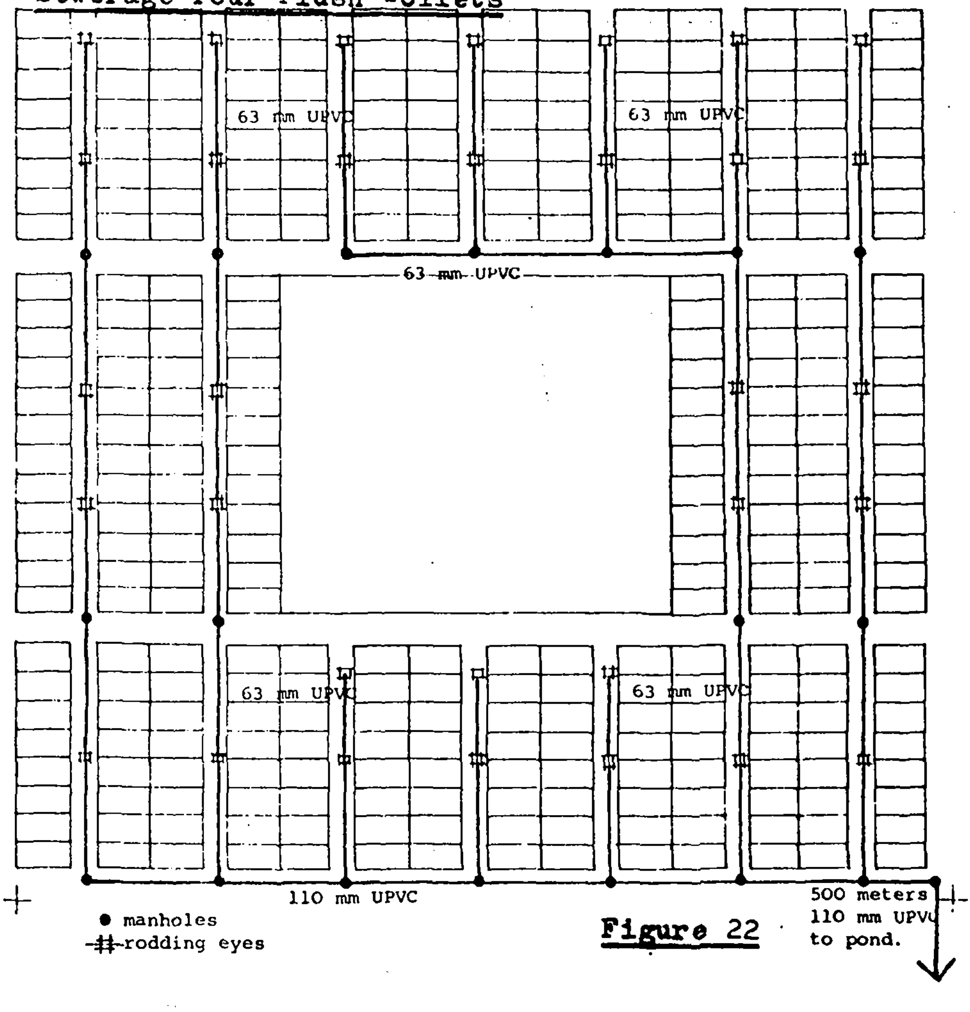
Water Supply Pour Flush Toilets



O water meter
X gate valves

Figure 21

Sewerage Pour Flush Toilets



● manholes
-#- rodding eyes

Figure 22

Sewered Pour Flush Toilets
Accounting Prices

,COSTS PER PLOT.

	ON PLOT COSTS	WATER SUPPLY pipes/fitt.	meters	SEWAGE COLLECTION	SEWAGE TREATMENT
Materials					Land costs
-local	2,270	81	76	372	
-imported (x 1,4)	791	126	212	370	103
Labour					Construction
-skilled	308	27	3	69	2,031
-unskilled	815	42	2	213	
Subtotal	4,184	276	293	1,026	2,134
Engineering design	209	29	--	51	106
Total	4,393	305		1,077	2,240
Yearly maintenance	41	12		10	19
Lifetime years	40	40	20	40	40

Every two years exhaust service , kshs 31,-.

COSTS PER SCHEME.

	ON PLOT COSTS	WATER SUPPLY pipes/fitt.	meters	SEWAGE COLLECTION	SEWAGE TREATMENT
Materials					Land costs 0.82hA x
-local	726,400	25,960	24,210	119,069	Kshs 40,000 =
-imported (x 1,4)	253,120	40,362	67,788	118,406	Kshs 32,816
Labour					Construction
-skilled	98,400	8,576	1,080	21,957	6,498m^3 x Kshs 100 =
-unskilled	260,800	13,564	766	68,741	649,800
Subtotal	1,338.720	88,462	93,844	328,173	682,616
Engineering design	66,936	9,153	--	16,408	32,490
Total	1,405,656	191,459		344,581	715,106
Yearly maintenance	13,000	3,840		3,281	6,130
Lifetime years	40	40	20	40	40

Every two years ,exhaust service, kshs 9,929.

SEWERED POUR FLUSH TOILETS

ACCOUNTING COSTS (in 1000 kshs) and PERSONS SERVED(Constant base year prices,1979)

year	on plot costs		water supply		sewage collec.		sewage treat.		total	persons
	cap	o&m	cap	o&m	cap	o&m	cap	o&m		
xxxx	xxxx	xxx	xxxx	xxx	xxxx	xxxx	xxxx	xxx	xxxxxx	xxxxx
01	702	0	96	0	172	0	374	0	1344	0
02	702	0	96	0	172	0	341	0	1311	0
03	0	12	0	4	0	3	0	6	25	1280
04	0	12	0	4	0	3	0	6	25	1920
05	0	12	0	4	0	3	0	6	25	2560
06	0	12	0	4	0	3	0	6	25	3200
07	0	12	0	4	0	13	0	6	35	3740
08	0	12	0	4	0	3	0	6	25	4480
09	0	12	0	4	0	3	0	6	25	5120
10	0	12	0	4	0	13	0	6	35	5760
11	0	12	0	4	0	3	0	6	25	5760
12	0	12	0	4	0	13	0	6	35	5760
↓										
22	0	12	94	4	0	13	0	6	129	5760
23	0	12	0	4	0	3	0	6	25	5760
24	0	12	0	4	0	13	0	6	35	5760
↓										
39	0	12	0	4	0	3	0	6	25	5760
40	0	12	0	4	0	13	0	6	35	5760
41	0	12	0	4	0	3	0	6	25	5760
42	0	12	0	4	0	13	0	6	35	5760
					Total Sum of present values				2729.72 /	30744

9.0 THE SEWERED AQUA PRIVY TOILET

The conventional aqua-privy toilet consists essentially of a squatting plate situated immediately above a small septic tank which discharges its effluents to an adjacent soakaway. The squatting plate has an integral drop-pipe of diameter 100-150 mm, the bottom of which is 10 cm below the water level in the tank. In this manner a simple water seal is achieved. In order to preserve the water seal, which is necessary to prevent fly and odour nuisance, it is essential that the tank is completely watertight and the user should add water to it daily, sufficient to replace the losses.

9.1 Conventional Aqua Privy Toilet

This conventional aqua-privy toilet has more or less become a failure in Africa for several reasons (Feachem 1979). First of all this type of toilet has often been placed in locations where there is no household water supply. Users have been reluctant to carry sufficient water - often because of social attitudes - with a result that the water level drops and the toilet becomes an open pit with all the related health hazards (de Kruijff 1978). Secondly, tank and effluent disposal pipes are often of very poor construction and design. If the tank cracks, the waterseal cannot be maintained. Furthermore, the effluent drop pipe is often too short or too long. A short pipe will carry the scum layer in to the soakaway pit; a long pipe will be blocked easily by the rising sludge.

Thirdly, since many tanks have been only single compartment design, flocculated sludge can be carried over to the soakaway pit particularly if the tanks are not regulatly emptied. The soakaway becomes clogged and it is very difficult to rectify this problem once it has occurred. Desludging of the tank will not help and a new soakaway pit has to be dug.

For these reasons, conventional aqua privy toilets cannot be recommended as a viable sanitation alternative. However, the combination of several improvements can safeguard against such failures.

9.2 Improved Aqua Privies

Aqua privies should only be built if water supply on the plot is provided. The waste water and sullage water should be automatically disposed of into the tank thus maintaining the water seal.

The tank should be made in two compartments, similar to the sewered pour flush toilet system. Sullage water should be disposed off into the second compartment, which is connected in such a way with the first compartment that the waste water can overflow into the first compartment to ensure maintenance of the waterseal. See Figure 23.

Sewered Aqua Privy Toilet

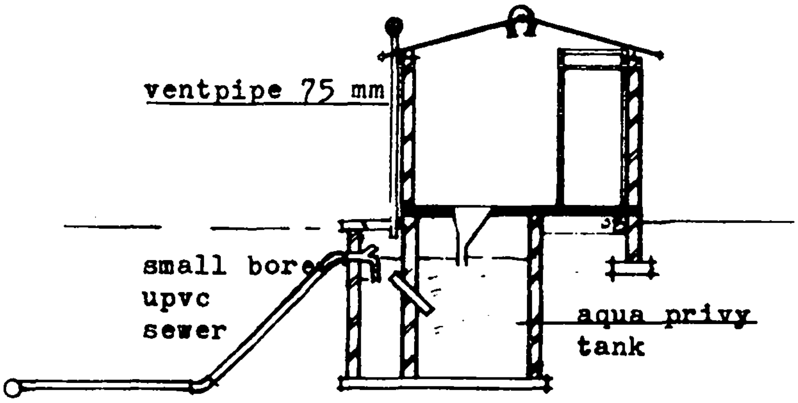


Figure 23

Effluent disposal is similar to the sewered pour flush toilet. (Whilst individual soakaways are a viable option where conditions are suitable, they are not considered in this study.)

The effluent is disposed off into the 63 mm lateral sewers to the sewage treatment ponds identical to the sewered pour flush toilet system.

The construction of an aqua privy tank is more critical than that for the pour flush toilet tank, since it will be very sensitive to cracks. Therefore, extreme care should be taken if this system is built on expansive soils such as black cotton.

The sewered aqua privy is, however, superior in performance to the sewered pour flush toilet in those areas where bulky anal cleansing materials are used. Furthermore, it can absorb temporary water shortages of a day or two before the system starts malfunctioning.

9.3 Basic data and design criteria for the model study

- Every plot is provided with individual water supply.
- One Fordilla valve is provided on the plot with one aqua privy. The septic tank is shared with one neighbouring plot.
- Individual water connections are not metered however branch connections are.
- No individual water storage is considered. (See Figure 24).

Water Supply

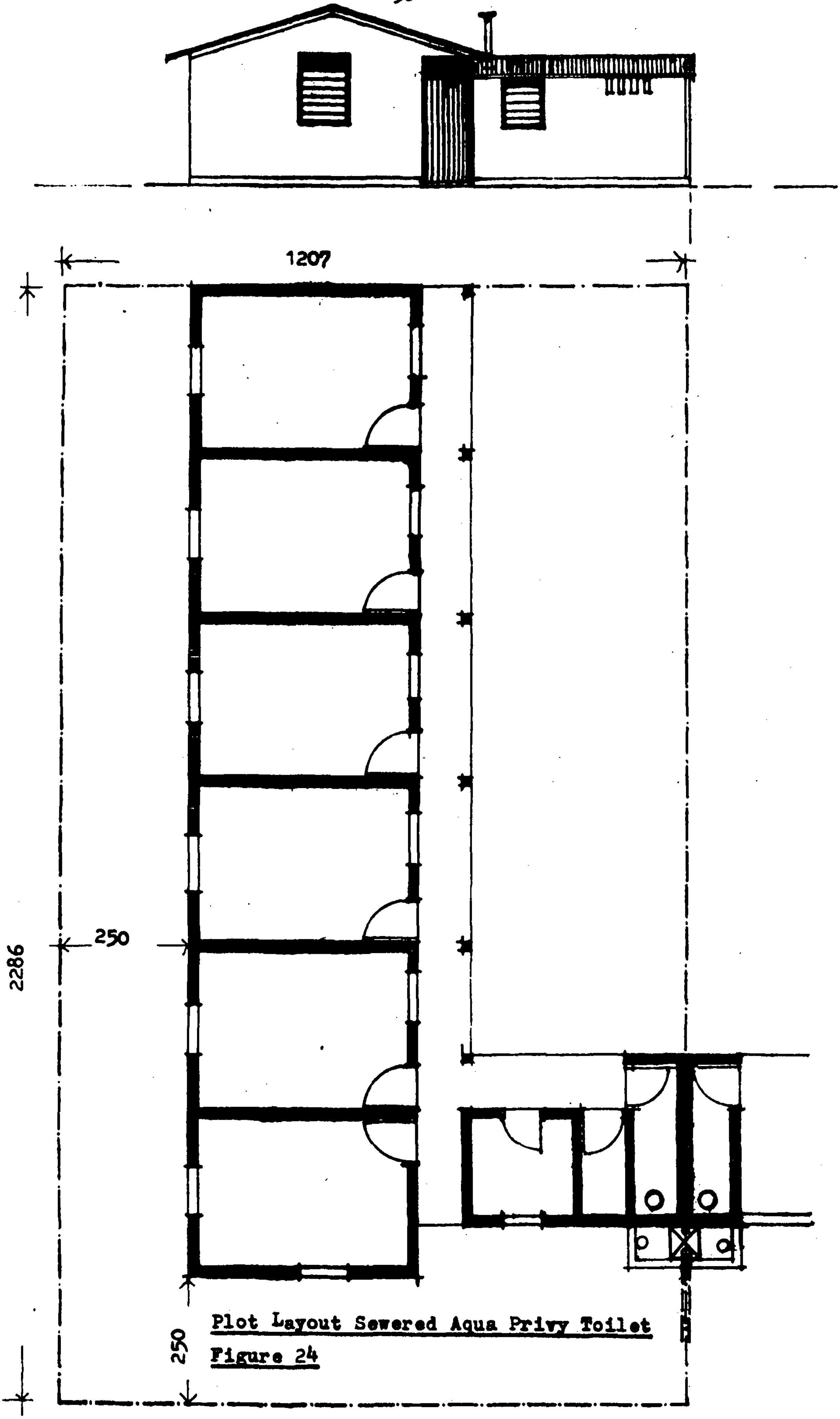
- A 4" UPVC water supply main is assumed to be located along one of the main streets.
- The minimum head at the point of connection under peak demand conditions is known to be about 25 metres (35 psi).
- The minimum allowable pressure at the taps is 20 metres, thus allowing a headloss of 5 metres across the distribution network.
- Extra flow capacity for fires is not considered.
- The water distribution network is a combination of looped and branched network. (See Figure 25).
- The individual house connection is of ½" gal. iron.
- The connection to two plots is by ½" polyethylene.
- Pipe materials of ½" upwards are polyethylene materials only.
- Gate valves are provided for every branch and parts of the loop.
- Every plot is connected by a Fordilla valve alone with no meter.
- Water consumption per person per day is assumed to be 30 litres.
- The peak hourly flow is assumed to be 3 times greater than the average flow.

Sewage disposal (See Figure 26)

- The average sewage flow is considered to be 80% of the water supply. The peak hourly flow is considered to be 2 times greater than the average flow. The first compartment of the tank is calculated on the basis of 0.120 m^3 per user and the second compartment on 0.02 m^2 per user. The total tank volume for two plots is therefore 36 x 0.12 + 36 x 0.02 = 5 m^3.
- Individual plot connections up to 4 plots by 40 mm UPVC sewer, are connected by Y branches.
- Main laterals are 63 mm UPVC.
- Distances between rodding points is not greater than 50 metres, and distances between manholes not greater than 150 metres.
- Manhole covers are heavy duty.
- The minimum velocity to retard settling of sediment is assumed to be 0.3. metres/second but may go as low as 0.15 metres/sec for the first 50 metres of every upper branch.
- Depth of sewer is a minimum of 1.20 metres under roads.
- The tank is vented by 75 mm g.i. pipe.
- Waste water drains via a drop pipe into the second compartment.

Sewage Treatment

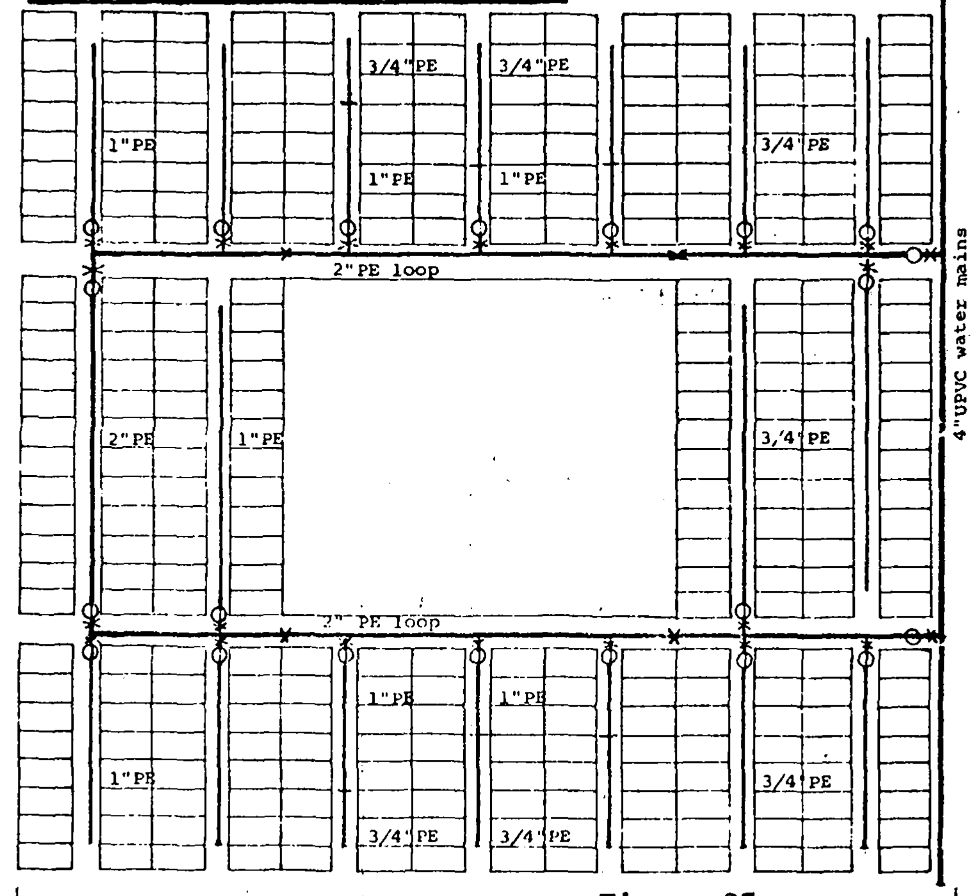
- Similar as pour flush sewered toilets.



Plot Layout Sewered Aqua Privy Toilet

Figure 24

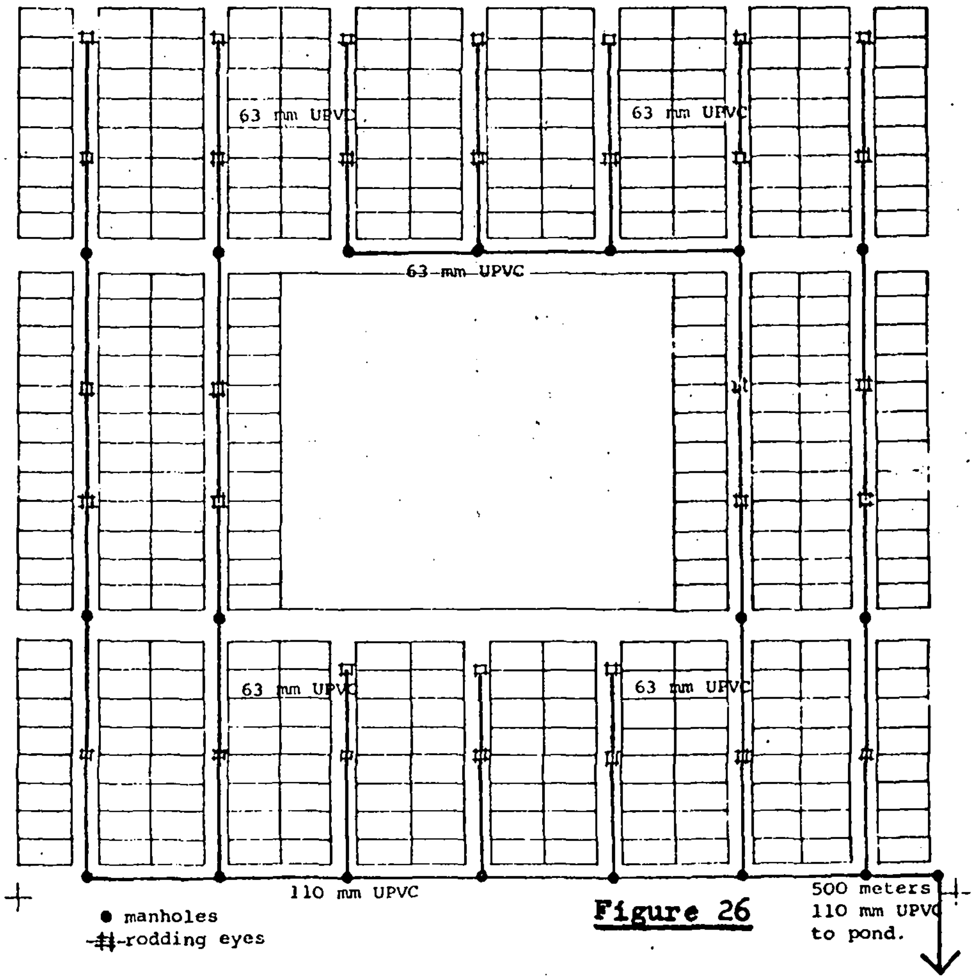
Water Supply Aqua Privy Toilets



O water meter
X gate valves

Figure 25

Sewerage Aqua Privy Toilets



● manholes
-‡-rodding eyes

Figure 26

Sewered Aqua Privy Toilets
Accounting Prices

COSTS PER PLOT

	ON PLOT COSTS	WATER SUPPLY pipes/fitt.	meters	SEWAGE COLLECTION	SEWAGE TREATMENT
Materials					
-local	2,008	81	76	372	Land costs
-imported (x 1,4)	655	126	212	370	103
Labour					Construction
-skilled	312	27	3	69	2,031
-unskilled	858	42	2	215	
Subtotal	3,833	276	293	1,026	2,134
Engineering design	192	29	--	51	106
Total	4,025	305		1,077	2,240
Yearly maintenance	37	12		10	19
Lifetime years	40	40	20	40	40

Every two years exhaust service, kshs 31,-.

COSTS PER SCHEME

	ON PLOT COSTS	WATER SUPPLY pipes/fitt.	meters	SEWAGE COLLECTION	SEWAGE TREATMENT
Materials	642,560	25,960	24,210	119,069	0.82hA x Kshs 40,000 =
-local					
-imported (x 1,4)	209,664	40,362	67,788	118,406	Kshs 32,816
Labour					Construction
-skilled	99,840	8,576	1,080	21,957	6.498m³ x Kshs 100 =
-unskilled	274,560	13,564	766	68,741	649,800
Subtotal	1.226,624	88,462	93,844	328,173	682,616
Engineering design	61,331	9,153	--	16,408	32,490
Total	1.287,955	191,459		344,581	715,106
Yearly maintenance	11,840	3,840		3,281	6.130
Lifetime years	40	40	20	40	40

Every two years exhaust service, kshs 9,929.

SEWERED AQUA PRIVY TOILETS

ACCOUNTING COSTS (in 1000 kshs) and PERSONS SERVED. (Constant base year prices, 1979)

year	on plot costs		water supply		sewage collec.		sewage treat.		total	persons
	cap	o&m	cap	o&m	cap	o&m	cap	o&m		
xxxx	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxxxx	xxxxx
01	644	0	96	0	172	0	374	0	1286	0
02	644	0	96	0	172	0	341	0	1253	0
03	0	12	0	4	0	3	0	6	25	1280
04	0	12	0	4	0	3	0	6	25	1920
05	0	12	0	4	0	3	0	6	25	2560
06	0	12	0	4	0	3	0	6	25	3200
07	0	12	0	4	0	13	0	6	35	3740
08	0	12	0	4	0	3	0	6	25	4480
09	0	12	0	4	0	3	0	6	25	5120
10	0	12	0	4	0	13	0	6	35	5760
11	0	12	0	4	0	3	0	6	25	5760
12	0	12	0	4	0	13	0	6	35	5760
↓										
22	0	12	94	4	0	13	0	6	129	5760
23	0	12	0	4	0	3	0	6	25	5760
24	0	12	0	4	0	13	0	6	35	5760
↓										
39	0	12	0	4	0	3	0	6	25	5760
40	0	12	0	4	0	13	0	6	35	5760
41	0	12	0	4	0	3	0	6	25	5760
42	0	12	0	4	0	13	0	6	35	5760
					Total sum of present values				2619.94 /	30744

10.0 REEDS ODOURLESS EARTH CLOSET

This type of toilet is an improved version of the ordinary pit latrine. The simple unimproved pit latrine has two major disadvantages: it usually smells and flies or mosquitoes breed in it. These disadvantages have led to the rejection of the pit latrine in favour of far more costly devices. However, fly and mosquito breeding and smells are almost completely absent in improved ventilated pit latrines. The construction of ordinary unimproved pit latrines should be stopped immediately and latrines which are in use should be converted to ventilated pit latrines.

10.1 ROECs design

Reeds Odourless Earth Closet is based on a offset pit. (See Figure 27). The main advantages are the following:

1. The pit is larger and thus has a longer lifespan.
2. The pit can easily be emptied, so that the toilet becomes a permanent facility.

Reeds Odourless Earth Closet

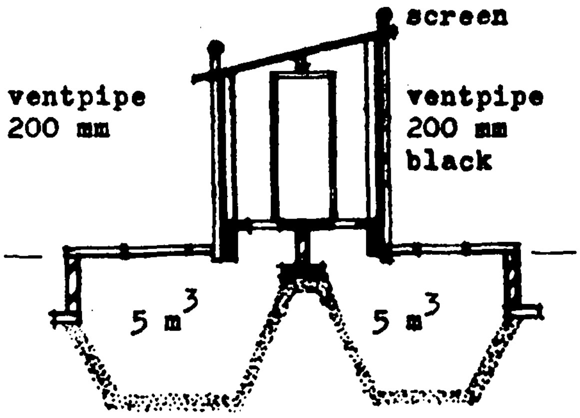


Figure 27

10.2 Ventilation

A black ventpipe (minimum dimensions of 200 mm) is connected to the pit. This ventpipe should be located on the sunny side of the toilet or where this is not possible, the pipe should protrude at least 60 cm above the toilet superstructure.

The air in the ventpipe will thus heat up and so create a vigorous updraft with a corresponding downdraft through the squatting plate. Any odors emanating from the pit contents will be therefore exhausted away via the ventpipe.

Furthermore, this type of ventilation assists in reducing fly and mosquito breeding. The strong draft discourages adult flies and mosquitoes from entering and laying eggs. In spite of this, however, some eggs will be laid into the excreta, but if the vent pipe is large enough to let light into the pit (and the inside of the superstructure is sufficiently dark) the adults will try to escape via the ventpipe. The top of the ventpipe is, therefore, covered by a gauze screen so that the flies are prevented from escaping and will die in the pit. The ventpipe and the gauze screen should be made out of corrosion resistant material.

10.3 Pits

ROECs have the advantage that the pits are partly offset and, therefore, can be very large. For purposes of design, the required capacity of a dry pit should be taken as 0.06 m^3 per person per year. This figure should be increased by 50% if resistant anal cleansing materials are used. The pit contents can be safely dug out after it has been sealed in the ground at least for two years.

After this time, the pit contents will contain no viable excreted pathogens whatsoever and can be handled by manual labour.

For this type of service, a second ROEC has to be built when the first one becomes full. After the second one is full, the first one can be used after emptying.

10.4 Maintenance

The maintenance requirements for ROECs are very simple, and consist principally of keeping the squatting plate and superstructure clean. Construction materials are standard and none generally has to be imported. Much of the construction can be done by the users by self help.

The cost of the superstructure will be the biggest component particularly because over a ten years period, two superstructures should be built.

The design of a simple moveable superstructure (for example prefabricated concrete panels) has advantages. The design in the model is based on one superstructure which gives access to the two pits. Every two years a council controlled emptying service should be provided. One pit should be emptied and thereafter the squatting plates should be shifted which, as a result, will seal off the used pit.

10.5 Upgrading possibilities

Because ROECs have no water requirements, (only a small amount is needed for cleaning of the plate) they can be used on sites with communal waterpoints.

In this synthetic study, it is assumed that communal waterpoints are provided for the first 8 years. The waterpoints are based on an improved design incorporating washing slabs so that people need only to carry to their houses that amount of water needed for personal cleaning and for cooking purposes.

In year 10 the system is upgraded to individual household water supply services by means of automatic self closing taps.

10.6 Sullage water disposal

If soils are sufficiently permeable, the sullage water can be disposed off on the plot. In this case, sullage water first passes a settlement tank so that solids are to be kept out of the effluent. The rate of infiltration of sullage water pretreated in this way is approximately three times higher than that of conventional septic tank effluent.

Soakaway pits

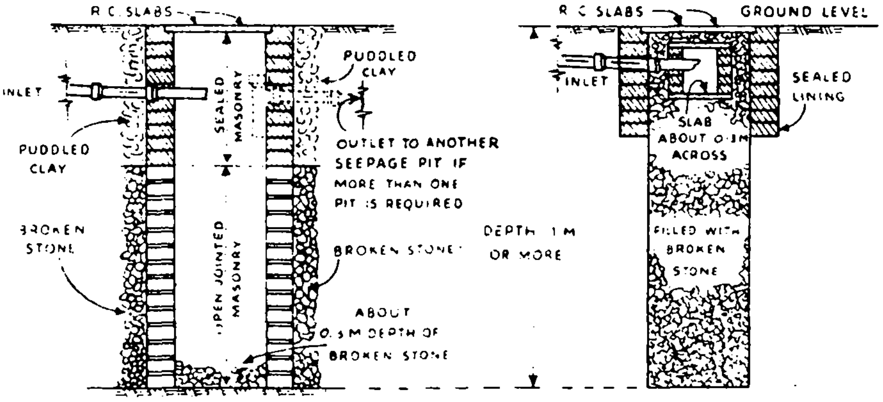


Figure 28 (**source Feachem 1978**)

For the purpose of design, a figure of 30 litres/m^2 of side-wall area per day should be used. A suitable design of a seepage pit is shown in Figure 28.

If soils are impermeable, sullage water can be disposed off in surface water drains. However, this is a potential health risk particularly in promoting of breeding of mosquitoes, unless the drainage construction is of a high standard and well maintained. This option is, therefore, not included in the calculations. For this situation the disposal of sullage water is achieved via a settlement tank into a small bore sewer system similar to that of the sewered pour flush toilet system.

The BOD of the sullage is still high, approximately 300 mg/litre is assumed. This sullage water is treated in one facultative pond to reduce the level to 60 mg/litre. It will contain some excreted pathogens, assumed to be about 4000 coliforms per 100 ml. This amount can be safely reduced to below 100 coliforms per 100 ml. in a facultative pond.

10.7 Advantages and disadvantages

The main advantages of ROECs are:-

1. very low annual costs
2. extreme ease of construction (maximum self-build)
3. absence of odour and minimal fly and mosquito nuisance
4. minimal water requirements
5. low level of municipal involvement
6. minimal risks to health
7. good potential for subsequent upgrading to, for example, pour flush toilets.

The main disadvantages are:-

1. unsuitable for very high density development
2. groundwater pollution is possible if water is drawn from shallow wells
3. separate requirements for sullage water disposal
4. cannot be built in rocky areas.

10.8 Basic data and design criteria for the model study - Phase 1

- Water supply by communal taps in the form of unsupervised standposts equipped with Fordilla valves and washing slabs.
- Every plot will have one ROEC. (See Figure 29).

Water supply

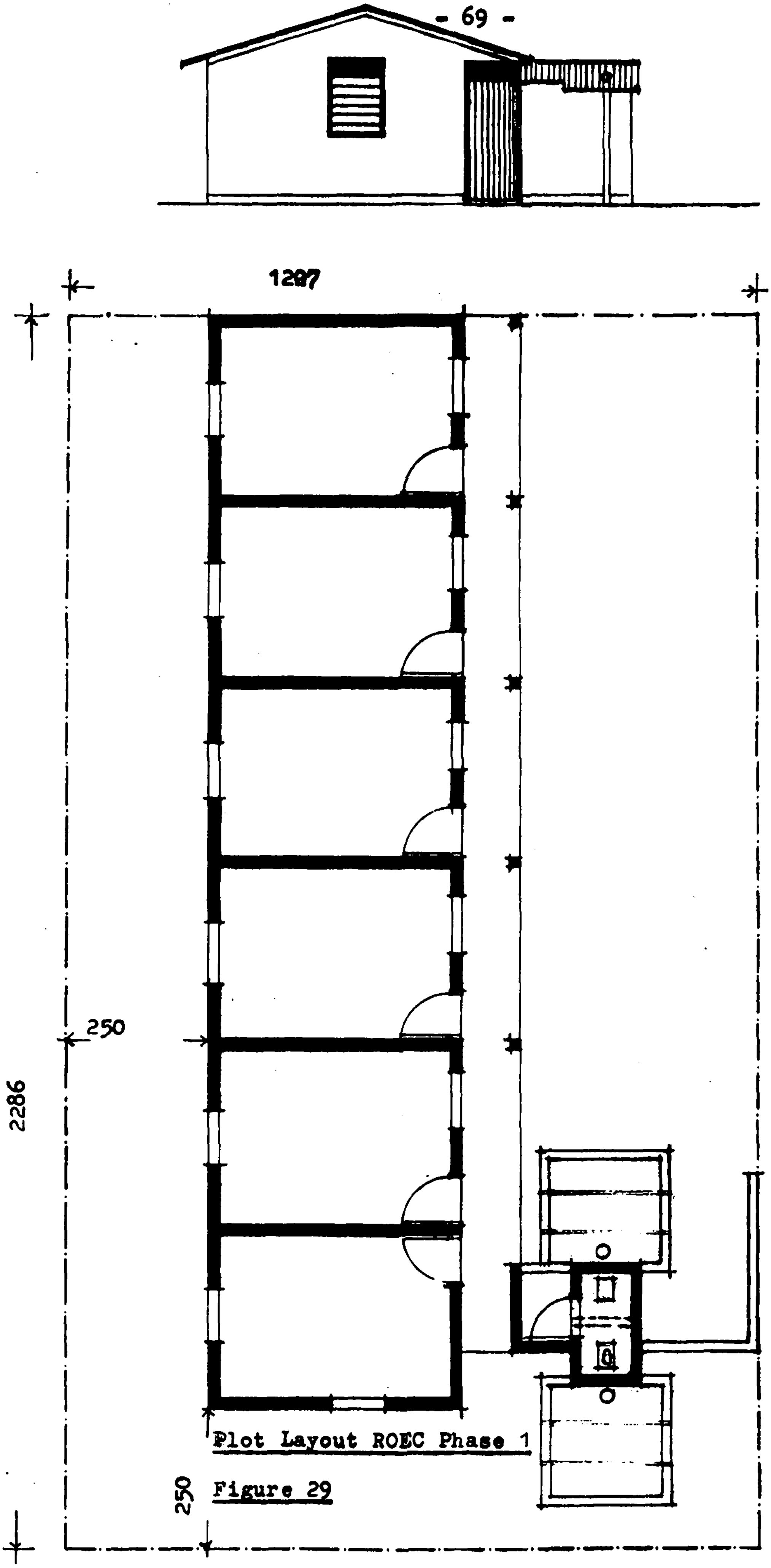
- A 4" UPVC water supply is assumed to be located along one of the main streets.
- The minimum head at the point of connection under peak demand conditions is known to be about 25 metres (35 psi).
- The minimum allowable pressure at the taps is 20 metres, thus allowing a headloss of 5 metres across the distribution network.
- Extra flow capacity for fires is not considered.
- The water distribution network is a branched system (SeeFigure 30).
- Dimension are calculated for stage 2.
- Max. walking to the public tap is 200 metres.
- One public tap (Fordilla valve) and one washing slab is provided for every 12 plots. (See Figure 31).
- The public water points are metered.
- Maximum plot occupancy during stage 1 is assumed to be 50% of the ultimate plot occupancy.
- Water consumption is assumed to be 20 litres per person per day.
- The peak hourly flow is considered to be 3 times greater than the average flow for 24 hours.

Sewage disposal

- Excreta disposal by means of Reeds Odorless Earth Closet.
- The emptying cycle is taken as 2 years and the design capacity as 0.1 m^3 per person per year The closet will

be closed when ¾ full.

- The volume of the pit is therefore 1.33 x 0.1 x 18 x 2 = 5 m^3.
- The pit is vented with a black vent pipe of 200 mm dimensions.
- Soakaway facilities should be provided at the communal water points. No individual soakaway facilities will be provided on plots.



Plot Layout ROEC Phase 1

Figure 29

Water Supply ROEC Phase 1

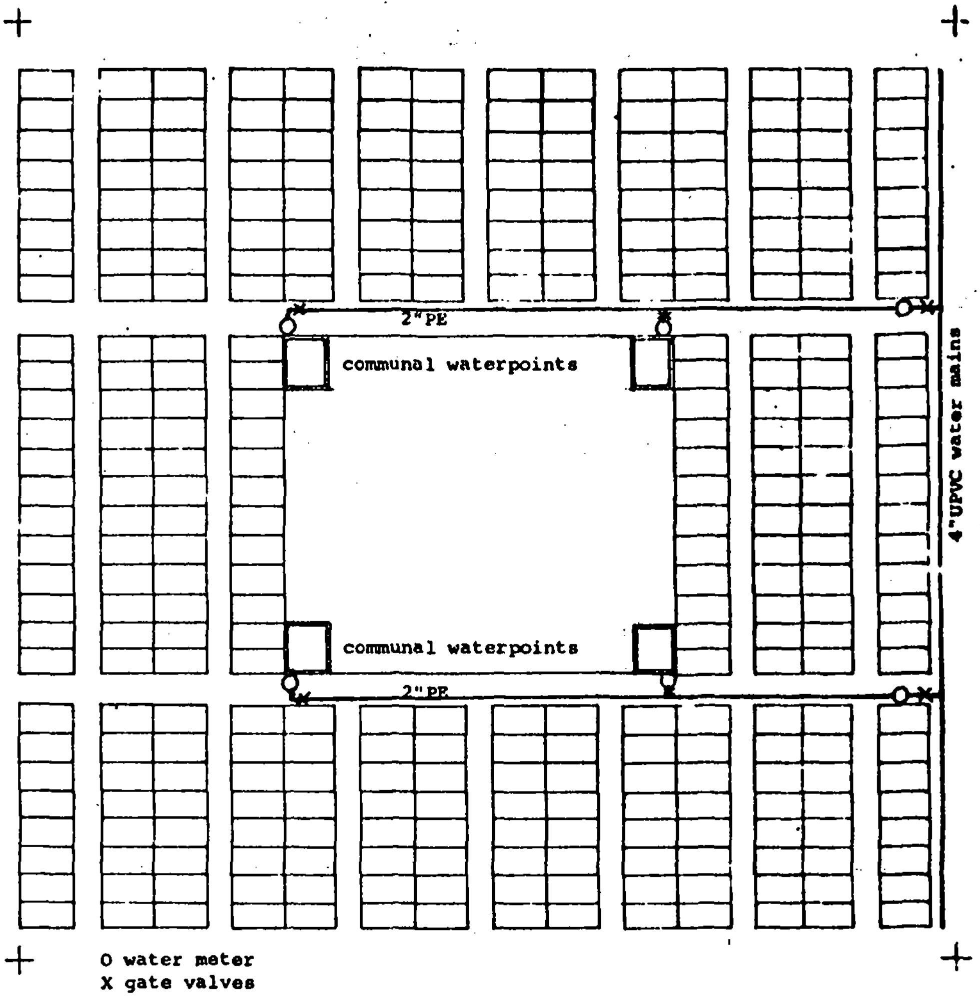
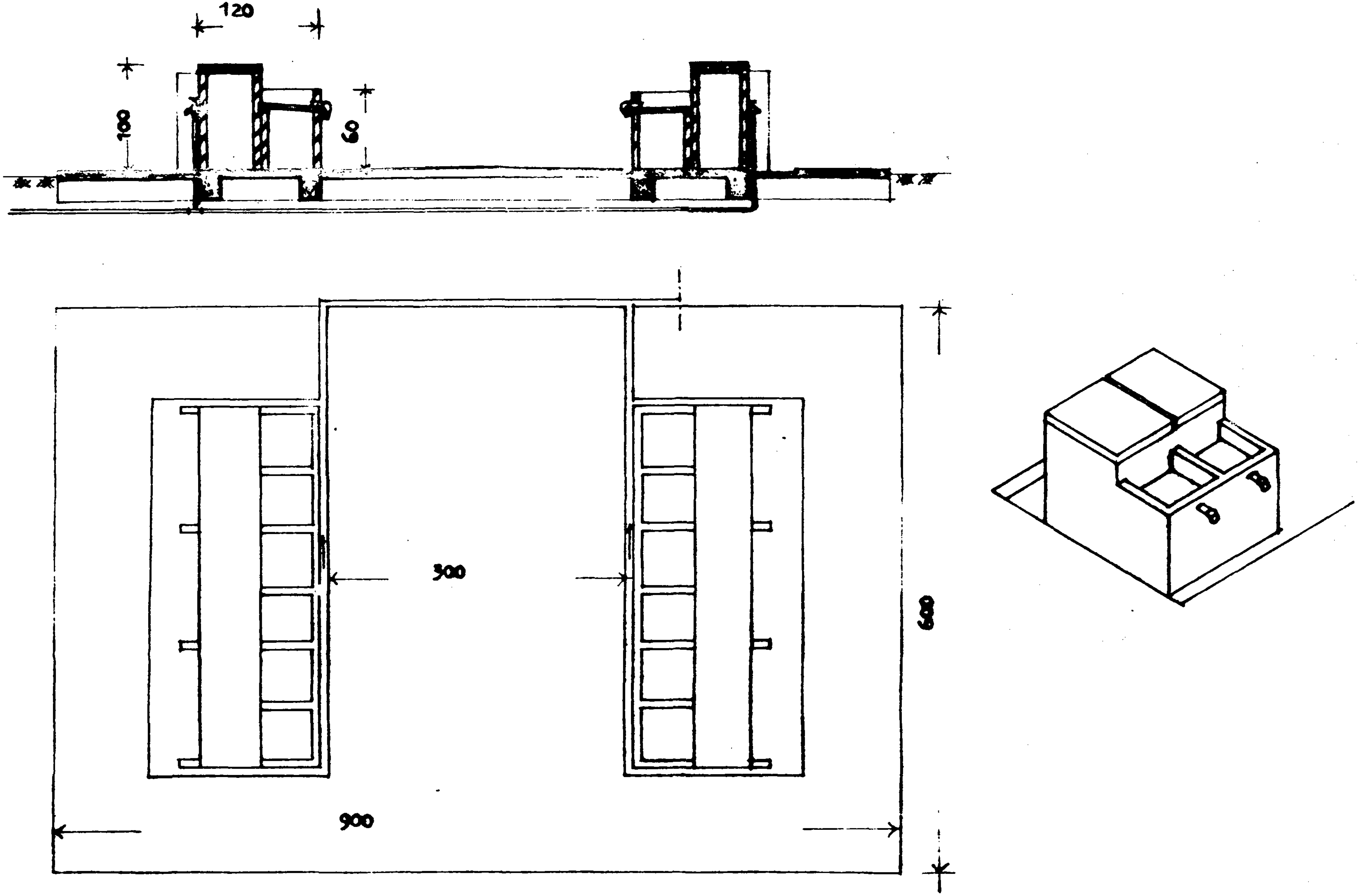


Figure 30



measurements in centimeters

Communal Waterpoints Figure 31

10.9 Basic data and design criteria for off site sullage disposal Phase 2

Reed Odorless Earth Closet

- Every plot is upgraded to individual water supply.
- One Fordilla valve tap and two ROEC's on every plot.
- Household sullage water disposal is by means of a settlement tank into small bore sewers. Full plot occupancy of 18 persons per plot is assumed. (See Figure 32).

Water supply

- The water distribution network is a combination of a looped and branched network. (See Figure 33).
- The individual house connection is considered to be of ½" gal. iron.
- The connections of two plot is by ½" polyethylene.
- Pipe materials greater than a ½" are polyethylene only.
- Gate valves are provided for every branch and parts of the loop.
- Every plot is supplied with a Fordilla valve with no water meter.
- Water consumption is assumed to be 30 litres per person per day.
- The peak hourly flow is assumed to be 3 times greater than the average flow for 24 hours.

Sewage disposal (See Figure 34)

- Excreta disposal is by Reed Odorless Earth Closets.
- Every plot is provided with two closets each with a volume of 5 m^3.
- The pits are vented with a black vent pipe of 200 mm.
- Household sullage disposal is via a settlement tank into a small bore sewer of 40 mm UPVC. Individual plot connections (up to four plots) is by 40 mm UPVC sewer and connected by Y branches. Main laterals are 63 mm.

- Distances between rodding points is not greater than 50 meters and distances between manholes not greater than 150 meters.
- Manhole covers are heavy duty.
- The minimum velocity to retard settling of sediment is assumed to be 0.3 meters/second but may go as low as 0.15 meters/sec for the first 50 meters of every upper branch.
- Depth of sewer is a minimum of 1.20 meters under roads.

Sewage treatment design criteria

Mean lowest monthly temperature 17^0

Ultimate design flow 138 m^3 daily

Maximum permissable surface loading 220 kg/ha/day

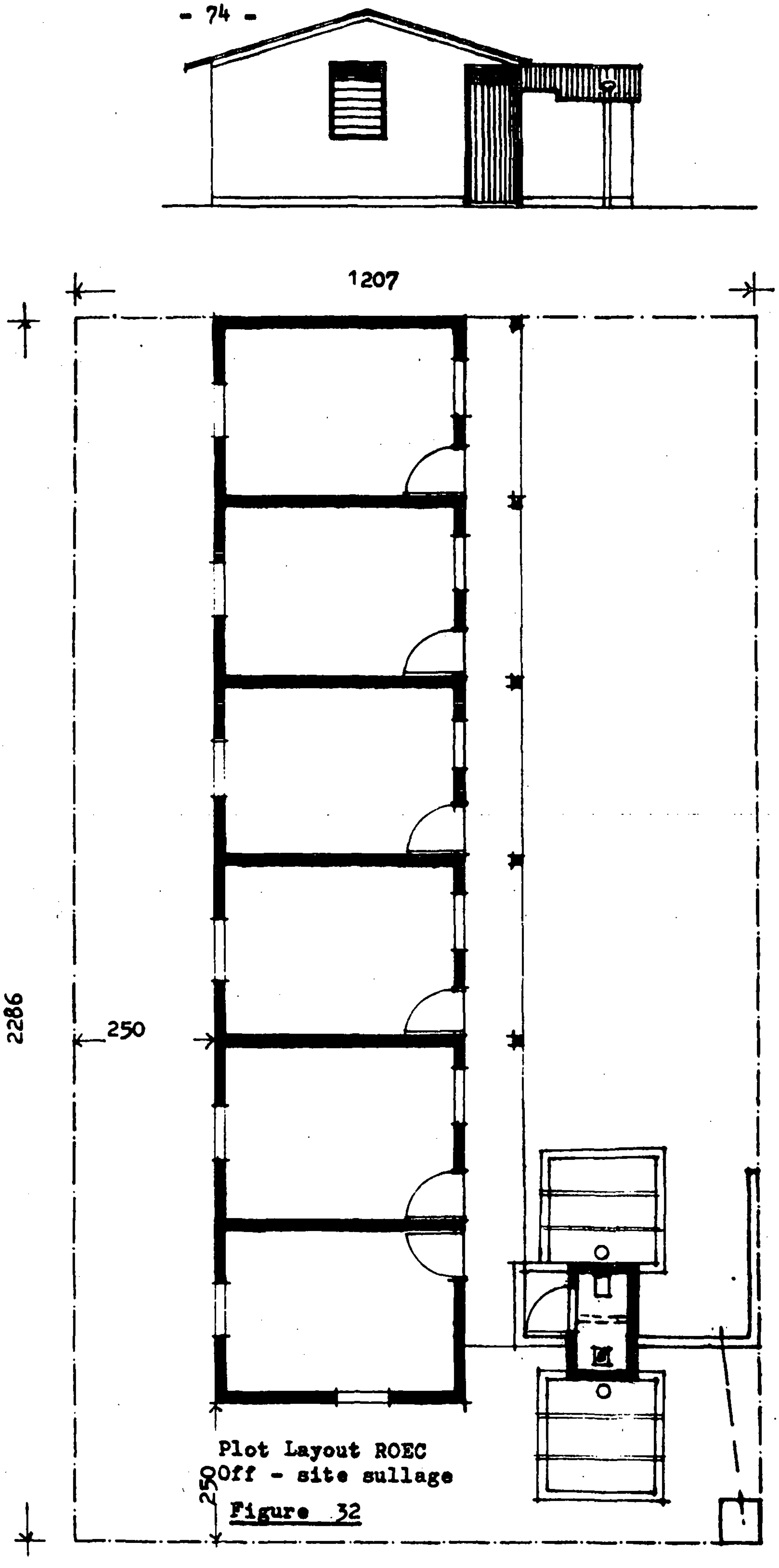
BOD effluent 300 mg /litre

Faecal coliform less than 4000 per 100 ml.

Permissable effluent flow from ponds is faecal coliform less than 100 per 100 ml.

Calculations are based on the formulas as presented in "Sewage treatment in Hot Climates" (Mara 1976).

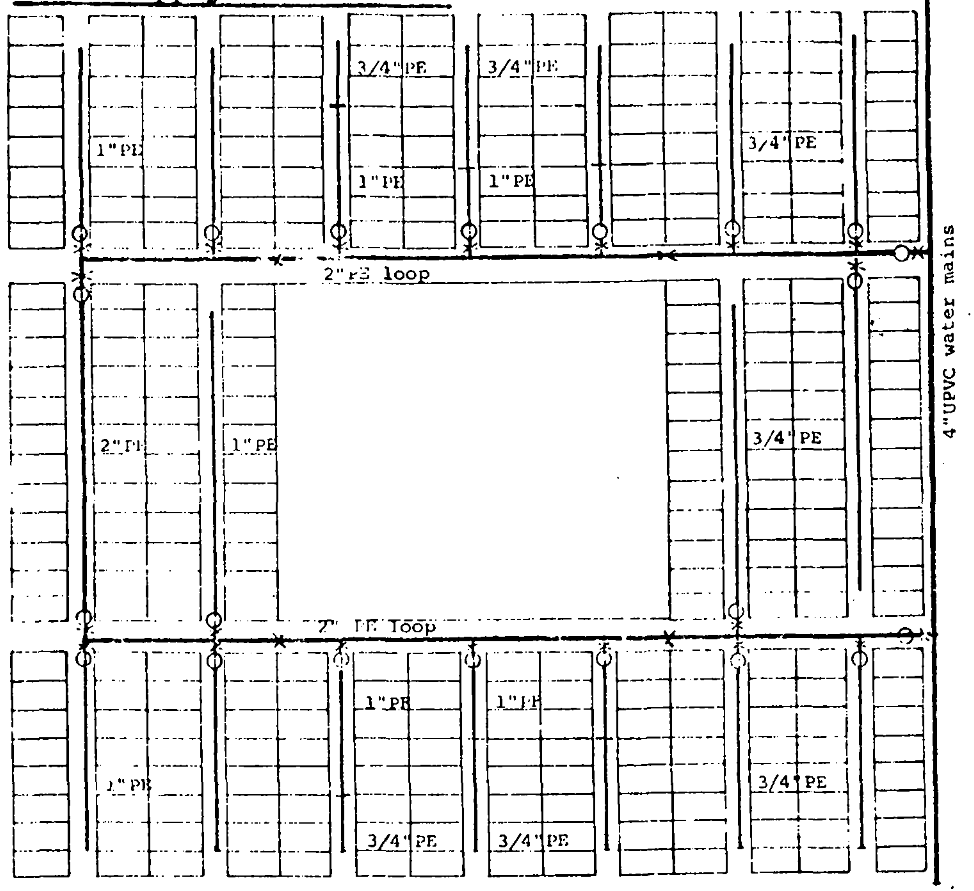
Size of facultative pond 2822 m^3; 1881 m^2



Plot Layout ROEC
Off - site sullage

Figure 32

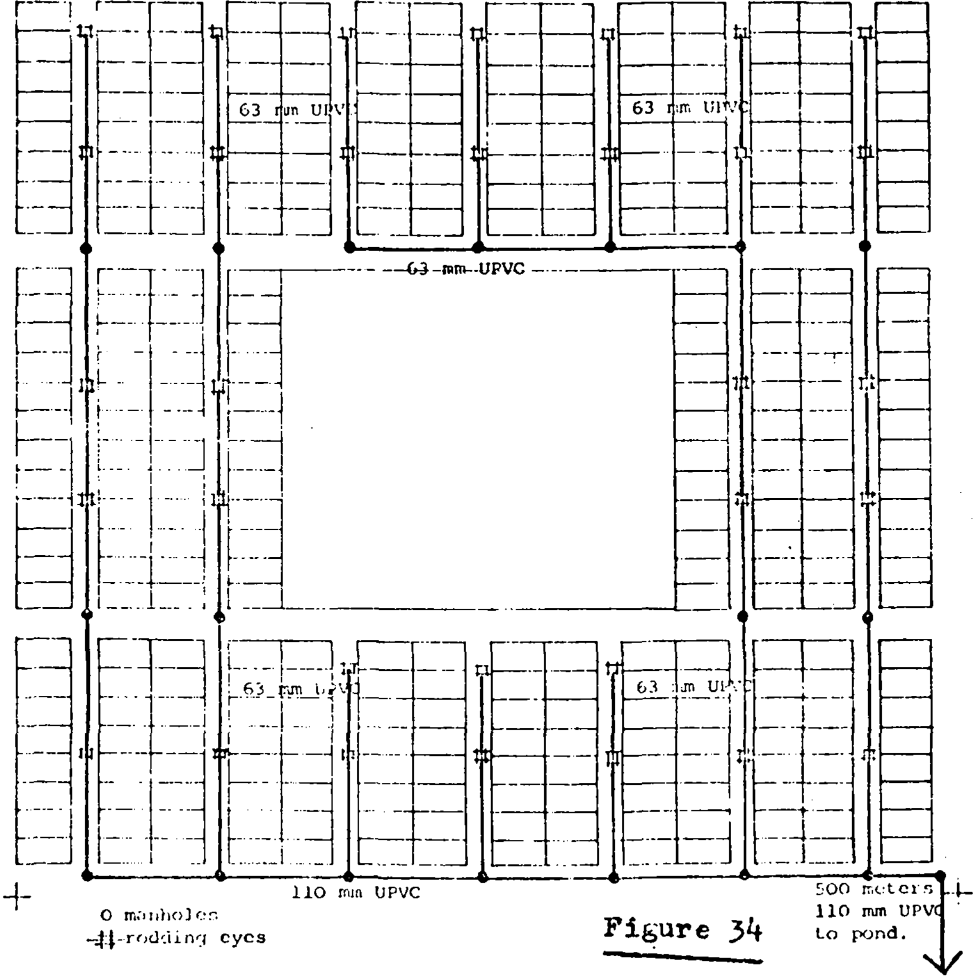
Water Supply ROEC Phase 2



O water meter
X gate valves

Figure 33

Off-site Sullage Disposal ROEC



O manholes
-‡‡-rodding eyes

Figure 34

ROEC Phase 1

Accounting prices

COSTS PER PLOT, ROEC Year 0

	ON PLOT COSTS	WATER SUPPLY		SEWAGE COLLECTION	SEWAGE TREATMENT
		pipes/fitt.	meters		
Materials					
-local	1,841	20	7		
-imported (x 1,4)	798	50	18		
Labour					
-skilled	217	8	1		
-unskilled	866	23	-		
Subtotal	3,722	101	26		
Engineering design	186	32	--		
Total	3,908	159			
Yearly maintenance	37	9	--		
Lifetime years	40	40			

ROECS are emptied after 4 years, then after 3 years and then every 2 years.
Emptying charges Kshs. 56,- per plot.

COSTS PER SCHEME, ROEC Year 0.

	ON PLOT COSTS	WATER SUPPLY		SEWAGE COLLECTION	SEWAGE TREATMENT
		pipes/fitt.	meters		
Materials					
-local	589,120	6,276	2,100		
-imported (x 1,4)	255,360	16,016	5,880		
Labour					
-skilled	69,440	2,476	1,120		
-unskilled	277,120	7,336	36		
Subtotal	1,191,040	32,104	8,136		
Engineering design	59,552	10,299	--		
Total	1,250,592	50,539			
Yearly maintenance	12,000	3,000	--		
Lifetime years	40	40	20		

ROECS are emptied after 4 years, then after 3 years and then every 2 years, emptying charges Kshs. 18,000,- per scheme.

ROEC Off-site sullage disposal

Accounting Prices

COSTS PER PLOT, Year 10

	ON PLOT COSTS	WATER SUPPLY pipes/fitt	.meters	SEWAGE COLLECTION	SEWAGE TREATMENT
Materials					
-local		70	69	783	Land costs
-imported (x 1,4)		110	193	817	35
Labour					
-skilled		27	3	242	Construction costs
-unskilled		42	2	336	882 '
Subtotal		249	267	2,178	917
Engineering design		--	--	51	10
Total		516		2,229	927
Yearly maintenance		13		10	9
Lifetime years		40	20	40	40

ROECS are emptied every two years, emptying charges kshs 57,-per plot.

COSTS PER SCHEME. Year 10.

	ON PLOT COSTS	WATER SUPPLY pipes/fitt	.meters	SEWAGE COLLECTION	SEWAGE TREATMENT
Materials					Land costs
-local		22,500	22,110	250,589	0.28hA x
-imported (x 1,4)		35,238	61,908	261,318	Kshs 40,000 = Kshs 11,200
Labour					Construction
-skilled		8,576	1,080	77,317	$2,821m^3$ x Kshs 100 =
-unskilled		13,564	766	107,461	Kshs 282,100
Subtotal		79,878	85,864	696,685	293,300
Engineering design		--	--	16,408	3,100
Total		165,742		713,093	296,400
Yearly maintenance	12,000	4,293	--	3,281	2,960
Lifetime years		40	20	40	40

ROECS are emptied every 2 years, emptying charges Kshs. 18,000,- per scheme.

REEDS ODOURLESS EARTH CLOSET (OFF-SITE SULLAGE DISPOSAL)
ACCOUNTING COSTS (in 1000 kshs) and PERSONS SERVED. (Constant base year prices, 1979)

year	on plot costs		water supply		sewage collec.		sewage treat.		total	persons
	cap	o&m	cap	o&m	cap	o&m	cap	o&m		
xxxx	xxxx	xxx	xxxx	xxx	xxxx	xxxx	xxxx	xxx	xxxxxx	xxxxx
01	625	0	25	0	0	0	15	0	665	00
02	625	0	25	0	0	0	0	0	650	00
03	0	12	0	3	0	0	0	0	15	1280
04	0	12	0	3	0	0	0	0	15	1920
05	0	12	0	3	0	0	0	0	15	2560
06	0	12	0	3	0	0	0	0	15	3200
07	0	30	0	3	0	0	0	0	33	3740
08	0	12	0	3	0	0	0	0	15	4486
09	0	12	0	3	0	0	0	0	15	5120
10	0	30	166	3	713	3	296	0	1208	5760
11	0	12	0	4	0	3	0	3	22	5760
12	0	30	0	4	0	3	0	3	40	5760
13	0	12	0	4	0	3	0	3	22	5760
14	0	30	0	4	0	3	0	3	40	5760
15	0	12	0	4	0	3	0	3	22	5760
16	0	30	0	4	0	3	0	3	40	5760
17	0	12	0	4	0	3	0	3	22	5760
18	0	30	0	4	0	3	0	3	40	5760
19	0	12	0	4	0	3	0	3	22	5760
20	0	30	0	4	0	3	0	3	40	5760
↓										
30	0	30	94	4	0	3	0	3	22	5760
31	0	12	0	4	0	3	0	3	40	5760
32	0	30	0	4	0	3	0	3	22	5760
↓										
42	0	30	0	4	0	3	0	3	40	5760

Prices in 1000 kshs

Total sum of present values 1862.329/30744

10.10 Basic data and design criteria for on-site sullage disposal Phase 2

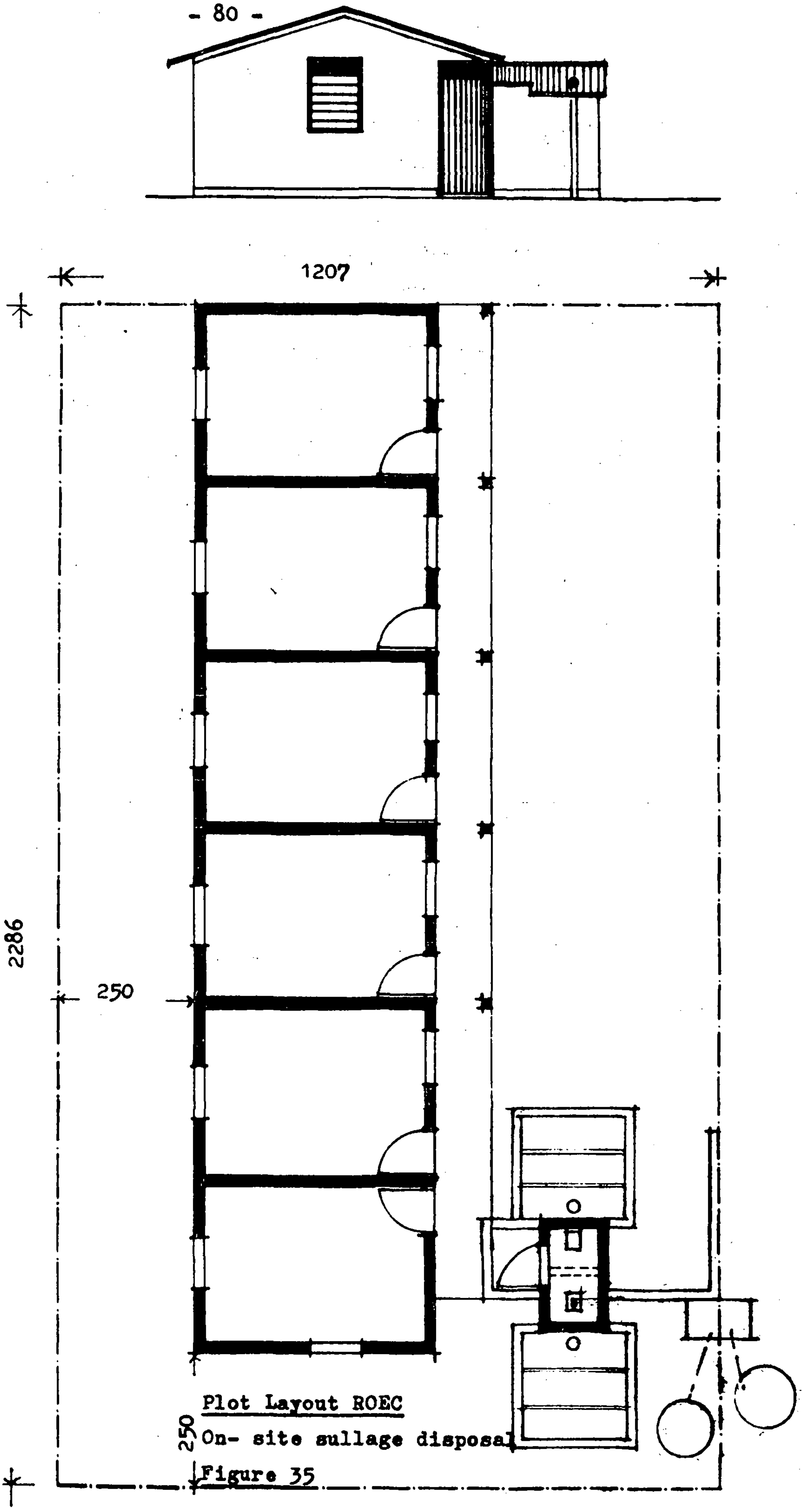
Reeds Odourless earth closet, similar as in par.10.9

Water supply similar as in par. 10.9

Sull Sullage water disposal

Maximum sullage water flow 450 litres / plot / day.

Maximum infiltration in soil 30 litres / m^2 / day.

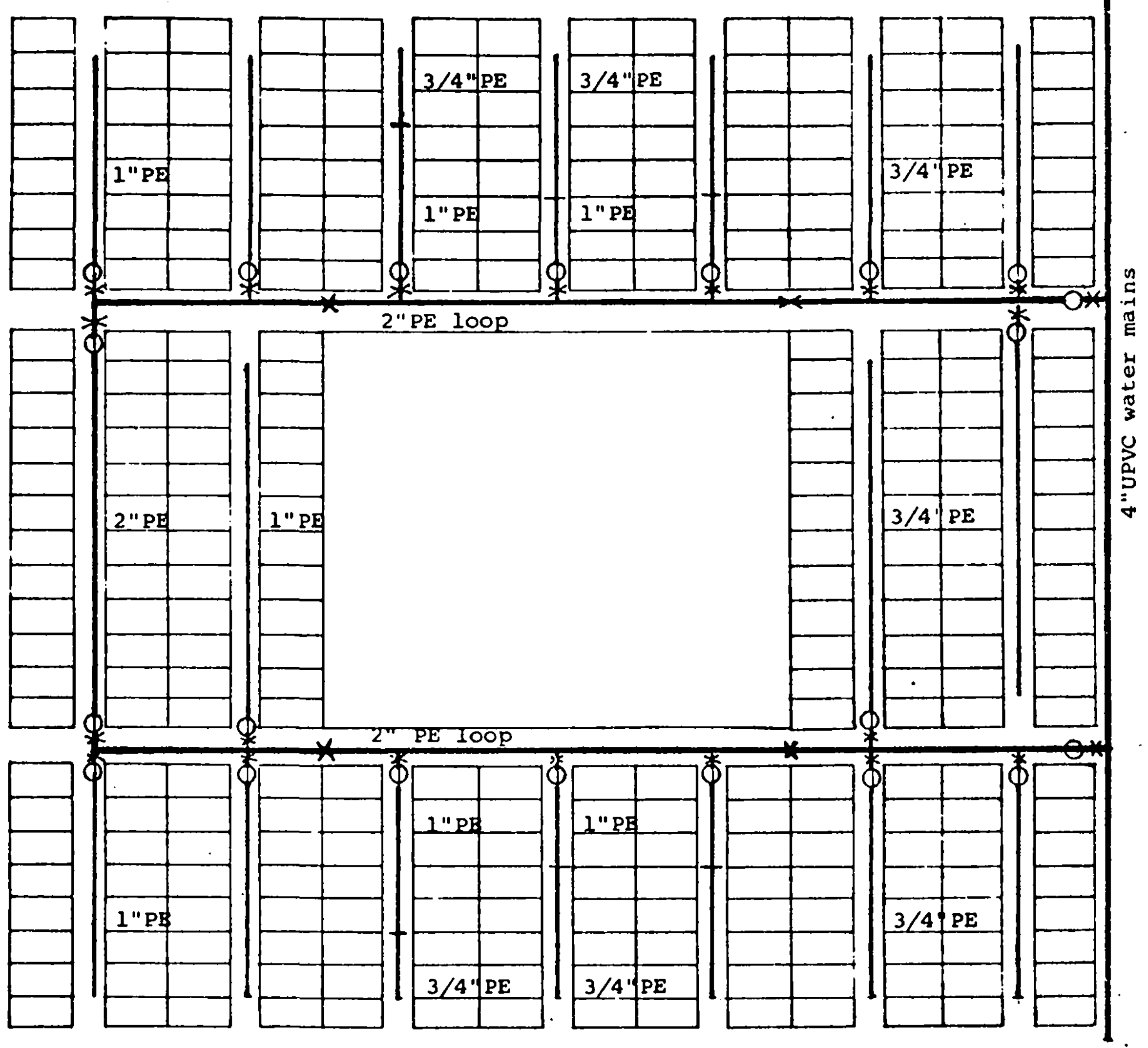


Plot Layout ROEC

On- site sullage disposal

Figure 35

Water Supply on-site sullage disposal



O water meter
X gate valves

Figure 36

ROEC On-site sullage disposal
Accounting prices

COSTS PER PLOT, ROEC Year 10.

	ON PLOT COSTS	WATER SUPPLY		SEWAGE COLLECTION	SEWAGE TREATMENT
		pipes/fitt	.meters		
Materials				SULLAGE CHAMBER	SOAKAWAY PIT
-local		70	69	411	140
-imported (x 1,4)		110	193	447	70
Labour					
-skilled		27	3	411	26
-unskilled		42	2	121	64
Subtotal		249	267	1,390	300
Engineering design		--	--	--	--
Total		516		1,390	300
Yearly maintenance	37	13		--	--
Lifetime years		40	20	40	40

ROECS ARE EMPTIED EVERY TWO YEARS, EMPTYING CHARGES KSHS 56,- PER PLOT.

COSTS PER SCHEME, ROEC Year 10.

	ON PLOT COSTS	WATER SUPPLY		SEWAGE COLLECTION	SEWAGE TREATMENT
		pipes/fitt	.meters		
Materials				SULLAGE CHAMBER	SOAKAWAY PIT
-local		22,500	22,110	131,520	44,800
-imported (x 1,4)		35,238	61,908	142,912	22,400
Labour					
-skilled		8,576	1,080	131,520	8,200
-unskilled		13,564	766	38,720	20,600
Subtotal		79,878	85,864	368,512	96,000
Engineering design		--	--	--	--
Total		165,742		368,512	96,000
Yearly maintenance	12,000	9,293		--	--
Lifetime years		40	20	40	40

ROECS are emptied every 2 years, emptying charges Kshs. 18,000,- per scheme.

REEDS ODOURLESS EARTH CLOSET (ON-SITE SULLAGE DISPOSAL)
ACCOUNTING COSTS (in 1000 kshs) and PERSONS SERVED. (Constant base year prices, 1979)

year	on plot costs		water supply		sewage collec.		sewage treat.		total	persons
	cap	o&m	cap	o&m	cap	o&m	cap	o&m		
xxxx	xxxx	xxx	xxxx	xxx	xxx	xxx	xxxx	xxx	xxxxxx	xxxxx
01	625		25	0	0	0	0	0	650	0
02	625		25	0	0	0	0	0	650	0
03	0	12	0	3	0	0	0	0	15	1280
04	0	12	0	3	0	0	0	0	15	1920
05	0	12	0	3	0	0	0	0	15	2560
06	0	12	0	3	0	0	0	0	15	3200
07	0	30	0	3	0	0	0	0	33	3740
08	0	12	0	3	0	0	0	0	15	4480
09	0	12	0	3	0	0	0	0	15	5120
10	0	30	166	3	368	0	96	0	663	5760
11	0	12	0	4	0	0	0	0	16	5760
12	0	30	0	4	0	0	0	0	34	5760
13	0	12	0	4	0	0	0	0	16	5760
14	0	30	0	4	0	0	0	0	34	5760
15	0	12	0	4	0	0	0	0	16	5760
16	0	30	0	4	0	0	0	0	34	5760
17	0	12	0	4	0	0	0	0	16	5760
18	0	30	0	4	0	0	0	0	34	5760
19	0	12	0	4	0	0	0	0	16	5760
20	0	30	0	4	0	0	0	0	34	5760
↓										
30	0	30	94	4	0	0	0	0	128	5760
31	0	12	0	4	0	0	0	0	16	5760
32	0	30	0	4	0	0	0	0	34	5760
↓										
42	0	30	0	4	0	0	0	0	34	5760

Total sum of present values 1614,83 / 30744

11.0 ECONOMIC COMPARISON OF SANITATION OPTIONS

11.1 Economic comparison excluding water costs

Applying the economic costing approach outlined in Section 5.0, the following average incremental cost per capita figures are obtained from the data in chapters 7-10 on each sanitation alternative.

Annual Average Incremental Cost per Capita

Conventional sewerage	Kshs $\frac{4.553.080}{30744}$	= Kshs 148	US$ 19.70
Sewered pour flush	Kshs $\frac{2.729.720}{30744}$	= Kshs 88	US$ 11.83
Sewered Aqua Privy	Kshs $\frac{2.619.940}{30744}$	= Kshs 86	US$ 11.36
ROEC (off site sullage)	Kshs $\frac{1.862.329}{30744}$	= Kshs 60	US$ 8.07
ROEC (on site sullage)	Kshs $\frac{1.614.830}{30744}$	= Kshs 53	US$ 7.00

These figures indicate that sewered pour flush toilets and sewered aqua privies can be provided for 60% of the cost of conventional sewerage. Aqua privies are marginal, cheaper, because of the possible simplification of the foundation of the superstructure. The cheapest system is the ROEC with on-site sullage disposal which costs only 36% of conventional sewerage. The superstructure is made out of permanent materials with a high finish, comparable with the other systems and these costs could be reduced if desired. In addition, pricing is based on contractor built construction, while, in fact, the ROEC with on site sullage disposal can be built almost completely with self help efforts and some technical assistance. Its costs could, therefore, be considerably reduced.

11.2 Economic comparison including water costs

However, the foregoing figures do not show the real economic cost differences between the alternatives because they do not include the costs of water.

Sanitation studies rarely include water costs but for a proper comparison these should obviously be included. As shown in Section 5, the average incremental cost of water in Nairobi, for the year 1975, was Kshs.2.293 per m^3. The average incremental cost of water is based on estimates for the Chania extension works. Now during actual construction of these, it appears that cost figures are far higher than anticipated. Higher figures for the AIC for water should, therefore, be used, but because of lack of data and time, the 1975 figure is used here. This figure is definitely too low and will, therefore, weigh in favour of water consuming solutions.

It is assumed that every person flushes the toilet 4 times a day. This will mean that for the conventional sewerage system, every person will use 40 litres of water daily. The sewered pour flush toilet will use 10 litres per person daily. The aqua privies and the ROEC's do not have additional water requirements.

Comparative total annual cost per capita.
(facility shared with 18 persons) 1979 prices Kshs (US$)

	Costs		Water			Total	
	Kshs.	US$		Kshs	US$	Kshs	US$
Conventional sewerage	148	(19.70)	$14,5m^3/$	33	(4,45)	181	(24,15)
Sewered pour flush	88	(11.73)	$3,7m^3/$	8	(1,11)	96	(12,84)
Sewered aqua privy	86	(11.33)	$- m^3 /$	-		86	(11,33)
ROEC off site sull	61	(807)	$-- m^3 /$	-		61	(8.07)
ROEC on site sullage	53	(700)	$- m^3 /$	-		53	(7.00)

A similar table is calculated for the total per plot costs.

Comparative total annual cost per plot
(18 prsons per plot) 1979 Kshs (US$)

	On/off plot		Water			Total	
	Kshs	US$		Kshs	US$	Kshs	US$
Conventional sewerage	2664	(354,60)	$262m^3/$	602	(80.35)	3266	(434.95)
Sewered Pour Flush	1584	(211,20)	$66m^3/$	150	(20.08)	1734	(231.28)
Sewered Aqua Privy	1553	(204,50)	$-m^3/$	-		1553	(204,50)
ROEC offsite sull.	1098	(146,40)	$-m^3/$	-		1008	(146,40)
ROEC on site sull.	954	(127,20)	$-m^3/$	-		954	(127,20)

The foregoing figures show clearly that the conventional sewerage system is the most expensive system. The annual cost per plot for the sewered pour flush toilet is 53% of the conventional sewerage cost.

The sewered aqua privy is even cheaper only 47% of the conventional sewerage cost. These systems are all based on waterborne sanitation.

The dry excreta disposal system is the cheapest,in spite of costing based on contractor built structures and excavation. If self help will be included it would be easily possible to reduce the cost further from 30% probably to 15% of the cost of conventional sewerage. Or in other words, 6 times the population served by conventional sewerage can be provided for the same cost with water and adequate excreta disposal facilities.

In spite of a superior performance of the sanitation alternatives, they are also considerably cheaper between 50% and 80%. Costing in this synthetic model was even in favour of conventional sewerage. Furthermore, several alternative sanitation techniques are suitable for stage wise development. Further costing breakdowns can be provided or calculated out of the present figures. That they are not included is the result of the time constraint of this particular study.

12.0 FUTURE DEVELOPMENTS AND RESEARCH NEEDS

12.1 Decision making

This study has been limited to a very few sanitation alternatives. Several sanitation technologies can be developed step-wise and improved over the years, but the calculations here have been more or less based on the ultimate design stage. However, if at a certain stage of development, (for example the aqua privy with individual soakaways) the system works well, there is no need for the ultimate stage of on-site sewerage.

Far more detailed costing procedures can be produced. Also far more sanitation alternatives can be studied. Elements of site characteristics have been completely excluded but are determining factors in both cost and technical performance. For example, the development of a low-income settlement in a remote area on almost flat lands (gradients below 1%) and impermeable soils presents particular design constraints. In any rational decision making process, conventional sewerage would almost certainly be excluded as a design option in this situation. The required pumping stations with back-up generators, the required trunk extensions etc. would be considered technically unwise as well as economically unjustified.

The development of a sewered aqua privy system or a ROEC with off site sullage disposal, both of which can work on almost flat areas, would be far more advantageous in cost and performance.

In view of the numerous viable alternatives available and the many different circumstances in which they may be required to operate, Government agencies, financing agencies and consultants should become much more hesitant to accept the ordinary run of the mill answers. Engineers, consultants etc. should be briefed to review the sanitation alternatives with an appropriate costing method.

Financing and Government agencies could serve the low-income population a lot better by considering appropriate techniques instead of automatically developing costly systems.

12.2 Appropriate sanitary engineering

For too long, the sanitary engineering profession has been ruled by European textbook knowledge that is inappropriate for developing countries. Statements such as: "universal accepted standards", "this is approved everywhere", etc., have down-graded the sanitary engineering profession. Sanitary engineering appropriate for developing countries is therefore a challenge to be met. Progress in this area appears to have ceased after the invention of the sewer.

With modern materials, improved old methods and innovative techniques, the basic needs of more people can be met at lower cost. International comparative experience may provide invaluable information. For example, the use of high density polyethylene, a cheap water pipe material, is now well tested but hardly ever used for urban developments. Automatic self-closing taps are used with success in Latin America but hardly at all in Africa. Sealed access UPVC sewerage systems for ordinary household sewage are used with success in Europe.

Pour flush latrine pans have been developed and used successfully in Asia. Ventilated improved pit latrines with flytraps have been tested In Tanzania. New and highly efficient methods of removing blocked pipes are available. We may look in vain for one housing scheme which has combined and integrated such technologies into one optimum solution for its particular circumstances. Yet in this way, a least cost, maximum performance solution could be found.

Every country has its own characteristics, cultural and social behaviour, soil conditions, water supply needs and diseases. There is a great need for truly innovative sanitation demonstration projects, not designed by the old fashioned breed of engineers, but by those who think as designers - creatively and with innovative.

12.3 Future developments

Such demonstration projects should be careful monitored so that lessons can be learned and knowledge can be gained for future developments. There is, for example, tremendous opportunity to investigate suitable sizes and designs of effluent pipes for septic tanks. The 63 mm UPVC pipe proposed in this present study can accommodate the flow of 2,700 persons so that it is still oversized and, therefore, unnecessarily costly.

Using septic tanks, it is possible to control the size of solids in the sewers to any desired limits. So why is it not possible to reduce sewers to 1½" polyethylene and to "mole plough" them into the ground thus keeping costs to an extremely low level?

And if we can keep the solids out of the sewers, why is it not possible to develop more appropriate pipe cleansing methods? A 1½" effluent pipe could easily be flushed through with the assistance of the waterpressure in the water mains, if we safeguards for backflows.

Slime accumulation in small sewer pipes could probably be attacked by biodegradable enzymen. In case of an accidental blockage would clearance not be possible with a device which releases a watershock into the sewer?

With water supply, the development of automatic self-closing taps is still in its infancy. It is quite shameful that in this age, we are unable to supply people with a non-leaking, low maintenance water tap. Why is it not possible to develop a cheap, easy to produce and locally repairable tap out of Nylon, ceramics, or UPVC injection moulding techniques?

There are many such unanswered questions to which it would be very worthwhile to find answers. If only 1% of the funds used for conventional sewerage were used for the development of those techniques, millions of other people could pick up the fruits of this type of research.

13.0 CONCLUSIONS

Presently there is an enormous distance between the urban poor living in an illegal settlement and between those few who are provided with all the conventional services in the present site and service schemes.

The type of services provided by these schemes are, however, hardly affordable for the majority of the urban poor.

The person who lives in an area where he shares one water tap with a thousand others will experience already a tremendous improvement in service level if he only has to share a water tap with 25 others. Similarly, with his excreta disposal facilities.

Ideas to bring a family in one giant step from a non-existing service level to an artificial high standard may perhaps pacify the administrators mind but will remain ideas and make little practical difference to the lives of the many thousands of families.

This study shows that there are many intermediate solutions to bridge this canyon in Kenya. If alternative sanitation options can become accepted by politicians and authorities and reflected in building codes, then larger parts of the population could be served with acceptable solutions at affordable costs. Furthermore, these systems can be made flexible so that improvements are possible as incomes rise.

Those who can afford the best should not impose their service level on others who can hardly survive in the urban environment.

In the case of residential developments, a proper assessment should be made of which services are present in the area. If sewage treatment works are already built for the town and connected to the site, probably the sewered pour flush or aqua privy will be the most appropriate solution. If no main services have been implemented and soils are suitable, possibly the ROECs are more appropriate.

It is essential to make a proper investigation of site characteristics, the communities concerned levels of affordability etc., before design decisions are made.

Kenya with its diversity of climates, ethnic groups, its specific soil conditions etc., should not be burdened with one universal sanitation system. This can become a costly mistake, particularly for those who cannot afford to pay for such mistakes.

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APPENDIX A

EXHAUST SERVICE

For this study a 1,8 m^3 tank truck is used . It is very flexible in traffic and does not require heavy duty pavement. However, since several different sizes of trucks are available, it would be worthwhile to do a cost-benefit analysis to determine which size of truck will be the most effective for a particular situation. This depends on septic tank sizing, sludge accumulation, distance to emptying site etc.

Cost of exhaust service

Cost of 1,8 m^3 exhaust truck	$ 18.000
Spare parts 50%	$ 9.000
Transport	$ 2.000 +
Total 5 years lifetime	$ 29.000

Total cost equipment $ 29.000 x 1,4 x K.Shs.7,5 =	K.Shs.304,500
Labourer and driver (5 years salary)	K.Shs. 72,000
Fuel and grease over 5 years (shadow priced)	K.Shs.120,800
Labour maintenance	K.Shs. 24,000
Total costs over 5 years	K.Shs.521,300

Emptying 7 tanks a day, 240 working days a year
5 x 240 x 7 = 8,400 tanks in 5 years time.

If the total scheme is serviced every two years, the costs will be $\frac{160}{8400}$ x K.Shs. 521,300 = K.Shs.9,929.

Sludge drying and disposal is assumed to be self-financing. The dried sludge can be resold as fertiliser.

APPENDIX B

WATER STORAGE

In the foregoing pages water storage is not included in the cost estimates. However, some considerations should be given to this point. Water storage is needed in the case where there is a possibility of temporary water shortages. It is considered that a one-day water supply is sufficient for this purpose. Water storage can be done in roof tanks in every individual house or, alternatively, bulk storage should be provided. At present individual storage is generally preferred. Particularly if conventional sewerage is used, sufficient water should be stored (at least on eaves level) to facilitate toilet flushing. Insufficient water storage will turn the flush toilet into a health hazard during water shortages.

For the site and service plot an occupancy is assumed of 18 persons per plot. This results in a water storage requirement of around 18 x 60 litres = 1,080 litres. However, in practice it appears to be very difficult and costly to install this amount of water in rooftanks. The weight of this water can make certain structural modifications necessary, and it is doubtful if low cost structures can absorb this load.

Furthermore, the system requires double plumbing. It has been a custom, taken from the British, that flush toilets and showers should not be directly connected with the mains but via the roof storage tanks. Only the kitchen tap may be directly connected with the mains.

Observations in site and service schemes show that individual water storage is often omitted or where it is installed, is too small to be effective. The cost of storing 1000 litres of water in rooftanks including additional plumbing is about K.Shs.1,500/- per plot.

In contrast to conventional sewerage, however, the alternative sanitation systems have very low water requirements. Only the pour flush toilet needs a small amount of flushing water. The aqua privies can absorb a temporary water shortage for some days before the water seal in the drop pipe will become inactive. The ROECs have no water requirements. In these cases, therefore, water is needed only for cooking and personal hygiene.

Consequently, in emergencies, only small quantities of water are necessary. As a result water storage can now be in bulk, within walking distance of the houses. In emergencies people will be able to carry water in buckets or containers to their houses. Observations show that if water is carried by hand, consumption is likely to drop to 10-15 litres per person per day. A storage of 20 litres/per person per day is therefore assumed to be adequate. A 9000 litre covered galvanised iron tank placed on a simple concrete foundation will cost about K.Shs.4,000/-. It can provided 450 persons with 20 litres of water. This will be a cheap solution and satisfy all basic health needs in emergencies. (See Figure 37).

APPENDIX C

FIRE REQUIREMENTS

Fire fighting in Kenya has a very low status. Fire trucks are mainly confined to the bigger towns, whilst the smaller urban centers rarely have any fire fighting equipment. What equipment exists is often out of order due to lack of spare parts.

There is nowadays a tendency to adopt the rule that every house in a housing scheme should be located within 100 metres of a fire hydrant. This fire hydrant should be located on a 4" looped watermain.

Given that low-cost housing is only single or occasionally two-storey, then for fire purposes, such water mains are highly over designed. This is imposing unnecessary costs for low-income housing estates. Furthermore, observations show that in fact numerous higher-income housing estates in Kenya do not have 4" water mains. This "standard" solution can, therefore, be seriously questioned for site and service schemes. Of course, even over designed water mains will be ineffective when the supporting equipment is not available. Other methods for fire fighting in low income housing estates should therefore be developed.

An alternative to having people waiting helplessly for the fire truck to arrive (assuming they have been able to find a working public call box from which to request the fire service) is to provide the community with the tools with which they can effectively fight a fire. A fire always start small and quick action can therefore be most important.

It has been suggested, that a "barefoot" sanitary technician should be employed by the council to deal with sanitation problems in the community (England, 1979). It is suggested here that this concept can be extended to cover fire fighting. The tasks of this technician, who lives in the housing estate will be:

- to maintain a close liaison with council officials
- to control and maintain watertaps
- to check toilet facilities for malfunctions on a regular basis
- to clear blockages in sewers
- to advise people on health related subjects
- to control refuse collection
- to fight fires in the estate and to perform preventive fire services.

It is anticipated that one technician will be employed for every 1,500 persons living in an estate. This "barefoot" sanitary technician should preferably be a woman who can relate well to the other women in the neighbourhood. She should receive a basic training in fire fighting and should be equipped with basic tools to fight fires. Therefore on the water supply laterals, gate valves with quick release connectors should be placed at regular distances. In addition every technician should be provided with two hoses each of 30 metres of 1½", fire axes and shovels.

Furthermore, the water storage tanks, as used in the alternative sanitation systems, can be integrated for fire fighting purposes. If the tanks are placed in strategic locations they can supplement the water obtained directly from the mains.

A portable pump mounted on a handcart would be located inside a housing scheme under the control of the technician.

Houses in site and services schemes are mostly single story dwellings, hence they do not need high pressure water to reach the roofs. In the plot layout, wayleaves of 5 metres are provided between the houses. (Figure [illegible]2).

Furthermore, the houses are mostly built out of permanent materials and roofs are normally galvanised iron sheets, which gives a good fire resistance.

If appropriate tools are provided to the community it would be possible to fight fires far more effectively than at present.

A combined water storage firefighting system is estimated to cost for the model scheme:

8 hoses 30 metres each with quick connectors	KShs.4,000/-
40 Gate valves, 1½"	KShs.4,000/-
Water storage tanks 9000 litres 18 x KShs. 4,000/-	KShs. 72,000/-
Portable pump mounted on handcart, axes, shovels	12,000/-
Total	KShs. 92,000/-

The annual average incremental cost for water storage and firefighting will be KShs.3/- per capita or KShs.54/- per plot for the alternative sanitation systems.

This in comparison with the conventional sewerage system: total costs for water storage and fire fighting equipment:

8 hoses of 30 metres each	K.Shs. 4,000/-
40 Gate valves 1½"	K.Shs. 4,000
Individual water storage tanks 320 x K.Shs. 1,500/-	K.Shs.480,000/-
Total	K.Shs.488,000/-

The annual average incremental cost for water storage and firefighting in the conventional sewerage system will be K.Shs.16/- per capita or KShs.288/- per plot.

Communal waterstorage tank

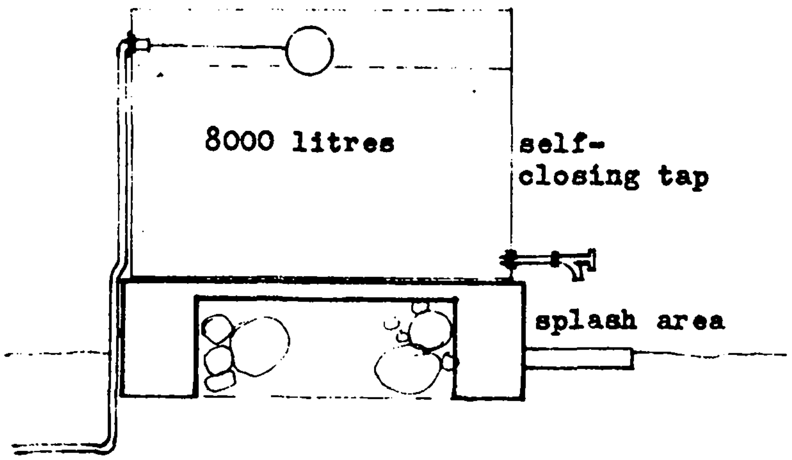

Figure 37